PROGRESS REPORT ON SYNERGY ANALYSIS, DECISIONS AND COORDINATION OF WORK

WP 3

July 24th, 2018

Identifying synergies between the 19 IoF2020 use cases with recommendations for follow-up actions to create more synergy in the project

IoF2020 has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 731884. Visit iof2020.eu for more information about the project.

DOCUMENT IDENTIFICATION

Project Acronym	IoF2020
Project Full Title	Internet of Food and Farm 2020
Project Number	731884
Starting Date	January 1st, 2017
Duration	4 years
H2020 Call ID & Topic	IOT-01-2016
Date of the DoA	2017-2021
Website	www.iof2020.eu

File Name	D3.9 Synergy Analysis Final.docx
Date	July 24th, 2018
Version	1.0
Status	Final
Dissemination level	PU: Public
Author	Jeroen van Grondelle, Cor Verdouw, Sjaak Wolfert (Wageningen University & Research)
Contact details of the coordinator	George Beers george.beers@wur.nl

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+ members 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

The backbone of the IoF2020 project consists of the 19 IoT use cases that are being developed and deployed across Europe. They take place across the agri-food sector, and include use cases from the dairy, arable, fruit, vegetable and meat sector. In this report we study the use cases, with the aim to identify and facilitate opportunities for synergy and reuse.

Within the IoF2020 project, a broad concept of reuse is used. It ranges from classical reuse of technical components and code, to sharing the experiences and practical lessons learned that come with scaling up technical solutions in real world environments.

Our analysis is based on the architectures that each use case drafted and that were published in D3.2: The IoF2020 Use Case Architectures and Overview of the Related IoT Systems. The architectures were studied from both a logical and a technological perspective, capturing what functionality the use cases realized using IoT technology, and what technological choices were made in realizing that functionality. The results have been validated by the use cases afterwards.

A number of technological aspects seem to be in line with the scaling up of existing solutions:

- There is quite a lot of heterogeneity within the project. For instance, a broad range of networking technologies and a large number of different cloud platforms are employed within the different use cases;
- The maturity of the sensor devices is what may be expected of a project that focuses on the higher technical readiness levels: quite a high number of the sensors used are commercially available or are standard part of larger equipment of machinery;
- State of the art, IoT specific networking protocols such as Lora and Sigfox are deployed by a large number of use cases.

The use cases offer state-of-the-art IoT functionality in an agri-food context:

- The use cases use a large range of sensors and measure a vast array of data dimensions;
- These data are used in advanced, state-of-the-art control loops. The majority of the use cases move beyond passive portals with sensor data and introduce intelligent, task-specific decision support for agri-food professionals and/or fully autonomous control loops that automatically trigger actuators based on sensor data and statistical data processing.

Based on the commonalities discovered in this analysis, this deliverable recommends to aim to realize synergy in a way that is consistent with a system of systems philosophy. This means that synergy is realized through measures during all the different realization phases rather than realizing synergy through upfront design, standardization or consolidation on a single platform. The proposed synergy actions include:

- **Drafting shared information model fragments for sensor data**, dealing with genericity in sensor domains across use cases, challenges in capturing time and location specific to IoT sensor data and challenges that arise from simultaneous training and application of statistical models and machine learning algorithms based on sensor data;
- **Including the synergy analysis results in the IoT Catalogue** that is being developed as part of WP3. This will allow for easy, interactive access to the technology and functionality of other use cases beyond the static reporting in this report. This may help use cases to discover project partners that may help them with practical challenges;
- **Organizing short, lightweight task forces** that produce practical lessons learned or guidelines for shared commonalities. A process is proposed for how use case partners can be in the lead in these task forces, potentially being facilitated by the supporting work packages. Topics should be chosen by the use cases based on their needs. A number of candidate topics is proposed based on the commonalities to jumpstart this process.

TABLE OF CONTENTS

EXECUTIVE SUMMARY 4

ABBREVIATIONS 9

LIST OF FIGURES 11

1. INTRODUCTION 13

1.1 WHY IS SYNERGY IMPORTANT 13

1.2 DIFFERENT KINDS OF SYNERGY 13

1.3 OBJECTIVES OF THIS DOCUMENT 16

1.4 OUR ANALYSIS APPROACH 16

2 TECHNOLOGIES USED IN THE USE CASES 20

2.1 CONNECTIVITY 20

2.2 NETWORK TOPOLOGY 21

2.3 DEVICE ARCHITECTURES 22

2.4 CLOUD PLATFORMS 23

2.4.1 FIWARE usage 24

2.4.2 Data management 25

2.5 LOCALIZATION 26

2.6 NON-FUNCTIONAL REQUIREMENTS 27

3 FUNCTIONALITY OF THE USE CASES 29

3.1 IOT FUNCTIONS 29

3.2 DOMAINS 30

3.3 DIFFERENT KINDS OF CONTROL FLOW 32

3.4 CHALLENGES AND OBJECTIVES ADDRESSED IN THE USE CASES 35

4 PROMISING COMMONALITIES 36

4.1 TECHNOLOGICAL COMMONALITIES 36

4.2 COMMONALITIES IN THE USE CASE DOMAINS 37

5 RECENT TRENDS IN INTERNET OF THINGS TECHNOLOGY 38

5.1 INTELLIGENT THINGS THROUGH AI 38

5.2 EDGE AND FOG COMPUTING 38

5.3 SECURITY 39

5.4 (PUBLIC) IOT PLATFORMS 39

5.5 ADOPTION OF IOT CONNECTIVITY STANDARDS 39

5.6 AUTONOMOUS DEPLOYMENT AND ENERGY HARVESTING 40

5.7 AUGMENTED REALITY 40

5.8 BLOCKCHAIN 40

6 POTENTIAL SYNERGY ACTIONS 41

6.1 REFERENCE DATA MODELS 41

6.1.1 Three aspects of data modelling 41

6.1.2 Next steps 42

6.2 CATALOGUE & MARKETPLACE 43

6.2.1 Use Cases: Practical Experiences with IoT Solutions 43

6.2.2 Audiences and Intended Use 43

6.2.3 Practical catalogue ideas 44

6.2.4 Wireframes 47

6.2.5 Next steps 48

6.3 TASK FORCES & GUIDELINES 48

6.3.1 Organizing synergy task forces 49

6.3.2 Potential Outcomes 49

6.3.3 Potential Topics 50

6.3.4 Next Steps 52

6.4 RECOMMENDATIONS FOR THE OPEN CALL 52

7 GENERAL CONCLUSIONS 53

APPENDIX A: VALIDATION FORM 55

ABOUT THE USE OF IOT 55

ABOUT THE TECHNOLOGIES USED 56

APPENDIX B LIST OF USE CASES IN IOF2020 58

ABBREVIATIONS

Abbreviation	Definition
AI	Artificial Intelligence
AR	Augmented Reality
BLE	Bluetooth Low Energy
COTS	Commercial Off-the-Shelf
EPCIS	Electronic Product Code Information Services
GLN	Global Location Number
GPS	Global Satellite Positioning
IoT	Internet of Things
LoRa/WAN	Long Range Wide Area Network
LPWAN	Low Power Wide Area Network
LR-WPAN	Low-Rate Wireless Personal Area Network
MEMS	Microelectromechanical Systems. A class of microscopically components that combine electrical techniques with mechanical (moving) parts.
PLC	Programmable Logic Controllers. Class of sensors, actuators, controllers and protocols that originate from industrial automation
PoC	Proof of Concept
QR code	Quick Response code. Standard for two-dimensional bar codes.
RFID	Radio Frequency Identification

SoC	System on a Chip
TRL	Technological Readiness Level
WAN	Wide Area Network

LIST OF FIGURES

FIGURE 1: THE CONNECTED SOLUTIONS MODEL BY PORTER 14
FIGURE 2: SCALING UP EXISTING IOT SOLUTIONS 14
FIGURE 3: A SYSTEM OF SYSTEMS APPROACH TO SYNERGY; THE PROJECTS AND ORGANIZATIONS AT THE BOTTOM ARE JUST A FEW EXAMPLES AND IS NOT AN EXHAUSTIVE LIST 15
FIGURE 4: ANALYSIS APPROACH 17
FIGURE 5: TAGGING THE ARCHITECTURES DELIVERABLE D3.2 18
FIGURE 6: SYNERGY IN THE LOGICAL VIEW 18
FIGURE 7: CONNECTIVITY PROTOCOLS USED IN THE USE CASES 21
FIGURE 8: NETWORK TOPOLOGY OF THE USE CASES 22
FIGURE 9: DEVICE ARCHITECTURES USED BY THE USE CASES 23
FIGURE 10: CLOUD PLATFORMS USED BY THE USE CASES 24
FIGURE 11: FIWARE COMPONENTS USED IN THE USE CASES 25
FIGURE 12: DATA MANAGEMENT ASPECTS OF THE USE CASES 26
FIGURE 13: THE USE OF LOCALIZATION TECHNOLOGIES 27
FIGURE 14: AGRI-FOOD SPECIFIC NON-FUNCTIONAL REQUIREMENTS 28
FIGURE 15: IOT FUNCTIONS 30
FIGURE 16: IOT FUNCTIONS OBSERVED IN THE USE CASES 30
FIGURE 17: WORD CLOUD OF INITIAL ANALYSIS OF DATA DIMENSIONS 31
FIGURE 18: DATA CATEGORIES USED IN THE USE CASES 32
FIGURE 19: TYPICAL FEEDBACK LOOP IN IOT SYSTEMS 33
FIGURE 20: TYPE OF IOT CONTROL LOOP OBSERVED IN THE USE CASES 34
FIGURE 21: SOLUTION VS PRACTICAL EXPERIENCE 43
FIGURE 22: NAVIGATING BETWEEN PRACTICAL EXPERIENCE AND IOT SOLUTION USED 45
FIGURE 23: EXPOSING THE USE CASES BASED ON BUSINESS OBJECTIVE OR CHALLENGE 46
FIGURE 24: A USE CASE VIEW BASED ON ARCHITECTURAL PRODUCT TYPOLOGY 46

FIGURE 25: OFFERING KNOWLEDGE BASE STYLE NAVIGATION BASED ON TAXONOMIES 47
FIGURE 26: WIREFRAME OF THE CATALOGUE 48
FIGURE 27: PROCESS FOR ORGANIZING A TASK FORCE 49

1. INTRODUCTION

Within the IoF2020 project 19 different use cases are developed that prove that IoT in the agri-food sector is beyond the initial stages and ready for scaling up. The use cases have been selected for the technical readiness required for large scale pilots.

1.1 WHY IS SYNERGY IMPORTANT

Although all use cases have their unique aspects, synergy between the use cases is important for a number of reasons.

Success and efficiency of the use cases - All use cases are scaling up their solutions to out-of-lab conditions. When these solutions are deployed at scale in practical contexts, similar challenges may arise. By sharing challenges and the strategies for addressing them, use cases do not waste time solving them in parallel and have a larger chance of successfully overcoming these challenges.

IoT adoption in agri and food beyond the project - By discovering synergy between the use cases, the IoF2020 project can have impact beyond the 19 specific solutions deployed within the project. By capturing the lessons learned and sharing these experiences, the project will help progress IoT adoption in the agri-food sector in other related scenarios as well.

1.2 DIFFERENT KINDS OF SYNERGY

Within the IoF2020 project, we have taken a broad perspective on reuse. This ranges from the classical reuse and sharing of system components and code to the sharing of successful approaches and lessons learned in the form of guidelines and designs. The reason for this is the nature of the IoF2020 project, and the high degree of heterogeneity it has to deal with as a consequence. There are two main reasons for this heterogeneity.

1) Internet of things, when taken beyond isolated use cases, inevitably leads to heterogeneity. Smart agri-food environments contain large number of different sensors and connected equipment. The information gathered impacts many processes and therefore leads to integration with the applications supporting these processes. A well-known model is the Connected solutions model by Porter (2014), which excellently illustrates the growing interconnectedness when IoT solutions mature (Figure 1).

