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# Foreword

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

The present document is part 1 of a multi-part deliverable covering SmartM2M; Extension to SAREF, as identified below:

Part 1: "Energy Domain";

Part 2: "Environment Domain";

Part 3: "Building Domain".

**Part 4: "Smart Cities Domain".**

Part 5: "Industry and Manufacturing Domains Domains".

Part 6: "Smart Agriculture and Food Chain Domain".

# Modal verbs terminology

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# 1 Scope

The present document presents SAREF4CITY, the SAREF extension for the Smart Cities Domain.

# 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.

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## 2.2 Informative references

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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 TR 103 411: "SmartM2M Smart Appliances SAREF extension investigation".

[i.2] ETSI TR 103 506: "SmartM2M; SAREF extension investigation; Requirements for Smart Cities 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

## 3.2 Abbreviations

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

DL Description Logic

OWL Web Ontology Language

SAREF Smart Appliances REFerence ontology

SAREF4CITY SAREF extension for the Smart Cities Domain

TR Technical Report

TS Technical Specification

URI Uniform Resource Identifier

W3C World Wide Web Consortium

WGS84 World Geodetic System 1984

# 4 SAREF4CITY ontology and semantics

## 4.1 Introduction and overview

The present document is a technical specification of SAREF4CITY, an extension of SAREF for the Smart Cities

domain. This extension has been created by investigating resources from potential stakeholders of the ontology such as standardization bodies (e.g. Open Geospatial Consortium), associations (e.g. Spanish Federation of Municipalities

and Provinces), IoT platforms (e.g. FIWARE) and European projects and initiatives (e.g. ISA2 programme) as reported in “ETSI TR 103 506 v1.1.1” [i.2]. In addition, the use cases defined in [i.2] were also taken into account, namely:

* **Use case 1**: eHealth and Smart Parking
* **Use case 2**: Air Quality Monitoring and Mobility
* **Use case 3**: Street Lighting, Air Quality Monitoring and Mobility

Taking into account ontologies, data models, standards and datasets provided by the identified stakeholders, a set of requirements were identified and grouped in the following categories: Topology, Administrative Area, City Object, Event, Measurement, Key Performance Indicator, and Public Service. Such requirements and categories were validated during the “SAREF4CITY Validation Workshop” at the IoT Week in Bilbao on the 4th of June of 2018. During the workshop, attendees validated the use cases proposed above and the list of requirements for the above-mentioned categories. According to the feedback and outcomes of the workshop, some actions were taken such as to discard some requirements, to eliminate duplicates, to clarify requirements, or to add new ones. The concrete decisions were reported in “ETSI TR 103 506 v1.1.1” [i.2]. The requriments listed in such document were taken as input for the ontology development. More precisely, the ontology conceptualization was done in a modular way in which one pattern was defined for each of the abovementioned categories.

After the first complete implementation of the ontology, a second validation workshop, the “Towards interoperability and harmonization of Smart City models with SAREF4CITY”, took place in the 22nd of November at the European Commision premises in Brussels. During the workshop the ontology was presented to a variety of stakeholders from industry to academia and public administration. Apart from observations and comments on the reuse and aligment with other ontologies, the discussion addressed more general questions like how to promote the adoption of SAREF or which is the technological and methodological support needed to create a SAREF ecosystem of collaborative ontologies.

SAREF4CITY is an OWL-DL ontology that extends SAREF and reuses another six ontologies. SAREF4CITY includes 31 classes (13 defined in SAREF4CITY and 18 reused from the SAREF, time, geosp, geo, foaf, dcterms, org, cpsv and time ontologies), 36 object properties (20 defined in SAREF4CITY and 16 reused from the SAREF, geosp, geo, and cpsv ontologies) and 7 data type properties (3 defined in SAREF4CITY and 4 reused from the SAREF ontology). SAREF4CITY focuses on extending SAREF in order to create a common core of general concepts for smart city data oriented to the IoT field. The main idea is to identifiy the core components, as mentioned, that could be extended for particular smart city subdomais, for example, specific KPIs for public transport.

