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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";

Part 7: "Automotive Domain";

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

Part 9: "Wearables Domain";

Part 10: "Water 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).

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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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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 (V3.1.1) (2020-02): "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 103 411 (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 (V1.1.2) (2020-04): "SmartM2M; Extension to SAREF; Part 4: 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/.

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 [1] 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://saref.etsi.org/saref4agri/
saref	https://saref.etsi.org/core/
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.

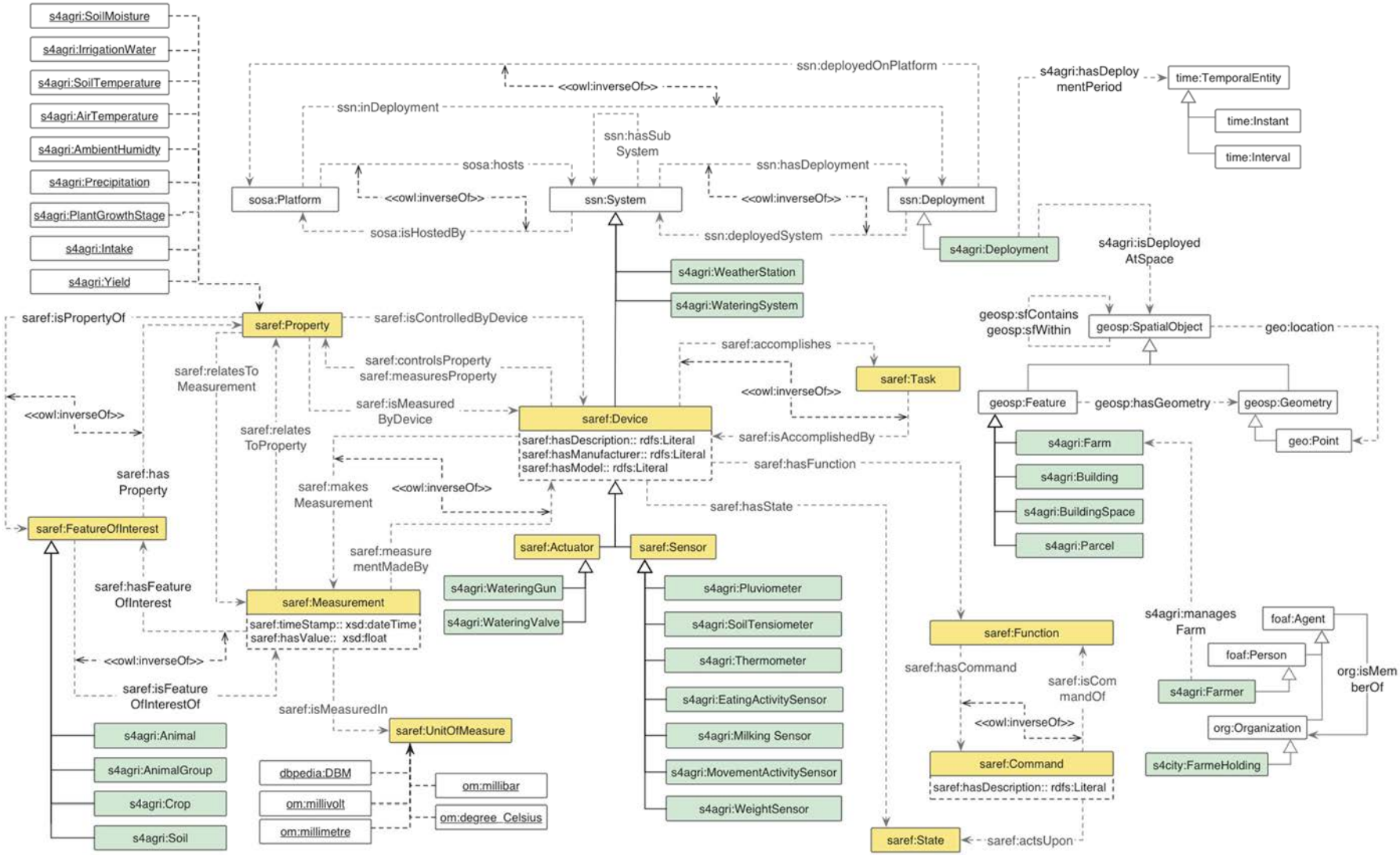

Figure 1: SAREF4AGRI overview

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.

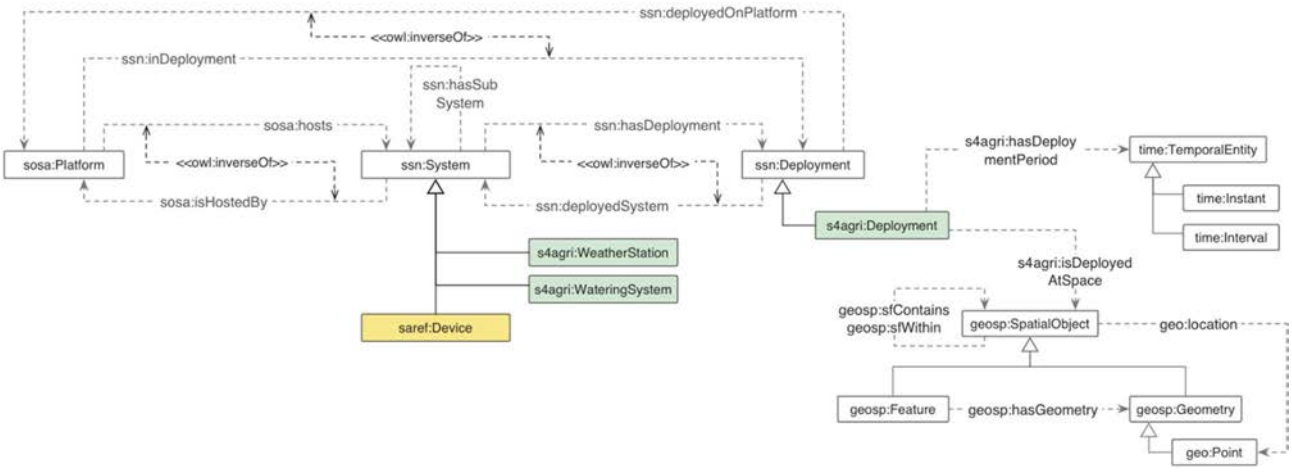

Figure 2: Platform, System and Deployment

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.

