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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
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Contents

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Smart Machine-to-Machine communications (SmartM2M).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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1 Scope

The result of the European Commission Study Group on Smart Appliances ontologies takes into account all the interest of the relevant stakeholders. The present document is an adaptation of the reviewed study to the structure of a normative deliverable. Additionally, it develops the mapping to oneM2M. Therefore the present document has two major objectives:

1) To provide a standardized framework for the Reference Ontology derived from the EC Study Group on Smart Appliances.

2) To map the Reference Ontology onto the elementary oneM2M.

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 reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

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

[1] European Commission and TNO: "Study on Semantic Assets for Smart Appliances Interoperability", final report, April 2015.

NOTE: Available at https://sites.google.com/site/smartappliancesproject/deliverables.

[2] European Commission and TNO: "Smart Appliances REFerence ontology (SAREF)", April 2015.

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

[3] European Commission and TNO: "D-S4 - SMART 2013-0077 - Smart Appliances - Mapping SAREF to short list assets.xlsx", February 2015.

NOTE: Available at https://sites.google.com/site/smartappliancesproject/documents.

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 reference document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

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 TS-0012: "Base Ontology".

NOTE: Available at ftp://ftp.onem2m.org/Work%20Programme/WI-0025/.

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

ontology: formal specification of a conceptualization, used to explicitly capture the semantics of a certain reality

smart appliances: devices, which are used in the household, e.g. for performing domestic work, and which have the ability to communicate with each other and which can be controlled via Internet

NOTE: The following appliances are covered: Home and buildings sensors (temperature, humidity, energy-plugs, energy clams, energy meters, water-flow, water quality, presence, occupancy, air monitors, environmental sensors, CO_2 sensors, weather stations, etc.) and actuators (windows, doors, stores); white goods, as classified by CECED; HVAC (heating, ventilation, and air conditioning), classified by Eu.bac; lighting, with use cases as defined by LightingEurope; micro renewable home solutions (solar panels, solar heaters, wind, etc.).

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

CECED	European Committee of Domestic Equipment Manufacturers
CENELEC	European Committee for Electrotechnical Standardization
DUL	DOLCE+DnS Ultralite
EC	European Commission
eu.bac	European building automation controls association
FAN	FlexiblePower Alliance Network
FIEMSER	Friendly Intelligent Energy Management Systems in Residential Buildings
HVAC	Heating, Ventilation, and Air Conditioning
Mirabel	Micro-Request-Based Aggregation, Forecasting and Scheduling of Energy Demand, Supply and Distribution
OM	Ontology of units of Measure
oneM2M	Partnership Project
OSGi™ DAL	Open Services Gateway initiative Device Abstraction Layer
OWL	Web Ontology Language
SAREF	Smart Appliances REFerence ontology
SEP2	Smart Energy Profile 2.0
SSN	Semantic Sensor Network
SUMO	Suggested Upper Merged Ontology
TNO	Netherlands Organisation for Applied Scientific Research
TR	Technical Report
TS	Technical Specification
UPnP®	Universal Plug and Play
URL	Uniform Resource Locator
W3C®	World Wide Web Consortium
WGS84	World Geodetic System 1984

4 Smart Appliances reference ontology and semantics

4.1 Introduction and overview

A study on "Available Semantics Assets for the Interoperability of Smart Appliances: Mapping into a Common Ontology as a M2M Application Layer Semantics" had been tendered by the European Commission and was carried out by TNO. Parts of the final report of this study [1] are copied to clauses 4.1 to 4.4.

The energy utilization of Smart Appliances can be reduced if they are managed and controlled on a system level. The system needs standardized interfaces to ensure interoperability. Many of the required standards already exist, but a common architecture does not, resulting in a market which is too fragmented and powerless. Therefore, a reference ontology of consensus was designed to cover the needs of all appliances relevant for energy efficiency.

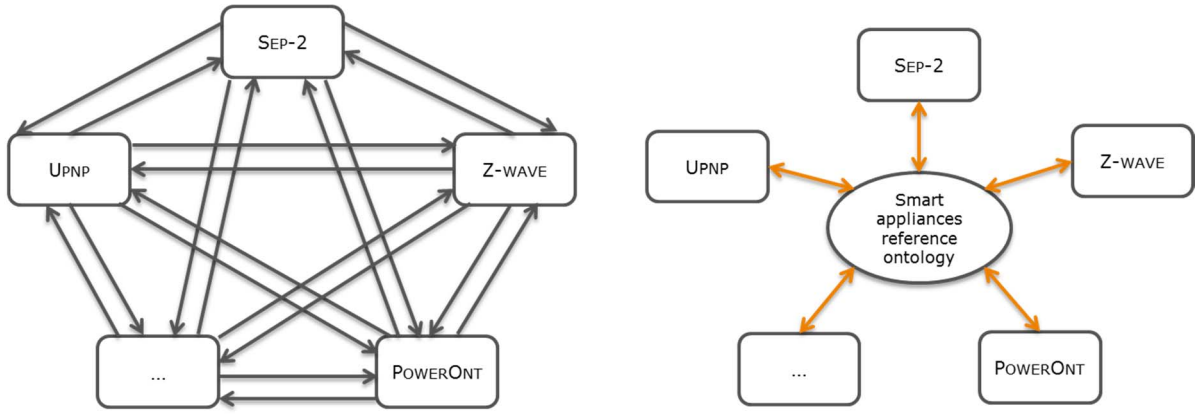
The study consisted of three tasks:

- **Task 1:** Take stock of existing semantic assets and use case assets.
- **Task 2:** Perform a translation exercise of each model (or use case) to a common ontology language and a mapping or matching exercise between all the models.
- **Task 3:** Propose a reference ontology and document the ontology into the ETSI M2M architecture.

About 50 different semantic assets had been identified that describe various properties of Smart Appliances in residential environments. After translating half of these assets into Web Ontology Language (OWL), 20 recurring concepts were used as initial building blocks for the Smart Appliances Reference ontology (SAREF). For SAREF in OWL language, see [2]. The concepts were mapped from the assets to SAREF to allow for translations between the ontologies.

SAREF explicitly specifies the recurring core concepts in the Smart Appliances domain, the main relationships between these concepts, and axioms to constrain the usage of these concepts and relationships. SAREF is based on the fundamental principles of **reuse and alignment** of concepts and relationships that are defined in existing assets, **modularity** to allow separation and recombination of different parts of the ontology depending on specific needs, **extensibility** to allow further growth of the ontology, and **maintainability** to facilitate the process of identifying and correcting defects, accommodate new requirements, and cope with changes in (parts of) SAREF.

Mappings to other concepts used by different assets/standards/models allow translation from the reference ontology to specific assets, reducing the effort of translating from one asset to another, since the reference ontology requires one set of mappings to each asset, instead of a dedicated set of mappings for each pair of assets. Figure 1 shows the role of the reference ontology in the mapping by means of sample assets. The mappings of SAREF to various assets/standards/models are available in [3].



NOTE: UPnP® and Z-Wave® are examples of suitable products available commercially. This information is given for the convenience of users of the present document and does not constitute an endorsement by ETSI of these products.

Figure 1: The role of SAREF in the mapping among different assets

SAREF is based on the following main concepts (in alphabetical order):

- Building Object (Door, Window).
- Building Space.
- Command (e.g. OnCommand, OffCommand, PauseCommand, GetCommand, NotifyCommand, SetLEvelCommand).
- Commodity (e.g. Electricity, Gas, Water).
- Device (e.g. Switch, Meter, Sensor, Washing Machine).
- Device Category.
- Duration Description.

- Function (Actuating Function, EventFunction, Metering Function, Sensing Function).
- Function Category.
- Profile.
- Property (Energy, Humidity, Light, Motion, Occupancy, Power, Pressure, Price, Smoke, Temperature, Time).
- Service.
- State.
- Task (e.g. Cleaning, Safety, Entertainment).
- Temporal Entity.
- UnitOfMeasure (e.g. Currency, EnergyUnit, Power Unit, Temperature Unit).

4.2 Principles

The Smart Appliances REFerence ontology (SAREF) is conceived as a shared model of consensus that facilitates the matching of existing assets in the smart appliances domain, reducing the effort of translating from one asset to another, since SAREF requires one set of mappings to each asset, instead of a dedicated set of mappings for each pair of assets.

Different assets share some recurring, core concepts, but they often use different terminologies and adopt different data models to represent these concepts. Using SAREF, different assets can keep using their own terminology and data models, but still can relate to each other through their common semantics. In other words, SAREF enables semantic interoperability in the smart appliances domain.

