ONEM2M TECHNICAL SPECIFICATION

Document Number	TS-0012-V3.7.3
Document Name:	Base Ontology
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Abstract:	oneM2M's Base Ontology constitutes a basis framework for specifying the semantics of data that are handled in oneM2M. Sub-classes of some of its concepts are expected to be defined by other bodies in order to enable semantic interworking. In particular interworking with non-oneM2M systems (e.g. Area Networks and their devices) should be facilitated.
Template Version:23 February 2015 (Do not modify)	

Contents

1 Scope

The present document contains the specification of the oneM2M Base Ontology. A formal OWL representation of the Base Ontology can be found at http://www.onem2m.org/ontology/Base_Ontology.
The present document also specifies an instantiation of the Base Ontology in oneM2M resources which can be used for semantic annotation and for ontology based interworking [4].

Finally an example is given how external ontologies can be mapped to the Base Ontology. The example uses the Smart Appliances REFerence (SAREF) ontology (http://ontology.tno.nl/saref).

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

The following referenced documents are necessary for the application of the present document.

[1] oneM2M TS-0011: "Common Terminology".

[2] oneM2M TS-0001: "Functional Architecture".

[3] W3C Recommendation: "RDF 1.1 Concepts and Abstract Syntax".

[4] oneM2M TS-0030: "Ontology based Interworking".

[5] oneM2M TS-0004: "Service Layer Core Protocol Specification".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] oneM2M Drafting Rules.

NOTE: Available at http://www.onem2m.org/images/files/oneM2M-Drafting-Rules.pdf.

[i.2] The Smart Appliances REFerence (SAREF) ontology.

NOTE: Available at http://ontology.tno.nl/saref/.

[i.3] Open-source ontology editor PROTÉGÉ.

NOTE: Available at http://protege.stanford.edu/.

[i.4] W3C OWL Working Group: "OWL 2 Web Ontology Language Document Overview".

NOTE: Available at http://www.w3.org/TR/owl2-overview/.

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in oneM2M TS-0011 [1] and the following apply:

annotation property: property that can be used to add information (metadata/data about data) to classes, individuals and Object/Data Properties

class: OWL standard ontology language from the World Wide Web Consortium (W3C) (see [i.4]), concepts are called "Classes"

concept: entity of an Ontology that has an agreed, well defined, meaning within the domain of interest of that ontology

NOTE: A concept is conceptually grouping a set of Individuals.

data property: property that relates an individual of a class to data of a specified type and range

interworked device: non-oneM2M device (NoDN) for which communication with oneM2M entities can be achieved via an Interworking Proxy Application Entity (IPE)

object property: property that relates an individual of a domain class to an individual of a range class

ontology: formal specification of a conceptualization, that is defining concepts as objects with their properties and relationships versus other concepts

ontology based interworking: ontology based interworking allows interworking with many types of non- oneM2M Area Networks and Devices that are described in the form of a oneM2M compliant ontology which is derived from the oneM2M Base Ontology (see [4])

NOTE: Ontology based interworking supports the interworking variant "full mapping of the semantic of the non-oneM2M data model to Mca" as indicated in clause F.2 of oneM2M TS-0001 [2].

property: in OWL standard ontology language properties represent relations among individuals

NOTE: Properties can be sub-categorized as object properties, data properties and annotation properties.

proxied device: virtual Device (i.e. a set of oneM2M resources together with an IPE) that represents the Interworked Device in the oneM2M System

relation: (also called "interrelation" or "property") stating a relationship among individuals

restriction: class of individuals based on the relationships that members of the class participate in

NOTE: Restrictions can be sub-categorized as: existential restrictions, universal restrictions, cardinality restrictions and hasvalue restrictions.

3.2 Abbreviations

For the purposes of the present document, the abbreviations given in oneM2M TS-0011 [1] and the following apply:

AE	Application Entity
OWL	Web Ontology Language
SAREF	Smart Appliances REFerence ontology
SPARQL	SPARQL Protocol and RDF Query Language

4 Conventions

The key words "Shall", "Shall not", "May", "Need not", "Should", "Should not" in the present document are to be interpreted as described in the oneM2M Drafting Rules [i.1].

5 General information on the oneM2M Base Ontology (informative)

5.1 Motivation and intended use of the ontology

5.1.1 Why using ontologies in oneM2M?

5.1.1.1 Introduction to ontologies

In a nutshell an ontology is a vocabulary with a structure. The vocabulary applies to a certain domain of interest (e.g. metering, appliances, medicine, etc.) and it contains concepts that are used within that domain of interest, similar to the "defined terms" in clause 3.1, "Definitions".

An ontology should:

- Capture a shared understanding of a domain of interest.
- Provide a formal and machine interpretable model of the domain.

The ontology lists and denominates these concepts which have agreed, well defined, meanings within the domain of interest (e.g. the concept of "Device" has an agreed, well defined, meaning within the scope of the Smart Appliances REFerence (SAREF) ontology see [i.2]).

Concepts do not identify individuals but they identify classes of individuals. Therefore, in the OWL standard ontology language from the World Wide Web Consortium (W3C) (see [3]), concepts are called "Classes".

The structure part of the ontology is introduced through agreed, well defined, relationships between its concepts. Such a relationship - in OWL called "Object Property" - links a *subject* concept to an *object* concept.

subject concept ➔ relationship ➔ *object* concept

in OWL:

domain Class ➔ Object Property ➔ *range* Class

EXAMPLE 1: In SAREF an Object Property "accomplishes" relates the "Device" class to the "Task" class:

Device ➔ accomplishes ➔ Task

Also the relationships/Object Properties of an ontology have agreed, well defined, meanings within the domain of interest. In the example above the "accomplishes" part of the relationship is well documented as part of SAREF (see [i.2]).

A second type of Properties in OWL is called "Data Properties". A Data Property is linking a subject Class to a data. These data may be typed or untyped.

EXAMPLE 2: In SAREF the Data Property "hasManufacturer" links the class "Device with data of datatype "Literal"":

Device ➔ hasManufacturer ➔ Literal

Again, the Data Properties of an ontology have agreed, well defined, meanings within the domain of interest.
In the example 2, the Data Property "hasManufacturer" indicates that the Literal, that is linked via this Data Property will indicate the manufacturer of the Device.

Data Properties can be considered similar to attributes in oneM2M.

A third type of Properties in OWL is called "AnnotationProperties". An Annotation Property is used to provide additional information about ontology elements like classes and instances, which typically are external to the ontology and would not be used for reasoning. Example usages for such additional information are for providing a creator, a version or a comment. The object of an annotation property is either a data literal, a URI reference, or an individual.

In general, an individual of a certain Class may or may not have a particular relation (Object Property, Data Property or Annotation Property) that is defined by the ontology. However, if such a relation exists for the individual then that relation should be used with the meaning specified by the ontology.

One additional, crucial aspect differentiates an ontology from a vocabulary with a structure. An ontology enables specified, allowed constructs (based on predicate logic) and can be represented in a formal, machine interpretable form e.g. by the OWL standard ontology language. This allows the creation of queries (e.g. through the SPARQL query language) that search for individuals of specified classes, having specified relationships, etc.

The OWL flavour OWL-DL (where DL stands for "Description Logic"), that is used in the present document and that is supported by the ontology-editing tool "Protégé" (see [i.3]), has the additional advantage that it is underpinned by a description logic. For ontologies that fall into the scope of OWL-DL a reasoner can be used to automatically check the consistency of classes, take what has explicitly stated in the ontology and use it to infer new information. OWL-DL ensures that queries are decidable.

Additionally, OWL-DL allows the creation of Intersection, Union and Complement classes, restrictions (e.g. on the required/allowed number of relationships for any individual of the Class along this property) an other useful constructs.

5.1.1.2 The purpose of the oneM2M Base Ontology

5.1.1.2.0 Introduction

Ontologies and their OWL representations are used in oneM2M to provide syntactic and semantic interoperability of the oneM2M System with external systems. These external systems are expected to be described by ontologies.

The only ontology that is specified by oneM2M is the oneM2M Base Ontology, as described in the present document. However, external organizations and companies are expected to contribute their own ontologies that can be mapped (e.g. by sub-classing, equivalence, etc.) to the oneM2M Base Ontology.

Such external ontologies might describe specific types of devices (as e.g. in the SAREF ontology) or, more generally, they might describe real-world "Things" (like buildings, rooms, cars, cities.) that should be represented in a oneM2M implementation. The value for external organizations and companies to provide their ontologies to oneM2M consists in supplementing oneM2M data with information on the meaning/purpose of these data. The OWL representation of that ontology provides a common format across oneM2M.

The oneM2M Base Ontology is the minimal ontology (i.e. mandating the least number of conventions) that is required such that other ontologies can be mapped into oneM2M.

5.1.1.2.1 Syntactic interoperability

Syntactic interoperability is mainly used for interworking with non-oneM2M devices in Area Networks. In this case an ontology - represented as an OWL file - that contains the Area Network specific types of communication parameters (names of operations, input/output parameter names, their types and structures, etc.) is used to configure an Interworking Proxy Entity (IPE).

With the help of this OWL file the IPE is able to allocate oneM2M resources (AEs, containers) that are structured along the Area Network specific parameters and procedures. This enables oneM2M entities to read/write from/into these resources such that the IPE can serialize the data and send/receive them from/to the devices in the Area Network.

The semantic meaning of these resources is implicitly given by the interworked Area Network technology.

Each ontology that describes a specific type of interworked Area Network needs to be derived from the oneM2M Base Ontology. In particular the device types of an ontology of an interworked Area Network need to be mapped (e.g. by sub-typing) into the concept "Interworked Device" of the oneM2M Base Ontology.

5.1.1.2.2 Semantic interoperability

Semantic interoperability is mainly used to describe functions provided by oneM2M compliant devices (M2M Devices).

EXAMPLE: Different, oneM2M compliant types of washing machines may all perform a Function like "washing-function","drying-function", "select wash temperature", etc., however the oneM2M resources (containers), through which these functions can be accessed, can have different resourceNames, child-structures and type of content.

In this case an ontology - represented as an OWL file -contains the specific types of the M2M Application Service and/or Common Service of the M2M Device (e.g. CRUD operation, resourceNames, child-structures and type of content, etc.) together with the Function of that service (e.g. "washing-function").

Each ontology that describe a specific type of M2M Device needs to be derived from the oneM2M Base Ontology. In particular the device type needs to be mapped (e.g. by sub-typing) into the concept "Device" of the oneM2M Base Ontology.

5.1.2 How are the Base Ontology and external ontologies used?

5.1.2.1 Overview

This clause describes how an external ontology that is compatible with the Base Ontology can be used in a joint fashion.

NOTE: Further use of external ontologies is left to subsequent releases.

5.1.2.2 Introduction to usage of classes, properties and restrictions

An ontology consists of Properties and Classes.

Properties represent relationships, and link individuals from the specified domain (a class) to individuals from the specified range (another class). There are two main types of properties in the Base Ontology, object properties and data properties. An object property describes a relationship between two object individuals. A data properties describes a relationship between an object individuals and a concrete data value that may be typed or untyped.

Classes are interpreted as sets of individuals, and sometimes classes are also seen as a concrete representation of concepts. In the Base Ontology, a Class can be directly defined by the class name and class hierarchy or defined by the properties characteristics of the individuals in the class. The latter method is known as restriction. The classes defined by restriction can be anonymous, which contains all of the individuals that satisfy the restriction.

In the Base Ontology, the restrictions can be divided as existential restrictions, universal restrictions and cardinality restrictions:

- Existential restrictions describe classes of individuals that participate in at least one (some) relationship along a given property to individuals that are members of the class, e.g. since a Device (Class: Device) has at least one function (Object Property: hasFunction) (Class: Function) that this device accomplishes, then (Class: Device) is a subclass of the anonymous class of (Object Property: hasFunction) *some* (Class: Function).

- Universal restrictions describe classes of individuals that for a given property only have relationships along this property to individuals that are members of the class. For example, since a subclass "Watervalve" of (Class: Device) only has a Function (Object Property: hasFunction) subclass "Open_or_Close_Valve" of (Class: Function), then (Class:Watervale) is a superclass of the anonymous class of (Object Property: hasFunction) *only* (Class: Open_or_Close_Valve).

- Cardinality restrictions describe classes of individuals that, for a given property, only have a specified number of relationships along this property to individuals that are members of the class.

5.1.2.3 Methods for jointly using the Base Ontology and external ontologies

If the Base Ontology is available and the external ontologies are compatible with the Base Ontology, the Base Ontology and the external ontologies can be jointly used in the following ways.

1) Classes and properties mapping:

- The names of the class and properties in different ontologies may be totally different, but the meanings of these class and properties can be relevant. Classes and properties mapping is used to link the relevant classes and properties in different ontologies.
- The descriptions for the classes and properties mapping relationship of the Base Ontology and external ontologies can be given in an ontology or a semantic rule depending on the frequency of the usage. For the frequent cases, it is better to give the mapping description in an ontology, even in the Base Ontology.
- The classes and properties mapping can be based on the properties defined in OWL and RDFs, e.g. rdfs:subClassOf, owl:equivalentClass, for classifying the hierarchy of the classes and properties in Base Ontology and external ontologies. The inheritance from upper properties and classes will be implied according to the mapped hierarchy. For example, when a class A in an external ontology is mapped as a subclass of the class B in the Base Ontology, it implies that the properties of class B in the Base Ontology will be inherited by the class A in the external ontology.

Table 1 gives a simple example for classes and properties mapping between two ontologies.

Table 1: An example for classes and properties mapping between two ontologies

Properties mapping			**Classes mapping**		
property I	mapping relationship	property II	class I	mapping relationship	class II
OntologyB: hasSwitch	rdfs:subPropertyOf	OntologyA: hasOperation	OntologyB : appliance	rdfs:subClassOf	OntologyA:device
OntologyA: hasPower	owl:equivalentProperty	OntologyB: hasPower	OntologyB :lamp	owl:equivalentClass	OntologyA:light
OntologyA: hasVendor	owl:equivalentProperty	OntologyB: hasManufacturer	OntologyB :Switch	rdfs:subClassOf	OntologyA:Operation

2) Individual annotation across multiple ontologies:

- Though the names of the class and properties in different ontologies may be totally different, the semantic annotation for individuals can be done based on these different ontologies respectively and independently. In this way, the knowledge from different ontologies are used together to describe the individuals.

Table 2 gives a simple example for individual annotation across two ontologies.

Table 2: An example for individual annotation across two ontologies

Individuals	**Semantic annotation based on Ontology A**		**Semantic annotation based on Ontology B**	
	Properties	**classes**	**properties**	**Classes**
Light A	rdf:type	Ontology A: Light	rdf:type	Ontology B:ledLight
	OntologyA: hasOperation	Ontology A:Open	OntologyB: hasColor	rdf:datatype="&xsd;string">'red' <
	OntologyA: hasStatus	rdf:datatype="&xsd;boolean">true <	OntologyB: hasSwitch	OntologyB:Switch
NOTE: The two methods can be used jointly or independently.				

The compatibility of two ontologies depends on their class hierarchies. When the class hierarchy of one ontology can be mapped as a part or an external part of the class hierarchy of the other ontology, they are compatible. When multiple ontologies are pairwise compatible, they are compatible.

5.2 Insights into the Base Ontology

5.2.1 General design principles of the Base Ontology

5.2.1.1 General Principle

The Base Ontology has been designed with the intent to provide a minimal number of concepts, relations and restrictions that are necessary for semantic discovery of entities in the oneM2M System. To make such entities discoverable in the oneM2M System they need to be semantically described as classes (concepts) in a - technology/vendor/other-standard specific - ontology and these classes (concepts) need to be related to some classes of the Base Ontology as sub-classes.

Additionally, the Base Ontology enables non-oneM2M technologies to build derived ontologies that describe the data model of the non-oneM2M technology for the purpose of interworking with the oneM2M System.

The Base Ontology only contains Classes and Properties but not instances because the Base Ontology and derived ontologies are used in oneM2M to only provide a semantic description of the entities they contain.

Instantiation (i.e. data of individual entities represented in the oneM2M System - e.g. devices, things, etc.) is done via oneM2M resources.

The Base Ontology is available at the web page:

- http://www.onem2m.org/ontology/Base_Ontology;

which contains the latest version of the ontology and individual versions of the ontology (see Annex A).

5.2.1.2 Essential Classes and Properties of the Base Ontology

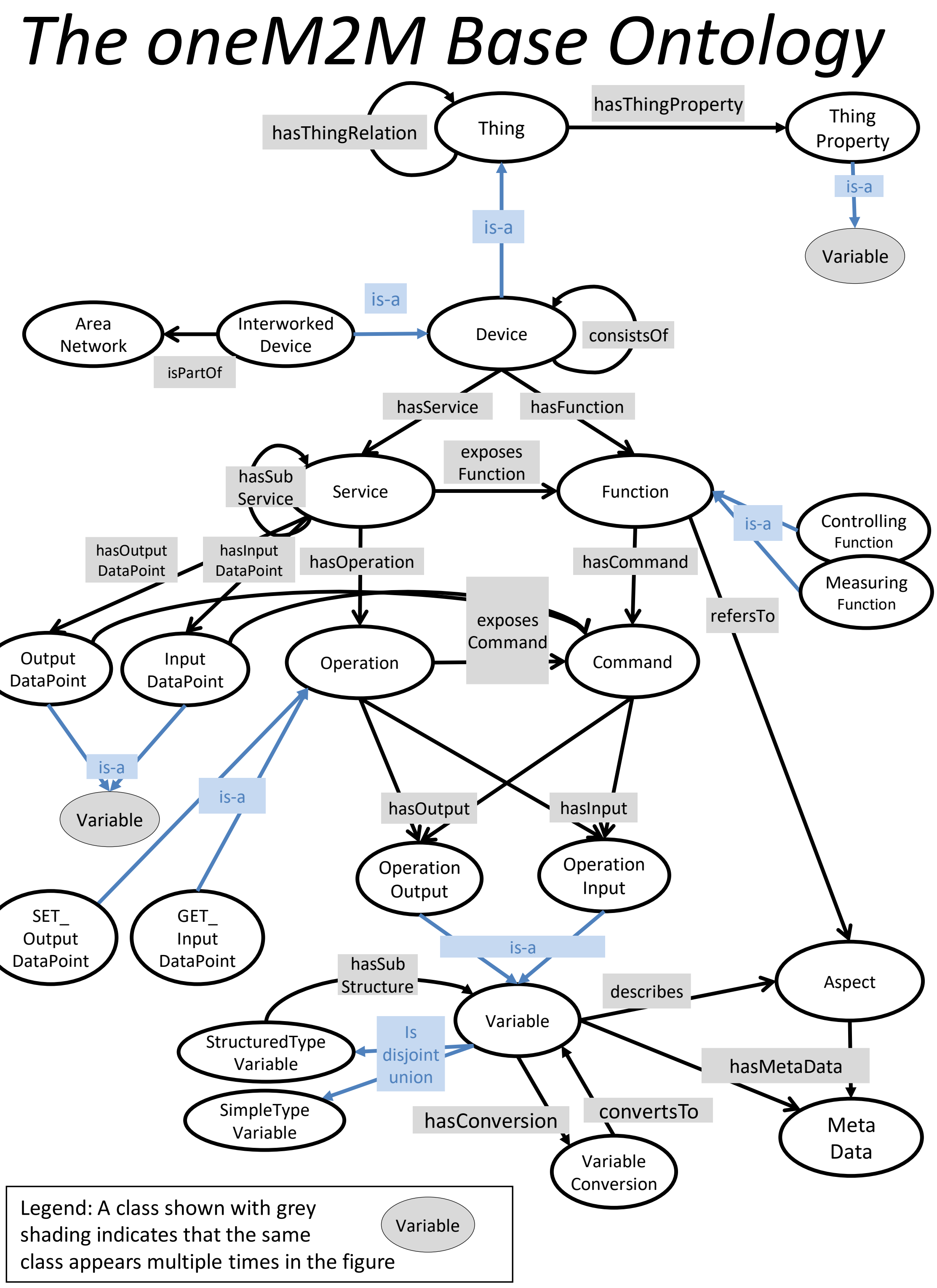


Figure 1: The oneM2M Base Ontology

Figure 1 shows the essential Classes and Properties of the Base Ontology. The nodes (bubbles) denote Classes whereas edges (arrows) denote Object Properties.