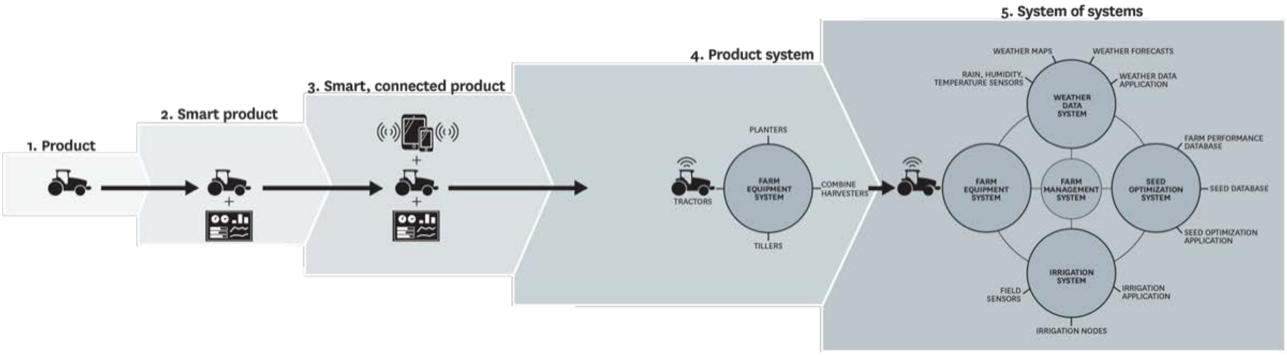

Figure 1: The Connected Solutions model by Porter[1]

2) Being a large-scale pilot, the project's main objective is to take promising applications of IoT in the agri-food sector and scale them up (Figure 2). This means that partners enter the project with existing solutions, and so inherently already have developed or selected devices, architectures and technologies before joining this project. Within the IoF2020 project itself, few of the use cases go through the type of greenfield design phase that allows for up front identification of shared requirements and shared development.

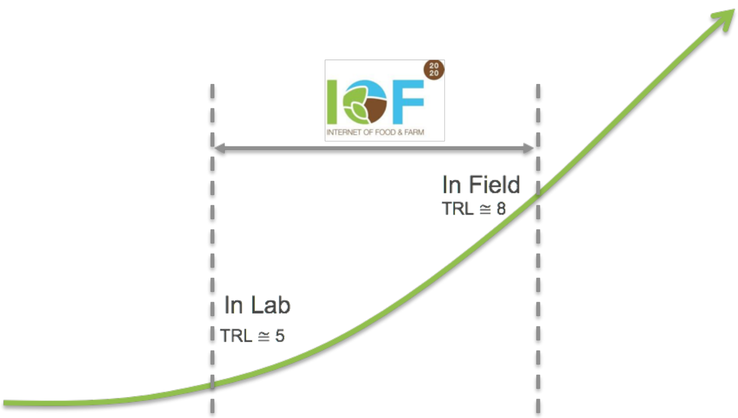

Figure 2: Scaling up existing IoT solutions

In addition to conventional reuse scenarios, reuse is therefore also approached from a portability perspective. When scaling up existing systems and solutions, adopting existing technical components from others into the architecture is not always easy. In those cases, transferring successful underlying

---

[1] Porter, M. E., & Heppelmann, J. E. (2014). How smart, connected products are transforming competition. *Harvard Business Review*, *92*(11), 64-88.

design strategies and patterns without adopting the actual technical components is a great way to benefit from earlier work from others. The same holds for transferring project results beyond the project: some of the collective insights developed in the project are best shared in the form of guidelines and patterns, ready for adoption into the sector specific offerings developed beyond the project.

Reuse is operationalized across the different phases of the project using the approach in Figure 3.

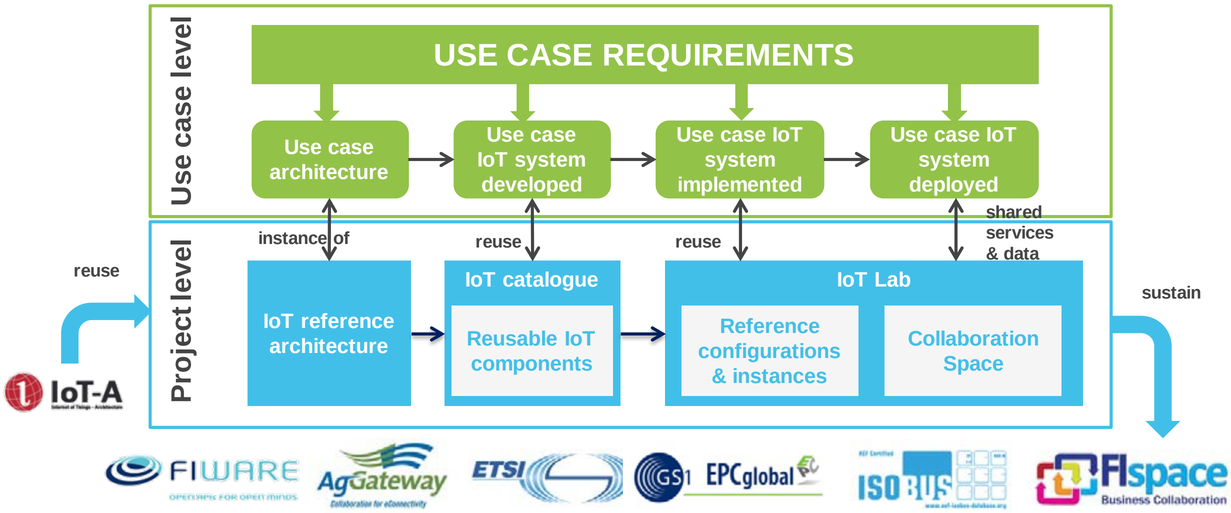

Figure 3: A system of systems approach to synergy; the projects and organizations at the bottom are just a few examples and is not an exhaustive list

It proposes different synergy measures during the different project phases:

- The use case architectures are based on a common technical reference architecture to create a shared understanding and to maximize synergies across multiple use case systems. Each use case within a trial designs a specific instance of the reference architecture to address its specific user requirements;
- The project provides a catalogue of reusable system components, which can be integrated in the IoT systems of multiple use cases to facilitate large-scale uptake. This repository goes beyond a checklist and includes practical guidelines and implementation tools.
- The IoF2020 lab will support the implementation of reusable IoT components in a testbed environment.
- Finally, IoF2020 will provide a Collaboration Space in which services and data can be shared as a key enabler to facilitate the interaction between the IoT systems of the use cases during deployment.

The broad approach to synergy could lead to a number of different scenarios.

Component reuse - The classical interpretation of reuse: A use case reuses a component that is developed and/or used in another use case. Variants are of course the reusing of components that are developed in earlier projects (for instance in the FIWARE family of projects) or buying existing components or services that are already manufactured commercially. With the relatively mature nature of the solutions in this scaling up projects, the latter two scenarios are observed quite frequently.

Shared development - Shared needs may be identified across use cases for which no components are available yet. In those cases, a single component could be developed for shared use by the use cases. Shared development could consist of technical development and/or software engineering, but also of shared installation and configuration of a single instance of a component for shared use. In a variant of this scenario, a technology partner in the project could provide a component that is used by more than one use cases. This scenario could be very feasible as part of the open call.

Sharing experiences and expertise - As depicted in Figure 3, different project phases ask for different forms of reuse. The same holds for sharing experiences and expertise. In the design and build phase, this could consist of typical architectural choices made and the criteria/requirements they meet. In the realization phase, lessons learned could help guide the selection of the most suitable (reusable) components given the specific use case context. And in deployment, field experience could be shared, such as for instance sensor particularities, placement issues, etc. This latter category is important given the scaling up nature of this project. Lessons learned and guidelines that help deploying IoT at scale efficiently are key to large scale adoption of IoT in the sector.

Data level synergy - In an IoT project, data collection and prediction is an important part of any solution. This could give rise to synergy at a data sharing level. Data collected and statistical models derived in one use case could enrich the predictions made in another use case.

1.3 OBJECTIVES OF THIS DOCUMENT

This document has the following objectives:

- Help use case partners identify use cases with shared challenges;
    - Related to the objectives of the catalogue, see section 6.2;
- Identify opportunities for sharing experience beyond the project;
- Help project partners identify potential gaps that may be filled in the open call.

1.4 OUR ANALYSIS APPROACH

This synergy analysis is based on a four-step process as depicted in Figure 4.

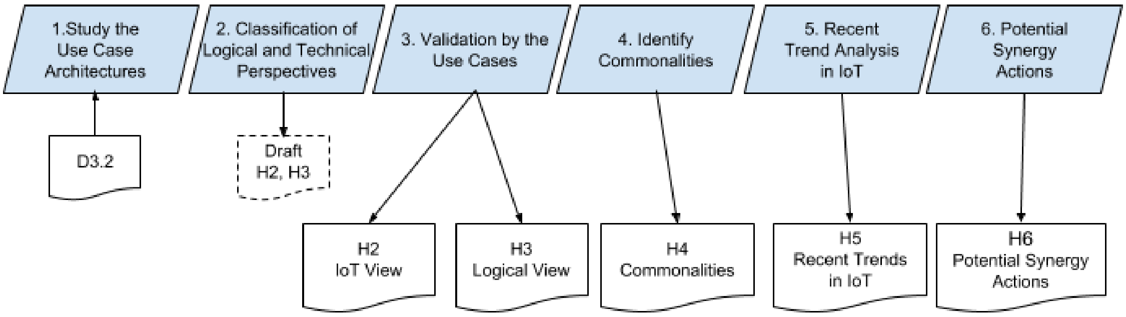

Figure 4: Analysis approach

1. Study the use case architectures

The main information base used in the analysis consisted of the use case architectures as reported by the use cases in D3.2. In this report, all use cases reported on their (technical) architectures. They all used the same five perspectives to describe their use case:

- Domain model;
- Deployment view;
- IoT Functional view;
- Business process hierarchy view;
- Interoperability endpoints.

See D3.2 for more details on this format.

In addition, the progress reports as presented during the IoF2020 workshop at the FIWARE summit in Malaga in November 2017 were used to answer questions that remained after studying the architectures report. The Malaga workshop focused on the technical aspects of the use cases, and the presentations given there proved to be an excellent addition to the information already available. Specifically in those instances where technical choices had not been made at the time of drafting of D3.2. Many white spots and open questions when drafting D3.2 had been addressed at the time of the workshop.

2. Classification of logical and technical perspectives

Early in the task, it was decided that synergy would not be studied at a technical component level, but rather at a higher use case level. Instead of trying to identifying whether use cases use the same or very similar components, we tried to identify whether use cases are trying to meet the same objective or requirement. This helps in discovering synergy in cases where use cases choose different realization strategies (the how) to underlying objectives that are actually very similar (the what). Also, it deals better with use cases that do express their objectives, but at the time of writing of the architectures document hadn't translated those objectives into technical components in their architecture report. Finally, we found that this approach matched better the broad concept of synergy we used in this task as described in the previous sections.

We chose to classify the use cases from two perspectives (Figure 5). The **logical view** describes the functionality of the use cases: What is IoT technology used for? What agri-food processes are affected by this and how? The **IoT view** describes what technologies are used in the use cases.

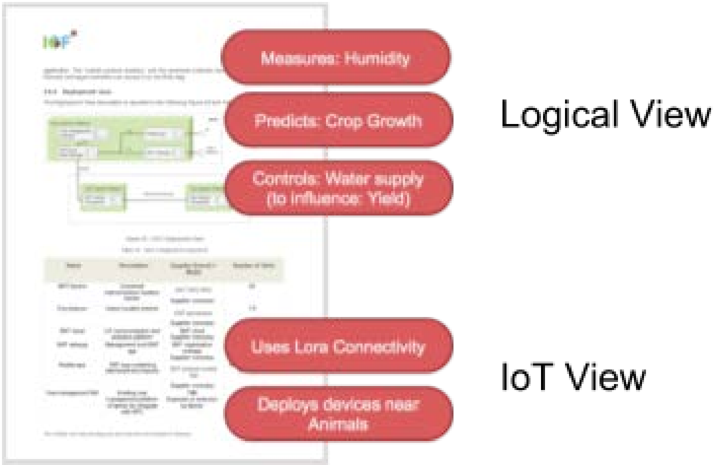

Figure 5: Tagging the architectures deliverable D3.2

In the logical view we chose to classify the use cases using a combination of verbs and nouns (Figure 6). A classification might be: "Use Case X <u>measures</u> *Soil Moisture*. This two-dimensional approach helps to identify synergy with use cases that perform different but related tasks. For instance: "Use Case Y <u>predicts</u> *Soil Moisture*".

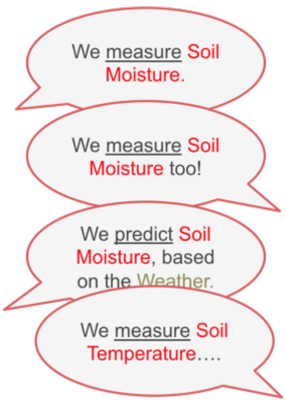

Figure 6: Synergy in the logical view

Please see the next chapter where the used classifications are described in more detail, alongside the outcomes of our analysis.

3. Validation by the use cases

After sharing the results of our desk research based on D3.2 and the Malaga workshop, we presented our findings in a webinar on January 17, 2018. In that session, all use case contact persons were asked to validate our interpretations. After the session, they were all sent a validation form that contained all our assertions about their use case in a structured way. They were asked to correct and complete these assertions. The WP2 support group facilitated this process, and the response rate was 100%.

