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Foreword

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

Modal verbs terminology

In the present document "**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 specifies the requirements for an initial semantic model for smart agriculture and food chain domain (AgriFood) based on a limited set of use cases and from available existing data models. The present document is developed in close collaboration with AIOTI, the H2020 Large Scale Pilots and with ETSI activities in the smart agriculture and food chain domain. Further extensions are envisaged in the future to cover entirely the smart agriculture and food chain domain. The associated ETSI TS 103 410-6 [i.13] will define the extension (i.e. the semantic model) for the smart agriculture and food chain domain based on the requirements and use cases specified in the present document.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

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] European Commission and TNO: "Smart Appliances REFerence ontology (SAREF)", April 2015.

NOTE: Available at http://ontology.tno.nl/saref.

[i.2] European Commission and TNO: "D-S4 Final Report - SMART 2013-0077 - Study on Semantic Assets for Smart Appliances Interoperability", March 2015.

NOTE: Available at https://sites.google.com/site/smartappliancesproject/documents.

[i.3] ETSI TS 103 264 (V1.1.1) (11-2015): "SmartM2M; Smart Appliances; Reference Ontology and oneM2M Mapping".

[i.4] ETSI TR 103 411 (V1.1.1) (02-2017): "SmartM2M; Smart Appliances; SAREF extension investigation".

[i.5] ETSI TS 103 410-1: "SmartM2M; Smart Appliances Extension to SAREF; Part 1: Energy Domain".

[i.6] ETSI TS 103 410-2: "SmartM2M; Smart Appliances Extension to SAREF; Part 2: Environment Domain".

[i.7] ETSI TS 103 410-3: "SmartM2M; Smart Appliances Extension to SAREF; Part 3: Building Domain".

[i.8] ETSI TR 103 545: "SmartM2M; Pilot test definition and guidelines for testing cooperation between oneM2M and Ag equipment standards".

[i.9] Brewster C: "The landscape of agrifood data standards: From ontologies to messages". EFITA WCCA 2017 conference, Montpellier, France, July 2017.

[i.10] Kempenaar C. et al.: "Big data analysis for smart farming. Results of TO2 project in theme food security".

NOTE: Available at http://edepot.wur.nl/391652.

[i.11] Verhoosel J. and Spek J.: "Applying Ontologies in the Dairy Farming Domain for Big Data Analysis". CEUR-WS Joint Proceedings of the 3rd Stream Reasoning (SR 2016) and the 1st Semantic Web Technologies for the Internet of Things (SWIT 2016) workshops, co-located with 15th International Semantic Web Conference (ISWC 2016), Kobe, Japan, October 2016.

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

[i.12] Abendroth L. J., Elmore R. W., Boyer M. J. & Marlay S. K.: "Corn growth and development", 2011.

[i.13] ETSI TS 103 410-6: "SmartM2M; Extension to SAREF; Part 6: Smart Agriculture and Food Chain Domain".

[i.14] ISO 11783 series: "Tractors and machinery for agriculture and forestry -- Serial control and communications data network".

[i.15] ETSI TS 103 410 series: "SmartM2M; Smart Appliances Extension to SAREF".

3 Definitions and abbreviations

3.1 Definitions

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

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

3.2 Abbreviations

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

AEF	Agricultural industry Electronics Foundation
AIOTI	Alliance for the Internet of Things Innovation
EPCIS	Electronic Product Code Information Services
FAO	Food and Agriculture Organization
GPS	Global Positioning System
GTIN	Global Trade Item Number
HTTP	HyperText Transfer Protocol
ICT	Information and Communications Technology
IoT	Internet of Things
ISOBUS	International Standard Organization Binary Unit System
NDVI	Normalized Difference Vegetation Index
RDF	Resource Description Framework
RFID	Radio-Frequency IDentification
RPM	Revolutions Per Minute
RTK	Real-Time Kinematic
SAREF	Smart Appliances REFerence ontology
SAREF4AGRI	SAREF extension for the AgriFood domain
SDF	Smart Dairy Farming
SKOS	Simple Knowledge Organization System
SKOS-XL	SKOS eXtension for Labels
STF	Specialists Task Force
TNO	Netherlands Organization for Applied Scientific Research
TR	Technical Report
TS	Technical Specification
XML	Extensible Markup Language

4 SAREF extension for the Smart Agriculture and Food Chain domain

SAREF [i.1] is a reference ontology for IoT created in close interaction with the industry during a study requested by the European Commission in 2015 [i.2] and subsequently transferred into an ETSI TS 103 264 [i.3].

