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TECHNICAL REPORT

SmartM2M;
Guidelines for consolidating SAREF with
new reference ontology patterns,
based on the experience from the ITEA SEAS project

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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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1 Scope

The present document specifies the functional requirements for a set of reference ontology patterns for the SAREF semantic model, along with guidelines for developing extensions to this semantic model for multiple engineering-related verticals. The present document has been developed leveraging the experience of the EUREKA ITEA 12004 SEAS (Smart Energy Aware Systems) project, and the development of the OGC&W3C SSN (Semantic Sensor Network) ontology. It illustrates the applications of the guidelines with use cases for Smart Energy, Smart Building, and Industry of the Future/Industry 4.0 verticals. The associated ETSI TS 103 548 [i.1] will define the update to SAREF and its extensions based on the requirements and guidelines specified in the present document.

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] ETSI TS 103 548: "SmartM2M; SAREF consolidation with new reference ontology patterns, based on the experience from the SEAS project".

[i.2] ETSI TS 103 264 (V2.1.1): "SmartM2M; Smart Appliances; Reference Ontology and oneM2M Mapping".

[i.3] ETSI TS 103 410-1 (V1.1.1): "SmartM2M; Smart Appliances Extension to SAREF; Part 1: Energy Domain".

[i.4] ETSI TS 103 410-2 (V1.1.1): "SmartM2M; Smart Appliances Extension to SAREF; Part 2: Environment Domain".

[i.5] ETSI TS 103 410-3 (V1.1.1): "SmartM2M; Smart Appliances Extension to SAREF; Part 3: Building Domain".

[i.6] ETSI TS 103 410-4 (V1.1.1): "SmartM2M; Extension to SAREF; Part 4: Smart Cities Domain".

[i.7] ETSI TS 103 410-5 (V1.1.1): "SmartM2M; Extension to SAREF; Part 5: Industry and Manufacturing Domains".

[i.8] ETSI TS 103 410-6 (V1.1.1): "SmartM2M; Extension to SAREF; Part 6: Smart Agriculture and Food Chain Domain".

[i.9] ETSI TR 103 411 (V1.1.1): "SmartM2M; Smart Appliances; SAREF extension investigation".

[i.10] A. Haller, K. Janowicz, S. Cox, D. Le Phuoc, K. Taylor, M. Lefrançois, R. Atkinson, R. García-Castro, J. Lieberman, C. Stadler: "Semantic Sensor Network Ontology". W3C Recommendation, 19 October 2017.

NOTE: Available at https://www.w3.org/TR/vocab-ssn/.

[i.11] M. Lefrançois, J. Kalaoja, T. Ghariani, A. Zimmerman: "The SEAS Knowledge Model", ITEA2 12004 Smart Energy Aware Systems Deliverable 2.2, January 2017.

NOTE: Available at http://w3id.org/seas/.

[i.12] M. Lefrançois, A. Zimmermann, N. Bakerally: "A SPARQL extension for generating RDF from heterogeneous formats", in Proc. Extended Semantic Web Conference, 2017.

NOTE: Available at http://w3id.org/sparql-generate.

[i.13] H. Rijgersberg, M.F.J. van Assem, J.L. Top: "Ontology of Units of Measure and Related Concepts." Semantic Web, 4, 1, 2013, pp. 3-13.

NOTE: Available at http://www.ontology-of-units-of-measure.org/page/om-2.

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

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

3.2 Symbols

Void.

3.3 Abbreviations

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

CHE	Concept Hierarchy Extension
CS	Concept Specialization
EMSE	École des Mines de Saint-Étienne, France
FOI	Feature Of Interest
FOIPD	Feature Of Interest, Properties and Devices
GECAD/ISEP	Knowledge Engineering and Decision-Support Research Center, School of Engineering, Polytechnic of Porto, Portugal
IoT	Internet of Things
IRI	Internationalized Resource Identifier
ITEA	Information Technology for European Advancement
OGC	Open Geospatial Consortium
OM	Ontology of Measurements
OWL	Web Ontology Language
PEP	Procedure Execution Ontology
PSD	Platform, System and Deployment
QUDT	Quantities, Units, and DataTypes
RDF	Resource Description Framework
RG	Research Group
RMS	Root Mean Square amplitude
RN	Phase R to Neutral
SAREF	Smart Appliances REFerence ontology
SEAS	Smart Energy Aware Systems
SN	Phase S to Neutral
SOSA	Sensor, Observation, Sample, and Actuator
SPARQL	SPARQL Protocol And RDF Query Language
SSN	Semantic Sensor Networks
STF	ETSI Specialist Task Force

