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Part 4: Syntactic interoperability

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## Introduction

This draft standard is based on international discussions in which the UK has taken an active part. Your comments on this draft are welcome and will assist in the preparation of the consequent standard. There is a high probability that this text could be adopted by CENELEC as a reference document for harmonization or as a European Standard. Recipients of this draft are requested to comment on the text bearing in mind this possibility.

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| 1  | 2                                             | (3)                                 | 4               | 5                                                                                                                                  | (6)                                                                      | (7)                                                |
|----|-----------------------------------------------|-------------------------------------|-----------------|------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|----------------------------------------------------|
| MB | Clause No./ Subclause No./Annex<br>(e.g. 3.1) | Paragraph/<br>Figure/<br>Table/Note | Type of comment | Comment (justification for change) by the MB                                                                                       | Proposed change by the MB                                                | Secretariat observations on each comment submitted |
|    | 3.1                                           | Definition 1                        | ed              | Definition is ambiguous and needs clarifying.                                                                                      | Amend to read '...so that the mains connector to which no connection...' |                                                    |
|    | 6.4                                           | Paragraph 2                         | te              | The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK. | Delete reference to UV photometer.                                       |                                                    |



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OF INTEREST TO THE FOLLOWING COMMITTEES:

SC 3D,TC 65,TC 100,SyC AAL

PROPOSED HORIZONTAL STANDARD:



Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.

FUNCTIONS CONCERNED:

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☐ ENVIRONMENT

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TITLE:

**Internet of Things (IoT) - Interoperability for Internet of Things Systems –Part 4:  
Syntactic interoperability**

NOTE FROM TC/SC OFFICERS:

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# INTERNET OF THINGS — INTEROPERABILITY FOR INTERNET OF THINGS SYSTEMS- PART 4: SYNTACTIC INTEROPERABILITY

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- This International Standard has been approved by vote of the member bodies, and the voting results may be obtained from the address given on the second title page.
- This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.
- The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be
- reconfirmed,
  - withdrawn,
  - replaced by a revised edition, or
  - amended.

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## INTRODUCTION

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

107 The series of ISO/IEC 21823 standards addresses issues that relate to interoperability both  
108 between different IoT systems and within a single IoT system. ISO/IEC 21823-1 [2] describes  
109 a general framework for interoperability for IoT systems. This includes a five facet model for  
110 interoperability which includes transport, syntactic, semantic, behavioural and policy.

111 A standard based on each of the facet shall provide specifications from its corresponding  
112 viewpoint for the IoT interoperability, each of the standard can refer to others but must be  
113 independent. Currently ISO/IEC 21823-2 [3] defines specifications from transport viewpoint.  
114 ISO/IEC 21823-3 [4] defines necessary requirements etc. from the semantic aspect. This  
115 ISO/IEC 21823-4 specifies the syntactic interoperability.

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

120 This part of standard at first provides the principle of how to achieve syntactic interoperability  
121 based on metamodel driven approaches. i.e., why the information exchange rules based on  
122 metamodels can support syntactic interoperability among different IoT systems will be  
123 elaborated. Secondly, requirements on information models such as metamodels and models  
124 of IoT Systems including IoT devices are described. Features related to IoT devices such as  
125 the identifier, device type, setup environments and functions need to be considered to  
126 accomplish syntactic interoperability among different information models utilized in IoT  
127 systems. Thirdly, a framework for processes on developing information exchange rules  
128 related to IoT devices from the syntactic viewpoint is provided. For example, what kinds of  
129 metamodels, what types of entities and relationships shall be selected are specified, and the  
130 procedure of how to build the information exchange rules from different information models  
131 are provided.

132 In Annex A, possible intrinsic and extrinsic properties of IoT devices are listed as informative  
133 information of Clause 6. In Annex B, use cases of how the syntactic interoperability according  
134 to specifications in this document among industrial IoT systems and IoT devices will be  
135 described.