SAREF contains core concepts that are common to several IoT domains and, to be able to handle specific data elements for a certain domain, dedicated extensions of SAREF can be created. Each domain can have one or more extensions, depending on the complexity of the domain. As a reference ontology, SAREF serves as the means to connect the extensions in different domains. The earlier document ETSI TR 103 411 [i.4] specifies the rationale and methodology used to create, publish and maintain the SAREF extensions.

The present document specifies the requirements for an initial SAREF extension for the Smart Agriculture and Food Chain domains based on a limited set of use cases and from available existing data models. The present document has been developed in the context of the STF 534 (https://portal.etsi.org/STF/STFs/STFHomePages/STF534.aspx), which was established with the goal to create SAREF extensions for the domains of Smart Cities, Smart Industry & Manufacturing, and Smart AgriFood. The STF 534 follows the outcomes of the earlier STF 513, which developed an updated the SAREF specification ETSI TS 103 264 [i.3], and the first extensions of SAREF in the energy [i.5], environment [i.6] and building [i.7] domains.

The STF 534 consists of the following two main tasks:

1) gather requirements, collect use cases and identify existing sources (e.g. standards, data models, ontologies, etc.) from the domains of interest (i.e. Smart Cities, Smart Industry & Manufacturing, and Smart AgriFood); and

2) produce extensions of SAREF for each domain based on these requirements.

The present document focuses on the extension of SAREF for the Smart Agriculture and Food Chain domain, which will result in a new ontology, called SAREF4AGRI, to be published in the companion ETSI TS 103 410-6 [i.13] as part of the SAREF extensions series ETSI TS 103 410 [i.15].

5 Related initiatives

5.1 Introduction

In this clause, some of the main related initiatives in terms of modelling and standardization in the Smart Agriculture and Food Chain domain are reviewed. Existing efforts range from national or international standardization initiatives to specific European or national projects related to these standardization initiatives. The potential stakeholders identified for the SAREF4AGRI extension can be classified as: farmers, industry vendors (e.g. suppliers of agriculture equipment and machinery, farm management systems, climate control systems for greenhouses, etc.), associations related to Internet of Things and Smart AgriFood, European projects, research community, platforms for IoT data processing, and standardization bodies. An overview of the landscape of agrifood standards including those for crop research, farming, food supply chain and food retail purposes is provided by Brewster 2017 [i.9] (for additional links to related literature, portals and repositories, see also http://aims.fao.org/activity/blog/agrovoc-and-other-community-agreements-agrifood-related-sectors).

5.2 Standardization initiatives and associations

5.2.1 AEF

The Agricultural Industry Electronics Foundation (AEF) (http://www.aef-online.org) is an independent organization founded on October 2008 by seven international agricultural equipment manufacturers and two associations. Currently, eight manufacturers and three associations work as core members of the AEF together with 200 general members. Their work aims at improving cross-manufacturer compatibility of electronic and electric components in agricultural equipment and to establish transparency about compatibility issues. Implementing international electronic standards is therefore a cornerstone of the AEF work.

While the AEF's intention is to enable mutually beneficial links between companies, the effort is first and foremost directed at their farming customers, i.e. to make work easier for them and to provide them with economic benefits. The AEF promotes compatibility across manufacturers or brands using standards, which is increasingly considered as a competitive advantage, as opposed to the idea of customers buying all their machinery from one manufacturer. Moreover, it aims to establish transparency about compatibility and to provide customers with relevant information prior to a purchase of agricultural machinery.

