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Foreword

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

Modal verbs terminology

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Introduction

The present document was drafted by ETSI Technical Committee SmartM2M to provide insight into the management of SAREF and its extensions. SAREF was created in 2014/2015 by TNO in a study requested by the European Commission. After finishing the study, SAREF was transformed into a Technical Specification by ETSI SmartM2M and published in November 2015. Since this period, a number of request for updates of SAREF were made, and a first extension of SAREF for the Energy Demand and Response domain was also created. To elaborate a strategy on the management of SAREF and identify possible extensions of SAREF in new domains, ETSI SmartM2M requested a Specialist Task Force (STF) to provide input on these topics.

A number of possible areas for extensions have been identified: energy demand and response, environment, buildings, agriculture and e-health/ageing well. The present document provides insight into the requirements from these domains, and provides the guidelines for the maintenance, extension and publication of SAREF and its extensions.

1 Scope

The present document presents the requirements gathered from the main smart appliances industrial actors to be exploited and implemented in the companion ETSI TS 103 410-1 [i.13], ETSI TS 103 410-2 [i.14] and ETSI TS 103 410-3 [i.15]. Next to that, the present document also provides input on the extension and maintenance of the SAREF ontology. The aforementioned technical specifications define extensions to the Smart Appliances reference ontology (SAREF) and the mapping to oneM2M as defined in ETSI TS 103 264 [i.3]. The objective is to include input from the industrial actors from the appliances domain including non-energy related aspects.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

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.

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

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

[i.2] 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.

[i.3] ETSI TS 103 264 (V1.1.1) (11-2015): "SmartM2M; Smart Appliances; Reference Ontology and oneM2M Mapping".

[i.4] ETSI TS 118 112: "oneM2M; Base Ontology (oneM2M TS-0012)".

[i.5] Gruber, T.: "Toward principles for the design of ontologies used for knowledge sharing", International Journal of Human-Computer Studies, Volume 43, Issues 5-6, November 1995, Pages 907-928.

NOTE: Available at http://www.sciencedirect.com/science/article/pii/S1071581985710816.

[i.6] IEC TR 62746-2: "Systems interface between customer energy management system and the power management system - Part 2: Use cases and requirements", 2015.

[i.7] EEBus, SPINE.

NOTE: Available at https://www.eebus.org/en/specifications/.

[i.8] Corcho, O., González, E. Deliverable D1.1. Kick-off meeting report. STARS4ALL project. March 2nd, 2016.

[i.9] Zamorano, J., García, C., González, R, Gallego, J., Pascual, S., Tapia, C., Nievas, M., Sánchez, A., Cardiel, N. Deliverable D4.1. Photometer sensor (prototype). STARS4ALL project. March 30th, 2016.

[i.10] "Variación espacial, temporal y espectral de la contaminación lumínica y sus fuentes: Metodología y resultados". Ph.D. thesis. Universidad Complutense de Madrid. February, 2015.

NOTE: Available at http://eprints.ucm.es/31436/.

[i.11] ISO 16739:2013: "Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries".

NOTE: Available at http://www.iso.org/iso/catalogue_detail.htm?csnumber=51622.

[i.12] Industry Foundation Classes (IFC) - Version 4 - Addendum 1. buildingSMART.

NOTE: Available at http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/.

[i.13] ETSI TS 103 410-1: "SmartM2M; Smart Appliances Extension to SAREF; Part 1: Energy Domain".

[i.14] ETSI TS 103 410-2: "SmartM2M; Smart Appliances Extension to SAREF; Part 2: Environment Domain".

[i.15] ETSI TS 103 410-3: "SmartM2M; Smart Appliances Extension to SAREF; Part 3: Building Domain".

