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INTERNET OF THINGS (IoT) – REFERENCE ARCHITECTURE

FOREWORD

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ISO/IEC 30141 has been prepared by subcommittee 41: Internet of Things and Digital Twin, of ISO/IEC joint technical committee 1: Information technology. It is an International Standard.

This second edition cancels and replaces the first edition published in 2018. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) conformance with ISO/IEC/IEEE 42010:2022;
b) improved usability;
c) implementation pattern support.

The text of this International Standard is based on the following documents:

Draft	Report on voting
JTC1-SC41/417/FDIS	JTC1-SC41/431/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1, and the ISO/IEC Directives, JTC 1 Supplement available at www.iec.ch/members_experts/refdocs and www.iso.org/directives.

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INTRODUCTION

0.1 General

This document is the second edition of the Internet of Things reference architecture (IoT RA). This document is in conformance with ISO/IEC/IEEE 42010:2022 requirements on architecture descriptions that are described in Annex B except for aspects, perspectives, decisions and rationale.

The IoT RA addresses systems that:

- use technology for sensing and operating on physical world entities;
- have components that interact through a digital network.

The IoT RA deals with related issues, like trustworthiness functions regarding both the physical and digital worlds.

This document can be used as a generic normative part of IoT domain-specific reference architectures (DSRAs). IoT DSRAs are in conformance with ISO/IEC/IEEE 42010:2022 requirements on architecture descriptions and enable consistency and alignment with other reference architectures within ISO/IEC JTC 1.

0.2 About Internet of Things (IoT)

IoT has broad implications in industry and society today and is likely to continue to have an impact on many aspects of our lives for many years to come. Various IoT applications and services have adopted IoT techniques to provide capabilities that were not possible earlier. IoT is one of the most dynamic areas of information and communication technologies.

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Fundamental to IoT are devices that interact with the physical world. Sensors collect the information about the physical world, while actuators can act upon the physical world. These field devices are connected to the digital world through network connections. Both sensors and actuators can be in many forms such as thermometers, accelerometers, video cameras, microphones, relays, heaters or industrial equipment for manufacturing or process control.

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IoT is the base for new business models or offerings and new working methods in industry and in the public sector. IoT is an essential enabler for other computing areas such as digital twins, artificial intelligence, cloud computing, big data, data analysis and more. Many application areas called "smart xxx" such as smart grid, smart cities, and even smart cars use IoT as an important technology capability.

IoT can be combined with other technologies to address complex requirements. For example, IoT can leverage cloud computing, including private cloud, public cloud, hybrid cloud, and multi-cloud, for resource provisioning and management. IoT can benefit from machine learning and big data for the analysis of sensor data to enable rapid decisions for improved control and efficiency. IoT with distributed ledger technology can ensure traceability in applications. IoT can take advantage of edge computing to distribute computing resources near the convergence of information technology and operational technology, where they are needed most. The IoT area continues to grow rapidly, and new IoT application areas continue to be found and invented. This document can serve these new technology and application areas.

0.3 IoT sources of information

For a given application field and purpose, the many IoT standards, guidelines, and initiatives in existence today work well on their own and are used by various IoT stakeholders. As a result, heterogeneity is a prominent aspect of IoT. However, support for the combination and interaction of these heterogeneous resources to enable interoperability and convergence between IoT standards and guidelines is necessary.

Stakeholder decisions about both a foundation for long-term investments and durable protection of current cornerstones is more difficult because of uncertainty about resource compatibility.

This document serves as a foundation for creating interoperability and alignment between IoT initiatives. The aim of this document is to bring different views together.

0.4 General principles of a reference architecture

This document is positioned as a reference architecture for IoT systems. It utilizes the terms, definitions, and relationships for best practices in architecture descriptions as outlined in ISO/IEC/IEEE 42010:2022 to:

- establish vocabulary, principles, guidance; and
- provide a description of IoT principles, capabilities, and interactions with the physical and digital worlds.

One of the primary purposes of the IoT RA is to support architects that want to design architectures or reference architectures for IoT systems. Normative parts of the IoT RA can then be included in an architecture closer to the realization of IoT systems.

Figure 1 shows how this document has been specified and how it will be used.

– This document conforms to ISO/IEC/IEEE 42010:2022 requirements for architecture descriptions [1][1] and uses guidelines from the "Best practices and guidelines for RA standards" standing document [2].

– Users of this document apply it to specify an IoT architecture that guides the implementation of an IoT system.

