ISO/IEC 21823-4

Edition 1.0 2022-03

INTERNATIONAL STANDARD

Internet of things (IoT) – Interoperability for IoT systems – Part 4: Syntactic interoperability

colour inside

ISO/IEC 21823-4:2022-03(en)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

ISO/IEC 21823-4

Edition 1.0 2022-03

INTERNATIONAL STANDARD

Internet of things (IoT) – Interoperability for IoT systems – Part 4: Syntactic interoperability

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 33.020

ISBN 978-2-8322-1083-4

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNET OF THINGS (IoT) –
INTEROPERABILITY FOR IoT SYSTEMS –

Part 4: Syntactic interoperability

FOREWORD

1) ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.
2) The formal decisions or agreements of IEC and ISO on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC and ISO National bodies.
3) IEC and ISO documents have the form of recommendations for international use and are accepted by IEC and ISO National bodies in that sense. While all reasonable efforts are made to ensure that the technical content of IEC and ISO documents is accurate, IEC and ISO cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC and ISO National bodies undertake to apply IEC and ISO documents transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC and ISO document and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC and ISO do not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC and ISO marks of conformity. IEC and ISO are not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this document.
7) No liability shall attach to IEC and ISO or their directors, employees, servants or agents including individual experts and members of its technical committees and IEC and ISO National bodies for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this ISO/IEC document or any other IEC and ISO documents.
8) Attention is drawn to the Normative references cited in this document. Use of the referenced publications is indispensable for the correct application of this document.
9) Attention is drawn to the possibility that some of the elements of this ISO/IEC document may be the subject of patent rights. IEC and ISO shall not be held responsible for identifying any or all such patent rights.

ISO/IEC 21823-4 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.

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

Draft	Report on voting
JTC1-SC41/255/FDIS	JTC1-SC41/269/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 ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs and www.iso.org/directives.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

In the world of the Internet of Things (IoT), heterogeneous systems and devices need to be connected and exchange data with others. How data exchange can be implemented becomes a key issue of interoperability among IoT industries. Information models (IMs), which can well represent specifications of data, are adopted and utilized to solve the interoperability problem. Meanwhile, as systems and devices in IoT can have different information models with different modelling methodologies and formats, interoperability based on different information models is recognized as an urgent problem. The IoT interoperability related systems and applications have an 11 trillion market potentially [1][1].

The ISO/IEC 21823 series standards address issues that relate to interoperability both between different IoT systems and within a single IoT system. ISO/IEC 21823-1 [2] describes a general framework for interoperability for IoT systems. It includes a five facet model for interoperability that includes transport, syntactic, semantic, behavioural, and policy viewpoints.

Different parts of ISO/IEC 21823, based on one of the facets, provide specifications from their corresponding viewpoints. Each of the parts can refer to others but is independent. Currently, ISO/IEC 21823-2 [3] defines specifications from the transport viewpoint, ISO/IEC 21823-3 [4] defines requirements, provides guidance, etc. from the semantic viewpoint, and ISO/IEC 21823-4 specifies the syntactic interoperability.

Syntactic interoperability means that exchanged information can be understood by the participating IoT systems which contain IoT devices. In more detail, the syntactic interoperability is related to the information models' representing formats, structures, and grammar of their modelling languages such as a length of a data string, constraints on data types, and forbidden characters.

This document first provides the principle of how to achieve syntactic interoperability based on metamodel-driven approaches. In other words, the reason why the information exchange rules based on metamodels can support syntactic interoperability among different IoT systems will be elaborated. Secondly, requirements on information models such as metamodels and models of IoT systems including IoT devices are described. Features related to IoT devices such as the identifier, device type, setup environments, and functions need to be considered to accomplish syntactic interoperability among different information models utilized in IoT systems. Thirdly, a framework for processes on developing information exchange rules related to IoT devices from the syntactic viewpoint is provided. For example, the kinds of metamodels, and the types of entities and relationships that shall be selected are specified, and the procedure of how to build the information exchange rules from different information models is provided.

In Annex A, possible intrinsic and extrinsic properties of IoT devices are listed as additional information of Clause 6. In Annex B, a use case of how the syntactic interoperability in accordance with specifications in this document among industrial IoT systems and IoT devices is described.

With this document, system and device vendors, who need to improve and/or develop their products to comply with IoT requirements, can implement specifications of this document to their products for an automatic or semi-automatic realization of IoT syntactic interoperability.

