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

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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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# 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.

Referenced documents which are not found to be publicly available in the expected location might be found at https://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] 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.

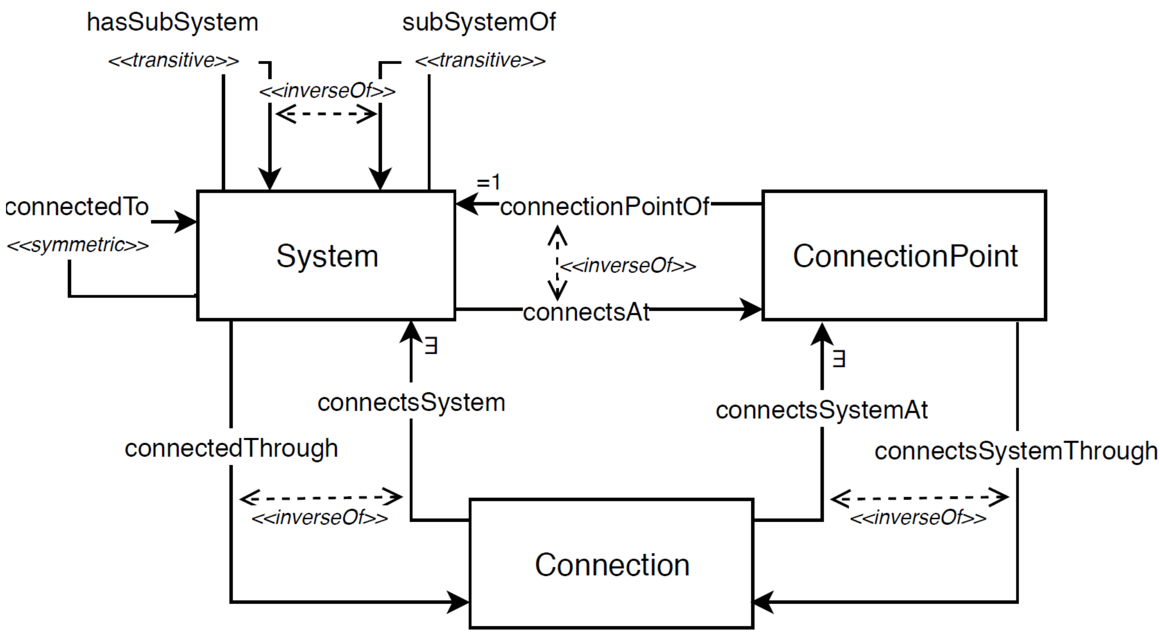


**Figure 1: SAREF4SYST overview**

## 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.

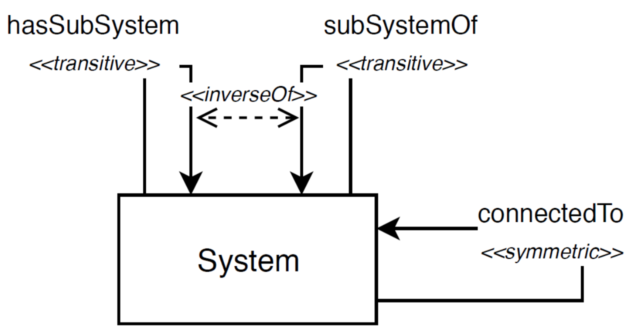


**Figure 2: SAREF4SYST: Systems, sub-systems**

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.

EXAMPLE 1: One can associate a s4syst:Connection with properties (saref:Property) that describe the interactions between the connected s4syst:Systems (e.g. population flow, exchange surface, contact temperature).

Figure 3 illustrates classes and properties that can be used to qualify connections between s4syst:Systems.