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 explicit 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

3.2 Abbreviations

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

AEC	Architecture Engineering and Construction
AEF	Agricultural Industry Electronics Foundation
AIOTI	Alliance for the Internet of Things Innovation
API	Application programming interface
CEM	Customer Energy Manager
CRUD	Create Read Update and Delete
DOI	Digital Object Identifier
E@H	Energy@Home association
EEBus	EEBus initiative
FM	Facilities Management
HFC	Hydrofluorocarbon
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
HVAC	Heating, Ventilation, and Air Conditioning
IFC	Industry Foundation Classes
IoT	Internet of Things
ISO	International Organization for Standardization
LOV	Linked Open Vocabularies
MQTT	MQ Telemetry Transport
OM	Ontology of units of Measure
ORSD	Ontology Requirements Specification Document
OWL	Web Ontology Language

PURL	Persistent Uniform Resource Locator
RPC	Remote Procedure Call
SAREF	Smart Appliances REFerence ontology
SAREF4BLDG	SAREF extension for the Building domain
SAREF4ENER	SAREF extension for the Energy domain
SAREF4ENVI	SAREF extension for the Environment domain
SQM	Sky Quality Meter
TESS	Telescope Encoder and Sky Sensor
TNO	Netherlands Organization for Applied Scientific Research
TR	Technical Report
TS	Technical Specification
UML	Unified Modeling Language
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
W3C	World Wide Web Consortium
WGS84	World Geodetic System 1984
XML	Extensible Markup Language

4 SAREF extension and maintenance

4.1 Extensions

SAREF is the core semantic model for smart appliances (see ETSI TS 103 264 [i.3]), which contains the data elements that are used in more than one domain. SAREF has a close relation with the oneM2M base ontology, for which mappings are defined. Since smart appliances can be used in and come from several domains, it is possible that specific data elements for a certain domain are not defined in SAREF. To be able to handle these additional data elements and provide a specific domain with a semantic model that fits all the needs of that domain, there is the possibility to create extensions to SAREF. This is depicted in Figure 1, in which SAREF is represented as the upper model and the extensions for different domains as triangles that generate from the upper model, specializing core concepts from SAREF. Each domain can have one or more extensions, depending on the complexity of the domain. Existing extensions of SAREF are highlighted in the left part of Figure 1 (i.e. for the Energy, Environment and Building domains), while other possible domains of interest are depicted in the right part. Figure 1 further depicts the equivalence of some concepts between SAREF and the oneM2M base ontology [i.4].

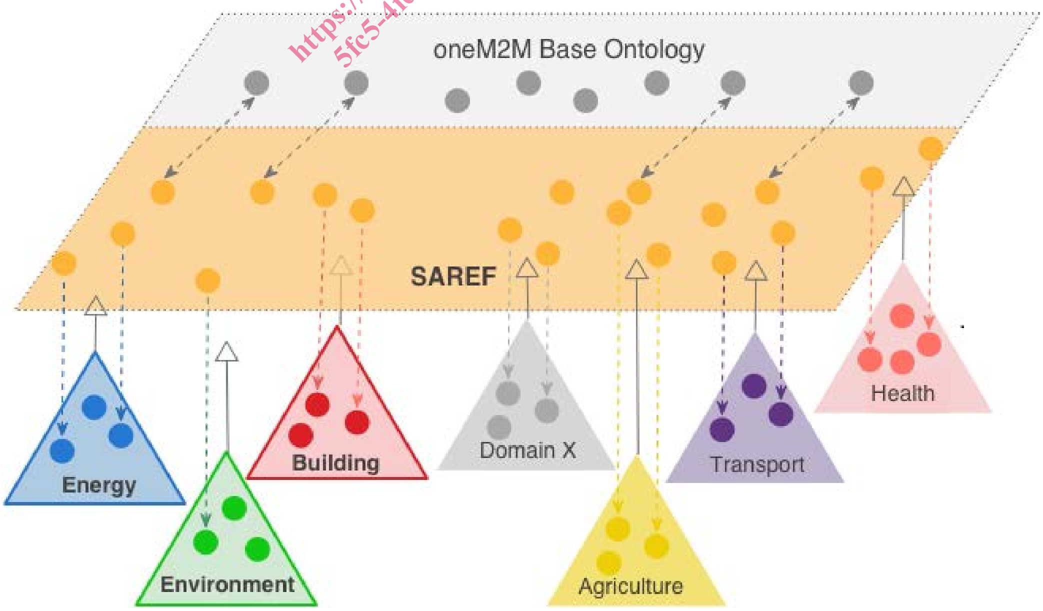

Figure 1: SAREF and extensions

As SAREF is the core semantic model for smart appliances, it functions as the connecting factor between the extensions in the different domains, and the domain specific extensions should reuse the parts of SAREF that are relevant for their domain. A domain specific extension should add new concepts that are not defined in SAREF. Furthermore, domain specific extension can also reuse concepts from other extensions.

