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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 5 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".

Modal verbs terminology

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1 Scope

The present document presents SAREF4INMA, a SAREF extension for the Industry and Manufacturing domains.

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 103 411 (V1.1.1) (2017-02): "SmartM2M; Smart Appliances; SAREF extension investigation".

[i.2] ETSI TR 103 507 (V1.1.1) (2018-10): "SmartM2M; SAREF extension investigation; Requirements for industry and manufacturing domains".

[i.3] ETSI TS 103 410-3 (V1.1.1) (2017-01): "SmartM2M; Smart Appliances Extension to SAREF; Part 3: Building Domain".

[i.4] ISO/IEC 11179-6: "Information technology -- Metadata registries (MDR) -- Part 6: Registration".

[i.5] ISO 29002 (all parts): "Industrial automation systems and integration -- Exchange of characteristic data".

[i.6] ISO 6532: "Portable chain-saws -- Technical data".

[i.7] BS EN 10204 (2004): "Metallic products -- Types of inspection documents".

[i.8] IEC 61512 (all parts): "Batch control".

[i.9] ISO/IEC 11578:1996: "Information technology - Open Systems Interconnection - Remote Procedure Call (RPC)".

[i.10] Recommendation ITU-T X.667/ISO/IEC 9834-8:2005:" Information technology -- Procedures for the operation of object identifier registration authorities: Generation of universally unique identifiers and their use in object identifiers".

[i.11] ETSI TS 103 264 (v.3, work in progress): "SmartM2M; Smart Applications; Reference Ontology and oneM2M Mapping".

[i.12] IEC 62264 (all parts): "Enterprise-control system integration".

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 explicitly 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:

ABS	Acrylonitrile Butadiene Styrene
BIC	Brainport Industries Campus
BS	British Standard
EAN	European Article Number
EN	European Norm
GS1	Global Standards One
GTIN	Global Trade Item Number
GUID	Globally Unique IDentifier
ID	Identifier
IEC	International Electrotechnical Commission
IRDI	International Registration Data Identifier
ISO	International Organisation for Standardization
ITF	Interleaved 2 of 5
ITU-T	International Telecommunication Union - Telecommunications sector
OWL	Web Ontology Language
OWL-DL	Web Ontology Language - Description Logic
QR	Quick Response code
RAMI	Reference Architectural Model Industry 4.0
RFID	Radio Frequency Identification
RPC	Remote Procedure Call
SAREF	Smart Applications REFerence ontology
SAREF4BLDG	SAREF extension for buildings
SAREF4INMA	SAREF extension for industry and manufacturing domains
TR	Technical Report
TS	Technical Specification
UCC	Uniform Commercial Code
UPC	Universal Product Code
UPC-A	Universal Product Code

NOTE: UPC-A is an 11 digit variation of UPC, as opposed to UPC-E which is the 6 digit variation.

UUID	Universally Unique Identifier

4 SAREF4INMA ontology and semantics

4.1 Introduction and overview

The present document is a technical specification of SAREF4INMA, an extension of SAREF that was created for the industry and manufacturing domain. SAREF4INMA was created to be aligned with related initiatives in the smart industry and manufacturing domain in terms of modelling and standardization, such as the Reference Architecture Model for Industry 4.0 (RAMI), which combines several standards used by the various national initiatives in Europe that support digitalization in manufacturing. These initiatives include, but are not limited to, the platform Industrie 4.0 in Germany, the Smart Industry initiative in the Netherlands, Industria 4.0 in Italy, the 'Industrie du future initiative' in France and more.

SAREF4INMA is an OWL-DL ontology that extends SAREF with 24 classes (in addition to a number of classes directly reused from the SAREF ontology and the SAREF4BLDG extension), 20 object properties (in addition to a number of object properties reused from the SAREF ontology and the SAREF4BLDG extension) and 11 data type properties. SAREF4INMA focuses on extending SAREF for the industry and manufacturing domain to solve the lack of interoperability between various types of production equipment that produce items in a factory and, once outside the factory, between different organizations in the value chain to uniquely track back the produced items to the corresponding production equipment, batches, material and precise time in which they were manufactured.

