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SmartM2M;
SAREF: Ontology Support for
Urban Digital Twins and usage guidelines

Reference

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Foreword

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

Modal verbs terminology

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).

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1 Scope

The present document provides a recap of the priority gaps concerning the modelling of complex DTs by exclusively using the SAREF ontology suite. Then, it is discussed how such gaps may be filled through the extension of the SAREF suite in two different directions (ETSI TS 103 264 [1]), i.e. the modelling of semantic services and the integration of time series. Such enhancement is validated through the instantiation of two use cases.

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".

2.2 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 103 827: "SmartM2M; SAREF: Digital Twins opportunities for the Ontology Context".

[i.2] W3C® Time Ontology in OWL.

[i.3] ETSI TR 103 911: "SmartM2M; SAREF; Investigation on SAREF Time-Series; Functional Design".

NOTE: The following reference is not publicly available at the date of publication and may be unavailable for an extended period of time.

[i.4] Towards a general theory of action and time. Artificial Intelligence 23, pp. 123-154. J.F. Allen. 1984.

[i.5] Actions and events in interval temporal logic: Spatial and Temporal Reasoning. O. Stock, ed., Kluwer, Dordrecht, Netherlands, pp. 205-245. J.F. Allen; G. Ferguson. 1997.

[i.6] ETSI TS 118 112 (V3.7.3): "oneM2M; Base Ontology (oneM2M TS-0012 version 3.7.3 Release 3)".

[i.7] EMSE Consortium Web page "Plateforme Territoire".

[i.8] ETSI TS 103 410-4: "SmartM2M; Extension to SAREF; Part 4: Smart Cities Domain".

[i.9] ETSI TS 103 410-3: "SmartM2M; Extension to SAREF; Part 3: Building Domain".

[i.10] ETSI TS 103 410-10: "SmartM2M; Extension to SAREF; Part 10: Water Domain".

[i.11] ETSI TS 103 410-11: "SmartM2M; Extension to SAREF; Part 11: Lift Domain".

[i.12] ETSI TS 103 410-2: "SmartM2M; Extension to SAREF; Part 2: Environment Domain".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

Digital Twin (DT): set of virtual information constructs that fully describes a potential or actual physical manufactured product from the micro atomic level to the macro geometrical level

ontology: formal specification of a conceptualization used to explicit capture the semantics of a certain reality

RESTful: according to the software architectural style that was created to guide the design and development of the architecture for the World Wide Web

3.2 Symbols

Void.

3.3 Abbreviations

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

AI	Artificial Intelligence
AMS	Administrative Management Service
API	Application Programming Interface
ArcGIS	Aeronautical Reconnaissance Coverage Geographic Information System
BIM	Building Information Models
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSV	Comma-Separated Values
DT	Digital Twin
IoT	Internet of Things
IP	Internet Protocol
IPR	Intellectual Property Rights
KPI	Key Performance Indicator
OWL	Web Ontology Language
OWL-DL	Web Ontology Language - Description Logic
PPM	Parts-Per-Million
RDF	Resource Description Framework
RDF-S	Resource Description Framework-Schema
REST	REpresentational State Transfer
SAREF	Smart Applications REFerence ontology
SR	Special Report
TS	Technical Specification
UML	Unified Modeling Languange
W3C®	World Wide Web Consortium

4 Recap of priority gaps

In ETSI TR 103 827 [i.1], it has been identified, through the analysis of the DT landscape with a focus on the urban domain, two priority gaps that, once solved, may enable the modelling of complex DT through the exclusive use of the SAREF suite:

1) to enhance the interoperable communication between entities composing a DT; and

2) to enable the modelling of time series to represent how a DT evolves through time.

It has also been discussed that the existing standards, overall, lack the capability to effectively generalize the representation of DTs and, most importantly, to model the interactions among the entities participating in complex DTs. The urban domain serves as a prominent setting where these deficiencies become apparent, given the necessity to develop digital counterparts of various entities that has to seamlessly communicate with each other. This communication aspect plays a pivotal role in shaping the DT within an urban domain as it acts as a catalyst for simulating interactions among diverse entity types. For instance, it enables the exposure of specific services that allow each entity to access information from others.

The establishment and administration of a DT involves the necessity of depicting the evolution of a Digital Twin Representation over time. Given this requirement, there is a need to define a methodology for modelling time series, as there are currently no established standards or semantic representations in SAREF for this purpose. Time series data assumes a pivotal role in validating the accuracy of a DT, serving as the ultimate reference for authenticity. Moreover, having a standardized approach to handling time series data offers the added benefit of serving as a data source for AI-based systems. This facilitates the aggregation and presentation of data in a way that enhances the value proposition of AI-based solutions through intelligent insights.

5 Extending SAREF to fill the priority gaps in modelling DTs

5.1 Extending SAREF to enable service modelling

This clause describes how services can be represented in the oneM2M Base ontology and in SAREF. Furthermore, it shows the relationship between service representations in both ontologies. More details about how services are represented in the oneM2M Base Ontology and in SAREF can be found in their respective specifications.

In oneM2M, a device (*oneM2M:Device*) is an entity that is designed to accomplish a particular task via the functions (*oneM2M:Service*) that it performs. In the context of oneM2M a device is always assumed to be capable of communicating electronically via a network. To accomplish its task, the device performs one or more functions (*oneM2M:Function*), which represent the activity necessary to accomplish the task for which a device is designed. These functions are exposed in the network as services (*oneM2M:Service*) of the device. A service is a representation of a function to a network that makes the function discoverable, registerable and remotely controllable in the network. More precisely, while a function describes the meaning of the device's activity the service is used to describe how such function is represented in a communication network and is therefore dependent on the technology of the network.