The prefixes and namespaces used in SAREF4CITY and in the present document are listed in Table 1.

Table 1: Prefixes and namespaces used within the SAREF4CITY ontology

|  |  |
| --- | --- |
| Prefix | Namespace |
| s4city | <https://w3id.org/def/saref4city> |
| saref | [https://w3id.org/saref#](https://w3id.org/saref) |
| cpsv | [http://purl.org/vocab/cpsv#](http://purl.org/vocab/cpsv) |
| dcterms | <http://purl.org/dc/terms/> |
| foaf | <http://xmlns.com/foaf/0.1/> |
| geo | [http://www.w3.org/2003/01/geo/wgs84\_pos#](http://www.w3.org/2003/01/geo/wgs84_pos) |
| geosp | [http://www.opengis.net/ont/geosparql#](http://www.opengis.net/ont/geosparql) |
| owl | [http://www.w3.org/2002/07/owl#](http://www.w3.org/2002/07/owl) |
| time | [http://www.w3.org/2006/time#](http://www.w3.org/2006/time) |
| rdf | [http://www.w3.org/1999/02/22-rdf-syntax-ns#](http://www.w3.org/1999/02/22-rdf-syntax-ns) |
| rdfs | [http://www.w3.org/2000/01/rdf-schema#](http://www.w3.org/2000/01/rdf-schema) |
| xsd | [http://www.w3.org/2001/XMLSchema#](http://www.w3.org/2001/XMLSchema) |

## 4.2 SAREF4CITY

### 4.2.1 General Overview

An overview of the SAREF4CITY ontology is provided in Figure 1. For all the entities described in this document, it is indicated whether they are defined in the SAREF4CITY extension or elsewhere by the prefix included before their identifier, i.e. if the element is defined in SAREF4CITY the prefix is s4city, while if the element is reused from another ontology it is indicated by a prefix according to Table 1.

Arrows are used to represent properties between classes and to represent some RDF, RDF-S and OWL constructs, more precisely:

* Plain arrows with white triangles represent the rdfs:subClassOf relation between two classes. The origin of the arrow is the class to be declared as subclass of the class at the destination of the arrow.
* Dashed arrows between two classes indicate a local restriction in the origin class, i.e. that the object property can be instantiated between the classes in the origin and the destination of the arrow. The identifier of the object property is indicated within the arrow.
* Dashed arrows with identifiers between stereotype signs (i.e. "<< >>") refer to OWL constructs that are applied to some ontology elements, that is, they can be applied to classes or properties depending on the OWL construct being used.
* Dashed arrows with no identifier are used to represent the rdf:type relation, indicating that the element in the origin of the arrow is an instance of the class in the destination of the arrow.

Datatype properties are denoted by rectangles attached to the classes, in an UML-oriented way. Dashed boxes represent local restrictions in the class, i.e. datatype properties that can be applied to the class they are attached to.

Individuals are denoted by rectangles in which the identifier is underlined.

Note that Figure 1 aims at showing a global overview of the main classes of SAREF4CITY and their mutual relations. More details on the different parts of Figure 1 are provided in clause 4.2.2 to clause 4.2.8.



Figure 1: SAREF4CITY overview

### 4.2.2 Topology

In the SAREF4CITY ontology existing models have been reused when needed in order to increase interoperability and to reduce effort in modelling general domains. As an example, for modelling the requirements related to the topology domain, standard ontologies already developed have been reused and connected to the SARE4CITY elements. As shown in Figure 2, for representing spatial objects the geosp:SpatialObject class from GeoSPARQL has been reused along with its subclasses geosp:Feature, geosp:Geomety and the properties geosp:sfContains, geosp:sfWithin and geosp:hasGeometry. In addition, the class geo:Point and the property geo:location have been reused from the W3C de-facto standard for geographical information “WGS84 Geo Positioning vocabulary” in order to be able to indicate that something is located at certain coordinates.