This modelling includes the `saref:FeatureOfInterest` (whose design pattern has been taken from the W3C SSN ontology) that provides the means to refer to the real world phenomena that is being observed in a given measurement (e.g. a cow can be defined in SAREF4AGRI as the feature of interest of a weight measurement made by a weight sensor). The reader is referred to the SAREF specification [1] for details about the modelling of measurements, whereas the present document includes details only for the new concepts created in SAREF4AGRI, such as the classes and instances added to support the livestock farming and smart irrigation use cases. Note that a work item ETSI TS 103 264 [1 has been opened to evolve the current SAREF core specification ETSI TS 103 264 [1] according to the latest developments in various sectors, including the input from the SAREF4AGRI extension in the present document. ETSI TS 103 264 [1 work item will result in an updated SAREF 3.0 core ontology. The following properties (to be included in SAREF 3.0) are reused in SAREF4AGRI to complete the model of measurements:

- `saref:isPropertyOf` (and its inverse `saref:hasProperty`) to link the property being observed with the feature of interest.
- `saref:hasFeatureOfInterest` (and its inverse `saref:isFeatureOfInterestOf`) to link a given measurement with the feature of interest being observed.
- `saref:measurementMadeBy` has been included as complement of the `saref:makesMeasurement`, as its inverse, to link a measurement and the device that produces it.

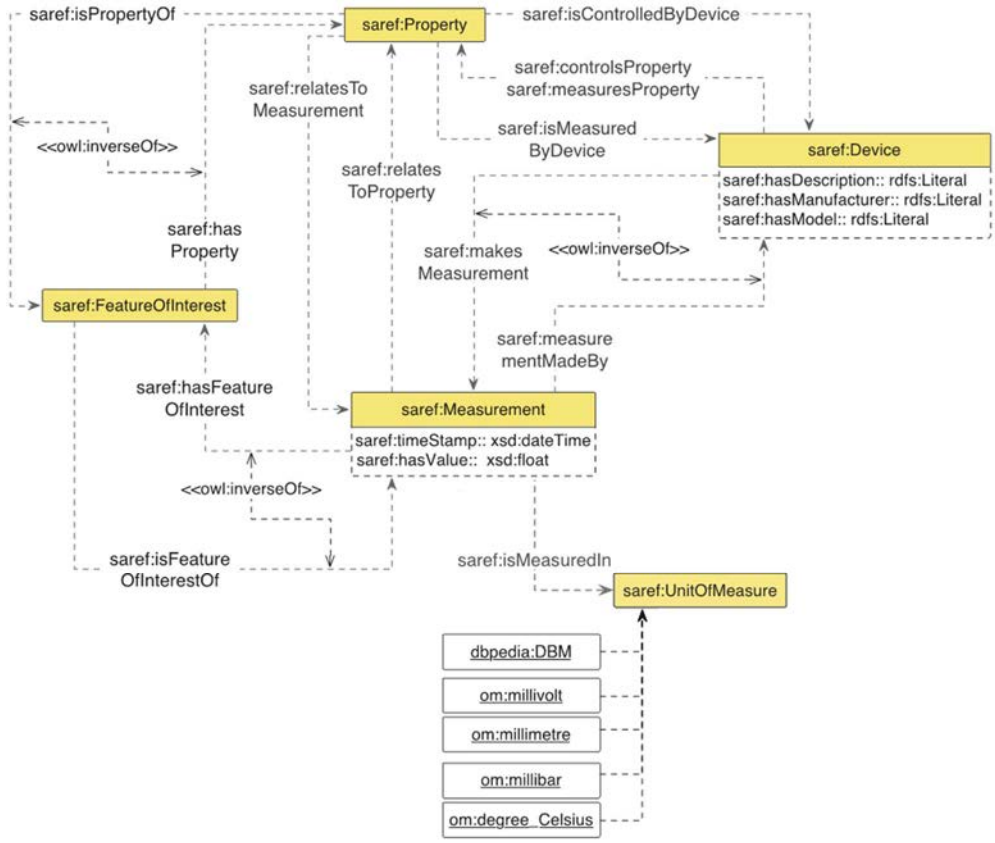

Figure 3: Measurement model

In order to support the Smart Irrigation use case, a number of units of measure have been added to SAREF4AGRI as instances of the `saref:UnitOfMeasure` class, namely `dbpedia:DBM` (decibel-milliwatts), `om:millivolt` (millivolt), `om:millimetre` (millimetre), `om:millibar` (millibar) and `om:degree_Celsius` (degree Celsius). Additionally, for the livestock farming use case the `om:Liter` unit has been added. These instances have been reused from DBpedia (https://wiki.dbpedia.org/) and the Ontology of units of Measure (OM) 2.0 (http://www.ontology-of-units-of-measure.org/).

In order to support the livestock farming use case (and potentially other use cases such as arable farming and horticulture in future SAREF4AGRI releases), the `s4agri:Animal`, `s4agri:AnimalGroup` and `s4agri:Crop` classes have been added to SAREF4AGRI as subclasses of `saref:FeatureOfInterest` (see clause 4.2.4).

In this way, measurements from relevant sensors (such as on animal activity movement, temperature, weight, milking yield, etc.) can be related via the `hasFeatureOfInterest` relation to specific e.g. (groups of) animals that are instances of the `saref:FeatureOfInterest` class. This relation is explained in more detail in the following clause.

4.2.4 Animal, Crop and Soil (Feature of Interest)

The main features of interest in SAREF4AGRI currently support (aspects of) the livestock farming and smart irrigation use cases and are represented by the `s4agri:Animal`, `s4agri:AnimalGroup`, `s4agri:Crop` and `s4agri:Soil` classes that are shown in Figure 4.