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

139

# INTERNET OF THINGS — INTEROPERABILITY FOR INTERNET OF THINGS SYSTEMS- PART 4: SYNTACTIC INTEROPERABILITY

## 1 Scope

This part of standard specifies the IoT interoperability from a syntactic point of view. In ISO/IEC 21823-1: Framework [2], five facets are described for IoT interoperability, i.e. transport, semantic, syntactic, behavioural and policy. In this document, the following specifications for IoT interoperability from 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

There are no normative references in this document.

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following 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(en)]

### 3.2

#### Metamodel

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

[Source: ISO/IEC 19506:2012 Information technology — Object Management Group Architecture-Driven Modernization (ADM) — Knowledge Discovery Meta-Model (KDM), 4]

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

### 3.3

#### Model

abstraction of some aspects of reality

[SOURCE: ISO 19109:2015, 4.15]

### 3.4

#### **Syntactic interoperability**

Interoperability such that the formats of the exchanged information can be understood by the participating systems

SOURCE: ISO/IEC 19941:2017, 3.1.4

Note 1 to entry: System means IoT system

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

## **4 Symbols (and abbreviated terms)**

For the purposes of this International Standard, the following abbreviations apply.

EPIoT      Extrinsic properties of physical IoT devices.

IPIoT      Intrinsic properties of physical IoT devices.

IoT      Internet of Things

JSON-LD      JavaScript Object Notation for Linking Data

UML      Unified Modelling Language

MOF      Meta-Object Facility (MOF)

## **5 Principle for IoT syntactic interoperability**

### **5.1 General**

In this clause, a principle for syntactic interoperability is specified. The applicability and availability of metamodel driven approaches for IoT syntactic interoperability are described. Furthermore, how information exchange rules can be created based on metamodels of IoT systems are also described.

### **5.2 Background**

#### **5.2.1 Relationships to standards from other facets of IoT interoperability**

In the series of ISO/IEC 21823, 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, which are transport, semantic, syntactic, behavioural and policy. A standard based on each of the facet shall provide specifications from its corresponding viewpoint. And each of the standard can refer to or can be independent from standards basing on other facets. ISO/IEC 21823-2 [3] defines specifications from transport viewpoint. ISO/IEC 21823-3 [4] defines necessary requirements etc. from the semantic aspect. This ISO/IEC 21823-4 addresses the syntactic interoperability which provides specifications from the syntax viewpoint.

#### **5.2.2 Metamodel and syntactic interoperability**

A metamodel, as the model's model, is described in [5] to specify the abstract syntax of the UML. The abstract syntax defines the set of UML modelling concepts, attributes, relationships and rules for combining concepts to construct partial UML models. In [5], "A formal definition of a common MOF-based metamodel that specifies the abstract syntax of the UML. The abstract syntax defines the set of UML modelling concepts, their attributes and their relationships, as well as the rules for combining these concepts to construct partial or complete UML models.

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**Table 1 Definitions of metamodel in various resources**

|   | Definition                                                                                                                                                                                                  | Resource                                                                                                                                                     |
|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 | model that specifies one or more other models                                                                                                                                                               | ISO/IEC 11179-3:2013(en), 3.2.80                                                                                                                             |
| 2 | logical information model that specifies the modelling elements used within another (or the same) modelling notation                                                                                        | IEEE 1175.1-2002 (R2007) IEEE Guide for CASE Tool Interconnections-Classification and Description, 3.8                                                       |
| 3 | metamodel Vm for a subset of IDEFobject is a view of the constructs in the subset that is expressed using those constructs such that there exists a valid instance of Vm that is a description of Vm itself | IEEE 1320.2-1998 (R2004) IEEE Standard for Conceptual Modelling Language Syntax and Semantics for IDEF1X97 (IDEFobject), 3.1.111                             |
| 4 | model containing detailed definitions of the meta-entities, meta-relationships and meta-attributes whose instances appear in the model section of a CDIF transfer                                           | ISO/IEC 15474-1:2002 Information technology — CDIF framework — Part 1: Overview, 4.2                                                                         |
| 5 | specification of the concepts, relationships and rules that are used to define a methodology                                                                                                                | [ISO/IEC 24744:2014 Software Engineering — Metamodel for development methodologies, 3.4                                                                      |
| 6 | model defining the concepts and their relations for some modelling notation                                                                                                                                 | ISO/IEC 15909-2:2011 Software and system engineering — High-level Petri nets — Part 2: Transfer format, 4.1.6                                                |
| 7 | special kind of model that specifies the abstract syntax of a modeling language                                                                                                                             | <i>ISO/IEC 19506:2012 Information technology — Object Management Group Architecture-Driven Modernization (ADM) — Knowledge Discovery Meta-Model (KDM), 4</i> |