5.2.2 AgGateway

AgGateway (http://www.aggateway.org/) is a non-profit consortium of businesses serving the agriculture industry. AgGateway manages standardization through the agriculture value chain (horizontal). Their mission is to promote and enable the industry's transition to digital agriculture and expand the use of information to maximize efficiency and productivity. AgGateway counts more than 230 member companies working within the following eight major segments: Ag Retail, Allied Providers (systems & software developers and service providers), Crop Nutrition, Crop Protection, Grain & Feed, Precision Agriculture, Seed, Specialty Chemical. Each segment forms a council that operates autonomously within the overall guidelines of AgGateway.

5.2.3 AIOTI

The Alliance for Internet of Things Innovation (https://aioti.eu/), founded by the European Commission in 2015, consists on thirteen working groups. The WG03 on IoT standardization is a horizontal working group that addresses, amongst other, the issue of semantic interoperability in the IoT that is especially relevant to SAREF. The WG06 on Smart Farming and Food Security is a vertical working group dedicated to IoT scenarios/use cases that allow monitoring and control of the plant and animal products life cycle ("from farm to fork").

5.3 Standards

The most relevant standard for this work is ISOBUS, a communication protocol for the agriculture industry promoted by AEF. ISOBUS is based on the ISO 11783 standard series, parts 1 to 14 [i.14] and AEF works to coordinate enhanced certification tests for the ISO 11783 standard [i.14]. In the past, every manufacturer used their own proprietary solutions, which required special adaption for every combination of tractor and implementations. In contrast, ISOBUS promotes a plug and play solution based on international standards that increase the safety, effectiveness, precision and efficiency of agricultural equipment, regardless of the manufacturer. All signals, such as speed, position of the lower links, power take-off RPM, etc. are available in a standardized form. The communication between the implement and the farm management system is also standardized and simplified through the use of ISO-XML.

5.4 Ontologies

The most relevant ontology for this work is AGROVOC (http://aims.fao.org/vest-registry/vocabularies/agrovoc-multilingual-agricultural-thesaurus), a controlled vocabulary developed by the Food and Agriculture Organization of the United Nations (FAO) that contains over 34 000 concepts available in 29 languages including food, nutrition, agriculture, fisheries, forestry, environment, etc. It is maintained by an international community of experts and institutions active in the area of agriculture and related domains. It is available as an SKOS-XL concept scheme and is also published as a linked data set.

5.5 European projects

5.5.1 IoF2020 (H2020 Large Scale Pilot)

The Internet of Food and Farm 2020 (IoF2020) project is the H2020 Large Scale Pilot that explores the potential of IoT-technologies for the European food and farming industry (https://www.iof2020.eu/). The goal is to leverage IoT technologies to make precision farming a reality and to take a vital step towards a more sustainable food value chain, drop the use of pesticide and fertilizer, optimize the overall efficiency, but also enable better traceability of food, leading to increased food safety. IoF2020 aims to build a lasting innovation ecosystem that fosters the uptake of IoT technologies by involving stakeholders along the food value chain together with technology service providers, software companies and academic research institutions.
Nineteen use-cases organized around five sectors (arable, dairy, fruits, meat and vegetables) develop, test and demonstrate IoT technologies in an operational farm environment all over Europe.

The full list of use cases is available at https://iof2020.eu/trials. The IoF2020 project can provide the environment of stakeholders and use cases to validate the SAREF4AGRI extension.

5.5.2 DISAC project

The Data Intensive Smart Agrifood Chains (DISAC) programme is a public-private partnership between twenty industrial parties and four knowledge institutes in the Netherlands (https://subsites.wur.nl/en/plb/PL-Projects/DISAC.htm). The focus is on arable farming and more precisely on precision farming for agricultural fields. Aim of the programme is to develop a communication infrastructure between sensors and agricultural machinery, which will enable site-specific and real-time adjustments to crop treatment, harvesting and grazing schemes. The programme consists of the following three different subprojects:

1) the electronic potato, which tries to use sensors to monitor and control the potato growing process in the field;

2) the N-sensor, which tries to improve the measurement of nitrates in the field; and

3) connectivity on the field for grassland management and weed control.