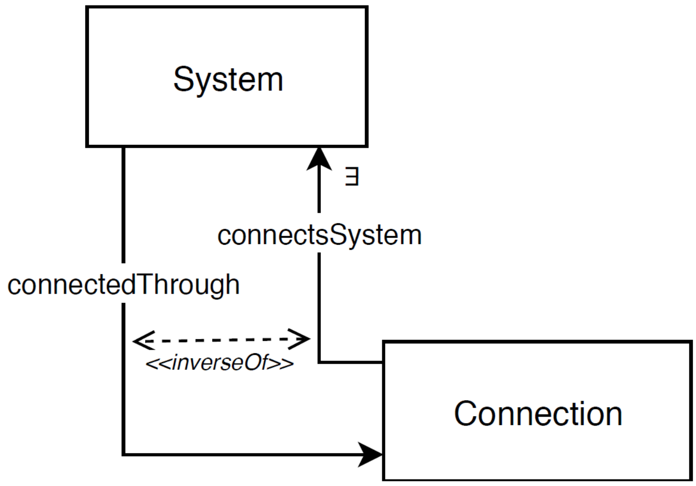


**Figure 3: Connections between systems**

EXAMPLE 2: A power connection between power systems describes the fact that these systems may exchange electricity.

```
<connection> s4syst:connectsSystem <electric_vehicle> ,
<electric_vehicle_service_equipment> .

<electric_vehicle> s4syst:connectedThrough <connection> .

<electric_vehicle_service_equipment> s4syst:connectedThrough
<connection> .
```

Table 5 summarizes restrictions that characterize a s4syst:System with respect to connection.

**Table 5: Restrictions of the s4syst:System class**

| Axiom | Definition |
|---|---|
| DisjointWith s4syst:Connection | No individual can be both a s4syst:System and a s4syst:Connection. |

Table 6 summarizes the restrictions that characterize the s4syst:Connection class.

**Table 6: Restrictions of the s4syst:Connection class**

| Axiom | Definition |
|---|---|
| DisjointWith s4syst:System | No individual can be both a s4syst:Connection and a s4syst:System |
| SubClassOf s4syst:connectsSystem some s4syst:System | For any s4syst:Connection there exists a s4syst:System that it connects. |

Table 7 summarizes the restrictions that characterize the s4syst:connectsSystem property.

**Table 7: Restrictions of the `s4syst:connectsSystem` property**

| Axiom | Definition |
|---|---|
| Domain: `s4syst:Connection` | The `s4syst:connectsSystem` connects only `s4syst:Connections`. |
| Range: `s4syst:System` | The `s4syst:connectsSystem` connects only to `s4syst:Systems`. |
| InverseOf `s4syst:connectedThrough` | If a `s4syst:Connection` connects a `s4syst:System`, then the latter is connected through the former. |

Table 8 summarizes the restrictions that characterize the `s4syst:connectedThrough` property.

**Table 8: Restrictions of the `s4syst:connectedThrough` property**

| Axiom | Definition |
|---|---|
| Domain: `s4syst:System` | The `s4syst:connectedThrough` connects only `s4syst:Systems`. |
| Range: `s4syst:Connection` | The `s4syst:connectedThrough` connects only to `s4syst:Connections`. |
| InverseOf `s4syst:connectsSystem` | If a `s4syst:System` is connected through a `s4syst:Connection`, then the latter connects the former. |

## 5.4 Connection Points of systems

A `s4syst:System` connects to other `s4syst:Systems` at connection points. A connection point belongs to one and only one `s4syst:System`, and can be described using the class `s4syst:ConnectionPoint`.

Figure 4 illustrates the classes and the properties that can be used to describe connection points of a `s4syst:System`.

EXAMPLE: An electric vehicle charging station may have three `s4syst:connectionPoints`: two plugs of different kind to which electric vehicles can connect, and a three-phase connection point to the public grid:

```
<electric_vehicle> s4syst:connectsAt <plug_high_voltage> ,
<normal_plug> , <three_phase_connection_point> .
```

One can then associate a `s4syst:ConnectionPoint` with properties (`saref:Property`) that describe it (e.g. position and speed, voltage and intensity, thermic transmission coefficient).