1 Numbers in square brackets refer to the Bibliography.

INTERNET OF THINGS (IoT) –
INTEROPERABILITY FOR IoT SYSTEMS –

Part 4: Syntactic interoperability

1 Scope

This part of ISO/IEC 21823 specifies the IoT interoperability from a syntactic point of view. In this document, the following specifications for IoT interoperability from a syntactic viewpoint are included:

– a principle of how to achieve syntactic interoperability among IoT systems which include IoT devices;

– requirements on information related to IoT devices for syntactic interoperability;

– a framework for processes on developing information exchange rules related to IoT devices from the syntactic viewpoint.

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) – Vocabulary*

3 Terms and definitions

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

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

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

3.1
instance
individual entity having its own value and possibly its own identity

[SOURCE: ISO 19103:2015 [5], 4.20]

3.2
metamodel
special kind of model that specifies the abstract syntax of a modelling language

Note 1 to entry: A model is an *instance* (3.1) of a metamodel

Note 2 to entry: IoT syntactic interoperability is achieved by information exchange rules through the structure, data format, and syntactic constraints using syntactic aspects of the metamodel.

[SOURCE: ISO/IEC 19506:2012 [6], modified – The description that follows the definition has been deleted. Notes to entry have been added.]

3.3
model
abstraction of some aspects of reality

[SOURCE: ISO 19109:2015 [7], 4.15]

3.4
property
particular characteristic of an object type

[SOURCE: ISO 16484-5:2017 [8], 3.2.74]

3.5
syntactic interoperability
interoperability such that the formats of the exchanged information can be understood by the participating systems

Note 1 to entry: System means IoT system.

Note 2 to entry: IoT device, IoT gateway, sensor and actuator are considered as system.

[SOURCE: ISO/IEC 19941:2017 [9], 3.1.4, modified – Notes to entry have been added.]

4 Abbreviated terms

CRS	coordinate reference system
EPIoT	extrinsic properties of physical IoT devices
IPIoT	intrinsic properties of physical IoT devices
IoT	Internet of Things
JSON	JavaScript Object Notation
MOF	Meta Object Facility
UML	Unified Modelling Language
XML	extensible markup language

5 Principle for IoT syntactic interoperability

5.1 General

In the ISO/IEC 21823 series, ISO/IEC 21823-1 [2] defines an overall framework for IoT interoperability. It specifies that IoT interoperability shall be supported by standards from five facets: transport, semantic, syntactic, behavioural, and policy. A standard based on each of the facets shall provide specifications from its corresponding viewpoint. Each of the standards can refer to or can be independent of standards based on other facets. ISO/IEC 21823-2 [3] defines specifications from the transport viewpoint. ISO/IEC 21823-3 [4] defines requirements, provides guidance, etc. from the semantic aspect. ISO/IEC 21823-4 (this document) addresses the syntactic interoperability that provides specifications from the syntax viewpoint.

5.2 Principle for IoT syntactic interoperability

In this subclause, a principle for IoT syntactic interoperability is specified. In order for an IoT system to achieve syntactic interoperability with other IoT systems and devices, the information exchange rules between their data are adopted.

The information exchange rules for syntactic interoperability provide the following types of information exchange.

a) Format exchange.

   – The term "format" is bound for a data format.

   – The "format exchange" means that information in different data formats can be exchanged.

   For example, data in the UML format can be exchanged with data in the XML format.

b) Structure exchange.

   – The term "structure" is bound for a data structure that has a hierarchy and branches.

   – The "structure exchange" means that information in different structures can be exchanged.

   For example, information defined in a hierarchical tree structure can be transformed into a flat tree structure.

c) Syntactic constraint exchange.

   – The term "constraint" is a condition related to syntax or syntactic requirements on data.

   – The "syntactic constraint exchange" means that information with different constraints can be exchanged.

   For example, data in IoT System1 have a value of one digit after the decimal point, and data in IoT System2 have a value of two digits after the decimal point. Their data accuracy exchange is classified into syntactic constraint exchange.

Furthermore, information of IoT systems is expressed with models. In each IoT system, its information can be represented with a metamodel, models, and instances [10]. In order to describe information exchange rules between IoT systems for their syntactic interoperability, syntactic aspects in their metamodels and models are utilized. In addition, specific requirements for metamodels, models, and information exchanges in the IoT domain are included in this document.