See Appendix A for the precise validation form used in this process.

4. Identifying commonalities

Based on the validated analysis, promising commonalities in the use cases' functionality and use of technologies are identified.

5. Trend analysis

In addition to the technological and functional analysis, we have performed a brief trend analysis in the IoT Market. In this analysis, we have focused on IoT topics that emerged in 2018. This might be relevant when identifying shared challenges and synergy between use cases as those are the topics that emerge after the proposal and planning phase of IoF2020 was completed.

6. Identifying and potential synergy actions

Based on the commonalities and trend analysis, a number of synergy actions is proposed that could be adopted by the project partners to leverage the synergy within the project.

2 TECHNOLOGIES USED IN THE USE CASES

The first 5 aspects all relate to the technology choices made in the different use cases.

For each technological aspect, we describe three things:

- the kinds of technologies we have observed in the project;
- the number of use cases that adopted a certain technology;
- our observations with respect to the adoption and use of that technology.

2.1 CONNECTIVITY

Being an IoT project, the choices about connectivity are maybe the most relevant technology choices made within the use cases from a project perspective. We have studied which connectivity standards and protocols are used in the different use cases. Note that most use cases typically use more than one protocol, and this is reflected in the chart below.

The connectivity protocols that we have observed throughout the IoF2020 project roughly fall into 3 categories.

General purpose connectivity protocols - Although the internet of things has spawned a number of innovations in the area of networking, existing general-purpose networking standards are still widely used too. Examples are Wi-Fi, conventional cellular communications, ethernet, and, often in the context of machines and equipment, serial interfaces.

IoT-specific connectivity protocol - In the context of the internet of things, a number of standards have been developed that combine long range with low power consumption. They are most frequently referred to as Low Power Wide Area Networks (LPWAN). Best known examples are LoRa and Sigfox, but also some specialized parts of the 4G and 5G cellular standards have similar properties. The low power consumption combined with long range is typically part of a trade-off: these standards support (very) low bandwidths. For example: LoRa gateways are claimed to have a range of tens of kilometres in the open field and can support thousands of nodes per gateway. But a typical LoRa node is only allowed to send the equivalent of 100-200 text messages per day.

Short range, low energy standards - Another class of standards supports short range connectivity in the tens to sometimes hundreds of meters. Examples of such standards are Bluetooth Low Energy (BLE) and a number of variants of the Low Rate Wireless Personal Area Network (LR-WPAN) protocol, such as Zigbee. The best-known examples of BLE are the beacon standards of Google and Apple respectively. The LR-WPAN family often support mesh-type networking across the different nodes to extend the range in which nodes can collaborate and communicate.

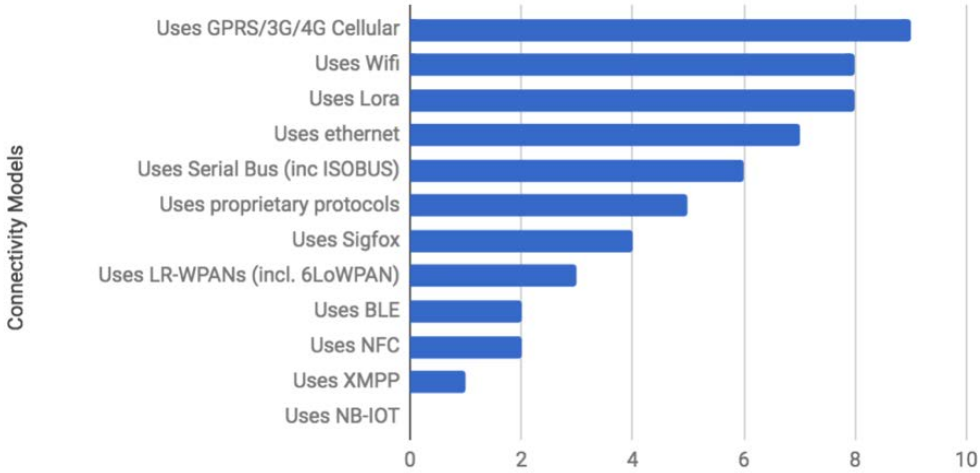

Figure 7: Connectivity protocols used in the use cases

Observations: IoT specific networking standards are very well adopted within the IoF2020 project. 12 of the 19 use cases use some form of LPWAN or LR-WPAN connectivity. Existing connectivity standards such as Cellular, Wifi, Bluetooth, Ethernet and Serial protocols are also still very relevant. Notable: The IoT specific 4/5G standards such as NB-IoT seem not to be used at all within the project.

2.2 NETWORK TOPOLOGY

Additionally, we have studied whether some common network topology ingredients are present in the use case architectures. We have studied three scenarios at the logical level.

Direct backend connectivity - The connected devices and sensors connect directly with the backend or server components, without any (local) infrastructure deployed or maintained as part of the use case solution.

Local gateways - The devices connect with locally deployed gateways. These might only provide connectivity or also perform computational tasks on the gateway. The latter is often called edge computing. Local computing may be necessary to support offline scenarios, or to lower connectivity requirements by pre-processing sensor data.

Mesh networking - The connected devices and sensors may create mesh networks, where device’s messages are communicated between multiple other devices directly until they reach their destination or some gateway to a larger network.

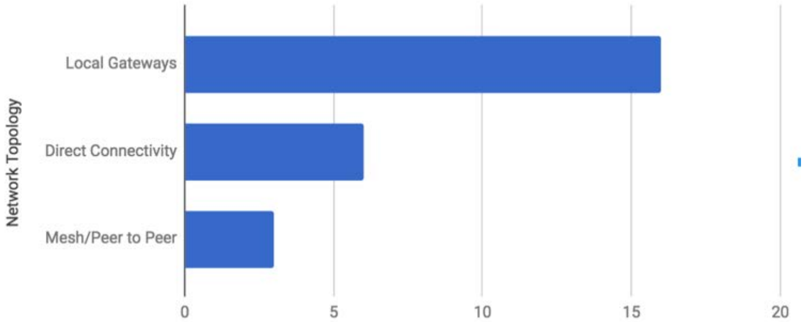

Figure 8: Network topology of the use cases

Observations: Many use cases deploy local gateways in some way. They inevitably are part of solutions that use short range technologies such as LR-WPAN. They are also deployed in long range networking scenarios, potentially for improving coverage in remote areas, or in the absence of local LPWAN coverage by telco providers altogether.

2.3 DEVICE ARCHITECTURES

All use cases in the project deploy some form of connected devices. We have studied the architecture of these devices and encountered the following categories of devices.

Commercially available devices - Many connected sensors are readily available commercially as COTS components and are not developed within the project. The same holds for machine integrated sensors that are for instance part of farming equipment and whose data can be accessed through some open interface. Finally, there are PLC based sensors and actuators that originate in industrial automation. As a consequence, all these three classes of devices are often to a large degree black boxes from a technical perspective.

Custom devices - Some devices deployed in the project are custom build, either within in the project or in earlier projects. But they are not available on the market as standards components. As such, the technologies that are used in developing them is known. In our analysis, we distinguish roughly between devices that are based on generic PC based components and devices that are based on IoT specific components. The latter class is based on small systems on a chip (SoC): low power logic boards with embedded connectivity. A lot of different chipsets have been developed the last few years. Arduino boards are famous and often used in prototyping and product development scenarios. Recently, many boards based on for instance ESP32 chips have been developed

RFID - Some use cases technologies that fall under the umbrella of Radio Frequency Identification (RFID). They include active RFID, where the device is powered and emits radio signals, and passive RFID, where an unpowered chip is receives electromagnetic energy transmitted from an RFID reader.

Example of active RFID are beacons, that are often based on Bluetooth LE or similar connectivity. Example of passive RFID is printed labels with a chip inside them, enabling reading the label from short distances with a reader with antenna.

Other - We have introduced a number of auxiliary categories in our analysis. Some use cases use mobile apps for data entry and or the sensors present on mobile phones. Some use cases use barcodes and QR codes to make devices recognizable by scanners and mobile phones. Although not technically connected, they may play an important role in configuration management in a multi device setup.

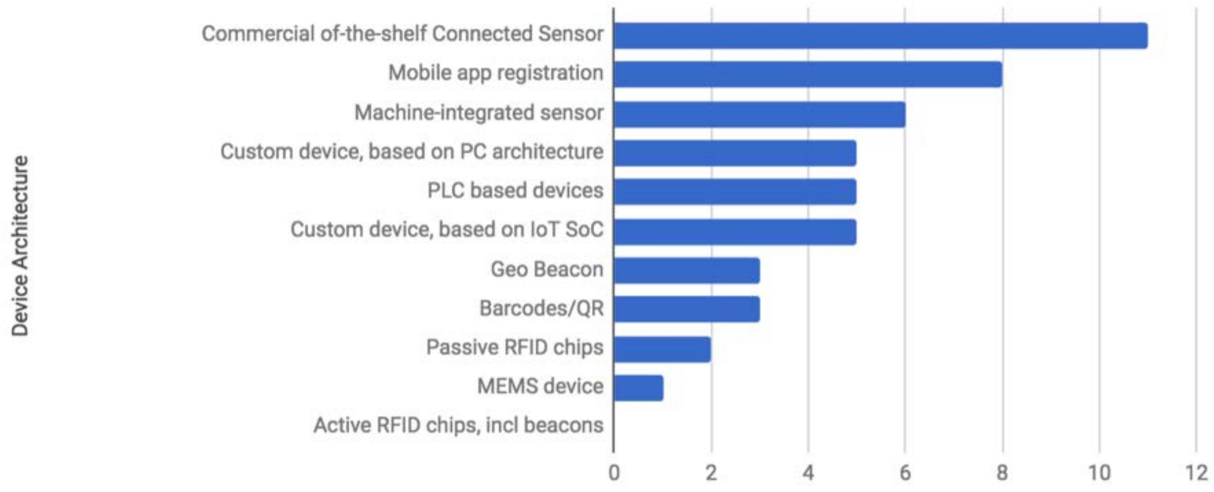

Figure 9: Device architectures used by the use cases

Observations: The most important observation is that the number of mature components is high. Many use cases use commercially available sensor platforms, existing connected features of their agri equipment or PLC based platforms.

2.4 CLOUD PLATFORMS

Most use cases use some (often cloud based) backend platform to store, process, report and act on the data. We have studied which platforms are used within the different use cases.

FIWARE based - A number of use cases use components from the FIWARE family. See the next section for more details about this category.

Agri-food specific platforms - We have encountered a number of agri-food specific platforms that have branched out into the IoT sphere, such as 365FarmNet, Akkerweb, Synelixis and Porphyrio,

Generic IoT platforms - We also encountered a number of domain independent IoT platforms, such as Bosch IoT, Amazon IoT. Sensolus is another example that ranges from tracking and tracing specifically.

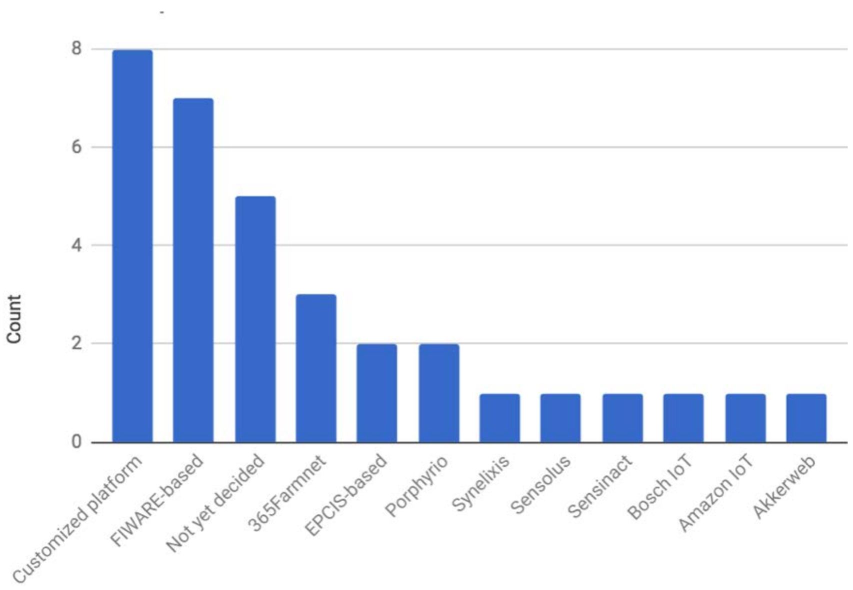

Figure 10: Cloud platforms used by the use cases

Observations: Main observation is the fact that the field of IoT platforms is unconsolidated and this reflects on the choices made in the project. The use cases use a large number of platforms. And a relatively high number of use cases report customization of the platform they use. And finally, a relatively high number of use cases reports their platform as to be decided at the time of drafting the D3.2 deliverable.

