INTERNET OF FOOD & FARM

D3.10 Open Call Realisation

WP 3

April 3rd, 2019

Technology related aspects of the open call and analysis of the innovations addressed by the selected use cases.

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	D3.10-OpenCallRealisation.docx
Date	April 3rd, 2019
Version	11
Status	Final
Dissemination level	PU: Public
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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+ 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 IoF2020 open call was published on June 5th 2018, in conjunction with the IoT week in Bilbao. It was calling for use cases realising IoT based solutions in the agri-food domain, addressing new regions and/or post-farm or other sectors in the agri-food domain. Around 6 Mio. Euro were available to support use cases, where it was intended to allocate 300 to 500 kEuro per use case. In a first phase until August 31st, the proposers were asked to pre-register their proposals to facilitate the organisation for inter-use case collaboration. The deadline for submitting the final proposals was September 30th 2018. After that, IoF2020 was supported by external experts to carefully evaluate the proposals and prepare the contracts. In early 2019, the selected 14 use cases start their operation and are presented to a larger stakeholder community at the IoF2020 Prague event.

The new use cases will become part of the IoF2020 community, aiming at the validation of IoT based solutions to present the lessons learned and experience gained to a larger stakeholder community, addressing the agri-food domain itself, but also other business domains providing their services or considering relevant synergies. At the same time, IoF2020 aims at supporting developers and integrators of IoT systems or overall IoT based solutions, helping them to understand the specifics of the agri-food domain and experienced issues. This includes the presentation of results in a form of reports like this Deliverable D3.10 (see also www.iof2020.eu/about/deliverables) as well as more interactive mediums, like the IoT catalogue (www.iot-catalogue.com).

The categorisation of use cases and their planned development was elaborated to ease the access to information and identification of potential contact points for an inter use case and inter trial collaboration. On top of that, it serves for upcoming analysis of use case related implementations with respect to interoperability, replicability and reusability of implemented IoT based solutions. This is considered as an interactive process, helping to understand to which degree new use cases will offer reusable components as well as to support their implementations with the reuse of available assets.

Finally, this report summarises the planned implementation and validation of IoT based solutions in the scope of a pan-European set of 14 new use cases – with experimentation sites in over 20 European Countries, also collaborating with the 19 use cases realised since IoF2020 project start. This will also offer an opportunity to different European regions to exchange experience locally, with regional show cases, helping to learn about the regional applicability of results. This shall also help to establish direct contacts within the stakeholder community, offering an opportunity to contribute to European networks of competence centres and digital innovation hubs currently emerging all over Europe.

Further information about the IoF2020 use cases is available on the IoF2020 website, detailing the use cases and providing related contact points (https://www.iof2020.eu/trials). Also, the new use cases will be added soon. For any other inquiries, you can contact the IoF2020 team via its contact point at the IoF2020 website (https://www.iof2020.eu/contact).

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Abbreviations

AEF	Agricultural Industry Electronics Foundation
AgGateway	Non-profit organization for industry's transition to digital agriculture
COTS	Commercial off the Shelf Product
D	Deliverable
ETSI	European Telecommunications Standards Institute
EU	European Union
FIWARE	Future Internet Software Initiative
GS1	Global Standards One
IoF 2020	Internet of Food and Farm 2020
IoT	Internet of Things
ISO	International Organization for Standardization
ITU-T	International Telecommunication Union - Telecommunication Standardization Sector
LSP	Large Scale Pilot
MVP	Minimum Viable Product
SME	Small and Medium sized Enterprise
UC	Use Case
UN/CEFACT	United Nations Centre for Trade Facilitation and Electronic Business
WP	Work package

1 Introduction

The IoF2020 project is developing, testing and validating IoT based solutions in its 19 “use cases”. Those use cases are grouped in 5 trial areas representing the agri-food sectors of:

- arable farming,
- dairy,
- fruits,
- vegetables and
- meat.

The overall combination of those use cases in different trial areas is considered as the so called “Large Scale Pilot” (LSP) in the agri-food domain, addressing smart farming and food security. IoF2020 is collaborating with 4 other LSPs active in the domains of:

- Reference zones in EU cities (SYNCHRONICITY),
- Wearables for smart ecosystems (MONICA),
- Smart living environments for ageing well (ACTIVAGE) and
- Autonomous vehicles in a connected environment (AUTOPILOT).

The overall objective of these LPSs is to foster the deployment of IoT solutions in Europe through integration of advanced IoT technologies across the value chain, demonstration of multiple IoT applications at scale and in a usage context, and as close as possible to operational conditions. Compared to existing solutions, the roadblocks to overcome include

- Integration and further research and development, where needed, of the most advanced technologies across the value chain (components, devices, networks, middleware, service platforms, application functions) and their operation at large scale to respond to real needs of end-users (public authorities, citizens and business), based on underlying open technologies and architectures that may be reused across multiple use cases and enable interoperability across those;
- Validation of user acceptability by addressing issues of trust, attention, security and privacy through pre-defined privacy and security impact assessments, liability, coverage of user needs in the specific real-life scenarios of the pilot,
- Validation of the related business models to guarantee the sustainability of the approach beyond the project.

WP3 of IoF2020 is specifically aiming at elaborating and validating potentials for IoT integration in real world agri-food processes. The objective is to understand the key challenges in the different IoF2020 trials as well as to identify reusable IoT components promising an uptake of IoT solution alternatives in this business domain. Hence, WP3 considers itself as a mediator between the IoT technology potentials and the use cases. In addition, it plays a role on how to elaborate and identify promising solution components that are concrete enough to deliver value adding features, while being still abstract enough to allow reuse by other real world use cases.

WP3 involves an initial team of partner organisations that provide a basic set of reusable technologies that could facilitate the realisation of IoT based solutions in the agri-food domain. This includes supporting the IoF2020 use cases in configuring and adapting basic IoT related enabling technologies as well as hosting solutions/services relevant for more than one end-user.

On top of that, IoF2020 initially planned the realisation of an open call to involve additional solution providers, use cases, additional regions or just IoT based enabling technologies not yet foreseen when starting the project in beginning of 2017.

After the thorough analysis of use cases, as presented in Deliverable D3.2 (“The IoF2020 Use Case Architectures and overview of the related IoT Systems”), the IoF2020 project discussed the needs for further test and validation in real world use cases. It was agreed within its consortium, the "Pilot Implementation Board" (i.e. an advisory board composed of independent external experts) and the European Commission, to specifically enlarge the IoF2020 ecosystem and create more impact in the European food and farming sector by realising additional use cases.

IoF2020 looked for proposals that present in a convincing way a high impact on the supply chain, a high level of technical feasibility & innovation as well as a strong economic sustainability. Proposals were searched for that include a coherent team of stakeholders representing the entire IoT supply chain (technology providers, service integrators, end-users, etc.).