The latter subproject uses standards for information exchange between machines in the field and the Farm Management Information System, such as AEF ISO-XML and the AgGateway ADAPT framework (https://adaptframework.org/). The relation between these standards and SAREF4AGRI can be further investigated.

5.5.3 DDINGS project

The Data-Driven Integrated Growing Systems (DDINGS) project is a Dutch national project that is targeted on data sharing and exchange for the improvement of greenhouse management. The project involves a large consortium of greenhouse equipment suppliers that provide appliances to monitor and control housing, windows, screen and climate of the greenhouse. The goal of the project is to combine data from the greenhouse appliances, as well as data from other external data sources, in order to perform meaningful data analysis. The ISOBUS standard is currently used in this area, but SAREF4AGRI could become especially relevant when alignment is needed in the information exchange between different appliances in the greenhouse.

5.5.4 SDF project

The Smart Dairy Farming project (http://www.smartdairyfarming.nl) is a Dutch national project that involved the main dairy industry organizations in the Netherlands. The goal of the project was to measure the improvement of the quality of life of the animals and use the results to better cater the individual needs of the cows, and to be able to detect symptoms of illness of the animal, making a positive impact on their wellbeing. Sensor equipment was used to monitor 300 cows at 7 dairy farms. A large amount of sensor data was generated on grazing activity, feed intake, weight, temperature and milk production of individual cows. Semantic alignment of similar concepts (but with different meaning) in various data sources was necessary for improved decision support and historical analysis. The generated data was used for decision support for the dairy farmers on feed efficiency in relation to milk production, by answering complex questions such as "How much food did an individual cow consume in a certain time period at a specific grassland parcel and how does this relate to the milk production in that period?". More details on the SDF project results can be found in the literature [i.10].

5.6 ETSI initiatives

The STF 542 is an ETSI Specialist Task Force (STF) dedicated to specify a pilot test plan for interfacing the oneM2M platform with agriculture machines and standards (https://portal.etsi.org/STF/STFs/STFHomePages/STF542.aspx). By making use of the oneM2M standards, the STF 542 produced ETSI TR 103 545 [i.8] to be used as input (parameters and measurement methods) for a pilot Plugtests™ event to validate the possible cooperation between the ETSI oneM2M standards and AEF ISOBUS standards implemented for communication inside and between agriculture and forestry machines.

The main scenario envisioned for the pilot Plugtests™ event consists in the dissemination of a warning message to vehicles passing-by as soon as an agriculture or forestry equipment from the fields has been detected to exit on the road. The coordination between the detection of this event and the sending of the notification message is envisioned using an oneM2M gateway in the tractor.

6 Use cases

6.1 Use case 1: On-farm precision farming

Arable farming, horticulture and livestock farming have seen considerable developments in the actual (or potential) use of ICT and by extension sensors. There are three steps to precision agriculture:

1) Collection of data with the maximum possible resolution concerning the farm plots or animals which are managed.

2) Analysis of this data (often requiring integration of multiple data sources) so as to plan a set of actions or treatments.

3) The actions or treatments are undertaken with great control and precision (again dependent on sensors and measuring equipment).

Three areas of application of precision agriculture methods have developed: crop farming, horticulture (especially under glasshouses) and livestock farming. There are multiple data sources used for this including GPS, meteorological data (both historic and current), remote observation (via satellite sources such as Copernicus) and local observation using near or proximal sensors. These multiple data sources need to be integrated so that a service offering decision support to the farmer can be provided. These services may be located on the local "Farm Management System" of the farmer or may be provided by a service over the network.

Proximal sensors include the following types:

a) location sensors (using GPS and RTK);

b) optical sensors to measure soil properties such as soil reflectance;

c) electrochemical sensors for soil properties such as Ph value;

d) mechanical sensors to measure properties such as soil compaction;

e) dielectric sensors to measure soil moisture;

f) airflow sensors measuring other soil properties; and

g) movement and temperature sensors usually for dairy or livestock.

In addition, one should mention on-field weather stations measuring temperature, humidity, air pressure, etc.