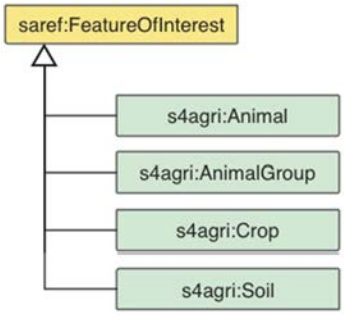

Figure 4: Animal, Crop and Soil

The `s4agri:Animal` class describes an animal that can be classified in SAREF4AGRI reusing the TAXRANK taxonomy vocabulary (http://purl.obolibrary.org/obo/taxrank.owl#). Besides the reuse of the TAXRANK taxonomy vocabulary, an animal is furthermore defined in SAREF4AGRI in order to have a birth and death date. An animal also has a unique identifier and can be part of one or more `s4agri:AnimalGroup` that are used to conduct experiments and observations on the livestock. Note that animals can be also specialized using subclasses, as is shown in the example in clause 4.3.1 with the `ex:LactatingCow` class that was created as a subclass of `s4agri:Animal`. Animals and animal groups are related to measurements via the `saref:FeatureOfinterest` concept of SAREF (see clause 4.2.3).

The `s4agri:Soil` class represents the upper layer of the earth in which plants grow. The `s4agri:Crop` class describes a collection of homogeneous plant species that is grown on a large scale commercially (especially a cereal, fruit, or vegetable) and is planted on a single location. A `s4agri:Crop` is grown on some `s4agri:Parcel`, which is an area of land, defined in SAREF4AGRI as subclass of the `geosp:Feature` (see clause 4.2.6). Moreover, `s4agri:Crop` is related to measurements via `saref:FeatureOfInterest` (see clause 4.2.3).

Table 3 and Table 4 summarize the definitions of the main classes and properties described above.

Table 3: Animal, Crop and Soil: class definitions

Class	Definition
s4agri:Animal	An individual and identifiable organism that feeds on organic matter, typically having specialized sense organs and nervous system and able to respond rapidly to stimuli. Animals can be further specialized using subclasses, for example, to represent a lactating cow that is a domesticated cow specialized for the production of milk.
s4agri:AnimalGroup	A collection of one or multiple s4agri:Animal.
s4agri:Crop	A collection of cultivated plants that is grown on a large scale commercially, especially a cereal, fruit, or vegetable.
s4agri:Soil	Upper layer of the earth in which plants grow.

Table 4: Animal and Crop: property definitions

Property	Definition
s4agri:Animal	
obo:TAXRANK_1000000 some obo:TAXRANK_0000000	The taxonomic ranking using TAXRANK.
s4agri:hasBirthDate max 1 xsd:dateTime	The birth date of an animal.
s4agri:hasDeathDate max 1 xsd:dateTime	The death date of an animal.
s4agri:hasID exactly 1 s4agri:ID	The unique identifier of an animal.
s4agri:isLocatedIn some geo:Feature	The physical location of an animal.
s4agri:isMemberOf some s4agri:AnimalGroup	An animal can be part of groups.
s4agri:name max 1 xsd:string	The name of an animal.
s4agri:AnimalGroup	
s4agri:hasMember some s4agri:Animal	The members of an AnimalGroup.
s4agri:receives some s4agri:Intake	The intake/consumption of an AnimalGroup.
s4agri:generates some s4agri:Yield	The yield generated by an AnimalGroup.
s4agri:isLocatedIn some geo:Feature	The physical location of an AnimalGroup.
s4agri:name max 1 xsd:string	The name of an AnimalGroup.
s4agri:Crop	
obo:TAXRANK_1000000 some obo:TAXRANK_0000000	The taxonomic ranking using TAXRANK.
s4agri:receives some s4agri:Intake	The intake/consumption of certain substances in a Crop.
s4agri:generates some s4agri:Yield	The yield generated by a Crop.
s4agri:hasPlantDate some xsd:DateTime	The day the crop is planted.
s4agri:hasHarvestDate some xsd:DateTime	The day the crop is harvested.
s4agri:Parcel	
s4agri:contains some s4agri:Crop	A parcel can contain some crops.
s4agri:name max 1 xsd:string	The name of a parcel.

4.2.5 Device

SAREF4AGRI extends the device hierarchy defined in SAREF in order to include devices needed to support the livestock farming and the smart irrigation use cases. These devices are shown in Figure 5. The devices included for the Smart Irrigation use case are: `s4agri:Pluviometer`, `s4agri:SoilTensiometer`, `s4agri:WeatherStation`, and `s4agri:WateringGun`. The devices included for the Livestock Farming use case are: `s4agri:MovementActivitySensor`, `EatingActivitySensor`, `s4agri:MilkingSensor`, and `s4agri:WeightSensor`.

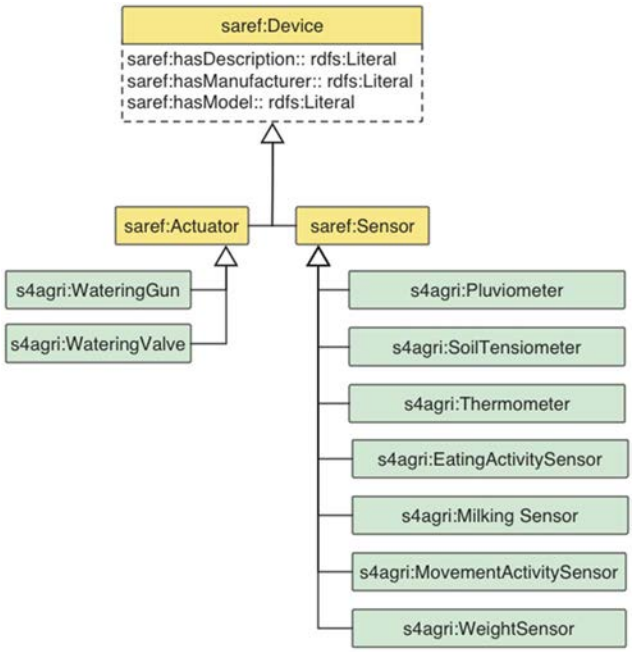

Figure 5: Device hierarchy

4.2.6 Property

SAREF4AGRI extends the property hierarchy defined in SAREF in order to include properties needed to support the livestock farming and the smart irrigation use cases. These devices are shown in Figure 6. The properties included for the smart irrigation use case are: `s4agri:SoilMoisture`, `s4agri:IrrigationWater`, `s4agri:SoilTemperature`, `s4agri:AirTemperature`, `s4agri:AmbientHumidity`, `s4agri:Precipitation` and `s4agri:PlantGrowthStage`.

