THE IOF2020 USE CASE ARCHITECTURES AND OVERVIEW OF THE RELATED IOT SYSTEMS

WP 3 - IOT

July 15th, 2018

Task T3.1 – Smart Agri-food Solution Reference Architecture and Interoperability Endpoints specification

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PROJECT SUMMARY

The internet of things (IoT) has a revolutionary potential. A smart web of sensors, actuators, cameras, robots, drones and other connected devices allows for an unprecedented level of control and automated decision-making. The project Internet of Food & Farm 2020 (IoF2020) explores the potential of IoT-technologies for the European food and farming industry.

The goal is ambitious: to make precision farming a reality and to take a vital step towards a more sustainable food value chain. With the help of IoT technologies higher yields and better-quality produce are within reach. Pesticide and fertilizer use will drop and overall efficiency is optimized. IoT technologies also enable better traceability of food, leading to increased food safety.

Nineteen use-cases organised around five trials (arable, dairy, fruits, meat and vegetables) develop, test and demonstrate IoT technologies in an operational farm environment all over Europe, with the first results expected in the first quarter of 2018.

IoF2020 uses a lean multi-actor approach focusing on user acceptability, stakeholder engagement and the development of sustainable business models. IoF2020 aims to increase the economic viability and market share of developed technologies, while bringing end-users' and farmers' adoption of these technological solutions to the next stage. The aim of IoF2020 is to build a lasting innovation ecosystem that fosters the uptake of IoT technologies. Therefore, key stakeholders along the food value chain are involved in IoF2020, together with technology service providers, software companies and academic research institutions.

Led by the Wageningen University and Research (WUR), the 70+ member consortium includes partners from agriculture and ICT sectors, and uses open source technology provided by other initiatives (e.g. FIWARE). IoF2020 is part of Horizon2020 Industrial Leadership and is supported by the European Commission with a budget of €30 million.

EXECUTIVE SUMMARY

In order to demonstrate the effectiveness of IoT solutions in a large spectrum of different agricultural domains and applications, the IoF2020 project has carefully selected 5 trials comprising 19 Use Cases (UCs), set in different regions of Europe. This is a key aspect to reflect the diversity of the agri-food domain, and perform evaluations in conditions, which are close to real scale and operational ones.

Each UC is managed by a separate, dedicated team, working autonomously. This ensures the materialization of test site associated with the UCs in relatively short time, allowing further iteration and enhancements over the duration of the project.

Building on the experience being generated on the field, the role of task T3.1 “Smart Agri-Food Solution Reference Architecture and Interoperability end-point specification” is to establish a common architectural view, for each of the UCs, which can be used as a “common ground” to establish IoT-enabled synergies and new added-value services.

In order to capture the essential architectural aspects of each UC, the task has followed a multi-view methodology compliant with international standards for modelling and specification of complex, software-intensive systems. Each use case is therefore described in terms of domain model, deployment view, functional view, business process hierarchy, information model, also highlighting the main identified interoperability end-points and assets identified for re-use, as well as gaps to be filled with future activities, as well as through the introduction of IoT developments. This document describes the results of such analysis.

An important part of the activity has been dedicated to the analysis of all the UC architectures from the point of view of Security, Privacy and Trust. Such view has been developed following the well-known STRIDE (Spoofing, Tampering, Repudiation, Information disclosure, Denial of service, Elevation of privilege) analysis.

Results documented in this report provide a “common ground” to establish IoT-based innovations in the next phases of the project, both within each UC, spawning across multiple UCs or even beyond the traditional limits of the agri-food sector.

TABLE OF CONTENTS

EXECUTIVE SUMMARY 4

1 INTRODUCTION 7

1.1 DEFINITIONS 8

1.2 USE CASE ARCHITECTURES TRIALS AND USE CASES OVERVIEW 9

1.3 UC ANALYSTS 1ST VERSION OF THE DELIVERABLE 12

1.4 UC ANALYSTS 2ND VERSION OF THE DELIVERABLE 13

2 RESULTS OF THE IOT ARCHITECTURE ANALYSIS 15

2.1 ARABLE UC 1.1: WITHIN-FIELD MANAGEMENT ZONING 15

2.2 ARABLE UC 1.2: PRECISION CROP MANAGEMENT 20

2.3 ARABLE UC 1.3: SOYA PROTEIN MANAGEMENT 32

2.4 ARABLE UC 1.4: FARM MACHINE INTEROPERABILITY 39

2.5 DAIRY UC 2.1 GRAZING COW MONITOR 48

2.6 DAIRY UC 2.2: HAPPY COW 54

2.7 DAIRY UC 2.3: HERDSMAN+ 63

2.8 DAIRY UC 2.4: REMOTE MILK QUALITY 71

2.9 FRUIT UC 3.1: FRESH TABLE GRAPES CHAIN 80

2.10 FRUIT UC 3.2: BIG WINE OPTIMIZATION 93

2.12 FRUIT UC 3.4: INTELLIGENT FRUIT LOGISTICS 113

2.13 VEGETABLE UC 4.1: CITY FARMING LEAFY VEGETABLES 121

2.14 VEGETABLE UC 4.2: CHAIN-INTEGRATED GREENHOUSE PRODUCTION 127

2.15 VEGETABLE UC 4.3: ADDED VALUE WEEDING DATA 139

2.16 VEGETABLE UC 4.4: ENHANCED QUALITY CERTIFICATION SYSTEM 150

2.17 MEAT UC 5.1: PIG FARM MANAGEMENT 161

2.18 MEAT UC 5.2: POULTRY CHAIN MANAGEMENT 174

2.19 MEAT UC 5.3: MEAT TRANSPARENCY AND TRACEABILITY 188

3 SECURITY, PRIVACY AND TRUST ANALYSIS 196

3.1 ARABLE UC 1.1: WITHIN-FIELD MANAGEMENT ZONING 196

3.2 ARABLE UC 1.2: PRECISION CROP MANAGEMENT 197

3.3 ARABLE UC 1.3: SOYA PROTEIN MANAGEMENT 197

3.4 ARABLE UC 1.4: FARM MACHINE INTEROPERABILITY 198
3.5 DAIRY UC 2.1 GRAZING COW MONITOR 199
3.6 DAIRY UC 2.2: HAPPY COW 200
3.7 DAIRY UC 2.3: HERDSMAN+ 200
3.8 DAIRY UC 2.4: REMOTE MILK QUALITY 201
3.9 FRUIT UC 3.1: FRESH TABLE GRAPES CHAIN 201
3.10 FRUIT UC 3.2: BIG WINE OPTIMIZATION 202
3.12 FRUIT UC 3.4: INTELLIGENT FRUIT LOGISTICS 203
3.13 VEGETABLE UC 4.1: CITY FARMING LEAFY VEGETABLES 203
3.14 VEGETABLE UC 4.3: ADDED VALUE WEEDING DATA 205
3.15 VEGETABLE UC 4.4: ENHANCED QUALITY CERTIFICATION SYSTEM 205
3.16 MEAT UC 5.1: PIG FARM MANAGEMENT 206
3.17 MEAT UC 5.2: POULTRY CHAIN MANAGEMENT 207
3.18 MEAT UC 5.3: MEAT TRANSPARENCY AND TRACEABILITY 207
3.19 NEXT STEPS FOR SECURITY, PRIVACY AND TRUST ANALYSIS 208

4 ASSESSMENT OF PROJECT RELATED KPI 209

5 OVERALL GAP ANALYSIS 211

5.1 GAP-FILLING PLANS 212

6 CONCLUSIONS 213

7 REFERENCES 214

7.1 LIST OF ACRONYMS 214
7.2 LIST OF FIGURES 216
7.3 LIST OF TABLES 218
7.4 BIBLIOGRAPHY AND WEB REFERENCES 221

Introduction

The IoF2020 “Internet of Food and Farm 2020” project aims at boosting the competitiveness of European agriculture on a global scale, by accelerating the adoption of the methodologies and products based on IoT technologies in the broad agriculture domain.

In order to demonstrate the effectiveness of IoT solutions in a large spectrum of different agricultural domains and applications, IoF2020 has carefully selected 5 trials comprising 19 Use Cases (UCs), set in different regions of Europe. This is a key aspect to reflect the diversity of the agri-food domain, and perform evaluations in conditions, which are close to real scale and operational ones.

From the organizational viewpoint, in order to ensure that all UCs can quickly achieve a working, operational status, since the early phases of the project, each UC is managed by a separate, dedicated team, working in proactive, highly autonomous fashion. This ensures the activation of UCs in relatively short time, allowing further iteration and enhancements over the duration of the project.

Building on the experience being generated on the field, the role of task T3.1 “Smart Agri-food Solution Reference Architecture and Interoperability end-point specification” is to establish a common architectural view, for each of the UCs. This is an important preparatory step towards further activities in the project, which aim at the full realization of the IoT vision across the 19 IoF2020 UCs, ensuring that deployed components and solutions can prospectively inter-operate so to deliver added-value functionalities to various stakeholders – possibly maximizing re-use of common IoT enablers across different UCs and trials. This can only be achieved by leveraging common interoperability end-points and data models and allowing secure and controlled exchange of information and capabilities across heterogeneous components.

This document, entitled “D3.2 - The IoF2020 Use Case Architectures and overview of the related IoT Systems” has been developed by Task T3.1 “Smart Agri-food Solution Reference Architecture and Interoperability Endpoints Specification” – supported by the WP2 team.

Its main goal is to provide an overview of the common interoperability end-points, re-usable components and added-value functionalities defined analysing the 19 IoF2020 UCs.

The detailed methodology followed to reach the analysis and the corresponding results reported in this document is described in the Deliverable “D3.1 - Guidelines for Use Case Analysis & Design”, issued at the same time of D3.2.

In order to capture the essential architectural aspects of each UC, the task has followed a multi-view methodology compliant with international standards for modelling and specification of complex, software-intensive systems. Each use case is therefore described in terms of domain model, deployment view, functional view, business process hierarchy, information model, also highlighting the main identified interoperability end-points and assets identified for re-use, as well as gaps to be filled with future activities, as well as through the introduction of IoT developments. The result of such analysis is reported in Section 0.

An important part of the activity has been dedicated to the analysis of all the UC architectures from the point of view of Security, Privacy and Trust. Such view has been developed following the well-known STRIDE (Spoofing, Tampering, Repudiation, Information disclosure, Denial of service, Elevation of privilege) analysis. Such thorough analysis has been developed individually for all the use cases, which has been documented in a set of detailed, confidential STRIDE document, one for each UC. The overall summary of such document is reported in section 3.

In section 4 an overall, aggregated, analysis of IoT-related gaps has been synthetized building upon the gap analysis of individual UCs described in section 0. Gaps which are common across different UCs have been grouped and been categorized, so to better support the planning of the most relevant gap-filling activities in the next phases of the project.

Finally, section 4 presents a preliminary assess of the project with respect to KPI Reusability. The project KPI Reusability indicates the reusability of project results in use cases and consists of three sub KPIs: the numbers of reused

- Technical components and Open platforms
- Business models
- Principles and guidelines for data governance and digital ethics

In its current status, the document reflects the latest available specifications of the UC at the time of release of the document. Due to the iterative nature of the project, further details will be specified in the next phases of the project. Specifically, reusable KPI Reusability will be further detailed in the upcoming D 3.7 Deliverable.

1.1 DEFINITIONS

In order to reduce potential ambiguities, the following list summarizes the definitions of some key concepts used in the subsequent analysis. The full list of acronyms used in this document is also available in section 7.1.

Actuator

An actuator is a component of a machine that is responsible for moving or controlling a mechanism or system.

Application Programming Interface (API)

An API is a set of commands, functions, protocols, and objects that programmers can use to create software or interact with an external system.

Connectors

Software and/or hardware components that ensure interoperability of any local component with any external IoT device or system.

Cloud computing

Cloud computing[i] is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models.

Dashboard

A dashboard is a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance.[ii]

Data broker

Data Broker is a software component that aggregates information from a variety of sources; processes it to enrich, cleanse or analyse it.

Data storage

Data storage is a service that stores data coming from different sources.

Fog computing

Fog computing[iii] is a system-level horizontal architecture that distributes resources and services of computing, storage, control and networking anywhere along the continuum from Cloud to Things.

Gateway

Gateway is a general term that refers to a node on a network that acts as an entrance to another network and often serves to translate between different communications protocols, data formats[iv], etc.

Middleware

The middleware is a software layer or a set of sub-layers interposed between the technological and the application levels.[v]

Predictive analysis

Predictive analysis is the act of mining historical data to forecast future events or trends.

Server

A server is a software program, or the computer on which that program runs, that provides a specific kind of service to client software running on the same computer or other computers on a network[vi].

Software Framework

Software framework is an abstraction in which software providing generic functionality can be selectively changed by additional user-written code, thus providing application-specific software

Web-service

The term Web Services[vii] refers to the technologies that allow for making connections. Services are what you connect together using Web Services. A service is the endpoint of a connection. Also, a service has some type of underlying computer system that supports the connection offered.

1.2 USE CASE ARCHITECTURES TRIALS AND USE CASES OVERVIEW

The project defines a set of multi-actor trials that reflect the diversity of the food and farming domain, including different actors and different supply chain roles, like logistics and consumption. The trials are composed of use cases, selected in interaction with the agri-food community, which address the most relevant challenges for the specific subsector concerned. The use cases follow a demand-driven approach in which IoT solutions for specific business needs are developed by a dedicated team of agri-food end users and IoT companies with a clear commercial drive, supported by R&D organisations.

5 trials including a coherent set of 19 use cases have been selected for the project. They are well-balanced in term of:

- Agricultural subsectors: it includes multiple agricultural products, i.e. arable produce (i.e. potatoes or soya), dairy, fruits (like grapes or olives), vegetables (i.e. tomatoes, lettuce), and meat (i.e. pork or beef).
- Application areas: the trials address coherent sets of challenges that are both important from an agri-food business perspective and promising from a technical IoT perspective.
- Each trial works with use cases that have a specific focus and complementary challenges.
- Early adopters and early majority farmers and food companies: 5 use cases focus on the early adopters, 11 instead focus on the majority and 3 uses cases include both types.
- Organic and conventional farming: The majority of the current use cases address both types of farming.

- Supply chain roles: the whole food chain is covered, from farming up to the consumer, including also input supply and processing, logistics (including packaging) and consumption.
- IoT technologies: the trials and use cases will integrate a multitude of technologies ranging from IoT devices (like sensors and actuators) and IoT connectivity to IoT intelligence covering the entire IoT value chain),
- Geographical coverage: the trials take place throughout Europe with partners from 18 countries.

The next subsections will introduce the trials and relative use cases (see Figure 1, for their locations).

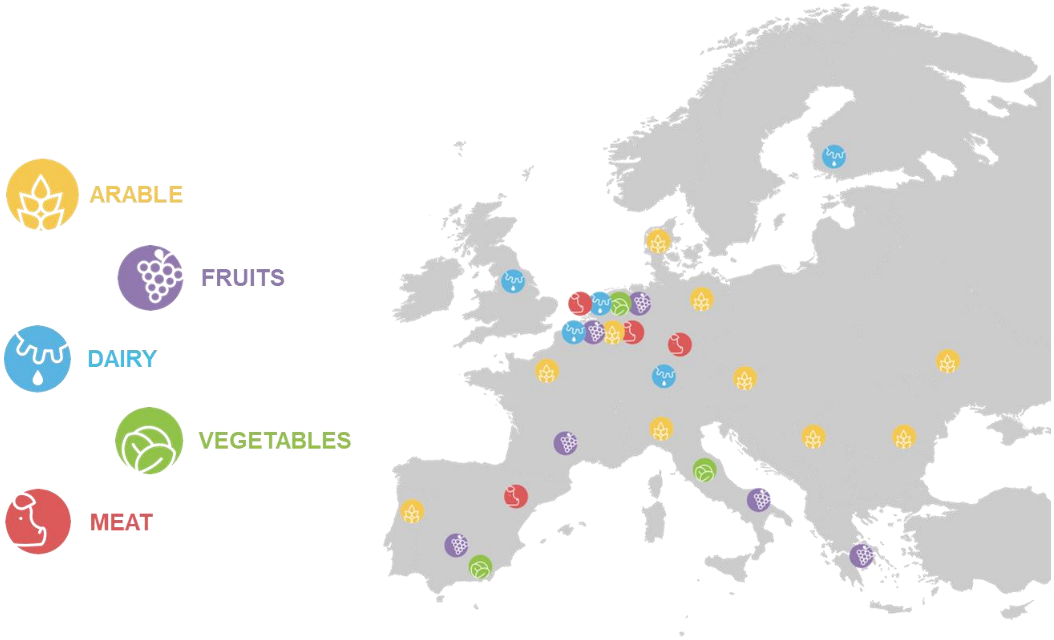


Figure 1 - Location of IoF2020 Use Cases

1.2.1 The Internet of Arable Farming

This trial aims to integrate operations across the whole arable cropping cycle by combining IoT technologies focusing on data acquisition (soil, crop and climate) in growing and storage of key arable crops such as potatoes, wheat and soya beans.

The trial consists of a coherent approach of three vertical use cases (1.1-1.3) and a horizontal one (1.4):

UC1.1: Within-field management zoning; it aims to define specific field management zones by developing and linking sensors and actuators with external data.

UC1.2: Precision Crop Management; it consists in the smart wheat crop management, through the use of sensors data embedded in a low-power, long-range network infrastructure

UC1.3: Soya Protein Management; it aims to improve protein production by combining sensor data and translate them into effective machine task operations.

UC1.4: Farm Machine; it has the objective to enable the Interoperability data exchange between field machinery and farm management information systems, in order to support cross-over pilot machine communication.

1.2.2 The Internet of Dairy Farming

This trial aims to demonstrate the use of real-time sensor data (e.g. neck collar), combined with GPS location data to create value in the dairy chain from “grass to glass”, obtaining a more efficient use of resources and production of quality foods, combined with a better animal health, welfare and environment implementation.

The trial consists of 4 coherent use cases:

UC2.1: Grazing Cow Monitor; it consists in monitoring and managing the outdoor grazing of cows, using GPS tracking within ultra-narrow band communication networks.

UC2.2: Happy Cow; it aims to improve dairy farm productivity, using 3D cow activity sensing and cloud machine learning technologies.

UC2.3: Silent Herdsman; it allows to herd alert management by a high node count distributed sensor network and a cloud-based platform for decision-making.

UC2.4: Remote Milk Quality; it aims to have remote quality assurance of accurate instruments and analysis & pro-active control in the dairy chain.

1.2.3 The Internet of Fruits

This trial aims to demonstrate IoT technology that is integrated throughout the whole supply chain from the field, logistics, processing to the retailer. Sensors in orchards and vineyards (like weather stations and thermal cameras) will be connected in the cloud and used for monitoring, early warning of pests and diseases and control (e.g. variable rate spraying or selective harvesting).

The trial consists of 4 coherent use cases:

UC3.1: Fresh table grapes chain; it requires the real-time monitoring and control of water supply and crop protection of table grapes and predicting shelf life.

UC3.2: Big wine optimization; it aims to optimize the cultivation and processing of wine by sensor-actuator networks and big data analysis within a cloud framework.

UC3.3: Automated olive chain; it includes automated field control, product segmentation, processing and commercialisation of olives and olive oil

UC3.4: Intelligent fruit logistics; it aims to handle the fresh fruit logistics through virtualization of fruit product s by intelligent trays within a low-power long-range network infrastructure.

1.2.4 The Internet of Vegetables

This trial focuses on a combination of environmental control levels: full-controlled indoor growing with an artificial lighting system, semi-controlled greenhouse production and non-regulated ambient conditions in open-air cultivation of vegetables.

The trial consists of 4 coherent use cases:

UC4.1: City farming leafy vegetables; it aims to innovate the vegetables value chain for leafy vegetables in convenience foods integrating indoor climate control and logistics.

UC4.2 Chain-integrated greenhouse production; it aims to integrate the value chain and quality innovation, using a full sensor-actuator based system in tomato greenhouses.

UC4.3 Added value weeding data; it consists in boosting the value chain by harvesting weeding data of organic vegetables obtained leveraging advanced visioning systems.

UC4.4 Enhanced quality certification system; it has the objective to have enhanced trust and simplification of quality certification systems by use of sensors, RFID tags and intelligent chain analyses.

1.2.5 The Internet of Meat

This trial aims to demonstrate how the growth of animals can be optimized and communication in the whole supply chain can be improved using automated monitoring and control of advanced sensor-actuator systems.

UC5.1: Pig farm management; it aims to optimize pig production management through interoperable on-farm sensors and slaughter house data.

UC5.2: Poultry chain management; it aims to optimize production, transport and processing of poultry meat by automated ambient monitoring & control and data analyses.

UC5.3: Meat Transparency and Traceability; it consists in enhancing transparency and traceability of meat based on a monitored chain event data.

1.3 UC ANALYSTS 1ST VERSION OF THE DELIVERABLE

The following Table 1 lists the lead architectural analysts which developed and documented the analysis presented in Section 0, building upon the inputs and the strong collaboration with the teams of the different UCs.

Table 1 - Analysts involved in the definition of IoT Architectures of UCs – 1st version of the Deliverable

UC	Lead IoT Architecture Analysts	Organization	Directly involved in the UC
1.1	T. Veenstra	CORIZON	No
1.2	C. Vivens, T. Milin	ORANGE	Yes
1.3	O. Di Marco, G. Urlini	ST-I	No
1.4	M. Enderle, F. Zipser, J. Dzatkowski	365-FN	Yes
2.1	J. Bert, F. Manoel	NXP	No
2.2	O. Di Marco, G. Urlini	ST-I	No
2.3	B. Almeida, T. Teixeira	UNPARALLEL	No
2.4	H. Sundmaeker, G. Große Hovest, A. Vyas	ATB	No
3.1	R. Tomasi, F. Rizzo	ISMB	No
3.2	L. Gürgen	CEA	Yes
3.3	J. Hierro, J. M. Cantera, F. López Aguilar; Á. Arranz	FF	No
3.4	H. Sundmaeker, G. Große Hovest, A. Vyas	ATB	Yes
4.1	J. Bert, F. Manoel	NXP	No
4.2	B. Almeida, T. Teixeira	UNPARALLEL	No
4.3	C. Verdouw	WECR	Yes
4.4	J. Hierro, J. M. Cantera, F. López Aguilar; Á. Arranz	FF	No
5.1	R. Tomasi, F. Rizzo	ISMB	Yes
5.2	M. Larrañaga Negro	IK4-TEKNIKER	Yes
5.3	B. Tekinerdogan, A. Kassahun	WU	Yes

Following the proposed methodology for the project, in the first phase, each UC lead architectural analysts have worked in autonomous fashion in cooperation with the UC team to develop the initial analysis. The results of such initial analysis have been aggregated and reviewed by the T3.1 and WP3 leader – and then circulated back the whole T3.1 team. After such first harmonization, the analysis has been iteratively improved by the lead analyst – working in cooperation with other analysts.

1.4 UC ANALYSTS 2ND VERSION OF THE DELIVERABLE

The following Table 1 lists the lead architectural analysts which updated the analysis presented in Section 0, building upon the inputs and the strong collaboration with the teams of the different UCs.

Table 2 - Analysts involved in the definition of IoT Architectures of UCs – during the update of the Deliverable (2nd version)

UC	Lead IoT Architecture Analysts	Organization	Directly involved in the UC
1.1	T. Veenstra	CORIZON	No
1.2	C. Vivens, T. Milin	ORANGE	Yes
1.3	O. Di Marco, G. Urlini	ST-I	No
1.4	M. Enderle, F. Zipser, M. Cartsburg	365-FN	Yes
2.1	J. Berg, K. Shekhar	NXP	No
2.2	O. Di Marco, G. Urlini	ST-I	No
2.3	B. Almeida, J. Abrantes	UNPARALLEL	No
2.4	H. Sundmaeker, G. Große Hovest, A. Vyas, R. Campos	ATB	No
3.1	M. Fina[1], V. Verrastro[2]	[1]Sysman Progetti & Servizi, [2]CIHEAMB	Yes
3.2	L. Gürgen[1], S. Kleisarchaki[1], M. Diaznava[2]	[1]CEA, [2]ST-I	Yes
3.3	J. Hierro, J. M. Cantera, F. López Aguilar; Á. Arranz	FF-FICODES	No
3.4	H. Sundmaeker, G. Große Hovest, A. Vyas, R. Campos	ATB	Yes
4.1	J. Berg, K. Shekhar	NXP	No
4.2	B. Almeida, J. Abrantes	UNPARALLEL	No
4.3	R. Robbemond	WECR	Yes
4.4	J. Hierro[1], J. M. Cantera[1], F. López Aguilar[1]; Á. Arranz[1]; R. Fernández[1], M. Balderacchi[2]	[1]FF-FICODES, [2]Valoritalia	No
5.1	T. Montanaro, D. Conzon	ISMB	Yes
5.2	E. Garcia, I. Fernandez Gonzalez	IK4-TEKNIKER	Yes
5.3	B. Tekinerdogan, A. Kassahun	WU	Yes

After an initial collection of updates from each UC and the consequent preliminary update of all the sections of this document, each UC lead architectural analysts have worked in autonomous fashion, in cooperation with the UC team, to check the consistency of the data inserted as an update and the actual update of the Deliverable. The results of such initial analysis have been aggregated and reviewed by the T3.1 and WP3 leader – and then circulated back the whole T3.1 team. After such first harmonization, the analysis has been iteratively improved by the lead analyst – working in cooperation with other analysts.

2 RESULTS OF THE IOT ARCHITECTURE ANALYSIS

2.1 ARABLE UC 1.1: WITHIN-FIELD MANAGEMENT ZONING

The general goal of this use case is within field management zoning and precision farming in arable crops with the use of sensors, connectivity, decision support tools and smart control equipment.

With the fast development of technologies due to the evolution of communication networks (mobile telephony, very high-speed connections and narrow band, short and long range), and availability of a wide range of new sensors, new opportunities are emerging in arable farming. In an agricultural context, these technologies help capture and transmit geo-localised real-time information at low cost. Once gathered, processed and analysed, the data help to measure and monitor the state of the agro-environment, e.g. soil, crop and climate. And when combined with agro-climatic and economic models, forecasts and advices for better tactical decisions and operational management of technical interventions can be given. Precision crop management has a major significance for future cropping systems.

2.1.1 Domain model

The domain model for UC1.1 is depicted in Figure 2.

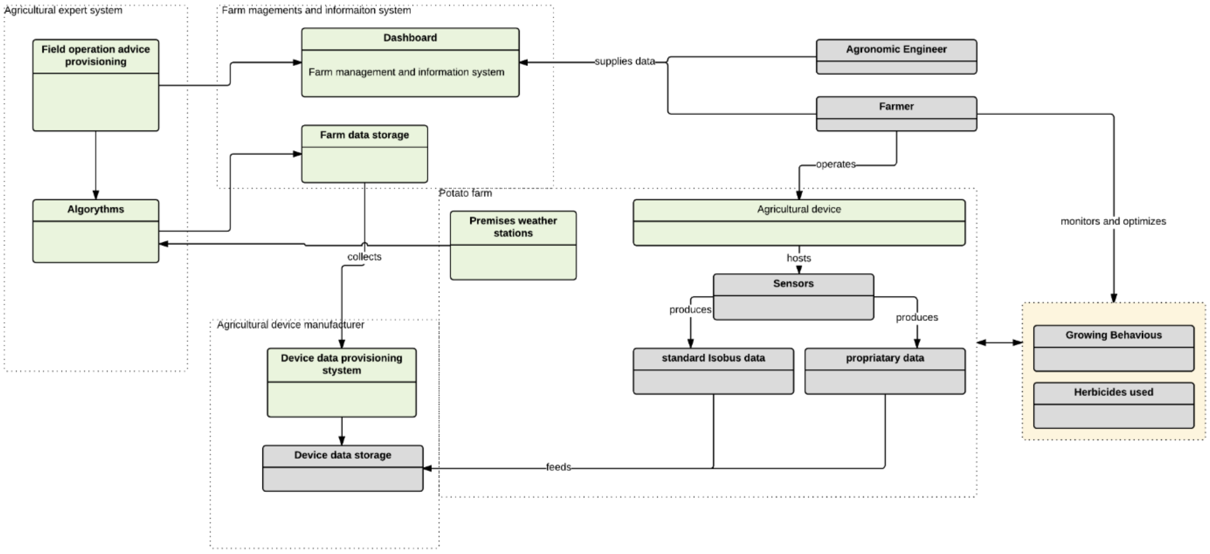


Figure 2 - UC1.1 Domain Model

Overall, the system allows **Farmers** to monitor and optimize the Growing Behaviour of potatoes and optimize the use of herbicides used while growing potatoes. The monitoring and optimization features heavily rely on IoT Devices and systems deployed on the field as well as on the agricultural devices used.

Crop and Field Sensors are sensing devices. They are used to monitor a wide number physical parameters. They are either permanently **connected** (installed in fixed position and periodically sending monitored data e.g. through wireless technologies) or **nomadic** i.e. temporarily deployed by human operators to measure and record parameters of interest in specific moments in time.

2.1.2 Deployment view

The Deployment diagram for UC1.1 is depicted in Figure 3.

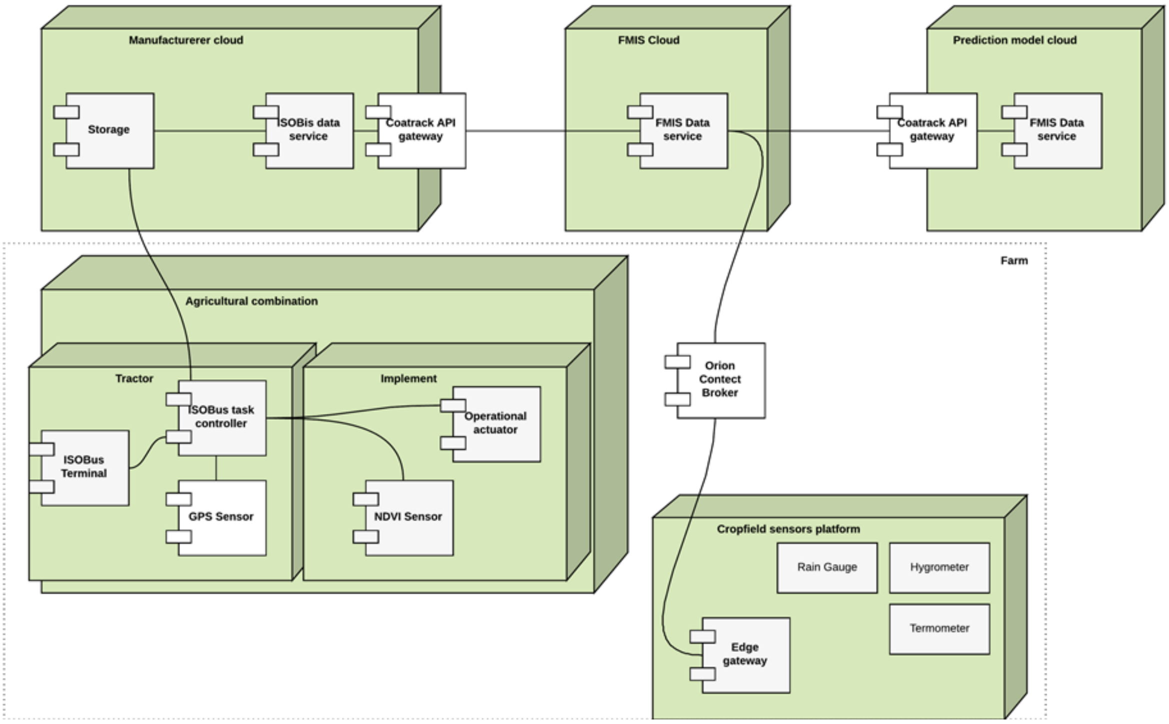


Figure 3 - UC1.1 Deployment View

The main components of this use case are deployed on the farm, either stationary on the field or mobile on the agricultural device. Data generated by the components on the agricultural device are transported to the manufacturers cloud solution using either an ISOBUS[viii] channel, or a proprietary data channel or both. The manufacturer exposes the generated data to any service authorized by the owner of the device using an ISOBUS compatible data service. The edge gateway is responsible to expose the generated sensor data to any service authorized by the owner. The FMIS could be such a service, operating on the farmers behalf to collect and maintain data produced by several sources on the farm. The FMIS could expose this collected data to any additional service like a cloud based prediction model.

2.1.3 IoT Functional view

The IoT functional view of this use case (depicted in Figure 4) is structured as following:

- *Application Layer*: ISOBus terminal on the agricultural device and the farm management information system application
- *Service support and application support layer*: Objects in the application domain are generally backed by objects in the service support and application support layer.
- *Network layer*: The communication between the agricultural device and the data services provided by the manufacturer are already provided by the manufacturer's isobus data channel and their proprietary data channel. Both are not further specified and can differ between manufacturers, which is not a problem when exposed by a standardized data service. The sensors are connected using the LoRa network.
- *Device layer*: sensors and actuators

- *Management Capabilities:* not yet considered in this UC
- *Security Capabilities:* not yet considered in this UC

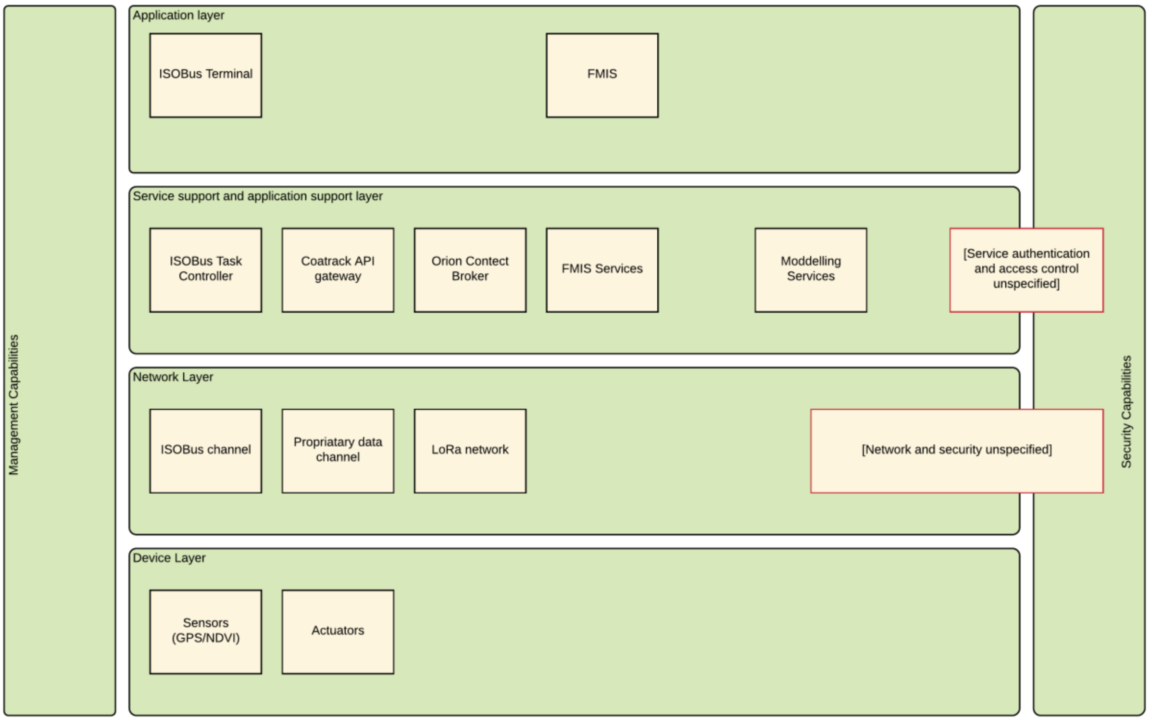


Figure 4 - UC1.1 IoT Functional View

2.1.4 Business Process Hierarchy view

The Business Process Hierarchy view for UC1.1 is depicted in Figure 5.

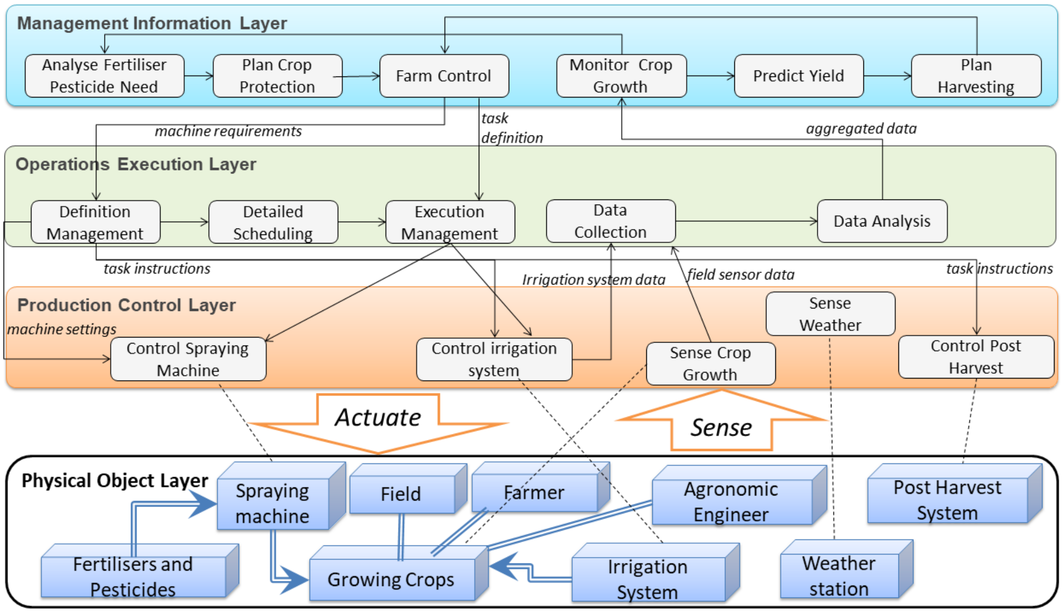


Figure 5 - UC1.1 Business Process Hierarchy view

Business Process Hierarchy View comprises four layers: *Physical Object Layer, Production Control Layer, Operations Execution Layer* and *Management Information Layer*.

In the **Physical Object Layer,** the relevant objects of this case are depicted: growing crops in the field, that are sensed with nomadic and connected sensors, irrigation system and weather station. The spraying machine applies pesticides and fertilisers to the crops based on specific conditions provided from upper levels. Irrigation system applies variable rate irrigation depending on the variation in the crop water needs. Post-harvest system is used for packaging facility in order to deliver the good quality product to the consumers.

The other layers include the main farm processes on different time horizons that are needed in this case to sense and control the physical objects. The starting point is sensing of crop growth in the **Production Control Layer** that generated field sensor data. The control modules are used to actuate commands to specific physical objects. All these data are collected and analysed in the **Operations Execution layer**. The aggregated data are used in the **Management Information Layer** to monitor crop growth. Next, the fertiliser and pesticide need is calculated based on the crop growth monitoring and weather data. The Farm Control triggers that the execution of these actions by sending the specific requirements task and task definition for spraying machine and irrigation system to the **Operations Execution Layer**. In this layer, the settings of the spraying machine and irrigation system are defined, the spraying and irrigation task are scheduled and the spraying and irrigation task instructions are sent to the **Production Control layer**.

2.1.5 Interoperability Endpoints

The interoperability endpoints are shown on Table 2.

Table 2 - UC1.1 Interoperability Endpoints

Interface name	Exposed by	Protocol	Notes
Farm management information system 365 FarmNet	Dashboard	HTTP (Web GUI)	https://www.365farmnet.com/
Machine data	API	To be defined	To be defined

2.1.6 Information model

The information model used in this UC is based upon the Data Reference Model Crop, whose open specifications are available online[ix]. In case data entities emerge, which are not considered in the current data model, dedicated extensions will be considered.

2.1.7 Summary of gaps

At the current stage, some gaps to be filled exists in the specifications, resulting in the need for further specification works to solve all the main issues. Such gaps are mostly currently existing in the specification of the security part – both on authentication and authorization.

2.1.8 Assets identified for re-use

The analysis of assets identified in UC1.1 is still on-going, but a few findings are already available:

- The 365 Farmnet dashboard has strong potential for re-use in several UCs.

- The information model adopted by UC1.1. has potential for adoption both stand-alone or cross-linked with other data models.
- There's potential for synergies related to the fact that other UCs may be adopting solutions compliant with the ISOBUS standard.
- The FIWARE Orion[x] Context Broker is used, consequently all its interfaces can be reused.

2.1.9 Collaboration with other Use Cases

A collaboration has been established with UC 1.2 and UC 1.4 to identify reusable components, especially UC 1.4 has focus on the common issues regarding interfaces and messaging in the Use Case 1.1, 1.2 and 1.3.

2.1.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, key performance indicators (KPIs) and performance targets.

The following Table 3 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability

Table 3 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC1.1)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May '18)	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	100	The discussion on which Crop and Field Sensors and actuators will be adopted is yet open so the reported values are not yet consolidated. The reported value includes more instances of: - Rain Gauge - Hygrometer - Thermometer - GPS Sensor - NDVI Sensor
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	4	- Farm Data Storage (1) - ISOBus data service (1) - FMIS Data service (1) - Cropfield sensors platform (1)
	Number of IoT applications available	2	- ISOBus terminal on the agricultural device - Farm management information system application
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1
	Number of FIWARE GEs instances	1	- FIWARE Orion Context Broker
	Number of open datasets used	0	
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	1	- FIWARE Orion Context Broker
	Average number of installations per reusable IoT component	0	

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May ‘18)	Short comment / qualitative estimation
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	1	- FIWARE Orion Context Broker
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies	20%	

2.2 ARABLE UC 1.2: PRECISION CROP MANAGEMENT

UC1.2 aims to improve competitiveness of farms and production value, consistently fitting with sustainable development. To address those challenges, partner ARVALIS[xi] has supported farmers on the implementation of digital technologies and services on farming. ARVALIS will coordinate a network of experimental digital farms to provide a better support to farmers on the path of digital progress. The concept of digital farms enables to look forward the future farm, by combining the best of sensors implementation, decision support tools in connection with field applications, and telecom services. The digital farms will provide ARVALIS the opportunity to test and develop services and Decision Support Tools (DST) in the same conditions as in farms.

In this UC, we will focus on nitrogen and irrigation in a precision crop management approach.

2.2.1 Domain model

The Domain model for UC1.2 is represented in Figure 6.

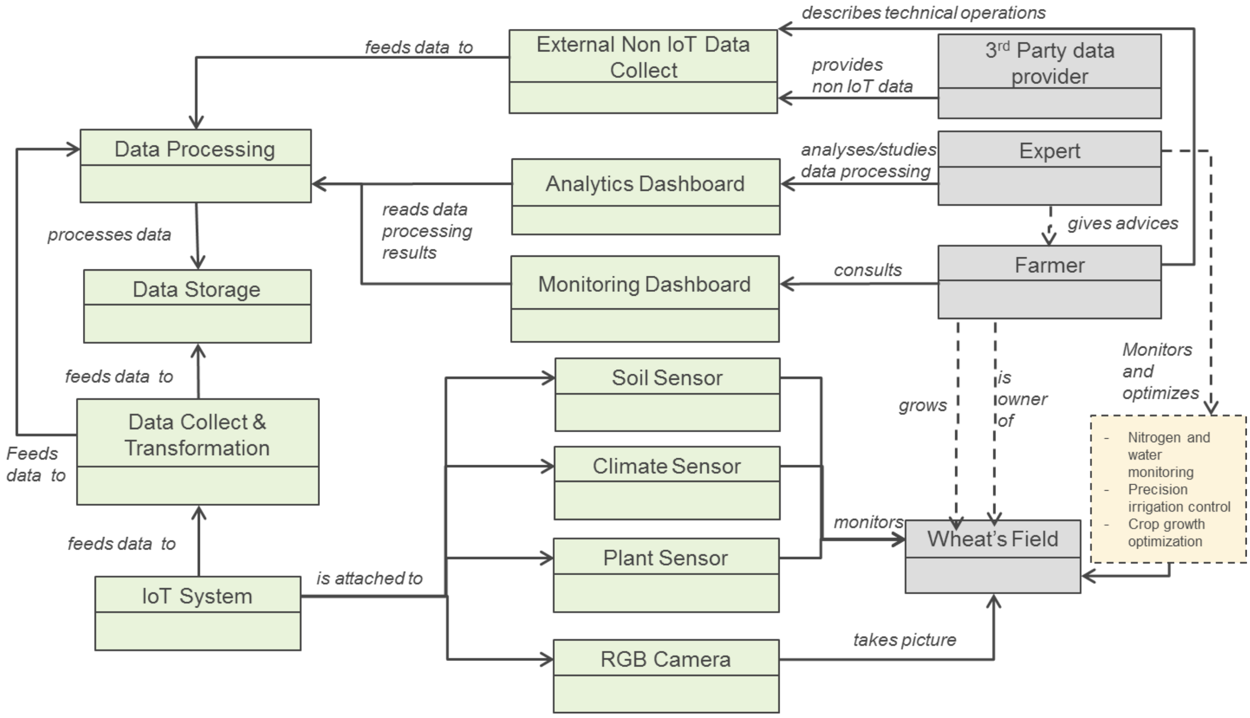


Figure 6 - UC1.2 Domain Model

<u>Main actors</u>

- **Wheat's Field** represents the physical entity that is monitoring
- **Farmer** represents a human user that is the owner of the wheat's field and grows it
- **Expert** represents a human user that analyses and processes collected information in order to give advices to farmer, the role of this actor is not precisely defined, the trial aims to describe his different functions and relations with the farmer
- **3rd party data provider** represents partners that provide data

Main components

- **Soil Sensor** monitors soil water potential and temperature of the wheat's field provide
- **Climate Sensor** monitors air temperature, relative humidity and solar radiation of the wheat's field
- **Plant Sensor** monitors crop growth through spectral reflectance and transmittance
- **RGB Camera** takes pictures to visually monitor the field
- **IoT System** represents the device where the different sensors are attached to, its main role is to transmit collected data
- **DATA TRANSFORMATION** represents service that collects and calibrates raw sensor data (to provide some corrections to initial measurements)
- **DATA STORAGE** represents service that stores data (raw data, enriched data, converted data, etc.) coming from different sources (sensors in an indirect way, external providers, etc.)
- **DATA PROCESSING** represents service that analyses and correlates different kind of data, produces indicators to improve crop management (nitrogen and water monitoring, precision irrigation control, crop growth optimization)
- **Monitoring Dashboard** offers tools (mobile app for example) to the farmer to access to the main information about his wheat's field
- **Analytics Dashboard** offers tools to give predictive information to the expert
- **External Non IoT DATA COLLECT** processes non IoT Data (weather forecast, geolocation, spatial information, technical operations led by the farmer, management practices, production objectives…)

2.2.2 Deployment view

To simplify the understanding of this view, two deployment views have been designed due to the two modes of connectivity of IoT Gateway (cellular connectivity, LoRa connectivity) as depicted in Figure 7 and Figure 8.

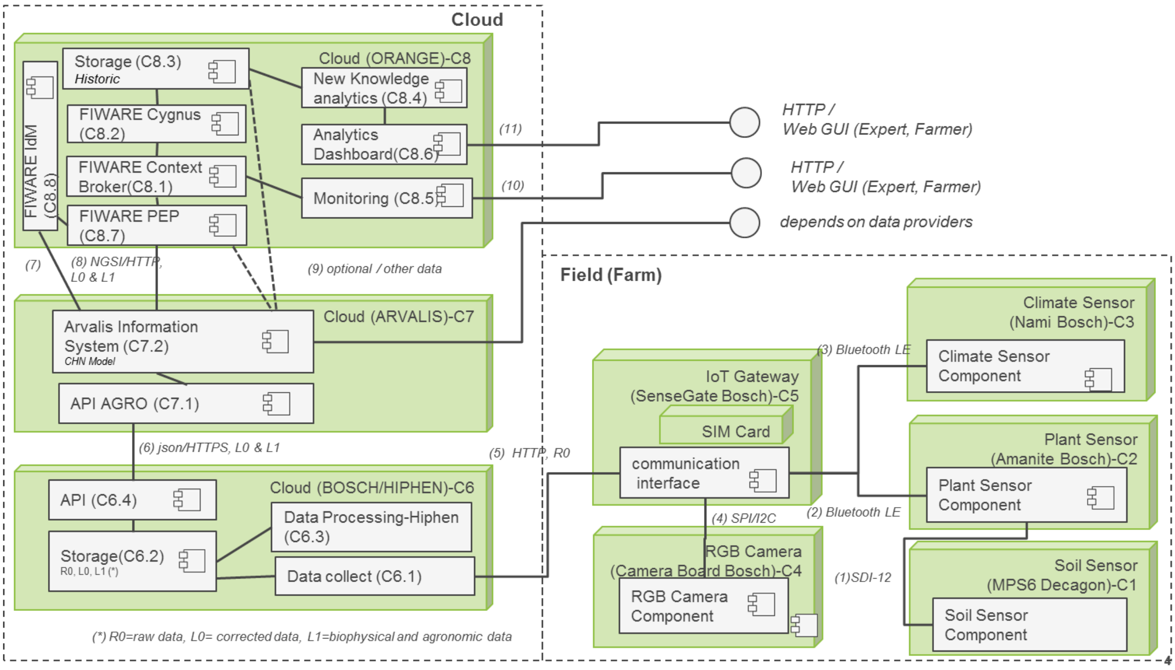


Figure 7 - UC1.2 Deployment View (Cellular Connectivity)

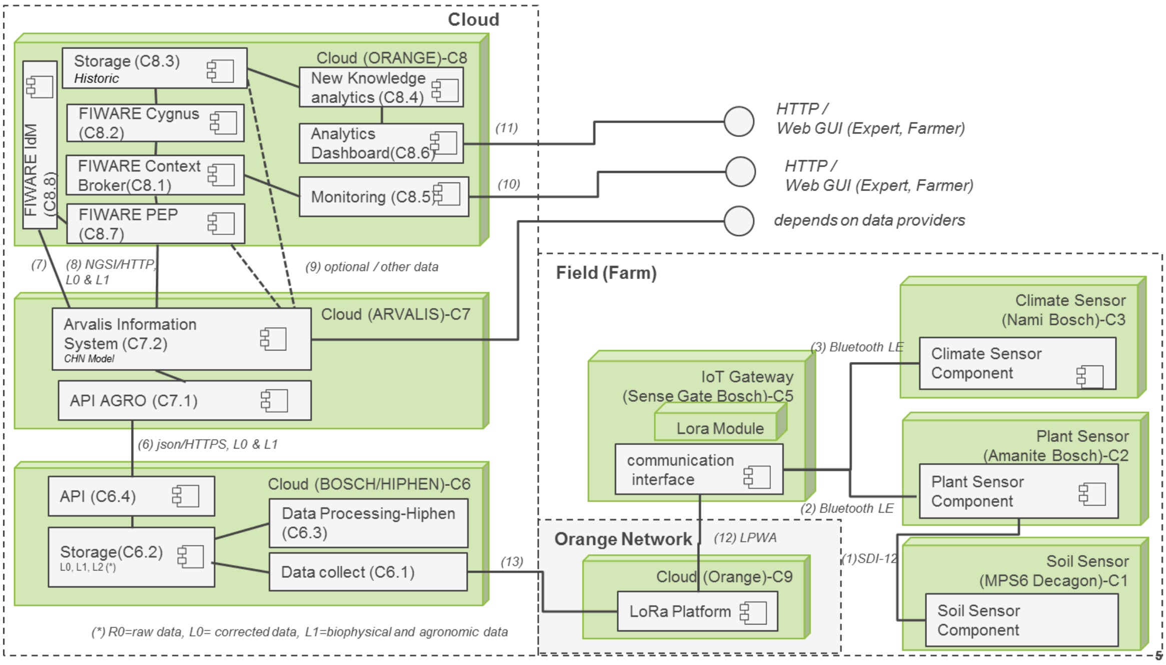


Figure 8 - UC1.2 Deployment View (LoRa Connectivity)

This architecture consists of several building blocks:

- a system of sensors deployed locally in the field with an embedded gateway to communicate to the platform in the network,
- a first cloud which interacts with all gateways to collect and process data,
- a second cloud which allow to enrich data with non IoT Information,

- a third cloud which provides analytic process and gives a business representation of information to End-users.

With LoRa connectivity,

- It is not possible to upload photo so the RGB camera sensor is not deployed
- It is necessary to show the LoRa Network component because it changes the way to collect data from IoT System

Details about the deployed components are summarized in Table 4.

Table 4 - UC1.2 Deployed Components

Name	Description	Supplier (brand+model)	Number of units(*)
Soil Sensor(C1)	sensor to monitor soil water potential and temperature	MPS6 Decagon	2x8
Climate Sensor(C2)	sensor to monitor air temperature relative humidity and solar radiation	Amanite Bosch	8
Plant Sensor(C3)	sensor to monitor crop growth through spectral reflectance and transmittance	Nami Bosch	8
RGB Camera(C4)	sensor to visually monitor the field	Camera Board Bosch	8 (not deployed with Lora connectivity)
IoT Gateway(C5)	device to transmit collected data	SenseGate Bosch	8
Cloud(C6)	components which collect the raw sensors data(L0), transform to corrected (calibration coefficients are applied) data(L1) and calculate biophysical data(L2)	Bosch/Hiphen	1
Cloud(C7)	components which use to transfer data (L1 & L2) coming from Bosh and other agronomic data coming from Arvalis Information System	Arvalis	1

Name	Description	Supplier (brand+model)	Number of units(*)
Cloud(C8)	components which manage a real time context of physical environment, store all data (L1,L2, other) in order to experiment data knowledge analysis	Orange (use of FIWARE components: context broker, PEP Proxy, IdM)	1
Orange LoRa Network(C9)	Network infrastructure to communicate with LoRa Device	Orange	*Not Applicable*

(*) information for the experiment year 1

2.2.3 IoT Functional view

The IoT functional view is depicted in Figure 9.

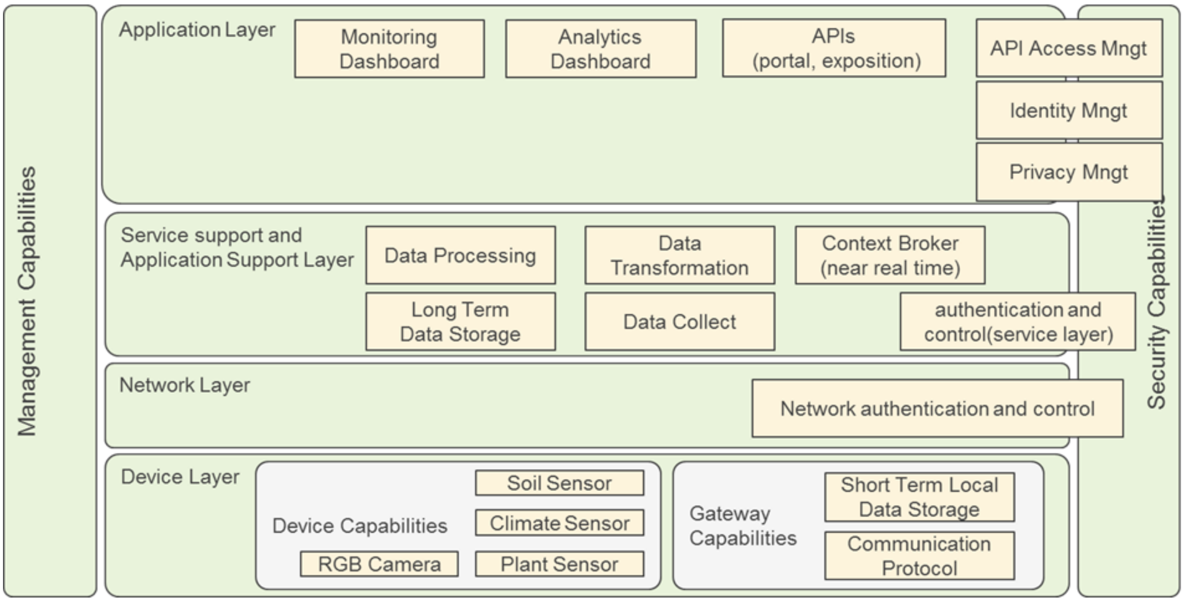


Figure 9 - UC1.2 IoT Functional View

It structured as following:

- *Application Layer*: functions that allow interaction with End-Users and API consumers,
- *Service support and Application Support Layer*: this layer groups all functional components that aim data processing as collection, storage, transformation, enrichment and aggregation,
- *Network Layer*: functions that provide communication in a secure way,
- *Device Layer*: embedded functions in sensors (measurement capabilities) and gateway (local storage, connectivity),
- *Security capabilities:* functions linked to security aspects, some functions have listed but it is not exhaustive, for example on each layer, it is necessary to implement components that are in

charge of authentication, authorization and right management, regarding privacy management is an essential function to handle data governance.

2.2.4 Business Process Hierarchy view

The Business Process Hierarchy view is described in Figure 10.

In the physical object layer, it is described the physical environment. In the context of this UC, it groups elements contributing to manage in best the supply of water and nitrogen in the crop. Technical equipment as sensors are not represented but they are physically installed in the field.

In the production layer, it represents the link between the physical world and the virtual world. So in this part, it can find processes that on one hand measure different kind of information in the field and on the other hand act on crop (irrigation or fertilization)

In the operation execution layer, it groups all computational tasks using collected information as well processes that take into account results of management information layer, it can be the creation of maps to plan irrigation or apply fertilizer.

In the management information layer, the defined processes take into account data from operation layer and apply business rules to obtain several indicators. With some additional analysis, these results allow to give advices and define an action plan like nitrogen application map or irrigation map.

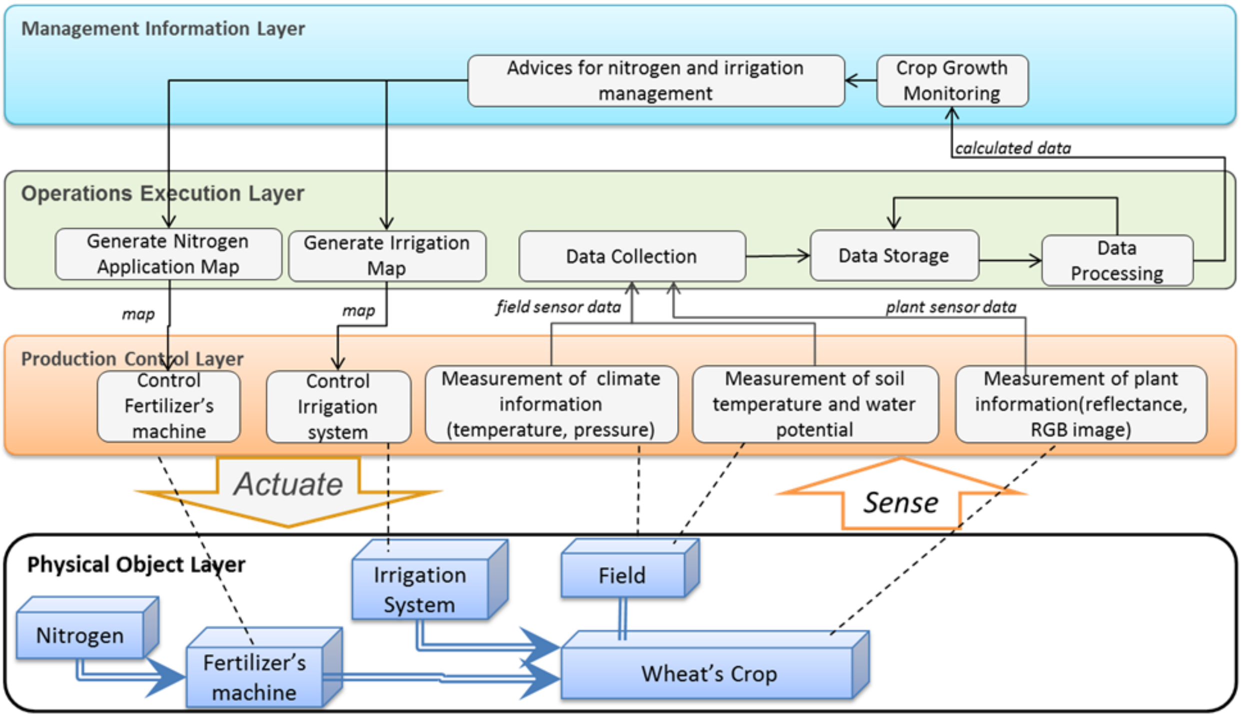


Figure 10: UC1.2 Business Process Hierarchy view

2.2.5 Interoperability Endpoints

The full list of identified interoperability end-points for UC1.2 is summarized in Table 5.

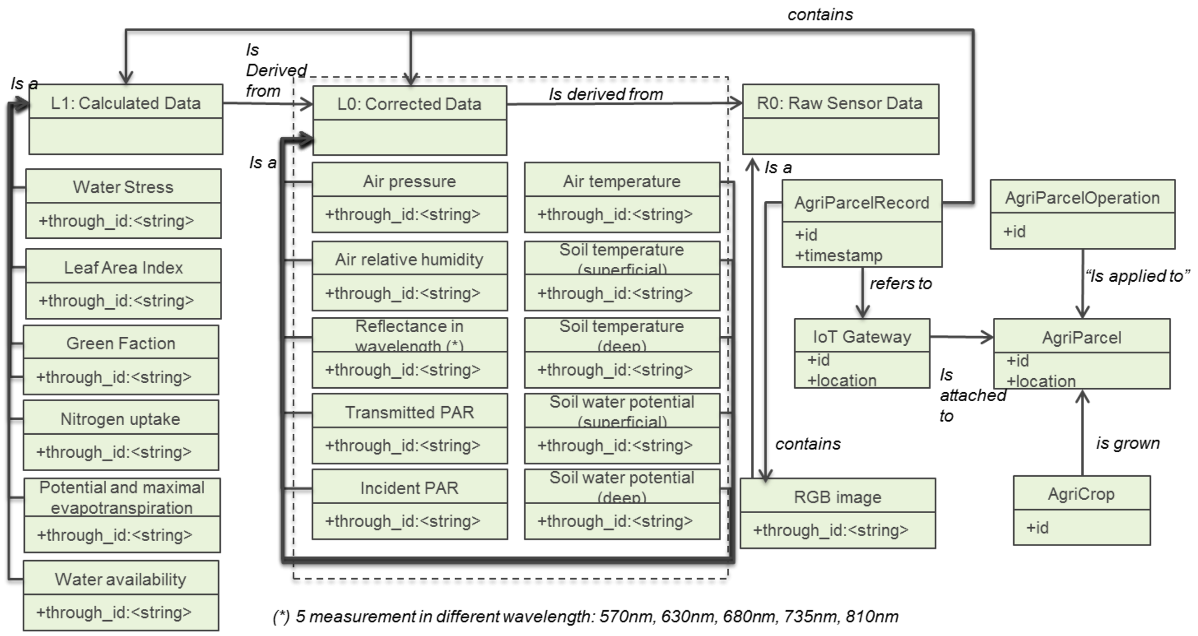
Table 5 - UC1.2 Interoperability Endpoints

Interface name (*)	Exposed by	Protocol	Notes
(1)	Soil Sensor(C1)	SDI-12	L0(raw data), wire communication
(2)	Climate Sensor(C2)	Bluetooth LE	L0(raw data)
(3)	Plant Sensor(C3)	Bluetooth LE	L0(raw data)
(4)	RGB Camera(C4)	SPI/I2C	L0(bmp), wire internal communication
(5)	IoT system(C5)	HTTP (Data in ASCII format with an AES128 signature)	information type: L0 cellular communication (M2M SIM card)
(6)	API Bosch(C6.3)	JSON/HTTPS	information type: L0, L1
(7)	FIWARE IdM(Identity Management) (C8.8)	OAuthV2, HTTP	API Access management (authentication, get Token and check Token)
(8)	FIWARE Context Broker(C8.1)	NGSI[xii]/HTTP	*description of data model is in progress* information type: L0, L1
(9)	FIWARE Context Broker(C8.1) or Storage (C8.3)	*to be scouted*	information type: other agronomic data
(10)	Monitoring(C8-5)	HTTP	
(11)	Analytics Dashboard(C8-6)	*to be scouted*	
(12)	IoT system(C5)	Bosch proprietary format	LPWA communication
(13)	LoRa PlatforrmData(C9)	Message Queue Telemetry Transport (MQTT) or HTTP with encrypted payload	

(*) information given in the column "Interface name" refers to the diagram "Deployment view".

2.2.6 Information model

The complete information model of UC1.2 is described in Figure 11 and Table 6.



(*) 5 measurement in different wavelength: 570nm, 630nm, 680nm, 735nm, 810nm

Figure 11 - UC1.2 Information Model

Table 6 - UC1.2 Information Model Details

Data ID	Measurement Technique	Physical Entity	Frequency of data collection	Associated data model and format
L0 (Data type): corrected data, it means that calibration coefficients are applied				
Air pressure	corrected data from direct measurement via **climate sensor**	Wheat's Field	1 reading/15mn 2 collections/day	hPa(unit)
Air relative humidity	corrected data from direct measurement via **climate sensor**	Wheat's Field	1 reading/15mn 2 collections/day	%(unit)
Reflectance in wavelength 570nm	corrected data from direct measurement via **plant sensor**	Wheat's Field	1 reading/15mn 2 collections/day	no unit
Reflectance in wavelength 630nm	idem	Wheat's Field	1 reading/15mn 2 collections/day	no unit
Reflectance in wavelength 680nm	idem	Wheat's Field	1 reading/15mn 2 collections/day	no unit
Reflectance in wavelength 735nm	idem	Wheat's Field	1 reading/15mn 2 collections/day	no unit
Reflectance in wavelength 810nm	idem	Wheat's Field	1 reading/15mn 2 collections/day	no unit
Transmitted PAR	corrected data from direct measurement via **climate sensor**	Wheat's Field	1 reading/15mn 2 collections/day	lux

Data ID	Measurement Technique	Physical Entity	Frequency of data collection	Associated data model and format
Incident PAR	corrected data from direct measurement via **climate sensor**	Wheat's Field	1 reading/15mn 2 collections/day	lux
Air temperature	corrected data from direct measurement via **climate sensor**	Wheat's Field	1 reading/15mn 2 collections/day	°C(unit)
Soil temperature (superficial)	corrected data from direct measurement via **soil sensor**	Wheat's Field	1 reading/15mn 2 collections/day	°C(unit)
Soil temperature (deep)	corrected data from direct measurement via **soil sensor**	Wheat's Field	1 reading/15mn 2 collections/day	°C(unit)
Soil water potential (superficial)	corrected data from direct measurement via **soil sensor**	Wheat's Field	1 reading/15mn 2 collections/day	kPa(unit)
Soil water potential (deep)	corrected data from direct measurement via **soil sensor**	Wheat's Field	1 reading/15mn 2 collections/day	kPa(unit)
RGB image		Wheat's Field	2 pictures/day 2 collections/day	bmp format
L1 (Data type): calculated data, it means that models are applied				
Water stress	calculated data	Wheat's Field	1 calculation/day	MPa
Leaf Area Index(LAI)	calculated data	Wheat's Field	1 calculation/day	Model to convert transmittance to LAI
Green Fraction	calculated data	Wheat's Field	1 calculation/day	RGB image analysis
Nitrogen uptake	calculated data	Wheat's Field	1 calculation/day	Model to convert spectral reflectance to N uptake
Potential and maximal evapotranspiration	calculated data	Wheat's Field	1 calculation/day	Model to combine crop and climatic data
Water availability	calculated data	Wheat's Field	1 calculation/day	Model to combine soil, crop and climatic data

2.2.7 Summary of gaps

Among the first release of this deliverable and the current update, some gaps were filled:

- Some software components described in the architecture of UC1.2 have been deployed in the cloud infrastructure (Bosch, Orange)
- At this stage the communication between the two clouds is not in real time: file transfer is yet used
- A first definition of a “data model” based on GSMA recommendations has been designed and NGSI API linked to this data model allow feeding the Context Broker.

Regarding the “data model”, UC 1.2 has suggested to start discussion about potential synergy within Trial 1 during the last Trial 1 meeting in Boigneville (France). This activity is on-going.

The following aspects were not yet completed investigated:

- Regarding the “new knowledge analytics” component, the ambition is to explore different tracks that will depend of stored data. It will be an investigation phase, thus at this stage, it is difficult to have a clear vision of the final result. In consequence, it could modify the interaction between actors and the system.
- Concerning the list of “other data” (cf. the end of the table in the previous paragraph), at this stage, this item has not been investigated. This point will be clarified in a second time in collaboration with Arvalis knowing this is closely linked to the previous point.

Identity and Privacy Management are two transversal subjects which had been identified but are not begun yet because it is necessary to clarify needs about data visualization:

- A component of Identity Management will be necessary to manage access to different dashboards, at present time no solution has been chosen.
- Another important point is about privacy management. The Bosch and Orange cloud infrastructures store and manage field sensor data and do not store any personal data. Potential impact of privacy management on the architecture has to be evaluated.

2.2.8 Assets identified for re-use

The list of assets currently identified for re-use is depicted in Table 7.

Table 7 - UC1.2 Assets identified for re-use

Component name	Short Description and role in the Use Case	Functional role	License
FIWARE Context Broker (ORION)	In the context of UC1.2, this component allows giving the real-time status of physical environment; it will be used a data model that represents physical entities and their attributes. The component is fed by data producers (in an indirect way by the sensors) and provide	In the ITU-T Y.2060 IoT Reference Model, this “Context Broker” function is located in the “Service Support and Application Support Layer”	AGPL v3

Component name	Short Description and role in the Use Case	Functional role	License
	context information to consumer applications. The main advantage of this component is the processing of heterogeneous data.		
Bosch IoT system: SenseGate, Camera Board, Amanite, Nami	These different sensors are used to monitor wheat's crops. It is possible to reuse these types of equipment for others crops	In the ITU-T Y.2060 IoT Reference Model, sensor is located in the "Device Layer"	Bosch proprietary

2.2.9 Collaboration with other Use Cases

One of the topics threated during the Stakeholder event taken in Almeria (1-2 March 2018) was related to the challenges linked to Data exchange standardisation. The most important evidence reported as a conclusion of such discussion is the difficulty to share data between different components or applications used in smart agriculture solution.

As a consequence, the partners involved in Trial 1 had a physical meeting in Boigneville in May 2018. They agreed on the necessity of starting a discussion on a minimal common data model within trial 1 in order to tackle the issue about data interoperability.
As a first step in this direction, they are collaborating to obtain a common view of "Temperature" shared among all the use cases. Deliberately, they are working on an environment data model that is obtained in a simple example used to see if it is possible to achieve the same vision.
To initiate this data model, UC1.2 decided to rely on GSMA recommendations which deal with "Harmonised Data Model". Such recommendations are grouped in a publish document[1] that describes different entities used in several sectors (like agricultural industry) and follows NGSIv2 specifications.
Within UC1.2, a first "data model" based on GSMA has been defined in year one and implemented in Orion Context Broker to store collected data from Bosch sensors.

The ambition is to use the same approach with other use cases (see diagram below) so that a new partner can use the same API which gives information about an AgriParcel without knowing the specific description of each data provider.