Figure 2: Topology model

Table 2 summarizes the properties that characterize the geosp:SpatialObject class in the context of the SAREF4CITY ontology.

Table 2: Properties of geosp:SpatialObject

|  |  |
| --- | --- |
| Property | Definition |
| geosp:sfContains only geosp:SpatialObject | The relation between spatial objects and the spatial objects that it might contain. |
| geosp:sfWithin only geosp:SpatialObject | The relation between spatial objects and the general spatial objects in which it is contained. |
| geo:location only geo:Point | The geographical coordinates in which a spatial object is located. |

Table 3 summarizes the properties that characterize the geosp:Feature class in the context of the SAREF4CITY ontology that are locally defined in such class, that is, it does not include those inherited from the superclasses. Through the rest of this document the same rule will be applied, that is, describing for each concept the restrictions locally defined rather than duplicating the top level ones through the hierarchy concepts.

Table 3: Properties of geosp:Feature

|  |  |
| --- | --- |
| Property | Definition |
| geosp:hasGeometry only geosp:Geometry | The geometrical figure that defines the spatial object. |

### 4.2.3 Administrative Area

The model defined to describe administrative areas in depicted in Figure 3. As it can be observed, this model heavily relies on the topology pattern. In this sense, the ability to connect administrative areas (e.g. a city) with their inner areas, (e.g. its neighbourhoods) is given by inheritance of the geosp:SpatialObject class and through the geosp:Feature class. That is, as s4city:AdministrativeArea is subclass of geosp:SpatialObject, the geosp:sfContains and geosp:sfWithin properties could be applied also to all the administrative areas defined, namely s4city:City, s4city:Country, s4city:District and s4city:Neighbourhood.



Figure 3: Administrative Area model

Table 4 summarizes the properties that are applied to the s4city:AdministrativeArea in the context of the SAREF4CITY ontology. It is worth noting that these properties are applied to s4city:AdministrativeArea and all its subclasses by inheritance mechanisms from the geosp:SpatialObject class.

Table 4: Properties of s4city:AdministrativeArea

|  |  |
| --- | --- |
| Property | Definition |
| geosp:sfContains only geosp:SpatialObject | The relation between spatial objects and the spatial objects that it might contain. |
| geosp:sfWithin only geosp:SpatialObject | The relation between spatial objects and the general spatial objects in which it is contained. |
| geo:location only geo:Point | The geographical coordinates in which a spatial object is located. |

### 4.2.4 City Object

The model developed to represent city objects is shown in Figure 3. As it can be observed, this model also relies on the topology pattern as for the administrative area case. Again, the ability to connect city objects with the city or with the parts in which they are located is done by means of the properties geosp:sfContains and geosp:sfWithin inherited from the geosp:SpatialObject class.



Figure 4: City Object model

Table 5 presents the properties that are applied to the s4city:SpatialObject in the context of the SAREF4CITY ontology. It is worth noting that these properties are applied to s4city:AdministrativeArea and all its subclasses by inheritance mechanisms from the geosp:SpatialObject class.

Table 5: Properties of s4city:CityObject

|  |  |
| --- | --- |
| Property | Definition |
| geosp:sfContains only geosp:SpatialObject | The relation between spatial objects and the spatial objects that it might contain. |
| geosp:sfWithin only geosp:SpatialObject | The relation between spatial objects and the general spatial objects in which it is contained. |
| geo:location only geo:Point | The geographical coordinates in which a spatial object is located. |

### 4.2.5 Event

Figure 5 presents the model developed to represent temporal and scheduled events. As it can be observed, the main concept of this pattern is the class s4city:Event. Such event is linked to the agent organizing it by means of the property s4city:organizedBy. Note that a public administration is a subclass of agent; therefore, this model includes the possibility of events being organized by public administrations as well as by other types of agents. The events can take place at a particular facility (s4city:Facility) which is indicated by the property s4city:takesPlaceAtFacility and at a given time, which is represented by the property s4city:takesPlaceAtTime that links the event to temporal entities (time:TemporalEntity) defined by the W3C Time ontology. Finally, as events can be part of bigger events, this relation has been modelled by means of the property s4city:isSubEventOf.



