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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° w061004871

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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 3 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 the SAREF extension for the building domain, based on the ISO 16739 [i.2] standard (IFC).

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/.

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

[i.2] ISO 16739-1:2024: "Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries -- Part 1: Data schema".

[i.3] buildingSMART: "Industry Foundation Classes (IFC) - Version 4 - Addendum 1".

[i.4] Villazón-Terrazas, B.: "Method for Reusing and Re-engineering Non-ontological Resources for Building Ontologies". Ph.D. Dissertation. Universidad Politécnica de Madrid. 2011.

[i.5] ETSI TS 103 410-3 (V1.1.1): "SmartM2M; Extension to SAREF; Part 3: Building Domain".

[i.6] ETSI TR 103 781 (V1.1.1): "SmartM2M; Study for SAREF ontology patterns and usage guidelines".

[i.7] 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:

HTML	Hyper Text Markup Language
IFC	Industry Foundation Classes
ISO	International Standardization Organization
OWL	Web Ontology Language
OWL-DL	Web Ontology Language Description Logic
PROV-O	The PROV Ontology
RDF	Resource Description Format
SAREF	Smart Applications REFerence ontology
TR	Technical Report
TS	Technical Specification
URI	Uniform Resource Identifier
W3C®	World Wide Web Consortium

4 SAREF4BLDG ontology and semantics

4.1 Introduction

The present document is a technical specification of SAREF4BLDG, an extension of the SAREF ontology [1] that was created based on the Industry Foundation Classes (IFC) standard for building information. It should be noted that not the whole standard has been transformed since it exceeds the scope of this extension, which is limited to devices and appliances within the building domain.

The present document is a major revision of SAREF4BLDG ontology extension, developed in the context of the STF 653 (https://portal.etsi.org/xtfs/#/xTF/653/), using updated reference ontology patterns specified in ETSI TS 103 548 [2] to solve the harmonization needs identified in ETSI TR 103 781 [i.6], with updated development framework and tools defined in ETSI TS 103 673 [i.7].

ETSI TS 103 410-3 [i.5] has been developed in the context of the STF 513, an ETSI specialists task force that was established with the goal to deliver the SAREF Core V2 and to extend SAREF id for the domains of Environment, Buildings and Energy (see https://portal.etsi.org/STF/STFs/STF-HomePages/STF513). The IFC specification is developed and maintained by buildingSMART International as its "Data standard" and, since its version IFC4, it is published as ISO 16739 [i.2]. SAREF4BLDG is meant to enable the (currently missing) interoperability among various actors (architects, engineers, consultants, contractors, and product component manufacturers, among others) and applications managing building information involved in the different phases of the building life cycle (Planning and Design, Construction, Commissioning, Operation, Retrofitting/Refurbishment/Reconfiguration, and Demolition/Recycling). By using SAREF4BLDG, smart appliances from manufacturers that support the IFC data model will easily communicate with each other. Towards this aim, SAREF4BLDG should be used to annotate (or generate) neutral device descriptions to be shared among various stakeholders.

SAREF4BLDG is an OWL-DL ontology that extends SAREF with 72 classes (67 defined in SAREF4EBLDG and 5 reused from the SAREF and geo ontologies), and 77 data type properties (76 defined in SAREF4EBLDG and 1 reused from the SAREF ontology).

SAREF4BLDG focuses on extending the SAREF ontology to include those devices defined by the IFC version 4 - Addendum 1 [i.3] and to enable the representation of such devices and other physical objects in building spaces.

The prefixes and namespaces used in SAREF4BLDG and along the present document are listed in Table 1.

Table 1: Prefixes and namespaces used within the SAREF4BLDG ontology

Prefix	Namespace
base (s4bldg)	https://saref.etsi.org/saref4bldg/
saref	https://saref.etsi.org/core/
owl	http://www.w3.org/2002/07/owl
prov	http://www.w3.org/ns/prov
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
dcterms	http://purl.org/dc/terms/
vann	http://purl.org/vocab/vann/
xml	http://www.w3.org/XML/1998/namespace

4.2 SAREF4BLDG

4.2.1 General overview

Figure 1 presents an overview of the classes (only the top levels of the hierarchy) and the properties included in the SAREF4BLDG extension. As it can be observed the classes `s4bldg:Building`, `s4bldg:BuildingSpace` and `s4bldg:PhysicalObject` have been declared as subclasses of the class `geo:SpatialThing` in order to reuse the conceptualization for locations already proposed by the geo ontology. The modelling of building objects and building spaces has been adapted from the SAREF ontology; in this sense, the new classes deprecate the `saref:BuildingObject` and `saref:BuildingSpace` classes. In addition, a new class has been created, the `s4bldg:Building` class, to represent buildings.