This is in line with broader industry trends. IoT platform consolidation is a recurring theme in industry analyst reports on IoT trends as of 2018. See also chapter 5 of this document.

An API based strategy for component development within the project may be needed to ensure that the components developed can be used in the context of different cloud platforms.

The responsibilities of an IoT platform are described relatively superficially in the source documentation. Aspects such as device management, enrolment, firmware deployment/upgrades and decentralized security models are important aspects and need early consideration when deploying IoT at scale. The configuration management strategies that are completely feasible when deploying tens of devices, break when a solution is scaled to thousands of devices.

2.4.1 FIWARE usage

With FIWARE being used relatively often and being a very modular platform, we also studied which components from the FIWARE ecosystem are used specifically.

Context broker - A broker that allows sharing objects and their properties, and supports updates, queries, registrations and subscriptions.

Device management and IoT Agent - This component collects data from devices using heterogeneous protocols and translates them into the standard platform language suitable for the context broker.

Identity management - A generic component that supports authentication tasks for users' access to networks, services and applications, including secure and private authentication from users to devices, networks and services.

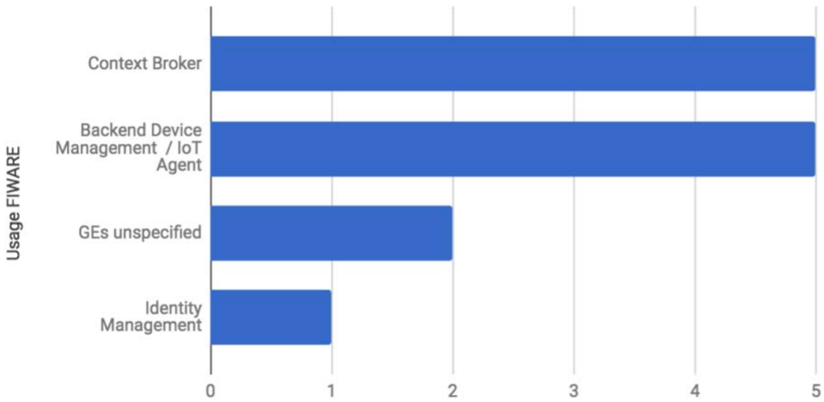

Figure 11: FIWARE components used in the use cases

2.4.2 Data management

Furthermore, we have studied what data management functions these platforms have and are used within the use cases. Although it is hard to break down such a generic, horizontal aspect of a technical architecture, we have used the following categories.

Data Validation - When collecting data, guaranteeing consistency and meaning of the data by validating against rules and constraints.

Data Transformation - Transforming the data as collected to a format that is more suitable for storage or sharing with others.

Data Storage - Storing the data for later use.

Data Processing - Deriving other (aggregated) data from the data collected. May include querying, reporting, statistical analysis and even machine learning.

Data Access Control - Restricting access to or operations on data to people with the right credentials.

Data Cleansing - Retroactively cleaning by detecting, correcting or removing corrupt records from storage.

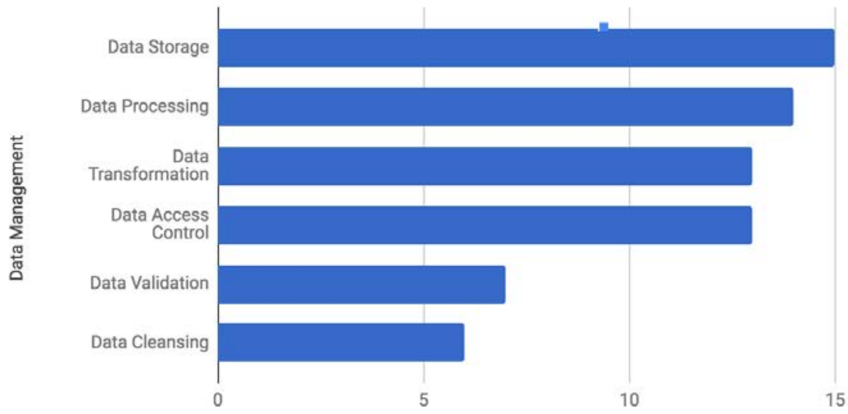

Figure 12: Data management aspects of the use cases

Observations: The quite general nature of this categorization of the data management task reflects the general level in which data management is described by the use cases in for instance D3.2. The analysis that most use cases do some form of data storage is perhaps not very noteworthy. At the same time, we have identified a number of shared concerns in data management, that are described in the potential synergy action on reference data models in section 6.1.

2.5 LOCALIZATION

A common aspect of agri-food IoT is that location awareness is part of many solutions. We have studied the use cases for which localization techniques they use when establishing location. We found a number of localization techniques in the use cases.

GPS - The de facto standard in localization. GPS calculates location based on the signal of a system of circa 33 satellites. When combined with recent augmentation techniques based on fixed points on earth, this leads to precision up to a few meters.

Triangulation based on IoT Connectivity - Both Lora and Sigfox are recently adding localization features. These are based on time differences in message receiving by different gateways that are at known, fixed locations. Note that the precision of the triangulation based on these timings does not compare with GPS's precision.

Beacons - Collection of active RFID techniques, often based on Bluetooth Low Energy profiles. Supports localization in a number of ways. In a coarse-grained scenario where either the beacon or the receiver has a fixed/known location, and on connecting, the other is associated to this location too. In more advanced, multi receiver or multi beacon scenarios, triangulation based on signal strength may be used.

GLN based - Although strictly speaking not a location measurement technique, the GLN is a standardized numbering scheme for encoding addresses. This can be used for encoding the known location of fixed resources or encode the location of mobile resources if it is measured using some other technique.

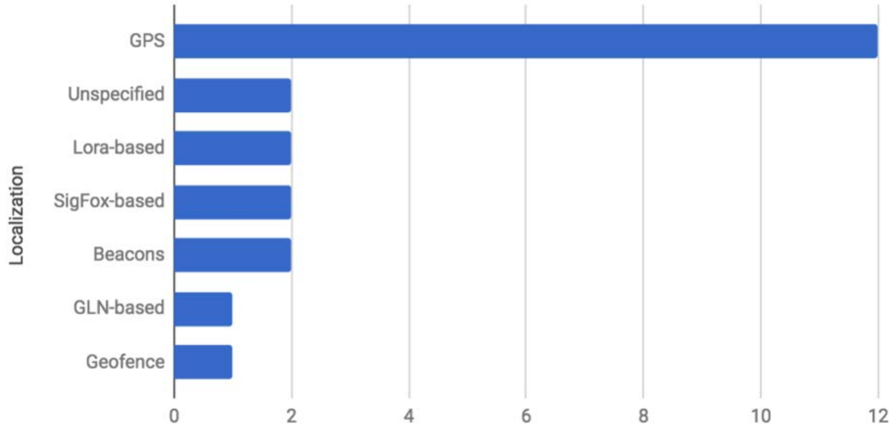

Figure 13: The use of localization technologies

Observations: Obviously GPS is the dominant localization technique amongst the use cases by far. At the same time, a number of use cases make other trade-offs and apply the upcoming techniques for (coarse grained) localization using IoT connectivity standards such as LoRa and Sigfox.

2.6 NON-FUNCTIONAL REQUIREMENTS

We have studied the use cases to identify whether there are specific non-functional requirements the use cases are dealing with. Specifically, we have looked for non-functional requirements for applying technology in an agricultural context.

We ended up studying the use cases for whether Internet of Things technology is deployed under the following conditions.

Deployed outdoor - Devices have to deal with outdoor temperatures, moisture and wet conditions.

Deployed near or in contact with food - Devices may have to comply with food safety regulations.

Deployed in places without access to power - Devices have to be self-reliant for power consumption, either through the use of batteries, solar or other means of energy harvesting.

Deployed near or on animals - Devices have to deal with specific requirements on animal safety and device ruggedness.

Deployed near sensitive equipment - Devices have to deal with specific demands on (the lack of) the electromagnetic interference they may infer.

Deployed under extreme temperatures - Devices may have to deal with specific challenges that come with either very high or very low temperature.

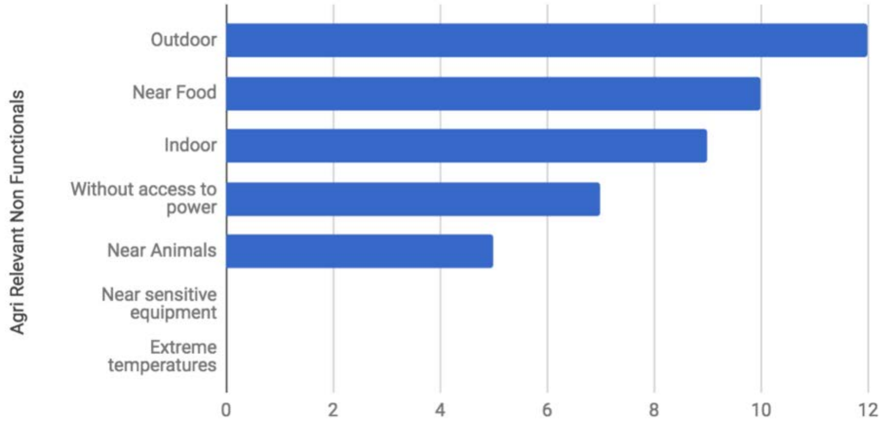

Figure 14: Agri-food specific non-functional requirements

Observations: Not surprising for a project like IoF2020, a large number of use cases deploys IoT in outdoor conditions and without access to power. The requirements and solutions that come with these conditions are quite generic mostly technical in nature.

The use cases that deploy near food and animals may face really sector specific challenges where relevant regulations require translation to the technical requirements that the devices need to meet.

3 FUNCTIONALITY OF THE USE CASES

In addition to analysing which technologies are used, we have performed a number of analyses to capture the functionality of the use case and the role of IoT technology plays in realizing that functionality.

3.1 IOT FUNCTIONS

The (connected) components in the use cases have a number of different functions. Use cases may, in some way:

- **Measure** data points, using some sensor technology;
- **Ingest** data from external data sources, such as other systems or third-party sources. For instance: retrieving weather data from the national weather service;
- **Derive** a data point, based on a generally accepted, fixed derivation function or model;
    - Example: Compute current soil moisture based on current electrical conductivity.
- **Predict** data points, based on historical data, statistical modelling and/or machine learning algorithms;
    - Example: Predict current soil moisture based on recent weather, based on a home-grown statistical model of soil moisture vs weather;
- **Monitor** a series of data points, to check that it stays with boundaries and/or to check for the occurrence of outliers;
- Automatically **control** machine operations and other (production) processes;
    - Example: Automatically activate the irrigation equipment based on water stress;
- Actively **assist in control** of machine operations and other (production) processes;
    - Example: alert the farmer that more irrigation is needed in a certain area, through a drought map that includes all relevant factors;
- Automatically **plan** tasks and processes
- **Assist in the planning** of tasks and processes
- Passively **report** information to agri-food professionals, through inclusion in portals, reports and dashboards;
- Actively **alert** agri-food professionals, through notification and/or messaging techniques;

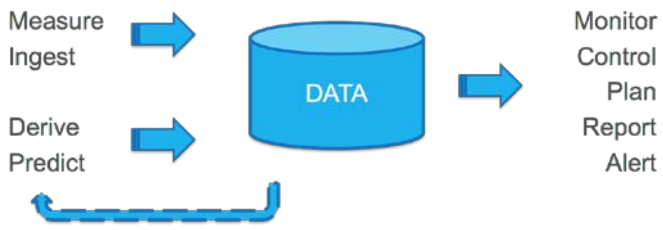

Figure 15: IoT functions

Note: The distinction between control and planning was introduced to distinguish between immediate actuation/intervention on an operational level and tactical planning processes where interventions are planned in advance based on predicted circumstances, constraints and resources.

In the logical view, we tried to identify all occurrences of these functions within the use cases. The frequency distribution of the different functions is shown in the next figure.