TB	Technical Body
THD	Total Harmonic Distortion
TN	Phase T to Neutral
TR	Technical Report
TS	Technical Specification
URI	Universal Resource Identifier
URL	Universal Resource Locator
W3C	World Wide Web Consortium

4 Consolidation of SAREF using ontology patterns

SAREF (V2.1.1) (ETSI TS 103 548 [i.2]) is a reference ontology for the IoT developed by ETSI SmartM2M in close interaction with the industry. SAREF contains core concepts that are common to several IoT domains and, to be able to handle specific data elements for a certain domain, dedicated extensions of SAREF have been created, for example SAREF4ENER (ETSI TS 103 410-1 [i.3]), SAREF4ENVI (ETSI TS 103 410-2 [i.4]), SAREF4BLDG (ETSI TS 103 410-3 [i.5]), and SAREF4CITY (ETSI TS 103 410-4 [i.6]), SAREF4INMA (ETSI TS 103 410-5 [i.7]), SAREF4AGRI (ETSI TS 103 410-6) [i.8]. Each domain can have one or more extensions, depending on the complexity of the domain. As a reference ontology, SAREF serves as the means to connect the extensions in different domains. The earlier document ETSI TR 103 411 [i.9] specifies the rationale and methodology used to create, publish and maintain the SAREF extensions.

Ontology patterns are like design patterns in object oriented programming. They describe structural, logical, naming, or documentation best practices that one can consider when building an ontology.

The present document provides an analysis of the potential of modularization and factorization of the SAREF core ontology (V2.1.1) (ETSI TS 103 548 [i.2]) as patterns.

Then, the present document specifies a set of ontology patterns for the modelling and the description of any kind of engineering-related data/information/systems; that may be used to consolidate SAREF.

Finally, the present document lists a set of issues that are identified in the current version of SAREF, and proposes changes to consolidate SAREF.

The present document has been developed in the context of the STF 556 (https://portal.etsi.org/STF/STFs/STFHomePages/STF556.aspx), which was established with the goal to consolidate SAREF and its community of industrial users based on the experience of the EUREKA ITEA 12004 SEAS (Smart Energy Aware Systems) project. The present document specifies requirements for an initial set of SAREF extensions instantiating the defined ontology patterns, for some use cases taken from SEAS project, therefore filling some of the representational gaps that were identified during this project.

5 Related initiatives

In this clause, some of the main related initiatives in terms of modelling reference ontology patterns for the IoT, and using these ontology patterns to develop ontologies, are reviewed.

- **Joint OGC and W3C Spatial Data on the Web working group:** the SSN (Semantic Sensor Network) ontology [i.10] is a modular ontology using some design patterns that were instantiated manually. One of these design patterns involves different kinds of systems and the procedures they execute: Sensors, Actuators and Samplers, execute Observation, Actuation and Sampling activities.

- **OntologyDesignPatterns.org:** This website references ontology design patterns, which are classified in different categories such as Content, Logical, or Lexico-Syntactic patterns.

- **EUREKA ITEA 12004 SEAS:** The SEAS ontology [i.11] is a modular and versioned ontology with all the terms it defines having the same namespace (https://w3id.org/seas/). It contains a core of SEAS reference ontology patterns that can be instantiated to create the SEAS ontology itself with a homogeneous and predictable structure for the modelling and the description of any kind of engineering-related data/information/systems. These design patterns and some of their instances fill some of the representational gaps that were identified in SAREF.