The graph in figure 1 can be read as follows:

- A **Thing** in oneM2M (Class: Thing) is an entity that can be identified in the oneM2M System.
  A Thing may have properties (Object Property: hasThingProperty).
  A Thing can have relations to other things (Object Property: hasThingRelation).
  E.g. A room that is modelled in oneM2M would be a Thing that could have a room-temperature as a ThingProperty (via hasThingProperty) and could have a hasThingRelation "isAdjacentTo" to another room.
  In general it is assumed that a Thing is not able to communicate electronically with its environment. However, the sub-class of Thing that ***is*** able to interact electronically is called a "Device".

- A **ThingProperty** (Class: ThingProperty) denotes a property of a Thing. A Thing can be described with (the values of) ThingProperties, but in general the Thing cannot influence that value or being influenced by it.
  A human or a computer or a device could set the value of a Thing's ThingProperty and possibly read it.
  A ThingProperty be can be retrieved or updated by an entity of the oneM2M System.
  E.g. the indoor temperature of the room could be a Value of a Thing "room", or the manufacturer could be a ThingProperty of a Thing "car".
  A ThingProperty of a thing can describe a certain Aspect, e.g. the indoor temperature describes the Aspect "Temperature" that could be measured by a temperature sensor.
  A ThingProperty of a Thing can have meta data.

- **Variable** (Class: Variable) constitutes a super class to the following classes: ThingProperty, OperationInput, OperationOutput, InputDataPoint, OutputDataPoint. Its members are entities that have some data (e.g. integers, text, etc., or structured data) that can change over time. These data of the Variable usually describe some real-world Aspects (e.g. a temperature) and can have MetaData (e.g. units, precision).
  A Variable can be structured, i.e. it can consist of (sub-) Variables.

  Additionally, the following sub-classes are defined in the Base Ontology:

  - **SimpleTypeVariable** (Class: SimpleTypeVariable) is a sub-class of Variable that only consists of Variables of simple xml types like xsd:integer, xsd:string, etc., potentially including restrictions.

  - **StructuredTypeVariable** (Class:StructuredTypeVariable) is a sub-class of class:Variable that describes a structured variable, composed of a set of other variables. This set of other variables can contain simple type variables (Class: SimpleTypeVariable) or also structured variables (Class: StructuredTypeVariable).

  Class:Variable is the disjoint union of classes SimpleTypeVariable and StructuredTypeVariable, i.e. any variable is either structured or simple type.

- **VariableConversion** (Class: VariableConversion) represents a conversion rule from the value range of one Variable into the value range of another Variable.

- **MetaData** (Class: MetaData) contain data (like units, precision-ranges, etc.) about the Values of a Thing or about an Aspect.
  E.g. the indoor temperature could have meta data: "Degrees Celsius".

- **A Device** (Class: Device) is a Thing (a sub-class of class:Thing) that is designed to accomplish a particular task via the Functions the Device performs.
  A Device can be able to interact electronically with its environment via a network.
  A Device contains some logic and is producer and/or consumer of data that are exchanged via its Services with other entities (Devices, Things) in the network. A Device interacts through the DataPoints and/or Operations of its Services.
  In the context of oneM2M a Device is always assumed to be capable of communicating electronically via a network (oneM2M or interworked non-oneM2M network):

  - In order to accomplish its task, the device performs one or more Functions (Object Property: hasFunction) (Class: Function).
    These Functions are exposed in the network as Services of the Device.

  - A Device can be composed of several (sub-) Devices (Object Property: consistsOf) (Class: Device).
    => consistsOf only Device.

  - Each Device (including sub-Devices) needs to be individually addressable in the network.

E.g. a "lightswitch" would be a device, a combined fridge/freezer would be a device that consists of a sub-device fridge and a sub-device freezer.

- A **Function** (Class: Function) represents the Function necessary to accomplish the task for which a Device is designed. A device can be designed to perform more than one Function.
  The Class: Function exhibits the - human understandable - meaning what the device "*does*":

  - A Function refers to (e.g. observes or influences) a certain Aspect.

  E.g. considering a "light switch" then a related Function could be "Controlling_ON_OFF".
  These Functions would refer to an Aspect "lighting", that is influenced by the device "light switch".

- Two sub-classes of class Function are defined in the Base Ontology:

  - **ControllingFunction** (Class: ControllingFunction) is a sub-class of Function that only controls/influences real world Aspects that the Function relates to.

  - **MeasuringFunction** (Class: MeasuringFunction) is a sub-class of Function that only measures/senses real world Aspects that the Function relates to.

- An **Aspect** (Class: Aspect) describes the real-world aspect that a Function relates to. Aspect is also used to describe a quality or kind of OperationInput- or OperationOutput variables. The Aspect could be a (physical or non-physical) entity or it could be a quality.

- A **Command** (Class: Command) represents an action that can be performed to support the Function. An Operation exposes a Command to the network. OperationInput and OperationOutput of the related Operation can parameterize the command.
  E.g. the Function "Dimming-Function" could have a Command "setPercentage", with a parameter that has values 0 - 100.

- A **Service** (Class: Service) is a representation of a Function to a network that makes the Function discoverable, registerable, remotely controllable in the network. A Service can represent one or more Functions. A Service is offered by a device that wants (a certain set of) its Functions to be discoverable, registerable, remotely controllable by other devices in the network:

  - While a Function describes the meaning of the device's Function the Service (Class: Service) is used to describe how such Function is represented in a communication network and is therefore dependent on the technology of the network.

  E.g. the Function: "turn_light_On_or_Off" could be exposed in the network by a Service "Binary Value Actuator".

  - A Service may be composed of smaller, independent (sub)Services, e.g. re-usable servicemodules.

- An **OutputDataPoint** (class: OutputDataPoint) is a Variable of a Service that is set by a RESTful Device in its environment and that provides state information about the Service. The Device updates the OutputDataPoint autonomously (e.g. at periodic times). To enable a third party to retrieve the current value of a OutputDataPoint (out of schedule) devices can also offer a SET_OutputDataPoint Operation to trigger the device to update the data of the OutputDataPoint.

- An **InputDataPoint** (class: InputDataPoint) is a Variable of a Service that is set by a RESTful Device in its environment and that the Device readsout autonomously (e.g. at periodic times). To enable a third party to instruct the device to retrieve (out of schedule) the current value of a InputputDataPoint devices can also offer a GET_InputDataPoint Operation to trigger the device to retrieve the data from the InputDataPoint.

NOTE 1: Input- and Output DataPoints are usually used by Devices (AEs) that communicate in a RESTful way, while Operations are the procedures that are used for remote procedure based communication. Operations are, however, also needed in RESTful systems to correlate output, that is produced by a device, to the input that triggered the production of that output.

- An **Operation** (Class: Operation) is the means of a Service to communicate in a procedure-type manner over the network (i.e. transmit data to/from other devices). An Operation is transient, i.e. an Operation can be invoked, possibly produces output and is finished.
  An Operation is a representation of a Command to a network:
  - An Operation can have OperationInput (data consumed by the Device) and OperationOutput (Data produced by the Device), as well as a Method that describes how the Operation is invoked over the network.
  - An Operation correlates the output data of the Operation to the input data that were used at Operation invocation.
- Two sub-classes of class Operation are defined in the Base Ontology:
  - **GET_InputDataPoint** (Class: GET_InputDataPoint) is a sub-class of Operation that may be offered by a Device to trigger the device to retrieve the data of an InputDataPoint
    (e.g. outside of the schedule when the device normally retrieves that DataPoint).
  - **SET_OutputDataPoint** (Class: SET_OutputDataPoint) is a sub-class of Operation that may be offered by a Device to trigger the device to update the data of an OutputDataPoint
    (e.g. outside of the schedule when the device normally updates that DataPoint).
- **OperationInput** (Class: OperationInput) describes the type of input of an Operation to a service of the device. The OperationInput class represents all possible values for that input (data types and -ranges or a list of enumerated individuals). An Operation can have multiple OperationInputs and/or OperationOutputs. If an instance of an Operation is executed then the input value to that Operation is an instance of its OperationInput classes (e.g. enumerated instances like "ON" or "OFF" for an OperationInput class that sets the state of a switch or a real number within a certain range for a "Temperature" OperationInput class for a thermostat).
- **OperationOutput** (Class: OperationOutput) describes the type of output of an Operation from a service of the device. The OperationOutput class represents all possible values for that OperationOutput (data types and -ranges or a list of enumerated individuals). An Operation can have multiple OperationInputs and/or OperationOutputs. If an instance of an Operation is executed then the output values of that Operation are instances of its OperationOutput classes.
- **Area Network** (Class: AreaNetwork):
  - An Area Network (see [1]) is characterized by its technology:
    - physical properties (e.g. "IEEE_802_15_4_2003_2_4GHz");
    - its communication protocol (e.g. "ZigBee_1_0");

    and potentially:
    - a profile (e.g. "ZigBee_HA").
- **Interworked Device** (Class: InterworkedDevice):
  - Is part of an AreaNetwork.

NOTE 2: An Interworked Device is not a oneM2M Device and can be only accessed from the oneM2M System by communicating with a "proxied" (virtual) device that has been created by an Interworking Proxy Entity (IPE).
The InterworkedDevice class describes the "proxied" (virtual) device that is represented in the oneM2M System as an individual <AE> resource or a child resource of the <AE> of its IPE.

5.2.2 Void

6 Description of Classes and Properties

6.1 Classes

6.1.1 Class: Thing

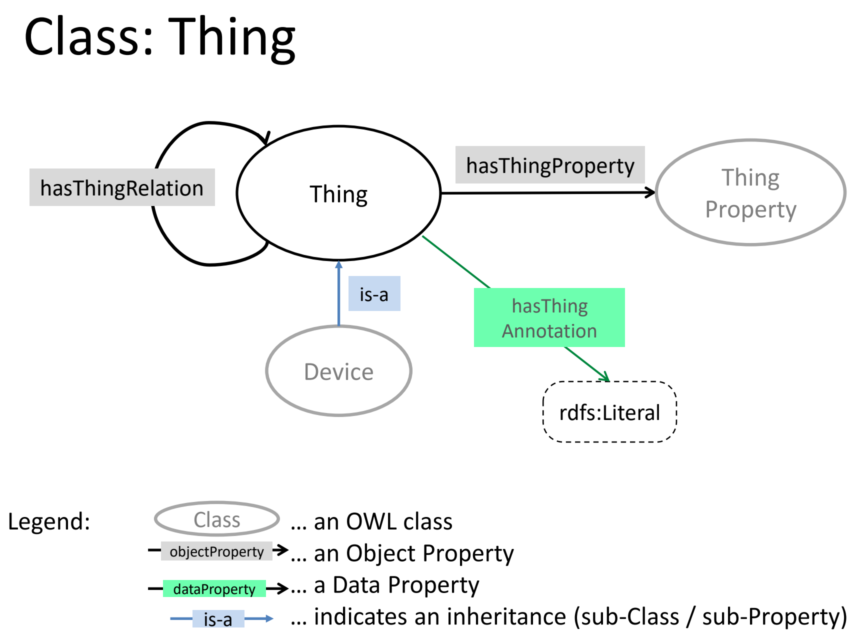


Figure 2: Thing

Description

- A **Thing** in oneM2M (Class: Thing) is an entity that can be identified in the oneM2M System.
  A Thing that is not a Device is not able to communicate electronically with its environment. However, the sub-class of Thing that ***is*** able to interact electronically is called a "Device".
  A Thing may have ThingProperties (Object Property: hasThingProperty). A Thing can have relations to other things (Object Property: hasThingRelation).
  Since a Thing that is not a Device is not able to communicate electronically it cannot influence the value of its ThingProperties or being influenced by it. Similarly a Thing cannot document its - real-world - relationships (via hasThingRelation) to other Things.

- E.g. A room that is modelled in oneM2M would be a Thing that could have a room-temperature as a ThingProperty and could have a relationship "isAdjacentTo" to another room.

Object Properties

This Class is the domain Class of Object Property:

- hasThingProperty (range Class: ThingProperty)

- hasThingRelation (range Class: Thing)

This Class is the range Class of Object Property:

- hasThingRelation (domain Class: Thing)

Data Properties

- hasThingAnnotation (range datatype: rdfs:Literal)

Superclass-subclass Relationships

This Class is subclass of:

- None

This Class is superclass of:

- Device

Restrictions

This Class is anonymous sub-class of:

- hasThingProperty only ThingProperty
  (Universal restriction: a Thing can *only* have a relationship "hasThingProperty" to other ThingProperties)

6.1.2 Class: ThingProperty

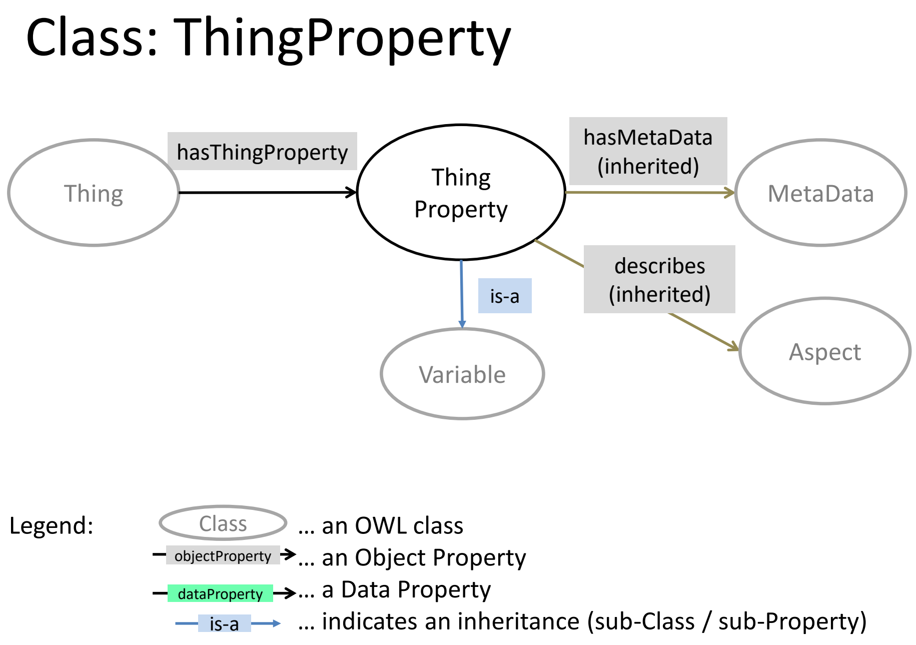


Figure 3: ThingProperty

Description

- A **ThingProperty** (Class: ThingProperty) denotes a property of a Thing. A ThingProperty can e.g. be observed or influenced by devices, or it constitutes static data about a Thing.
  E.g. the indoor temperature of the room could be a ThingProperty of a Thing "room".
  A ThingProperty of a thing can describe a certain Aspect, e.g. the indoor temperature describes the Aspect "Temperature" that could be measured by a temperature sensor.
  A ThingProperty of a Thing can have meta data.
- The class ThingProperty is a sub-class of the Variable class.

Object Properties

This Class is the domain Class of Object Property:

- describes (range Class: Aspect)
  (inherited from class: Variable)
- hasMetaData (range Class: MetaData)
  (inherited from class: Variable)

This Class is the range Class of Object Property:

- hasThingProperty (domain Class: Thing)

Data Properties

This Class is part of the domain Class of Data Property:

- Inherited from class: Variable

Superclass-subclass Relationships

This Class is sub-class of:

- Variable

This Class is super-class of:

- None

Restrictions

- None

6.1.3 Class: Aspect

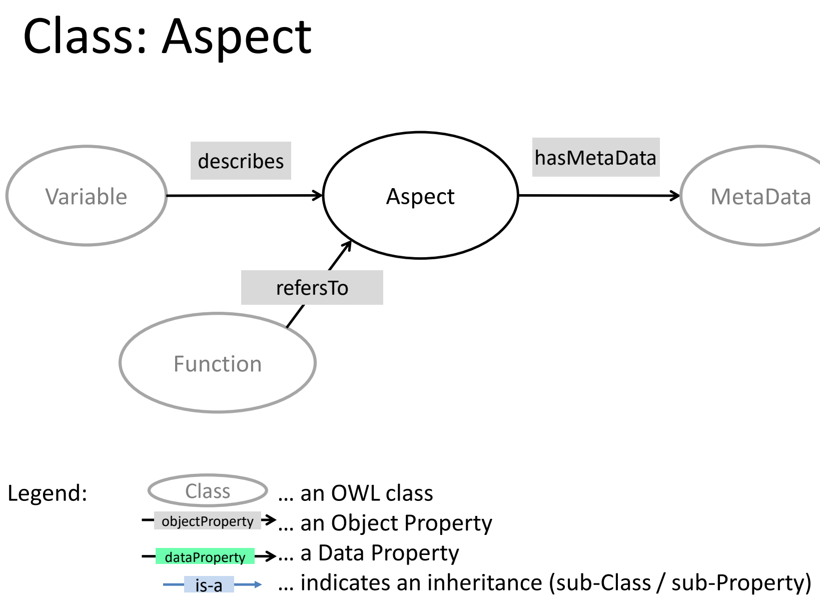


Figure 4: Aspect

Description

- An **Aspect** (Class: Aspect) describes the real-world aspect that a Function relates to. Aspect is also used to describe the quality or kind of a Variable.
  The Aspect could be a (physical or non-physical) entity or it could be a quality.

Object Properties

This Class is the domain Class of Object Property:

- hasMetaData (range Class: MetaData)

This Class is the range Class of Object Property:

- refersTo (domain Class: Function)

- describes (domain Class: Variable)

Data Properties

- None

Superclass-subclass Relationships

This Class is sub-class of:

- None

This Class is super-class of:

- None

Restrictions

- None

6.1.4 Class: MetaData

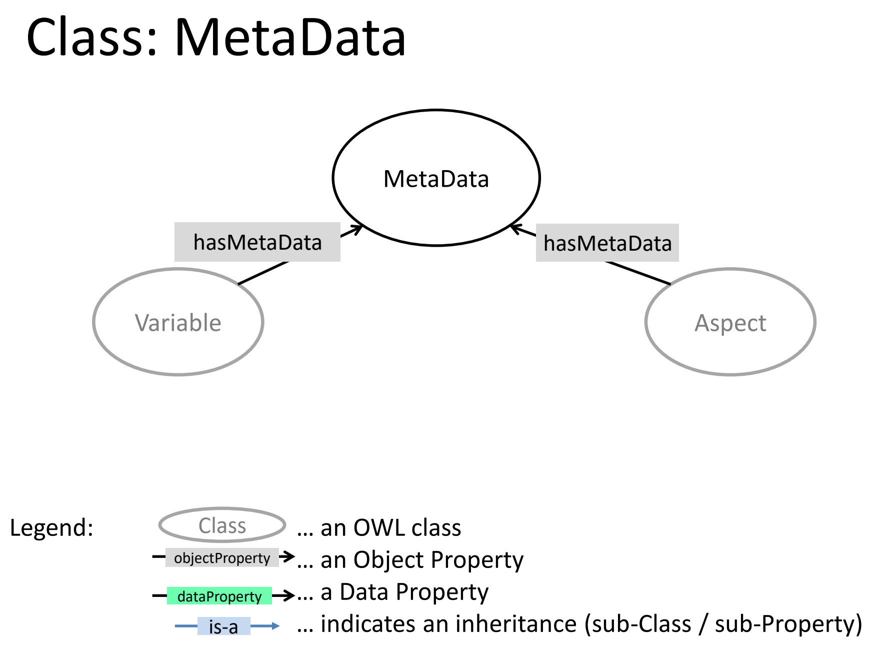


Figure 5: MetaData

Description

- **MetaData** (Class: MetaData) contain data (like units, precision-ranges …) about a Variable or about an Aspect.
  E.g. the indoor temperature could have as meta data an individual "Celsius_Scale" that specifies that the temperature needs to be understood as degrees Celsius.