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[1] https://www.gsma.com/iot/wp-content/uploads/2016/06/CLP.26-v4.0.pdf

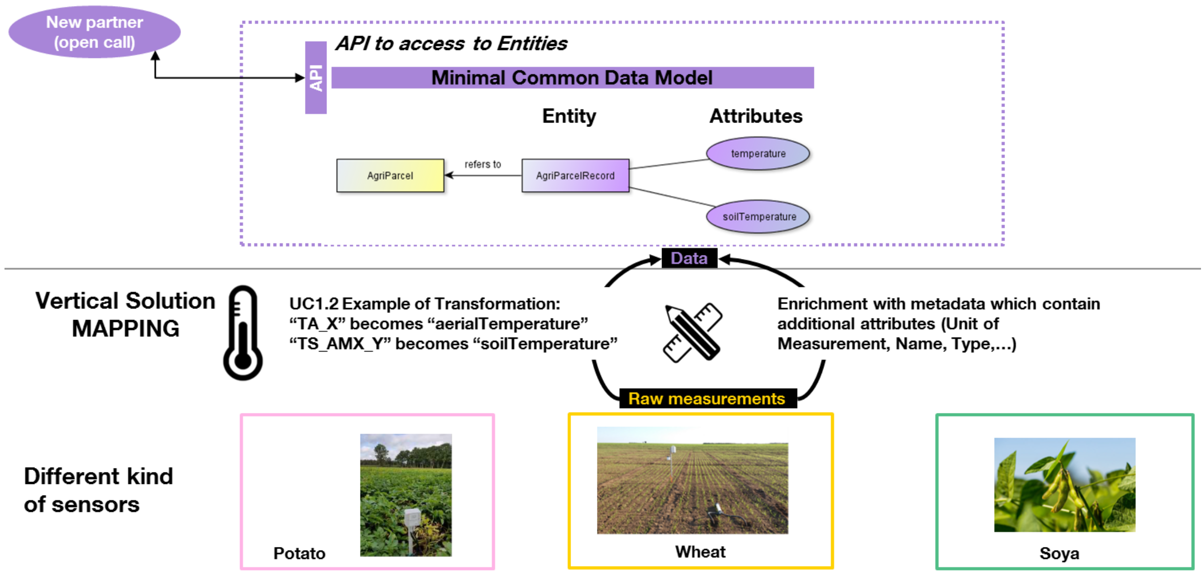


Figure 12 – Minimal common data model discussion

At the current moment, this vision was only shared and discussed, but no decision related to this potential synergy was taken at this stage. Obviously, UC1.2 will carry on studying this important issue with the objective to propose a first definition of a minimal common data model. Thus, it could offer an opportunity to initiate building blocks of semantic interoperability.

In parallel, UC1.4 is experimenting AgGateway's ADAPT solution to deal with another kind of interoperability at machine level.

2.2.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets.

The following Table 8 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability

Table 8 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project.(UC 1.2)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May '18)	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	15	- Bosch IoT sensor
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	3	- Bosch IoT Platform - Arvalis Gateway - Fiware platform (provided by Orange)
	Number of IoT applications available	2	- Bosch IoT Platform, - FIWARE platform (provided by Orange)
Usage of open IoT	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May ‘18)	Short comment / qualitative estimation
architectures and platforms	Number of FIWARE GEs instances	4	- FIWARE Pep Proxy - Cygnus - FIWARE Orion Context Broker - STH comet
	Number of open datasets used	/	Not yet available
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	/	Not yet available
	Average number of installations per reusable IoT component	/	Not yet available
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	2	- FIWARE Pep Proxy - FIWARE Orion Context Broker (based on NGSI)
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies	/	Not yet available

2.3 ARABLE UC 1.3: SOYA PROTEIN MANAGEMENT

Coping with the challenge that the EU is not self-sufficient in terms of vegetable proteins, the goal of UC1.3 is the significantly increase of European self-sufficiency in plant protein supply. The challenge in this niche for soybean producers is to meet the protein levels as they are required by their customers. The selection of the right soybean variety is the most important decision to fulfil the requirements. But additionally, also environmental factors and agronomic practices are influencing the performance of the varieties. A decision-support-system in place which supports farmers in the most critical crop and soil management questions can be able to boost the production capacity of European producers to provide the growing demand of high-quality soybeans for the rapidly developing processing vegetable protein industry in Europe. UC1.3 is so aimed to develop a site-specific management to investigate agronomic and environmental factors that influence yield and protein in soybean crop to then support farmers in understanding how to achieve good yields in terms of quantity (to/ha) and quality (proteins/ha) by the support of precision/smart farming technology. Therefore, soil and climate data coming from sensor network and machines in the field will be available and ready to be put in a common platform to support farming decision. The UC will take place in Austria and Italia.

Our proposal consists in the adoption of an integrated **MEMS sensor & MEMS actuator system**, to collect and investigate the environmental factors on each site. Using MEMS sensors, the farmer will collect environmental data in the **wireless network**, while the **MEMS actuators** allow to obtain a **very fine control of site specific herbicide application or pesticides** that will be delivered on demand, on site and only based on specific sensor inputs from the environmental conditions. Using the information collected by a sensor & actuator **network** (soil, climate and actuation data), would be possible to investigate the influence yield (ton/ha) and quality (%protein in soybean).

The **MEMS actuator**, introduced in this Use Case, would allow the optimisation of the use of irrigation or fertilisation. The key actors are **conventional or organic farmers,** organic producers for food and feed market will benefit from a better harvest quality (protein content), it is expected to result in concrete benefits for the farmer, the society and the environment.

The measured data from the network of distributed sensors will be collected through a wireless connectivity technology so as to allow real-time monitoring of the environmental and soil parameters and simplify the deployment of sensorized nodes on the field.

Two different technology for the wireless network are proposed in this article offering a great flexibility in the way sensors and gateway can be connected. Both options rely on a Sub-1GHz wireless communication network.

The first option can be used in all cases where a local wireless gateway can be installed. In this case all sensor and actuator nodes can be interconnected using a mesh network approach based on the 6LowPAN communication protocol. This enables each node to establish a bi-directional communication with the gateway on a long distance. All the data and relevant information will transit through the local gateway either, then to the Cloud service.

The second option proposed is based on the Sigfox technology and allows each and all of the sensor nodes to communicate the measured data directly to the Cloud service, without the need of a local gateway installation. Sigfox technology relies on a national-wide infrastructure of gateway pre-installed by local national network operators. National coverage and roll-out plans for the different countries can be verified on the Sigfox web site.

Both the proposed solution will make use of a single radio transceiver (S2-LP) featuring ultra-low-power and highly-efficient performances.

In all cases where a local monitoring, maintenance service or configuration of the node is required, it's highly suggested to provision the node with a Bluetooth Low Energy radio, besides the Sub-1GHz S2-LP radio transceiver. Such a dual-radio node will offer the possibility to interact locally with the node through a smartphone equipped with a Smart App – local configuration, software upgrade, maintenance or provisioning of the node during network setup can be easily achieved. Bluetooth Low Energy communication is offered through the BlueNRG Application Processor family. A dual-radio BLE and SIGFOX sub-system is made readily available by the joint usage of BlueNRG Application Processor and S2-LP radio. Just sensors and actuators needs to be added to this sub-system.

The proposed wireless networking solutions simplify the adoption of the remote monitoring technology, as per below advantages:

- Low cost installation of large sensor and actuator networks
- No need for a pre-existing communication infrastructure
- Ultra-low-power technology well-fitting battery-operated nodes (up to 10 years battery lifetime)
- Easy and simple expandability of the networked sensors
- Low maintenance and ownership costs
- Real-time monitoring of measured parameters

With such wireless connected sensor network or with the proposed integrated sensors & actuators systems, the farms will have following benefits, in particular:

- large room for technical improvement in cultivation and processing phases
- increasing the efficiency of production
- decreasing environmental impact
- should be scaled on protein production
- several local initiatives developed value chains
- to increase the value of European soybean production
- sustainability of production systems
- fulfilment of social standards
- non GM origin
- local/proximity production

SOIA ITALIA is the leader partner of the UC and it is responsible for provide Ideation and coordination of the project, plus all the field activities in Italy. Collection of the data in IT and AT, elaboration of the data coming from the field and agronomic report about use case. Donau Soja Association will be the supporting Partner helping SOIA ITALIA to define farmers and technical requirements reviewing literature and screening market available farming technology. STMicroelectronics Italy can provide the sensor available technologies & products.

2.3.1 Domain model

The domain model for UC1.3 is depicted in Figure 13.

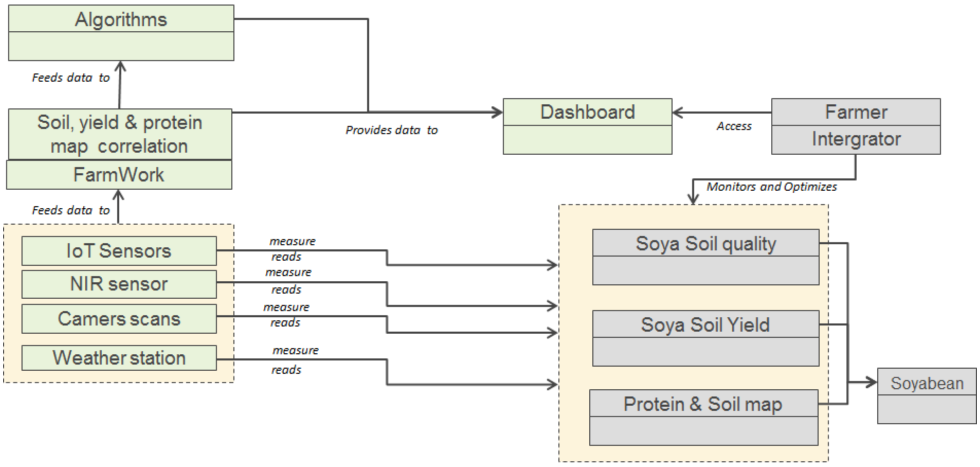


Figure 13 – UC1.3 Domain Model

In this use case, a **Farmer** is interested in monitoring and optimizing the **agronomical & environmental factors that influence yield and protein in soybean crop**.

IoT sensors for harvest & field monitoring are deployed in the farm to measure such parameters of interest. Data monitored by IoT sensors is locally or remotely stored and combined with **climate or environmental sensors** to a **Data Storage System**, which feed dedicated algorithm suitable to extract comfort, manipulation and growing models – which are made available to the Integrator through a dedicated web-based Dashboard into a DDS specified for soybean. The Integrator may deal or coincide with the Farmer.

2.3.2 Deployment view

The Deployment diagram for UC1.3 is depicted in Figure 14. Components in this use case are deployed either locally (i.e. in the Farm) or remotely.

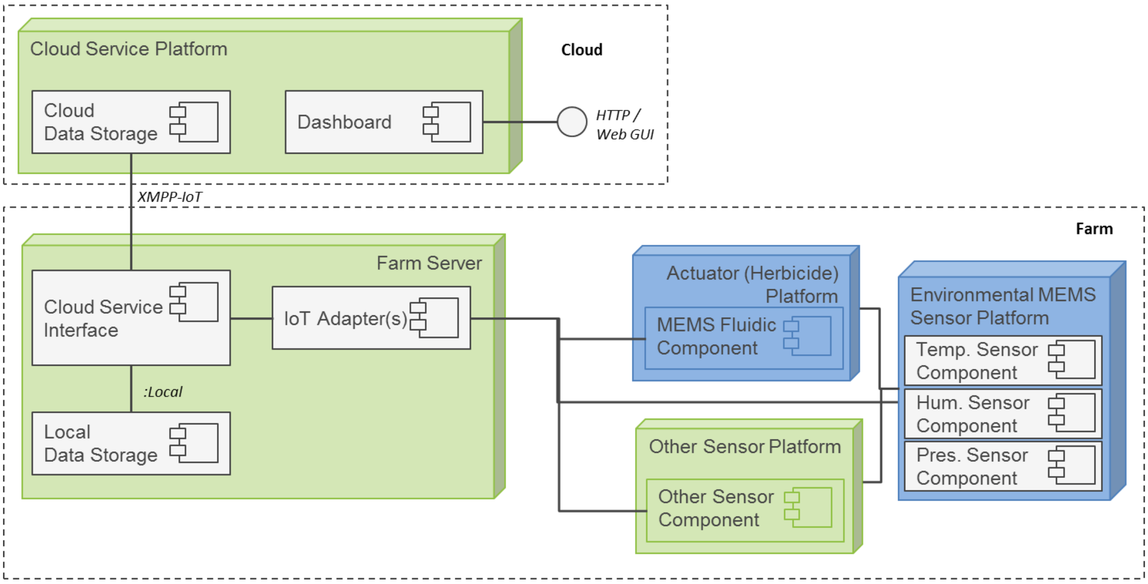


Figure 14 - UC1.3 Deployment scheme

In the Farm, three different physical, dedicated sensor platforms are deployed, namely the Environmental MEMS sensor platform, the Actuator (Herbicide and Water) Platform, and Other Sensor Platform. The Farm Server corresponds to a dedicated, stand-alone PC installed in a protected location in the farm or could be a Mobile app installation. The platforms are all connected to the local farm LAN (Local Area Network), which is a traditional Ethernet-based local network, which is specifically used to inter-connect these nodes to the Farm Server. This is done by means of specific over-IP protocols through a short rage BLE connection or longer range IoT communication protocols.

The Farm server is a general-purpose x86-64 PC running Linux, which integrates the interface to the IoT platforms, includes a local storage of data, and provide the interface to the cloud service.

The Farm Server is connected though the Internet, to proper cloud services. The cloud platform should include data storage system that stores the information received from the Farm Servers. It should include also an interface to the users that can visualize and manipulate different types of data, depending on the specific authorizations.

The summary of deployed components for UC1.3 is provided in Table 9.

Table 9 - UC1.3 Deployed Components

Name	Description	Supplier (brand) + Model	Number of units
Environmental MEMS sensors	MEMS Temperature sensors MEMS Humidity Sensors MEMS Pressure sensors	STMicroelectronics, STTS751 STMicroelectronics, HTS221 STMicroelectronics, LPS33HW	TBD
NIR sensors		TBD	TBD
Low-Power Wireless Connectivity	Sub-1GHz RF transceiver: 6LowPAN protocol or SIGFOX network Bluetooth Low Energy (optional)	STMicroelectronics, S2-LP STMicroelectronics, BlueNRG-2	1 per node
Farm Server	FARM gateway running integration/communication layers including VIRTUS, ebbits middleware components and adaptation layers	Raspberry PI v3 or better	1 per farm
Cloud Service Platform	Remote server or service hosting the applications	Unknown	1, overall
Local Data Storage	Local non-relational database	MongoDB version v3.4.4	1 per Farm server

2.3.3 IoT Functional view

The IoT functional view of this use case (depicted in Figure 15) is structured as following and will be updated after the UC interview:

- *Application Layer*: in this layer, there is a web-based dashboard for visualize collected IoT data
- Service support and application support layer: both Generic support capabilities and Specific support capabilities are shown in this use case. There are particular capabilities like Business Intelligence Dashboard for analyse data and provide an overview of farm status and warnings in case status is not optimal; a Fusion Engine Service for elaborate the data. In addition, there are common capabilities which can be used by different IoT applications, such as Cloud Data Storage.
- *Network layer*: there are both Networking Capabilities and Transport Capabilities that first provide relevant control functions of network connectivity and second focus on providing connectivity for the transport of IoT service and application specific data information. Network and transport connectivity are provided directly from the suggested Sub-1GHz wireless technologies, enabling highly efficient long-range communication (LPWAN) up to tens of kilometers: 6LowPAN, SIGFOX (with the optional Bluetooth LE 2.4GHz radio for local interaction with Smart App).
- *Device layer*: device layer will be updated. It's assumed that this use case includes general functions of device and gateway, sensors and actuations are able to gather and upload information directly or indirectly to the communication network (with 6LowPAN through a local gateway or directly to the Cloud service through SIGFOX networking) and can directly or indirectly receive information from communication network. The devices in this use case can construct networks in an ad-hoc networking based on the specific technology. Regarding Gateway Capabilities, supported devices are connected through Sub-1GHz wireless technology (multiple interfaces) and protocol conversion.
- *Management Capabilities*: in this use case, there is no specific information about management capabilities. So, it is assumed that this use case includes general functions based on the specific technology.
- *Security Capabilities*: in this use case, there is no specific information about security capabilities. So, it is assumed that this use case includes general functions based on the specific technology.

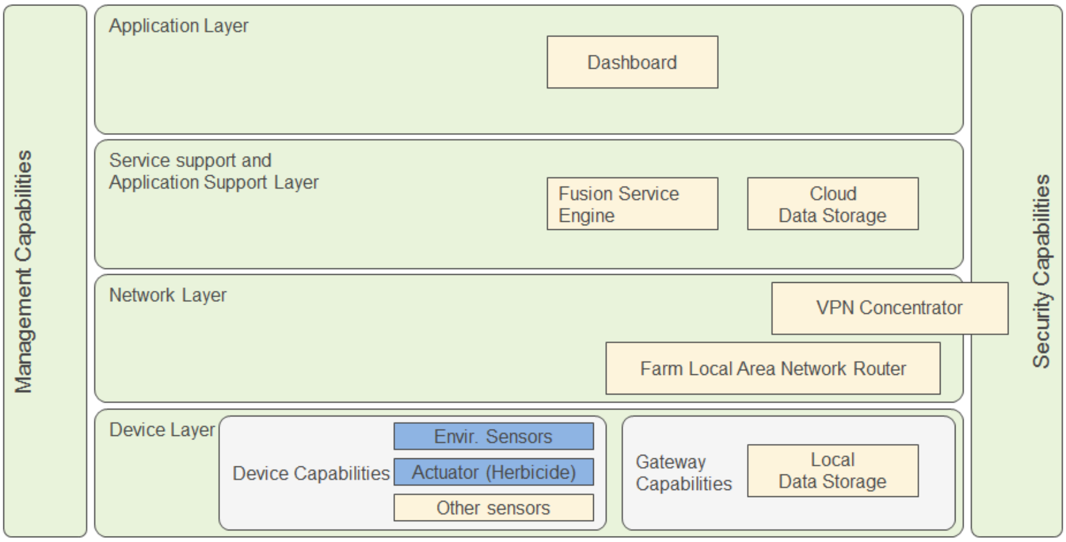


Figure 15 – UC1.3 IoT Functional View

2.3.4 Business Process Hierarchy view

The overall process hierarchy is still under definition, but a first draft is reported in Figure 16.

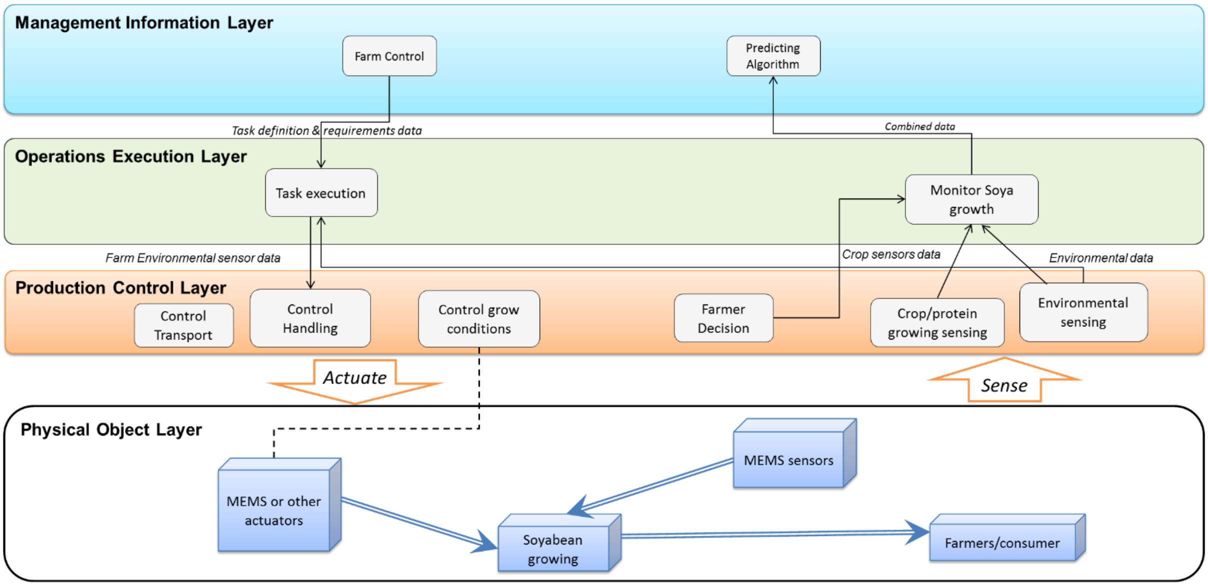


Figure 16 - UC1.3 Business Process Hierarchy view

2.3.5 Interoperability Endpoints

The interoperability endpoints are under definition, but a preliminary list is shown in Table 10.

Table 10 - UC1.3 Interoperability Endpoints

Interface name	Exposed by	Protocol	Notes
Climate Control Interface	Climate Control	To be specified	It will probably a wired sensor
Other sensors interface	To be specified	To be specified	It will probably a wired sensor
Farm Server interface	Farm Gateway	To be specified	Application-level profiles to be further specified during developments

2.3.6 Information model

Since a number of business related aspects have not yet been formalized and specified in detail, the information model of UC1.3 is under completion. Standard options such as the data model already adopted in UC1.1 (see Section 2.1.6) is being considered for application also in this use case.

2.3.7 Summary of gaps

The specification of UC1.3 is almost fully defined, but there a number of points still need to be clarified and verified for feasibility.

More specifically, the feasibility of implementing MEMS actuators is still to be verified as such devices do not yet exists on the market and to be fully specified.

2.3.8 Assets identified for re-use

The assets identified for re-use are shown on Table 11 and will be confirmed or updated in subsequent phases of the projects.

Table 11 - UC1.3 Assets identified for re-use

Component name	Short Description and role in the Use Case	Functional role	License
Nir sensor	Evaluation of moisture or other crop parameters	Sensor	No license needed

2.3.9 Collaboration with other Use Cases

They are collaborating with UC1.4 and UC3.1 to identify reusable components.

2.3.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets.

The following Table 12 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability

Table 12 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC1.3)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May '18)	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	7	- Environmental MEMS Temperature sensor (1 per node) - Environmental MEMS Humidity Sensor (1 per node) - Environmental MEMS Pressure sensor (1 per node) - NIR sensors (1 per node) - Sub-1GHz RF transceiver (1 per node) - 6LowPAN protocol or SIGFOX network (1 per node) - Bluetooth Low Energy (optional: 1 per node)
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	3	- Farm Server (1 per farm) - Cloud Service Platform (1, overall) - Local Data Storage (1 per Farm server)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May ‘18)	Short comment / qualitative estimation
	Number of IoT applications available	2	- Business Intelligent Dashboard - Web-based dashboard for visualize collected IoT data
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1
	Number of FIWARE GEs instances	0	
	Number of open datasets used	/	Not yet available
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	/	Not yet available
	Average number of installations per reusable IoT component	/	Not yet available
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	/	Not yet available
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies	/	Not yet available

2.4 ARABLE UC 1.4: FARM MACHINE INTEROPERABILITY

Farmers have arable machines from different vendors. They want these machines to work seamlessly together. Work orders should be send from his Farm Management Information System (FMIS) to the appropriate machines and after the tasks have been executed the work records should be send back to the FMIS. The Farmer wants to see real-time data of his machines, too. This UC tries to find solutions for the interoperability of machines and Farm Management Information Systems.

2.4.1 Domain model

The Domain model view of UC1.4 is depicted in Figure 17.

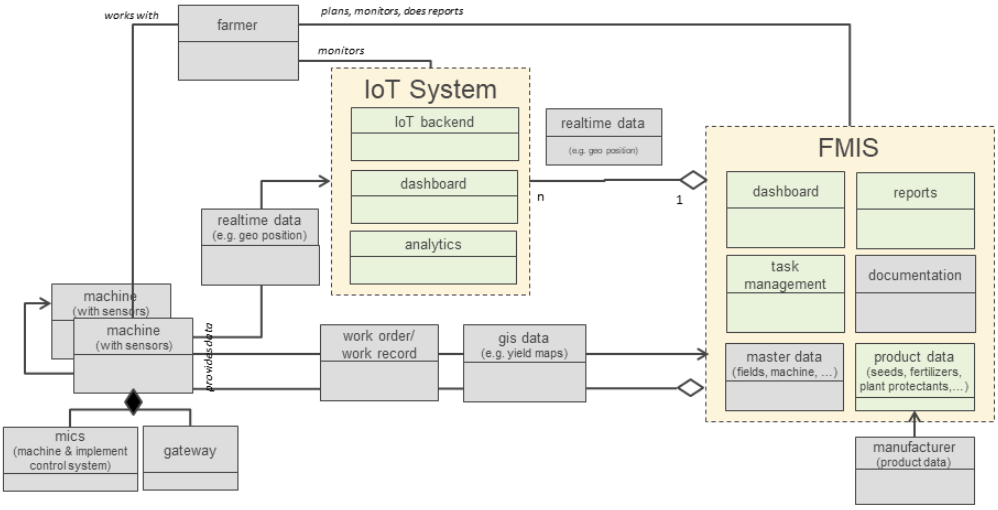


Figure 17 - UC1.4 Domain Model

In this UC, a Farmer is interested in monitoring and doing task management with arable farming machines from different manufactures.

There are mainly three different **types of machine data** which is exchanged between machines and farm management systems:

- **work orders/work records (task data)**: the machine/the driver of a machine gets work orders and after finishing his task he provides a record of this task
- **real-time data**: e.g. geo position data, speed, diverse counter data
- **geographic information system (GIS) related data**: e.g. yield maps, application maps

The real-time data is transmitted to an IoT system.

The FMIS aggregates the data from several machines/manufactures. The dashboard shows real-time data from several connected machines/manufacturers.

Work orders are planned in the FMIS system and exchanged with the machines. Results (work records) are then transferred back to the FMIS. The FMIS stores the results for doing reports.

The FMIS is also connected to manufactures for getting the right product data (e.g. seeds, fertilizers, plant protectants).

There is also a machine-to-machine communication, where machines want to communicate with each other directly without a backend.

2.4.2 Deployment view

The Deployment view of UC1.4 is depicted in Figure 18.

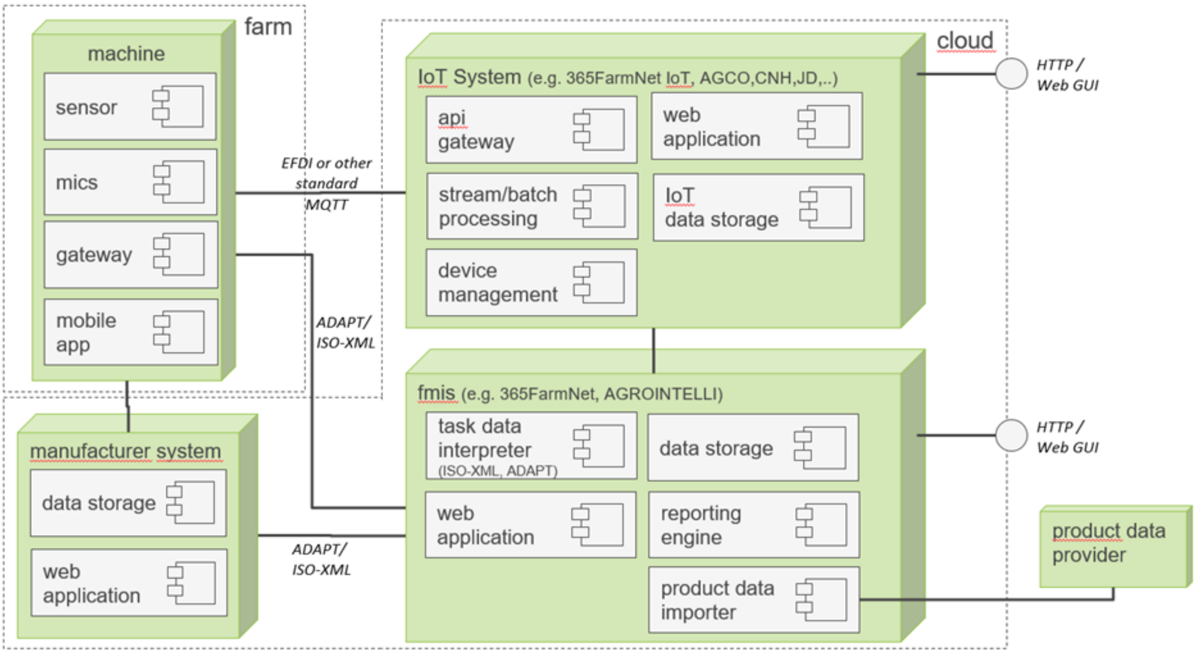


Figure 18 - UC1.4 Deployment View

The solutions consist of the following main deployment units.

Machine: this is the arable farming machine at the farm (e.g. tractor, combined harvester). The machine has different sensors (e.g. geo position, yield measurement) and collects data. The mics (machine and implement control system) is the local Information Technology (IT) system and bus at the machine. It is also responsible for the data exchange between tractor and implement.

Manufacturer System: Some manufactures have already an IT backend in place for communication with the machine to exchange task data or spatial data.

IoT Backend: The IoT backend collects the real-time data from the machines. It can analyse the data in stream processing or for historical analysis. It offers a frontend (web based, app) for users to e.g. have a real-time view on their machines. The IoT Backend can be part of the manufacturer system or operates independently.

FMIS: The FMIS collects data from different machines/manufacturers. It can get task data directly from the machines (e.g. USB) or it gets task data from the manufacturer backend. It also connects to the IoT systems to show real-time data. The FMIS stores task data from different machines/vendors for a comprehensive documentation and farm report. The FMIS has product data in place (e.g. data about fertilizers, plant protectants, seeds) and can combine this data with the machine data.

The description of deployed components is further deployed in Table 13.

Table 13 - UC1.4 Deployed Components

Name	Description	Supplier (brand) + Model	Number of Units
machine	tractors,combined harvesters, field chopper, seeding technology,…	Kverneland, AGCO/Fendt, CNH, Grimme, CLAAS (UC1.3)	To be specified
manufacturer system	system for machine communication, frontend for manufacturer tasks (e.g. task management)	FENDT VarioDoc, Case telematics system (new), Kverneland new telematics system (new), DKE	To be specified
IoT system	system to store IoT/real-time data	365FarmNet IoT, AGCO Agcommand, CNH, Kvernaland, CLAAS Telematics, DKE	To be specified
FMIS	farm management solution	365FarmNet	To be specified
Agriculture software systems	e.g. logistics, route planning	AGROINTELLI	To be specified
mobile app	app to send real-time position data	365FarmNet Active	To be specified
product data	plant protection data	e.g. homologa	To be specified

2.4.3 IoT Functional view

The IoT functional view for UC1.4 is depicted in Figure 19.

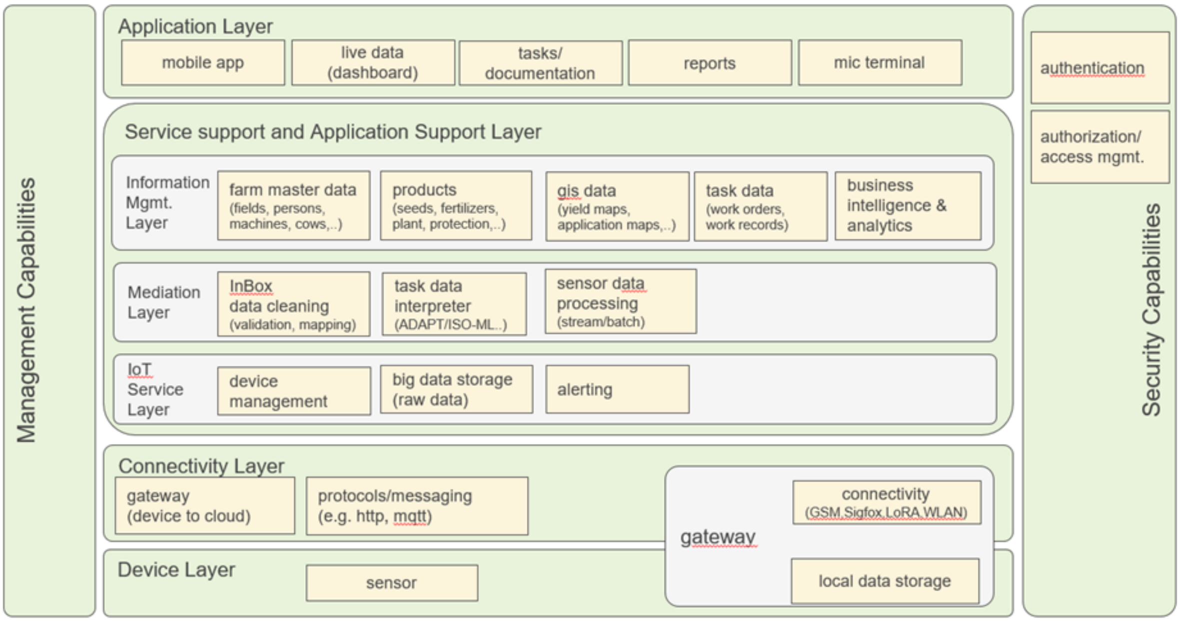


Figure 19 - UC1.4 IoT Functional View

The functional view of this UC is structured as follows:

- **Application Layer**: contains the applications/GUIs with which the end-users interact;
- **Service Support and Application Support Layer**: this layer contains master data and services which are offered to the application layer. The following list summarizes this offered data and services:
  - farm master data, catalogue data and task data provided to the applications (e.g. farms, machines, fertilizers, yield maps, work records, etc.)
  - services for reporting/business intelligence and analytics functionality
  - InBox, a data cleaning service which interprets, validates/maps, completes incoming task data from machines to the farm's data
  - task data interpreter for handling various machine data formats (e.g. ISO-XML/ADAPT/EFDI)
  - alerting functionalities
  - device management
  - components for data storage and data processing (stream/batch)
- **Connectivity Layer**: this is the "data transport layer" for the interactions among the network, protocols and gateways
- **Device Layer**: contains the devices/sensors

2.4.4 Business Process Hierarchy view

The Business Process Hierarchy view for UC1.4 is depicted Figure 20.

UC1.4 is more a general UC for machine ↔ FMIS communication.

The main **management process** is to plan, execute and document the tasks which have to be done on the field. With the reporting of the tasks the processes can be adjusted and optimized for the following planning.

In the **physical object layer** we have the machines (tractors + implements, combined harvesters, etc.) which bring products (e.g. seeds, fertilizers, plant protections) on the fields.

In the **production control layer** we have the resources, which have to be controlled in the process: the persons running the machines and the machines themselves (tractors). To monitor the production, we have sensors on the machines, on the fields and satellite data can be used e.g. to monitor crop growth.

To **operate the process,** a detailed scheduling for the persons and machines is necessary. Machines execution has to be planned and the live data helps the farmers in logistic coordination.

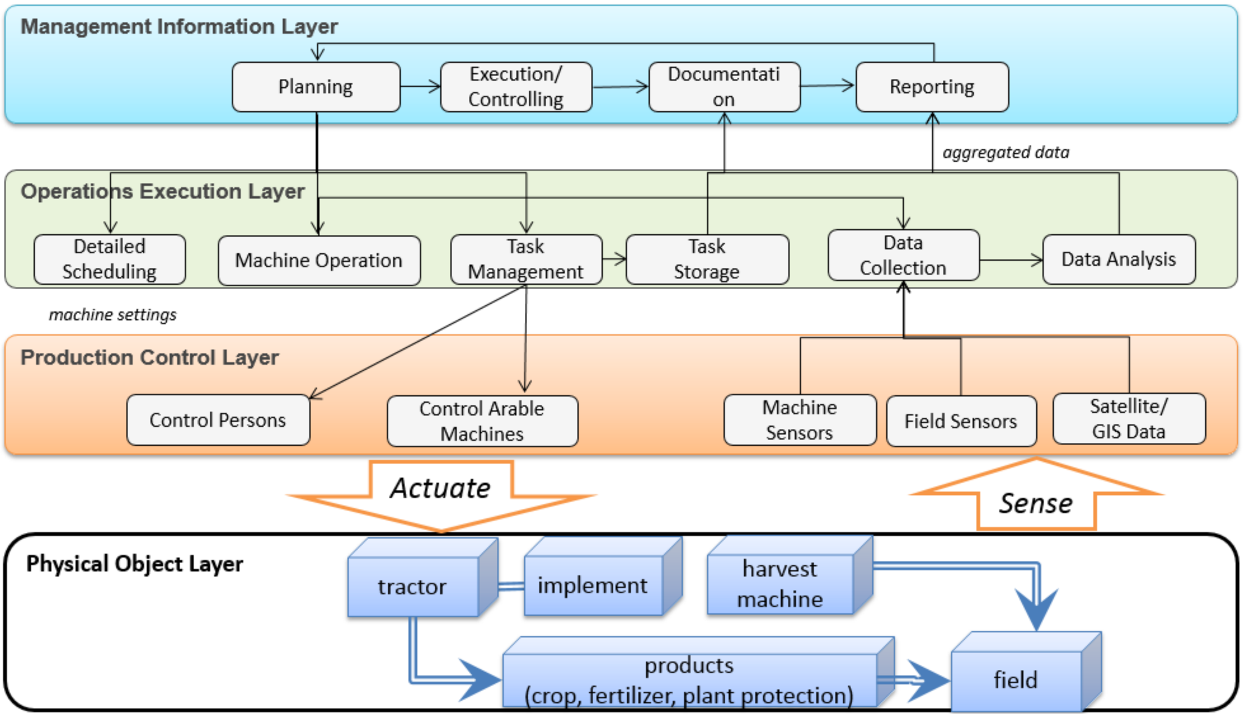


Figure 20 - UC1.4 Business Process Hierarchy view

2.4.5 Interoperability Endpoints

The interoperability endpoints are shown in the following Table 14.

Table 14 - UC1.4 Interoperability Endpoints

Interface name	Exposed by	Protocol	Notes
MCIS/Manufacturer Systems	Terminals, Web-Services	ISO-XML, ADAPT,	
Real-Time Data		mqtt, EFDI or other standard	

Interface name	Exposed by	Protocol	Notes
FMIS API	365FarmNet	REST/JSON	
Product databases	e.g. homologa for plant protection	REST/JSON	No standard yet (e.g. NGSI)

2.4.6 Information model

The information model for UC1.4 is depicted in the following Figure 21.

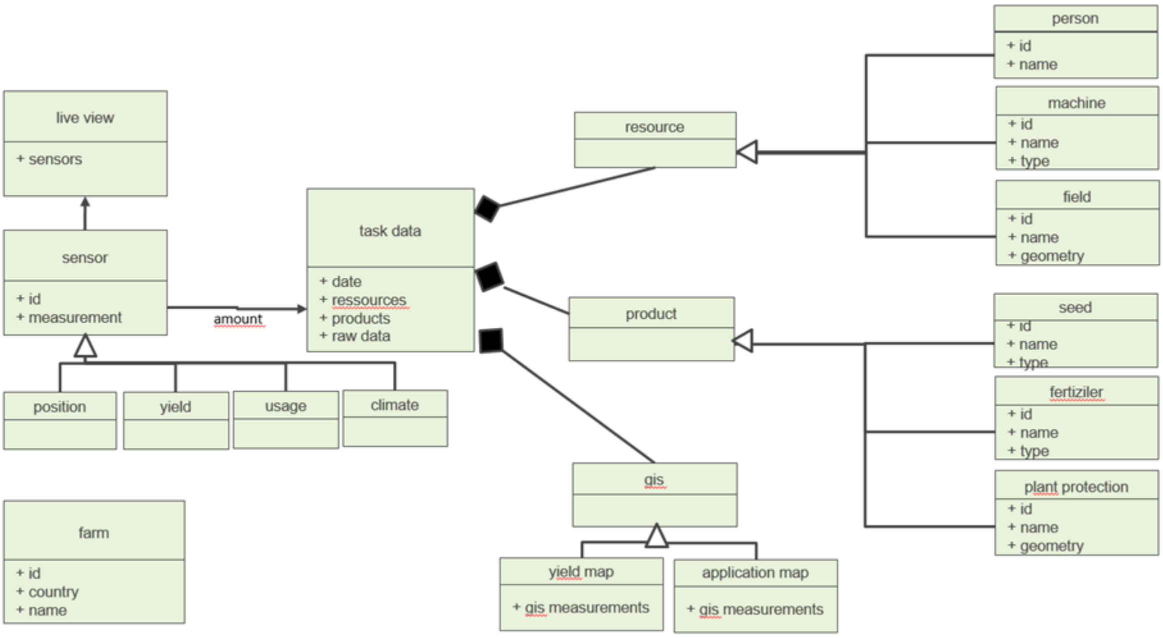


Figure 21 - UC1.4 Information Model

Sensors deliver live data of machine activity, field data, climate (temperature, humidity...). They can be used stand-alone to have a live view of the farm.

The **sensor data** on the machines can also be used to give further information about the task, the machine has full-filled (e.g. fuel consumption, amount of used seeds/fertilizers/plant protections/…). A **task data** combines this sensor data with the further task data: which **resources** were used to fulfil the task (which persons, machines, on which fields) and which **products** were used (which fertilizers/seeds/plant protections). **GIS data** covers all the aggregated spatial related data which is delivered from the machines (e.g. yield maps) or to the machines (e.g. application maps for fertilizing).

To fulfil legal restraints, it is necessary to document the products, which were used.

The complete information model of UC1.4 is described in Table 15.

Table 15 - UC1.4 Information Model Details

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Position	GNSS	soya & potatoes	Min. 2 Hz	coordinates NMEA
Grain Yield	Grain mass flow	soya & potatoes	Min. 2 Hz	mass flow (kg/s) - ISOXML
Grain quality	Grain moisture content	soya & potatoes	Min. 2 Hz	moisture content (%) ISOXML?
Actual Working Width	ISOBUS	All possible field crops	Every 5 m	mm
Total Fuel Consumption	ISOBUS	All possible field crops	Every 5 m	ml
Rear Hitch Position	ISOBUS	All possible field crops	Every 5 m	%
Front Hitch Position	ISOBUS	All possible field crops	Every 5 m	%
Rear PTO output shaft speed	ISOBUS	All possible field crops	Every 5 m	rpm
Front PTO output shaft speed	ISOBUS	All possible field crops	Every 5 m	rpm
Ambient Temperature	ISOBUS	All possible field crops	Every 5 m	mK
Actual Work State	ISOBUS	All possible field crops	Every 5 m	
Tire Pressure	ISOBUS	All possible field crops	Every 5 m	kPa
Engine Speed	ISOBUS	All possible field crops	Every 5 m	rpm
Total Worked Area	ISOBUS	All possible field crops	Every 5 m	m^2
Total Distance (Working)	ISOBUS	All possible field crops	Every 5 m	mm
Total Distance (Not working)	ISOBUS	All possible field crops	Every 5 m	mm

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Total Time (Working)	ISOBUS	All possible field crops	Every 5 m	s
Total Time (Not working)	ISOBUS	All possible field crops	Every 5 m	s
Total Vehicle Operation Hours	ISOBUS	All possible field crops	Every 5 m	s

2.4.7 Summary of Gaps

- UC1.4 is a more general use case to identify how machine<->machine, machine<->FMIS communication can be realized. It is necessary to define some more concrete uses cases for implementation.
- Evaluate how existing standards fulfil the requirements and identify of IoF project maybe can have influence in extending the standards.

2.4.8 Assets identified for re-use

The assets identified for re-use are shown on the following table.

Table 16 - UC1.4 Assets identified for re-use

Component name	Short Description and role in the Use Case	Functional role	License
standard for machine<>machine and machine<->fmis communication	standard for data model (e.g. ISO-XML, ADAPT) and for data transfer (e.g. EFDI, other standard), both for task data AND real-time data	To be further specified	No specific licenses identified yet
IoT Backend for real-time machine data	IoT Backend to store the standardized machine real-time data	To be further specified	No specific licenses identified yet
task data interpreter service	service which can read different machine formats and transform between formats (e.g. ISO-XML, ADAPT)	To be further specified	No specific licenses identified yet

Component name	Short Description and role in the Use Case	Functional role	License
Product service/standard: seeds	standard format for seeds to exchange seed data, service to get admitted seeds for one country	would be useful to fulfil legal requirements for usage and documentation	No specific licenses identified yet
Product service/standard: plant protection	To be further specified	To be further specified	No specific licenses identified yet
Product service/standard: fertilizers	To be further specified	To be further specified	No specific licenses identified yet
Field service/standard	EU standard for exchanging field data or service to interpret different country-specific field formats	To be further specified	No specific licenses identified yet
GIS service/standard	Standard for exchange of gis information (e.g. yield maps) and services to store/ load/interpret gis data	To be further specified	No specific licenses identified yet

2.4.9 Collaboration with other Use Cases

There is collaboration with UC 1.1, UC 1.2 and UC 4.3. There are some re-uses in storing of map data in a gis service (e.g. soil maps, weed maps).

2.4.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets.

The following Table 21 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability

Table 17 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC1.4)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May ‘18)	Short comment / qualitative estimation
Integrated and adapted	Number of IoT devices implemented (especially sensors and actuators)	/	The discussion on which sensors and actuators will be adopted is yet open so the reported values are not yet consolidated

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May ‘18)	Short comment / qualitative estimation
IoT components	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	3	- IoT system - FMIS - Agriculture software systems
	Number of IoT applications available	2	- Mobile app - Web application
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1
	Number of FIWARE GEs instances	0	
	Number of open datasets used	/	Not yet available
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	/	Not yet available
	Average number of installations per reusable IoT component	/	Not yet available
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	/	Not yet available
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies	/	Not yet available

2.5 DAIRY UC 2.1 GRAZING COW MONITOR

The objective of this UC is to monitor automatically and in real-time the outdoor grazing (pasturing) of cows in the context of ammonia emission reduction and marketing of “pasture milk”. To achieve this object the ‘StickNTrack’ tracker module, developed by partner Sensolus[xiii], combined with Bluetooth Low Energe (BLE) technology[xiv], will be used into the agricultural domain, as a solution to track cattle outdoors. It is important to be able to verify the numbers of hours that individual cows spent outside on the pasture in the context of ammonia emission reduction and the marketing of “free-range milk” or “pasture-milk”. This UC is located in in Belgium and Netherlands and have some specific challenge to take up:

- Define stakeholder requirements for positioning system
- Develop a system which is able to determine whether a cow is inside or outside the dairy barn
- Automatically gather positioning data
- Identify locations of interest (e.g. feeding alley)

To do this, this UC is composed of 3 different partners:

- Eigen Vermogen van het Instituut voor Landbouw en Visserijonderzoek (ILVO), Belgium.
- Contextwise BVBA (Sensolus), Belgium.
- Inagro vzw (Inagro), Belgium.

2.5.1 Domain model

The Domain Model description is reported in the following Figure 22.

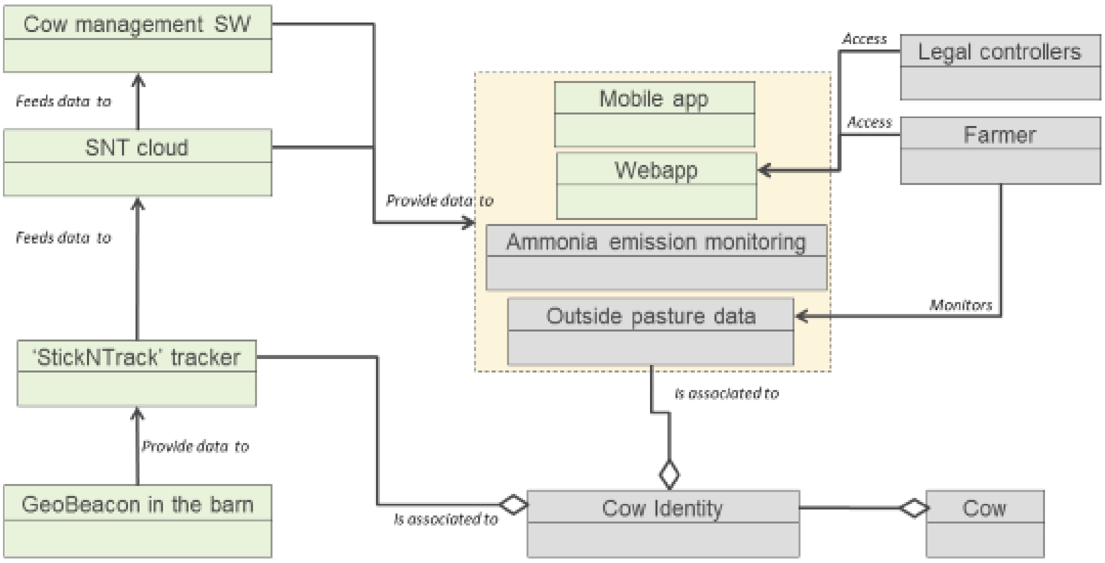


Figure 22 - UC2.1 Domain Model

In this use case, a Farmer is interested in monitoring the duration of outdoor grazing of individual cows.

A 'StickNTrack' (SNT) tracker is installed on the collar of each cow which is associated with the cow ID. A system of geolocation is used to know the position of the cow (outside: GPS; inside: GeoBeacon installed in the barn). Then data are sent from the trackers to the SNT cloud to be stored, a software named 'Cow management'runs algorithms on these data and provides data to a mobile and a web application. The 'outside pasture duration' and the ammonia emission monitoring are now numeric, Farmers and legal controllers can access it on the Web App.

2.5.2 Deployment view

The Deployment View description is reported in the following Figure 23 and Table 18.

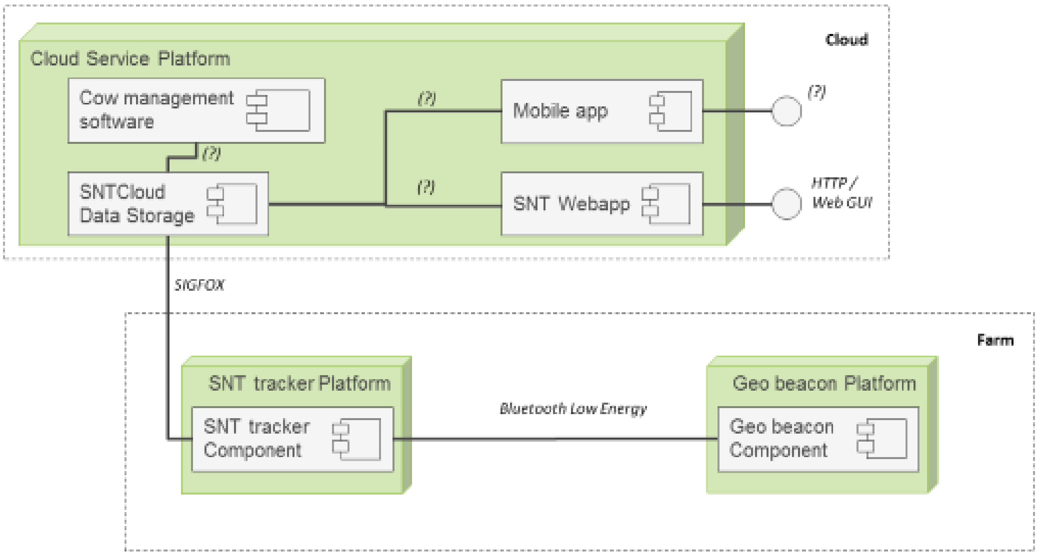


Figure 23 - UC2.1 Deployment View

Table 18 - UC2.1 Deployed Components

Name	Description	Supplier (brand) + Model	Number of Units
SNT tracker	Combined indoor/outdoor location tracker	SNT GPS PRO Supplier: sensolus	50
Geo beacon	Indoor location tracker	SNT geobeacon Supplier: sensolus	1-5
SNT cloud	IoT communication and analytics platform	SNT cloud Supplier: sensolus	1
SNT webapp	Management and SNT app	SNT organization webapp Supplier: sensolus	3 organization subscriptions
Mobile app	SNT app containing dashboard and reports	SNT android mobile app Supplier: sensolus	Included by webapp subscription
Cow management SW	Existing cow management platform of farmer (to integrate with API)	TBD Depends on selection by farmer	1

The SNT tracker platform is installed on the cow collar and the Geo beacon platform inside the barn. The SNT tracker component gets its geolocation information directly from GPS (outdoor) or from Geo beacon through BLE (indoor).

The SNT tracker Platform is connected to the Cloud Service Platform through a Sigfox link where the data are stored on the component SNT Cloud. Another component ‘cow management software’ use these data to generate input for grazing and ammonia emission monitor. The data stored on the SNT Cloud are accessible using a mobile application or a SNT Web App.

2.5.3 IoT Functional view

The mapping towards the IoT Functional View are described in Figure 24.

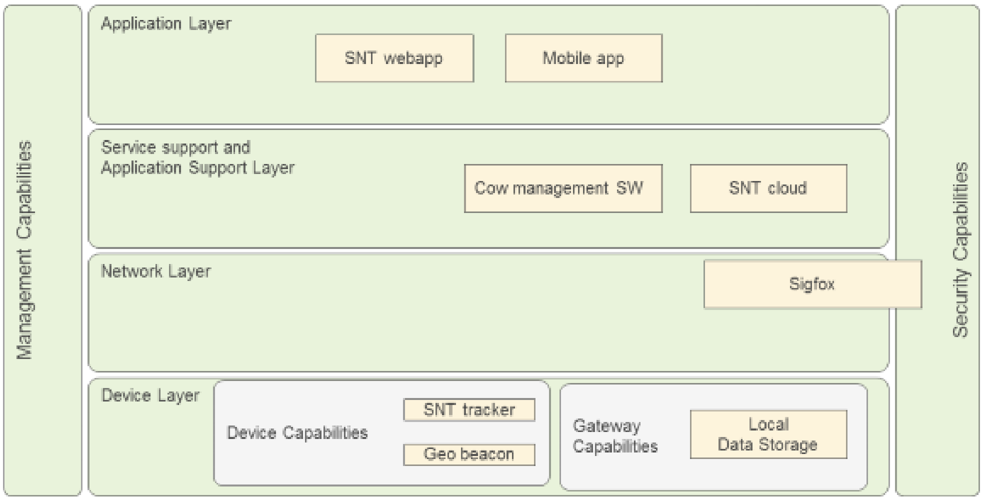


Figure 24 – UC2.1 IoT Functional View

2.5.4 Business Process Hierarchy view

The Business Process Hierarchy for UC2.1 is shown in Figure 25.

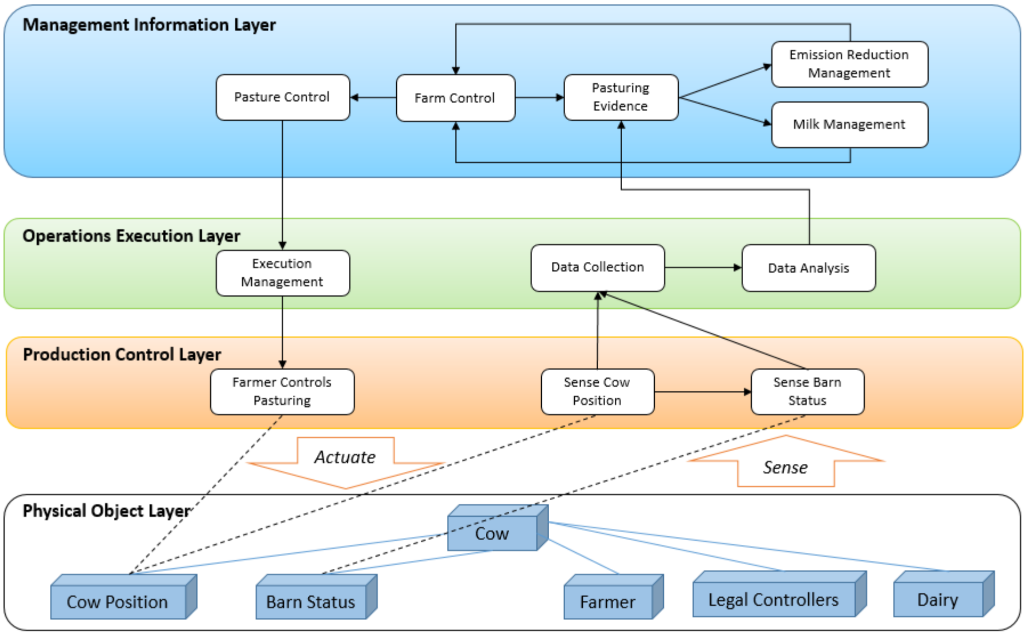


Figure 25 - UC2.1 Business Process Hierarchy view.

In the physical object layer, the cow position and barn status are relevant for the farmer and dairy to verify that cows have been pastured and the produced milk can be named pasture milk. Similarly, legal controllers can verify that cows have been pastured as a measure to reduce emissions. To achieve this, the Production Control Layer includes sensing of cow position and barn status, whereas the farmer controls the actual pasturing. In the Operations Execution Layer, data collection and data analysis are performed. In the Management Information layer, evidence of pasturing is provided, which affects emission reduction management and milk management. Both affect farm control, which determines pasture control.

2.5.5 Interoperability Endpoints

The interoperability endpoints are shown on Table 19.

Table 19 - UC2.1 Interoperability Endpoints

Interface name	Exposed by	Protocol	Notes
SNT tracker interface	Sensolus 'StickNTrack'	Sigfox[xv]	N/A
Geo beacon	Sensolus 'Geo beacon'	BLE	N/A

2.5.6 Information model

The initial Information Model of UC2.1 is reported in the following Figure 26 and Table 20.

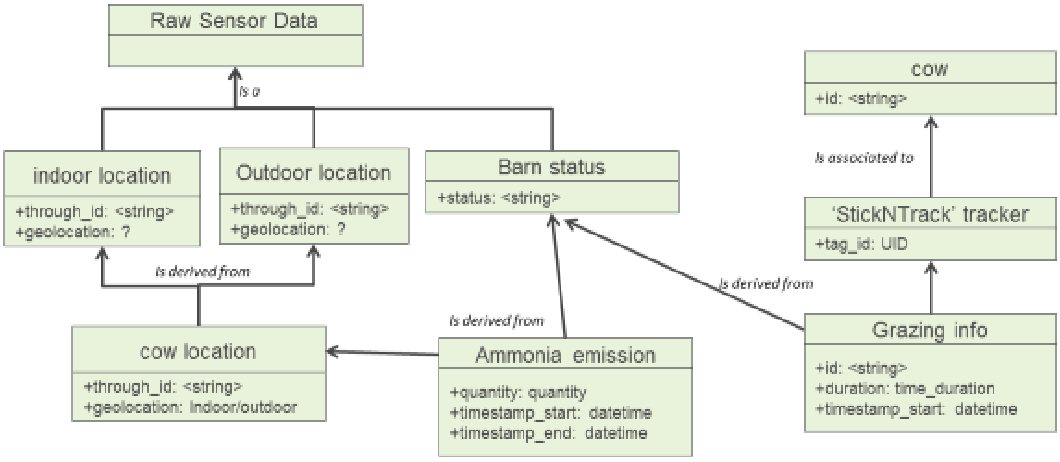


Figure 26 – UC2.1 Information Model

Table 20 - UC2.1 Information Model Details

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Outdoor location of the cow	SNT GPS tracker	Cows	Every 15 minutes / or on stop (in research)	Timestamped outdoor location - JSON
Indoor location of the cow(s)	Combined geobeacon-SNT tracker + analytics	Cows	Every 10 minutes / or on stop (in research)	Timestamped location - JSON

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Status of the barn (empty/not empty)	Combined geobeacon-SNT tracker + analytics	Cows	Every 10 minutes	Timestamped Zone where animal resides - JSON
Location of the cow(s) in specific indoor or outdoor area	Combined geobeacon-SNT tracker +analytics	Cows	Every 10 minutes	Timestamped Zone where animal resides - JSON
Number of hours moved by a cow(s)	Geobeacon-SNT tracker +analytics	Cows	Continuously, send to the cloud every 15 minutes	Number of hours moved - JSON
Number of hours of specific status of the barn	Combined geobeacon-SNT tracker + analytics	Cows	Continuously, send to the cloud every 15 minutes	Number of hours empty - JSON

2.5.7 Summary of gaps

This UC is, at this date, well defined and is kept in a simple and clear structure, some investigations have already been made even if some questions must be answered. Some specific gaps identified for UC2.1 is defined in the following:

- The process for the installation of the IoT device on the cow collar still need to be checked.
- The connectivity between the different elements on the service cloud platform still need to be defined.
- The interface of the Mobile application also need to be defined.
- The Re-usable will be defined when interested parties will show up.
- Some deployment/field test area still need to be identified.

2.5.8 Assets identified for re-use

Beyond the assets defined in previous sections, the current list of assets identified for re-use in UC2.1 are summarized in Table 21.

Table 21 – UC2.1 Assets identified for re-use

Component name	Short Description and role in the Use Case	Functional role	License
Some components to make data accessible by other parties via API access	To Be Defined	To Be Defined	To Be Defined bi-laterally

2.5.9 Collaboration with other Use Cases

They are not collaborating with other Use Cases.

2.5.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets.

The following Table 22 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability

Table 22 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC2.1)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May '18)	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	55	- 50 SNT tracker - 1-5 Geo beacon - 1 SNT cloud
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	3	- Geo beacon platform - Cloud Service Platform - Sigfox link
	Number of IoT applications available	3	- SNT webapp (1 per organization - 3 organization in total) - Mobile app (1) - Cow management SW (1)
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1
	Number of FIWARE GEs instances	0	
	Number of open datasets used	/	Not yet available
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	/	Not yet available
	Average number of installations per reusable IoT component	/	Not yet available
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	/	Not yet available
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies	/	Not yet available

2.6 DAIRY UC 2.2: HAPPY COW

The goal of this Use Case is to significantly increase the adoption of sensor technology within farm management to monitor cow behaviours to predict issues, give insights on heat detection and health, and recommend solutions to farmers. An Artificial Intelligence based agent will enable to gather and interpret these data to really help farmers to improve dairy farming by understanding animal and herd characteristics if the information is delivered in a manner that is useful and fits to the farmer.

The key actors are **conventional or organic dairy sector farmers - Cows,** where the cows' movement are monitored with some motion sensors. In this UC we plan to deploy the use of **motion MEMS sensor (accelerometer)**, together with **MEMS Pressure & Temperature sensors**. These sensors are supposed to be used in the neck of the cow (more comfortable position) during daily activity. Once back to the farm and during the night the data are transmitted through an high-efficient, long-range wireless communication network and sent to the data storage for interpretation and decision taking. We also envisage the possibility to have a full integrated platform by implementing also environmental MEMS sensors (Pressure, temperature) to the farm.

The measured data from the network of distributed sensors (cow sensors) will be collected through a wireless connectivity technology so as to allow daily monitoring of the cow parameters and simplify the adoption of this technology.

Two different technology for the wireless network are proposed in this article offering a great flexibility in the way cows' sensors and farm gateway can be connected. Both options rely on a Sub-1GHz wireless communication network (LPWAN).

The first option can be used in all cases where a local wireless gateway can be installed. In this case all cow sensor nodes can be interconnected using a mesh network approach based on the 6LowPAN communication protocol. This enables each node to establish a convenient and easy-to-install wireless communication with the gateway on a long distance. All the data and relevant information will transit through the local gateway either, then to the Cloud service.

The second option proposed is based on the Sigfox technology and allows each and all of the sensor nodes to communicate the measured data directly to the Cloud service, without the need of a local gateway installation. Sigfox technology relies on a national-wide infrastructure of gateway pre-installed by local national network operators. National coverage and roll-out plans for the different countries can be verified on the Sigfox web site.

Both the proposed solution will make use of a single radio transceiver (S2-LP) featuring ultra-low-power and highly-efficient performances.

In all cases where a local monitoring, maintenance service or configuration of the node is required, it's highly suggested to provision the node with a Bluetooth Low Energy radio, besides the Sub-1GHz S2-LP radio transceiver. Such a dual-radio node will offer the possibility to interact locally with the node through a smartphone equipped with a Smart App – local configuration, software upgrade, maintenance or provisioning of the node during network setup can be easily achieved. Bluetooth Low Energy communication is offered through the BlueNRG Application Processor family. A dual-radio BLE and SIGFOX sub-system is made readily available by the joint usage of BlueNRG Application Processor and S2-LP radio. Just sensors need to be added to this sub-system.

The proposed wireless networking solutions simplify the adoption of the remote monitoring technology, as per below advantages:

- Low cost installation of large distributed sensor network
- No need for a pre-existing communication infrastructure
- Ultra-low-power technology well-fitting battery-operated nodes (up to 10 years battery lifetime)
- Easy and simple expandability of the networked sensors
- Low maintenance and ownership costs
- Real-time monitoring of measured parameters

With these integrated sensors systems, the farms will have a full monitor of health & fertility of the cows in their environment, in particular:

- Improve productivity by providing cow health fertility with targeted advices, increasing number of cows but keeping same quality level and animal welfare
- decreasing labour
- Spread IoT knowledge among farmers
- Collect and gather data about movement & health
- Determine the accuracy of insight and detections in a controlled experiment

- Improving the productivity and efficiency of a farm
- Developing an artificial intelligence algorithm that informs farmers about the health state of cows

The UC will take place in Netherlands, Belgium, Germany, Poland, Ireland.

Connecterra is the leader partner of the UC and it is responsible for provide hardware & platform integration for the trial. The hardware is used to gather cow behaviour information, the MEMS sensors will be provided by STMicroelectronics Italy. The platform is used to generate insights and will be trained/improved throughout the trial, also will it be integrated with other software (like the IoF2020 proposed 365Farmnet platform) to extend the possibilities.

2.6.1 Domain model

The domain model for UC2.2 is depicted in Figure 27.

In this use case, the Farmer is interested in monitoring **health & behaviours of individual Cows.**

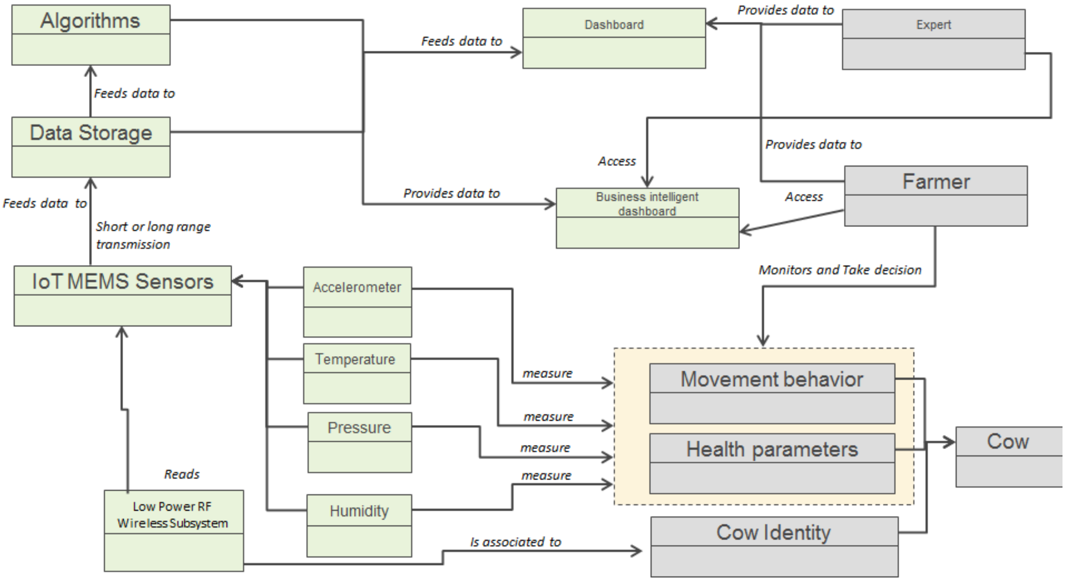


Figure 27 – UC2.2 Domain Model

In this use case, a **Farmer** is interested in monitoring and optimizing the **fertility & health behaviour** of individual Cows.

IoT **MEMS accelerometer sensors** are deployed in the farm and are available to measure such parameters of interest. We suggest including in the collar, together with an appropriate MEMS accelerometer, other sensors like MEMS **Pressure & temperature** in order to get the full condition of individual Cow. Data measured from the collar sensors is wirelessly transmitted to the local gateway (6LowPAN) or directly to the Cloud server (SIGFOX). Optionally a Bluetooth Low Energy radio can enable local monitoring, configuration and maintenance of the cow sensor through a smartphone equipped with a proper Smart App.

In such a way the data monitored by IoT sensors is locally transferred via Sub-1GHz wireless communication and stored to a **Data Storage System**, which feed dedicated algorithm suitable to extract movement and health behaviors to monitor fertility performance figures – which are made available to the Farmer through a dedicated web-based **Dashboard**.

We propose to include MEMS **temperature, pressure**, **and humidity** sensors also to monitor climate in the barn.

The data acquired are processed locally, in order to reduce the data transmitted, and remotely, to understand the behaviour and the status of the cows. This information is made available to the Farmer, and eventually to other experts like veterinarians.

2.6.2 Deployment view

The Deployment diagram for UC2.2 is depicted in Figure 28.

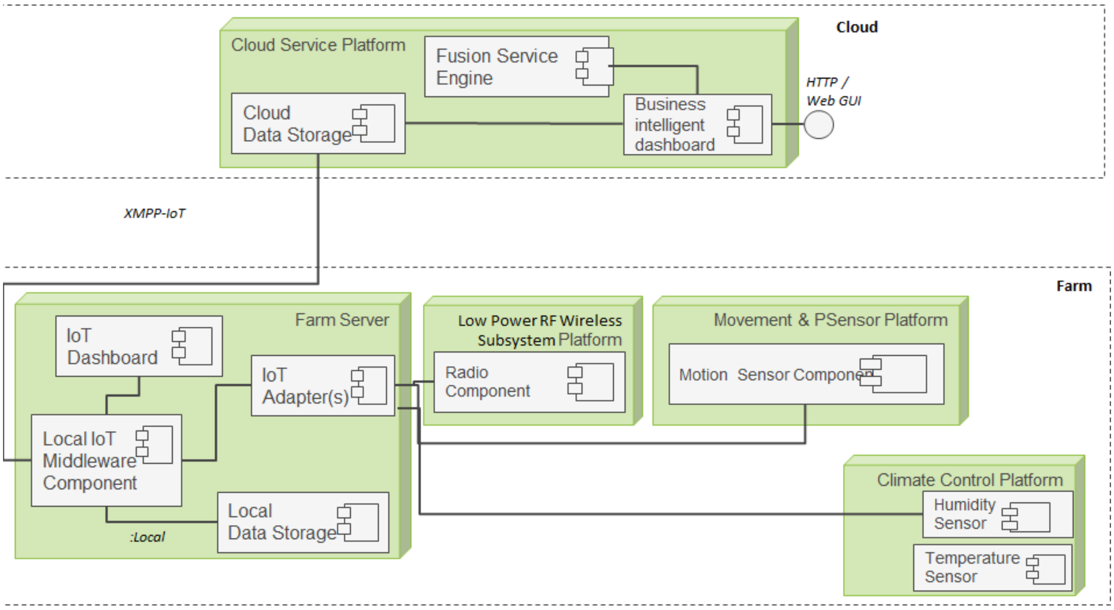


Figure 28 – UC2.2 Deployment View

Components in this use case are deployed either locally (i.e. in the **Farm**) or remotely (i.e. in the **Cloud** or in a self-hosted cloud server).

In the Farm, 3 different physicals, dedicated sensor platforms are deployed, namely the **Sub-1GHz (and BLE, optional) Radio Platform**, the **Movement & Pressure sensor Platform**, and the **Climate Control Platform**. Platform correspond to a dedicated, stand-alone PC installed in a protected location in the farm. The nodes implementing these five platforms are dedicated PCs, and they are all connected to the local farm LAN (Local Area Network), which is a traditional Ethernet-based local network, which is specifically used to inter-connect these nodes to the **Farm Server**.