229

230 There are also other definitions for metamodel in the standard world. Some of them are listed  
 231 in Table 1 as concluded in the “ISO/IEC/IEEE 24765:2017(en) Systems and software  
 232 engineering — Vocabulary”. In this document, the 7th definition of metamodel, i.e., the  
 233 definition of “ISO/IEC 19506:2012 Information technology — Object Management Group  
 234 Architecture-Driven Modernization (ADM) — Knowledge Discovery Meta-Model (KDM)” [6] is  
 235 adopted. From this definition it's clear that an approach of creating information exchange  
 236 rules with elements available in metamodels is actually based on the syntax and therefore is  
 237 acceptable for syntactical interoperability. In this document, the information exchange rules  
 238 for syntactic interoperability provide the following types of information exchange;

#### 239 **Format exchange.**

- 240 – The format is data format
- 241 – The format exchange means information in different data formats can be exchanged
- 242 – E.g., data in UML format can be exchanged with those in XML format

#### 243 **Structure exchange.**

- 244 – The structure is a data structure that has hierarchy and branches
- 245 – The structural exchange means information in different structures can be exchanged.
- 246 – E.g., information defined in a hierarchical tree structure can be transformed to a flat tree  
 247 structure.

#### 248 **Constraint exchange.**

- 249 – The constraint is a condition or requirements on data.
- 250 – The constraint exchange means information with different constraints can be exchanged.
- 251 – E.g., Data in IoT system1 have data accuracy of 0.1, and data in IoT system2 have data  
 252 accuracy of 0.01, their data accuracy exchange rules are classified into constraint  
 253 exchange rules.

254

### 5.2.3 Metamodel driven approaches supporting interoperability issues

Metamodel driven information exchange and interoperability approaches are adopted as holistic approaches in industry domains ([7] [8]) to enable model-driven engineering approaches in the area of information integration and interoperation. With 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 to a same metamodel. i.e., information exchange rules can be reused by IoT systems and IoT devices which have their information models in compliance to the same metamodel. Furthermore, as this document focus on syntactic interoperability among different IoT systems and IoT devices, specific requirements for metamodels, models and information exchanges in the area of IoT shall be included.