The properties included for the livestock farming use case are: `s4agri:Yield` (which can further be specialized in subclasses, such as MilkYield, CropYield, MeatYield, MilkYield, etc. as needed) and `s4agri:Intake` (which can further be specialized in subclasses, such as FoodIntake for animals, FertilizerIntake for crops, etc. as needed).

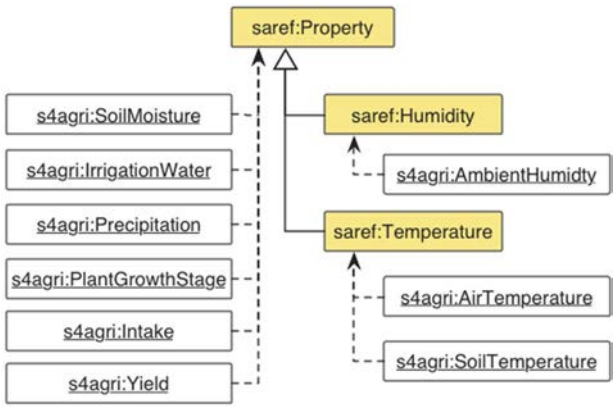

Figure 6: Property hierarchy

Table 5 summarizes the definitions of the classes described above.

Table 5: Intake and Yield: class definitions

Class	Definition
s4agri:Intake	The amount of food or other substance taken into the body of an animal or into the soil.
s4agri:Yield	The produced amount of food for animals or of agricultural products.
s4agri:SoilMoisture	The amount of water or humidity contained in the soil.
s4agri:IrrigationWater	The amount of water falling in the soil by irrigation methods.
s4agri:Precipitation	The amount of water falling in the soil by natural process (e.g. rain).
s4agri:PlantGrowthStage	The level or stage of growth of the plant.
s4agri:AmbientHumidity	The amount of water vapour in the air.
s4agri:AirTemperature	The degree or intensity of heat present in the air.
s4agri:SoilTemperature	The degree or intensity of heat present in the soil.

4.2.7 Topology

SAREF4AGRI adopts the same topology modelling pattern that is adopted in the SAREF4CITY extension [i.3], where existing standard ontologies have been reused for this purpose. As shown in Figure 7, for representing spatial objects in SAREF4AGRI, the `geosp:SpatialObject` class from GeoSPARQL has been reused along with its subclasses `geosp:Feature`, `geosp:Geometry` and the properties `geosp:sfContains`, `geosp:sfWithin` and `geosp:hasGeometry`. In addition, the class `geo:Point` and the property `geo:location` have been reused from the "WGS84 Geo Positioning vocabulary" (which is the W3C de-facto standard for geographical information) in order to be able to indicate that something is located at certain coordinates.

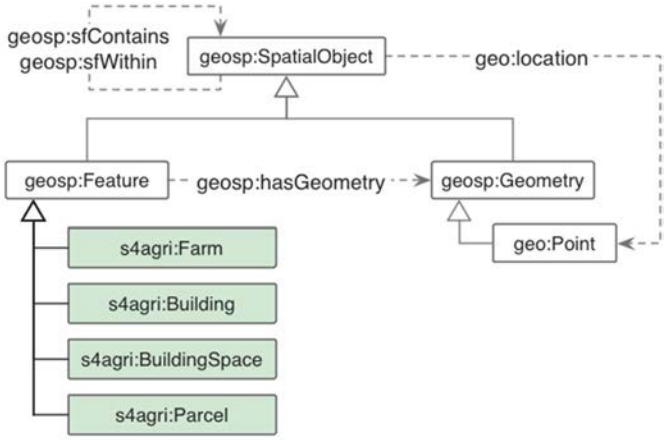

Figure 7: Topology model

For the purpose of SAREF4AGRI, the `geosp:Feature` class has been extended with the following subclasses:

- the s4agri:Farm
- the s4agri:Building
- the s4agri:BuildingSpace
- the s4agri:Parcel

A `s4agri:Farm` can contain one or more `s4agri:Building` and `s4agri:Parcel` (via the `geosp:sfContains` relation). Note that these types of feature are used in the present document as examples, but more feature types (and building types) can be added as needed. Moreover, a `s4agri:Building` can be further decomposed in one or more `s4agri:BuildingSpaces` (once again via the `geosp:sfContains` relation). As subclasses of `geosp:Feature`, all the classes mentioned above inherit the possibility to have a physical geometric description using `geosp:Geometry`, if needed (e.g. especially relevant for `s4agri:Parcel`). As subclasses of `geosp:SpatialObject`, all the classes mentioned above also inherit the possibility to use the `geo:location` property to indicate that something is located at certain coordinates (e.g. especially relevant for `s4agri:Bulding`).

4.2.8 Person and Organization

As it is modelled in the SAREF4CITY extension [i.3], also SAREF4AGRI reuses the FOAF vocabulary (http://xmlns.com/foaf/0.1/) and Schema.org vocabulary (https://schema.org/) to represent the concepts of Person and Organization. Figure 8 shows that in SAREF4AGRI the `foaf:Person` and `org:Organization` classes are extended with the `s4agri:Farmer` and `s4agri:FarmHolding` subclasses to describe farmers and their organizations. Both `foaf:Person` and `org:Organization` are subclass of `foaf:Agent`. Organizations (e.g. `s4agri:FarmHolding`) have members (e.g. farmers). Both `s4agri:Farmer` and `s4agri:FarmHolding` can manage some `s4agri:Farm`.