The Farm Server is a general-purpose ruggedized x86-64 PC running Windows 10 IoT Enterprise, which host 2 dedicated "**IoT Adapter**" components, one "**Local IoT Middleware Component**" and one "**Local Data Storage**" built upon a standard MongoDB installation.

The Farm Server is connected though the Internet to a global VPN, which allows secure communications towards a private Cloud Service platform. The cloud platform runs: a "**Cloud Data Storage**" service, receiving data via XMPP-IoT from Farm Servers; a **Business Intelligent Dashboard**, accessible via HTTPS; a **Fusion Engine Service** running **Algorithms**.

The summary of deployed components for UC2.2 is provided in Table 23.

Table 23 - UC2.2 Deployed Components

Name	Description	Supplier (brand) + Model	Number of Units
Motion MEMS sensors	Accelerometer	STMicroelectronics. LIS3DH, LIS2DW12	1 per animal
Environmental MEMS sensors	MEMS Temperature sensor MEMS Humidity Sensor MEMS Pressure sensor	STMicroelectronics, STTS751 STMicroelectronics, HTS221 STMicroelectronics, LPS33HW	1 per animal + 1 per farm 1 per animal + 1 per farm 1 per animal + 1 per farm
Farm Server	FARM gateway running integration/communication layers including VIRTUS, ebbits middleware components and adaptation layers	Raspberry PI v3 or better	1 per farm
Cloud Service Platform	Remote server or service hosting the applications	Unknown	1, overall
Local Data Storage	Local non-relational database	MongoDB version v3.4.4	1 per Farm server
Low-Power Wireless Connectivity	Sub-1GHz RF transceiver (6LoWPAN or SIGFOX communication)	STMicroelectronics, S2-LP	1 per animal + 1 per farm
	Bluetooth Low Energy	STMicroelectronics, BlueNRG-2	1 per animal

2.6.3 IoT Functional view

The functional view of this use case (see Figure 29) is structured as follows:

- Application Layer: contains the Dashboard applications/GUIs the end user interacts with
- Service Support and Application Support Layer: the components for data processing (stream processing, batch processing, storage)
- Network Layer: this is the “data layer” with the network, protocols and gateways
- Devise Layer: contains the MEMS devices/sensors

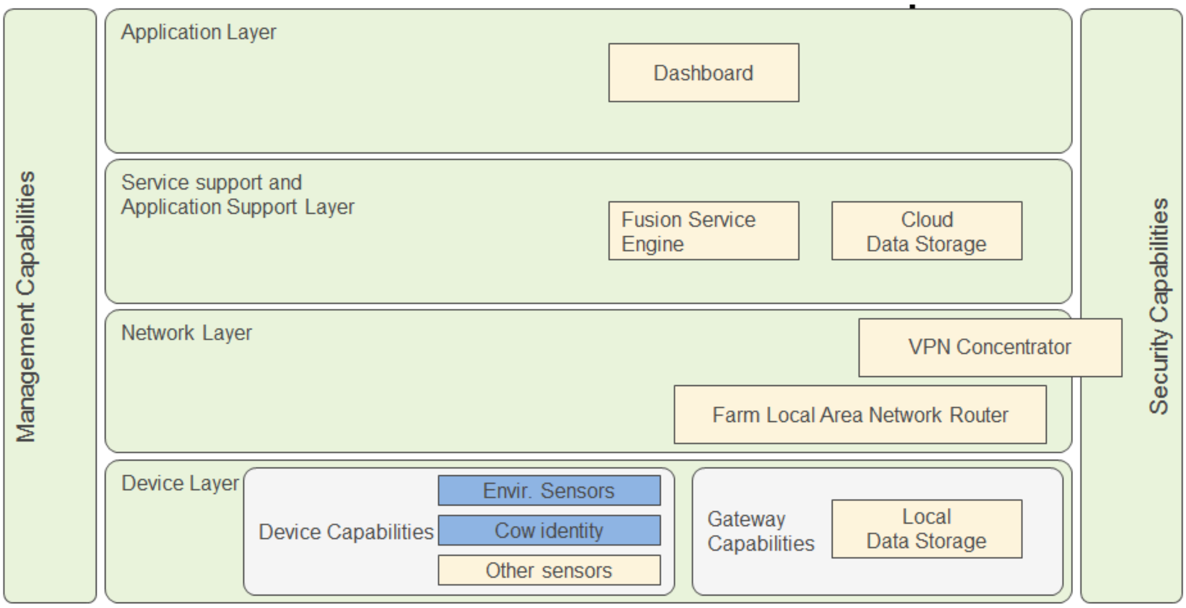


Figure 29 – UC2.2 IoT Functional View

2.6.4 Business Process Hierarchy view

The overall process hierarchy is still under definition. A current draft is reported in Figure 30.

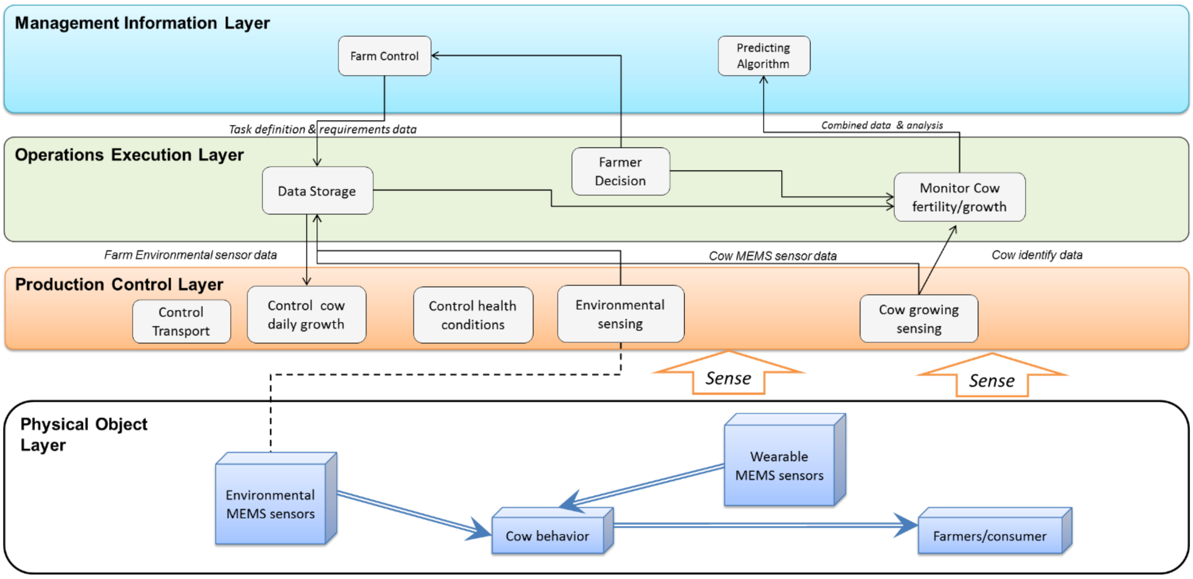


Figure 30 - UC2.2 Business Process Hierarchy view.

2.6.5 Interoperability Endpoints

The interoperability endpoints are shown on Table 24.

Table 24 – UC2.2 Interoperability Endpoints.

Interface name	Exposed by	Protocol	Notes
Collar Sensor Interface	Collar Movement	TBD (Proprietary)	Production collars use radio transmission to local base station and allow data access via database
Low-Power Wireless Connectivity	Location	Proprietary	Location sensor will be wireless capable of interfacing with SigFox network
Movement /Fertility Measurement	movement	Proprietary	Acquire the behaviour measurements that will be accessed via database/cloud

2.6.6 Information model

The Information model for UC2.2 is depicted in Figure 31.

On the left side, there are the entities of **MEMS sensors** and they have, like minimal information, an unique identifier. Those MEMS sensors are classified in “Raw Sensor Data” and they are humidity, temperature, movement sensors. Duration is used for describing the period of event and timestamp_start shows the time when the event is started.

The wireless Sub-1GHz communication network (LPWAN) allows to transmit the data from the cow sensors directly to the local Farm gateway and data storage or directly to the Cloud server (via SIGFOX). Daily growth, health and genetics data are batch data that are linked with a Cow. Climate entity is a batch data and is derived from humidity and temperature entities linked to a specific barn.

Other batch data, useful for the system, are linked with farm. These have, like minimal information, a unique identifier.

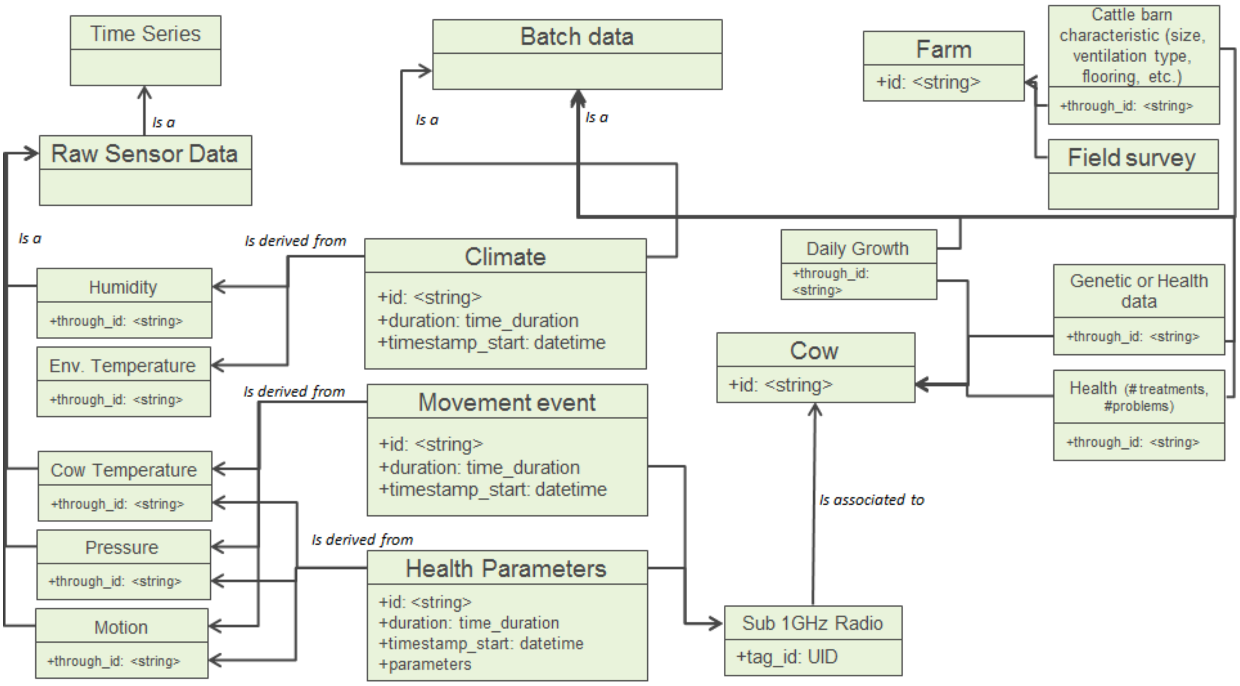


Figure 31 – UC2.2 Information Model

2.6.7 Summary of gaps

The specification of UC2.2 is almost defined, but there are some points not clear.

- At present time, there are some test farms that need further specification and to be defined.
- For reasons of data confidentiality, it is necessary to understand what data can be shared with the use case 2.2
- Others to be reviewed

2.6.8 Assets identified for re-use

The assets identified for re-use are shown on Table 25.

Table 25 – UC2.2 Assets identified for re-use

Component name	Short Description and role in the Use Case	Functional role	License
MEMS sensors	MEMS Sensor to monitor individual/group movement of Cows	"Device and Network Layer'	This is a hardware component (no special licenses needed)
Sub-1GHz RF radio	6LoWPAN or SIGFOX radio for each cow collar	Remote monitoring of measured sensors data	RF national regulations
Bluetooth Low Energy	Local interaction with Smartphone App	Setup, maintenance and software upgrades	BT SIG certification and national RF regulations

Component name	Short Description and role in the Use Case	Functional role	License
Farm Gateways	Farm gateway running integration/communication layers	“Device and Network Layer”	Apache v2
Cloud Service	Service hosting the applications	“Service support and application support layer” In the Business Process Hierarchy view, this is in “Production Control Layer” and “Operations Execution layer”	Apache v2

2.6.9 Collaboration with other Use Cases

They are not collaborating with other Use Cases.

2.6.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets.

The following Table 26 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability.

Table 26 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC2.2)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May ‘18)	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	9	- Motion MEMS sensors (1 per animal) - Environmental MEMS Temperature sensor (1 per animal + 1 per farm) - Environmental MEMS Humidity Sensor (1 per animal + 1 per farm) - Environmental MEMS Pressure sensor (1 per animal + 1 per farm) - Sub-1GHz RF transceiver (1 per animal + 1 per farm) - Bluetooth Low Energy (1 per animal + 1 per farm)
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	3	- Farm Server (1 per farm) - Cloud Service Platform (1, overall) - Local Data Storage (1 per Farm server)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May '18)	Short comment / qualitative estimation
	Number of IoT applications available	1	- Business Intelligent Dashboard
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1
	Number of FIWARE GEs instances	0	
	Number of open datasets used	/	Not yet available
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	/	Not yet available
	Average number of installations per reusable IoT component	/	Not yet available
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	/	Not yet available
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies	/	Not yet available

2.7 DAIRY UC 2.3: HERDSMAN+

This Use Case aims to implement an IoT platform and the development of the different technological resources that it needs to acquire and validate information from a dairy supply chain. The platform has the challenge of informing the farming community about the benefits of adopting technology-based solutions, new economic models, animal Fertility and animal Health.

2.7.1 Domain model

The domain model for UC2.3 is depicted in Figure 32.

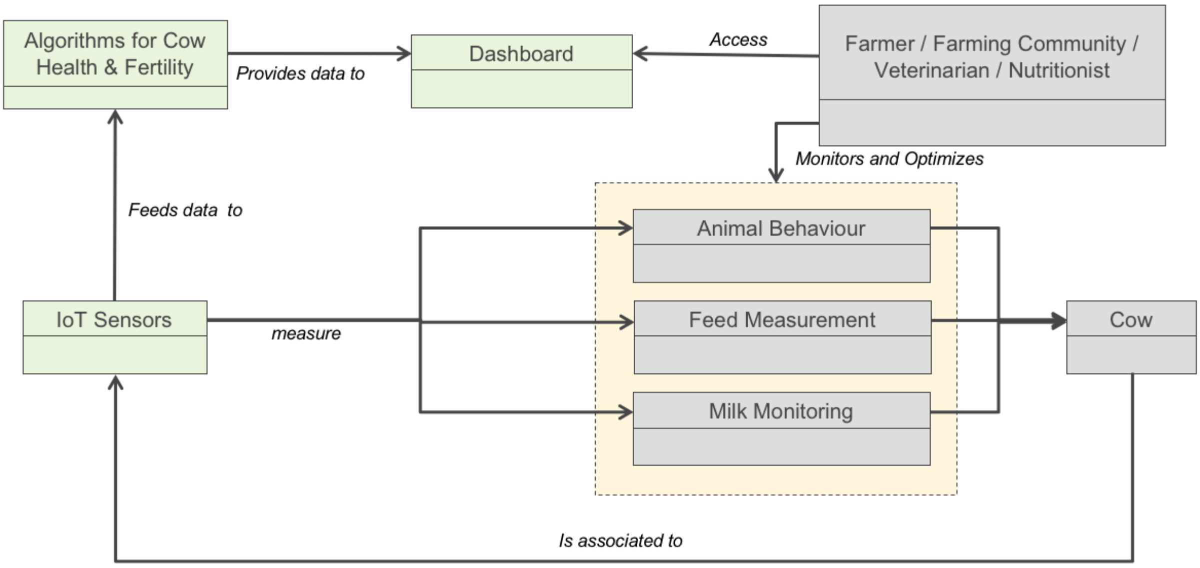


Figure 32 – UC2.3 Domain Model.

The main goal of this Use Case is the acquisition and modelling of data that help in monitoring and decision at a dairy farming sector.

The Farmer is interested in optimizing the processes of Animal Behaviour, Feed Measurement and Milking Monitoring of each cow, such as the Production Performance Environment and the Fertility and Health monitoring, to alert on the early detection of the onset of an illness condition.

To acquire this interest data measurements are distributed IoT sensors in strategic points of the farm.

The Collar Interface is an IoT sensor that allow to identify each cow in strategic areas. This identification is possible because each cow has a Collar Sensor in the neck, which is associated exclusively with is ID (cow ID).

The data values acquired by the IoT-sensors are stored in a Data Storage System which uses a dedicated algorithm to extract information, such as the health and fertility of cows, which is subsequently available to the Farmer and to the Third parties through a dedicated Dashboard on the Web.

2.7.2 Deployment view

The Deployment diagram for UC2.3 is depicted in Figure 33.

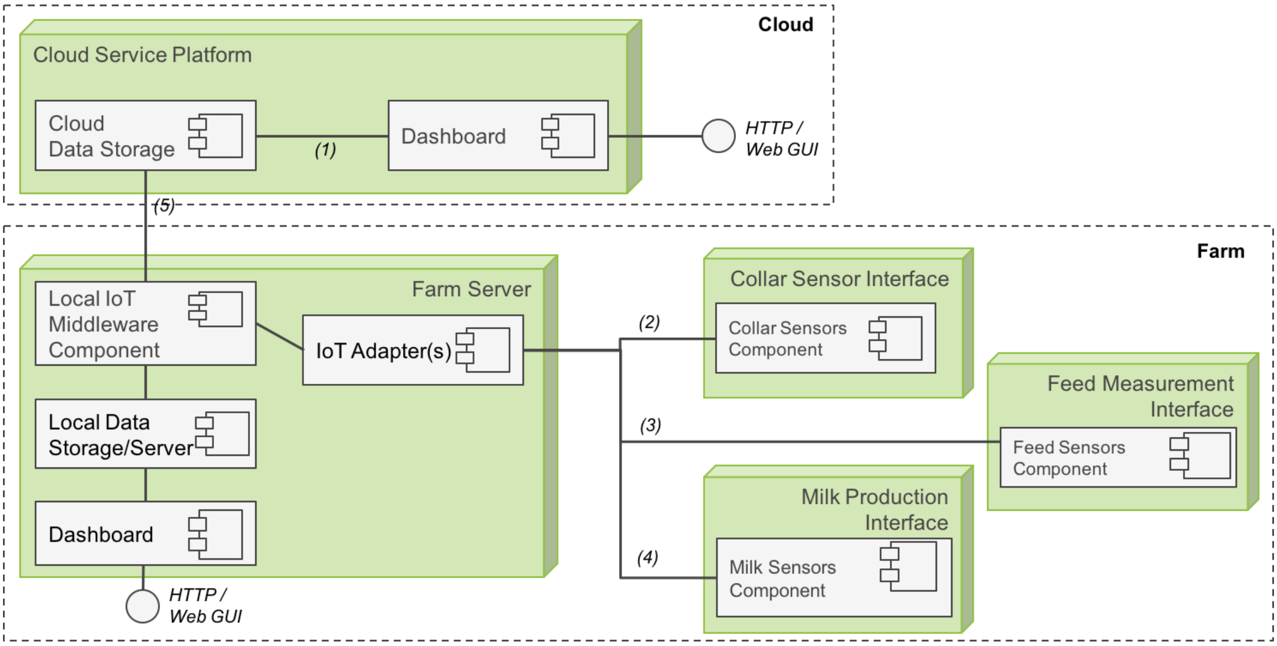


Figure 33 – UC2.3 Deployment View.

In this Use Case the components are implemented locally in the Farm and remotely in the Cloud Service Platform.

There are three physical sensor platforms in the Farm: “Collar Sensor Interface”, “Feed Measurement Interface” and “Milk Production Interface”. The nodes of Each platform are dedicated PCs with specific software that are connected to the local farm network Local Area Network (LAN) and used to inter-connect to the Farm Server.

The protocols (1) to (5) depicted in the diagram have Proprietary standards.

The Farm server host the three dedicated “IoT Adapter” components, the “Local IoT Middleware Component” (a LoRa Gateway), the “Local Data Storage”, allow the communications to the “Cloud Service Platform” and allow the available information in a Dashboard.

The “Cloud Service Platform” runs: a “Cloud Data Storage” service, receiving data via (5) from Farm Servers and the available information in a “Dashboard” via (1).

The summary of deployed components for UC2.3 is provided in Table 27.

Table 27 – UC2.3 Deployed Components.

Name	Description	Supplier (brand) + Model	Number of units
Merlin 2 Robot	Milking	Fullwood	3
Lely model a	Milking	Lely	3
Robot	Feed measurement	T4	3
Mono Box Robot	Milking	GEA	2
Automatic Feed	Feed measurement	GEA	2
Q series PLC	Feed measurement	ForFarmers	2
Collar Sensor	Neck mounted collars attached to each cow	Afimilk (Silent Herdsman)	500
Collar Sensor Interface	Interface to read the movement/behaviour of each cow	Proprietary	3 (1 per Farm)
Local Data Storage / Server	Farm gateway running integration and communications layers / Local Database	Semtech (LoRa Gateway)	3 (1 per Farm)
Cloud Service Platform	Remote server/service hosting the applications.	AWS (Amazon Cloud)	1

2.7.3 IoT Functional view

The IoT functional view of this use case (depicted in Figure 34) is structured as following:

- Application Layer: Contains the Dashboard that allow the interaction with users through a GUI.
- Service support and Application Support Layer: Is composed by the “Cloud Data Storage” that receive and store the data from each farm local network.
- Network Layer: these layers is composed by the “Farm Local Area Network” that provide control functions of network connectivity and to transport the data information and the “Gateway” and the Has the capability to wirelessly connect to the sensors in order to receive the data.
- Device Layer: The “Device Capabilities” Futures the “Collar Sensors” that use radio transmission to local base station, the “Feed Sensors” that have the capability to acquire the

Feed measurements and the “Milk Sensors” with the capability to receive information about the milk production.

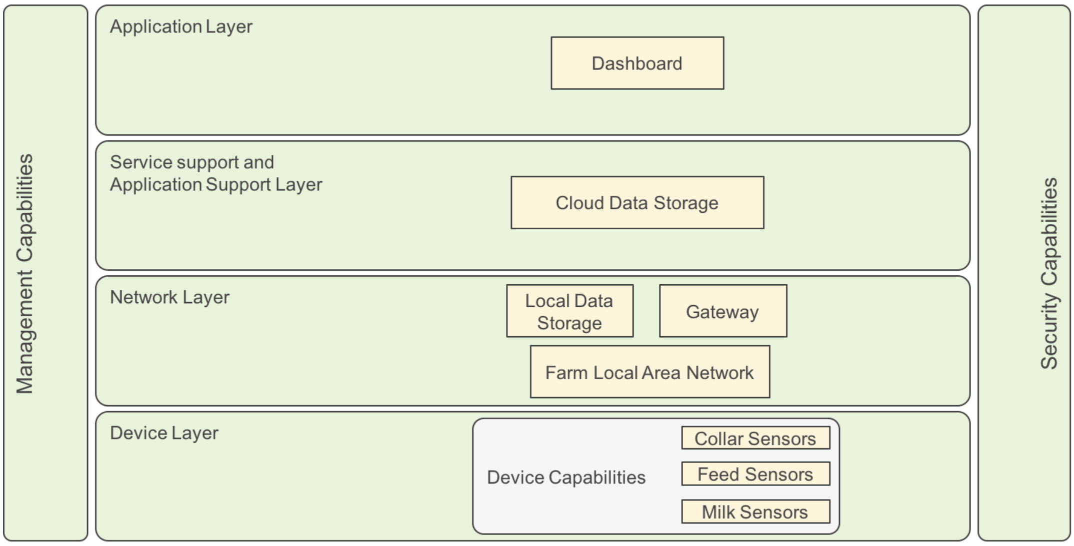


Figure 34 – UC2.3 IoT Functional View.

2.7.4 Business Process Hierarchy view

he Business Process Hierarchy view for UC2.3 is depicted in Figure 35.

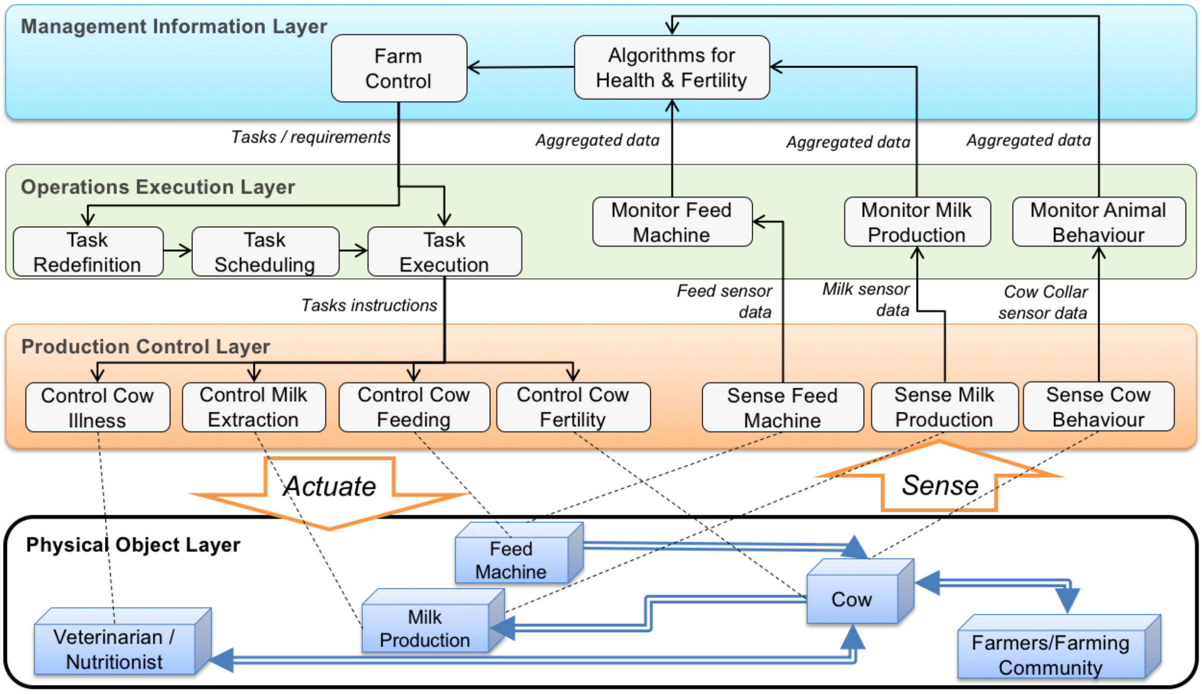


Figure 35 – UC2.3 Business Process Hierarchy view.

Business Process Hierarchy View comprises four layers: *Physical Object Layer, Production Control Layer, Operations Execution Layer* and *Management Information Layer*. This diagram shows the supply of food resources to cows, the detection of their behaviour and the milk production in order to optimize cows’ health and the quality of milk production.

In the “Physical Object Layer” are presented relevant objects of this case: The cow behaviour, are sensed by “Collar Sensor”. In the “Production Control Layer” the “Feed Machine” provides the feed to the cows. The “Milk Production” performed the cow’s milk extraction. Farmers/Veterinarian have active interaction by the acquired information from sensors in the farm.

The data are collected and analysed in the “Operations Execution Layer” and are used to monitor the cow behaviour, the milk production, and the cow feed measurement in order to control the farm.

The aggregated data are used in the “Management Information Layer” to monitor where “The Farm Control” triggers the execution of actions by sending requirements task and the task definition to the “Operations Execution Layer”. The “Task Redefinition” defines the tasks for each control the “Detailed Scheduling” schedule the respective tasks that are executed through the “Task Execution”.

2.7.5 Interoperability Endpoints

The interoperability endpoints are shown on Table 28.

Table 28 – UC2.3 Interoperability Endpoints.

Interface name	Exposed by	Protocol	Notes
Collar Sensor Interface	Collar Movement Collar ID	Proprietary	Production collars use radio transmission to local base station and allow data access via database
Milk Production Interface	Milk Production Milk quality range	Proprietary	Allows information about the milk production via database
LoRa Location Interface	Location	LoRa Network (Low Power Wide Area Network – LPWAN)	Location sensor will be wireless capable of interfacing with LoRa network
Feed Measurement Interface	Feed consumption	Proprietary	Acquire the Feed measurements that will be accessed via database/cloud

2.7.6 Information model

The Information model for UC2.3 is depicted in Figure 36 and Table 29.

The “CollarSensor” is associated to the “Cow”, including the identification of each Cow (Cow ID) and has a frequency of data collection of 1 reading every milking period per cow. The “Location” gives information about the local latitude, longitude, elevation and timestamp (and others TBC) using local LoRa network with a frequency reading of 10 minutes.

The “CollarMovement” allows information about eating, rumination and timestamp with a data collection frequency of 1 reading every 90 seconds. The “FeedConsumption” have a data collection frequency that gives relevant information about the weight per cow and timestamp.

The “MilkQualityRange” is associated to the “MilkProduction” and offers information about fat, protein, lactose and conductivity and has a frequency of data collection of 1 reading every milking period per cow. The “MilkProduction” gives information about the milk production per teat and the timestamp with a frequency of data collection of 1 reading every milking period per cow too.

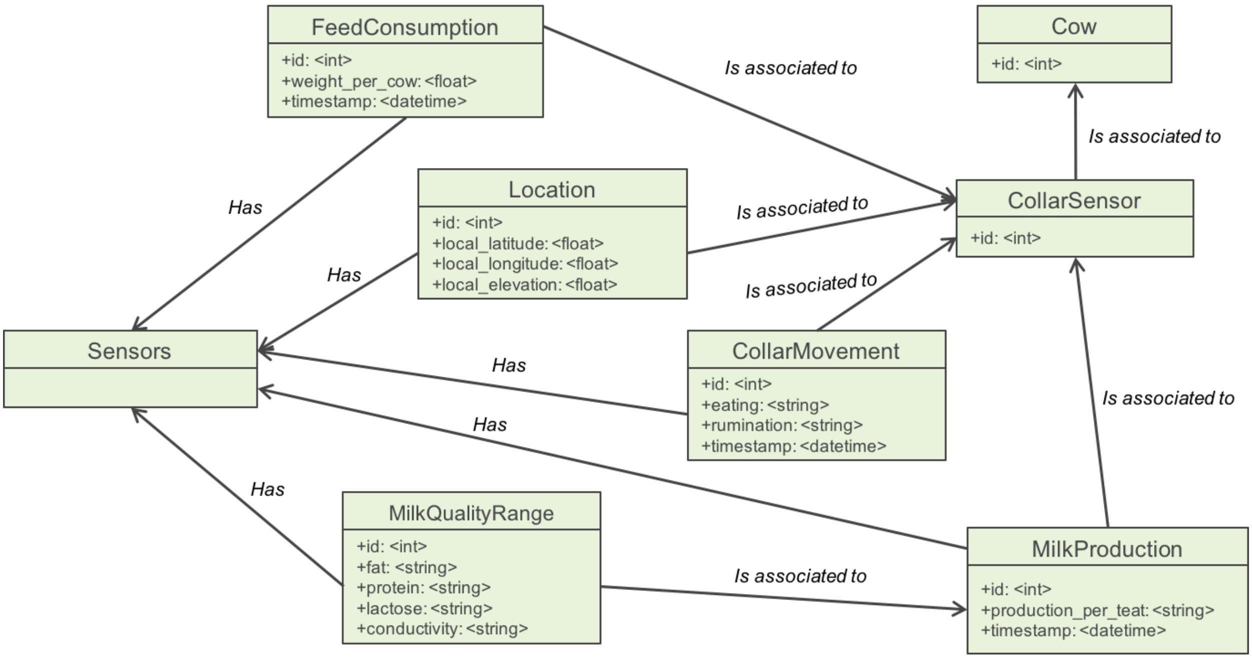


Figure 36 – UC2.3 Information Model.

Table 29 – UC2.3 Information Model Details.

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Collar movement	Sensor	Cows	1 readings every 90 s	Eating, rumination and other + timestamp
Milk production	Sensor	Cows	1 reading every milking period per cow	Milk production per teat (kg) + timestamp
Milk quality range	Sensor	Cows	1 reading every milking period per cow	Inc. fat, protein, lactose and conductivity + timestamp

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Cow ID	Sensor	Cows	1 reading every milking period per cow	Identification of cow
Location	Sensor	Cows	Reading every 10 min	Local latitude, longitude and elevation with timestamp using local LoRa network on each site
Feed consumption	Sensor	Cows	10Hz	Weight per cow + timestamp

2.7.7 Summary of gaps

The main gaps identified for UC2.3 are reported in the following:

- Lack of a technological resource to determine the location of individual animals. Potential collaboration with UC 2.1. will improve the acquired data;
- Several milking robots to generate measurements of milk quality with sensors that need frequent calibration. Development of a remote calibration approach in order to enhance the assurance of measurements by the milk quality sensors. Collaboration with UC 2.4

2.7.8 Assets identified for re-use

The assets identified for re-use are shown on Table 30.

Table 30 – UC2.3 Assets identified for re-use.

Component name	Short Description and role in the Use Case	Functional role	License
Silent Herdsman	Collars that can be deployed on other farms	Collar in the cow's neck that allows to identify each one of them.	www.afimilk.com

2.7.9 Collaboration with other Use Cases

Table 31 - UC2.3 Collaborations with other Use Cases.

Use Case Number	Potential for sharing components or approaches identified	Potential for integration of data/services identified
Use Case 2.1	One of the missing features from the suite of technologies within UC2.3 is a determination of the location of individual animals.	Great potential to enhance the data from UC2.3.
Use Case 2.2	UC2.2 is concerned with the development of a neck-mounted device that indicates the health of individual animals.	Potential to carry out a competitive performance analysis with other neck mounted devices.
Use Case 2.4	UC2.3 has a number of milking robots which generate in-line measurements of milk quality. These sensors need frequent calibration. The development of a remote calibration approach would enhance the assurance of measurements generated by in-line milk quality sensors.	Demonstration of an on-line calibration methodology.

2.7.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets.

The following Table 32 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability.

Table 32 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC2.3)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May '18)	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	600	- Collars (600)
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	6	- platforms (3) - gateways (3)
	Number of IoT applications available	3	- Fertility (1) - rumination (1) - eating (1)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May ‘18)	Short comment / qualitative estimation
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1
	Number of FIWARE GEs instances	0	
	Number of open datasets used	0	
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	1	- collar
	Average number of installations per reusable IoT component	600	- collars (600)
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	0	All proprietary
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies	0	

2.8 DAIRY UC 2.4: REMOTE MILK QUALITY

Use case 2.4 aims at the sustainable improvement of milk and dairy testing processes. It is led by QLIP, a key stakeholder for quality analyses, realising over 14,000,000 analyses annually in its own premises. QLIP is a knowledge centre within this area and closely collaborates with partners like food processors that use the analysis services of QLIP and operate their own laboratories/ laboratory equipment, while usually working on a smaller scale. Therefore, those small laboratories specifically focus on the usage of related Infrared analysis instruments and in practice the IR instruments are often operated by (factory) operators, skilled in efficient processing, but may lack knowledge of the advanced instruments and its proper maintenance and calibration. Thus, QLIP provides calibration services, which include the provision of calibrated milk (and other dairy) samples and consultancy by QLIP experts that regularly maintain and calibrate the instruments at other laboratories, based on their long-time and extensive knowledge with respect to the instrument operation and the specifics of IR analysis of milk. Using those maintenance and calibration services directly reduces costs for the smaller laboratories, since building up internal knowledge and experts seems not as cost efficient as using external consultancy services. Furthermore, inaccurate measurements (inducted by operators with a lack of knowledge about laboratory equipment and measurement) can mean valuable dairy end products do not meet specifications, potentially costing the manufacturer tens of thousands of euros.

On top of that, when analysing the centralisation of milk analyses in the past and observing most recent trends in the dairy market, one might consider a reasonable probability that this centralising trend might be reversed and result in a higher degree of local on-site and even on-farm testing, when applicable. As a matter of fact Qlip itself is working with partners on a small, but high quality IR-device to make this come true. However, this is currently not part of this project. This could result in a dramatic increase of requests for maintenance and calibration services, while the trend towards the production of high quality products might also increase the demand for higher quality and safety levels at lower costs with higher processing efficiency.

From a strategic perspective, this expected development towards more decentralised and high quality production, needs also to be analysed from a more holistic point of view. The continuous digitisation of farms, production and collaboration offers the possibility to derive large amounts of data that will enable a highly sophisticated characterisation and classification of production and value adding steps that go beyond pure tracking and tracing of data, but enabling to derive required information and knowledge to correlate very specific indicators, probably enabling the generation of early warning signs for stakeholders that might enable a pro-active control of quality and costs along the value chain. IoT is considered one of the strategic enabling technologies of utmost importance to generate data from diverse equipment, objects as well as animals. It will facilitate the distributed and decentralised gathering of data in harsh environment, while data storage and exchange can even buffer states of particular disconnection and limited bandwidth, while combining an event-based processing with subsequent aggregation and analysis of large sets of data.

However, this situation requires a multi-layer strategy combined with a step-wise development and experimentation in different settings. The current processes and instruments are operated rather fully disconnected, asking for manual intervention and local presence of experts, not necessarily allowing real-time reaction to quality deviations. The analytical instruments need to be digitised and adding features for remote control, maintenance and calibration. This is considered as a key enabler before being able to further combine IoT related data from the surrounding processes. This requires a stepwise approach by QLIP, asking in the first iterations to enhance analytical instruments in close collaboration of QLIP maintenance and calibration experts with the producers of the analytical instruments. In the following iterations, the combination with IoT enhanced objects, equipment and animals would take place in carefully designed experiments for evaluating the potentials of enhancing data with information and knowledge for an optimal maintenance and calibration of instruments.

This approach cannot be realised in a fully sequential way with isolated steps just focused on the remote maintenance and calibration before starting the introduction of IoT enhanced data acquisition. Therefore, it is foreseen to have different layers for realising advanced solutions for analysis equipment maintenance and calibration. The digitisation of instruments is the basic layer, while the IoT potentials shall be considered in different additional layers, while each layer needs to be coordinated on a different time scale and in cooperation with a different stakeholder setting.

From an initial perspective, those different technology layers could be considered as rather independent settings:

- Infrared instruments would need to be enhanced with additional technology (e.g. sensors, actuators, connectivity) and a platform for remote maintenance and calibration would need to be realised.
- The dynamic involvement of individuals is required what would ask for technical and organisational communication approaches.
- Gathering of data in different agricultural steps need to be enabled that would require the integration with existing systems (e.g. facilitating connectivity with existing FMIS).
- Using additional IoT enabled approaches for gathering data in basic farm settings (e.g. enhancing existing equipment like milking installation or even milk robots) and at regularly changing locations (i.e. due to moving cattle herds).
- Virtualising individual animals with sensors, enabling to correlate different aspects in the overall production process.
- Milk batch control and organisational approaches to handle the detailed information on item level (e.g. individual cattle, automatic feeder) with the subsequent handling of milk that is stored in tanks accumulating milk from different fields, stables, farmers, or even places/ regions.

Due to the overall complexity, QLIP was deciding to mainly focus on the analysis instruments in the first steps, while this somehow distracts the attention from basic IoT technologies. At the same time, it is clear that one shall consider the subsequent steps already as soon as possible to avoid later drawbacks in terms of data models, organisational principles, equipment capabilities as well as stakeholder involvement. Therefore, it was agreed to start at some later point compared to the other IoF2020 use cases, mainly focus on the remote maintenance and calibration features at the beginning and handle the core IoT requirements as an accompanying task, while also aiming at an intense collaboration with the other use cases 2.1, 2.2 and 2.3 in the dairy trial to allow for the elaboration of reusable approaches and technologies.

2.8.1 Domain model

The domain model for UC2.4 is depicted in Figure 37.

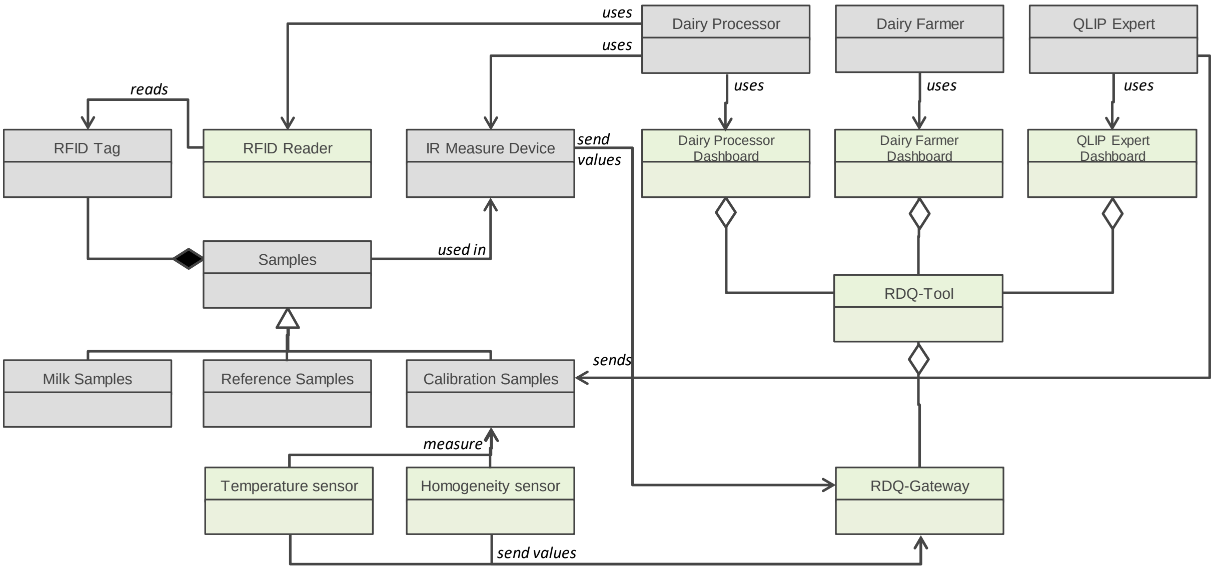


Figure 37 – UC2.4 domain model.

Overall, QLIP is developing a Remote Dairy Quality (RDQ) system, which includes three dashboards and a gateway. The gateway will receive test results from samples made in infra-red measuring devices located at dairy processors and send the results to the RDQ tool to be stored. The dairy processor usually starts the IR measuring device with a reference sample for control, and then uses it with the necessary milk samples. The historical data of test results performed in an IR measuring device enables the QLIP Expert to prepare a specific maintenance and calibration plan, using the dedicated dashboard, and prepare calibration samples to be sent to the dairy processor, whenever necessary. The dairy farmer can access the specific dashboard to review relevant information about the animals, which can be extrapolated from the milk test results, and drive adjustments in feeding, for example.

All samples include an RFID tag (at the moment just a barcode), which is read before inserting the sample in the machine, allowing to keep track of the results. The calibration samples have additional information about temperature and homogeneity, registered by local sensors, before they are used. These calibration samples have a concrete composition, tailored for the specific IR measuring device. The calibration process depends on the quality of the samples used, which need to be at a correct temperature and be homogenized before inserted in the machine.

Currently, QLIP is still not using RFID-tags but still simple barcodes instead. Once we will be talking decentralized testing and the volume goes up it is indeed likely we will adapt RFID. Especially since it is a technology we are familiar with in our “on premise” samples.

The farmer dashboard will only get in place once decentralized testing becomes a reality and is not something we have developed at the moment.

2.8.2 Deployment view

The deployment diagram for UC2.4 is depicted in Figure 38.

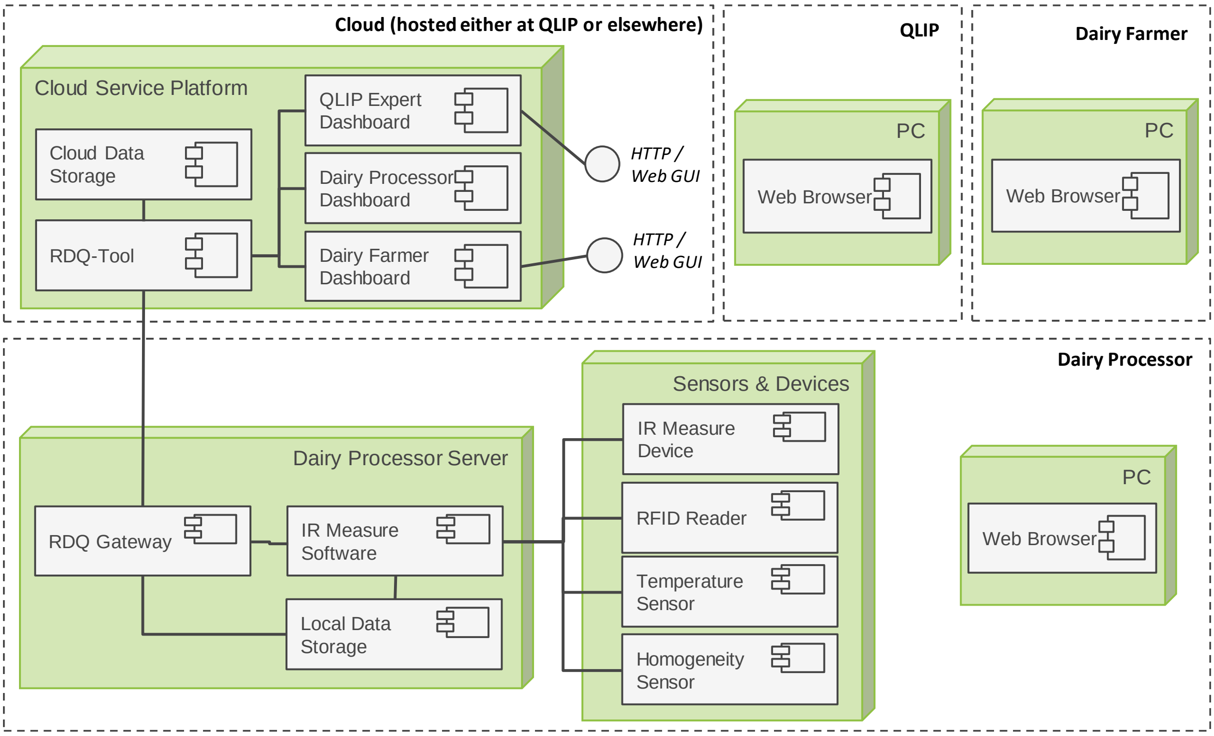


Figure 38 – UC2.4 deployment view.

The main components of this use case are deployed in a cloud infrastructure, either hosted at QLIP or elsewhere. This includes the core RDQ tool, the associated data storage and the three dashboards. The RDQ gateway will be deployed at the dairy processor's site, where the IR measurement device is, which will connect to the gateway to enable sending all test results to RDQ. The sensors are also deployed at the dairy processor, since they are used to identify the samples (RFID) and obtain measurements about their quality (temperature and homogeneity).

The three main actors involved in this use case, QLIP expert, dairy processor and dairy farmer will access their respective dashboards using a standard web browser, in a laptop, desktop or mobile device.

Table 33 lists the deployed components in UC2.4. It must be noted that the components indicated are per measuring device. A client usually has one measuring device, but it can have more. In this case, the amount of devices is scaled up. QLIP will then manage and handle the devices of all its clients. QLIP is performing test to select specific suppliers and models of the listed devices.

Table 33 – UC2.4 Deployed Components.

Name	Description	Supplier (brand) + Model	Number of units
IR Measure Device	The infrared measuring device that analyses the milk samples.	Foss, Delta Instruments	1
RFID Tag	A tag identifying uniquely each milk sample.	To be specified	n
RFID Reader	The device to read the tags and identify the milk samples.	To be specified	1

Name	Description	Supplier (brand) + Model	Number of units
Temperature Sensor	A sensor to obtain the temperature of the milk samples.	To be specified	1
Homogeneity Sensor	A sensor to analyse the homogeneity of milk samples.	To be specified	1

2.8.3 IoT functional view

The IoT functional view of this use case is depicted in Figure 39 and is structured as followed:

- *Application layer:* The three dedicated dashboards for the three actors involved in the use case, i.e. QLIP expert, dairy processor and dairy farmer.
- *Service support and application support layer:* contains the objects that provide functionality to the application layer. In this use case, this is primarily the RDQ tool and associated cloud data storage. The use case is considering developing possible connectors to existing FMIS.
- *Network Layer:* The communication between the several layers still needs to be defined. However, the infrared measure software belongs to the network layer, and connects the physical devices to the gateway.
- *Device layer:* includes the physical components or devices in the use case, which are the RFID reader, the infrared measuring device and sensors to measure temperature and homogeneity.
- *Management and Security Capabilities:* The use case still needs to address these capabilities.

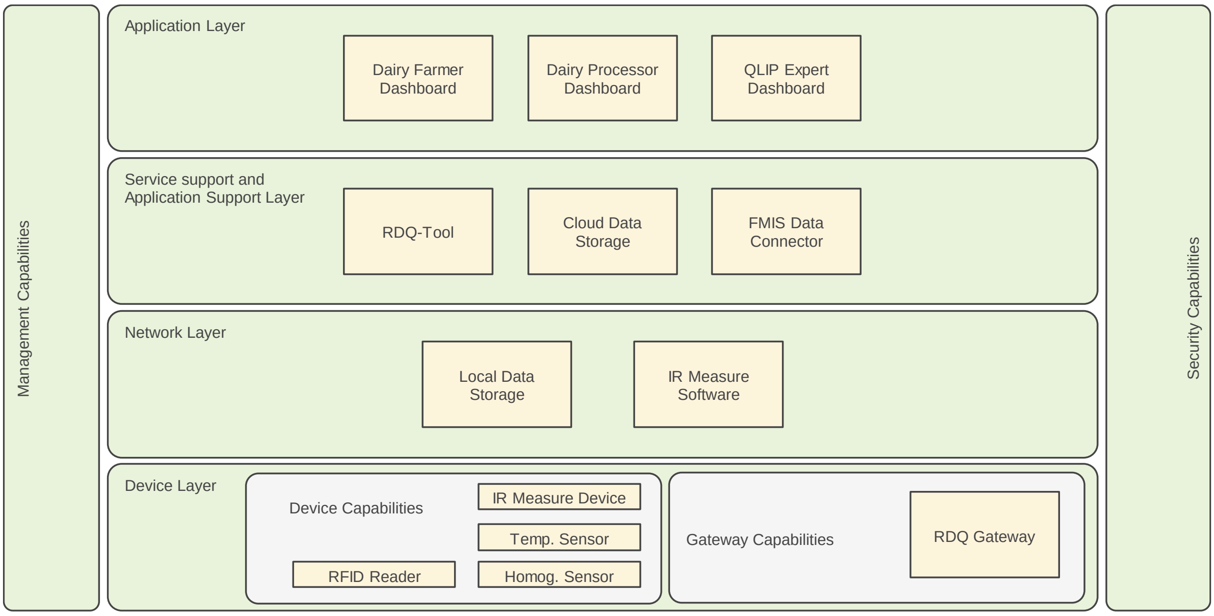


Figure 39 – UC2.4 IoT functional view.

2.8.4 Business Process Hierarchy view

Figure 40 depicts the business process hierarchy view for UC2.4.

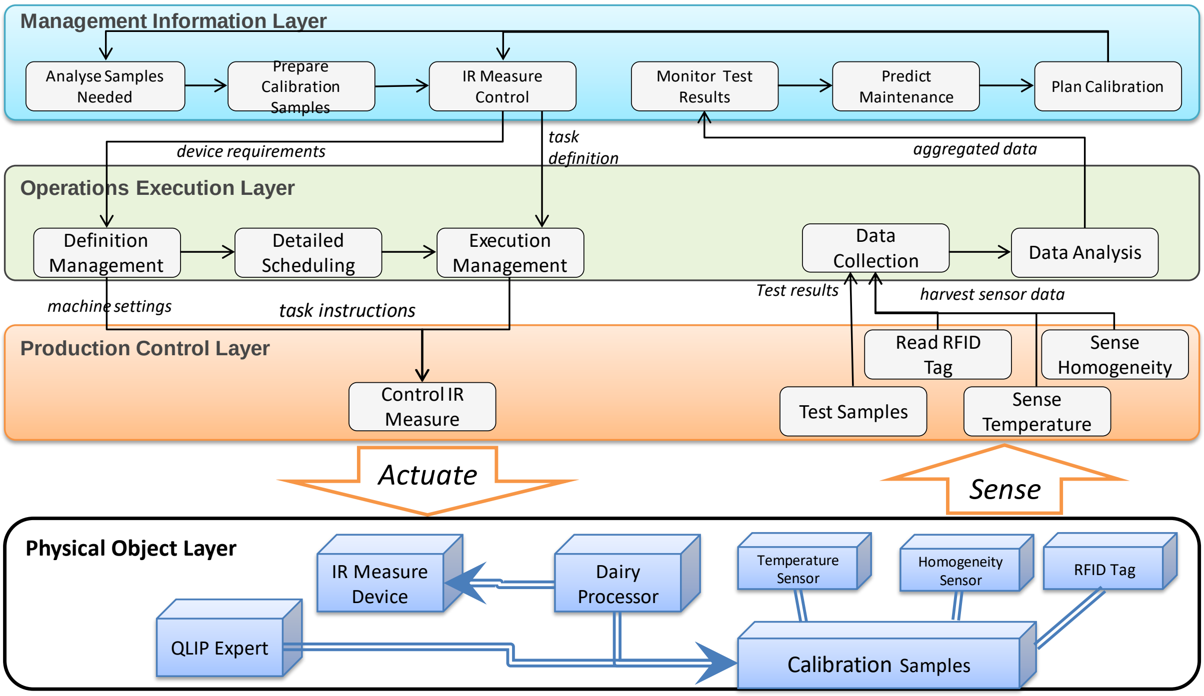


Figure 40 – UC2.4 business process hierarchy view.

The business process hierarchy view represents two main cycles of sensing and actuating over four layers. For this use case, the following process occurs:

- The sensors and devices are represented in the physical object layer, and operated in the production control layer. The values resulting from sensors and devices are collected in the operations execution layer, analysed and further pushed to the management information layer. Here, the test results are processed and added to existing historical data of the same device. This data set enables the definition or adjustment of the maintenance and calibration plan for the specific infrared measuring device. The plan includes the calibration events, which will require QLIP to prepare appropriate calibration samples to be sent to the dairy processor.
- When there is a need for maintenance or calibration, the system will support the identification of the suitable samples, analysing the historical data (see previous step). The calibration plan and samples are defined in the management information layer and passed on to the operations execution layer, where they are translated into specific tasks and scheduled in the daily operation. The tasks are then passed to the production control layer, to be transmitted to the specific infrared measuring device, making the necessary actuation.

2.8.5 Interoperability endpoints

The interoperability endpoints are shown on Table 34.

Table 34 – UC2.4 Interoperability Endpoints.

Interface name	Exposed by	Protocol	Notes
IR Measuring	IR Measuring Device	To be specified	Exposes the unique identifier of the measuring device and the results obtained from all samples analysis
Analysis Data	RDQ Gateway	To be specified	Exposes the results from all the samples analysed in a processed manner (combining analysis results, with sensor data)
Milk Sample IDs	RFID Reader	To be specified	Exposes unique identifier of each milk sample to be analysed
Temperature data	Temperature sensor	To be specified	Raw data from wireless sensor
Homogeneity data	Homogeneity sensor	To be specified	Raw data from wireless sensor

2.8.6 Information model

The information model of UC2.4 is depicted in Figure 41 and described in Table 35.

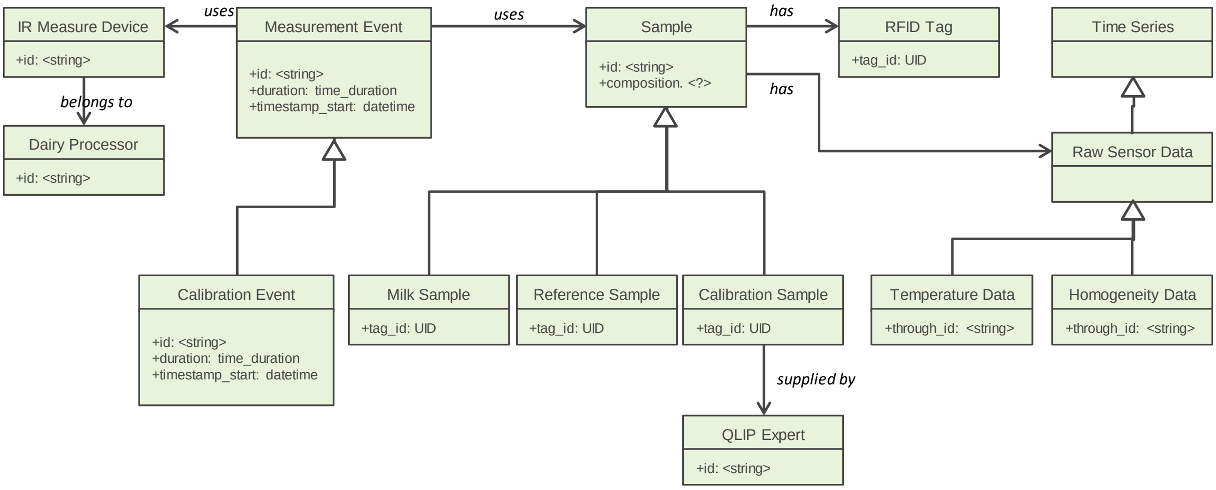


Figure 41 – UC2.4 information model.

The data model represents the several entities used in the use case architecture:

- QLIP Expert and Dairy Processor are the two main actors involved in the use case.
- IR Measure Device is installed in a dairy processor site and is used to process all samples.
- There are three types of samples: calibration, reference and milk. The samples are all used in the same machine and all have RFID tags attached.

Table 35 – UC2.4 Information Model Details.

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
RFID Tag	Obtained from RFID Reader	Milk sample	To be specified	To be specified
Temperature	Obtained from temperature sensor	Milk sample	To be specified	To be specified
Homogeneity	Obtained from homogeneity sensor	Milk sample	To be specified	To be specified

2.8.7 Summary of gaps

The specification of UC2.4 is ongoing and several aspects need to be still defined. This is aligned with the strategy of developing an MVP that can be quickly tested and assess on the field.

The use case has already identified the following gaps that still need to be addressed in the specification:

- Identify most suitable communication protocols for the RDQ gateway, to enable communication with several vendors of IR measuring devices.
- Specify how to properly read temperature and homogeneity of calibration samples, and collect these values, right before the samples are introduced in the IR measuring device.
- Address management and security capabilities.

2.8.8 Assets identified for re-use

The assets identified for re-use are shown on Table 36.

Table 36 – UC2.4 Assets identified for re-use.

Component name	Short Description and role in the Use Case	Functional role	License
RDQ Gateway	This component aggregates the data from sensors, handling the local data storage and then exposing the processed data to the upper layers, namely the RDQ Tool.	This component is in the device layer.	To be specified
RDQ Tool	This component processes data from all existing gateways, optimizing calibration and maintenance for all IR measuring devices being managed. It is the central component of the use case. It provides all the functionality to three dedicated dashboards.	This component is part of the Service support and application support layer.	To be specified

2.8.9 Collaboration with other Use Cases

UC2.4 is aiming at an intense collaboration with the other use cases 2.1, 2.2 and 2.3 in the dairy trial to allow for the elaboration of reusable approaches and technologies.

2.8.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets. The following Table 37 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability.

Table 37 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC2.4)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May '18)	Target values	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	3	19,500	
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	1	180	
	Number of IoT applications available	1	80	

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May '18)	Target values	Short comment / qualitative estimation
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	1	19	
	Number of FIWARE GEs instances		40	
	Number of open datasets used		40	
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions		20	
	Average number of installations per reusable IoT component		5	
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards		20	
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies		75%	

2.9 FRUIT UC 3.1: FRESH TABLE GRAPES CHAIN

The goal of this UC is to test, develop and disseminate architectures, methodologies and strategies, allowing integration of heterogeneous IoT and Remote Sensing technologies on production and chain-level into a coherent system, for creating a sustainable Fruit Sector.

The UC will take place in two countries: in Italy, all the activities will be developed in organic farming, instead in Greece in integrated farming.

CIHEAM-IAMB is the leader partner of the UC and it is responsible for all the implementation of the use-case activities. APOFRUIT is involved in the project as end-user in Italian pilot. SYSMAN P&S provides Decision Support System (DSS) solution for irrigation and fertilization management and cloud infrastructure. AUA will be responsible for the coordination of the Greek pilot site and it will work in close with Synelixis (IoT provider on precision farming solutions), Pegasus (end user) and the other partners that work in the Italian pilot site. S-COM will support the CIHEAM-IAMB activities within the organic agriculture and UNIBAS will support CIHEAM-IAMB with the researchers experience and laboratory equipment for grape post-harvest manage

2.9.1 Domain model

The domain model for UC3.1 is depicted in Figure 42.

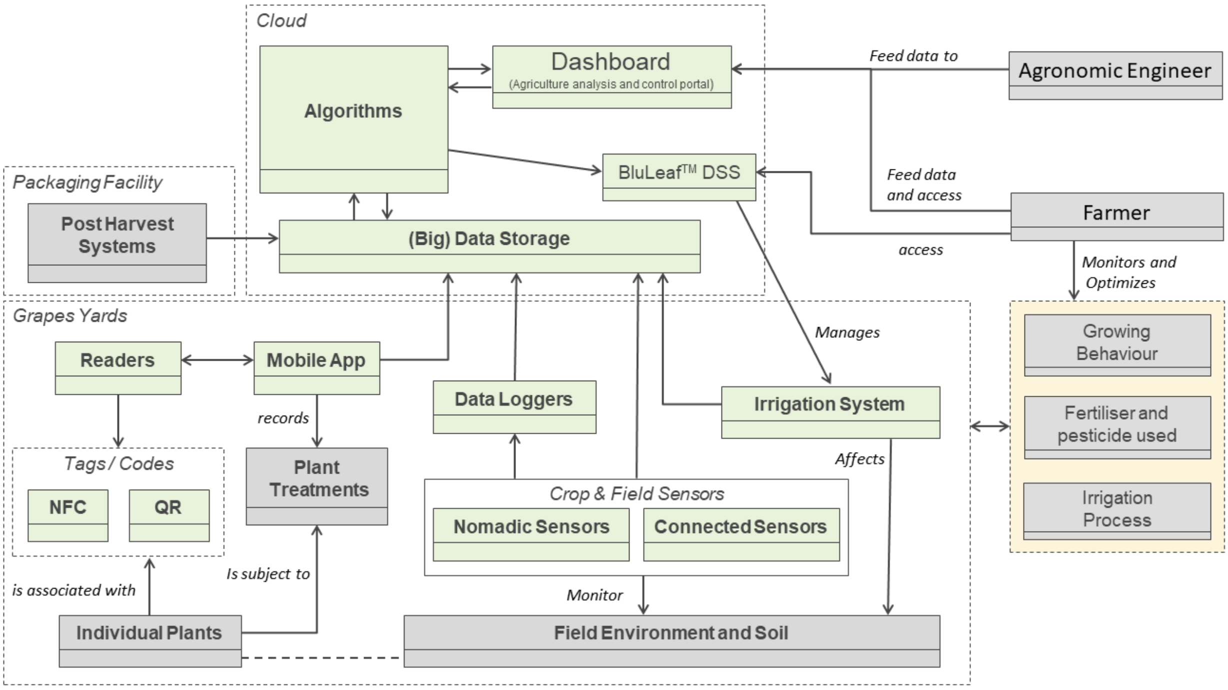


Figure 42 - UC3.1 Domain Model

Overall, the system allows **Farmers** to monitor and optimize the Growing Behaviour of grapes, jointly with the amounts of fertilizer and pesticides used, as well as the irrigation process. The monitoring and optimization features heavily rely on IoT Devices and systems deployed on the field, both in the packaging facility and in the grapes yards.

Crop and Field Sensors are sensing devices used to monitor a wide number of physical parameters. They can be either **connected** (installed in fixed position and periodically sending monitored data via cables, point-to-point wi-fi links and narrowband networks) or **nomadic** (temporarily deployed by human operators to measure and record parameters of interest in specific moments in time).

Data from both types of sensors can be either directly transmitted to **the remote Data Logger** (**field** or **virtual**), and so directly stored on the remote Data Storage, or recorded in a **local Data Logger**. Data from the local Data Logger is periodically downloaded by human operators and uploaded to the remote **Data Storage.**

Specifically, every parcel and/or orchard is associated with a **NFC** tag and **QR** code. The mobile application, by using a reader, can read the identities and directly get access to: plan treatments, daily activities and DSS for irrigation management. This data is directly transmitted to the remote **Data Storage**. In addition, the **Irrigation System** is a wireless network of actuators for controlling water valves and pumps. Data are directly transmitted to the remote **Data Storage.**

On top of this architecture, the **BlueLeaf^{TM} DSS** (Decision Support System), is used by the farmers to manage their irrigation systems. Based on the data provided from **Data Storage**, in fact the BlueLeaf^{TM} DSS **Algorithms** are used to elaborate the decision for managing the **Irrigation System**.

The **Algorithms** element fosters mathematical models and logical intelligence to provide information to the **DSS** and the **Dashboard** exposed by its web portal, on which it is possible to view/analyse sensor data from **Farmers**. In addition, the **Dashboard** allows to **Agronomic Engineers** and **Farmers** to provide data that the system uses to take decisions to optimize the Growing Behaviour of grapes, and manage irrigation and fertilization processes.

2.9.2 Deployment view

The Deployment diagram for UC3.1 is depicted in Figure 43.

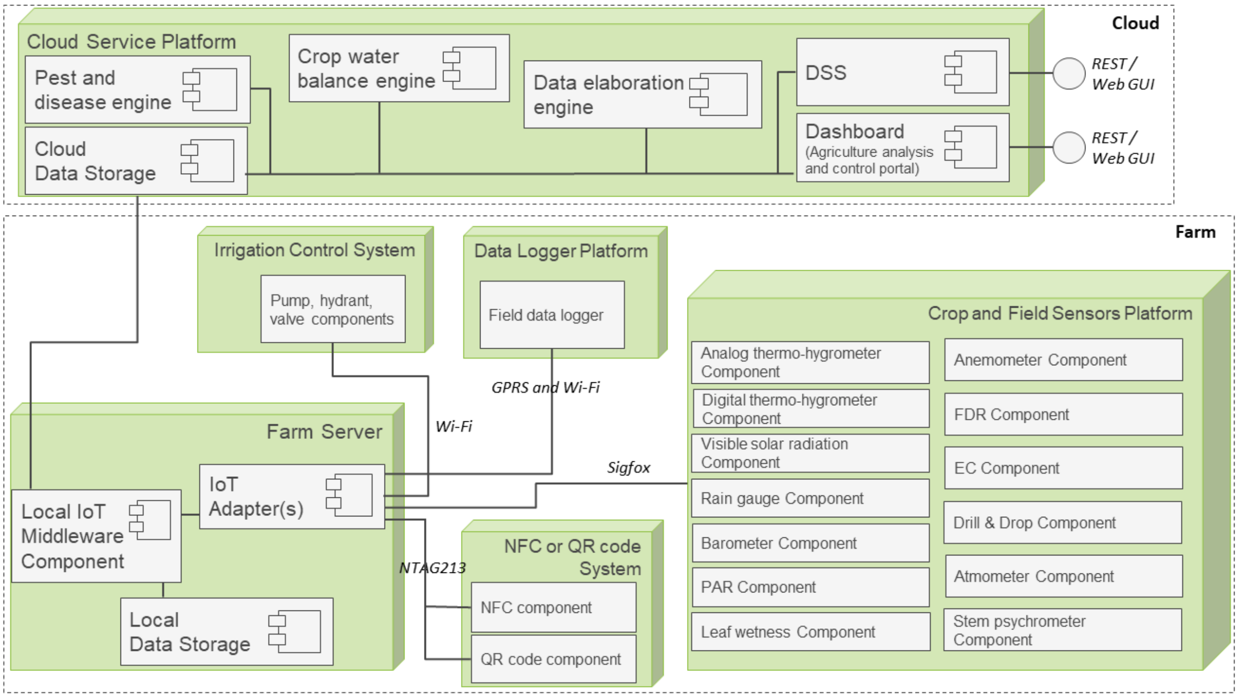


Figure 43 - UC3.1 Deployment View

Components in this UC are deployed either locally (in the **Farm**) or remotely (in the **Cloud**).

In the Farm, the **Crop and Field Sensors Platform** includes different sensors (connected and nomadic) used to monitor a wide number of physical parameters. Actually, some sensors are connected to **field Data Logger** through cables and/or a Wi-Fi point-to-point connection while others are fully independent, long-lasting battery powered and send their data through the Sigfox narrowband network to a **virtual Data Logger** (**IoT Adapter**). While the **field Data logger** sends data to cloud services through a GPRS connection, the **virtual** one, developed by the Italian technology provider Sysman, puts data, acquired independently from each sensor, directly on the cloud and makes them available to users through a custom Web/Mobile application. This evolution of the project IoF2020 **took place in Q2 2018**.

There are two different deployed systems: the **Irrigation Control** system**,** connected to the Farm via Wi-Fi or GPRS for the irrigation management process and the **NFC or QR code** system (the standard NTAG213 is used from NFC component and the ISO/IEC 18004:2006 for crop and plot monitoring).

The **Farm server** is a set of dedicated-to-the-farm software applications, part of the **Cloud Server Platform**, which includes the “**IoT Adapter**” components, the “**Local IoT Middleware Component**” and the “**Local Data Storage**” used to get data from remote devices.

The **Cloud Service Platform** is hosted at Sysman Progetti & Servizi’s premises. The cloud platform runs: a “**Cloud Data Storage**” service which receives data from **Farm Server**; a **Dashboard** (Agriculture analysis and control portal), accessible via HTTPS; a **Pest and Disease Engine** running algorithms to support farmer in pest management activities (this pest and disease engine will be developed and implemented during the lifetime of the project); a **Crop Water Balance Engine** running algorithms to support farmer in the irrigation process.

The summary of deployed components for UC3.1 is provided in Table 38.