Each domain specific extension should be specified as a separate TS in order to ensure that domain specific extensions can be maintained independently of each other and also independently of SAREF. Numbering of SAREF extensions will be based on the following schema: ETSI TS 103 410-X (where X is a positive integer. Naming of SAREF extensions will be based on the following schema: SAREF4XXXX (where XXXX are letters). For example, the extension of SAREF for the energy domain is specified in ETSI TS 103 410-1 [i.13] and is named SAREF4ENER. The extension of SAREF for the environment domain is specified in ETSI TS 103 410-2 [i.14] and is named SAREF4ENVI. The extension of SAREF for the building domain is specified in ETSI TS 103 410-3 [i.15] and is named SAREF4BLDG. Future extensions will follow the same numbering and naming schema.

Extensions can be created within an ETSI committee or outside of ETSI, but for standardization, they have always to pass through the ETSI SmartM2M committee.

Once a year, a check should be performed by ETSI SmartM2M on all extensions to identify concepts and properties that are used in more than one extension, as it could be desirable to move them to SAREF (to keep its role as a reference ontology with core concepts common to several domains).

4.2 Maintenance

SAREF and all the extensions created within the ETSI community are maintained using an approach as open as possible. This means that it is possible for every stakeholder (for SAREF and the domain specific extensions) to provide input on the maintenance of the models and participate in discussions on the improvement of the models.

Furthermore, it is also expected that extensions of SAREF will not only be created within the ETSI community, but also outside. ETSI should play an important role in the standardization of extensions of SAREF by allowing the models created outside of ETSI to be fed as input into the SmartM2M group and stimulating external stakeholders to provide their continuous input over time.

The formal standardization activities of SAREF and turning the drafts into Technical Specifications should be handled by the SmartM2M technical body within ETSI. Furthermore, the SmartM2M group should also be in charge of the vision on the development of SAREF and ensuring that the extensions created are in line with this vision.

As soon as any group or association has created an extension to SAREF and provided it as a contribution to ETSI SmartM2M as candidate to become a Technical Specification, the ETSI SmartM2M technical body will perform a set of predetermined checks to decide whether the proposed extension is accepted. Checks to be performed are:

- Is the extension a proper ontology according to the criteria specified in clauses 4.4 and 4.5?
- Were all relevant stakeholders in the domain involved in the creation process of the extension?
- Is the group that created the extension willing to work on the maintenance of the extension?
- Is SAREF properly used, and is the extension not adding concepts that are already present in SAREF?
- Is the extension properly documented?
- Is the extension in line with the vision of ETSI SmartM2M?

While working on the maintenance, it is important that SAREF and the domain specific extension are kept aligned: as soon as there is a number of domain specific extensions and concepts that occur in several domains are identified, these concepts should be moved as upper concepts in SAREF as a reference for all domains. Furthermore, every domain specific extension should have a maintenance strategy/schedule to ensure consistency and allow input from relevant stakeholders.

4.3 Specification

This clause describes a possible specification process for creating extensions of SAREF. The goal of the ontological requirements specification process is to extract the set of requirements that will guide the implementation and validation of the ontology. This process will allow identifying the purpose and scope of the ontology in the different use cases and to generate a list of requirements (in form of Competency Questions) that will guide the posterior development (and that will be updated along such development).

Figure 2 provides an overview of the ontology requirements specification process followed and its relation with the rest of the ontology development process. In this figure, the following information is included:

- **Actors.** The different roles involved in each activity. These roles can be:
  - Users. The potential end users of the ontology. This group includes software developers that will make use of the ontology within their applications.
  - Experts. Experts in the domains covered by the ontology. This role does not need to be knowledgeable about ontology development.
  - Ontology development team. This role represents ontological engineers and ontology developers with high knowledge on ontology implementation languages, techniques, tools, etc.
- **Activities.** The activities to be carried out in the process.
- **Outputs.** The products derived from each activity and that will serve as input to the posterior activities.