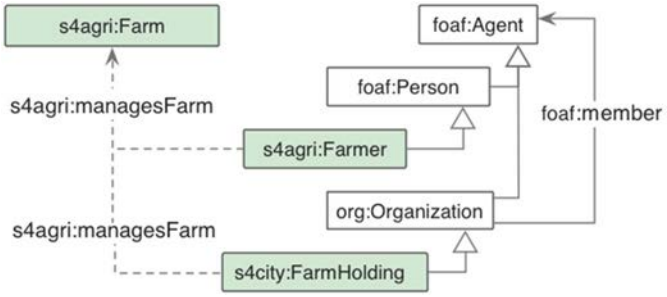

Figure 8: Person and Organization model

4.3 Instantiating SAREF4AGRI

4.3.1 Livestock farming

This clause shows an example of how to instantiate the SAREF4AGRI extension of SAREF for the livestock farming use case. The example describes a family company owned farm that grows certain crops and owns lactating cows. Various sensors are used in the farm to monitor animals and crops.

The first part of the example is related to the organizational aspects of the farm and is shown in Figure 9.

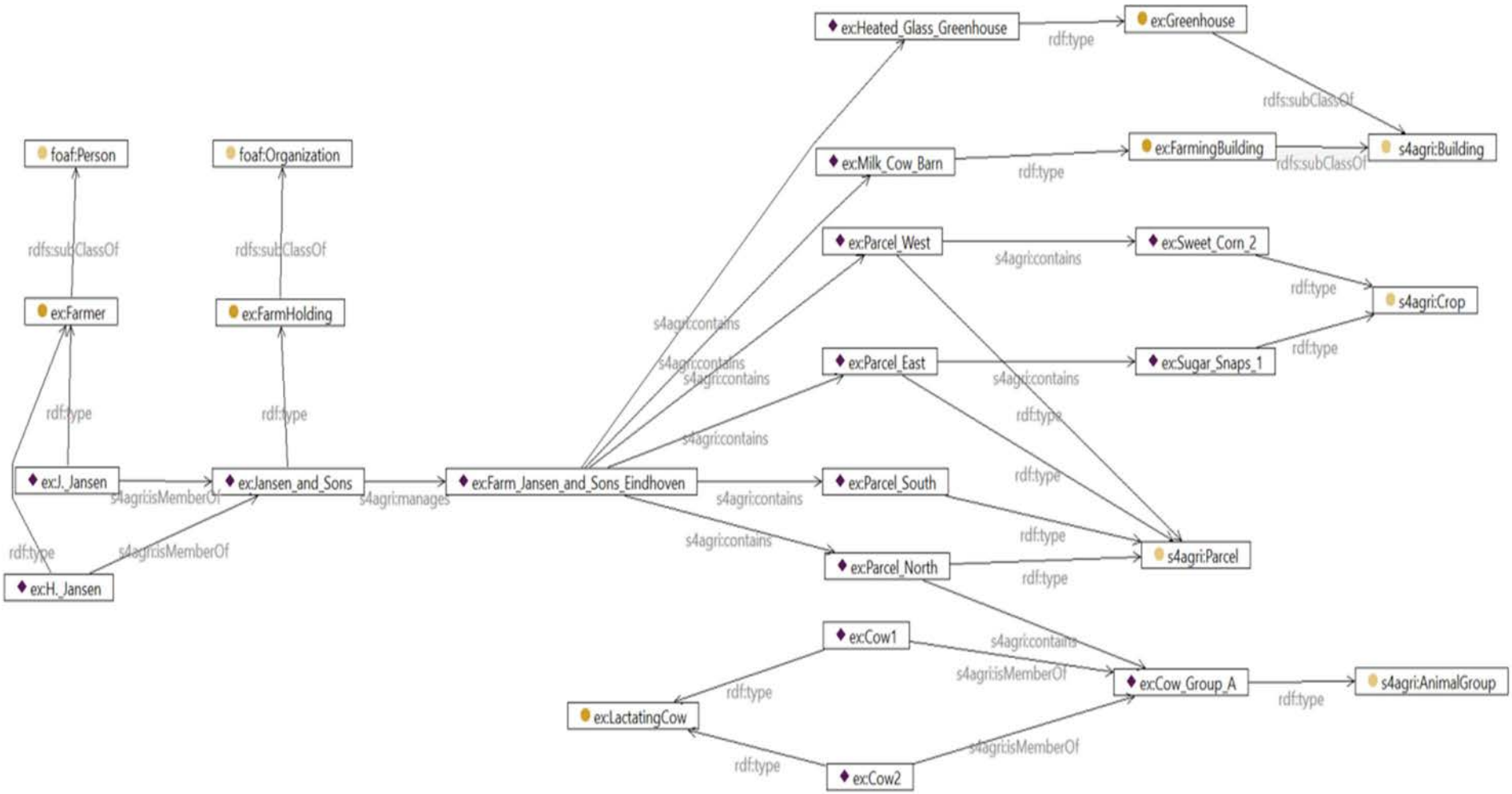

Figure 9: Farm example

Figure 9 shows two instances of a farmer, namely *ex:H. Jansen* and *ex:J. Jansen*, which are both members of the `s4agri:FarmHolding` *ex:Janse an Sons*. The organization manages the `s4agri:Farm` *ex:Farm Jansen and Son Eindhoven*.

Note that the `s4agri:Farm` is a subclass of `geosp:Feature` and consequently of `geo:SpatialObject`, which enables to describe the exact geometrical aspects of the area. Moreover, *ex:Farm Jansen and Son Eindhoven* contains the following additional instances of type `geosp:Feature`:

- four `s4agri:Parcel` (ex:Parcel South, ex:Parcel West, ex:Parcel North, ex:Parcel East)
- two `s4agri:Building` (ex:Milk Cow Barn, ex:Heated Glass Greenhouse)

Furthermore, the figure shows that *ex:Parcel East* and *ex:Parcel West* both contain some `s4agri:Crop` (*ex:Sweet Corn 1* and *ex:Sweet Corn 2*, respectively). Additionally, *ex:Parcel North* contains the `s4agri:AnimalGroup` *Cow Group A*, which consists of the `s4agri:Animals` *ex:Cow1* and *ex:Cow2*. Finally, Figure 9 shows that *ex:Parcel South* does not contain anything.