### 5.3 An overall structure of the proposed approach

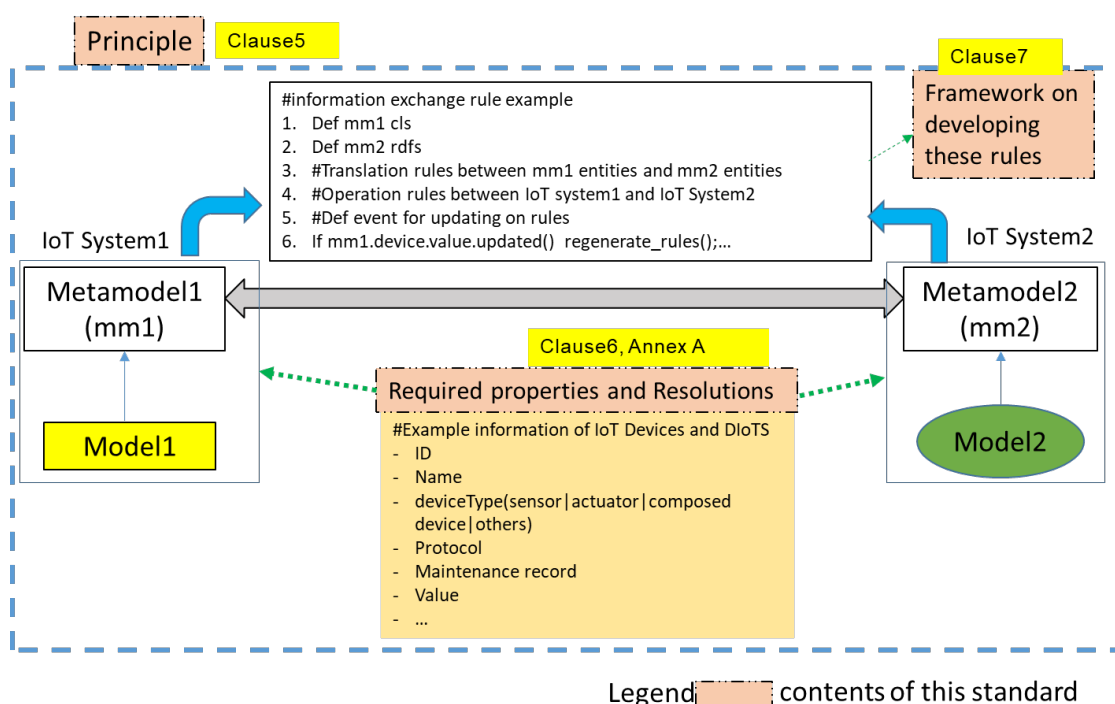


**Figure 1 An overall structure of the proposed approach**

Figure1 illustrates an overall structure of the proposed approach. In Figure1, there are IoT System1 and IoT System2. In either IoT system, in order to express its information, it contains a metamodel and model which can include instance data. In order to achieve syntactic interoperability between these two systems, the information exchange rules based on metamodels of both IoT systems need to be created. In order to create information exchange rules, their required properties, and resolutions to support executing information exchange need to be analysed and defined.

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

- In clause 5, the background of the metamodel and its applicability in the area of solving syntactical interoperability issues are explained. The methodology of how to create information exchange rules among heterogeneous IoT systems/devices is specified.
- In clause 6, requirements on IoT related information are described. These requirements include required properties and resolutions for mismatches between IoT systems. For example, an identifier of a IoT system or a IoT device is a required property. Regarding mismatches occurred during information exchange between involved IoT systems, resolutions are required to supplement these mismatches. For example, the frequency requesting information exchange are different/not matched in involved IoT systems, syntactic resolutions are required to fill up this mismatch. Descriptions of required

properties are specified in 6.3 and 6.4, and required properties and resolutions for mismatches are analysed and described in 6.2.