The primary objective of the Open Call was to increase the scale and impact of the IoF2020 initiative. The Open Call aimed at an evolution of the existing project consortium by involving new use case teams to enlarge the number of IoF2020 stakeholders. The underlying objective was to substantially enlarge the number of actual IoT-users in areas and production sectors with growth potential. The idea was to attract new use case teams preferably led by partners from the private business sector. The participation of innovative SMEs in use cases was encouraged and to specifically enable SMEs to test innovative technologies and services. Therefore, the IoF2020 open call was aiming at the attraction of

- IoT use cases in new regions:
  as the eastern part of Europe was not covered, and, to a lesser extent, also the northern part of Europe. Proposals for new use cases in EU member states not yet involved in IoF2020, including associated countries, were therefore encouraged to apply.
  Although the ecosystem and context in other countries can be very different from the countries where initial use cases took place, it was encouraged to learn from the existing use cases reusing IoT innovations and technologies already developed and tested. New use cases could of course also choose to combine their own equipment with useful elements from current IoF2020 solutions. In this way, it was expected that the impact of current IoF2020 solutions is maximized.
- Post-farm use cases and other sectors:
  Use cases from EU member states already involved in IoF2020 were welcomed that extend the impact of IoF2020 in the post-farm segments of the supply chain. Complementary areas could be proposed for e.g. logistics, processing, retail and in particular the end-consumer. Use cases addressing other subsectors (e.g. other crops, animals, etc.) were also encouraged, as well as use cases addressing new business models with focus on SMEs.

Finally, 14 new use cases were selected, incorporating different types of IoT based solutions, complementing the initial set realised by the first 19 use cases. From a technical perspective, diverse solution components are required in those use cases to assure a smooth operation in the agri-food processes. To facilitate the related work, technologies for diverse purposes were discussed and analysed accordingly. They can be generally classified as elements to sense, communicate, aggregate, store and analyse data as well as to create and provide knowledge or to control specific steps in agri-food business processes. At the same time, non-functional technologies like components to assure security, privacy and trust as well as to facilitate interoperability, discovery and performance have to be taken into account.

Work package 3 on IoT technologies in IoF2020 was taking care for this technology related analysis, while discussing specific needs with the use cases. The objective was to identify those requirements that shall be additionally tested and validated by the new IoF2020 use cases selected by the open call. Therefore, this report summarises aspects considered relevant for additional validation, while offering innovative characteristics pertinent for the realisation of competitive solutions.

The document is structured as follows:

- Section 2 outlines the overall methodological approach and cooperation applied to create synergies and promote the test and validation of IoT based solutions in the scope of the IoF2020 open call preparation.
- Section 3 outlines enabling technologies considered as reusable components for different IoF2020 use cases. This was also considered as basic collaboration potentials between existing and new use cases.
- Section 4 outlines the technology related selection criteria used for the proposal evaluation.

- Section 5 summarises a collection of enabling technologies generally considered as basic enablers to realise innovative IoT based solutions in the agri-food domain.
- Section 6 provides an overview of topics to be addressed by the selected 14 new use cases.
- As the IoF2020 open call was searching for a synergetic collaboration of initial and new use cases, section 7 summarise the resulting collaboration between the use cases.
- In the Annex you will also find more detailed information about the use cases running from the start of the IoF2020 project as well as about the use cases selected in the open call.

2 Overall Approach of IoF2020 and related Synergies

2.1 IoF2020 Architectural Process

IoF2020 started in the beginning of 2017, with an initial set of 19 use cases validating a complimentary set of IoT based solutions in different stages of the agri-food chain and involving diverse combinations of related agri-food stakeholders. To facilitate the communication of experience gained and coordinate the collaboration of the different teams inside and outside of the project, both of the following dimensions are structured and managed accordingly:

- Trial and use case perspective
  - Use Case Requirements:
    The work of each IoF2020 use case is based on end-user requirements that were analysed by each use case team as well as in close collaboration with providers of specific IoT related solution components.
  - Use Case Architecture:
    Each use case elaborated different views of its architecture to identify synergies among the use cases, even when not addressing the same trial area in IoF2020.
  - IoT System Development for each Use Case:
    Each use case is developing a self-contained scenario, to validate a tangible solution operated in a real agri-food setting.
  - Implemented IoT Systems in the IoF2020 Use Cases
    Each use case is implementing an IoT based system that reflects an underlying business model, enabling the validation of costs and benefits relevant for the end-users.
  - Deployed IoT systems
    All the IoT based systems are deployed, tested and validated either in a fully operational setting or in parallel operation by end-users from the specific agri-food processes addressed.
- IoT and technology related perspective
  - Collaboration Space:
    A team of technology providers are offering a kind of collaboration space that provides access to different technologies, facilitating the realisation of IoT based solutions.
  - Reference Configurations/ Instances:
    Specific instances are developed and provided to the use cases, aiming at an enlarged dimension of reusability.
  - Reusable IoT System Components:
    The IoT catalogue is compiling information about the realised solutions to help a wider developer audience to understand features provided by each solution component.
  - IoT Reference Architecture:
    The elaboration of a reference architecture for IoT in agri-food shall facilitate the classification of solutions and cooperation to realise synergies and reuse individual components.

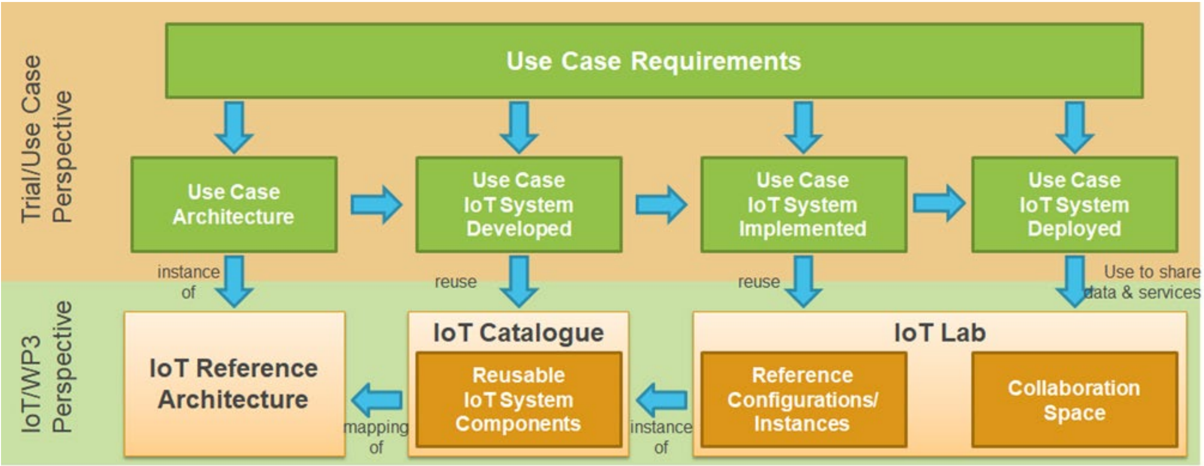

Figure 1: IoF2020 approach to coordinate the validation of IoT based solutions in relation to an IoT reference architecture.

