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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Internet of things and smart cities and communities – Requirements and use cases

Requirements of things description in the Internet of things

Recommendation ITU-T Y.4203

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Recommendation ITU-T Y.4203

Requirements of things description in the Internet of things

Summary

Recommendation ITU-T Y.4203 specifies requirements for an effective way of representing things, as far as possible, in a homogeneous way.

The things description is a tool to realise the representation of physical things as virtual things of the information world to facilitate automatization, interoperability and composability for the Internet of things (IoT) applications. Things description specifies a general way for how to map physical things in the physical world to virtual things in the information world to enable things of the IoT to be effectively discovered, interpreted and used.

The focus of this Recommendation is on the following two concerns of things description:

1) representing physical things as virtual things to map physical things into the information world;
2) representing the relationship of virtual things to reflect the relationship of the represented physical things.

The corresponding requirements of things description in the IoT are specified, including:

– high-level requirements of things description in IoT;
– requirements on the characterization aspects of things description in IoT.

This Recommendation may be relevant for the matters addressed by Recommendation ITU-T Y.4114 "Specific requirements and capabilities of the Internet of things for big data", e.g., semantic related data processing.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.4203	2019-02-13	20	11.1002/1000/13857

Keywords

Internet of things, physical things, requirements, things description, virtual things.

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FOREWORD

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Requirements of things description in the Internet of things

1 Scope

This Recommendation specifies requirements of things description in the Internet of things (IoT).

Things description specifies a general way for how to map physical things in the physical world to virtual things in the information world in order to enable things of the IoT to be effectively discovered, interpreted and used. This Recommendation concerns not only representing physical things as virtual things to map the physical things into information world, but also representing the relationship of virtual things to reflect the relationship of the represented physical things.The scope of this Recommendation includes:

– introduction of things description in the IoT;

– requirements of things description in IoT.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.4100] Recommendation ITU-T Y.4100/Y.2066 (2014), *Common requirements of the Internet of things*.

[ITU-T Y.4111] Recommendation ITU-T Y.4111/Y.2076 (2016), *Semantics based requirements and framework of the Internet of things*.

[ITU-T Y.4401] Recommendation ITU-T Y.4401/Y.2068 (2015), *Functional framework and capabilities of the Internet of things*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 device [b-ITU-T Y.4000]: With regard to the Internet of things, this is a piece of equipment with the mandatory capabilities of communication and the optional capabilities of sensing, actuation, data capture, data storage and data processing.

3.1.2 Internet of things (IoT) [b-ITU-T Y.4000]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

NOTE 1 – Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled.

NOTE 2 – From a broader perspective, the IoT can be perceived as a vision with technological and societal implications.

3.1.3 thing [b-ITU-T Y.4000]: With regard to the Internet of things, this is an object of the physical world (physical things) or the information world (virtual things), which is capable of being identified and integrated into communication networks.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 abstraction based things description: With regard to the Internet of things, a type of things description based on an abstraction based description methodology that maps individual information models of things into a unified abstract information model.

3.2.2 hybrid things description: With regard to the Internet of things, a special type of abstraction based things description that embeds semantics based things description or its reference identifier.

3.2.3 semantics based things description: With regard to the Internet of things, a type of things description based on semantic technologies.

NOTE – A semantics based things description includes ontologies and makes use of semantics based description language and techniques [ITU-T Y.4111].

3.2.4 things description: With regard to the Internet of things, the description associated with the (physical and virtual) things representing the characteristics of the associated things according to their application-dependent information model.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

API	Application Programming Interface
HDMI	High-Definition Multimedia Interface
HTTP	Hypertext Transfer Protocol
IoT	Internet of things
JSON	JavaScript Object Notation
LPWAN	Low-Power Wide-Area Network
MQTT	Message Queuing Telemetry Transport
USB	Universal Serial Bus
VGA	Video Graphics Array
XML	Extensible Markup Language

5 Conventions

In this Recommendation:

The keywords "**is required to**" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keywords "**is recommended**" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

The keywords "**can optionally**" and "**may**" indicate an optional requirement which is permissible, without implying any sense of being recommended. These terms are not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

6 Introduction of things description in IoT

6.1 Overview of things description in IoT

As the number of IoT devices, services and users grow, the requirements of IoT applications on automatization, interoperability and composability, among others, become increasingly urgent.