Figure 10 elaborates on *ex:Parcel North* that contains the *ex:Cow Group A* with two cows (i.e. *ex:Cow1* and *ex:Cow2*) which are similarly taxonomically described using the `TAXRANK` taxonomy vocabulary. The *ex:Cow Group A* generates `s4agri:MilkYield`, which is a type of `s4agri:Yield` and consequently a `s4agri:Property`. The example contains one instance of *Milk Yield* that represents the outcome of the milking procedure of a certain cow. The *Milk Yield* instance is measured in *om:Liter* by the *ex:MilkYieldSensor*. The *ex:MilkYieldSensor* is of type `s4agri:MilkingSensor`, which is a `saref:Sensor`, and thus a FunctionRelated `saref:Device`. Figure 10 further shows that the sensor is contained in an *ex:Milking Machine*, which is a `saref:Device`, and the *ex:Milking Machine* has a sensor that measures the yield. The measurements are directly linked to the sensor, instead of to the milk machine itself, because a large machine can have multiple sensors.

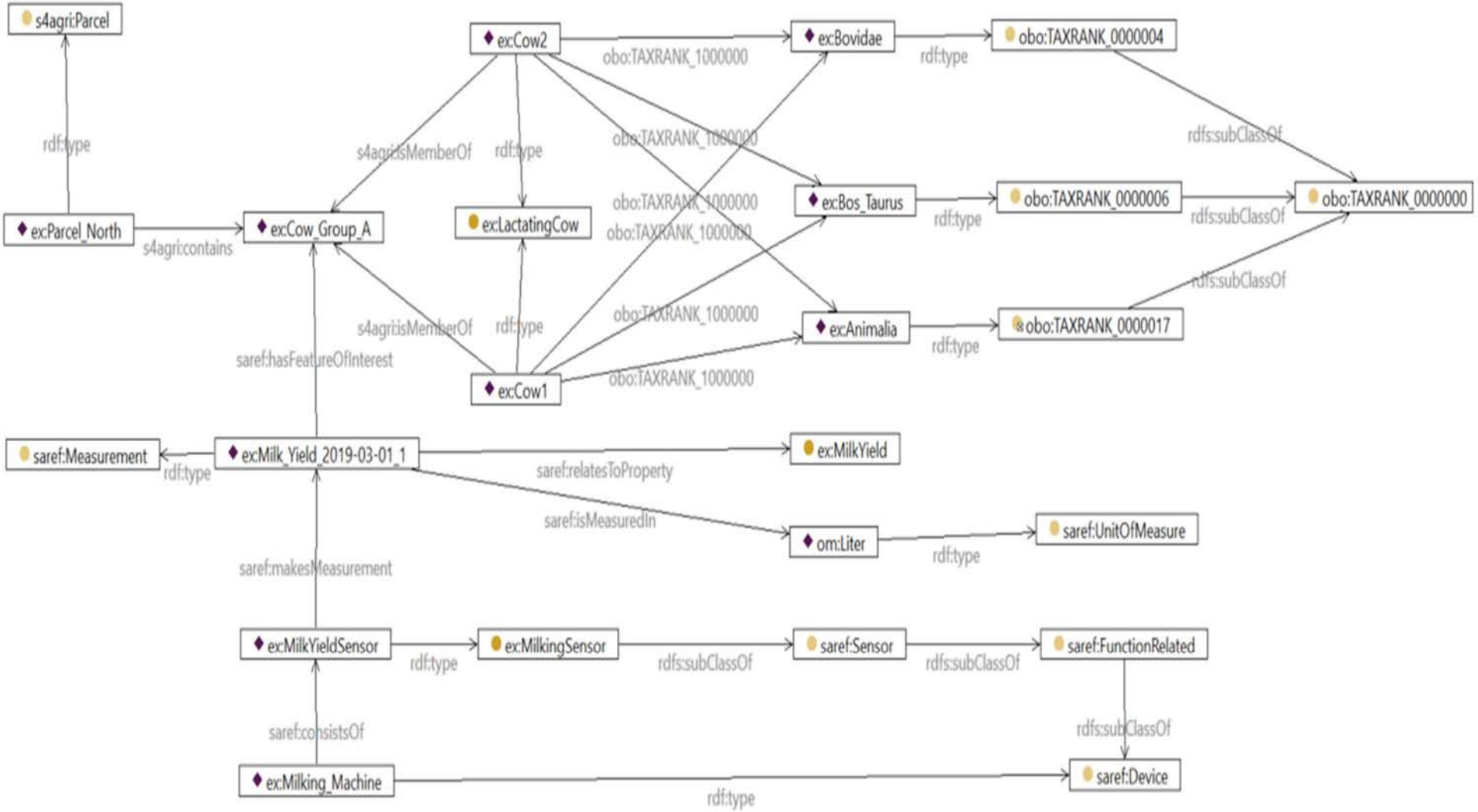

Figure 10: Cow, milking sensor and measurement example

Figure 11 further shows an example of another `s4agri:AnimalGroup`, namely *ex:Cow Group B*. This `s4agri:AnimalGroup` only contains a single cow (i.e. *ex:Cow3*) whose eating activity is being monitored by *ex:Cow Eating Activity Sensor 33*. This `s4agri:EatingActivitySensor` made two measurements about the cow eating activity (i.e. the minutes a cow eats per hour).

