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Part 4: Smart Cities Domain

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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";

Part 7: "Automotive Domain";

Part 8: "eHealth/Ageing-well Domain";

Part 9: "Wearables Domain";

Part 10: "Water Domain";

Part 11: "Lift Domain";

Part 12: "Smart Grid Domain";

Part 13: "Maritime Domain".

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

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.

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 Applications; Reference Ontology and oneM2M Mapping".

[2] ETSI TS 103 548: "SmartM2M; SAREF reference ontology patterns".

[3] Void.

2.2 Informative references

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

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TR 103 506 (V1.1.1): "SmartM2M; SAREF extension investigation; Requirements for Smart Cities".

[i.2] ETSI TR 103 781: "SmartM2M; Study for SAREF ontology patterns and usage guidelines".

[i.3] ETSI TS 103 673: "SmartM2M; SAREF Development Framework and Workflow, Streamlining the Development of SAREF and its Extensions".

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
IoT	Internet of Things
ISA²	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 Modelling Language
W3C®	World Wide Web Consortium

4 SAREF4CITY ontology and semantics

4.1 Introduction and overview

The present document is a technical specification of SAREF4CITY, an OWL-DL ontology that extends SAREF [1] for the Smart Cities domain.

SAREF4CITY V2.1.1 is a major revision of SAREF4CITY, using updated reference ontology patterns specified in ETSI TS 103 548 [2] to solve the harmonization needs identified in ETSI TR 103 781 [i.2], with updated development framework and tools defined in ETSI TS 103 673 [i.3].

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 [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.

The current version of the ontology, V2.1.1, represents the adaptation of the previous SAREF4CITY conceptualization according to the new SAREF core and the homogenization process across extensions.

SAREF4CITY is an OWL-DL ontology that extends SAREF and reuses seven other ontologies. SAREF4CITY includes 124 classes (13 defined in SAREF4CITY and 111 reused from the SAREF, time, sf, geo, foaf, dc, org, cpsv, skos and time ontologies), 103 object properties (18 defined in SAREF4CITY and 85 reused from the SAREF, geo, skos and cpsv ontologies) and 13 data type properties (6 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://saref.etsi.org/saref4city/
saref	https://saref.etsi.org/core/
cpsv	http://purl.org/vocab/cpsv#
dc	http://purl.org/dc/terms/
foaf	http://xmlns.com/foaf/0.1/
geo	http://www.opengis.net/ont/geosparql#
sf	http://www.opengis.net/ont/sf#
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#
skos	http://www.w3.org/2004/02/skos/core#

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.