5.3 Relevant technologies for syntactic interoperability

5.3.1 Metamodel and syntactic interoperability

A metamodel, as the model's model, consists of statements about models. Especially in the UML as described in [10], the metamodel specifies the abstract syntax of the UML. The abstract syntax defines the set of UML modelling concepts, attributes, relationships as well as rules for combining concepts to construct partial UML models.

There are also other definitions for metamodel in ISO/IEC and IEEE standards. Some of them are listed in Table C.1 in Annex C. Several metamodel definitions in different resources are collected in ISO/IEC/IEEE 24765:2017 [11]. In this document, Definition 7 of metamodel in Table C.1, i.e. "special kind of model that specifies the abstract syntax of a modelling language", is adopted. From this definition, it is clear that an approach of creating information exchange rules with elements available in metamodels is actually based on the syntax and therefore is acceptable for syntactical interoperability. UML, OWL (Ontology Language), OntoML (Ontology Markup Language [12]), XML, etc. are modelling languages adopted and utilized in different systems and domains.

5.3.2 Metamodel-driven approaches supporting interoperability issues

Metamodel-driven information exchange and interoperability approaches are adopted as holistic approaches in industry domains [13], [14] to enable a model-driven engineering approach in the area of information integration and interoperation. By creating declarative mapping specifications, i.e. exchange rules, automatic information exchange can be executed at run-time and off-line among heterogeneous systems and devices. As the metamodel-driven approaches tackle the interoperability problems at a higher abstraction level than models, it can increase the efficiency of achieving interoperability among heterogeneous systems and devices which comply with the same metamodel. In other words, information exchange rules can be reused by IoT systems and IoT devices whose information models are in compliance with the same metamodel.

5.4 The overall structure of the proposed approach

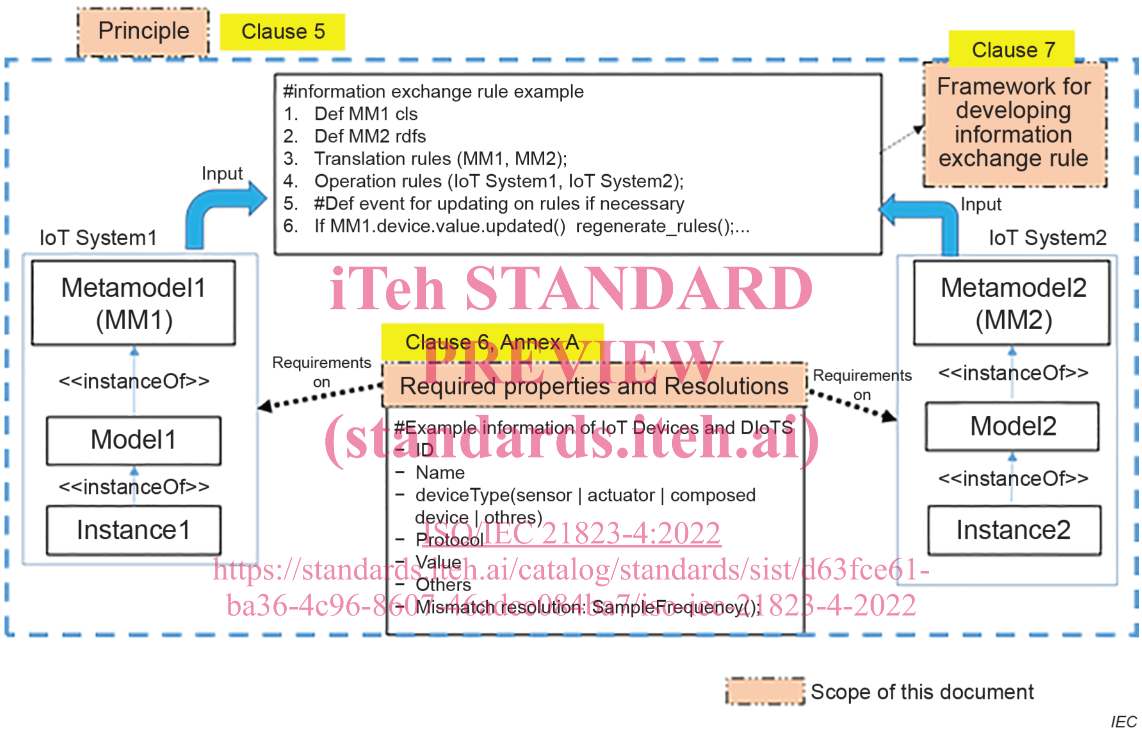


Figure 1 – The overall structure of the proposed approach

Figure 1 illustrates the overall structure of the proposed approach. Figure 1 shows two IoT systems: IoT System1 and IoT System2. In each IoT system, its information consists of a metamodel, model, and instance data. In order to achieve syntactic interoperability between these two systems, the information exchange rules based on the metamodels of both IoT systems need to be created. To create information exchange rules, their required properties and resolutions to support executing information exchange need to be analysed and defined.