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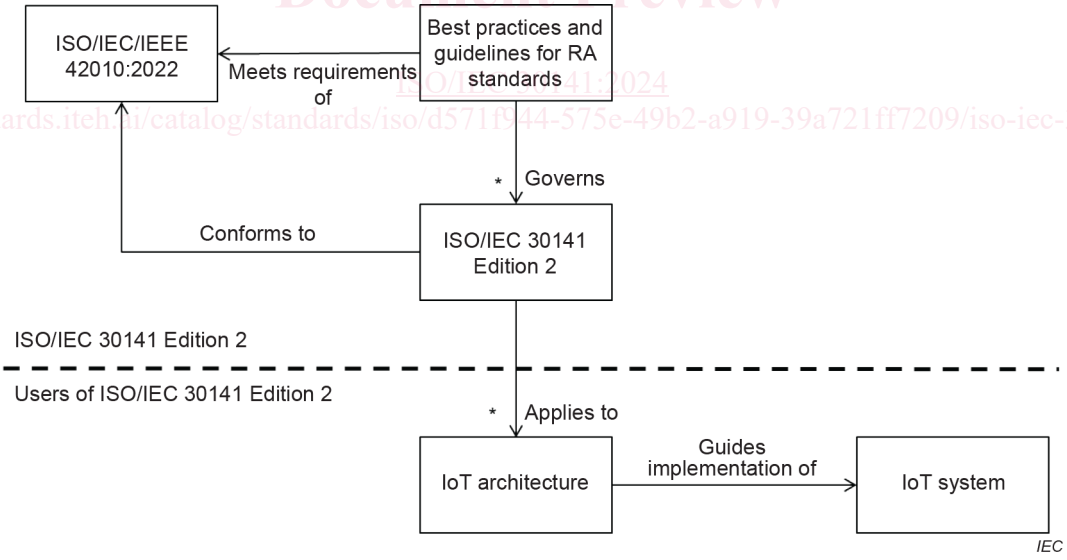

Figure 1 – Using the IoT RA standard

[1] Numbers in square brackets refer to the Bibliography.

INTERNET OF THINGS (IoT) – REFERENCE ARCHITECTURE

1 Scope

This document specifies an Internet of Things (IoT) reference architecture (IoT RA). The IoT RA is a generalization of existing practice including the distinguishing characteristics of IoT systems and other fundamental characteristics exhibited by IoT systems. The IoT RA addresses stakeholder concerns related to the business value of IoT systems. The IoT RA also addresses the interactions between the IoT system, the users, and the physical environment. Implementation of IoT systems is also addressed in this document. Among the characteristics specified in the IoT RA are abstract functions within IoT systems and a variety of structures that are used to construct IoT systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 20924, *Internet of Things (IoT) and digital twin – Vocabulary*

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 20924 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

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- ISO Online browsing platform: available at https://www.iso.org/obp
- IEC Electropedia: available at https://www.electropedia.org

4 Abbreviated terms

AI	artificial intelligence
API	application programming interface
ASD	application and service domain
BSS	business support systems
CM	conceptual model
CPS	cyber physical system
CPO	chief privacy officer
DPO	data protection officer
DSC	dynamic service composition
DSRA	domain specific reference architecture
ETL	extract, transform, load
HMI	human machine interface
HTTP	Hypertext Transfer Protocol
ICT	information and communication technologies

IoT	Internet of Things
IT	information technology
LAN	local area network
LoB	line of business
OMD	operation and management domain
OSS	operational support systems
OT	operational technology
PED	physical entity domain
PII	personally identifiable information
RA	reference architecture
RAID	resource access and interchange domain
SCD	sensing and controlling domain

5 IoT RA context

5.1 Overview

This document specifies a reference architecture for the Internet of Things using the ISO/IEC/IEEE 42010:2022 requirements for architecture descriptions. While this document is intended to be used in many situations and by many different stakeholders, the focus is on the needs of architecture developers of an IoT system description, their perspectives, concerns, and the architecture views they most likely encounter. In particular, it focuses on those involved in creating a specific IoT reference or solution architecture that depends on IoT.

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This document is interesting and educational for anyone with interest in IoT. However, the document is of special interest for those people looking to:

- harmonize standards or reference architectures of other IT and OT domains with this generic IoT RA;
- develop either IoT software, or IoT hardware, or both;
- provide services involving IoT;
- procure or implement IoT systems;
- integrate IoT with other IT technology.

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For all the interests mentioned above, applying parts of this document to develop or implement IoT domain-specific architecture (DSRA) is a useful approach. These descriptions can be either standalone or integrated with other IoT related architecture descriptions.

Further, depending on the interest, different sections of the document have more relevancy. While some parts provide an overview, some parts provide more information regarding different aspects of IoT.

This document can also be used as normative reference in a DSRA. The document can then serve as a base for the IoT part of that DSRA, leaving application concerns, use cases and so forth to the DSRA. The DSRA can specify how the IoT RA is intended to be used for the specific domain. A DSRA can also specify conformance to parts of this document.