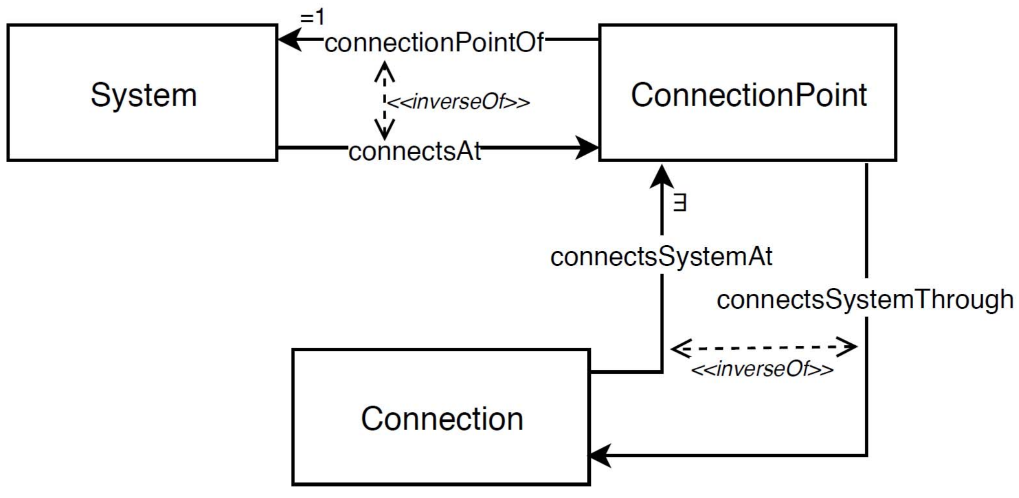


**Figure 4: SAREF4SYST: Connection points of systems, where other systems connect**

Table 9 summarizes additional restrictions that characterize the `s4syst:System` class with respect to connection points.

**Table 9: Additional restrictions of the `s4syst:System` class**

| Axiom | Definition |
| --- | --- |
| DisjointWith `s4syst:ConnectionPoint` | No individual can be both a `s4syst:System` and a `s4syst:ConnectionPoint`. |

Table 10 summarizes additional restrictions that characterize the `s4syst:Connection` class with respect to `s4syst:ConnectionPoints`.

**Table 10: Restrictions of the `s4syst:Connection` class**

| Axiom | Definition |
| --- | --- |
| DisjointWith `s4syst:ConnectionPoint` | No individual can be both a `s4syst:Connection` and a `s4syst:ConnectionPoint`. |
| SubClassOf `s4syst:connectsSystemAt` some `s4syst:ConnectionPoint` | For any `s4syst:Connection` there exists a `s4syst:ConnectionPoint` that it connects a system at. |

Table 11 summarizes restrictions that characterize the `s4syst:ConnectionPoint` class.

**Table 11: Restrictions of the `s4syst:ConnectionPoint` class**

| Axiom | Definition |
| --- | --- |
| DisjointWith `s4syst:System` | No individual can be both a `s4syst:System` and a `s4syst:ConnectionPoint`. |
| DisjointWith `s4syst:Connection` | No individual can be both a `s4syst:Connection` and a `s4syst:ConnectionPoint`. |
| SubClassOf `s4syst:connectionPointOf` exactly 1 `owl:Thing` | A `s4syst:ConnectionPoint` is always the `s4syst:ConnectionPoint` of something (some `s4syst:System`). |

Table 12 summarizes restrictions that characterize the `s4syst:connectedThrough` property.

**Table 12: Restrictions of the `s4syst:connectionPointOf` property**

| Axiom | Definition |
| --- | --- |
| Domain: `s4syst:ConnectionPoint` | Only `s4syst:ConnectionPoints` may be subject of a `s4syst:connectionPointOf` property. |
| Range: `s4syst:System` | Only `s4syst:systems` may be object of a `s4syst:connectionPointOf` property. |
| Functional | A `s4syst:ConnectionPoint` may be the `s4syst:connectionPoint` of only one `s4syst:System`. |
| InverseOf: `s4syst:connectsAt` | If a `s4syst:ConnectionPoint` is a `s4syst:ConnectionPoint` of a `s4syst:System`, then the latter connects at the former. |

Table 13 summarizes restrictions that characterize the `s4syst:connectsAt` property.