SAREF explicitly specifies recurring core concepts in the smart appliances domain, the main relationships between these concepts, and axioms to constrain the usage of these concepts and relationships. SAREF has been created based on the following fundamental principles:

- **Reuse and alignment** of concepts and relationships that are defined in existing assets. Since a large amount of work was already being done in the smart appliances domain, nothing has been re-invented, but harmonized and aligned what was already there. SAREF is based on the core concepts that were identified as especially relevant to describe the existing assets. Despite the heterogeneity of these existing assets, when considering their semantic coverage, three main trends could be identified with focus on:

  1) devices, sensors and their specification in terms of functions, states and services;

  2) energy consumption/production information and profiles to optimize energy efficiency; and

  3) building related semantic models.

  In SAREF these trends are called, **function-related**, **energy-related** and **building-related**, respectively. SAREF includes not only the necessary concepts and relationships to characterize these trends individually, but also to link these trends to each other. For example, the concept of **building space** links function-related assets to building-related assets, since a device designed to accomplish a certain function is located in a specific room of the home or office in a building. Another example is the concept of **profile** that links function-related assets to energy-related assets, since a device designed to accomplish a certain function can be associated with a certain energy/power profile that can be used for energy optimization purposes.

- **Modularity** to allow separation and recombination of different parts of the ontology depending on specific needs. SAREF provides building blocks that can be combined to accommodate different needs and points of view. The starting point is the concept of **device**, which is actually common to all assets considered in the study, although some assets may refer to it with different names, such as **resource** or **product,** but mappings for that are provided. For example, a "switch" is a device. A device is always designed to accomplish one or more **functions**, therefore, SAREF offers a lists of basic functions that can be eventually combined in order to have more complex functions in a single device. For example, the switch mentioned above 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" function 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, so that it is easy and intuitive to combine devices, functions and states. The switch considered in our example can be found in one of the two states "on" or "off". SAREF also provides a list of **properties** that can be used to further specialize the functioning of a device. For example, a "light switch" specializes the more general "switch" described above for the purpose of controlling the "light" property. An extensive explanation of SAREF, its classes and relationships is presented in the next clause.

- **Extensibility** to allow further growth of the ontology. Different stakeholders can specialize the SAREF concepts according to their needs and points of view, add more specific relationships and axioms to refine the general (common) semantics expressed in the reference ontology, and create new concepts, as long as they explicitly link these extensions to at least one existing concept and/or relationship in SAREF. The minimum requirement is that any extension/specialization shall comply with SAREF.

- **Maintainability** to facilitate the process of identifying and correcting defects, accommodate new requirements, and cope with changes in (parts of) SAREF. According to the extensibility criterion mentioned above, a new module/ontology can be created to further extend/specialize concepts of SAREF.

4.3 SAREF

SAREF focuses on the concept of device, which is defined in the context of the Smart Appliances study as "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". Examples of devices are a light switch, a temperature sensor, an energy meter, a washing machine. A washing machine is designed to wash (task) and to accomplish this task it performs the start and stop function. The `saref:Device` class and its properties are shown in Figure 2.

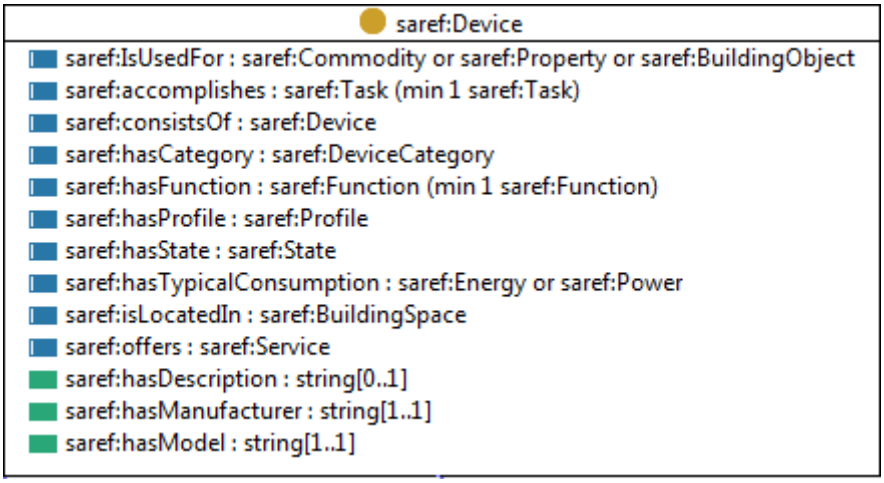


Figure 2: Device class and its properties

A saref:Device shall have some properties that uniquely characterize it, namely its model and manufacturer (saref:hasModel and saref:hasManufacturer properties, respectively). Optionally, a description of the device can also be provided (saref:hasDescription property). These properties are depicted in Figure 2 using green rectangles that represent **OWL Datatype properties**, which are properties that relate a class (the Device class here) to data values, namely a **string** data value in this example. In contrast, **OWL Object properties** are represented using blue rectangles and relate a class to another class. For example, the saref:isLocatedIn object property in Figure 2 relates the saref:Device class to the saref:BuildingSpace class, whereas a building space defines the physical spaces of the building where a device is located, such as a kitchen or a living room. Figure 3 shows the saref:BuildingSpace class and its properties.

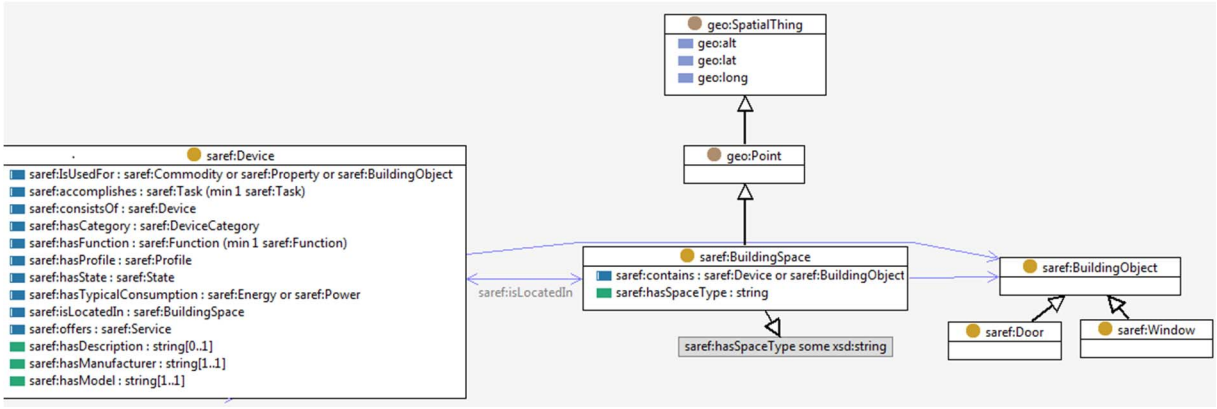


Figure 3: Building Space and Building Object classes

A building space contains devices or building objects (the saref:BuildingObject class), where building objects are objects in the building that can be controlled by devices, such as doors or windows that can be automatically opened or closed by an actuator. A building space has also a saref:hasSpaceType property that can be used to specify the type of space, for example, the living room or the bedroom. The saref:BuildingSpace class provides the link to the FIEMSER model that describes building related concepts, therefore, there is no need to further elaborate on these concepts in SAREF since they are covered elsewhere. Moreover, a building space is a geo:Point characterized by a certain altitude, latitude and longitude, which are provided by the W3C® WGS84 geo positioning vocabulary that have been imported in SAREF. Note that the W3C® WGS84 geo vocabulary is referred to using the geo: prefix, which distinguish it from the classes and properties of SAREF, which are referred to using the saref: prefix.

The saref:hasCategory object property in Figure 2 relates the saref:Device class to the saref:DeviceCategory class, which provides a way to classify devices into certain categories. Note that when analyzing the semantic assets in task 1 three main trends have been identified in the context of the Smart Appliances study with focus on:

1) devices, sensors and their specification in terms of functions, states and services;

2) energy consumption information and profiles to optimize energy efficiency; and

3) building related data models.

Therefore, according to these trends, it is proposed to classify devices in three main categories that are called saref:FunctionRelated, saref:EnergyRelated and saref:BuildingRelated, respectively. These categories are shown in Figure 4.