Figure 1 presents the close interconnection of the use case perspective with the technology dimension. It was considered as a basic prerequisite to map individual solutions with a more generic perspective to enable a wider relevance and reuse of experienced gained. On top of that, IoF2020 elaborated an overview of technology fields presented in Deliverable D3.3, detailing opportunities and barriers for system development, specifically including an overview of key enabling technologies as well as outlining so called interoperability points. The open call announcement recommended Deliverable D3.3 as a reference document when preparing a proposal.

2.2 Categorisation of Functional Components

The development, implementation and deployment of the IoT systems in specific use cases, as indicated in Figure 1, aims at the realisation of an overall IoT based solution that shall fulfil end-user requirements in terms of business benefits as well as reasonable costs and efforts. In IoF2020, it is validated to which degree this will be achieved by the specific use cases. At the same time, it is the objective to gather experience helpful for a wider target audience aiming at the implementation of similar solutions or addressing corresponding challenges.

However, to generate helpful validation results it is important to understand the components used to realise the overall IoT based solution. Since considering an overall and very specific solution environment, it is usually quite complicated to help others to understand which part of the overall solution could be reused for another type of use case. IoF2020 analysed all the use cases and elaborated an overview of the technologies used and functionalities provided as well as identifying promising commonalities. This was presented in Deliverable D3.9 (“Progress Report on Synergy Analysis, Decisions and Coordination of Work”). This work was used as input for populating the IoT Catalogue (http://www.iot-catalogue.com) that lists the IoF2020 use cases with information about the developed solutions.

In preparation of the IoF2020 open call, this was also further discussed with respect to the potentials for being able to uptake solutions and related components by third parties, as it is rather difficult in terms of replicability of a solution. Therefore, the following Figure 2 aims to categorise such solution components, as preparation to discuss the potential for tangible reuse and preparing the development of specific reusable components in the scope of the IoT work package in IoF2020.

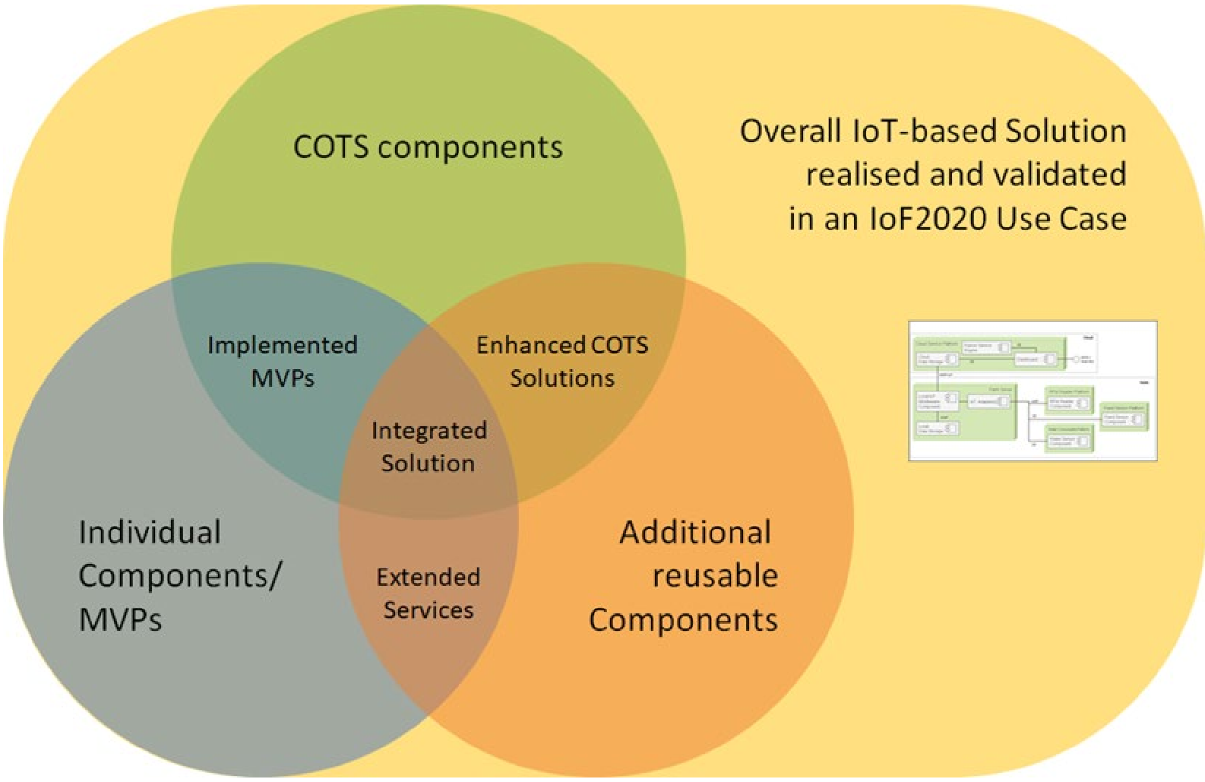

Figure 2: General categorisation of functional solution components.

From a functional perspective, possible components of IoT based solutions realised in the IoF2020 use cases were classified by the following categories:

- ***COTS components***
  These commercial off the shelf solution components can be usually acquired based on standard contracts from specific third parties. Examples are products like SigFox or LoRa communication offered by telecommunication service providers or standard/extended RFID tags used for identification and/or sensing.
- ***Enhanced COTS solutions***
  COTS components that require a specific customisation to be used in the scope of a specific solution.
- ***Individual components/MVPs***
  Very specific and highly individual implementations, reflecting a specific business logic that is usually very complicated to transfer to other end-users or environments.
- ***Implemented MVPs***
  Implemented MVPs are replicable products that can be provided to different end-users of the same type and purpose in the business process. However, a reuse by other developers is usually not targeted, unless the owner is aiming at a partner strategy to cover e.g. other regions or compatible solution scenarios outside the initial competence area.
- ***Additional reusable components***
  Such components usually provide technical features for a specific purpose that can be reused when implementing an overall solution. Generally, the model of Software as a Service is considered as part of this category, as well as open source used to provide individual features. In IoF2020, especially the implementations provided in the scope of WP3, including also the FI-WARE initiative, are considered as this kind of reusable components.
- ***Extended services***
  These are adaptations of reusable components for a specific purpose in relation to the identified

end-user requirements. In general, it is considered that the basic reusability is reduced when extending the services accordingly.