Object Properties

This Class is the domain Class of Object Property:

- None

This Class is the range Class of Object Property:

- hasMetaData (domain Class: Variable)
- hasMetaData (domain Class: Aspect)

Data Properties

- None

Superclass-subclass Relationships

This Class is sub-class of:

- None

This Class is super-class of:

- None

Restrictions

- None

6.1.5 Class: Device

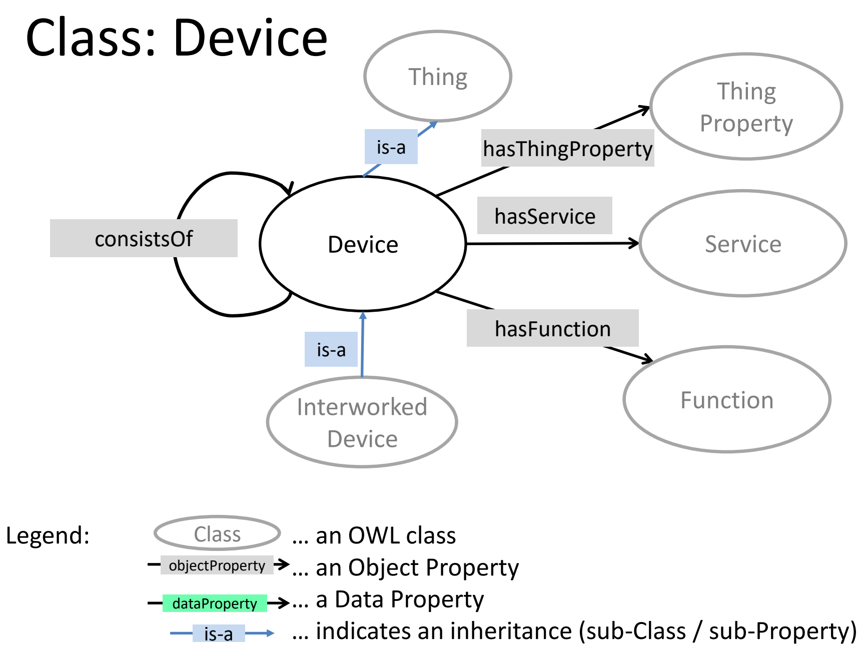


Figure 6: Device

Description

- A **Device** (Class: Device) is a Thing (a sub-class of class:Thing) that is designed to accomplish a particular task via the Functions the Device performs.
  A Device can be able to interact electronically with its environment via a network. A Device contains some logic and is producer and/or consumer of data that are exchanged via its Services with other oneM2M entities (Devices, Things) in the network. A Device may be a physical or non-physical entity.
  A Device interacts through the DataPoints and/or Operations of its Services:

  - In order to accomplish its task, the device performs one or more Functions.
  - These Functions are exposed in the network as Services of the Device.
  - A Device can be composed of several (sub-) Devices.
  - Each Device (including sub-Devices) needs to be individually addressable in the network.

Object Properties

This Class is the domain Class of Object Property:

- consistsOf (range Class: Device)
- hasService (range Class: Service)
- hasFunction (range Class: Function)
- hasThingProperty (range Class: ThingProperty)
  (inherited from Class:Thing)

This Class is the range Class of Object Property:

- consistsOf (domain Class: Device)

Data Properties

- None

Superclass-subclass Relationships

This Class is sub-class of:

- Thing

This Class is super-class of:

- InterworkedDevice

Restrictions

This Class is anonymous sub-class of:

- hasFunction min 1 Function
  (Universal restriction: a Device needs to have a relationship "hasFunction" to at least 1 Function)
- hasService only Service
  (Universal restriction: a Device can have a relationship "hasService" *only* to Services)

6.1.6 Class: InterworkedDevice

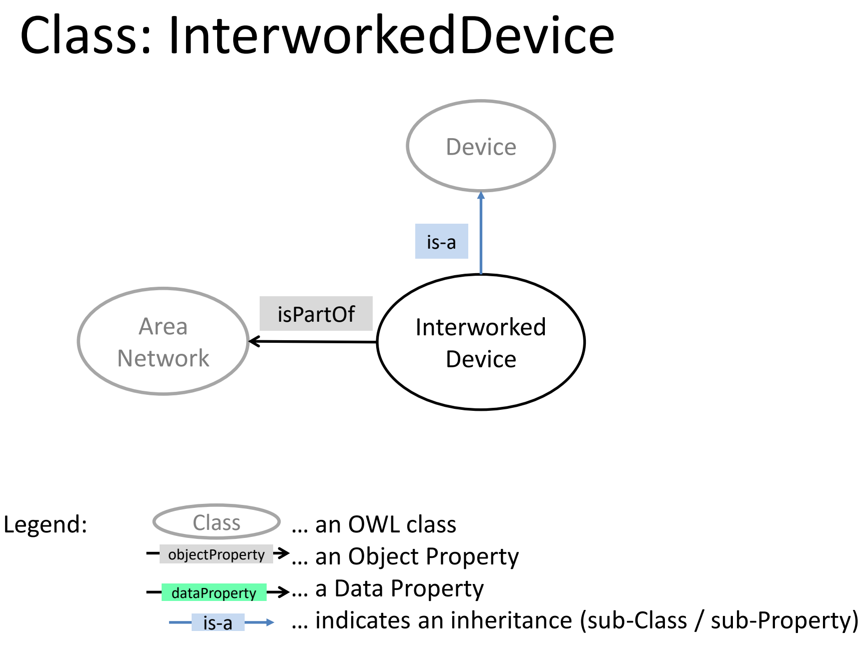


Figure 7: InterworkedDevice

Description

- An **InterworkedDevice** (Class: InterworkedDevice) is a Device - e.g. in an Area Network - that does not support oneM2M interfaces and can only be accessed from the oneM2M System by communicating with a "proxied" (virtual) device that has been created by an Interworking Proxy Entity.

Object Properties

This Class is the domain Class of Object Property:

- isPartOf (range Class: AreaNetwork)

This Class is the range Class of Object Property:

- None

Data Properties

- None

Superclass-subclass Relationships

This Class is sub-class of:

- Device

This Class is super-class of:

- None

Restrictions

- None

6.1.7 Class: AreaNetwork

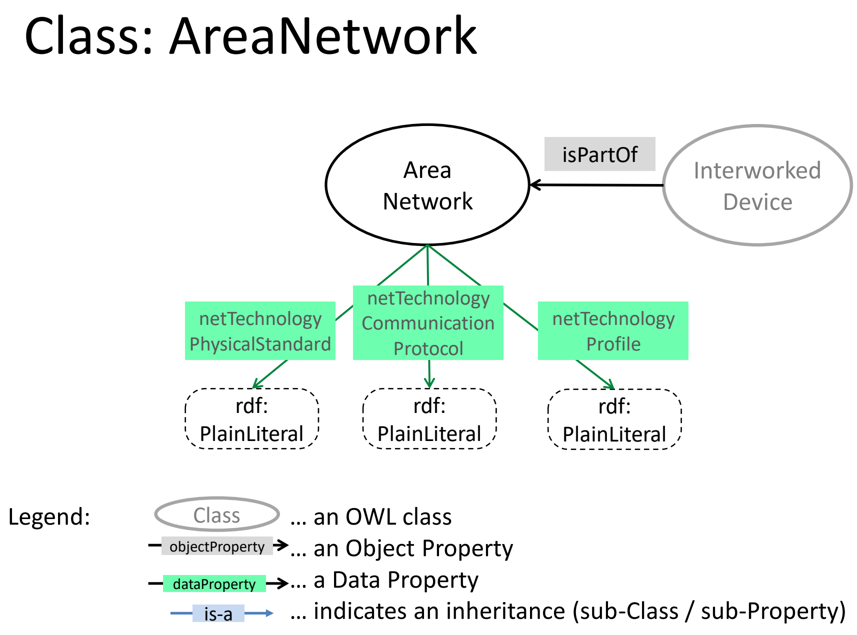

Class: AreaNetwork
Area Network
isPartOf
Interworked Device
netTechnology PhysicalStandard
netTechnology Communication Protocol
netTechnology Profile
rdf: PlainLiteral
rdf: PlainLiteral
rdf: PlainLiteral
Legend:
Class ... an OWL class
objectProperty ... an Object Property
dataProperty ... a Data Property
is-a ... indicates an inheritance (sub-Class / sub-Property)

Figure 8: AreaNetwork

Description

- An **AreaNetwork** (Class: AreaNetwork) is a Network that provides data transport services between an Interworked Device and the oneM2M System. Different area Networks can use heterogeneous network technologies that may or may not support IP access.

Object Properties

This Class is the domain Class of Object Property:

- None

This Class is the range Class of Object Property:

- isPartOf (domain Class: InterworkedDevice)

Data Properties

- netTechnologyPhysicalStandard (range datatype: rdf:PlainLiteral) which serves for Identification of the physical properties of an Area Network technology (e.g. IEEE_802_15_4_2003_2_4GHz)

- netTechnologyCommunicationProtocol (range datatype: rdf:PlainLiteral) which serves for Identification of a communication protocol (e.g. ZigBee_1_0)

- netTechnologyProfile (range datatype: rdf:PlainLiteral) which serves for Identification of a profile (e.g. ZigBee_HA) of an Area Network technology

Superclass-subclass Relationships

This Class is sub-class of:

- None

This Class is super-class of:

- None

Restrictions

- None

6.1.8 Class: Service

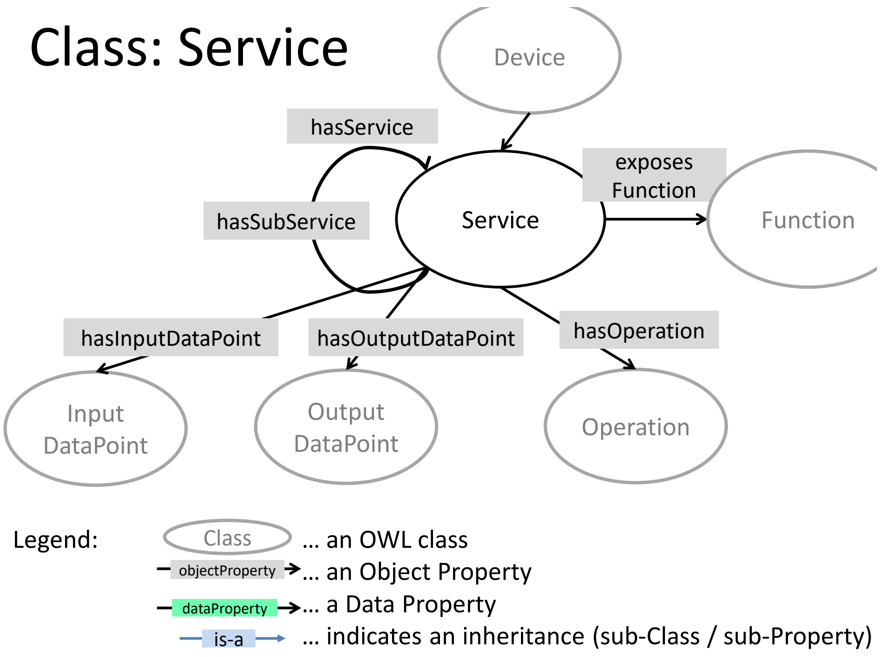


Figure 9: Service

Description

- A **Service** (Class: Service) is an electronic representation of a Function in a network. The Service exposes the Function to the network and makes it discoverable, registerable and remotely controllable in the network.
  A Service is offered by a device that wants (a certain set of) its Functions to be discoverable, registerable, remotely controllable by other devices in the network.
  A Service can expose one or more Functions and a Function can be exposed by one or more Services.

- The Input- and Output DataPoints and Operations of a Service may have the same names as for a different Service, however the Service to which they belong differentiates how they are addressed in the Device (e.g. via a port specific to the Service).

NOTE: While a Function describes the - human understandable - meaning of a Service of the device the Service is used to describe how such Function is represented in a communication network and can be accessed by electronic means. The Service and its Operations is therefore dependent on the technology of the network, hard- and software of the device.

- E.g. the Function: "turn_light_On_or_Off" could be exposed in the network by a Service "UPDATE Binary Value".

  - Object Property "hasSubService" is expresses the fact that Services can be composed of independent (sub)Services.
    E.g. a Service could thus be composed out of multiple (reusable) service modules. A Dimmer could contain a module "binaryActuator" to turn on/off and additionally "setInteger0-255Actuator" to set the dimming level.

Object Properties

This Class is the domain Class of Object Property:

- exposesFunction (range Class: Service)

- hasOperation (range Class: Operation)

- hasInputDataPoint (range Class: InputDataPoint)
- hasOutputDataPoint (range Class: OutputDataPoint)
- hasSubService (range Class: Service)

If for a Service an Operation, Input-, OutputDataPoint or sub-Service is mandatory then the related Object Property (hasOperation, hasInputDataPoint, hasOutputDataPoint, hasSubService) shall have a Property Restriction with cardinality "min 1".

This Class is the range Class of Object Property:

- hasService (domain Class: Device)
- hasSubService (domain Class: Service)

Data Properties

- None

Superclass-subclass Relationships

This Class is sub-class of:

- None

This Class is super -class of:

- None

Restrictions

- hasOperation only Operation
- exposesFunction some Function
  (Universal restriction: at least one of the relationship "exposesFunction" of a Service needs to point to a Function)
- hasInputDataPoint only InputDataPoint
- hasOutputDataPoint only OutputDataPoint

6.1.9 Class: Function

6.1.9.0 General description

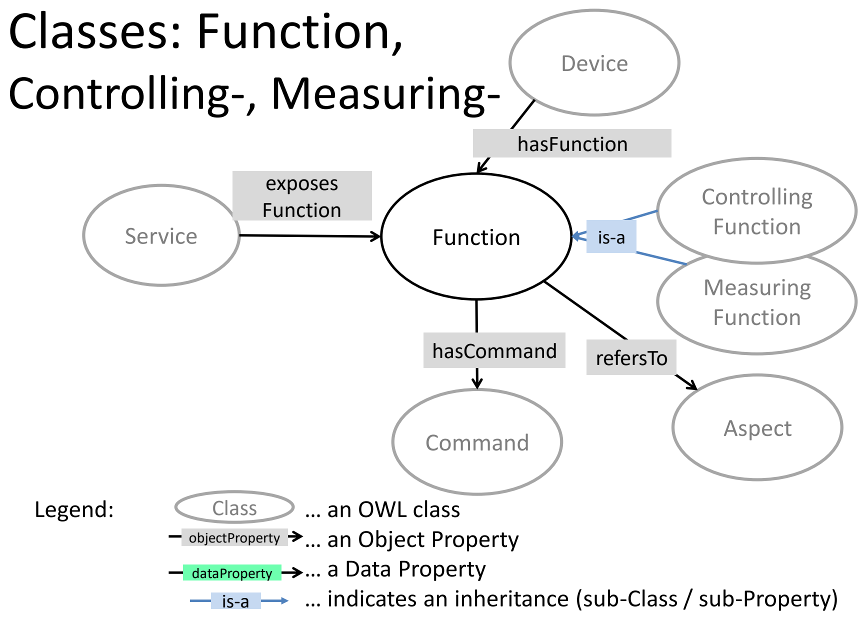


Figure 10: Function

Description

- A **Function** (Class: Function) represents a particular function necessary to accomplish the task for which a Device is designed. A device can be designed to perform more than one Function.
  The Function exhibits the - human understandable - meaning what the device "*does*".
- A Function refers to (e.g. observes or influences) some real-world aspect(s), that can be modelled as a Class: Aspect.
- E.g. considering a "light switch" then a related Function could be "Controlling_ON_OFF" or "Controlling Brightness". These Functions would refer to an Aspect "light-control".
- A Function of a Device can be influenced/observed by a human user through the Commands that this Function has and that are offered to the user.

Object Properties

This Class is the domain Class of Object Property:

- hasCommand (range Class: Command)
- refersTo (range Class: Aspect)

This Class is the range Class of Object Property:

- exposesFunction (domain Class: Service)
- hasFunction (domain Class: Device)

Data Properties

- None

Superclass-subclass Relationships

This Class is sub-class of:

- None

This Class is super-class of:

- ControllingFunction
- MeasuringFunction

Restrictions

- None

6.1.9.1 Class: ControllingFunction

Description

- A **ControllingFunction** (Class: ControllingFunction) represents a Function that has impacts on the real world, but does not gather data. In general a ControllingFunction has Commands (and/or Operations of its related Services) that receive input data.
- E.g. a thermostat would have "temperature-adjustment" as a ControllingFunction.

Object Properties

This Class is the domain Class of Object Property:

- None

This Class is the range Class of Object Property:

- None

Data Properties

- None

Superclass-subclass Relationships

This Class is sub-class of:

- Function

This Class is super-class of:

- None

Restrictions

- None

6.1.9.2 Class: MeasuringFunction

Description

- A **MeasuringFunction** (Class: MeasuringFunction) represents a Function that has no impacts on the real world, but only gathers data. In general a MeasuringFunction has Commands (and/or Operations of its related Services) that generate output data.
- E.g. a temperature sensor would have "temperature-sensing" as a MeasuringFunction.

Object Properties

This Class is the domain Class of Object Property:

- None

This Class is the range Class of Object Property:

- None

Data Properties

- None

Superclass-subclass Relationships

This Class is sub-class of:

- Function

This Class is super-class of:

- None

Restrictions

- None

6.1.10 Class: Operation

6.1.10.0 General description

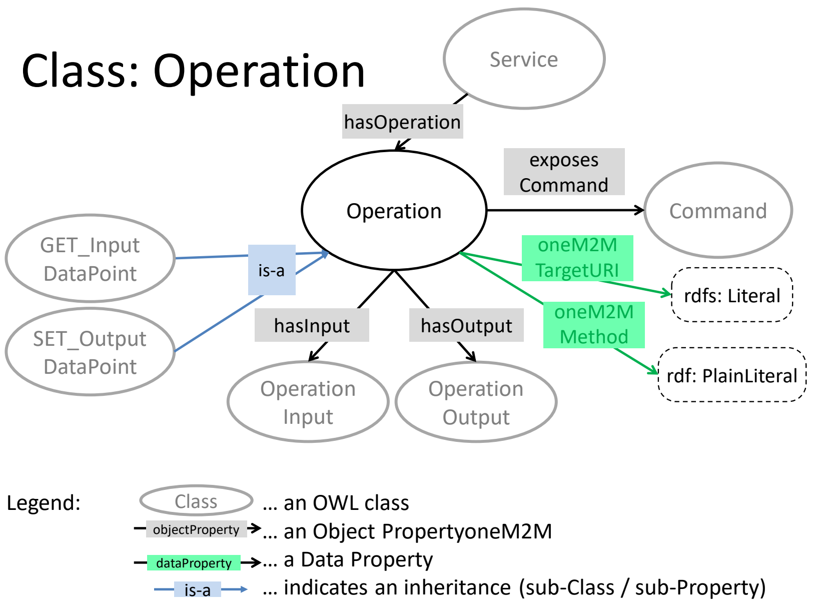


Figure 11: Operation

Description

- An **Operation** (Class: Operation) is the means of a Service to communicate in a procedure-type manner over the network (i.e. transmit data to/from other devices). It is the -machine interpretable- exposure of a -human understandable- Command to a network.
  An Operation is transient. I.e. an Operation can be invoked, possibly produces output and is finished:
  - A non-oneM2M Device or a oneM2M entity (e.g. an AE) can invoke an Operation of the Device (oneM2M Device or InterworkedDevice) and that invocation can trigger some action in the Device. If an Operation has input data it may receive input data from:
    - OperationInput

    and potentially produce output data into:
    - OperationOutput
  - An Operation correlates the output data of the Operation to the input data that were used at Operation invocation.