In Figure 1:

– lines starting with "#" denote comment lines;

– in the text box of "information exchange rule example", sample information for syntactic interoperability is listed;

– in the text box of "required properties and resolutions", example properties and syntactic resolution for mismatch are listed.

In this document, three major clauses are specified to support achieving IoT syntactic interoperability.

a) In Clause 5, relevant technologies of the metamodel and their applicability in the area of solving syntactical interoperability issues are explained. The methodology of how to create information exchange rules among heterogeneous IoT systems and devices is specified. The information exchange rules are in general categorized into two groups:

   1) translation rules that specify transformations among elements in metamodels. Details are in 5.6;

   2) operation rules that specify mismatches between IoT systems. Details are in 6.3.

b) In Clause 6, requirements on IoT-related information are specified. Requirements include:

   1) firstly, the required properties related to IoT devices for translation rules (specified in 6.2). For example, an identifier of an IoT system or an IoT device is a required property;

   2) secondly, the required properties and resolutions for mismatches between IoT systems for operation rules. Mismatches occur during information exchange between IoT systems. Resolutions are required to resolve these mismatches. For example, if the time interval requesting information exchange is different, i.e. not matched in involved IoT systems for their interoperability, then syntactic resolutions are required to fill up this mismatch. Required properties and resolutions for mismatches are analysed and described in 6.3.

c) In Clause 7, a framework of how to create information exchange rules is specified. The necessary procedures to realize the IoT syntactic interoperability following the proposed approach are defined. Whether it is necessary to create or extend an IoT system's metamodel, what kinds of information exchange rules are defined, and how exchange rules can be executed and evaluated are also described.

5.5 The methodology of metamodel-driven information exchange

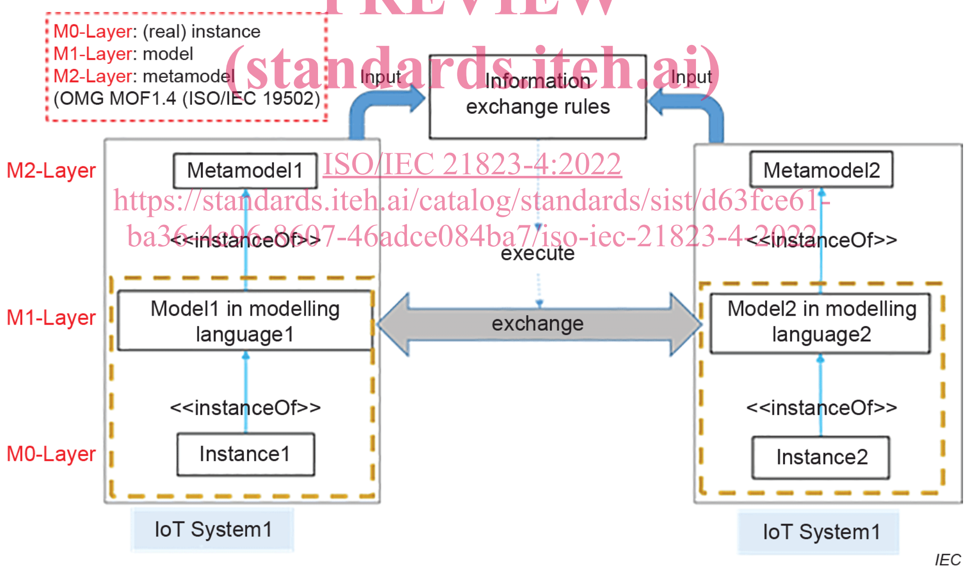


Figure 2 – Model hierarchies and metamodel-driven information exchange rules

During the last decades, in the field of model-based engineering (MBE), models have been constructed to represent information from the physical world. The community of OMG proposes MOF (ISO/IEC 19502 [15]), a four-layer modelling architecture to describe models. Models here in general include the instance in M0-Layer, the model in M1-Layer, the metamodel in M2-Layer, and the meta-metamodel in M3-Layer. M3-Layer is not included in this document thus it is omitted from Figure 2.