Proximal sensors measure a variety of parameters including: (in the soil) moisture/humidity, Ph value, salinity, compaction, (on plant) plant colour (NDVI), (on animal) movement, temperature, etc.

The measurements from the sensors have to be integrated for the purpose of any decision support service. The decision service will thus enable the planning of (for example) a fertilisation or spraying plan for an arable field, a decision to irrigate or harvest (in a horticulture or greenhouse context), a treatment plan for sick animals (in a livestock scenario).

A concrete example of the precision farming use case is provided by the livestock farming use case in Smart Dairy Farming (SDF) project. The livestock farming use case in this project is concerned with the inherent semantic interoperability problem in decision support information in a variety of big data sources containing sensor data of individual cows. Semantic alignment is achieved using ontologies and linked data mechanisms on a large amount of sensor data from different data sources (12 GB of yearly sensor data were transformed into 350 GB of RDF triples), such as grazing activity, feed intake, weight, temperature and milk production of 300 cows at 7 dairy farms in The Netherlands. This livestock farming use case is considered a suitable use case to be covered by the SAREF4AGRI extension.

The following example applications have been developed to show how the resulting linked data semantic solution can be used for decision support and historic analysis [i.11]:

- Visualize the relation between bodyweight and milk yield of individual cows during the lactation period in 2014. For each individual cow, the development of bodyweight and milk yield during the lactation period can be drawn in a graph. In addition, the increase/decrease of the bodyweight on a weekly basis during that same period can also be presented. Finally, an overall view of the average weight over all the cows of the same parity can be depicted. Using these views, the farmer can derive possible relationships between the bodyweight and the milk yield.

- Visualize similar relations between the different types of feed and milk yield of individual cows during the lactation period in 2014. For each individual cow, the development of total feed intake and milk yield during the lactation period can be drawn in a graph. In addition, the division of the total feed intake over various feed types during that same period can be presented. Finally, an overall view of the total feed intake over all the cows of the farmer can be depicted. Using these views, the farmer can derive possible relationships between the intake of different types of feed and the milk yield.

6.2 Use case 2: Smart irrigation

Not only for economic reasons but also for environmental ones, local governments and citizens aim at improve processes and life-style habits in order to save precious and scarce resources. One critical resource, which is also threatened by climate change and weather conditions in many areas, is water. Specially, for farmers there is a need to reduce water consumption while keeping the culture and crop quality.

In the agricultural domain, usually farmers need to observe natural phenomena in order to decide about which activities to be carried out over the land. For example, farmers go to the farmland to check whether the plants need water by applying different techniques; then the irrigation system can be activated, if needed. However, those activities have a low-accuracy due to the human lack of precision in observations and also to the rapid changes of the natural environment. Therefore, this reduces productivity and yield in agriculture.

Applying context-aware systems to manage irrigation activities in farming has demonstrated benefits regarding water saving and even increasing the crop quality, for example preventing soil damage due to over-irrigation. These systems are meant to modify or adapt their behaviour according to changes in the application context [i.11]. The first step of the context-aware systems is usually the context acquisition process for what in smart irrigation can be done by the deployment of a, normally wireless, network of sensors in the field. However, there are still challenges that context-aware systems should face in the agricultural domain, for example the natural obstacles, battery's lifetime in a wireless scenario, and the heterogeneity in objects, devices and measurement types.

AgroTechnoPole (http://www.irstea.fr/en/all-news/institute/agrotechnopole-auvergne-rhone-alpes-creation-unprecedented-structure-innovation) is a centre for experiments in robotics and digital agriculture located in Montoldre, France. In this scenario, a deployment of a smart irrigation use case is being developed by means of a context-aware system. In this centre, 10 measurement stations have been deployed, each containing three soil sensors at depths of 10, 20 and 30 cm. The pilot site also counts with a pluviometer and sensors for ambient temperature, ambient humidity and light.