**Table 13: Restrictions of the `s4syst:connectsAt` property**

| Axiom | Definition |
| --- | --- |
| Domain: `s4syst:System` | Only `s4syst:Systems` may be subject of a `s4syst:connectsAt` property. |
| Range: `s4syst:ConnectionPoint` | Only `s4syst:ConnectionPoint` may be object of a `s4syst:connectsAt` property. |
| InverseOf: `s4syst:connectionPointOf` | If a `s4syst:System` connects at a `s4syst:ConnectionPoint`, then the latter is a `s4syst:ConnectionPoint` of the former. |

Table 14 summarizes restrictions that characterize the `s4syst:connectSystemThrough` property.

**Table 14: Restrictions of the `s4syst:connectSystemThrough` property**

| Axiom | Definition |
|---|---|
| Domain: `s4syst:ConnectionPoint` | Only `s4syst:ConnectionPoints` may be subject of a `s4syst:connectsSystemThrough` property. |
| Range: `s4syst:Connection` | Only `s4syst:Connections` may be object of a `s4syst:connectsSystemThrough` property. |
| InverseOf: `s4syst:connectsSystemAt` | If a `s4syst:ConnectionPoints` connects a `s4syst:System` through a `s4syst:Connection`, then the latter connects the `s4syst:System` at the former. |

Table 15 summarizes restrictions that characterize the `s4syst:connectsSystemAt` property.

**Table 15: Restrictions of the `s4syst:connectsSystemAt` property**

| Axiom | Definition |
|---|---|
| Domain: `s4syst:Connection` | Only `s4syst:Connections` may be subject of a `s4syst:connectsSystemAt` property. |
| Range: `s4syst:ConnectionPoint` | Only `s4syst:ConnectionPoints` may be object of a `s4syst:connectsSystemAt` property. |
| InverseOf: `s4syst:connectSystemThrough` | If a `s4syst:Connection` connects a `s4syst:System` at a `s4syst:ConnectionPoint`, then the latter connects the `s4syst:System` through the former. |

Table 16 summarizes property chain axioms that characterize the SAREF4SYST properties.

**Table 16: Property chain axioms on the SAREF4SYST properties**

| Axiom | Definition |
|---|---|
| Property chain `s4syst:connectsAt o s4syst:connectsSystemThrough` is sub-property of `s4syst:connectedThrough` | If a `s4syst:System` connects at one of its `s4syst:ConnectionPoint` to some `s4syst:Connection`, then the `s4syst:System` connects through this `s4syst:Connection`. |
| Property chain `s4syst:connectsSystemAt o s4syst:connectionPointOf` is sub-property of `s4syst:connectsSystem` | If a `s4syst:Connection` connects a `s4syst:ConnectionPoint` of a `s4syst:System`, then it connects that `s4syst:System`. |

# 6 SAREF4SYST pattern instantiation for verticals

## 6.1 Introduction

Instantiations of the SAREF4SYST pattern are subsets of ontologies that define sub-classes and/or sub-properties of the classes and properties defined in clause 5. SAREF or SAREF extensions should contain instantiations of the SAREF4SYST pattern.

Clauses 6.2 to 6.4 define how such instantiations are made.

## 6.2 Systems and sub-systems

### 6.2.1 Sub-classes of `s4syst:System`

An instantiation of the SAREF4SYST pattern may define a sub-class of the `s4syst:System` class. If defined, it shall have an English-tagged label (`rdfs:label`) ending with "System". The local name of its IRI shall be a camel case form of its English-tagged label.

EXAMPLE: `s4syst-ex:ElectricPowerSystem` has English-tagged label `"Electric Power System"@en`

It shall have an English-tagged comment (`rdfs:comment`) that defines it in natural language.