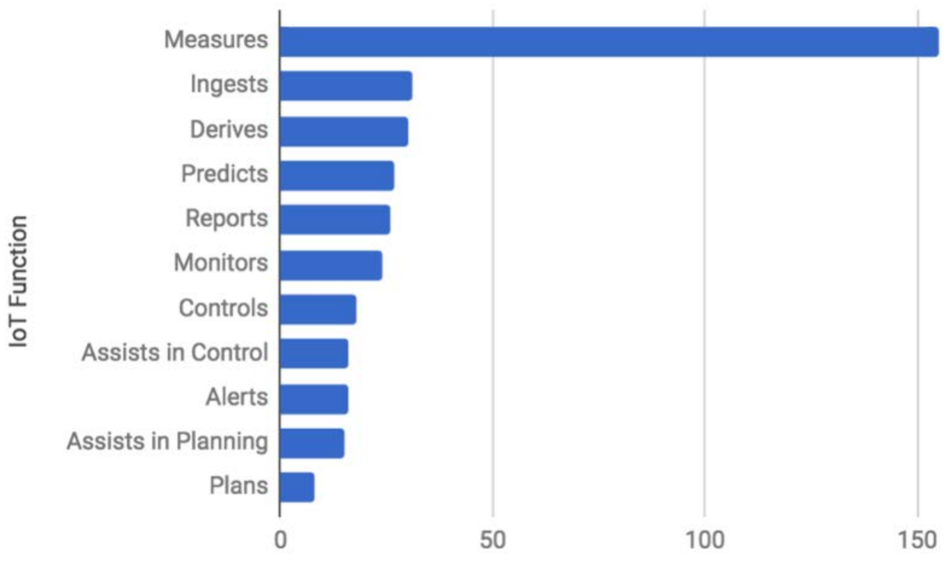

Figure 16: IoT functions observed in the use cases

Observations: Within the project, there is a strong emphasis on the application of sensors in the agri-food processes. But the other functions are also present across the board. This observation is related to the analysis made about the different kinds of control cycles in the project in section 3.3.

3.2 DOMAINS

The use cases deal with a wide range of data dimensions. These data include both highly specific attributes of specialized production processes (i.e. nutrition levels in water) and more general environment measurements (i.e. air temperature and humidity). Often, naming variations occurred across the use cases for what essentially is the same data dimension.

To illustrate the diversity in data dimensions we found in our analysis, we created a word cloud with all data dimensions as they were identified by the use cases themselves in the use case architectures document.

Figure 17: Word cloud of initial analysis of data dimensions

Based on an analysis of the data dimensions as reported by the use cases in their own words, a rough categorization was made. We believe this will help discover synergy better. Even if some dimensions may have been subtly misclassified, this categorization helps use cases find other use cases that deal with similar data dimensions much better.

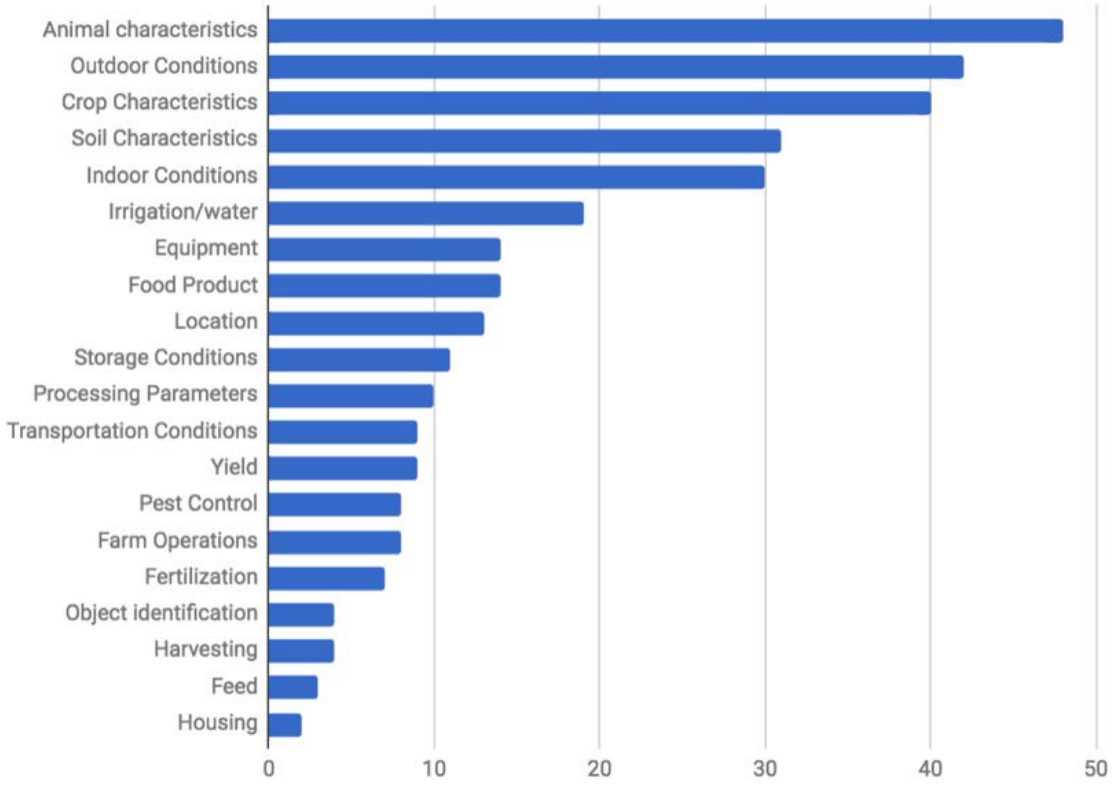

Figure 18: Data categories used in the use cases

3.3 DIFFERENT KINDS OF CONTROL FLOW

Another perspective to capture the functional aspects of the use cases is the role IoT technology plays in the control cycle.

A common abstraction for a system control cycle consists of sensors, a brain and actuators.

- The sensors provide the inputs from the outside world to the system;
- The brain applies logic to those facts to draw conclusions and assert additional facts;
- Based on these conclusions, actuators may interact with the outside world to influence it;
- These effects are then observed by the sensors, completing the control cycle.

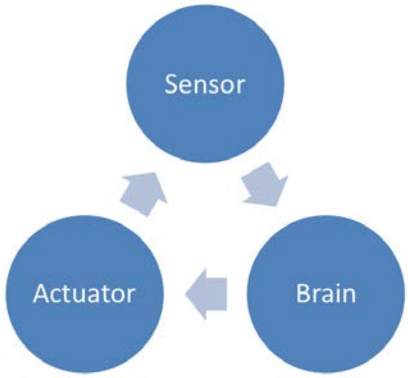

Figure 19: Typical feedback loop in IoT systems

We have observed that the use cases implement (roughly) three kinds of control cycles:

Information Centric - The farmer or other agri-food professionals are provided with sensor information, both current and historical, that enable them to take their own decision in an informed way. Typically, these use cases offer dashboards as the main channel of interaction for its users. Often, these dashboards include descriptive analytics. Sometimes these use cases also alert farmers when sensor values are outside fixed tolerances.

Task Oriented Decision Support - The farmer is actively supported in his/her decision making by intervention suggestions, planning proposals or other task-specific artefacts. These suggestions are always interpreted and frequently adjusted by the farmer during the actual decision making. These use cases typically include statistical models or algorithms in their architecture to predict outcomes and predict the influence of potential interventions on the outcomes. The actuation that follows from the farmer's decisions may or may not be executed in an automated/connected way;

Automated Control and/or Planning - The system autonomously intervenes based on sensor data to reach pre-set objectives or optimize selected outcome variables. The farmer in principle applies the interventions as selected/configured by the system, but of course can manually override and adjust for exceptional situations. This requires that the statistical models and algorithms within the architecture are mature enough and that interventions can be executed through connected actuators. To this end, the architectures of these use cases may for instance include the calculation of machine settings or other operational parameters.

These classifications of the control cycle can be mapped to the sensor, brain, actuators metaphor:

- Information centric use cases have many sensors, and limited components that qualify as brain or actuator. In cases where connected actuators are deployed, they mainly act as remote controls with no inherent intelligence of their own;

- Task oriented decision support typically combines sensors with brain components that translate outside measurements to suggestions for next best action/interventions for the professionals. And again: Connected actuators act as remote controls for the farmer and are often not automatically connected to the brain module that provides the farmer with suggestions;
- Automated control and/or planning use cases typically provide a closed loop of sensing, applying logic, rules or machine learning to deriving next steps and automatically effectuating these steps by triggering the actuators.

We have tagged all use cases against these three scenarios based on the IoT functions in the last paragraph.

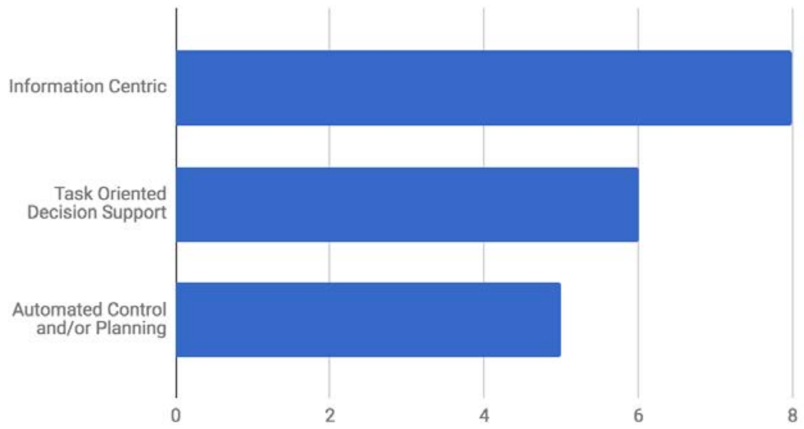

Figure 20: Type of IoT control loop observed in the use cases

Observations: We see a distribution of the scenarios that seems to match the use cases of IoT in general. Many IoT initiatives across sectors start with remote/connected sensing and sharing this information with professionals. But increasingly, IoT projects are blending with machine learning efforts to offer smart digital services based on the raw data. In those cases where the statistical models or machine learning algorithms become trustworthy enough, there is an increasing willingness to grant these models actual control.

Note that the decision support should not be seen as an immature stage before fully automated control per se. In that sense, these three scenarios should not be read as a roadmap where every use case should strive for full automation. There is a distinct class of problems where supporting experts with decision support is probably the desirable end state.

Given that interpretation, we believe that having half the use cases reaching some level of decision support or automated control signifies that the use case mix of IoF 2020 is state-of-the-art.

3.4 CHALLENGES AND OBJECTIVES ADDRESSED IN THE USE CASES

Although the synergy analysis focused on capturing the functionality of the 19 use cases in an accessible way, we also made a preliminary analysis of the business objectives and corresponding KPI's the use cases represent. Reason for this preliminary analysis was the collaboration between the synergy analysis team and the catalogue team.

This preliminary categorization is based on WP4 deliverable D4.1, the text of the original proposal (i.e. table 3) and on discussions in Wageningen with the WP4 team. It needs to be further refined and aligned with WP4 before used in the catalogue.

- Increase Productivity
    - Optimize growing conditions
    - Increase efficiency of harvesting
- Reducing Waste and Losses
    - Prevent decay
    - Prevent damages
- Improve Quality
    - Prevent rejections
- Reducing Environmental Impact
    - Increase resource efficiency
        - Including Fuel, Energy
    - Decrease water consumption
    - Reduce pollution with pesticides, herbicides, fungicides
    - Reduce amount of fertilizers
    - Reduce emissions
- Public Health/Societal
    - Provide traceability
    - Early warning of food safety issues
    - Better work conditions
    - Reduce amount of medicines
    - Improve animal welfare

To prevent redundant work for the use cases, this taxonomy was not included in the validation. More information on the relation between the synergy analysis and the catalogue is provided in the section on the Catalogue.

4 PROMISING COMMONALITIES

Based on the logical and technological analysis of the use cases in the previous chapters, we have identified a number of promising commonalities.

Note that this list is not limitative. The analysis results can also be used ad hoc to find use cases that use the same technologies, solve similar problems or operate in similar contexts to share challenges and ask for advice.

4.1 TECHNOLOGICAL COMMONALITIES

Based on the classifications in the IoT view, we have identified a number of innovative technological aspects of our project that are relevant to a number of use cases. For the names of the use cases corresponding with the number see Appendix B.

Commonality	**Use Cases (see App. B)**
Low Power Long Range Connectivity - LPWAN	1.1, 1.2, 2.1, 2.3, 3.1, 3.2, 3.3, 3.4, 4.1, 4.4
Short-Range Networking (LR-PWAN, BLE)	1.2, 1.3, 2.1, 4.1, 5.2
Localization	1.1, 1.2, 1.3, 1.4, 2.1, 2.2, 2.3, 2.4, 3.1, 3.2, 3.3, 3.4, 4.2, 4.3, 4.4
Autonomous Deployment	1.3, 2.1, 2.2, 3.1, 3.4, 4.4, 5.2
Best Practices in Modelling Sensor Data	All
FI-Ware Generic Enablers	1.2, 3.1, 3.3, 3.4, 4.2, 5.1, 5.2
- Publish/Subscribe Context Broker - Orion Context Broker	1.2, 3.3, 3.4?, 5.2
- Backend Device Management – especially IoT Agent	3.1, 3.3, 4.2, 4.4, 5.2
EPCIS Experiences	3.4, 5.3
365FarmNet	1.1, 1.4

4.2 COMMONALITIES IN THE USE CASE DOMAINS

Based on the logical view, we have identified a number of domain centric commonalities that a relative high number of use cases share. For the names of the use cases corresponding with the number see Appendix B.

