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

D3.8: Recommendations on Research Priorities and Innovation Strategies to Standardisation 2

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Abstract

Deliverable D3.8 of EU-IoT relates with the work under development in WP3 – Catalyst, Task 3.3, focused on strengthening the bridge between IoT research under development in ICT-56, and Standards Development Organisations. The report provides a mapping of relevant pre-normative activities and Standardisation bodies, including relevant documentation and contact points, as well as its mapping based on the EU-IoT Scope Areas, and IoT European competitiveness domains. D3.8 provides a full perspective of recommendations on research priorities and innovation strategies for Standardisation derived from several activities developed in the context of WP3, in cooperation with other WPs.

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

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EXECUTIVE SUMMARY

D3.8 “*Recommendations on research priorities and innovation strategies to standardisation Version 2*” is focused on providing: i) a thorough analysis of IoT/Edge relevant standardisation, pre-standardisation/pre-normative initiatives as well as key standards; ii) a standardisation mapping across the end-to-end IoT perspective, and per vertical domain, which can assist active and future NGIoT projects in a faster search for SDOs and standards to contribute to iii) an overview on the standardisation efforts of ongoing H2020 ICT-56 RIAs; v) research and innovation strategy recommendations that can assist future positioning of RIAs in standardisation.

D3.8 is an update to D3.7 “*Recommendations on research priorities and innovation strategies to standardisation Version 1*”, released in September 2022. While D3.7 presents the methodology followed to derive recommendations and an early status of contributions of ICT-56 projects to standardisation, D3.8 focuses on the final set of recommendations, based on an update of status, and based on additional external European consulted sources.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	3
TABLE OF CONTENTS	4
LIST OF FIGURES	6
LIST OF TABLES	7
ACRONYMS	8
1 INTRODUCTION	11
1.1 Document Structure.....	12
1.2 EU-IoT Scope Areas.....	12
1.3 ICT-56 RIAs.....	12
2 THE SDO MAPPING TOOL	14
2.1 Collected Data	14
2.2 Online SDO Tool	14
3 PERSPECTIVE ON KEY IOT STANDARDS ACROSS SDOS	16
3.1 SDOs.....	16
3.1.1 3GPP: 3rd Generation Partnership	16
3.1.2 CENELEC: European Committee for Electrotechnical Standardisation.....	16
3.1.3 CSA: Connectivity Standards Alliance	17
3.1.4 ETSI: European Telecommunications Standards Institute	17
3.1.5 GS1	18
3.1.6 IEC: International Electrotechnical Commission.....	19
3.1.7 IEEE: Institute of Electrical and Electronics Engineering.....	19
3.1.8 IETF: Internet Engineering Task Force	20
3.1.9 ISO: International organisation for standardisation.....	21
3.1.10 ITU-T: International Telecommunication Union	22
3.1.11 OASIS: Organization for the Advancement of Structured Information Standards	22
3.1.12 3.2.2 ODVA	23
3.1.13 3.2.3 OGC: Open Geospatial consortium.....	23
3.1.14 OPC: Open Platform Communications.....	24
3.1.15 OMG: Object Management Group	24
3.1.16 oneM2M	24
3.1.17 W3C Web of Things.....	25
3.2 Pre-Standardisation Entities	25
3.2.1 5G-ACIA: 5G Alliance for Connected Industries and Automation	25
3.2.2 5G IA: 5G Infrastructure Association.....	26
3.2.3 6G-IA: 6G Smart Networks and Services Industry Association	26
3.2.4 IRTF: Internet Research Task Force.....	26

3.3	Alliances and Consortia Developing Efforts towards SDOs.....	27
3.3.1	5GAA: 5G Automotive Association	27
3.3.2	AIOTI: Alliance for Internet of Things Innovation.....	28
3.3.3	BBF: Broadband Forum.....	28
3.3.4	BDVA: Big Data Value Association	28
3.3.5	Gaia-X: A federated data infrastructure for Europe	29
3.3.6	GSMA Alliance	29
3.3.7	ECISO: European Cybersecurity Association	29
3.3.8	EFFRA: European Factories of the Future Research Association.....	29
3.3.9	IDSA: International Data Spaces	30
3.3.10	IIC: Industrial Internet Consortium	30
3.3.11	LoRA Alliance	30
3.3.12	OAA: Open Automotive Alliance	31
3.3.13	OCF: Open Connectivity Foundation	31
3.3.14	OMA: Open Mobile Alliance.....	31
3.3.15	ONF: Open Networking Foundation.....	31
3.3.16	O-RAN: Operator Defined Open and Intelligent Radio Access Networks	32
3.3.17	OSA: OpenAir Interface Alliance.....	32
3.3.18	RISC-V International.....	32
3.3.19	VDMA: Mechanical and Plant Engineering Association	33
3.3.20	Weightless Alliance.....	33
4	HELPER FOR SDO CONTRIBUTIONS	34
4.1	SDO Mapping End-to-End	34
4.2	SDO Mapping per Domain.....	35
4.3	Summary of Key Standards per Entity	36
5	ICT-56 RIAS RESEARCH PRIORITIES TOWARDS STANDARDISATION.....	39
5.1	Current Status per RIA	39
6	RECOMMENDATIONS	45
6.1	Strengthening Research Priorities Towards SDOs.....	45
6.1.1	IoT interfaces/tactile Internet.....	45
6.1.2	Far Edge.....	45
6.1.3	Near Edge	46
6.1.4	Infrastructure	46
6.1.5	Data Spaces	46
6.2	Innovation Strategies.....	46
7	CONCLUSIONS	48
ANNEX I	49
8	REFERENCES	50



LIST OF FIGURES

Figure 1: The EU-IoT SDO mapping tool, example relying on a selection of specific keywords. 15

Figure 2: Mapping of SDOs, pre-standardisation entities, and alliances/consortia supporting standardization efforts to the EU-IoT scope areas. 34

Figure 3: Mapping of SDOs (green), pre-standardisation entities (yellow) and alliance/consortia (blue) to the different vertical domains. 35





LIST OF TABLES

Table 1: Main differences between D3.7 and D3.8. 11

Table 2: Metadata collected for the SDO analysis. 14

Table 3: Summary of key IoT standards per SDO. 36

Table 4: Perspective on current research priorities of RIAs towards SDOs, where “M” stands for monitoring, and “C” stands for contributions to standards..... 39



ACRONYMS

Acronym	Description
3GPP	3rd Generation Partnership Project (3GPP)
5G-ACIA	5G Alliance for Connected Industries and Automation
5G-IA	5G Infrastructure Association
6G IA	6G Smart Networks and Services Industry Association
AB	Advisory Board
AI	Artificial Intelligence
AIOTI	Alliance for Internet of Things Innovation IVZW
AMQP	Advanced Message Queuing Protocol
AR	Augmented Reality
BBF	Broadband Forum
BDVA	Bid Data Value Association
CENELEC	European Committee for Electrotechnical Standardisation
CIP	Common Industrial Protocol
CORBA	Common Object Request Architecture
CSA	Connectivity Standards Alliance
D2D	Device to Device
DDS	Data Distribution Service
DetNet	Deterministic Networking
EC	European Commission
EC-GSM-IoT	Extended Coverage GSM IoT
ECISO	European Cybersecurity Association
EGPRS	Enhanced General Packet Radio Service
ETSI	European Telecommunications Standards Institute
FAIR	Findable, Accessible, Interoperable, and Reusable
Gaia-X	A federated data infrastructure for Europe
GDM	Global Data Model
GS1	GS1
GSM	Global System for Mobile communications
GSMA	GSMA Alliance
H2020	Horizon 2020
IDSA	International Data Spaces Association
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineering
IETF	Internet Engineering Task Force

Acronym	Description
IIC	Industrial Internet Consortium
IoT	Internet of Things
IP	Internet Protocol
IRTF	Internet Research Task Force
ISO	International organisation for standardisation
IT	Informational Technology
ITU-T	International Telecommunication Union
LD	Linked Data
LDACS	L-band Digital Aeronautical Communications System
LoRA	LoRa Alliance
LPWAN	Low Power Wide Area Network
LTE	Long Term Evolution
MANO	Management and Network Orchestration
MEC	Multi Access Edge Computing
ML	Machine Learning
MQTT	Message Queuing Telemetry Transport
MTC	Machine Type Communications
NB-IoT	Narrow Band IoT
NFV	Network Function Virtualization
NGIoT	Next Generation Internet of Things
NIST	National Institute of Standards and Technology
OAA	Open Automotive Alliance
OASIS	Organization for the Advancement of Structured Information Standards
OCF	OCF, Open Connectivity Foundation
ODVA	ODVA
OGC	Open Geospatial consortium
OMA	Open Mobile Alliance
OMG	Object Management Group
oneM2M	One M2M Standards for M2M and the Internet of Things
ONF	Open Networking Foundation
OPC	Open Platforms Communication Foundation
OPC UA	OPC Unified Architecture (OPC UA)
ORAN	Operator Defined Open and Intelligent Radio Access Networks
OSA	OpenAir interface Alliance
OT	Operational Technology

Acronym	Description
PSM	Power Saving Mode
PubSub	Publish/Subscribe
QoE	Quality of Experience
RAN	Radio Access Networks
RAT	Radio Access Technology
RIA	Research and Innovation Action
RISC-V	RISC-V International
RNC	Radio Network Controller
SAREF	Smart Applications REference
SDN	Software Defined Networking
SDN	Software Defined Networking
SDO	Standards Development Organisation
SDO	Standards and Development Organization
SDR	Software Defined Radio
Std	Standard
TOSCA	Topology and Orchestration Specification for Cloud Applications
TSN	Time Sensitive Networking
URLLC	Ultra-reliable Low Latency Communications
VDMA	Mechanical and Plant Engineering Association
VR	Virtual Reality
W3C/WoT	World Wide Web Consortium/Web of Things
Weightless	Weightless Alliance
WoT	Web of Things
YANG	Yet Another Next Generation

1 INTRODUCTION

The EU-IoT standardisation activities described in this deliverable have been developed under the umbrella of Work Package 3 (WP3) – Catalyst, Task 3.3. WP3 has the overall main goal of assisting the acceleration of the *Next Generation IoT (NGIoT)* initiative by engaging all relevant stakeholders in growing and strengthening a large-embracing ecosystem, while creating synergies among them. The smart goals of WP3 have been defined as follows:

1. Broader IoT Ecosystem - open platform for a sustainable human-centric IoT community, to grow the NGIoT ecosystem and assist in partnership creation and stakeholders networking, via actions that facilitate and promote the direct engagement of relevant stakeholders, reaching out to inexperienced players and across different research and innovation communities.
2. Transfer and knowledge exchange on open-source, pre-normative and normative activities, to ensure development and adoption of innovative human-centric IoT concepts and solutions, fostering effective technology transfer and expertise exchange, while mapping NGIoT efforts into open-source, pre-Standardisation and Standardisation activities.
3. Engagement, to assist community building, ecosystem shaping, acceleration to contribute to the creation of a living and sustainable hub for all IoT initiatives in Europe.
4. Foster early adoption of products and innovative concepts, by providing concepts to stakeholders.