The full list of use cases, standards and requirements that guided the creation of SAREF4INMA are described in the associated ETSI TR 103 507 [i.2]. The "zero defect manufacturing" use case has been used as basis for the creation of SAREF4INMA in the present document. This use case is concerned with improving the manufacturing process in terms of flexibility to timely change from one manufactured product to another, generating as little yield loss as possible. Also the "smart services for product in use" and "smart product lifecycle" use cases are acknowledged in the associated ETSI TR 103 507 [i.2] as especially relevant for SAREF4INMA, as they pose semantic interoperability issues for, respectively:

1) the manufacturing companies that remain responsible for the proper functioning of a product during its entire lifecycle, also when the product has left the factory; and

2) the various, interacting parties involved in the value chain (e.g. manufacturer, user, servicing organization, parts supplier, etc.) that need to refer to a common digital footprint of a product to allow for its management during its entire lifecycle.

Note that SAREF4INMA specified in the present document provides a first SAREF extension for the industry and manufacturing domain, based on the (limited set of) use cases mentioned above and an initial list of standards for digitalization, communication, engineering and life-cycle, covering relevant concepts such as factory, production equipment, item, material and batch, as described in ETSI TR 103 507 [i.2]. However, as all the SAREF ontologies, SAREF4INMA is a dynamic semantic model that should be used, validated and improved over time with and by the stakeholders in the industry and manufacturing domain in an iterative and interactive manner to accommodate more use cases, standards and generate new requirements as needed.

The prefixes and namespaces used in SAREF4INMA and in the present document are listed in Table 1.

Table 1: Prefixes and namespaces used within the SAREF4INMA ontology

Prefix	Namespace
s4inma	https://w3id.org/def/saref4inma#
saref	https://w3id.org/saref#
s4bldg	https://w3id.org/def/saref4bldg#
dcterms	http://purl.org/dc/terms/
owl	http://www.w3.org/2002/07/owl#
rdf	http://www.w3.org/1999/02/22-rdf-syntax-ns#
rdfs	http://www.w3.org/2000/01/rdf-schema#
skos	http://www.w3.org/2004/02/skos/core#
om	http://www.wurvoc.org/vocabularies/om-1.8/
xsd	http://www.w3.org/2001/XMLSchema#
geo	http://www.w3.org/2003/01/geo/wgs84_pos#

4.2 SAREF4INMA

4.2.1 General Overview

An overview of the SAREF4INMA ontology is provided in Figure 1, where rectangles containing an orange circle are used to denote classes created in SAREF4INMA, while rectangles containing a green circle denote classes reused from other ontologies, such as SAREF or SAREF4BLDG. For all the entities described in the present document, it is indicated whether they are defined in the SAREF4INMA extension or elsewhere by the prefix included before their identifier, i.e. if the element is defined in SAREF4INMA the prefix is `s4inma`, while if the element is reused from another ontology it is indicated by a prefix according to Table 1 (e.g. `saref` refers to SAREF and `s4bldg` refers to SAREF for building).

Arrows with white triangles on top 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.

Directed arrows are used represent properties between classes.

Note that Figure 1 aims at showing a global overview of the main classes of SAREF4INMA and their mutual relations. More details on the different parts of Figure 1 are provided from clause 4.2.2 to clause 4.2.4.