As one of the fundamental elements of all IoT systems, things need to be described via a machine understandable method in an efficient way in order to facilitate the IoT system's representation of things into the information world [ITU-T Y.2060]. The things description is a tool to realize the representation of physical things as virtual things of the information world to facilitate automatization, interoperability and composability for IoT applications.

There are two aspects for things description to represent physical things in the information world:

– representing physical things as virtual things to map physical things into the information world;

– representing the relationship of virtual things to reflect the relationship of the represented physical things.

6.1.1 Representing physical things as virtual things

There are two typical cases for things description to represent physical things as virtual things.

Case 1

– case 1-a involves representing a single physical thing as a single virtual thing, as shown in Figure 1, where the virtual thing represents and acts on behalf of the physical thing in the information world;

– case 1-b involves representing a single physical thing as the instance of a single class of virtual things, as shown in Figure 2.

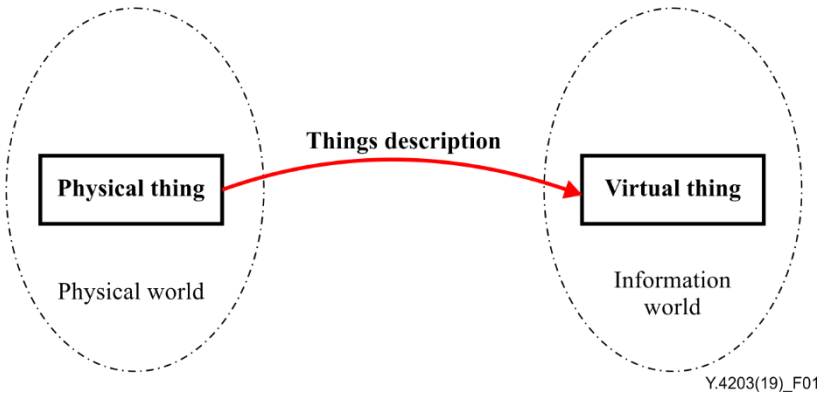

Figure 1 – Representation of a single physical thing as a single virtual thing via things description

NOTE 1 – A typical example of case 1-a is a single sensor physical thing represented by a corresponding virtual thing in the information world.

Some physical things in the physical world can be grouped into one class of physical things according to appropriate abstraction and then this class of physical things can be represented by one class of virtual things. The individual physical things can be represented by instances of the class.

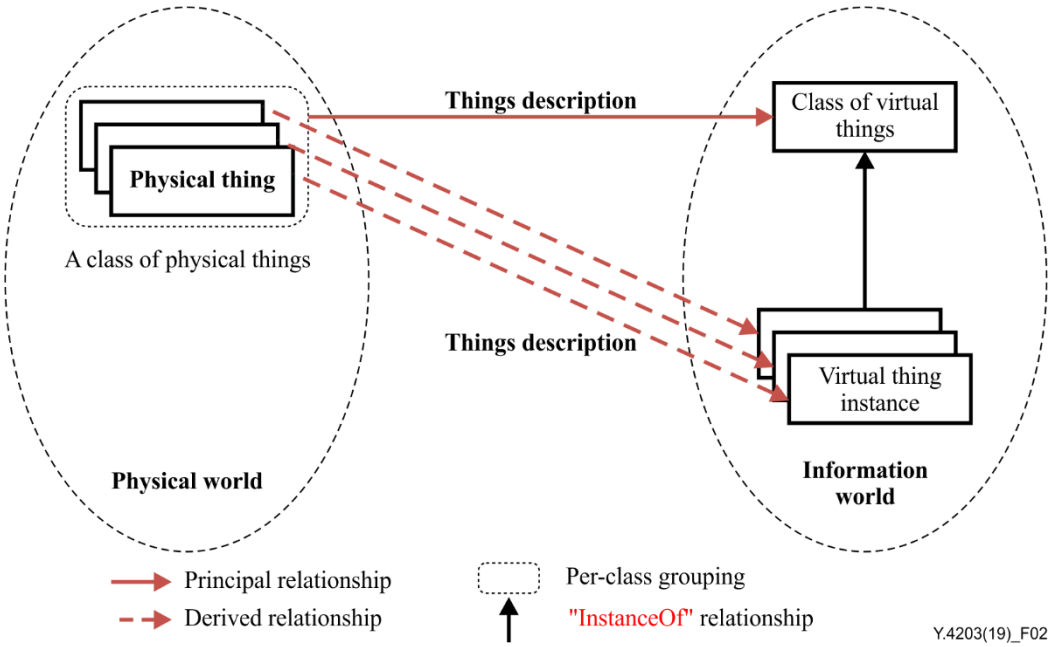

Figure 2 – Representation of an individual physical thing as an instance of a single class of virtual things via things description