The standardisation activities described in this deliverable relate with WP3 goals 2 and 4.

This deliverable corresponds to an update of Deliverable D3.7, and the key differences between D3.7 and D3.8 are explained in Table 1.

Table 1: Main differences between D3.7 and D3.8.

WP3 activity	Deliverable Section and
To develop a methodology to interact with IoT and Edge computing-oriented SDOs, pre-Standardisation (pre-normative) and other normative entities, based on i) the current needs and actions of the supported <i>Research and Innovation Actions (RIAs)</i> ; ii) interaction with other CSAs and additional entities; iii) feedback from the EU-IoT pool of experts.	D3.7, section 2
To create an initial database of <i>Standardisation Development Organisations (SDOs)</i> and discuss potential interactions with RIAs.	D3.7, section 3 and SDO online tool.
To debate on an initial set of research priorities.	D3.7 section 4
To develop events, white papers, and other tools within EU-IoT and with contributions from the broader NGIoT community, which could assist in igniting the discussion on relevant research priorities.	D3.7, Annex I
To regularly update the SDO database, to facilitate access to SDOs by RIAs.	D3.8, section 2, and 3
To provide guidelines to assist future projects in a faster search of relevant SDOs and standards, from an IoT end-to-end perspective, and per domain	D3.8m section 4
To analyse the status of standardisation involvement of RIAs, understanding gaps and best practices.	D3.8, section 5
To derive a final set of recommendations towards standardisation.	D3.8, section 6

1.1 Document Structure

The document structure is as follows:

- **Chapter 2: The SDO mapping tool.** Provides a final update on the collected SDO data and standards, being the data collected presented in Annex I.
- **Chapter 3: Perspective on Key IoT Standards across SDOs.** Provides a list of relevant standards in the context of NGIoT.
- **Chapter 4: Helper for SDO Contributions.** Provides a mapping of SDOs from an end-to-end IoT perspective and per domain.
- **Chapter 5: Research Priorities Towards Standardisation in ICT-56.** Describes the key research contributions of the ICT-56 RIAs about SDOs and standards.
- **Chapter 6: Recommendations.** Provides a list of research and innovation strategy recommendations towards standardisation, derived from the meetings, interviews and studies developed during the full project duration and taking into consideration both active RIAs, and future projects.
- **Chapter 6: Conclusions.** Concludes the deliverable.

1.2 EU-IoT Scope Areas

The collecting, mapping and analysis work developed in EU-IoT had as basis the methodology that has been described in D3.7 section 2, and considering the end-to-end IoT perspective that EU-IoT adopted, based on “scope areas”, as follows:

- **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 managing sovereignty across decentralized data spaces.

1.3 ICT-56 RIAs

ICT-56 counts with six NGIoT flagship projects (ICT-56 RIAs), which have been developing efforts towards standardisations, among other contributions:

- [ASSIST-IoT](#): Architecture for Scalable, Self-*, human-centric, Intelligent, Secure, and Tactile next generation IoT.
- [VEDLIoT](#): VEDLIOT: Very Efficient Deep Learning in IoT.
- [IntellIoT](#): Intelligent, Distributed, Human-centred and Trustworthy IoT Environments.
- [IoT-NGIN](#) : Next Generation IoT as part of Next Generation Internet.

- [Ingenious](#) : Next-GENeration IoT sOlutions for the Universal Supply chain.
- [TERMINET](#): NexT GeneRation Smart InterconnectEd IoT.

These projects started between October and November 2020 and are expected to finish in October 2023. The analysis here described has been conducted based on input provided by each project and extracted from the standardisation-oriented deliverables.

2 THE SDO MAPPING TOOL

The NGIoT SDO mapping tool has been developed to i) assist in understanding the current positioning of projects towards the most relevant SDOs in the context of IoT; ii) assist RIAs in their search for potential SDOs. For the development of the tool and analysis of the potential impact of RIAs, the following sources have been considered:

- [StandICT](#) landscape documents, catalogues, etc.
- [EC documentation concerning roll-up plans](#) for ICT standardisation.
- [AIOTI Working Group Standardization](#).
- Multiple events developed with RIAs in EU-IoT, across WP2 and WP3.
- Consultation with the EU-IoT Expert Groups.
- Websites, and relevant public documents of the different SDOs.

2.1 Collected Data

Table 2 provides a description of the meta-data collected for each SDO, providing information for each field.

Table 2: Metadata collected for the SDO analysis.

Field	Description
Acronym	Acronym of the entity
Name	Title of the entity
Scope	European, Regional, International
EU-IoT Areas	IoT interfaces; near Edge; far Edge; infrastructure; Data spaces (multiple choice). "All areas" has been used to identify the mapping across all areas.
Domains	European competitiveness domains, stemming from the European Commission definition of Industrial competitiveness clusters within Horizon Europe, in alignment with the UN's Sustainable Development Goals. "Horizontal" stands for all domains.
Stakeholders	EU-IoT identified stakeholder groups: Industry/SMEs; Government; Research; Policy makers; Academia.
Description	Public description of the entity
Key IoT Standards	A small set of key standards being addressed as relevant in the context of Edge and IoT.
URL	Public URL
ICT-56 projects involved	Mapping of current project contributions to the SDO
Membership	Type of membership, e.g., paid, free, volunteer
Additional Keywords	The definition of technological scope is based on the value-chain of Internet services, from an end-to-end perspective. Examples of additional keywords considered are data analytics; data processing; telecommunications; 5G; 6G; cybersecurity; IoT; Edge; Sovereignty; trustworthiness; tactile Internet, SDN

2.2 Online SDO Tool

To assist in a stronger interaction with SDOs, the collected data has been integrated online in a searchable tool, on the EU-IoT Website via the URL <https://www.ngiot.eu/archive-Standardisation-bodies/>. The tool, illustrated in Figure 1, is searchable via different fields, e.g., European domain, EU-IoT scope area, stakeholder group, standard, ICT-56 project, or even specific keywords.

FILTER & SEARCH

Types of body ▾ Domains ▾ European/international ▾ Projects involved ▾ All areas,data spaces,Emergent applications,far edge,FarEdge,Infrastructure,interfaces,IoT applications,Near,Near and Far Edge,near Edge ▾

Industry ▾ 6G,Cellular ▾ network

Mechanical and Plant Engineering Association

With more than 3,300 members, the VDMA is the largest network organization and important voice for mechanical engineering in Germany and Europe. The association represents the common economic, technical and scientific interests of this unique and diverse industry.

Acronym: VDMA

Membership: Payed membership, then volunteer WGs

Domain: Energy ,Manufacturing

European/international: European/German

Project involved:

keyword: 5G ,6G ,Connectivity ,Interoperability ,Wireless

IoT scope: All areas

Stakeholder: Industry ,research

Type of body: Alliances and Consortia

International Telecommunication Union

The International Telecommunication Union (ITU) is the United Nations specialized agency for information and communication technologies – ICTs. Founded in 1865 to facilitate international connectivity in communications networks, we allocate global radio spectrum and satellite orbits, develop the technical standards that ensure networks and technologies seamlessly interconnect, and strive to improve access to ICTs to underserved communities worldwide. Every time you make a phonecall via the mobile, access the Internet or send an email, you are benefitting from the work of ITU.

Acronym: ITU-T

Membership: Payed membership

Domain: Horizontal

3rd Generation Partnership Project (3GPP)

The 3rd Generation Partnership Project (3GPP) unites [Seven] telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as “Organizational Partners” and provides their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies. The project covers cellular telecommunications technologies, including radio access, core network and service capabilities, which provide a complete system description for mobile telecommunications. The 3GPP specifications also provide hooks for non-radio access to the core network, and for interworking with non-3GPP networks. 3GPP specifications and studies are contribution-driven, by member companies, in Working Groups and at the Technical Specification Group level. The three Technical Specification Groups (TSG) in 3GPP are: Radio Access Networks (RAN),

Figure 1: The EU-IoT SDO mapping tool, example relying on a selection of specific keywords.

The online tool can be used by ICT-56 RIAs and future projects to look for SDOs that may be relevant in terms of topics. For instance, a project may add the keyword “network” in search and combine it with additional keywords that are provided in the tool, e.g., 5G, to obtain a list of potential SDOs, pre-standardisation entities, fora, as illustrated in Figure 1.

3 PERSPECTIVE ON KEY IOT STANDARDS ACROSS SDOS

This section provides an overview of key standards directly concerning IoT. The aim of this section is **not to present an exhaustive list of standards**, but to disseminate key standards which can assist RIAs in a faster search of relevant SDOs and working groups (WGs) to position their research. The different entities have been categorized into: Standardisation; pre-standardisation; Consortia and Alliances (or fora), as defined in the EU-IoT deliverable D3.7.

The data presented in each section is based on the collected metadata described in section 2.1.

3.1 SDOs

3.1.1 3GPP: 3rd Generation Partnership

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure	All	Industry, research	policy, Paid	SDN, 3G, 5G, cellular, telecommunications

[3GPP](#) has, since its release-13, been addressing the needs of an IoT market with focus on infrastructure. Its technologies have been categorized across three areas:

- **eMTC**, covering LTE enhancements for Machine Type Communications, derived from work in release-12, e.g., new *power saving mode (PSM)*. Key aspects in this context, in addition to improved energy efficiency, concern extended coverage with variable rates (~10 kbps to 1 Mbps depending on coverage needs).
- **NB-IoT**, focusing on new radio aspects on the LTE platform for low-power wide area networks (LPWAN), to optimize the integration of equipment on the far Edge, and in indoors scenarios. The key aspect being overseen is the support for a massive number of devices (~50.000 per cell), and better mobility support.
- **EC-GSM-IoT**, focusing on EGPRS enhancements together with PSM, thus allowing GSM/EDGE to be prepared for IoT. The key aspects, in addition to energy efficiency, and support for a massive number of devices, concerns improved security in comparison to GSM/EDGE.

3.1.2 CENELEC: European Committee for Electrotechnical Standardisation

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure, Interfaces	All	Industry	Paid	OT/IT, measurement, energy, interfaces

The CEN and [CENELEC](#) communities assist Europe in reaping the benefit of innovative technologies such as Digital Skills, Industrial Data, Artificial Intelligence, also understanding the impact of emerging technologies. The core of different standards covers two main aspects: security in IoT, and integration of *Operational Technology (OT)* into *Information Technology (IT)*. Relevant areas of work are:

- **Cybersecurity and Data protection**, being addressed by the CEN-CENELEC/**JTC13** Cybersecurity and data protection.
- **CENELEC/TC 65X** "*Industrial process measurement control and automation*" is a relevant source for cybersecurity related standards in the context of OT to IT integration. A relevant standard in this context is the **EN IEC 62443** series of standards for OT, usually applied

in manufacturing and critical infrastructures, but also across power utilities, healthcare, and transport systems.