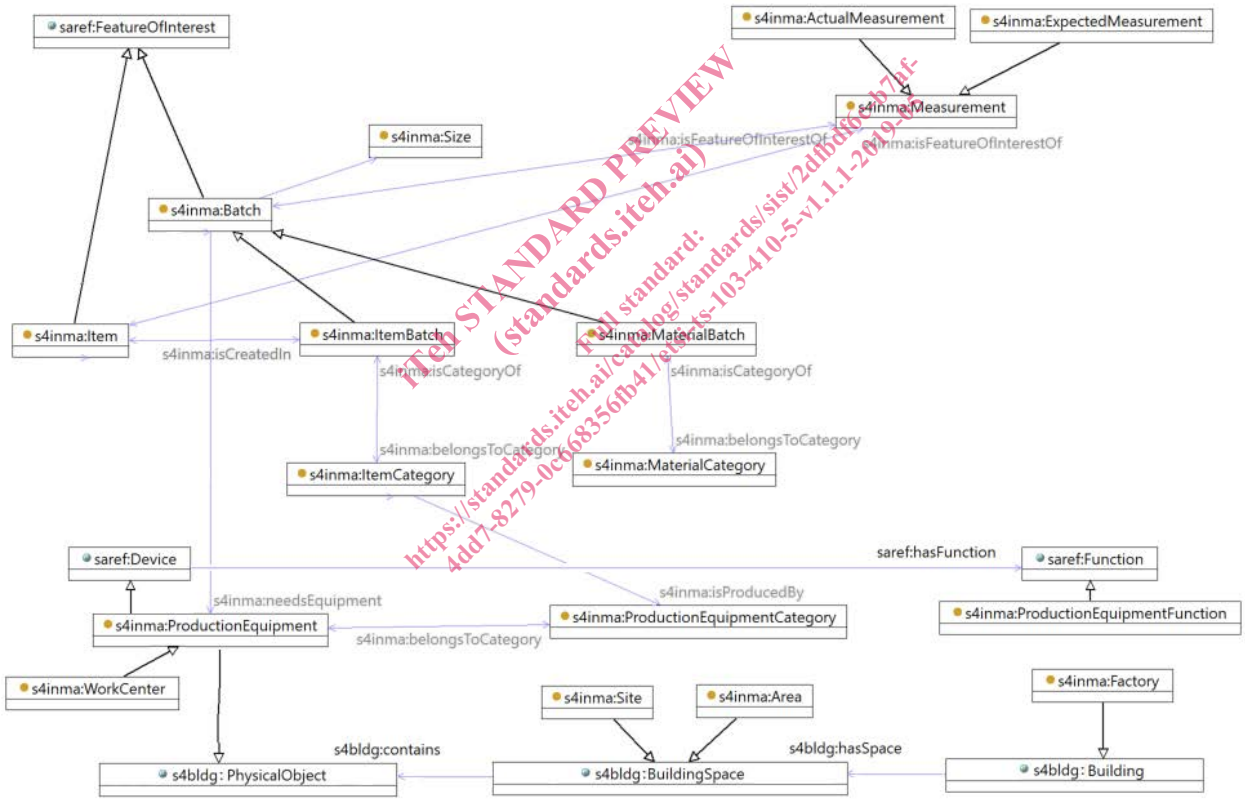

Figure 1: SAREF4INMA overview

Figure 2 shows the hierarchy of classes and properties defined in SAREF4INMA.

Orange circles represent classes of SAREF4INMA. Object properties - which are properties between two classes - are denoted by blue rectangles, while datatype properties - which are properties between a class and a data type, such as `xsd:string` or `xsd:dateTime` - are denoted by green rectangles.


Classes
s4inma:Area
s4inma:Batch
s4inma:ItemBatch
s4inma:MaterialBatch
s4inma:Factory
s4inma:ID
s4inma:GTIN12ID
s4inma:GTIN13ID
s4inma:GTIN14ID
s4inma:GTIN8ID
s4inma:IRDI
s4inma:UUID
s4inma:Item
s4inma:ItemCategory
s4inma:MaterialCategory
s4inma:Measurement
s4inma:ActualMeasurement
s4inma:ExpectedMeasurement
s4inma:ProductionEquipment
s4inma:WorkCenter
s4inma:ProductionEquipmentCategory
s4inma:ProductionEquipmentFunction
s4inma:Site
s4inma:Size
Properties
s4inma:belongsToCategory
s4inma:consistsOfBatch
s4inma:consistsOfItem
s4inma:creates
s4inma:hasFeatureOfInterest
s4inma:hasIdentifier
s4inma:hasGTIN12ID
s4inma:hasGTIN13ID
s4inma:hasGTIN14ID
s4inma:hasGTIN8ID
s4inma:hasIRDI
s4inma:hasUUID
s4inma:hasSize
s4inma:hasUpdate
s4inma:isCategoryOf
s4inma:isCreatedIn
s4inma:isFeatureOfInterestOf
s4inma:isProducedBy
s4inma:needsEquipment
s4inma:produces
s4inma:hasCertificate
s4inma:hasIDValue
s4inma:hasGTIN12IDValue
s4inma:hasGTIN13IDValue
s4inma:hasGTIN14IDValue
s4inma:hasGTIN8IDValue
s4inma:hasIRDIValue
s4inma:hasUUIDValue
s4inma:hasModelNumber
s4inma:hasSerialNumber
s4inma:hasVersion

Figure 2: SAREF4INMA classes and properties hierarchy

4.2.2 Item and Batch

This clause focuses on the classes of SAREF4INMA that describe an item produced in a factory. The classes of interest, which are `s4inma:Item`, `s4inma:ItemCategory`, `s4inma:MaterialCategory`, `s4inma:Batch`, `s4inma:ItemBatch`, `s4inma:MaterialBatch` and `s4inma:ID`, are shown in Figure 3.