- ***Integrated solutions***
  The deployed IoT based system can be usually considered as an integrated solution, offered to a defined group of end-users based on explicitly agreed contracts and business model. Due to the deployment and configuration in a specific environment, those solutions are usually very specific, and replication to another end-user context requires efforts.

The identification of those categories facilitated the discussion on the strategic objectives to validate IoT based solutions in the context of LSP projects and specifically by those new use cases searched in the open call. Therefore, IoF2020 added a specific request in the open call document that was also harmonised with the other LSP projects and specifically the SynchroniCity project.

2.3 Joint Initiative of the Large Scale Pilot Projects

The five LSP projects are organising their collaboration in “activity groups” in relation to different topics of joint interest. Initiated by the IoF2020 and SynchroniCity projects, it was agreed that a joint effort on key aspects and potential synergies for cross LSP collaboration in the scope of the different open calls could facilitate the related efforts to validate IoT based solutions. Therefore, a joint requirement was elaborated for the open call specification documents. It highlights that all proposals shall aim at interoperability, replicability and reuse of the envisaged results as listed in the following.

- Interoperability:
  Envisaged IoT based solutions submitted in the open call shall use established open standards as far as possible. Proposals shall explain how the solutions will avoid a vendor lock-in by pointing out key interoperability points in the architecture and which standards-based mechanisms will be used at those points, or where the teams are actively contributing aligning to the current work of related standard development organisations (e.g. AEF, AgGateway, ETSI, GS1, ISO, ITU-T, UNCEFACT).
- Replicability:
  The IoF2020 project offers an IoT catalogue to present the solutions deployed and validated in the scope of the project. Also, the proposals selected in the scope of the open call need to confirm they will provide access to their lessons learnt, best practices, tutorials, guidelines and an overview of deployed technical components. Open Source licenses and free access to the developed software components is not a must, but considered desirable. However, a tangible business model is considered a prerequisite that shall finally correspond to the selected licensing scheme and envisaged commercialisation strategy.
- Reuse:
  Proposals shall explain how they assure to reuse existing technological components to avoid reinventing the wheel. Reuse of results developed and/or validated in the initial IoF2020 use cases including open initiatives like FIWARE as well as from other open sources initiatives will be evaluated positive.

Hence, a general objective of the proposed use cases shall be to validate IoT based solutions in a way that facilitates an understanding by different stakeholders on how IoT and related technologies can be applied in the food and farming industry, with a view of creating interoperable and portable solutions. Therefore, the identification of “interoperability points” shall be mapped to the use case’s architecture.

3 Potential Reusable Elements for IoF2020 Use Cases

This chapter summarises a part of the accompanying work in the IoT work package that analysed the use case requirements in detail. Due to the sensitive nature of this work, the related report on deliverable D3.7 ("Compilation of Use Case Requirements") was classified as restricted document and only a public summary of this work is available via the IoF2020 website (https://www.iof2020.eu/about/deliverables).

In the scope of this work, an overview of reusable components was elaborated, which are relevant for the IoF2020 use cases. The objective is to join efforts and create related synergies in the IoF2020 project for the development of related implementations. The following Figure 3 presents those reusable components in the context of an architectural perspective and the related layers from IoT devices up to the application and business process layers.

Figure 3: Potential reusable components to be further analysed, realised and potentially hosted in IoF2020.

The IoF2020 work package 3 analysed the proposals selected for funding with respect to their needs and potential usage of reusable components. The underlying objective is to harmonise efforts for validation of specific components, increase the efficiency and enlarge the validation context. As soon as the new use case teams sign their contracts and start their operational work in January/February 2019, next steps for collaboration and coordination of activities are carried out.

4 Technology related Selection Criteria in the Open Call

As outlined before, the key objective of the IoF2020 open call was to enlarge the project with additional use cases in new regions as well as to address post-farm use cases and other sectors. Nevertheless, also the technological dimension of the new use cases was considered highly relevant to work on the validation of IoT based solutions not yet well proven in the agri-food domain and would help following adopters to learn from the experience gained.

Therefore, the following requirement was added to the open call for proposals with respect to the technology impact and use of standards:

> *"The proposed product or service must consist of an innovative, credible IoT concept and make significant use of data. Proposals for realising IoT based solutions shall aim at demonstrating interoperability, replicability and reuse of the envisaged results. Results shall be presented to a wider stakeholder audience as well as presenting the results in the IoF2020 related IoT catalogue."*

To reflect this requirement in the scope of the evaluation by independent external experts, also explicit evaluation criteria was added to the call, rating the technology impact and use of standards:

- IoT solution, concept and innovation
  - This criterion rates the innovativeness, credibility and feasibility of the technological IoT concept, and also security & data privacy.
  - The proposed product or service should make significant use of data from connected devices or develop IoT devices itself.
- Interoperability, replicability and reusability of the developed solution.
  - This criterion rates how far the use case demonstrates interoperable, replicable and/or reusable components, systems or solutions. The usage of standards is highly appreciated, while using open system initiatives will be positively evaluated. The offering of open data is also considered as very valuable and will be evaluated positively.

The evaluators assessed those criteria on a scale from 1 to 10, while those two criteria had each a weighting of 1 in an overall set of 11 criteria with an overall accumulated weighting of 15 (i.e. resulting in an overall weighting of 13% for the criteria assessing technology impact and use of standards).

5 Enabling Technologies facilitating Realisation of Innovative IoT based Solutions in Agri-Food

For the initial use cases, as mentioned above, the IoF2020 team analysed the usage of IoT related technologies and use case requirements. This was the baseline for working on components valuable for reuse in a related use case context. At the same time, WP4 supported the refinement of underlying business models, taking into account both technological and business process related innovation.