6 Use cases

6.1 Introduction

The SEAS (Smart Energy Aware Systems) project was a 35 partners and 13 500 000 € project that ran from February 2014 to December 2016 (https://itea3.org/project/seas.html), and received the ITEA Award of Excellence 2017. Its goal was to design and develop an eco-system of smart things and services, collectively capable of optimizing the energy efficiency within the future Smart Grid. 100 use cases were defined by 35 partners, from which some identified gaps not yet covered by SAREF to be filled in the SEAS knowledge model. SAREF focuses on the notion of Device, while industry use cases often require some description of the physical systems and their connections, value association for their properties, and the activities by which such value association is done. The SEAS ontology development was initiated during a workshop that gathered 45 participants during 3 days and continued with close collaborations between ontology engineering experts, domain experts, and industry software architects.

6.2 Use case 1: Smart Energy

6.2.0 Introduction

New SAREF ontology patterns can be used to homogeneously represent knowledge that is relevant for use cases in the Smart Energy domain.

6.2.1 Types, topology and properties of the Features Of Interest

- An Actuator Switch acts on the state of a specific device. Given a device, one should be able to know what are the switches that can act on it.

- A Smart-Meter measures the energy consumption of the energy grid at a certain point of the energy grid.

- Electric power systems can exchange electricity with other electric power systems. The electric energy can flow both ways in some cases (from the Public Grid to a Prosumer), or in only one way (from the Public Grid to a Load). Electric power systems can be made up of different sub-systems. Generic sub-types of electric power systems include producers, consumers, storage systems, transmission systems. The properties that are relevant for these systems include power production, consumption, energy stored. These properties may be measured or acted on by IoT devices.

- Electric power systems may be connected one to another through electrical connection points. An Electric power system may have multiple connection points (Multiple Winding Transformer generally have one single primary winding with two or more secondary windings). Generic sub-types of electrical connection points include plugs, sockets, direct-current, single-phase, three-phase, connection points. The properties that are relevant for these connection points include Voltage, Resistance, Conductance, Reactance, Susceptance, and can be measured between two wires of the connection points.

- An Electrical connection may exist between two Electric power systems at two of their respective connection points. Generic sub-types of electrical connections include Single-phase Buses, Three-phase Buses. A single-phase electric power system can be connected using different configurations at a three-phase bus (RN, SN, TN types). The properties that are relevant for a three-phase electric bus include voltage between the different wires R, S, T, N (R-to-N, S-to-N, R-to-S, etc.). IoT devices can be used to measure and control this voltage at different points of the grid.

6.2.2 Kinds of measures

- Every electric power device potentially consumes and produces electric power, and stores electric energy. Over a given period of time, different Smart Meters may measure different aggregated values for these quantities. E.g. cumulative (sum), maximum, minimum, average.

- Quantities that evolve periodically are usually described in terms of their frequency, the peak, RMS amplitude, THD of the quantity value. Smart Meters may measure different aspects of a direct current, single-phase alternating current, or three-phase alternating electric current.

- Some properties are controllable, such as the consumption or production of electric power systems. The reduction, augmentation, cut, move flexibility, of a specific controllable property can be evaluated (and valuated).

6.3 Use case 2: Smart Building

6.3.0 Introduction

New SAREF ontology patterns can be used to homogeneously represent knowledge that is relevant for use cases in the Smart Building domain.

6.3.1 Types, topology, and properties, of the Features Of Interest

- A light switch acts on the luminosity of a specific room. Given a room, one should be able to know what light switch may be used to change the luminosity in this room.
- Temperature Sensors, Heaters, Coolers, observe or act on a specific zone of a building. Given a zone, one should be able to know what are the devices that observe or act on the temperature in this zone.
- Buildings, Storeys, Spaces, are different sub-types of Zones. Zones can contain sub-zones. Zones can be adjacent or intersect with other zones. The properties that are relevant for these systems include temperature, luminosity, humidity, pressure, population. These properties may be measured or acted on by IoT devices.
- Two zones may share one or more connections. For example some fresh air may be a created inside a storey if it has two controllable openings to the exterior at different cardinal points. Different properties may be relevant depending on the connection between zones. Observing and controlling the flow of humans or animals, total heat transfer, pressure difference, wind speed, may be relevant for controllable openings.