A command (*oneM2M:Command*) represents an action that can be performed to support a function. An operation (*oneM2M:Operation*) exposes a command to the network (i.e. an operation is a representation of a command to a network). An operation is the means of a service to communicate in a procedure-type manner over the network (i.e. transmit data to/from other devices). Moreover, an operation is transient, i.e. an operation can be invoked and can possibly produce an output when it finishes.

An operation can have an input (data consumed by the device) and an output (data produced by the device). An operation input (*oneM2M:OperationInput*) describes the type of input of an operation to a service of the device. An operation output (*oneM2M:OperationOutput*) describes the type of output of an operation from a service of the device. An operation can have multiple inputs and/or outputs. Moreover, the operation input and the operation output of an operation can parameterize the command exposed to the network.

Additionally, if the device communicates in a RESTful way, then output data points and input data points can be defined. An output data point (*oneM2M:OutputDataPoint*) is a variable of a service that provides state information about the service. The device updates the output data point autonomously (e.g. at periodic times) to enable a third party to retrieve its current value. An input data point (*oneM2M:InputDataPoint*) is a variable of a service that the device reads out autonomously (e.g. at periodic times) to enable a third party to instruct the device to retrieve its current value. Moreover, input data points and output data points expose commands to the network. When a device communicates in a RESTful way, then updating an input data point triggers an action in the device once the device has read out the data from the input data point. Similarly, when a device sets the data of an output data point then it provides state information about the device.

The *oneM2M:Device* class and its properties are shown in Figure 1.

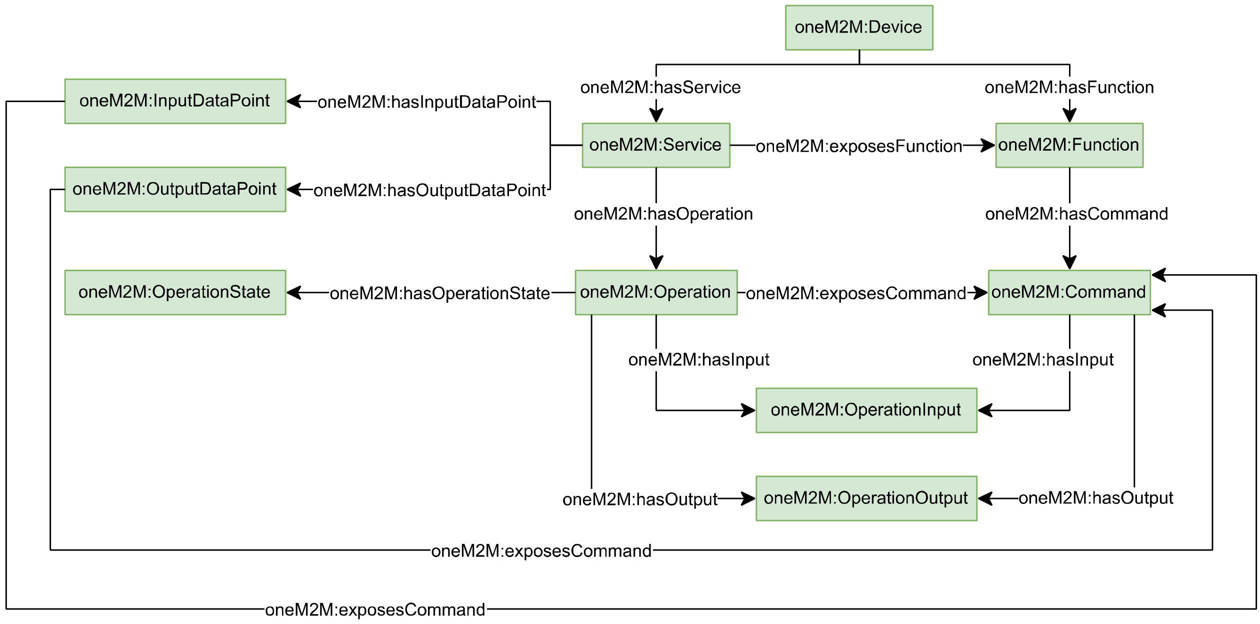

Figure 1: oneM2M service

An aspect (*oneM2M:Aspect*) describes the real-world aspect that a function relates to. The aspect could be a (physical or non-physical) entity, or it could be a quality. A function refers to (e.g. observes or influences) a certain aspect. In oneM2M, a variable (*oneM2M:Variable*) represents entities that have some data (e.g. integers, text, etc. or structured data) that can change over time. These data usually describe some real-world aspects, (e.g. temperature).

The *oneM2M:Aspect* class and its properties are shown in Figure 2.