NOTE 2 – A typical example of case 1-b is a group of identical sensor physical things, where each sensor physical thing can be represented, in the information world, by a virtual thing instantiated from a single virtual thing class.

Case 2

– case 2 involves representing a composition or aggregation of physical things as a single virtual thing. In this case, as shown in Figures 3 and 4, some physical things in the physical world can be grouped into one composite or aggregate physical thing according to appropriate composition or aggregation relationship and this composite or aggregate physical thing can be represented by one virtual thing.

NOTE 3 – In the case of a composition relationship, as shown in Figure 3, where the composite physical thing "owns" its component physical things (in a sense where the component physical things cannot be reused or shared by other virtual things), the individual physical things are not necessarily represented independently by distinct virtual things of the component physical things. A typical example of composition is a complex machinery like a car, composed of a multitude of component physical things, that can be represented by a single virtual thing in the information world.

NOTE 4 – In the case of an aggregation relationship, as shown in Figure 4, where the aggregate physical thing "uses" its component physical things (in a sense where the component physical things can be reused or shared by other virtual things), the individual physical things are necessarily represented independently by distinct virtual things of the component physical things. A typical example of aggregation is a group of sensor physical things, the group being represented by one single virtual thing that aggregates the information coming from each individual sensor physical thing.

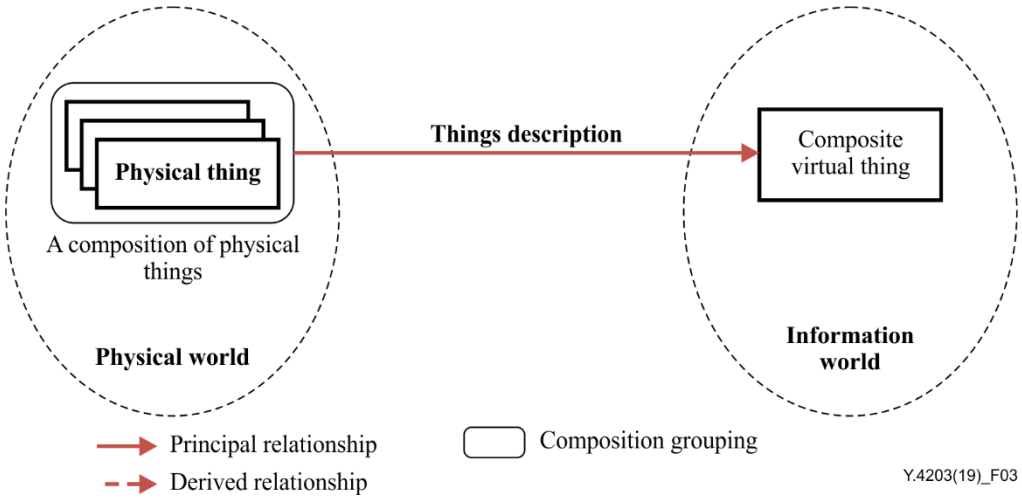

Figure 3 – Representation of a composition of physical things as a single virtual thing via things description

