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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 4 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";

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

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1 Scope

The present document presents SAREF4CITY, an extension of SAREF 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.

[1] ETSI TS 103 264 (V2.1.1) (2017-03): "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.

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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 103 506 (V1.1.1) (2018-09): "SmartM2M; SAREF extension investigation; Requirements for Smart Cities".

[i.2] ETSI TS 103 264 (V3.1.1): "SmartM2M; Smart Applications; Reference Ontology and oneM2M Mapping".

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 explicit 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:

API	Application Programming Interface
DL	Description Logic
ISA^2	Interoperability solutions for public administrations, businesses and citizens
KPI	Key Performance Indicator
OWL	Web Ontology Language
OWL-DL	Web Ontology Language - Description Logic
RDF	Resource Description Framework
RDF-S	Resource Description Framework Schema
SAREF	Smart Applications REFerence ontology
SAREF4CITY	SAREF extension for the Smart Cities domain
TR	Technical Report
TS	Technical Specification
UML	Unified Modeling Language
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. ISA^2 programme) as reported in ETSI TR 103 506 [i.1]. In addition, the use cases defined in [i.1] 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 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 [i.1]. The requirements 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" one, took place on the 22nd of November 2018 at the European Commission 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 alignment 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 six other 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 identify the core components, as mentioned, that could be extended for particular smart city subdomains, for example, 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#
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#
geosp	http://www.opengis.net/ont/geosparql#
owl	http://www.w3.org/2002/07/owl#
time	http://www.w3.org/2006/time#
rdf	http://www.w3.org/1999/02/22-rdf-syntax-ns#
rdfs	http://www.w3.org/2000/01/rdf-schema#
xsd	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 the present 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 from clause 4.2.2 to clause 4.2.8.

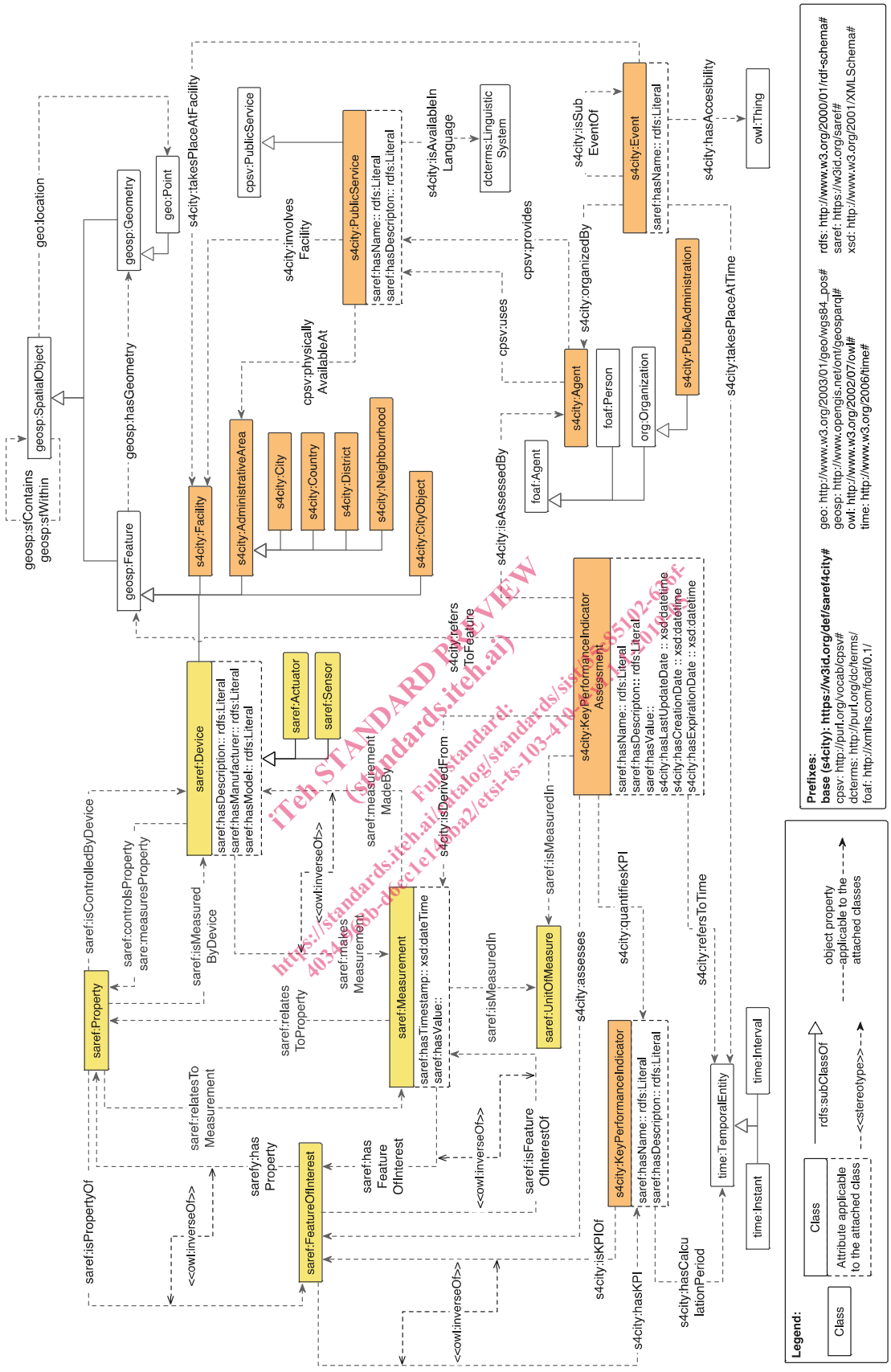

Figure 1: SAREF4CITY overview

4.2.2 Topology

In the SAREF4CITY ontology existing models have been reused when needed in order to increase interoperability and 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:Geometry` 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.

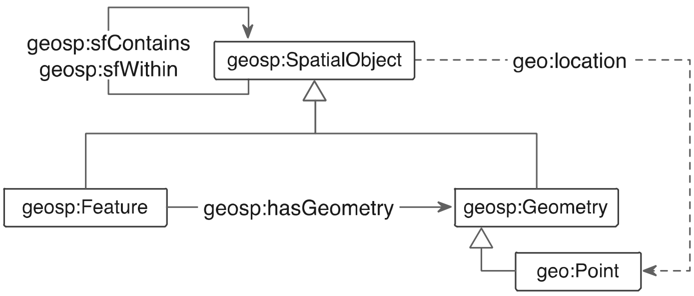

Figure 2: Topology model

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 the present 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 is depicted in Figure 3. As it can be observed, this model heavily relies on the topology pattern described in clause 4.2.2. 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 also be applied to all the administrative areas defined, namely `s4city:City`, `s4city:Country`, `s4city:District` and `s4city:Neighbourhood`.