Table 38 - UC3.1 Deployed Components

Name	Description	Supplier (brand) + Model	Number of Units
Post harvest equipment	Cold storage rooms; O2 and CO2 analyser; Data logger for temperature and humidity control; temperature and humidity probes; MA Packaging machine	Ninetek srl refrigeration; Servomex; Analog device; Ninetek srl; Ninetek srl	1; 1; 1; 45; 1
Blow	Blow is applied on containers for food and allows the control of gaseous exchanges between the inside and outside of a container. In detail, the device is suitable for the conservation of fruits and vegetables because it allows the control, following natural metabolic processes, of the composition of the head space inside the package allowing the entrance of the oxygen and/or the exit of carbon dioxide and/or gaseous metabolites. The use of blow in addition with the controlled atmosphere packaging technology for the experimental trials it opens a new perspective in the storage and shipment of conventional and organic table grape due to the device efficacy and to the possibility to be directly applied on the surface of a normal package.	Ninetek srl	1200

Name	Description	Supplier (brand) + Model	Number of Units
BluLeaf™ DSS	DSS for irrigation and pest management	Sysman Progetti & Servizi	1
Overall cloud service	Remote services for BluLeaf™ operations	Sysman Progetti & Servizi	1
GPRS Field data logger with solar panel	Data logger to acquire data from sensors	NetSens	4
Thermo-hygromer sensor with Sigfox technology	Sensor to measure environmental temperature and humidity	Sysman Progetti & Servizi/Unknown manufacturer	1
Anemometer sensor with Sigfox technology	Sensor to measure wind speed and direction	Sysman Progetti & Servizi/Unknown manufacturer	1
Rain gauge with Sigfox technology	Sensor to measure the amount of rain precipitation	Sysman Progetti & Servizi/Unknown manufacturer	1
FDR sensor with Sigfox technlogy	Sensor to measure volumetric soil water content and temperature	Sysman Progetti & Servizi/Unknown manufacturer	1
Wi-Fi Field data logger with solar panel	Data logger to acquire data from sensors	NetSens	1
Irrigation control system with solar panel	Wi-Fi unit to program and activate irrigation valves	NetSens	1
Rain gauge (Crop and field sensors)	Sensor to measure the amount of rain precipitation	NetSens	1
Barometer (Crop and field sensors)	Sensor to measure atmospheric pressure	NetSens	1
Analog thermo-hygrometer sensor (Crop and field sensors)	Sensor to measure environmental temperature and humidity	NetSens	6

Name	Description	Supplier (brand) + Model	Number of Units
Digital thermo-hygrometer sensor (Crop and field sensors)	Sensor to measure environmental temperature and humidity	NetSens	1
Visible solar radiation sensor (Crop and field sensors)	Sensor to measure solar radiation	NetSens	3
PAR sensor (Crop and field sensors)	Sensor to measure Photosynthetically Active Radiation	NetSens	4
Leaf wetness sensor (Crop and field sensors)	Sensor to measure leaf's wetness	NetSens	2
Anemometer sensor (Crop and field sensors)	Sensor to measure wind speed and direction	NetSens	3
FDR sensor (Crop and field sensors)	Sensor to measure volumetric soil water content and temperature	NetSens	4
EC sensor (Crop and field sensors)	Sensor to measure soil electrical conductivity	NetSens	4
Drill & Drop sensor (Crop and field sensors)	Sensor to measure soil moisture	Sentek	2
Atmometer sensor (Crop and field sensors)	Sensor to measure water evaporation rate	Tecno.El	2
Stem psychrometer sensor (Crop and field sensors)	Sensor to measure stem water potential	ICT International	1

Name	Description	Supplier (brand) + Model	Number of Units
Basic IoT Board (BIB)	IoT data logger to acquire data from sensors	Nettrotter	1
Customized pendants with NFC tag and QR Code	Water and UV resistant pendant to identity crops and add marks for pest management	Unknown manufacturer	500
WSN Platform	Wireless network sensors and probes for data capturing in fields	*Synelixis – SynField*	*3*
Irrigation automation	Wireless network actuators for controlling water valves and pumps	*Synelixis – SynField*	*1*
Agriculture analysis and control portal	Web portal for viewing/analysing sensor data, specifying algorithms and models and automatic actuator control	*Synelixis – SynField*	*NA*

2.9.3 IoT Functional view

The IoT functional view of this UC (depicted in Figure 44) is structured as following:

- *Application Layer*: there is an agriculture application for **irrigation and fertilization management**.
- *Service support and application support layer*: both Generic support capabilities and Specific support capabilities are shown in this UC. There are particular capabilities like **DSS** for irrigation and pest management; a **crop water balance engine** for reduce water wastage, caused by inappropriate irrigation scheduling and/or inefficient water application systems; a **pest and disease engine** for reduce the use of fertilisers and pesticides (this pest and disease engine will be developed during the lifetime of the project). In addition, there are common capabilities which can be used by different IoT applications, such as **Data elaboration engine** and **Cloud Data Storage**.
- *Network layer*: there are both Networking Capabilities and Transport Capabilities that first provide relevant control functions of network connectivity and second focus on providing connectivity for the transport of IoT service and application specific data information. Network and transport connectivity are provided directly from specific technologies. In this UC, the

technologies involved are Wi-Fi, GPRS, Sigfox and NFC. The same happen for mobility management capability that use specific protocol based on technology used.

- *Device layer*: Device Capabilities include **sleeping and waking-up** for reduced energy consumption (sleeping and waking-up capabilities have been implemented in Q2 2018 and, from first measurements, batteries could have an **autonomy of 1.5+ years**). Sensors and actuators can gather and upload information directly or indirectly to the communication network and can **directly or indirectly** receive information from communication network. The devices in this use case can be used to implement ad-hoc networks based on the specific technology. Regarding Gateway Capabilities, devices used within the UC support wired or wireless communication technologies (**multiple interfaces**) and **protocol conversion**.
- *Management Capabilities:* in this UC, there are not specific information about management capabilities. So, it is assumed that this UC includes general functions based on the specific technology.
- *Security Capabilities:* in this UC, there are not specific information about security capabilities. So, it is assumed that this UC includes general functions based on the specific technology.

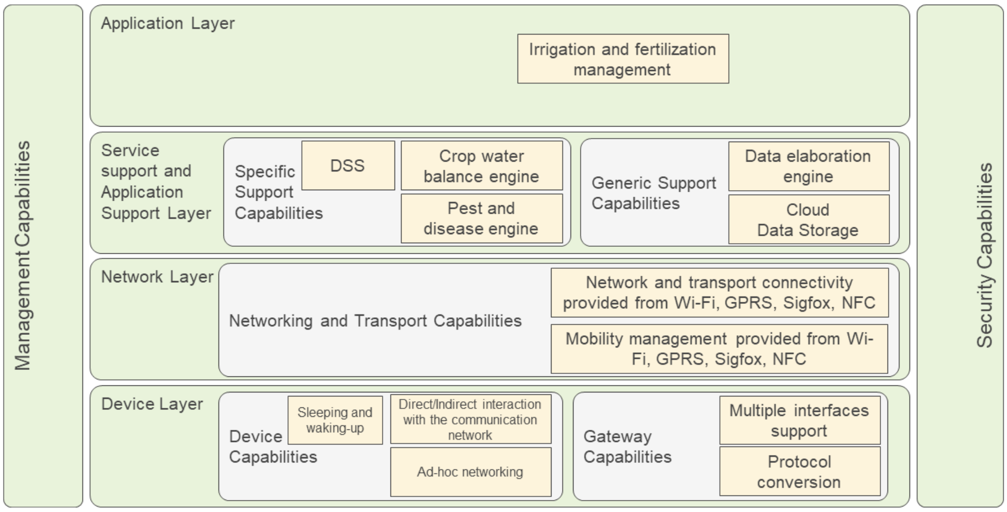


Figure 44 - UC3.1 IoT Functional View

2.9.4 Business Process Hierarchy view

The Business Process Hierarchy view for UC3.1 is depicted in Figure 45.

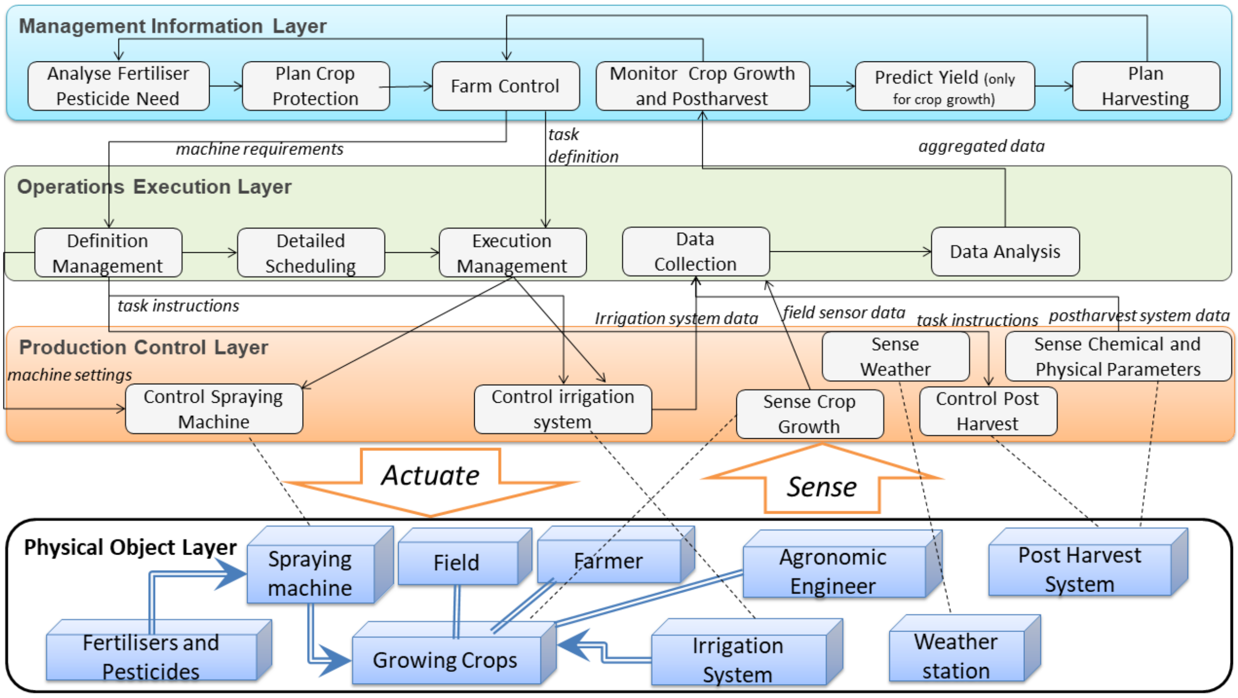


Figure 45 - UC3.1 Business Process Hierarchy view

Business Process Hierarchy View comprises four layers: *Physical Object Layer, Production Control Layer, Operations Execution Layer* and *Management Information Layer*.

In the **Physical Object Layer,** the relevant objects of this case are depicted: growing crops in the field, that are sensed with nomadic and connected sensors, irrigation system and weather station. The spraying machine applies pesticides and fertilisers to the crops based on specific conditions provided from upper levels. Irrigation system applies variable rate irrigation, depending on the variation in the crop water needs. Post-harvest system is used for packaging facility in order to deliver the good quality product to the consumers.

The other layers include the main farm processes on different time horizons that are needed in this case to sense and control the physical objects. The starting point is sensing of crop growth in the **Production Control Layer** that generated field sensor data. The control modules are used to actuate commands to specific physical objects. All these data are collected and analysed in the **Operations Execution layer**. The aggregated data are used in the **Management Information Layer** to monitor crop growth and postharvest. Next, the fertiliser and pesticide need is calculated based on the crop growth monitoring and weather data. The Farm Control triggers that the execution of these actions by sending the specific requirements task and task definition for spraying machine and irrigation system to the **Operations Execution Layer**. In this layer, the settings of the spraying machine and irrigation system are defined, the spraying and irrigation task are scheduled and the spraying and irrigation task instructions are sent to the **Production Control layer**.

2.9.5 Interoperability Endpoints

The interoperability endpoints are shown on Table 39.

Table 39 - UC3.1 Interoperability Endpoints

Interface name	Exposed by	Protocol	Notes
Agriculture analysis and control portal	Dashboard	HTTP (Web GUI)	http://synfield.synelixis.com

2.9.6 Information model

The Information model for UC3.1 is depicted in Figure 46 and Table 40.

On the left side there are the entities of sensors and they have, like minimal information, a unique identifier. Those sensors are classified in raw sensor data and they are in general crop & field sensors (solar radiation, leaf wetness, air velocity & direction, rainfall, soil temperature, soil moisture, soil electrical conductivity).

Micro-climate of grape event, which is derived from previous entities, has a unique identifier, value is used to represent the measure, unit describes the unit of measure based on International System and timestamp shows the time when the event is happened.

Water flow and water pressure are a raw sensor data and they have, like minimal information, a unique identifier. Water consumption event is derived from previous entities and it has the same attributes of micro-climate of grape event.

The events of this information model are linked with NFC tag or QR code, that they have a tag_id in Unique identifier (UID) format, and they are associated to field and crop entity. The last entity has an id in string format, a description in string format and the coordinates in DMS format.

Vigour and soil electrical conductivity (EM-38 Sensor) are classified like a field survey. This latter is derived from micro-climate of grape event.

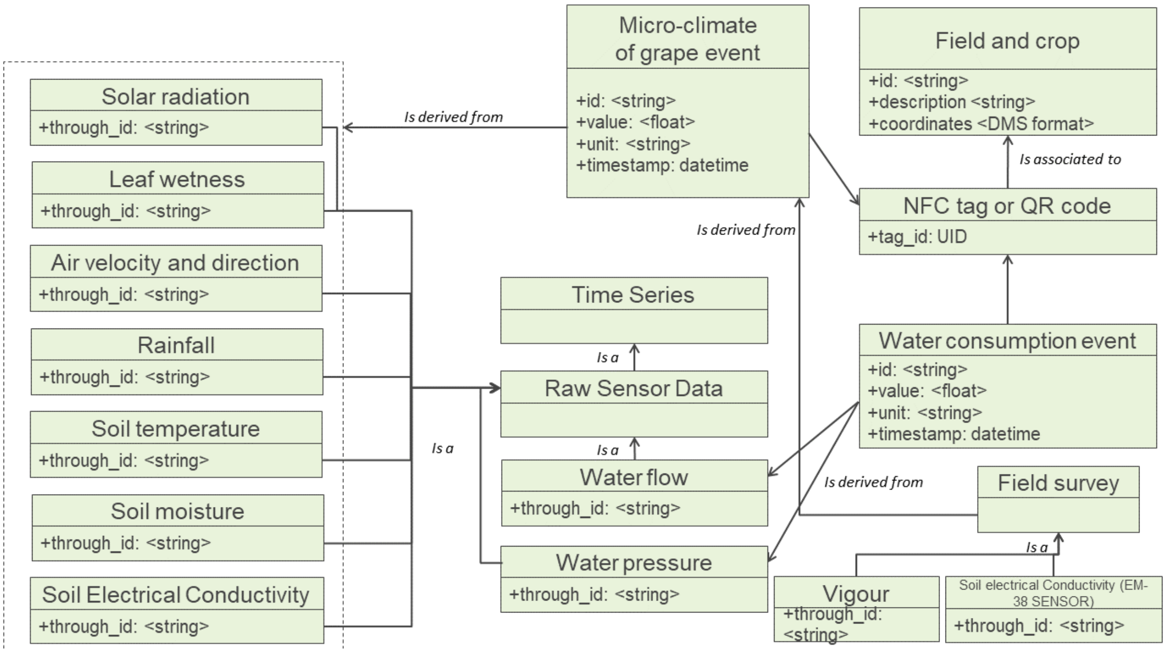


Figure 46 - UC3.1 Information Model

Table 40 - UC3.1 Information Model Details

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Air temperature, air humidity, wind speed and direction, visible solar radiation, PAR, leaf wetness, soil water content and temperature, soil electrical conductivity, water evaporation rate	Direct from sensors Openfield	Organic table grape	3/5 mins	Custom JSON + FIWARE format to be deployed
Air temperature, air humidity, PAR, leaf wetness, wind speed and direction, soil moisture, water evaporation rate	Direct from sensors Trilling system	Organic table grape	3/5 mins	Custom JSON + FIWARE format to be deployed
Air temperature, air humidity, wind speed and direction, rain precipitation, atmospheric pressure, visible solar radiation, soil water content and temperature, soil electrical conductivity	Direct from sensors Openfield	Organic table grape	3/5 mins	Custom JSON + FIWARE format to be deployed
Status of solenoid valves	Direct from sensors	Organic table grape	One time	Human readable format
Data for: pest recognition, disease marker, treatment activities, treatment monitoring	Direct from crops with mobile APP through NFC/QR Code	Organic table grape	On demand from farmers	Custom string

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Data from DSS	Direct with smartphone APP	Organic table grape	On demand from farmers	Human readable format
Metadata for deterministic model	Kc coefficient	Organic table grape	On start-up (tuning may be required at a later time)	Numeric value
Metadata for DSS	Stress index sensitivity between phenological stages, water availability, water constraint	Organic table grape	On start-up (tuning may be required at a later time)	Numeric value

2.9.7 Summary of gaps

The specification of UC3.1 is almost defined, but there are some points not clear, as listed in the following

- At present time is not clear if and how the data from Post-Harvest Systems are collect to the IoT platform.
- further work should be performed to clarify security and privacy aspects.

2.9.8 Assets identified for re-use

The assets identified for re-use are shown on Table 41

Table 41 - UC3.1 Assets identified for re-use

Component name	Short Description and role in the Use Case	Functional role	License
BluLeaf™ DSS (http://www.bluleaf.it)	BluLeaf™, its commercial DSS solution for irrigation and fertilization management. It is suitable for every farm that require a DSS to support day-by-day activities	In the ITU-T Y.2060 IoT Reference Model, this is in the “Service Support and Application Support Layer” In the Business Process Hierarchy view, “BluLeaf™ DSS” is in “Operations Execution Layer”	Commercial
IoT Station (http://iot.sys-man.it)	IoT Station	In the ITU-T Y.2060 IoT Reference Model, this is in	Commercial

Component name	Short Description and role in the Use Case	Functional role	License
		the "Management Information Layer" In the Business Process Hierarchy view, it is part of the "Production Control Layer"	
Agriculture analysis and control portal (http://synfield.synelixis.com)	This component is a Web portal for viewing/analysing sensor data, specifying algorithms/models and automatic actuator control	In the ITU-T Y.2060 IoT Reference Model, this is in the "Application Layer" In the Business Process Hierarchy view, "Agriculture analysis and control portal" is in "Operations Execution Layer"	Free & commercial

2.9.9 Collaboration with other Use Cases

An active collaboration to support the design and implementation of the DSS (Decision Support System) for irrigation management of Soya crops has been started with UC 3.2. More collaborations are going to start with other UCs from Q3 2018.

2.9.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, key KPIs and performance targets.

The following Table 42 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability

Table 42 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC3.1)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May '18)	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	11	- SIGFOX (4) - GPRS (5) - WIFI ISM (2)
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	6	- SigFox, LORA, GPRS, WiFi ISM – wireless networks (total = 4) - NFC tags (1) - VDL –Gateway/ IoT Platform (1)
	Number of IoT applications available	2	- IOF2020 web and mobile applications (1) - Blueleaf (1)
Usage of open IoT	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May '18)	Short comment / qualitative estimation
architectures and platforms	Number of FIWARE GEs instances	0	
	Number of open datasets used	0	
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	/	Not yet available
	Average number of installations per reusable IoT component	/	Not yet available
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	2	Blueleaf IOF2020 web
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies	0	

2.10 FRUIT UC 3.2: BIG WINE OPTIMIZATION

In conventional and, even more, in organic viticulture and wine-making important goals can be achieved using IoT technologies which include remote sensing and control actuators, information collections both in vineyards and cellars, big data analysis and management, and decision making. In this way increased efficiency can be achieved in inputs and labour resulting in higher quality, profit and environ-mental sustainability along with decrease in production cost.

This use case will address both Conventional (for vineyard and cellar phase in France) and Organic (for cellar phase in Italy) production systems.

The IoT solutions developed in the project will reduce costs (man power, fertilizers, materials, electricity, water, etc.), improve the vineyards and cellars management by making decision in real-time based on more precise information and weather forecasting resulting with an increase of vine yield and wine quality.

2.10.1 Domain model

The domain model is designed to handle the following objectives:

- Real time weather conditions monitoring at parcel and vineyard level.
- Optimization of potable water resources during wine production.
- Reduction of costs related to the production and commercialization by increasing inputs efficiency.
- Frequent and inexpensive check – at cellar level - of key indicators of wine quality to prevent technological accidents during winemaking phases
- Continuous monitoring of wine conditions throughout transport, storage and distribution, to bring wine at its best quality expression to final consumer.

It lays on the traditional elements of the secular wine making process, from the vineyard to the wine bottle (in blue), including modern devices such as cooling system and automatic harvester. The domain model proposes to add supplementary IoT elements (in green): sensors, cloud services, and applications.

The Figure 47 diagram below depicts the traditional, not so traditional and IoT elements necessary for the use case, and summarizes also the relations between all these elements.

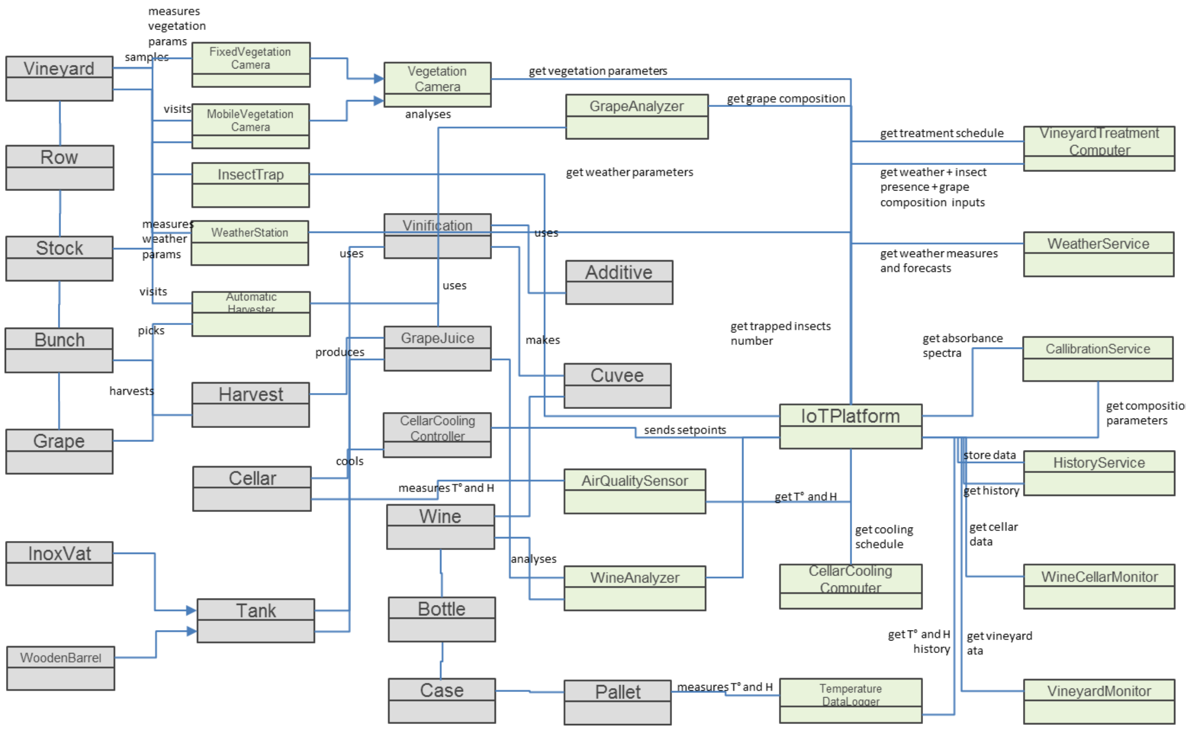


Figure 47 - UC3.2 Domain Model

2.10.2 Deployment view

The Figure 48 diagram below, shows how the main IoT elements are deployed in the vineyard domain and in the cloud.

IoT devices in the vineyard (weather stations, insect traps, mobile and fixed vegetation cameras), in the cellar (spectrophotometer, air quality sensor, cooling controller); and in the distribution chain (temperature data logger) transmit their data to the cloud though the IoT platform, hosted in local gateways and in a cloud server. The cloud IoT platform uses cloud services (data storage, treatment, composition parameter calibration, cooling optimisation) and third-party weather service platform.

The communication protocols used among the different components is based on Lora[xvi]. Consequently. the various sensors, deployed at the cellar and vineyard, are connected to the corresponding LORA gateway and each message is being forwarded to a LoRaWAN server within the so called "*The Things Network* (TTN)".

The goal of The Things Network is to be very flexible in terms of deployment options. The preferred option is to connect to the public community network hosted by The Things Network Foundation or its partners. In this case the Application connects to a Public Community Network Handler, usually using the MQTT API.

The Cayenne Low Power Payload (LPP)[xvii] standard is used within all the connections.

In addition, the used Data Types is conforming to the IPSO Alliance Smart Objects Guidelines, which identifies each data type with an "Object ID".

Three IPSO objects are needed:

- Temperature: This IPSO object is used over a temperature sensor to report a remote temperature measurement. It also provides resources for minimum/maximum measured values and the minimum/maximum range that can be measured by the temperature sensor. The unit used here is degree Celsius (ucum:Cel).

- Humidity: This IPSO object is used over a humidity sensor to report a remote humidity measurement. It also provides resources for minimum/maximum measured values and the minimum/maximum range that can be measured by the humidity sensor. The unit used here is relative humidity as a percentage (ucum:%).
- Battery level readings: periodics level battery measurement. (%)

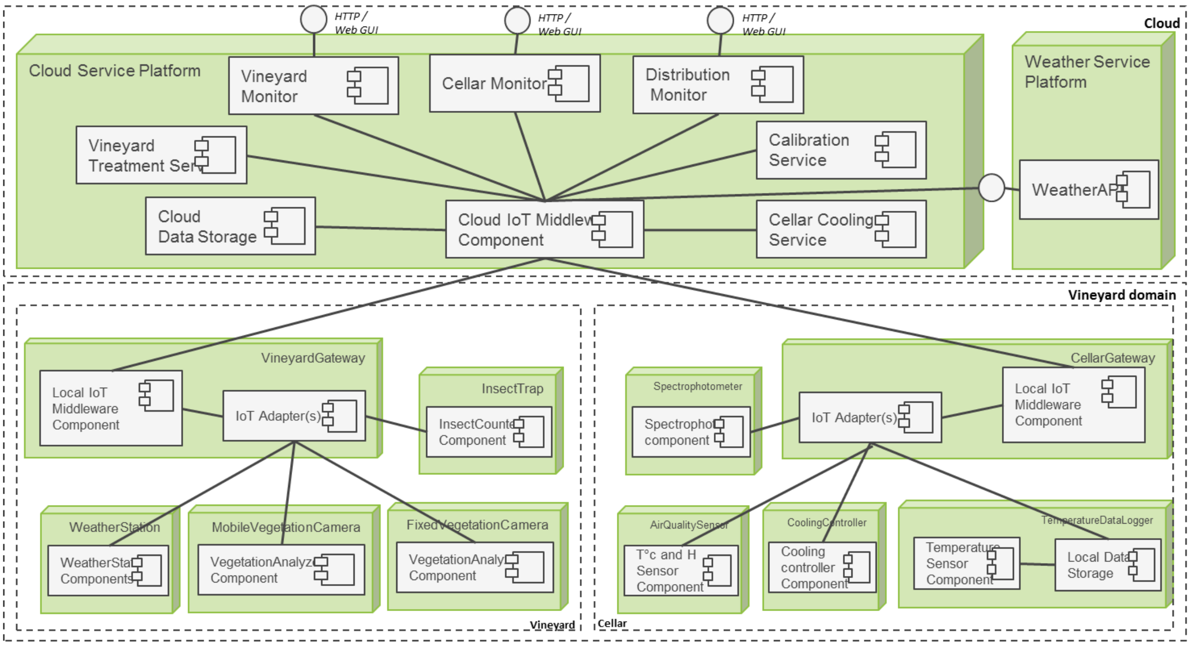


Figure 48 - UC3.2 Deployment View

The summary of deployed components for UC3.2 is provided in Table 43.

Table 43 - UC3.2 Deployed Components

Name	Description	Supplier (brand) + Model	Number of Units
Vineyard Complete Weather station	Monitoring weather conditions in the vineyards: • Temperature • Hygrometry • Barometric pressure • wind speed and direction • Solar Radiation • Rainfall	DEMETTER and Davis stations/Vantage Pro2 Plus 2 (6162, 6163) + ST LoRA module (B-L072Z-LRWAN1)	9 Estimated
Vineyard degraded Weather station	Monitoring micro-climes (weather conditions) in the vineyards: • Temperature • Hygrometry	Hobo U23 Pro V2 Temp/Rh + ST LoRA module (B-L072Z-LRWAN1)	34 Estimated
Mobile vision sensor	Monitoring Phenological vine stages High frequency camera mounted on tractors to	Basler camera with 6mm lens Odroid C2 computer Xenon flash ST LoRA module	1 Estimated

Name	Description	Supplier (brand) + Model	Number of Units
Fixed vision sensor (also called Fixed Vegetarian Camera)	Monitoring Phenological vine stages Low consumption camera fixed on a pole	Raspberry Pi Raspberry Pi NoIR camera LED lighting + ST LoRA module (B-L072Z-LRWAN1)	1 Estimated
Insect Trap camera	Monitoring insects in the vine and their potential identification, a trap equipped with a camera	Raspberry Pi Zero Raspberry Pi camera LED Lighting + LoRA module	1 Estimated
Positioning System (GPS)	Perform all positioning operations including tracking, acquisition, navigation and data transmission. (It is part of each block of the vineyard components)	ST's TESEO III + ST LoRA module (B-L072Z-LRWAN1)	5 Estimated
Cellar Temperature/ humidity sensors nodes	Monitoring cellar conditions: • Temperature • Hygrometry	omni Instruments/ RH 631 Wall Temperature and Humidity Transmitter Mount + ST LoRA module (B-L072Z-LRWAN1)	27 Estimated
Electricity sensor node	Monitoring electricity consumption	WebdynSun + ST LoRA module (B-L072Z-LRWAN1)	9 Estimated
Water sensor node	Monitoring water consumption	to be specified + ST LoRA module (B-L072Z-LRWAN1)	26 Estimated
Air conditioning sensor node	Monitoring and alarm generation in case of detection of malfunctioning of air condition in the cellars	to be specified + ST LoRA module (B-L072Z-LRWAN1)	8 Estimated
Sensors for Wine production	Monitoring of temperature kinetic during win fermentation and aging	Sensors with WiFi connectivity are already available. They will be connected to the IoT System	to be specified
LoRA Gateway	Gateway used to gather the data coming from LoRa sensors nodes and to encapsulate into Ethernet frames	Lorrier-lr2-iot-lora-gateway 868 MHz	2 Estimated
Telecom Gateway	Gateway Supporting Ethernet – ADSL To transmit data to the Cloud	Orange Gateway + Potential Ethernet Hubs	2 Estimated

Name	Description	Supplier (brand) + Model	Number of Units
sensiNact, IoT platform	An open platform for collecting, aggregating, storing and processing IoT data	CEA	2 Estimated
Process2Wine	Web and Mobile Software solution for the wine production	Ertus	2 Estimated
Remote Quality control in wine making	FTIR-spectrometer compact reader Bluetooth	ISVEA	1 Estimated
Data logger for Wine shipment	Temperature sensor NFC Bluetooth	VINIDEA	10
CloudService Platform	Cloud server hosting all services and applications	sensiNact	1
WeatherService Platform	Cloud server hosting weather service	Weather service supplier TBD	1
Cloud IoT Middleware Component	Cloud instance of IoT platform	sensiNact	1
Cloud Data Storage	No SQL database	Cassandra	1
CellarCooling Computer	Service that computes schedules for cellar cooling	to be specified	1
CalibrationService	Service that computes composition parameters from diffusion spectra	to be specified	1
Vienyard TreatmentService	Service that computes treatments schedules	to be specified	1
Monitors (vineyard, cellar, distribution)	GUI monitoring web app	to be specified	1

2.10.3 IoT Functional view

The Figure 49 diagram below, shows a schematic representation of the functional model for the use case 3.2.

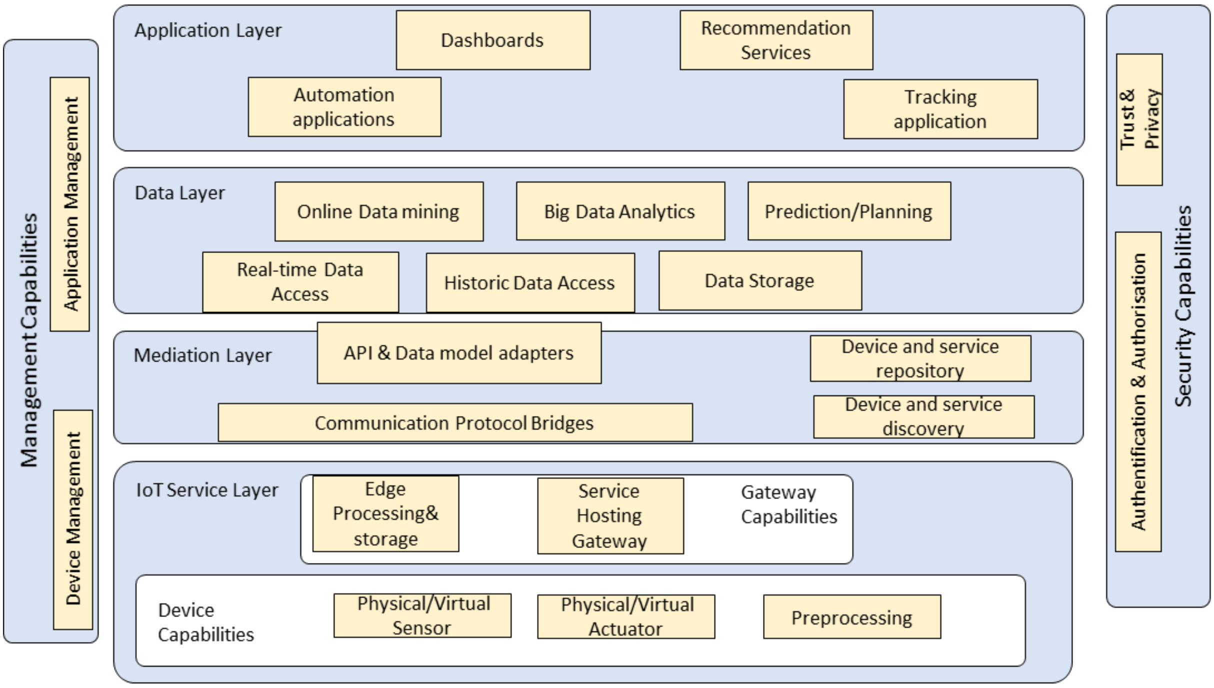


Figure 49 - UC3.2 IoT Functional View

2.10.4 Business Process Hierarchy view

The Figure 50 below presents a view of the business process between the physical object, production control, operation execution and management information four layers.

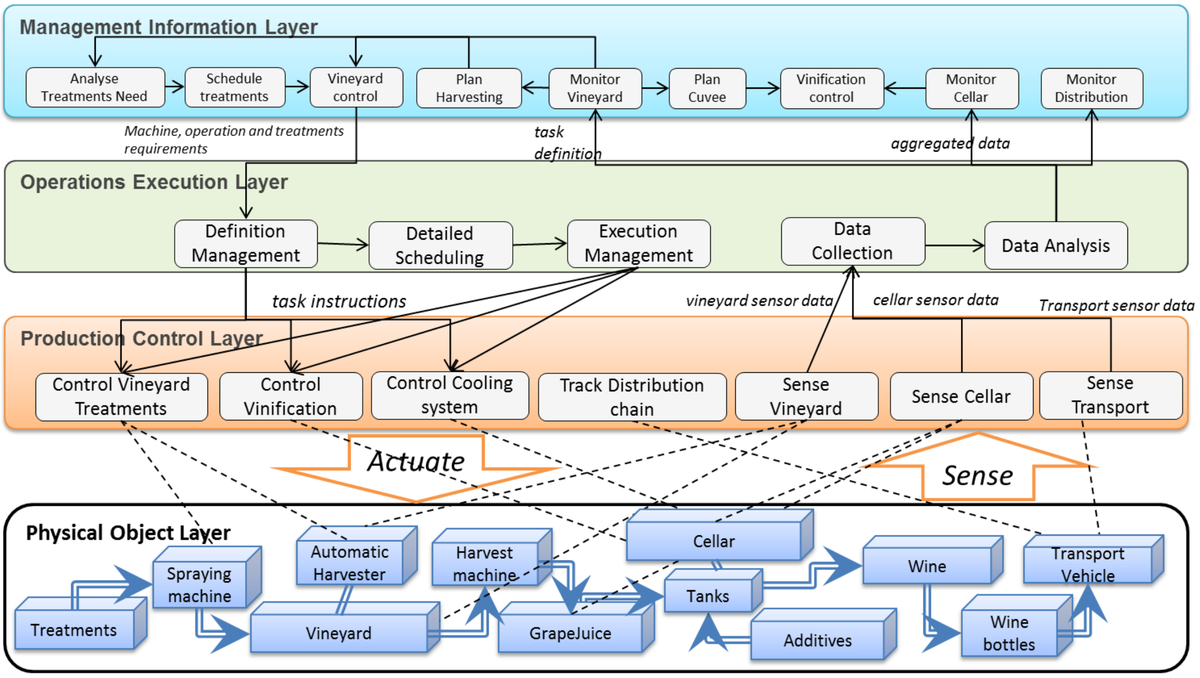


Figure 50 - UC3.2 Business Process Hierarchy view

2.10.5 Interoperability Endpoints

As reported in the Deployment View section, the sensiNact platform is used as IoT platform, with its modular architecture. As a consequence, it allows to activate several bridges dedicated to connection with:

- hardware devices (sensors and actuators) through their IoT edge protocols using the sensiNact southbound bridges, application and other IoT platforms;
- applications, services and other IoT platforms, through dedicated interoperability protocols, using the sensiNact northbound bridges.

The below Figure presents an overview of the communication protocols brought by the sensiNact IoT platform.

Figure 51 - Overview of the sensiNact communication bridges

New bridges can be implemented and added in order to extend the sensiNact platform and enhance its interoperability skills. The figure below details the available bridges around sensiNact, as they are provided today to the IoF use case. This figure shows the extension points: for southbound (SB) bridges, for northbound (NB) bridges and for applications.

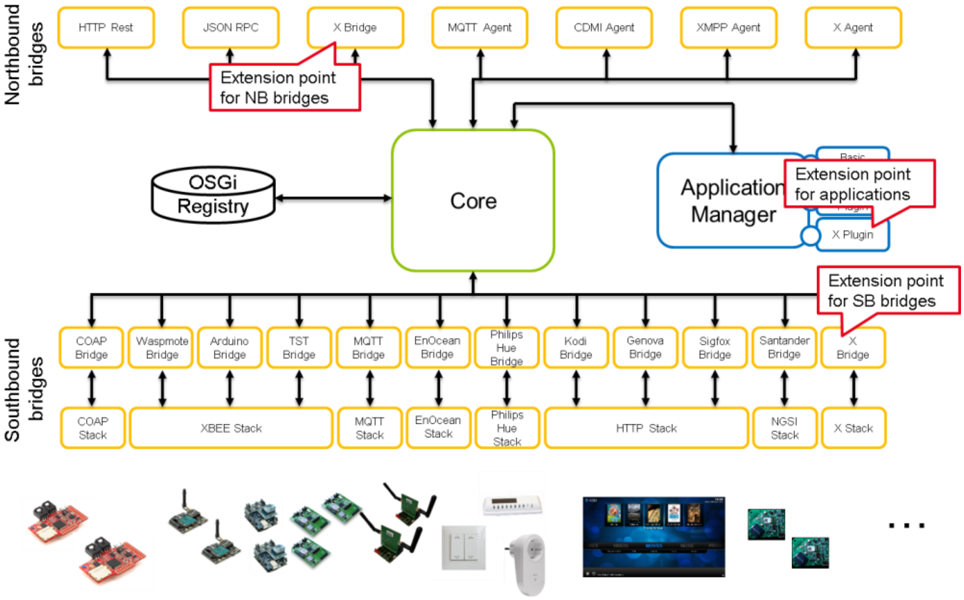


Figure 52 - Extension points for the sensiNact platform interoperability

2.10.6 Information model

The Information model for UC3.2 is depicted in Figure 53 and Table 44.

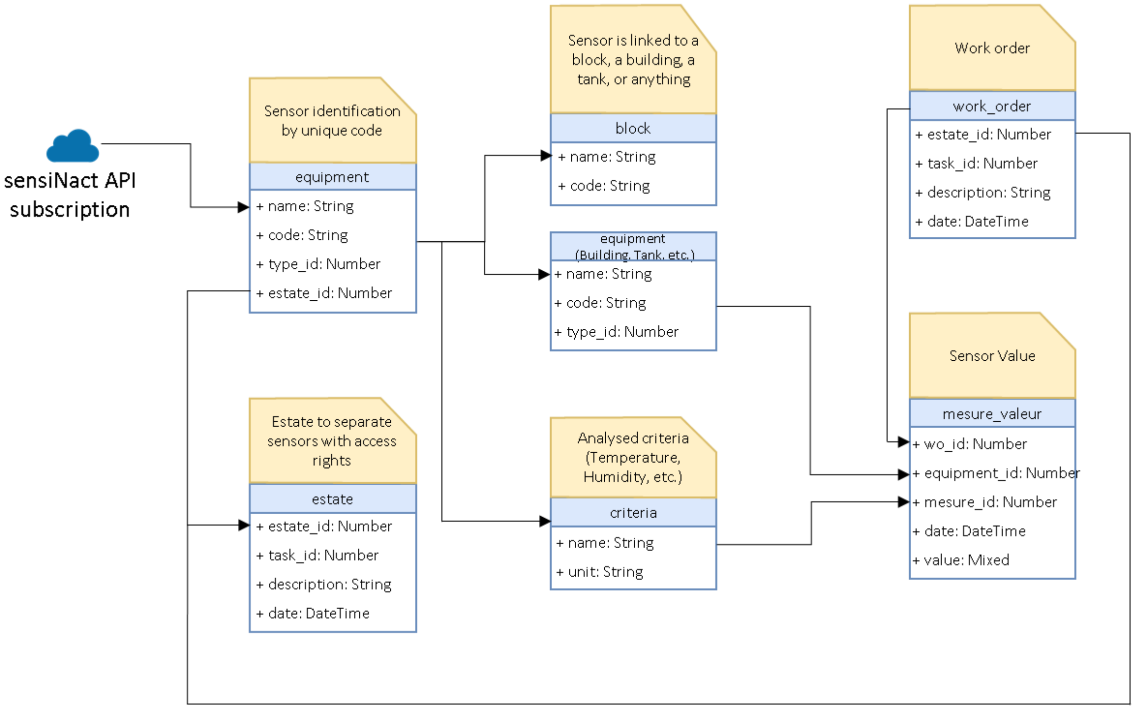


Figure 53 - UC3.2 Information Model

Table 44 - UC3.2 Information Model Details

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Temperature	Temperature sensor	In the 5 Denis Dubourdieu Domains	Every 15 minutes	°C
Hygrometry	Hygrometry sensor	In the 5 Denis Dubourdieu Domains	Every 15 minutes	RH
Barometric/ Atmospheric Pressure	Barometer sensor	In the 5 Denis Dubourdieu Domains	Every 15 minutes	mmHg, hPa/mb
Wind Speed	Anemometer + weather vane	In the 5 Denis Dubourdieu Domains	Every 15 minutes	km/h, m/s
Wind direction	Anemometer + weather vane	In the 5 Denis Dubourdieu Domains	Every 15 minutes	Points, angular degrees
Solar Radiation	Pyranometer	In the 5 Denis Dubourdieu Domains	Every 15 minutes	W/m2
Rain Fall	Rain gauge	In the 5 Denis Dubourdieu Domains	Every 15 minutes	mm

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Number of insects detected	Embedded computer vision	Domaines Denis Dubourdieu	2 days	number/cm2
Phenological stages	Embedded computer vision	Domaines Denis Dubourdieu	2 days	to be specified
Harvest estimation	Offline computer vision	Domaines Denis Dubourdieu	Monthly	to be specified
Plant vigor	Embedded computer vision	Domaines Denis Dubourdieu	Weekly	to be specified
Geographic Coordinates	GPS System	In the 5 Denis Dubourdieu Domains	Follow up of Tractors Navigation	Latitude and Longitude Coordinates
Electricity consumption	Electricity meter	In the 5 Denis Dubourdieu Domains	Measurement on line according to operation detection	Kw/h
Water Consumption	Water meter	In the 5 Denis Dubourdieu Domains	Measurement on line according to operation detection	M3
Air Conditioning Parameters	TBD	In the 5 Denis Dubourdieu Domains	TBD	TBD
Temperature in the fermentation and aging tanks	Probes	In the 5 Denis Dubourdieu Domains	TBD	°C
Wine Key Parameters	FTIR analysis	Tuscan Winery; Denis Dubourdieu Domains	Daily or twice during harvest and vinification, otherwise Weekly	Alcohol [%], Sugar [g/L], Total acidity [g/L Tartaric acid], Volatile acidity [g/L Acetic acid], pH, Malic, Lactic and Tartaric acids [g/L], YAN [mg/L]
Temperature on shipping conditions	Temperature sensor and data logger	Any where (trucks, ships, planes, etc.)	Every 15 minutes	°C/Timestamp

2.10.7 Summary of gaps

The current vineyard and wineries solutions are most of them individual building blocks, too specific software (one solution for one need: traceability, production management, sustainability evaluation; and too time consuming) and costly. Today, software solutions are not good enough to ensure a real capital gain but associate with automated captors a new market will open.

A new generation of solutions are coming based on IoT and supported by Telecom operators where communication costs will depend on the among of data transmitted. This increases the operational costs for the wine growing and producer having a particular impact on the small and middle ones.

In this Use case, the proposed solution will be primary based on a LoRa private network which allows, cost free, the transmission of any among of data in line with the goal to introduce massively sensors in the vineyard and the winery. Furthermore, this solution will have the trans-mission properties of long range and good penetration reducing the need of repeaters and consequently reducing the infrastructure costs. The LoRa network will be deployed as much as possible in the winery and coexist with the existing networks such as WiFi and Ethernet. Currently, the various sensors deployed at the cellar and vineyard are connected to the LORA gateway. The data produced from all sensors are transmitted to The Things Network in real time.

Second, the proposed solution will cover the full value chain and built on open solutions. Special attention will be done to provide open APIs for databases and user interfaces to facilitate its reuse for third parties, for instance, data analysis and user interfaces providers. Currently, all data received by the TTN network are forwarded to the sensiNact platform thatallows third parties to access real-time data through an open Swagger API. Furthermore, it provides the ability to save those data into a historic Cassandra database, located in CEA servers. The stored data can be easily accessed by a similar Swagger API.

Third, the solution will be developed, validated and deployed in collaboration with Denis Dubourdieu Domains (5 each one with its own Vineyard and Winery) in Graves and Barsac areas in Bordeaux region. The main DDD's goal is to monitor and gather the sensing data coming from the five domains to perform data analysis and decision making, at anytime and anywhere, to improve the vine yield and wine production at cost effective to keep its competitiveness.

The innovation that the project wants to introduce in the paradigm of analytical control of wine, is to develop an uncoupled analytical system, preferably based on FTIR technology for multi-parameter analysis – already largely applied in wine sector – where the acquisition of the spectra is done at the production site, with inexpensive devices and simplified procedures, while the elaboration of data to obtain the desired value is done remotely through internet data exchange. In this case the unit cost per sample would greatly decrease, and even small wineries in remote areas could optimize their assessment system, with strong increase in quality and consistency of the products.

For remote assessment of bottled wine quality during distribution, the project aims to develop an inexpensive device able to automatically and continuously measure temperature, the main parameter influencing wine evolution over time. This assessment can be done at fixed intervals during the shelf life period, and the obtained data sent through internet to a central system where they are elaborated. The system, kept under the control of the producers, allows for early identification of the problem and of the period when it is originated, and consequently to take the necessary measures to prevent quality reduction or to avoid its repetition in next deliveries. As each wine has a specific response to temperature extremes, the ineffective range of temperature can be defined for every single wine through a preventive sensitivity test based for instance on the variation of absorbance at a specific wavelength, and allow the set-up of specific transportation requirements for each wine. Ex-post, a reading of this parameter, coupled with the temperature data pattern, can allow the exact identification of the delivery step where a damage to the wine occurred.

2.10.8 Assets identified for re-use

The assets identified for re-use are shown on Table 45.

Table 45 - UC3.2 Assets identified for re-use

Component name	Short Description and role in the Use Case	Functional role	License
STM32L0 Discovery kit LoRa, low-power wireless (B-L072Z-LRWAN1)	LoRA connectivity module to connect any sensor/actuator to a LoRA network	In the ITU-T Y.2060 IoT Reference Model, this is in the "Device and Network Layer" In the Business Process Hierarchy view, this is in "Physical Object Layer"	-
ST TESEO III of GNSS	Global Navigation Satellite System	In the ITU-T Y.2060 IoT Reference Model, this is in the "Service support and application support layer"	-

Component name	Short Description and role in the Use Case	Functional role	License
Lorrier-lr2-iot-lora-gateway 868 MHz	LoRA Gateway	In the ITU-T Y.2060 IoT Reference Model, this is in the "Device and Network Layer" In the Business Process Hierarchy view, this is in "Physical Object Layer"	-
sensiNact ioT platform	IoT platform	In the ITU-T Y.2060 IoT Reference Model, this is in the "Device and Network Layer" In the Business Process Hierarchy view, this is in "Physical Object Layer"	EPL (Eclipse Public License)
Process2Wine	Web and Mobile Software solution for the wine production	In the ITU-T Y.2060 IoT Reference Model, this is in the "Application Layer"	-

2.10.9 Collaboration with other Use Cases

They are not collaborating with other Use Cases at the moment of writing, but they started some discussion about the possibility of reusing Lora and the Sensinact framework in other situations.

2.10.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets.

The following Table 46 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability

Table 46 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project.(UC3.2)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May '18)	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	121	- Vineyard Complete Weather station (9 Estimated) - Vineyard degraded Weather station (34 Estimated) - Mobile vision sensor (1 Estimated) - Fixed vision sensor (1 Estimated) - Insect Trap camera (1 Estimated) - Positioning System (GPS) (5 Estimated) - Cellar Temperature/ humidity sensors nodes (27 Estimated) - Electricity sensor node (9 Estimated) - Water sensor node (26 Estimated) - Air conditioning sensor node (8 Estimated)

Target outcomes	**Key Performance Indicators (KPIs)**	**Estimated current value (May '18)**	**Short comment / qualitative estimation**
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	26	- LoRA Gateway (2 Estimated) - Telecom Gateway (2 Estimated) - sensiNact, IoT platform (2 Estimated) - Process2Wine (2 Estimated) - Remote Quality control in wine making (1 Estimated) - Data logger for Wine shipment (10) - CloudService Platform (1) - WeatherService Platform (1) - Cloud IoT Middleware Component (1) - Cloud Data Storage (1) - CellarCooling Computer (1) - CalibrationService (1) - Vienyard TreatmentService (1)
	Number of IoT applications available	1	- Monitors (vineyard, cellar, distribution) (1)
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1
	Number of FIWARE GEs instances	0	
	Number of open datasets used	0	
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	/	Not yet available
	Average number of installations per reusable IoT component	/	Not yet available
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	2	- LoRA - SensiNact
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies	0	

2.11 Fruit UC 3.3: Automated olive chain

The European Union (EU) is the largest producer (accounting almost three quarters) and consumer (accounting two thirds) of olive oil in the world. However, this situation is changing rapidly due to the increase in olive tree plantations in other countries and the disease problem (*Xylella fastidiosa)* that currently affects Italy mainly. IoT provides an excellent solution for conserving this competitive advantage by monitoring and optimizing the different processes involving olives, and particularly cropping, yielding and producing olive oil.

2.11.1 Domain model

The domain model for UC3.3 is depicted in Figure 54.

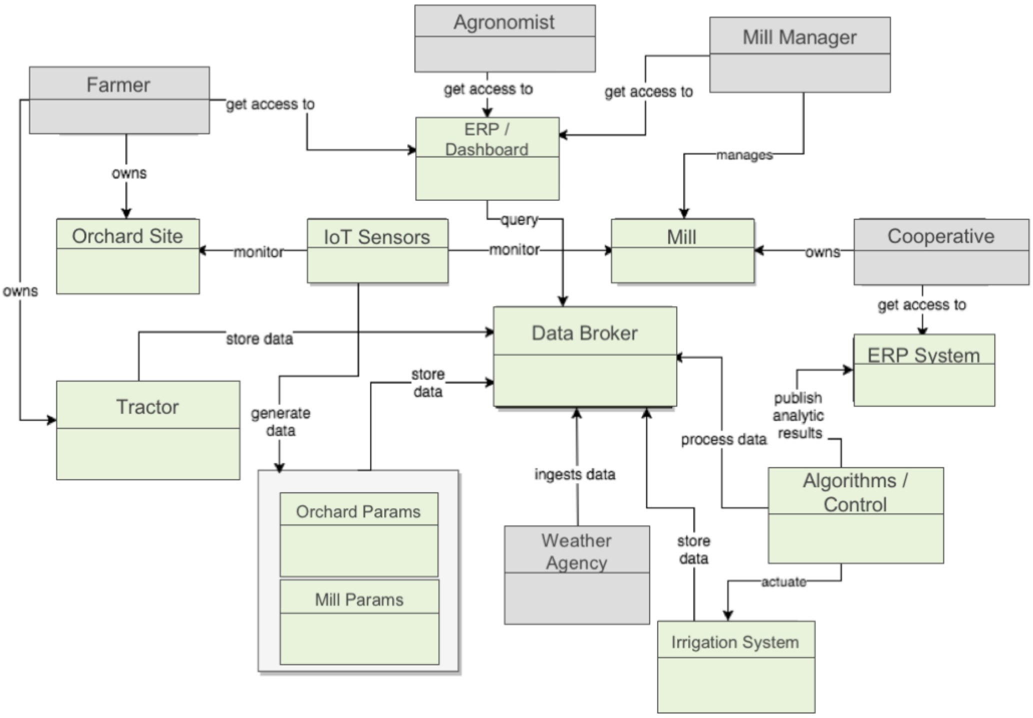


Figure 54 - UC3.3 Domain Model

Farmers will be able to monitor and optimize the growing behaviour of olives, jointly with the irrigation process. The monitoring and optimization features heavily rely on IoT Devices and systems deployed on the field, including tractors. In addition, other contextual data is ingested to the system such as weather forecasts provided by public agencies or geographical information about parcels, soil types, etc. From the point of view of the farmer, the final aim is to optimize crops by saving water, fertilisers and other resources while at the same time being able to predict undesired behaviours such as pests.

Agronomists will be able to monitor the processes, making decisions and taking proper actions to increase productivity and avoid risks. The dashboard and Enterprise Resource Planning (ERP) will be there to assist them.

Cooperatives of farmers and **agronomists** will have extensive knowledge about the quality of olives delivered to oil mills and its influence over the upcoming oil production processes.

Mill managers will be allowed to control and to optimize the oil production processes so that improving the overall quality and maximizing KPIs.

In the end, the interactions between **farmers**, **cooperatives** and **mills** will be dramatically improved so that they will precisely know the inputs and outputs of the processes involved. Ultimately, all the KPIs will be measurable leading to a dramatic increase of productivity and efficiency.

IoT devices are used to monitor a wide number of physical parameters. They are either permanently **connected** (installed in fixed position and periodically sending monitored data e.g. through wireless technologies) or **nomadic** i.e. temporarily deployed by human operators to measure and record parameters of interest in specific moments in time.

The **Irrigation System** is a wireless network of actuators for controlling water valves and pumps. Data are directly transmitted to the remote **Data Broker.**

In the **Algorithms** element, there are models and intelligence for supporting the **ERP** and the **Dashboard**. The latter element, is a web portal for viewing/analysing sensor data by **Farmer**, **Agronomic Engineer** and **Farmer / Cooperative**, which can be used from the system to make decisions to optimize the growing behaviour of olives, and manager irrigation and fertilization processes, while at the same time preventing pests and diseases. In addition, predictive analyses can be conducted so that it can be estimated the quality of the olive oil produced taking into account characteristics of the harvested crop.

2.11.2 Deployment view

The Deployment diagram for UC3.3 is depicted in Figure 55 and Table 47.

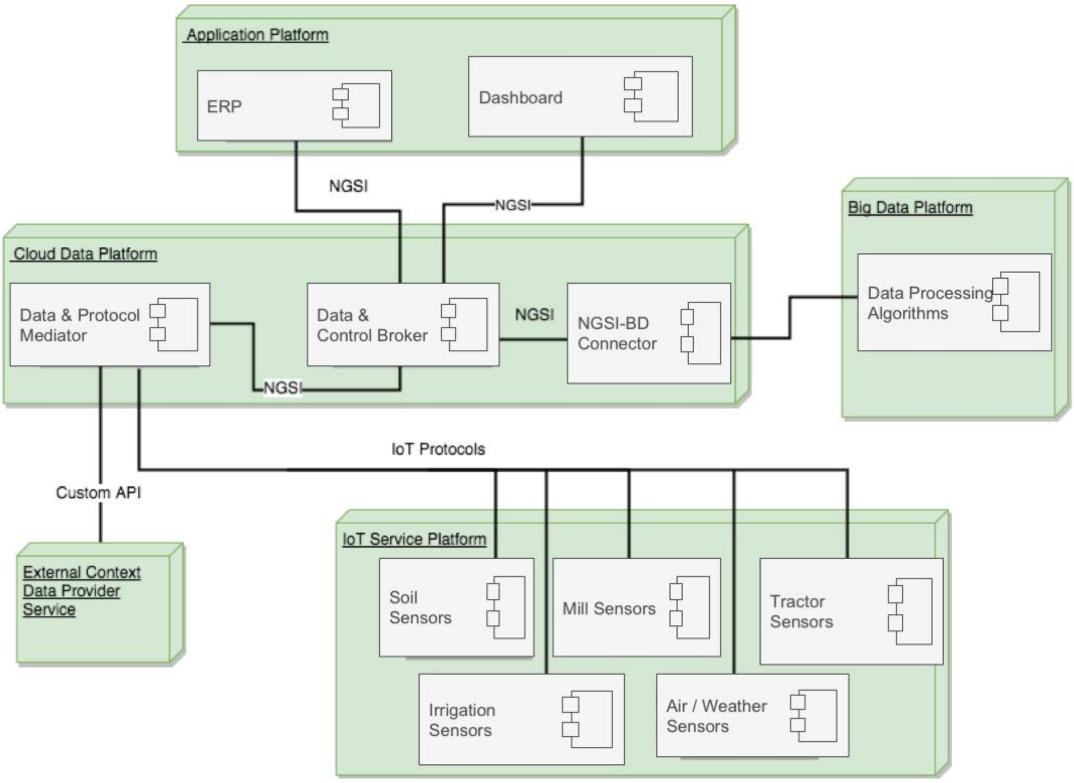


Figure 55 - UC3.3 Deployment View

Components in this UC are deployed both locally (in the **Farm, Tractor** or **Mill**) and remotely (in the **Cloud**).

In the Farm, the **IoT Service Platform** includes different sensors (permanently connected and nomadic) used to monitor a wide number of physical parameters. The communication protocols include but are not limited to Lora and Isobus (for tractors).

A **Data & Protocol Mediator** component is able to understand the different IoT protocols supported by the concerned devices so that all the data coming from sensors is properly gathered. Then, this component will harmonise such data (according to common information models) and will publish it to the **Data & Context Broker** component. In addition, the **Data & Protocol Mediator** will be in charge of interacting with external providers of contextual information (for instance weather agencies) and to ingest such data into the system, so that it can be made available to the **data processing algorithms**.

The **Data & Context Broker** will be storing real time data managed by the system. In addition, it offers APIs that will allow the ERP and the dashboard to consume or subscribe to such data. Last but not least, it offers an interface that allows to actuate over devices when needed.

There can be algorithms or (complex event processing) that work directly over real time data. Nonetheless, there is an additional component named **NGSI-BD connector** that will allow to generate all the historical datasets corresponding to the potentially huge volumes of data generated by the system. If needed, all this data can be moved to a Big Data store, so that analysis algorithms can benefit from its availability. Any new insights obtained from Big Data analysis can be propagated back to the Data & Context broker, so that in the end new information is made available to the dashboard or DSS.

Table 47 - UC3.3 Deployed Components

Name	Description	Supplier (brand) + Model	Number of Units
Irrigation automation	Wireless network actuators for controlling water valves and pumps	*to be specified*	*1*
Agriculture analysis and control portal	Web portal for viewing/analysing sensor data, specifying algorithms and models and automatic actuator control	*to be specified*	*NA*
Orion Broker	NGSI-compliant open source data & context broker	*FIWARE open source*	*1*
IoT Agent	In the role of Data & Protocol adaptor, diverse IoT / NGSI Agents capable of understanding Lora / MQTT / Isobus or any other IoT communication layer or protocol	*FIWARE open source*	*to be specified*
VWC soil sensor	To measure soil VWC	*to be specified*	*to be specified*
Electrical Conductivity soil sensor	To measure soil electrical conductivity	*to be specified*	*to be specified*
Temperature soil sensor	To measure soil temperature	*to be specified*	*to be specified*
Weather station	To measure meteorological parameters	*to be specified*	*to be specified*
Resistive sensor	To measure leaf wetness	*to be specified*	*to be specified*

Name	Description	Supplier (brand) + Model	Number of Units
Pyranometer	To measure solar radiation	*to be specified*	*to be specified*
Flow sensor (Hall effect)	To measure water flow	*to be specified*	*to be specified*
Water pressure	Pressure sensor (gauge)	*to be specified*	*to be specified*
NIR	Near Infrared Sensor	*to be specified*	*to be specified*
John Deere Devices compliant with Isobus	Tractor sensors	*to be specified*	*to be specified*

2.11.3 IoT Functional view

The IoT functional view of this use case (depicted in Figure 56) is structured as follows:

- *Application Layer*: Allows the different human actors to interact with the system. It is composed by a dashboard and an ERP system. Both of them are intended to allow human experts to make better decisions with regards to the optimization of the olive oil production.
- *Data Layer:* It is in charge of storing all the data generated by the system (coming from southbound devices and other context information sources) and offering programmatic mechanisms (common APIs) to consume and to subscribe to it. In addition, it provides all the connectors needed to interconnect the data layer with complementary data stores, for instance historical databases based on Relational Database Management System (RDBMS), Hadoop or others.
- *Analytics layer.* It is intended to analyse the data coming from the data layer. By gaining insights or by training machine learning models, new information can be inferred to be exploited by human actors. The analytics layer usually feeds this new information to the data layer, to make it available using common APIs.
- *Mediation layer.* The aim of this layer is to mediate between disparate data sources and the data layer. Such data sources are typically IoT devices and external context data sources (weather agencies, open data platforms, etc.). Besides, it incorporates all the adaptors needed to properly harmonise the data as per the information models defined by the project or by existing industry initiatives (GS-1, GSMA, etc.).
- *IoT service layer*: Placed at the southbound, it is composed by IoT devices, gateways, network protocols and related software layers intended to provide all the sensed data to the northbound layers. In addition, it offers common programmatic interfaces which allow to actuate over devices.
- *Context data layer*: It encompasses all the existing data sources that provide extra information needed for the system. Meteorological information, information about plagues, diseases, geographical data (situation of parcels, etc.) and other publicly available.

- *Management Capabilities:* in this UC, there are not specific information about management capabilities. So, it is assumed that this use case includes general functions based on the specific technology.
- *Security Capabilities:* in this UC, there are not specific information about security capabilities. So, it is assumed that this UC includes general functions based on the specific technology.

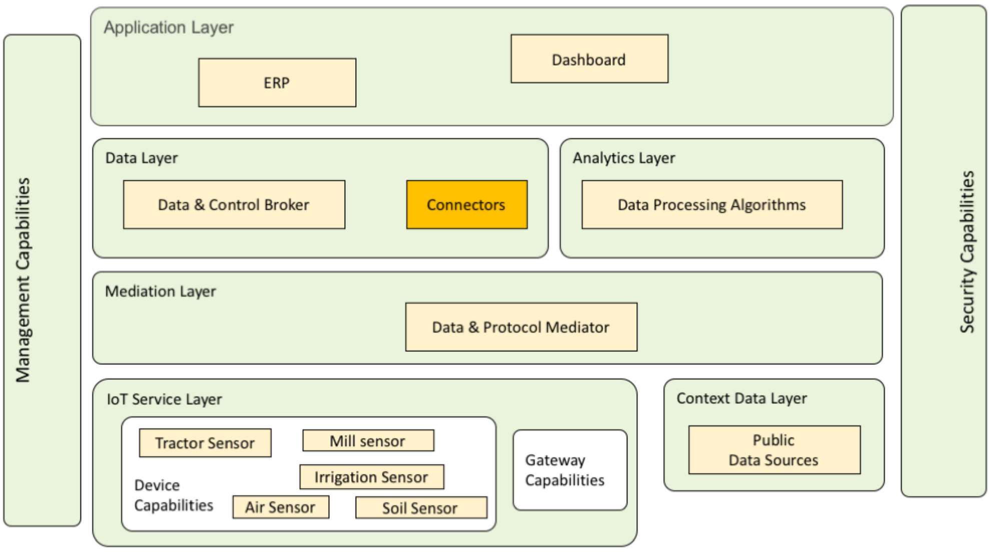


Figure 56 - UC3.3 IoT Functional View

2.11.4 Business Process Hierarchy view

The Business Process Hierarchy view for UC3.3 is depicted in Figure 57.

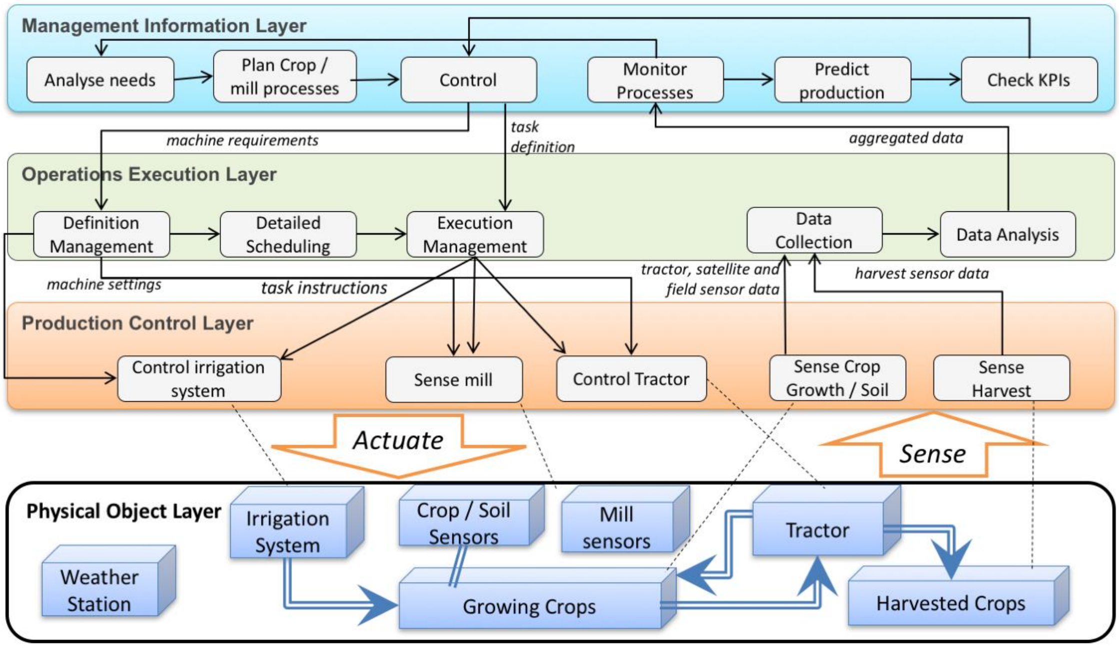


Figure 57 - UC3.3 Business Process Hierarchy view

Business Process Hierarchy View comprises four layers: *Physical Object Layer, Production Control Layer, Operations Execution Layer* and *Management Information Layer*.

In the **Physical Object Layer,** the relevant objects of this case are depicted: growing crops in the field, that are sensed with nomadic and connected sensors, irrigation system and weather station. Irrigation system applies variable rate irrigation depending on the variation in the crop water needs. In addition, the tractor is in charge of harvesting or providing the adequate treatments to the crops. Last but not least, all the sensors used for the oil production in mills are modelled.

The other layers include the main processes on different time horizons that are needed in this case to sense and control the physical objects. The starting point is sensing of crop growth in the **Production Control Layer** that generated field sensor data. The control modules are used to actuate commands to specific physical objects. All this data are collected and analysed in the **Operations Execution layer**. The aggregated data are used in the **Management Information Layer** to monitor crop growth. Next, the crop needs are calculated based on the crop growth monitoring and weather data. The Farm Control triggers that the execution of these actions by sending the specific requirements task and task definition for tractors and irrigation system to the **Operations Execution Layer**. In this layer, the settings of the irrigation system are defined, the irrigation task is scheduled and the spraying and irrigation task instructions are sent to the **Production Control layer**. Similar processes can be applied to oil production and its corresponding KPIs.

2.11.5 Interoperability Endpoints

The interoperability endpoints are shown on Table 48.

Table 48 - UC3.3 Interoperability Endpoints

Interface name	Exposed by	Protocol	Notes
ERP —> Data Broker	Data Broker	NGSI 10	FIWARE NGSIv2 binding
Data Broker → Big Data Platform Connector	Big Data Platform Connector	NGSI10	FIWARE NGSIv2 binding
Mediator —> Data Broker	Data Broker	NGSI 10	FIWARE NGSIv2 binding
IoT Device —> Mediator	Mediator	MQTT / LWM2M	Application-level profiles to be further specified during developments
Data Broker – Mediator (Command)	Mediator	NGSI 9	Mediator will behave as a context provider so that commands can be executed

2.11.6 Information model

The Information model for UC3.3 is depicted in Figure 58 and Table 49.

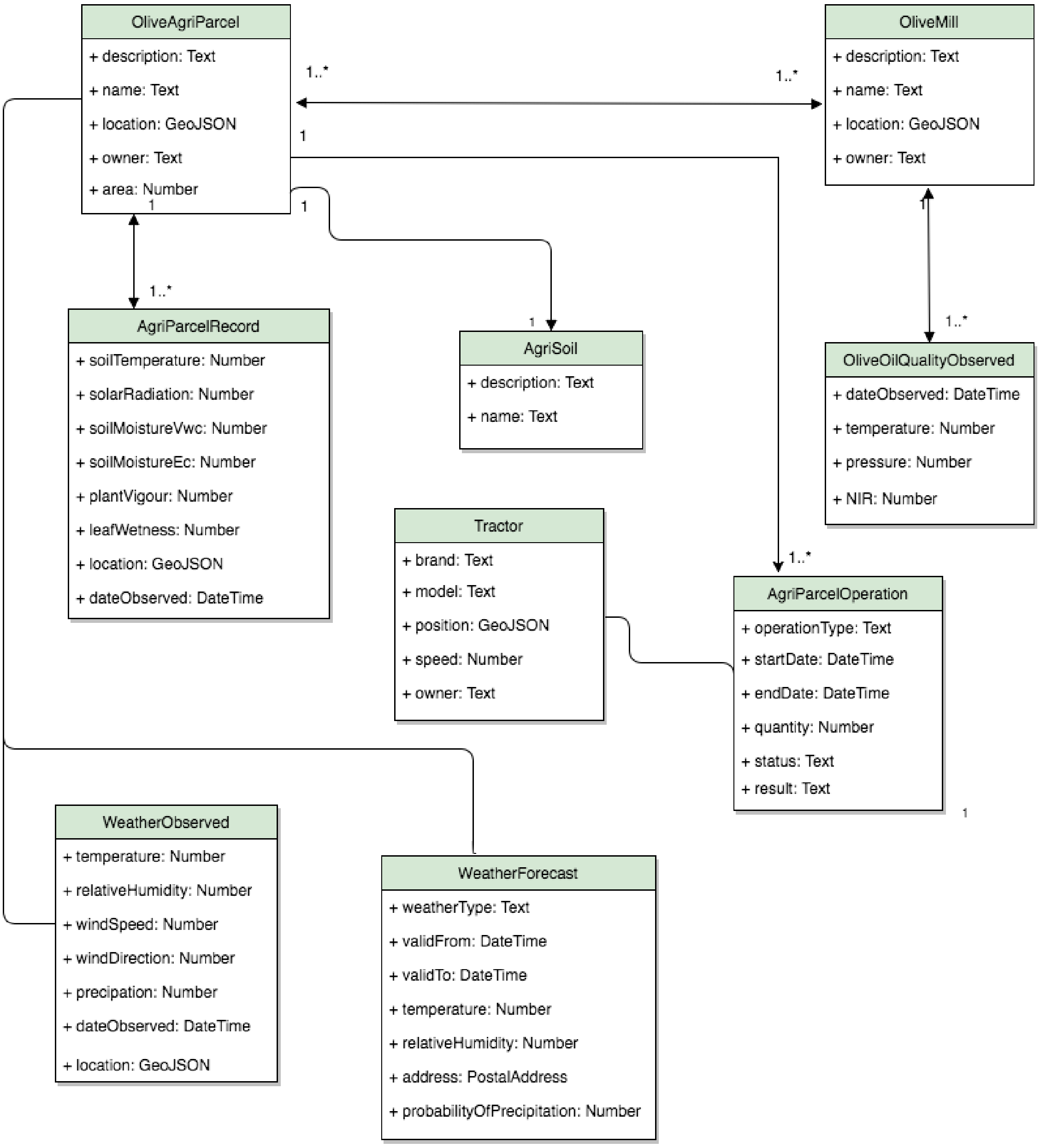


Figure 58 - UC3.3 Information Model

Table 49 - UC3.3 Information Model Details

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Weather data	Weather station	WeatherObserved	to be specified	GSMA
Weather forecast	Open APIs offer by weather agencies	WeatherForecast	to be specified	GSMA

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Soil parameters	Direct from sensors	AgriParcelRecord	to be specified	GSMA + Extensions
Orchard parameters	Direct from sensors / NIR	AgriParcelRecord	to be specified	GSMA + Extensions
Mill parameters	Direct from sensors	OliveOilQualityObserved	to be specified	Custom FIWARE NGSI entity
Tractor status / operations	Isobus	Tractor	to be specified	Custom FIWARE NGSI entity

2.11.7 **Summary of gaps**

The specification of UC3.3 is almost defined and some FIWARE generic enablers are already in use, but there are some points not clear. The main gaps currently being resolved are reported in the following

- more work is needed to specify in details the security and privacy aspects.
- The exact number, brand/model of many devices to be deployed is still under definition.