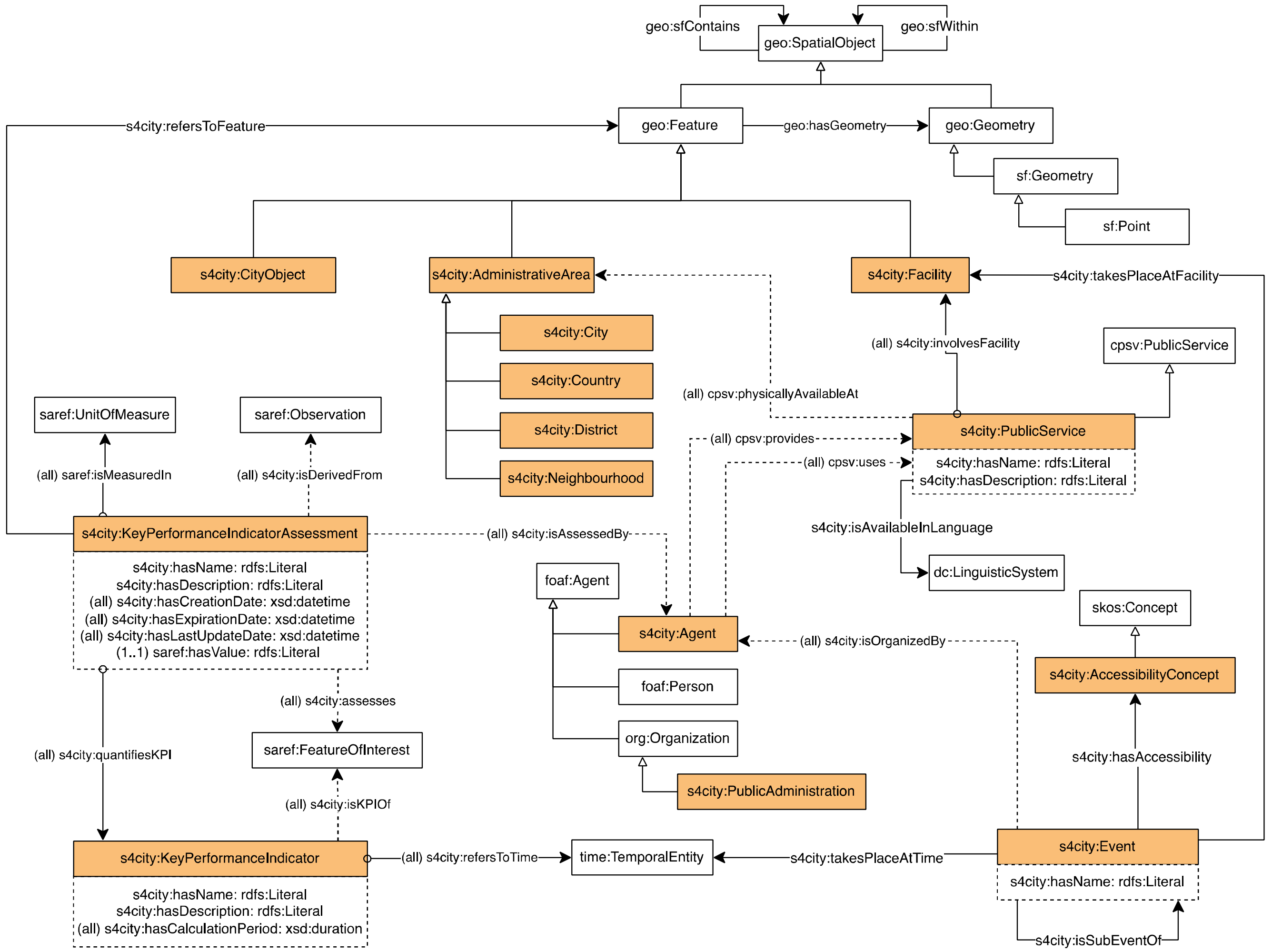

Figure 1: SAREF4CITY overview

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 `geo:SpatialObject` class from GeoSPARQL has been reused along with its subclasses `geo:Feature`, `geo:Geometry` and the classes from the simple features ontology sf:Geometry and sf:Point and the properties `geo:sfContains`, `geo:sfWithin` and `geo:hasGeometry`.

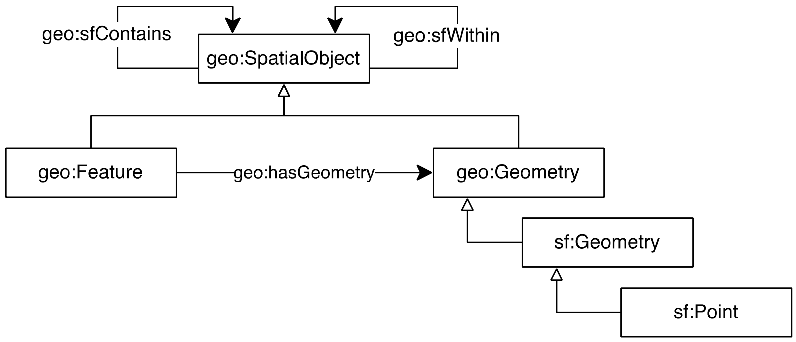

Figure 2: Topology model

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 `geo:SpatialObject` class and through the `geo:Feature` class. That is, as `s4city:AdministrativeArea` is subclass of `geo:SpatialObject`, the `geo:sfContains` and `geo:sfWithin` properties could also be applied to all the administrative areas defined, namely `s4city:City`, `s4city:Country`, `s4city:District` and `s4city:Neighbourhood`.

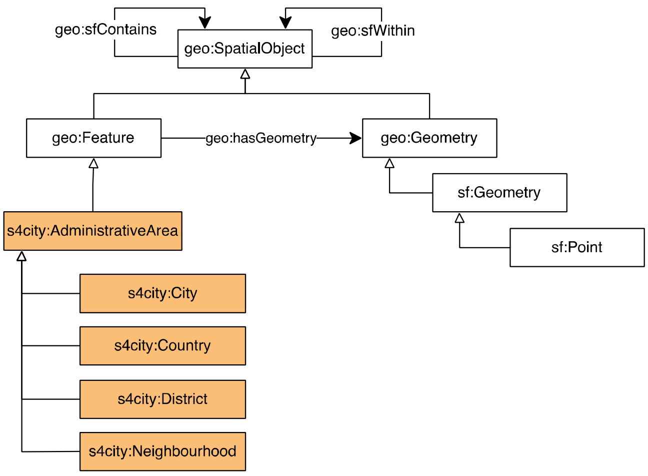

Figure 3: Administrative Area model

4.2.4 City Object

The model developed to represent city objects is shown in Figure 4. This model also relies on the topology pattern described in clause 4.2.2, as for the administrative area case. The ability to connect city objects with the city or with the parts in which they are located is enabled by means of the properties `geo:sfContains` and `geo:sfWithin` inherited from the `geo:SpatialObject` class.