- **EN 17529** ‘*Data protection and privacy by design and by default*’, to support the GDPR.
- **CEN/TC 224** ‘*Personal identification and related personal devices*’ addresses IoT privacy-related standardisation solutions (e.g., EN 419212-4:2018 on ‘Application Interface for Secure Elements for Electronic Identification, Authentication and Trusted Service’).
- **CEN/TC 225** ‘*Automatic Identification and Data Capture (AIDC) technologies*’ works in the field of automatic identification and data capture techniques such as 1D and 2D optical data carriers, RFID and RTLS.
- **CLC/TC 57** ‘*Power systems management and associated information exchange*’ has notably developed European Standards for data models in power systems (EN IEC 61850-x), Application Program interfaces (EN IEC 61970-x) and Data and Communication security (EN IEC 62351-x).
- **CLC/TC 205** ‘*Home and Building Electronic Systems (HBES)*’ has started, in 2018, to develop a European Standard on IoT Semantic Ontology Model Description (prEN 50090-6-2), which will explain the HBES IoT Model structures, semantically expressing the current HBES Open System solutions, with the goal of improving the semantic information HBES IoT gateways or HBES IoT devices provide.

3.1.3 CSA: Connectivity Standards Alliance

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Far interfaces	Edge, All	Industry, research, policy makers	Associate member, free; additional membership paid.	Wireless technology, interoperability, telecommunications

[CSA](#) defines itself as the alliance driving universal open standards to allow all objects to securely connect and interact. CSA, formerly known as ZigBee alliance, focuses on the use of short-range wireless to interconnect objects, being the core technology **ZigBee** or alternatives, such as **Matter**, the de facto standard for smart home automation.

3.1.4 ETSI: European Telecommunications Standards Institute

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure, dataspace, near Edge	All	Industry, researchers	policy, Paid	Information, interoperability, Edge

[ETSI](#) provides members with an open, inclusive, and collaborative environment. This environment supports the timely development, ratification and testing of globally applicable standards for ICT-enabled systems, applications, and services. ETSI has over 900+ member organizations drawn from 65 countries and five continents. ETSI therefore drives several IoT relevant standards, being a summary of those:

- [SAREF \(ETSI TS 103 264\)](#) is a reference ontology for smart appliances, which is a first ontology standard in the IoT ecosystem and sets a template and a base for development of similar standards for other industries, to unlock the full potential of IoT. SAREF is mapped onto the oneM2M Base Ontology (rf. To section 3.1.16). The SAREF model is being extended to add semantic models for data associated with smart cities, industry and manufacturing, smart agriculture and the food chain, water, automotive, eHealth/aging well and wearables.

- Several Group Specifications are being developed by the study group **ISG CIM** (*Context Information Management*) to assist publications in publishing, discovering, updating and accessing context information, initially for a broad range of smart city applications and later on other areas. A particular focus is enabling exchange of linked data and context information, using a simple API, **NGSI-LD (ETSI GS CIM 009 V1.2.1)** based on JSON-LD, and a high-level data model (**ETSI GS 006 V1.1.1**) referencing existing (or new) taxonomies and ontologies.
- **DECT-2020** is a series of standards, of which **TS 103 636** parts 1, 2, 3 and 4 are the most relevant ones, provided by the *ETSI TC Digital Enhanced Cordless Telecommunications (DECT)* to support low-power wireless technologies. DECT-2020 is a new radio interface with the objective to meet the URLLC and MTC requirements.
- **TS 103 645** and **EN 303 645** provide a globally applicable security standard for consumer IoT, the “*Cyber Security for Consumer Internet of Things*”.
- **Multi-Access Edge Computing** offers the de-facto near Edge solution supporting an open RAN to third-parties.
- **Open-source MANO**, developing an open-source Management and Orchestration (MANO) stack aligned with ETSI NFV Information Models. As a community-led project, OSM delivers a production-quality MANO stack that meets operators' requirements for commercial NFV deployments.

In addition, ETSI works across diverse groups defining interoperability aspects such as “user-centric approach in digital ecosystem” (focusing on the QoE of users), and different activities related with wireless systems for IoT, ranging from smart body area networks (TC SmartBAN) or ultra-narrowband radio technology interoperability, applied in LPWAN networks.

3.1.5 GS1

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure	All	Industry	Documents free; membership paid for services	Wireless technology, interoperability, telecommunications

GS1 defines standards for uniquely identification and tracking of product information, assets, etc. These standards define with several services to empower industry’s digital transformation, by providing a set of data services, such as verification of product identity, data quality.

Key standards provided by GS1 are:

- **GS1 Architecture Principles**. Describes the architectural design proposed by GS1.
- **GS1 System Architecture** (Release 11.1, Mar 2023). Defines and describes the GS1 system architecture, showing how each part of the system is related and outlines the underlying technical foundations that have guided their design.
- **Semantic Data Modelling Technical Bulletin** (Release 1.0, Jun 2021). Normatively referenced by the GS1 System Architecture Release 10.0, Section 6.5. GS1 data models can be defined independently of data formats, using Semantic Web/Linked Data standards.

3.1.6 IEC: International Electrotechnical Commission

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Interfaces, far edge, near Edge, infrastructure	All	Industry, researchers, policy,	Paid	interfaces, security, Energy, power, TSN

Founded in 1906, the IEC (International Electrotechnical Commission) is the world's leading organization for the preparation and publication of international standards for all electrical, electronic, and related technologies. These are known collectively as “electrotechnology”.

[IEC](#) addresses key aspects in terms of infrastructure. Examples of relevant standards in this context are:

- **IEC/IEEE 60802 TSN Profile for Industrial Automation.** Jointly developed with the IEEE, this standard defines time-sensitive networking profiles for industrial automation. The profiles select features, options, configurations, defaults, protocols, end stations, LANs, focusing on industrial networks.
- **IEC 62872-2-2022 “Internet of Things (IoT) – Application framework for industrial facility demand response energy management’** presents an IoT application framework for industrial facility demand response energy management (FDREM) for Smart Grids, enabling efficient exchange between industrial facilities (OT) and IoT (IT).

3.1.7 IEEE: Institute of Electrical and Electronics Engineering

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure, far Edge	All	Industry, researchers	Paid	wireless, TSN, 5G

The [IEEE](#) is a professional association that develops, defines, and reviews electronics and computer science standards. Its mission is "to foster technological innovation and excellence for the benefit of humanity. It provides a series of standards focusing on the support of networking infrastructures for the Internet. In the context of IoT, it has several relevant standards:

- **IEEE P2413-2019** aims at defining a standard for the architectural framework of IoT, comprising descriptions of different IoT domains and abstractions, as well as common aspects to improve interoperability.
- **IEEE 1451-99** focuses on developing a standard for harmonization of IoT devices and systems. This standard defines a method for data sharing, interoperability, and security of messages over a network, where sensors, actuators and other devices can interoperate, regardless of underlying communication technology.
- **IEEE 2700** proposes a common framework for sensor performance specification terminology, e.g., units, conditions.
- **IEEE P2510** defines quality measures, controls, parameters, and definitions for sensor data related to IoT implementations.

In addition to these core IoT standards, IEEE addresses additional IoT aspects in the core of different IEEE Standards Series:

- **IEEE Std 802.3 series** on Ethernet, where several efforts are being driven to address TSN integration across IIoT environments.
- **IEEE Std 802.11 series on wireless LANs**, where several efforts are focusing on the use of novel Wi-Fi standards, such as Wi-Fi 6, Wi-Fi 7 in IoT.

- **IEEE Std 18888 series**, focusing on green community control networks.

3.1.8 IETF: Internet Engineering Task Force

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	All	All	Industry, researchers	Free	Edge, IP, networking, routing, decentralisation

The mission of the [IETF](#) is to make the Internet work better by producing high quality, relevant technical documents that influence the way people design, use, and manage the Internet. The IETF develops standards related with the Internet operation in a volunteer way, based on different areas. The IETF focuses therefore on TCP/IP protocols.

Relevant standards to consider are:

- [RFC 8240](#), which documents several requirements and challenges specific to IoT devices.
- [RFC 8520](#) provides a component-based architecture for Manufacturer Usage Descriptions (MUD), an aspect that is relevant to allow for an adequate access control of IoT devices.
- [RFC72228](#), which defines terminology for constrained-node networks.

Several working groups focus on the development of standards for IoT. Out of these, the following WGs are relevant for RIAs to address different IoT aspects:

- [IoT operations \(iotops\)](#) focuses on the overall requirements of device onboarding and lifecycle management for an operational deployment of IoT; factory provisioning; access control of devices to network resources; isolation, quarantine of devices, etc.
- [Software updates for Internet of things \(suit\)](#) addresses an interoperable approach to allow for secure updates of firmware in IoT devices.
- The [A Semantic Definition Format for Data and Interactions of Things \(asdf\)](#) working group The objective of the ASDF working group is to develop SDF into a standards-track specification for thing interaction and data modelling. The ASDF interacts with OneDM, and with other IETF groups. It also links with the IRTF formal description techniques (FDT) research group (rf. To IRTF, section 3.2.4) and with the IRTF T2TRG, as well as with the T2T WISHI programme (focus on Things models and related specifications).
- The [Reliable and Available Wireless \(raw\)](#) working group focuses on high reliability and availability for IP connectivity over a wireless medium. RAW extends the **DetNet** Working Group concepts to provide for high reliability and availability for an IP network utilizing scheduled wireless segments and other media, e.g., frequency/time-sharing physical media resources with stochastic traffic: IEEE Std. 802.15.4 time slotted channel hopping (TSCH), 3GPP 5G ultra-reliable low latency communications (URLLC), IEEE 802.11ax/be, and L-band Digital Aeronautical Communications System (LDACS), etc. Like DetNet, RAW will stay abstract to the radio layers underneath, addressing the Layer 3 aspects in support of applications requiring high reliability and availability.
- The [Deterministic Networking \(DetNet\)](#) working group focuses on deterministic data paths that operate over Layer 2 bridged and Layer 3 routed segments, where such paths can provide bounds on latency, loss, and packet delay variation (jitter), and high reliability. The Working Group addresses Layer 3 aspects in support of applications requiring deterministic networking. The Working Group collaborates with IEEE802.1 TSN, which is responsible for Layer 2 operations, to define a common architecture for both Layer 2 and Layer 3. Example applications for deterministic networks include professional and home audio/video, multimedia in transportation, engine control systems, and other general industrial and vehicular applications being considered by the IEEE 802.1 TSN Task Group.

- The [Media Type Maintenance \(mediaman\)](#) focuses on the haptics top-level media type requests, considering different requirements and considering also semantic abstractions derived from YANG.
- The [Autonomic Networking Integrated Model and Approach \(anima\)](#) develops and maintains specifications and documentation for interoperable protocols and procedures for automated network management and control of professionally managed networks.
- The [Constrained RESTful environments \(CoRE\)](#) provides a framework for resource-oriented applications intended to run on constrained IP networks. Key standards are RFC 6690 (CoRE link format), RFC7252, RFC7641, RFC 7390 (CoAP protocol).
- The [Lightweight Authenticated Key Exchange \(lake\)](#) WG focuses on a lightweight authenticated key exchange protocol for OSCORE.
- The [IPv6 Over Low Power WPAN \(6lowpan\)](#) Working Group developed standards to ensure interoperability between smart object networks and defining the necessary security and management protocols and constructs for building such networks.
- The [IPv6 over Networks of Resource-constrained Nodes \(6lo\)](#) focuses on IPv6 adaptation mechanisms to short-range wireless, such as “Bluetooth Low Energy” (RFC 7668), ITU-T G.9959 (as used in Z-Wave, RFC 7428).
- The [IPv6 Over Low Power Wide-Area Networks \(lpwan\)](#) documents providing an overview of the baseline LPWA technologies (RFC8376), compression and fragmentation (RFC8724). The group will continue to produce new standards track work to optimize IPv6-based communications to the end devices.
- The [Application-Layer Traffic Optimization \(alto\)](#) developed an HTTP-based protocol and reported proof-of-concepts of ALTO based solutions supporting applications such as content distribution networks (CDN). Relevant aspects in this WG concern a far Edge integration via ALTO (RFC7971). Key standards: RFC 5693 (problem statement); RFC7285 (ALTO protocol); RFC9240 (Entity Property Maps)

3.1.9 ISO: International organisation for standardisation

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	All	All	Industry, policy makers, research	Via national institutes for standardisation	Security, quality management, environment

[ISO](#) is an independent, non-governmental international organization with a membership of 165 national standards bodies.