2.11.8 **Assets identified for re-use**

The assets identified for re-use are shown on Table 50.

Table 50 - UC3.3 Assets identified for re-use

Component name	Short Description and role in the Use Case	Functional role	License
Orion Broker	Orion is an open source implementation of a context information broker exposing FIWARE NGSIv2 interfaces based on OMA NGSI10	In the ITU-T Y.2060 IoT Reference Model, this is in the “Service support and application support Layer”	Open source
IoT Agents	Plays the role of protocol and data mediator providing southbound data coming from IoT and other sources to the northbound broker layer	In the ITU-T Y.2060 IoT Reference Model, this is in the “Service support and application support Layer”	Open source

2.11.9 Collaboration with other Use Cases

They are not collaborating with other Use Cases at the moment of writing, but they started some discussion about the possibility of reusing the FIWARE Orion Context Broker in other situations.

2.11.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets.

The following Table 51 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability

Table 51 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC3.3)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May ‘18)	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	16	- 4 meteorological Station - 10 devices for Soil measurement and actuator in irrigation system - 2 NIR sensors in Olive Mills
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	16	- 1 LoRA - 13 4G communications - 2 IoT platforms (Orion Context Broker and IoT Agents)
	Number of IoT applications available	2	- Sensor and probes monitoring - Irrigation actuators
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1
	Number of FIWARE GEs instances	1	- FIWARE Orion Context Broker based on NGSI
	Number of open datasets used	2	- Sensor and probes monitoring - Irrigation actuators
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	2	- Lora - FIWARE Orion Context Broker based on NGSI
	Average number of installations per reusable IoT component	/	Even though all the devices installed could be reusable, this information is not available to the UC analyst
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	2	- LoRa - FIWARE Orion Context Broker based on NGSI
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies	0	

2.12 FRUIT UC 3.4: INTELLIGENT FRUIT LOGISTICS

The use case’s strategic objective is to connect IoT-enabled Returnable Trade Items (RTIs) with smart applications, to open a new dimension of added value services in multi-actor fruit and vegetable supply networks. The main stakeholder and UC leader is Euro Pool System, returnable packaging pool provider and European market leader for returnable packaging in the fruit and vegetable sector. Existing Euro Pool System RTIs will be equipped with IoT devices to enable the RTIs to transmit information during their transport and their usage by Euro Pool System’s customers.

The use case will take place in Germany, and besides Euro Pool System the following partners will be involved: the technology provider Mieloo & Alexander as integration partner, the research institute ATB as research and ICT development partner, the standardisation organisation GS1 as expert regarding

RTI identification and Electronic Product Code Information Services[xviii] (EPCIS), and the Semiconductor manufacturer NXP as IoT technology and solution provider.

2.12.1 Domain model

The domain model for UC3.4 is depicted in Figure 59.

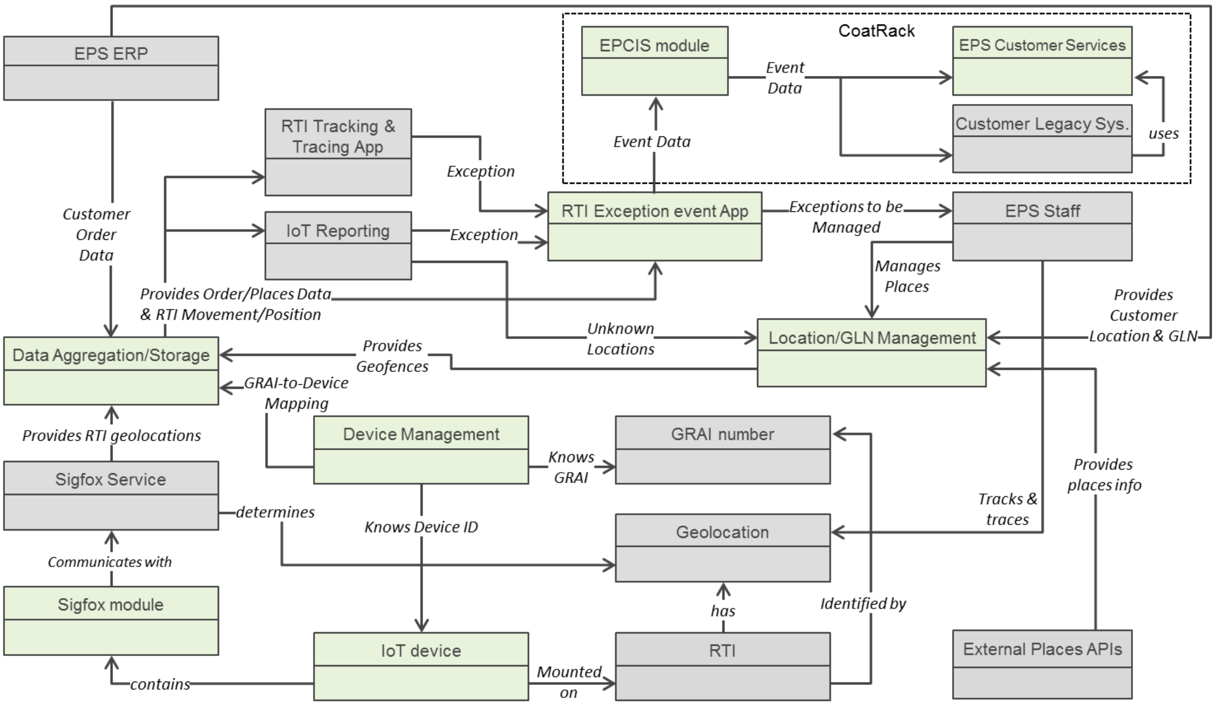


Figure 59 – UC3.4 Domain Model

Euro Pool System (EPS), the main stakeholder in use case 3.4, is operating a pool of around 140 million **RTIs**, which are used by its customers to transport produce (i.e. fruit and vegetables), usually from farm to retail. Each RTI is uniquely identified by a Global Returnable Asset Identifier (**GRAI) number**, which is represented by a decimal number, a barcode and a QR-code on the RTI. By equipping an amount of the RTIs with **IoT devices**, the objective is to turn passive boxes into active items.

This shall facilitate **RTI tracking and tracing** as well as an optimal usage and free circulation of RTIs. This shall also help to guarantee a proper operation of the pool of Euro Pool System RTIs.

It is foreseen to use a long range low bandwidth communication protocol to maximize life-time of **the IoT devices** and to enable determining the RTI position. In the first version of the IoT devices, the positioning is supported by the **Sigfox "Spot'it" service**, i.e. the RTIs regularly send their ID to Sigfox, and based on these transmissions Sigfox provides the geolocation of the RTIs. However, initial experiments with this technology came to the conclusion that the accuracy of the geo-localisation is currently not yet accurate enough for the requirements of this use case. Therefore, also a GPS chip will be used in the next prototype, to increase the accuracy of the RTI geo-localisation.

This real-time monitoring of RTIs will be integrated with existing systems for monitoring and planning their usage as well as combined with the classical RTI identification technologies. Furthermore, the current **ERP** and **External Places APIs** can be used to identify locations and to manage Global Location Numbers **(GLN)s** in relation to the Euro Pool System customers. Geofences around known locations will be applied to detect exceptions, e.g. RTIs being at "unauthorized" locations or staying at specific authorized locations for an unusually long time.

In a later phase, it could be foreseen to offer an **EPCIS interface** and additional **EPS customer services** to enable customers or partners of Euro Pool System to access event data that is relevant for a specific party.

2.12.2 Deployment view

The deployment diagram for UC3.4 is depicted in Figure 60.

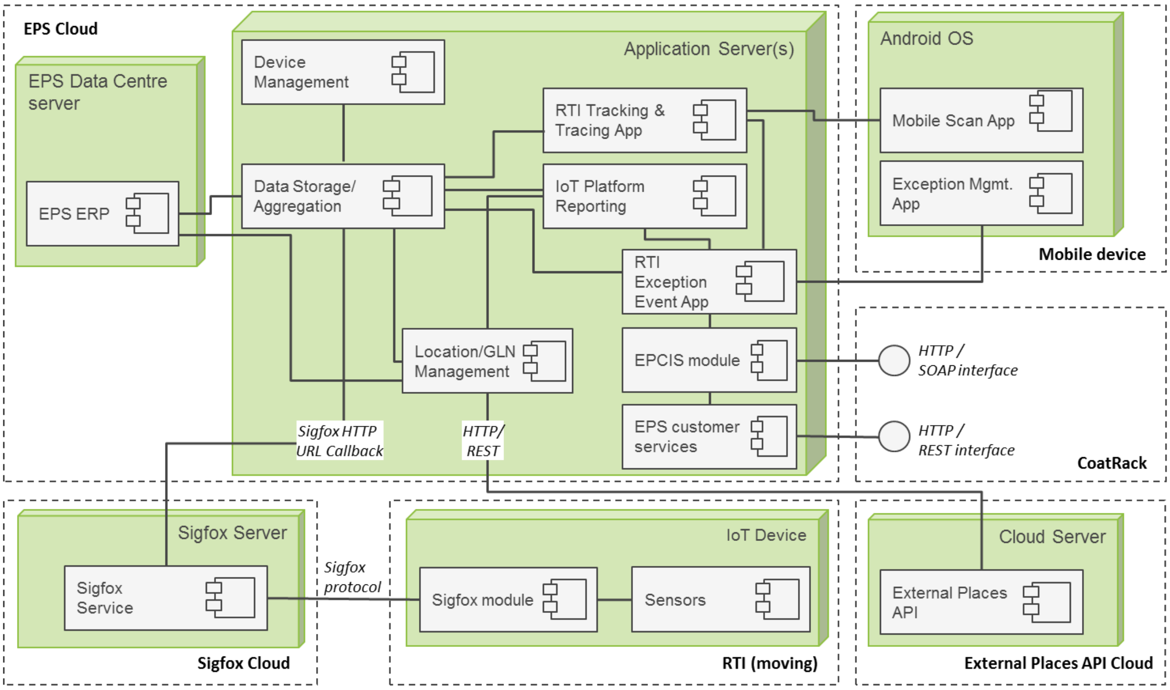


Figure 60 – UC3.4 Deployment View

The **IoT devices** will be mounted on the **RTI** that will freely circulate between Euro Pool System and their customers. Each RTI is a unique and autonomous object. They will communicate via a long range low bandwidth communication protocol. At the current moment, **Sigfox** was selected, due to its regional availability and the option to determine the position of the device via the network service. The **Sigfox service** shall be used via a subscribe / callback mechanism to regularly gather the data sent by RTIs.

The **IoT Platform** will be installed on an external **application server** to gather data as well as to facilitate the analysis of acquired position data, providing customized reports to EPS staff. The specific interfaces to the **RTI exception event app** need to be agreed, while it will operate its own database to facilitate the analysis. The **location and exception management** will be realised on an application server, also facilitating the integrated usage of **mobile apps**, usually running on **Android devices**.

In a later phase, it could be foreseen to offer an **EPCIS interface** and **additional EPS customer services** to enable customers or partners of **Euro Pool System** to access event data that is relevant for a specific party. The **CoatRack** module, developed in the scope of WP3 of IoF2020, could be used as infrastructure to make these interfaces/services available to customers.

Additional information about the components to be deployed in UC3.4 is given in Table 52.

Table 52 – UC3.4 components to be deployed

Name	**Description**	**Supplier (brand) + Model**	**Number of Units**
Sigfox module	Enable connectivity of the product	Sigfox (for first version)	1 per RTI (First some 20-30, later possibly up to 1000)
Geolocation Sensor	To estimate where the device / RTI is	to be specified main supplier: NXP	1 per RTI
Battery	Will determine the life duration / maintenance of the product	to be specified	1-2 per RTI
Environmental Sensors (t.b.d)	Collect information about the environment/condition of the RTI	To be defined, main supplier: NXP	to be specified
IoT platform	Existing software for analysis of object status	To be specified	1
Cloud applications server(s)	Remote server(s) or service(s) hosting the applications	to be specified	to be specified
RTI Exception Event App	End user application to support the EPS staff	To be developed in the scope of UC3.4	1
EPCIS Interface	Standard interface to provide added-value services to authorised external parties	To be developed and possibly integrated with CoatRack	1
Mobile device	To scan and access data	General purpose Android device	2-5 for test phase, later for each depot
External places API	To discover information about event data	To be defined	To be defined
RTI Tracking & Tracing App	Existing EPS-internal solution for tracking and tracing of RTIs	Custom-developed solution	1
Location Management App	Supporting EPS staff in defining geo-fences.	To be developed in the scope of UC3.4	1

2.12.3 IoT Functional view

The IoT functional view of this use case is depicted in Figure 61. **Device layer**: The prototype of the IoT device mounted on the RTI will include a module for **GPS** positioning. In a later version of the device, additional capabilities/sensors could possibly be added. A **Sigfox module** will be included in the IoT device prototype, enabling it to directly interact with the communication network.

At a later point in time, it will be decided which sensors are finally required or how to possibly modularize the **IoT device,** enabling a later selection of which data is required. This is also the base for making a cost-benefit analysis as well as to balance battery capacity with required energy for operational usage.

On the **network layer**, the **Sigfox communication** network will be used for communication between the **IoT device** and **the Sigfox cloud**, while the **Data Aggregation/Storage** module in the EPS cloud will provide a callback interface to get RTI position information from Sigfox via the **Internet**.

The service support and Application Support Layer comprises external services to get data about positions/places and EPS services to provide data to customers.

The **Application layer** comprises all applications to be used by the EPS staff.

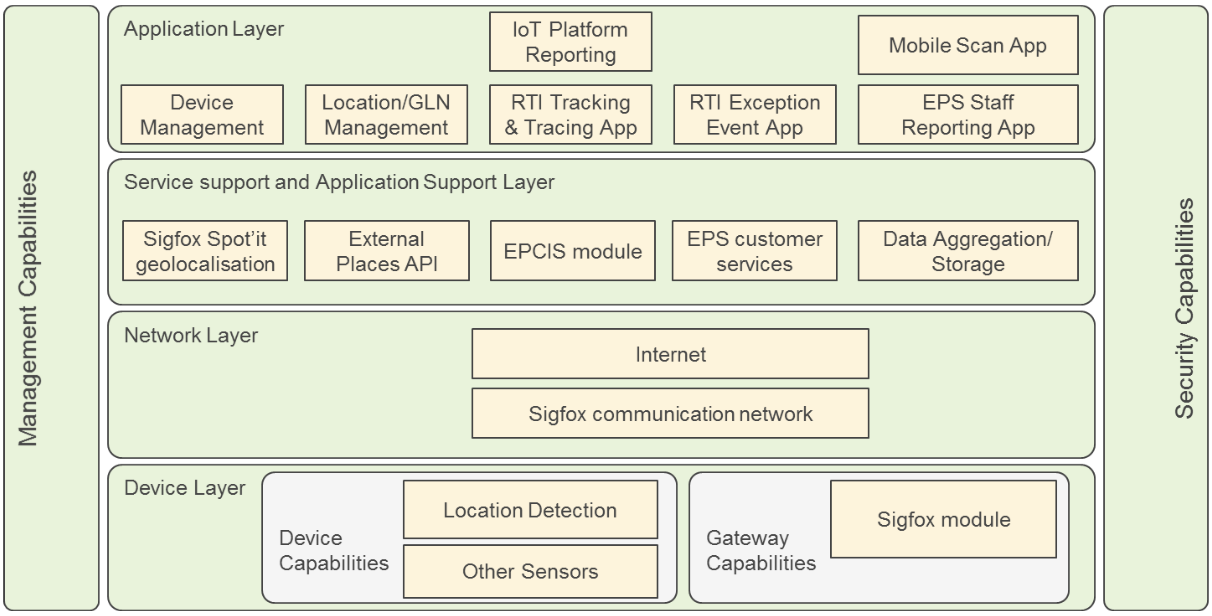


Figure 61 – UC3.4 IoT Functional View

2.12.4 Business Process Hierarchy view

The Business Process Hierarchy view for UC3.4 is depicted in Figure 62.

The main purpose of the solution is to facilitate a free circulation of RTIs from the Euro Pool System pool as well as to guarantee a proper operation of the pool and avoid misuse of the Euro Pool System Models. Therefore, **the management information layer** is representing the key supportive activities of Euro Pool System when the RTIs are circulating from the Euro Pool System depot to their customers and backwards to the depots for an appropriate cleaning. An example of a related customer chain are farmers providing produce to traders, which are shipping produce to retailers. Those retailers are distributing the produce within the RTIs to their points of sale (e.g. supermarket) and collect empty RTIs for being able to return them to a Euro Pool System depot.

Therefore, on the **operations execution layer**, Euro Pool System is taking care for a timely processing and shipment of customer orders. At the same time, data is gathered to facilitate the operational preparation and load balancing in the different Euro Pool System depots.

The specific tasks are initiated on **the production control layer**, to realise the cleaning process itself as well as to organize the shipment in between depots as well as to the customers, while this includes different interactions with customers as well as logistic service providers. At the same time, Euro Pool System is operating the equipment for gathering the required data.

The physical object layer is presenting the circular process in relation to the RTI usage by Euro Pool System customers (i.e. from depot storage, over usage up to the reception and cleaning of used RTI in the depots) as well as potential exceptional situations that might cause issues and need to be handled.

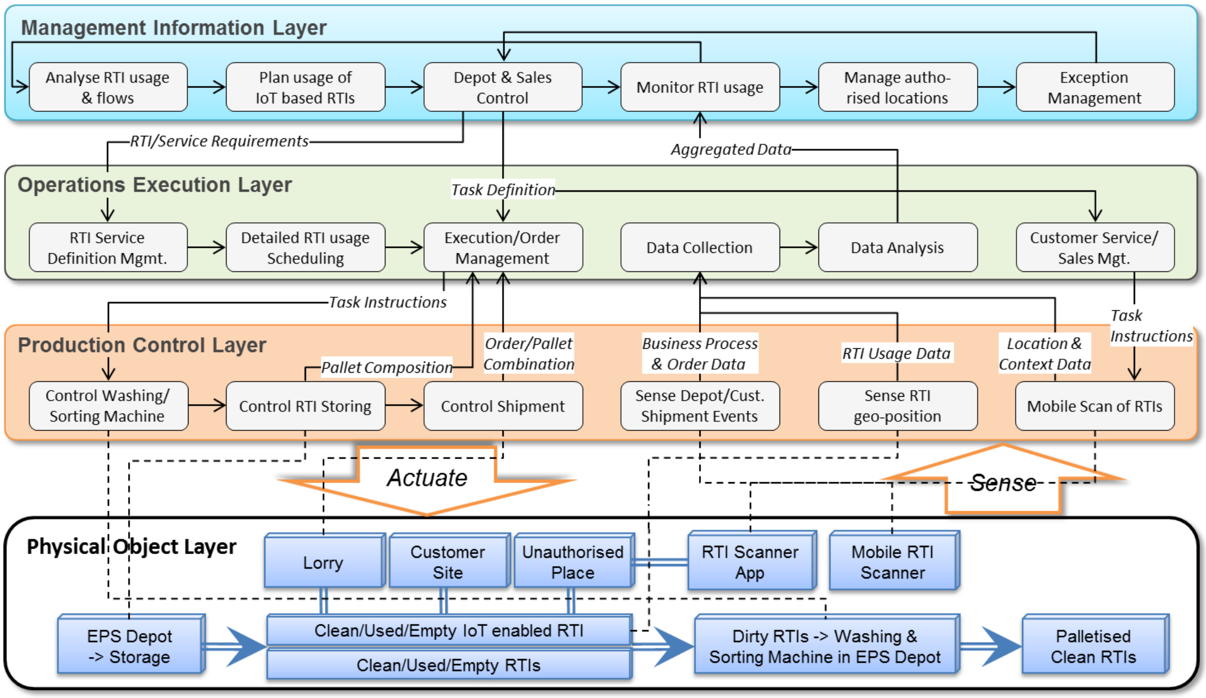


Figure 62 – UC3.4 Business Process Hierarchy view

2.12.5 Interoperability Endpoints

The interoperability endpoints are shown in Table 53.

Table 53 – UC3.4 Interoperability Endpoints

Interface name	Exposed by	Protocol	Notes
Sigfox callback interface	Sigfox	Sigfox HTTP URL callback	Service provided by Sigfox to get device information via a callback URL https://blog.sigfox.com/create-callback-sigfox-backend/
Order/Places and RTI position data	Data Aggregation/Storage Module	to be specified	Aggregation of all RTI positions and RTI scans as well as geofences to make them available for diverse systems.
IoT Platform	IoT Event System	to be specified	Interface to get exception information (location, place, # of RTIs, customer, flows and other??)
RTI_TT	RTI tracking & tracing Application	To be agreed	Interface to provide information about discovered RTIs
Places and Geofences	Location/GLN Management	EPCIS messages via HTTP	Provision of all locations of current and potential customers as well as other places

Interface name	Exposed by	Protocol	Notes
RTI Device ID	Device Management	To be agreed	Providing the mapping of IoT device ID to the GRAI of the related RTI
EPCIS events (t.b.d.)	EPCIS database?	To be agreed	EPCIS events about RTI movements/ exceptions
RTI GRAI scans	Mobile Barcode Reader	To be agreed	Scan of GRAIs that were acquired in combination with an order, shipment and/or customer ID
Customer Interface (t.b.d.)	EPS customer service	To be agreed	Provide information about RTI movements/ exceptions to EPS customers

2.12.6 Information model

Main elements of the information model (see Figure 63) are the unique identification of **orders**, **pallets** and **RTIs** as well as the geographical information that is required to identify the position of RTIs. The position is represented by **geo-locations**, **geo-fences** as well as **places**, while the latter represents the position in relation to the stakeholder that is currently using, storing or handling the RTI (e.g. **depot**, **farm**, **warehouse**, **retail location**). Relevant for the application will also be information about **places outside of RTI handlers' sites**, where RTIs sometimes stay for a longer time (e.g. motorway rest areas, farmer's market squares).

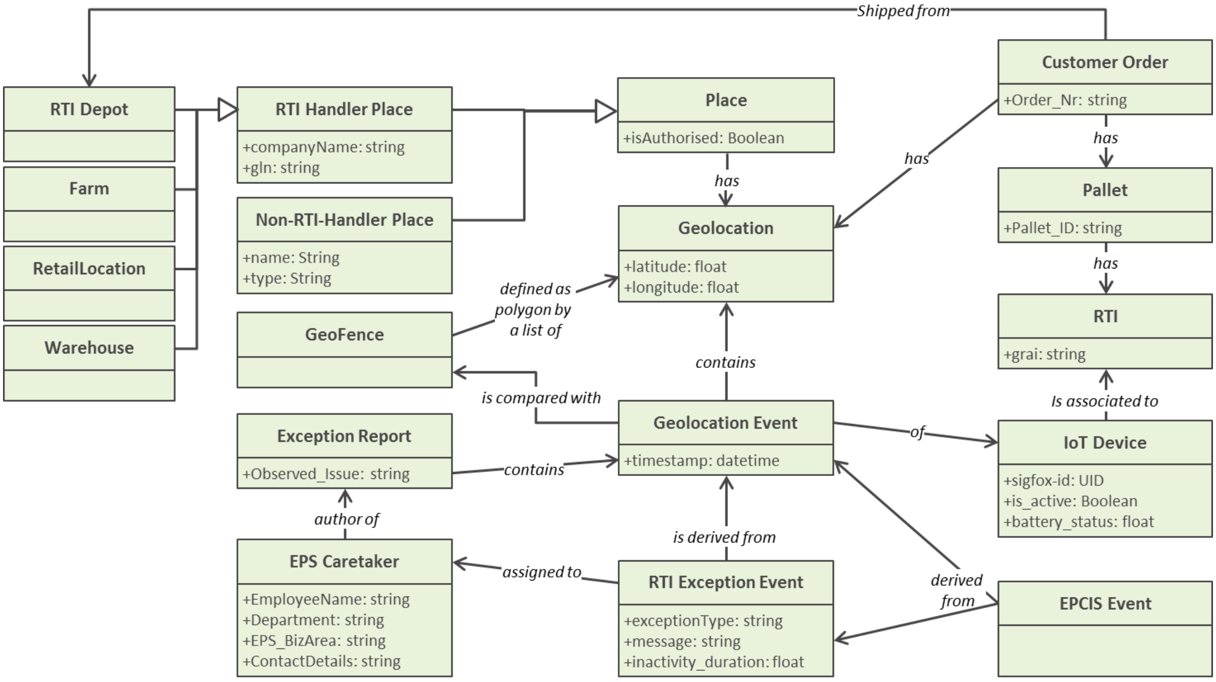


Figure 63 – UC3.4 Information Model

Additional information about the data to be collected and processed is given in Table 54.

Table 54 – UC3.4 Information Model Details

Data	**Measurement Technique**	**Physical Entity**	**Frequency of Data Collection**	**Associated data model/format**
RTI Location	Geolocalisation by Sigfox Spot'it service; GPS positioning	IoT enabled RTI	About 6 times a day; frequency could be adapted according to future use case needs	GRAI, Geoposition
RTI/Pallet handling event	Mobile scanners in the usual business process for e.g. object, aggregation, transaction or quantity events	all RTI types also aggregated on pallets	Usually at the EPS depot for commissioning, shipping and receiving RTIs; once per RTI rotation	GRAI, datetime, customer ID, GLN and/or geo-position
Issue report	App based scans with smartphones by EPS staff	Pallets & RTI	On request	GRAI, Geoposition, issue report
Clearing reports	EPS customers are reporting RTI movements – receiving and shipping of RTIs – from their suppliers and to their customers	RTI	For an RTI transfer from one EPS customer realm to another customer – could be in average 3-4 RTI transfers during one RTI rotation	Usually only RTI types and number (quantity event); in the future possibly individual GRAIs

2.12.7 Identified challenges and gaps

The following challenges related to UC3.4 were identified in the first phase and will have to be addressed in the next steps:

- Sensing Device combined with RTI
  - Determining the geo-position with the Sigfox network feature was tested at the beginning of the project, however as of now the accuracy does not satisfy the UC requirements. Therefore, also GPS positioning is tested in the current project phase, to find a solution with a sufficient accuracy.
  - The NXP prototype is assembled with different additional sensors for location detection.
  - Further synergies shall be discussed with ST Microelectronics to identify opportunities and or interoperability of hardware modules of different providers.
- Is it possible to set-up a LoRa testbed and user group inside IoF2020 to join forces on the test of prototypes? The KPN LoRa network could be used accordingly. In addition, the possible use of LoRa will be further investigated by UC3.4.
- What are the most appropriate solutions for data acquisition and aggregation to avoid a vendor lock-in and to facilitate the long-term provision of data to diverse systems, both inside EPS and at their customers? Could the FIWARE context broker combined with other FIWARE enablers satisfy related requirements?
- Are there solutions to locate IoT enabled things like RTIs at reasonable costs and operating conditions (e.g. sufficient battery life time, size, operating conditions)?
- Is there an agri-food best practice on how to describe locations (e.g. by GLN, GGN, geo-position, geo-fence)?

2.12.8 Assets identified for re-use

The assets identified for re-use are shown in Table 55.

Table 55 – UC3.4 Assets identified for re-use

Component name	Short Description and role in the Use Case	Functional role	License
IoT Platform	Software for event analysis and visualisation/ reporting	Flow analysis and reporting software	Commercial
IoT chip	Mounted on RTI, containing IoT module and different sensors – to be decided of which sensors to use/keep	Sensing device	Commercial
EPS RTI	Reusable crate (RTI: Returnable Transport Item) for the transport of perishable produce, usually from farm to supermarket with unique identification (GRAI)	Physical thing	Commercial
Mobile Scanner	Mobile hardware and app-based smartphone scanner for acquiring RTI's GRAI	Data capturing devices	Commercial
CoatRack	Platform for enabling the offering of services to customers and software developers to use available data for added value features, also enabling monetization of services	Collaboration platform	Open service platform

2.12.9 Collaboration with other Use Cases

UC3.4 is not in direct collaboration with other Use Cases at the moment of writing, however several possibilities for possible future collaboration have been identified. If other use cases would also like to track/trace position and/or other information along the supply chain, the hardware mounted on the RTIs could be reusable by other use cases.

It should also be discussed in how far interfaces to FMIS could be implemented in order to get data about the fruits and vegetables transported in the RTIs. The idea behind is that several other use cases collect data on the farm, and this data could be "connected" to the RTI, which does not stay on the farm but travels though the supply chain.

2.13 VEGETABLE UC 4.1: CITY FARMING LEAFY VEGETABLES

City Farming enables the production of high quality vegetables in a very predictable and reliable manner, unaffected by diseases and independent of seasonal influences. City Farming is the production of vegetables in a fully controlled environment, where optimal growth conditions are present at all times, and unwanted influences are kept out. This allows for a very clean production, without the need to use pesticides, as well as a very constant and high product quality. City Farming is based on hydroponic principles, focusing at present on lettuce varieties, other leafy vegetables and herbs. This Use Case will be implemented in Netherlands and is supported by 2 partners:

- Philips, Netherlands
- Staay Fresh Care, Netherlands

2.13.1 Domain model

The Domain Model description is reported in the following Figure 64.

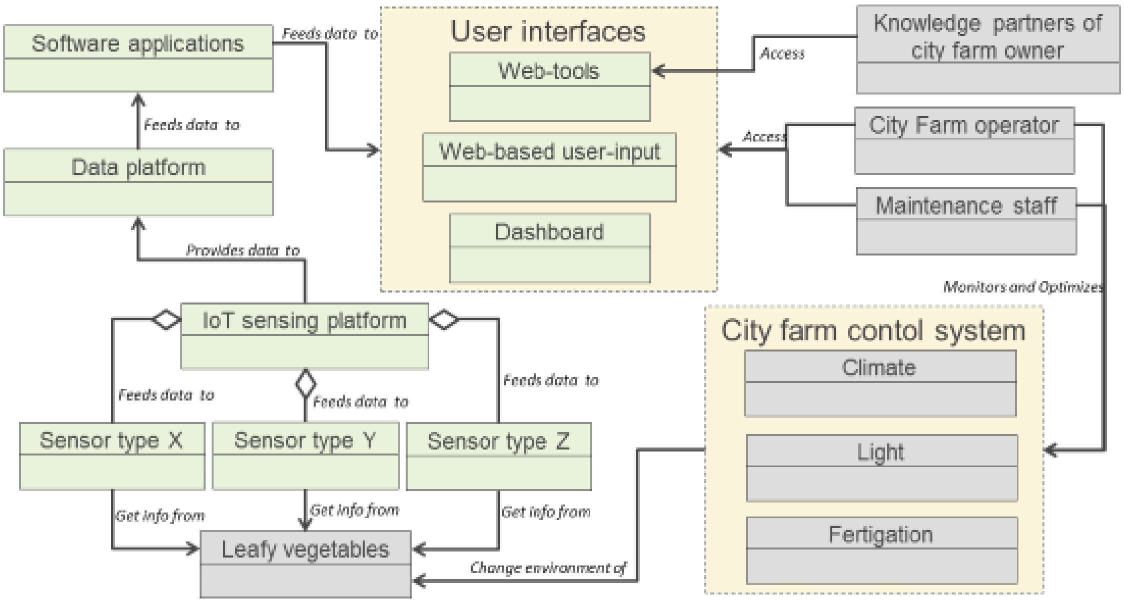


Figure 64 – UC4.1 Domain Model

In this UC, a Farmer is interested in monitoring and optimizing the environment condition of leafy vegetables in a controlled area.

IoT sensors are deployed in the growing area and measure such parameters of interest. All this information is then aggregated on an ‘IoT sensing platform’ and transmit to a data platform to be processed by applicative software. Different users can access these data using web interfaces. The city farm operators and the maintenance staff can monitor and optimize the ‘City farm control system’.

2.13.2 Deployment view

The Deployment View description is reported in the following Figure 65 and Table 56.

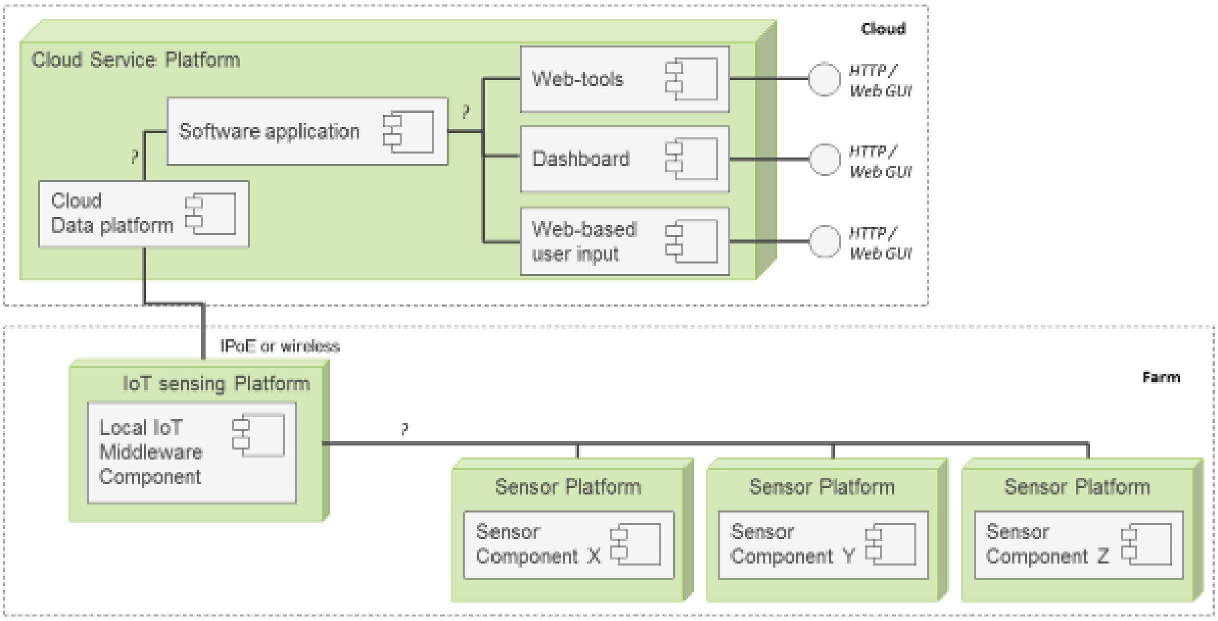


Figure 65 – UC4.1 Deployment View

Table 56 - UC4.1 Deployed Components

Name	Description	Supplier (brand) + Model	Number of Units
Sensors	to be specified	to be specified	Order of 100
IoT sensing platform	The intention is to use common building blocks such as microcontrollers with embedded Linux or Linux-based microcomputers, and I2C communication with sensors	to be specified	1
Data platform	Cloud-based data storage with IT backend (including restful API layer)	ASP.NET MVC approach, e.g. hosted by Microsoft Azure	1
Data link	to be specified	to be specified	2 - 10
Software applications	Dashboards and tools for commissioning and growth recipe definition	Philips Lighting	2
Dynamic lighting control system	Lighting control based on controller with coded mains protocol for lighting control and web-access as well as interface to central city farm control computer	Philips Lighting	2

Components in this use case are deployed either locally (i.e. in the Farm) or remotely (i.e. in the Cloud). In the Farm, different dedicated sensor is deployed. They are all connected to the IoT sensing Platform, which is connected to the cloud service platform. On these platforms is implemented a cloud data platform, the software application and the web interfaces.

2.13.3 IoT Functional view

The mapping towards the IoT Functional View are described in Figure 66.

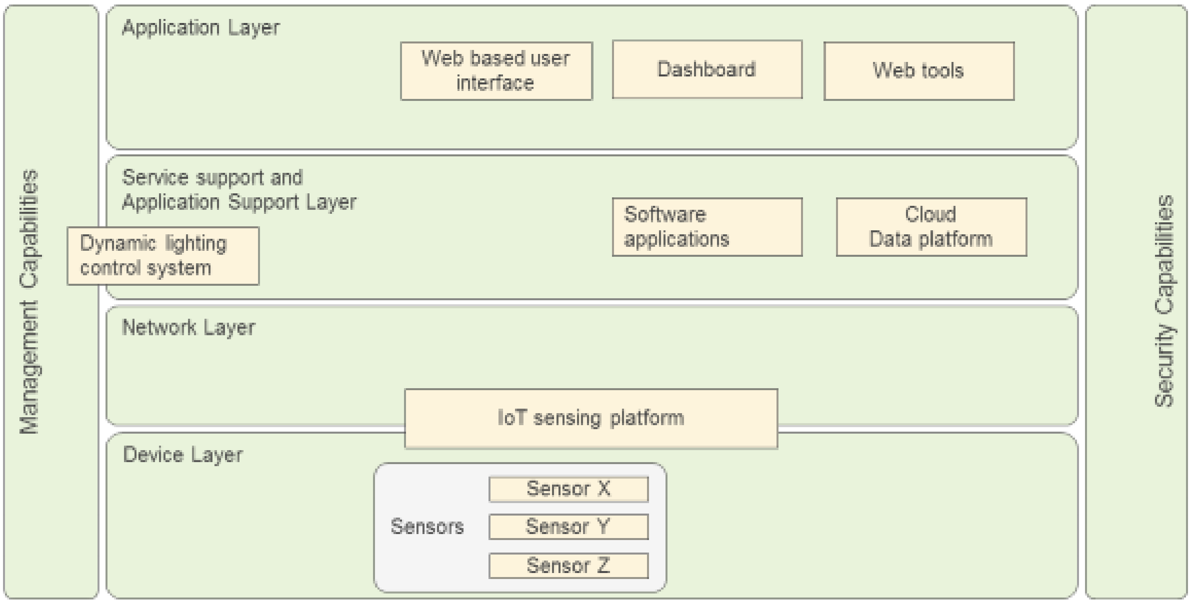


Figure 66 – UC4.1 IoT Functional View

2.13.4 Business Process Hierarchy view

The Business Process Hierarchy view for UC4.1 has not yet defined at the current stage, due to some UC-specific considerations still being developed.

2.13.5 Interoperability Endpoints

The Interoperability Endpoints for the use case 4.1 (see Table 57) still needs to be refined due to some UC specific internal considerations.

Table 57 - UC4.1 Interoperability Endpoints

Interface Name	Exposed by	Protocol	Notes
IPoE or wireless	to be specified	IEEE 802.11 (WiFi) or 802.15.4 (ZigBee or LoRa) in case of wireless	-
I2C	to be specified	I2C	-
Modbus	to be specified	Modbus	-
Restful API	to be specified	HTTPS, JSON	-

2.13.6 Information model

The initial Information Model of UC4.1 is reported in the following Figure 67 and Table 58.

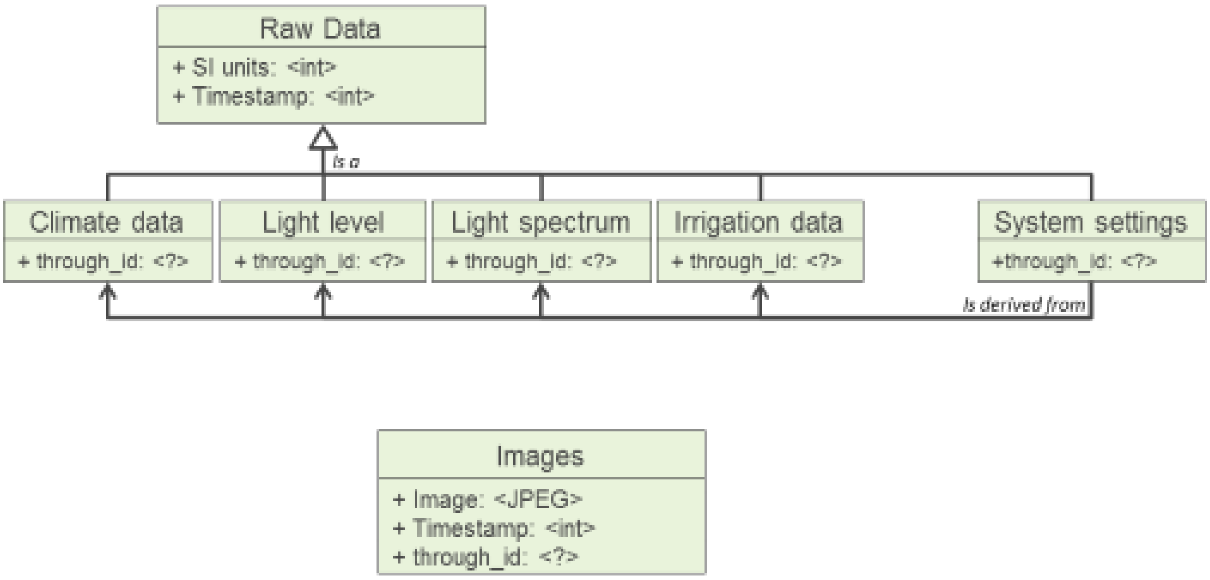


Figure 67 – UC4.1 Information Model

Table 58 - UC4.1 Information Model Details

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Climate data	Sensors that measure temperature, relative humidity, CO_2 level	Leafy vegetables, such as lettuce	10 minute interval	SI units, JSON frame, SIO 8601 timestamp
Light level	Calibrated sensors (based on photodiode with dedicated filter in front)	Leafy vegetables, such as lettuce	10 minute interval	SI units, JSON frame, ISO 8601 timestamp
Light spectrum	Multispectral light sensors	-	10 minute interval	SI units, JSON frame, ISO 8601 timestamp
Irrigation data	Sensors to measure pH, and EC (and possibly dissolved oxygen (DO), oxidation-reduction potential (ORP), and elemental composition of nutrient solution)	Leafy vegetables, such as lettuce	10 minute interval	SI units, JSON frame, ISO 8601 timestamp
System settings	-	Leafy vegetables, such as lettuce	10 minute interval and events when occurring	SI units, JSON frame, ISO 8601 timestamp

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Images	VIS and NIR IP cameras	-	10 minute interval	JPEG, ISO 8601 timestamp

2.13.7 Summary of gaps

Many points that need to be defined within UC4.1. However, this project is using an iterative approach to define their needs, so most of the gaps below will be defined during the development of the project.

List of gaps of the UC 4.1:

- Definition of the sensors to be deployed.
- The IoT sensing platform need to be defined.
- The level of implementation of the IoT technology must be clarified.
- Treatment on the data need to be defined.
- Definition of the interface between the sensors and the IoT sensing platform.
- Definition of the interfaces between the elements on the cloud platform.
- Risk management need to be filled.

2.13.8 Assets identified for re-use

The assets identification for the use case 4.1 still needs to be defined due to some UC specific internal considerations.

2.13.9 Collaboration with other Use Cases

They are not collaborating with other Use Cases at the moment of writing.

2.13.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets.

The following Table 59 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability

Table 59 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC4.1)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May '18)	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	Order of 100	
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	Order of 8	- IoT sensing platform (1) - Data platform (1) - Data link (2-10) - Dynamic lighting control system (2)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May ‘18)	Short comment / qualitative estimation
	Number of IoT applications available	2	- Software applications (2)
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1
	Number of FIWARE GEs instances	0	
	Number of open datasets used	/	Not yet available
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	/	Not yet available
	Average number of installations per reusable IoT component	/	Not yet available
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	/	Not yet available
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies	/	Not yet available

2.14 VEGETABLE UC 4.2: CHAIN-INTEGRATED GREENHOUSE PRODUCTION

Development of an IoT web-based traceability and DSS in the greenhouse tomato production involving large amount of data, physical and virtual sensors, models, and algorithms focusing on important aspects like water and energy use efficiency, safety, transparency, for both conventional and organic supply chain traceability systems of tomato.

2.14.1 Domain Model

The Domain Model description is reported in the following Figure 68.

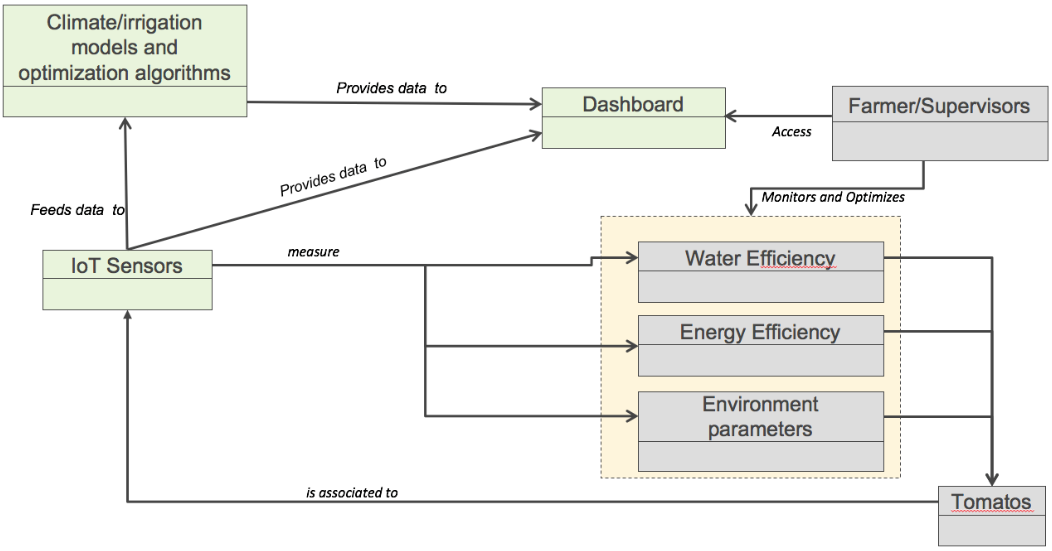


Figure 68 – UC4.2 Domain Model

The main goal of this Use Case is a development of an IoT web-based traceability and Decision Support System in the greenhouse tomato production.

It will be useful to measure the water efficiency, energy efficiency and Environment parameters. Using these values through a Climate/irrigation models and optimization algorithms it will be possible to monitor and optimize the tomato production.

The Farmers/Supervisors will be able to interact with a dashboard and being a decision maker taking in account the help given by the algorithms.

2.14.2 Deployment View

The Deployment view for UC4.2 is described in Figure 69 and Table 60.

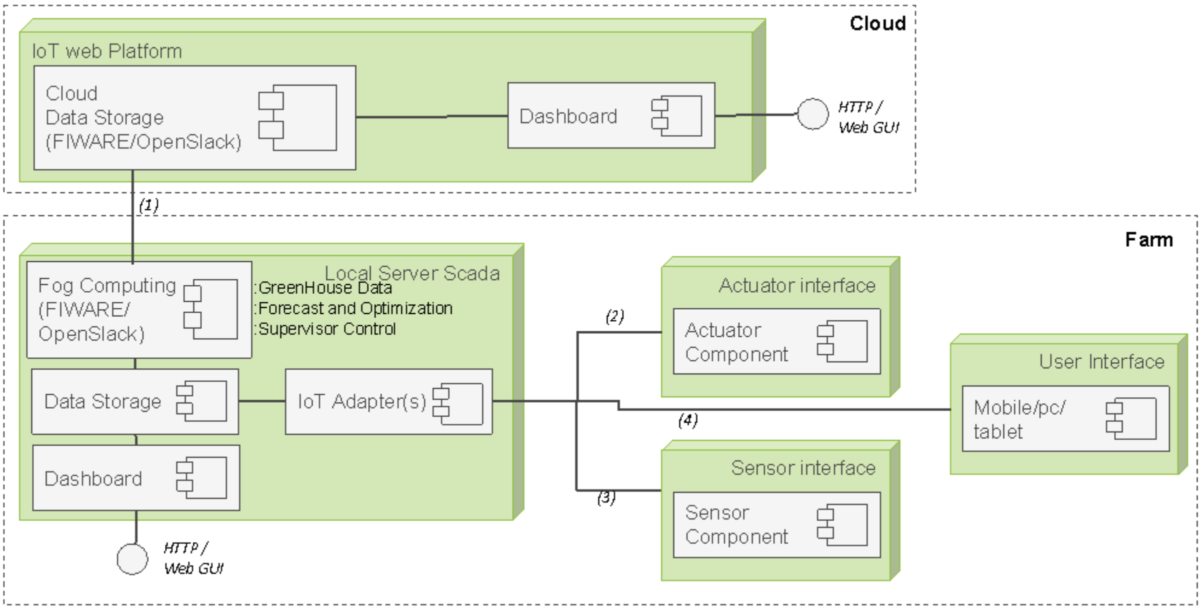


Figure 69 - UC4.2 Deployment View

The architecture is divided in two sectors: Farm and Cloud. The Farm is composed by the sensors (can be connected wireless or by cable) (3), actuators (2), a Local Server Scada and mobile/pc/tablet (4) which can be used by workers in farm to send info locally wirelessly. The Local Server Scada is composed by a device which receive the signal from the sensors and send them to the Data Storage. That info can be accessed locally by a IoT backend (Dashboard). Will exist also a Fog computing treating Green-House Data, Forecast and Optimization and Supervisor Control.

The Cloud will have software based in OpenStack and Fiware, which will help to pro-vide a public and private cloud. It will be also possibly access that info through a dash-board. The connection to the internet will be made by a wireless or cabled internet service provider (1).

Table 60 - UC4.2 Deployed Components

Name	Description	Supplier (brand) + Model	Number of Units
Temperature and humidity sensor	Sensor to monitor the outside and greenhouse temperature and humidity	Vaisala HC2S3	2
Water content sensor	Sensor to monitor the water content in soilless bags	Decagon devices GS1	2
Water content, EC and temperature sensor	Sensor to monitor the water content, EC and temperature in soilless bags	Decagon devices GS3	1
Sun calibration quantum sensor	Sensor to monitor the PAR radiation	Apogee SQ-110	1
Self-powered pyranometer	Sensor to monitor the Global radiation	Apogee SP-110	1
CO2 Monitor	Sensor to monitor the CO_2 concentration in outside and greenhouse air	Vaisala GMP222	2
Server	Server to install FIWARE platform	HP proliant DL360	1
Computer	Computer to develop IoT platform	Lenovo Yoga 900-13isk2 80ue	1
Computer	Computer to monitor the experimental greenhouse	DIY PC	1
Mini-computer	Mini-computer to use during the FIWARE test	Arduino Uno	1
Mini-computer	Mini-computer to use as crop camera	Raspberry pi 3	2

Name	Description	Supplier (brand) + Model	Number of Units
Camera	Camera to monitor the crop growth and plagues	Raspberry V2 Daylight	2
Crop monitoring	Platform to monitor crop growth, transpiration, water-content, EC, Temperature and radiation	Gremon Systems Trutina energy and irrigation (poner servicio de pago)	1
Crop monitoring Cloud service	Data service for Gremon Systems Trutina	Gremon Systems	48 months
OpenStack	Private and public cloud	OpenStack	1
FIWARE	IoT enabler	FIWARE.org	1
Thermic camera	Camera to monitor the crop growth and plagues	N/A	1

2.14.3 IoT Functional View

The IoT Functional View for UC4.2 is described in Figure 70.

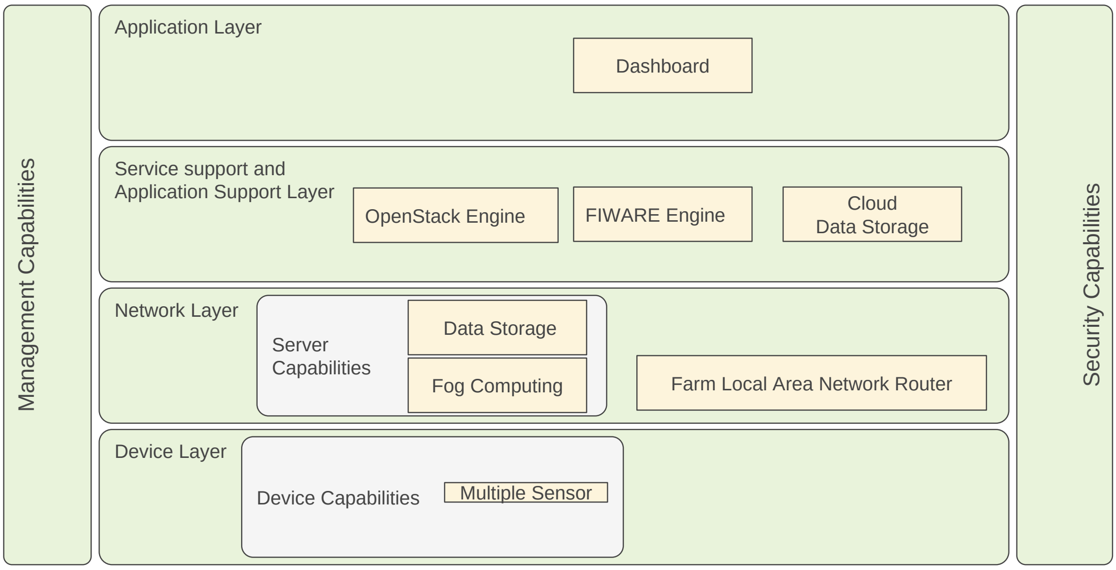


Figure 70 – UC4.2 IoT Functional View

Application Layer: Contains the Dashboard that allow the interaction with the user through a GUI.

Service support and Application Support Layer: Is composed by the "Cloud Data Storage" that receive and store the data from each farm network, FIWARE Engine and OpenStack.

Network Layer: This layer is composed by the "Farm Local Area Network" that provide control functions of network connectivity and to transport the data information and the "Server" has the capability to store information and make processing.

Device Layer: The "Device Capabilities" include multiple sensor which will be needed to collect the information from farm.

The Fog Computing also uses OpenStack and FIWARE.

2.14.4 Business Process Hierarchy view

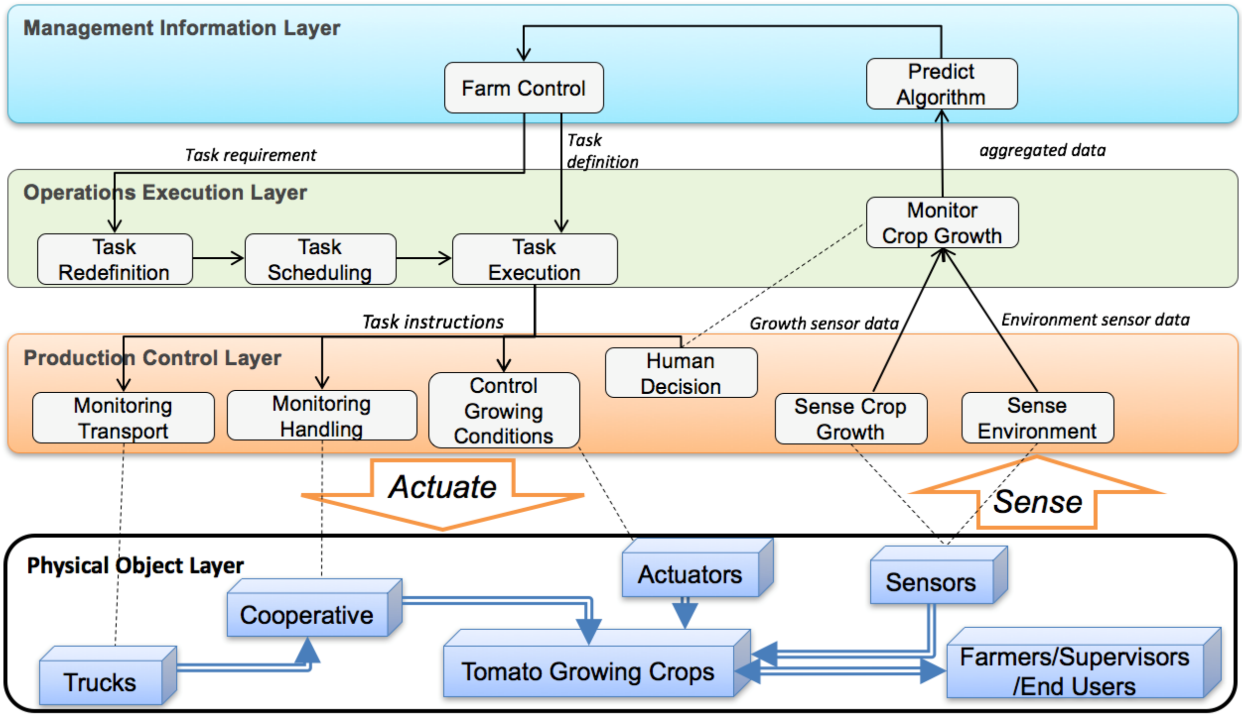


Figure 71 – UC4.2 Business Process Hierarchy View

This diagram shows how the growing crops tomato can be optimized and improved using sensors and actuators.

In the Physical Object Layer the relevant objects of this case are depicted:

- Truck which will do the transport (also provide info about transport climate variable, distance, duration and intrusion in the backdoor truck)
- Cooperative which will treat about the handling (also provide info about tomato production)
- Actuators will have the possibility to interact with technology, for example ventilation or fertigation
- Sensors will be sensing environment and growing crops variables, like temperatures, wind speed/direction, rain, soil temperature and so on
- Farmers/Supervisors/End Users will have in some way interaction with Tomato Growing Crops. End Users will have access to information about tomato production. Farmers and Supervisors

will be an active part always having the option to check information (sensors for example) in real time in the farm.

In the Production Control Layer, we will sense the crop grow and environment values. Will be available monitoring about transport, handling and actuators. It will also exist Human decision at this level taking in account the information monitored by the sensors.

In the Operations Execution Layer, the data which was collected by sensors will be monitored in this layer. The aggregated will be used in the Management Information Layer which using a predict Algorithm will generate “controls”, which we can call Farm control. Now returning to Operations Execution Layer the Farm Control triggers that the execution of these actions by sending the specific task requirements and task definition to the Operations Execution Layer. In this layer the tasks are redefined, scheduled and the task execution is sent to the Production Control layer. This last layer has multiple controls which will process then implements the specific task and executes the instruction.

2.14.5 Interoperability Endpoints view

The main list of interoperability end-points identified within UC4.2 is depicted in Table 61.

Table 61 - UC4.2 Interoperability Endpoints

Interface name	Exposed by	Protocol	Notes
WI-FI	Mobile phones/Computer/Tablet	IEEE 802.11	-
Ethernet	Computer	IEEE 802.3	-
USB	Sensors	IEEE 1394	-
RS-232	Sensors	IEEE 1394	-
SDI-12	Sensors	Serial-Digital Interface	-

2.14.6 Information model

The initial Information Model of UC4.2 is reported in the following Figure 72 and Table 62.

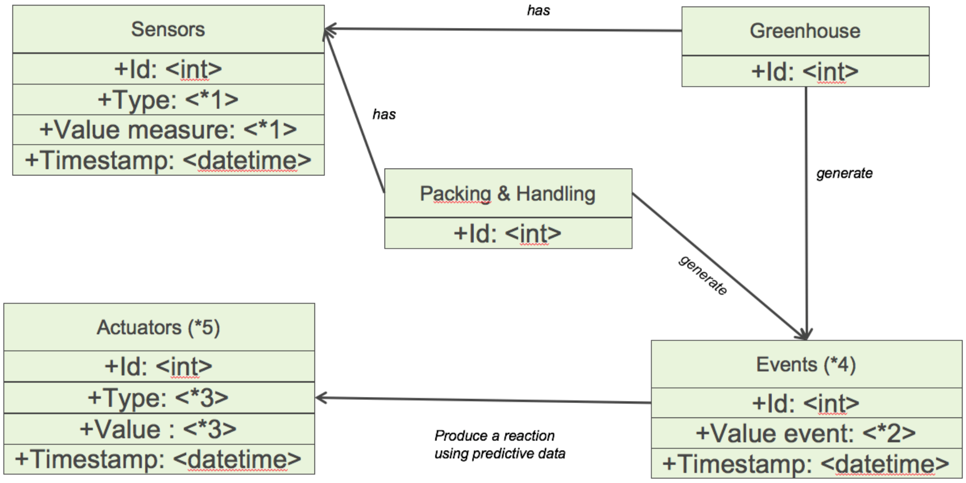


Figure 72 – UC4.2 Information Model

Notes: *1=> It depends on which sensor; *2=> it depends on which events; *3=> it depends on which actuator; *4=> like pesticides limit, production estimation; *5=> like ventilation, fertigation, humidification, heating, artificial light and so on.

There are a lot of type sensors and actuators. The schema doesn't represent all of them. Only the general flow.

Table 62 – UC4.2 Information Model Details

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
External temperature	Sensor	Tomato crop	30 s	Air temperature (ºC) – timestamp in every sample
External humidity	Sensor	Tomato crop	30 s	Air humidity (%) – timestamp in every sample
Wind speed	Sensor	Tomato crop	30 s	Wind speed (m s-1) – timestamp in every sample
Wind direction	Sensor	Tomato crop	30 s	Wind direction (º) – timestamp in every sample
Raining detector	Sensor	Tomato crop	30 s	Raining presence (Yes/No) – timestamp in every sample

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
External CO2	Sensor	Tomato crop	30 s	Air CO2 (ppm) – timestamp in every sample
External Global Radiacion	Sensor	Tomato crop	30 s	Radiation (W m-2) – timestamp in every sample
Active Power	Sensor	Tomato crop	30 s	Electrical consumption (W) – timestamp in every sample
Reactive Power	Sensor	Tomato crop	30 s	Electrical consumption (W) – timestamp in every sample
Electrical frequency	Sensor	Tomato crop	30 s	Electrical frequency (Hz) – timestamp in every sample
Inlet temperature for heating	Sensor	Tomato crop	30 s	Water temperature (ºC) – timestamp in every sample
Outlet temperature for heating	Sensor	Tomato crop	30 s	Water temperature (ºC) – timestamp in every sample
CO2 tank temperature	Sensor	Tomato crop	30 s	CO2 temperature (ºC) – timestamp in every sample
Heating water temperature	Sensor	Tomato crop	30 s	Water temperature (ºC) – timestamp in every sample
Dehumidification grid temperature	Sensor	Tomato crop	30 s	Grid temperature (ºC) – timestamp in every sample
Dehumidification outlet temperature	Sensor	Tomato crop	30 s	Air temperature (ºC) – timestamp in every sample

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Dehumidification inlet temperature	Sensor	Tomato crop	30 s	Air temperature (ºC) – timestamp in every sample
Greenhouse temperature	Sensor	Tomato crop	30 s	Air temperature (ºC) – timestamp in every sample
Greenhouse humidity	Sensor	Tomato crop	30 s	Air humidity (%) – timestamp in every sample
Greenhouse global radiation	Sensor	Tomato crop	30 s	Radiation (W m-2) – timestamp in every sample
Greenhouse PAR radiation	Sensor	Tomato crop	30 s	PAR radiation (W m-2) – timestamp in every sample
Greenhouse CO2	Sensor	Tomato crop	30 s	Air CO2 (ppm) – timestamp in every sample
Greenhouse soil temperature	Sensor	Tomato crop	30 s	Soil temperature (ºC) – timestamp in every sample
Greenhouse Internal Radiation	Sensor	Tomato crop	30 s	Global radiation (W m-2) – timestamp in every sample
Aerothermal heater	SCADA	Tomato crop	30 s	Use of heating (on/off) – timestamp in every sample
Dehumidification	SCADA	Tomato crop	30 s	Use of dehumidification (on/off) – timestamp in every sample
Humidification	SCADA	Tomato crop	30 s	Use of humidification (on/off) –

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
				timestamp in every sample
Side ventilation	SCADA	Tomato crop	30 s	Use of side ventilation (on/off) – timestamp in every sample
Top ventilation	SCADA	Tomato crop	30 s	Use of top ventilation (on/off) – timestamp in every sample
Heating pump	SCADA	Tomato crop	30 s	Use of heating pump (on/off) – timestamp in every sample
LEDs Lamps	SCADA	Tomato crop	30 s	Use of LEDs lamps (on/off) – timestamp in every sample
Blower	SCADA	Tomato crop	30 s	Use of CO2 blower (on/off) – timestamp in every sample
Irrigation pump	SCADA	Tomato crop	30 s	Use of irrigation pump (on/off) – timestamp in every sample
Irrigation valve	SCADA	Tomato crop	30 s	Use of irrigation valve (on/off) – timestamp in every sample
3 ways valve CO2	SCADA	Tomato crop	30 s	Use of 3 ways valve (on/off) – timestamp in every sample
Leaf wetness	Sensor	Tomato crop	30 s	Water condensation on leaves (%) – timestamp in every sample

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Substrate Water Content	Sensor	Tomato crop	30 s	Substrate water content (%) – timestamp in every sample

2.14.7 Summary of gaps

No gaps identified.

2.14.8 Assets identified for re-use

Table 63 lists the assets identified for re-use in UC4.2.

Table 63 – UC4.2 Assets identified for re-use

Component Name	Short Description and role in the Use Case	Web Page	License
OpenStack	Software to make private and public cloud	https://www.openstack.org/	open
FIWARE components	It´s the software used in the IoT Platform	https://github.com/Fiware	open
Sensors	It is used to measure values	N/A	private

2.14.9 Collaboration with other Use Cases

Table 64 lists the collaborations of UC4.2 with other use cases.

Table 64 - UC4.2 Collaboration with other Use Cases

Use Case Number	Potential for sharing components or approaches identified	Potential for integration of data/services identified
UC 1.1	Crop growth modelling	Results of the prediction of the crop growth/
UC 3.3	Knowledge about FIWARE platform	Data sharing in FIWARE

Use Case Number	Potential for sharing components or approaches identified	Potential for integration of data/services identified
UC 3.3	Support developing a IoT solution for vegetables supply chain	ERPs integration in FIWARE
UC 3.3	ISO-Bus protocol development	Help about working with communication protocols, ISO-BUS
UC 4.4	Knowledge about Quality Standard and how to test different solutions	Quality standard and its implementation in IoT platform, also in the test of different solutions for sensor applied to the agriculture

2.14.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets.

The following Table 65 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability

Table 65 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC4.2)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May ‘18)	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	83	- 63 types of sensor - 20 actuator in average per deploy. Commercial farms has less sensors (7)
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	12	
	Number of IoT applications available	1	1 adapted for every farmer.
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1
	Number of FIWARE GEs instances	1	- FIWARE Orion Context broker
	Number of open datasets used	1	
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	7	From table 5.4 re-usable components from work plan.
	Average number of installations per reusable IoT component	0	
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	2	- OpenStack - FIWARE Orion Context Broker
	% of identified standardization gaps that resulted in pre-normative	0	

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May ‘18)	Short comment / qualitative estimation
	change proposals submitted to IoT standardization bodies		

2.15 VEGETABLE UC 4.3: ADDED VALUE WEEDING DATA

This UC utilizes the machine vision data of automated intra row weeding machines for better control of farm operations, including crop growth monitoring and yield prediction.

2.15.1 Domain model

The Domain Model of UC4.3 is depicted in the following Figure 73.

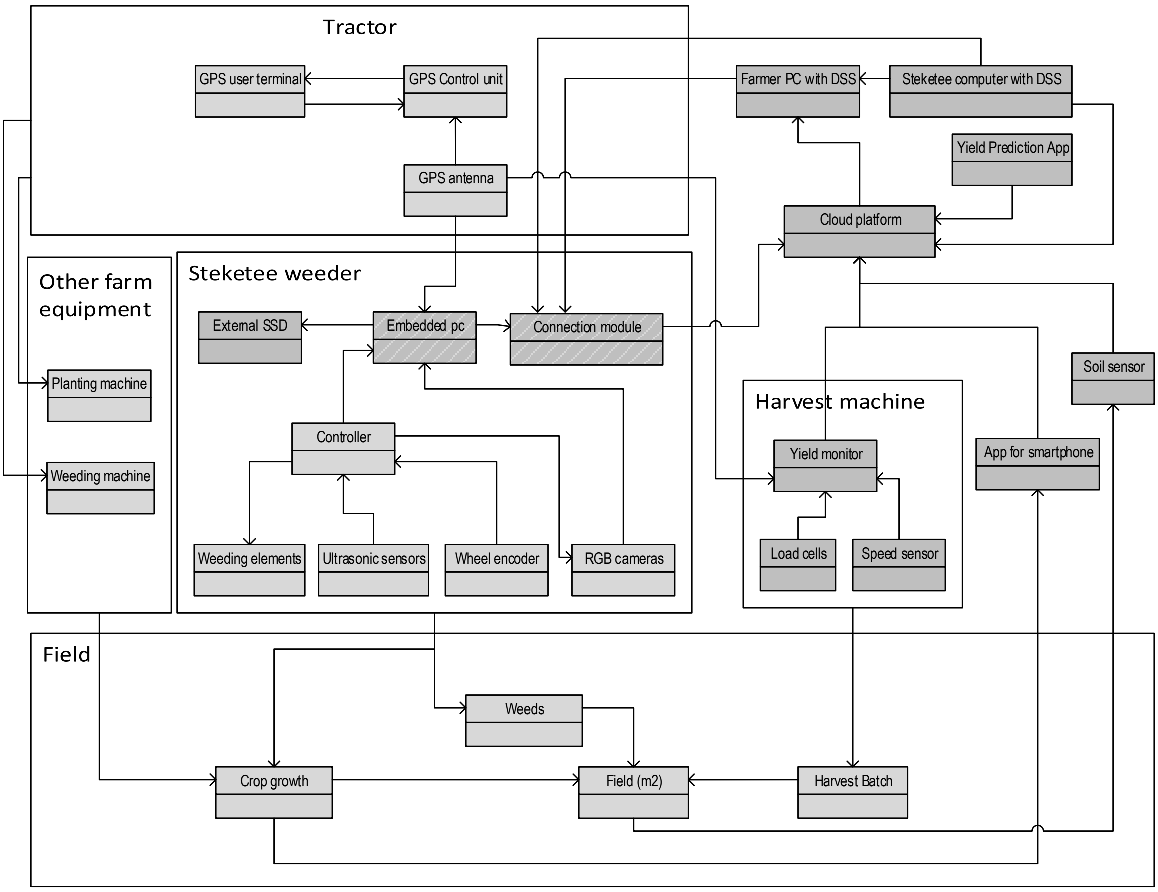


Figure 73 – UC4.3 Domain Model

The main components in the domain model are the Steketee Weeder, Field, Tractor and Harvest machine. These components contain the elements, which give information to the system. Besides the elements within the components, there are a few stand-alone elements, which are a source of information like the soil sensor or the app for the smartphone.