6.3.2 Kinds of measures

- Temperature, pressure, humidity, can be observed or acted upon by dedicated IoT devices. An observation may be instantaneous, or aggregated over a period of time: maximum, minimum, average. Derived properties may be evaluated, like the number of occurrences for a certain temperature rising above a threshold.
- Depending on the quantity, derived quantities may be observed such as the sum (interesting for properties like flows of humans/animals, or rain precipitation), or the growth rate (important for controlling the pressure in specific zones like planes or cleanrooms).

7 Analysis of the modularization and factorization potential of SAREF

7.1 Introduction

This clause provides an analysis of the potential of modularization and factorization of the SAREF core ontology (V2.1.1) (ETSI TS 103 548 [i.2]). It highlights inter-dependent parts of the ontology, parts that are more or less *central*, and parts that are repeated homogeneously for different concepts (patterns). The result of this analysis is illustrated on Figure 1, and detailed in the next clauses.

7.2 Modularization

In Figure 1, a box illustrates a module constituted by a subset of concept declarations and axioms of SAREF core (V2.1.1) (ETSI TS 103 548 [i.2]). Each module has a label in bold font, and the lower part of the box lists the concept declarations that belong to this module. Axioms are not shown in Figure 1. For example, the box labelled **Service-core** contains the concept declarations and axioms related to the terms `saref:Service`, `saref:isOfferedBy`, `saref:offers`, `saref:represents`. The terms `saref:Function` and `saref:hasFunction` will also be grouped in one single module because they share a similar name.

A directed link between two boxes illustrate a dependency between the two modules. The label of a link explicits the rationale, and potentially the condition, for this dependency. For example, the module **Service-core** depends on the module **Functions and Commands** because there exists an axiom in SAREF stating that every `saref:Service` represents some `saref:Function`. Therefore, `saref:Service` cannot be defined without the `saref:Function`. In general, restrictions such as existential cardinality restrictions and minimal cardinality restrictions are used to decide on the direction of a dependency.

The grouping of concept declaration and axioms of SAREF in modules and the orientation of the dependencies between modules is partly made by choosing to view SAREF according to a certain perspective, and partly for intuitive reasons. For example, it makes sense to consider that `saref:Property` can be defined independently of `saref:Measurement`, but not the other way around. Therefore, the dependency link will be oriented from **Measurement-core** to **Property-core**.

It is necessary to group the concepts and axioms related to functions and commands into one single module **Functions and Commands**, because there exists axioms in SAREF stating that every `saref:Function` is associated to at least one `saref:Command`, and vice versa.

This analysis can be used to discuss conceptual issues in the axiomatization of SAREF. For example, SAREF (V2.1.1) (ETSI TS 103 548 [i.2]) contains an axiom that specifies that every `saref:Task` is accomplished by at least one `saref:Device`. This results in the module **Task-core** depending on the module **Device-core**, which is odd. In fact, tasks should be defined independently of devices.

Second, this analysis can be used to modularize SAREF core (V2.1.1) (ETSI TS 103 548 [i.2]): modules or group of modules with no incoming dependencies are not required for other modules. They could be safely filtered out in the documentation on the portal or in some embedded implementation of SAREF, without impacting the rest of the documentation or application. For example, the two modules **Service-core** and **specific Service** have no incoming dependency, therefore they are not essential to the specification of the rest of the ontology.

7.3 Factorization

In Figure 1, a box with an underlined label represents a pattern which can be applied to different concepts. For example, the pattern **specific Sensor** can be instantiated for `saref:SmokeSensor` and `saref:TemperatureSensor`. The pattern **specific Function** can be instantiated for `saref:ActuatingFunction`, `saref:OpenCloseFunction`, etc.

These instantiated patterns have dependency links with other modules, and potentially other patterns. The latter are to be understood as dependencies between two specific pattern instances. For example, the instance of pattern **specific Function** for `saref:OpenCloseFunction` has a dependency to instance of pattern **specific Command** for `saref:OpenCommand` and `saref:CloseCommand`, because they are the types of commands this function can have.

This factorization analysis is used to extract the existing ontology patterns in SAREF core (V2.1.1) (ETSI TS 103 548 [i.2]). Future evolutions of SAREF may progressively migrate to using languages and tools to generate the ontology from patterns and some description of the instances of these patterns. A proof of concept of such a pattern instantiation mechanism for SAREF is implemented using the SPARQL-Generate RDF transformation language [i.12].