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

## 5.4 Methodology of the metamodel driven information exchange rules

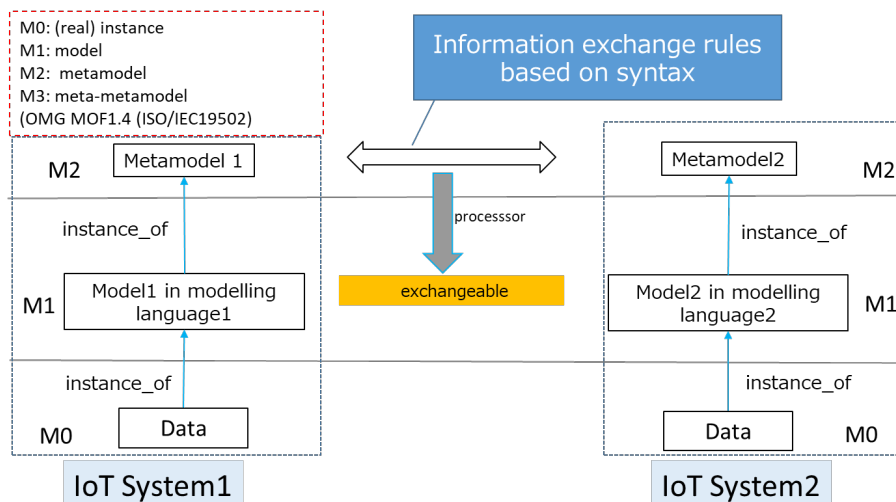


**Figure 2 Methodology of metamodel driven information exchange rules**

During the last decades, in the field of model based engineering(MBE), models are constructed to represent information from physical world. The community of OMG proposes MOF (ISO/IEC 19502 [9]), a four-layer modelling architecture to describe models. Models here in general include instance or data in M0-layer, model in M1-layer,metamodel in M2-layer and meta-metamodel in M3-layer.

As shown in Figure 2, the model in M1-layer defines structures, available entities, relationships etc. for data in the M0-layer, and the metamodel in M2-layer specifies syntax for the models. The M3-layer is not included in this document thus it's omitted in the figure. Therefore, models in M1-layer are instances of their metamodel in M2-layer, and data in M0-layer are instances of their models. For each metamodel, it can have many models, and for each model it can also have lot of instance data.

From syntactic aspect, information exchange rules as projections allow to convert model/data in all layers from specific system to model/data in another system in modelling environment. The projection rules based on metamodels in the upper layer are applicable to transformation of models in their lower layers([10] [11]).

## 5.5 Information exchange rules

### 5.5.1 Categories of Information exchange rules

For a IoT system including IoT devices, in order to achieve syntactic interoperability with other IoT systems and devices, the information exchange rules are adopted. As shown in Figure 3., the information exchange rules can be classified into two categories: “I. Translation rules” and “II. Operation rules”.

- “I. Translation rules” are based on elements and entities in the metamodels of both IoT systems. Translation rules are created to convey model/data of IoT systems.

- “II. Operation rules” are specified to supplement mismatches between two IoT systems. Potential operational mismatches which happen during processes of achieving interoperability are detected. In order to solve these mismatches, necessary properties and available resolutions are specified. Mismatches which cannot be resolved from syntactic viewpoints are out of the scope. Simultaneously, resolutions not based on

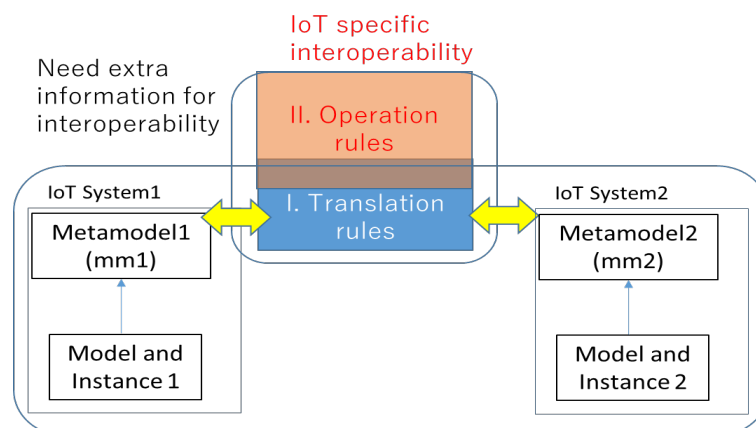


**Figure 3 Categories of information exchange rules**

syntactic approaches for mismatches are also out of the scope.