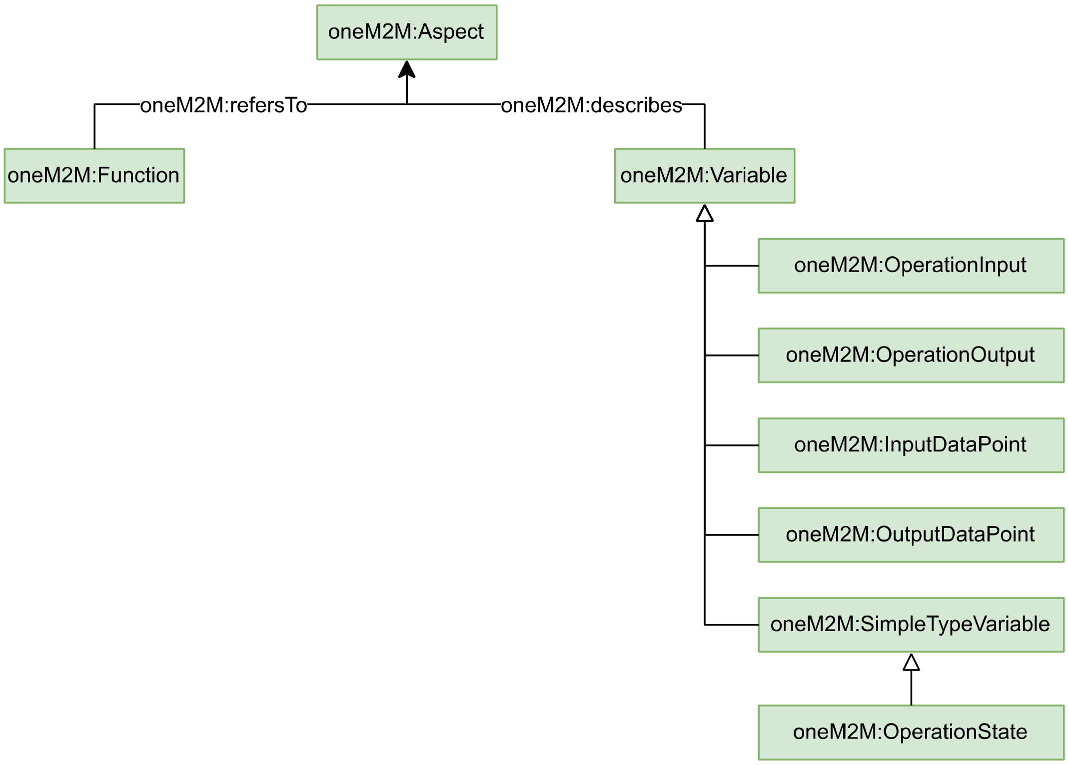

Figure 2: oneM2M aspect

In SAREF, a device (*saref:Device*) is defined as a tangible object designed to accomplish a particular task in households, common public buildings or offices. To accomplish this task, the device performs one or more functions (*saref:Function*). A function is defined as the functionality necessary to accomplish the task for which a device is designed. A device offers a service (*saref:Service*), which is a representation of a function to a network that makes this function discoverable, registerable and remotely controllable by other devices in the network. A command (*saref:Command*) is defined as a directive that a device has to support to perform a certain function.

Depending on the function(s) it performs, a device can be found in a corresponding state (*saref:State*). A command can act upon a state to represent that the consequence of a command can be a change of state of a device. Note that a command may act upon a state but does not necessarily act upon a state.

The *saref:Device* class and its properties are shown in Figure 3.

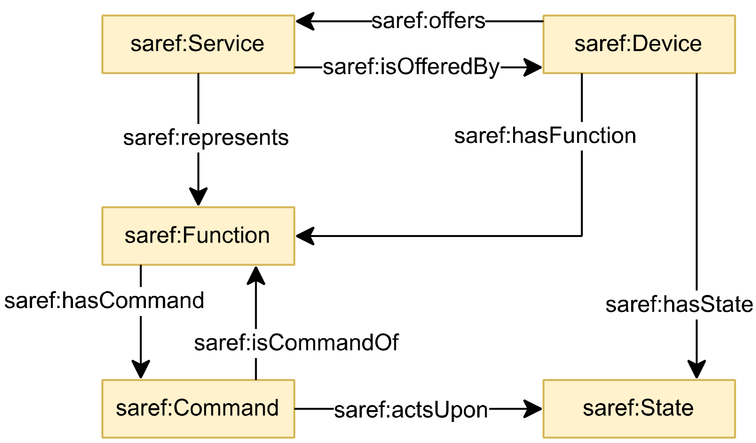

Figure 3: SAREF service

Both SAREF and oneM2M describe devices designed to perform a specific task using different functions. These functions are discoverable, registrable and remotely controllable by other devices in the network through services. In addition, the functions are realised by different actions. However, oneM2M defines a more extensive system for defining services than SAREF. For this reason, oneM2M can be used to represent services together with SAREF.

The relationship between SAREF and oneM2M is shown in Figure 4.

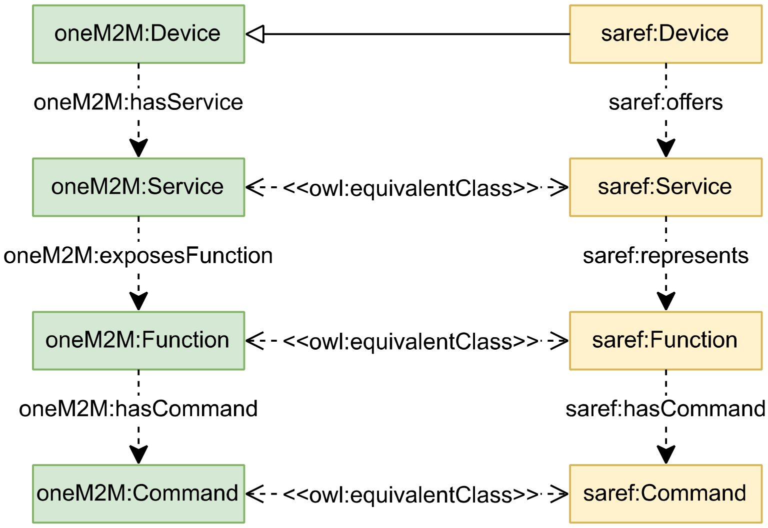

Figure 4: Relationship between SAREF and oneM2M

5.2 Extending SAREF to enable time series modelling

The second priority gap to fill related to the modelling of time series aiming to equip SAREF (ETSI TS 103 264 [1]) with the appropriate conceptualization to represent the relationships between the data observed within each DT and the timing metadata associated with them. In the present document, it is described the pathway that is intended to be followed to define and adopt the appropriate conceptualization to model time series within the context of DTs. It is important to remark that the state of the art in knowledge representation does not provide a shared conceptualization of time series. However, there are few ingredients that can be used as starting point towards achieving the time series modelling goal, i.e. the W3C® Time Ontology [i.2], the oneM2M base ontology [i.6] and the ETSI TR 103 911 [i.3].