The core of standards concerning IoT is a joint effort of ISO/IET, the ISO/IEC JTC 1/SC 41 *‘Internet of Things and related technologies*. This joint community has developed the **ISO/IEC 30141** (*IoT reference architecture*) and **ISO/IEC 20924** (*IoT vocabulary*). A relevant set of work has also been developed in the context of IoT cybersecurity (ISO/IEC 27400, ISO/IEC 27402, and ISO/IEC 27402). Additional relevant ongoing work, where RIAs can get involved can be checked in the ISO/IEC/JTC 1/SC 41 Website, and a summary is as follows:

- IoT trustworthiness framework (**ISO/IEC 30149**).
- Methodology for trustworthiness of IoT system/device (**ISO/IEC 30147**).
- Data exchange platform requirements for IoT services (**ISO/IEC 30161**).
- Compatibility requirements and model for devices within industrial IOT systems (**ISO/IEC 30162**).
- Several IoT use-cases.

- Monitoring the ongoing regulatory, market, business, and technology IoT requirements.

3.1.10 ITU-T: International Telecommunication Union

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	All	All	Industry, policy makers, research	Paid	Requirements, security, architecture

The International Telecommunication Union (ITU) is the United Nations specialized agency for information and communication technologies – ICTs. Relevant standards from [ITU-T](#) are:

- **ITU-T Y.4000/Y.2060** “*Overview of the IoT*” provides a definition of IoT.
- Several ITU-T SG20 approved standards provide information on requirements. SG20 works in cooperation with oneM2M and TM Forum. A few examples of relevant standards in this context are: Recommendation **ITU-T Y.4202** “*Framework of wireless power transmission application service*”; **ITU-T Y.4203** “*Requirements of things description on the Internet of Things*”; Recommendation **ITU-T Y.4208** “*IoT requirements for support of edge computing*”; Recommendation **ITU-T Y.4210** “*Requirements and use cases for universal communication module of mobile IoT devices*”.
- The **SG20 Joint Coordination Activity on Internet of Things and Smart Cities and Communities (JCA-IoT and SC&C)** develop efforts towards an integration of IoT in the context of Smart Cities and Smart communities.
- The **ITU-T SG11** focuses on specifications that assist testing of IIoT. The Recommendation **ITU-T Q.3952** “*The architecture and facilities of a model network for Internet of things testing*”, Recommendation **ITU-T Q.4060** “*The structure of the testing of heterogeneous Internet of things gateways in a laboratory environment*”, Recommendation **ITU-T Q.4062** “*Framework for IoT Testing*” and Recommendation **ITU-T Q.4063** “*The framework of testing of identification systems used in IoT*” are relevant standards in this context.
- **ITU-T SG17** focuses on security and cybersecurity recommendations for IoT. In this context, **ITU-T X.1361** “*Security framework for the Internet of things based on the gateway model*”, **ITU-T X.1362** “*Simple encryption procedure for Internet of things (IoT) environments*”, **ITU-T X.1363** “*Technical framework of personally identifiable information (PII) handling system in Internet of things (IoT) environment*”, **ITU-T X.1364** “*Security requirements and framework for narrow band Internet of things*”, **ITU-T X.1365** “*Security methodology for use of identity-based cryptography in support of Internet of Things (IoT) services over telecommunication networks*”, are some relevant standards to be checked.

3.1.11 OASIS: Organization for the Advancement of Structured Information Standards

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure, interfaces, Edge	All	Industry	Paid	Protocols, interoperability

[OASIS](#) works on the development, convergence, and adoption of open standards for cybersecurity, blockchain, Internet of Things (IoT), emergency management, cloud computing, legal data exchange, energy, content technologies, and other areas. OASIS covers several relevant standards in IoT:

- The OASIS *Message Queuing Telemetry Transport (MQTT)* is a lightweight

Publish/Subscribe messaging protocol that can transport from remote locations/devices involving small code footprints (e.g., 8-bit, 256KB ram controllers), low power, low bandwidth, with some levels of QoS. MQTT also has been approved as ISO/IEC 20922:2016. A known variant of MQTT is MQTT-Sparkplug, which defines a relevant architecture for the integration of Industrial IoT.

- The *Advanced Message Queuing Protocol (AMQP)* is a Publish/Subscribe (PubSub) communication protocol, like MQTT [6].
- The *Topology and Orchestration Specification for Cloud Applications (TOSCA)* is a specification based on YAML to enable the interoperable description of application and infrastructure Cloud services and relationships, being interoperable with different container orchestrators.

3.1.12 3.2.2 ODVA

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure, interfaces, far Edge	Manufacturing	Industry	Paid	Protocols, interoperability, industrial automation

Founded in 1995, [ODVA](#) is a global association whose members comprise the world's leading automation companies. ODVA's mission is to advance open, interoperable information and communication technologies in industrial automation. ODVA recognizes its media independent network protocol, the **Common Industrial Protocol or "CIP"** — and the network adaptations of CIP — EtherNet/IP, DeviceNet, CompoNet and ControlNet — as its core technology and the primary common interest of its membership. For future interoperability of production systems and the integration of the production systems with other systems, ODVA embraces the adoption of commercial-off-the-shelf (COTS) and standard, unmodified Internet, and Ethernet technologies as a guiding principle wherever possible. EtherNet/IP exemplifies this principle — the world's number one industrial Ethernet network.

3.1.13 3.2.3 OGC: Open Geospatial consortium

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Data spaces, far Edge	All	Industry, research	Paid	Semantics, Web, geo-location-

[OGC](#) is an international consortium of more than five hundred businesses, government agencies, research organizations, and universities driven to make geospatial (location) information and services FAIR - Findable, Accessible, Interoperable, and Reusable. OGC defines and maintains standards for location-based, spatio-temporal data and services. Hence, OGC integrates recommendations to IoT about integration of data across the Web, extraction, fusion, and data spaces. Key aspects and specifications in the context of IoT are:

- [SensorThings API](#) is a standard that provides an open and unified framework to interconnect IoT sensing devices, data, and applications over the Web.
- [Open GeoSMS](#) is an OGC standard that provides developers with an extended SMS interface to facilitate communication of location across services and devices.

3.1.14 OPC: Open Platform Communications

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure, far Edge	Manufacturing	Industry, research	Paid	Protocols, interoperability

The [Open Platform Communications \(OPC\) Foundation](#) is an SDO focusing on the development of a series of standards and specifications for industrial telecommunication. OPC has as basis *on Object Linking and Embedding (OLE)* for process control. An industrial automation task force developed the original standard in 1996 under the name OLE for Process Control.

OPC develops one of the most relevant communication architecture standards for Industry 4.0, **OPC UA** (OPC Unified Architecture). OPC UA supports a semantic data description to support the integration and communication of machines within a shopfloor, in a secure way. For further details on OPC refer to [6].

3.1.15 OMG: Object Management Group

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	All	All	Industry	Paid	Modelling, semantics

[OMG](#) provides a neutral forum where best practices from a wide range of fields can be discussed and standards can be generated that drive the adoption and innovation of innovative technology spanning industries worldwide.

Known OMG standards are the Data-distribution Service for Real-time Systems (**DDS**); the Common Object Request Broker Architecture (**CORBA**), Unified Modelling Language (**UML**), System Modelling Language (**SysML**), among others.

3.1.16 oneM2M

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Interfaces, far edge	All	Industry	Paid	interoperability

[oneM2M](#) is a global partnership project founded in 2012 integrating the world's leading ICT standards development organizations, notably: ARIB (Japan), ATIS (United States), CCSA (China), ETSI (Europe), TTA (USA), TSDSI (India), TTA (Korea) and TTC (Japan). The goal of the organization is to create a global technical standard for interoperability concerning the architecture, API specifications, security, and enrolment solutions for Machine-to-Machine and IoT technologies based on requirements contributed by its members.

oneM2M as a global community creates requirements, architecture, API specifications, security solutions and interoperability for Machine-to-Machine and IoT technologies. The oneM2M specifications provide a framework to support a wide range of applications and services such as smart cities, smart grid, connected car, home automation, public safety, and health.

oneM2M provides the [following resources](#):

- oneM2M standards library.
- oneM2M set of developer resources for users that wish to build oneM2M devices and platforms from oneM2M specifications.

- Implementation guidelines, software testing steps.
- [Git](#) with several examples of IoT tutorials.

3.1.17 W3C Web of Things

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Data spaces, interfaces, far Edge	All	Industry, research	Free To ensure royalty-free Web standards, participants must be W3C and WoT WG Members and acknowledge the W3C Patent Policy .	Semantics, Web

The [World Wide Web Consortium \(W3C\)](#) is an international community where Member organizations, full-time staff, and the public work together to develop Web standards. W3C's mission is to lead the Web to its full potential. Relevant to IoT is the use of linked data being addressed via the *W3C Web of Things (WoT)* working group:

- The **WoT architecture** W3C Recommendation specification describes the abstract architecture for the W3C Web of Things. It defines the terminology that is used by all other WoT building blocks. The specification defines a conceptual framework that can be mapped onto a variety of concrete deployment scenarios.
- The **WoT Thing Description** W3C Recommendation defines a formal model for a Thing Description, where a Thing is an abstraction of a physical or virtual entity that provides interactions to and participates in the Web of Things. As it is based on linked data, it can be combined with other semantics, e.g., the GDPR vocabulary from the Data Privacy Community Group.

Ongoing work (candidate recommendations) relevant to IoT are:

- The **WoT Profile Specification** defines a Profiling Mechanism and a WoT Core Profile which enables out of the box interoperability among things and devices. Out of the box interoperability implies that devices can be integrated into various application scenarios without deep level adaptations. Typically, only minor configuration operations are necessary (such as entering a network key or IP address) to use the device in a certain scenario. These actions can be done by anyone without specific training.
- The **WoT Discovery specification** defines a mechanism to provide access to WoT Thing Descriptions in both local and global contexts. WoT Thing Descriptions can be retrieved from services running either on a Thing itself (that is, directly from self-describing objects), or from a directory service that provides a searchable database of WoT Thing Descriptions.