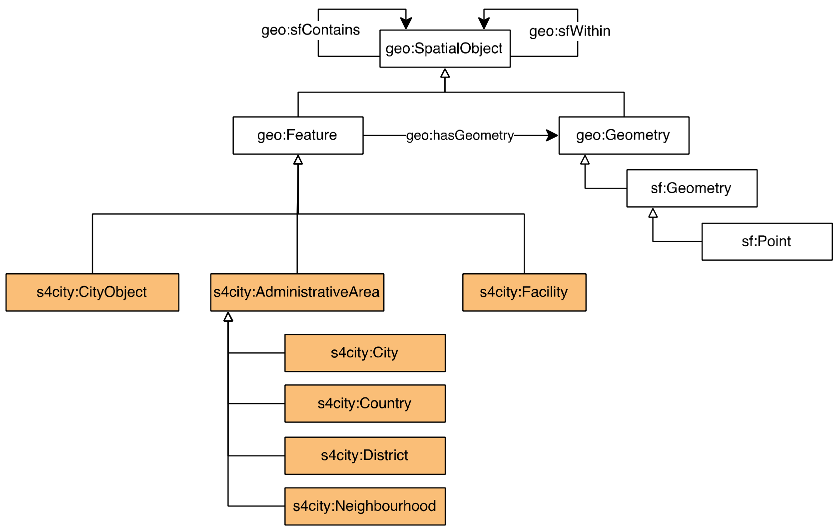

Figure 4: City Object model

4.2.5 Event

Figure 5 presents the model developed to represent temporal and scheduled events. The main concept of this pattern is the class `s4city:Event`. Such event is linked to the agent organizing it by means of the `s4city:organizedBy` property. 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 `s4city:takesPlaceAtFacility` property and at a given time, which is represented by the `s4city:takesPlaceAtTime` property 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`.

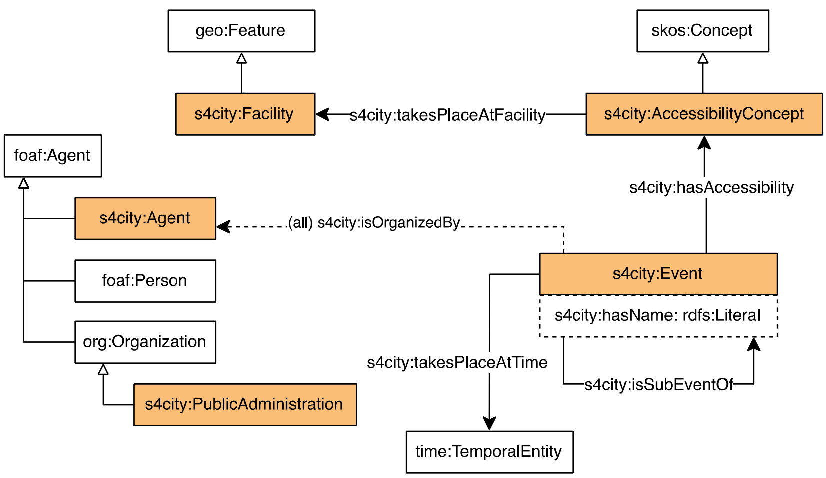

Figure 5: Event model

Table 2 summarizes the properties that characterize the `s4city:Event`.

Table 2: Properties of s4city:Event

Property	Definition
s4city:isOrganizedBy only s4city:Agent	The relation between events and agents, that can be persons or organizations, that organize the event.

4.2.6 Observation

The modelling of observation in the SAREF4CITY ontology totally relies on the observation model proposed in SAREF. This modelling includes the `saref:FeatureOfInterest` class 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, the reader is referred to the SAREF specification for details about SAREF modelling including here details only for the new concepts.

4.2.7 Key Performance Indicator

Figure 6 provides an overview of the modelling of Key Performance Indicators (KPI). 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 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 `saref:FeatureOfInterest` by means of the property `s4city:isKPIOf`. It should be noted that the inverse relation of `s4city:isKPIOf` is also defined, more precisely, the relation `s4city:hasKPI` links a given `saref:FeatureOfInterest` to its KPIs represented as instances of `s4city:KeyPerformanceIndicator`. 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 `saref: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:refersToFeature` is included in the model. In case the KPI represents a value extracted from an aggregation of observations, the property `s4city:isDerivedFrom` can be used to link to such observations (`saref:Observation`). 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.