Commonality	**Use Cases (see App. B)**
Crop Characteristics (multiple techniques, measure vs predict)	1.1, 1.2, 3.1, 3.2, 3.3, 4.1, 4.2, 4.3,
Soil Sensors	1.1 1.2, 1.3, 1.4, 3.1, 3.3, 4.2, 4.3, 4.4
Weather/Outdoor Conditions Sensors	1.1, 1.2, 1.3, 1.4, 3.1, 3.2, 3.3, 3.4, 4.2, 5.2
Animal Characteristics	2.1, 2.2, 2.3, 2.4, 5.1, 5.2, 5.3
Indoor/Storage/Transportation Conditions	3.1, 3.2, 3.4, 4.1, 4.2, 5.1, 5.2, 5.3
Evaluation/Validation of Autonomous Control Models and Algorithms (Irrigation, Fertilization, Harvest Planning, Animal Health, Fertility, etc.)	1.1, 1.2, 1.3, 1.4, 2.3, 3.1, 3.2, 3.3, 4.1, 4.2, 4.3, 5.3

5 RECENT TRENDS IN INTERNET OF THINGS TECHNOLOGY

The field of IoT technology is developing rapidly. As part of our analysis, we have performed brief desk research into the current technology trends and forecasts for (the application of) Internet of Things technology. We have focused on trends that have emerged in 2017 or later, and thus emerged well after the proposal for IoF2020 was drafted by the partners. It is interesting to see whether these trends either align with challenges in the use cases and study whether they provide approaches and technologies to address these challenges. These trends may also be interesting to address for the Open Call that was launched at the 5th of June 2018 and will close on the 30th of September 2018 (see www.IoF2020\opencall).

We found the following recurring themes in professional literature and technology analyst's reports:

1. Intelligent Things through AI
2. Edge Computing
3. Security
4. Public IoT platforms
5. Adoption of IoT connectivity standards
6. Autonomous deployment and energy harvesting
7. Augmented Reality
8. Blockchain

5.1 INTELLIGENT THINGS THROUGH AI

Internet of Things technology is in the market's expectations increasingly bound to the use of Artificial Intelligence and Advanced Analytics. The term connected things becomes synonymous to intelligent or smart things. Having sensor data available increasingly implies turning that data into action and doing smart, automated things based on the available data. Increasingly, artificial intelligence is needed/used for this.

Note: This observation aligns well with control loop typology introduced in section 4.2.

5.2 EDGE AND FOG COMPUTING

In the traditional IoT model, raw sensor data is communicated directly into the cloud for processing and analysis. But increasingly, data processing, filtering and analysis is performed close to or on the connected things, at the "edge" of the network.

This way, only interpreted/meaningful data is communicated to the cloud. This reduces network load in situations of constrained connectivity, and may even introduce support for offline scenarios where actuation is needed when the device is offline. It further may have privacy benefits as no raw sensor data is sent to the cloud.

Increasingly, (public) IoT platforms are developing support for the dynamic/transparent partitioning of logic between things, edge nodes/gateways and the cloud infrastructure.

Note: In the Network topology section in chapter 2.2 we observed that the majority of use cases deploy some form of local gateways.

5.3 SECURITY

In the last two years, the security of Internet of Things devices has become a large topic. When deployed in business-critical use cases, device identity, secure connectivity, and data/device integrity are key requirements.

Because of the computationally constrained nature of many devices, strong security mechanisms that are developed for more powerful phones and PC’s are often not applied in the context of connected devices. Also, patching and upgrading firmware on IoT devices is less common than it is for server-based IT infrastructures, in part because they are deployed remotely and low bandwidth IoT connectivity does not always enable the transmission of complete firmware updates.

5.4 (PUBLIC) IOT PLATFORMS

With the rise of the Internet of Things, a large number of cloud oriented IoT platforms have emerged. They focus on device management, security and edge computing. In 2018, a certain consolidation seems to take place. Important question is whether this consolidation will favor the large, general purpose platforms, or there also is a role for sector specific niche platforms.

Note: The fragmentation mentioned in literature is in line with the relative high number of cloud platforms adopted by the use cases.

5.5 ADOPTION OF IOT CONNECTIVITY STANDARDS

An evolving topic is that of the adoption of the range of IoT inspired connectivity standards. Long range, low bandwidth standards such as LoRa and Sigfox seem to gain traction. At the same time, the family of cellular standards is producing a number of standards too, such as Cat-M (also: Cat-M1) and NB-IOT (also: Cat-M2). All these standards have different technical properties, such as available bandwidths and roaming options. Though the cellular based standards arrived at the market slightly later than the other two, the Telco’s are often able to offer large coverage through their existing infrastructure.

Note: Although LoRa and Sigfox are well adopted across the use cases, no use case seems to use NB-IoT. Possibly, some variants may have been coded under the more general 3G cellular category.

5.6 AUTONOMOUS DEPLOYMENT AND ENERGY HARVESTING

Many IoT use cases depend on distributed and remote deployment of devices. Until recently, combining batteries with low energy consumption was the main option in these cases. The last few years, a number of startups have explored new ways of truly autonomous deployment. By applying solar and other energy harvesting techniques, and further optimizing energy use, they try to offer autonomous devices that can be deployed indefinitely without the need for replacing batteries.

5.7 AUGMENTED REALITY

Increasingly, sensor data is not treated as a data point alone, but as the basis for a so-called “Digital Twin” to the physical object. This also leads to user experience development where the digital world and physical object are combined in single, “immersive” experiences. For instance, by applying Augmented Reality to bring the digital aspects to the physical world.

5.8 BLOCKCHAIN

The blockchain may be hyped, and ill-understood sometimes, yet it may be relevant because of its unique features: It potentially offers tamperproof transparency of (IoT) transactions in large ecosystems, without the need for a central, trusted entity or “owner” of the registry.

6 POTENTIAL SYNERGY ACTIONS

There is a number of ways to leverage the technological and functional commonalities observed. The main benefit from shared insight into commonalities lies with the use cases themselves. Awareness of which use cases use the same technologies, deal with similar data domains or try to address similar business objectives allows for (informal) contact when challenges arise.

In areas where many use cases may face challenges, organized but lightweight forms of knowledge sharing may be useful too. Especially in areas where we all succeed, but learn hard lessons, capturing this knowledge may increase our productivity and provide valuable impact beyond the project.

In this chapter, we propose a number of practical synergy actions that could be undertaken by the project members. The initiative/interest should probably lie with the use case partners, and the supporting work packages could facilitate where useful.

6.1 REFERENCE DATA MODELS

We propose to develop/share generic data model fragments for capturing typical sensor domains in the project. Using the same data models for similar data has a number of benefits.

Reduction of work - Data modelling can be a lot of work, and typically is not done first time right if the models are created from scratch. This leads to porting data from early in the project to the data model as it involved during the project.

Data interoperability - Aligning data models for shared sensor domains in the project leads to the data interoperability that enables comparing results or even data sharing across use cases.

Adopting open standards - When creating reference data models, adopting existing open standards should be considered. These standards typically have a certain completeness and maturity that is not easily reached by project efforts from scratch. And they can facilitate data interoperability beyond the project: In the project we have access to data adhering to those standards. And if we produce our data according to the standards, uptake beyond the project is easier.

6.1.1 Three aspects of data modelling

Based on our analysis of the use cases, we believe there are a number of different aspects of data modelling that could benefit from canonical fragments to be used across the use cases and beyond the project.

Canonical domain object models - The primary aspect is canonical modelling of common domain aspects. For example: A generic list of attributes that describe the properties of soil, including standardized naming, units of measure and ranges. Where possible, these fragments should be based on existing open standards.

Modelling approaches for IoT data - The fact that all the data is captured and used in the context of internet of things adds some specific modelling challenges, such as:

- How to capture the time aspect of measurements;
    - How to capture measurements that are incidental, campaign-oriented or regularly/on a fixed interval?
    - What information about time is needed to allow different data streams, with different timing nature, to be compared or combined meaningfully?
- How to capture the location aspect of measurements:
    - How to capture the granularity of measurements? For instance: This temperature was measured at location X, but is intended to be represent the whole field?
    - How do we deal with/capture the precision of the location measurement that comes with different localization technologies?
    - How to deal with location capturing for nomadic vs fixed instrument measurements? For instance: Do we capture the location of the sensor and/or do we capture the location of the measurement?
    - How do we deal with combining or comparing data streams of different location granularity?
- How do we deal with (re)batching when measuring "material" properties?
    - Many measurements of bulk products translate into properties of a batch when dealt with in the supply chain, both on the farm and later in the production chain. How do we deal with (re)packaging after harvesting? And with batching in (local) storage?

Modelling approaches for statistical and machine learning - Many of the use cases use the data recorded for building statistical models and machine learning and predict instead of measure the same data later on. This leads to a number of specific data modelling challenges:

- What data is needed for production and what data is needed for (re)training and validation of the statistical algorithms?
- How do we distinguish which data points are measured and which are predicted? And if they are predicted, based on what (version of a) model?

6.1.2 Next steps

If the use cases think this is useful, it seems logical to address this work as part of or in collaboration with Task 3.3.

6.2 CATALOGUE & MARKETPLACE

A catalogue of project components is developed as part of WP3. The catalogue is crucial infrastructure for synergy and impact of the IoF2020 project. The project develops components, knowledge and experiences that are worth sharing within and beyond the IoF2020 project.

The information gathered as part of the synergy analysis could very well be integrated into the catalogue. As part of the synergy analysis, we have collaborated with the catalogue team to ensure that the synergy data would be useful in the context of the catalogue. Some of the ideas and assumptions we made are documented here.

6.2.1 Use Cases: Practical Experiences with IoT Solutions

When studying the IoF2020 use cases, we observed that use cases combine two things:

- They all develop or adopt an IoT solution that offers new functionality using IoT technology;
- They all apply it in a practical agri-food process to validate whether it addresses the use case's business objective or challenge.

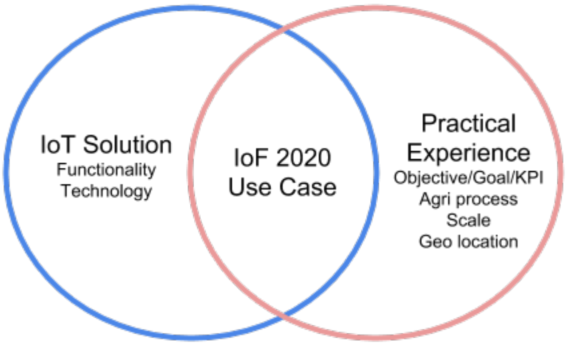

Figure 21: Solution vs practical experience

This WP3 synergy analysis focuses on the first aspect, analysing the functional and technological properties of the solutions. The business objectives/goals and KPI's are studied in WP4.

Given the project's emphasis on scaling up and market adoption, it is useful to expose the use cases in the catalogue from both angles.

6.2.2 Audiences and Intended Use

From an internal perspective, the catalogue may have a similar audience as this document has. Questions that may be interactively answered using the catalogue are:

- Who is applying the same technologies as I am?
- Who is measuring the same data as I am?
- Who is actuating the same type of equipment as I do?
- Who is addressing the same business objectives as I do?

External audiences may include agri-food system integrators, but certainly also technology minded agri-food professionals and farmers. The questions they have probably depend on their knowledge level and awareness of IoT possibilities. They may include:

- Find an IoT Solution that offers given functionality or uses a technology;
    - And what practical experience exists with that solution?
- Find practical examples of the use of IoT that address my business challenge;
    - And what IoT solutions did they use?
- More exploratory questions of IoT use cases in Europe today;
    - What is IoT used for in food and agri-food today?
    - What business objectives are addressed using IoT?
    - What underlying technologies are used in agri-food IoT?

6.2.3 Practical catalogue ideas

As part of that process we adopted a visual, design-oriented way of working. This has led to number of wireframes visualizing the expected use of the catalogue as described in the previous section. Note that these are not actual designs: they are meant for discussing options, and actual adoption of these ideas may look quite different.

6.2.3.1 Navigation between Practical Experience and IoT Solutions

We think navigating between IoT solutions and the practical context they have been used in could be useful in the catalogue. Both perspectives answer different questions our audience may have, but the ‘other’ perspective is almost always the follow up question:

- If a professional finds experiences with IoT technology that would be useful for him/her, the specific IoT solutions used in that use case answer the follow up ‘how’ question;
- If a technology-oriented integrator finds the right IoT solution, the practical experiences with that IoT solution provide the evidence of maturity and business reasons to adopt that solution.