Figure 5: Event model

Table 5 summarizes the properties that characterize the s4city:Event.

Table 6: Properties of s4city:Event

|  |  |
| --- | --- |
| Property | Definition |
| s4city:isOrganizedBy only foaf:Agent | The relation between events and agents, that can be persons or organizations, that organizes the event. |
| s4city:isSubEventOf only s4city:Event | The relation between an event and the general events in which they can be co-located. |
| s4city:takesPlaceAtFacility only s4city:Facility | The relation between an event and the city facility in which it take place. |
| s4city:takesPlaceAtTime only time:TemporalEntity | The relation between an event and the temporal entity in which it is scheduled. |
| s4city:hasAccesibility only owl:Thing | The relation between an event and its type of accessibility. |

### 4.2.6 Measurement

As it can be observed in Figure 6 the modelling of measurements in the SAREF4CITY ontology heavily relies on the measurement model proposed in SAREF. The only concept added to such modelling is the s4city:FeatureOfInterest one that provides the means to refer to the real world phenomena that is being observed in the given measurement. In order to reduce duplication with SAREF documentation, we refer the reader to the SAREF specification for details about SAREF modelling including here details only for the new concepts. The properties added to the model are:

* s4city:isPropertyOf (and its inverse s4city:hasProperty): to link the property being observed with the feature of interest.
* s4city:hasFeatureOfInterest (and its inverse s4city:isFeatureOfInterestOf): that allows linking a given measurement with the feature of interest being observed.
* s4city:measurementMadeBy: this property has been included as complement of the saref:makesMeasurement, as its inverse, to link a measurement and the device that produces it.



Figure 6: Measurement model

Table 7 summarizes the properties that characterize the s4city:FeatureOfInterest.

Table 7: Properties of s4city:FeatureOfInterest

|  |  |
| --- | --- |
| Property | Definition |
| s4city:hasProperty only saref:Property | The relation between a feature of interest and the property than can be observed for it. |
| s4city:isFeatureOfInterestOf only saref:Measurement | The relation between a feature of interest and the measurements made about it. |
| s4city:hasKPI only saref:KeyPerformanceIndicator | The relation between a feature of interest and the key performance indicators that can be used to measure some characteristic of the feature of interest. |

### 4.2.7 Key Performance Indicator

Figure 7 provides an overview of the modelling of Key Performance Indicators (KPI). As it can be observed, the KPI modelling involves two main concepts, namely s4city:KeyPerformanceIndicator and s4city: KeyPerformanceIndicatorAssessment. This distinction is needed to decouple the definition of a KPI in general terms, for example the mean of air pollution per week, and a particular value of such KPI, for example the mean value of air pollution last week in Madrid.

A s4city:KeyPerformanceIndicator is related to a s4city:FeatureOfInterest by means of the property s4city:isKPIOf. The calculation period of a s4city:KeyPerformanceIndicator is indicated by the property s4city:hasCalculationPeriod. The name and a natural language description of the s4city:KeyPerformanceIndicator are indicated by the attributes s4city:hasName and s4city:hasDescription, respectively.