Figure 5 provides an overview of how these three ingredients interact together with an abstraction of a small conceptual model working as a glue upon them. Then, there are summarized the details of each ingredient and how they may contribute to the definition of a time series conceptual model for DTs.

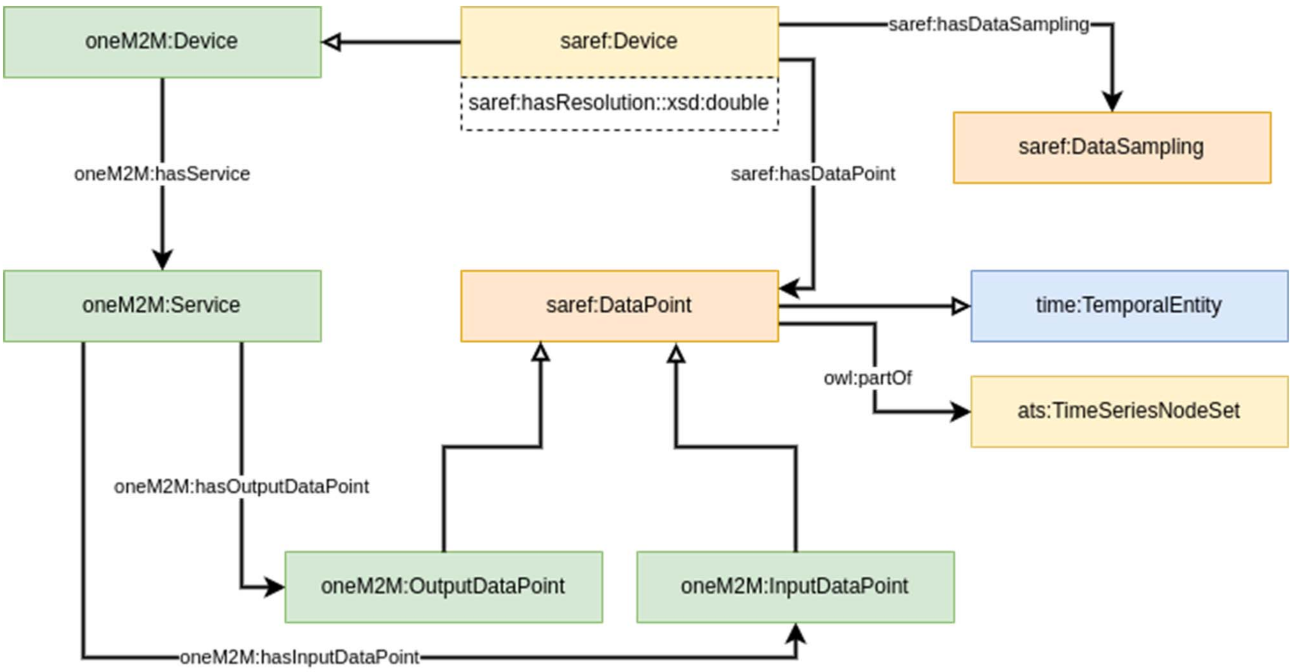

Figure 5: Abstraction of time series modelling within SAREF and relations with existing ontologies

A *saref:Device* produces data points (i.e. instances of *saref:DataPoint*) with the resolution (i.e. the time interval between two data points) described through the *saref:hasResolution* datatype property. Each data point contains all relevant information of interest related to the state of the *saref:Device*. This solution brings to SAREF what it has been roughly described within the oneM2M base ontology where each *oneM2M:Device* has a *oneM2M:Service* that has both a *oneM2M:OutputDataPoint* and *oneM2M:InputDataPoint* (the details of how these entities are defined within the oneM2M base ontology are provided below). A *saref:Device* may also adopt a specific data sampling strategy to aggregate the produced data instead of providing their raw version. This aspect is modelled through the *saref:DataSampling* concept. To express the temporal relationships between different instances of *saref:DataPoint*, these are defined as subclass of the *time:TemporalEntity* concept defined within the W3C® Time Ontology in order to enable the representation of and the reasoning on the temporal aspects between the produced *saref:DataPoint*. Finally, each instance of the *saref:DataPoint* class belongs to a time series, as defined within the SAREF extension described in ETSI TR 103 911 [i.3], as a part of an ats:TimeSeriesNodeSet object defined as a collection of multiple measurement data each made up of a name, value, type, and unit all with the same unique time-index value. This way, the measurements observed on each device are included within the time series extension of SAREF and may be exploited for reasoning purposes.

The W3C® Time Ontology provides a vocabulary for expressing facts about topological (ordering) relations among instants and intervals, together with information about durations, and about temporal position including date-time information. Time positions and durations may be expressed using either the conventional (Gregorian) calendar and clock or using another temporal reference system such as Unix-time, geologic time, or different calendars.

The basic structure of the ontology is based on an algebra of binary relations on intervals (e.g. meets, overlaps, during) developed by Allen [i.4], [i.5] for representing qualitative temporal information, and to address the problem of reasoning about such information.

The ontology starts with a class *time:TemporalEntity* with properties *time:hasBeginning* and *time:hasEnd* that link to the temporal instants that define its limits, and *time:hasTemporalDuration* to describe its extent. There are two subclasses: *time:Interval* and *time:Instant*, and they are the only two subclasses of *time:TemporalEntity*. Intervals are things with extent. Instants are point-like in that they have no interior points, but it is generally safe to think of an instant as an interval with zero length, where the beginning and end are the same.

The idea that time intervals are the more general case and time instants are just a limited specialization is the first key contribution of Allen's analysis.

The class *time:Interval* has one subclass *time:ProperInterval*, which corresponds with the common understanding of intervals, in that the beginning and end are distinct, and whose membership is therefore disjoint from *time:Instant*.