### 6.2.2 Sub-properties of `s4syst:hasSubSystem` and `s4syst:subSystemOf`

An instantiation of the SAREF4SYST pattern may define a sub-property of the `s4syst:hasSubSystem` property or the `s4syst:subSystemOf` property. If defined, it shall have an English-tagged label (`rdfs:label`), and the local name of its IRI shall be a mixed case form of its English-tagged label. The label of the sub-property shall use the same morpho-syntactic structure as its super-property.

EXAMPLE 1: `s4syst-ex:subElectricPowerSystemOf` with English-tagged label `"sub electric power system of"@en`

A sub-class of `s4syst:System` shall have an English-tagged comment (`rdfs:comment`) that describes in natural language how the properties of the sub-system contribute to the properties of the super-system.

EXAMPLE 2: `s4syst-ex: subElectricPowerSystemOf` has English-tagged comment that contains `"The consumed electricity of an electric power consumer system contributes to the consumed electricity of its super electric power consumer system"`.

A sub-class of `s4syst:System` may be defined as a sub-class or equivalent class of an anonymous class having an existential or universal restriction on the `s4syst:hasSubSystem` or `s4syst:subSystemOf` property. If so, the class shall be `s4syst:System` or one of its sub-classes.

### 6.2.3 Sub-properties of `s4syst:connectedTo`

An instantiation of the SAREF4SYST pattern may define a sub-property of the `s4syst:connectedTo` property. If defined, it shall have an English-tagged label (`rdfs:label`), and the local name of its IRI shall be a mixed case form of its English-tagged label.

EXAMPLE 1: `s4syst-ex:exchangesElectricityWith` has English-tagged label `"exchanges electricity with"@en`

It shall have an English-tagged comment (`rdfs:comment`) that describes in natural language how the connected `s4syst:System`s interact.

A sub-property of the `s4syst:connectedTo` property may be symmetric. If so, it shall define a common domain and range that is `s4syst:System` or one of its sub-classes. The English-tagged comment shall reflect this symmetry. The comment shall mention the domain and range `s4syst:System`s.

EXAMPLE 2: `s4syst-ex:exchangesElectricityWith` has English-tagged comment `"Links an electric power system to another electric power system with which it may exchange electricity."@en`

If a sub-property of the `s4syst:connectedTo` property is not symmetric, then an inverse (`owl:inverseOf`) of this property may be defined. If defined, the English-tagged labels and comments of these two properties shall reflect this aspect.

EXAMPLE 3: s4syst-ex:powers has English-tagged comment "Links an electric power system to another electric power system to which it sends electricity."@en, and s4syst-ex:isPoweredBy has English-tagged comment "Links an electric power system to another electric power system from which it receives electricity."@en

## 6.3 Connections between systems

### 6.3.1 Sub-classes of s4syst:Connection

An instantiation of the SAREF4SYST pattern may define a sub-class of the s4syst:Connection class. If defined, it shall have an English-tagged label (rdfs:label) ending with "Connection". The local name of its IRI shall be a camel case form of its English-tagged label.

EXAMPLE 1: s4syst-ex:ThreePhasePowerBusConnection has English-tagged label "Three-Phase Power Bus Connection"@en

A sub-class of the s4syst:Connection class shall have an English-tagged comment (rdfs:comment) that defines it in natural language.

EXAMPLE 2: s4syst-ex:ThreePhasePowerBusConnection has English-tagged comment "A three-phase power bus connection is a connection between electric power systems composed of four wires (plus the protective earth): wires R, S, T, for the phases; wire N for the neutral."@en

A sub-class of the s4syst:Connection class may have a universal restriction on the property s4syst:connectsSystem to s4syst:System or one of its sub-classes. If so, then the label or the comment of the sub-class of s4syst:Connection and the sub-class of s4syst:System shall show this relation ostensibly.