The pure existence/usage of an individual IoT related technology in a use case does not necessarily create a breakthrough or innovation per se. For example, it might be helpful to install numerous communication gateways on fields or greenhouses, but to which degree this technology will foster the realisation of innovative solutions is questionable. Also, potential technologies for sensing diverse types of parameters in a ubiquitous manner will face the process constraints in relation to a trade-off of benefits, costs and operational capacities (e.g. battery life, bandwidth, accuracy, item reuse, complying harsh conditions). Hence, the innovation capacity of IoT enablers can be considered as a kind of hen and egg problem, not directly delivering easy innovation procedures or recipes. Therefore, IoF2020 added an IoT related technology short list to the open call that is considered as a collection of features offering solution alternatives for process related challenges. This list did not exclude the usage of other enabling technologies but rather trying to trigger the validation of discussed IoT technology that might be valuable for a wider developer and end-user community. The list as included in the open call is presented in the following:

- Security by Design, facilitating e.g.
  - Authorisation & authentication in distributed system architectures
  - Identity and role based management for outdoor solutions serving multi-tenants
  - Management of access rights to data – taking into account decentralised settings, without central governance and distributed data storage. Allowing information sharing along supply chains, while enabling context based access or revocation of access rights.
  - Secure encryption and management of decryption based on ownership of objects – e.g. allowing only the temporary owner of products to access related data
  - Dynamic presentation of data according to purpose. Allowing to use same data baselines to enable reporting for different purpose – from provision of anonymised data to the detailed reporting e.g. in case of crisis situations. At the same time, building upon existing IoT and agri-food related standards.
- Indoor positioning of moving objects
  - Realising indoor positioning as an add-on to outdoor positioning, as those moving objects are both indoor and outdoor. One solution fitting both conditions would also be an alternative.
  - Validating communication technology alternatives for indoor settings, while the moving object might also move to an outdoor setting (e.g. a cow in a farm and on the field), taking into account existing solutions (e.g. WiFi, BLE) as well as upcoming innovative solutions.
- Long range low power communication
  - Not specific to a certain communication technology (e.g. based on LoRa, SigFox or NB-IoT)
  - Validating scalability of operation of thousands or even millions of devices at one place
  - Usage under harsh conditions
  - Deployment in the field, able to satisfy demands on environmental protection (e.g. usage of batteries in outdoor settings)
- Outdoor positioning at low power consumption – alternative to classical GPS solutions
  - Positioning with higher accuracy, compared to current solutions (e.g. SigFox based positioning is rather not sufficient for precision agriculture or positioning of objects)
  - Enabling to find an object by position, especially if an object cannot be discovered by sight.
- Context-based decision support
  - Making use of FIWARE context broker based solution, based on standardised interfaces (i.e. NGSI 10)

- Developing context models for specific purpose and an open source based approach for open and free usage
  - Methodology for context model development and usage
- Low cost weather stations
- Theft protection of IoT devices that are exposed in a rural setting
- Peer-to-peer networks in rural settings for local data exchange, allowing larger data volume (e.g. compared to LoRa solutions) and trusted connections.
- Realising a MEMS based sensor and actuator system for precision farming in a real world setting
  - Development and validation of a business model canvas
  - Aiming at a tangible solution, while including the required agricultural knowledge base for smart control
- Communication between FMIS and machines of the farmer.
  - Based on ISOBUS approach developed in IoF2020 use case 1.4 (Farm Machine Interoperability)
  - Involving visualisation of real-time data from machines
  - Validating the usage with different types of FMIS and machinery from different agricultural equipment manufacturers
  - Validating the usage with a large amount of farmers also in situation of sharing machinery by numerous farmers using FMIS from different software providers
- IoT based solution, generating big data and making use of the data with machine learning algorithms
  - Realising a tangible solution based on a real world setting
  - High focus on usability and exploitation of the knowledge e.g. for precision farming.
- IoT Marketplace Innovations

Therefore, the Open Call was not looking for technologies as such, but a validation of solutions addressing specific challenges and issues in the agri-food domain. Accompanying, IoF2020 highlighted the added value of proposals to validate specific technologies still lacking adoption in the agri-food domain, while not yet having a sound evidence about costs, benefit and implementation challenges. Basic technology examples like blockchain and big data are such potentials already applied by frontrunners, but a wide adoption and validation is still missing. On top of that, it was considered very useful and strategic to incorporate technologies that can have a positive impact in multiple UCs and possibly trials. Thus, addressed technologies should be horizontally applicable for IoT based solutions.

In conclusion, IoF2020 is aiming at the realisation of innovative IoT based solutions, while every proposal submitted had to explain its novelty and how it intends to present its results to a larger target audience and specifically to European stakeholders from the food and farming sectors. Therefore, the following had to be highlighted in the proposals:

- Envisaged solutions shall be deployed in real world settings and used by a sufficient amount of end users in daily practice for a proper validation and collection of results for dissemination.
- Proposals had to balance novelty and maturity of the envisaged IoT based solutions to involve real end users. Envisaged solutions must not just aim at a “proof of concept”, but be able to clearly validate a specific feature promising to realise a clear value proposition for the related end users.
- The reuse of results and knowledge provided by the current 19 use cases and envisaged cooperation of the stakeholders had to be explained. This had to be reflected in the work plan, further detailing the envisaged support and effort it will imply for the existing use case teams.
- Reuse existing results and knowledge had to detail potential issues with respect to the usage of datasets and/or intellectual property that current end users would be expected to provide for a proper implementation of the solution.
- The envisaged novelty can be realised in the deployed IoT based technology, the envisaged business model and/or in the business processes to be realised by the end-users.

These criteria were also seen as aspects to assure interoperability, replicability and reusability of the proposed IoT solutions as previously highlighted in section 2.3.

6 Evolution of IoF2020 with New Regions and Post-Farm Uses Cases

IoF2020 involved 19 use cases right from the start of the project. In the first 24 months, each of those use cases was implementing IoT based solutions as presented in Deliverable D3.2 (IoF2020 use case architectures and overview of the related IoT systems). As indicated before, those use cases were grouped in 5 trial areas where they are realising and validating IoT based solutions, providing features relevant to specific steps in the agri-food value chain as presented in the following Figure 4.