The concepts `s4bldg:Building` and `s4bldg:BuildingSpace` are related to each other by means of the properties `s4bldg:hasSpace` and `s4bldg:isSpaceOf`; such properties are defined as inverse properties among them. These properties might also be used to declare that a `s4bldg:BuildingSpace` has other spaces belonging to the class `s4bldg:BuildingSpace`.

The relationship between building spaces and devices and building objects has also been transferred and generalized from the SAREF ontology. In this regard, a `s4bldg:BuildingSpace` can contain (represented by the property `s4bldg:contains`) individuals belonging to the class `s4bldg:PhysicalObject`. This generalization has been implemented in order to support building spaces to contain both building objects and devices. Accordingly, the classes `s4bldg:BuildingObject` and `saref:Device` are declared as subclasses of `s4bldg:PhysicalObject`.

Finally, the class representing building devices, namely `s4bldg:BuildingDevice`, is defined as a subclass of both `saref:Device` and `s4bldg:BuildingObject`. This class is a candidate for replacing the `saref:BuildingRelated` class.

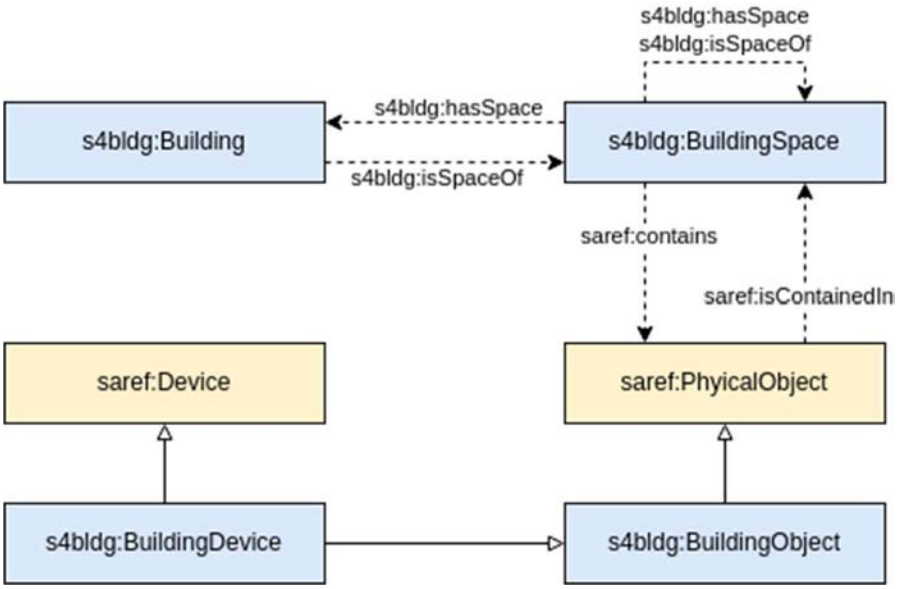

Figure 1: General overview of the top levels of the SAREF4BLDG extension

Table 2 summarizes the restrictions that characterize a `s4bldg:BuildingSpace`.

Table 2: Restrictions of the s4bldg:BuildingSpace class

Property	Definition
s4bldg:contains **only** s4bldg:PhysicalObject	A building space contains entities represented only by instances of s4bldg:PhysicalObject.
s4bldg:hasSpace **only** s4bldg:BuildingSpace	A building has spaces represented only by instances of s4bldg:BuildingSpace.
s4bldg:isSpaceOf **only** (s4bldg:Building or s4bldg:BuildingSpace)	A building is spaces of entities represented only by instances of the classes s4bldg:Building or s4bldg:BuildingSpace.

Table 3 summarizes the restrictions that characterize a `s4bldg:PhysicalObject`.

Table 3: Restrictions of the s4bldg:PhysicalObject class

Property	Definition
s4bldg:contains **only** s4bldg:PhysicalObject	A physical object contains entities represented only by instances of s4bldg:PhysicalObject.
s4bldg:isContained **only** (s4bldg:Building or s4bldg:BuildingSpace)	A physical object is contained in entities represented only by instances of the classes s4bldg:Building or s4bldg:BuildingSpace.