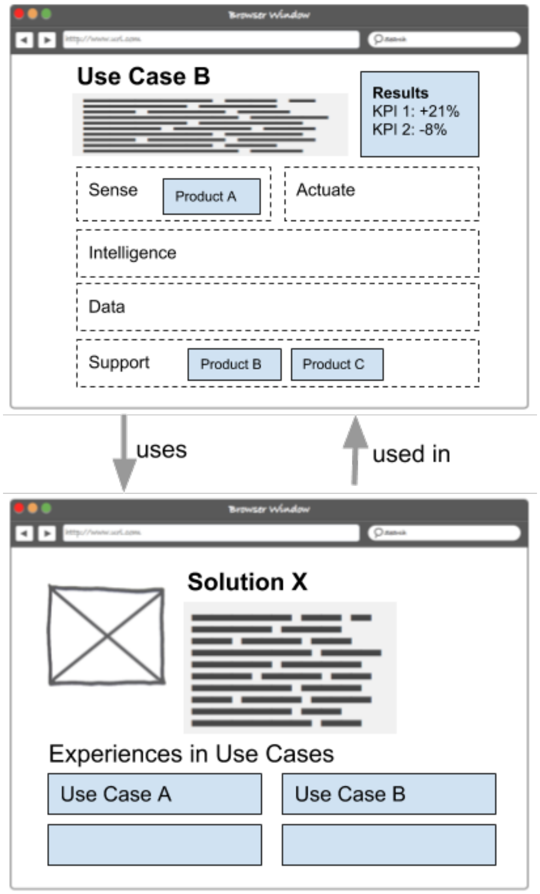

Figure 22: Navigating between Practical Experience and IoT Solution used

6.2.3.2 Expose Use Cases by Business Objective

Within the IoF2020 project there is a lot of emphasis on the business objectives and KPI's reached by the use of IoT in the agri-food sector. The benefits of IoT will ultimately be the reason behind adoption of IoT and the use cases provide important evidence. The catalogue should reflect this.

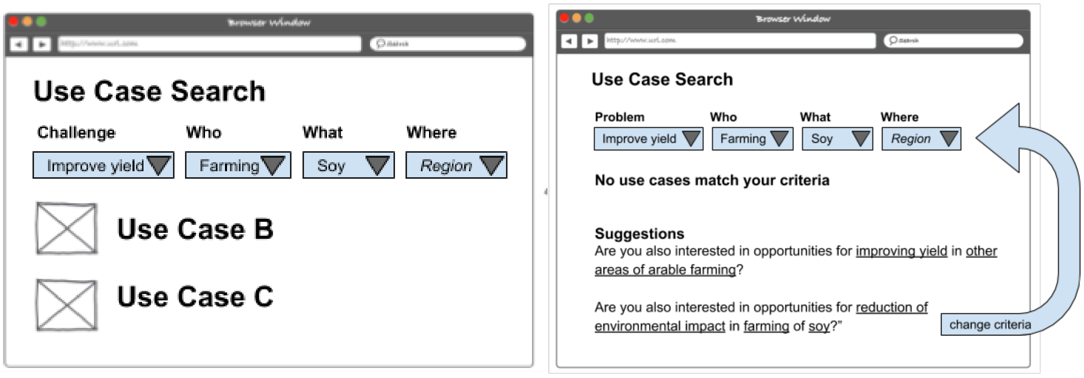

Figure 23: Exposing the use cases based on business objective or challenge

The Use Case Search could use the taxonomy of KPI's developed in WP4. A preliminary taxonomy we used during our Task is in Chapter 3.

6.2.3.3 Visualize Use Cases using Architectural Typology from D3.2

Could we present the solutions used in the use case grouped or even visually layered by their type? For instance, by grouping the products according to the categorization of Sense -> Intelligence -> Actuate. And potentially an extra layer for supporting products, such as data platforms etc.

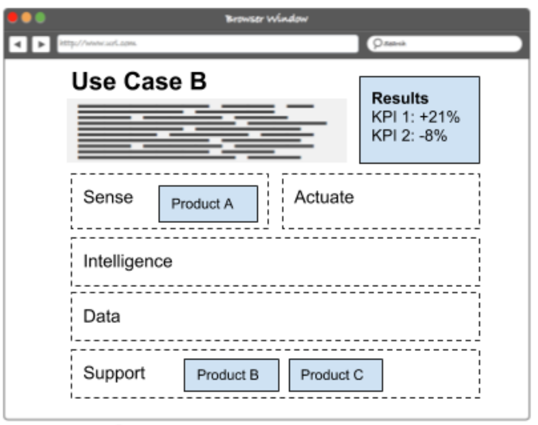

Figure 24: A Use Case view based on architectural product typology

6.2.3.4 Navigation in addition to filtering

In the first versions of the catalogue, the taxonomies were mainly used to offer filtering/facetted search. Could we also expose them in a knowledge base oriented fashion?

We could have a Main page which explains the Sense -> Intelligence -> Actuate model and offers navigation links to three corresponding pages. On the Sensor page, some general information is shared about sensors in general, and a list of sensors is shown.

On a page about IoT connectivity, we could for example introduce the relevant standards and link to a page per standard. That page would provide background for the standard, and of course a list with all the products that support that standard. It could also provide links to guidelines and other synergy results relevant to that networking standard.

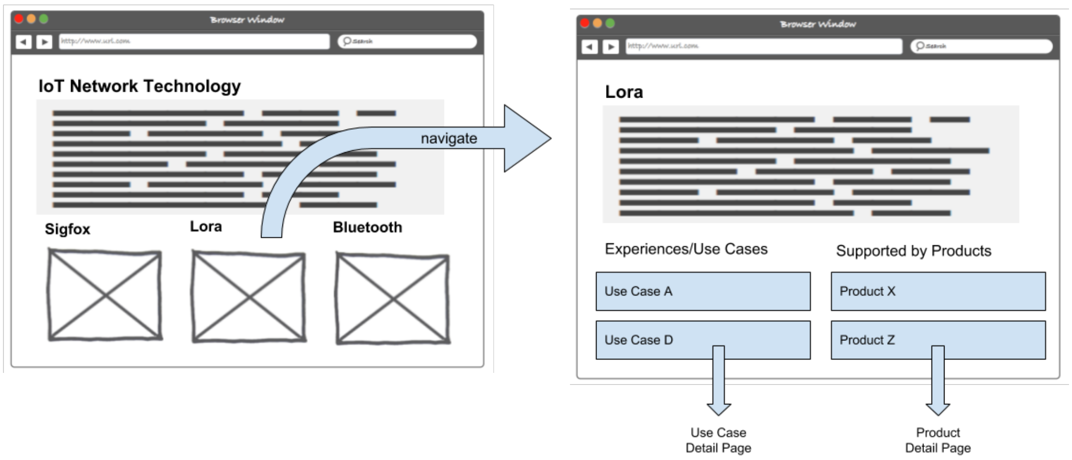

Figure 25: Offering knowledge base style navigation based on taxonomies

6.2.4 Wireframes

These wireframes led to the following site map for the catalogue.

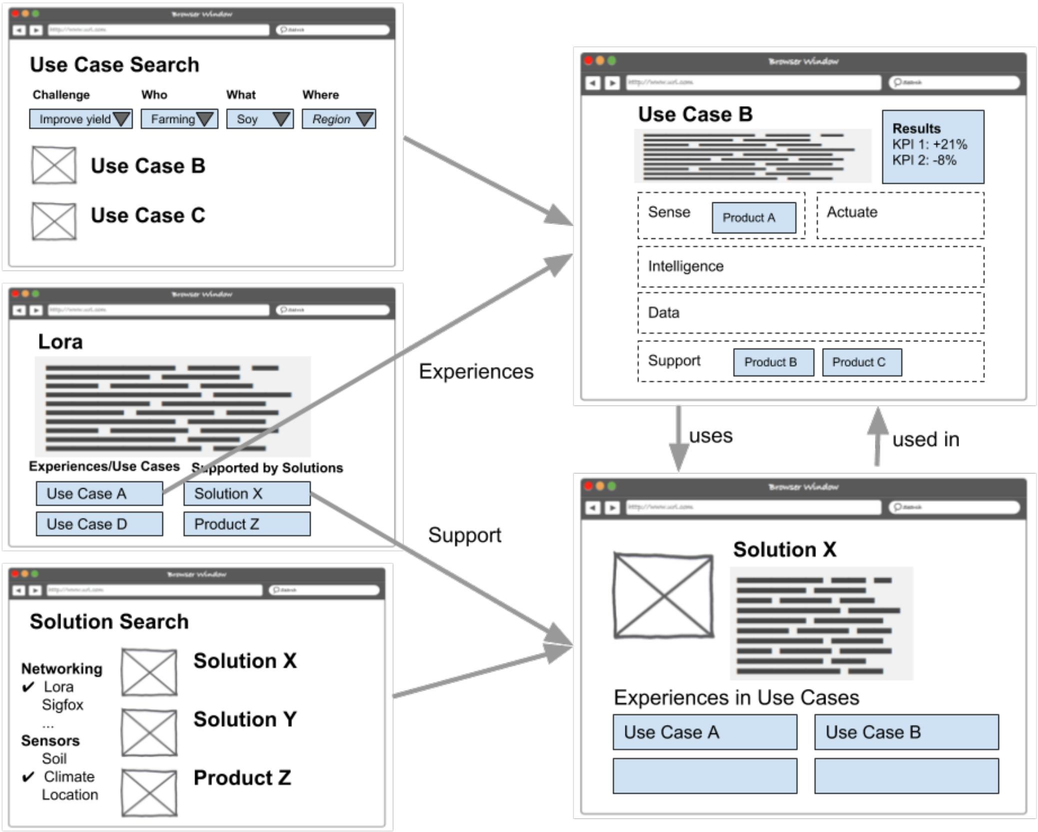

Figure 26: Wireframe of the catalogue

6.2.5 Next steps

The catalogue development is in progress and these ideas have been shared and discussed early in the project. Obviously, the catalogue team has a number of additional design challenges, such as developing a cross sectoral knowledge base. They will factor into their design what they deem useful. The T3.5 team is of course available for follow up discussions in the future.

6.3 TASK FORCES & GUIDELINES

An important aspect of IoF2020 is realizing synergy between the use cases. By sharing experiences and lessons learned on common challenges and technologies in scaling up, we get to spend more time on the unique aspects and objectives of every use case. Furthermore, by capturing the lessons learned in this project, we increase its impact beyond the project by facilitating the agri-food sector in the uptake of internet of things technology. In the next subsections we propose a practical approach for sharing lessons and experiences through short, lightweight collaborations that lead to practical outcomes. We propose a number of potential topics to illustrate our ideas.

6.3.1 Organizing synergy task forces

The synergy analysis performed in WP3 clearly shows that the 19 IoF2020 use cases have commonalities in lots of areas, such the use of similar IoT technologies, measuring similar data or changing similar agri-food processes through automation. Based on this analysis, we have proposed to organize a number of synergy task forces.

Task force =

- A short, lightweight collaboration,
- Between participants from the IoF2020 use cases and external partners,
- Leading to a compact, but concrete outcome, such as for instance a guideline for selection and implementation of a specific technology.

Task forces should not lead to a completely new area of responsibilities and work for the partners. We hope that by agreeing compact and practical outcomes, the effort will be highly synergetic and beneficial to the work done within the use case. We propose to form these task forces using this 5-step process.

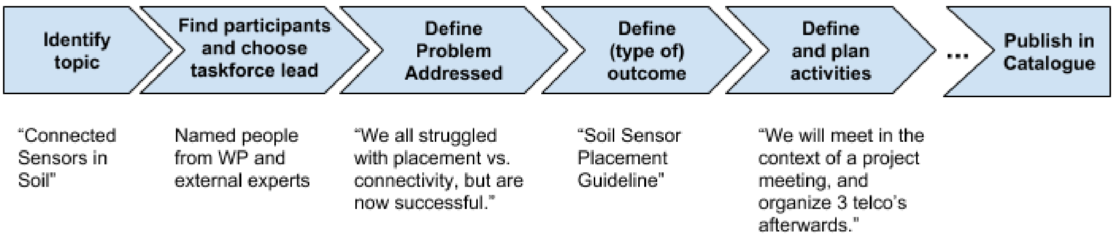

Figure 27: Process for organizing a task force

6.3.2 Potential Outcomes

A task force should lead to a concrete result. Some examples of outcomes could be:

(Best) Practices

If multiple use cases have dealt with similar challenges successfully, best practices may be derived from this experience. Members could share the practices they developed, and why/in what context they worked.

Guidelines

If the solutions chosen by the use cases were dependent on their individual contexts or requirements, guidelines may be derived when to choose which type of solution. These contextual guidelines may include trade-offs between quality vs cost, or dealing with use-case specific requirements such as for instance regional climate conditions. Example: The cheaper sensor works great in dry climates, but loses precision in wet circumstances.

