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SmartM2M;
SAREF consolidation with new reference ontology patterns, based on the experience from the SEAS project

Reference

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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

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1 Scope

The present document specifies a new reference ontology pattern for the SAREF semantic model [1], which leverages the experience of the EUREKA ITEA 12004 SEAS (Smart Energy Aware Systems) project [i.1], and the development of the OGC & W3C SSN (Semantic Sensor Network) ontology [i.2]. It also defines how this pattern may be instantiated for the verticals, and point to examples for the Smart Energy and the Smart Building domains. The present document is based on the requirements and guidelines defined in the associated ETSI TS 103 549 [i.3] document.

2 References

2.1 Normative references

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

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

[1] ETSI TS 103 264: "SmartM2M; Smart Appliances; Reference Ontology and oneM2M Mapping".

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

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

[i.2] 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.3] ETSI TR 103 549: "SmartM2M; Guidelines for consolidating SAREF with new reference ontology patterns, based on the experience from the ITEA SEAS project".

[i.4] ETSI TS 103 410-1 (V1.1.1): "SmartM2M; Smart Appliances Extension to SAREF; Part 1: Energy Domain".

[i.5] ETSI TS 103 410-2 (V1.1.1): "SmartM2M; Smart Appliances Extension to SAREF; Part 2: Environment Domain".

[i.6] ETSI TS 103 410-3 (V1.1.1): "SmartM2M; Smart Appliances Extension to SAREF; Part 3: Building Domain".

[i.7] ETSI TS 103 410-4 (V1.1.1): "SmartM2M; Extension to SAREF; Part 4: Smart Cities Domain".

[i.8] ETSI TS 103 410-5 (V1.1.1): "SmartM2M; Extension to SAREF; Part 5: Industry and Manufacturing Domains".

[i.9] ETSI TS 103 410-6 (V1.1.1): "SmartM2M; Extension to SAREF; Part 6: Smart Agriculture and Food Chain Domain".

[i.10] ETSI TR 103 411 (V1.1.1): "SmartM2M; Smart Appliances; SAREF extension investigation".

[i.11] M. Lefrançois, A. Zimmermann, N. Bakerally: "A SPARQL extension for generating RDF from heterogeneous formats", In Proc. Extended Semantic Web Conference, 2017.

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

smart application: application using devices which have the ability to communicate with each other and which can be controlled

3.2 Symbols

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

RN	Wire 'R' (phase R) to wire 'N' (Neutral)
SN	Wire 'S' (phase S) to wire 'N' (Neutral)
TN	Wire 'T' (phase T) to wire 'N' (Neutral)

3.3 Abbreviations

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

DL	Description Logics
EMSE	École des Mines de Saint-Étienne, France
EUREKA	European Research Coordination Agency
IRI	Internationalized Resource Identifier
ITEA	Information Technology for European Advancement
OGC	Open Geospatial Consortium
OWL	Web Ontology Language
OWL-DL	Web Ontology Language – Description Logics
RDF	Resource Description Framework
SAREF	Smart Applications REFerence ontology
SEAS	Smart Energy Aware Systems
SPARQL	SPARQL Protocol And RDF Query Language
SSN	Semantic Sensor Networks
STF	ETSI Specialist Task Force
TR	Technical Report
TS	Technical Specification
USB	Universal Serial Bus
W3C®	World Wide Web Consortium

4 SAREF4SYST ontology and semantics

4.1 Introduction

SAREF V2.1.1 [1] 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 [i.4], SAREF4ENVI [i.5], SAREF4BLDG [i.6], and SAREF4CITY [i.7], SAREF4INMA [i.8], SAREF4AGRI [i.9]. 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.10] specifies the rationale and methodology used to create, publish and maintain the SAREF extensions.

The present document is the technical specification of SAREF4SYST, a generic extension of ETSI TS 103 264 SAREF [1] that defines an ontology pattern which can be instantiated for different domains. SAREF4SYST defines Systems, Connections between systems, and Connection Points at which systems may be connected. These core concepts can be used generically to define the topology of features of interest, and can be specialized for multiple domains. The topology of features of interest is highly important in many use cases. If a room holds a lighting device, and if it is adjacent with an open window to a room whose luminosity is low, then by turning on the lighting device in the former room one may expect that the luminosity in the latter room will rise.

The SAREF4SYST ontology pattern can be instantiated for different domains. For example to describe zones inside a building (systems), that share a frontier (connections). Properties of systems are typically state variables (e.g. agent population, temperature), whereas properties of connections are typically flows (e.g. heat flow).

SAREF4SYST has two main aims: on the one hand, to extend SAREF with the capability or representing general topology of systems and how they are connected or interact and, on the other hand, to exemplify how ontology patterns may help to ensure an homogeneous structure of the overall SAREF ontology and speed up the development of extensions.