The class time:ProperInterval also has one subclass, *time:DateTimeInterval*. The position and extent of a *time:DateTimeInterval* is an element in a *time:GeneralDateTimeDescription*.

Relations between intervals are the critical logic provided by Allen's analysis and implemented in the ontology. Relations between intervals can be defined in a relatively straightforward fashion in terms of *time:before* and identity on the beginning and end points. The thirteen elementary relations shown below are the second key contribution of Allen's analysis. These support unambiguous expression of all possible relations between temporal entities, which allows the computation of any relative position or sequence. Note that the standard interval calculus assumes all intervals are proper, so their beginning and end are different.

Two additional relations: In (the union of During, Starts and Finishes) and Disjoint (the union of Before and After) are not shown in the Figure 6 but are included in the ontology.

The properties *time:hasTemporalDuration*, *time:hasBeginning* and *time:hasEnd*, together with a fourth generic property *time:hasTime*, support the association of temporal information with any temporal entity, such as an activity or event, or other entity. These provide a standard way to attach time information to things, which may be used directly in applications if suitable, or specialized if needed.

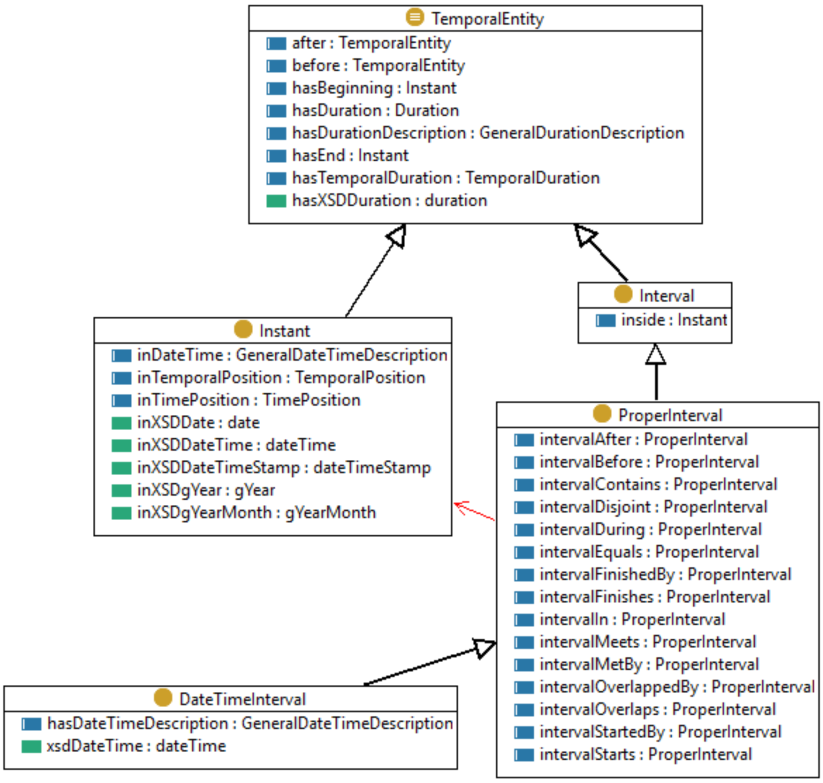

Figure 6: Conceptualization of the main concepts of the Time Ontology

The oneM2M base ontology [i.6] provides basic concepts to represent data points. The conceptual model is quite rough with respect to the purposes of time series, but it provides few basic concepts vaguely related to time series. The left part of Figure 1 shows the two concepts *oneM2M:OutputDataPoint* and *oneM2M:InputDataPoint*. A *oneM2M:OutputDataPoint* is a *oneM2M:Variable* of a *oneM2M:Service* that is set by a RESTful *oneM2M:Device* in its environment and that provides state information about the *oneM2M:Service*. The *oneM2M:Device* updates the *oneM2M:OutputDataPoint* autonomously (e.g. at periodic times). To enable a third party to retrieve the current value of a *oneM2M:OutputDataPoint* (out of schedule) devices can also offer a SET_OutputDataPoint *oneM2M:Operation* to trigger the device to update the data of the *oneM2M:OutputDataPoint*. Instead, a *oneM2M:InputDataPoint* is a *oneM2M:Variable* of a *oneM2M:Service* that is set by a RESTful *oneM2M:Device* in its environment and that the *oneM2M:Device* reads out autonomously (e.g. at periodic times). To enable a third party to instruct the device to retrieve (out of schedule) the current value of a *oneM2M:InputputDataPoint* devices can also offer a GET_InputDataPoint *oneM2M:Operation* to trigger the device to retrieve the data from the *oneM2M:InputDataPoint*.

Finally, ETSI TR 103 911 [i.3] provides the preliminary ideas about the modelling of time series extension of SAREF at a general level. The document is a technical description of an OWL-DL compliant ontology that extends SAREF with a cross-domain time series extension. The document provides a comparison among several current time series ontologies as well as examples to illustrate their differences. In addition to the concepts of *Time*, *Service,* and *Function* a time series depends upon the mapping between independent and dependent variables, especially in light of statistical and machine learning algorithms. The advantages and disadvantages of several existing time series and service ontologies are discussed as well. The main idea beyond the modelling of a time series extension, that is also in-line with what is expected to represent time series associated with DTs, is based on the concept of synchronized time series. A synchronized time series is characterized by the dependence of each measurement variable sequence on the time variable. In the course of data collection, the measurement streams from various devices are aligned with timestamps at discrete and consistent intervals, termed an Instant. It is anticipated that diverse devices may sample at distinct constant intervals, and these variations can be seamlessly aggregated. Consequently, the Sequence class transforms into the AlignedSequence class. The main objective of this suggested requirement is to facilitate the analytical comparison of multiple measurement data streams. The scope limitation is exemplified by considering the counter-example of network stack software, which organizes messages from different IP channels into a time-ordered message stream. The proposed time series ontology presupposes a total ordering of time, where every element in the dataset is comparable with every other element, as opposed to a partial ordering that is reflexive, antisymmetric, and transitive. This proposal streamlines the final time series ontology, albeit at the expense of restricting its applicability to the measurement data stream post-integration. The concept of discrete time is similarly simplified, acknowledging that individual measurement devices may possess unique clocks and timing intervals. For a dynamic or real-time IoT data stream, an edge device is necessary to perform the ordering function. Notably, the proposed time series ontology deliberately overlooks the idea of concurrent or branching time, as the data alignment process linearizes all temporal measurements. Figure 7 shows an overview of the time series extension proposed for SAREF. While the detailed description of each concept is provided in Clause 5.4 of ETSI TR 103 911 [i.3].