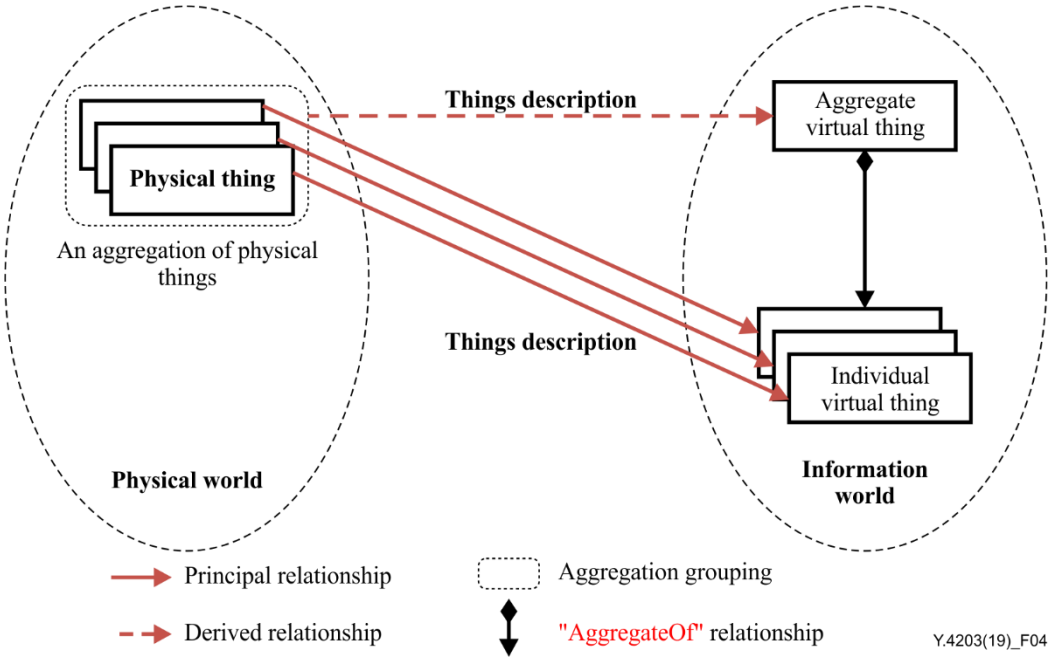

Figure 4 – Representation of an aggregation of physical things as a single virtual thing via things description

Many types of physical things need to be integrated. Because of the heterogeneity of the physical things, the representation of the physical things is usually considered from different angles via different information models in order to meet different practical deployment requirements. This heterogeneity of representation for a given thing often causes issues of incompatibility for the corresponding virtual things' handling in case it is necessary to integrate these heterogeneous virtual things in a single application.

6.1.2 Representing the relationship among virtual things

The relationships among virtual things can be represented, as shown in Figure 5. The representation can indirectly reflect the relationships among the associated physical things in order to support virtual thing relation operations, e.g., discovery, composition and reasoning.

NOTE 1 – A typical example for this case is the relationship related to location, e.g., light A is in room B of building C. Other types of relationships between virtual things can be described via things description, in order

to express particular relationships related to the corresponding application domain (e.g., correspondance between virtual things representing body sensors belonging to the same patient in e-health monitoring context, specialisation relationship between virtual things representing different kinds of motion detection sensors suited for different specific application scenarios, ad hoc relationships between virtual things).

In addition, more relationships can also be introduced in the information world to represent the relationship among virtual things for describing the hierarchy.

NOTE 2 – A typical example for this case is a relationship of equivalence, in terms of replacability, between two virtual things in the information world. Another example can be a relationship of sub-class.

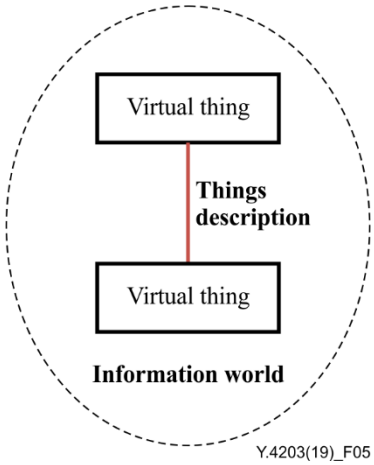

Figure 5 – Representation of the relationships among virtual things via things description

6.2 The relationship between things description, information model and description language

Things description can be implemented via the support of an information model and a description language.

An information model [b-Information Modelling] in software engineering is a representation of concepts and relationships, constraints, rules, and operations to specify data semantics [b-Information Semantics] of virtual things for a chosen domain of discourse.

The description language is a tool which can be used to describe the information model of the virtual thing. Examples of the description language include, but are not limited to, JavaScript object notation (JSON) [b-JSON] and Extensible Markup Language (XML) [b-XML].

The relationships between virtual thing, information model and description language are shown in Figure 6.