3.2 Pre-Standardisation Entities

3.2.1 5G-ACIA: 5G Alliance for Connected Industries and Automation

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Data spaces, infrastructure	Manufacturing	Industry, research	Paid	5G, cellular, data processing, data analytics, AI

[5G-ACIA's](#) overall goal is to apply industrial 5G in the best possible way. Members jointly strive to make sure that the interests of the industrial domain are adequately considered in 5G standardization and regulation. Together, they discuss and evaluate technical, regulatory, and

business aspects with respect to 5G for the industrial domain. In 5G-ACIA, members can contribute to different working groups, benefiting of a better understanding on the usage of industrial 5G environments; having access to endorsed testbeds and to show-cases.

3.2.2 5G IA: 5G Infrastructure Association

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure	All	Industry, research	Paid	5G, cellular, AI

[5G IA](#) represents the private side and the European Commission the public side. The 5G IA is committed to the advancement of 5G in Europe and to building global consensus on 5G. To this aim, the Association brings together a global industry community of telecoms & digital actors, such as operators, manufacturers, research institutes, universities, verticals, and SMEs.

With the end of the H2020 programme, 5GPPP will merge into 5G IA and members are invited to apply to join 5G IA.

5G IA has several working groups and members can contribute to the definition of a common vision, involving the definition of [future relevant areas](#); Key Performance Indicators (KPIs), etc.

3.2.3 6G-IA: 6G Smart Networks and Services Industry Association

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure, far Edge, data spaces, near Edge	All	Industry, research	Paid	5G, cellular, AI

[6G-IA](#) is the voice of European Industry and Research for next generation networks and services. Its primary objective is to contribute to Europe's leadership on 5G, 5G evolution and SNS/6G research. The 6G-IA represents the private side in both the 5G Public Private Partnership (5G-PPP) and the *Smart Networks and Services Joint Undertaking (SNS JU)*. In the 5G-PPP and SNS JU, the European Commission represents the public side.

The 6G-IA brings together a global industry community of telecoms & digital actors, such as operators, manufacturers, research institutes, universities, verticals, SMEs, and ICT associations. Different working groups assist in defining joint work, towards a better definition of a 6G vision.

Pre-standardisation work in 6G-IA is developed in the context of the Pre-Standardization WG, which aligns with different SDOs, developing a roadmap of relevant standardization bodies for beyond 5G. Additional working groups can be checked here.

3.2.4 IRTF: Internet Research Task Force

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	All	All	Industry, research	Free	Internet, Edge, Decentralisation

The [IRTF](#) focuses on longer term research issues related to the Internet building a path for innovative research (e.g., quantum) to be further developed in the context of the IETF.

The IRTF currently comprises different focused, long-term Research Groups, which relate with Internet protocols, applications, architecture, and technology. Research Groups have the stable long-term membership needed to promote the development of research collaboration and teamwork in exploring research issues. Participation is by individual contributors, rather than by representatives of organizations. The research groups, in our opinion, related with IoT are:

- **CFRG, Crypto Forum research group.** CFRG serves as a bridge between theory and practice, bringing new cryptographic techniques to the Internet community and promoting an understanding of the use and applicability of these mechanisms via Informational RFCs (in the tradition of, e.g., RFC 1321 (MD5) and RFC 2104 (HMAC)).
- **COINRG, computing in the network** research group, explores existing research and fosters investigation of “Compute in the Network” and resultant impacts to the data plane. The goal is to investigate how to harness and to benefit from this emerging disruption to the Internet architecture to improve network and application performance as well as user experience. COIN will encourage scrutiny of research solutions that comprehend the re-imagining of the network to be a place where routing, compute, and storage blend.
- **DINRG, Decentralized Internet Infrastructure**, researchers open research issues in decentralizing infrastructure services such as trust management, identity management, name resolution, resource/asset ownership management, and resource discovery. The focus of DINRG is on infrastructure services that can benefit from decentralization or that are difficult to realize in local, potentially connectivity-constrained networks.
- **HPRC, Human Rights Protocols Considerations**, is chartered to research whether standards and protocols can enable, strengthen, or threaten human rights, as defined in the Universal Declaration of Human Rights (UDHR) [1] and the International Covenant on Civil and Political Rights (ICCPR) [2], specifically, but not limited to the right to freedom of expression and the right to freedom of assembly.
- **ICNRG Information-centric networking**, addresses the Pub Sub ICN approach, to evolve the Internet infrastructure to directly support applications, focusing on a data-centric approach.
- **NMRG, Network management research group**, focuses on management services that interface with the current Internet management framework. This includes communication services between management systems, which may belong to different management domains, as well as customer-oriented management services. A relevant aspect in the context of IoT is Intent-Based Networking (IBN), which provides high-level, user-friendly abstractions to describe business and operational goals, and alleviates the need for the user to know and derive the technical details on how to achieve those goals.
- **NWCRG, Coding for efficient network communications**, focuses on the research of Network Coding principles and methods that can benefit Internet communication. Network coding is relevant in the context of future IoT applications, such as Metaverse, being a key pillar of semantic communications, for instance.
- **T2TRG, Thing-To-Thing**, investigates open research issues in turning a true “Internet of Things” into reality, an Internet where low-resource nodes (“things”, “constrained nodes”) can communicate among themselves and with the wider Internet, to partake in permissionless innovation. The focus of the T2TRG is on issues that touch opportunities for standardization in the IETF, i.e., it will start at the adaptation layer connecting devices to IP, and end at the application layer with architectures and APIs for communicating and making data and management functions (including security functions) available.

3.3 Alliances and Consortia Developing Efforts towards SDOs

3.3.1 5GAA: 5G Automotive Association

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
EU	All	Transportation	Industry	Paid	Interoperability, edge, 5G, mobility

[5GAA](#) is a global, cross-industry organisation of companies from the automotive, technology, and telecommunications industries (ICT), working together to develop end-to-end solutions for future mobility and transportation services. Created in September 2016, 5GAA has rapidly expanded to include key players with a global footprint in the automotive, technology and telecommunications industries. This includes automotive manufacturers, tier-1 suppliers, chipset/communication system providers, mobile operators, and infrastructure vendors.

3.3.2 AIOTI: Alliance for Internet of Things Innovation

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	All	All	Industry, research, policy makers	Paid	interoperability, edge, semantics, energy, data processing, data analytics

[AIOTI](#) drives, on behalf of our members business, policy, research and innovation development in the IoT & Edge Computing and other converging technologies across the Digital Value Chain to support digitization in Europe, and competitiveness of Europe. AIOTI counts with distinct groups where members can get involved, driving the vision of IoT in Europe, both from a theoretical and operational perspective.

3.3.3 BBF: Broadband Forum

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure, data spaces	All	Industry, research, policy makers	Paid	Telecommunications, interoperability, connectivity

[BBF's](#) mission is to unlock the potential for new markets and profitable revenue growth by leveraging innovative technologies and standards in the home, intelligent small business, and multi-user infrastructure of the broadband network. The innovative use of NFV, SDN, Ultra-Fast access, IoT, and open-source innovation enables the delivery of exciting ultra-fast broadband services, for the connected home and business, access and converged 5G infrastructure and Cloud. BBF mission is to accelerate the adoption of the work to bring new, valuable services and insights to our member companies, and to the whole broadband community who benefit from our work.

3.3.4 BDVA: Big Data Value Association

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Data spaces	All	Industry, research, policy makers	Paid	Data analytics, data processing

[BDVA](#) is an industry-driven international not-for-profit organisation with more than two hundred members all over Europe and a well-balanced composition of large, small, and medium-sized industries as well as research and user organizations. BDVA is the private counterpart to the EU Commission to implement the Big Data Value PPP program. BDVA and the Big Data Value PPP pursue a common shared vision of positioning Europe as the world leader in the creation of Big Data Value.

The mission of the BDVA is to develop the Innovation Ecosystem that will enable the data and AI-driven digital transformation in Europe delivering maximum economic and societal benefit and achieving and sustaining Europe's leadership on Big Data Value creation and Artificial

Intelligence.

3.3.5 Gaia-X: A federated data infrastructure for Europe

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Data spaces	All	Industry, research, policy makers	Paid	Sovereignty, data processing, trustworthiness

[Gaia-X](#) is a project initiated by Europe for Europe. Its aim is to develop common requirements for a European data infrastructure. Therefore openness, transparency, and the ability to connect to other European countries are central to Gaia-X. Representatives from seven European countries are currently involved in the project. We want to invite other European partners to join the project and to contribute to its development. Many dialogues are already underway and will be further intensified. Furthermore, Gaia-X is in continuous exchange with the European Commission.

3.3.6 GSMA Alliance

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure	All	Industry	Paid	Connectivity, 5G, cellular

The [GSMA](#) represents the interests of mobile operators worldwide, uniting more than 750 operators with almost four hundred companies in the broader mobile. Key aspects are key industry priorities such as 5G, IoT, Roaming, Security and SIM Technology.

3.3.7 ECSO: European Cybersecurity Association

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	All	All	Industry, research	Paid; documents free	Cybersecurity

[ECSO](#) is a European, cross-sectoral membership organisation that contributes to developing cybersecurity communities and building the European cybersecurity ecosystem. ECSO federates the European Cybersecurity public and private sector, including large companies, SMEs and start-ups, research centres, universities, end-users and operators of essential services, clusters, and associations, as well as the local, regional, and national public administrations across the European Union Members States, the European Free Trade Association (EFTA) and H2020 Programme associated countries.

3.3.8 EFFRA: European Factories of the Future Research Association

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Europe	All	Manufacturing	Industry, research, policy makers	Paid	Digitisation, supply-chain

[EFFRA](#) is a non-for-profit, industry-driven association promoting the development of new and innovative production technologies. EFFRA has been representing the private side of the manufacturing partnership with the EC. Named under Horizon 2020, Factories of the Future to become Made in Europe nowadays under Horizon Europe.

The key objective of EFFRA is to promote pre-competitive research on production technologies within the [European Research Area](#) by engaging the European Commission through partnerships.

The [Made in Europe partnership](#) will be the voice and driver for sustainable manufacturing in Europe. It will boost European manufacturing ecosystems towards global leadership in technology, circular industries, and flexibility. The Partnership will contribute to a competitive, green, digital, resilient, and human-centric manufacturing industry. It will be at the centre of a twin ecological and digital transition, both a driver and subject to these changes.

3.3.9 IDSA: International Data Spaces

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Europe	Data spaces	All	Industry, research, policy makers	Paid	Data spaces, interoperability, business models

[IDSA](#) is a coalition of more than 130 member companies that share a vision of a world where all companies self-determine usage rules and realize the full value of their data in secure, trusted, equal partnerships; and we are making that vision a reality. IDSA goal concerns the creation of a global standard for international data spaces (IDS) and interfaces, as well as fostering the related technologies and business models that will drive the data economy of the future across industries.

3.3.10 IIC: Industrial Internet Consortium

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	All	Manufacturing	Industry, research, policy makers	Paid	Supply-chain, manufacturing, digitisation

The [IIC](#) was founded in March 2014 to bring together the organizations and technologies necessary to accelerate the growth of the industrial internet by identifying, assembling, testing, and promoting best practices. Members work collaboratively to speed the commercial use of advanced technologies. Membership includes small and large technology innovators, vertical market leaders, researchers, universities, and government organizations.