As shown in Figure 2, the model in M1-Layer defines structures, available entities, relationships, etc. for instances in M0-Layer, and the metamodel in M2-Layer specifies the syntax for the models. Therefore, models in M1-Layer are the instances of their metamodel in M2-Layer, i.e. M1-Layer has relationships with M2-Layer as "<<instanceOf>>". And the same relationships exist between M0-Layer and M1-Layer. Each metamodel can have many models and each model can have many instances. In Figure 2, Model1 in IoT System1 is the model of Instance1, and Metamodel1 is the metamodel of Model1. Model2 and Metamodel2 in IoT System2 have the same relationships.

From the syntactic point of view, information exchange rules as projections allow converting information in all layers from a specific system to information in another system in a modelling environment. The information exchange rules based on metamodels in M2-Layer are applicable to the transformation of models in M1-Layer [15][16] because the information in M1-Layer is defined with elements available in M2-Layer. The same relationships are applicable to M1-Layer and M0-Layer. Therefore, the metamodel-based information exchange rules are applicable to its models and instances.

5.6 Information exchange rules

5.6.1 Categories of information exchange rules

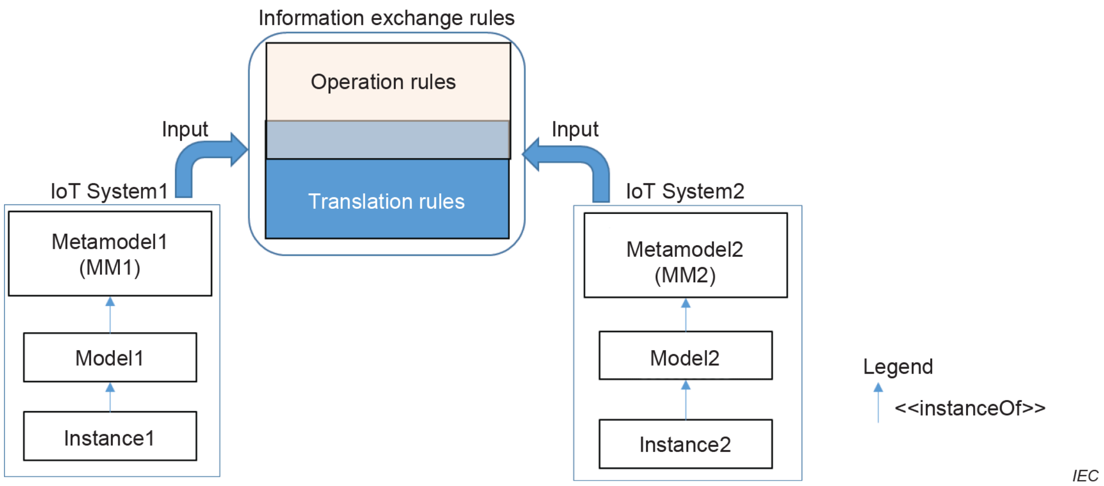
As explained in 5.2 and 5.5, for an IoT system including IoT devices (IoT System1), in order to achieve syntactic interoperability with other IoT systems and devices (IoT System2), information exchange rules are adopted. Figure 3 shows that the information exchange rules can be classified into two categories.

– Translation rules

  Translation rules are created with elements in the metamodels of IoT System1 and IoT System2. Elements in the metamodels are classes, properties, relationships, etc. Transformation rules among these elements are defined and named "translation rules" in order to achieve structure, data format, and syntactic constraints transformations between IoT systems. Required properties for translation rules are specified in 6.2.

– Operation rules

  Operation rules are specified to resolve mismatches between two IoT systems. Potential operational mismatches that happen during processes of achieving interoperability are detected. To solve these mismatches, necessary properties and available resolutions are specified. Mismatches that cannot be resolved from syntactic viewpoints are out of the scope. Simultaneously, resolutions not based on syntactic approaches for mismatches are also out of the scope. Details of the operation rules are specified in 6.3.



The overlapped area includes properties used both in translation rules and operation rules.

Figure 3 – Categories of information exchange rules