In the **Steketee Weeder** images will be processed to extract field information like crop size, growing stage and weed pressure. The machine was developed to perform intra-row weeding. To extract more management information from the field we would like to add the elements depicted in the Steketee weeder component to the machine. With this information the development team can make a better DSS for the Farmer.

The **field component** contains all elements, which have direct influence on the total yield from the field. The weed and crop are used in the Weeder as inputs to determine where to actuate the weeding elements. When there is an optimum control of these elements this lead will to a higher yield with the same input material. In the **Harvest machine** a yield monitor will be added to get feedback on the performance of the crop. The yield of the crop is the final result of all actions performed in the last year and years before. In an advanced stage of the project, this information will be used to predict the optimum harvesting date and the estimated coming yield.

The **tractor component** contains the GPS information which is used to process the information from the field in a spatial way. This will give the opportunity to perform site specific measures on the field.

All these elements will lead to two DSS's, one DSS for the machine settings for the Steketee weeder and one DSS for field/crop management.

2.15.2 Deployment model

The Deployment model for UC4.3 is depicted in Figure 74.

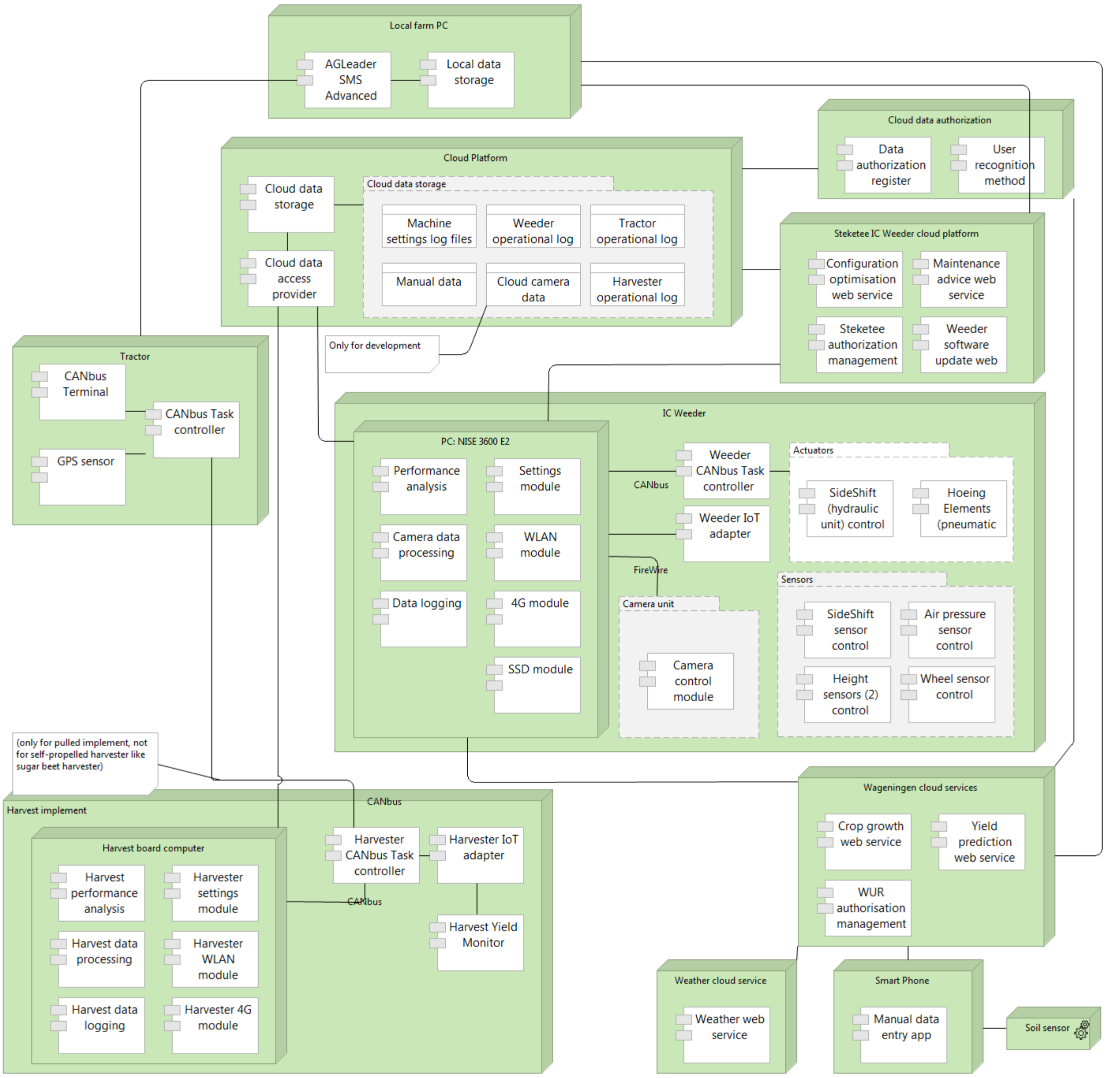


Figure 74 –UC4.3 Deployment Model

For the weeding task the **image processing** of the camera images will be done online in the IC weeder. This way the weeder can run through the field and after weeding information like weed pressure and crop size is directly available. The data that are generated during operation are first logged on the machine. After the operation they are transferred to cloud storage. Besides the weed/crop data the **settings** file will be logged as well. This will be used by Steketee to improve the settings of the machine by learning settings from all types of weed/crop/field circumstances. Initially it will be used for generating advised settings.

The **cloud platform** will be the storage for all data from the IC weeder, harvester, Farm Management Information System (FMIS) and services from Steketee and WUR. All nodes are in a way connected to the cloud to have one central data storage point. Data from the cloud can be downloaded by Steketee or WUR, processed and put back on the cloud to be used by the farmer. This can be used directly in the IC weeder (e.g. settings update) or via the FMIS for the farmer to be used as decision support.

Note: Field data and machine settings may be stored at different clouds. This is still to be decided.

The main components of the deployment diagram are listed in Table 66.

Table 66 - UC4.3 Deployed Components

Name	Description	Supplier (brand) + Model	Number of Units
GPS unit	GPS unit on the tractor	AgLeader	1 per tractor
Weeding Machine	Tractor implement for vision-based weeding	Steketee	1 per tractor
Embedded PC Weeding Machine	Embedded PC on the weeding machine for local image/data processing	PC:NISE 3600	1 per weeding machine
Camera Unit Weeding Machine	RGB camera of the weeding machine that takes pictures of the weed/crops/soil	Stingray F-046C van AVT	1 per weeding machine
SideShift Weeding Machine	Sensor and Actuator for hydraulic unit control	to be specified	1 per weeding machine
Hoeing Elements	Pneumatic Unit Control actuator	to be specified	1 per weeding machine
Height sensor	Sensor to measure the height	to be specified	2 per weeding machine
Air pressure sensor	Sensor to measure the air pressure	to be specified	1 per weeding machine

Name	Description	Supplier (brand) + Model	Number of Units
Wheel sensor	Sensor to measure wheel speed	to be specified	1 per weeding machine
Harvest machine	Self-propelled sugar beet harvester	Holmer T430	1 (contractor)
Harvest machine	Pulled pumpkin harvester	Moty KE3000 Hydro S	1 (contractor)
Harvest board computer	Embedded PC on the harvest machine for local (weight) data processing	Precision Makers YieldMasterPro	1 per harvest machine
Harvest yield monitor	Sensor that measures harvest weight	Precision Makers YieldMasterPro	1 per harvest machine
Farm cloud platform	IoT platform of the farmer to store camera and sensor data, machine settings and task instructions	to be specified	1
Weeder cloud platform	Cloud platform of the weeding machine vendor (Steketee) for maintenance and optimisation of machine settings	to be specified	1
Cloud data authorisation	Web service for authentication	to be specified	1
Local farm PC	Local farm management system	AGLeader SMS Advanced	1 per farm
Yield Prediction cloud service	DSS for yield prediction	Wageningen Plant Research app	1
Weather cloud service	Web service for detailed weather forecasts	Meteoblue (365Farmnet)	1
Smart Phone	App for manual data entry by the farmer	Android/iOS	1 per farmer

2.15.3 IoT Functional view

The IoT functional view of UC4.3 is depicted in Figure 75.

The **Application Layer** includes an IoT dashboard for the farmer and the machine vendor (Steketee). The machine vendor's dashboard is used to setup the machine, to optimize and update the settings and for maintenance purposes. The farmer's dashboard is used for operational sensing of weed pressure, crop growth and harvest, as well as for monitoring the execution of farming tasks. The AgLeader system supports the usage of sensing data for farm management, including yield prediction, planning of farm operations and triggering the execution

The **Service and Application Support Services Layer** comprises web services and cloud data management capabilities that are used by the dashboards and farm management system in the application layer.

The **Network Layer** includes different kinds of wired and wireless interfaces for connecting the weeding machine, tractor and harvester and for communication of machines and sensors with the cloud systems.

The **Device Layer** includes generic Device Capabilities for the sensors and actuators that are embedded in the weeding and harvesting machines and for soil sensors in the field. The terminals on the weeder and harvester are the main gateways that include local data processing and storage (e.g. of the images). The tractor terminal is used as a GPS gateway.

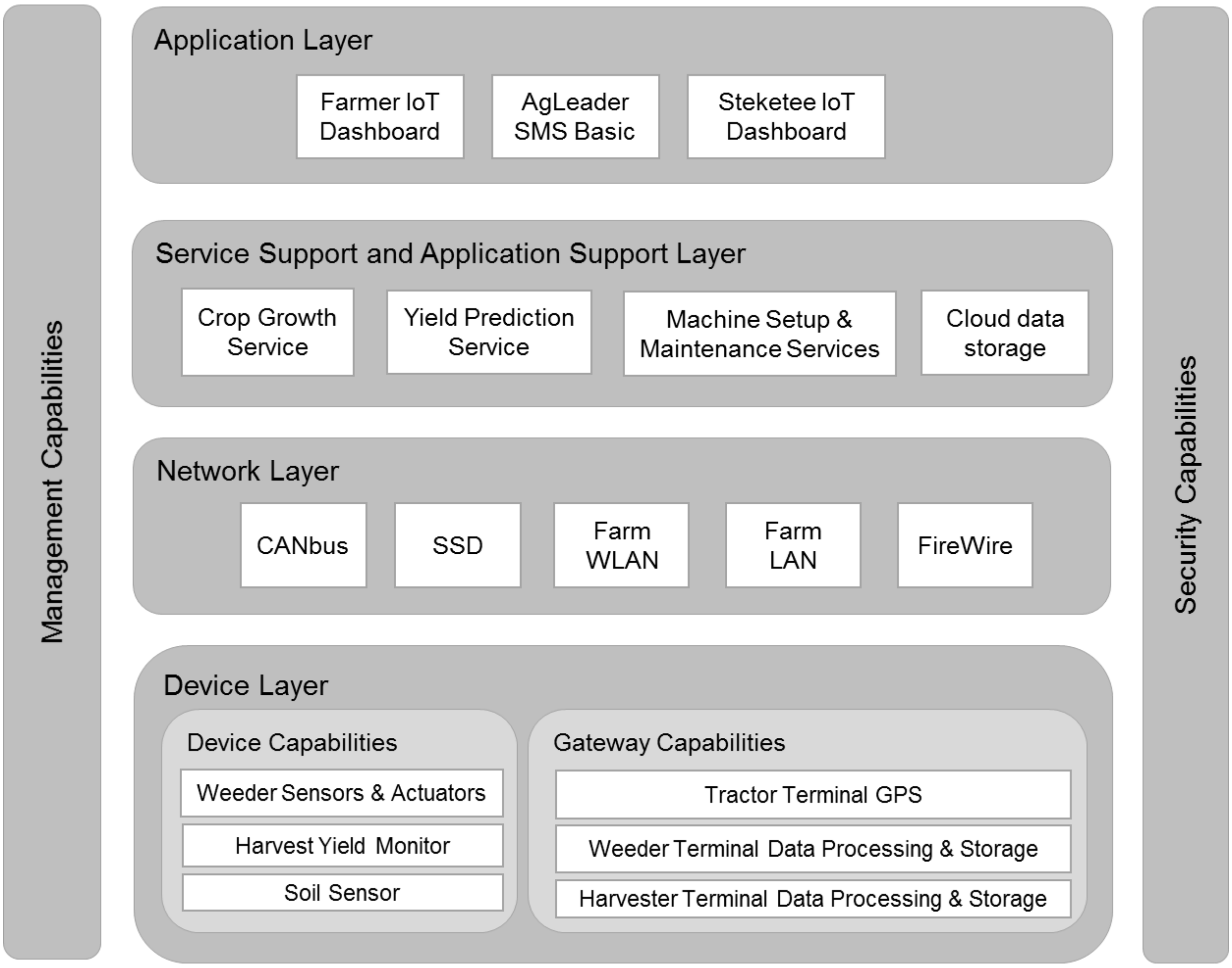


Figure 75 – UC4.3 IoT Functional View

2.15.4 Business Process Hierarchy model

The Process Hierarchy view provides an overview of the business processes and their interrelations. The business processes are layered according to their position in the production control hierarchy, ranging from operational control of physical objects to enterprise management level.

Figure 76 provides the Process Hierarchy Model of UC4.3.

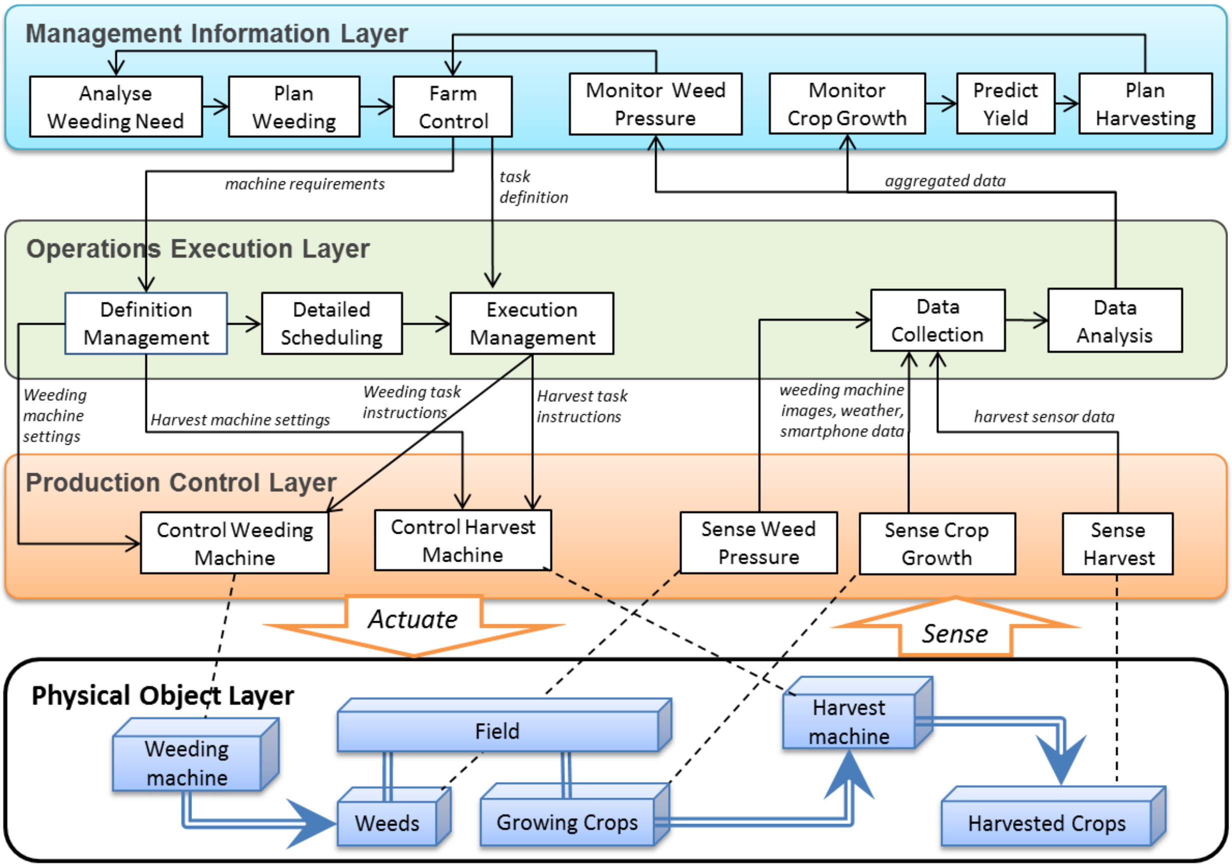


Figure 76 – UC4.3 Process Hierarchy Model

This model shows how sensing data of weed pressure, crop growth and harvest is used for precision weeding and farm management.

In the Physical Object Layer, the relevant objects of this case are depicted: weeds and growing crops in the field. The weeding machine detects and removes the weeds. Once the crops are ready for consumption, they are harvested with a harvest machine. The other layers include the main farm processes on different time horizons that are needed in this case to sense and control the physical objects.

In the Production Control Layer includes the operational processes to (physically) sense and control the weeds, crops and harvest. The weed pressure and crop growth are sensed by cameras and sensors in the weeding machine. The harvest machine includes a sensor for yield monitoring. This data is collected and analyzed in the Operations Execution layer. The aggregated data are used in the Management Information Layer to monitor crop growth and weed pressure. Next, the location-specific weeding need is calculated based on the weeding pressure monitoring and specific weeding tasks are planned. Alongside, also the expected yield is predicted based on the crop growth monitoring and translated into a detailed harvest planning. Both the weeding and harvesting plans may result in location-specific farm operations. The Farm Control triggers that the execution of these actions by sending the specific machine requirements and task definition to the Operations Execution Layer. In this layer the settings of the weeding and harvesting machine are defined, the weeding or harvesting task is scheduled and the machine-readable task instruction (precision task map) is sent to the Production Control layer. The machine control process of the weeder or harvester, then, implements the specific machine settings and executes the specific instruction.

2.15.5 Interoperability Endpoints

This Interoperability Endpoints view (see Table 67) summarizes the main end-points which can be exploited to integrate available systems to other systems.

Table 67 – UC4.3 Interoperability Endpoints

Interface name	Exposed by	Protocol	Notes
Weeding Machine interface	Steketee Weeding machine	WLAN, 3G/4G and manual (SSD)	Interface to get image data of the weeding machine and to control machine setting and task instructions.
Harvest Machine interface	Harvest machine	csv	Interface to get harvest data of the harvesting machine.
GPS	Tractor	NMEA	GPS interface on the tractor to get position data
Farm Cloud Data interface	Farm cloud data platform	To be specified	API to access farm cloud platform for camera and sensor data, machine settings and task instructions
Weeder Cloud Data interface	Steketee Cloud data platform	To be specified	API to access weeder cloud for maintenance and optimisation of machine settings
Yield prediction interface	Yield prediction service WPR	To be specified	API to access app for yield prediction

2.15.6 Information model

The Information View description of UC4.3 is reported in the following diagram and in Table 68.

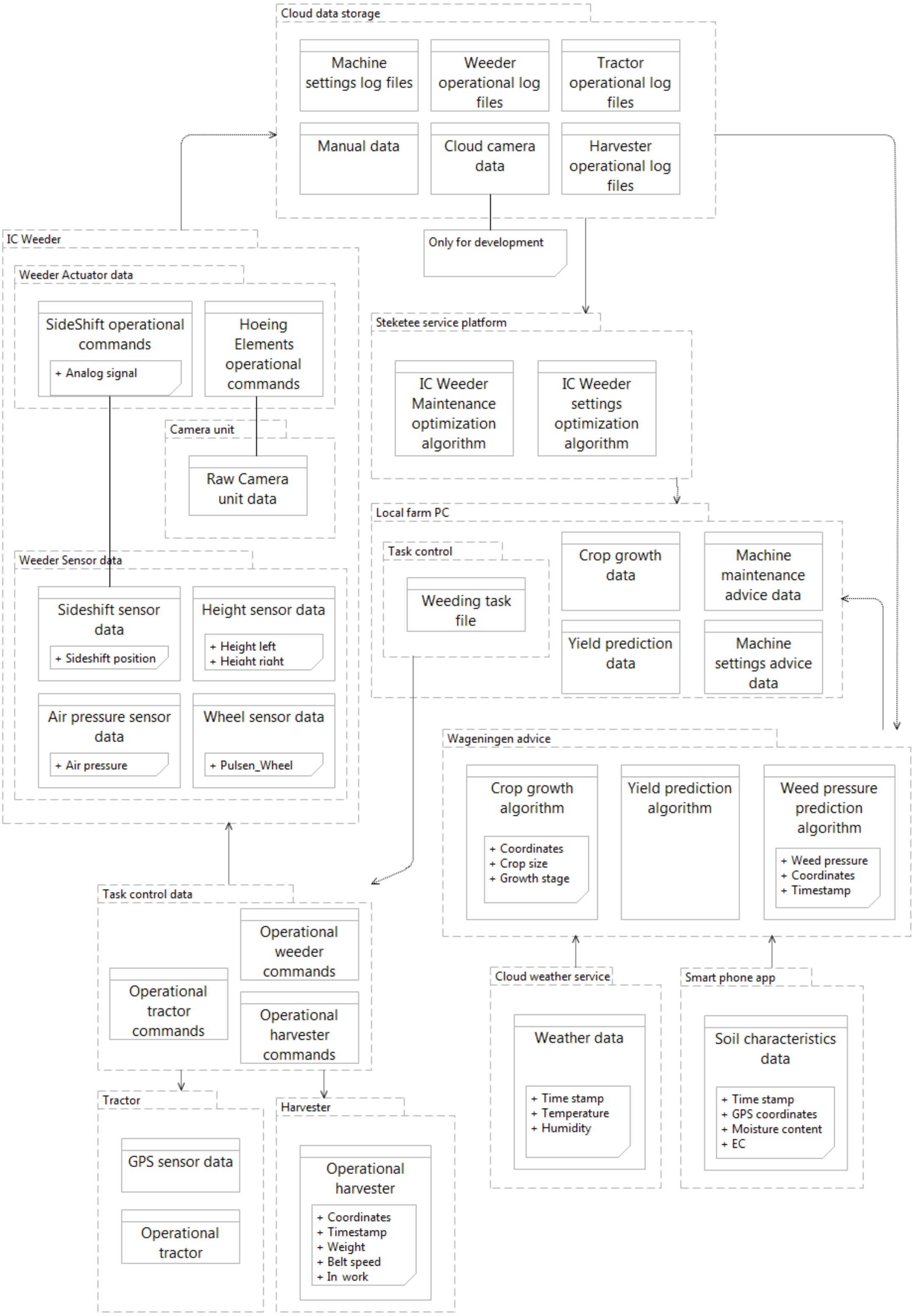


Figure 77 – UC4.3 Information Model

In the information model above the most important data elements are identified. This view is closely related to the application functionalities in the deployment view and the information exchanged between them. It distinguishes:

- Operational data flows (commands, responses, actuals)
- Expert rules data (e.g. algorithms)
- Advice data (alerts, predictions)
- Management data (definitions, schedules, capabilities, performance)

In Table 68 those data elements are highlighted that are IoT and/or operation specific, like device sensor data and actual condition information.

Table 68 – UC4.3 Information View

Data ID	Measurement Technique	Physical Entity	Frequency of data collection	Associated data model and format
Raw camera unit data	Camera sensor	IC Weeder	Continuous during operation up to 61 fps	RGB camera pictures
Sideshift sensor data	Sideshift sensor	IC Weeder	Continuous during operation	Sideshift data
Height sensor data	Height sensor	IC Weeder	Continuous during operation	Height data
Air pressure sensor data	Air pressure sensor	IC Weeder	Continuous during operation	Air pressure data
Wheel sensor data	Wheel sensor	IC Weeder	Continuous during operation	Wheel data
GPS sensor data	GPS sensor	Tractor	Continuous during operation	GPS location
Cloud weather service	Online web service	External	Upon request of yield prediction app	Location-specific weather
Soil characteristics data	Manual data entry in smartphone app	Smart phone	to be specified	to be specified

2.15.7 Summary of gaps

This specification of UC4.3 describes the architecture as far as possible in the current state of the UC. It is reviewed and completed by the UC team. However, not all technical choices are made yet due to the agile and iterative development approach. Especially the following issues have to be completed in a later stage:

- **Farm cloud platform**: the UC has not yet selected the IoT platform of the farmers to store, process and monitor camera and sensor data. For this component a reusable component / generic enabler is intended to be selected and implemented; As a cloud platform, to represent the data in heatmaps, 365FarmNet was chosen. Currently the functionality to upload sensor data is under development and will be available from June/July 2018.

- **Weeder cloud platform**: the UC has not yet selected the cloud platform of the weeding machine vendor (Steketee) for maintenance and optimisation of machine settings. For this component a reusable component / generic enabler is intended to be selected and implemented (i.e. will not be provided by the UC);
- **Cloud data authorization module**: the UC intends to manage authorization and security in a separate module for authentication; for this component a reusable component / generic enabler is intended to be selected and implemented (i.e. will not be provided by the UC);
- The **supplier (brand) and model** of the SideShift Hoeing Elements, Height Sensor, Air pressure sensor and Wheel Sensor of the Weeding Machine have to be specified (choice is already made).
- The **specific protocols** of the Farm Cloud Data interface, Weeder Cloud Data interface and Yield prediction interface still have to be decided and specified.
- The **frequency of data collection and associated data models** of the identified data elements have to be detailed in a later stage. Weeding data will be collected on average two times a year from the field, for sugar beets and pumpkins. This will be influenced by the occurrence of weed in the field. If the weed pressure is low, there will be less weedings and with a higher weed pressure there will be more weeding and data available.
- A rather complete STRIDE security analysis has been done. However, in this stage of the project it appeared to be complicated to perform a detailed **DREAD grading** of the identified risks.

2.15.8 Assets identified for re-use

A number of components adopted in specific use cases, may have potential for re-use or integration in other use cases. In order to facilitate the identification of such components, a table will be prepared for each use case, following the template described in Table 69.

Table 69 – UC4.3 Assets identified for re-use

Component name	Short Description and role in the Use Case	Functional role	License
Camera Data Processing Algorithm	This service analyses the RGB pictures of the weeding camera and detects the crops and weeds.	Data analysis	Commercial
Harvest yield monitor	Sensor on the harvest machine that measures harvest weight	Sensing device	Commercial (Precision Makers YieldMasterPro)
Crop Growth Web Service	Web service for monitoring crop growth	Application support	Commercial

Component name	Short Description and role in the Use Case	Functional role	License
Yield Prediction Web Service	DSS for yield prediction based on crop sensing data	Application support	Commercial

2.15.9 Collaboration with other Use Cases

During the Stakeholder event taken in Almeria (1-2 March 2018) meeting some use cases were identified as interesting use cases to set up collaboration. These use cases are UC1.1 (arable within field management zoning), UC1.2 (sensors network for smart wheat crop management) and UC1.3 (soybean protein management). Until now there is no concrete collaboration yet. We are investigating for concrete collaboration in the coming period.

2.15.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets.

The following Table 70 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability

Table 70 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC4.3)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May ‘18)	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	9	- GPS unit (1 per tractor) - Weeding Machine (1 per tractor) - Camera Unit Weeding Machine (1 per weeding machine) - SideShift Weeding Machine (1 per weeding machine) - Hoeing Elements (1 per weeding machine) - Height sensor (2 per weeding machine) - Air pressure sensor (1 per weeding machine)) - Wheel sensor (1 per weeding machine)
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	10	- Embedded PC Weeding Machine (1 per weeding machine) - Harvest machine (1 (contractor)) - Harvest board computer (1 per harvest machine) - Harvest yield monitor (1 per harvest machine) - Farm cloud platform (1) - Weeder cloud platform (1) - Cloud data authorisation (1) - Local farm PC (1 per farm) - Yield Prediction cloud service (1)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May ‘18)	Short comment / qualitative estimation
			- Weather cloud service (1)
	Number of IoT applications available	2	- Yield Prediction cloud service (1) - Weather cloud service (1)
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1
	Number of FIWARE GEs instances	0	
	Number of open datasets used	0	
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	/	Not yet available
	Average number of installations per reusable IoT component	/	Not yet available
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	0	
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies	0	

2.16 VEGETABLE UC 4.4: ENHANCED QUALITY CERTIFICATION SYSTEM

The main goal of this UC is to enable a revolution in the support to certification schemes and integration. The certification of agro-food systems and products is a pillar of EU quality policy, implemented through the wide regulatory framework on PDO production, put into place more than 40 years ago, and the organic production system regulation, in force for more than 20 years. At world level the EU is a frontrunner in quality systems, often followed by other countries that refer to EU as an example. Currently, a large share of EU food and beverages market value (especially export) is due to guaranteed quality products (wines, cheese, olive oil, cured processed meat ... and organic). The quality guarantee system allows EU food products to enter world markets and keep their high-quality profile and consequently the revenues.

To offer an improvement in terms of reliability and agility of implementation, IoT can provide solutions based on traceability tools, on-line registration of operations, continuous mass balances basis on sensors and immediate communication to producer and to certification bodies. This UC will try to facilitate the process to recover all the information needed to obtain the precise quality associate to the Vine production in which EU countries have an important presence in terms both of production and exports (SIAN is the national log book register. All the operation done on wine are registered daily on this system).

2.16.1 Domain model

The domain model for UC4.4 is depicted in Figure 78.

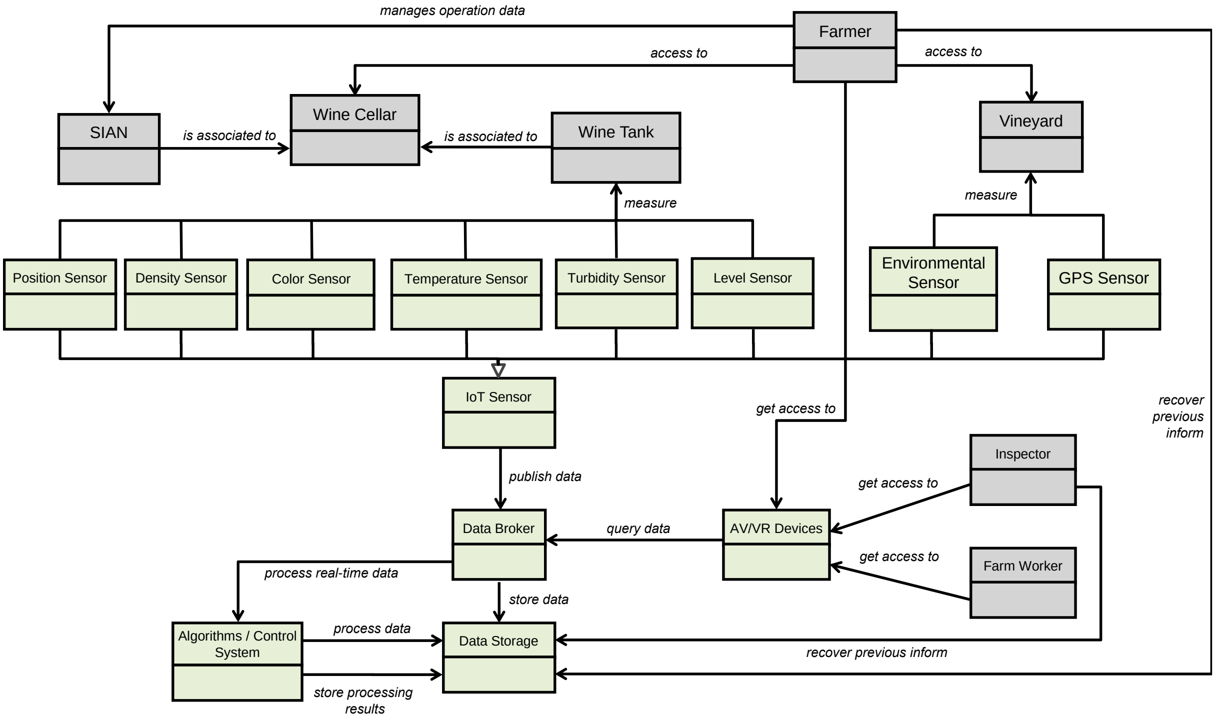


Figure 78 - UC4.4 Domain Model

In this use case, a **Farmer** is interested in monitoring and optimizing the Wine Quality and Vineyard production in order to obtain a complete traceability from the field to the bottle of the quality of the wine product, in the same way that they can obtain a complete proof of concept about the wine quality and the production method that was used to produce their wine. He is also in charge of performing daily updates of operation data to **SIAN**, the National Agricultural Information System, as well as manage and maintain this data. SIAN is a kind of national log book register. All the operations done on wine are registered on this system per daily basis.

Inspectors, can access to the information that it is published by the Wine Cellar related to the management of the wine production and will take in an easy way all the information needed to certificate the quality of the wine. The introduction of this architecture facilitates the process to collect data and produce automatic analysis about the quality of the product. Additionally, the quality inform that it is produced during the Quality Certification process is stored in the system. In this way, the farmers and inspectors have the possibility to take a look to the previous informs and take decision about the next steps to improve the production quality. They can also get SIAN information and check whether the notified data is correct or not.

Farm Workers, can access to the different monitoring information and take decision almost in real time to improve the overall quality of the wine production. Additionally, the different operations that they were actuating in the Vineyard and the results of those operations will be kept for historical purpose in order to have all the treatments that were taking into the vineyard and the results that they were produced.

In the end, the interactions between **Farmers**, **Farm Workers** and **Inspectors** with this solution are will be definitely improved and therefore they will know in real time what is the status of the field what are the treatment that they keep and more important what is the quality of the product and how we can improve it.

Vineyard will be monitored in terms of environmental conditions in order to know whatever information that could be relevant to know on every moment the estimated production of grapes and the quality from them. Therefore, each vineyard operation is registered to know why we need it and the date in which they are realized, the date in which they were operated and the results obtained from them. **Wine Tank**, it is other important component in terms of Wine Quality, therefore a complete monitoring of the wine conditions should be kept in order to know the quality of the production. This one is the smallest element that can be monitored in the cellar. Different measurements are kept from different tanks to be sure that the quality of the result is in line with the expected results. For this reason, **Wine Cellar** kept different quality values for each Wine Tank to produce accordingly a homogenised quality results in the wine production. Additionally, this solution could introduce the possibility to produce different wine qualities, depends of the market and final consumer or just facilitate to know which Wine Tank we should use to produce a high-quality product.

IoT Sensors (Environmental Sensor, GPS Sensor, Position Sensor, Density Sensor, Color Sensor, Temperature Sensor, Turbidity Sensor, and Level Sensor) are used to monitor a wide number of physical parameters associated to the field and to the Wine Tank. They are either permanently **connected** (installed in fixed position into the Wine Tank in order to produce context information periodically through any wireless technology) or **nomadic** (they are deployed only in punctual time to produce a measurement and record the context information, which is the case of GPS and Position Sensor).

The context information provided by IoT Sensors are collected by the **Data Broker** in order to keep the current status of all the Vineyard and Wine Tank. This information will be used to be shown in the AR / VR Devices to inform Farmers, Farm Workers and Inspectors in real time of the overall status of the production. Besides, the context information is sent to the historical data base in the **Data Storage** component.

The **Algorithms / Control System** will analyse the context information data and provide actions (decisions) based on predefined rules to improve the production quality. It should work either in **real time** (taking the information directly from the Data Broker) or make **predictive analysis** (taking into account the historical information that it is kept in the Data Storage system).

2.16.2 Deployment view

The Deployment diagram for UC4.4 is depicted in Figure 79.

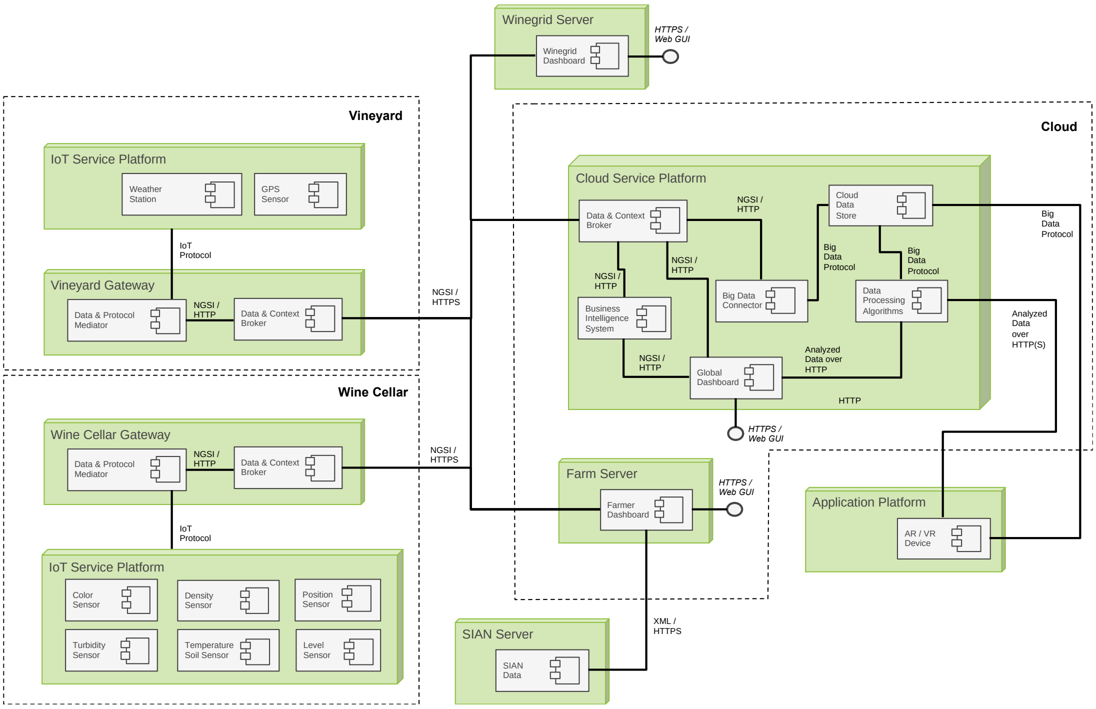


Figure 79 – UC4.4 Deployment View

Components in this UC are deployed either locally (in the **Farm, Wine Cellar** and **Vineyard**) and remotely (in the **Cloud** or in a **Self-Hosted Cloud Server**).

In the Farm, the **IoT Service Platforms** include different sensors (permanently connected and nomadic), used to monitor a wide number of physical parameters. The communication protocol includes but is not limited to MQTT.

A **Data & Protocol Mediators** component is able to understand the different IoT protocols supported by the concerned devices. Therefore, all the context information coming from the different sensors is properly manage. Additionally, this component is in charge of the data harmonization through common information modes. This harmonized data is finally published into the **Data & Context Broker** component.

The **Data & Context Broker** will be storing the current context information of our sensing system. Besides, it offers an API that allows us to consume the information through queries and subscribe to them in order to automatically receive notifications when the status change. Last but not least, it offers an interface that allows to actuate over sensors when it is needed (and it is allowed by them).

There can be algorithms or (complex event processing) that work directly over real time data using **Business Intelligence Systems.** Nonetheless, there is an additional component named **Big Data Connector** that allows to store this real-time information and in all the historical datasets corresponding to the potentially huge volumes of data generated by the system. All this data is moved to a **Cloud Data Store** from which **Data Processing Algorithms** can make some type of analysis and prediction.

Global Dashboard, developed in the Cloud Service Platform, allows the user to collect all the context information received from sensors but also the predictive and analytics results obtained from historical data. The **Farmer Dashboard** deployed in the **Farm Server** is the portal that shows basically the context information recovered by the different sensors just in case that the Farmer can access locally to the information published by those sensors. It also allows the Farmer to get access to the SIAN server, mainly for having operation data daily updated, but also for consulting the data of their own competence. The **Winegrid Dashboard** is provided by WatGrid, the sensor provider, as an alternative way to see real-time data regarding Wine Tanks in the Wine Cellar.

The summary of deployed components for UC4.4 is provided in Table 71.

Table 71 – UC4.4 Deployed Components

Name	Description	Supplier (brand) + Model	Number of units
Orion Context Broker	NGSI-compliant open source Data & Context Broker	FIWARE open source	3 or more depends of Wine Cellar distribution
IoT Agent	In the role of Data & Protocol Mediator, diverse IoT / NGSI Agents capable of understanding LoRa / MQTT or any other IoT communication layer or protocol	FIWARE open source	to be specified
Farm Server	FARM gateway running integration/communication layers	Linux Server	1 per farm

Name	Description	Supplier (brand) + Model	Number of units
Vineyard Gateway	Vineyard gateway running integration/communication layers related to vineyard	Raspberry PI v3 or better	1 per farm
Wine Cellar Gateway	Vineyard gateway running integration/communication layers related to Wine Cellar and Wine Tanks	Raspberry PI v3 or better	1 per farm
Cloud Service Platform	Remote server or service hosting the applications and Historical data	to be specified	1, overall
Local Data Storage	Local non-relational database just to keep the short term historical data to be manage by the dashboard	MongoDB version v3.4	1 per Farm server
AR / VR Device	Provide monitoring information in real time about the quality status of the Vineyard and Wine Tank	to be specified	1 per Farm
GPS Sensor	Provide GPS location of the different	to be specified	1 per Farm (really, we only need to get the location the first time so could be rent).
Environmental Sensor	To provide key environmental parameters such as humidity, temperature, CO2…	to be specified	1 per Farm
Position Sensor	Provide the location of each of the Wine Tank inside of the Wine Cellar	WatGrid - WineGrid	1 per Wine Tank

Name	Description	Supplier (brand) + Model	Number of units
Temperature sensor	To measure wine temperature	WatGrid - WineGrid	1 per Wine Tank
Volumetric Sensor	To measure volumetric content of each Wine Tank	WatGrid - WineGrid	1 per Wine Tank
Color Sensor	A spectrometer to measure wine color	WatGrid - WineGrid	1 per Wine Tank
Turbidity Sensor	To measure wine turbidity	WatGrid - WineGrid	1 per Wine Tank
Business Intelligence System	To make real-time analysis of the context information obtained from the sensors	to be specified	1
Winegrid Server	To provide data visualizations regarding Wine Cellar deployed sensors	Watgrid	1

2.16.3 IoT Functional view

The IoT functional view of this use case (depicted in Figure 80) is structured as following:

- *Application Layer*: in this layer, there is a web-based **Farmer Dashboard** for visualizing collected IoT data in the Farm or Vineyard, as well as for getting access to SIAN server. In the same way, there is a web-based **Global Dashboard** to show also the analysed data from historical storage and also from real-time analysis. Last but not least, Farmers, Farm Workers and Inspectors have the possibility to access to those data through **AR / VR device**.
- *Service Support Layer*: It supports the mediation between different data sources and the data layer through the use of the **Data & Context Broker**. Such data sources are typically IoT devices defined in the Device Layer. Additionally, this layer incorporates all the **Data & Protocol Mediator** to properly harmonise the data as per the information models defined by the project or by existing industry initiatives (GS-1, GSMA, etc.).
- *Data Support Layer:* It is a layer in which all the context information is managed and stored for real-time analysis through **Business Intelligence System** or batch processed using **Data Processing Algorithms**. Besides, the layer provides the **Big Data Connectors** needed to interconnect the data layer with complementary **Cloud Data Stores**, for instance historical databases based on RDBMS, Hadoop or other big database systems.
- *Network layer*: there are both Networking Capabilities and Transport Capabilities that first provide relevant control functions of network connectivity and second focus on providing connectivity for the transport of IoT service and application specific data information. Network and transport connectivity are provided directly from specific technologies. In this use case, the technologies involved could be, but not limited to them, **Wi-Fi**, **LoRa** and **MQTT**. Last but not

least, a VPN dedicate connectivity could be defined, in order to access to the context information and more important to secure the actuations over the different sensors.

- *Device layer*: Placed at the southbound, it is composed by IoT devices, gateways and AR / VR Devices intended to provide all the sensed data to the northbound layers. In addition, it offers common programmatic interfaces, which allow to actuate over devices.
- *Management Capabilities:* in this UC, there is no specific information about management capabilities. So, it is assumed that this UC includes general functions based on the specific technology.
- *Security Capabilities:* in this UC, there is no specific information about security capabilities. So, it is assumed that this UC includes general functions based on the specific technology.

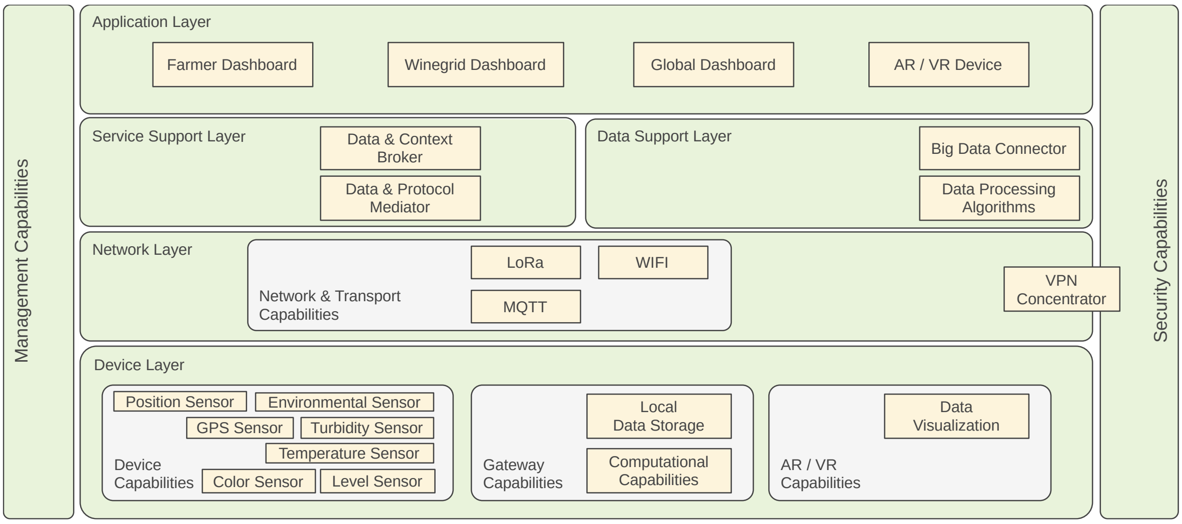


Figure 80 – UC4.4 IoT Functional View

2.16.4 Business Process Hierarchy view

The Business Process Hierarchy view for UC4.4 is depicted in Figure 81.

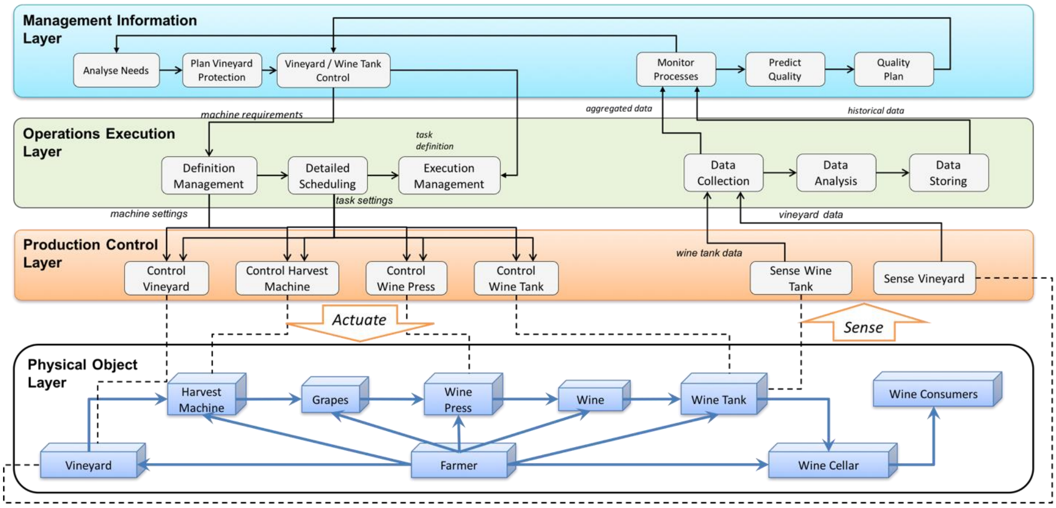


Figure 81 – UC4.4 Business Process Hierarchy view

Business Process Hierarchy View comprises four layers: *Physical Object Layer, Production Control Layer, Operations Execution Layer* and *Management Information Layer*.

In the **Physical Object Layer,** the relevant objects of this UC are depicted: Vineyard, Harvest Machine, Grapes, Wine Press, Wine, Wine Tank and Wine Cellar, that are sensed with IoT sensors and batch data. A Farmer is interested in monitoring and optimizing the quality wine production in the same way that he/she is interested in health status of the vineyard in order to produce the best possible grapes.

The other layers include the main farm processes on different time horizons that are needed in this case to sense and control the physical objects. The starting point is sensing of vineyard and wine tank in the **Production Control Layer** that generated IoT sensors data. This data is collected and analysed in the **Operations Execution layer**. The aggregated data and historical data are used in the **Management Information Layer** to monitor the complete quality chain in the wine production of a wine cellar. Next, an overview of vineyard and wine tanks statuses are calculated based on the context information provided Production Control Layer. This information is used to estimate any correction action to increase the overall production quality of the wine cellar providing a complete and precise information to farmers and farmer workers.

2.16.5 Interoperability Endpoints

The interoperability endpoints are shown on Table 72.

Table 72 – UC4.4 Interoperability Endpoints

Interface name	Exposed By	Protocol(s) *	Notes
Data & Protocol Mediator → Data & Context Broker	Data & Context Broker	NGSI 10	FIWARE NGSI v2
Data & Context Broker → Data & Context Broker	Data & Context Broker	NGSI 10 / NGSI 9	FIWARE NGSI v2 (NGSI 10) NGSI 9: One of the brokers will behave as a context provider so that commands can be executed.
IoT Devices → Data & Protocol Mediator	Data & Protocol Mediator	MQTT / LWM2M	Application-level profiles to be further specified during developments.
Data & Context Broker → Data & Protocol Mediator (Command)	Data & Protocol Mediator	NGSI 9	Mediator will behave as a context provider so that commands can be executed.
Data & Context Broker → Farmer Dashboard	Data & Context Broker	NGSI 10	FIWARE NGSIv2
Data & Context Broker → Big Data Connector	Data & Context Broker	NGSI 10	FIWARE NGSI v2

Interface name	Exposed By	Protocol(s) *	Notes
Big Data Injection → Cloud Data Storage	Cloud Data Storage	to be specified	It depends to the application-level profiles to be further specified during developments.
Cloud Data Storage → Data Processing Algorithms	Big Data Platform	to be specified	Probably HDFS, but It depends to the application-level profiles to be further specified during developments.
Data Processing Algorithms → Global Dashboard	Big Data Platform	to be specified	It depends to the application-level profiles to be further specified during developments.
Data Processing Algorithms → AR/VR Devices	AR/VR Devices	to be specified	It depends to the application-level profiles to be further specified during developments. Probably, we should include here a Data & Protocol Mediator to send data to the AR/VR Devices.
Cloud Data Storage → AR/VR Devices	AR/VR Devices	to be specified	It depends to the application-level profiles to be further specified during developments. Probably, we should include here a Data & Protocol Mediator to send data to the AR/VR Devices.
Farmer Dashboard → SIAN Server	SIAN Server	XML / HTTPS	It depends on SIAN system.

2.16.6 Information model

The Information model for UC4.4 is depicted in Figure 82 and Table 73.

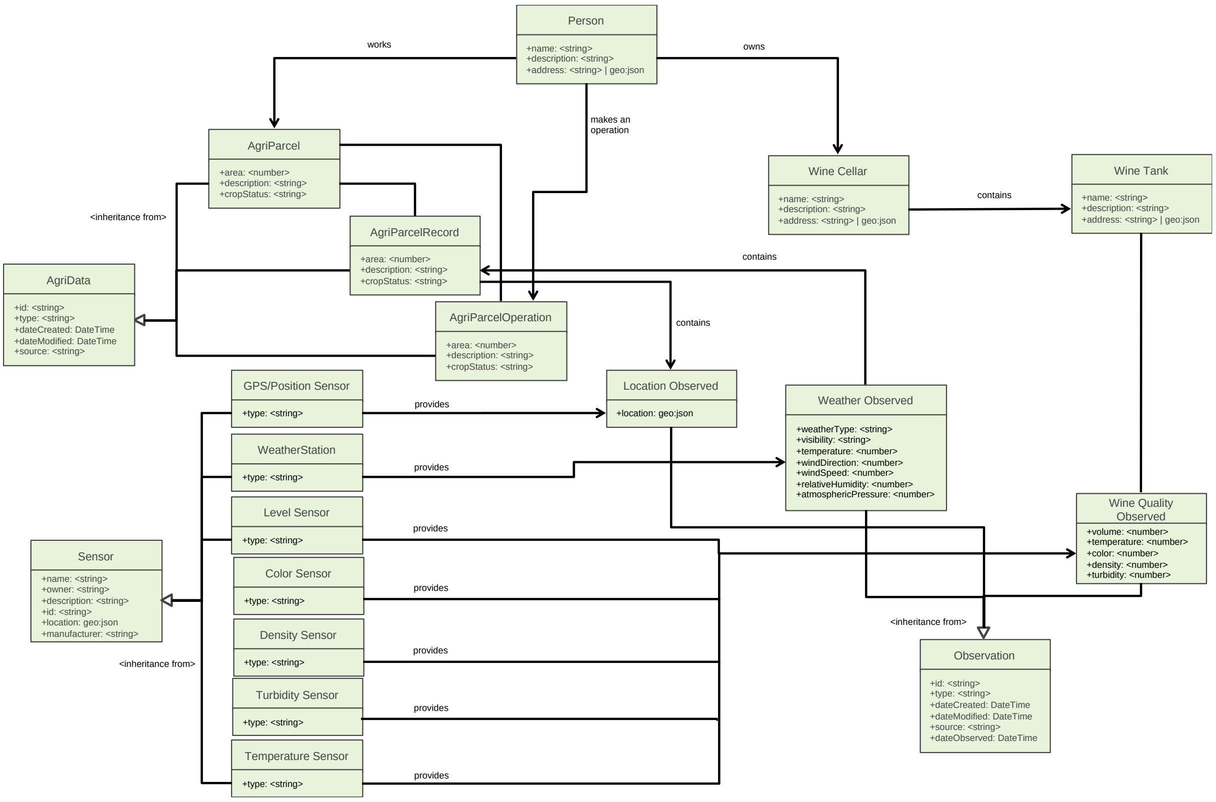


Figure 82 – UC4.4 Information Model

Table 73 – UC4.4 Information Model Details

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model / format
Weather data	Weather station	WeatherObserved	to be specified	GSMA
Soil parameters	Direct from sensors	AgriParcelRecord	to be specified	GSMA + Extensions
Operation data	Direct from Farmer actuations operation	AgriParcelOperation	to be specified	GSMA + Extensions
Orchard parameters	Direct from sensors	AgriParcelRecord	to be specified	GSMA + Extensions
Wine Tank Quality parameters	Direct from sensors	Wine Quality Observed	to be specified	Custom FIWARE NGSI entity

2.16.7 Summary of gaps

The specification of UC4.4 is almost defined, but there are some points not clear.

- The security and privacy management of data is not so clear and it is very important to clarify this aspect in the UC.

2.16.8 Assets identified for re-use

The assets identified for re-use are shown on Table 74.

Table 74 – UC4.4 Assets identified for re-use

Component name	Short Description and role in the Use Case	Functional role	License
Orion Context Broker	Orion is an open source implementation of a context information broker exposing FIWARE NGSIv2 interfaces based on OMA NGSI10.	In the ITU-T Y.2060 IoT Reference Model, this is in the "Service support and application support Layer"	Open source
IoT Agents	Plays the role of protocol and data mediator providing southbound data coming from IoT and other sources to the northbound broker layer.	In the ITU-T Y.2060 IoT Reference Model, this is in the "Service support and application support Layer"	Open source
Cygnus	Plays the role of big data injector providing connection between IoT Data and Big Data platform in order to keep historical data.	In the ITU-T Y.2060 IoT Reference Model, this is in the "Service support and application support Layer".	Open source

2.16.9 Collaboration with other Use Cases

They are not collaborating with other Use Cases at the moment of writing. However, discussion has been fostered to find possible collaborations and introducing reusable components. The involved Ucs are 1.3, 3.1, 3.2, 3.4, 5.1, 5.2, 5.3.

2.16.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets.

The following Table 75 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability

Table 75 - : KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC4.4

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May ‘18)	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	3	- level+temperature sensors on barrel (2) - position sensor on tablet. (1)
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	1	- gateway with wireless network (1)
	Number of IoT applications available	1	- software prototype (1)
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1
	Number of FIWARE GEs instances	1	- FIWARE Orion Context Broker
	Number of open datasets used	0	all the datasets are proprietary
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	2	- FIWARE Orion Context Broker based on NGSI (1) - Cygnus (1)
	Average number of installations per reusable IoT component	/	Not yet available
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	2	- FIWARE Orion Context Broker based on NGSI (1) - Cygnus (1)
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies	0	

2.17 MEAT UC 5.1: PIG FARM MANAGEMENT

The main goal of this UC is to enable a revolution in the management of pig farms via optimal use of data throughout the chain. This UC will work on collecting crucial information, automating data collection and linking data to provide feedback to the farmer via an easy-to-use interface (a Pig Business Intelligence dashboard). This data will then enable valuable information transfer to other relevant stakeholders in the future as well (breeders, food processors, feed suppliers, veterinarians, etc.). The UC will take place in Belgium and Netherlands.

ILVO is the leader partner of the UC and it is responsible for performing a willingness to pay survey, analyse boar taint data and analyse individual level data. Vion is an end-user for slaughterhouses & food processing, ZLTO is an end-user for farmers’ organization task. Porphyrio and ISMB are Technology providers involved in developing Business Intelligence dashboard and IoT platform.

2.17.1 Domain model

The domain model for UC5.1 is depicted in Figure 83.

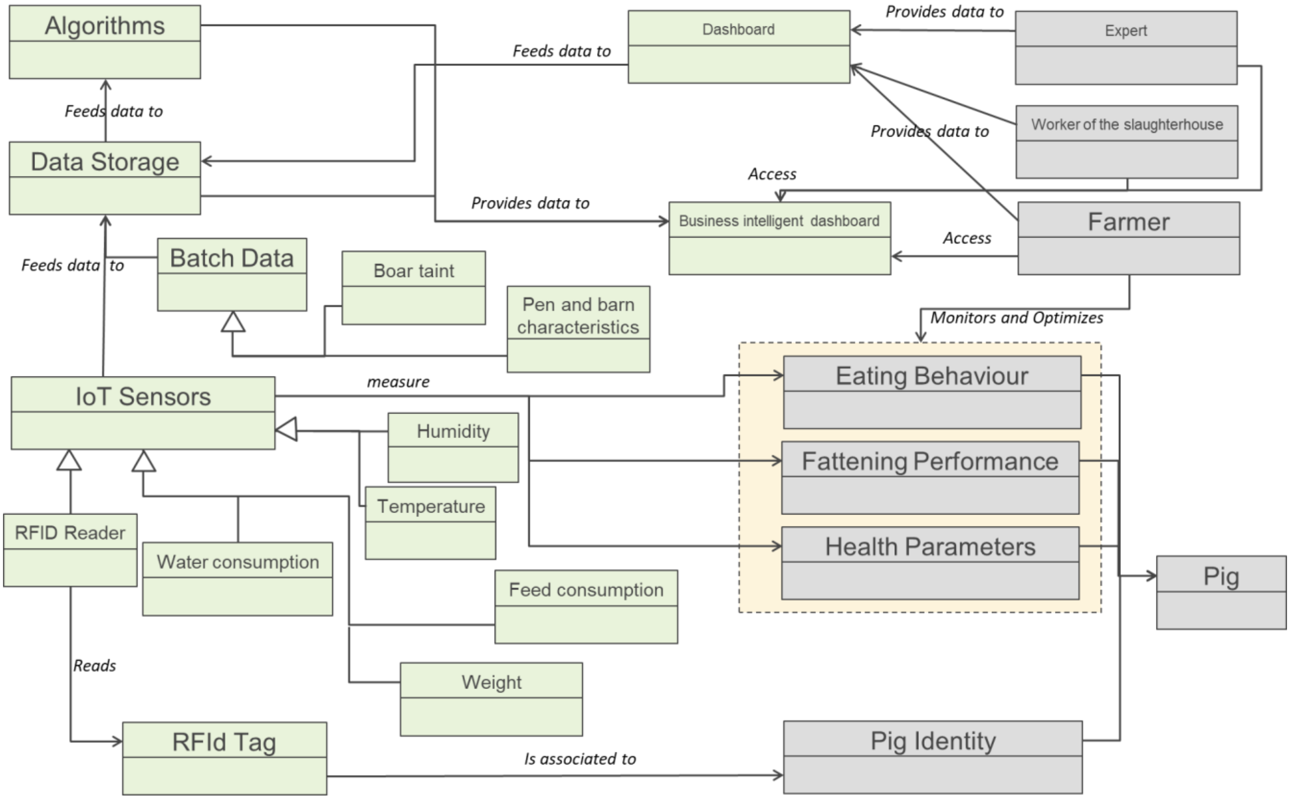


Figure 83 - UC5.1 Domain Model

In this UC, a **Farmer** is interested in monitoring and optimizing the **Feed and Water Consumption**, **Fattening Performance** and **Health Parameters** of Pigs.

IoT sensors deployed in the farm are available to measure such parameters of interest. A special IoT sensor, namely the **RFID Reader**, can be used to track individual pigs in specific areas where other sensors are active. This combination is exploited to associate measures with the Identity of each pig. This is possible because each Pig is associated with a unique **RFID Tag** physically attached to its ear, which is in turn uniquely associated with the **Pig Identity**.

Other IoT sensors are weight scales, **water** and **feed** consumption sensors that, using the information associated with Pig Identity, allow to measure the weight and the water and feed consumption for individual pigs. When RFID identification is not present on these sensors, group level information is obtained without feedback about the individual pigs. This group level monitoring is most commonly used in practice.

Finally, there are **temperature, relative humidity** and **light intensity** sensors used to monitor climate in the barn.

Input data provided from farmers and/or experts are the **Batch Data**. They are **Pen and Barn Characteristics**, information that gives values regarding barns and pens. Another kind of this data is **Boar Taint** that is measured via a human sniffer at the slaughter line, to detect this unpleasant odour that can occur in entire male carcasses.

Data monitored by IoT sensors and batch data are stored to a **Data Storage** System, which feed dedicated **algorithms** suitable to extract eating behaviour, fattening performance and pig health figures – which are made available to the Farmer through a dedicated web-based **Business Intelligent Dashboard**.

Expert, worker of the slaughterhouse and farmer provide data to a dedicated web-based **Dashboard.**

2.17.2 Deployment view

The Deployment diagram for UC5.1 is depicted in Figure 84.

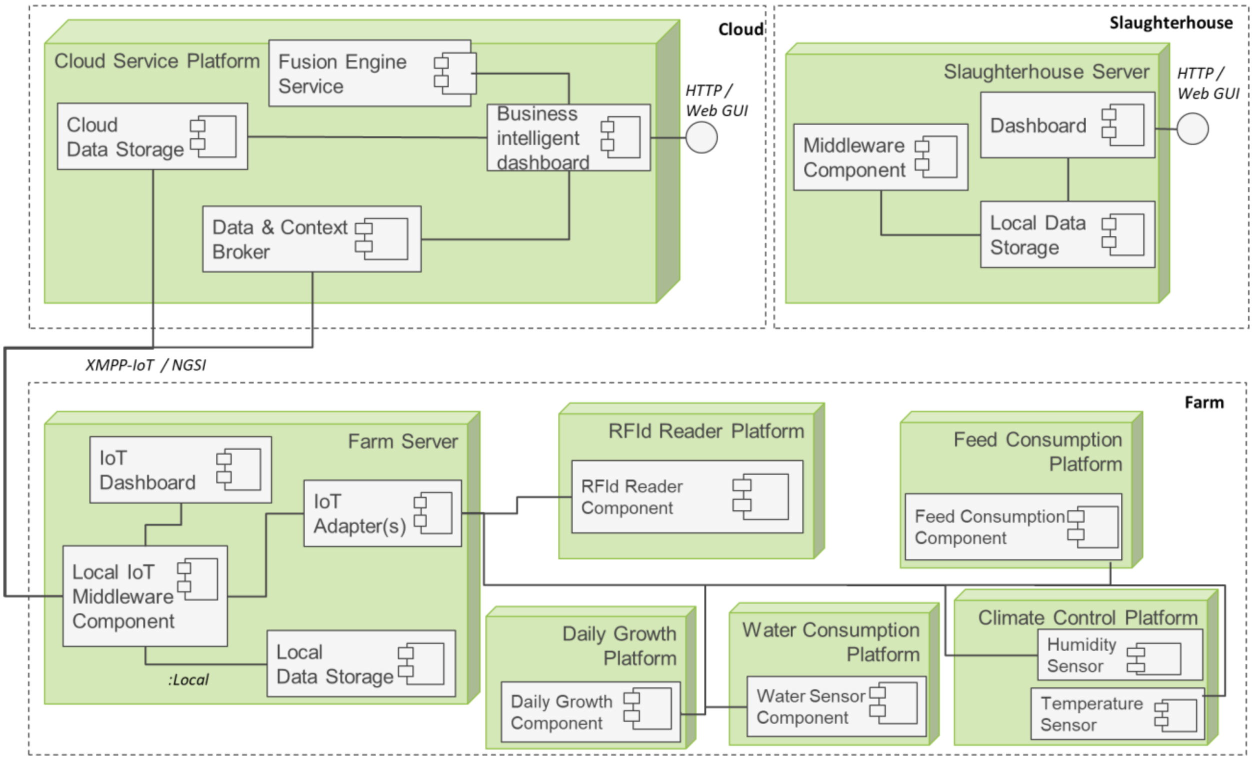


Figure 84 - UC5.1 Deployment View

Components in this UC are deployed either locally (i.e. in the **Farm** and in the **Slaughterhouse**) or remotely (i.e. in the **Cloud** or in a self-hosted cloud server).

In the Farm, five different physicals, dedicated sensor platforms are deployed, namely the **RFID Reader Platform**, the **Water Consumption Platform**, the **Feed Sensor Platform**, the **Daily Growth Platform** and the **Climate Control Platform**. Platform corresponds to a dedicated, stand-alone PC installed in a protected location in the farm. The nodes implementing these five platforms are dedicated PCs, and they are all connected to the local farm Local Area Network (LAN), which is a traditional ethernet-based local network, which is specifically used to inter-connect these nodes to the **Farm Server**.

The Farm Server is a general-purpose ruggedized x86-64 PC running Windows 10 IoT Enterprise, which hosts five dedicated "**IoT Adapter**" components, one "**Local IoT Middleware Component**" and one "**Local Data Storage**" built upon a standard MongoDB installation.

The Farm Server is connected though the Internet to a global VPN, which allows secure communications towards a private Cloud Service platform. The cloud platform runs: a "**Cloud Data Storage**" service and a "**Data & Context Broker**", that receive data via XMPP-IoT or NGSI from Farm Servers; a **Business Intelligent Dashboard**, accessible via HTTPS; and a **Fusion Engine Service** running **Algorithms**.

The summary of deployed components, with the already known suppliers for 1 out of 5 farms, for UC5.1 is provided in Table 76. The components for other farms will be different, and it will depend on the analysis of the technologies already available on the farm.

Table 76 - UC5.1 Deployed Components

Name	Description	Supplier (brand) + Model	Number of Units
Water consumption sensor	Sensor to monitor individual/group water consumption of pigs	GHM Meettechniek Flowmeter MID1-008AP001E with LABO-MID1-008UNS	8
Feed consumption sensor	Sensor to monitor individual/group feed consumption of pigs	Nedap Pig Performance Testing System	4
Daily Growth sensor	Sensor to monitor individual/group weight gain of pigs	Nedap Pig Performance Testing System	4
Climate control	Sensor to monitor climate in the barn (temperature, relative humidity)	Monnit Wireless Temperature, Light & Humidity Sensor - Commercial Coin Cell Powered	12
Others (f.e. cough index)	Other sensors available at the farms	to be specified (Cough monitor)	to be specified
RFID Reader	RFID Reader for feeding and drinking patterns of individual pigs	HF RFID system (FEIG/DTE Automation)	8 for drinking + 4 for feeding
RFID Tags	RFID tag attached to pig	HID Global IN Tag 300SLI, and other type for ind. feed consumption (to be specified)	500
Slaughterhouse Local DB	Data base including slaughterhouse recordings of 2000 pigs	VION database	1 per slaughterhouse
Slaughterhouse Middleware Component	Slaughterhouse gateway running integration/ communication layers including VIRTUS, ebbits middleware components and adaptation layers	to be specified	1 per slaughterhouse

Name	Description	Supplier (brand) + Model	Number of Units
Slaughterhouse Dashboard	Web-based dashboards for visualize and insert data	ISMB	1 per slaughterhouse
Farm Local IoT Middleware Component	FARM gateway exposing data to other components	Advantech Fanless Box PC ARK-2230L	1 per farm
Farm IoT adapters	FARM gateway running integration/ communication layers including VIRTUS, ebbits middleware components and adaptation layers	ISMB	1 per farm
Farm Local Data Storage	Local database installed in farm	Mongo DB	1 per farm
Overall Cloud Service	Remote server or service hosting the applications	to be specified	1
Cloud Business Intelligent Dashboard	Web-based dashboards for visualize and insert data	PORPHYRIO	1
Cloud Data Storage	Cloud database	Mongo DB	1
Data & Context Broker	NGSI-compliant open source data & context broker	*FIWARE open source*	1

2.17.3 IoT Functional view

The IoT functional view of this UC (depicted in Figure 85) is structured as following:

- *Application Layer*: in this layer, there is a web-based dashboard to visualize collected IoT data.
- *Service support and application support layer*: both Generic support capabilities and Specific support capabilities are shown in this use case. There are particular capabilities like **Business Intelligence Dashboard** to analyse data and provide an overview of farm status and warnings in case status is not optimal; a **Fusion Engine Service** to elaborate the data. In addition, there are common capabilities, which can be used by different IoT applications, such as **Cloud Data Storage** and **Data & Context Broker**.