Through multiple activities and programs, the Industrial Internet Consortium helps technology users, vendors, system integrators and researchers achieve tangible results as they seek to digitally transform across the enterprise. The resources of the IIC – developed collaboratively over the years by industry experts from around the globe and across all industries – give organizations the guidance needed to strategically apply digital technologies and achieve digital transformation.

3.3.11 LoRA Alliance

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure	All	Industry, research	Paid	Telecommunications, interoperability, connectivity

The [LoRa Alliance](#)® is the fastest growing technology alliance. A non-profit association that has become one of the largest alliances in the technology sector, committed to enabling large scale deployment of LPWAN IoT through the development and promotion of the [LoRaWAN](#)® open

standard. Members benefit from a vibrant ecosystem of active contributors offering solutions, products & services, which create new and sustainable business opportunities.

Through standardisation and the accredited certification scheme the LoRa Alliance® delivers the interoperability needed for LPWA networks to scale, making LoRaWAN® the premier solution for global LPWAN deployments.

3.3.12 OAA: Open Automotive Alliance

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Far, Near Edge	Transportation	Industry	Upon contact, for automotive stakeholders	Automotive, interoperability, edge

The [OAA](#) is a global alliance of technology and auto industry leaders committed to bringing the Android platform to cars since 2015.

3.3.13 OCF: Open Connectivity Foundation

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Interfaces, far Edge	All	Industry, research, policy makers	Paid, but free access to documents	5G, data processing, interoperability

[OCF](#) represents a merge of the former OCF association, sponsor of the IoTivity open-source project, and the AllSeen Alliance, which provides the AllJoyn® open source IoT framework.

OCF has as members leaders across multiple industries and expects to define the connectivity requirements to improve interoperability between the billions of devices in IoT. OCF will deliver a specification, an open-source implementation and a certification program ensuring interoperability regardless of form factor, operating system, service provider or transport technology creating a "Network of Everything". The OCF invites the industry to participate in this effort as it brings together companies from diverse markets including Automotive, Consumer Electronics, Enterprise, Healthcare, Home Automation, Industrial and Wearables, amongst others.

3.3.14 OMA: Open Mobile Alliance

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	All	All	Industry	Paid, but free access to documents	Agile standardization, ICT

[OMA Specworks](#) defines an agile process for standardization, having in mind ICT entities. Its process defines a basic, comprehensive set of steps and tools for developing technical specifications. OMA provides several WGs, free to be followed and to contribute. OMA's specifications provide specific recommendations for an adequate data processing based on linked data and semantic approaches.

3.3.15 ONF: Open Networking Foundation

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure, near Edge, far Edge	All	Industry, research, policy makers	Paid	SDN, 5G

[ONF](#) is an operator-driven, community-led non-profit consortium fostering and democratizing innovation in software-defined programmable networks. Through ecosystem building, advocacy, research, and education, ONF is accelerating the state-of-the-art in open networking and catalysing creation and adoption of open disaggregated solutions leveraging open-source software.

3.3.16 O-RAN: Operator Defined Open and Intelligent Radio Access Networks

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure, near Edge, far Edge	All	Industry, research, policy makers	Paid	5G RAN, interoperability, open access

[O-RAN ALLIANCE's](#) mission is to re-shape the RAN industry towards more intelligent, open, virtualised and fully interoperable mobile networks. The new O-RAN standards will enable a more competitive and vibrant RAN supplier ecosystem with faster innovation to improve user experience. O-RAN based mobile networks will at the same time improve the efficiency of RAN deployments as well as operations by the mobile operators. To achieve this mission, O-RAN develops three principal areas of work:

- Specification effort, where it extends RAN standards towards openness and intelligence.
- [Open software development](#) for the RAN, in cooperation with the Linux foundation.
- Testing and integration, supporting its members in testing and integration of O-RAN implementations.

3.3.17 OSA: OpenAir Interface Alliance

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure	All	Industry, research	Paid for entities; free for individuals (limited access)	5G RAN, interoperability, open access

[OSA](#) is the home of OpenAirInterface, an open software that gathers a community of developers from around the world, who work together to build wireless cellular Radio Access Network (RAN) and Core Network (CN) technologies.

3.3.18 RISC-V International

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Far interfaces Edge,	All	Industry, research, policy makers	Community member free (academia, research); industry paid memberships	Hardware, RISC-V

[RISC-V International](#) is the global non-profit home of the open standard RISC-V *Instruction Set Architecture (ISA)*, related specifications, and stakeholder community.

RISC-V combines a modular technical approach with an open, royalty-free ISA — meaning that

anyone, anywhere can benefit from the IP contributed and produced by RISC-V. As a non-profit, RISC-V does not maintain any commercial interest in products or services. As an open standard, anyone may leverage RISC-V as a building block in their open or proprietary solutions and services.

Relevant work being developed in the context of RISC-V is the new era of processor innovation, where open-source hardware solutions are being combined with open-source operating systems. A key work developed concerns the Ubuntu deployment for RISC-V.

3.3.19 VDMA: Mechanical and Plant Engineering Association

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
EU/German	Far Edge, near Edge, interfaces	Manufacturing, Energy	Industry, research	Paid	Interoperability, 5G, Wi-Fi, AI/ML, automation

With more than 3,300 members, [VDMA](#) is the largest network organization and an important voice for mechanical engineering in Germany and Europe. The association represents the common economic, technical, and scientific interests of this unique and diverse industry and focuses on digitisation and industry 4.0.

3.3.20 Weightless Alliance

Scope	EU-IoT Scope	Domains	Stakeholders	Membership	Keywords
Int	Infrastructure	All	Industry, research	Based on contact	Wireless technology, interoperability, telecommunications

The [Weightless Alliance](#) is a non-profit international alliance dedicated to the continual integration of Weightless technology a specification is a LPWAN networking protocol for IoT.

Weightless technology brings benefits in the context of large-scale sensing scenarios, with frequent uplink/downlink transmissions, and a high demand for reliability. The protocol stack is embedded in two main hardware components: the base station and end device module.

4 HELPER FOR SDO CONTRIBUTIONS

This section provides the collected SDO mapping from an IoT end-to-end perspective, and from a vertical domain perspective. The aim of this exercise is to provide projects with a better understanding of the positioning of each SDO, thus contributing to a better definition of contributions.

The section ends with a listing of the key standards per SDO, collected in section 3.1.

4.1 SDO Mapping End-to-End

Figure 2 provides an overview of the areas of action of the different SDOs (green), pre-standardisation entities (yellow), and alliances/consortia described in the prior sections (blue), against the different EU-IoT scope areas.

HUMAN/IOT INTERFACES	FAR EDGE	NEAR EDGE	INFRA STRUCTURE	DATA SPACES
	CSA		5G-PPP	
	CEN-CENELEC		CEN-CENELEC	
			ETSI	
			GS1	
		IEC		
	IEEE		IEEE	
		IETF		
		ISO		
		ITU-T		
OASIS	OASIS		OASIS	
	ODVA		OPC	
	OGC			OGC
	OPC			
		OMG		
oneM2M				
				W3C WoT
W3C WoT				
			5G ACIA	
			5G IA	
			6G IA	
		IRTF		
		AIOTI		
				BBF
				BDVA
				Gaia-X
	OAA		GSMA	
		IIC		
OCF			LORA	
		OMA		
		O-RAN		
RISC-V			Weightless	
	VDMA			

Figure 2: Mapping of SDOs, pre-standardisation entities, and alliances/consortia supporting standardization efforts to the EU-IoT scope areas.

Regarding SDOs, IETF, ISO, ITU-T and OMG provide standards that support IoT from an end-to-end perspective. Far Edge is the scope area that has more SDOs mapped (14), followed by infrastructure (13).

Pre-standardisation, which is highly relevant to assist in defining a future, aligned vision for RIAs, cover Infrastructure and data spaces. IRTF is the sole entity that provides a broad scope of topics from an IoT end-to-end perspective.

For IoT, a relevant number of alliances and consortia are driving efforts towards interoperability across hardware and software, providing easy access to industry and research members. Relevant to cite is the broad effort of AIOTI and of the IIC.

4.2 SDO Mapping per Domain

The mapping per domain considers the following vertical domains, relevant in the context of ICT-56:

- Manufacturing
- Energy
- Health and Well-Being
- Society
- Smart Cities
- Agriculture
- Transportation and Logistics

Figure 3 provides the SDOs per domain. As shown, in terms of SDOs, the key SDOs cover different domains, being the exception OPC and ODVA, that focus on Manufacturing.

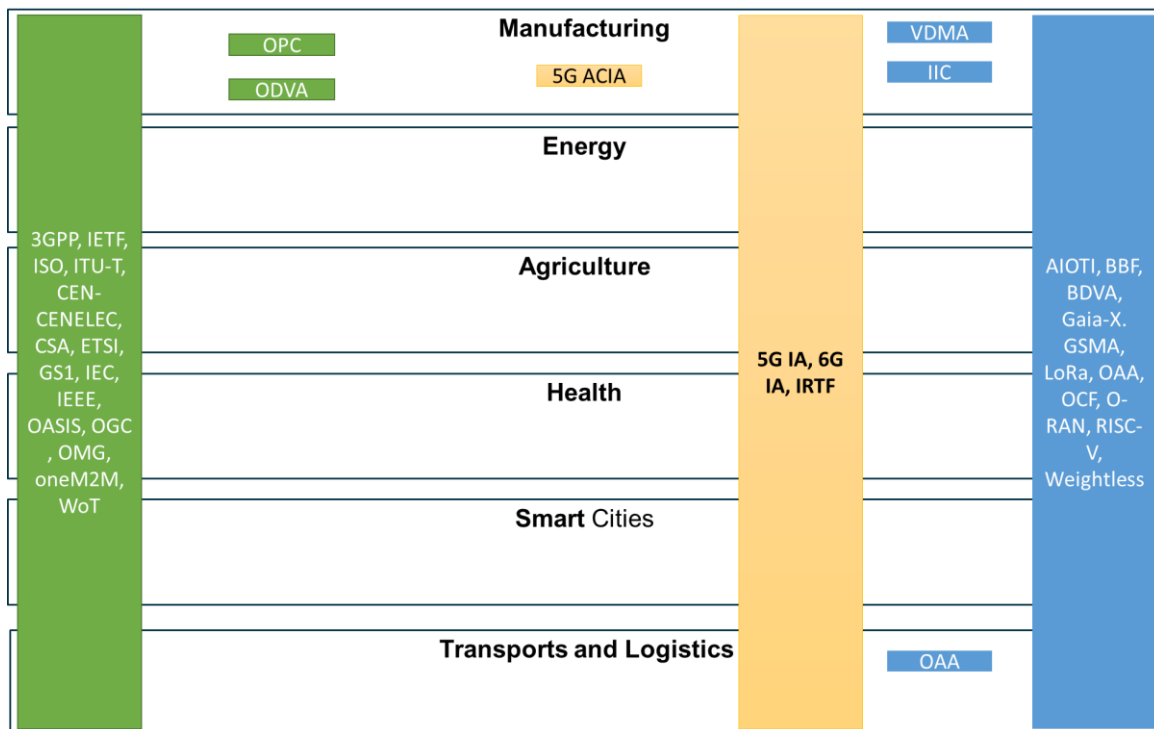


Figure 3: Mapping of SDOs (green), pre-standardisation entities (yellow) and alliance/consortia (blue) to the different vertical domains.