Given this situation, the context-aware system for improving smart irrigation systems being tested in Montoldre is considered a suitable use case to be covered by the SAREF4AGRI extension. In this sense, this use case would trigger the inclusion of new concepts, devices, properties to be observed, functions and commands to be executed in the SAREF ontology, and overall the challenge of taking into account the spatio-temporal nature of the deployments in the agricultural domain.

6.3 Use case 3: Agriculture or forestry equipment from the fields in the road

The description of this use case of the ETSI initiative STF 542 can be found in ETSI TR 103 545 [i.8] and is considered a suitable use case to be covered by the SAREF4AGRI extension.

6.4 Additional use cases

6.4.1 Greenhouses

The greenhouse use case focuses on the collaboration and information sharing between various appliances in the greenhouse that are used to monitor and control the greenhouse itself as well as its climate. Information sharing between the climate computer in the greenhouse and equipment to generate or control temperature, CO2, humidity and light needs to be aligned. Also, alignment between information in the greenhouse and data sources outside the greenhouse might be part of the use case, e.g. information source on local weather predictions and energy stock markets. The DDINGS project is a candidate to provide more details on this use case, as well as a playground for testing the SAREF extensions developed by the STF 534. An additional use case on greenhouses concerns a greenhouses cooperative that buys and sells energy together. This cooperative makes it possible to provide the smart grid with a buffer functionality: in case there is a demand for more electricity, the cooperative can fulfil this demand using the gas-turbines that transform gas to electricity; in case there is an excess of electricity on the grid, a collective of greenhouses can transform this excess electricity into heat. One greenhouse cannot provide the energy flexibility by itself, but a joint collaboration can provide a valuable buffer solution for the smart grid. This use case is relevant as it connects the SAREF extension for Agrifood (greenhouses use case) to the SAREF extension for Energy, which addresses demand response use cases to control smart appliances in the consumer premises (smart home) in a flexible way depending on the energy availability and price incentives from the smart grid.

As it is necessary for the STF 534 to make choices and limit the number of use cases that can be implemented within the timeframe and resources available, the greenhouse use cases are postponed as a future activity in the SAREF roadmap for the Agrifood domain.

6.4.2 Food chain

In the food chain, the main use of sensors lies in the integration of sensor data in tracking and tracing. Barcode and RFID scanning has been standardised by GS1 (an organisation that develops standards for business communication, such as barcodes, EPCIS, GTIN etc.) but the cool and cold chain sensors measuring temperature and other parameters are not so obviously standardised. In this use case, sensors are present in a freezer truck or on a returnable packaging measuring movement, temperature, and possibly light (floriculture). These measurements can be used to a) determine if there is any break in the cold chain (e.g. meat or ice-cream), and b) adjust the expected shelf-life of the food product. While there exist commercial products that offer multiple sensors (temperature, movement, location, etc.), these are still too expensive for large scale uptake.

The food chain use case is rather complex and involves a large number of stakeholders and message standards in the supply chain. As it is necessary for the STF 534 to make choices and limit the number of use cases that can be implemented within the timeframe and resources available, it is recommended to focus on the livestock farming and smart irrigation use cases for the first SAREF4AGRI extension and consider the food chain use cases in future versions of the SAREF4AGRI extension.

7 Requirements

7.0 Introduction

Competency questions have been extracted from the following use cases as the basis to create SAREF4AGRI:

- Livestock farming.
- Smart irrigation.
- Agriculture or forestry equipment from the fields in the road.

These competency questions include the following:

- List of requirements for the livestock farming use case provided by the SDF project.
- List of requirements for the smart irrigation use case provided by the AgroTechnoPole centre for experiments in robotics and digital agriculture.

- List of requirements for the agriculture or forestry equipment from the fields in the road use case provided by the STF 542 on the integration of the oneM2M platform with agricultural machines and standards.

The associated requirements are presented in the following clauses. Due to the fact that some requirements are extracted from the use cases or from already existing models, these requirements can be defined either as competency questions with answers or as statements.