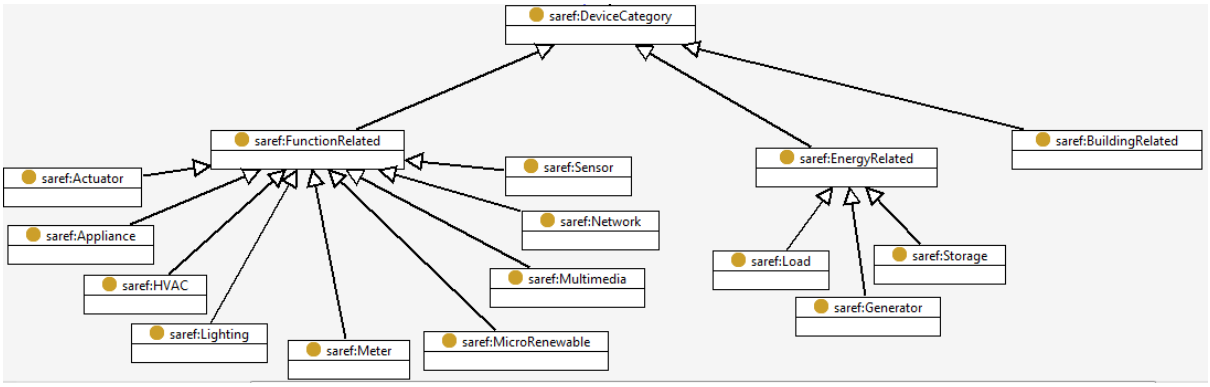


Figure 4: Device Category class

Depending on which trend a certain semantic asset focuses, this asset can be assigned to one of these categories. For example, Echonet, EnOcean®, OSGi™ DAL, SEP2, and UPnP® could identify their devices with the category `saref:FunctionRelated`, FAN and Mirabel could be assigned to the category `saref:EnergyRelated`, while FIEMSER devices would better fit under the category `saref:BuildingRelated`. Moreover, some assets can belong to several categories, for example, PowerOnt and CENELEC could be assigned to both the `saref:FunctionRelated` and `saref:EnergyRelated` categories. In any case, the assignment of devices provided by specific assets to a certain category is not mandatory and is completely flexible since the asset's owners are free to define a new category as a subclass of `saref:DeviceCategory` that suits better to their point of view.

SAREF is conceived in a modular way in order to allow the definition of any device from pre-defined building blocks, based on the function(s) that the device is designed for and the purpose for which it is used. Therefore, Figure 2 shows that a `saref:Device` shall accomplish at least one function (`saref:hasFunction min 1 saref:Function`), and can be used for (`saref:isUsedFor` property) the purpose of i) offering a commodity, such as `saref:Water` or `saref:Gas`; ii) sensing, measuring and notifying a property, such as `saref:Temperature`, `saref:Energy` and `saref:Smoke`, respectively; or iii) controlling a building object, such as a `saref:Door` or a `saref:Window`. Moreover, a device may consists of other devices (`saref:consistsOf` property). For example:

- a washing machine is a device that has category `saref:Appliance`, accomplishes the task `saref:Washing` and performs an actuating function of type `saref:StartPauseFunction`. Note that from an energy related perspective, a washing machine also belongs to the category `saref:Load`. This shows the flexibility of SAREF that trough the `saref:DeviceCategory` class allows the same device to be classified in different ways without creating inconsistencies;
- a sensor is a device that has category `saref:Sensor` and performs a `saref:SensingFunction`;
- a temperature sensor is a device that consists of a sensor, has category `saref:Sensor`, performs the `saref:SensingFunction` and is used for the purpose of sensing a property of type `saref:Temperature`;
- a smoke sensor is a device that consists of a sensor, has category `saref:Sensor`, performs the `saref:SensingFunction` and `saref:EventFunction`, and is used for the purpose of sensing a property of type `saref:Smoke` and notifying that a certain threshold has been exceeded;
- a switch is a device that has category `saref:Actuator` and performs an actuating function of type `saref:OnOffFunction` or `saref:OpenCloseFunction`;
- a door switch is a device that consists of a switch, has category `saref:Actuator`, performs the `saref:OpenCloseFunction` and is used for the purpose of controlling a building object of type `saref:Door`;
- a dimmer lamp is a device that has category `saref:Lighting` and `saref:Actuator`, performs an actuating function of type `saref:LevelControlFunction` and is used for the purpose of controlling a property of type `saref:Light`;
- a meter is a device that has category `saref:Meter` and performs a `saref:MeteringFunction`;

- an energy meter is a device that consists of a meter, has category `saref:Meter`, performs the `saref:MeteringFunction` and is used for the purpose of measuring the `saref:Energy` property.

More types of devices, sensors, actuators, etc. exist and can be defined to extend SAREF. The devices described above represent some examples that aim at explaining the rationale behind SAREF.

A function is represented in SAREF with the `saref:Function` and is defined as *"the functionality necessary to accomplish the task for which a device is designed"*. Examples of functions are the `saref:ActuatingFunction`, `saref:SensingFunction`, `saref:MeteringFunction` and `saref:EventFunction`. The `saref:Function` class and its properties are shown in Figure 5.

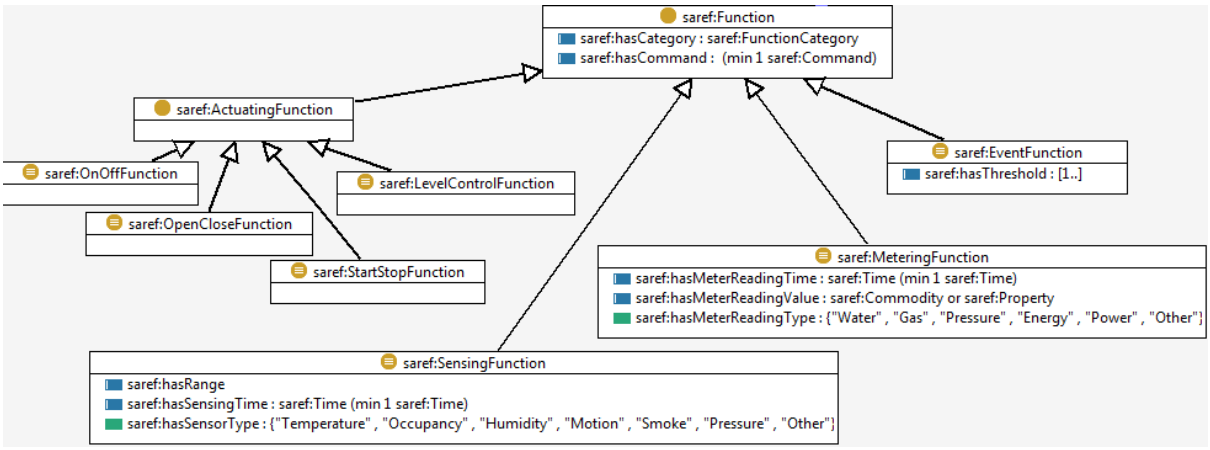


Figure 5: Function class and its properties

A `saref:Function` can belong to a function category (`saref:hasCategory` property). Analogously to the `saref:DeviceCategory` class, it was decided to leave the `saref:FunctionCategory` class open in order to grant the asset's owners the flexibility to use their own categories. For example, OSGi™ DAL could map its `osgidal:FunctionType` class to SAREF, defining `osgidal:FunctionType` as a subclass of `saref:FunctionCategory`. Figure 5 further shows that a `saref:Function` shall have at least one command associated to it (`saref:hasCommand min 1 saref:Command`). Figure 6 shows the list of commands currently available in SAREF. This list is used here for illustration purposes and can be extended with new commands.