SAREF4SYST consists both of a core ontology, and guidelines to create ontologies following the SAREF4SYST ontology pattern. The core ontology is a lightweight OWL-DL ontology that defines 3 classes and 9 object properties.

Use cases for ontology patterns are described extensively in ETSI TR 103 549 [i.3]. Clauses 4.2 and 4.3 extract use cases for the SAREF4SYST ontology pattern.

4.2 Use case 1: Smart Energy

The present clause illustrates how SAREF4SYST can be used to homogeneously represent knowledge that is relevant for use cases in the Smart Energy domain:

- 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.

- 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.

- 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).

4.3 Use case 2: Smart Building

The present clause illustrates how SAREF4SYST can be used to homogeneously represent knowledge that is relevant for use cases in the Smart Building domain:

- Buildings, Storeys, Spaces, are different sub-types of Zones. Zones can contain sub-zones. Zones can be adjacent or intersect with other zones.
- Two zones may share one or more connections. For example some fresh air may be created inside a storey if it has two controllable openings to the exterior at different cardinal points.

4.4 Namespaces

The prefixes and namespaces used in SAREF4SYST and along the present document are listed in Table 1.

Table 1: Prefixes and namespaces used in the present document

Prefix	Namespace
saref	https://saref.etsi.org/saref#
s4syst	https://saref.etsi.org/saref4syst#
s4syst-ex	https://saref.etsi.org/saref4syst/example/
owl	http://www.w3.org/2002/07/owl#
rdf	http://www.w3.org/1999/02/22-rdf-syntax-ns#
rdfs	http://www.w3.org/2000/01/rdf-schema

5 SAREF4SYST Core Ontology

5.1 General overview

A graphical overview of the SAREF4SYST ontology is provided in Figure 1. In such figure:

- Rectangles are used to denote Classes. The label of the rectangle is the identifier of the Class.
- Plain arrows are used to represent Object Properties between Classes. The label of the arrow is the identifier of the Object Property. The origin of the arrow is the domain Class of the property, and the target of the arrow is the range Class of the property.
- Dashed arrows with identifiers between stereotype signs (i.e. "<< >>") refer to OWL axioms that are applied to some property. Four pairs of properties are inverse one of the other; the property `s4syst:connectedTo` is symmetric, and properties `s4syst:hasSubSystem` and `s4syst:hasSubSystem` are transitive.
- A symbol =1 near the target of an arrow denotes that the associated property is functional. A symbol ∃ denotes a local existential restriction.

Clauses 5.2 to 5.4 describe the different parts of the SAREF4SYST core ontology describing the different conceptual modules of the ontology.

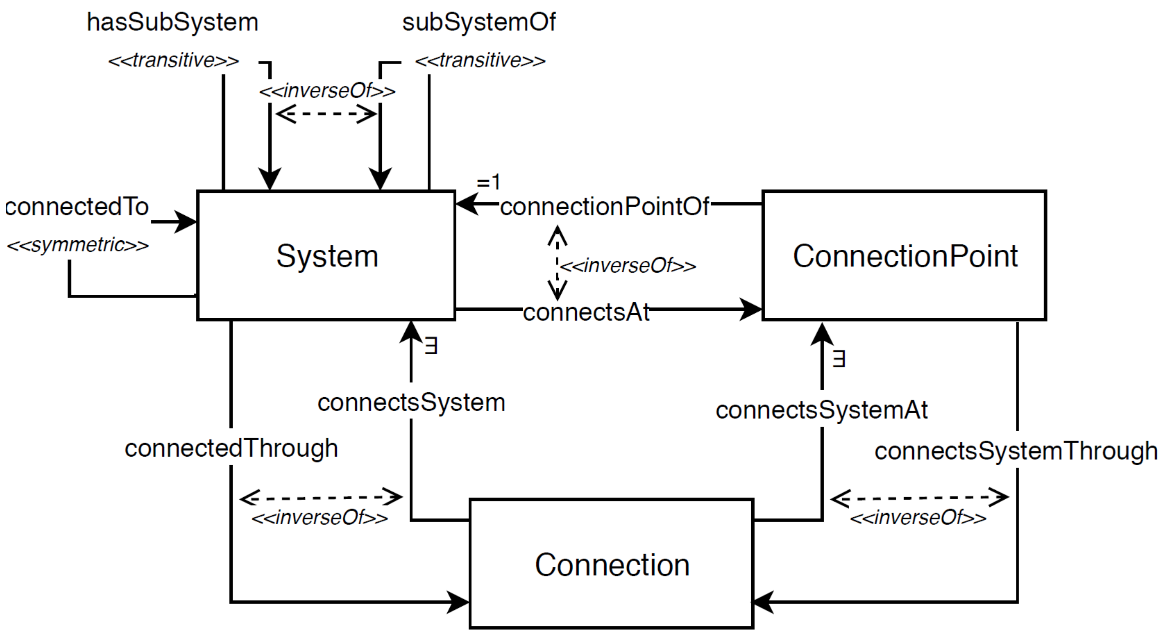

Figure 1: SAREF4SYST overview

5.2 Systems and sub-systems

A `s4syst:System`, is defined as a part of the universe that is virtually isolated from the environment.