EXAMPLE 3: The class s4syst-ex:ElectricalConnection has a universal restriction on the property s4syst:connectsSystem to seas-ex:ElectricPowerSystem.

A sub-class of the s4syst:Connection class may be defined as disjoint from other sub-classes of s4syst:Connection.

EXAMPLE 4: The following classes are pairwise disjoint:
s4syst-ex:SinglePhasePowerBusConnection,
s4syst-ex:SplitPhasePowerBusConnection,
s4syst-ex:ThreePhasePowerBusConnection.

### 6.3.2 Sub-properties of s4syst:connectedThrough

An instantiation of the SAREF4SYST pattern may define a sub-property of the s4syst:connectedThrough property. If defined, it shall have an English-tagged label (rdfs:label), and the local name of its IRI shall be a mixed case form of its English-tagged label. The label of the sub-property should use the same morpho-syntactic structure as its super-property.

EXAMPLE 1: s4syst-ex:connectedInStarThrough has English-tagged label "connected in star through"@en

A sub-property of the s4syst:connectedThrough property shall have an English-tagged comment (rdfs:comment) that describes in natural language how the connected s4syst:Systems interact.

EXAMPLE 2: s4syst-ex:connectedInStarThrough has English-tagged comment "Links an electric power system to a three-phase power bus connection with which it is connected with a star configuration."@en

A sub-property of the s4syst:connectedThrough property may have an inverse property. If defined, the English-tagged labels and comments of these two properties shall reflect this aspect.

EXAMPLE 3: `s4syst-ex:connectedInStarThrough` and `s4syst-ex:connectsSystemInStar` are inverse properties.

A sub-class of the `s4syst:System` class may have an existential restriction on a sub-property of `s4syst:connectedThrough` to some sub-class of `s4syst:Connection`.

EXAMPLE 4: `s4syst-ex:ElectricPowerTransformer` has existential restrictions on `s4syst-ex:primarilyConnectedThrough` and `s4syst-ex:secondarilyConnectedThrough` to `s4syst-ex:ElectricalConnection`.

A sub-property of the `s4syst:connectedThrough` property may be defined as disjoint from other sub-properties of `s4syst:connectedThrough`.

EXAMPLE 5: The following properties are disjoint: `s4syst-ex:connectsSystemInStar` and `s4syst-ex:connectsSystemInTriangle`.

### 6.3.3 Sub-properties of `s4syst:connectsSystem`

An instantiation of the SAREF4SYST pattern may define a sub-property of the `s4syst:connectsSystem` property. If defined, it shall have an English-tagged label (`rdfs:label`), and the local name of its IRI shall be a mixed case form of its English-tagged label. The label of the sub-property should use the same morpho-syntactic structure as its super-property.

EXAMPLE 1: `s4syst-ex:connectsSystemInStar` has English-tagged label `"connects system in star"@en`

A sub-property of the `s4syst:connectsSystem` property shall have an English-tagged comment (`rdfs:comment`) that describes in natural language how the connected `s4syst:systems` interact.

EXAMPLE 2: `s4syst-ex:connectsSystemInStar` has English-tagged comment `"Links a three-phase power bus to one of the electric power systems it connects with a star configuration."@en`

A sub-property of the `s4syst:connectsSystem` property may have an inverse property. If defined, the English-tagged labels and comments of these two properties shall reflect this aspect.

EXAMPLE 3: `s4syst-ex:connectsSystemInStar` and `s4syst-ex:connectedInStarThrough are inverse properties.`

## 6.4 Connection Points of systems

### 6.4.1 Sub-classes of `s4syst:ConnectionPoint`

An instantiation of the SAREF4SYST pattern may define a sub-class of the `s4syst:ConnectionPoint` class. If defined, it shall have an English-tagged label (`rdfs:label`) ending with "Connection Point". The local name of its IRI shall be a camel case form of its English-tagged label.

EXAMPLE 1: `s4syst-ex:ThreePhaseConnectionPoint` has English-tagged label `"Three-Phase Connection Point"@en`

A sub-class of the `s4syst:ConnectionPoint` class shall have an English-tagged comment (`rdfs:comment`) that defines it in natural language.