Object Properties

This Class is the domain Class of Object Property:

- exposesCommand (range Class: Command)
- hasInput (range Class: OperationInput)
- hasOutput (range Class: OperationOutput)

If for an Operation an OperationInput and/or OperationOutput is mandatory then the related Object Property (hasInput, hasOutput) shall have a Property Restriction with cardinality "min 1".

This Class is the range Class of Object Property:

- hasOperation (range Class: Service)

Data Properties

- oneM2MMethod (range data type: rdf:PlainLiteral)
- oneM2MTargetURI (range data type: rdfs: Literal)

Superclass-subclass Relationships

This Class is sub-class of:

- None

This Class is super-class of:

- GET_InputDataPoint
- SET_OutputDataPoint

Restrictions

- exposesCommand only Command
- hasInput only OperationInput
- hasOutput only OperationOutput

6.1.10.1 Class: GET_InputDataPoint

Description

- **GET_InputDataPoint** (Class: GET_InputDataPoint) is an Operation that may be offered by a Device to trigger the device to retrieve the data of an InputDataPoint
(e.g. outside of the schedule when the device normally retrieves data from that DataPoint)

Object Properties

This Class is the domain Class of Object Property:

- None

This Class is the range Class of Object Property:

- None

Data Properties

- None

Superclass-subclass Relationships

This Class is sub-class of:

- Operation

This Class is super-class of:

- None

Restrictions

- None

6.1.10.2 Class: SET_OutputDataPoint

Description

- **SET_OutputDataPoint** (Class: SET_OutputDataPoint) is an Operation that may be offered by a Device to trigger the device to update the data of an OutputDataPoint
(e.g. outside of the schedule when the device normally updates that DataPoint)

Object Properties

This Class is the domain Class of Object Property:

- None

This Class is the range Class of Object Property:

- None

Data Properties

- None

Superclass-subclass Relationships

This Class is sub-class of:

- Operation

This Class is super-class of:

- None

Restrictions

- None

6.1.11 Class: Command

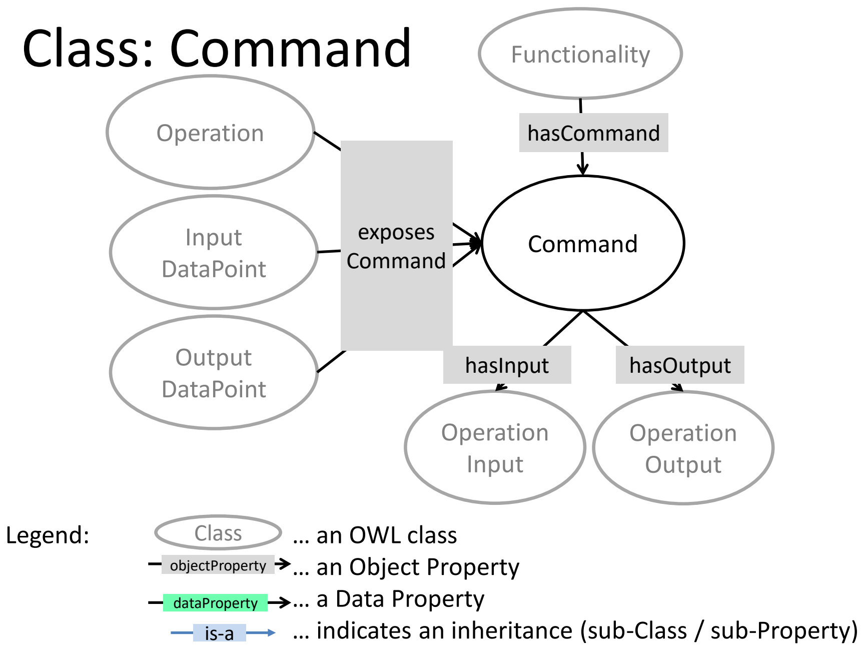


Figure 12: Command

Description

- A **Command** (Class: Command) represents an action that can be performed to support the Function. A Command is the -human understandable - name of that action that is invoked in a device or is reported by the device. An Operation exposes a Command to the network. OperationInput and OperationOutput of the related Operation can parameterize the command.
  E.g. the Function "dimming-Function" of a light switch that remotely controls a light could have a Command "setLightIntensity", with a parameter that has values 0 - 100 %.

  Also InputDataPoints and OutputDataPoints expose Commands to the network. When a Device communicates in a RESTful way then changing (UPDATEing) an InputDataPoint triggers an action in the Device once the Device has read out the data from the InputDataPoint.
  Similarly, when a Device sets the data of an OutputDataPoint then it provides state information about the Device.

NOTE: In RESTful systems the names of Input- and OutputDataPoints are usually chosen in such a way that they express the Command, i.e. the human-understandable meaning (e.g. a binary InputDataPoint of a lightswitch could have a name "Set_Light_Status"). Updating a DataPoint can be interpreted as executing a Command.

Object Properties

This Class is the domain Class of Object Property:

- isExposedByOperation (range Class: Operation)
- hasInput (range Class: OperationInput)
- hasOutput (range Class: OperationOutput)

This Class is the range Class of Object Property:

- hasCommand (domain Class: Function)

- exposesCommand (domain Class: Operation OR InputDataPoint OR OutputDataPoint)

Data Properties

- None

Superclass-subclass Relationships

This Class is sub-class of:

- None

This Class is super-class of:

- None

Restrictions

- hasInput only OperationInput
  (Universal restriction: a Command can have a relationship "hasInput" *only* to OperationInput)
- hasOutput only OperationOutput
- hasInputDataPoint only InputDataPoint
- hasOutputDataPoint only OutputDataPoint

6.1.12 Class: OperationInput

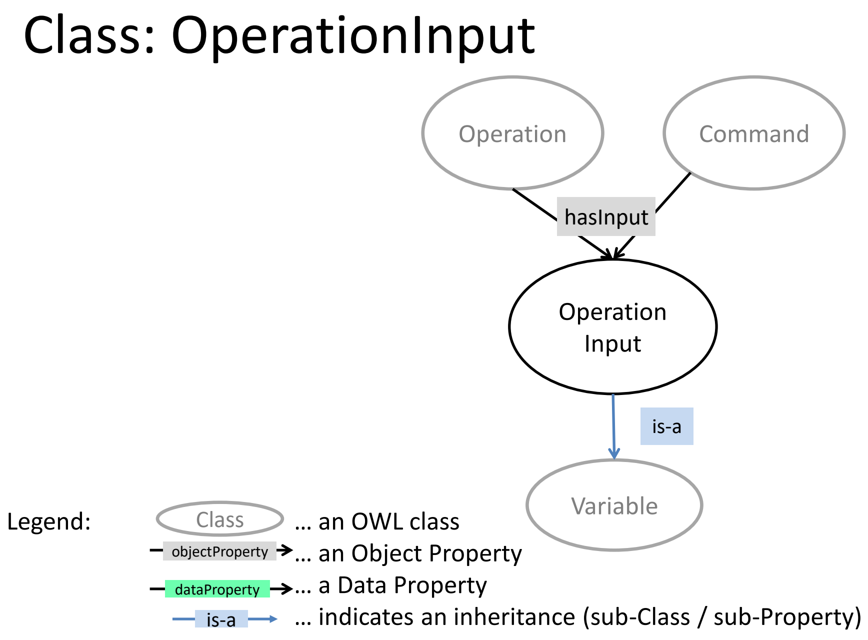


Figure 13: OperationInput

Description

- **OperationInput** (Class: OperationInput) describes an input of an Operation of a Service. OperationInput also describes the input of a Command:
  - OperationInput is transient. An instance of OperationInput is deleted when the instance of its Operation is deleted.
  - An Operation/Command may have multiple OperationInputs and/or OperationOutputs. If an instance of an Operation is invoked then the input value to that Operation shall be an instance of its OperationInput class.

Object Properties

This Class is the domain Class of Object Property:

- hasMetaData (range Class: MetaData)
  (inherited from class:Variable)
- describes (range Class: Aspect)
  (inherited from class:Variable)

This Class is the range Class of Object Property:

- hasInput (domain Class: Operation)
- hasInput (domain Class: Command)

Data Properties

This Class is part of the domain Class of Data Property:

- Inherited from class: Variable

Superclass-subclass Relationships

This Class is sub-class of:

- Variable

This Class is super-class of:

- None

Restrictions

- None

6.1.13 Class: OperationOutput

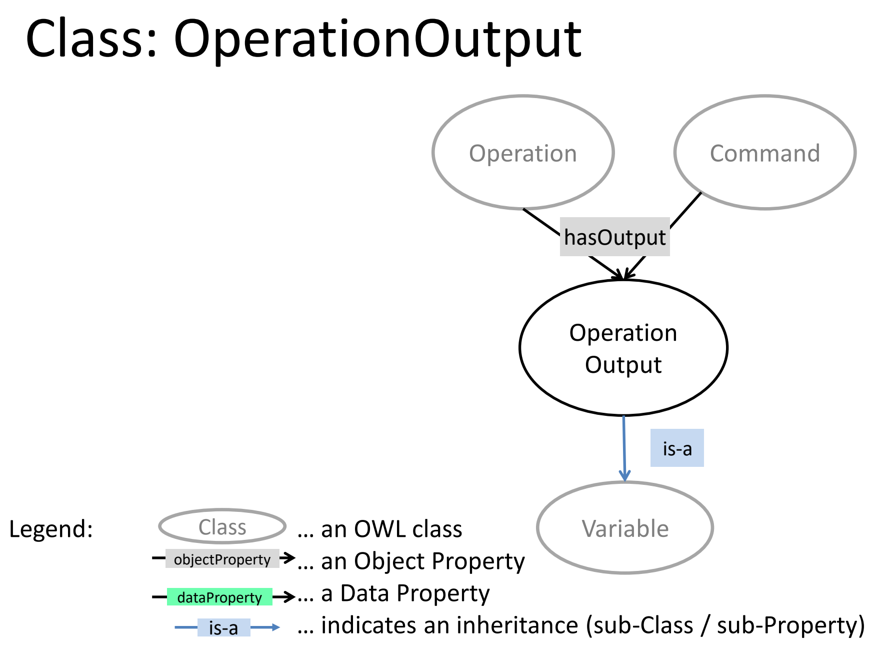


Figure 14: OperationOutput

Description

- **OperationOutput** (Class: OperationOutput) describes an output of an Operation. OperationOutput also describes the output of a Command:
    - OperationOutput is transient. An instance of OperationOutput is deleted when the instance of its Operation is deleted.
    - An Operation/Command may have multiple OperationInputs and/or OperationOutputs.

Object Properties

This Class is the domain Class of Object Property:

- hasMetaData (range Class: MetaData)
  (inherited from class:Variable)
- describes (range Class: Aspect)
  (inherited from class:Variable)

This Class is the range Class of Object Property:

- hasOutput (domain Class: Operation)
- hasOutput (domain Class: Command)

Data Properties

This Class is part of the domain Class of Data Property:

- Inherited from class: Variable

Superclass-subclass Relationships

This Class is sub-class of:

- Variable

This Class is super-class of:

- None

Restrictions

- None

6.1.14 Class: InputDataPoint

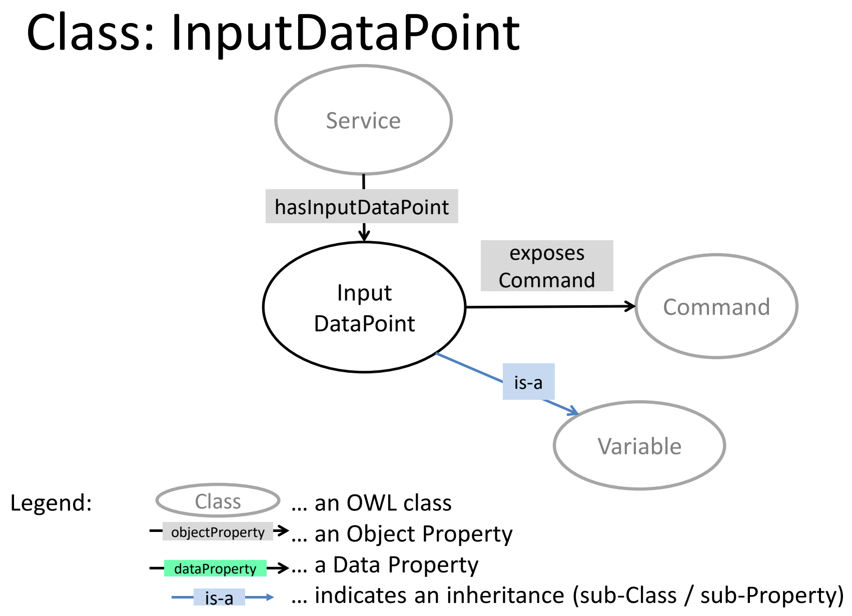


Figure 15: InputDataPoint

Description

- **InputDataPoint** (Class: InputDataPoint) is a Variable of a Service that is accessed by a RESTful Device in its environment and that the Device reads out autonomously (e.g. at periodic times). To enable a third party to instruct the device to retrieve (out of schedule) the current value of a InputputDataPoint devices often also offer a GET_InputDataPoint Operation to trigger the device to retrieve the data from the InputDataPoint.

Object Properties

This Class is the domain Class of Object Property:

- hasMetaData (range Class: MetaData)
  (inherited from class:Variable)

- describes (range Class: Aspect)
  (inherited from class:Variable)

This Class is the range Class of Object Property:

- hasInputDataPoint (domain Class: Service)

- hasInputDataPoint (domain Class: Command)

Data Properties

This Class is part of the domain Class of Data Property:

- Inherited from class: Variable

Superclass-subclass Relationships

This Class is sub-class of:

- Variable

This Class is super-class of:

- None

Restrictions

- None

6.1.15 Class: OutputDataPoint

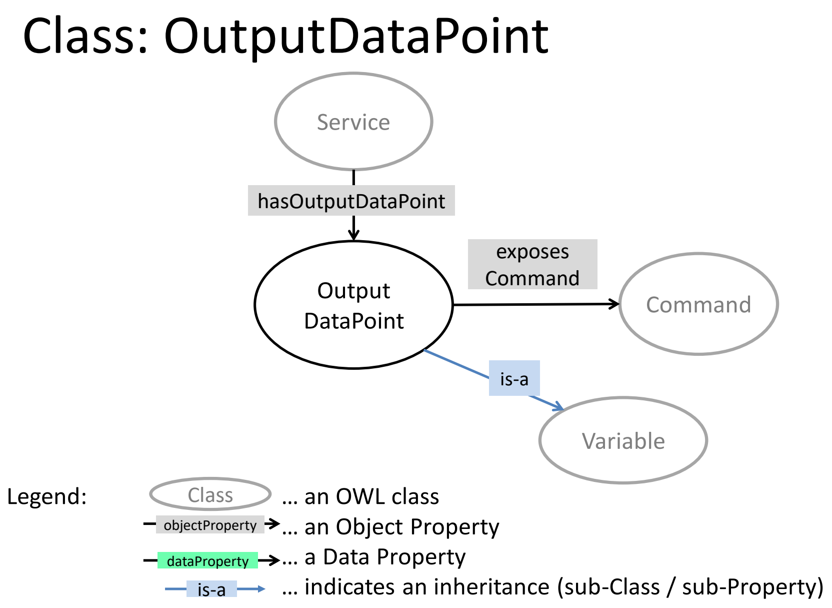


Figure 16: OutputDataPoint

Description

- **OutputDataPoint** (Class: OutputDataPoint) is a Variable of a Service that is set by a RESTful Device in its environment and that the Device updates autonomously (e.g. at periodic times). To enable a third party to instruct the device to update (out of schedule) the current value of a OutputputDataPoint devices often also offer a SET_OutputDataPoint Operation to trigger the device to update the data of the OutputDataPoint.

Object Properties

This Class is the domain Class of Object Property:

- hasMetaData (range Class: MetaData)
  (inherited from class:Variable)

- describes (range Class: Aspect)
  (inherited from class:Variable)

This Class is the range Class of Object Property:

- hasOutputDataPoint (domain Class: Service)

- hasOutputDataPoint (domain Class: Command)

Data Properties

This Class is part of the domain Class of Data Property:

- Inherited from class: Variable

Superclass-subclass Relationships

This Class is sub-class of:

- Variable

This Class is super-class of:

- None

Restrictions

- None

6.1.16 Class: Variable

6.1.16.0 General description

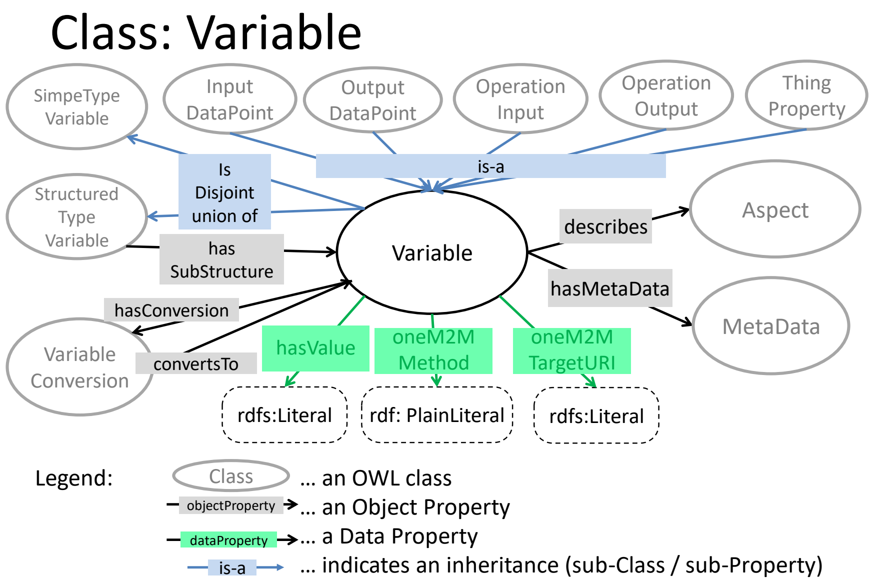


Figure 17: Variable

Description

- A **Variable** (Class: Variable) constitutes a super class to the following classes: ThingProperty, OperationInput, OperationOutput, InputDataPoint, OutputDataPoint. Additionally, class:Variable is the disjoint union of classes: SimpleTypeVariable and StructuredTypeVariable, i.e. any member of class:Variable is also member of either SimpleTypeVariable or StructuredTypeVariable.
  The members of class:Variable are entities that store some data (e.g. integers, text, etc., or structured data) that can change over time. These data of the Variable usually describe some real-world Aspects (e.g. a temperature) and can have MetaData (e.g. units, precision, etc.).

Object Properties

This Class is the domain Class of Object Property:

- hasMetaData (range Class: MetaData)
- describes (range Class: Aspect)
- hasConversion (range Class: VariableConversion)

This Class is the range Class of Object Property:

- hasSubStructure (domain Class: Variable)
- convertsTo (domain Class: VariableConversion)

Data Properties

- oneM2MMethod (range datatype: rdf:PlainLiteral)
  This data property contains a oneM2M Method through which the oneM2M instantiation of the value of the Variable can be manipulated by the communicating entity:

  - It contains the string "RETRIEVE" for retrieving the variable when the oneM2M resource is of type <container> or <flexContainer>. This applies to sub-classes: OperationOutput, OutputDatapoint, ThingProperty.

  - It contains the string "CREATE" for updating the variable when the oneM2M resource is of type <container>. This applies to sub-classes: OperationInput, InputDatapoint, ThingProperty.