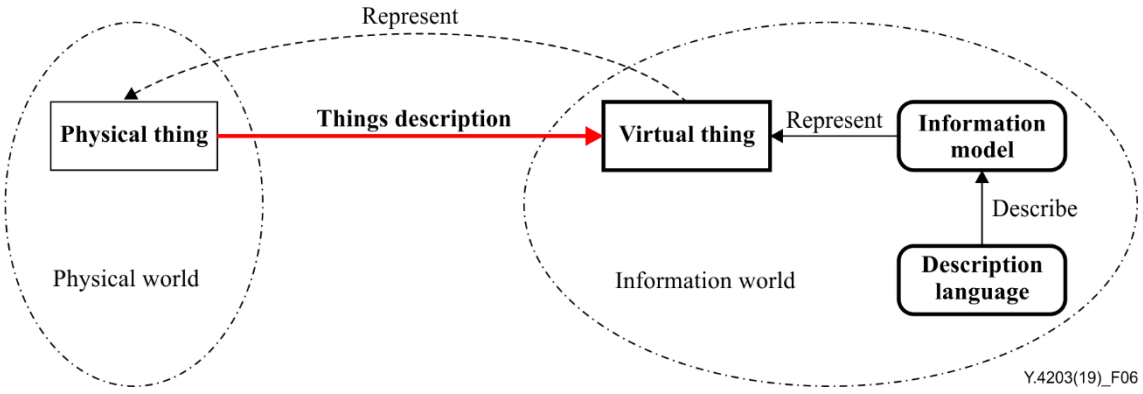

Figure 6 – Virtual thing, information model and description language

6.3 Types of things description in IoT

There may be a variety of possible ways to provide things description in practical IoT systems. The following describes three typical ways: semantics based things description, abstraction based things description and hybrid things description based on semantics and abstraction methodologies.

– semantics based things description

Semantics based things description is a type of things description based on a semantics description methodology. The information model used in semantics based things description is represented in ontologies using the ontology languages (e.g., Web Ontology Language (OWL) [b-OWL]).

NOTE 1 – Semantics based things description uses semantic description language (e.g., Resource Description Framework (RDF) [b-RDF]) and ontologies (e.g., [b-ITU-T Y.4500.12], [b-W3C SSN-XG]) to describe the things.

Owing to the advantages of semantics technologies, semantics based things description allows machine understandability of descriptions, to support better interoperability, intelligent automation and smart discovery. However, the semantics based things description is relatively heavy so it is not popular for lightweight devices.

– abstraction based things description

Abstraction based things description is a type of things description based on an abstraction methodology that maps individual information models of things into a unified abstract information model. The information model in abstraction based things description is common for a class of devices, and is represented by predefined template(s).

NOTE 2 – JSON and XML are popular data-formats for the representation of abstraction based things description.

Compared to semantics based things descriptions, abstraction based things description is simple and light weight, so it is widely used. However, its lack of explicitness does not permit good support for interoperability, intelligent automation and smart discovery.

– hybrid things description

Hybrid things description with semantics and abstraction methodology is a special type of abstraction based things description that embeds the semantics things description or its reference identifier into one element of the template as shown in Figure 7.

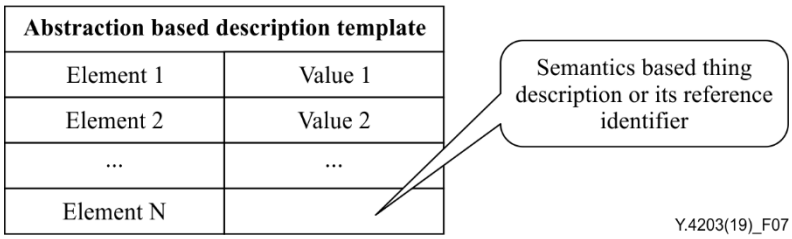

Figure 7 – Illustration example of hybrid things description

NOTE 3 – From a practical perspective, the semantics things description can be implemented by other components (e.g., platform, application server) than the device. Thus, a hybrid things description can maintain all advantages of a semantics based things description while avoiding heavy description on the device side.