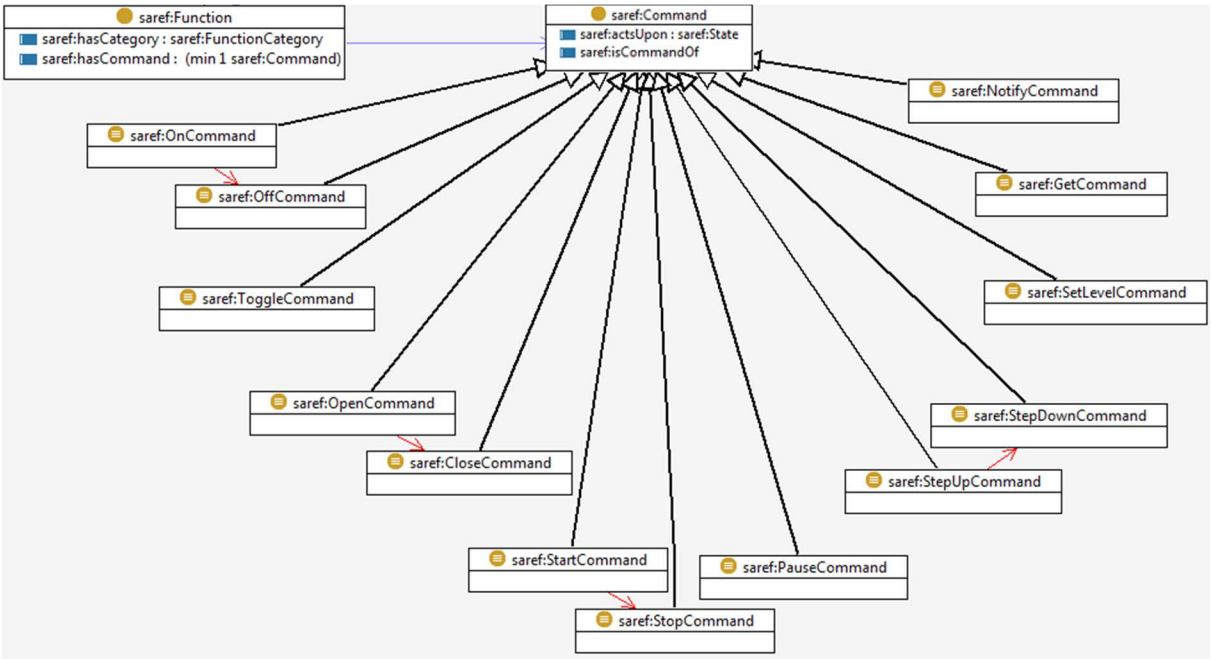


Figure 6: Command class

For example:

- The `saref:ActuatingFunction` allows to "transmit data to actuators, such as level settings (e.g. temperature) or binary switching (e.g. open/close, on/off)":
  - The actuating function of type `saref:OnOffFunction` in Figure 5 allows to "*switch on and off an actuator*". This function allows the commands `saref:OnCommand`, `saref:OffCommand` and `saref:ToggleCommand` shown in Figure 6, whereas the `saref:OnCommand` is disjoint from the `saref:OffCommand`.
  - The actuating function of type `saref:LevelControlFunction` in Figure 5 allows to *"do level adjustments of an actuator in a certain range (e.g. 0%-100%), such as dimming a light or set the speed of an electric motor"*. This function allows the commands `saref:SetLevelCommand` (which can be of type `saref:SetAbsoluteLevel` or `saref:SetRelativeLevel`), `saref:StepUpCommand` and `saref:StepDownCommand` shown in Figure 6, whereas the `saref:StepUpCommand` is disjoint from the `StepDownCommand`.
- The `saref:SensingFunction` in Figure 5 allows to "*transmit data from sensors, such as measurement values (e.g. temperature) or sensing data (e.g. occupancy)*". This function allows the command `saref:GetCommand` shown in Figure 6.
- The `saref:EventFunction` in Figure 5 allows to "*notify another device that a certain threshold value has been exceeded*". This function allows the command `saref:NotifyCommand` shown in Figure 6.

Figure 6 further shows that a command can act upon a state (`saref:actsUpon` relation) to represent that the consequence of a command can be a change of state of the device. Note that a command may act upon a state, but does not necessarily act upon a state. For example, the `saref:OnCommand` acts upon the `saref:OnOffState`, but the `saref:GetCommand` does not act upon any state, since it only gives a directive to retrieve a certain value.

Depending on the function(s) it performs, a device can be found in a corresponding `saref:State`, as shown in Figure 7. For example, a switch can be found in the `saref:OnOffState`, which is characterized by the values `ON` or `OFF` (`saref:hasValue` property). Note that SAREF is not restricted to binary states such as the `saref:OnOffState` , but allows to define also n-ary states (see, for example, the `saref:MultiLevelState` class).

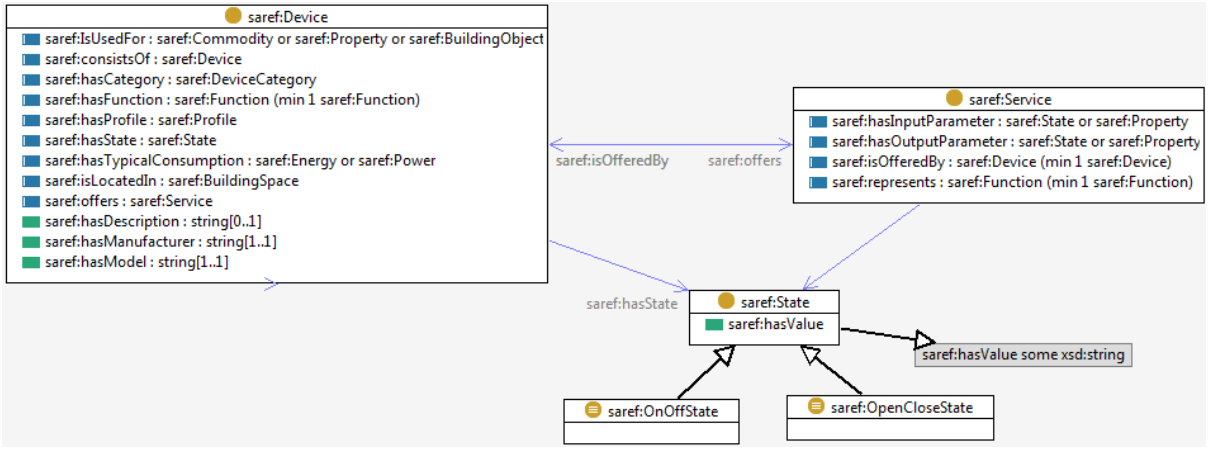


Figure 7: State and Service classes

Figure 7 further shows that a device offers a service (the `saref:Service` class), which is a representation of a function to a network that makes this function discoverable, registerable and remotely controllable by other devices in the network. A service shall represent at least one function (`saref:represents min 1 saref:Function`) and is offered by at least one device that wants (a certain set of) its function(s) to be discoverable, registerable and remotely controllable by other devices in the network (`saref:isOfferedBy min 1 saref:Device`). Multiple devices can offer the same service. A service shall 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 (`saref:hasInputParameter` and `saref:hasOutputParameter` properties).

For example, a light switch can offer the service of remotely switching the lights in a home through mobile phone devices that are connected to the local network. This "remote switching" service represents the `saref:OnOffFunction` previously described, it shall have a `saref:State` as input parameter, e.g. with value `"ON"` , and a `saref:State` has output parameter, namely with value `"OFF"` in this example since the input state value was `"ON"`.

Moreover, a device in SAREF can be characterized by a profile that can be used to optimize the energy efficiency in the home or office under consideration. Figure 8 shows the `saref:Profile` class and its properties.

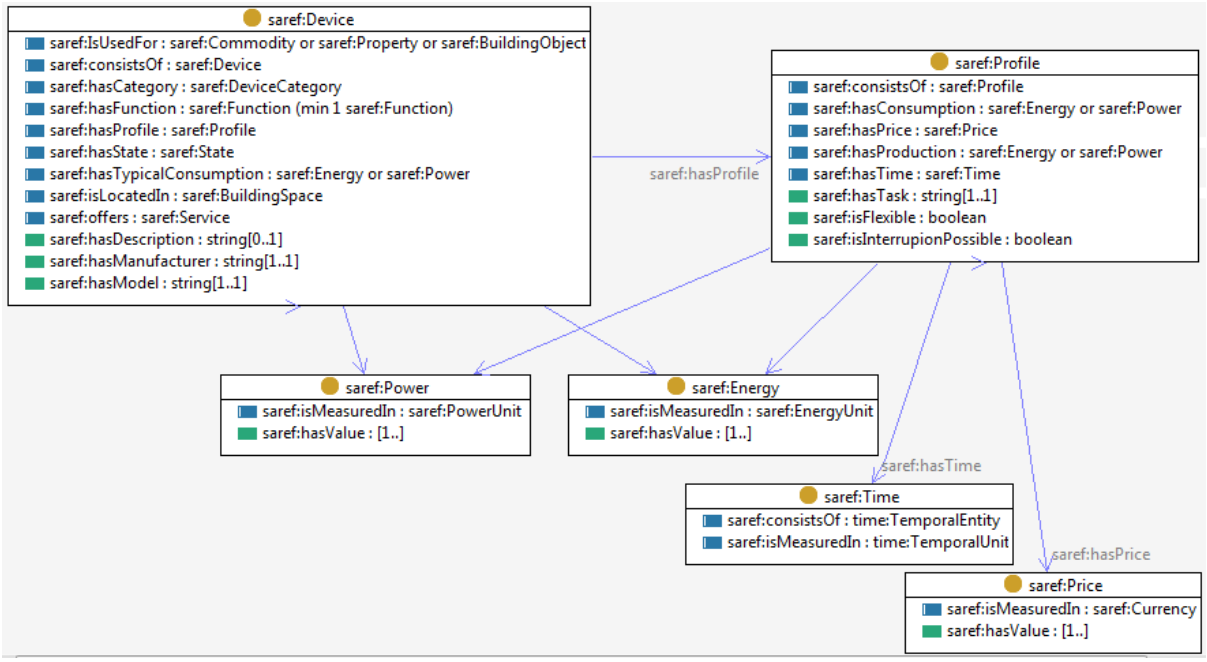


Figure 8: Profile class

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 shown in Figure 8. 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).