  - It contains the string "UPDATE" for updating the variable when the oneM2M resource is of type <flexContainer>. This applies to sub-classes: OperationInput, InputDatapoint, ThingProperty.

- oneM2MTargetURI (range data type: rdfs: Literal)
  This data property contains the URI of a oneM2M resource (<container> or <flexContainer>) through which the oneM2M instantiation of the value of the Variable can be manipulated by the communicating entity. It can contain an absolute address or an address relative to the <semanticDescriptor> resource that holds the RDF description of the Variable.
  That address could be e.g. the value of the parentID for the <container> or <flexContainer> of a Input- or OutputDataPoint which has child-resource of type <semanticDescriptor> that holds the RDF description of the DataPoint.

Superclass-subclass Relationships

This Class is sub-class of:

- None

This Class is super-class of:

- ThingProperty
- OperationInput, OperationOutput
- InputDataPoint
- OutputDataPoint
- SimpleTypeVariable
- StructuredTypeVariable

Union Relationship

This Class is disjoint union of classes:

- SimpleTypeVariable
- StructuredTypeVariable

Restrictions

- None

6.1.16.1 Class: SimpleTypeVariable

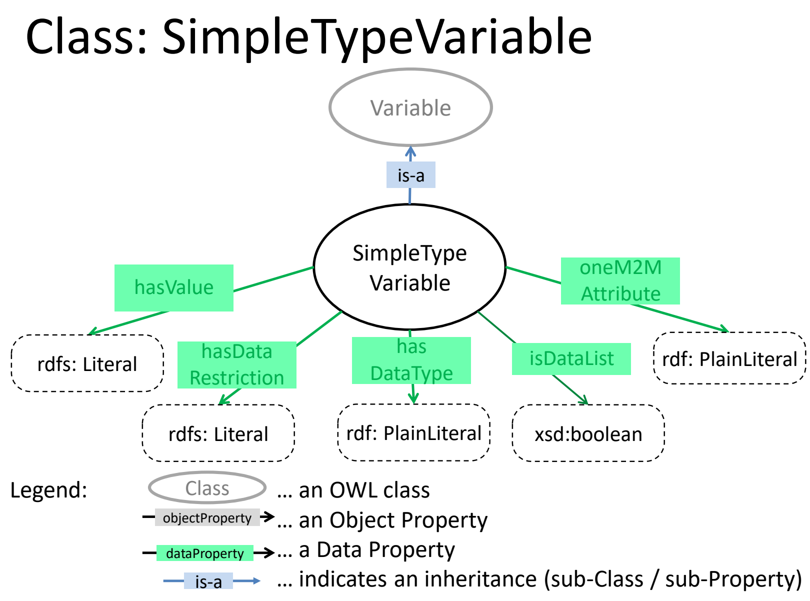


Figure 18: SimpleTypeVariable

Description

- **SimpleTypeVariable** (Class: SimpleTypeVariable) is a sub-class of class:Variable that only consists of Variables of simple xml types like xsd:integer, xsd:string, etc., potentially including restrictions.

  The simple datatypes and -restrictions contained in "OWL 2 Web Ontology Language Structural Specification and Functional-Style Syntax (Second Edition)" [i.4] are supported.

Object Properties

This Class is the domain Class of Object Property:

- None

This Class is the range Class of Object Property:

- None

Data Properties

This Class is part of the domain Class of Data Property:

- Inherited from class: Variable.
  (see clause 6.1.17)

- hasValue (range data type: rdfs: Literal)
  This data property contains the value of the Variable if that value is part of the semantic description and is not contained in a different resource (identified by the oneM2MTargetURI data property). Storing the value of a Variable in a semantic description (i.e. as part of the RDF description in the semanticDescriptor resource) is useful for values that are relatively static (e.g. the name of the manufacturer):

  - Data properties "hasValue" and "oneM2MTargetURI" are mutually exclusive. Only one of the two shall be instantiated.

- oneM2MAttribute (range data: rdf:PlainLiteral)
  This Data Property contains the name of the attribute of the oneM2M resource (of type <container> or <flexContainer>) that is referenced with the oneM2MTargetURI and that stores the value of the SimpleTypeVariable.

- hasDataType (range datatype: rdf:PlainLiteral)
  This Data Property contains the datatype of the SimpleTypeVariable as text string.

- hasDataRestriction (range datatype: rdf:PlainLiteral)
  This Data Property contains a restriction of value of the SimpleTypeVariable.

- isDataList (range datatype: xsd:boolean)
  This Data Property if the SimpleTypeVariable is a list (i.e. contains multiple values).

Superclass-subclass Relationships

This Class is sub-class of:

- Variable

This Class is super-class of:

- None

Disjointness Relationship

This Class is disjoint with class:

- StructuredTypeVariable (a variable is either simple or structured)

Restrictions

- hasDataType exactly 1 rdf:PlainLiteral
- hasDataRestriction only rdf:PlainLiteral
- hasSubStructure exactly 0 Variable

NOTE: A Simple Type Variable has a data type but no other variables as sub-structure.

6.1.16.2 Class: StructuredTypeVariable

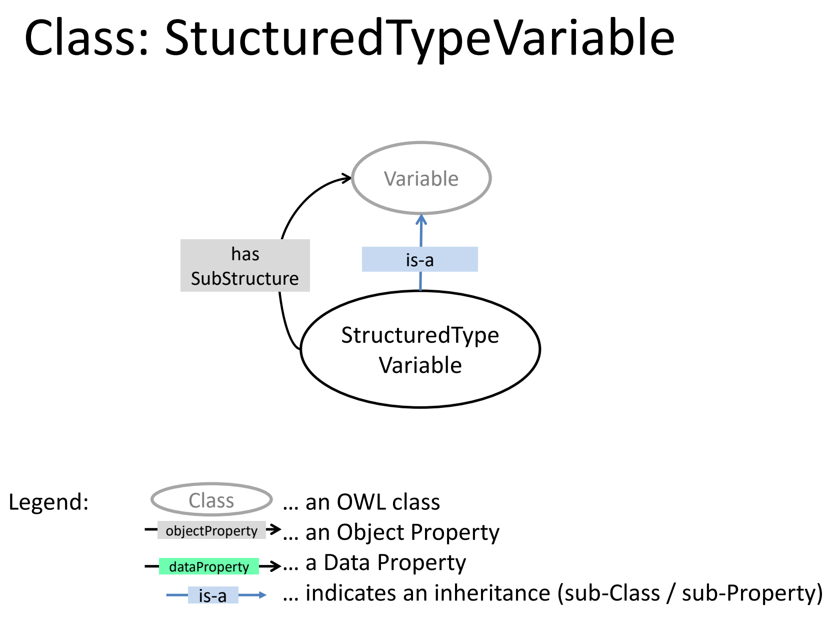


Figure 19: Variable

Description

- **StructuredTypeVariable** (Class: StructuredTypeVariable) is a sub-class of class:Variable that describes a structured variable, composed of a set of other variables. This set of other variables can contain simple type variables Class: SimpleTypeVariable) or also structured variables (Class: StructuredTypeVariable).
  Object Property: hasSubStructure relates a StructuredTypeVariable to its set of composing other variables.

Object Properties

This Class is the domain Class of Object Property:

- hasSubStructure (range Class: Variable)

This Class is the range Class of Object Property:

- hasSubStructure (range Class: Variable)

Data Properties

- None

Superclass-subclass Relationships

This Class is sub-class of:

- Variable

This Class is super-class of:

- None

Disjointness Relationship

This Class is disjoint with class:

- SimpleTypeVariable (a variable is either simple or structured)

Restrictions

- hasSubStructure min 1 Variable (a structured variable has at least one other variable as substructure)

6.1.17 Void

6.1.18 Class: VariableConversion

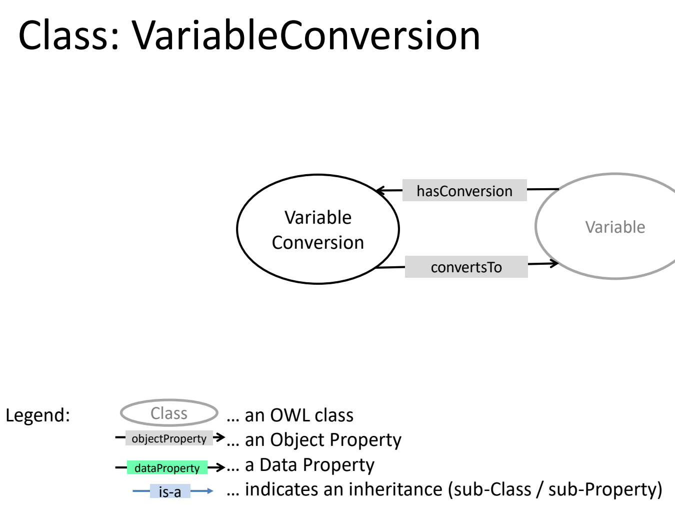


Figure 20: VariableConversion

Description

- A **VariableConversion** (Class: VariableConversion) represents a conversion rule from the value range of one Variable into the value range of another Variable. The plain text specification of that rule is contained in the annotation property rdfs:comment.

Object Properties

This Class is the domain Class of Object Property:

- convertsTo (range Class: Variable)

This Class is the range Class of Object Property:

- hasConversion (domain Class: Variable)

Data Properties

- None

Annotation Properties

- rdfs:comment (range: string)
  This OWL pre-defined annotation property shall be used to contain a textual specification of the rules to convert the variable in the domain class of Object Property: hasConversion to the variable in the range class of Object Property: convertsTo.

Superclass-subclass Relationships

This Class is sub-class of:

- None

This Class is super-class of:

- None

6.2 Object Properties

6.2.1 Void

6.2.2 Void

6.2.3 Object Property: consistsOf

Description

- A Device can consist of (i.e. be composed) of several (sub-) Devices.

Domain Class

- Device

Range Class

- Device

6.2.4 Object Property: describes

Description

- A Variable describes an Aspect (a quality or kind).

Domain Class

- Variable

Range Class

- Aspect

6.2.5 Object Property: exposesCommand

Description

- A -machine interpretable- Operation or an Input/OutputDataPoint of a Service exposes a -human understandable- Command to a network.

Domain Class

- Operation

Range Class

- Command

6.2.6 Object Property: exposesFunction

Description

- A Service exposes a Function to the network and makes it discoverable, registerable and remotely controllable in the network.

Domain Class

- Service

Range Class

- Function

6.2.7 Object Property: hasCommand

Description

- A Function of a Device can be influenced/observed by a human user through the Commands that this Function has and that are offered to the user.

Domain Class

- Function

Range Class

- Command

6.2.8 Object Property: hasFunction

Description

- In order to accomplish its task, a Device performs one or more Functions

Domain Class

- Device

Range Class

- Function

6.2.9 Object Property: hasInput

Description

- An Operation of a Service of the Device or a Command of a Function of the Device can have OperationInput data.

Domain Class

- Operation
- Command

Range Class

- OperationInput

6.2.10 Object Property: hasInputDataPoint

Description

- A Service of the Device can have InputDataPoints. Communicating entities write data into InputDataPoints and the Device retrieves the data at times according to an internal schedule.

Domain Class

- Service

Range Class

- InputDataPoint

6.2.11 Object Property: hasMetaData

Description

- A Variable can have MetaData (like units, precision-ranges, etc.)

Domain Class

- Variable

Range Class

- MetaData

6.2.12 Void

6.2.13 Object Property: hasOperation

Description

- A Service communicates by means of Operations over the network to transmit data to/from other devices.

Domain Class

- Service

Range Class

- Operation

6.2.14 Void

6.2.15 Void

6.2.16 Object Property: hasOutput

- An Operation of a Service of the Device or a Command of a Function of the Device can have OperationOutput data.

Domain Class

- Operation
- Command

Range Class

- OperationOutput

6.2.17 Object Property: hasOutputDataPoint

Description

- A Service of the Device can have OutputDataPoints. The Device writes data into OutputDataPoints at times according to an internal schedule and the communicating entities retrieves the data.

Domain Class

- Service

Range Class

- OutputDataPoint

6.2.18 Object Property: hasService

Description

- The Functions of a Device are exposed in the network as Services of the Device.

Domain Class

- Device

Range Class

- Service

6.2.19 Object Property: hasSubStructure

Description

- A structured Variable can be composed of (sub-)Variables.

Domain Class

- StructuredTypeVariable

Range Class

- Variable

6.2.20 Object Property: hasThingProperty

Description

- A Thing may have properties that can be described by Values.

Domain Class

- Thing

Range Class

- ThingProperty

6.2.21 Object Property: hasThingRelation

Description

- A Thing may have relations to itself or to other Things.

Domain Class

- Thing

Range Class

- Thing

6.2.22 Object Property: hasConversion

Description

- A Variable (in the domain of Object Property: hasConversion) can have a conversion rule (the VariableConversion in the range of Object Property: hasConversion) to convert the value range of the Variable into the value range of another Variable.

Domain Class

- Variable

Range Class

- VariableConversion

6.2.23 Object Property: convertsTo

Description

- The conversion rule (the VariableConversion in the domain of Object Property: hasConversion) converts the value range of a given Variable (see clause 6.2.22 Object Property: hasConversion) into the value range of another Variable (the Variable in the range of Object Property: convertsTo).

Domain Class

- VariableConversion

Range Class

- Variable

6.2.24 Void

6.2.25 Object Property: isPartOf

Description

- An InterworkedDevice consist a part of an AreaNetwork.

Domain Class

- InterworkedDevice

Range Class

- AreaNetwork

6.2.26 Object Property: refersTo

Description

- A Function of a Device can refer to a certain Aspect (a quality or kind) that is measured or controlled by that Function.
  E.g. a temperature sensor would refer to the Aspect "Temperature" that it measures.

Domain Class

- Function

Range Class

- Aspect

6.3 Data Properties

6.3.1 Data Property: hasDataType

Note that in the present document the name space identifier for:

- "https://www.w3.org/TR/xmlschema11-2" shall be referred to using the prefix: xs

Description

- This Data Property specifies the data type of the SimpleTypeVariable as URI. Only those simple data types - listed below - that oneM2M TS-0004 [5] incorporated from XML Schema are permissible.

Domain Class

- SimpleTypeVariable

Range Datatype

- *xsd:string*

Permissible URIs are:

- for Numbers types
  (possible restrictions: minInclusive, maxInclusive, minExclusive, maxExclusive):
  - *xs:decimal*
  - *xs:integer*
  - *xs:float*
  - *xs:double*
  - *xs:nonNegativeInteger*
  - *xs:positiveInteger*
  - *xs:unsignedLong*
  - *xs:unsignedInt*
  - *xs:unsignedShort*
- for XML Simple types
  (possible restrictions: length, minLength, maxLength, pattern):
  - *xs:anySimpleType*
- for String types
  (possible restrictions: xs:length, xs:minLength, xs:maxLength, xs:pattern):
  - *xs:string*
  - *xs:normalizedString*
  - *xs:token*
  - *xs:language*
  - *xs:NCName*
- for Boolean Values (no restrictions):
  - *xs:boolean*

- for Binary Data types
  (possible restrictions: xs:minLength, xs:maxLength, xs:length):
  - *xs:hexBinary*
  - *xs:base64Binary*
- for IRIs
  (possible restrictions: xs:minLength, xs:maxLength, xs:length, xs:pattern):
  - *xs:anyURI*
- for Time Instants
  (possible restrictions: xs:minInclusive, xs:maxInclusive, xs:minExclusive, xs:maxExclusive):
  - *xs:dateTime*
  - *xs:duration*

6.3.2 Data Property: hasDataRestriction

6.3.2.0 General description

Description

- This Data Property specifies the restrictions on the data type of the SimpleTypeVariable.

Domain Class

- SimpleTypeVariable

Range Datatype

- rdf:PlainLiteral

The Data Property "hasDataRestriction" shall always be sub-classed as one of the following specializations.

The range of a sub-classed Data Property "hasDataRestriction" shall be instantiated as the value restricting the data. E.g. a value 100 in the range of Data Property: hasDataRestriction_minInclusive specifies that the SimpleTypeVariable can only take values greater or equal to 100.

6.3.2.1 Data Property: hasDataRestriction_minInclusive

Description

- This Data Property specifies the lower bounds for numeric values (the value shall be greater than or equal to this value) allowed for the SimpleTypeVariable.

It applies to:

- xs:decimal
- xs:integer
- xs:nonNegativeInteger
- xs:positiveInteger
- xs:unsignedLong
- xs:unsignedInt
- xs:unsignedShort
- xs:dateTime

- xs:duration

Domain Class

- SimpleTypeVariable

Range Datatype

- (xsd:float or xsd:integer)

6.3.2.2 Data Property: hasDataRestriction_maxInclusive

Description

- This Data Property specifies the upper bounds for numeric values (the value shall be less than or equal to this value) allowed for the SimpleTypeVariable.

It applies to:

- xs:decimal
- xs:integer
- xs:nonNegativeInteger
- xs:positiveInteger
- xs:unsignedLong
- xs:unsignedInt
- xs:unsignedShort
- xs:dateTime
- xs:duration

Domain Class

- SimpleTypeVariable

Range Datatype

- (xsd:float or xsd:integer)

6.3.2.3 Data Property: hasDataRestriction_minExclusive

Description

- This Data Property specifies the lower bounds for numeric values (the value shall be greater than this value) allowed for the SimpleTypeVariable.

It applies to:

- xs:decimal
- xs:integer
- xs:nonNegativeInteger
- xs:positiveInteger
- xs:unsignedLong
- xs:unsignedInt

- xs:unsignedShort
- xs:dateTime
- xs:duration

Domain Class

- SimpleTypeVariable

Range Datatype

- (xsd:float or xsd:integer)

6.3.2.4 Data Property: hasDataRestriction_maxExclusive

Description

- This Data Property specifies the upper bounds for numeric values (the value shall be less than this value) allowed for the SimpleTypeVariable.

It applies to:

- xs:decimal
- xs:integer
- xs:nonNegativeInteger
- xs:positiveInteger
- xs:unsignedLong
- xs:unsignedInt
- xs:unsignedShort
- xs:dateTime
- xs:duration

Domain Class

- SimpleTypeVariable

Range Datatype

- (xsd:float or xsd:integer)

6.3.2.5 Data Property: hasDataRestriction_length

Description

- This Data Property specifies the exact number of characters or list items allowed of the SimpleTypeVariable. Shall be equal to or greater than zero.

It applies to:

- xs:anySimpleType
- xs:string
- xs:normalizedString
- xs:token

- xs:language
- xs:NCName
- xs:hexBinary
- xs:base64Binary
- xs:anyURI

Domain Class

- SimpleTypeVariable

Range Datatype

- xsd:nonNegativeInteger

6.3.2.6 Data Property: hasDataRestriction_minLength

Description

- This Data Property specifies the minimum number of characters or list items allowed of the SimpleTypeVariable. Shall be equal to or greater than zero.

It applies to:

- xs:anySimpleType
- xs:string
- xs:normalizedString
- xs:token
- xs:language
- xs:NCName
- xs:hexBinary
- xs:base64Binary
- xs:anyURI

Domain Class

- SimpleTypeVariable

Range Datatype

- xsd: nonNegativeInteger

6.3.2.7 Data Property: hasDataRestriction_maxLength

Description

- This Data Property specifies the maximum number of characters or list items allowed of the SimpleTypeVariable. Shall be equal to or greater than zero.

It applies to:

- xs:anySimpleType
- xs:string

- xs:normalizedString
- xs:token
- xs:language
- xs:NCName
- xs:hexBinary
- xs:base64Binary
- xs:anyURI

Domain Class

- SimpleTypeVariable

Range Datatype

- xsd:nonNegativeInteger

6.3.2.8 Data Property: hasDataRestriction_pattern

Description

- This Data Property specifies the restrictions of the SimpleTypeVariable to a subset of strings containing the exact sequence of characters that are acceptable.