The relation between a specific assessment of a KPI (s4city:KeyPerformanceIndicatorAssessment) and the general KPI definition (s4city:KeyPerformanceIndicator) can be established by means of the property s4city:quantifiesKPI. A s4city:KeyPerformanceIndicatorAssessment is related to the s4city:FeatureOfInterest by means of the property s4city:assesses. The temporal entity to which the assessment of the KPI refers to is represented by the property s4city:refersToTime. The agent assessing the KPI is linked by means of the property s4city:isAssessedBy. In order to express the administrative area or geographical location assessed by the KPI, the property s4city:refersToSpace is included in the model. In case the KPI represents a value extracted from a aggregation of measurements, the property s4city:isDerivedFrom can be used to link to such measurements (saref:Measurement). The unit of measure in which a KPI value is expressed is indicated by means of the reused property saref:isMeasuredIn while the value itself is indicated by the attribute saref:hasValue. The name and a natural language description of the s4city:KeyPerformanceIndicatorAssessment are indicated by the attributes s4city:hasName and s4city:hasDescription, respectively. The creation, expiration and last update dates of the value are represented by the attributes s4city:hasCreationDate, s4city:hasExpirationDate and s4city:hasLastUpdateDate, respectively.



Figure 7: Key Performance Indicator model

Table 8 summarizes the properties that characterize the s4city:KeyPerformanceIndicator class.

Table 8: Restrictions of the s4city:KeyPerformanceIndicator class

|  |  |
| --- | --- |
| Property | Definition |
| s4city:hasCalculationPeriod only time:TemporalEntity | The relation between a KPI and its calculation period. |
| s4city:isKPIOf only s4city:FeatureOfInterest | The relation between a KPI and the feature of interest it assesses. |
| saref:hasDescription only rdfs:Literal | The description of the KPI. |
| saref:hasName only rdfs:Literal | The name of the KPI. |

Table 9 summarizes the properties that characterize the s4city:KeyPerformanceIndicatorAssessment class.

Table 9: Restrictions of the s4city:KeyPerformanceIndicatorAssessment class

|  |  |
| --- | --- |
| Property | Definition |
| s4city:assesses only s4city:FeatureOfInterest | The relation between a KPI assessment and the feature of interest it assesses. |
| s4city:hasCreationDate only xsd:dateTime | The creation date of a KPI assessment |
| s4city:hasExpirationDate only xsd:dateTime | The expiration date of a KPI assessment |
| s4city:hasLastUpdateDate only xsd:dateTime | The last update date of a KPI assessment |
| s4city:isAssessedBy only foaf:Agent | The relation between a KPI assessment and the agent who assesses it. |
| s4city:isDerivedFrom only saref:Measurement | The relation between a KPI assessment and measurement it might aggregates. |
| s4city:quatifiesKPI only s4city:KeyPerformanceIndicator | The relation between a KPI assessment and the general description of KPI it quantifies. |
| s4city:refersToTime only time:TemporalEntity | The relation between a KPI assessment and the temporal point or interval it refers to. |
| saref:hasDescription only rdfs:Literal | The description of the KPI assessment. |
| saref:hasName only rdfs:Literal | The name of the KPI assessment. |
| saref:hasValue exactly 1 rdfs:Literal | The value of the KPI assessment. |
| saref:isMeasuredIn only saref:UnitOfMeasure | The relation between a KPI assessment and the units of measure the KPI value is expressed on. |

### 4.2.8 Public Service

The model developed to describe public services within the SAREF4CITY ontology is depicted in Figure 4. The main entity included is the s4city:PublicService class which is a specialization of the reused concept cpsv:PublicService class defined in the Public Service vocabulary provided by the ISA vocabularies European initiative. The relation facility in which the service is provided is indicated by the s4city:involvesFacility. It can be also be possible to indicate in which administrative area it is provided, for example a neighbourhood, by means of the property cpsv:physicallyAvailableAt. The public services that an agent (foaf:Agent) provides or uses are indicated by means of the properties cpsv:provides and cpsv:uses, respectively. The languages in which a service is provided are indicated by the property s4city:isAvailableInLanguage. The name and a natural language description of the s4city:PublicService are indicated by the attributes s4city:hasName and s4city:hasDescription, respectively.



Figure 8: Public Service model

Table 10 summarizes the properties that characterize the s4city:PublicService class.