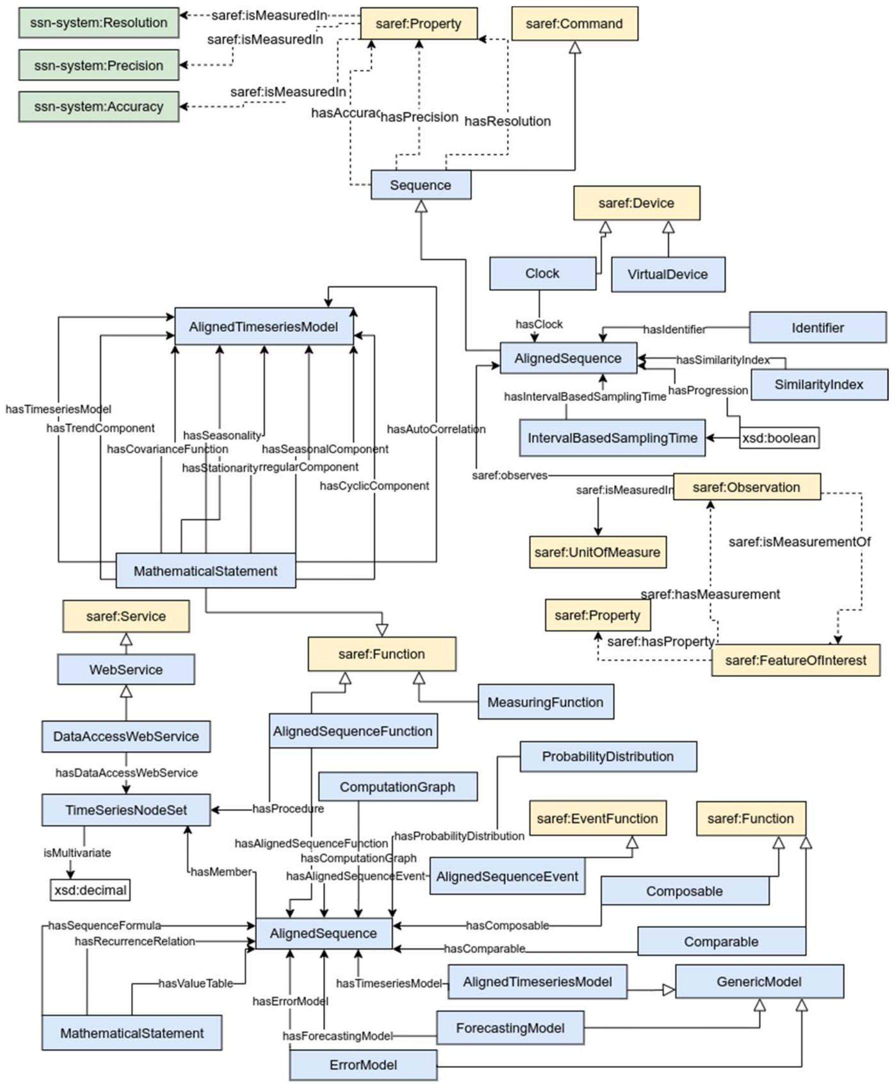

Figure 7: Overview of the proposed time series ontology

6 Usage of SAREF within Urban Digital Twin use cases

6.1 Introduction

For the entities described in the present document, it is indicated whether they are defined as a SAREF extension or elsewhere by the prefix included before their identifier, i.e. if the element is defined in SAREF4CITY (ETSI TS 103 410-4 [i.8]) the prefix is `s4city`, whereas if the element is reused from another ontology, it is indicated by a prefix according to Table 1.

Table 1: Prefixes and namespaces used within use case descriptions.

Prefix	Namespace
s4lift	https://saref.etsi.org/saref4lift/
s4city	https://saref.etsi.org/saref4city/
s4syst	https://saref.etsi.org/saref4syst/
saref	https://saref.etsi.org/core/
dcterms	http://purl.org/dc/terms/
geo	http://www.w3.org/2003/01/geo/wgs84_pos#
geosp	http://www.opengis.net/ont/geosparql#
rdf	http://www.w3.org/1999/02/22-rdf-syntax-ns#
rdfs	http://www.w3.org/2000/01/rdf-schema#
owl	http://www.w3.org/2002/07/owl#
ssn-system	http://www.w3.org/ns/ssn/systems/
vann	http://purl.org/vocab/vann/
voaf	http://purl.org/vocommons/voaf#
xsd	http://www.w3.org/2001/XMLSchema#

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 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.

6.2 Digital Twin Victoria

Digital Twin Victoria [i.2] is a program to create a virtual replica of the State of Victoria, Australia. The program supports developing the digital foundations for a future-ready Victoria, employing data to reply to new questions and make better data-led decisions. Their vision is to create Victoria online so that government, industry and the community can collaborate through shared open data, technology and algorithms to enhance real-world results and set the State as a place of relevant data and innovation. This program will unlock value for Victorians through economic recovery through digital workflows that reduce red tape, smarter and faster government services through digital data and platforms, and stronger and more resilient communities through spatial technology.