It applies to:

- xs:string
- xs:normalizedString
- xs:token
- xs:language
- xs:NCName

Domain Class

- SimpleTypeVariable

Range Datatype

- xsd:string

6.3.3 Data Property: hasValue

Description

- This data property contains the value of the Variable if that value is part of the semantic description and is not contained in a different resource (identified by the oneM2MTargetURI data property). Storing the value of a Variable in a semantic description (i.e. as part of the RDF description in the semanticDescriptor resource) is useful for values that are relatively static (e.g. the name of the manufacturer):
  - Data properties "hasValue" and "oneM2MTargetURI" are mutually exclusive. Only one of the two shall be instantiated.

Domain Class

- SimpleTypeVariable

Range Datatype

- rdfs: Literal

6.3.4 Data Property: netTechnologyCommunicationProtocol

Description

- Identifies a communication protocol (e.g. ZigBee_1_0)

Domain Class

- AreaNetwork

Range Datatype

- netTechnologyCommunicationProtocol rdf:PlainLiteral

6.3.5 Data Property: netTechnologyPhysicalStandard

Description

- netTechnologyPhysicalStandardIdentification of the physical properties of an Area Network technology (e.g. IEEE_802_15_4_2003_2_4GHz).

Domain Class

- AreaNetwork

Range Datatype

- rdf:PlainLiteral

6.3.6 Data Property: netTechnologyProfile

Description

- netTechnologyProfileIdentification of a profile (e.g. ZigBee_HA) of an Area Network technology.

Domain Class

- AreaNetwork

Range Datatype

- rdf:PlainLiteral

6.3.7 Data Property: oneM2MTargetURI

Description

- oneM2MTargetURI (range data type: rdfs: Literal)
  This data property contains the URI of a oneM2M resource (<container> or <flexContainer>) through which the oneM2M instantiation of the value of the Variable can be manipulated by the communicating entity. It can contain an absolute address or an address relative to the <semanticDescriptor> resource that holds the RDF description of the Variable.
  That address could be e.g.:

  - The value of the parentID for the <container> or <flexContainer> of a Input- or OutputDataPoint which has child-resource of type <semanticDescriptor> that holds the RDF description of the DataPoint.

Domain Class

- Operation
- Variable

Range Datatype

- rdfs:Literal

6.3.8 Data Property: oneM2MAttribute

Description

- This Data Property contains the name of the attribute of the oneM2M resource of type <flexContainer> or the child resource of the oneM2M resource of type <container> that is referenced with the oneM2MTargetURI and that stores the value of the SimpleTypeVariable:
  - if the resource-type of the oneM2M resource that is referenced with the oneM2MTargetURI is <container> then this Data Property shall contain the text string "#latest".

Domain Class

- SimpleTypeVariable

Range Datatype

- rdf:PlainLiteral

6.3.9 Data Property: oneM2MMethod

Description

- This data property contains a oneM2M CRUD Method through which the oneM2M instantiation of the value of the Variable can be manipulated by the communicating entity:
  - It contains the string "RETRIEVE" for retrieving the variable when the oneM2M resource is of type <container> or <flexContainer>. This applies to sub-classes: OperationOutput, OutputDatapoint, ThingProperty.
  - It contains the string "CREATE" for updating the variable when the oneM2M resource is of type <container>. This applies to sub-classes: OperationInput, InputDatapoint, ThingProperty.
  - It contains the string "UPDATE" for updating the variable when the oneM2M resource is of type <flexContainer>. This applies to sub-classes: OperationInput, InputDatapoint, ThingProperty.

Domain Class

- Variable
- Operation

Range Datatype

- rdf:PlainLiteral

6.3.10 Data Property: hasThingAnnotation

Description

- This data property contains a description of a Thing.

NOTE: Data Property: hasThingAnnotation should be used in cases where the annotation data do not change very often and/or where they are usually not the subject of semantic operations (e.g. semantic discovery). Otherwise Object Property: hasThingProperty should be used.

E.g. a certain type of Device could have the model (as a numeric description) or the name of the manufacturer (as a textual annotation).

Domain Class

- Thing

Range Datatype

- rdfs: Literal

6.3.11 Data Property: isDataList

Description

- This data property indicates if a SimpleTypeVariable contains a list if data or a single datum:
  - If a sub-class of class: SimpleTypeVariable specifies (i.e. is sub-class of anonymous class of:) "isDataList ***value*** **TRUE**" then the data type is a list (0..n) of values of the base type given by Data Property: hasDataType.
  - If a sub-class of class: SimpleTypeVariable specifies (i.e. is sub-class of anonymous class of:) "isDataList ***value*** **FALSE**" or has no data property: isDataList then the data type is a single value given by Data Property: hasDataType.

Domain Class

- SimpleTypeVariable

Range Datatype

- xsd:boolean

6.4 Annotation Properties

6.4.1 Annotation Property: resourceDescriptorLink

Description

- The *resourceDescriptorLink* annotation property is used to refer to a *semanticDescriptor* resource that contains more information about its subject. Its subject may be any individual and the range shall be the data literal or URI reference that represents the address of the *semanticDescriptor*:
  - For a oneM2M instantiation of the Base Ontology the *resourceDescriptorLink* annotation property is used to annotate instances that appear in the range of object properties. The URI points to the *semanticDescriptor* that contains more information about the instance of that class.

NOTE: In OWL DL it is not allowed to define property axioms on annotation properties, i.e. it is not possible to define a domain and a range within the ontology itself.

Domain Class

- owl:Thing

Range Datatype

- *xsd:anyURI*

7 Instantiation of the Base Ontology and external ontologies to the oneM2M System

7.1 Instantiation rules for the Base Ontology

7.1.1 Instantiation of classes of the oneM2M Base Ontology and derived external ontologies in the oneM2M System

7.1.1.1 General on instantiating classes of the Base Ontology in the oneM2M System

Clause 7.1.1 describes how the Base Ontology shall be instantiated in the oneM2M System.

Every class of the Base Ontology (or a sub-class thereof) shall be instantiated in a *descriptor* attribute of a oneM2M resource of type <*semanticDescriptor*>. A <*semanticDescriptor*> resource may instantiate multiple classes.

That <*semanticDescriptor*> resource shall:

a) Contain instantiations of classes in the RDF data [3] of its *descriptor* attribute:

   - Every instance of a class shall be globally identified within the oneM2M Solution using the *rdf:about* attribute that contains a URI (e.g. based on a MAC address of a Device) that is unique within the oneM2M Solution.

NOTE 1: The choice of a suitable unique URI is out of scope of oneM2M.

b) Contain an Ontology-Ref attribute that identifies the class whose instantiation is described in the *descriptor* attribute. Depending on the instantiation this is a class in the Base Ontology or a class of another ontology that is a sub-class of (includes equals to) a class in the Base Ontology as defined in clause 5.1.2.2.

The <*semanticDescriptor*> shall also contain:

a) The instantiated Object Properties for which the instantiated class is the domain class.

b) The instantiated Data Properties for which the instantiated class is the domain class.

NOTE 2: Instantiations of the domain class and the range class of an object property may be contained in different <*semanticDescriptor*> resources.

If the range class of an object property is instantiated in a <*semanticDescriptor*> resource that is different to the <*semanticDescriptor*> resource in which the domain class is instantiated then the <*semanticDescriptor*> of the instance of the domain class shall contain:

a) an instance of the *resourceDescriptorLink* annotation property that contains the URI of the <*semanticDescriptor*> of the instance of the range class.

For specific classes that are indicated in clause 7.1.1.2 (in particular classes that are derived from class:Variable) the values of Data Properties may be stored in the parent resource of that <*semanticDescriptor*> instead of the RDF data [3] of the *descriptor* attribute.

Any class of a derived external ontology shall be either:

- a sub-class of a class of the Base Ontology; or
- the range class of some Object Property whose domain class is a class (e.g. class:Thing) or sub-class of the Base Ontology.

If a class of a derived external ontology is a sub-class of a class of the Base Ontology then it shall be instantiated in the same way as the class of the Base Ontology.

If a class of a derived external ontology is not a sub-class of the Base Ontology but is the range class of some Object Property whose domain class is a class or sub-class of the Base Ontology then it shall be instantiated in the data of the *descriptor* attribute of the <*semanticDescriptor*> child resource of the oneM2M resource that instantiates the sub-class of the Base Ontology.

7.1.1.2 Instantiation of individual classes of the Base Ontology

The <*semanticDescriptor*> resource is a child-resource of another resource type (e.g. <*AE*>, <*container*>, <*contentInstance*>, <*flexContainer*>) that may contain data of the entity that is described by the <*semanticDescriptor*>.
As these resources describe application data oneM2M leaves the decision what resource type to use to the implementor.

However, TS-0030 "Ontology-based Interworking" [4] specifies a choice of resource types -mainly <*flexContainer*>*s* - as parent resources of the <*semanticDescriptor*>*s* for the purpose of that interworking.
This is the basis of the following sections.

An overview of the oneM2M resources that are parent resources of the <*semanticDescriptor*>*s* for instantiating the classes of the oneM2M Base Ontology is shown in the figure 21. Different colours indicate different resource types.

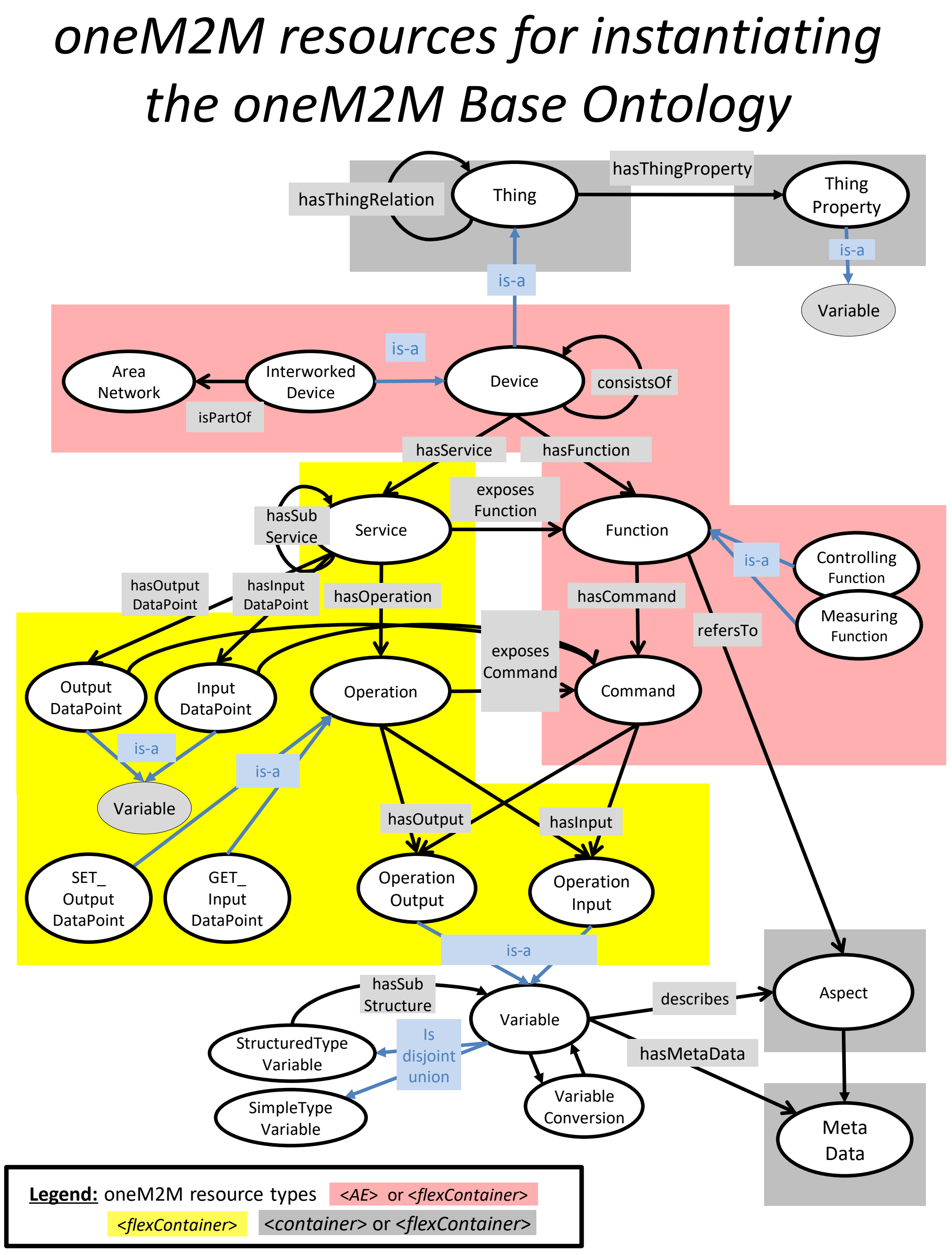


Figure 21: oneM2M instantiation of the Base Ontology

- The **Device** class of the oneM2M Base Ontology (or a sub-class thereof that is not an InterworkedDevice) shall be instantiated in the data of the *descriptor* attribute of a resource of type <*semanticDescriptor*> that is a child resource of an <*AE*>.

  The Device instance is identified using the *rdf:about* attribute that contains a URI (e.g. the MAC address) that is unique within the oneM2M Solution.

  The application logic (identified by its APP-ID of the Device) is provided by the Application Entity (AE) of that Device.

- The **InterworkedDevice** class of the oneM2M Base Ontology (or a sub-class) shall be instantiated in the data of the *descriptor* attribute of a resource of type <*semanticDescriptor*> that is a child resource of:

    - an <*AE*> resource, created by its Interworking Proxy Application Entity (IPE); or, alternatively
    - a <*flexContainer*> resource that is a child resource of the <*AE*> resource of its Interworking Proxy Application Entity (IPE).

    The InterworkedDevice instance is identified using the *rdf:about* attribute that contains a URI (e.g. the device identifier of the device in the interworked system) that is unique within the oneM2M Solution.

NOTE 1: The *resourceID* of a <*node*> resource that stores the node specific information where this Device or Interworked Device resides can be contained in the *nodeLink* attribute of the <*flexContainer*> or <AE>.

NOTE 2: The reason for the different instantiation of Device and InterworkedDevice is the following:

Case 1 - native oneM2M device

- A oneM2M device (ASN, ADN - and potentially MN) always has an AE and an <*AE*> resource. Therefore the Device class for a oneM2M device needs to be instantiated in the *descriptor* attribute of the <*semanticDescriptor*> child resource of that <*AE*>.

Case 2 - interworked (non-oneM2M) device

- In the case of an interworked (non-oneM2M) device the IPE may:
    - Instantiate the InterworkedDevice class for the interworked (non-oneM2M) devices in the *descriptor* attribute of the <*semanticDescriptor*> child resource of the IPE's own <*AE*>.
    - The IPE can create multiple <*AE*> resources, one for each interworked device.
      In this case each interworked device needs to be instantiated in the descriptor attribute of the <semanticDescriptor> child resource of that newly created <*AE*>.
    - The IPE can create multiple <*flexContainer*> resources as child resources of its own <*AE*> resource, one for each interworked device.
      In this case each interworked (non-oneM2M) device needs to be instantiated in the descriptor attribute of the <*semanticDescriptor*> child resource of that <*flexContainer*>.

- The **AreaNetwork** class (or a sub-class) shall be instantiated in the data of the *descriptor* attribute of the <*semanticDescriptor*> child resource of the oneM2M resource that instantiates the InterworkedDevice class:

    - The Data Properties "anTechnologyCommunicationProtocol", "anTechnologyPhysicalStandard" and "anTechnologyProfile" are instantiated in the *descriptor* attribute of the <*semanticDescriptor*> child resource of the oneM2M resource that instantiates the InterworkedDevice class.

- The **Service** class (or a sub-class) shall be instantiated in the data of the *descriptor* attribute of the <*semanticDescriptor*> child resource of a specialization of <*flexContainer*> resource that is a child-resource of the oneM2M resource that instantiates the InterworkedDevice class.

    The instance is identified using the *rdf:about* attribute that contains the URI of the Device concatenated with the letter "*" and the class name of the Service (e.g. 00:11:2F:74:2C:8F*MyService).

- The **Function** class (or sub-class) shall be instantiated in the data of the *descriptor* attribute of the <*semanticDescriptor*> child resource of the oneM2M resource that instantiates the Device class.

    The instance is identified using the *rdf:about* attribute that contains the URI of the Device concatenated with the letter "*" and the class name of the Function (e.g. 00:11:2F:74:2C:8F*MyFunction).

- The **Command** class (or sub-class) shall be instantiated in the data of the *descriptor* attribute of the <*semanticDescriptor*> child resource of the oneM2M resource that instantiates the Device class.

    The instance is identified using the rdf:about attribute that contains the URI of the Function concatenated with the letter "*" and the class name of the Command (e.g. 00:11:2F:74:2C:8F*MyFunction*MyCommand).

- The **Operation** class (or sub-classes) shall be instantiated in the *descriptor* attribute of the <*semanticDescriptor*> child resource of a specialization of a <*flexContainer*> resource that is a child-resource of the <*flexContainer*> resource that instantiates the Service.

  The instance is identified using the *rdf:about* attribute that contains the URI of the Device concatenated with the letter "*" and the class name of the Service, concatenated with the letter "*" the class name of the Operation
  (e.g. "00:11:2F:74:2C:8F*MyService*MyOperation").

- The **OperationInput** and **OperationOutput** class (or sub-class) shall be instantiated in the data of the *descriptor* attribute of the <*semanticDescriptor*> child resource of a <*flexContainer*> resource that instantiates the Operation.

  The instance is identified using the rdf:about attribute that contains the URI of the OperationInstance concatenated with the letter "*" and the class name of the OperationInput or OperationOutput
  (e.g. 00:11:2F:74:2C:8F*MyService*MyOperation*MyOperationOutput).

- The **InputDataPoint** and **OutputDataPoint** class (or sub-class) shall be instantiated in the data of the *descriptor* attribute of the <*semanticDescriptor*> resource of the Service.

  The instance is identified using the *rdf:about* attribute that contains the URI of the Service concatenated with the letter "*" and the class name of the InputDataPoint or OutputDataPoint
  (e.g. 00:11:2F:74:2C:8F*MyService*MyInputDataPoint).

- The **Aspect** class (or sub-classes) may be instantiated in the data of the *descriptor* attribute of the <*semanticDescriptor*> child resource of a <*container*> or <*flexContainer*> resource.

  The instance is identified using the using the rdf:about attribute that contains a URI that is unique within the oneM2M Solution.

NOTE 3: The choice of a suitable unique URI is out of scope of oneM2M.

- The **Thing** class (or sub-classes) may be instantiated in the data of the *descriptor* attribute of the <*semanticDescriptor*> child resource of a <*container*> or <*flexContainer*> resource:

  - The instance is identified using the using the rdf:about attribute that contains a URI that is unique within the oneM2M Solution.

NOTE 4: The choice of a suitable unique URI is out of scope of oneM2M.

  - The range of an instantiation of Object Property "hasThingRelation" that links the instance of the Thing to the instance of a second Thing shall be annotated with an Annotation Property: resourceDescriptorLink which shall contain a reference to the resource of type <*semanticDescriptor*> that instantiates the second Thing.

NOTE 5: This reference could refer to Thing, or a Device (as a sub-class of Thing).

  - The range of an instantiation of an Object Property "hasThingProperty" that links the instance of the Thing to an instance of a ThingProperty shall be annotated with an Annotation Property: resourceDescriptorLink which shall contain a reference to the resource of type <*semanticDescriptor*> that instantiates the ThingProperty <*semanticDescriptor*>.

- The **ThingProperty** class (or sub-class) shall be instantiated in the data of the *descriptor* attribute of the <*semanticDescriptor*> of the Thing <*container*> or <*flexContainer*>.

  The instance is identified using the *rdf:about* attribute that contains the URI of the Thing concatenated with the letter "*" and the class name of the ThingProperty (e.g. *[some (potentially out of oneM2M scope) Thing URI]**MyThingProperty).