4.2.2 Device Taxonomy

The main contribution of this extension is the representation of the devices defined in the IFC standard and their connections to SAREF. In this sense, a hierarchy consisting in 62 classes has been created taking into account the subset of the IFC hierarchy related to devices, as defined in the buildingSMART documentation (https://standards.buildingsmart.org/IFC/RELEASE/IFC4/ADD1/HTML/annex/annex-c/common-use-definitions/index.htm), and adding several classes to clarify its categorization. The device classes are organized into 6 hierarchical levels that, for the sake of clarity, will be displayed in Figure 2 and Figure 3.

Figure 2 shows the first five levels of the hierarchy. Since transport elements (`s4bldg:TransportElement`) and vibration isolations (`s4bldg:VibrationIsolation)` are not classified under IFC elements, they belong directly to the class `s4bldg:Device`. The building elements are divided into `s4bldg:ShadingDevice` and `s4bldg:DistributionDevice`. In fact, most of the device types included in IFC belong to the distribution device category which contains the classes s`4bldg:DistributionControlDevice` and `s4bldg:DistributionFlowDevice.` The hierarchy under the `s4bldg:DistributionFlowDevice is` depicted in Figure 3.

As can be observed in Figure 2, some classes defined in SAREF4BLDG are also defined in the SAREF ontology. More precisely, this occurs in the classes `s4bldg:Actuator` and `s4bldg:Sensor` that extend the classes `saref:Actuator` and `saref:Sensor`, respectively. This decision has been taken because in the SAREF4BLDG extension these concepts refer to specific sensors and actuators that are placed in or related to buildings.