Table 10: Properties of Public Service

|  |  |
| --- | --- |
| Property | Definition |
| cpsv:physicallyAvailableAt only s4city:AdministrativeArea | The relation between a public event and the administrative area in which it is available. |
| s4city:involvesFacility only s4city:Facility | The relation between a public event and the city facility in which it is provided. |
| s4city:isAvailableInLanguage only dcterms:LinguisticSystem | The relation between a public event and the language in which it is available. |
| saref:hasDescription only rdfs:Literal | The description of the public service. |
| saref:hasName only rdfs:Literal | The name of the public service. |

## 4.3 Instantiating SAREF4CITY

This clause shows an example of how to instantiate the SAREF4CITY extension of SAREF. This example shows the use of different patterns included in SAREF4CITY ontology. First of all, we can see how a camera (ex:Camera1) measures the speed of a car (ex:Car35) in the information attached to the individual ex:Camera1Measurement200, which provides a value of 35Km/hour. The position of the car at that moment is captured by the instance ex:CarLocation2018-11-20T13-30-00 with points to the geographical coordinates in which the car is located and also to the road segment in which it is included. It can be observed, that such road segment might contain (see property geosp:sf:Contains) other city objects a lamppost or a building.

The KPI pattern is also instantiated in the example. The instance ex:RoadSegment50Congestion2018-11-20T13-30-00 reference the value (70%) of the road congestion the 2018-11-20 at 13:20. Such value is assessed by the public administration ex:City4. In the calculation of such value the speed of the cars (ex:CarsSpeed2018-11-20), the pollution (ex:Polution2018-11-20) and GMaps API (ex:GMapsAPI2018-11-20) values has been taken into account as it can be observed from the property s4ctiy:isDerivedFrom property between the KPI value and the different saref:Measurement instances.

In the example the event ex:basketMatch23, as sub event of the ex:basketWeek2018, is described. It can be seen that the match is accessible by metro, is organized by ex:City4 and takes place at the facility ex:BasketArena7.

Finally, some examples of public services are shown. One service example is the ex:HealthService123 that involves the facility ex:BasketArena7 and is available in Spanish. Such service is available in area ex:neighbourhood34 that is contained in ex:City4, which is the service provider organization. In addition, another service, ex:Bus33Service, is provided by another organization, in this case ex:TransportCo.



## 4.4 Observations about SAREF4CITY

From the development of the SAREF4CITY ontology it has been observed the need for including the s4city:FeatureOfInterest concept in SAREF. Due to the general nature of such concept and its potential need in other extensions, for example SAREF4AGRI, such concept is proposed to be transferred to the SAREF ontology.

In the same line, the property s4city:measurementMadeBy is proposed to be included into SAREF as inverse of saref:makesMeasurement to complete such model.

It should be mentioned that no reuse for concepts representing events has been done from the ISA vocabularies as such vocabulary is under development. It is planned to link to such concepts when the ISA public event vocabulary is released.

Finally, it is worth mentioning that the Lexvo dataset (<http://www.lexvo.org/>) is proposed to be reused when linking to languages by means of the s4city:isAvailableInLanguage property. For example, the URI for representing the Spanish language in a 3-digit ISO639 code would be <http://www.lexvo.org/page/iso639-3/spa>.

Annex A (informative):  
Approach

The approach that was followed to create SAREF4CITY…

Annex B (informative):  
Bibliography

* ETSI TS 103 264: "SmartM2M; Smart Appliances; Reference Ontology and oneM2M mapping".
* ETSI TS 103 267: "SmartM2M; Smart Appliances; Communication Framework".
* ETSI TS 102 689: "Machine-to-Machine communications (M2M); M2M Service Requirements".

# History

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| **Document history** | | |
| V0.0.1 | 20-06-2018 | Early draft for approval at SmartM2M#46 |
| V0.0.2 | 28-11-2018 | First version of the document |
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