- *Network layer*: there are both Networking Capabilities and Transport Capabilities that first provide relevant control functions of network connectivity and second focus on providing connectivity for the transport of IoT service and application specific data information. Network and transport connectivity are provided directly from specific technologies. In this UC, the technologies involved are Wi-Fi, GPRS, XMPP-IoT, and NGSI. The same happens for Mobility Management Capabilities that use specific protocols based on the technology used.
- *Device layer*: in this UC, there is no specific information about the device layer. So, it is assumed that this UC includes general functions of device and gateway. Device Capabilities include **sleeping and waking-up** to reduce energy consumption; the sensors and actuators are able to gather and upload information **directly or indirectly** to the communication network and can **directly or indirectly** receive information from communication network. The devices in this UC can construct networks in an ad-hoc networking based on the specific technology. Regarding Gateway Capabilities, supported devices are connected through different kinds of wired or wireless technologies (**multiple interfaces**) and **protocol conversion**.
- *Management Capabilities:* in this UC, there is no specific information about management capabilities. So, it is assumed that this UC includes general functions based on the specific technology.
- *Security Capabilities:* in this UC, there is no specific information about security capabilities. So, it is assumed that this UC includes general functions based on the specific technology.

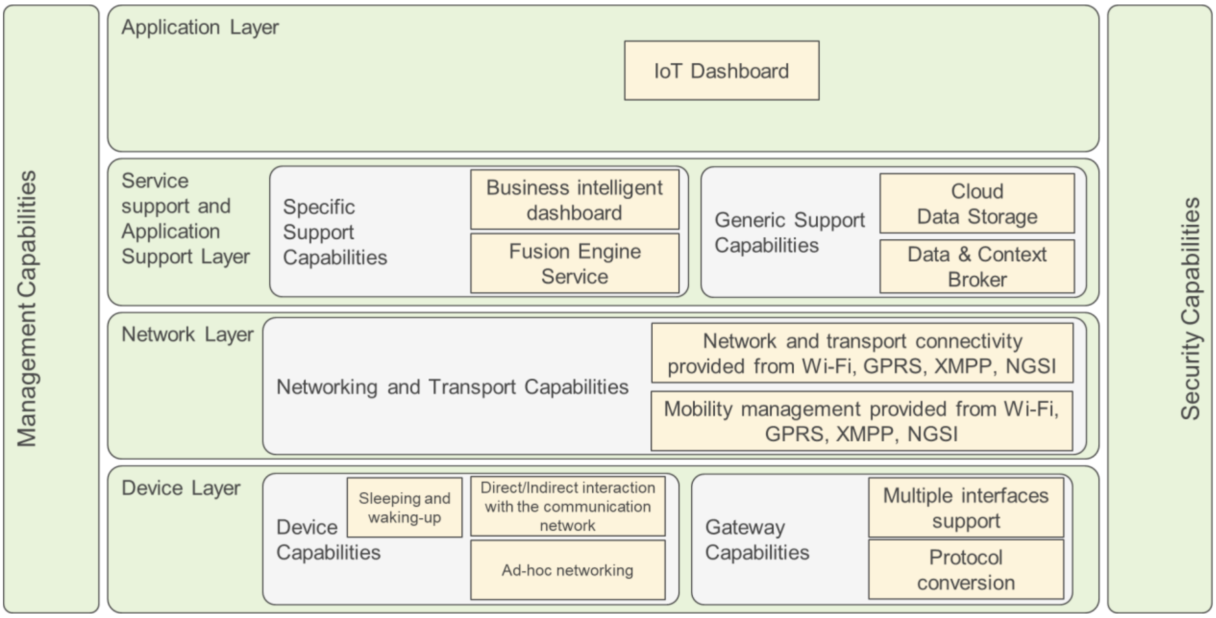


Figure 85 - UC5.1 IoT Functional View

2.17.4 Business Process Hierarchy view

The Business Process Hierarchy view for UC5.1 is depicted in Figure 86.

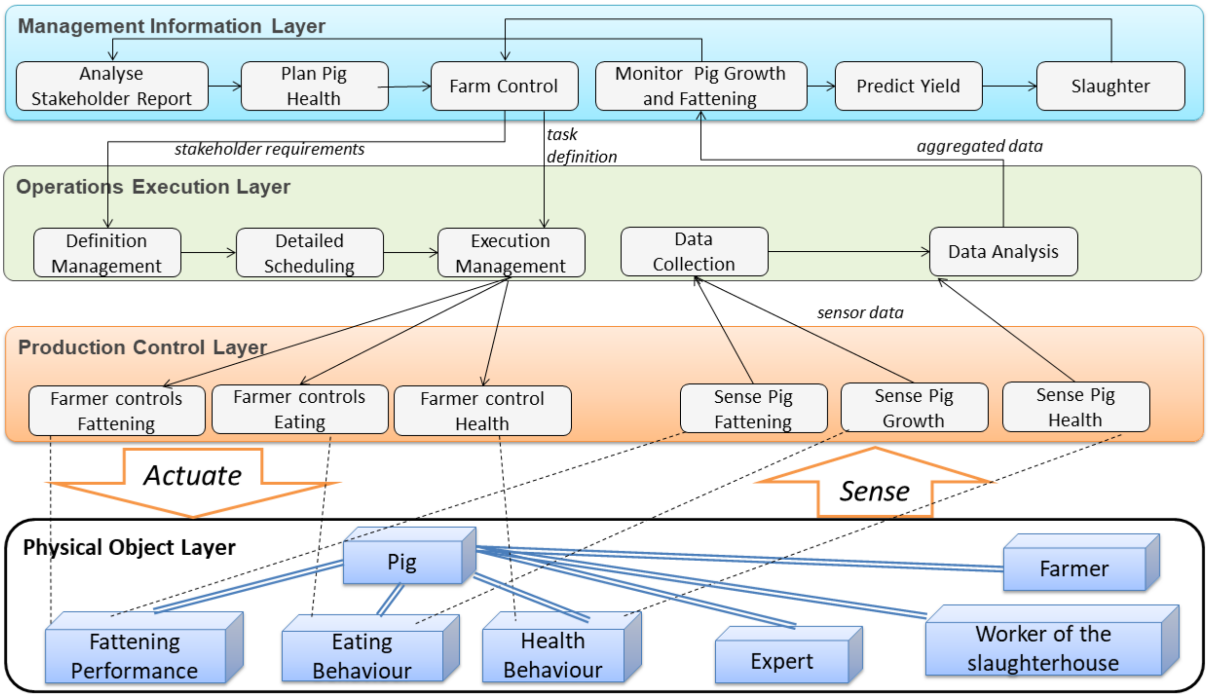


Figure 86 - UC5.1 Business Process Hierarchy view

Business Process Hierarchy View comprises four layers: *Physical Object Layer, Production Control Layer, Operations Execution Layer* and *Management Information Layer*.

In the **Physical Object Layer,** the relevant objects of this UC are depicted: fattening performance, eating behaviour, health behaviour, that are sensed with IoT sensors and batch data. A Farmer is interested in monitoring and optimizing the Eating Behaviour, Fattening Performance and Health Parameters of individual Pigs. An expert is interested to access the system in case of boar taint problems detected, and workers of the slaughterhouse to provide data regarding carcass, boar taint, transport and waiting times.

The other layers include the main farm processes on different time horizons that are needed in this case to sense and control the physical objects. The starting point is sensing of pig fattening and growth in the **Production Control Layer** that generated IoT sensors data. This data is collected and analysed in the **Operations Execution layer**. The aggregated data is used in the **Management Information Layer** to monitor pig growth and fattening. Next, an overview of farm status and pig health is calculated based on the pig growth and fattening monitoring, providing information for farmer, expert and worker of the slaughterhouse.

2.17.5 Interoperability Endpoints

The interoperability endpoints are shown on Table 77.

Table 77 - UC5.1 Interoperability Endpoints

Interface name	Exposed by	Protocol	Notes
Water Consumption Sensor Interface	Water Consumption Sensor	GHM Meettechniek Flowmeter MID1-008AP001E with LABO-MID1-008UNS	It will probably be a wired sensor
Feed Consumption Sensor Interface	Feed Consumption Sensor	to be specified	It will probably be a wired sensor
Daily Growth Sensor Interface	Daily Growth Sensor	to be specified	It will probably be a wired sensor
Climate Control Interface	Climate Control	Monnit Wireless Temperature & Humidity Sensor - Commercial Coin Cell Powered	It will probably be a wireless sensor
Other sensors interface	to be specified	to be specified	It will probably be a wired sensor
RFId Reader Interface	RFId Reader	LLRP (over IP, local)	Global EPC Standard
RFID Tag interface	RFID Tag	UHF or HF	(These Standards RFID radio protocols)
Slaughterhouse DB interface	Slaughterhouse Local Data Storage	Standard SQL End-point (over IP)	Only available on local network.
Slaughterhouse Server interface	Slaughterhouse Middleware Component	XMPP/Virtus or MQTT/Linksmart	Application-level profiles to be further specified during developments
Farm Server interface	Farm Server	XMPP/Virtus or MQTT/Linksmart + ICE 2	Application-level profiles to be further specified during developments
Cloud Service DB Interface	Cloud Data Storage	XMPP/Virtus or HTTP/Virtus	Application-level profiles to be further specified during developments

Interface name	Exposed by	Protocol	Notes
Data & Context Broker	Cloud Service Platform	NGSI	Connection between Farm Platforms and Porphyrio Platform through FIWARE´s context Broker

2.17.6 Information model

The Information model for UC5.1 is depicted in Figure 87 and Table 78.

On the left side, there are the entities of sensors and they have, like minimal information, a unique identifier. Those sensors are classified in “Raw Sensor Data” and they are humidity, temperature, water consumption, feed consumption and presence sensors. Drinking event, that is derived from water consumption and/or presence, has a unique identifier, duration is used for describing the period of event and timestamp_start shows the time when the event is started. The same applies for eating event that it is derived from feed consumption and/or presence.

An RFID tag, that it has a tag_id in Unique identifier (UID) format, is associated to a pig. Every drinking event and eating event are in correlation with RFID tag, so in this way it is possible to link each event to a pig. Daily growth, health and genetics data are batch data, linked with the pig. Climate entity is a batch data and is derived from humidity and temperature entities, linked to a specific barn or pen.

Other batch data, useful for the system, are boar taint, carcass parameters and transport & waiting time that are linked with slaughter. Finally, pen and barn characteristic and survey are batch data and they are linked with farm. These have, like minimal information, a unique identifier.

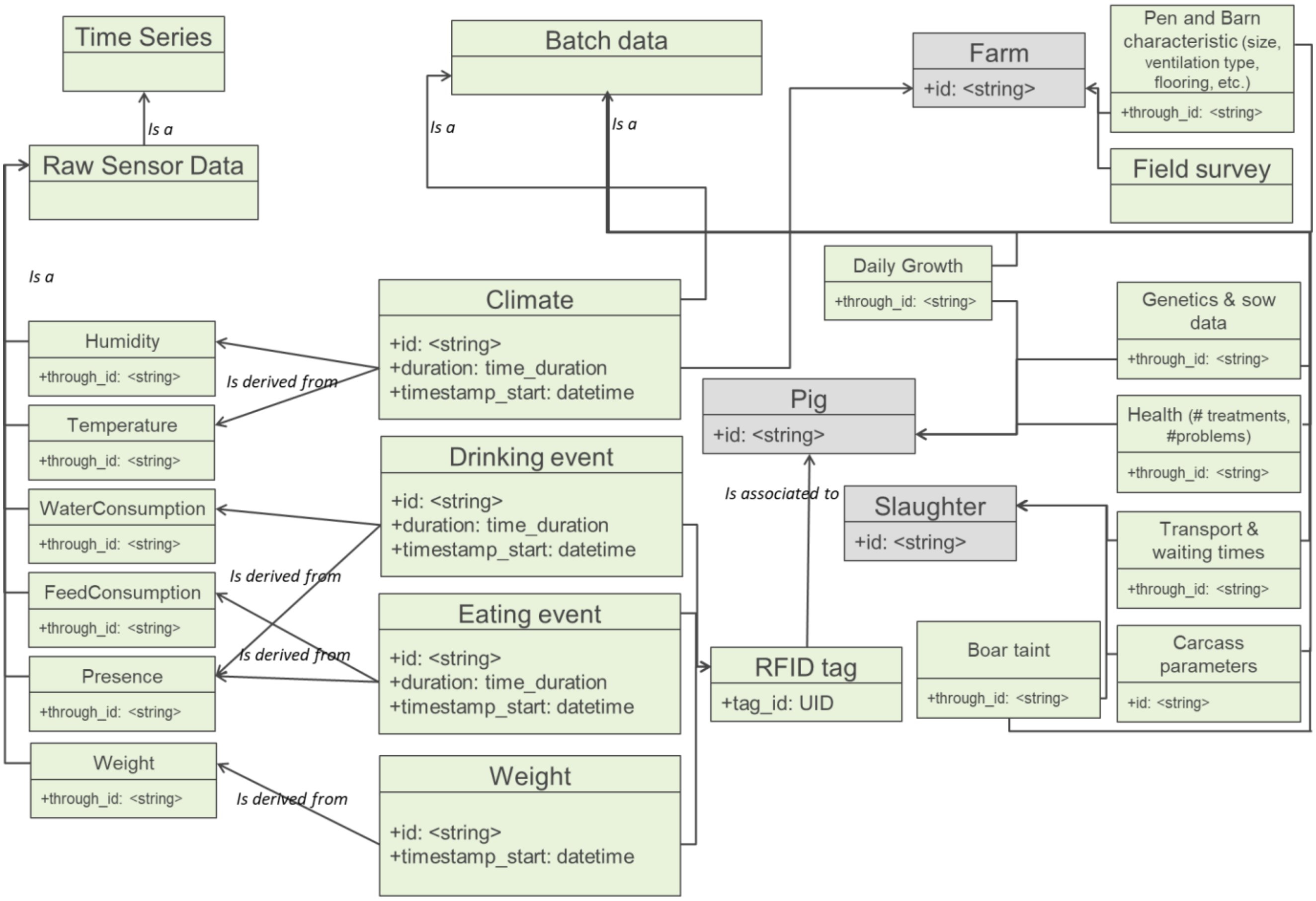


Figure 87 - UC5.1 Information Model

Table 78 - UC5.1 Information Model Details

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Survey results	Electronic survey	People	1 survey	
Carcass data	VION database	All batches	At slaughter	Carcass parameters from VION database
Boar taint	Human sniffers	All batches	At slaughter	Occurrence (%)
Transport & waiting times	Schedules	All batches	At slaughter	Duration (hr)
Genetics & sow data	FMIS	All batches	At insemination & birth	Boar and sow line, parity, # piglets

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Pen and Barn characteristic	Site visit	All batches	Once per barn	Size (m²), ventilation type, flooring, etc.
Batch characteristics	Notes, site visit	All batches	Once per batch	Pen, group size, composition, etc.
Health	Notes, treatments	All batches	Daily	Treatments (#), problems (#)
Water Consumption	Sensor	All batches	1x /hour	Water consumed (Litres)
Feed Consumption	Sensor	All batches	1x /hour	Feed consumed (Kg)
Daily Growth	Sensor	All batches	1 x / day	Weight measured (Kg)
Climate	Sensor	All batches	1 x / day	Temp (°C), Humidity (RH)
Ind. feed consumption	Feeding station + RFID	60 pigs *3 rounds	1 x / hour	Feed consumed (Kg), timestamps (start/end)
Ind. weight	Weighing scale + RFID	120 pigs *3 rounds	1 x / day	Weight (Kg), timestamp
Ind. water intake	Flowmeter + RFID	120 pigs *3 rounds	1 x / hour	Water consumed (Litres), timestamps (start/end)
Ind. feeding behaviour	RFID sensor	120 pigs *3 rounds	1 x / hour	RFID readings
Ind. drinking behaviour	RFID sensor	120 pigs *3 rounds	1 x / hour	RFID readings

2.17.7 Summary of gaps

The specification of UC5.1 is almost defined, but there are some points not clear.

- At present time, there are some test farms that need further specification and to be defined.
- For reasons of data confidentiality, it is necessary to understand what data can be shared with the use case 5.3

2.17.8 Assets identified for re-use

The assets identified for re-use are shown on Table 79.

Table 79 - UC5.1 Assets identified for re-use

Component name	Short Description and role in the Use Case	Functional role	License
Water consumption sensor	Sensor to monitor individual/group water consumption of pigs	In the ITU-T Y.2060 IoT Reference Model, this is in the “Device and Network Layer” In the Business Process Hierarchy view, this is in “Physical Object Layer”	This is a hardware component (no special licenses needed)
RFID Reader	RFID Reader for feeding and drinking patterns of individual pigs	In the ITU-T Y.2060 IoT Reference Model, this is in the “Device and Network Layer” In the Business Process Hierarchy view, this is in “Physical Object Layer”	This is a hardware component (no special licenses needed)
RFID Tag	RFID tag attached to pig	In the ITU-T Y.2060 IoT Reference Model, this is in the “Device and Network Layer” In the Business Process Hierarchy view, this is in “Physical Object Layer”	This is a hardware component (no special licenses needed)
Farm and Slaughterhouse Gateways	Farm and Slaughterhouse gateway running integration/communication layers	In the ITU-T Y.2060 IoT Reference Model, this is in the “Device and Network Layer” In the Business Process Hierarchy view, this is in “Physical Object Layer”	Apache v2

Component name	Short Description and role in the Use Case	Functional role	License
Cloud Service	Service hosting the applications	In the ITU-T Y.2060 IoT Reference Model, this is in the “Service support and application support layer” In the Business Process Hierarchy view, this is in “Production Control Layer” and “Operations Execution layer”	Apache v2
Data & Context Broker	Orion is an open source implementation of a context information broker exposing FIWARE NGSIv2 interfaces based on OMA NGSI10.	In the ITU-T Y.2060 IoT Reference Model, this is in the “Service support and application support layer” In the Business Process Hierarchy view, this is in “Production Control Layer” and “Operations Execution layer”	Affero General Public License (GPL) version 3

2.17.9 Collaboration with other Use Cases

They collaborated with UC 5.2 to:

- introduce the FIWARE Orion Context Broker and all the related plugins to address security needs;
- reuse the dashboard already developed for their UC and already able to interact with Orion
- recreate a data model similar to the one already used in the UC 5.2 as compatibility measure.

They also collaborated with UC 5.3 to:

- improve the data model to better respect standards
- let UC 5.3 suggests measures to foster transparency and traceability.

2.17.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets.

The following Table 80 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability

Table 80 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC5.1)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May '18)	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	540	- RFID tags (500) - heterogeneous sensors (40)
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	8	- Slaughterhouse Local DB - Slaughterhouse Middleware Component - Farm Local IoT Middleware Component - Farm IoT adapters - Farm Local Data Storage - Overall Cloud Service - Cloud Data Storage - Data & Context Broker
	Number of IoT applications available	3	- Slaughterhouse Dashboard - Farm IoT Dashboard - Cloud Business Intelligent Dashboard
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1
	Number of FIWARE GEs instances	3	- Fiware Orion Data & Context Broker (replicated in each farm) - Fiware Identity Manager (1) - Fiware PEP Proxy (1)
	Number of open datasets used	0	
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	/	Not yet available
	Average number of installations per reusable IoT component	/	Not yet available
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	2	- FIWARE Orion Context Broker based on NGSI - VIRTUS based on XMPP-IoT, MQTT protocol, RFID
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies	/	Not yet available

2.18 MEAT UC 5.2: POULTRY CHAIN MANAGEMENT

The main goal of this UC is to have an efficient growth and improvement of physical condition of poultry to obtain a desired and accurate end weight and physical condition required by the processing plant, respecting the animal welfare. This will be done linking the different steps of the chain (farm, logistics and processing), using sensor technologies and smart data analytics on big data platforms. In that sense, this UC will operate at three levels, where IoT technology brings value, and moreover, linkage between these steps adds the second level of value.

1. Farm level – Need to monitor and optimize growing process
2. Logistics – Need to monitor and optimize broiler handling and transport, including planning
3. Processing plant – Need to optimize slaughtering and improve profitability and product-market fit

This use case will collect crucial information in each of the steps, in order to provide data analysis through different models (weight predictor model, comfort model…) and easy to use dashboards to the different operators of the ecosystem (farmers, vets, slaughterhouse managers…).

IK4-TEKNIKER is the leader partner of the UC and will be the responsible of the deployment and evolution of the WSN to measure different parameters (humidity, temperature, luminosity, ammonia, CO_2) on farms and trucks, as well as collaborating with PORPHYRIO as technology providers for Business Intelligence dashboard, IoT platform and data analytic models. SADA is the end user owner of the farms, transport and slaughterhouse infrastructure, whose role will be based on the Definition of the overall requirements of the UC. Last, EXAFAN will be the responsible of the integration and evolution of their farm equipment with the UC architecture.

2.18.1 Domain model

The domain model for UC5.2 is depicted in Figure 88.

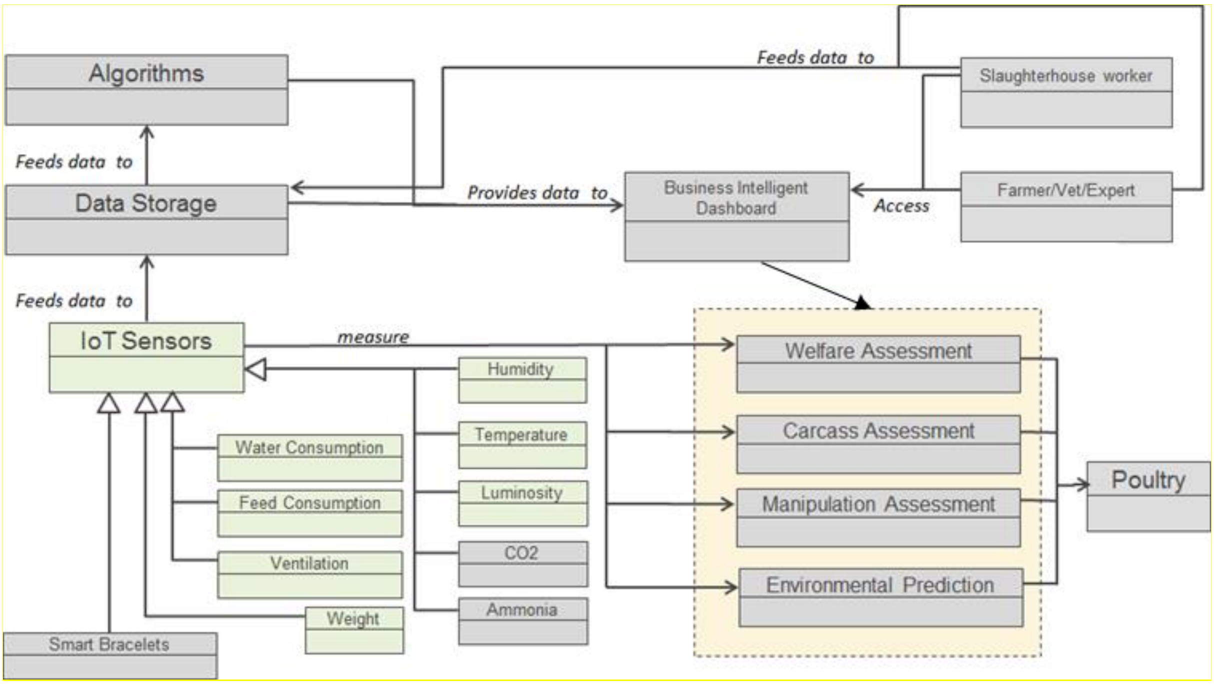


Figure 88 - UC5.2 Domain Model

In this UC, the farmer, vet and expert are interested in monitoring and optimizing the comfort, manipulation and growing performance of poultry. IoT sensors are deployed in the farm to measure the parameters, indicated in Figure 88. Data monitored by IoT sensors is locally and remotely stored to a Data Storage System, which feed dedicated algorithm suitable to extract Welfare, Carcass, Manipulation Assessment and Environmental Prediction models – which are made available to the Farmer, Vet, Expert and slaughterhouse worker through a dedicated web-based Business Intelligent Dashboard. The statistical data of the different batches is also introduced into the data storage to feed the different algorithms, both during the farm phase (i.e. number of deaths) or at slaughterhouse level (i.e. the average weight).

2.18.2 Deployment view

For the better understanding of the deployment view diagrams, these have been divided in three parts; Figure 89, where the cloud services and their interactions are represented; Figure 90, where the farm components and their interactions between them and between the cloud services are shown, for phase 1 and 2 respectively; Figure 91, where the transport and slaughterhouse components and their interactions between them and between the cloud services are shown, for phase 1 and 2 respectively.

Components in this UC are deployed either locally (i.e. in the Farm and Slaughterhouse) or remotely (i.e. in the IK4-TEKNIKER's Servers Infrastructure and in a self-hosted cloud server hosted by project partner PORPHYRIO).

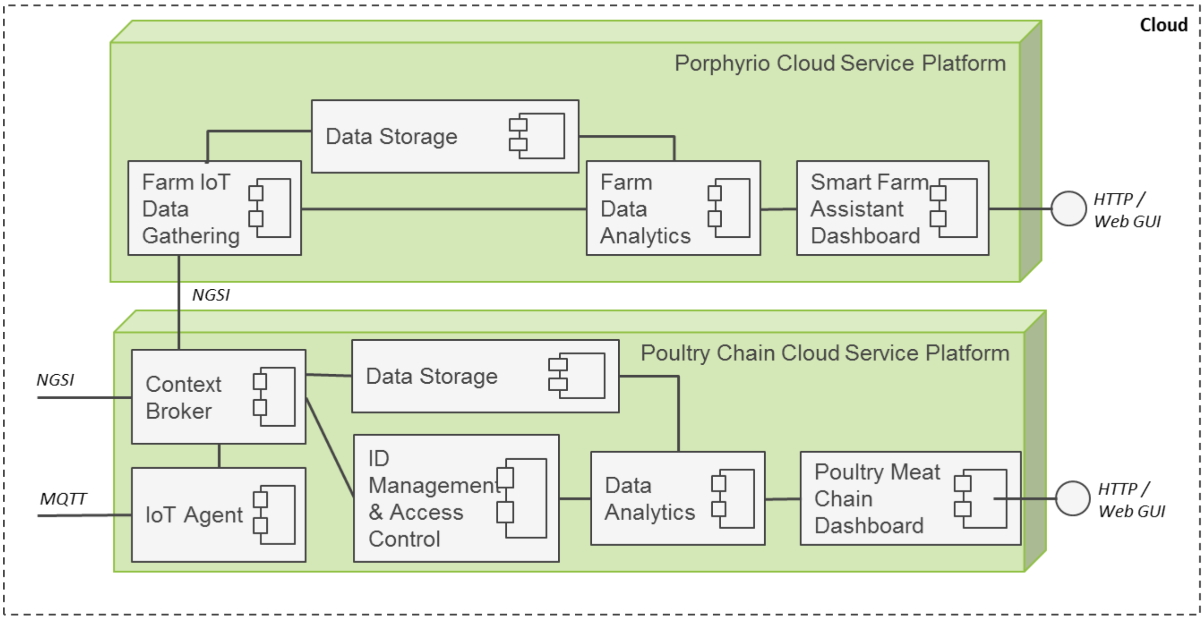


Figure 89 –UC5.2 Cloud Deployment Diagram

The architecture has been designed to include already developed cloud services of PORPHYRIO in the farm and new services that are going to be developed at chain level by IK4-TEKNIKER based on FIWARE components. In that sense, the information collected in the farm will be collected by the FIWARE context broker, directly through NGSI interfaces or through the IoT Agent (by MQTT) depending on the IoT device deployed in the device layer (see the following figure and explanation). In the Poultry Chain Cloud platform, several processes will be developed, such as data storage, ID Management and Access Control, Data Analytics for the development of different models, and visualization through the Poultry meat Chain Dashboard. Besides, Context Broker provides the interface between Poultry Chain Cloud and PORPHYRIO Cloud platforms through a NGSI interface, to exchange needed information to perform specific services (data from farms, results of specific models from PORPHYRIO data analytics, etc…)

The following figures explain farm components and their relations.

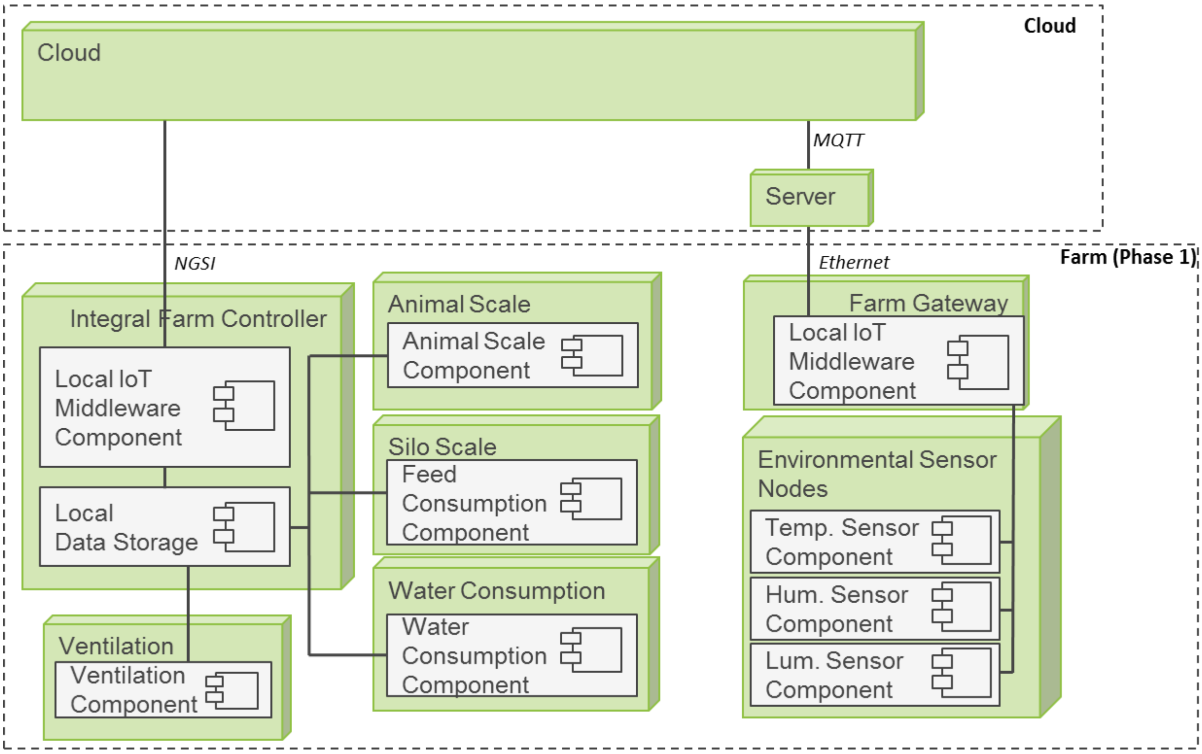


Figure 90 – UC5.2 Farm Deployment Diagram (Phase 1)

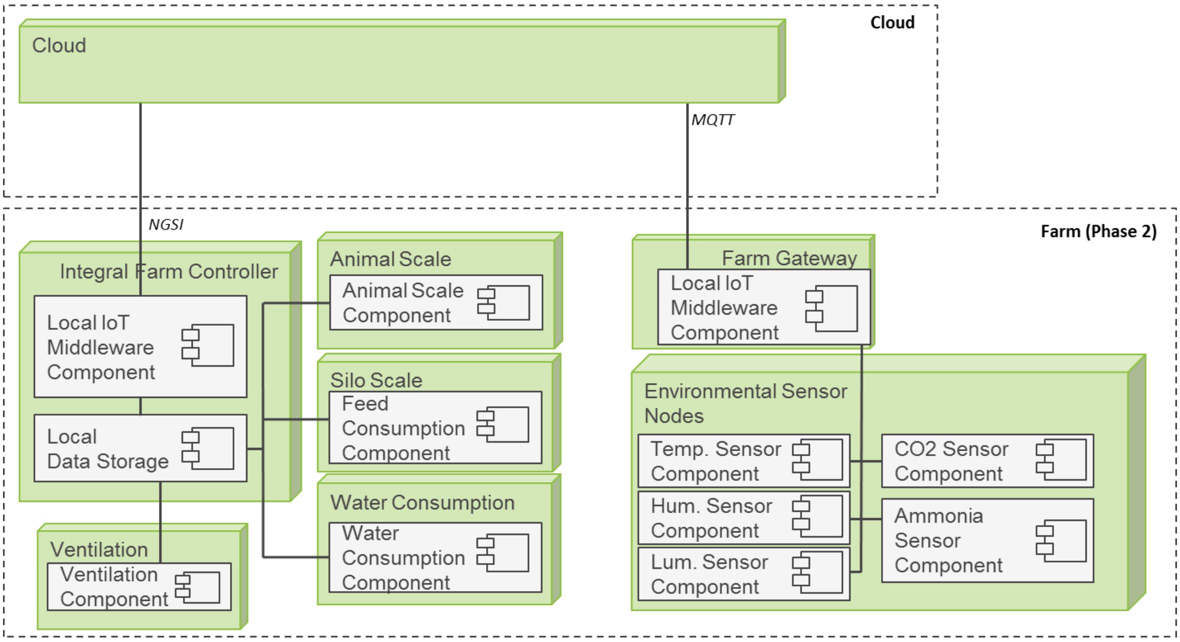


Figure 91 – UC5.2 Farm Deployment Diagram (Phase 2)

In the Farm, four different physical, dedicated sensor components are deployed, namely the Animal Scale, the Silo Scale, Water Consumption and the Environmental Sensor Nodes. Each component corresponds to a dedicated, specific sensor hardware node(s). Besides, there are two different Controllers or Gateways:

- The integral Farm Controller which is a dedicated standalone computer able to collect data from Animal Scale, the Silo Scale, and water consumption by a specific protocol developed by EXAFAN.

It has a local DB and will implement a specific middleware to send the info to the cloud through NGSI.

- The Phase 1 Farm Gateway, a dedicated hardware that collects data from the different wireless (IEEE 802.15.4) environmental sensors nodes and send it remotely through an Ethernet connection to a dedicated server, which send the data by MQTT to the cloud through a specific middleware.
- The Phase 2 Farm Gateway, a dedicated hardware that collects data from the different wireless (IEEE 802.15.4) environmental sensors nodes and send it to the cloud through MQTT.

The following figures explain transport slaughterhouse components and their relations.

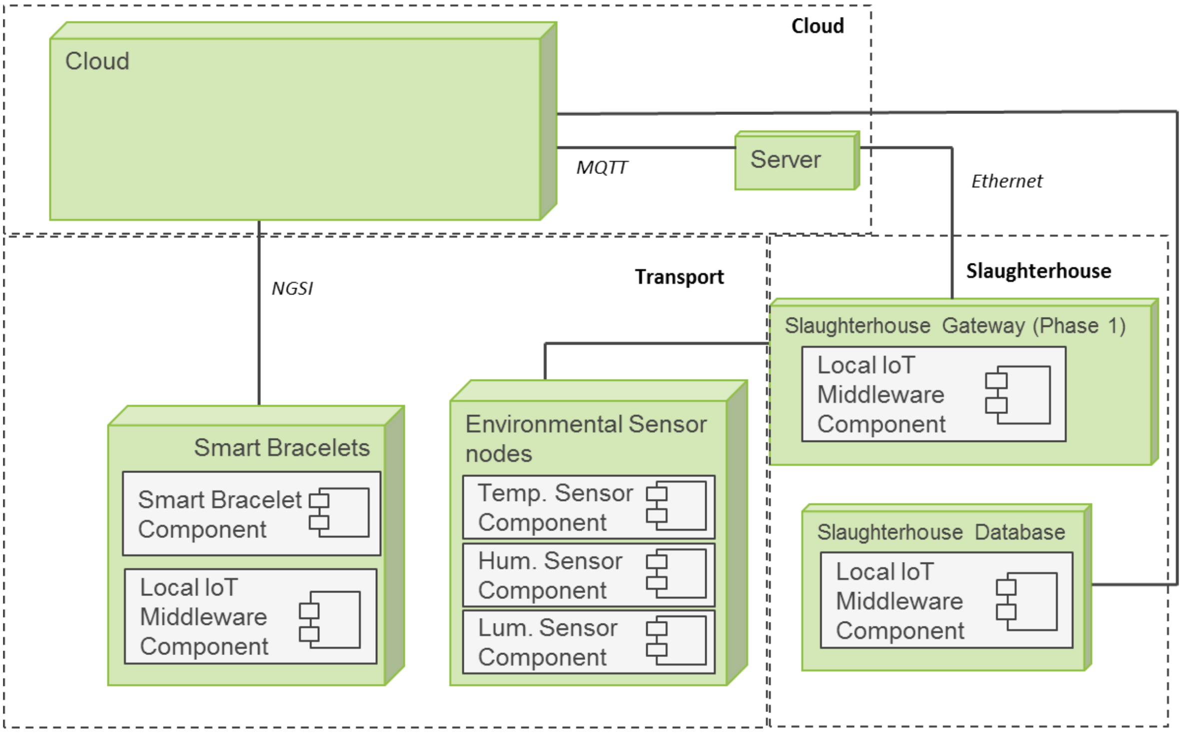


Figure 92 –UC5.2 Transport and Slaughterhouse Phase 1 Deployment Diagram

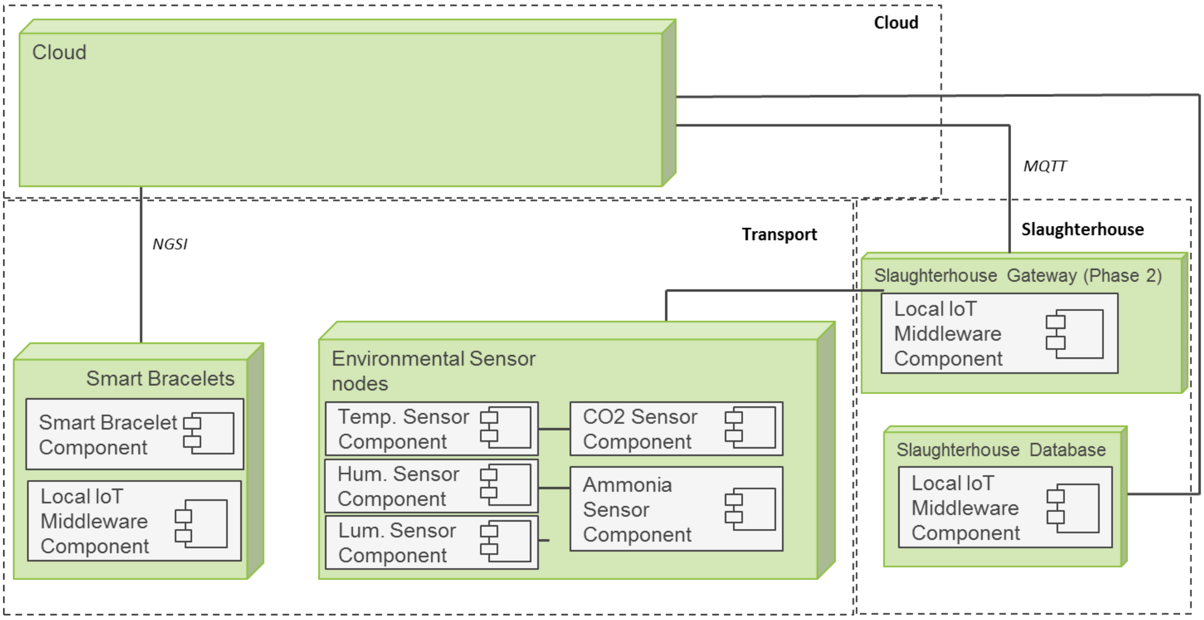


Figure 93 –UC5.2 Transport and Slaughterhouse Phase 2 Deployment Diagram

In the Transport, two different physical, dedicated sensor platforms are deployed, namely the Smart Bracelet platform and the Environmental Sensor Platform. Each platform corresponds to a dedicated, specific sensor hardware node. In the case of the Smart Bracelet component, it will implement a specific middleware to send the data to the cloud by NGSI. The environmental sensor nodes will work as explained in the farm.

Besides, there are two different "Gateways" in each phase. The Slaughterhouse Gateway, a dedicated hardware that works in the same way as Farm gateway, and the Slaughterhouse database, a DB (to be specified) which will implement an IoT middleware to send the info to the cloud by NGSI.

The summary of deployed components UC5.2 is provided in Table 81.

Table 81 - UC5.2 Deployed Components

Name	Description	Supplier (brand) + Model	Number of Units
Animal Scale	First phase static scales (wired). Second phase dynamic scales, battery operated (wireless)	EXAFAN proprietary solution	8
Silo scale	- For gathering data of feed consumption, measuring silo weight	Standard industrial Load cells and EXAFAN Electronic solution for the weighting system	12
Water Consumption sensor	Mechanical element in line with the main water supply.	Counter element from standard industrial supplier	4
Environmental sensor node	First phase sensors with temperature, luminosity and humidity. Second phase sensors with temperature, luminosity, humidity, CO2 and ammonia.	- IK4-TEKNIKER proprietary solution	65
Smart bracelets	The smart wearable includes: Accelerometer, Gyroscope, Electromyography and Inertial measurement unit	to be specified	5
Integral Farm Controller	Main controller of elements in farm to optimal conditions of animals (with communications capacity)	EXAFAN proprietary solution	4
Farm and slaughterhouse gateway	Hardware device that collects the information delivered by the environmental sensor nodes	- IK4-TEKNIKER proprietary solution	5
Slaughterhouse DB	Database to collect all relevant parameters of the slaughterhouse process output	N/A	1

Name	Description	Supplier (brand) + Model	Number of Units
Slaughterhouse Gateway	Software gateway in charge of collecting, storing (in C8) and sending the data to the cloud	N/A	1
Cloud Services	Poultry Meat Chain Platform based on FIWARE components for data collection, storage and analytics.	IK4-TEKNIKER	N/A
Cloud Services	The Porphyrio Smart Farm Assistant is a Big Data SaaS solution hosted in Amazon, available through internet (all browsers) and smartphone (ios, android)	PORPHYRIO	N/A

2.18.3 IoT Functional view

The IoT functional view of this UC (depicted in Figure 94) is structured as following:

- *Application Layer*: in this layer, there are web-based dashboards to visualize collected IoT data from farm and transport, as well as the results of the different analytic models (comfort model, manipulation model, and growing model).
- *Service support and application support layer*: both Generic support capabilities and Specific support capabilities are shown in this use case. There are particular capabilities like **Business Intelligence Dashboard** for analyse data and provide an overview of farm status and warnings in case status is not optimal; a **Fusion Engine Service** for elaborate the data. In addition, there are common capabilities which can be used by different IoT applications, such as **Cloud Data Storage and ID Management and Access Control**.
- *Network layer*: there are both Networking Capabilities and Transport Capabilities that first provide relevant control functions of network connectivity and second focus on providing connectivity for the transport of IoT service and application specific data information. Network and transport connectivity are provided directly from specific technologies. In this use case, the technologies involved are a proprietary protocol based on IEEE 802.15.4 for communication between Environmental Sensor Nodes, MQTT, NGSI, Ethernet and proprietary protocols for communication between the different sensors deployed by EXAFAN and the Integral Farm Controller.
- *Device layer*: Device Capabilities include **sleeping and waking-up** to reduce energy consumption as well as ad-hoc networking based on the specific technology of the environmental sensors. Regarding Gateway Capabilities, they have local storage capabilities.
- *Management Capabilities:* in this UC, there is no specific information about management capabilities. So, it is assumed that this UC includes general functions based on the specific technology.
- *Security Capabilities:* in this UC, apart from ID management and Access Control, there is no specific information about security capabilities. So, it is assumed that this UC includes general functions based on the specific technology.

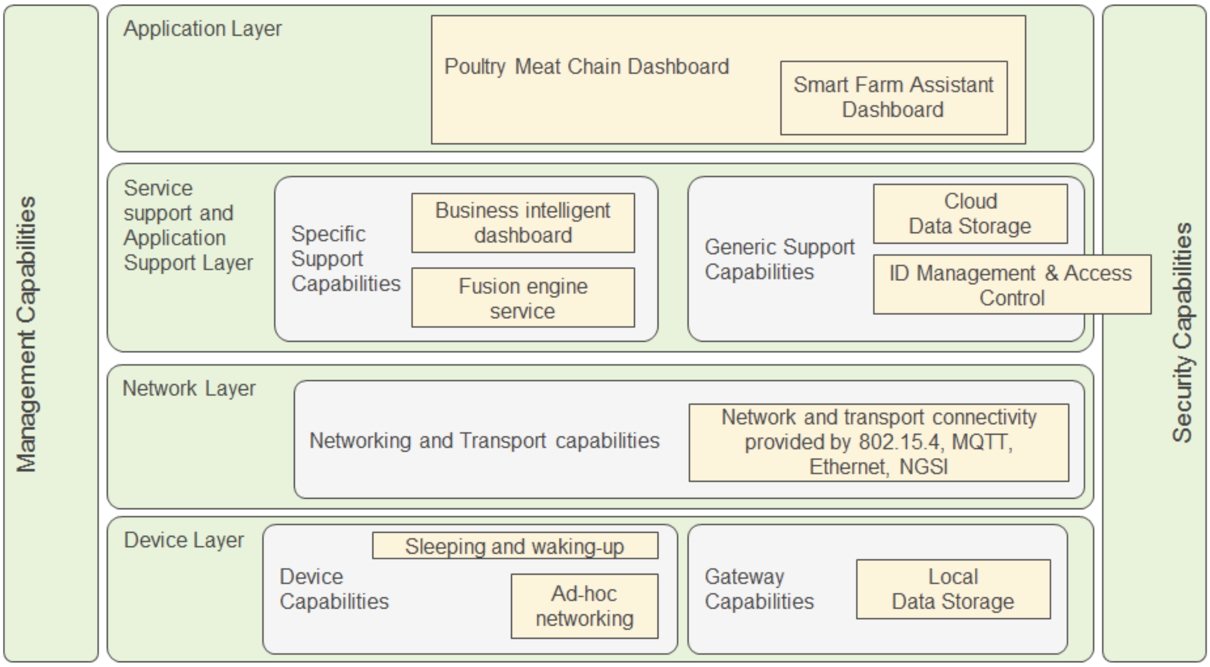


Figure 94 - UC5.2 IoT Functional View

2.18.4 Business Process Hierarchy view

The Business Process Hierarchy view for UC5.2 is depicted in Figure 95.

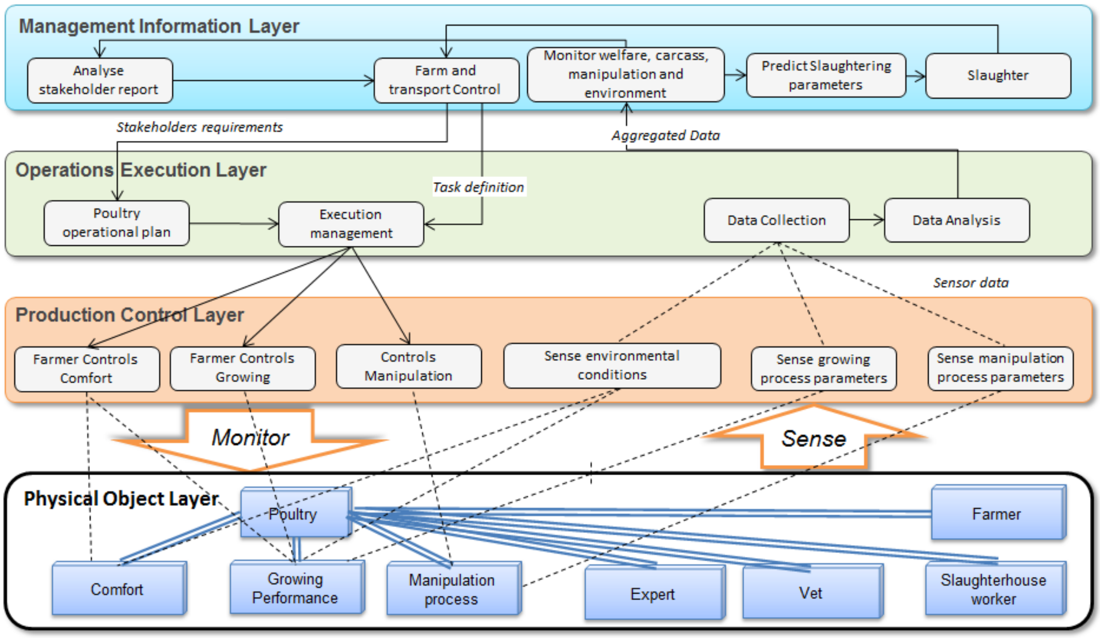


Figure 95 - UC5.2 Business Process Hierarchy view

Business Process Hierarchy View comprises four layers: Physical Object Layer, Production Control Layer, Operations Execution Layer and Management Information Layer.

In the Physical Object Layer, the relevant objects of this UC are depicted: welfare, carcass and manipulation assessment and environmental prediction, whose needed parameters are sensed with IoT sensors and statistical data.

The farmer, expert and vet are interested in monitoring and optimizing the welfare and the carcass performance of the poultry. Besides, the expert and vet are also interested to monitor and optimize the manipulation process, while the slaughterhouse worker will provide input data to the system.

The other layers include the main farm processes on different time horizons that are needed in this case to sense the physical objects. The starting point is sense the different parameters of the farm and transport in the **Production Control Layer** that are generated by IoT sensors data. This data is collected and analysed in the **Operations Execution layer**. The aggregated data is used in the **Management Information Layer** to monitor poultry welfare, carcass and manipulation assessment and environmental prediction. Next, an overview of poultry status and is calculated providing information for farmer, expert and worker of the slaughterhouse. This information will be later used to provide the different stakeholders support to take decision on the poultry operational plan, for them to actuate (no direct actuation by the technological solution) if necessary.

2.18.5 Interoperability Endpoints

The interoperability endpoints are shown on Table 82.

Table 82 - UC5.2 Interoperability Endpoints

Interface name	Exposed by	Protocol	Notes
Animal Scale interface	Animal scale	First phase wired with Exafan proprietary protocol / Second phase Wireless 802.11g	Connected to the Integral Farm Controller
Silo scale interface	Silo scale	Transport protocol RS485	Connected to the Integral Farm Controller
Water consumption sensor interface	Water consumption sensor	Pulses each certain amount of water (EXAFAN proprietary protocol)	Connected to the Integral Farm Controller
Environmental sensor interface	Environmental sensor	Wireless, IEEE 802.15.4	Connected to Farm or slaughterhouse Gateway
Smart bracelets interface	Smart bracelets	NGSI	Connection through FIWARE´s context Broker
Integral Farm controller interface	Integral Farm controller	NGSI	Connection through FIWARE´s context Broker
Farm gateway interface	Farm gateway	MQTT	Connection through FIWARE´s IoT Agent

Interface name	Exposed by	Protocol	Notes
Slaughterhouse DB interface	Slaughterhouse DB	NGSI	Connection through FIWARE´s context Broker
Slaughterhouse gateway interface	Slaughterhouse gateway	MQTT	Connection through FIWARE´s IoT Agent
Cloud service interface	N/A	NGSI	Connection between Porphyrio´s Farm Platform and Poultry Meat Chain Platform through FIWARE´s context Broker

2.18.6 Information model

The different models to be developed within the UC 5.2 are fed by different data from sensors and other sources. The Information model for UC5.2 is depicted in Figure 96 and Table 83, and shows the direct relationships between the different data sources and their associated data models.

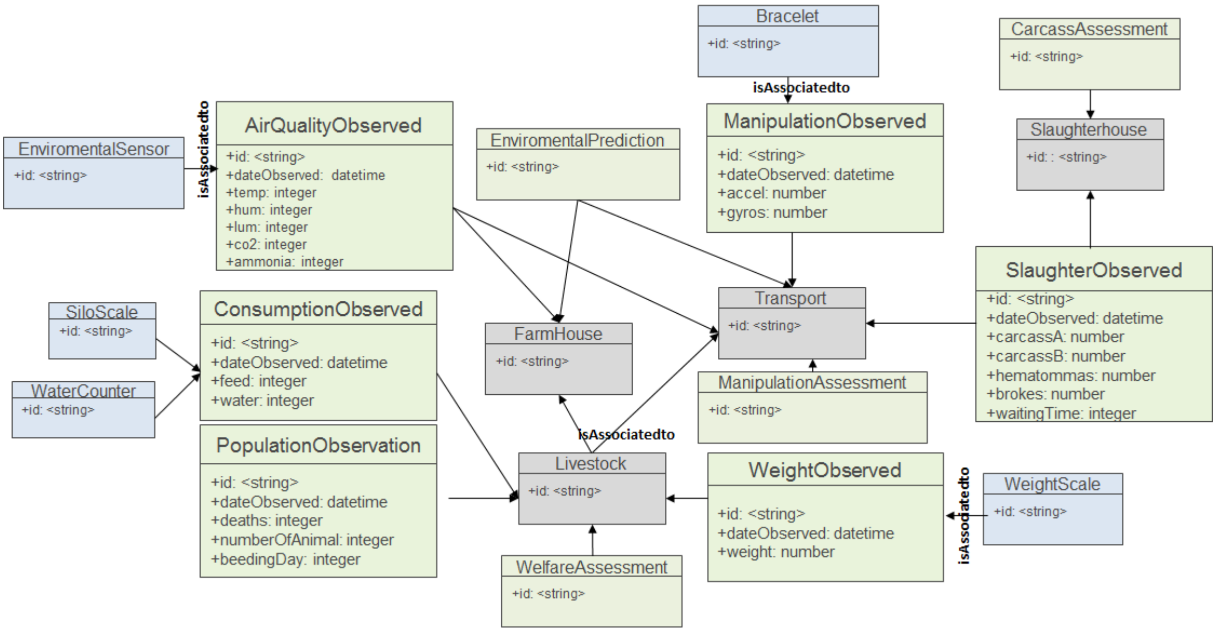


Figure 96 - UC5.2 Information Model

Table 83 - UC5.2 Information Model Details

Data	Measurement Technique	Physical Entity	Frequency of Data Collection	Associated data model/format
Temperature	Sensor	poultry	5 min	ºC
Humidity	Sensor	poultry	5 min	RH (%)
Luminosity	Sensor	poultry	5 min	Lux
Ammonia	Sensor	poultry	5 min	ppm
CO2	Sensor	poultry	5 min	ppm
Animal weight	Sensor	poultry	1x /hour	Kg
Water Consumption	Sensor	poultry	1x /hour	Litres
Ventilation	Sensor	poultry	1x /hour	to be specified
Feed Consumption (Silo weight)	Sensor	poultry	1x /hour	Feed consumed (g)
Slaughterhouse data	Manual	poultry	Every rearing	to be specified

2.18.7 Summary of gaps

The specification of UC5.2 is almost defined, but there are some points not clear.

- There are some interfaces still under definition
- Although some components have proprietary interfaces, the final connection might be through gateways or controllers with standard interfaces (NGSI, MQTT)

2.18.8 Assets identified for re-use

The assets identified for re-use are shown on Table 84.

Table 84 - UC5.2 Assets identified for re-use

Component name	Short Description and role in the Use Case	Functional role	License
Animal Scale	Animal scale to obtain birds weight	In the ITU-T Y.2060 IoT Reference Model, this is in the "Device and Network Layer" In the Business Process Hierarchy view, this is in "Physical Object Layer"	This is a hardware component (no special licenses needed, EXAFAN proprietary solution)
Water consumption sensor	Water consumption sensor to measure water consumption of the whole farm	In the ITU-T Y.2060 IoT Reference Model, this is in the "Device and Network Layer" In the Business Process Hierarchy view, this is in "Physical Object Layer"	This is a hardware component (no special licenses needed, EXAFAN proprietary solution)
Silo scale	Silo scale to obtain the feed consumption of the whole farm (weighting the feed silos)	In the ITU-T Y.2060 IoT Reference Model, this is in the "Device and Network Layer" In the Business Process Hierarchy view, this is in "Physical Object Layer"	This is a hardware component (no special licenses needed, EXAFAN proprietary solution)
Environmental sensor nodes	Environmental sensor nodes to obtain parameters in the farm and transport (temperature, humidity, luminosity, ammonia and CO2)	In the ITU-T Y.2060 IoT Reference Model, this is in the "Device and Network Layer" In the Business Process Hierarchy view, this is in "Physical Object Layer"	This is a hardware component (no special licenses needed, IK4-TEKNIKER proprietary solution)
Smart bracelets	Smart bracelets to measure several parameters of the workers during the poultry loading into the trucks	In the ITU-T Y.2060 IoT Reference Model, this is in the "Device and Network Layer" In the Business Process Hierarchy view, this is in "Physical Object Layer"	This is a hardware component (no special licenses needed, specific vendor proprietary solution)

Component name	Short Description and role in the Use Case	Functional role	License
Integral Farm Controller	Integral Farm Controller that receives the data from animal scale, silo scale and water consumption sensors	In the ITU-T Y.2060 IoT Reference Model, this is in the “Device and Network Layer” In the Business Process Hierarchy view, this is in “Physical Object Layer”	This is a hardware component (no special licenses needed, EXAFAN proprietary solution)
Farm and slaughterhouse gateways	Farm and slaughterhouse gateway to gather data from the environmental sensors	In the ITU-T Y.2060 IoT Reference Model, this is in the “Device and Network Layer” In the Business Process Hierarchy view, this is in “Physical Object Layer”	This is a hardware component (no special licenses needed, IK4-TEKNIKER proprietary solution)
Slaughterhouse DB	Database where parameters of the slaughterhouse are connected	In the ITU-T Y.2060 IoT Reference Model, this is in the “Service support and application support layer” In the Business Process Hierarchy view, this is in “Production Control Layer” and “Operations Execution layer”	to be specified
Slaughterhouse Gateway	Virtual slaughterhouse gateway that sends the data to FIWARE cloud services	In the ITU-T Y.2060 IoT Reference Model, this is in the “Service support and application support layer” In the Business Process Hierarchy view, this is in “Production Control Layer” and “Operations Execution layer”	to be specified

Component name	Short Description and role in the Use Case	Functional role	License
Cloud Service	Service hosting the applications for Poultry Meat Chain and PORPHYRIO platform.	In the ITU-T Y.2060 IoT Reference Model, this is in the “Service support and application support layer” In the Business Process Hierarchy view, this is in “Production Control Layer” and “Operations Execution layer”	to be specified

2.18.9 Collaboration with other Use Cases

They collaborated with UC 5.1 to:

- Share with them the knowledge about the FIWARE Orion Context Broker and all the related plugins to address security needs;
- Share with them the knowledge about the existing dashboard for poultry
- Let them use a data model similar to the one already used as compatibility measure.

They also collaborated with UC 5.3 to:

- improve the data model to better respect standards
- let UC 5.3 suggests measures to foster transparency and traceability.

2.18.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets.

The following Table 85 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability

Table 85 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC5.2)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May ‘18)	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	55	- Environmental sensors at Farm (TEK) (40) - Environmental sensors for transport (TEK) (5) - scales for silos and 2 scales at farm (EXA) (8)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May ‘18)	Short comment / qualitative estimation
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	9	- Farm platform (POR) (1) - Poultry meat chain platform (TEK) (1) - Farm Controller (EXA) (2) - Gateways for environmental sensors (3) - local IoT middleware for smart watches (1) - local IoT middleware for slaughterhouse (1)
	Number of IoT applications available	2	- Farm dashboard (POR) (1) - Farm environmental predictor (TEK) (1)
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1
	Number of FIWARE GEs instances	5	- FIWARE Orion Context Broker (1) - FIWARE Identity Manager (1) - FIWARE PEP Proxy (1) - Cygnus (1) - IOT Agent (1)
	Number of open datasets used	1	- AEMET (1)
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	/	Not yet available
	Average number of installations per reusable IoT component	/	Not yet available
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	1	- FIWARE Orion Context Broker (data models, MQTT protocol, NGSI protocol
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies		

2.19 MEAT UC 5.3: MEAT TRANSPARENCY AND TRACEABILITY

The objective of this UC is to develop, deploy, and demonstrate transparency system that enables tracking and tracing in the meat, particularly pork, sector.

The UC doesn’t deploy its own sensors and IoT platform but will instead collaborate either other UCs to gather transparency data and make it accessible.

WU leads this UC and EECC will design, implement and deploy the transparency system. GS1 Germany, the other partner in this UC will develop the data models and define requirements.

2.19.1 Domain model

Figure 97 depicts the domain model for UC5.3, showing the key actors, the software entities and how these two interact. There are two key actors in the UC5.3: the pig farmers and a third party (*3p*) transparency system provider. There is one key software component in this UC, which a transparency system.

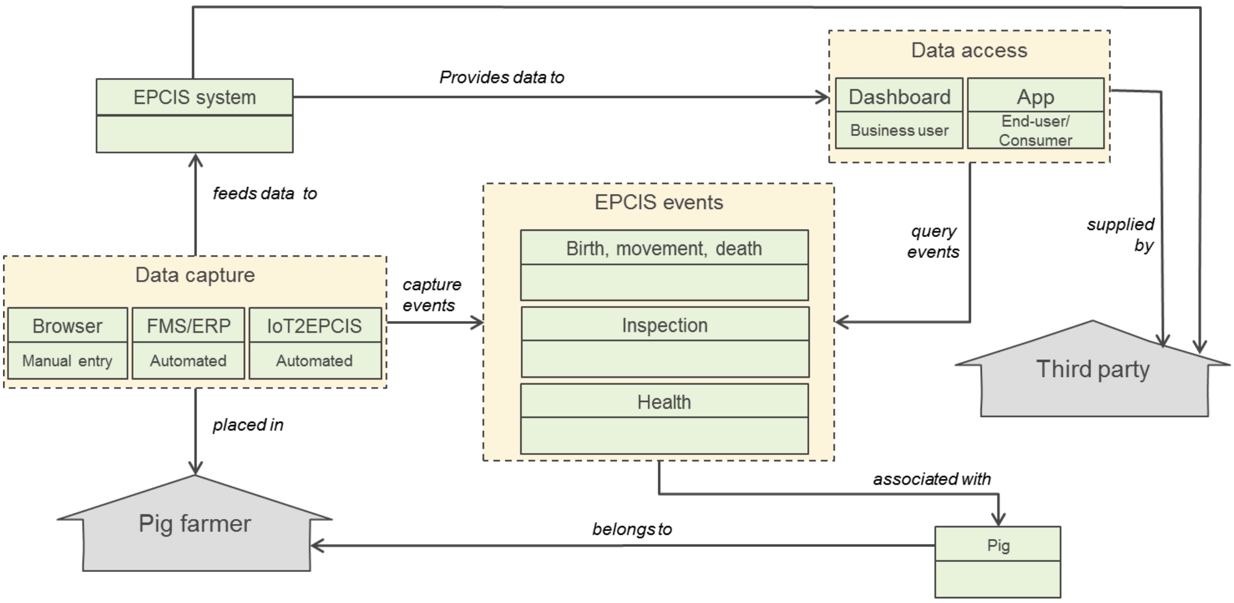


Figure 97 – UC5.3 Domain Model

The transparency system is generic and can be applied in any one of the UCs involved in production, and transportation of goods. The UC targets mainly the meat sector, particularly pig farming and seeks collaboration with UC5.1.

The main system in the use case is a transparency system that is based on the GS1 systems of standards, mainly the EPCIS standard. We refer to this system simple as *EPCIS system*. The system provides a repository of transparency data and two sets of interfaces. The interfaces are data capture and data query interfaces.

The system can be deployed centrally and optionally at each farm. In the UC the EPCIS system will be deployed centrally. We thus refer to the system in a singular. The system deployed centrally is referred to as shared EPCIS systems; those deployed at farms are referred to as private EPCIS systems.

The shared EPCIS system aims to enable pig farmers to share transparency data across entire meat supply chain easily. Deploying a private EPCIS system is costly and difficult to manage for small business. Compliance to the EPCIS standard enables farmers to share transparency data in any supply chain in which EPCIS compliant transparency systems are deployed.

The UC doesn't deploy its own IoT sensors but relies on other UCs for capturing and transforming IoT data into EPCIS data, called EPCIS events. EPCIS events in UC5.3 refers to things that happen in the processes of pig farming.

Though IoT sensors deployed at farms measure a diverse array of parameters of interest, only that data of interest for transparency will be transferred to the EPCIS system. Therefore, the UC will provide a meta-data model for classifying data of interest for the transparency system and resulting EPCIS system provides access control, data validation and aggregation features.

Since the transparency system provided by this UC relies on data gathered by other use cases, the EPCIS system should be integrated with the system provided by other UCs, particularly farm management (FMS) and ERP systems. Besides the EPCIS system provides Web GUI (manual data entry and query) user interfaces.

2.19.2 Deployment view

Figure 98 depicts the deployment view for UC5.3. The main product of the UC is a generic transparency system. The system consists of 5 components and will mainly be deployed centrally. Optionally, the transparency system may be deployed locally (as a private EPCIS system) at each farm. The private

EPCIS system will have only limited features: mainly, EPCIS repository and Web GUI. To enable the sharing of transparency data, the shared EPCIS system batch queries the private EPCIS systems. The other components shown in the figure are not provided by the UC but are required for the UC to be implemented.

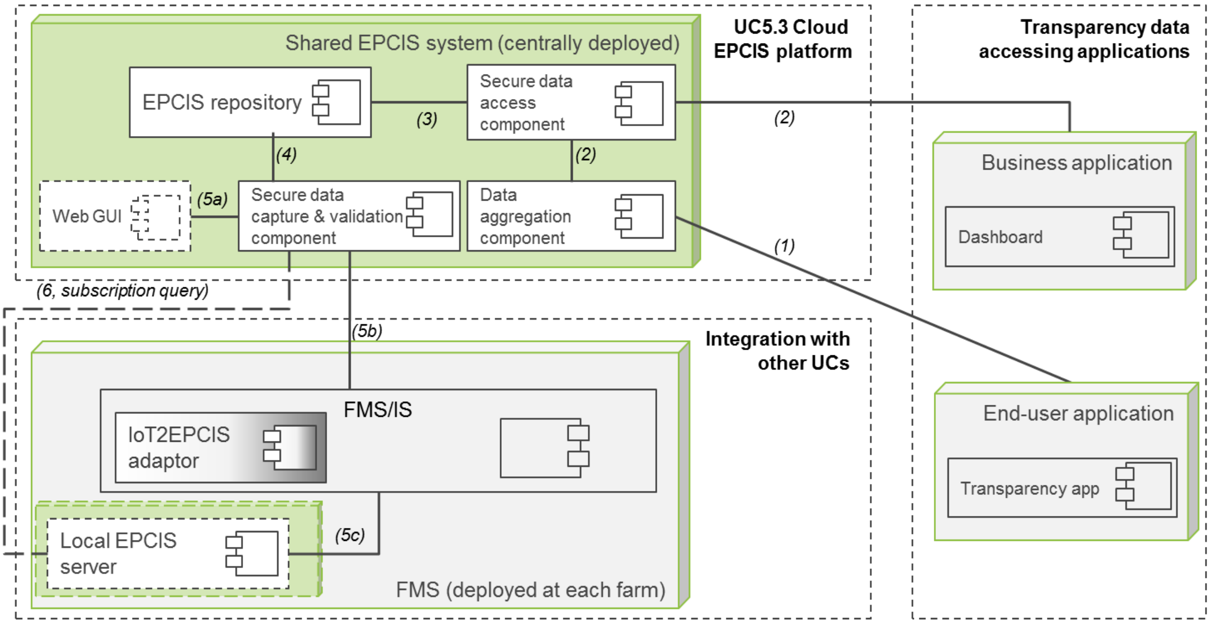


Figure 98 – UC5.3 Deployment View

The shared EPCIS platform provides the following sub components:

- EPCIS server: This component is a standard EPCIS server with standard EPCIS data capture and data query interfaces. These interfaces lack access control and data validation features.
- Web GUI: A web GUI enables users to enter transparency data manually. Manual data entry will mainly be used for testing purposes. In the UC, data will be captured through a secure data capture and validation web-service.
- Secure data capture and validation: This component provides a web-service for capturing data with security and data validation features. The component ensures that only valid EPCIS data is captured into the EPCIS system and that, the data comes from authorized sources only (*i.e.* it provides access control).
- Secure data access: This component provides a web-service for accessing data from the EPCIS system. The component provides access control features.
- Data aggregation: This component aggregates data in the form that is useful and meaningful to end-users.

A private EPCIS system may optionally be deployed at farms. This is however not recommended because the initial and maintenance costs of the system are restrictive.

Other systems that should already be in place and need to be integrated with the EPCIS system are:

- FMS/IS: A FMS or any other Information System (IS), such as ERP, is the source of data for the EPCIS system. The shared EPCIS system will be integrated with existing IS.
- IoT2EPCIS: Alternatively, an IoT-to-EPCIS (IoT2EPCIS) bridge should be developed by collaborating UCs (in collaboration with UC5.3) in order to transfer transparency data from their IoT platforms to the shared EPCIS system.

- Transparency data accessing applications: These are applications that access the EPCIS system and display information to end users. There are generally two types of such applications. Dashboards may be used to support managerial decision making. Transparency apps may be used both businesses and consumers to get transparency information.

The linkages among the components are:

(1) Data aggregations web-service and business applications, such as dashboards, will use this web-service interface to securely retrieve raw transparency data
(2) Consumer applications, such as transparency mobile apps, will use this web-service interface to securely retrieve aggregated transparency information
(3) The secure data access web service will use standards EPCIS data query interface to retrieve transparency data
(4) The secure data capture web service will use standards EPCIS data capture interface to store transparency data
(5) Web GUIs and FMSs will use these web-services interfaces (i.e. *5a*, *5b* and *5c*) to store transparency data into EPCIS system. *5a* is used by Web GUI to securely enter transparency data manually. *5b* is used to
(6) The secure data access web service will batch query (subscription query) the private EPCIS system using this interface.

2.19.3 IoT Functional view

The IoT functional view of this UC is depicted in Figure 99.

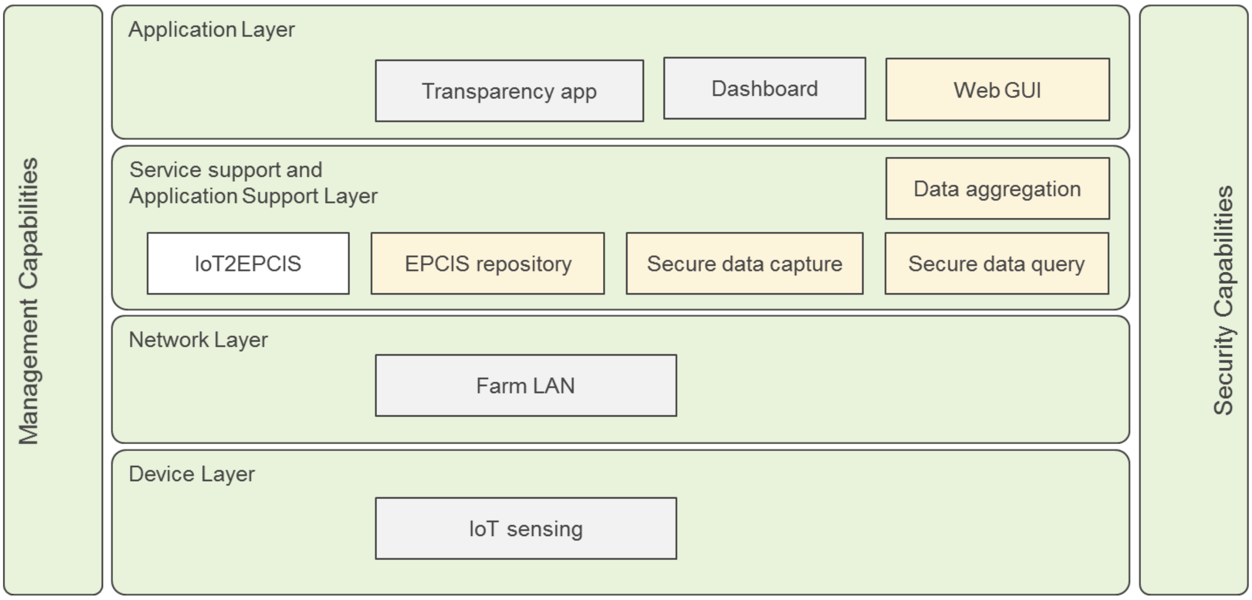


Figure 99 – UC5.3 Deployment View

The UC does not deploy sensors or IoT platforms; instead, the UC provides added values to the IoT platforms deployed. Therefore, the device and network layer refers to the IoT platforms that will be made available by collaborating UCs.