In terms of pre-standardisation, 5G ACIA focuses on the manufacturing domain, while all other pre-standardisation entities cover the full spectrum. In what concerns existing consortia and alliances, there is a similar pattern, where all entities provide coverage for use-cases across the different domains; VDMA and IIC have specific focus on Manufacturing, and OAA has specific focus on the automotive (Transportation) domain.

4.3 Summary of Key Standards per Entity

Table 3 provides a listing of the key standards related to different aspects of IoT, as has been described in section 3.1, to assist projects in a faster search.

Table 3: Summary of key IoT standards per SDO.

SDO	Key IoT Standards
3GPP	3GPPP release thirteen, comprising enhancements in terms of eMTC, NB-IoT, EC-GSN-IoT
CEN-CENELEC	<ul style="list-style-type: none"> • CEN-CENELEC/JTC13 – cybersecurity • CENELEC/TC 65X “Industrial process measurement control and automation” • EN IEC 62443 series • EN 17529 ‘Data protection and privacy by design and by default – support for GDPR • CEN/TC 224 ‘Personal identification and related personal devices. • CEN/TC 225 ‘Automatic Identification and Data Capture (AIDC) technologies’ • CLC/TC 57 ‘Power systems management and associated information exchange’ • CLC/TC 205 ‘Home and Building Electronic Systems (HBES)’
CSA	<ul style="list-style-type: none"> • Zigbee • Z-Wave • Matter
ETSI	<ul style="list-style-type: none"> • SAREF • MEC • DECT-2020 • TS 103 645 and EN 303 645 • MANO
GS1	<ul style="list-style-type: none"> • GS1 Architecture principles • GS1 architecture specification • Semantic Data Modelling Technical Bulletin
IEC	<ul style="list-style-type: none"> • IEC/IEEE 60802 TSN Profile for Industrial Automation • IEC 62872-2-2022 “Internet of Things (IoT)
IEEE	<ul style="list-style-type: none"> • IEEE P2413-2019 aims at defining a standard for the architectural framework of IoT, comprising descriptions of different IoT domains and abstractions, as well as common aspects to improve interoperability. • IEEE 1451-99 focuses on developing a standard for harmonization of IoT devices and systems. This standard defines a method for data sharing, interoperability, and security of messages over a network, where sensors, actuators and other devices can interoperate, regardless of underlying communication technology. • IEEE 2700 proposes a common framework for sensor performance specification terminology, units, conditions, and limits is provide. • IEEE P2510 defines quality measures, controls, parameters, and definitions for sensor data related to IoT implementations. • IEEE Std 802.3 series on Ethernet, where several efforts are being driven to address TSN integration across IIOT environments. • IEE Std 802.11 series on wireless LANs, where several efforts are focusing on the use of novel Wi-Fi

SDO	Key IoT Standards
	<p>standards, such as Wi-Fi 6, Wi-Fi 7 in IoT.</p> <ul style="list-style-type: none"> IEEE Std 18888 series, focusing on green community control networks.
IETF	<ul style="list-style-type: none"> RFC 8240, which documents several requirements and challenges specific to IoT devices. RFC 8520 provides a component-based architecture for Manufacturer Usage Descriptions (MUD), an aspect that is relevant to allow for an adequate access control of IoT devices. RFC72228, which defines terminology for constrained-node networks. Refer to each of the WGs described in section 3.1.8 for further standards.
ISO	<ul style="list-style-type: none"> ISO/IEC JTC 1/SC 41 'Internet of Things and related technologies' ISO/IEC 30141 (IoT reference architecture) ISO/IEC 20924 (IoT vocabulary). ISO/IEC 27400, ISO/IEC 27402, and ISO/IEC 27402, IoT cybersecurity. ISO/IEC 30149, IoT trustworthiness framework- ISO/IEC 30147, Methodology for trustworthiness of IoT system/device. ISO/IEC 30161, Data exchange platform requirements for IoT services ISO/IEC 30162, Compatibility requirements and model for devices within industrial IOT systems
ITU-T	<ul style="list-style-type: none"> ITU-T Y.4000/Y.2060 "Overview of the IoT" ITU-T Y.4202 "Framework of wireless power transmission application service" ITU-T Y.4203 "Requirements of things description on the Internet of Things." ITU-T Y.4208 "IoT requirements for support of edge computing." ITU-T Y.4210 "Requirements and use cases for universal communication module of mobile IoT devices." ITU-T Q.3952 "The architecture and facilities of a model network for Internet of things testing," Recommendation. ITU-T Q.4060 "The structure of the testing of heterogeneous Internet of things gateways in a laboratory environment," Recommendation. ITU-T Q.4062 "Framework for IoT Testing" and Recommendation ITU-T Q.4063 "The framework of testing of identification systems used in IoT." ITU-T X.1361 "Security framework for the Internet of things based on the gateway model." ITU-T X.1362 "Simple encryption procedure for Internet of things (IoT) environments" ITU-T X.1363 "Technical framework of personally identifiable information (PII) handling system in Internet of things (IoT) environment" ITU-T X.1364 "Security requirements and framework for narrow band Internet of things" ITU-T X.1365 "Security methodology for use of identity-based cryptography in support of Internet of Things (IoT) services over telecommunication networks," are some relevant standards to be checked
OASIS	<ul style="list-style-type: none"> MQTT AMQP TOSCA
ODVA	<ul style="list-style-type: none"> Common Industrial Protocol or "CIP"
OGC	<ul style="list-style-type: none"> SensorThingsAPI OpenGeoSMS
OPC	<ul style="list-style-type: none"> OPC-UA
OMG	<ul style="list-style-type: none"> DDS SysML CORBA
WoT	<ul style="list-style-type: none"> WoT Architecture



SDO	Key IoT Standards
	<ul style="list-style-type: none"><li data-bbox="368 226 1444 268">• WoT Thing Description



5 ICT-56 RIAS RESEARCH PRIORITIES TOWARDS STANDARDISATION

5.1 Current Status per RIA

Table 4 covers contributions to SDOs, based on public deliverables focusing on standardisation, provided by the RIAs, and based on information collected in EU-IoT via WP5 T5.3, Impact assessment. These deliverables provide a view into month eighteen of the projects, and therefore the table cannot provide a final view into contributions. In the table, monitoring (**M**) implies that RIAs follow an SDO, following study groups or the development of specific standards. Contribution (**C**) implies that RIAs follow specific study groups (as in monitoring) and in addition contribute actively to the development of an existing or future standard.

Table 4: Perspective on current research priorities of RIAs towards SDOs, where “M” stands for monitoring, and “C” stands for contributions to standards.

Entity	ASSIST-IoT [9]	VEDLIoT	IntelloT [10]	IoT-NGIN [11]	inGenious [12]	TERMINET
3GPP			C	C new features from 5G device management API	6 C RAN1, RedCap UE, UL synchronization	M WGs focused on AI and Edge computing (IEEE SA), specially IEEE P2961
CENELEC			M			
ETSI	C: SmartM2M use-cases, STF601 (cross domain usability) SmartM2M STF 602 SAREF: Industry adoption facilitation and oneM2M		C	C OSM, resource management APIs and protocols	M ETSI NFV, ETSI OSM, ETSI ZTM	M-C In general, within the TERMINET project, following and investigating ETSI TeraFlow SDN and ETSI MANO / MEC standards. Focused on orchestration across the computing continuum, abstraction layer for digital twins, device inventories and discovery.
IEC				M		C UC6: Mixed Reality and ML Supported Maintenance and Fault Prediction of IoT-based Critical Infrastructure, for the New Generation of RTU device following: IEC 61850-3, Communication networks and systems for power utility automation; IEC 60255-26: Measuring relays and protection equipment. UC3: Smart, Sustainable and Efficient Buildings, following: IEC 62443-2/3/4: Security for industrial communication networks and automation and control systems IEC/IEEE 42010:2011, Systems and software engineering -- Architecture description



Entity	ASSIST-IoT [9]	VEDLIoT	IntelloT [10]	IoT-NGIN [11]	inGenious [12]	TERMINET
IEEE	<p>C</p> <p>Collaborative Edge Computing, C/AISC/CEC; Federated Machine Learning, C/AISC/FML; Following up the selected Working Groups: Tactile Internet, COM/MobiNet -SC/TI, Security</p> <p>Assessment Framework for the IoT Application Deployments, COM/MobiNet -SC/IOTAF</p>		<p>M</p> <p>TSN aspects</p>			<p>M</p> <p>In general, within the TERMINET project, following and investigating:</p> <p>-IEEE 3652.1-2020- Guide for Architectural Framework and Application of Federated Machine Learning</p> <p>-A reference architecture combining network softwarization and message-oriented middleware technology to provide explicit support for quality-aware Digital Twin technology in I4.0 environments and beyond</p> <p>-P. Bellavista , M. Fogli, L. Foschini, C. Giannelli, L. Patella and C. Stefanelli, “A Framework for QoS-Enabled Semantic Routing in Industrial Networks: Overall Architecture and Primary Protocols”, IEEE Future Networks World Forum, Canada, October 2022 https://datatracker.ietf.org/doc/draft-bellavista-semantic-sdn-mom/</p> <p>IEEE 1232-2010: Artificial Intelligence Exchange and Service Tie to All Test Environments (AI-ESTATE)</p> <p>IEEE 1636-2018: Software Interface for Maintenance Information Collection and Analysis</p>
IETF		M	<p>M</p> <p>DetNet WG, TSN</p>			<p>M</p> <p>In general, within the TERMINET project, following and investigating IETF standards related to communications, networking, and network management.</p>
ITU-T	<p>C</p> <p>G13: Future networks, with focus on IMT-2020, cloud computing and trusted network infrastructures</p> <p>Following up the SG20: IoT, smart cities & communities</p>			M		M
ISO		M				C





Entity	ASSIST-IoT [9]	VEDLIoT	IntelloIoT [10]	IoT-NGIN [11]	inGenious [12]	TERMINET
						<p>In the premise of UC1: User Centric Devices in Smart Farming, following:</p> <ul style="list-style-type: none"> • ISO 9001: 2008: Certified quality management systems • ISO 22000: 2005: food safety management • ISO 14001: 2004: environmental management • ISO 22400: Automation systems and integration <p>In the premise of UC4: Prediction and Forecasting System for Optimizing the Supply Chain in Dairy Products, following:</p> <ul style="list-style-type: none"> • ISO 9001:2015 Certification regarding Quality Management Systems <p>In the premise of UC6: Mixed Reality and ML Supported Maintenance and Fault Prediction of IoT-based Critical Infrastructure, following:</p> <ul style="list-style-type: none"> • ISO 13374: Condition monitoring and diagnostics of machines <p>In general, within the TERMINET project, following and investigating:</p> <ul style="list-style-type: none"> • ISO SC6 WG7 - RINA reference Architecture and core protocols • ISO/IEC DIS 23894: Information technology — Artificial intelligence — Guidance on risk management. • ISO/IEC CD 5338: Information technology — Artificial intelligence — AI system life cycle processes • ISO/IEC AWI TR 5469: Artificial intelligence — Functional safety and AI systems • ISO/IEC DTR 24368: Information technology — Artificial intelligence — Overview of ethical and societal concerns • ISO/IEC CD 5392: Information technology