### 5.5.2 Information exchange rules expression

Information exchange rules shall include required properties and resolutions for IoT syntactic interoperability. Information exchange rules can be expressed with various languages. Some well-known languages such as QVT(Query/View/Transformation, [12]), OCL(Object Constraint Language,[13]), ATL(Atlas Transformation Language, [14]), TGG(Triple graph grammar, [15] [16]) and so on can be applied to describe information exchange rules among different metamodels and models. In this document, sample information exchange rules are described in Annex B. However, an implementation of this document can define information exchange rules with its favourite language and data format.

## 6 Requirements on information related to IoT devices

### 6.1 General

In this clause, requirements on the information which are necessary for syntactic interoperability are described. The information here shall be defined in the metamodel or a model of a IoT system or a IoT device.

In coincidence with the two categories of the information exchange rules described in 5.5.1, the requirements for the information related to IoT devices are also classified into two groups: the requirements on “II. Operation rules” and those on “I. Translation rules”. As shown in Figure 4;

- Required properties and resolutions for “II. Operation rules” are specified in 6.2. These required properties and resolutions shall be created and provided by Dataset1 of Clause 7.
- Requirements on “I. Translation rules” are further divided into two groups depending on required properties. One group is “Required intrinsic properties of physical IoT devices” and the other is “Required extrinsic properties of physical IoT device”( [17] [18]). They are respectively specified in 6.3 and 6.4.

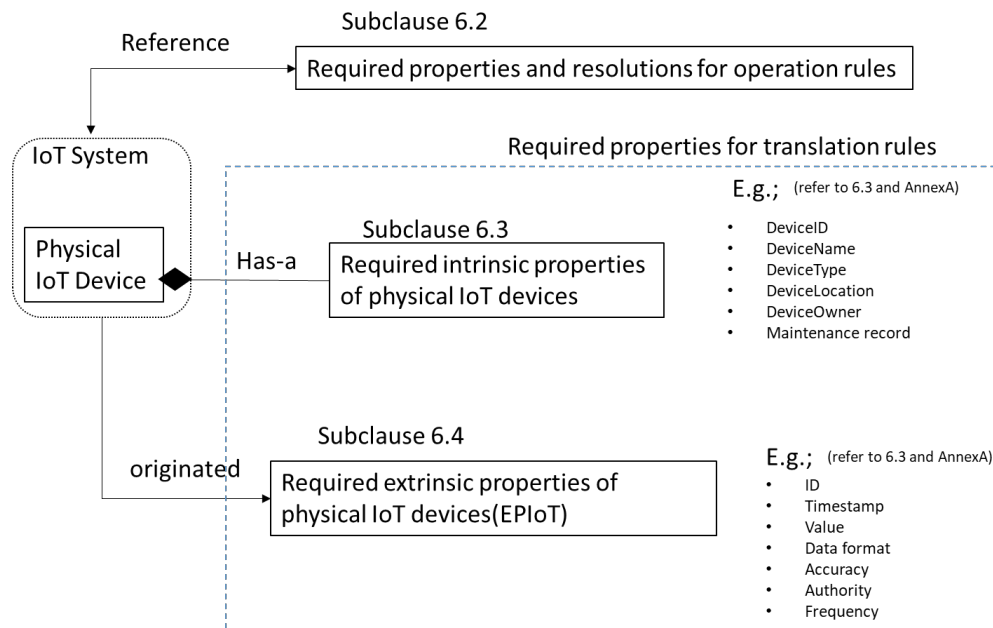


**Figure 4 Classifications of requirements on information related to IoT devices**

## 6.2 General requirements on the operation rules

### 6.2.1 Overview of mismatches between IoT systems

Required properties and resolutions for “II. Operation rules” are related to the mismatches between what one IoT system is expecting and what the other IoT system can provide. In order to supplement mismatches happened between IoT systems while exchanging data, required properties and possible resolutions shall be defined. These required properties and resolutions are defined as requirements on the operation rules.