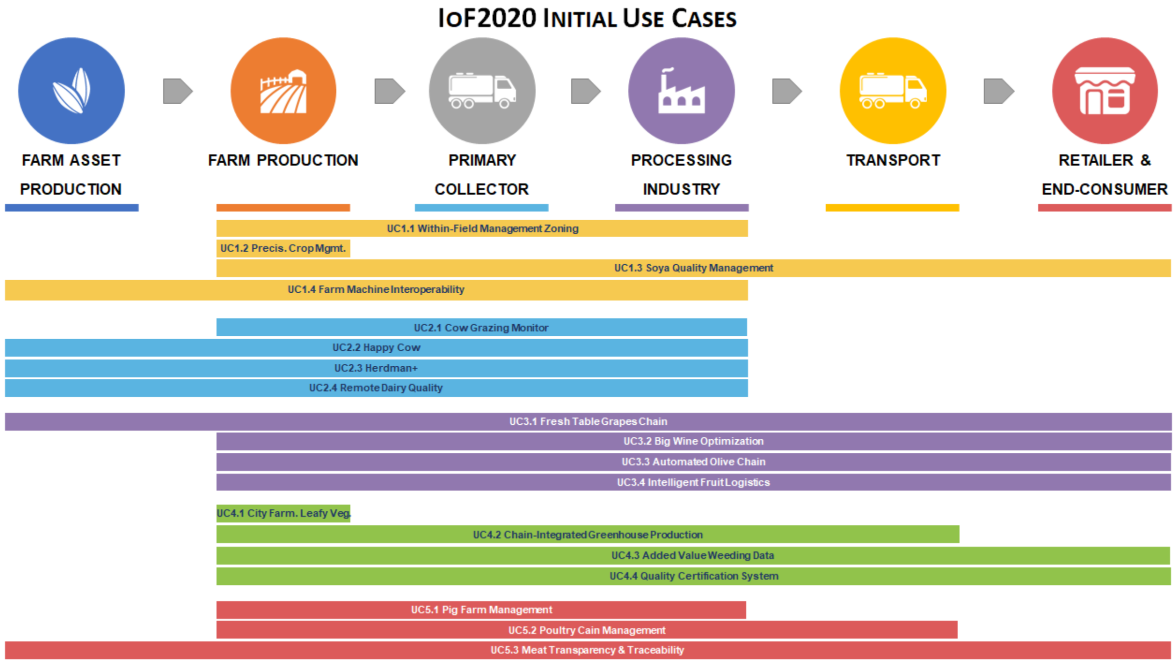

Figure 4: Initial IoF2020 use cases in relation to generic steps of an agri-food value chain.

This high-level categorisation of use cases is not detailing the specific solution instantiation in complex agri-food value networks. It rather highlights the boundaries of developed solutions and envisaged business models with respect to the stakeholder involvement to facilitate uptake of experience gained and lessons learned by interested parties. Especially the evolution of the initial set of IoF2020 use cases in new regions by additional use cases intends to build upon those initially validated solutions as well as to extend their dimension with additional business, technical or regional aspects. The following Figure 5 presents the steps of the agri-food value chain addressed by the use cases selected by the open call.

As presented in Figure 5, all the use cases address the farm production, where six of those fourteen use cases (i.e. 43%) have a focus on the farm production itself. Three use cases also address farm asset production, somehow considering the farmer as a type of end-consumer of key assets required for the farm operation. Those cases serve as validation of customer-supplier relations, as the use cases covering post-farm steps also do. An overall amount of eight use cases (i.e. 57% of selected use cases) address more than one step in the agri-food value chain, usually aiming at the validation of a horizontal interaction along the chain, where of course also vertical interaction in single steps of the chain are addressed. Only three use cases are reaching up to the retailer and end-consumer. At the current moment, those use cases are not planning for extensive end-consumer involvement for validation, but aiming at the provision of information along the chain, empowering retailers to offer new data sets and added-value information/services to consumers. Depending on the complexity of the related agri-food chain, especially the transport step needs to be considered as a kind of accompanying task that could be required as an intermediary in between specific steps (i.e. either horizontal or also vertical interaction in the chain or in repetitive types of stakeholders like several processors interacting with each other). This addresses the classical logistics function, while the farm and harvest related transport is covered by the primary collectors, representing a special type of transport support in the agri-food chain, usually from field/farm to processor. From a stakeholder perspective, farm production and processing might also be located at one stakeholder that integrates farming and the processing of the produce (e.g. winery operating its own vineyards). At the same time, the complexity of interdependencies is also driven by the agri-food sector itself. Short chains like harvesting of fruits and vegetables directly transported to retailers and sold to consumers are rather simple. Chains with diverse steps for processing food products based on diverse ingredients (e.g. production of pizza that includes ingredients from different sectors like wheat from arable, milk from dairy, pineapple from fruits, tomatoes from vegetables and ham from the meat sector) are rather complex, since it is not just a mix of individual basic ingredients, but a compilation of inputs that itself are originating from previous processing steps before being used for producing the pizza as an end-product.

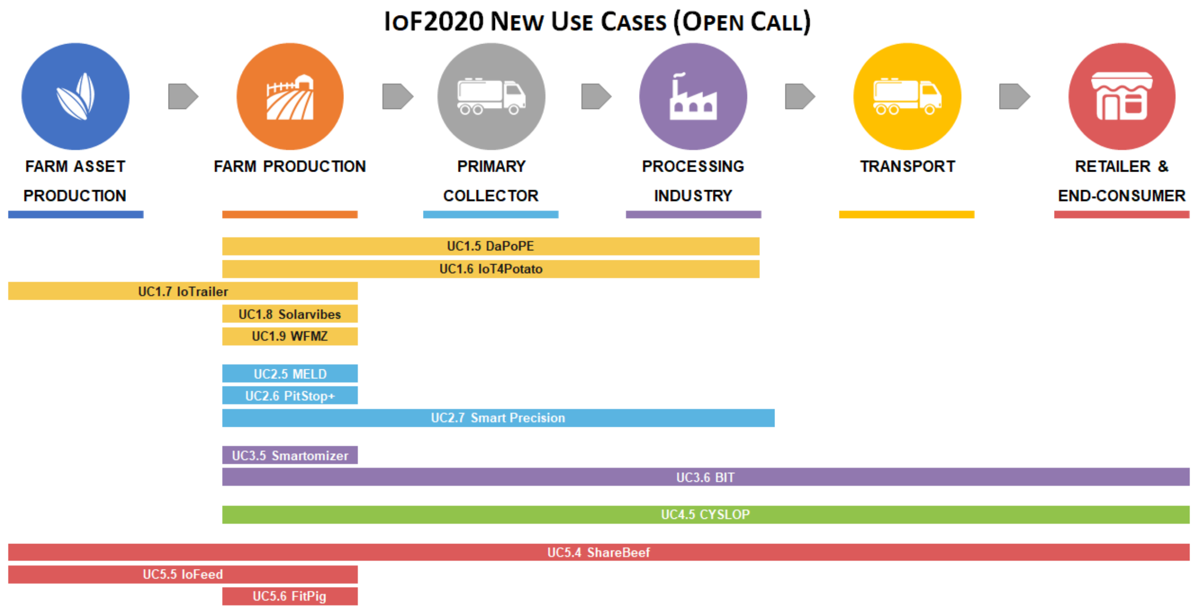

Figure 5: Steps in the agri-food value chain addressed by the use cases that were selected by the IoF2020 Open Call.

In parallel to the design of agri-food chains or better to say networks, the quality and quantitative performance of agri-food networks directly relates to the location of farming (e.g. due to weather, soil, water supplies, available equipment, education of farmers, size of farms, available private and public ICT infrastructure, Internet connectivity in rural areas). This was also the reason to attract additional regions by the open call not yet covered by the initial 19 IoF2020 use cases. This evolution offers the opportunity to test and validate IoT based solutions that were already successfully deployed in the initial region or in a local setting involving a specific setting of required stakeholders. The following Figure 6 provides an overview of this evolution with adding diverse testbeds in around 22 regions.