Entity	ASSIST-IoT [9]	VEDLIoT	IntelloIoT [10]	IoT-NGIN [11]	inGenious [12]	TERMINET
						<ul style="list-style-type: none"> – Artificial intelligence – Reference architecture of knowledge engineering
OGC				M Point of Interest SWG (W3C POI, ISO 19112, ISO 19155)		
W3C WoT			C W3C WoT TD v1.0 standard. Use-cases presentation, focus on TD as run-time resources; Extension of TD to include AI-related details, e.g., AI metadata, capabilities			C In general, within the TERMINET project, following and investigating: -W3C CCG: Credentials Community Group - W3C DID: Decentralized Identifier
ECSO	M Gaps in cybersecurity domain. Contribution to cybersecurity white papers and best practices.			C cochair of WG6.2 Digital Transformation in Verticals		
AIOTI	C Contributions to white papers – vision, IOTI Computing Continuum Requirements on IoT/Edge Computing & Optical Communication		C			
BDVA	M-C EBDVF 2021.			M		
RISC-V		C Open hardware focus: SPGA and accelerator development				
5G ACIA			C use cases for Edge	M 5G performance		

Entity	ASSIST-IoT [9]	VEDLIoT	IntelloIoT [10]	IoT-NGIN [11]	inGenious [12]	TERMINET
			computing in a 5G environment of a manufacturing shop floor as well as distributed AI.	in an industrial environment and validating several POC (Proof of Concept) and prototypes		
5G IA			M			
ONF				M contribute the PCF for managing network slicing as Open Source		
EFFRA				M Living-labs results		
5GAA					M Tele Operation Driving data flow aspects	
Gaia-X			M	M		
PICMG		C PICMG COM-HPC				

The six flagship ICT-56 RIAs are contributing to the key, broader SDOs: **3GPP**, **ETSI**, **IEC**, **IEEE**, **IETF**, **ITU-T**, **ISO**, **W3C WoT**. The SDOs where more contributions are provided are **3GPP** and **ETSI**, as expected, due to the nature of ICT-56.

In terms of standardisation fora, a project is targeting **RISC-V**. Most projects provide contributions to **AIOTI**, **5G ACIA** and **5G IA**.

In terms of specific contributions to standards:

- **3GPP**. New features to the API management; to the PHY Layer (RAN1 WG); 3GPP RedCap; uplink synchronization.
- **ETSI**, SAREF in terms of industry adoption facilitation, SmartM2M use-cases, STF601 (cross domain usability); ETSI OSM; device-side TSN.
- **IEEE**, contributions concerning collaborative Edge computing (C/AISC/CEC); federated learning (C/AISC/FML); assessment framework for IoT application deployments (COM/MobiNet-SC/IOTAF).
- **ITU-T**, **G13**: Future networks, with focus on IMT-2020, cloud computing and trusted networks.
- **W3C**: Use-cases presentation, focus on TD as run-time resources; Extension of TD to include AI-related details, e.g., AI metadata, capabilities.
- **RISC-V**: Open hardware focus: SPGA and accelerator development in the context of the



RISC-V ISA.



6 RECOMMENDATIONS

This section provides recommendations concerning research priorities towards standardisation, and towards innovation strategies, providing a final update to the content presented in the EU-IoT D3.7.

The recommendations provided here are targeting not only the current ICT-56 projects but envisioning also future projects focusing on IoT aspects.

6.1 Strengthening Research Priorities Towards SDOs

6.1.1 IoT interfaces/tactile Internet

Several projects adopt AR/VR, novel, and mobile smart wearables across different domains. In terms of Tactile interfaces, the projects already cover highly relevant aspects, such as end-to-end synchronization, security, and trustworthiness. SDOs such as 3GPP, IEEE and ETSI seem to, based on the compiled information, have a significant number of contributions. About standardisation fora relevant contributions are already being developed in the context of AIOTI, for instance, regarding semantic technologies.

Additional possibilities to position research in this context could be:

- **IETF**, across different working groups, via contributions to existing drafts or RFCs. Currently, there are several drafts defining and collecting requirements for tactile Internet and haptics in the mediaman WG (rf. to section 3.1.8).
- **IEEE**, the [P1918 “Tactile Internet Working Group”](#) is also a relevant placeholder where projects can contribute to in this context.
- **ITU-T**, [Tactile Internet](#), contributing to the different study groups, in particular SG16 (Multimedia) and SG17 (Security).

6.1.2 Far Edge

The key research directions currently being addressed by the ICT-56 RIAs concern the handling of local AI decisions via federated learning, intelligent offloading across near and far Edge. Several projects address brownfield integration (OT-IT) and the use of open-hardware in the context of IoT systems. Contributions to hardware (RISC-V) have also been developed. The far Edge topics are therefore currently positioned in terms of articulation of end-user devices towards a 5G core; relevant contributions in terms of **ETSI OSM**; **ETSI SAREF** and **W3C/WoT** have already been provided.

The extension of functionality to the far Edge; the miniaturization of AI across constrained Edge devices, Pub Sub approaches to further decentralize communication across the Edge are aspects that are still in the beginning of their development and therefore, far Edge is a relevant area in terms of research input towards SDOs. **We propose additional contributions to consider in this context:**

- **IETF**. In **raw**, RIAs can propose and address specific use-cases and derive requirements that can benefit the overall community. In **iotops**, aspects such as OT-IT integration, large-scale onboarding, and trustworthiness would be valuable.
- **OPC**, concerning the integration and articulation of TSN end-user devices into manufacturing environments; and of requirements in terms of traffic across the different use-cases.

- **ITU-T Y.4208: Internet of Things**, for further updates concerning the use of Edge.
- **ISO, ISO/IEC TR23188:2020** future updates.

6.1.3 Near Edge

The different projects have been significantly contributing to ETSI regarding near Edge aspects, be it in what concerns ETSI MEC, ETSI MANO. Aspects described concern the use of device or edge intelligence based on federated learning; integration of functions to support intelligent offloading and synchronisation between near and far Edge. Aspects also concerning the articulation of TSN user-devices across the near Edge are also addressed.

6.1.4 Infrastructure

Several projects are addressing significant infrastructure aspects, ranging from open hardware aspects, until the evolution of the 5G core. Relevant contributions were already provided to ETSI OSM (NFV orchestration aspects); deterministic support; RAN1 improvements; 5G reduced capacity device integration (REDCAP). In this context, the key SDOs of **IEEE**, **ITU-T**, **3GPP** and **ETSI** have been addressed.

Additional aspects that we would like to highlight are:

- **IETF**, Contributions towards existing standards or proposals for new ones across, e.g., **DetNet** (TSN integration across an IP core), **raw** (wireless integration), **alto** (network exposure functions).
- **IEEE**, contributions across the overall spectrum of the IEEE Std 802.3 and 802.11 series are feasible, and required, in terms of a flexible integration across the far Edge-Cloud.
- **ITU-T**, the cybersecurity contributions, derived from the existing areas, could be beneficial to the existing projects.

6.1.5 Data Spaces

In the context of data spaces, projects have been focusing on the use of semantic technologies (**W3C WoT**); on the use of AI-based Knowledge representation and improving IoT task/process management and configuration and on achieving cross-domain interoperability (**ETSI SAREF**).

The RIAs have also been contributing to different fora in this context, such as **AIOTI**, **Gaia-X**, **BDVA**.

No further recommendations in this context.

6.2 Innovation Strategies

In terms of research contributions towards SDOs, RIAs have followed a similar macro methodology, starting by the definition of use-case requirements, involving direct meetings and data collection across the involved stakeholders. Derived from both functional and non-functional technological and business requirements, specific SDOs and working groups can be identified at an early stage. A follow-up phase where different SDOs are analysed, derived from tools like the ones proposed in this deliverable, and derived also from knowledge from the standardisation departments of industrial partners can assist projects in building a path towards significant contributions to SDOs.

The methodology to approach standardisation requires partners to identify different approaches. Usually, partners that are members of specific SDOs facilitate the analysis and search for relevant standards, being also entry points to the consortium.

Another approach considers first an identification of concrete research contributions; discussion across the consortium; and positioning of the work.

Usually, the definition on potential entry points for a project is defined in an individual way, targeting the identified SDOs during the project lifetime.

This methodology is beneficial in the sense that it is a directed methodology, consuming only the required resources.

The following global recommendations are defined:

- About the analysed data, a global recommendation is to consider **also open SDOs such as the IETF**, and to derive a strategy across different WGs, increasing the visibility of HE projects in this context. Use-cases and requirements; new mechanisms; and interoperability are relevant aspects that can be positioned across the full IoT spectrum.
- During the design of use-cases, it is also important to consider pre-standardisation entities, such as the **IRTF**. Contributions derived from current projects seem not to be available yet; the IRTF also proportionate the creation of **new research groups**, which can therefore assist in developing and disseminating better the research being developed in RIAs.
- Open-source and open standards contributions can also be positioned in open-source related fora, such as **AIOTI, BDVA, Gaia-X**.
- The different stages of work can be positioned across fora (**dissemination and feedback in specific domains**); pre-standardisation (**technology vision and influencing**); and then in SDOs. The innovation plans should consider these three categories of entities.

7 CONCLUSIONS

The EU-IoT Deliverable D3.8 provides a set of recommendations towards a stronger application of European research contributions across SDOs, having for these defined specific scopes (derived from knowledge areas) and key standards.

The deliverable, of which [the EU-IoT standardisation catalogue tool](#) is an integrated part, provides also a helper for SDO contributions, aiming at assisting current and future projects with information on key standardisation entities and initiatives that focus on IoT and Edge computing.

The main contributions in this deliverable can be summarised as follows:

- The analysis conducted concerning SDOs shows that there is a high level of fragmentation in terms of SDOs and standards focusing on IoT, creating issues in terms of interoperability (rf. to section 3).
- The relevant SDOs for IoT and Edge have a focus articulated across multiple domains (rf to section 4); in manufacturing, relevant SDOs such as OPC are single domain.
- The active ICT-56 RIAs have been providing relevant research contributions across key SDOs, namely, 3GPP, ETSI, IEEE, ITU-T, and covering research contributions across the full end-to-end IoT spectrum (interfaces, far and near edge; infrastructure; data spaces).
- A good level of monitoring towards CEN-CENELEC, IEC, ISO, IETF, is also provided in current projects.
- Future projects should consider targeting in a stronger way open standards entities such as the IETF, where different groups facilitate entrance of projects.
- Future projects should consider innovation strategies that take into consideration, based on the different stages of research development, standardisation fora and pre-standardisation, in addition to SDOs.



ANNEX I

EU-IoT standardisation catalogue (StandardisationOPenSourceList2023.xls), also available online at: <https://www.ngiot.eu/archive-standardisation-bodies/>



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