The program is led by Land Use Victoria and the platform itself is built using CSIRO Data61's TerriaJS library for building rich, web-based geospatial data explorers at https://vic.digitaltwin.terria.io/. The approach to formulate a use case made use of the dataset search portal at https://discover.data.vic.gov.au/dataset/. Search terms included "water+device", "industry+device", "building+device", "camera+speeding" and "building+industry+water". The majority of the 4 000 + datasets are images tagged with geospatial coordinates and presented through an ArcGIS GeoServices REST API (and CSV file). The "water+device" query returned 5 datasets from the Melbourne Water Corporation, but all were about the water contained in storage dams. Many of the datasets pointed to dead links. These static datasets are linked almost exclusively to each other by geospatial coordinates. Specific Building Information Models (BIM) such as the Sunbury Train Station permitted walk-throughs of geospatial objects. Searching on "web+service" returned the set of REST API verbs available for querying the Land Use Victoria datasets.

The modelling approach uses SAREF semantic Devices and a *PublicService* to model data from the dataset "Environmental resources consumed, including air travel, chemicals, electricity, fuel, gas, water, and waste generated 2013-14" for the City of Melbourne by querying for "waste+water+building". The Environmental data includes energy consumed and generated as well as greenhouse gas emissions from Melbourne's Council assets and a portion of its supply chain. The use case exposes services that compare the water and energy consumed for any three buildings in the dataset in any two industries. That is, the services relate water consumption by type of industrial building to the wastewater they produce indexed by time.

The SAREF extensions SAREF4CITY (ETSI TS 103 410-4 [i.8]), SAREF4BLDG (ETSI TS 103 410-3 [i.9]) and SAREF4WATR (ETSI TS 103 410-10 [i.10]) allow for the precise modelling of buildings and managed water flow within a city context, as shown in Figure 8. The inclusion of a Device supports the use case as a dynamic processor of data. An *AlignedSequence* with its associated *AlignedTimeseriesModel* and set of *TimeSeriesNodeSets* could be linked into the water consumption use case at the s4watr:WaterDevice, s4bldg:BuildingDevice, and saref:Measurement entities. The extensions are colour-coded in figure 8.

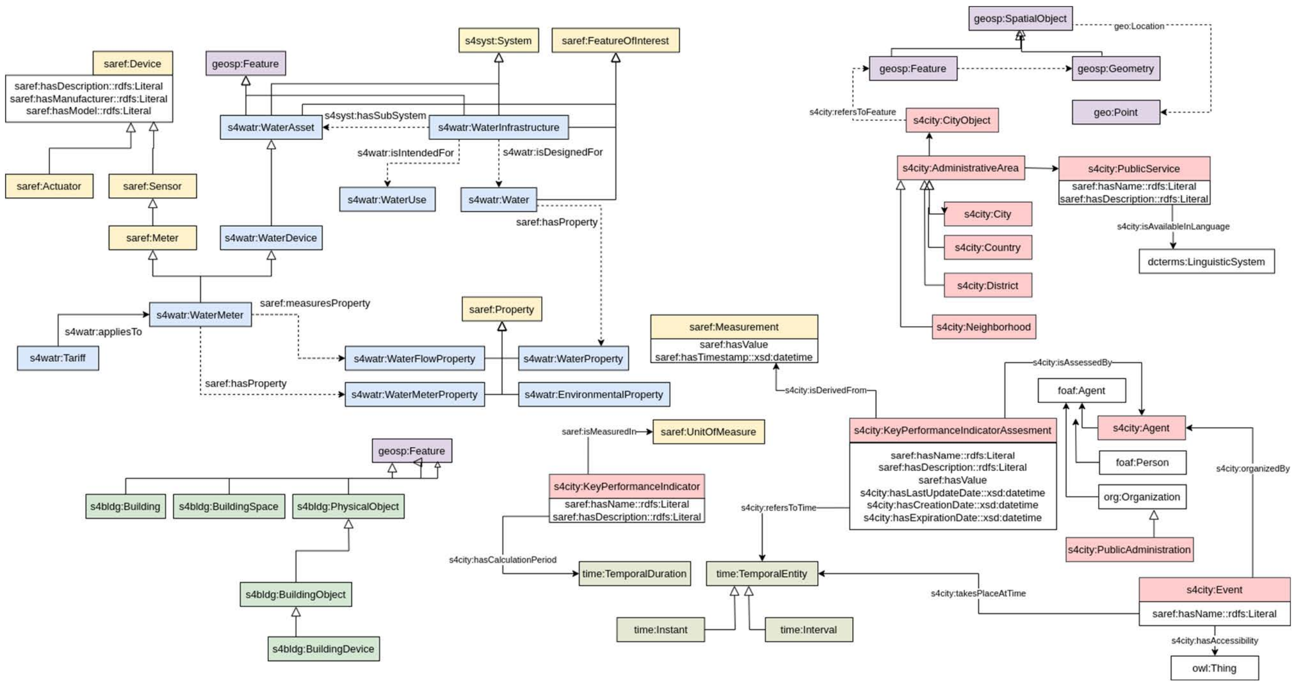

Figure 8: SAREF diagram of water consumption use case for Digital Twin Victoria

6.3 Interoperable Urban Digital Twins

Cities are complex systems where different DTs may be developed for different domains (e.g. mobility, environment, health). This use case motivates the need for semantic interoperability and coordination mechanisms between DTs within a cross-vertical application.