NOTE: The system properties are typically state variables (e.g. consumed or stored energy, agent population, temperature, volume, humidity).

Figure 2 illustrates classes and properties that can be used to define connected systems and their sub-systems.

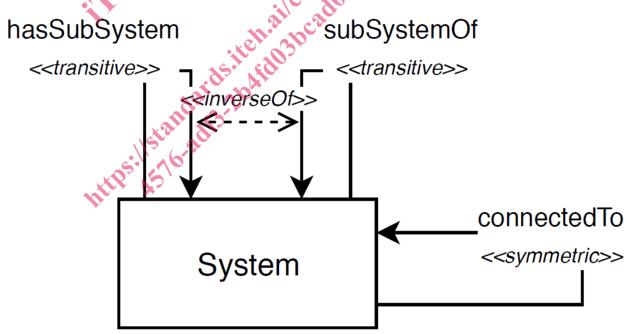

Figure 2: SAREF4SYST: Systems, sub-systems

A system may be connected to other systems that are part of its environment. This is modelled by a property named `s4syst:connectedTo`, which is symmetric.

EXAMPLE 1: `<electric_vehicle> s4syst:connectedTo <electric_vehicle_service_equipment> .`

Connected systems interact in some ways. The exact meaning of interact is defined by sub-properties of `s4syst:connectedTo`.

EXAMPLE 2: For the electricity to directly flow between an electric vehicle service equipment <electric_vehicle_service_equipment> and an electric vehicle <electric_vehicle>, then they should be linked by property s4syst-ex:exchangesElectricityWith:.

```
<electric_vehicle> s4syst-ex:exchangesElectricityWith
<electric_vehicle_service_equipment> .
```

A system can be a sub-system of another system. This is modelled using the transitive properties s4syst:subSystemOf and s4syst:hasSubSystem.

EXAMPLE 3:
```
<battery> s4syst:subSystemOf <electric_vehicle>.
```

Properties of subsystems somehow contribute to the properties of the super system. The exact meaning of this contribution is defined by sub properties of s4syst:subSystemOf.

EXAMPLE 4: If one wants to model the fact that the consumption power of a fridge <fridge/1> contributes to the consumption power of the kitchen, <kitchen/1>, then one may use a sub-property of s4syst:subSystemOf named s4syst-ex:subElectricPowerSystemOf.

```
<fridge/1> s4syst-ex:subElectricPowerSystemOf <kitchen/1> .
```

Table 2 summarizes the restrictions that characterize the s4syst:hasSubSystem property.

Table 2: Restrictions of the s4syst:hasSubSystem property

Axiom	Definition
Domain: s4syst:System	The s4syst:hasSubSystem connects only s4syst:Systems.
Range: s4syst:System	The s4syst:hasSubSystem connects only to s4syst:Systems.
InverseOf s4syst:subSystemOf	If a s4syst:System has for sub-system another s4syst:system, then the latter is a sub-system of the former.
Transitive	The sub-system of a sub-system is a sub-system.

Table 3 summarizes the restrictions that characterize the s4syst:subSystemOf property.

Table 3: Restrictions of the s4syst:subSystemOf property

Axiom	Definition
Domain: s4syst:System	The s4syst:subSystemOf connects only s4syst:Systems.
Range: s4syst:System	The s4syst:subSystemOf connects only to s4syst:Systems.
InverseOf s4syst:hasSystem	If a s4syst:System is a sub-system another s4syst:System, then the latter has for sub-system the former.
Transitive	The super-system of a super-system is a super-system.

Table 4 summarizes the restrictions that characterize the s4syst:connectedTo property.

Table 4: Restrictions of the s4syst:connectedTo property

Axiom	Definition
Domain: s4syst:System	The s4syst:connectedTo connects only s4syst:Systems
Range: s4syst:System	The s4syst:connectedTo connects only to s4syst:Systems
Symmetric	If a s4syst:System is connected to another, then the latter is connected to the former.

5.3 Connections between systems

A connection between two s4syst:Systems, modelled by s4syst:connectedTo, describes the potential interactions between connected s4syst:Systems. A connection can be qualified using class s4syst:Connection.