The `saref:Power` and `saref:Energy` classes are characterized by a certain value (`saref:hasValue` property) that is measured in a certain unit of measure represented by the `saref:UnitOfMeasure` class, namely `Kilowatt` and `Kilowatt_Hour`, respectively. Analogously, the `saref:Price` class is characterized by a certain value (`saref:hasValue` property) and is measured using a certain `saref:Currency,` which is a subclass of the `saref:UnitOfMeasure` class.

The `saref:Time` class allows to specify the "time" concept in terms of instants or intervals according to the existing W3C® Time ontology that was imported in SAREF to avoid defining this concept from scratch. The concepts of the W3C® Time ontology that are useful for the purpose of SAREF are shown in Figure 9. It is referred to W3C® Time ontology with the `time:` prefix in order to distinguish from the classes and properties of SAREF, which are referred to using the `saref:` prefix.

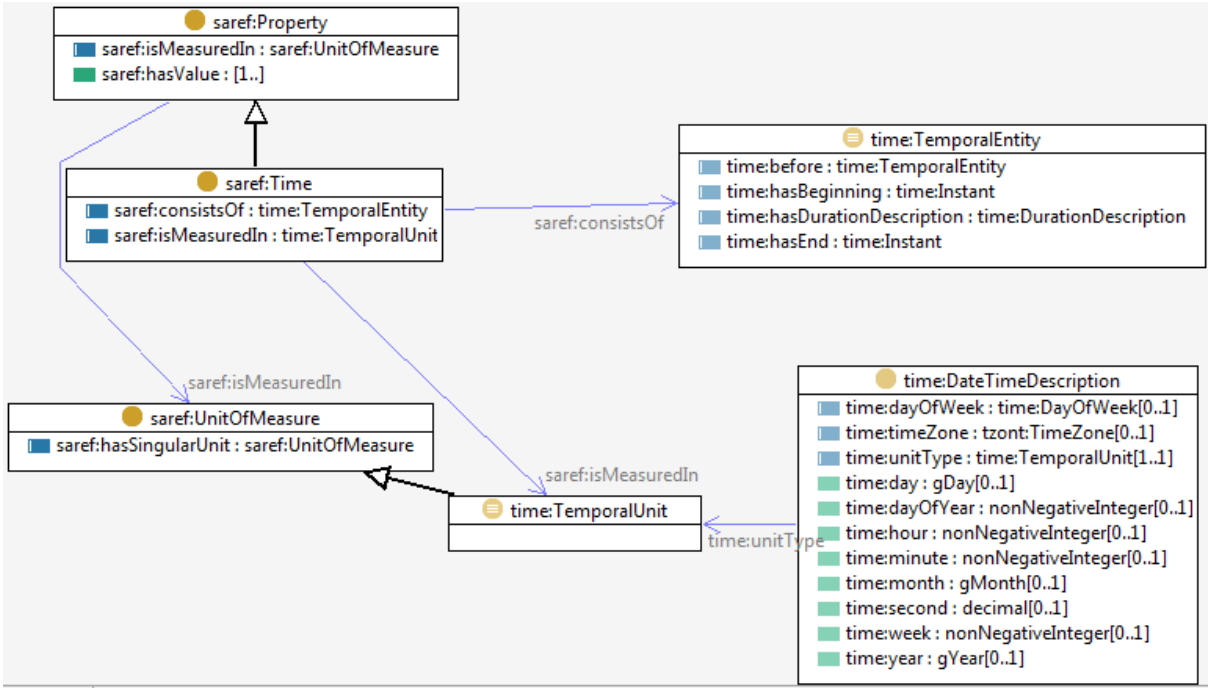


Figure 9: Time class

NOTE: W3C®, EnOcean®, and OSGi™ are examples of suitable products available commercially. This information is given for the convenience of users of the present document and does not constitute an endorsement by ETSI of these products.

4.4 Observations about SAREF

SAREF currently does not contain explicit references to upper ontologies such as DUL or SUMO. The use of upper ontologies is a best practice in ontology engineering , but the smart appliances industry - main user of SAREF - is very pragmatic and is not acquainted with high-level upper ontologies. Introducing DUL would have unnecessarily complicated the understanding and, consequently, the adoption of SAREF by the smart appliances industry. Anyway, SAREF has been built on a solid ontological foundation and can be related to DUL, but this will not be done at this early stage of SAREF in order not to confuse the smart appliances industry's users. Furthermore, SAREF currently has mappings to the W3C® SSN ontology, which is in turn related to DUL. Therefore, SAREF currently includes an indirect reference to DUL through the W3C® SSN ontology. An ontology is regarded as an artifact that includes precise definitions of the ontology concepts in natural language e.g. 'an appliance is a tangible object designed to accomplish a particular task in households, such as cooking or cleaning. In order to accomplish this task, the appliance performs one or more functions'. In the "saref.ttl file" that contains the OWL version of SAREF, these definitions can be found as `rdfs:comment` properties attached to the most important SAREF classes. Due to the large amount of concepts in SAREF, the definitions of self-explanatory concepts, e.g. `saref:OnCommand` class, are omitted. Table 1 shows a summary of the main SAREF definitions.

Table 1: Summary of main SAREF definitions

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 FIEMSER, 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 shall 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.

CONCEPT	DEFINITION
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 caracterizes 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 shall 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.
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 it said 10 Watt, it is actually mean 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). It is proposed here a list of some units of measure that are relevant for the purpose of the Smart Appliances ontology, but this list can be extended.

Usually, it would be common practice for an ontology developer to create hierarchies of device categories as subclasses (types) of the `saref:Device` class, as shown in Figure 10 (a). In contrast, is was decided to adopt in SAREF a flat classification of devices under the `saref:Device` class - in other words, no hierarchies of device types - and provide device categories using the `saref:hasCategory` relation, as shown in Figure 10 (b). This was a specific design choice to simplify SAREF as much as possible for its users and keep it as much as possible independent from subjective choices. For example, most of the users would classify `TemperatureSensor` and `SmokeSensor` as subclasses of `Sensor`, as depicted in Figure 10 (a). But this is an easy example. If it is needed to add a new device of type `MobilePhone`, where the users of SAREF would add it? One could say it is a subclass of `MultimediaDevice`, but another user could argue that it is a subclass of `Sensor`. To make it even more difficult, what happens if it is needed to define a new type of combined sensor such as `TemperatureHumiditySensor`? Should it be a subclass of `TemperatureSensor` or `HumiditySensor` or a subclass of both? In order to avoid this type of issues, which require choices that are too specific/subjective and would harm the general applicability of SAREF, it was decided to have a flat list of devices under the `saref:Device` class with no further hierarchy, even if it is in principle possible to create hierarchies. It is then possible to assign devices from this flat list to device categories using the `saref:hasCategory` relation to the `saref:DeviceCategory` class. Users can eventually define their own categories under the `saref:DeviceCategory` class and other users can simply ignore categorizations that are not relevant for them.