The modelling approach uses SAREF metering devices and services to monitor the amount of particulate pollution [i.7] (PM2.5 microns or less measured in $\mu g/m^3$) in cities situated close to multiple large-scale mining and extractive industries nearby since the mines blow dust into the city under certain environmental conditions. Particulate sensors are therefore placed strategically at the city outskirts. Sky-facing photometric measurements are also recorded. The analysis then compares particulate measurements to photometric measurements .The particulate measurements feed directly into the control of street lamp illumination levels as well as government warnings about dangerous air quality conditions. Thus, this use case depends upon and outputs specific threshold Key Performance Indicators (KPI) events. The time series *AlignedSequenceEvent*, which fires upon a value threshold surpassed, satisfies these KPI events.

The approach is organized as follows:

- The light/pollution sensors and street lamps are connected to their actuators (Device sub-classes).
- The sensors and lamps produce luminosity and Parts-Per-Million (PPM) measurements which are compared to threshold illumination/pollution KPIs.
- The measurements are fed to an Administrative Management Service (AMS), which can issue air quality reports.
- The AMS is located in an administrative building, computational data processing services are located in another building, and engineering support services are located in a third building.
- The s4envi:LightSensor class is added for the sake of consistency.
- Each building has its own lift system.

These components can be mapped to classes and properties in the SAREF extensions SAREF4CITY (ETSI TS 103 410-4 [i.8]), SAREF4BLDG (ETSI TS 103 410-3 [i.9]), SAREF4LIFT (ETSI TS 103 410-11 [i.11]) and SAREF4ENVI (ETSI TS 103 410-2 [i.12]) in the following way, as shown in Figure 9. Again, a time series *AlignedSequence* would be linked into the pollution monitoring use case at the saref:Device and saref:Measurement entities.

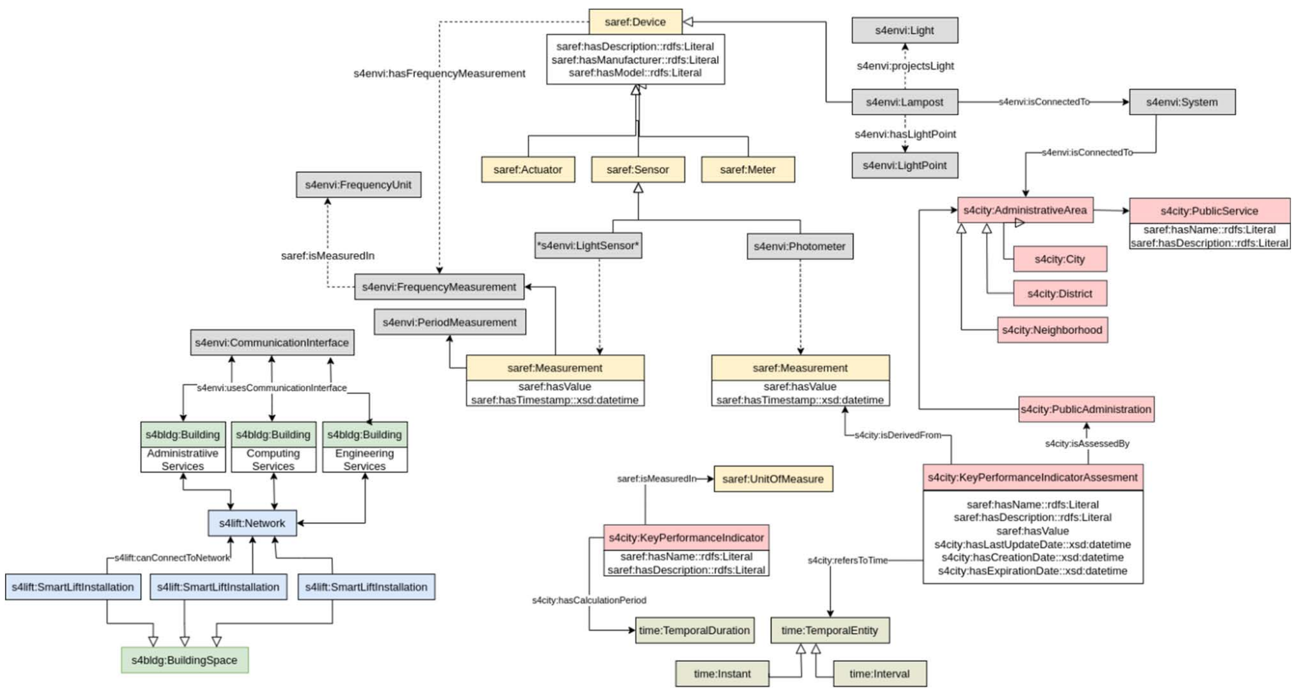

Figure 9: SAREF diagram of interoperable urban light/pollution use case

7 Observations

The present document aimed to provide a comprehensive set of guidelines about how the SAREF suite may fill the priority gaps identified in ETSI TR 103 827 [i.1] and how it may be extended and applied concerning the modelling of complex DTs. Such guidelines represent important insights the engineers should follow to make DTs-based system more useful from the data perspective and to avoid the gathering of data that are useless with respect to the purpose of specific scenarios. Indeed, accurate data collections play an important role in process of increasing the overall trustworthy of an DTs-based system to make it usable in concrete settings.

For this reason, examples of use cases have been included to show how complex DTs may be instantiated through the proposed guidelines. The provided set may be extended with further requirements. However, the content of the present document works as a perfect basis towards the definition of a standard about the modelling of complex DTs.

Annex A (informative): Change History

Date	Version	Information about changes
January 2024	V0.0.5	Stable Draft updated and reviewed by Technical Officer and STF leader.
February 2024	V0.0.6	Figure 7 and the content of Clause 6 updated and Technical Officer review for ***editHelp!*** publication pre-processing

History

Document history		
V1.1.1	March 2024	Publication