7.1 Livestock farming

The list of requirements for the livestock farming use case has been extracted from the SDF project, where interviews with the dairy farmers were conducted to derive the information needed to provide them with proper decision support on feed efficiency in relation to milk production. The farmers can use such a system for decision support purposes on various daily operations, such as which amount of feed to provide to which cow in which period, when to inseminate a specific cow and how to deal with the transition of a cow towards calving. In this scenario, queries of interest for the farmers are the following [i.11]:

- Select an overview with the number of cows of a farmer.
- Select the list of cows with number and parity.
- Select feed per type per day over all cows of a farmer.
- Select average weight over all cows per day per parity.
- Select static info for a cow.
- Select weight per day in lactation period.
- Select weight and milk yield per day in lactation period.
- Select milk yield per day in lactation period.
- What is the average weight per day over the last lactation period of a cow of a farmer?
- How much feed did an individual cow consume in a certain time period at a specific grassland parcel and how does this relate to the milk production in that period?

To be answered, these queries need information on raw measurements (sensor data), which is defined in table 1, and more complex cow's activities, which are defined in table 2.

Table 1: Requirements for the livestock farming use case: Measurements

Id	Competency Question/Statement	Answer
AGRI-1	What type of sensors are used for smart dairy farming?	Sensors that allow to measure activity, weight, temperature, milk yield and feed-intake of the cows.
AGRI-2	A sensor has a vendor.	
AGRI-3	A sensor measures a certain property.	
AGRI-4	A property is associated with a cow.	
AGRI-5	A property has a name and a value.	
AGRI-6	A sensor is associated with a measurement.	
AGRI-7	A measurement belongs to a specific sensor.	
AGRI-8	A measurement is associated with a specific cow.	
AGRI-9	A measurement shall have a timestamp to express the date and time of the measurement	
AGRI-10	A measurement shall always have a value.	
AGRI-11	How is a measurement uniquely identified?	A measurement is uniquely identified by the life number of the cow under consideration, the datetime in which the measurement was done, and the sensor that made the measurement.
AGRI-12	How is a cow identified?	A cow has a name and a life number.
AGRI-13	A cow belongs to a farm.	

Table 2: Requirements for the livestock farming use case: Cows and their Activities

Id	Competency Question/Statement	Answer
AGRI-14	What type of livestock is used in the smart dairy farming use case?	Cows.
AGRI-15	What are the cows monitored for?	Grazing, feed intake, weight, temperature and milk production. In particular, the cows are monitored for their eating activity, high activity, high active minutes, number of movements and rumination activity.
AGRI-16	A cow has a weight and a temperature.	
AGRI-17	Are there different type of cows?	Yes, cows are distinguished in lactating cows and non-lactating cows.
AGRI-18	How is the grazing activity of the cow defined?	A cow grazes on some parcel.
AGRI-19	What are the characteristics of the parcel a cow grazes on?	A parcel has a name and is characterized by a biomass, a centre point and a surface. A parcel also contains a grass amount.
AGRI-20	How is the grass amount measured?	Grass amount has a weight and a timepoint when the measurement is done.
AGRI-21	How is the feed intake of the cow defined?	A cow eats during a certain feeding period. A cow has a certain feed intake.
AGRI-22	The feeding period of the cow has a start time and an end time.	
AGRI-23	The feed intake can be monitored for an individual cow or for a group of cows that take part in a grazing experiment.	
AGRI-24	How is the feed intake measured?	The feed intake has a weight, a start time and an end time of when the measurement is done.
AGRI-25	The feed intake is differentiated depending on the type of feed.	
AGRI-26	What are the type of feed?	The types of feed are concentrate, grass or roughage. Roughage can be further distinguished in grass, hay, maize, silage and straw.
AGRI-27	All types of feed are characterized by some parameters.	
AGRI-28	What are the feed parameters?	The feed parameters are: 1) feed units milk; 2) intestinal digestible protein; and 3) unstable protein balance.
AGRI-29	How is the milk production of the cow measured?	Measuring the milk yield given by a cow.
AGRI-30	What are the characteristics of the milk yield?	The milk yield has a weight, a start time and an end time of when the measurement is done.
AGRI-31	How is the weight measured?	There are different types of weighing equipment in the farm, for example Lely.BodyWeight and GallAGRI-herDairyScale.dsweight.