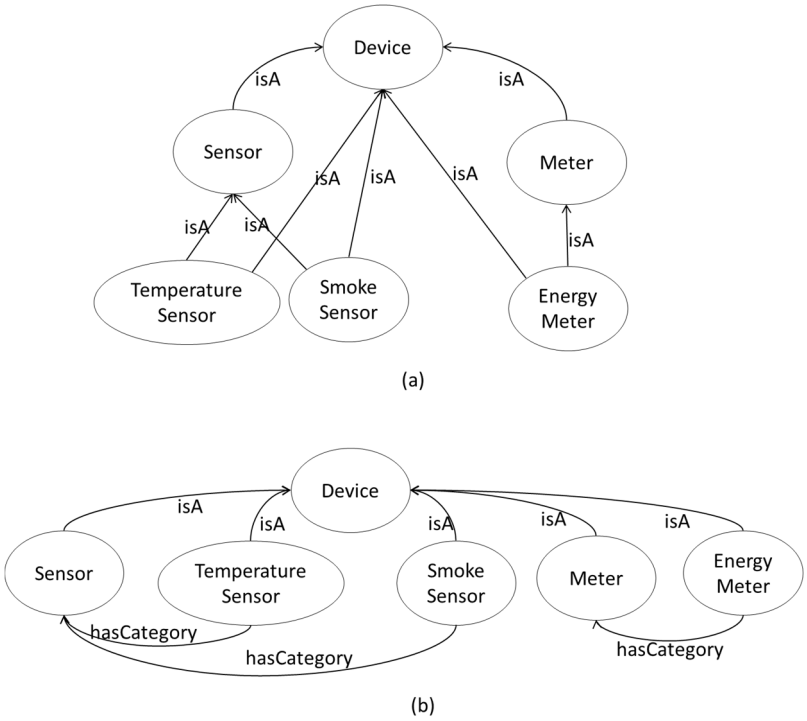


Figure 10: Device categories as subclasses of Device (a) vs. using the has Category relation (b)

The scope of SAREF was limited to an indoor managed domain, such as a building managed by a building manager or an apartment managed by a user. This scope also includes the outdoor premises that belong to the considered indoor managed domain, in other words, a pergola that is part of the building is also within the scope, as well as a sensor located under that pergola. Note that the smart city domain was not considered, i.e. if the same sensor that is under the pergola is also in a street, then the sensor in the street is out of the scope of SAREF. However, since in principle the sensor in the street can be also defined using the SAREF definition of device, it is possible in the future to extend the scope of SAREF also to outdoor domains (e.g. smart cities) managed by managers different than building managers or apartment users considered here, such as for example an administrative manager of the city government.

4.5 Extensions of SAREF

The goal of the present document is to have a system, in which SAREF can be used, e.g. for conformance tests of SAREF. The horizontal oneM2M architecture (as the follow-up system of the ETSI M2M architecture) is chosen as a system to be used with SAREF in order to facilitate the communication between the Smart Appliances and any remote application. If SAREF is used with the oneM2M architecture, SAREF requires more fine-grained modelling of services than given in the original (TNO) SAREF. Thus, SAREF requires extensions. The main point is that the original SAREF is rather weak regarding the modelling of services and it is not sufficient to do a complete mapping to a system like oneM2M in such a way that an application is actually able to call the modelled service using the oneM2M resource structure in the end.

SAREF is extended by the concepts Operation, Method, Target, Input, and Output (see, red bubbles in Figure 11). An Operation is a means of a service to communicate over the network. It shall specify the method, the target and the input and output parameters necessary to execute the operation. The methods that are needed for oneM2M are CREATE, RETRIEVE, UPDATE, DELETE and NOTIFY and are specified as individuals of the Method class. The target for oneM2M is specified using the hasTargetURL data property of target.

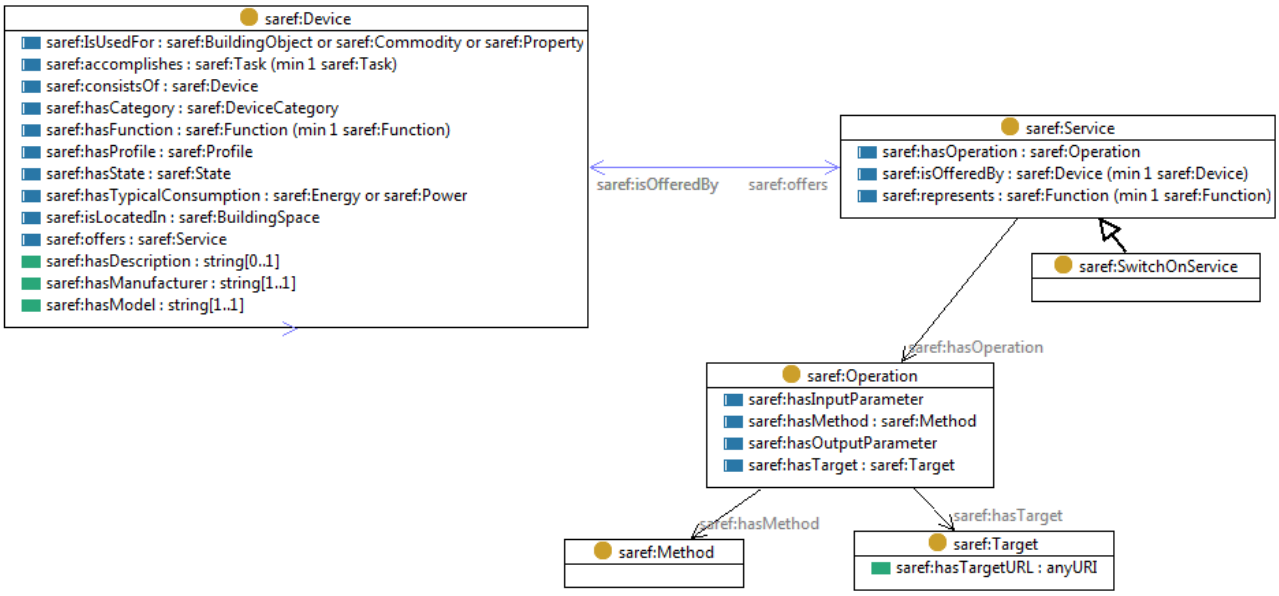


Figure 11: Service and Operation

The extensions are shown in Figure 11 to clarify the difference with the original TNO SAREF, see Figure 7.
A service shall specify the device that is offering the service, the function(s) to be represented and the operation(s) (saref:hasOperation min 1 saref:Operation) that can be executed. An operation specifies the method (e.g. RETRIEVE), the target URL, and the input and output parameters necessary to execute the operation (saref:hasInputParameter and saref:hasOutputParameter properties).

For example, a light switch can offer the service of remotely switching the lights in a home through mobile phone devices that are connected to the local network. This "remote switching" service represents the saref:OnOffFunction previously described. The corresponding operation shall specify the method (e.g. UPDATE), the target URL, and a saref:State as input parameter, e.g. with value "ON", and a saref:State has output parameter, namely with value "OFF" in this example since the input state value was "ON".

The extended SAREF is called ETSI SAREF. The Turtle version of ETSI SAREF belongs to the present document.

NOTE 1: Available at http://uri.etsi.org/m2m/saref.

It can be opened with any ontology editor, such as TopBraid Composer™, Protégé and NeOn.

NOTE 2: TopBraid Composer™ is an example of a suitable product available commercially. This information is given for the convenience of users of the present document and does not constitute an endorsement by ETSI of this product.

5 Mapping on oneM2M resources

NOTE 1: This clause describes how ETSI SAREF is to be used with the oneM2M architecture. The idea is to map ETSI SAREF to the oneM2M base ontology. For the oneM2M base ontology, oneM2M is in the process of defining mapping rules that map some key concepts to oneM2M resources, e.g. creating an Application Entity resource for a device like a washing machine and creating containers, e.g. for storing the status of the washing machine. The ETSI SAREF description of the device will be stored in a semantic descriptor child resource of the Application Entity resource representing the device.

NOTE 2: As the oneM2M base ontology is not stable yet, the mapping on oneM2M resources will be specified in the revision of the present document. A draft of the mapping as of September 2015 is given in annex A.

Annex A (informative): Mapping on oneM2M Resources

A.1 Mapping of ETSI SAREF to oneM2M base Ontology

A.1.1 Introduction

In oneM2M TS-0012 [i.1], oneM2M has created a base ontology that describes key classes, relations and properties that are relevant for enabling semantic functionalities within oneM2M systems, as well as enabling interoperability between applications and interworking with existing non-oneM2M technologies. The approach is that given a semantic description of instances according to the oneM2M base ontology, a oneM2M resource structure can be automatically created.