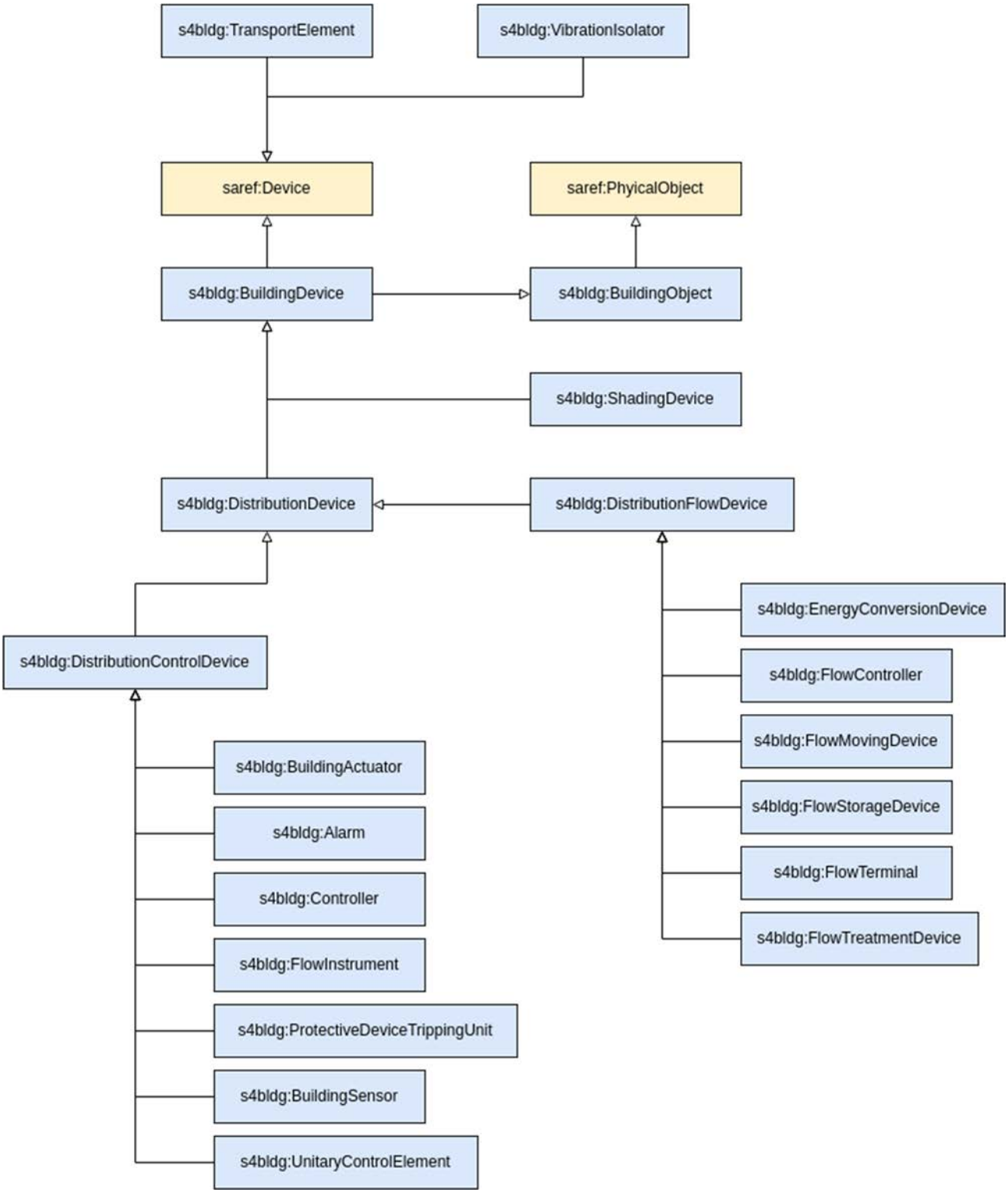

Figure 2: Device hierarchy in SAREF4BLDG (Part 1)

