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Part 6: Smart Agriculture and Food Chain 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 6 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 SAREF4AGRI, an extension of SAREF for the Smart Agriculture and Food Chain Domain.

2 References

2.1 Normative references

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

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The following referenced documents are necessary for the application of the present document.

[1] ETSI TS 103 264 (V2.1.1) (2017-03): "SmartM2M; Smart Appliances; Reference Ontology and oneM2M Mapping".

2.2 Informative references

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

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

[i.1] ETSI TR 103 411 (V1.1.1) (2017-02): "SmartM2M Smart Appliances SAREF extension investigation".

[i.2] ETSI TR 103 511 (V1.1.1) (2018-10): "SmartM2M; SAREF extension investigation; Requirements for AgriFood domain".

[i.3] ETSI TS 103 410-4 (V1.1.1) (2019-04): "SmartM2M; Smart Appliances Extension to SAREF; Part 6: Smart Cities Domain".

[i.4] Verhoosel J. and Spek J.: "Applying Ontologies in the Dairy Farming Domain for Big Data Analysis". Proceedings of the 1st Semantic Web Technologies for the Internet of Things (SWIT) 2016 workshop, co-located with 15th International Semantic Web Conference (ISWC 2016), Kobe, Japan, October 2016, pg. 91-100, CEUR.

NOTE: Available at http://ceur-ws.org/Vol-1783/.

[i.5] ETSI TS 103 264 (V3.1.1): "SmartM2M; Smart Applications; Reference Ontology and oneM2M Mapping".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

ontology: formal specification of a conceptualization, used to 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:

AEF	Agricultural industry Electronics Foundation
FOAF	Friend of a Friend
GPS	Global Positioning System
ICAR	Global Standard for Livestock Data
IT	Information Technology
NDVI	Normalized Difference Vegetation Index
OM	Ontology of units of Measure
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
SAREF4AGRI	SAREF extension for the Smart Agriculture and Food Chain Domain
SAREF4BLDG	SAREF extension for buildings
SAREF4CITY	SAREF extension for Smart Cities
SOSA	Sensor Observation Sampling Actuator
SSN	Semantic Sensor Network
STF	Specialists Task Force
TR	Technical Report
TS	Technical Specification

4 SAREF4AGRI ontology and semantics

4.1 Introduction and overview

The present document has been developed in the context of the STF 534, an ETSI specialists task force that was established with the goal to extend SAREF for the domains of Smart Cities, Smart Industry & Manufacturing, and Smart AgriFood (https://portal.etsi.org/STF/stfs/STFHomePages/STF534). In particular, the present document is a technical specification of SAREF4AGRI, an OWL-DL ontology that extends SAREF for the Smart Agriculture and Food Chain domain. The intention of SAREF4AGRI is to connect SAREF with existing ontologies (such as W3C SSN, W3C SOSA, GeoSPARQL, etc.) and important standardization initiatives and ontologies in the Smart Agriculture and Food Chain domain, including ICAR for livestock data (https://www.icar.org/), AEF for agricultural equipment (http://www.aef-online.org), Plant Ontology Consortium for plants (http://archive.plantontology.org), AgGateway for IT support for arable farming (http://www.aggateway.org/), as mentioned in the associated SAREF4AGRI requirements document ETSI TR 103 511 [i.2].

To show the potential of SAREF4AGRI, the present document focuses on two examples, which are the "livestock farming" and "smart irrigation" use cases. Various other examples exist in the Smart Agriculture and Food Chain domain, such as arable farming, horticulture, agricultural equipment, greenhouses and food chain, as mentioned in [i.2] (for an exhaustive list of use cases, see also the H2020 Large Scale Pilot "Internet of Food and Farm 2020 (IoF2020)" at https://iof2020.eu/trials). However, it was necessary to make actionable choices within the STF 534 timeframe and the available resources, thus livestock farming and smart irrigation have been chosen as the two initial examples to create SAREF4AGRI. As a next step, it is recommended to further refine the proposed livestock farming and smart irrigation examples to add relevant sensors that are not considered yet, and also consider additional use cases to create new releases of SAREF4AGRI, following and extending the examples provided in the present document. As all the SAREF ontologies, SAREF4AGRI is a dynamic semantic model that is meant to evolve over time. Therefore, the stakeholders in the AgriFood domain (starting from the ICAR, AEF and AgGateway initiatives) are invited to use, validate and provide feedback on SAREF4AGRI, collaborating with the SAREF ontology experts to improve and evolve SAREF4AGRI in an iterative and interactive manner, so that changes and additions can be incorporated in future releases of the present document.