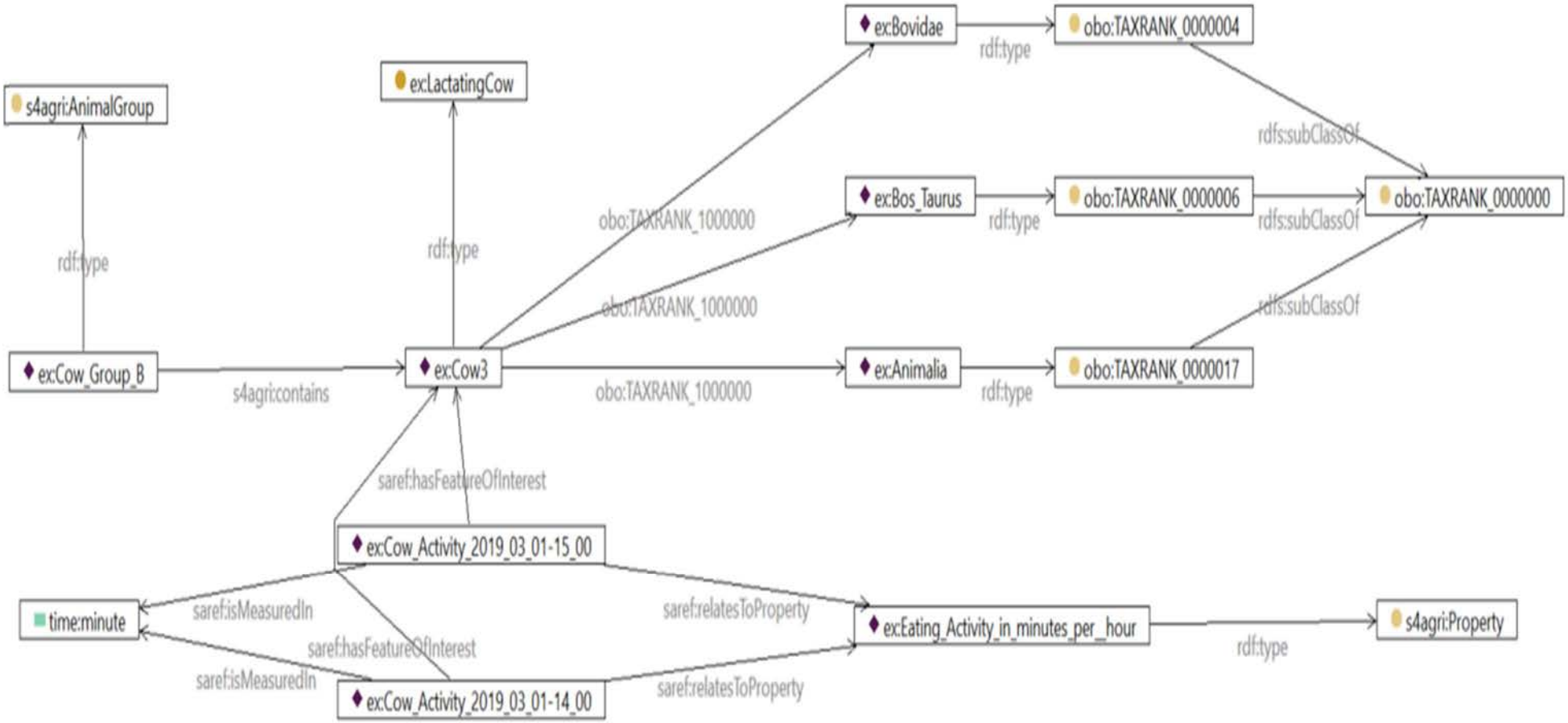

Figure 11: Cow, eating activity sensor and measurement example

4.3.2 Smart Irrigation

This clause shows an example of how to instantiate the SAREF4AGRI extension of SAREF to represent the deployment of some sensors and an example of measurement for the smart irrigation use case. This example is shown in Figure 12.