General oneM2M resources are created for those ontology instances that are related to functionalities. They will enable application interactions and thus concern dynamic aspects. Other, more static aspects like the manufacturer of a device will be stored in special semantic descriptor resources that are attached to general oneM2M resources, e.g. there is oneM2M resource representing a device which has a semantic descriptor resource attached that contains semantic information related to the device, e.g. the manufacturer. Such a semantic descriptor resource also contains information concerning the relation to other resources, e.g. operations that can be executed.

A two step approach for the mapping of ETSI SAREF instances to oneM2M resources is used. In the first step, key ETSI SAREF classes are mapped to oneM2M base ontology classes by defining an "is-a" relation between the ETSI SAREF and the oneM2M class. Thus instances modelled according to those ETSI SAREF classes for which such a definition exists, are also automatically modelled accorting to the corresponding oneM2M base ontology classes. In the second step, the oneM2M instantiation rules are applied to those instances of ETSI SAREF classes that are derived from oneM2M classes. Not all ETSI SAREF classes can be mapped to base ontology classes as ETSI SAREF models certain aspects that are closely related to the smart appliance application domain and the base ontology is meant to be agnostic to specific application domains. If no equivalent oneM2M base ontology classes exist, e.g. for Commodity, the respective ETSI SAREF instances are stored together with ETSI SAREF instances with which they are connected through an object property and which are mapped to the oneM2M base ontology.

In clause A.1 the mapping of ETSI SAREF classes on oneM2M base ontology classes is described, in clause A.2 the application of oneM2M instantiation rules are defined.

A.1.2 Sub-class relationships of ETSI SAREF with the Base Ontology

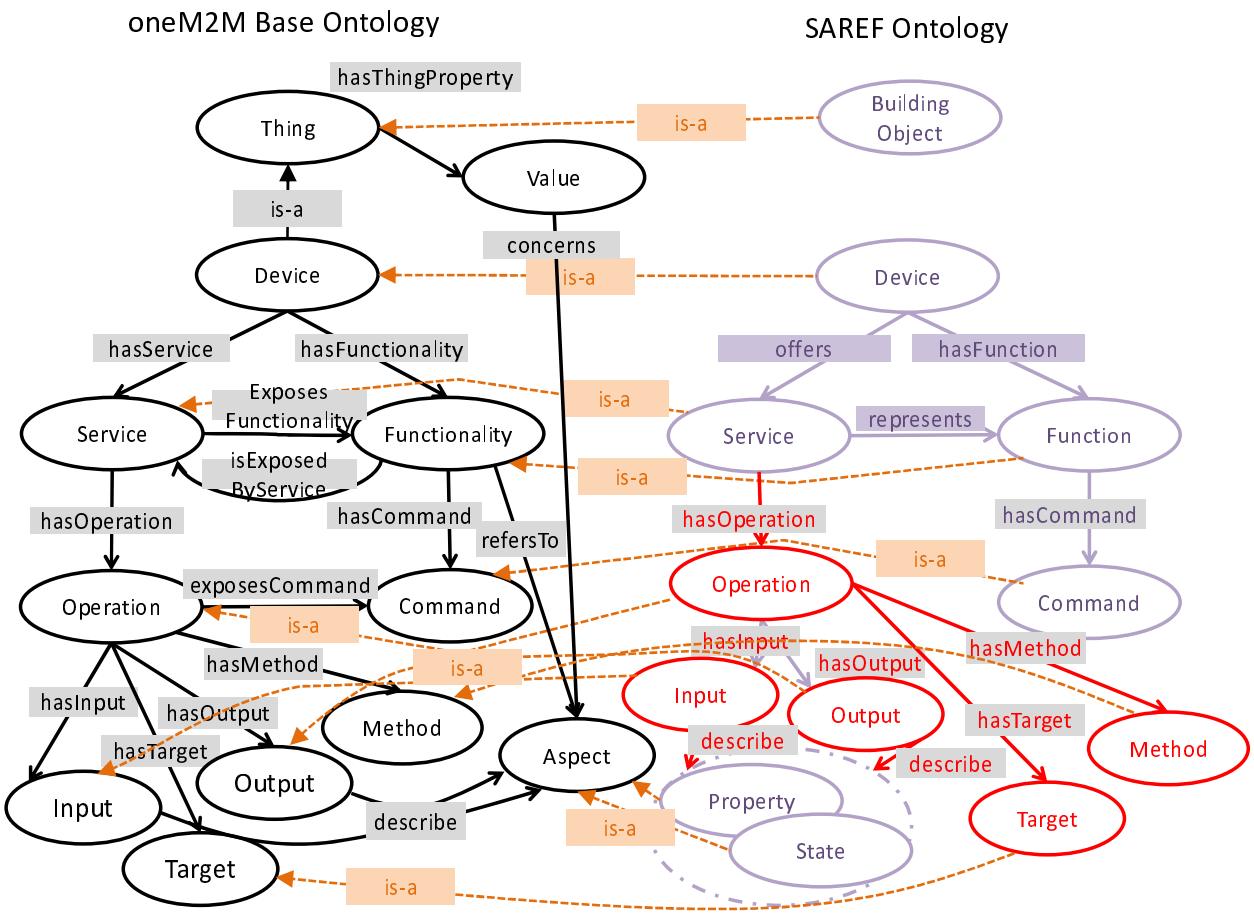


Figure A.1: Mapping of ETSI SAREF to the oneM2M Base Ontology

Figure A.1 shows the mapping of ETSI SAREF to the oneM2M Base Ontology. `is-a` relationships (modelled as `rdfs:subClassOf`) are introduced between the key classes of ETSI SAREF and the oneM2M Base Ontology. These are needed to be able to apply the oneM2M instantiation rules to the semantic description of entities that are described according to ETSI SAREF.

`rdfs:subPropertyOf` relationships are introduced between the ETSI SAREF properties and oneM2M properties, where this is applicable. These relationships are not shown in Figure A.1, but will be explained following the class mappings.

Table A.1 shows which ETSI SAREF class is a subclass of which oneM2M class. As a result all oneM2M instantiation rules defined for the oneM2M class can also be applied to the instance of the respective ETSI SAREF class.

Table A.1: ETSI SAREF classes as subclasses of oneM2M classes

ETSI SAREF class	oneM2M base ontology class
saref:Device	oneM2M:Device
saref:Service	oneM2M:Service
saref:Function	oneM2M:Functionality
saref:Operation	oneM2M:Operation
saref:Command	oneM2M:Command
saref:Input	oneM2M:Input
saref:Output	oneM2M:Output
saref:Target	oneM2M:Target
saref:Method	oneM2M:Method
saref:Property	oneM2M:Aspect
saref:State	oneM2M:Aspect
saref:BuildingObject	oneM2M:Thing

Table A.2 shows which ETSI SAREF property is a subproperty of which oneM2M property.

Table A.2: ETSI SAREF properties as subproperties of oneM2M classes

ETSI SAREF property	oneM2M property
saref:offers	oneM2M:hasService
saref:hasFunction	oneM2M:hasFunctionality
saref:represents	oneM2M:exposesFunctionality
saref:hasOperation	oneM2M:hasOperation
saref:hasCommand	oneM2M:hasCommand
saref:hasInput	oneM2M:hasInput
saref:hasOutput	oneM2M:hasOutput
saref:hasMethod	oneM2M:hasMethod
saref:hasTarget	oneM2M:hasTarget
saref:describe	oneM2M:describe

In addition to the ETSI SAREF classes that are directly subclassed as shown in Table A.1, all the ETSI SAREF classes that are subclasses of these classes are transitively subclasses of oneM2M classes and thus the oneM2M instantiation rules can also be applied. The respective subclasses for which this is the case are shown in Figure A.2, Figure A.3, Figure A.4, Figure A.5 and Figure A.6, respectively.