- The sub-classes of the **Variable** class shall be instantiated in the data of the *descriptor* attribute of the <*semanticDescriptor*> child resource of resources of a <container> or <*flexContainer*>.
  If the Variable has a structure (if it is composed of (sub-)Variables) - i.e. it is not a SimpleTypeVariable then:
  - The instance of the Variable shall have instances of object property "hasSubStructure" and each instance contains in its range an instance of a (sub-) Variable. If that (sub-)Variable is part of a different <*semanticDescriptor*> resource then the range of an object property "hasSubStructure" shall be annotated with an annotation property: "resourceDescriptorLink" which shall contain a reference to the resource of type <*semanticDescriptor*> that instantiates the (sub-)Variable.
  - The<*semanticDescriptor*> shall contain an instance of data property "oneM2MTargetURI" which shall contain the URI of the parent <container> or <*flexContainer*> resource.
  - If data property "oneM2MTargetURI" is instantiated then the data property "oneM2MAttribute" shall also be instantiated and contain:
    - In the case of a <*flexContainer*> the name of the *customAttribute* in the <*flexContainer*> resource).
    - In the case of a <*container*> the value "#latest".
  - The<*semanticDescriptor*> shall have instances of the data property "oneM2MMethod" which indicates a oneM2M CRUD Method through which the oneM2M instance of the value of the Variable can be manipulated by a communicating entity:
    - It contains the string "RETRIEVE" for retrieving the variable when the oneM2M resource is of type <container> or <flexContainer>. This applies to sub-classes: OperationOutput, OutputDatapoint, ThingProperty.
    - It contains the string "CREATE" for updating the variable when the oneM2M resource is of type <container>. This applies to sub-classes: OperationInput, InputDatapoint, ThingProperty.
    - It contains the string "UPDATE" for updating the variable when the oneM2M resource is of type <flexContainer>. This applies to sub-classes: OperationInput, InputDatapoint, ThingProperty.
- The sub-classes of the **SimpleTypeVariable** class shall be instantiated in the data of the *descriptor* attribute of the <*semanticDescriptor*> child resource of resources of a <container> or <*flexContainer*>.
  The data properties are the same as for instances of the Variable class.
  In addition:
  - The data property "hasValue" contains the value of the Variable if that value is part of the semantic description and is not contained in a different resource (identified by the oneM2MTargetURI data property).

NOTE 6: Storing the value of a Variable in a semantic description (i.e. as part of the RDF description in the <*semanticDescriptor*> resource) is useful for values that are relatively static (e.g. the name of the manufacturer).

- Data properties "hasValue" and "oneM2MTargetURI" are mutually exclusive. Only one of the two shall be instantiated for a SimpleTypeVariable.
- The **VariableConversion** class represents a conversion rule between different Variables:
  - A VariableConversion that exists between variables of a Command (OperationInput/-Output) and variables of the related Operation (OperationInput/-Output) or Input-/OutputDatapoints is not instantiated as resource in the oneM2M System.
    It documents how parameters of a Command of a Function needs to be interpreted when a related Operation (OperationInput/-Output) or Input-/OutputDatapoints of the corresponding Service is invoked.

- A VariableConversion that exists between variables of two Services of a single or two different Devices specifies a functionality of the oneM2M AE which implements the Device:

    - If an Operation *OA* that has an OperationInput *OAI* of a Device *A* is invoked
and
OAI is related via Object Property: hasConversion to a VariableConversion *VC*
and
VC is related via Object Property: convertsTo to an OperationInput *OBI* of an Operation *OB* of Device *B*
then Device A shall convert OperationInput *OAI* according to the rules specified in VariableConversion *VC*into OperationInput *OBI* and invoke Operation *OB* in Device *B*.

EXAMPLE: Assume a "dimming" Command for controlling a lightbulb.
In the case of an Abstract Device A the corresponding Operation A has an OperationInput parameter that can take values 0 - 100.
In the case of an actual Device B the Operation B implementing the same Command has an OperationInput parameter of 3 bit size (i.e. integer range 0-7).
In this case the OperationInput of Operation A has an Object Property hasConversion to a VariableConversion *VC* and *VC* has an Object Property convertsTo to the OperationInput of Operation B of Device B.
The comments Annotation Property of *VC* describes how to convert the value in the range of 0-100 in the OperationInput of Operation A to the OperationInput in the range of 0-7 of Operation B.
Using this information, an "abstraction" application can convert the OperationInput of Device A to the OperationInput of Device B and invoke the Operation on Device B.

- The **MetaData** class (or sub-classes) may be instantiated in the data of the descriptor attribute of the <*semanticDescriptor*> child resource of any resource type that allows a <*semanticDescriptor*> child resource.

  The instance is identified using the using the rdf:about attribute that contains a URI that is unique within the oneM2M Solution.

7.1.2 Instantiation of Object Properties

Object properties relate an instance of domain class to an instance of the range class.
They shall be instantiated in the data of the *descriptor* attribute of the <*semanticDescriptor*> resource that instantiates the domain class of the object property.

If the range class of an Object Property is instantiated in a different resource than the instantiation of the domain class then the range class of an Object Property shall be annotated with the Annotation Property: resourceDescriptorLink which shall contain a reference to that resource.

7.1.3 Instantiation of Data Properties

Data properties shall be instantiated in the data of the *descriptor* attribute of the <*semanticDescriptor*> resource that instantiates the domain class of the data property.

7.1.4 Instantiation of Annotation Properties

Annotation properties may be instantiated in the data of the *descriptor* attribute of any <*semanticDescriptor*> resource.

For a oneM2M instantiation of the Base Ontology the resourceDescriptorLink annotation property is used to annotate the range of object properties with the URI of the <*semanticDescriptor*> that contains the instance (that holds the RDF description of the instance) of the range class of the object property.

The resourceDescriptorLink annotation property is not part of the semantic description but is used to refer to a <*semanticDescriptor*> resource that contains more information about its subject. It is resolved by combining the content of the *descriptor* attributes of the <*semanticDescriptor*> resources before a semantic operation (e.g. SPARQL query) is performed.

7.2 Common mapping principles between the Base Ontology and external ontologies

The Base Ontology can be mapped to other external ontologies (e.g. SAREF, SSN, etc.). The following principles are applied for the mapping between ontologies:

- Principle 1 - Classes Mapping (owl:equivalentClass):
  - Making the statement X owl:equivalentClass Y essentially means that two named classes are synonymous, i.e. that all instances of class X are instances of class Y and vice versa.
  - Using this principle, two classes specified in different ontologies are declared to be equivalent.
- Principle 2 - Properties Mapping (owl:equivalentProperty):
  - The owl:equivalentProperty construct can be used to state that two properties have the same property extension. Syntactically, owl:equivalentProperty is a built-in OWL property with rdf:Property as both its domain and range.
  - Using this principle, if two properties are declared to be equivalent, two properties have the same semantics or meaning.
- Principle 3 - Class Instances Mapping (owl:sameAs):
  - The property owl:sameAs is used to state that two individuals (i.e. class instances) are the same.
  - Using this principle, two class instances specified in different ontologies are declared to be equivalent.
- Principle 4 - SubClass Mapping (rdfs:subClassOf):
  - The property rdfs:subClassOf is used to state that the class extension of a class description is a subset of the class extension of another class description.
  - Making the statement X rdfs:subClassOf Y essentially means that all instances of class X are instances of class Y.
- Principle 5 - SubProperties Mapping (rdfs:subPropertyOf):
  - The property rdfs:subPropertyOf is used to state that one property is the subproperty of another property. Syntactically, the domain and range of rdfs:subPropertyOf are both of type rdf:Property.
  - Making the statement X rdfs:subPropertyOf Y essentially means that all resources related by property X are also related by property Y.

When using the above principles for the mapping between the Base Ontology and an external ontology, the hierarchy and relations of the classes and properties defined in these two ontologies should be carefully considered since there may exist some incompatible points after mapping due to the inheritance of the properties.

8 Void

9 Void

Annex A (normative): OWL representation of Base Ontology

The OWL representation of Base Ontology is provided in a separate document.

The Base Ontology is available at the oneM2M Gitlab web page for MAS/BaseOntology:

- https://git.onem2m.org/MAS/BaseOntology.

That page contains the latest version of the (RDF/XML) OWL representation of the ontology under the URL:

- https://git.onem2m.org/MAS/BaseOntology/raw/master/base_ontology.owl.

and individual versions of the (RDF/XML) OWL representation of the ontology under the URL:

- https://git.onem2m.org/MAS/BaseOntology/raw/x_y_z/base_ontology.owl, (where x, y, z signify the version numbering for major- minor- and editorial changes of the Base Ontology).

  E.g. https://git.onem2m.org/MAS/BaseOntology/raw/2_2_0/base_ontology.owl

Annex B (informative): Mappings of selected external ontologies to the Base Ontology

B.1 Mapping of SAREF

B.1.1 Introduction to SAREF

The following description of the SAREF ontology is copied from the following site: https://sites.google.com/site/smartappliancesproject/ontologies/reference-ontology.

It provides an introduction to the scope and objectives of SAREF ontology:

"*The Smart Appliances REFerence (SAREF) ontology is a shared model of consensus that facilitates the matching of existing assets (standards/protocols/datamodels/etc.) in the smart appliances domain. The SAREF ontology provides building blocks that allow separation and recombination of different parts of the ontology depending on specific needs.*

The starting point of SAREF is the concept of Device (e.g. a switch). Devices are tangible objects designed to accomplish one or more functions in households, common public buildings or offices. The SAREF ontology offers a lists of basic functions that can be eventually combined in order to have more complex functions in a single device. For example, a switch offers an actuating function of type "switching on/off". Each function has some associated commands, which can also be picked up as building blocks from a list. For example, the "switching on/off" is associated with the commands "switch on", "switch off" and "toggle". Depending on the function(s) it accomplishes, a device can be found in some corresponding states that are also listed as building blocks.

A Device offers a Service, which is a representation of a Function to a network that makes the function discoverable, registerable and remotely controllable by other devices in the network. A Service can represent one or more functions. A Service is offered by a device that wants (a certain set of) its function(s) to be discoverable, registerable, remotely controllable by other devices in the network. A Service must specify the device that is offering the service, the function(s) to be represented, and the (input and output) parameters necessary to operate the service.

A Device in the SAREF ontology is also characterized by an (Energy/Power) Profile that can be used to optimize the energy efficiency in a home or office that are part of a building."

A formal description of the ontology is provided via this link: http://ontology.tno.nl/saref/.

Table B.1 provides a list of SAREF concepts - source http://www.etsi.org/images/files/Events/2015/201502_SMARTAPP/D-S4 - SMART 2013-0077 - Smart Appliances - Final Study Report_v1.0.pdf.

Table B.1: List of SAREF concepts

Concept	Definition
Building Object	A Building Object is an object in the building that can be controlled by devices, such as a door or a window that can be automatically opened or closed by an actuator.
Building Space	According to FEIMSER, a Building Space in SAREF defines the physical spaces of the building. A building space contains devices or building objects.
Command	A Command is a directive that a device should support to perform a certain function. A command may act upon a state, but does not necessarily act upon a state. For example, the ON command acts upon the ON/OFF state, but the GET command does not act upon any state, since it gives a directive to retrieve a certain value with no consequences on states.
Commodity	A Commodity is a marketable item for which there is demand, but which is supplied without qualitative differentiation across a market. SAREF refers to energy commodities such as electricity, gas, coal and oil.
Device	A Device in the context of the Smart Appliances study is a tangible object designed to accomplish a particular task in households, common public buildings or offices. In order to accomplish this task, the device performs one or more functions. For example, a washing machine is designed to wash (task) and to accomplish this task it performs the start and stop function.
Device Category	A Device Category provides a way to classify devices according to a certain point of view, for example, the point of view of the user of the device vs. the device's manufacturer, or the domain in which the device is used (e.g. smart appliances vs. building domain vs. smart grid domain), etc.
Function	A Function represents the particular use for which a Device is designed. A device can be designed to perform more than one function.
Function Category	A Function Category provides a way to classify functions according to a certain point of view, for example, considering the specific application area for which a function can be used (e.g. light, temperature, motion, heat, power, etc.), or the capability that a function can support (e.g. receive, reply, notify, etc.), and so forth.
Profile	A Profile characterizes a device for the purpose to optimize the energy efficiency in the home or office in which the device is located. The saref:Profile class allows to describe the energy (or power) production and consumption of a certain device using the saref: hasProduction and saref:hasConsumption properties. This production and consumption can be calculated over a time span (the saref:hasTime property) and, eventually, associated to some costs (the saref:hasPrice property).
Property	A Property is anything that can be sensed, measured or controlled in households, common public buildings or offices.
Service	A Service is a representation of a function to a network that makes the function discoverable, registerable, remotely controllable by other devices in the network. A service can represent one or more functions. A Service is offered by a device that wants (a certain set of) its function(s) to be discoverable, registerable, remotely controllable by other devices in the network. A Service should specify the device that is offering the service, the function(s) to be represented, and the (input and output) parameters 144 necessary to operate the service.
State	A State represents the state in which a device can be found, e.g. ON/OFF/STANDBY, or ONLINE/OFFLINE, etc.
Task	A Task represents the goal for which a device is designed (from a user perspective). For example, a washing machine is designed for the task of cleaning.
Unit of Measure	The Unit of Measure is a standard for measurement of a quantity, such as a Property. For example, Power is a property and Watt is a unit of power that represents a definite predetermined power: when 10 Watt is mentioned, it actually means 10 times the definite predetermined power called "watt". Our definition is based on the definition of unit of measure in the Ontology of units of Measure (OM). A list of some units of measure that are relevant for the purpose of the Smart Appliances ontology is proposed here, but this list can be extended.

B.1.2 Class mapping relationship between SAREF and the Base Ontology

This clause provides an example on how the principle specified in clause 7.2 can be applied to the mapping between the Base Ontology and SAREF.

Using two different ontologies (i.e. Base_Ontology.owl and SAREF.owl), a new ontology can be created using the mapping principles, i.e. adding mapping relationships into the union of these two ontologies as a new mapped ontology.

As a simple case, the following illustrates the subClass mapping between oneM2M:Device and saref:Device. The following shows that saref:Device is a subclass of oneM2M:Device.

NOTE 1: The full sub-classing and sub-Properties relationships between SAREF and the oneM2M base ontology can be found in the file BO_SAREF.owl on the oneM2M gitlab pages at: https://git.onem2m.org/MAS/BaseOntology/tree/master/Example_usage_of_the_Base_Ontology_-_combinig_SAREF_and_BO.
For use in an ontology browser (e.g. Protégé) the raw version (https://git.onem2m.org/MAS/BaseOntology/raw/master/Example_usage_of_the_Base_Ontology_-_combinig_SAREF_and_BO/BO_SAREF.owl) should be used.

There are two popular OWL syntax: OWL/XML or RFD/XML.

OWL/XML syntax for sub-class mapping is:

```
    <Import>http://www.onem2m.org/ontology/Base_Ontology</Import>
    <Import>http://ontology.tno.nl/saref</Import>

    <SubClassOf>
        <Class IRI="http://ontology.tno.nl/saref#Device"/>
        <Class IRI="http://www.onem2m.org/ontology/Base_Ontology#Device"/>
    </SubClassOf>
```

```
RFD/XML syntax for subclass mapping is:
   <rdf:Description rdf:about="http://ontology.tno.nl/saref#Device">
        <rdfs:subClassOf rdf:resource="http://www.onem2m.org/ontology/Base_Ontology#Device"/>
    </rdf:Description>
```

Then, all instances of saref:Device are instances of oneM2M:Device.

Figure B.1 shows the class hierarchy of the new mapped ontology with mapping saref:Device as subClass of oneM2M:Device.

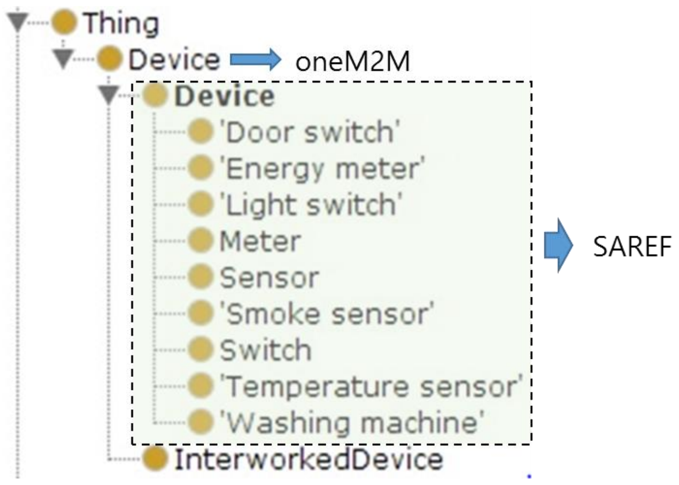


Figure B.1: Class hierarchy of a mapped ontology with mapping saref:Device as subClass of oneM2M:Device

Considering both the definition and the relations of the classes in SAREF and the Base Ontology, table B.2 gives the possible subclass mapping between SAREF and the Base Ontology.

Table B.2: Sub-class mapping between SAREF and the Base Ontology

Class in SAREF	Mapping relationship	Class in Base Ontology
saref:BuildingObject	rdfs:subClassOf	oneM2M:Thing
saref: BuildingSpace	rdfs:subClassOf	oneM2M:Thing
saref:Commodity	rdfs:subClassOf	oneM2M:Thing
saref:Property	rdfs:subClassOf	oneM2M:InputDataPoint OR oneM2M:OutputDataPoint
saref:UnitOfMeasure	rdfs:subClassOf	oneM2M:MetaData
saref:MeteringFunction	rdfs:subClassOf	oneM2M:MesuringFunction
saref:State	rdfs:subClassOf	oneM2M:InputDataPoint OR oneM2M:OutputDataPoint
saref:Profile,	rdfs:subClassOf	oneM2M:Thing
saref:Task	rdfs:subClassOf	oneM2M:ThingProperty
saref:DeviceCategory	rdfs:subClassOf	oneM2M:ThingProperty
saref:FunctionCategory	rdfs:subClassOf	oneM2M:Aspect

NOTE 2: Mapping SAREF classes into sub-classes of the Base Ontology is only relevant for the oneM2M System as this sub-class relationship enables a standardized instantiation of these SAREF classes as oneM2M resources.

For the purpose of semantic discovery also sub-classing some Base Ontology classes to SAREF classes can be done. Thus oneM2M Devices, Functions, Services … for which instances (oneM2M resources) exist in a oneM2M Solution can be discovered as SAREF instances if these resources are annotated with their semantic description in the appropriate <*semanticDescriptor*> child resources and if the semantic description is made available to SAREF.

Mutual sub-class relationships (rdfs:subClassOf) result in equivalent classes (owl:equivalentClass), i.e. any instance of one class is also an instance of the equivalent class.

Table B.3: Equivalence-class mapping between SAREF and the Base Ontology

Class in SAREF	Mapping relationship	Class in Base Ontology
saref:Device	owl:equivalentClass	oneM2M:Device
saref:Command	owl:equivalentClass	oneM2M:Command
saref:Function	owl:equivalentClass	oneM2M:Function
saref:Service	owl:equivalentClass	oneM2M:Service
saref:ActuatingFunction	owl:equivalentClass	oneM2M:ControllingFunction
saref:SensingFunction	owl:equivalentClass	oneM2M:MesuringFunction

Object Properties of the Base Ontology, for which domain- and range classes have equivalent classes in the SAREF ontology, can have equivalent Object Properties in SAREF.

Table B.4: Equivalent Property mapping between SAREF and the Base Ontology

Object Property in SAREF	Mapping relationship	Object Property in Base Ontology
saref:offers	owl:equivalentProperty	oneM2M:hasService
saref:consistsOf	owl:equivalentProperty	oneM2M:consistsOf
saref:represents	owl:equivalentProperty	oneM2M:exposesFunction
saref:hasCommand	owl:equivalentProperty	oneM2M:hasCommand

B.1.3 Mapping SAREF to oneM2M resource structure

B.1.3.1 Introduction

Mapping an ontology to oneM2M describes how an instance of that ontology may be represented under oneM2M resource structure. This clause proposes a recommended way to map SAREF to oneM2M.