The livestock farming and smart irrigation use cases used as basis to create SAREF4AGRI in the present document are concerned with the integration of multiple data sources for the purpose of providing decision support services located on the local "Farm Management System" of the farmers or provided by a service over the network. Multiple data sources of interest include GPS, meteorological data (both historic and current), remote observation (via satellite sources such as Copernicus) and local observation using near or proximal sensors. As an extension of SAREF, which is a semantic model for IoT that describes smart devices and applications in terms of their functions, services, states and measurements [1], SAREF4AGRI is concerned with the description of proximal sensors that measure a variety of relevant parameters for agriculture, including: (on animal) movement, temperature, etc., (in the soil) moisture/humidity, Ph value, salinity, compaction, (on plant) plant colour (NDVI), etc. The measurements from these sensors need to be integrated by a decision support service to enable the planning of (for example) a treatment plan for animals (in a livestock scenario), or a decision to irrigate or harvest (in an irrigation, horticulture or greenhouse context). The requirements used to create the SAREF4AGRI extension specified in the present document are described in the associated ETSI TR 103 511 [i.2].

The prefixes and namespaces used in SAREF4AGRI and in the present document are listed in Table 1.

Table 1: Prefixes and namespaces used within the SAREF4AGRI ontology

Prefix	Namespace
s4agri	https://w3id.org/def/saref4agri#
saref	https://w3id.org/saref#
dbpedia	http://dbpedia.org/resource/
dcterms	http://purl.org/dc/terms/
owl	http://www.w3.org/2002/07/owl#
om	http://www.wurvoc.org/vocabularies/om-1.8/
rdf	http://www.w3.org/1999/02/22-rdf-syntax-ns#
rdfs	http://www.w3.org/2000/01/rdf-schema#
sosa	http://www.w3.org/ns/sosa/
ssn	http://www.w3.org/ns/ssn/
xsd	http://www.w3.org/2001/XMLSchema#
geo	http://www.opengis.net/ont/geosparql#
wgs84	http://www.w3.org/2003/01/geo/wgs84_pos#
foaf	http://xmlns.com/foaf/spec/#
taxrank	http://purl.obolibrary.org/obo/taxrank.owl#
org	https://schema.org/

4.2 SAREF4AGRI

4.2.1 General Overview

An overview of the SAREF4AGRI ontology is provided in Figure 1. For all the entities described in the present document, it is indicated whether they are defined in the SAREF4AGRI extension or elsewhere by the prefix included before their identifier, i.e. if the element is defined in SAREF4AGRI, the prefix is `s4agri`, 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 SAREF4AGRI 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.