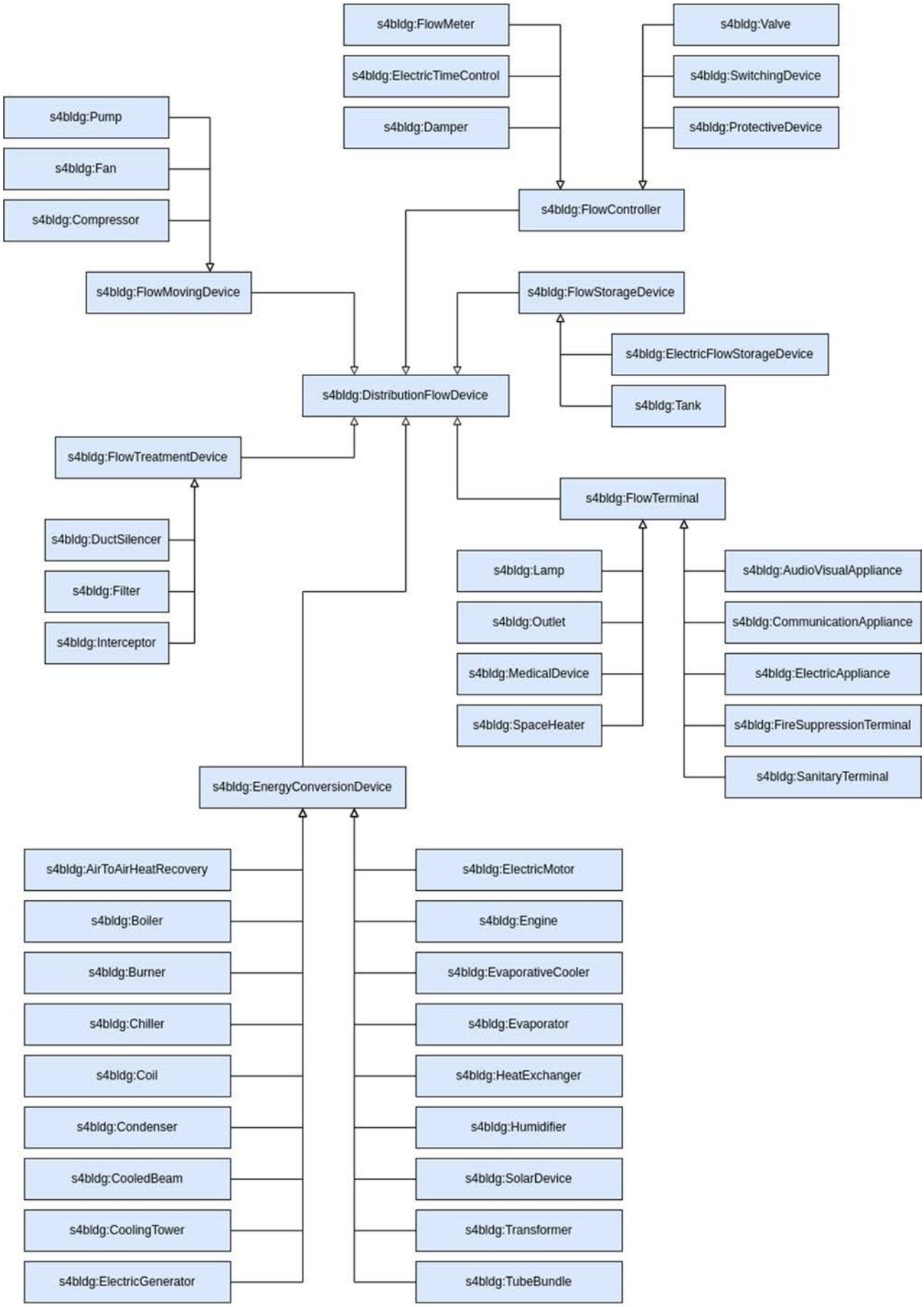

Figure 3: Device hierarchy in SAREF4BLDG (Part 2)

For each class extracted from the IFC specification, `rdfs:label` and `rdfs:comment` annotations have been generated including the identifier and an excerpt of the definition provided in the IFC online documentation. In addition, provenance information has been included using the PROV-O ontology (https://www.w3.org/TR/prov-o/), which has been published by the W3C as recommendation. In our case, the property `prov:hadPrimarySource` is used to link each class with:

a) the online document in IFC describing the concept; and

b) the online document in IFC describing the properties defined for such concept.

It should be noted that properties are not specified in IFC for all the concepts but just for those representing particular devices. That is, there is no description of properties for the following general classes:

- `s4bldg:EnergyConversionDevice, s4bldg:FlowController, s4bldg:FlowMovingDevice, s4bldg:FlowStorageDevice, s4bldg:FlowTerminal, and s4bldg:FlowTreatmentDevice.`

In addition, the classes created in this extension have been related to the ifcOWL ontology (https://w3id.org/ifc/IFC4_ADD1) when possible. This relation has been declared by means of the annotation property `rdfs:seeAlso` from the SAREF4BLDG classes to the ifcOWL ones. Listing 1 includes an excerpt of the ontology in the Turtle syntax that shows an example of a class including the annotations from the IFC specification, provenance references to the IFC class and property definition, and the mapping to the corresponding ifcOWL concept.

```
### Class definition

s4bldg:Compressor rdf:type owl:Class ;

   rdfs:label "Compressor"@en ;

   rdfs:subClassOf s4bldg:FlowMovingDevice ;

   rdfs:comment "A compressor is a device that compresses a fluid typically used
in a refrigeration circuit."@en ;

### Provenance information for class definition

   prov:hadPrimarySource   <http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/
schema/ifchvacdomain/lexical/ifccompressor.htm> ;

### Provenance information for class properties

   prov:hadPrimarySource   <http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/
schema/ifchvacdomain/pset/pset_compressortypecommon.htm> ;

### Mapping to ifcOWL classes

  rdfs:seeAlso <https://w3id.org/ifc/IFC4_ADD1#IfcCompressor> .
```

Listing 1: Class definition example including documentation, mappings and provenance information

4.2.3 Device Properties

In the SAREF4BLDG extension 177 instance of the class `saref:Property` and 77 datatype properties (82 defined in SAREF4EBLDG and 1 reused from the SAREF ontology) have been included. 172 out the 177 properties and 75 out of the 83 datatype properties have been created according to the IFC specification of properties for devices.

For each of the created object and datatype properties, their documentation from IFC has been attached as documentation, including information about their use, such as the expected units of measurement.

The naming of the created object and datatype properties is consistent with the naming used in IFC. More precisely, the names of the properties in the ontology are the names assigned in IFC transformed into Camel Case starting with lowercase. For example, the property "IdealShaftPower" (extracted from https://standards.buildingsmart.org/IFC/RELEASE/IFC4/ADD1/HTML/schema/ifchvacdomain/pset/pset_compressortypecommon.htm) has been transformed into the object property `s4bldg:idealShaftPower`.