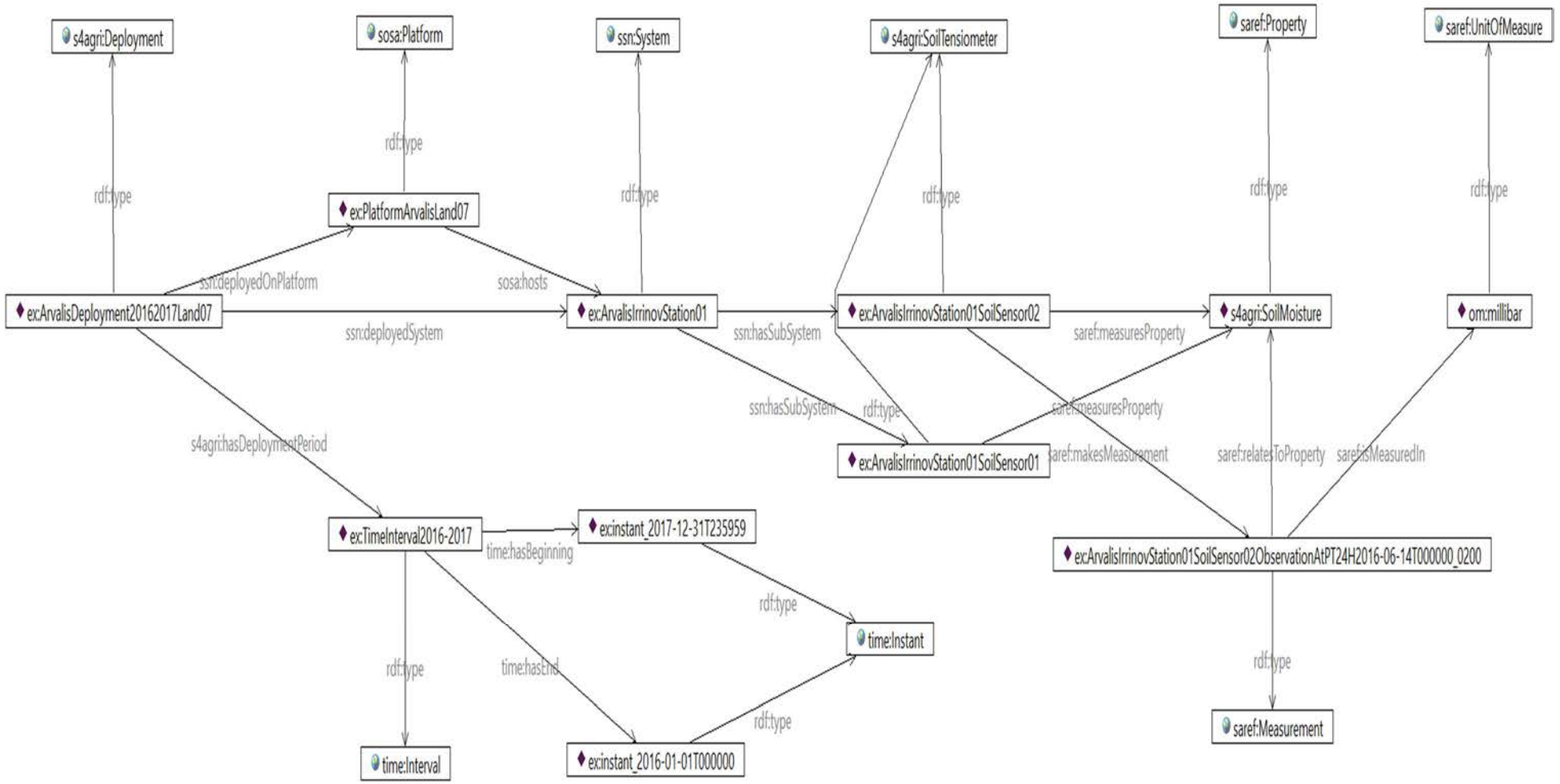

Figure 12: Smart Irrigation example

The ex:ArvalisDeployment20162017Land07 deployment is deployed in the ex:PlatformArvalisLand07 platform and has a deployed system, namely the smart irrigation station ex:ArvalisIrrinovStation01. The deployment takes place in the time interval between January 2016 and the end of 2017, defined as ex:TimeInterval2016-2017.

The deployed system, ex:ArvalisIrrinovStation01, is composed of two sensors identified by the URIs ex:ArvalisIrrinovStation01SoilSensor01 and ex:ArvalisIrrinovStation01SoilSensor02 which are linked from the system by the property ssn:hasSubSystem. Both sensors are of the type ex:SoilTensiometer. Both sensors measure (saref:measuresProperty) the soil moisture property (s4agri:SoilMoisture). The sensors are located at different depths in the soil, as it is indicated by the geo:alt property, i.e. ex:ArvalisIrrinovStation01SoilSensor01 is located at 30 cm depth and ex:ArvalisIrrinovStation01SoilSensor02 is located at 60 cm, considering that the geo:alt property express the dimensions in decimal meters.

A measurement taken by the ex:ArvalisIrrinovStation01SoilSensor02 sensor is also depicted, namely the measurement ex:ArvalisIrrinovStation01SoilSensor02ObservationAtPT24H2016-06-14T000000_0200. This measurement is about (saref:relatesToProperty) the soil moisture property (s4agri:SoilMoisture). This measurement has a value of 1 490,0 expressed in millibars (om:millibar).

Annex A (informative): Approach

To create the SAREF4AGRI extension specified in the present document, a combination of bottom-up and top-down approaches was followed. First, the SAREF4AGRI extension has been developed bottom-up from a set of requirements extracted from the livestock farming and smart irrigation examples (also considering existing ontologies in the sector, such as the Common Dairy Ontology in [i.4]). Note that although various other examples exist in the AgriFood sector (such as arable farming, horticulture, agricultural equipment, greenhouses, food chain, etc.), it was necessary to make actionable choices within the STF 534 timeframe and the available resources, therefore livestock farming and smart irrigation have been chosen as the two initial examples to create SAREF4AGRI.

As a second step, following a top-down approach, the SAREF4AGRI extension development has been driven by reuse in order to connect SAREF with already existing ontologies (such as SOSA, SSN, FOAF, Schema.org, GeoSPARQL and WGS84).

Afterwards, following the process defined in [i.1], the ontological engineers with the support of domain experts considered existing AgriFood standards (e.g. ICAR, ISOBUS, etc.) and vocabularies (e.g. TAXRANK). A list of the considered standards is detailed in [i.2]. Finally, an initial version of the ontological requirements for SAREF4AGRI was proposed, which was then refined together with domain experts in order to obtain a stable version of the requirements and create SAREF4AGRI.

As mentioned, SAREF concepts and properties have been reused and extended. The following classes and properties have been directly reused from SAREF:

- saref:Device
- saref:Measurement
- saref:Property
- saref:makesMeasurement
- saref:relatesToMeasurement
- saref:isMeasuredIn

The following classes and properties have been reused in SAREF4AGRI to complete the model of measurements:

- `saref:FeatureOfInterest` to define the feature of interest being observed in a certain measurement.
- `saref:isPropertyOf` (and its inverse `saref:hasProperty`) to link the property being observed with the feature of interest.
- `saref:hasFeatureOfInterest` (and its inverse `saref:isFeatureOfInterestOf`) to link a given measurement with the feature of interest being observed.
- `saref:measurementMadeBy` as complement of the `saref:makesMeasurement`, as its inverse, to link a measurement and the device that produces it.

The following classes and properties have been directly reused from FOAF:

- foaf:Agent
- foaf:Person
- foaf:member

The following classes and properties have been directly reused from Schema.org:

- org:Organization

The following classes and properties have been directly reused from GeoSPARQL:

- geosp:SpatialObject
- geosp:Feature
- geosp:Geometry
- geosp:sfContains

The following classes and properties have been directly reused from WGS84:

- geo:Point
- geo:location

The following classes and properties have been directly reused from SOSA:

- sosa:Platform

The following classes and properties have been directly reused from SSN:

- ssn:System
- ssn:deployedOnPlatform
- ssn:deployedSystem
- ssn:Deployment

Finally, the Time ontology (http://www.w3.org/2006/time), which is already reused by SAREF, has also been reused in SAREF4AGRI.

As a next step, it is recommended to further refine the 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.

Annex B (informative): Bibliography

- ETSI TS 103 267 (V2.1.1) (2020-02): "SmartM2M; Smart Applications; Communication Framework".
- ETSI TS 102 689 (V1.1.1) (2010-08): "Machine-to-Machine communications (M2M); M2M Service Requirements".

History

Document history		
V1.1.1	May 2019	Publication
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