Figure 2 also provides the workflow of activities indicating the order in which they are carried out. In this sense it can be observed that after an implementation cycle the workflow goes back to the ontological requirements specification phase in which new requirements to be implemented will be chosen.

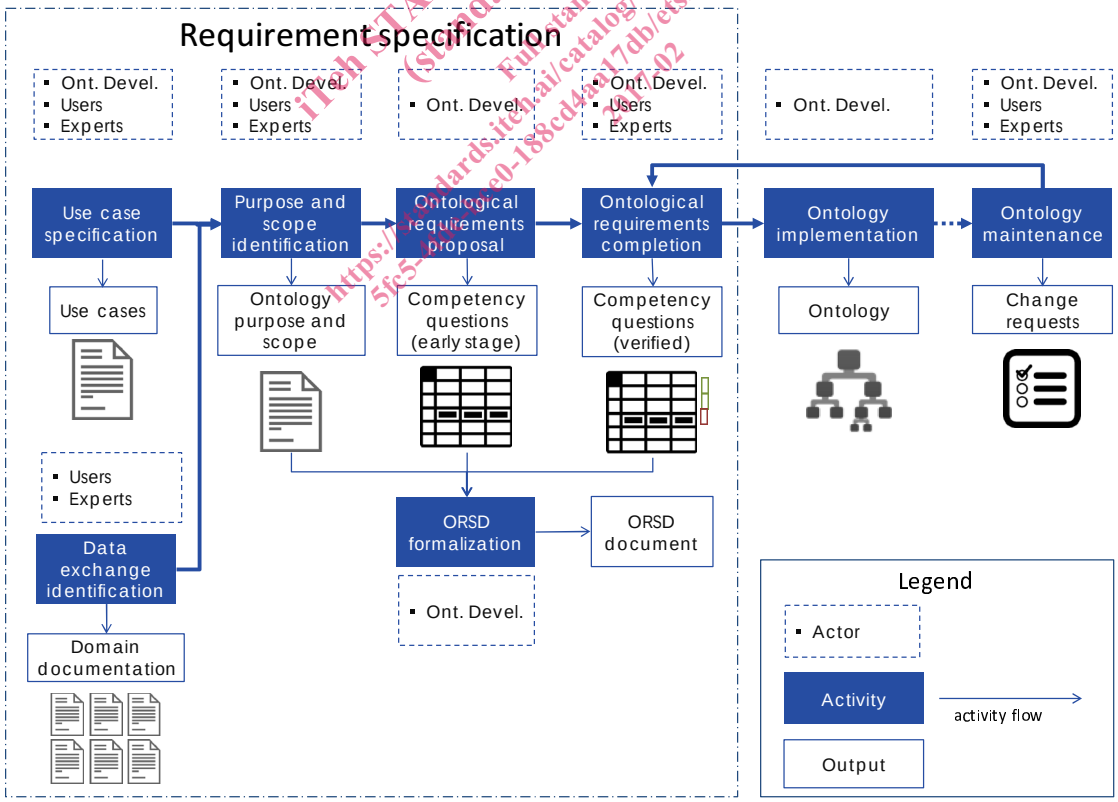

Figure 2: Ontology development process

The activities to be carried out during the ontology requirements specification process are the following:

- **Data exchange identification.** The goal of this activity is to provide the ontology development team with the necessary documentation about the domain to be modelled. In this case such documentation might origin from domain experts and/or users. The documentation to be shared might correspond to: manuals, datasets, standards, API specifications, data formats, etc.
- **Use case specification.** The goal of this activity is to collect a general description of the applications or processes in which the ontology to be developed may be used. These descriptions are written in natural language by domain experts and software developers who could be assisted by the ontology development team if required.
- **Purpose and scope identification.** The goal of this activity is to define the purpose and scope of the ontology for each of the use cases identified. During this activity, the ontology development team works in collaboration with users and domain experts to define the purpose and scope of each ontology or ontology module to be developed.
- **Ontological requirements proposal.** Taking as input the documentation and data provided by domain experts and users, the ontology development team generates a first proposal of the ontological requirements written in the form of Competency Questions [i.5]. The means used for gathering requirements follows a tabular approach in which the following fields are included: Requirement identifier, Competency question (question and answer or a statement in natural language), Provenance information (origin of the requirement), Comments, Relation with other requirements, Priority, and Status (proposed, accepted, rejected).
- **Ontological requirements completion.** During this activity, domain experts and users in collaboration with the ontology development team validate whether the ontology requirements defined in the previous step are correct and complete.
- **Ontological Requirement Specification Document (ORSD) formalization.** During this activity, the ORSD document is compiled by ontology developers. Such compilation of requirements would be taken as a first backlog that will trigger the ontology implementation phase.

4.4 Implementation

SAREF and its extensions should be high-quality ontology standards that provide additional value (e.g. break new ground, fill in an important gap, provide additional value compared to similar efforts, etc.), with high potential of being adopted by others, persistently accessible and available for reuse, and characterized by an exemplary design and technical quality. Concerning the design and technical quality, the most widely adapted, objective criteria for the design of ontologies for knowledge sharing are the principles proposed by Gruber [i.5]. SAREF and its extensions should therefore be implemented according to these criteria. Gruber's criteria can be summarized as follows:

- **Clarity.** For achieving clarity in ontological definitions, Gruber emphasizes the importance of:
  1) independence from social and computational contexts by using formalism;
  2) the use of logical axioms that provide a complete definition, i.e. a predicate defined by necessary and sufficient conditions;
  3) documentation supported by natural language.
- **Coherence.** Gruber states that definitions in an ontology should be logically consistent with the inferences that can be derived from these definitions. Further there should also be consistency between the logical axioms and their natural language documentation to maintain coherence. Extensions should be therefore checked using popular reasoners for logical consistency.
- **Extendibility.** The design of the ontology should enable monotonic extensions of the ontology, i.e. one should be able to define new terms for special use based on the existing vocabulary in a way that a revision of the existing definitions is not necessary.

- **Minimal encoding bias.** To encourage wider adoption of the ontology, Gruber proposes the use of a conceptualization mechanism that minimizes the dependencies on encoding formats (i.e. design choices should not be made purely for the convenience of notation or implementation). SAREF has been formalized in OWL-DL, which is a W3C standard for representing ontologies on the Web and has its foundations in Description Logics. Multiple serialization formats are available for the ontology (Turtle, RDF/XML). The axiomatization in SAREF is therefore accessible to all tools and frameworks that support these serializations. It is recommendable that SAREF extensions to follow the same formalization and serializations.
- **Minimum ontological commitment.** An ontology should make assertions that require only the minimum commitment sufficient to support the knowledge sharing activities, providing the parties that use the ontology with the flexibility to extend and specialize the ontology as needed.

4.5 Publication

The first SAREF technical specification ETSI TS 103 264 (V1.1.1) [i.3] was published as a collection of two documents, which could be downloaded together as a zip-file:

- Technical specification document in PDF format.
- Ontology file in Turtle format.

While this may be the normal method for publishing standards in ETSI, this is not the most suitable method for publishing ontologies. The main reason is that ontologies such as SAREF and its extensions should become part of the Semantic Web to ensure that the community will start adopting them. Publishing ontologies as Technical Specifications in zip-files hinders the possibility for the Semantic Web community to find and access the ontology, and therefore should be discouraged in ETSI.

In contrast, SAREF and its extensions should be made available according to the following best practices for publishing ontologies in the Semantic Web as defined by the W3C (https://www.w3.org/TR/swbp-vocab-pub/):

- Make the ontology available at a persistent URI, such as PURL, DOI or w3id, which redirects the HTTP requests against this persistent URI to another URL of choice (for example on an ETSI server) in which the ontology is actually located. This guarantees that the ontology will always be accessible at the same URI, even if its actual location changes.
- Enable content negotiation to make it possible to access SAREF on one URI, and depending on the request of the user give back machine-processable content (.rdf, .owl, .ttl) or human-readable content (HTML). The HTML documentation will be given as multiple hyperlinked HTML documents plus an overview document.
- Specify an appropriate license for the ontology, such as the creativecommons.org or opensources.org licenses.
- Make the ontology findable by registering it into community registries, such as the Linked Open Vocabularies (LOV, see http://lov.okfn.org/).