Listing 2 includes an excerpt of the ontology in the Turtle syntax that shows an example of an object property and a datatype property including the annotations from the IFC specification.

```
### Object property definition example

s4bldg:idealShaftPower rdf:type owl:ObjectProperty ;

  rdfs:comment "Compressor shaft power under ideal conditions. Usually measured
in Watts (W, J/s)."@en ;

  rdfs:label "ideal shaft power"@en .

### Datatype property definition example

s4bldg:hasHotGasBypass rdf:type owl:DatatypeProperty ;

  rdfs:range xsd:boolean ;

  rdfs:comment "Whether or not hot gas bypass is provided for the compressor. TRUE
= Yes, FALSE = No."@en ;

  rdfs:label "has hot gas bypass"@en .
```

Listing 2: Property definition example including documentation

Table 4: Void

Table 5 shows the list of datatype properties extracted from IFC and the classes for which each property might be applied.

Table 5: List of datatype properties extracted from IFC and the classes for which the properties are defined

Datatype properties	Class(es)
s4bldg:accessType	s4bldg:Tank
s4bldg:application	s4bldg:Humidifier
s4bldg:arrangement	s4bldg:HeatExchanger
s4bldg:bladeAction	s4bldg:Damper
s4bldg:bladeEdge	s4bldg:Damper
s4bldg:bladeShape	s4bldg:Damper
s4bldg:capacityControl	s4bldg:CoolingTower
s4bldg:capacityControlType	s4bldg:Fan
s4bldg:capacityPeople	s4bldg:TransportElement
s4bldg:circuitType	s4bldg:CoolingTower
s4bldg:colorAppearance	s4bldg:Lamp
s4bldg:colorRenderingIndex	s4bldg:Lamp
s4bldg:controlStrategy	s4bldg:CoolingTower
s4bldg:endShapeType	s4bldg:Tank
s4bldg:energySource	s4bldg:Burner
	s4bldg:Engine
	s4bldg:SpaceHeater
	s4bldg:Boiler
s4bldg:evaporationCoolant	s4bldg:Evaporator
s4bldg:evaporationMediumType	s4bldg:Evaporator
s4bldg:failPosition	s4bldg:Actuator
s4bldg:finishColor	s4bldg:CooledBeam
s4bldg:fireExit	s4bldg:TransportElement
s4bldg:flowArrangement	s4bldg:EvaporativeCooler
	s4bldg:CoolingTower
s4bldg:frameSize	s4bldg:ElectricMotor
s4bldg:frameType	s4bldg:Damper
s4bldg:hasDefrost	s4bldg:AirToAirHeatRecovery
s4bldg:hasExteriorInsulation	s4bldg:DuctSilencer

Datatype properties	Class(es)
s4bldg:hasHotGasBypass	s4bldg:Compressor
s4bldg:hasLock	s4bldg:SwitchingDevice
s4bldg:hasPartWinding	s4bldg:ElectricMotor
s4bldg:hasTurbulator	s4bldg:TubeBundle
s4bldg:heatTransferDimension	s4bldg:SpaceHeater
s4bldg:heatTransferMedium	s4bldg:SpaceHeater
s4bldg:heatTransferTypeEnum	s4bldg:AirToAirHeatRecovery
s4bldg:integratedLightingType	s4bldg:CooledBeam
s4bldg:internalControl	s4bldg:Humidifier
s4bldg:isExternal	s4bldg:ShadingDevice
s4bldg:isFreeHanging	s4bldg:CooledBeam
s4bldg:isGuarded	s4bldg:ElectricMotor
s4bldg:isIlluminated	s4bldg:SwitchingDevice
s4bldg:isNeutralPrimaryTerminalAvailable	s4bldg:Transformer
s4bldg:isNeutralSecondaryTerminalAvailable	s4bldg:Transformer
s4bldg:isPluggableOutlet	s4bldg:Outlet
s4bldg:isWaterStorageHeater	s4bldg:Boiler
s4bldg:lampBallastType	s4bldg:Lamp
s4bldg:lampCompensationType	s4bldg:Lamp
s4bldg:legend	s4bldg:SwitchingDevice
s4bldg:manualOverride	s4bldg:Actuator
s4bldg:mechanicalOperated	s4bldg:ShadingDevice
s4bldg:mediaSource	s4bldg:AudioVisualAppliance
s4bldg:motorDriveType	s4bldg:Fan
s4bldg:motorEnclosureType	s4bldg:ElectricMotor
s4bldg:operatingMode	s4bldg:Boiler
s4bldg:operation	s4bldg:Damper
s4bldg:orientation	s4bldg:Damper
s4bldg:patternType	s4bldg:Tank
s4bldg:pipeConnectionEnum	s4bldg:CooledBeam
s4bldg:placementType	s4bldg:Coil
	s4bldg:SpaceHeater
s4bldg:powerSource	s4bldg:Compressor
s4bldg:readOutType	s4bldg:FlowMeter
s4bldg:refrigerantClass	s4bldg:Evaporator
	s4bldg:Compressor
	s4bldg:Condenser
s4bldg:remoteReading	s4bldg:FlowMeter
s4bldg:roughness	s4bldg:ShadingDevice
s4bldg:secondaryCurrentType	s4bldg:Transformer
s4bldg:shadingDeviceType	s4bldg:ShadingDevice
s4bldg:shortCircuitVoltage	s4bldg:Transformer
s4bldg:sprayType	s4bldg:CoolingTower
s4bldg:standard	s4bldg:ProtectiveDeviceTrippingUnit
s4bldg:storageType	s4bldg:Tank
s4bldg:switchFunction	s4bldg:SwitchingDevice
s4bldg:temperatureClassification	s4bldg:SpaceHeater
s4bldg:transformerVectorGroup	s4bldg:Transformer
s4bldg:valveMechanism	s4bldg:Valve
s4bldg:valveOperation	s4bldg:Valve
s4bldg:valvePattern	s4bldg:Valve
s4bldg:waterFlowControlSystemType	s4bldg:CooledBeam

