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SmartM2M;
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Reference Ontology and oneM2M Mapping

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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/.

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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

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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].

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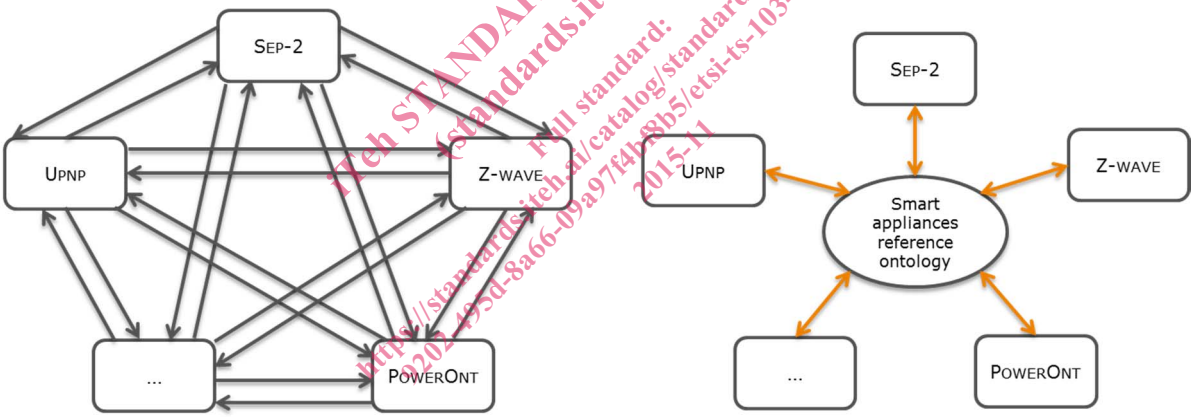

NOTE: UPnP® and Z-Wave® are examples of suitable products available commercially. This information is given for the convenience of users of the present document and does not constitute an endorsement by ETSI of these products.

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.

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- **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.

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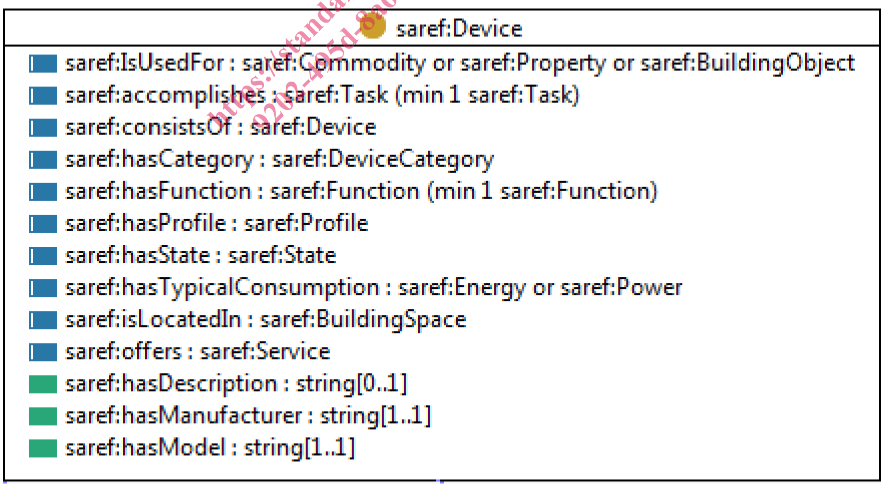

Figure 2: Device class and its properties

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.

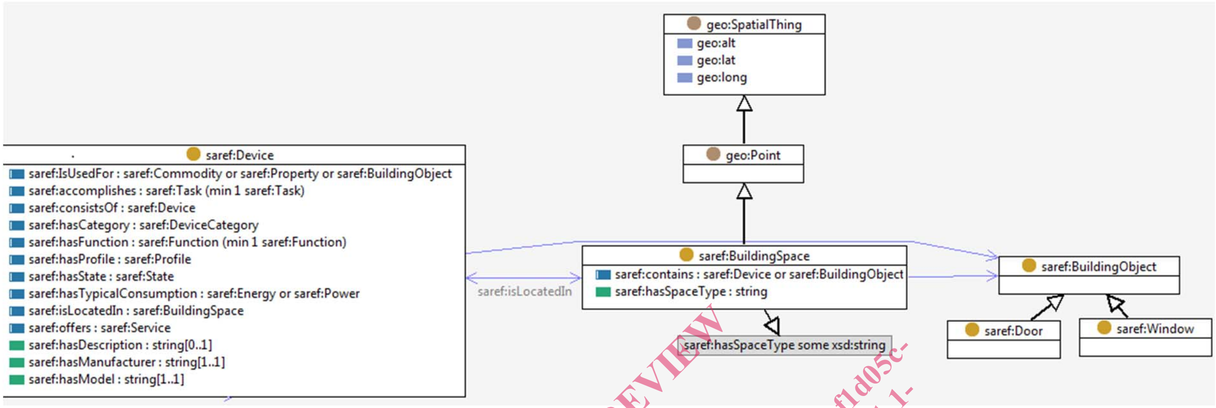

Figure 3: Building Space and Building Object classes

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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.