This document conforms to ISO/IEC/IEEE 42010:2022 requirements on architecture descriptions [1], which is described in Annex B. This ensures that the IoT RA aligns with other RAs that conform to ISO/IEC/IEEE 42010:2022 requirements on architecture descriptions. The IoT RA is intended to be used with one or more architecture description frameworks (in accordance with ISO/IEC/IEEE 42010:2022) to create an architecture description for a system of interest.

ISO/IEC/IEEE 42010:2022 provides terms, definitions, and relationships for best practices in architecture descriptions of the architecture of a system of interest. Consequently, all conforming architecture descriptions can be interpreted in a consistent way. Conformance to ISO/IEC/IEEE 42010:2022 requirements for architecture descriptions makes this document a vital part of a cohesive family of standards, including those standards dealing with interoperability.

5.2 Stakeholders and concerns

Table 1 shows a list of viewpoints, stakeholders, and concerns.

Table 1 – List of viewpoints, stakeholders, and concerns

Viewpoint	Stakeholders	Concerns
Foundational IoT viewpoint	– Architect – Project manager – Programme manager – Standards expert – People concerned with the fundamentals of IoT – Domain experts – Business manager – System owner	What is IoT? What are the essential characteristics of IoT systems? What is new (and different) about the concept of IoT? Is a given system or component an IoT system or component? What are the implications of the concept of IoT?
Business viewpoint	– Business manager – System owner – Architect	How to leverage the various capabilities of an IoT system to provide value for a business? How to use IoT for innovative new business models? How do characteristics of an IoT system influence business and system owner?
Usage viewpoint	– System architect – Project manager	How do users (both human and digital) interact with the IoT system? How does the IoT system interact with the physical entity of interest?
Functional viewpoint	– Architect – Project manager – Programme manager – IoT standards expert – Business manager – System owner	What are the types of abstract functions that need to be implemented in an IoT system?
Trustworthiness viewpoint	– System architect – Security engineer – Security manager – Privacy manager – Project manager – Business manager	How to design an IoT system with a level of confidence that meets trustworthiness goals. How to assure the implemented system meets design goals.
Construction viewpoint	– System architect – Project manager – System designer	What types of design are useful when creating an IoT system to meet a given set of requirements? What types of design are useful when creating an IoT component to meet a given set of requirements?

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6 IoT RA viewpoints and views

6.1 Overview

The essence of an architecture description lies in the architecture views that it provides. Each view is governed by a corresponding viewpoint. The developers and professional practitioners who are charged with elaboration of the architecture description can adopt the architecture views provided in this document. The different architecture views result from modelling and narrative descriptive activities of the architecting effort.

An architecture viewpoint states relevant information focusing on a particular topic. This information is a collection of concerns, often expressed in use cases, stakeholders provide about the constructed artefacts that they believe are important to the topic. Viewpoints specify the architecture view or views it governs. The architecture viewpoint also identifies modelling or narrative paradigms for generating the architecture view or views.

This document specifies six architecture views and their governing viewpoints:

– an IoT foundational viewpoint in 6.2;
– a business viewpoint in 6.3;
– a usage viewpoint in 6.4;
– a functional viewpoint in 6.5;
– a trustworthiness viewpoint in 6.6;
– a construction viewpoint in 6.7.

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Subclause 6.2 presents the foundational IoT viewpoint and the corresponding view which frames the concerns related to the essential characteristics of IoT. The viewpoint addresses concerns related to the fundamental aspects of IoT by specifying the foundational building blocks of IoT enabled systems as architecture views. These views represent the different concepts related to IoT (for example: principles, devices, and connectivity).

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Subclause 6.3 presents the business viewpoint and the corresponding view.

Subclause 6.4 presents the usage viewpoint and the corresponding view.

Subclause 6.5 presents the functional viewpoint and the corresponding functional views that describe the IoT reference architecture from the perspective of key functions. The viewpoint addresses concerns related to the fundamental functional aspects of IoT by specifying the foundational building blocks of IoT enabled systems as architecture views. These views represent the functional capabilities of IoT related data, management, communication, interfaces, etc.

Subclause 6.6 presents the trustworthiness viewpoint and provides means for implementing a trust model to consider when creating an IoT product or solution.

Subclause 6.7 presents the construction viewpoint and the corresponding construction views that describe the IoT reference architecture from the perspective of implementation architectures. The viewpoint addresses concerns related to the fundamental implementation aspects of IoT by specifying the different patterns as architecture views. Examples of patterns described in this document include the IoT component capability, the RAMI4.0, the IoT user, the IoT enterprise system, the enterprise networking, and the IoT enterprise usage patterns.