4.6 Extension domains

A number of domains have been identified as possible domains for extending SAREF. For three of them extensions have been defined (Energy, Environment and Building); for the other ones, extensions could be created in the near future.

Energy demand response

In the energy domain the associations Energy@Home and EEBus are working on interconnecting smart appliances to be able to perform demand and response use cases on the electricity grid. For this domain an extension has been defined, and the use cases presented are defined in clause 5.1.1.

Environment

Due to the positive connotations about security, wealth and modernity, people tend to illuminate the environment intensively. However, such exceed of artificial illumination, in addition to the waste of energy it represents, also interferes with astronomical observatories, disrupts ecosystems and has adverse health effects. In this context, light pollution is defined as excessive, misdirected or obtrusive artificial light. Based on input from the STARS4ALL project, an extension has been defined based on the use cases defined in clause 5.1.2.

Buildings

A more efficient interaction and integration of actors, methods and tools during the different phases of the building life cycle is being demanded in the Architecture, Engineering and Construction (AEC) and Facilities Management (FM) fields. Along its life cycle, multiple tools interact with building models to extract information for different purposes (e.g. energy demand, appliance characteristics, etc.). Therefore, mechanisms to facilitate the exchange of data between actors along the different stages of the building life cycle and to provide the required interoperability between tools are needed. As the ISO standard data model Industry Foundation Classes (IFC) [i.11] supports interoperability between data and tools, it was decided to extend the SAREF ontology with the subset of the ISO IFC standard related to devices and appliances. An extension has been defined based on the IFC standard [i.11] and the use cases defined in clause 5.1.3.

Health/Ageing well

Another possible extension of SAREF is an extension for the health domain. A number of parties are looking into connecting smart appliances in the home to allow citizens to live longer in their own home, or to be able to better support them remotely. The AIOTI Working Group 5 and the European Commission are interested in creating an ontology for Healthy Ageing, it is worthwhile to discuss this ontology and to see whether there is a link with SAREF. Furthermore, it is important to take into account the activities of the Continua Alliance (http://www.continuaalliance.org/) to ensure alignment with their activities when working on an extension of SAREF. Continua is publishing design guidelines that indicate how existing standards from different standardization bodies should be combined to ensure interoperability between personal health devices. The standards used also facilitate the exchange of data. For an extension of SAREF, it would be interesting to ensure that all data exchanged based on the Continua design guidelines is defined in the SAREF extension so that full mappings are possible.

Agriculture

An additional potential extension of SAREF is an extension for the agriculture domain, which is seen as one of the domains where the implementation of IoT could have a big impact. The Agricultural Industry Electronics Foundation (AEF) establishes and continues the international development and expansion of electronic and electrical technology as well as the implementation of electronic standards and coordinates the international cooperation in agricultural electronics technology. As the AEF is highly involved with the electronic and electrical technology for the agricultural domain, it is very interesting to ensure that an extension of SAREF includes all the data elements that are defined by the AEF to ensure that the SAREF extension could be fully mapped to the AEF standards.

5 Use cases and requirements

5.1 Use cases

5.1.1 Use cases from Energy@Home and EEBus

The Energy@Home and EEBus use cases require an extension of SAREF for Energy@Home (http://www.energy-home.it) - abbreviated in the rest of the document as E@H - and EEBus (http://www.eebus.org/en) to enable the interconnection of their different data models. Its purpose is to facilitate the interoperability between EEBus and E@H devices in demand response scenarios. By using this extension, smart appliances from manufacturers that support the EEBus or E@H data models will be able to communicate with one another using any energy management system at home or in the cloud, abstracting from the specifics of the underlying communication protocols.