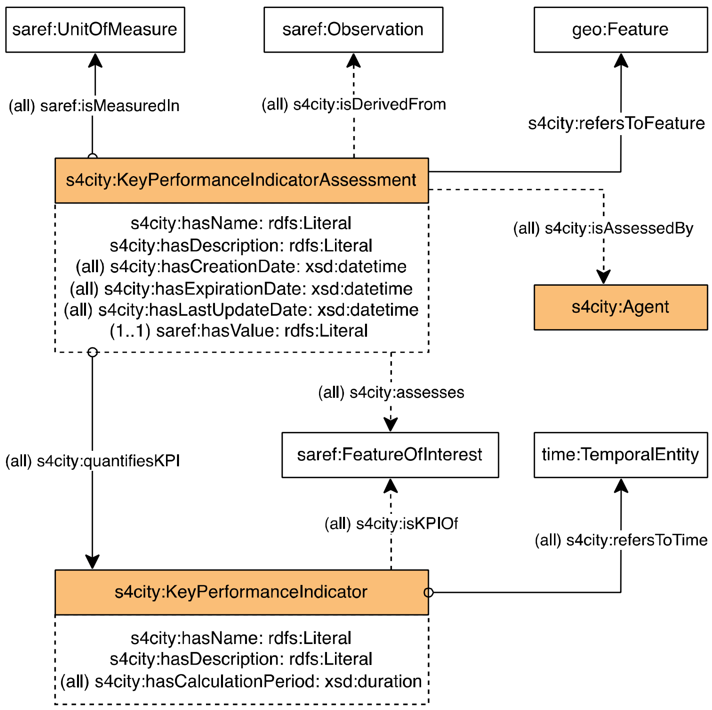

Figure 6: Key Performance Indicator model

Table 3 summarizes the properties that characterize the `s4city:KeyPerformanceIndicator` class.

Table 3: Restrictions of the s4city:KeyPerformanceIndicator class

Property	Definition
s4city:hasCalculationPeriod only xsd:duration	The relation between a KPI and its calculation period.
s4city:isKPIOf only saref:FeatureOfInterest	The relation between a KPI and the feature of interest it assesses.

Table 4 summarizes the properties that characterize the `s4city:KeyPerformanceIndicatorAssessment` class.

Table 4: Restrictions of the s4city:KeyPerformanceIndicatorAssessment class

Property	Definition
s4city:assesses only saref: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 s4city:Agent	The relation between a KPI assessment and the agent who assesses it.
s4city:isDerivedFrom only saref:Observation	The relation between a KPI assessment and the observations it aggregates.
s4city:quatifiesKPI only s4city:KeyPerformanceIndicator	The relation between a KPI assessment and the general description of the KPI it quantifies.
s4city:refersToTime only time:TemporalEntity	The relation between a KPI assessment and the temporal point or interval it refers to.
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 7. 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 facility in which the service is provided is indicated by the `s4city:involvesFacility` property. It can be also 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 (`s4city: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.

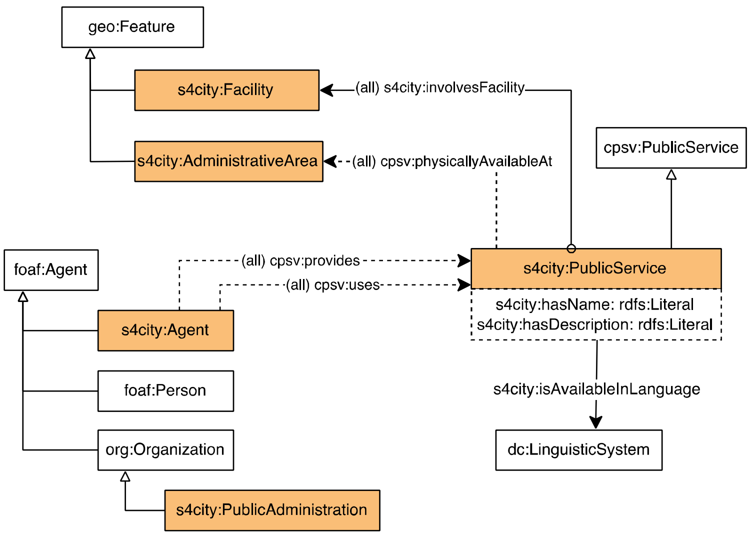

Figure 7: Public Service model

Table 5 summarizes the properties that characterize the `s4city:PublicService` class.

Table 5: 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.