For whichever type of things description, the following properties may need to be considered, according to specific requirements, when mapping a physical thing into a virtual thing:

– basic information of the thing, referring to clause 7.2.1;

– usage information of the thing, referring to clause 7.2.2;

– working structure of the thing to support the composition of things, referring to clause 7.2.3;

– physical feature of the thing, referring to clause 7.2.4.

7 Requirements of things description in IoT

7.1 High-level requirements of things description in IoT

– self-containment

The things description in IoT is recommended to cover the description of the various aspects related to the things so that the IoT components can easily interoperate.

– processability

The things description in IoT is required to be easily processed by IoT applications.

– scalability

The things description in IoT is required to support extensions of the things' information models.

NOTE 1 – Drivers of this requirement include the continuously increasing number and capacity of information models.

– interoperability

The things description in IoT is recommended to support a unified description framework so that different applications can make use of things descriptions independently from the specific applications the things descriptions have been originally developed for.

– identification

The things description in IoT is required to provide identification mechanisms so that different things can be uniquely identified.

– conciseness

The things description in IoT is recommended to be compact so that the things' information can be transferred and processed efficiently.

NOTE 2 – IoT applications may benefit from conciseness in case of real-time or near-real-time processing requirements and especially in constrained resource environments.

– integrity and coherence

The things description in IoT is recommended to provide embedded integrity verification information, e.g., checksum, digital signature, and conformity rules, so that things' information can be *a posteriori* verified.

– validity

The things description in IoT is required to cover characteristics of the things that are truly representative of the qualities it is trying to describe.

– traceability

The things description in IoT is required to provide time traceability information (e.g., timestamp), so that a thing's description historical information can be traced, e.g., for analysis, verification, investigation or debugging purposes by IoT applications.

In addition, the things description in IoT is recommended to provide provenance traceability information (e.g., data source).

– adaptability

The things description in IoT is required to support adaptability to new description languages and information models for different IoT application domains.

– version control

The things description in IoT is recommended to support version control mechanisms, so that things' description information versions can be easily identified, and modifications can be tracked and rolled back if necessary.

NOTE 3 – Concurrent versions of the same thing's description can also be maintained for different application purposes.

7.2 Requirements on the characterization aspects of things description in IoT

7.2.1 Requirements on the basic information description

The basic information description is required to be supported in the things description. The following are the requirements on the basic information description:

– identification description

The identifiers of the thing are required to be described in the things description so that the thing can be identified, e.g., using a unique identifier to identify a sensor.

– type description

The type of the thing is required to be described in the things description, e.g., the type of devices such as temperature sensor type.

– time information description

The time information related to the thing, e.g., creation time, modification time and expiration time, is recommended to be described in the things description.

– location information description

The location information related to the thing, e.g., absolute location and relative location, is recommended to be described in the things description.

– provenance information description

The provenance information related to the thing, e.g., manufacturer information, serial number, production batch, is recommended to be described in the things description.

– contextual information description

The contextual information related to the thing, e.g., measurement units, nominal measurement intervals, operation conditions, precision rates, is recommended to be described in the things description.

– operation information description

The operation information related to the thing, e.g., the temperature measurement operation of a temperature sensor, is recommended to be described in the things description.

– functionality information description

The functionality information related to the thing, e.g., the functions of the thing operations and their impacts, is recommended to be described in the things description if the semantics based description is adopted.

As an example, the function of the measurement operation of a temperature sensor can be measuring the temperature of the place where the temperature sensor is located. The impact of the cooler operation of an air conditioner can be decreasing the room temperature where the air conditioner is located.

Other basic information including the basic information related to specific domains can also be described in the things description for better understanding of the basic properties of the things when used in specific domains.

7.2.2 Requirements on the usage information description

The usage information description is required to be supported in the things description. The following are the requirements on the usage information description:

– input and output information description

The input and output information of the thing operations is required to be described in the things description so that the thing can be used via sending new input information and retrieving output information.

An example of the input information is the action parameter of an actuator. An example of the output information is the measured data of a sensor.

– access information description

The access information of the thing operations is recommended to be described in the things description so that the thing can be used with the appropriate access manner. It may also include information to support appropriate levels of confidentiality, integrity and authenticity of communications.

NOTE – In some cases where the access manner is carried by the communication protocols and application programming interfaces (APIs) and known by the component hosting the thing and by the component that intends to access the thing, it is not necessary to describe it in the things description. However, for general interoperability purpose, the access manner can be described in the things description for other components that do not have priori knowledge of access manner to access.