As an example of a complete class definition including all its properties, Table 6 summarizes the restrictions that characterize a `s4bldg:Compressor`, using the properties extracted from IFC. The example contains different types of properties that are representative enough for the rest of the transformed classes. It should be noted that the full ontology documentation will be available online in HTML format, since including all the restrictions in the present document would make it unmanageable.

Table 6: Restrictions of the s4bldg:Compressor class

Property	Definition
s4bldg:powerSource **only** xsd:string	The power source of a compressor value is indicated only by xsd:string.
s4bldg:refrigerantClass **only** xsd:string	The refrigeration class of a compressor value is indicated only by xsd:string.
s4bldg:hasHotGasBypass **only** xsd:boolean	Whether a compressor has a hot gas bypass is indicated only by values of xsd:boolean.

4.3 Discussions about SAREF4BLDG

In the following, several observations about potential uses of the SAREF4BLDG ontology are listed.

It should be mentioned that the range of the `s4bldg:shortCircuitVoltage` object property is open to different representations of complex numbers. In this sense, when reusing the ontology users should define the class to be used to represent complex numbers or reuse an existing one.

In addition, the list of building devices should not be considered exhaustive, the current classification represents those devices described in IFC. It might be needed to extend the hierarchy in the case of new devices related to buildings are described in new versions of IFC or are needed for a particular use case.

Furthermore, it is expected that concrete use cases will either reuse the existing classes to represent their devices or specialize some of these classes to cover specific device types (e.g. by creating a hierarchy of boiler devices under the `s4bldg:Boiler` class).

Annex A (informative): Approach

During the development of this extension, the ontological requirements were directly extracted from the IFC specification. The reason for this is that no domain experts providing real uses cases were available, even though some conversations with experts in order to clarify doubts have taken place. However, the requirements have been aligned with the uses cases in the building sector that have been defined in the "W3C Linked Building Data Community Group" (https://www.w3.org/community/lbd/) and are publicly accessible (https://www.w3.org/community/lbd/wiki/Seed_Use_Cases).

The first step for developing this SAREF extension has been to extract ontological requirements taking the IFC specification [i.3] as a starting point. In order to select the subset of IFC that is relevant in the context of a SAREF extension, the boundaries of the concepts that have been included are delimited by the term "device", that is, every entity that can be classified as a device has been taken into account. The detailed process for extracting the requirements is provided in ETSI TR 103 411 [i.1]. This step was crucial due to the fact that IFC is organized according to different architectural process views and it does not contain a clear classification of devices as they are distributed in different branches of a broader classification.

Once the concepts to be represented, their descriptions and their properties were extracted from IFC, a non-ontological resource reengineering process [i.4] was carried out. This process consisted in the transformation of the non-ontological resource, in this case the IFC documentation, into an ontological resource following a TBox transformation approach. That is, the original resource was transformed in the terminological box (TBox) of a knowledge base (i.e. the ontology).

For each concept selected from the IFC documentation a class together with its additional information was created, as shown in Listing 1. Each class was then classified under the reused class `saref:Device` and according to the hierarchy proposed in IFC [i.3] (https://standards.buildingsmart.org/IFC/RELEASE/IFC4/ADD1/HTML/annex/annex-c/common-use-definitions/index.htm).