Figure 6: Indicative testbed locations of the initial IoF2020 use cases and the evolution by use cases selected in the open call.

The following section 6.1 further details the challenges and technologies addressed by the new use cases.

6.1 Key Challenges and Technologies addressed in the New Use Cases

The 14 new use cases plan to develop a varying set of IoT based solutions in the five trial areas of IoF2020. In the scope of the WP3 related work in IoF2020, the use cases were analysed from a technological perspective. This shall facilitate the collaboration with the new teams as well as identifying needs and potentials of reusing IoT related technologies. The following aspects were compiled:

- IoT solution to be developed in the use case, solving a specific problem in one or more trial areas;
- Specific IoT enabling technology that shall be tested in the new use case; these are sensors, actuators, communication components and other IoT related devices or systems to be deployed and validated. In most cases, these can be considered as kind of one or more COTS components that will be integrated in the overall solution.
- Main technology focus for the solution, describes the purpose for which the most development effort will be used in the use case; when taking into account the general categorisation of functional solution components. This aspect explains where to focus when implementing, extending, integrating or enhancing solutions, services or MVPs.
- Key challenges list the main issues the use case has to overcome to deliver the proposed solution, usually representing the underlying motivation for realising the integrated solution;
- Infrastructure identifies main components, technologies, protocols and standards required as a baseline environment for making use of the overall technical solution. The used infrastructure can be characterised as additional reusable or COTS components with respect to reusability and replicability, while we also referenced the usage of specific protocols or standards with respect to interoperability.

The result of this analysis is presented in the following Table 1.

Table 1: Solutions, challenges and technologies in the new use cases.

Trial	Use Case	Solution to be developed	IoT Technology used	Solution's Main Technology Focus	Key Challenges	Infrastructure Used
Arable	UC 1.5 DaPoPE	Solution to collect data from potato farmers (field and shed) and provide it to processing companies.	MS Azure IoT platform and component for yield prediction based on drone data.	Test and adopt appropriate solution for yield calibre measurement on a harvester machine. Develop a visualization module to display calibre measurement on a yield map and a shed visualization module.	Setup of measurement method for calibre measurement. Select appropriate traceability solution for shed visualization.	Microsoft API platform EFDI, ADAPT, ISOXML, MQTT
	UC 1.6 IoT4Potato	Extend existing IoT-based Smart Farming solution, gaiasense, to provide context-aware decision support services for irrigation, pest management and fertilization for potato producers.	IoT stations (gaiatrons) to collect atmospheric and soil data. FIWARE Orion Context Broker and Cygnus.	Develop and adapt models to evaluate cultivation conditions and estimate risks that can be mitigated by irrigation, fertilization and pest management actions. Upgrade existing platform with FIWARE generic enablers.	Extend the gaiasense smart farming solution with innovative and interoperable FIWARE-powered IoT-based services. Establish a data collection infrastructure, consisting of dense networks of (low cost) weather/ soil stations.	FIWARE Orion Context Broker, Cygnus, Identity Management Control, CKSN MongoDB NGSI GeoJSON GSMA, GPRS, 3G gaiasense platform
	UC 1.7 IoTrailer	IoT-based fully automated 'silo' detection system to guarantee correct delivery of bulk contents to silos and respective registration (authentication).	Wireless reader for TAG identification.	Develop a silo-trailer identification system, based on an existing wireless reader.	Connection to all silos, independent of their coupling type. System for automated silo detection independent of trailer type or brand. System resistance to extreme weather, shock, vibration and electricity electrostatic.	PLC controller track & trace system LoRa, LPWAN, WiFi, RS232, NFC Qi

Trial	Use Case	Solution to be developed	IoT Technology used	Solution's Main Technology Focus	Key Challenges	Infrastructure Used
	UC 1.8 Solar-vibes	Hardware and software solution to monitor soil parameters and micro climate to help farmers adopt sustainable farm practices and improve overall efficiency.	Solar-powered device that monitors soil pH, moisture and temperature, micronutrients and micro climate.	Further develop existing hardware towards easy installation and one button push activation to collect data. Develop machine learning algorithms to analyse crop health based on crop images.	Demonstrate sensor-based farm management. Enable farmers to use as little chemicals as possible.	AWS cloud services MQTT, HTPP GSM, GPRS, LoRa
	UC 1.9 WFMZ	Develop a system using data from soil, climate, crop, yield and hyperspectral sensors for yield prediction, arable field management and crop management.	Automated drone system with hyperspectral camera.	Develop spectral image data analysis method for potato plants. Assemble, connect and integrated necessary hardware. Development of API for data exchange with external services and systems.	Algorithms for hyperspectral imaging data analysis. Connection/link of hyperspectral imaging sensors data to database and data storage platform. Big data analysis infrastructure for automated analysis of spectral images.	MAVLink, ISO/IEC 24730, Isobus WiFi, LoRa, GPS UAV and hyperspectral imager BaySpecCubeCreator (image processing software) SpectroRadiometer ENVI-BSQ, BMP, ROI spectra, GEO-JSON
Dairy	UC2.5 MELD	Solution using leg mounted sensors and machine learning for early lameness detection in cows.	Long range pedometers and collar-based monitor for cows. IBM Watson IoT platform.	Extend existing machine learning algorithms to include additional cluster models.	Integrate existing Lame Detection as a Service (LDaaS) into IoF2020 architecture. Validate machine learning approach to early lameness detection.	IBM Watson IoT platform. MQTT, RS485, USB, LoRa, WiFi NGSI, GS1 GSMA