An example of access information is communication protocols and APIs related to the access, e.g., hypertext transport protocol (HTTP), message queuing telemetry transport (MQTT) protocol [b-ISO MQTT] and oneM2M APIs [b-oneM2M API].

7.2.3 Requirements on the working structure description

The working structure description is recommended to be supported in the things description to support the composition of things. The following are the requirements on the working structure description:

– composition structure description

The composition structure description of the thing is recommended to be described in the things description to support the composition of things.

Examples of the composition structure parameters include, but are not limited to, "parallel or serial" and "once or loop".

– composition element description

The composition element description of the thing is recommended to be described in the things description to support the composition of things. As an example, the composition element can be the operation of other things, e.g., opening of a device, output the measured data of a sensor.

– composition logic description

The composition logic description of the thing is recommended to be described in the things description to support the composition of things. The composition logic is the working logic of the composition elements based on the composition structure.

In a device cooperation case, an example of the composition logic is "when the temperature sensor measured data is greater than 30, then open the air conditioning".

In a complex measurement case, an example of the composition logic is the average of all the measured data of the involved sensors.

7.2.4 Requirements on the physical feature description

The physical feature description is recommended to be supported in the things description in order to enable simulation of physical things in the information world.

NOTE 1 – The physical feature description can greatly benefit physical thing design and integration design of physical things.

– physical size description

The physical size description of the thing is recommended to be provided in the things description to support the simulation of a physical thing and related device. The physical size description facilitates not only single physical thing and related device design, but also composition of multiple physical things.

NOTE 2 – As an example, simulation is a normal way for device design and composition of devices in many application areas

– physical interface description

The physical interface description of the thing is recommended to be provided in the things description to support the simulation of aggregation and composition of physical things. It may also facilitate the simulation of the interconnection between different physical things.

There are multiple types of physical interfaces, e.g., universal serial bus (USB), high-definition multimedia interface (HDMI), video graphics array (VGA), differing on aspects such as shape, size, pins, number and distribution. These aspects have to be considered in the physical interface description.

– material property description

The material property description of the thing is recommended to be described in the things description to support the simulation of physical things from an environmental adaptability point of view. The material properties may take into account, but are not limited to, temperature, humidity, acidity and alkalinity, resistance to compression and density.

Appendix I

An example of usage of things description

(This appendix does not form an integral part of this Recommendation.)

Communication networks based on low-power wide-area network (LPWAN) technologies are widely deployed in many countries. IoT devices can be connected to these communication networks where things description can help for interworking of IoT devices by applications.

Figure I.1 shows the steps involved in how IoT device interworking can be enabled by things description.

– step 1: The IoT device with its things description (e.g., pieces of information which may be coded as a JSON file) registers to a things description registry. The things description registry stores the IoT device's things description and the corresponding addressing information related to the IoT device;

– step 2: The IoT application queries the things description registry with a set of things description related parameters. Based on the received inquiry and associated parameters, the things description registry finds out the things description and the discovery information of the IoT device(s) which matches the query;

– step 3: Based on the identified things description of the IoT device, the IoT application can initiate to interwork with the IoT device using the required configurations, e.g., access protocols.

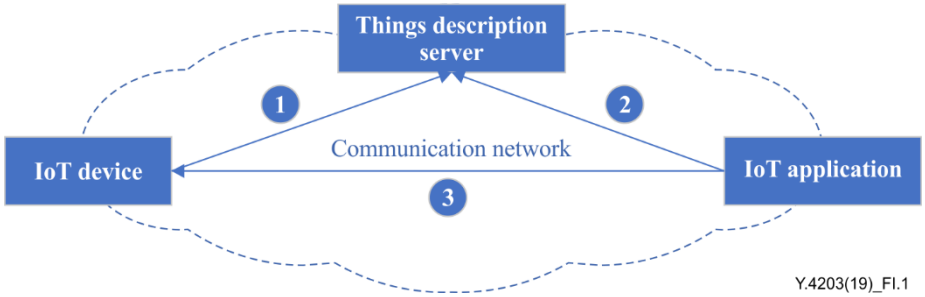

Figure I.1 – IoT device interworking enabled by things description

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