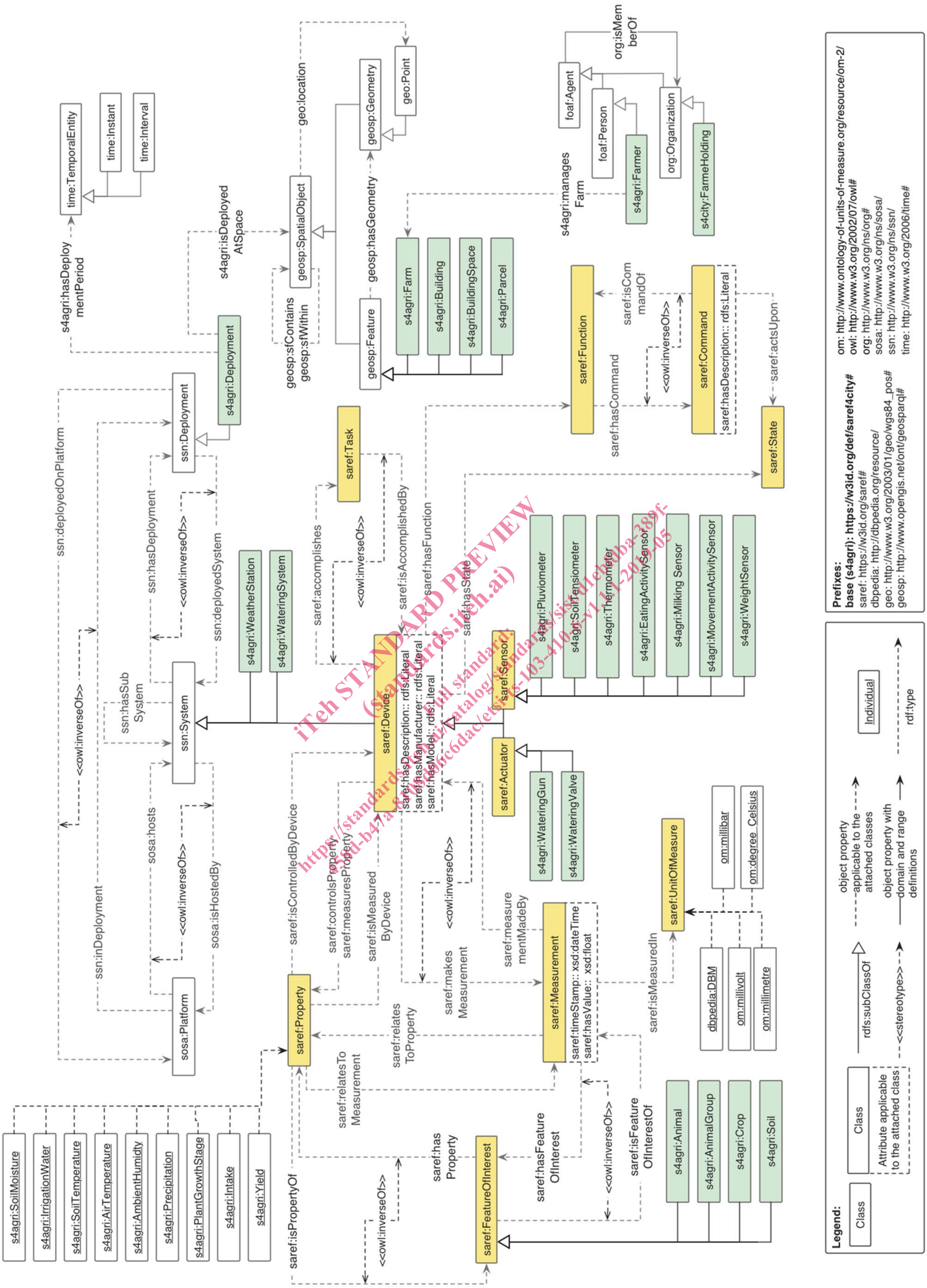

Figure 1: SAREF4AGRI overview

4.2.2 Platform, System and Deployment

The model defined in SAREF4AGRI for representing platforms, systems and deployments is depicted in Figure 2. The main entities in the modelling are represented by the `ssn:System` and `ssn:Deployment` classes. Note that the design patterns for modelling these concepts have been taken from the W3C SSN ontology and, as a best practice for reuse, the SAREF4AGRI model refers directly to the URIs of the SSN (http://www.w3.org/ns/ssn/) and SOSA (http://www.w3.org/ns/sosa/) ontologies.