An Item is a tangible object that represents either the goods produced by an organization's production process or individually traced supplies (i.e. sub-assemblies of supplies). An item can be individually traced using an ID. SAREF4INMA allows to use several types of IDs, such as the Global Trade Item Number (GTIN) defined by GS1 (https://www.gs1.org/), used by organizations to uniquely identify their trade items as products or services that are priced, ordered or invoiced at any point in the supply chain. There are four GTIN formats (GTIN-8, GTIN-12, GTIN-13, GTIN-14) and SAREF4INMA defines classes and properties for each of them. SAREF4INMA defines also classes and properties to associate items to the International Registration Data Identifier (IRDI), which is based on the international standards ISO/IEC 11179-6 [i.4], ISO 29002 [i.5] and ISO 6532 [i.6]. An example of relevant standard that uses IRDIs is the eCl@ss specification (https://www.eclass.eu/en/) for grouping materials, products and services. Other types of IDs are defined in SAREF4INMA, such as the Universally Unique Identifier (UUID), or can be further defined ad-hoc by the ontology users by creating new classes as subclasses of the `s4inma:ID` class.

An Item can recursively consist of other items (e.g. a shaver consists of a shaver head, motor and body) and can be the feature of interest of a measurement (e.g. a shaver can be the feature of interest of a temperature measurement made by a welding machine used to join different parts in the production of the shaver). An item is created exactly in one ItemBatch, which describes a uniform collection of items produced at a certain time using a certain production equipment. An ItemBatch consists of a set of items with similar properties (e.g. a certain brand and model of sensors made using a certain production line). An ItemBatch is a specialization of the more general Batch, which can be further specialized in a MaterialBatch. The difference between ItemBatch and MaterialBatch is that individual items can be traced in an ItemBatch (e.g. it is possible to trace an individual metal sheet in an ItemBatch), whereas it is not possible to exactly trace material in a MaterialBatch, (e.g. it is not possible to trace the exact piece of raw plastic material from a MaterialBatch, as the raw plastic is a volume, not identifiable in a specific sheet like in the case of metal sheets).

Material batches can be equipped with quality certificates, such as the BS EN 10204:2004 [i.7] category 3.1 steel quality certificate (https://standardsdevelopment.bsigroup.com). These certificates provide additional information about the material in the batch. Furthermore, MaterialBatches belong to some MaterialCategory, which describes a certain type of material (e.g. a certain type of steel sheets). Analogously, item batches belong to some ItemCategory, which describes a single type of Items (e.g. a certain type of sensor). An ItemCategory is in turn produced by some ProductionEquipmentCategory (see clause 4.2.3). The essential properties of each Item in all ItemBatches are the same. However, each ItemBatch might use different MaterialBatches and/or different ProductionEquipment. Therefore, small deviations between batches might occur, while the essential properties of all Items related to an ItemCategory are similar. Finally, the time that a batch is produced can be recorded using the `time:hasBeginning` and `time:hasEnd` properties.