The applications of this UC are transparency application and dashboard to visualize transparency information and Web GUI to enter transparency data. The UC will not provide transparency application or dashboards. Instead, the UC provides web-services in the app/service support layer, in order to enable collaborating use case, develop the required end-user applications.

2.19.4 Business Process Hierarchy view

The business process hierarchy of UC5.3 is depicted in Figure 100. The UC does not deploy sensors or IoT platforms; therefore, the physical and production control layers are mainly the concern of the collaborating UCs.

The UC works with transparency data called events. The events are shared by the underlying IoT platform or IS. In the operational execution layer, the UC checks the validity of events and the access rights of the party that shared or access the events. In this layer meta information is used to enrich the entry or access requests. In the management information layer transparency data is presented to managers and end-users in user-friendly and meaningful manner.

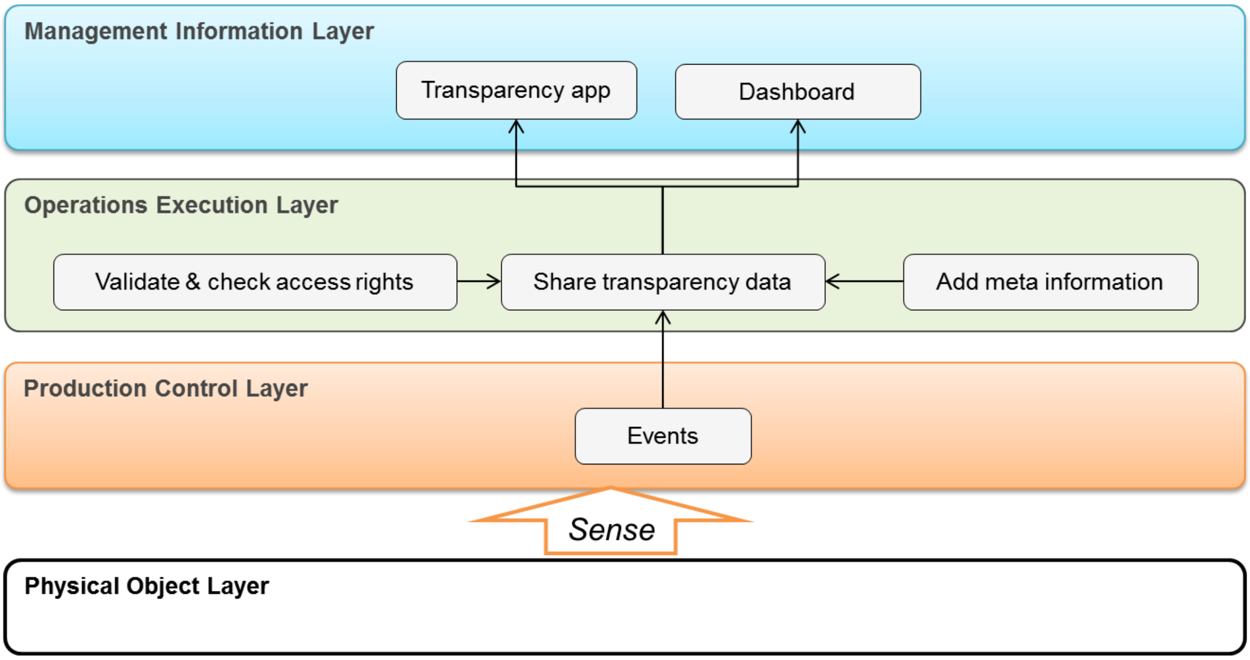


Figure 100 – UC5.3 Business Process Hierarchy

2.19.5 Interoperability Endpoints

Table 86 summarizes the two main end-points of the EPCIS system. The first two interfaces are partially defined in the current EPCIS standard which is publicly available from GS1. The data validation and access control aspects of these interfaces will be designed by EECC. The data aggregation interface is new. It will be designed in collaboration with stakeholders.

Table 86 – UC5.3 Interoperability Endpoints

Interface name	Exposed by	Protocol	Notes
Secure data capture interface	Secure data capture and validation component	SOAP/REST	Built on top of the EPCIS Standard interface
Secure data capture interface	Secure data access component	SOAP/REST	Built on top of the EPCIS Standard interface

Interface name	Exposed by	Protocol	Notes
Data aggregation interface	Data aggregation component	SOAP/REST	Will be designed by EECC in collaboration with stakeholders

2.19.6 Information model

The high-level Information model of UC5.3 is given in Figure 101. The data handled in this UC should comply with the EPCIS specification. The data captured are called EPCIS events and consist of five data items, generally referred to as: WHAT, WHEN, WHERE, WHY and ILMD. Data is encoded followed a standardized XML. Below we describe the contents of XML documents that encode EPCIS events.

The WHAT data item refers to the identity of the objects. The main object of interest in this UC is pigs and most of the data is entered about the things that happen to pigs, such as birth, feed, medication and transfer. Pigs are identified by their eartags. Data is captured at farms by either manually scanning tags (eartag or barcode) or electronically detecting through IoT sensors. Sensed data is transferred to FMS or IoT2EPCIS adapter. The identity is converted to an Electronic Product Code (EPC) which is a standard identification protocol in EPCIS systems.

The WHEN data item refers to the date and time of the event (for instance the time an eartag is scanned). It is captured automatically when the object is scanned. When data is captured manually the user should enter the date and time manually.

The WHERE data item refers to the location where an event occurred. The location refers to the address of the pig farm and is identified by a GLN. For large farms where there are multiple sensing locations, the location identifier may have to be constructed from farm address and the specific read point where the event is read. The combination of these two location data is identified with serialized GLN (SGLN) identification numbering system.

The WHY data item refers to the business context that is defined by two data items: business step and dispositions. Business step represents the activity that triggered the event. An example of a standard business steps is commissioning. Commissioning signifies the creation of a new object (for instance, a birth of a piglet), which will be assigned a new eartag ad this a new EPC. Disposition represents the state of the object (or objects) after the event has occurred. For instance, all newly commissioned objects are assigned Active disposition. Other disposition types are destroyed, inactive, expired, etc.

Any additional static information about the object (the specific pig) is captured as key-value pair data and are referred to as Instance-Level Master Data (ILMD).

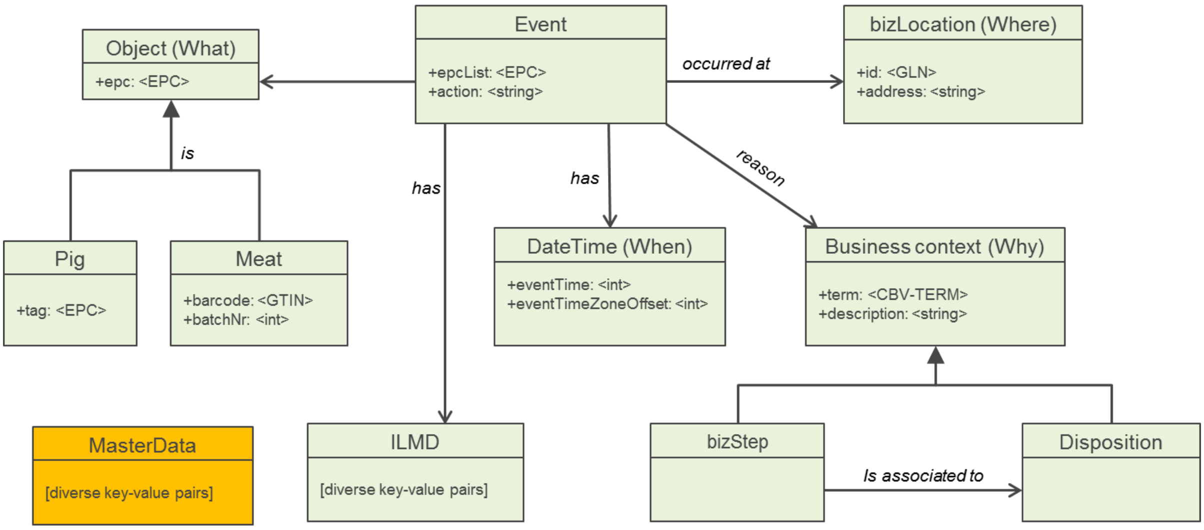


Figure 101 – UC5.3 Information Model

Currently a meta-data model that elaborates the high-level data model shown in Figure 101 is being developed.

2.19.7 Summary of gaps

The above specifications are not final but work in progress. The following are gaps that have to be addressed within the UC or in collaboration with other UCs. These gaps identified here are consistent with the work plan “Use case 5.3: work plan” submitted in March 2017.

Aspects for whom the UC team is explicitly asking for support: The UC doesn’t have own experimental site or direct stakeholders. In fact, the EPCIS system being developed in UC5.3 can be considered a generic enabler that could be deployed and used by stakeholders of other UCs. Collaboration with UC5.1 is the most obvious choice. Collaboration with other UCs is vital for the success of UC5.3.

Aspects that need further specification by the UCs: The information model given in 2.19.6 is high-level model. A transparency system required detailed data model about the kinds of information that need to be shared. This aspect also depends on collaboration with other UCs and the standardization (WP3.2) group.

Aspects of the UC that hamper realization: Transparency requires sharing data. Sharing data is a sensitive subject for some of the actors of the port supply chain. The business case for realizing and EPCIS transparency system needs further study. Collaboration with WP4 is vital for this purpose.

2.19.8 Assets identified for re-use

The EPCIS system is the main output of UC5.3 and it is a generic product that can be deployed in many other UCs.

2.19.9 Collaboration with other Use Cases

They collaborated with UC 5.1 and 5.2 to:

- improve their data model to better respect standards
- suggest measures to foster transparency and traceability.

2.19.10 Assessment of project related KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets.

The following Table 87 summarizes the estimated current value of the KPIs identified for this UC as a basis to assess the overall project KPI Reusability.

Table 87 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC5.2)

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May '18)	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	/	UC5.3 doesn't deploy its own IoT devices. The stakeholders do have own IoT devices. Currently, we have access to data and we know that RFID tags and hand-held devices are used. We have no further information about the IoT devices implemented at the slaughterhouse.
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	/	See comment above
	Number of IoT applications available	4	- EPCIS server - Data capturing application / IoT2EPCIS - Data accessing application / dashboard - Authentication and access control
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	1	- Reference Architecture described in D3.1
	Number of FIWARE GEs instances	0	/
	Number of open datasets used	0	/
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	/	Not yet available
	Average number of installations per reusable IoT component	/	Not yet available
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	1	EPCIS system (based on GS1 standard)
	% of identified standardization gaps that resulted in pre-normative change proposals submitted to IoT standardization bodies	1	We are contributing to the standardization sensor data capture in EPCIS

3 SECURITY, PRIVACY AND TRUST ANALYSIS

With the emergence of technologies associated to the Internet of Things, more and more sensitive assets are now connected to the internet. The ‘security, privacy & trust’ problem for the IoT is growing every day.

At the same time, no generic solution exists to treat this problem. Every project is different and has its own specificities. This is the reason why security concerns must be addressed from the beginning of a project development and not after its final design.

To understand the specificities of the projects using IoT technologies, a security analysis has been performed for each of the 19 Use Cases of the project IoF2020. This analysis is based on a methodology called STRIDE. It is used to identify the potential threats which can be exploited by attacker on a system. The STRIDE methodology is frequently used for high-level software. We modified it to fit the requirements of embedded software. It consists of different steps and integrates a rating of every threat’s severity. The rating method, named DREAD, classifies each threat according to five characteristics. The completed analysis gives a clear view on the distribution and severity of each threat. With that analysis, resources to resolve them can be assigned accordingly.

STRIDE analysis steps

1. Identification of the assets
2. Identification of the use cases
3. Identification of the system’s architecture view
4. Identification of the potential threats
5. Evaluation of the severity of all potential threats
6. Specification of the threat’s resolution

DREAD rating focus points

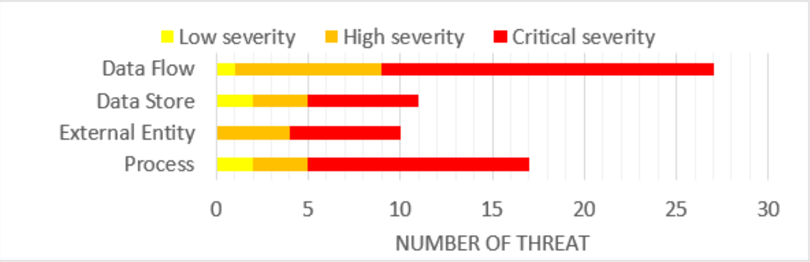
- Damage Potential
- Reproducibility
- Exploitability
- Number of Affected users
- Discoverability

3.1 ARABLE UC 1.1: WITHIN-FIELD MANAGEMENT ZONING

3.1.1 System analysis

Summary: 47% of attackable elements are data flows. Critical threats are present on every type all element.

Name of the STRIDE element	Number of element*
Process	3
External Entity	5
Data Store	3
Data Flow	10
Total	21

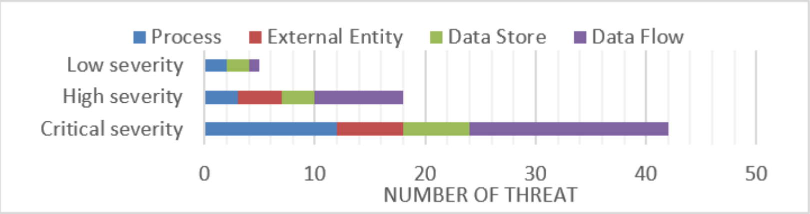


* Elements comprise all soft- and hardware components of the use case architecture.

3.1.2 Threat analysis

Summary: 64% of the threats have a critical severity and 27% a high severity.

Level of severity	Number of threat*
Critical (rating >= 2)	42
High (rating >= 1.8)	18
Low (rating < 1.8)	5



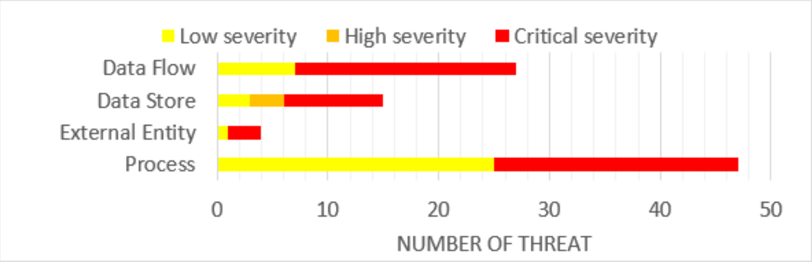
* Threat: potential sources of attacks towards the use case architecture.

3.2 ARABLE UC 1.2: PRECISION CROP MANAGEMENT

3.2.1 System analysis

Summary: 50% of attackable elements are data flows. External entities cause the least threats. Most of the critical threats are located on the Data Flows and processes.

Name of the STRIDE element	Number of element*
Process	8
External Entity	3
Data Store	4
Data Flow	15
Total	30

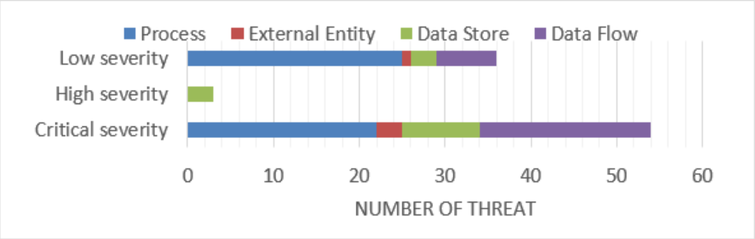


* Elements comprise all soft- and hardware components of the use case architecture.

3.2.2 Threat analysis

Summary: 58% of the threats have a critical severity. Only +/- 3% have a high severity.

Level of severity	Number of threat*
Critical (rating >= 2)	54
High (rating >= 1.8)	3
Low (rating < 1.8)	36



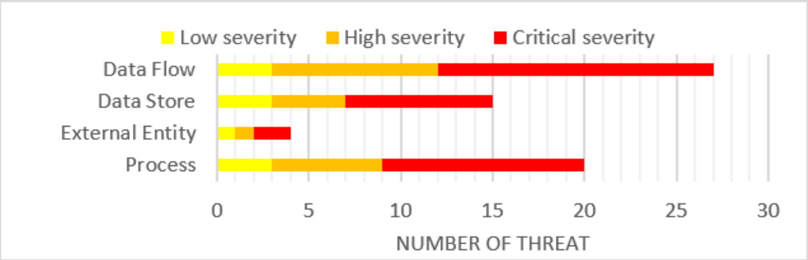
* Threat: potential sources of attacks towards the use case architecture.

3.3 ARABLE UC 1.3: SOYA PROTEIN MANAGEMENT

3.3.1 System analysis

Summary: 47% of attackable elements are data flows. External entities cause the least threats. Most of the critical threats are located on the Data Flows and processes.

Name of the STRIDE element	Number of element*
Process	4
External Entity	3
Data Store	4
Data Flow	10
Total	21

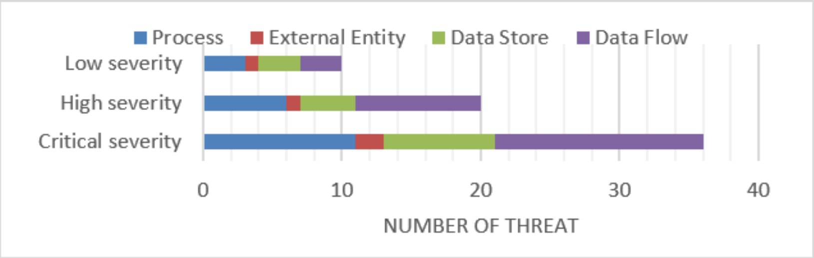


* Elements comprise all soft- and hardware components of the use case architecture.

3.3.2 Threat analysis

Summary: 54% of the threats have a critical severity.

Level of severity	Number of threat*
Critical (rating >= 2)	36
High (rating >= 1.8)	20
Low (rating < 1.8)	10



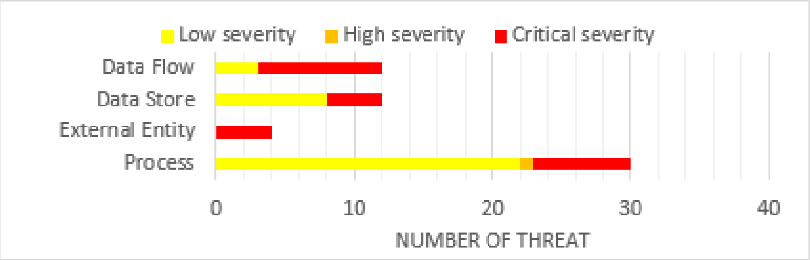
* Threat: potential sources of attacks towards the use case architecture.

3.4 ARABLE UC 1.4: FARM MACHINE INTEROPERABILITY

3.4.1 System analysis

Summary: 47% of attackable elements are data flows. External entities cause the least threats. Critical threats are present on all different element.

Name of the STRIDE element	Number of element*
Process	5
External Entity	2
Data Store	3
Data Flow	9
Total	19

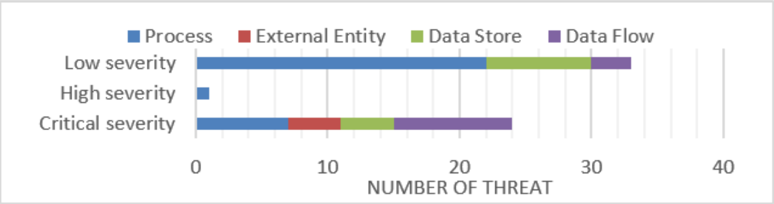


* Elements comprise all soft- and hardware components of the use case architecture.

3.4.2 Threat analysis

Summary: The threats are mainly composed of two severity level : critical and low. 41% of the threats have a critical severity and 56% a low severity.

Level of severity	Number of threat*
Critical (rating >= 2)	24
High (rating >= 1.8)	1
Low (rating < 1.8)	33



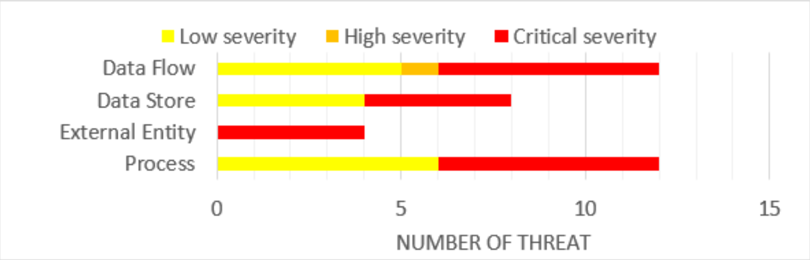
* Threat: potential sources of attacks towards the use case architecture.

3.5 DAIRY UC 2.1 GRAZING COW MONITOR

3.5.1 System analysis

Summary: Most of attackable elements are data flows and processes. External entities cause the least threats. Most of the critical threats are located on the Data Flows and processes.

Name of the STRIDE element	Number of element*
Process	2
External Entity	2
Data Store	2
Data Flow	5
Total	11

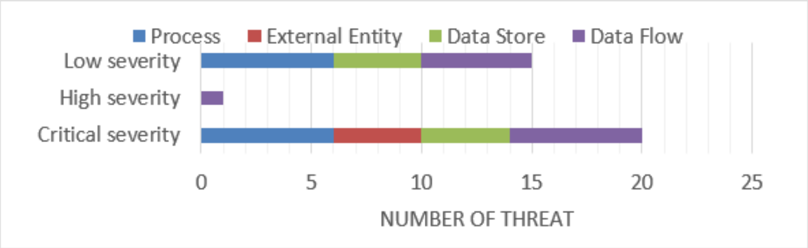


* Elements comprise all soft- and hardware components of the use case architecture.

3.5.2 Threat analysis

Summary: 55% of the threats have a critical severity and 41 % a low severity.

Level of severity	Number of threat*
Critical (rating >= 2)	20
High (rating >= 1.8)	1
Low (rating < 1.8)	15



* Threat: potential sources of attacks towards the use case architecture.

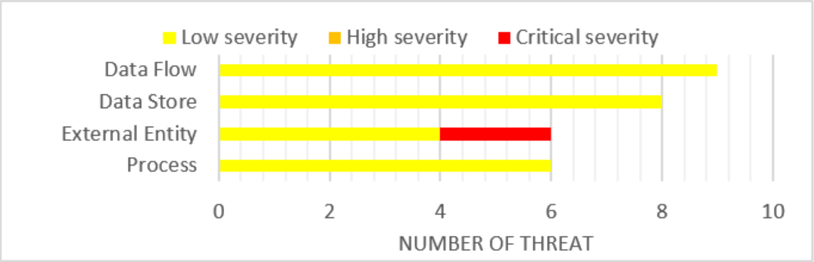
Based on the above findings from the STRIDE exercise an implementation plan to address the threats on data flows and processes has been drafted in order to improve upon these easy-to-reach improvements with respect to security. The high and critical severity threats, which represents more than 50% of the threats identified will be addressed by providing dedicated hard- and software solutions throughout a dedicated catalogue.

3.6 DAIRY UC 2.2: HAPPY COW

3.6.1 System analysis

Summary: 46% of attackable elements are data flows. External entities and processes cause the least threats. Critical threats are only present on the external entities.

Name of the STRIDE element	Number of element*
Process	2
External Entity	3
Data Store	2
Data Flow	6
Total	13

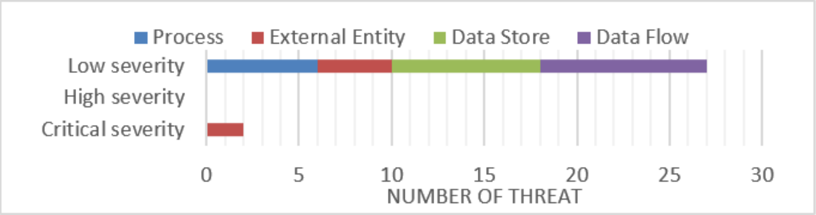


* Elements comprise all soft- and hardware components of the use case architecture.

3.6.2 Threat analysis

Summary: 92% of the threats have a low severity, the others threats have a critical severity.

Level of severity	Number of threat*
Critical (rating >= 2)	2
High (rating >= 1.8)	0
Low (rating < 1.8)	23



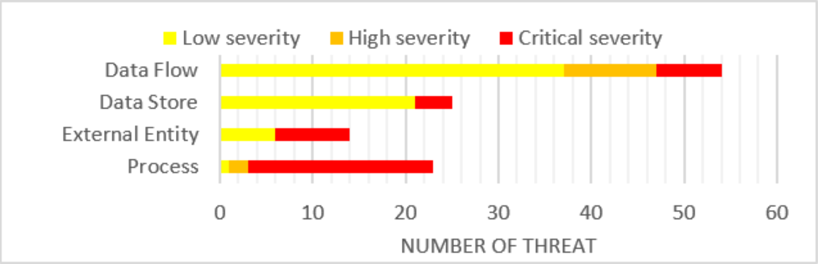
* Threat: potential sources of attacks towards the use case architecture.

3.7 DAIRY UC 2.3: HERDSMAN+

3.7.1 System analysis

Summary: 48% of attackable elements are data flows. Most of the critical threats are present on the processes and the external entities.

Name of the STRIDE element	Number of element*
Process	4
External Entity	7
Data Store	7
Data Flow	17
Total	35

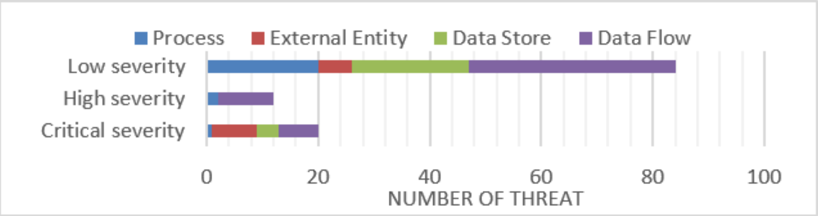


* Elements comprise all soft- and hardware components of the use case architecture.

3.7.2 Threat analysis

Summary: 17% of the threats have a critical severity and 72% a high severity.

Level of severity	Number of threat*
Critical (rating >= 2)	20
High (rating >= 1.8)	12
Low (rating < 1.8)	84



* Threat: potential sources of attacks towards the use case architecture.

3.8 DAIRY UC 2.4: REMOTE MILK QUALITY

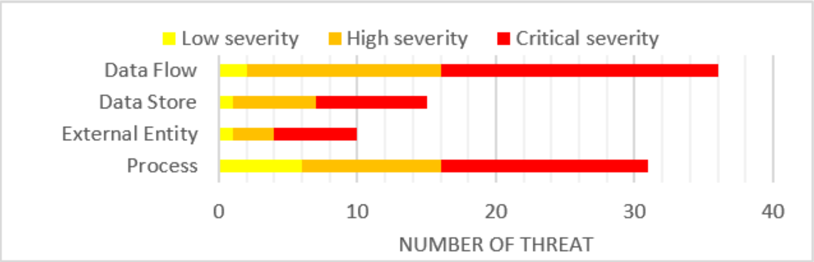
As explained in section 2.8, QLIP is coordinating the underlying remote milk quality infrastructure that is currently addressing the technical issues for calibration of instruments and analysing the workflow potentials to provide consultancy and knowledge to distributed instruments at the customer site. In the next steps a STRIDE analysis will take place, as soon as the first deployment views can be elaborated.

3.9 FRUIT UC 3.1: FRESH TABLE GRAPES CHAIN

3.9.1 System analysis

Summary: 48% of attackable elements are data flows. Most of the critical threats are present on the data flows and on the processes.

Name of the STRIDE element	Number of element*
Process	5
External Entity	5
Data Store	4
Data Flow	13
Total	27

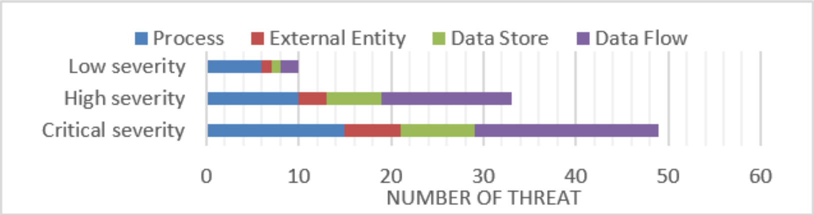


* Elements comprise all soft- and hardware components of the use case architecture.

3.9.2 Threat analysis

Summary: 53% of the threats have a critical severity and 35% a high severity.

Level of severity	Number of threat*
Critical (rating >= 2)	49
High (rating >= 1.8)	33
Low (rating < 1.8)	10



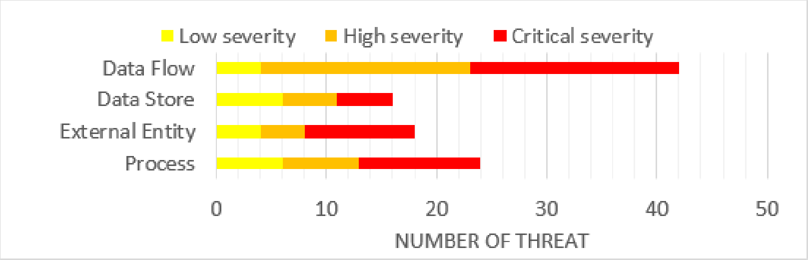
* Threat: potential sources of attacks towards the use case architecture.

3.10 FRUIT UC 3.2: BIG WINE OPTIMIZATION

3.10.1 System analysis

Summary: Most of attackable elements are data flows and external entities. Due to their number, the data stores cause the least threats. Most of the critical threats are located on the Data Flows and processes.

Name of the STRIDE element	Number of element*
Process	4
External Entity	9
Data Store	4
Data Flow	16
Total	33

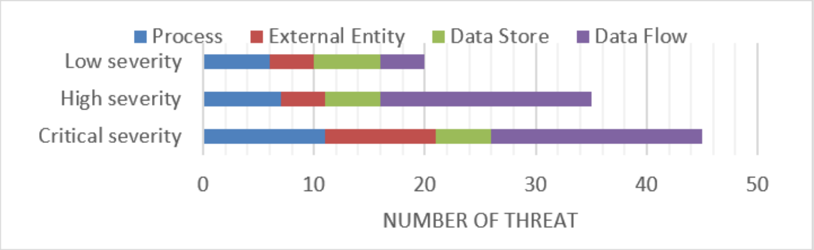


* Elements comprise all soft- and hardware components of the use case architecture.

3.10.2 Threat analysis

Summary: 45% of the threats have a critical severity and 35% a high severity.

Level of severity	Number of threat*
Critical (rating >= 2)	45
High (rating >= 1.8)	35
Low (rating < 1.8)	20



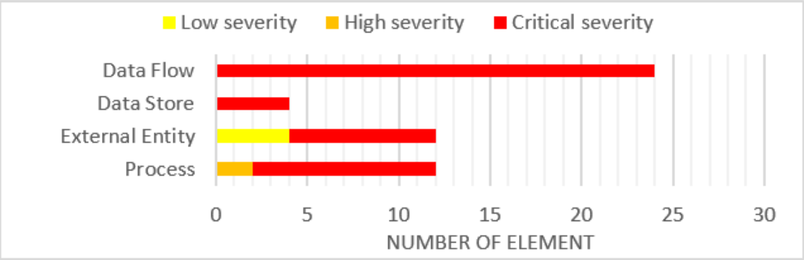
* Threat: potential sources of attacks towards the use case architecture.

3.11 Fruit UC 3.3: Automated olive chain

3.11.1 System analysis

Summary: Close to 50% of attackable elements are data flows.

Name of the STRIDE element	Number of element*
Process	2
External Entity	6
Data Store	1
Data Flow	8
Total	17

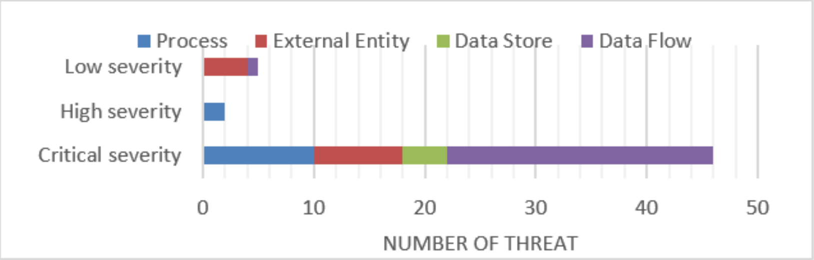


* Elements comprise all soft- and hardware components of the use case architecture.

3.11.2 Threat analysis

Summary: Almost all of the threats have a critical severity. Half of them are located on Data Flow.

Level of severity	Number of threat*
Critical (rating >= 2)	46
High (rating >= 1.8)	2
Low (rating < 1.8)	4



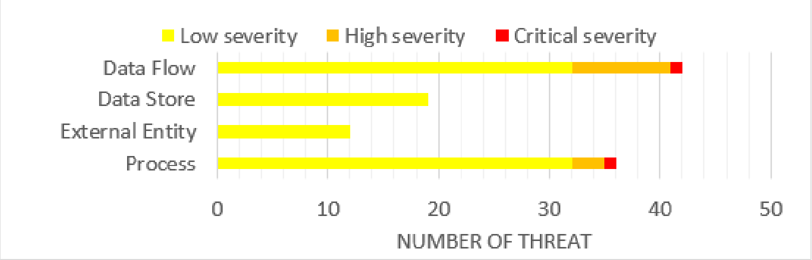
* Threat: potential sources of attacks towards the use case architecture.

3.12 FRUIT UC 3.4: INTELLIGENT FRUIT LOGISTICS

3.12.1 System analysis

Summary: 50% of attackable elements are data flows. External entities cause the least threats. All the critical threats are located on the Data Flows and processes.

Name of the STRIDE element	Number of element*
Process	6
External Entity	6
Data Store	5
Data Flow	15
Total	32

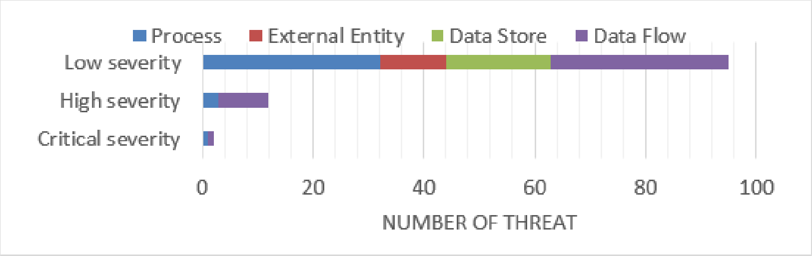


* Elements comprise all soft- and hardware components of the use case architecture.

3.12.2 Threat analysis

Summary: Less than 2% of the threats have a critical severity. 87% have a low severity.

Level of severity	Number of threat*
Critical (rating >= 2)	2
High (rating >= 1.8)	12
Low (rating < 1.8)	90



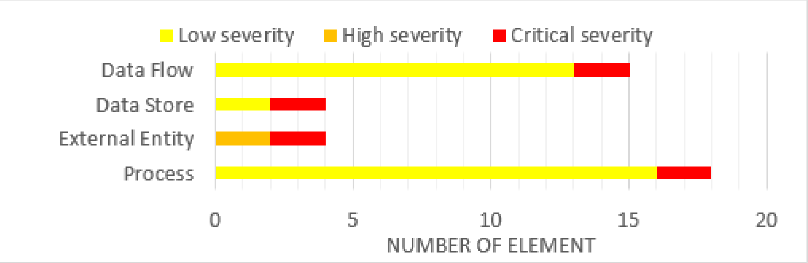
* Threat: potential sources of attacks towards the use case architecture.

3.13 VEGETABLE UC 4.1: CITY FARMING LEAFY VEGETABLES

3.13.1 System analysis

Summary: Close to 75% of attackable elements are data flows and processes. Most of the threats on the data flows and processes have a low severity.

Name of the STRIDE element	Number of element*
Process	3
External Entity	2
Data Store	1
Data Flow	5
Total	11

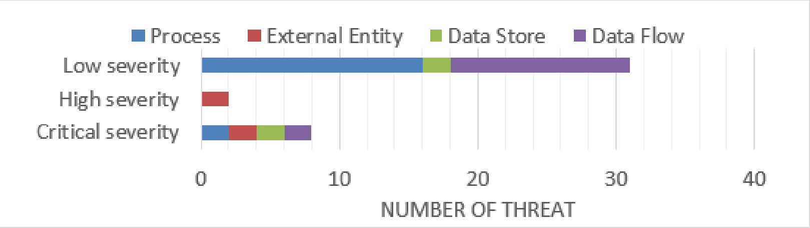


* Elements comprise all soft- and hardware components of the use case architecture.

3.13.2 Threat analysis

Summary: Almost 75% of the threats have a low severity.

Level of severity	Number of threat*
Critical (rating >= 2)	8
High (rating >= 1.8)	2
Low (rating < 1.8)	31



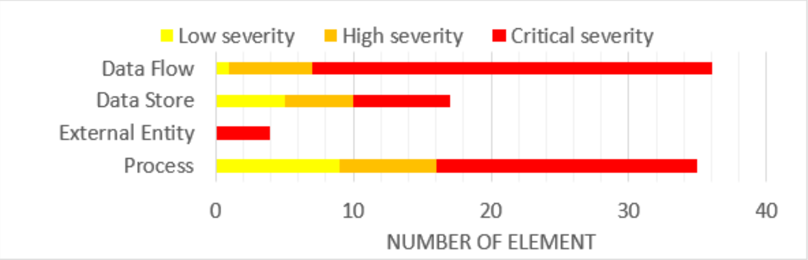
* Threat: potential sources of attacks towards the use case architecture.

Based on the above findings from the STRIDE exercise an implementation plan to address the threats on data flows and processes has been drafted in order to improve upon these easy-to-reach improvements with respect to security. The high and critical severity threats will be addressed by providing dedicated hard- and software solutions throughout a dedicated catalogue. Vegetable UC 4.2: Chain-integrated greenhouse production.

3.13.3 System analysis

Summary: 75% of attackable elements are data flows and processes. Most of the critical threats are located on the Data Flow and the processes.

Name of the STRIDE element	Number of element*
Process	6
External Entity	2
Data Store	5
Data Flow	12
Total	24

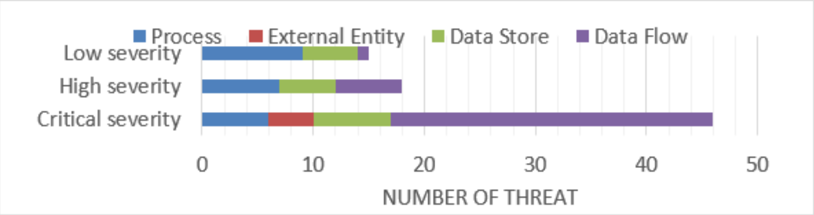


* Elements comprise all soft- and hardware components of the use case architecture.

3.13.4 Threat analysis

Summary: Most of the threats have a critical severity. Almost half of them are located on Data Flow.

Level of severity	Number of threat*
Critical (rating >= 2)	15
High (rating >= 1.8)	18
Low (rating < 1.8)	54



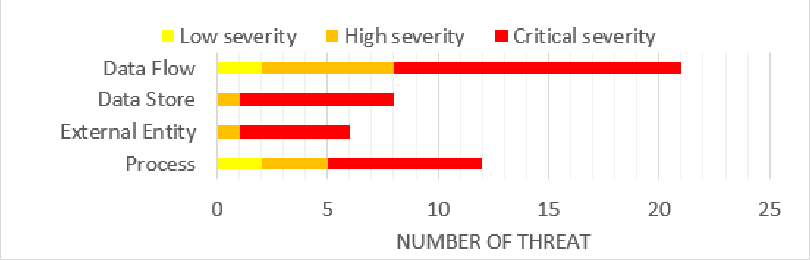
* Threat: potential sources of attacks towards the use case architecture.

3.14 VEGETABLE UC 4.3: ADDED VALUE WEEDING DATA

3.14.1 System analysis

Summary: 50% of attackable elements are data flows. Most of the critical threats are also present on the data flows.

Name of the STRIDE element	Number of element*
Process	2
External Entity	3
Data Store	2
Data Flow	7
Total	14

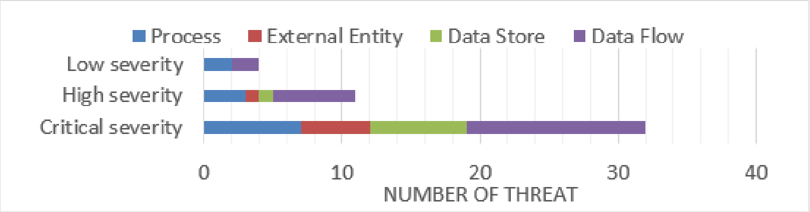


* Elements comprise all soft- and hardware components of the use case architecture.

3.14.2 Threat analysis

Summary: 68% of the threats have a critical severity and only 8% a low severity.

Level of severity	Number of threat*
Critical (rating >= 2)	32
High (rating >= 1.8)	11
Low (rating < 1.8)	4



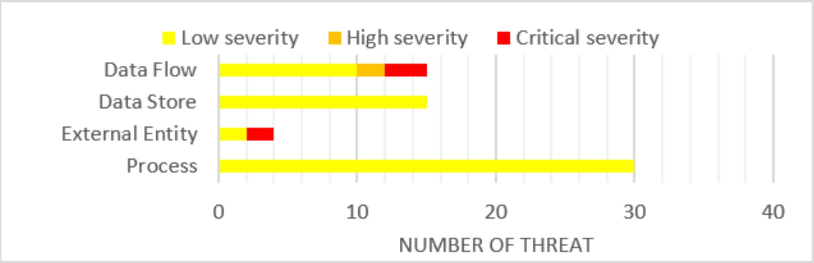
* Threat: potential sources of attacks towards the use case architecture.

3.15 VEGETABLE UC 4.4: ENHANCED QUALITY CERTIFICATION SYSTEM

3.15.1 System analysis

Summary: 40% of attackable elements are data flows. The critical threats are located only on the data flows and on the external entities.

Name of the STRIDE element	Number of element*
Process	5
External Entity	2
Data Store	5
Data Flow	12
Total	30

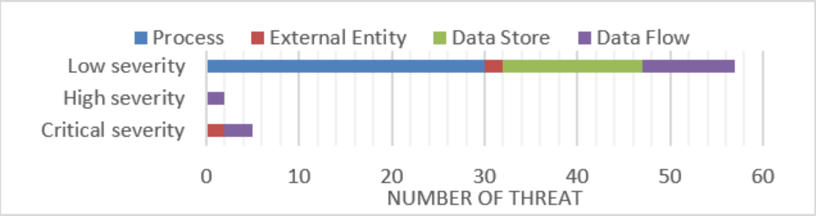


* Elements comprise all soft- and hardware components of the use case architecture.

3.15.2 Threat analysis

Summary: 89% of the threats have a low severity, only 7% a critical severity.

Level of severity	Number of threat*
Critical (rating >= 2)	5
High (rating >= 1.8)	2
Low (rating < 1.8)	57



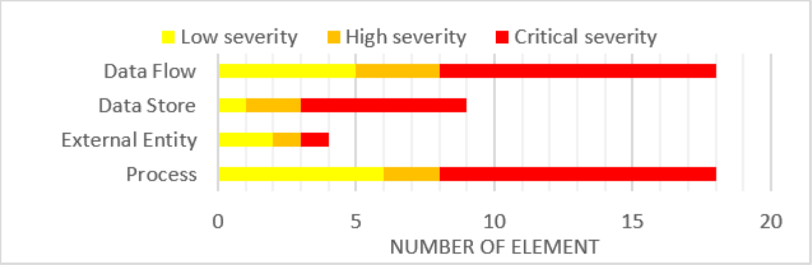
* Threat: potential sources of attacks towards the use case architecture.

3.16 MEAT UC 5.1: PIG FARM MANAGEMENT

3.16.1 System analysis

Summary: Close to 66% of attackable elements are data flows and processes. Half of the threats on the data flows and processes have a critical severity.

Name of the STRIDE element	Number of element*
Process	3
External Entity	2
Data Store	3
Data Flow	7
Total	15

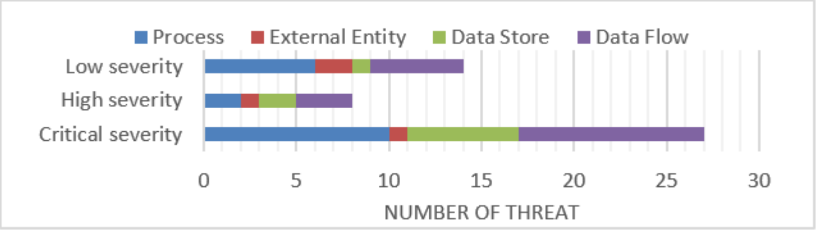


* Elements comprise all soft- and hardware components of the use case architecture.

3.16.2 Threat analysis

Summary: Almost 55% of the threats have a critical severity.

Level of severity	Number of threat*
Critical (rating >= 2)	27
High (rating >= 1.8)	8
Low (rating < 1.8)	14



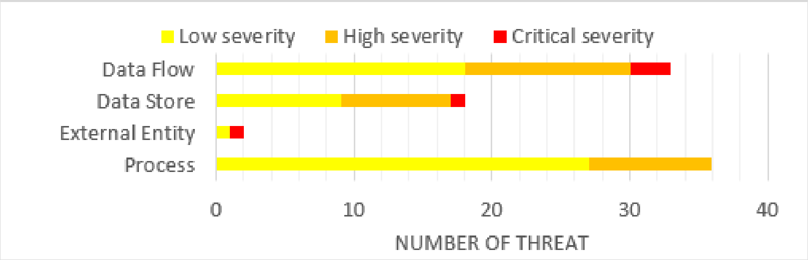
* Threat: potential sources of attacks towards the use case architecture.

3.17 MEAT UC 5.2: POULTRY CHAIN MANAGEMENT

3.17.1 System analysis

Summary: Close to 66% of attackable elements are data flows and processes. External entities cause the least threats. Most of the critical threats are located on the Data Flow.

Name of the STRIDE element	Number of element*
Process	6
External Entity	1
Data Store	5
Data Flow	11
Total	23

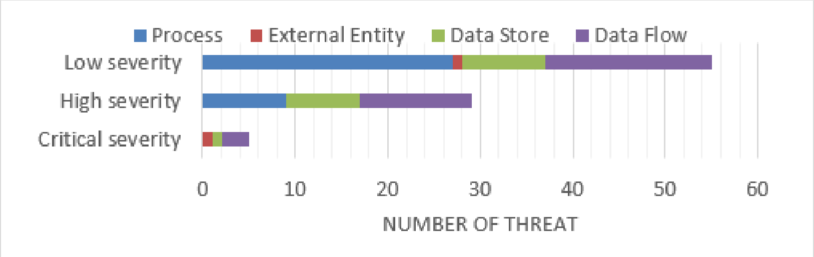


* Elements comprise all soft- and hardware components of the use case architecture.

3.17.2 Threat analysis

Summary: Most of the threats have a low severity. Only +/- 5% have a critical severity.

Level of severity	Number of threat*
Critical (rating >= 2)	5
High (rating >= 1.8)	30
Low (rating < 1.8)	55



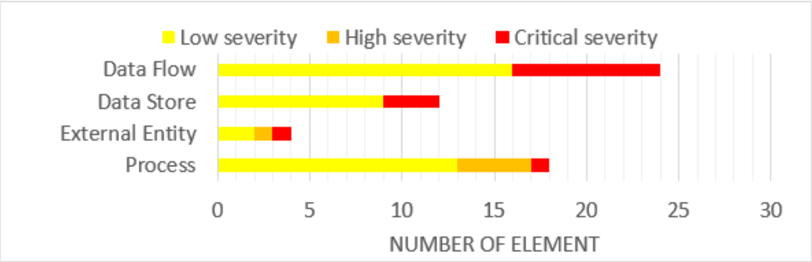
* Threat: potential sources of attacks towards the use case architecture.

3.18 MEAT UC 5.3: MEAT TRANSPARENCY AND TRACEABILITY

3.18.1 System analysis

Summary: 50% of attackable elements are data flows. External entities cause the least threats. Most of the critical threats are located on the Data Flow.

Name of the STRIDE element	Number of element*
Process	3
External Entity	2
Data Store	3
Data Flow	8
Total	16

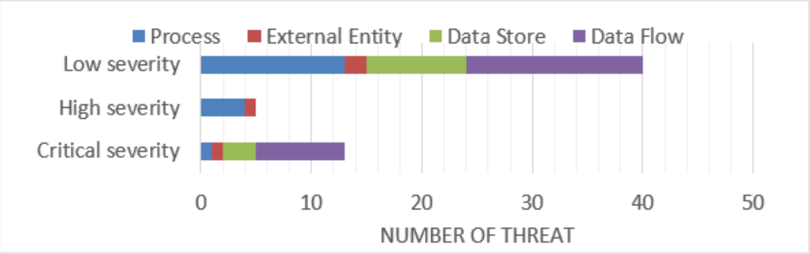


* Elements comprise all soft- and hardware components of the use case architecture.

3.18.2 Threat analysis

Summary: most of the threats have a low severity. 22% have a critical severity.

Level of severity	Number of threat*
Critical (rating >= 2)	13
High (rating >= 1.8)	5
Low (rating < 1.8)	40



* Threat: potential sources of attacks towards the use case architecture.

3.19 NEXT STEPS FOR SECURITY, PRIVACY AND TRUST ANALYSIS

The potential threats are identified and sorted according to their severity. The designer teams have the information on where and how strong the security features must be implemented.

- As a first step, they can focus efforts to resolve the threats with the highest severity.
- After their resolution, the Security, Privacy and Trust analysis document should be updated and re-evaluated to keep a track of system changes and improvements in security.

4 ASSESSMENT OF PROJECT RELATED KPI

The progress on the project objective will be measured on basis of the target outcomes, KPIs and performance targets. This shall also be realised by WP3 with respect to technology and IoT development related aspects. Therefore, the project steering group was defining a list of KPIs that can also be used as a basis to assess the overall project KPI Reusability, which we should measure every three months and evaluate during our quarterly physical PSG meetings. Since the KPI reusability indicates the reusability of project results in use cases and consists of three sub KPIs and numbers of reused:

- Technical components and Open platforms
- Business models
- Principles and guidelines for data governance and digital ethics

WP 3 is specifically focusing on the reuse of technical components and open platforms.

For being able to further detail the envisaged target outcomes of the IoF2020 project, the following measurement of KPIs.

Table 88: KPIs for the measurement of WP3 related target outcomes of the IoF2020 project.

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May '18)	Target values	Short comment / qualitative estimation
Integrated and adapted IoT components	Number of IoT devices implemented (especially sensors and actuators)	1677	19,500	Sum of the numbers reported in each Use Case
	Number of IoT communication components implemented (wireless networks, IoT platforms, gateways, etc.)	34	180	Sum of the numbers reported in each Use Case
	Number of IoT applications available	20	80	Sum of the numbers reported in each Use Case
Usage of open IoT architectures and platforms	Number of IoT Reference Architecture instances	19	19	Sum of the numbers reported in each Use Case
	Number of FIWARE GEs instances	3	40	- FIWARE Pep Proxy (5) - FIWARE Orion Context Broker (7) FIWARE Identity Manager (2)
	Number of open datasets used	2	40	Sum of the numbers reported in each Use Case
Reuse of IoT components	Number of IoT components that are reused in multiple IoT solutions	5	20	- FIWARE Pep Proxy (5) - Cygnus (2) - FIWARE Orion Context Broker (7) FIWARE Identity Manager (2) - LoRA Gateway (2)
	Average number of installations per reusable IoT component	/	5	Early to know at M18
Advancement IoT standardization in agri-food	Number IoT Systems based on existing IoT standards	6	20	- FIWARE Pep Proxy (5) - Cygnus (2) - FIWARE Orion Context Broker (7) FIWARE Identity Manager (2) - STH comet - IOT Agent from UC 5.2 (1)
	% of identified standardization gaps that resulted in pre-normative		75%	

Target outcomes	Key Performance Indicators (KPIs)	Estimated current value (May '18)	Target values	Short comment / qualitative estimation
	change proposals submitted to IoT standardization bodies			

5 OVERALL GAP ANALYSIS

An overall, aggregated analysis of IoT-related gaps has been performed building upon the gap analysis reported in Section 2. Overall, observed gaps fall in one or more of the following categories that, due to yet early state of the project, do not differ too much from the ones reported in the first version of this document:

- **Incomplete UC specifications**: many UCs still need to specify in details part of the key features of the systems deployed in their scenarios; this status is mostly associated with the iterative nature of the project, which makes more convenient to start by deploying the simplest/most mature systems first before taking (bad) decisions – but nevertheless introduces some uncertainties, which make more difficult to plan for common developments and architectures.

- **Unclear security requirements:** as described in Section 3, a first cyber-security analysis of most UCs has been performed using the STRIDE methodology; at the present stage, such analysis has been useful to make sure that design/specification activities also accounted for security aspects. Despite this, the STRIDE analysis is most effective when applied to complete, operational systems, also considering organizational and business-related aspects. For this reason, at the current stage of the project, for most UCs, the analysis doesn't allow proper definition and application of security-related counter-measures and must be considered high-level/incomplete, still requiring a more precise level of details to draw final conclusions.

  Nonetheless, in the last months NXP has worked at the definition of some guidelines that, starting from the STRIDE analysis reported in this document, will guide all the Use Cases in the adoption of all the necessary security measures.

- **Unclear privacy/data ownership requirements:** as in the case of security-related aspects, it is difficult to plan technical/architectural aspects when the data ownership/data access aspects are not fully clarified. An additional complication exists in the definition of such aspects: as multiple parties may be involved in the creation, maintenance and exploitation of flows of data from the field, it is really difficult to accomplish the need of building a very precise picture of who operates the systems generating data, who has access to it, in which form (raw, aggregated, elaborated, etc.) and for what reason (functional reasons, maintenance purposes, audit, etc.).

- **Lack of details in the Data Model:** while most individual UCs have relatively clear specifications about the types of data (and meta-data), which is handled in their own case, a more detailed analysis is required to map data models of UCs among each other, with more general data models established in the agri-food domain and with higher-level data models in place in horizontal IoT applications.

- **Lack of knowledge about possible performance of IoT products in UC conditions**: many UCs face the need to selecting IoT technologies to use (sensors, gateways, platforms, etc.), but they lack the experience necessary to predict how a specific technology will perform on the field (e.g. in terms of robustness, ease of integration, etc.), prior to make a final decision. The situation is expected to improve thanks to the lessons learned from the first field deployments.

- **Uncertainty about fitness with product/technology roadmaps:** beyond the need to understand how a specific IoT product/platform/standard can fit the need of a specific UC *today*, some UCs also face the problem of understanding whether future evolutions/roadmaps for that specific product/platform/standard are moving in a direction which is compatible with the future needs of the UCs.

- **Need for support in choosing (or developing) components for specific needs or problems of UCs:** in some cases, while the UC needs have been clearly addressed, some support is needed in identifying specific existing IoT tools suitable to solve specific problems. There are also cases for whom a specific existing solution fully meeting the expectation of the UC has not been found in the consortium or in the market.

5.1 GAP-FILLING PLANS

During the last months, WP2 and WP3 have already collaborated to fill the gaps reported in the previous version of this document, however, the analysis reported in the previous paragraph reveals the need of continuing to invest time in collaborations aiming at collaboratively fill the gaps outlined above, as well as the specific technical gaps existing in individual UCs.

In the following, an overview of the strategy that will be followed for gap-filling is reported for each class of gaps mentioned above:

- **"Incomplete UC specifications"**: use the experience of the first on-going deployments to clarify all the missing technical details . Parameters that needs to be clarified and fine-tuned (e.g. the frequency of data collection from specific sensors) should be kept highlighted as "system variables", so that multiple options can be evaluated before making final choices. Promote initiatives, like an IoT catalogue, to report the updated details of each Use Case in a shared platform that can foster the development of new solutions.
- **"Unclear security requirements"** and **"Unclear privacy/data ownership requirements:"** Due to the scale of UCs, data-collection agreements in each test site can provide already significant inputs about how real end-user would like to see the issue managed in close-to-real conditions; evaluate how data anonymization techniques can play a role in the problem. In addition, the security guidelines provided by NXP can foster the adoption of all the needed security measures.
- **"Lack of details in the Data Model":** since data models can vary and evolve over time, it would be too ambitious to deliver a single, static model for all the data handled across the UCs; the project should therefore keep a more fluid approach, adopting techniques to dynamically define, manage and inter-link context data associated with the pilots. The main advice is to start by incorporating and mapping the low-level data models of APIs and protocols used on the field.
- **"Lack of knowledge about possible performance of IoT products in UC conditions"**: the experience from the first deployment should provide significant lessons learned on this aspect; whereas needed, short-lived comparative demonstrations of technologies and feasibility tests should be organized in lack of valid information about performance of specific systems on the field. The lessons learned could, then, be reported in the following deliverables or in a shared platform, like an IoT catalogue to foster new developments.
- **"Uncertainty about fitness with product/technology roadmaps:"** specific workshops should be held to present product/platform roadmap (e.g. in the case of FIWARE components) which may also be used to draw valid inputs from agri-food end-users about their future plans and expectations about IoT components.
- **"Need for support in choosing (or developing) components for specific needs or problems of UCs:"** continue the collaboration between WP2 and WP3 so that the need for new developments and/or indications about IoT technology is pursued.

6 CONCLUSIONS

Results documented in this report provide a “common ground” to establish IoT-based innovations in the next phases of the project, both within each UC, spawning across multiple UCs or even beyond the traditional limits of the agri-food sector.

The analysis has been updated in M18 (June 2018), resulting in the publication of the current updated version of this document.

Considering that the project is not yet completed (it will finish in M48), the description of each Use Case is not yet consolidated. However, the results elaborated and presented in deliverable D3.2 represent a milestone to facilitate the collaboration with the use cases in WP2 as well as to coordinate the work in WP3. Specifically, Tasks 3.3, 3.4 and 3.5 will use this input for their upcoming activities to provide and host the technical baseline and to further harmonise the needs and opportunities between the use cases and an external target audience.

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- API: Application Programming Interface
- AWS: Amazon Web Services
- BLE: Bluetooth Low Energy
- DB: Database
- DO: Dissolved Oxygen
- DSS: Decision Support System
- DST: Decision Support Tools
- EPC: Electronic Product Code
- EPCIS: Electronic Product Code Information Services
- EPS: Euro Pool System
- ERP: Enterprise Resource Planning
- EU: European Union
- FMIS: Farm Management Information System
- GIS: Geographic Information System
- GPRS: General Packet Radio Service
- GPS: Global Positioning System
- GUI: Graphical User Interface
- HF: High Frequency
- HLA: High Level Architecture
- HTTP: HyperText Transfer Protocol
- HTTPS: HyperText Transfer Protocol over Secure Socket Layer
- I2C: Inter-Integrated Circuit
- IEEE: Institute of Electrical and Electronic Engineers
- ILMD: Instance-Level Master Data
- IoF2020: Internet of Food and Farm 2020
- IoT: Internet of Things
- IPoE: Internet Protocol over Ethernet
- IS: Information System
- ISO: International Organization for Standardization
- IT: Information Technology
- JPEG: Joint Photographic Experts Group
- JSON: JavaScript Object Notation
- KPI: Key Performance Indicator
- LAI: Leaf Area Index
- LAN: Local Area Network
- LLRP: Low Level Reader Protocol
- LPWAN: Low-Power Wide-Area Network
- LWM2M: Lightweight M2M
- M2M: Machine-to-machine
- MEMS: Micro Electro-Mechanical Systems
- MQTT: Message Queue Telemetry Transport
- MVC: Model-View-Controller
- NFC: Near Field Communication

- NIR: Near infrared
- ORP: Oxidation-Reduction Potential
- PC: Personal Computer
- PLC: Programmable Logic Controller
- QR Code: Quick Response Code
- R&D: Research and Development
- RF: Radio frequency
- RFID: Radio Frequency IDentification
- RTI: Returnable Trade Items
- SCADA: Supervisory Control And Data Acquisition
- SI: International System of Units
- SNT: StickNTrack
- SOAP: Simple Object Access Protocol
- SPI: Serial Peripheral Interface
- UC: Use Case
- UHF: Ultra High Frequency
- UID: Unique identifier
- UML: Unified Modeling Language
- USB: Universal Serial Bus
- VPN: Virtual Private Network
- XML: eXtensible Markup Language
- XMPP: Extensible Messaging and Presence Protocol

7.2 LIST OF FIGURES

Figure 1 - Location of IoF2020 Use Cases........10
Figure 2 - UC1.1 Domain Model........15
Figure 3 - UC1.1 Deployment View........16
Figure 4 - UC1.1 IoT Functional View........17
Figure 5 - UC1.1 Business Process Hierarchy view........17
Figure 6 - UC1.2 Domain Model........20
Figure 7 - UC1.2 Deployment View (Cellular Connectivity)........22
Figure 8 - UC1.2 Deployment View (LoRa Connectivity)........22
Figure 9 - UC1.2 IoT Functional View........24
Figure 10: UC1.2 Business Process Hierarchy view........25
Figure 11 - UC1.2 Information Model........27
Figure 12 – Minimal common data model discussion........31
Figure 13 – UC1.3 Domain Model........34
Figure 14 - UC1.3 Deployment scheme........34
Figure 15 – UC1.3 IoT Functional View........36
Figure 16 - UC1.3 Business Process Hierarchy view........37
Figure 17 - UC1.4 Domain Model........39
Figure 18 - UC1.4 Deployment View........40
Figure 19 - UC1.4 IoT Functional View........42
Figure 20 - UC1.4 Business Process Hierarchy view........43
Figure 21 - UC1.4 Information Model........44
Figure 22 - UC2.1 Domain Model........49
Figure 23 - UC2.1 Deployment View........49
Figure 24 – UC2.1 IoT Functional View........51
Figure 25 - UC2.1 Business Process Hierarchy view.........51
Figure 26 – UC2.1 Information Model........52
Figure 27 – UC2.2 Domain Model........56
Figure 28 – UC2.2 Deployment View........57
Figure 29 – UC2.2 IoT Functional View........59
Figure 30 - UC2.2 Business Process Hierarchy view.........59
Figure 31 – UC2.2 Information Model........61
Figure 32 – UC2.3 Domain Model.........63
Figure 33 – UC2.3 Deployment View.........64
Figure 34 – UC2.3 IoT Functional View.........66
Figure 35 – UC2.3 Business Process Hierarchy view.........66
Figure 36 – UC2.3 Information Model.........68
Figure 37 – UC2.4 domain model.........73
Figure 38 – UC2.4 deployment view.........74
Figure 39 – UC2.4 IoT functional view.........75
Figure 40 – UC2.4 business process hierarchy view.........76
Figure 41 – UC2.4 information model.........77
Figure 42 - UC3.1 Domain Model........81
Figure 43 - UC3.1 Deployment View........82
Figure 44 - UC3.1 IoT Functional View........87

Figure 45 - UC3.1 Business Process Hierarchy view.......88
Figure 46 - UC3.1 Information Model.......89
Figure 47 - UC3.2 Domain Model.......94
Figure 48 - UC3.2 Deployment View.......95
Figure 49 - UC3.2 IoT Functional View.......98
Figure 50 - UC3.2 Business Process Hierarchy view.......98
Figure 51 - Overview of the sensiNact communication bridges.......99
Figure 52 - Extension points for the sensiNact platform interoperability.......99
Figure 53 - UC3.2 Information Model.......100
Figure 54 - UC3.3 Domain Model.......105
Figure 55 - UC3.3 Deployment View.......106
Figure 56 - UC3.3 IoT Functional View.......109
Figure 57 - UC3.3 Business Process Hierarchy view.......109
Figure 58 - UC3.3 Information Model.......111
Figure 59 – UC3.4 Domain Model.......114
Figure 60 – UC3.4 Deployment View.......115
Figure 61 – UC3.4 IoT Functional View.......117
Figure 62 – UC3.4 Business Process Hierarchy view.......118
Figure 63 – UC3.4 Information Model.......119
Figure 64 – UC4.1 Domain Model.......122
Figure 65 – UC4.1 Deployment View.......122
Figure 66 – UC4.1 IoT Functional View.......124
Figure 67 – UC4.1 Information Model.......125
Figure 68 – UC4.2 Domain Model.......127
Figure 69 - UC4.2 Deployment View.......128
Figure 70 – UC4.2 IoT Functional View.......130
Figure 71 – UC4.2 Business Process Hierarchy View.......131
Figure 72 – UC4.2 Information Model.......133
Figure 73 – UC4.3 Domain Model.......139
Figure 74 –UC4.3 Deployment Model.......140
Figure 75 – UC4.3 IoT Functional View.......143
Figure 76 – UC4.3 Process Hierarchy Model.......144
Figure 77 – UC4.3 Information Model.......146
Figure 78 - UC4.4 Domain Model.......151
Figure 79 – UC4.4 Deployment View.......152
Figure 80 – UC4.4 IoT Functional View.......156
Figure 81 – UC4.4 Business Process Hierarchy view.......156
Figure 82 – UC4.4 Information Model.......159
Figure 83 - UC5.1 Domain Model.......162
Figure 84 - UC5.1 Deployment View.......163
Figure 85 - UC5.1 IoT Functional View.......166
Figure 86 - UC5.1 Business Process Hierarchy view.......167
Figure 87 - UC5.1 Information Model.......170
Figure 88 - UC5.2 Domain Model.......175
Figure 89 –UC5.2 Cloud Deployment Diagram.......176

Figure 90 – UC5.2 Farm Deployment Diagram (Phase 1) 177
Figure 91 – UC5.2 Farm Deployment Diagram (Phase 2) 177
Figure 92 –UC5.2 Transport and Slaughterhouse Phase 1 Deployment Diagram 178
Figure 93 –UC5.2 Transport and Slaughterhouse Phase 2 Deployment Diagram 178
Figure 94 - UC5.2 IoT Functional View 181
Figure 95 - UC5.2 Business Process Hierarchy view 181
Figure 96 - UC5.2 Information Model 183
Figure 97 – UC5.3 Domain Model 189
Figure 98 – UC5.3 Deployment View 190
Figure 99 – UC5.3 Deployment View 191
Figure 100 – UC5.3 Business Process Hierarchy 192
Figure 101 – UC5.3 Information Model 194

7.3 LIST OF TABLES

Table 1 - Analysts involved in the definition of IoT Architectures of UCs – 1st version of the Deliverable 12
Table 2 - UC1.1 Interoperability Endpoints 18
Table 3 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC1.1) 19
Table 4 - UC1.2 Deployed Components 23
Table 5 - UC1.2 Interoperability Endpoints 26
Table 6 - UC1.2 Information Model Details 27
Table 7 - UC1.2 Assets identified for re-use 29
Table 8 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project.(UC 1.2) 31
Table 9 - UC1.3 Deployed Components 35
Table 10 - UC1.3 Interoperability Endpoints 37
Table 11 - UC1.3 Assets identified for re-use 38
Table 12 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC1.3) 38
Table 13 - UC1.4 Deployed Components 41
Table 14 - UC1.4 Interoperability Endpoints 43
Table 15 - UC1.4 Information Model Details 45
Table 16 - UC1.4 Assets identified for re-use 46
Table 17 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC1.4) 47
Table 18 - UC2.1 Deployed Components 50
Table 19 - UC2.1 Interoperability Endpoints 52
Table 20 - UC2.1 Information Model Details 52
Table 21 – UC2.1 Assets identified for re-use 53
Table 22 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC2.1) 54
Table 23 - UC2.2 Deployed Components 58
Table 24 – UC2.2 Interoperability Endpoints 59
Table 25 – UC2.2 Assets identified for re-use 61

Table 26 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC2.2) 62
Table 27 – UC2.3 Deployed Components. 65
Table 28 – UC2.3 Interoperability Endpoints. 67
Table 29 – UC2.3 Information Model Details. 68
Table 30 – UC2.3 Assets identified for re-use. 69
Table 31 - UC2.3 Collaborations with other Use Cases. 70
Table 32 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC2.3) 70
Table 33 – UC2.4 Deployed Components. 74
Table 34 – UC2.4 Interoperability Endpoints. 77
Table 35 – UC2.4 Information Model Details. 78
Table 36 – UC2.4 Assets identified for re-use. 79
Table 37 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC2.4) 79
Table 38 - UC3.1 Deployed Components 83
Table 39 - UC3.1 Interoperability Endpoints 89
Table 40 - UC3.1 Information Model Details 90
Table 41 - UC3.1 Assets identified for re-use 91
Table 42 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC3.1) 92
Table 43 - UC3.2 Deployed Components 95
Table 44 - UC3.2 Information Model Details 100
Table 45 - UC3.2 Assets identified for re-use 102
Table 46 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project.(UC3.2) 103
Table 47 - UC3.3 Deployed Components 107
Table 48 - UC3.3 Interoperability Endpoints 110
Table 49 - UC3.3 Information Model Details 111
Table 50 - UC3.3 Assets identified for re-use 112
Table 51 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC3.3) 113
Table 52 – UC3.4 components to be deployed 116
Table 53 – UC3.4 Interoperability Endpoints. 118
Table 54 – UC3.4 Information Model Details 120
Table 55 – UC3.4 Assets identified for re-use. 121
Table 56 - UC4.1 Deployed Components 123
Table 57 - UC4.1 Interoperability Endpoints 124
Table 58 - UC4.1 Information Model Details 125
Table 59 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC4.1) 126
Table 60 - UC4.2 Deployed Components 129
Table 61 - UC4.2 Interoperability Endpoints 132
Table 62 – UC4.2 Information Model Details 133
Table 63 – UC4.2 Assets identified for re-use. 137
Table 64 - UC4.2 Collaboration with other Use Cases 137

Table 65 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC4.2)........ 138
Table 66 - UC4.3 Deployed Components 141
Table 67 – UC4.3 Interoperability Endpoints........ 145
Table 68 – UC4.3 Information View 147
Table 69 – UC4.3 Assets identified for re-use........ 148
Table 70 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC4.3........ 149
Table 71 – UC4.4 Deployed Components........ 153
Table 72 – UC4.4 Interoperability Endpoints........ 157
Table 73 – UC4.4 Information Model Details 159
Table 74 – UC4.4 Assets identified for re-use........ 160
Table 75 - : KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC4.4........ 161
Table 76 - UC5.1 Deployed Components 164
Table 77 - UC5.1 Interoperability Endpoints 168
Table 78 - UC5.1 Information Model Details 170
Table 79 - UC5.1 Assets identified for re-use 172
Table 80 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC5.1)........ 174
Table 81 - UC5.2 Deployed Components 179
Table 82 - UC5.2 Interoperability Endpoints 182
Table 83 - UC5.2 Information Model Details 184
Table 84 - UC5.2 Assets identified for re-use 185
Table 85 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC5.2)........ 187
Table 86 – UC5.3 Interoperability Endpoints........ 192
Table 87 - KPIs for the measurement of WP3 related target outcomes of the IoF2020 project (UC5.2)........ 195
Table 88: KPIs for the measurement of WP3 related target outcomes of the IoF2020 project. 209

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