The `ssn:System` class in the SSN ontology represents a system and is components as specific devices, actuators or sensors. Moreover, the `ssn:Deployment` class from the SSN ontology describes the deployment of one or more systems on a `sosa:Platform` for a particular purpose for a given time period. SAREF4AGRI defines a `saref:Device` as subclass of an `ssn:System` and extends the `ssn:Deployment` class by means of the `s4agri:Deployment` class. In this way, it is possible to represent a specific installation of a certain agricultural system (e.g. a smart irrigation system) in a given space (expressed by means of the property `s4agri:hasDeploymentPeriod`) and at a given temporal frame (expressed by means of the property `s4agri:isDeployedAtSpace`) where SAREF4AGRI devices (e.g. a pluviometer, a soil tensiometer, a weather station and a watering gun) can be deployed. The deployment can involve a given `sosa:Platform` which hosts the system deployed in such deployment. In order to represent temporal information the TIME ontology has been reused. For the geographical information both the GeoSPARQL ontology (http://www.opengis.net/ont/geosparql#) and the WGS84 Geo vocabulary (http://www.w3.org/2003/01/geo/wgs84_pos#) are reused.

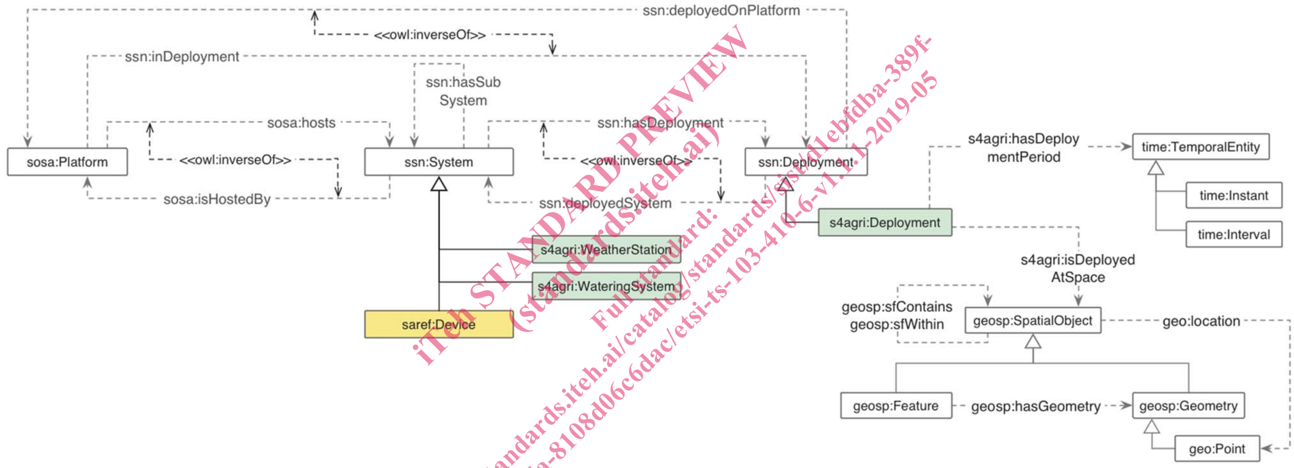

Figure 2: Platform, System and Deployment

Table 2 summarizes the properties that characterize the `s4agri:Deployment` class.

Table 2: Properties of Deployment

Property	Definition
s4agri:Deployment ssn:deployedOnPlatform some sosa:Platform	The relation between a deployment and the platform in which it is deployed.
s4agri:Deployment ssn:deployedSystem some ssn:System	The relation between a deployment and the system deployed.
s4agri:Deployment s4agri:hasDeployementPeriod some time:TemporalEntity	The relation between a deployment and the time span during which the systems are deployed.
s4agri:Deployment s4agri:isDeployedAtSpace somegeosp:SpatialObject	The relation between a deployment and the spatial area in which the systems are deployed.

4.2.3 Measurement

As shown in Figure 3, the modelling of measurements in SAREF4AGRI relies on the measurement model proposed in SAREF to express information about a certain property to be measured, its measured value, its measurement unit and the time of the measurement.