EXAMPLE 2: `s4syst-ex:ThreePhaseConnectionPoint` has English-tagged comment `"A three-phase connection point is a connection point composed of four wires (plus the protective earth): wires R, S, T, for the phases; wire N for the neutral."@en`

A sub-class of the `s4syst:ConnectionPoint` class may have a universal restriction on the property `s4syst:connectsSystemThrough` or one of its sub-properties to a sub-class of `s4syst:Connection`. If so, then the label or the comment of the sub-class of `s4syst:ConnectionPoint` and the sub-class of `s4syst:Connection` shall show this relation ostensibly.

A sub-class of the `s4syst:ConnectionPoint` class may have a universal restriction on the property `s4syst:connectionPointOf` to a sub-class of `s4syst:System`. If so, then the label or the comment of the sub-class of `s4syst:ConnectionPoint` and the sub-class of `s4syst:System` shall show this relation ostensibly.

EXAMPLE 3: `s4syst-ex:IlluminableZoneFrontierConnectionPoint` has a universal restriction on the property `s4syst:connectsSystemThrough` to the class `s4syst-ex:LightTransmissionSystemConnection`, has a universal restriction on the property `s4syst:connectionPointOf` to the class `s4syst ex:IlluminableZoneSystem`, and has English-tagged comment `"The class of zones frontiers _on_ which one may measure/effect luminosity, and perceive brightness. Illuminable zones are surfaces such as walls, tables, sheer curtains, mirrors, windows. Light may be reflected, absorbed, and transmitted by illuminable zone frontier connection points."@en`

### 6.4.2 Sub-properties of `s4syst:connectionPointOf`

An instantiation of the SAREF4SYST pattern may define a sub-property of the `s4syst:connectionPointOf` property. If defined, it shall have an English-tagged label (`rdfs:label`), and the local name of its IRI shall be a mixed case form of its English-tagged label. The label of the sub-property should use the same morpho-syntactic structure as its super-property.

A sub-property of the `s4syst:connectionPointOf` property shall have an English-tagged comment (`rdfs:comment`) that describes in natural language how the connected `s4syst:System` interact.

### 6.4.3 Sub-properties of `s4syst:connectsAt`

An instantiation of the SAREF4SYST pattern may define a sub-property of the `s4syst:connectsAt` property. If defined, it shall have an English-tagged label (`rdfs:label`), and the local name of its IRI shall be a mixed case form of its English-tagged label. The label of the sub-property should use the same morpho-syntactic structure as its super-property.

EXAMPLE 1: `s4syst-ex:connectsPrimarilyAt` has English-tagged label `"connects primarily at "@en`

A sub-property of the `s4syst:connectsAt` property shall have an English-tagged comment (`rdfs:comment`) that describes in natural language how the connected `s4syst:System` interact.

EXAMPLE 2: `s4syst-ex:connectsPrimarilyAt` has English-tagged comment `"Links an electric power transformer system to its primary connection point."@en`

A sub-class of `s4syst:System` may be equivalent to an anonymous class having a universal restriction on `s4syst:connectsAt` or one of its sub-properties to a sub-class of `s4syst:ConnectionPoint`. If so, then the label or the comment of the sub-class of `s4syst:System` and the sub-class of `s4syst:ConnectionPoint` shall show this relation ostensibly.

EXAMPLE 3: `s4syst-ex:USBCommunicationDeviceSystem` is equivalent to an anonymous class having a universal restriction on `s4syst:connectsAt` to the class `s4syst-ex:USBCommunicationConnectionPoint`, and has English-tagged comment `"The class of communication devices capable of communicating using the USB protocol."@en`

### 6.4.4 Sub-properties of `s4syst:connectsSystemThrough`

An instantiation of the SAREF4SYST pattern may define a sub-property of the `s4syst:connectsSystemThrough` property. If defined, it shall have an English-tagged label (`rdfs:label`), and the local name of its IRI shall be a mixed case form of its English-tagged label. The label of the sub-property should use the same morpho-syntactic structure as its super-property.