4.3 Instantiating SAREF4CITY

Figure 8 shows an example of how to instantiate the SAREF4CITY extension of SAREF. This example shows the use of different patterns included in the SAREF4CITY ontology. First of all, 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 35 Km/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 `geo:sf:Contains`) other city objects such as a lamppost or a building.

The KPI pattern is also instantiated in the example. The instance `ex:RoadSegment50Congestion2018-11-20T13-30-00` refer to the value (70 %) of the road congestion on 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 the GMaps API (`ex:GMapsAPI2018-11-20`) values have been taken into account as it can be observed from the `s4city:isDerivedFrom` property between the KPI value and the different `saref:`Observation 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:BusService33`, is provided by another organization, in this case `ex:TransportCo`.

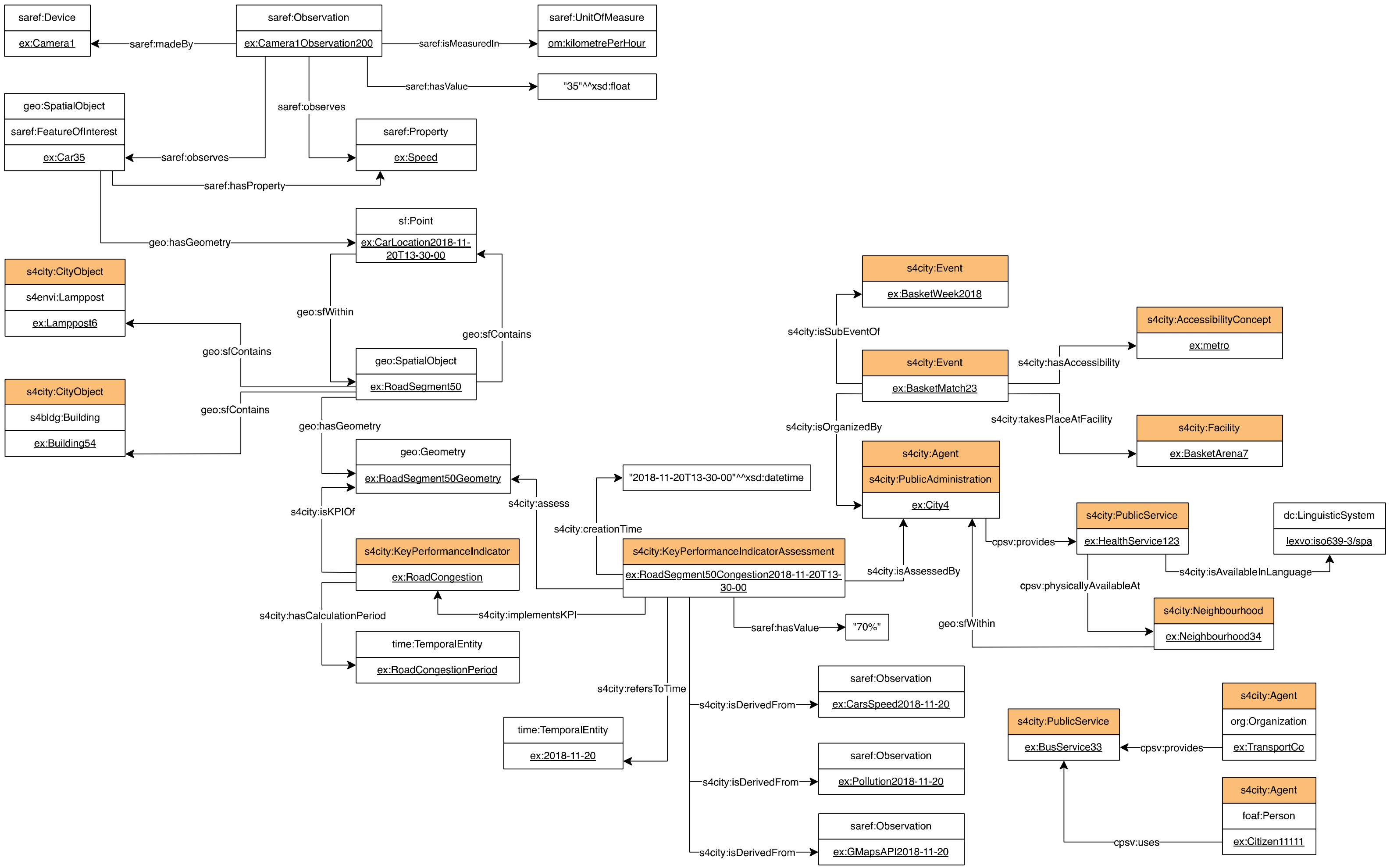

Figure 8: SAREF4CITY Road Congestion example

History

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V1.1.1	May 2019	Publication
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