7.2 Smart Irrigation

Table 3 shows the requirements extracted from the smart irrigation use case.

Table 3: Requirements for the smart irrigation use case

Id	Competency Question/Statement	Answer
AGRI-32	Which sensors are deployed in the system?	Tensiometer (soil moisture sensor), agricultural weather station, pluviometre.
AGRI-33	Which actuators are deployed in the system?	Travelling gun.
AGRI-34	Which properties need to be observed?	Soil moisture, ambient temperature, soil temperature, ambient humidity, precipitation, water received during irrigation, plant growth stAGRI-e.
AGRI-35	Which units of measure is soil moisture measured in?	Cbars but some sensors provide raw date in custom units, for example watermark tensiometres.
AGRI-36	Which units of measure is ambient temperature measured in?	ºC.
AGRI-37	Which units of measure is soil temperature measured in?	ºC.
AGRI-38	Which units of measure is ambient humidity measured in?	%.
AGRI-39	Which units of measure is precipitation measured in?	Millimetre.
AGRI-40	Which units of measure is water received during irrigation measured in?	Millimetre.
AGRI-41	Which units of measure is plant growth stAGRI-e measured in?	There are several systems to decide the plant growth stAGRI-e. For example [i.12].
AGRI-42	How many deployments are there?	3.
AGRI-43	What is the location of deployment X?	Montoldre plot 7.
AGRI-44	For how long was deployment X deployed?	6 years.
AGRI-45	How many platforms are part of deployment X?	4.
AGRI-46	What is the network topology?	Star, ring, line, tree, etc.
AGRI-47	Which nodes are connected to node Y?	Nodes R, S and T.
AGRI-48	Which communication protocol is used?	Zigbee™.
AGRI-49	Which is the status of node Y?	Idle (other options: active, etc.).
AGRI-50	Which is the role of node Y?	Sensor (other options: actuator, routing).
AGRI-51	Which is the location of sensor Y?	Coordinates (46.34082,3.432527) depth 30 cm.
AGRI-52	Which is the latest value measured by the tensiometers in a 30 cm depth?	150 in watermark scale.
AGRI-53	Which actions does the travelling gun X provide?	Irrigation.
AGRI-54	Which crop is cultivated in the plot Z?	Maize.

7.3 Agricultural machines from the field on the road

The STF 542 developed a data model that provides the semantics of the data to be exchanged through the M2M platform for the use case on agricultural machines from the field on the road. The parameters for this data model (and therefore the requirements for the SAREF4AGRI extension based on this data model) are defined in ETSI TR 103 545 [i.8].

8 Conclusions

The present document describes the use cases taken into account for the development of the SAREF4AGRI extension, namely:

1) livestock farming;
2) smart irrigation; and
3) agriculture or forestry equipment from the fields in the road.

The present document further defines the final requirements to be implemented in the SAREF4AGRI extension (54 requirements). In addition, the requirements developed by the STF 542 and defined in ETSI TR 103 545 [i.8] will also be taken into account when developing SAREF4AGRI.

Validation of these requirements is expected to be carried out while creating the SAREF4AGRI extension, leveraging the related initiatives identified in the present document.

Several additional use cases of interest exist in the AgriFood domain and are acknowledged in the present document as relevant, as they present semantic interoperability issues that could be supported by the SAREF4AGRI extension, such as the information exchange between machines for precision farming in the field and the Farm Management Information System, and the information sharing between climate computers in the greenhouse and equipment to generate or control temperature, CO2, humidity and light. However, there is a limited number of use cases that can be considered within the timeframe and resources available in the STF 534. It is therefore recommended to take into account these use cases in future versions of the SAREF4AGRI extension.

Annex A:
Bibliography

- ETSI TS 103 267: "SmartM2M; Smart Appliances; Communication Framework".
- ETSI TS 118 101: "oneM2M; Functional Architecture (oneM2M TS-0001)".
- ETSI TS 118 102: "oneM2M;Requirements (oneM2M TS-0002)".

History

Document history		
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