Figure 5 shows an example of IoT mismatch and its syntactic resolution. The “IoT system2” requires single precision data for every change events, where “IoT system1” can provide one decimal place data every hour. Required properties for this mismatch are “significant figure” and “recording pattern”. The “significant figure” describes the smallest difference in the value of a data being observed that would result in perceptibly different values of the result. The “recording pattern” describes whether data is acquired periodically or change bases.

These kinds of mismatches are intended to be resolved by the operation rules. However, for each mismatch it can have resolution methods from various perspectives such as syntactic, policy-based, and so on. Only syntactic resolutions are specified and others are out of the

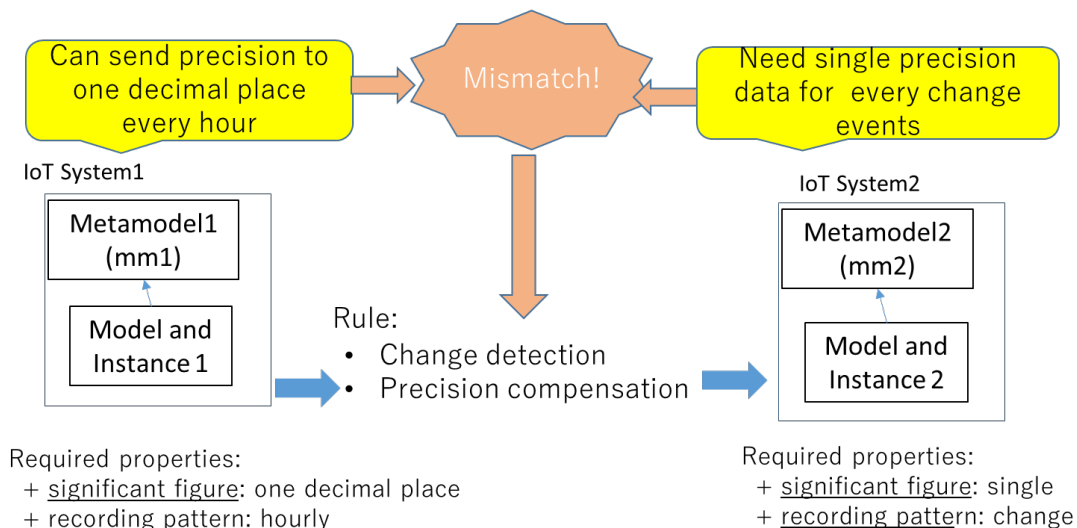


**Figure 5 Mismatches between IoT systems**

scope.

## **6.2.2 Required properties and syntactic resolutions for potential IoT mismatches**

In this clause, required properties and syntactic resolutions for potential IoT mismatches are described.

Table 2 lists potential mismatches between IoT systems.

- The required properties and syntactic resolutions for each mismatch are specified
- The classification of syntactic resolutions (C:Constraint, S:Structure, F:Format) is also specified in the “Type” column of this table.
- For reference, other resolution except those from syntactic aspects is listed as “Other resolution(informative)” which by itself is out of the scope.
- For reference, the data quality indicators defined in ISO/IEC 25012 [19] which might be effected by the mismatches are described. To avoid degradations of data quality while exchanging information between IoT systems, the resolutions which supplement mismatches shall be considered.

Table 2 shows a minimum list of mismatches. Other mismatches continuously occurring in real IoT systems regarding syntactic interoperability shall be flexibly investigated.

| Name      | Mismatch                 | Type | Required properties(normative)                           | Syntactic Resolution (normative) | Other Resolution (informative)     | Effectuated Data Quality (ISO 25012) | Example              |
|-----------|--------------------------|------|----------------------------------------------------------|----------------------------------|------------------------------------|--------------------------------------|----------------------|
| mismatch1 | Synchronization mismatch | C    | LatestSynchronizedTime TimeSynchronization:={True False} | Adjustments or calibration       | specified with the tables in 6.2.2 | consistency                          | different time stamp |

**Table 2 Required properties and resolutions for potential IoT mismatches**