B.1.3.2 Mapping rules

Mapping ontologies to the oneM2M resource structure may be provided through a list of mapping rules. The oneM2M Base Ontology instantiation rules in clause 7.1 apply. Currently no additional mapping rules apply.

B.1.3.3 Example showing instantiation in the oneM2M resource structure

This clause gives an example of how oneM2M resources and their semantic annotations based on the Smart Appliance REFerence Ontology (SAREF) [i.2] can be used to describe a device representing a smart appliance.
It assumes that the Instantiation rules in clause 7 and the sub-class mapping relationship between SAREF and the Base Ontology (clause B.1.2) apply.

The example taken from SAREF is a (simplified) washing machine:

- The washing machine has been manufactured by manufacturer **XYZ**.
- XYZ describes this type of washing machine as "`Very cool Washing Machine`".
- The model of the type of washing machine is **XYZ_Cool.**
- The state of the washing machine is given by SAREF:state: **WashingMachineStatus** that can take the values "WASHING" or "STOPPED" or "ERROR".
- The washing machine has an actuating function: **StartStopFunction** which has three commands:
  - **ON_Command**
  - **OFF_Command**
  - **Toggle_Command**
- The related service of the washing machine that represents that actuating function is of class: **SwitchOnService** from SAREF. It has:
  - an InputDataPoint: **BinaryInput** (to expose command ON_Command and OFF_Command); and
  - an Operation: **ToggleBinary** (to expose command Toggle_Command).
- The washing machine has also a metering function: **MonitoringFunction** that and sets the WashingMachineStatus.
- This WashingMachineStatus is provided as an the OutputDataPoint of a service **MonitorService** which exposes the MonitoringFunction to the network.
- The washing machine is located at **My_Bathroom.**

NOTE: "InputDataPoint", "OutputDataPoint" and "Operation" are not specified in SAREF, they are classes of the oneM2M Base Ontology.

This example will identify the specific washing machine by the URI: "WASH_XYZ_123". WASH_XYZ_123 that is an instance of class: XYZ_Cool which is contained in XYZ's ontology: http://www.XYZ.com/WashingMachines.
The ontology "http://www.XYZ.com/WashingMachines" that contains the model type "XYZ_Cool" is compliant to SAREF, which is turn is compliant to the oneM2M Base Ontology (see clause B.1.2).

Figure B.2 shows some sub-classing relationships between XYZ_Cool, SAREF and the oneM2M Base Ontology.

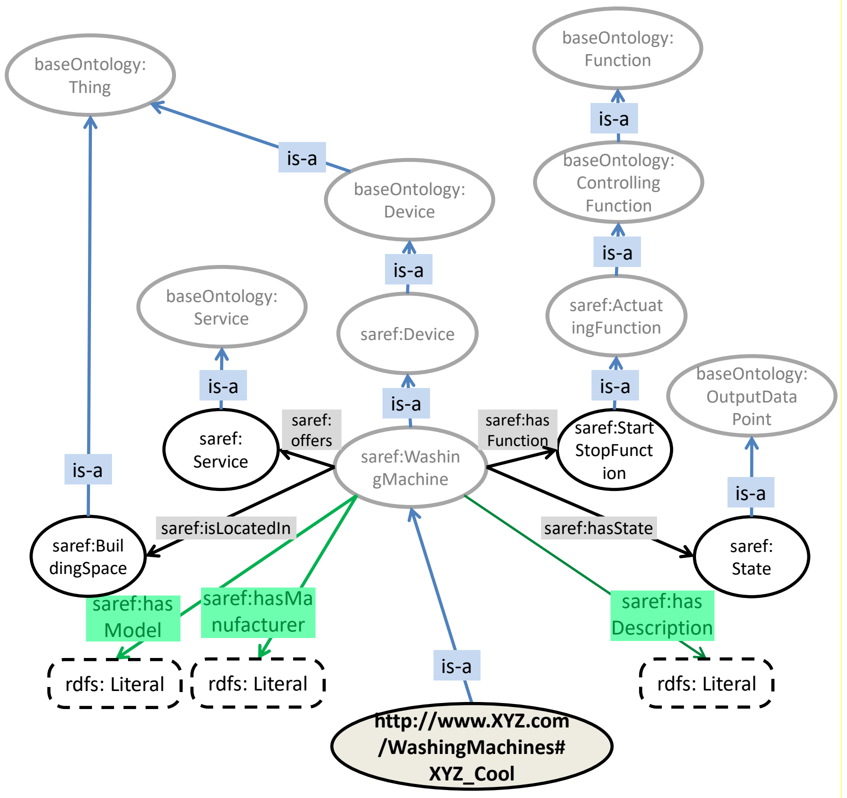


Figure B.2: Sub-classing relationships between XYZ_Cool, SAREF and the oneM2M Base Ontology

According to clause 7.1.1.2 the washing machine - as a sub-class of the oneM2M:Device class - needs to be instantiated in the data of the *descriptor* attribute of a resource of type *<semanticDescriptor>* that is a child resource of an *<AE>*.

EXAMPLE:

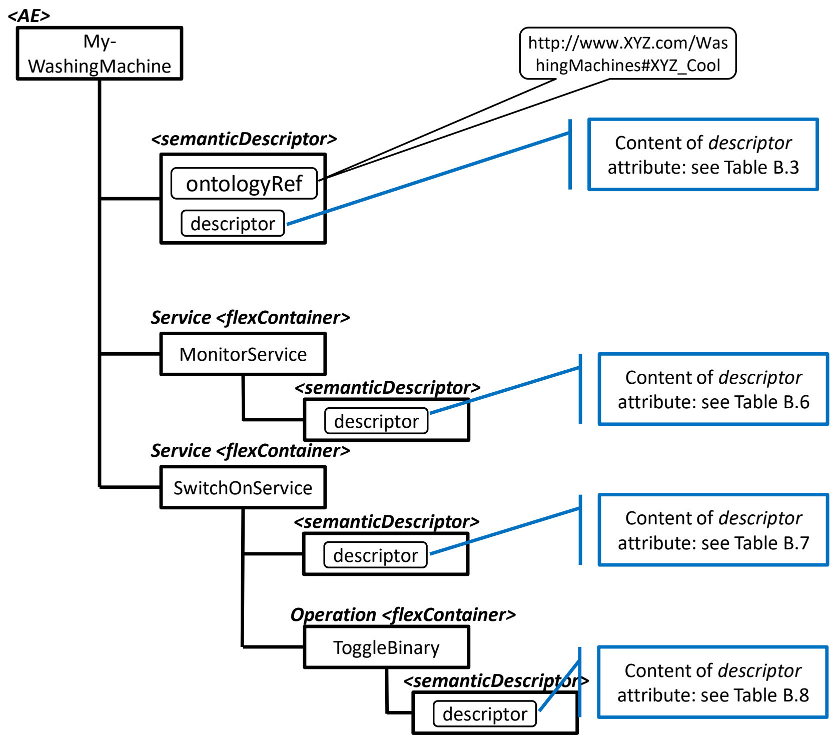
- that <AE> resource could have resourceID = "00000001" and have a resourceName "My-WashingMachine"
- Its CSE-relative address would be:

  Non-Hierarchical:

  - "00000001"

  Hierarchical:

  - "./My-WashingMachine"
- The URI of the washing machine instance (i.e. the value of "rdf:about=") could e.g. be its serial number: http://www.XYZ.com/WashingMachines/SerialNumbers/WASH_XYZ_123.



<AE>
My-WashingMachine
http://www.XYZ.com/WashingMachines#XYZ_Cool
<semanticDescriptor>
ontologyRef
descriptor
Content of *descriptor* attribute: see Table B.3
Service <flexContainer>
MonitorService
<semanticDescriptor>
descriptor
Content of *descriptor* attribute: see Table B.6
Service <flexContainer>
SwitchOnService
<semanticDescriptor>
descriptor
Content of *descriptor* attribute: see Table B.7
Operation <flexContainer>
ToggleBinary
<semanticDescriptor>
descriptor
Content of *descriptor* attribute: see Table B.8

Figure B.3: Resource structure of smart washing machine <AE> and its child-resources

Figure B.3 shows the resource structure of a <AE> resource representing the smart washing machine. Its *semanticDescriptor*> child resource has an ontologyRef attribute, which contains the URI of the ontology concept of the smart washing machine, e.g. "http://www.XYZ.com/WashingMachines#XYZ_Cool" (not shown in the figure: the ontologyRef attributes in the semanticDescriptors of the child resources, e.g. http://www.XYZ.com/WashingMachines#SwitchOnService). The ontology http://www.XYZ.com/WashingMachines needs to include - and creates sub-classing relationships with - SAREF and the oneM2M Base Ontology.

The <*AE*> resource representing the smart washing machine contains as child-resources:

- a <*semanticDescriptor*> resource that contains the rdf description of the washing machine WASH_XYZ_123 in its descriptor attribute;
- two <*flexContainer*> child-resources for Services and their <semanticDescriptor>s are used for modelling the services SwitchOnService and MonitorService;
- the SwitchOnService in turn has a child resource of type <*flexContainer*> for Operations (and its <*semanticDescriptor*>) which is to expose the Toggle_Command;
- one *customAttribute* of the SwitchOnService <*flexContainer*> is used for holding the values for InputDataPoint: BinaryInput;
- one *customAttribute* of the MonitorService <*flexContainer*> is used for holding the values for OutputDataPoint: WashingMachineStatus.

The RDF in the following tables shows the semantic annotation stored in the semanticDescriptor resources related to the washing machine.

Table B.5: RDF annotation contained in the descriptor attribute of the <*semanticDescriptor*> resource of a SAREF washing machine <*AE*> *resource*

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:saref="http://ontology.tno.nl/saref/"
    xmlns:oneM2M="http://www.onem2m.org/ontology/Base_Ontology/"
    xmlns:xs="http://www.w3.org/2001/XMLSchema"
    xml:base="http://www.XYZ.com/WashingMachines/SerialNumbers/">
    <rdf:Description rdf:about="WASH_XYZ_123">
        <rdf:type rdf:resource="http://www.XYZ.com/WashingMachines#XYZ_Cool"/>
        <saref:hasManufacturer>XYZ</saref:hasManufacturer>
        <saref:hasDescription>Very cool Washing Machine</saref:hasDescription>
        <saref:hasState rdf:resource="WASH_XYZ_123*WashingMachineStatus"/>
        <saref:hasFunction rdf:resource="WASH_XYZ_123*StartStopFunction"/>
        <saref:hasFunction rdf:resource="WASH_XYZ_123*MonitoringFunction"/>
        <saref:hasService rdf:resource="WASH_XYZ_123*SwitchOnService"/>
        <saref:hasService rdf:resource="WASH_XYZ_123*MonitorService"/>
        <saref:isLocatedIn rdf:resource="My_Bathroom"/>
    </rdf:Description>

    <rdf:Description rdf:about="WASH_XYZ_123*WashingMachineStatus">
        <oneM2M:resourceDescriptorLink rdf:resource=
        "./My-WashingMachine/MonitorService/semanticDescriptor"/>
    </rdf:Description>

    <rdf:Description rdf:about="WASH_XYZ_123*StartStopFunction">
        <rdf:type rdf:resource="https://w3id.org/saref#ActuatingFunction"/>
        <saref:hasCommand rdf:resource="WASH_XYZ_123*StartStopFunction*ON_Command"/>
        <saref:hasCommand rdf:resource="WASH_XYZ_123*StartStopFunction*OFF_Command"/>
        <saref:hasCommand rdf:resource="WASH_XYZ_123*StartStopFunction*Toggle_Command"/>
    </rdf:Description>

    <rdf:Description rdf:about="WASH_XYZ_123*StartStopFunction*ON_Command">
        <rdf:type rdf:resource="https://w3id.org/saref#OnCommand"/>
    </rdf:Description>

    <rdf:Description rdf:about="WASH_XYZ_123*StartStopFunction*OFF_Command">
        <rdf:type rdf:resource="https://w3id.org/saref#OffCommand"/>
    </rdf:Description>

    <rdf:Description rdf:about="WASH_XYZ_123*StartStopFunction*Toggle_Command">
        <rdf:type rdf:resource="https://w3id.org/saref#ToggleCommand"/>
    </rdf:Description>

    <rdf:Description rdf:about="WASH_XYZ_123*SwitchOnService">
        <oneM2M:resourceDescriptorLink rdf:resource=
        "./My-WashingMachine/SwitchOnService/semanticDescriptor"/>
    </rdf:Description>

    <rdf:Description rdf:about="WASH_XYZ_123*MonitorService">
        <oneM2M:resourceDescriptorLink rdf:resource=
        "./My-WashingMachine/MonitorService/semanticDescriptor"/>
    </rdf:Description>

    <rdf:Description rdf:about="WASH_XYZ_123*MonitoringFunction">
        <rdf:type rdf:resource="https://w3id.org/saref#MeteringFunction"/>
        <saref:hasCommand rdf:resource="WASH_XYZ_123*MonitoringFunction*WashingMachineStatus"/>
    </rdf:Description>

    <rdf:Description rdf:about="My_Bathroom">
        <rdf:type rdf:resource="https://w3id.org/saref#BuildingSpace"/>
        <oneM2M:resourceDescriptorLink rdf:resource=
        "//m2m.service.com/SomeIN-CSE/ResourceName_of_My_Bathroom/semanticDescriptor"/>
    </rdf:Description>

</rdf:RDF>
```

Table B.6: RDF annotation contained in the descriptor attribute of the <*semanticDescriptor*> resource of the MonitorService service <*flexContainer*> resource

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:saref="http://ontology.tno.nl/saref/"
    xmlns:oneM2M="http://www.onem2m.org/ontology/Base_Ontology/"
    xmlns:xs="http://www.w3.org/2001/XMLSchema"
    xml:base="http://www.XYZ.com/WashingMachines/SerialNumbers/">
    <rdf:Description rdf:about="WASH_XYZ_123*MonitorService">
        <rdf:type rdf:resource="https://w3id.org/saref#Service"/>
        <saref:represents rdf:resource="WASH_XYZ_123*MonitoringFunction"/>
        <oneM2M:hasOutputDataPoint rdf:resource="WASH_XYZ_123*MonitorService*WashingMachineStatus"/>
    </rdf:Description>

    <rdf:Description rdf:about="WASH_XYZ_123*MonitorService*WashingMachineStatus">
        <rdf:type rdf:resource="https://w3id.org/saref#State"/>
        <oneM2M:oneM2MTargetURI rdf:resource=
        "./My-WashingMachine/MonitorService"/>
        <oneM2M:oneM2MAttribute>WashingMachineStatus</oneM2M:oneM2MAttribute>
        <oneM2M:hasDataType>xs:string</oneM2M:hasDataType>
        <oneM2M:hasDataRestriction_pattern>"WASHING"|"STOPPED"|"ERROR"
</oneM2M:hasDataRestriction_pattern>
        <oneM2M:oneM2MMethod>RETRIEVE</oneM2M:oneM2MMethod>
    </rdf:Description>


    <rdf:Description rdf:about="WASH_XYZ_123*WashingMachineStatus">
        <rdf:type rdf:resource="https://w3id.org/saref#State"/>
        <oneM2M:oneM2MTargetURI rdf:resource=
        "./My-WashingMachine/MonitorService"/>
        <oneM2M:oneM2MAttribute>WashingMachineStatus</oneM2M:oneM2MAttribute>
        <oneM2M:hasDataType>xs:string</oneM2M:hasDataType>
        <oneM2M:hasDataRestriction_pattern>"WASHING"|"STOPPED"|"ERROR"
</oneM2M:hasDataRestriction_pattern>
        <oneM2M:oneM2MMethod>RETRIEVE</oneM2M:oneM2MMethod>
    </rdf:Description>


</rdf:RDF>
```

NOTE: In table B.6 "WashingMachineStatus" appears twice:
- as "WASH_XYZ_123*WashingMachineStatus"
which is the object of object property device:hasState - indicating the state of the device
- as "WASH_XYZ_123*MonitorService*WashingMachineStatus"
which is the object of object property service:hasOutputParameter - indicating an output parameter of the MonitorService.
Both have the same oneM2MTargetURI, thus referencing the same value.

Table B.7: RDF annotation contained in the descriptor attribute of the <*semanticDescriptor*> resource of the SwitchOnService service <*flexContainer*> resource

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:saref="http://ontology.tno.nl/saref/"
    xmlns:oneM2M="http://www.onem2m.org/ontology/Base_Ontology/"
    xmlns:xs="http://www.w3.org/2001/XMLSchema"
    xml:base="http://www.XYZ.com/WashingMachines/SerialNumbers/">
    <rdf:Description rdf:about="WASH_XYZ_123*SwitchOnService">
        <rdf:type rdf:resource="https://w3id.org/saref#SwitchOnService"/>
        <saref:represents rdf:resource="WASH_XYZ_123*StartStopFunction"/>
        <oneM2M:hasInputDataPoint rdf:resource="WASH_XYZ_123*SwitchOnService*BinaryInput"/>
        <oneM2M:hasOperation rdf:resource="WASH_XYZ_123*SwitchOnService*ToggleBinary"/>
    </rdf:Description>

    <rdf:Description rdf:about="WASH_XYZ_123*SwitchOnService*BinaryInput">
        <rdf:type rdf:resource="https://w3id.org/saref#Property"/>
        <oneM2M:exposesCommand rdf:resource="WASH_XYZ_123*StartStopFunction*ON_Command"/>
        <oneM2M:exposesCommand rdf:resource="WASH_XYZ_123*StartStopFunction*OFF_Command"/>
        <oneM2M:oneM2MAttribute>BinaryInput</oneM2M:oneM2MAttribute>
        <oneM2M:hasDataType>xs:boolean</oneM2M:hasDataType>
        <oneM2M:oneM2MMethod>UPDATE</oneM2M:oneM2MMethod>
    </rdf:Description>

    <rdf:Description rdf:about="WASH_XYZ_123*SwitchOnService*ToggleBinary">
        <oneM2M:resourceDescriptorLink rdf:resource=
        "./My-WashingMachine/SwitchOnService/ToggleBinary/semanticDescriptor"/>
    </rdf:Description>

    <rdf:Description rdf:about="WASH_XYZ_123*StartStopFunction">
        <oneM2M:resourceDescriptorLink rdf:resource=
        "./My-WashingMachine/semanticDescriptor"/>
    </rdf:Description>

</rdf:RDF>
```

Table B.8: RDF annotation contained in the descriptor attribute of the <*semanticDescriptor*> resource of the ToggleBinary operation <*flexContainer*> resource

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:saref="http://ontology.tno.nl/saref/"
    xmlns:oneM2M="http://www.onem2m.org/ontology/Base_Ontology/"
    xmlns:xs="http://www.w3.org/2001/XMLSchema"
    xml:base="http://www.XYZ.com/WashingMachines/SerialNumbers/">
    <rdf:Description rdf:about="WASH_XYZ_123*SwitchOnService*ToggleBinary">
        <rdf:type
rdf:resource="http://www.onem2m.org/ontology/Base_Ontology/base_ontology#Operation"/>
        <oneM2M:exposesCommand rdf:resource="WASH_XYZ_123*StartStopFunction*Toggle_Command"/>
    </rdf:Description>

    <rdf:Description rdf:about="WASH_XYZ_123*StartStopFunction*Toggle_Command">
        <oneM2M:resourceDescriptorLink rdf:resource=
        "./My-WashingMachine/semanticDescriptor"/>
    </rdf:Description>

</rdf:RDF>
```

History

Publication history		
V3.7.3	Februrary 2019	Release 3 - Publication