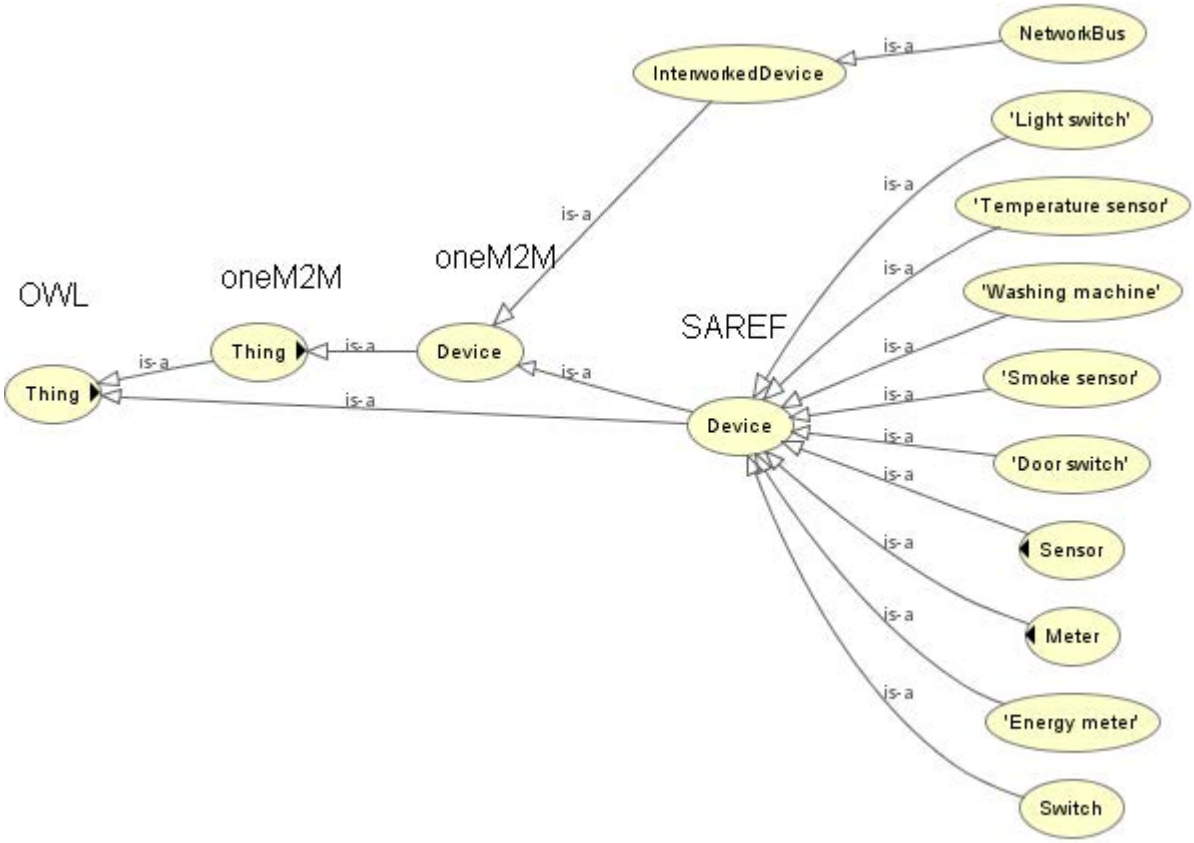


Figure A.2: Subclasses of oneM2M:Device

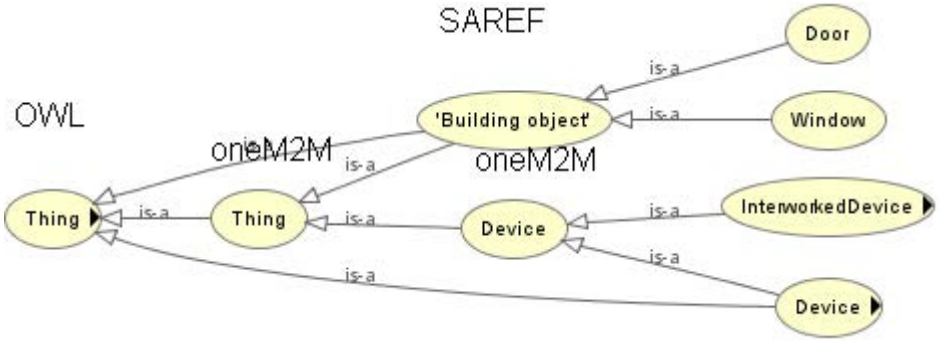


Figure A.3: Subclasses of oneM2M:Thing

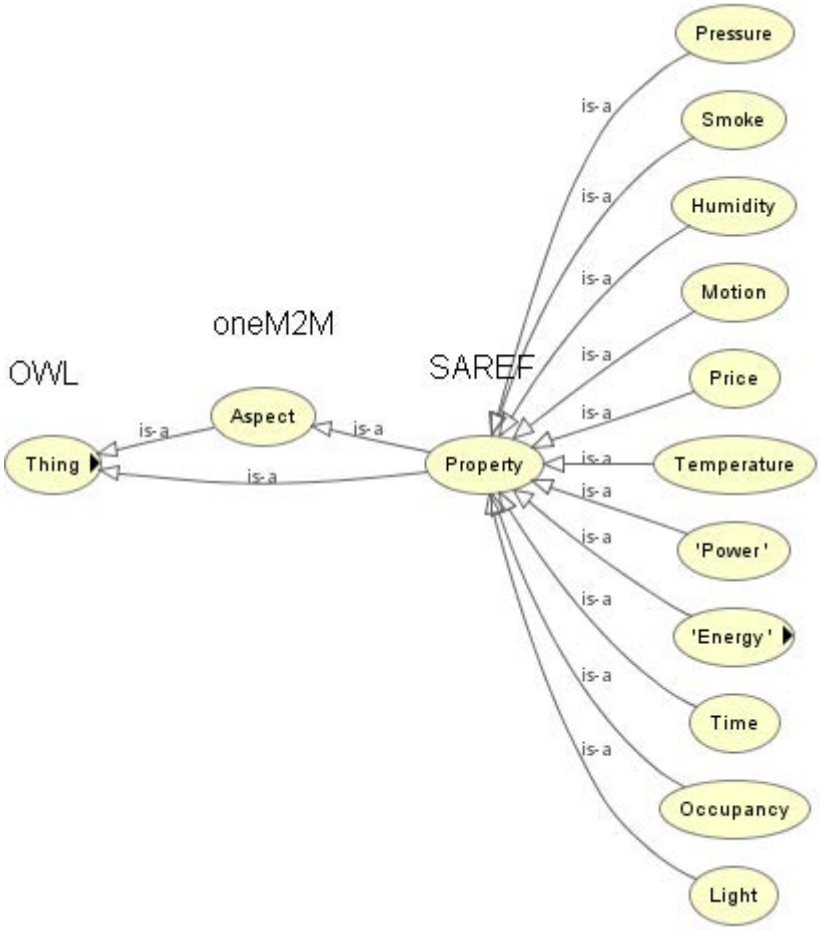


Figure A.4: oneM2M:Aspect

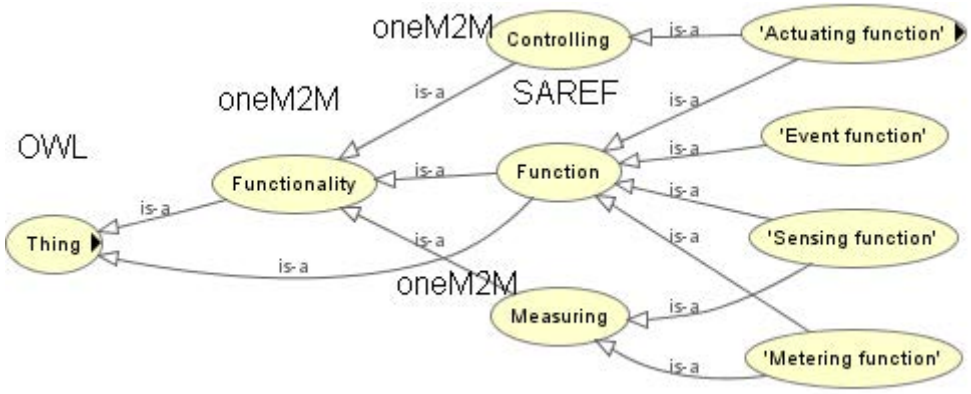


Figure A.5: oneM2M:Functionality

Figure A.6: oneM2M:Service

A.2 Instantiation Rules for Creating the oneM2M Resource Structure

The Smart Appliances oneM2M Mapping should follow the instantiation rules defined in clause 7 of oneM2M TS-0012 [i.1] "Base Ontology".

Annex B (informative): Bibliography

- ETSI TS 103 267: "SmartM2M; Smart Appliances; Communication Framework".
- ETSI TS 102 689: "Machine-to-Machine communications (M2M); M2M Service Requirements".
- ETSI TS 102 690: "Machine-to-Machine communications (M2M); Functional architecture".
- ETSI TS 102 921: "Machine-to-Machine communications (M2M); mIa, dIa and mId interfaces".
- ETSI TR 101 584: "Machine-to-Machine communications (M2M); Study on Semantic support for M2M Data".

History

Document history		
V1.1.1	November 2015	Publication