IFC defines the concept "Element"; however, this concept is too broad to be reused since it refers to devices and any other element than can appear in a building. This issue also appears in other levels of the hierarchy; for example, IFC defines the concept "Distribution element" which contains devices but also many other elements that are not devices. In this case the class `s4bldg:DistributionDevice` has been created in order to restrict the use to devices. This decision has been taken for the following classes: `s4bldg:BuildingDevice`, `s4bldg:DistributionDevice`, `s4bldg:DistributionControlDevice`, and `s4bldg:DistributionFlowDevice`.

For each class, its associated properties described in IFC have been transformed into object or datatype properties. It is worth noting that not all the properties defined in the IFC standard have been transformed because, for example, in some cases the definition of the properties assigned to the classes included only the property identifier (which in RDF can be considered to be the URI of the given instance) and its status (which indicates whether the element previously existed or is a new item in a retrofitting project). An example can be seen in the concept "Controller" (https://standards.buildingsmart.org/IFC/RELEASE/IFC4/ADD1/HTML/schema/ifcbuildingcontrolsdomain/pset/pset_controllertypecommon.htm).

Furthermore, during the process, the datatypes associated in IFC to each property have been identified and analysed in order to transform them into OWL. That is, not all the properties defined in IFC have been transformed in the same way. Table A.1 details the decisions taken for each datatype appearing in IFC properties.

Table A.1: Property transformations from IFC to OWL

IFC datatype	Transformation to OWL
logical	Transform to datatype property with range xsd:boolean
boolean	Transform to datatype property with range xsd:boolean
natural	Transform to datatype property with range xsd:nonNegativeInteger
integer	Transform to datatype property with range xsd:integer
string	Transform to datatype property with range xsd:string
{string}	Transform to datatype property with range xsd:string
Real (associated to a P_SINGLEVALUE)	Transform to object property that would be used to link to an instance of saref:Measurement
real (associated to a P_BOUNDEDVALUE)	Transform to two object properties (one for maximum value and another for minimum value) that would be used to link to an instance of saref:Measurement
ratio	Transform to object property that would be used to link to an instance of saref:Measurement
real ratio	Transform to object property that would be used to link to an instance of saref:Measurement
normalized ratio	Transform to object property that would be used to link to an instance of saref:Measurement
positive ratio	Transform to object property that would be used to link to an instance of saref:Measurement
complex	Transform to object property with open range

Finally, local restrictions for each class have been added indicating the expected use of each of the properties that can be applied to a class.

As mentioned, SAREF concepts have been extended when they needed to be specialized and properties from SAREF have been reused. In addition, other ontologies have been reused following the SAREF practices. More precisely the following classes have been extended:

- `saref:Device with s4bldg:BuildingDevice, s4bldg:TransportElement and s4bldg:VibrationIsolation`
- `saref:Actuator with s4bldg:Actuator`
- `saref:Sensor with s4bldg:Sensor`
- `geo:SpatialThing with s4bldg:PhysicalObject`

The following classes and properties have also been directly reused:

- `saref:hasValue`

As already commented some entities firstly defined in the SAREF4ENVI and SAREF4BLDG extensions have been included into SAREF3.1.1, and now are directly reused, namely:

- `saref:Observation`
- `saref:makesObservation`
- `saref:hasProperty`
- `saref:relatesToProperty`

Annex B (informative): Bibliography

- ETSI TS 103 267: "SmartM2M; Smart Applications; Communication Framework".
- ETSI TS 102 689: "Machine-to-Machine communications (M2M); M2M Service Requirements".
- ETSI TS 118 101: "oneM2M, Functional Architecture (oneM2M TS-0001)".
- ETSI TS 118 102: "oneM2M; Requirements (oneM2M TS-0002)".

Annex C (informative): Change history

Date	Version	Information about changes
10.12.2023	V1.1.3	Mauro: published version V1.1.2 taken as basis and change version to V1.1.3
16.12.2023	V2.0.1	Joachim: Version number set to V2.0.1, Annex Change History added
01.10.2024	V2.1.1	Technical Officer review before publication pre-processing after TB approval

History

Document history		
V1.1.1	January 2017	Publication
V1.1.2	May 2020	Publication
V2.1.1	October 2024	Publication