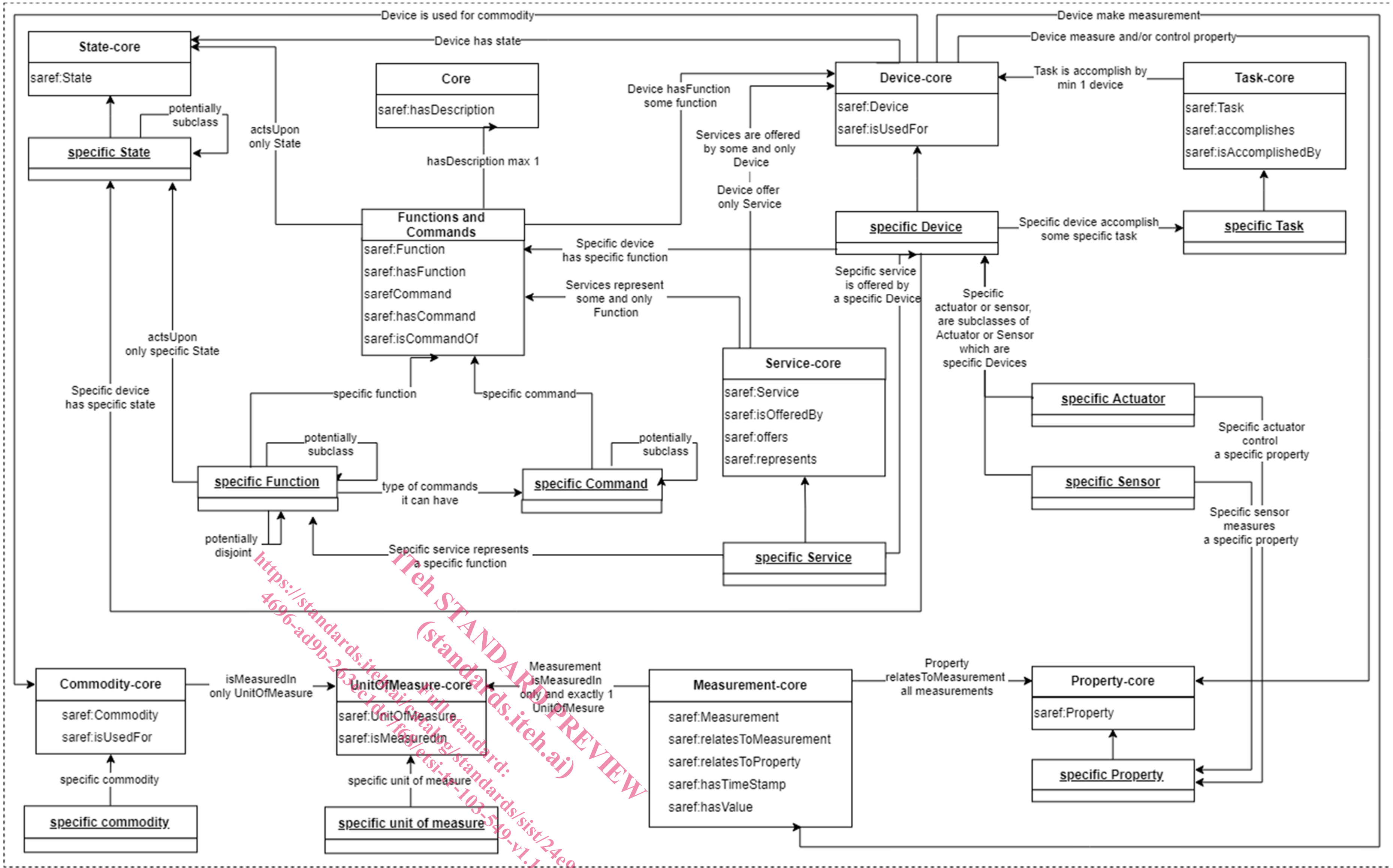

Figure 1: Analysis of the modularization and factorization potential of SAREF-Core (V2.1.1)