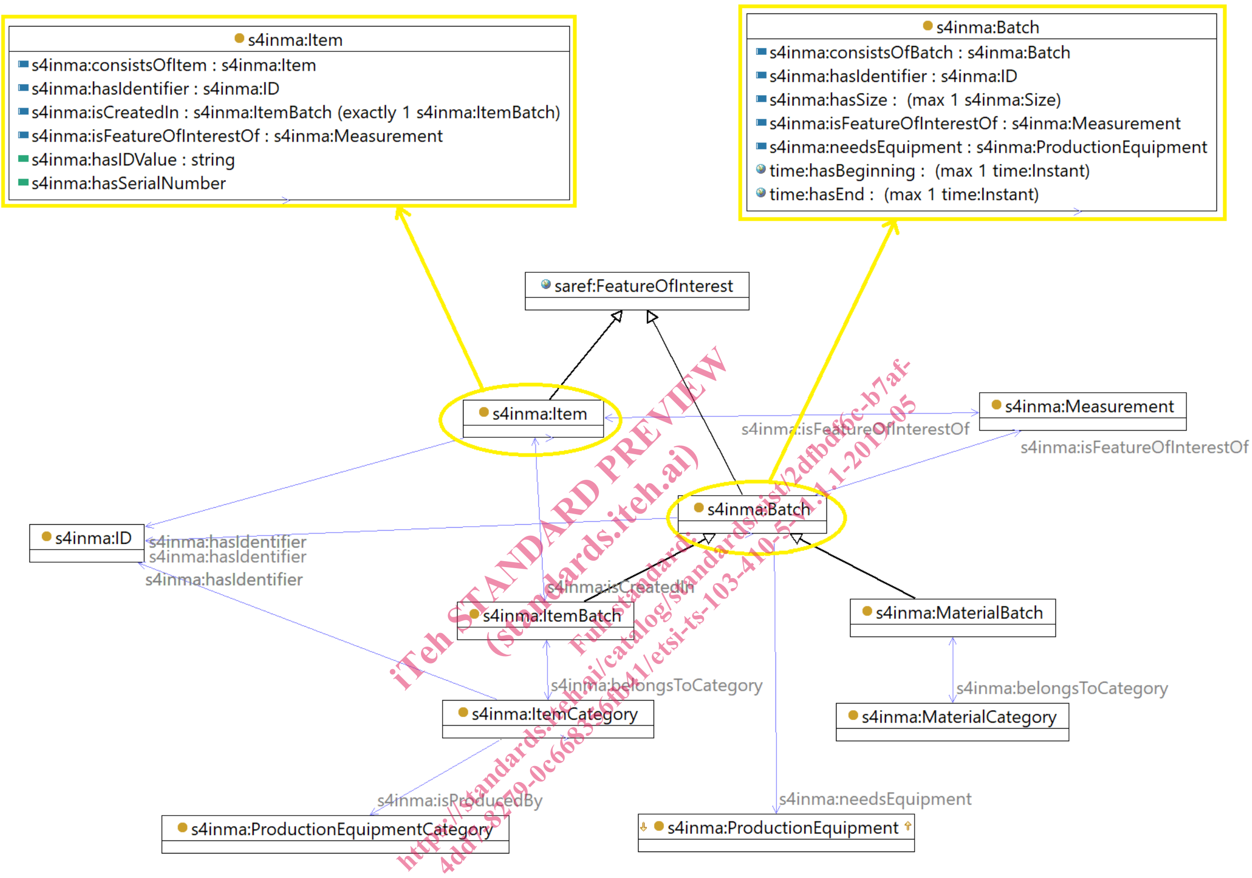
s4inma:Item
s4inma:consistsOfItem : s4inma:Item
s4inma:hasIdentifier : s4inma:ID
s4inma:isCreatedIn : s4inma:ItemBatch (exactly 1 s4inma:ItemBatch)
s4inma:isFeatureOfInterestOf : s4inma:Measurement
s4inma:hasIDValue : string
s4inma:hasSerialNumber
s4inma:Batch
s4inma:consistsOfBatch : s4inma:Batch
s4inma:hasIdentifier : s4inma:ID
s4inma:hasSize : (max 1 s4inma:Size)
s4inma:isFeatureOfInterestOf : s4inma:Measurement
s4inma:needsEquipment : s4inma:ProductionEquipment
time:hasBeginning : (max 1 time:Instant)
time:hasEnd : (max 1 time:Instant)
saref:FeatureOfInterest
s4inma:Item
s4inma:Measurement
s4inma:isFeatureOfInterestOf
s4inma:isFeatureOfInterestOf
s4inma:Batch
s4inma:ID
s4inma:hasIdentifier
s4inma:hasIdentifier
s4inma:hasIdentifier
s4inma:isCreatedIn
s4inma:ItemBatch
s4inma:MaterialBatch
s4inma:belongsToCategory
s4inma:belongsToCategory
s4inma:ItemCategory
s4inma:MaterialCategory
s4inma:isProducedBy
s4inma:needsEquipment
s4inma:ProductionEquipmentCategory
s4inma:ProductionEquipment

Figure 3: Item, Batch and related classes