Identify Shared Component

If multiple use cases are looking to fulfil the same requirements by technical development, an outcome might be to identify components that could be (co)developed and shared. The actual development of such a component typically requires effort beyond the scope of a task force. After identifying the need, they could for instance be (co)developed by pooling use case efforts. Or external technology could be brought in through for instance the open call.

Sharing Knowledge and Experiences

By participating in a task force with participant that deal with similar challenges, the sharing of knowledge and experiences is inevitable. Whether in the exploratory phase or in working on a shared outcome, if multiple use cases have to deal with similar requirements or challenges and are all struggling, a concrete task force outcome could be shared problem statement. This could be used to look within the project for support or could be used as input for the open call.

6.3.3 Potential Topics

In this section we describe a number of possible topics that could benefit from a task force. These candidates are based on synergy observed in the synergy analysis. For each topic, we also include some potential questions or trade/offs that could be the basis for a guideline or other type of outcome. We are interested to hear your ideas on other aspects that could be addressed within these topics or additional topics all together.

Low Power Connectivity

A large number of use cases is deploying some new networking technology like for instance Lora, Sigfox or LR-WPAN. They are developed for the typical range and power consumption requirements of IoT. Interesting questions to share practices may be:

- When to apply direct connectivity and when to combine short range protocols with local gateways?
- What are best practices and trade-offs when connecting sensors using ultra low bandwidth networking?

Weather Stations

Within the projects a large number of different weather stations is deployed. They differ in what they measure, how many are deployed (1 per farm, 1 per field), the connectivity model and ultimately we believe also their price range.

- What are shared requirements for weather stations, and what specific situations ask for additional features?

- What is the trade-off when choosing deployment per farm or per field. And for what usage is online weather data also sufficient?

Trust in IoT-based Decisions

As described in the synergy analysis, IoT can play different roles within the decision and control loop. It ranges from passively providing information to agri-food professionals, to offering pro-active task-oriented decision support on choosing best course of action, to fully automatic control loops based on IoT driven sensors and actuators.

- What are success factors for agri-food professionals to trust the advice and operational decisions from an IoT based information system? And how can use cases use these success factors to improve the technology acceptance of their intelligent/autonomous offerings?
- In what situations are system-based decisions acceptable to agri-food professionals? Is this based on potential impact? Or overlap with their own expertise? Or their perception of being in control?
- What are validation approaches of intelligent/autonomous technologies that can be used within the use cases based on these success factors?

FIWARE in Agri and Food

FIWARE and its enabling technologies are used within the IoF2020 project in a number of use cases. This includes the context broker technology and the IoT agent.

- What are successful ways of deploying context broker as backend for a sensor and actuator infrastructure? Could a reference design or best practices be derived from the use cases?
- How are the different Generic Enablers combined in a successful way?
- What can be learned from earlier Agri-Food FIWARE projects such as SmartAgriFood2, FInish, Fractals?
- Since agri-food is one of the three focus themes of the FIWARE Foundation, these activities could be further embedded in and supported by the FIWARE Foundation.

Crop Characteristics

Measuring and predicting crop characteristics are part of a large number of our use cases. A rather wide range of metrics is measured, from crop growth, evapotranspiration and water consumption, to predicting fertilizer and pesticide need, to assessing growing and development stage insect pressure or diseases. Underlying sensor techniques range from spectral reflectance to image processing.

- Are there guidelines or best practices to support crop sensor selection?
- Are there guidelines or best practices to support sensor deployment? How many sensors/measurements are needed for meaningful results?

- Is there a trade-off between the different underlying sensor techniques or even predicting instead of measuring some of these crop characteristics?

Soil Characteristics

A large number of use cases measures soil characteristics. Moisture and temperature, composition and compaction. Underlying: Electrical conductivity and/or radar/radio?

- Are there guidelines or best practices to support soil sensor selection?
- Are there guidelines or best practices to support sensor deployment? How many sensors/measurements are needed for meaningful results?
- Is there a trade-off between the different underlying sensor techniques or even predicting instead of measuring some of these crop characteristics?

6.3.4 Next Steps

The idea behind the task forces is that they are brief, practical collaborations in the context of and beneficial to the existing tasks of the use cases. WP3 will facilitate the formation of relevant task forces through the following actions:

- The intermediary results and the concept of task forces has been presented in a webinar for all use cases;
- The WP3 contact persons will discuss this deliverable with the use cases and assess need for /interest in task force topics;
- At the next plenary meeting, the deliverable will be presented again.

6.4 RECOMMENDATIONS FOR THE OPEN CALL

The Open Call as published in June 2018 emphasizes interoperability, replicability and re-use as important contribution sought in new use cases. Applicants may find important information in this deliverable when choosing and positioning their potential contribution to the project.

Furthermore, chapter 5 on recent IoT trends may point to technological challenges, and trends in addressing them, that could help propose meaningful contributions to the consortium. Although new technology is not a primary driver of the open call, considering new technologies available is encouraged.

7 GENERAL CONCLUSIONS

A number of technological aspects seem to be in line with the scaling up of existing solutions within the project:

- There is quite a lot of heterogeneity within the project. For instance, a broad range of networking technologies and a large number of different cloud platforms are employed within the different use cases;
- The maturity of the sensor devices is what may be expected of a project of our technical readiness level: Quite a high number of the sensors used are commercially available or are standard part of larger equipment of machinery;
- State of the art, IoT specific networking protocols such as Lora and Sigfox are deployed by a large number of use cases.

The use cases offer state-of-the-art IoT functionality in agri-food context:

- The use cases use a large range of sensors and measure a vast array of data dimensions;
- This data is used in advanced, state-of-the-art control loops. The majority of the use cases move beyond passive portals with sensor data and introduce intelligent, task specific decision support for agri-food professionals and/or fully autonomous control loops that automatically trigger actuators based on sensor data and statistical data processing.

We have performed a small trend analysis into recent IoT challenges and trends that were discussed with an IoT professional and analysed literature in 2018. Some of those trends and challenges seem relevant to the project also, based on the year one architecture documentation studied:

- IoT platforms increasingly support IoT specific management aspects, including device security, device deployment/enrolment and firmware management. These aspects require different levels of support at different scales.
    - While the devices at PoC scale can easily be managed ad-hoc/manually, advanced remote, automated deployment and management are needed if large fleets of devices are deployed to large numbers of locations. These aspects are less documented in the D3.2 architectures, and may need additional attention in the later project years;
    - Also, the amount of effort required of specialists when implementing a solution at a farm is crucial and needs to be in line with the proposed business model. High scalability of solutions requires either a partner channel that can implement and maintain the solution, or consumer grade user friendliness that allows for self-management. These choices immediately reflect in the business model, in terms of running cost levels and the need for upfront investment. This may also be a topic addressed in WP4.

- IoT platform consolidation seems imminent. Components developed within the solutions should probably be prepared for migration between platforms or support reuse across platforms altogether, for instance using API's as abstraction layers;
- Edge computing is increasingly a topic. IoT platforms increasingly support easy (re)partitioning of solution logic across devices, gateways and cloud backend. Within the project, the majority of use cases uses some form of local gateways. They might benefit from the recent developments in this area.

Based on the commonalities discovered in this analysis, the project aims at realizing synergy in a way consistent with a system of systems philosophy. Rather than realizing synergy through up front design, standardization or consolidation on a single platform, synergy is realized through measures during all the different realization phases. The reasons for this are twofold:

- Connected solutions lead to heterogeneous environments: IoT solutions are typically based on the coupling of sensors and actuators with (existing) back office systems. The focus is more on (re)combination of existing (sub)systems than on greenfield development of complete monolithic systems;
- Most use cases are based on existing components: Inherent to the scaling up nature of the IoF2020 project, a large majority of the use cases is based on earlier work and existing components. That means that many technical choices have been made, and very few components are developed from scratch.

The proposed synergy actions include:

- Drafting shared information model fragments for sensor data, dealing with genericity in sensor domains across use cases, challenges in capturing time and location specific to IoT sensor data and challenges that arise from simultaneous training and application of statistical models and machine learning algorithms based on sensor data;
- Including the synergy analysis results in the IoT Catalogue that is being developed as part of WP3. This will allow for easy, interactive access to the technology and functionality of other use cases beyond the static reporting in this report. This may help use cases to discover project partners that may help them with practical challenges;
- Organizing short, lightweight task forces that produce practical lessons learned or guidelines for shared commonalities. A process is proposed for how use case partners can be in the lead in these task forces, potentially being facilitated by the supporting work packages. Topics should be chosen by the use cases based on their needs. A number of candidate topics is proposed based on the commonalities to jumpstart this process.

APPENDIX A: VALIDATION FORM

This is the validation form used in the validation step. It consists of two parts. The first asks questions about the functionality of the use case, the second about technological aspects of the use case. In both categories, the questions where pre-filled based on our desk research of the use case architectures.

ABOUT THE USE OF IOT

Which data are **measured**?	
Which data are **derived** from other data? (For instance based on a generally accepted fixed computation method?	
Which data are **ingested** from external data source?	
Which data are **predicted**, based on statistical models or machine learning algorithms?	
Which data are **monitored**, to check that they stay within boundaries and/or no outliers occur?	
Which machine operations and other processes are **automatically controlled** by a system?	
Which machine operations and other processes are **controlled** by humans, but specifically **assisted** by a system?	
Which tasks and processes are **planned automatically** by a system?	

Which tasks and processes are **planned** by humans, but specifically **assisted** by a system?	
Which data are **reported** on to users, through system generated reports and dashboards?	
Which data triggers **alerts** to users when out of bounds for instance.	

In case of questions, please contact Cor Verdouw (cor.verdouw@wur.nl) or Jeroen van Grondelle (jeroen@vangrondelle.com).

ABOUT THE TECHNOLOGIES USED

Network Technology		**Device Architecture**	
	Uses Wifi		Commercial of-the-shelf Connected Sensor
	Uses BLE		PLC based devices
	Uses Lora		Mobile app registration
	Uses NB-IOT		Machine-integrated sensor
	Uses GPRS/3G/4G Cellular		Custom device, based on PC architecture
	Uses Serial Bus (inc ISOBUS)		Custom device, based on IoT SoC
	Uses Sigfox		Passive RFID chips
	Uses XMPP		Barcodes/QR
	Uses GPRS		Geo Beacon
	Uses ethernet		MEMS device
	Uses LR-WPANs (incl. 6LoWPAN)		Active RFID chips, incl beacons
	Uses proprietary protocols		
	Uses RFID standards	***Non Functional Requirements***	

	Uses NFC		Deployment Outdoors
	Uses barcodes/QR-codes		Near Animals
	Uses GPS		Near Food
			Greenhouse
IoT/cloud platform			Near sensitive equipment
	Not yet decided		Without access to power
	Unknown		Indoor
	Customized platform		
	FIWARE-based	***Network Topology***	
	365Farmnet		Direct Connectivity
	Bosch IoT		Mesh/Peer to Peer
	Sensolus		Local Gateways
	Amazon IoT		
	Synelixis	***Location Technology***	
	Sensinact		GPS
	EPCIS-based		SigFox-based Triangulation
	Porphyrio		Lora-based Triangulation
			Beacons
Data management			GLN-based
	Data Transformation		Unspecified
	Data Processing		Geofence
	Data Cleansing		
	Data Storage	**Kind of Control Flow**	
	Data Access Control		Information Centric
	Data Validation		Task Oriented Decision Support
			Automated Control and/or Planning

Please put an "X" in front of any technology used within your use case.

APPENDIX B LIST OF USE CASES IN IOF2020

The IoF2020 project consists of 19 use cases grouped by 5 trials. More information about the use cases can be found at https://www.iof2020.eu/trials

Nr.	Name	Trial
1.1	Within Field Management Zoning	Arable
1.2	Precision Crop Management	Arable
1.3	Soya Protein Management	Arable
1.4	Farm Machine Interoperability	Arable
2.1	Grazing Cow Monitor	Dairy
2.2	Happy Cow	Dairy
2.3	Silent Herdsman	Dairy
2.4	Remote Milk Quality	Dairy
3.1	Fresh Table Grapes Chain	Fruit
3.2	Big Wine Optimization	Fruit
3.3	Automated Olive Chain	Fruit
3.4	Intelligent Fruit Logistics	Fruit
4.1	City Farming Leafy Vegetables	Vegetable
4.2	Chain Integrated Greenhouse Production	Vegetable
4.3	Added Value Weeding Data	Vegetable

4.4	Enhanced Quality Certification System	Vegetable
5.1	Pig Farm Management	Meat
5.2	Poultry Chain Management	Meat
5.3	Meat Transparency and Traceability	Meat