EXAMPLE 1: `s4syst-ex:connectsSystemInSNThrough` has English-tagged label `"connects system in SN through."@en`

A sub-property of the `s4syst:connectsSystemThrough` property shall have an English-tagged comment (`rdfs:comment`) that describes in natural language how the connected `s4syst:System` interact.

EXAMPLE 2: `s4syst-ex:connectsSystemInSNThrough` has English-tagged comment `"Links a single phase connection point to a three-phase power bus connection with which it is connected with a SN configuration."@en` A sub-property of `the s4syst:connectsSystemThrough` property may have an inverse property. If defined, the English-tagged labels and comments of these two properties shall reflect this aspect.

EXAMPLE 3: `s4syst-ex:connectsSystemInSNThrough` and `s4syst-ex:connectsSystemInSNAt` are inverse properties.

A sub-property of the `s4syst:connectsSystemThrough` property may be defined as disjoint from other sub-properties of `s4syst:connectsSystemThrough`.

EXAMPLE 4: The following properties are disjoint: `s4syst-ex:connectsSystemInStarThrough` and `s4syst-ex:connectsSystemInTriangleThrough.`

### 6.4.5 Sub-properties of `s4syst:connectsSystemAt`

An instantiation of the SAREF4SYST pattern may define a sub-property of the `s4syst:connectsSystemAt` property. If defined, it shall have an English-tagged label (`rdfs:label`), and the local name of its IRI shall be a mixed case form of its English-tagged label. The label of the sub-property should use the same morpho-syntactic structure as its super-property.

EXAMPLE 1: `s4syst-ex:connectsSystemInStarAt` has English-tagged label `"connects system in star at."@en`

A sub-property of the `s4syst:connectsSystemAt` property shall have an English-tagged comment (`rdfs:comment`) that describes in natural language how the connected `s4syst:System` interact.

EXAMPLE 2: `s4syst-ex:connectsSystemInStarAt` has English-tagged comment `"Links a three-phase power bus connection to one of the three-phase connection points it connects with a triangle configuration."@en`

A sub-class of `s4syst:Connection` may have an existential or universal restriction on `s4syst:connectsSystemAt` or one of its sub-properties to a sub-class of `s4syst:ConnectionPoint`. If so, then the label or the comment of the sub-class of `s4syst:Connection` and the sub-class of `s4syst:ConnectionPoint` shall show this relation ostensibly.

EXAMPLE 3: `s4syst-ex:USBCommunicationConnection` has an universal restriction on `s4syst:connectsSystemAt` to the class `s4syst-ex:USBCommunicationConnectionPoint,` and has English-tagged comment `"The class of USB communication connections between communication devices."@en`

A sub-property of the `s4syst:connectsSystemAt` property may have an inverse property. If defined, the English-tagged labels and comments of these two properties shall reflect this aspect.

EXAMPLE 4: `s4syst-ex:connectsSystemInSNAt` and `s4syst-ex:connectsSystemInSNThrough` are inverse properties.

A sub-property of the `s4syst:connectsSystemAt` property may be defined as disjoint from other sub-properties of `s4syst:connectsSystemThrough`.

EXAMPLE 5: The following properties are disjoint: `s4syst-ex:connectsSystemInStarAt` and `s4syst-ex:connectsSystemInTriangleAt`.

## 6.5 Examples for the Smart Grid domain and the Smart Building domain

Different examples of instantiations of the SAREF4SYST pattern can be found at https://saref.etsi.org/saref4syst/example, including for the Smart Grid domain and the Smart Building domain.

The sources of the ontology and the examples can be found at https://forge.etsi.org/rep/SAREF/saref4syst.

The examples are automatically generated using the SPARQL-Generate RDF transformation engine developed at EMSE [i.11].

# History

| Document history | | |
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