Trial	Use Case	Solution to be developed	IoT Technology used	Solution's Main Technology Focus	Key Challenges	Infrastructure Used
	UC 2.6 Pitstop+	System, comprising feeder and designated mineral supplements, to improve productivity of dairy cows.	Ear tags. PitStop feeder.	Establish electronic data transfer from IACS registers to Pitstop. Analyse correlation between recorded behaviour against their health and performance to adapt algorithms.	Precision mineral supplementation of dairy cows. System working on high variations in temperatures in a dusty, humid atmosphere with high concentrations of ammonia and other aggressive gases.	HDX, FDX ISO LoRa, LAN, WAN HTTP Ear tags Mineral Feeder Microsoft Azure SQL
	UC2.7 Smart Precision	Smart multi-sensor devices equipped with long range low power communication technology for precision dairy and beef cattle monitoring	Small-sized rumen bolus measuring physiological data (temperature, rumen and body activity, pH level) and geo location tracking with NB-IoT or LoRa.	Develop a stand-alone device that does not require installation of local or farm specific communication systems, but directly connects the Internet and hence the central cloud-based server application system.	Realise a measurement device operated in vivo, while sensing a set of parameters and communicating with an external infrastructure. Decentralised measured data provides the input for datamining and machine learning based forecasts, alerts, and predictions.	Cloud-based server environment, able to communicate with boluses everywhere, where NB-IoT or LoRa network is available. Optimized Firmware versions of the used technology shall also be deployed in the sensors throughout their operation period.
Fruit	UC3.5 Smartomizer	Use smartomizers, i.e. IoT-enabled air blast atomizing sprayers, to reduce use of plant protection product in three agricultural sectors (cherry, apple and almond productions).	IoT-enabled air blast atomizing sprayer.	Precise automatic adaptation of smart sprayers to field, field zone and plant conditions. Implement context broker and interfaces (to ERP, FMIS).	Increase the sustainability of food production in Europe through significant reduction of pesticide use. Globally and openly drive the development in IoT for speciality or 3D crops.	FIWARE Orion Context Broker HTTPS, REST/JSON ADAPT, H3O Sprayer Control System and Gateway

Trial	Use Case	Solution to be developed	IoT Technology used	Solution's Main Technology Focus	Key Challenges	Infrastructure Used
	UC 3.6 BIT	System to monitor the complete wine and beverage value chain to prevent shipping and storage damages and establish direct connection between producers, final sellers and consumers.	Self-powered device to track and trace boxes/packages.	Track and trace device with temperature, humidity and accelerometer sensors and microprocessor for data-processing algorithms. Prescriptive analytics application to process data. Blockchain application to certify data.	Increase traceability to prevent product spoilage during transport. Provide data on product handling throughout the value chain to the final consumer.	Blockchain NFC, Bluetooth, WiFi, LTE TCP/IP, MQTT, UMTS OAuth2 HTML5 API with REST and JSON
Vegetables	UC 4.5 CYSLOP	Platform to optimise crop cultivation practices, organise food supply chain and provide data to consumers.	FIWARE-based IoT platform (QUHOMA) Weather stations, air and soil sensors, irrigation programmers, QR scanner. Data marketplace to share data over the value chain.	Integrate CEP, analytics and big data tools in the IoT platform to provide additional data services.	Implement on-farm and microclimate monitoring and improve irrigation management. Collect and deliver traceability information over the supply chain. Supply information services to support the retail business ecosystem.	EPCIS and IoT2EPCIS (NGSI to EPCIS adapter) FIWARE Orion Context Broker, Cygnus, Perseo PEP, PDP STH Comet MongoDB JSON, MQTT 6LoWPAN, BLE, WiFi

Trial	Use Case	Solution to be developed	IoT Technology used	Solution's Main Technology Focus	Key Challenges	Infrastructure Used
Meat	UC 5.4 Share-Beef	Shared value system to integrate and share data from different segments of the food supply chain to improve decision making related to resource efficiency and customer satisfaction.	IoT smart collars, IoT ear tags, weather and soil stations. FIWARE-based IoT platform.	Develop model to harmonize raw data collected from different IoT devices. Develop machine learning algorithms for crop status and productivity, animal status, productivity and welfare, animal growth, transport welfare, and slaughter welfare. Collect requirements and develop a FIWARE-based interoperable platform.	Improved productivity and quality of crops for animal feeding. Improve animal welfare in livestock farms, feedlot and slaughterhouses. Provide data about production conditions, animal health and welfare to the consumer.	FIWARE Orion context broker, IoT Agent MQTT, OneM2M, HTTP/REST, JSON, BLE SigFox, 2G73G/4G, NBIoT, LoRa RFID, GPS NGSI v2, NGSI-10 MongoDB
	UC 5.5 IOFeed	Smart Feed Logistics Platform with 3D camera to monitor silos' stock levels, supporting two business models centred on the farmer and supplier.	INSYLO devices (3D camera) FiWARE IoT Stack, Identity Management GE, Cygnus/Perseo	Develop business intelligence features for feed demand forecast, automatic restocking and logistics optimization. Integrate the Smart Feed Logistics Platform into the information management system of the feed supplier.	Develop an integral feedstock management system to optimise animal feed supply chain. IoT technology to monitor amount of feed in silos.	FIWARE Orion Context Broker, Cygnus, IoT Agent, Identity Management, CKAN 6LoWPAN, GPRS, LWm2M, MQTT HTML5 MongoDB INSYLO IoT cloud platform NGSI, oAuth2

Trial	Use Case	Solution to be developed	IoT Technology used	Solution's Main Technology Focus	Key Challenges	Infrastructure Used
	UC 5.6 FitPig	Solution to monitor pigs' heart rate and activity using an ear tag to provide a context-based alarm and decision support to increase animal health.	RFID ear tags FIWARE Enablers (LwM2M IoT Agent, Orion Context Broker, Cygnus, STH Comet, Perseo, KeyStone/PDP Keypass/PEP-Still-Skin)	New sensor to monitor pig's heart rate placed in ear (photoplethysmographic sensor embedded into an ear tag).	Monitor animal health to improve food safety and animal wellbeing. Improve management of piglet mortality. Platform for veterinarians to do periodic health monitoring. Forecast meat demand.	LwM2M IoT Agent FIWARE Orion Context Broker GRAFANA platform SmartSpot (gateways) LoRa, WiFi, GPRS, BLE JSON, NGSI

6.2 Overview on the IoT related Focus of the new Use Cases

As highlighted above, the use cases were analysed from a technological perspective to facilitate the collaboration with new teams as well as identifying needs and potentials of reusing IoT related technologies. Therefore, section 6.1 listed the different IoT technologies intended to be used in the new use cases. To underst to which degree or for whom such solutions and the experience gained can be relevant, WP3 elaborated a classification of IoT related implementations, taking into account different dimensions:

- Degree to which solutions can be assigned to the virtual or digital world:
  - Architectural Dimension based on the classification approach as elaborated for the analysis of use case requirements, presented in the IoF2020 Deliverable D3.7 (Compilation of Use Case Requirements) – see also Figure 3.
  - Focus of a solution with respect to the relevance of either software or hardware based implementations, while usually all areas include a mix of both. This focus might also be a way for assessing the relevance of "Things" in the different parts of an overall IoT based solution deployed in a real world context accordingly.
- Degree of Replicability:
  - Categories of functional components to assess the degree of customisation to a specific solution scenario in the real world – see also section 2.2 and Figure 2.
  - Relation to the requirements of a specific business domain to understand for which stakeholders a solution could be relevant.

Those dimensions are presented in the following Figure 7 and were used to categorise the IoT technology intended of being used (see Table 1) by the new use cases in Figure 8.

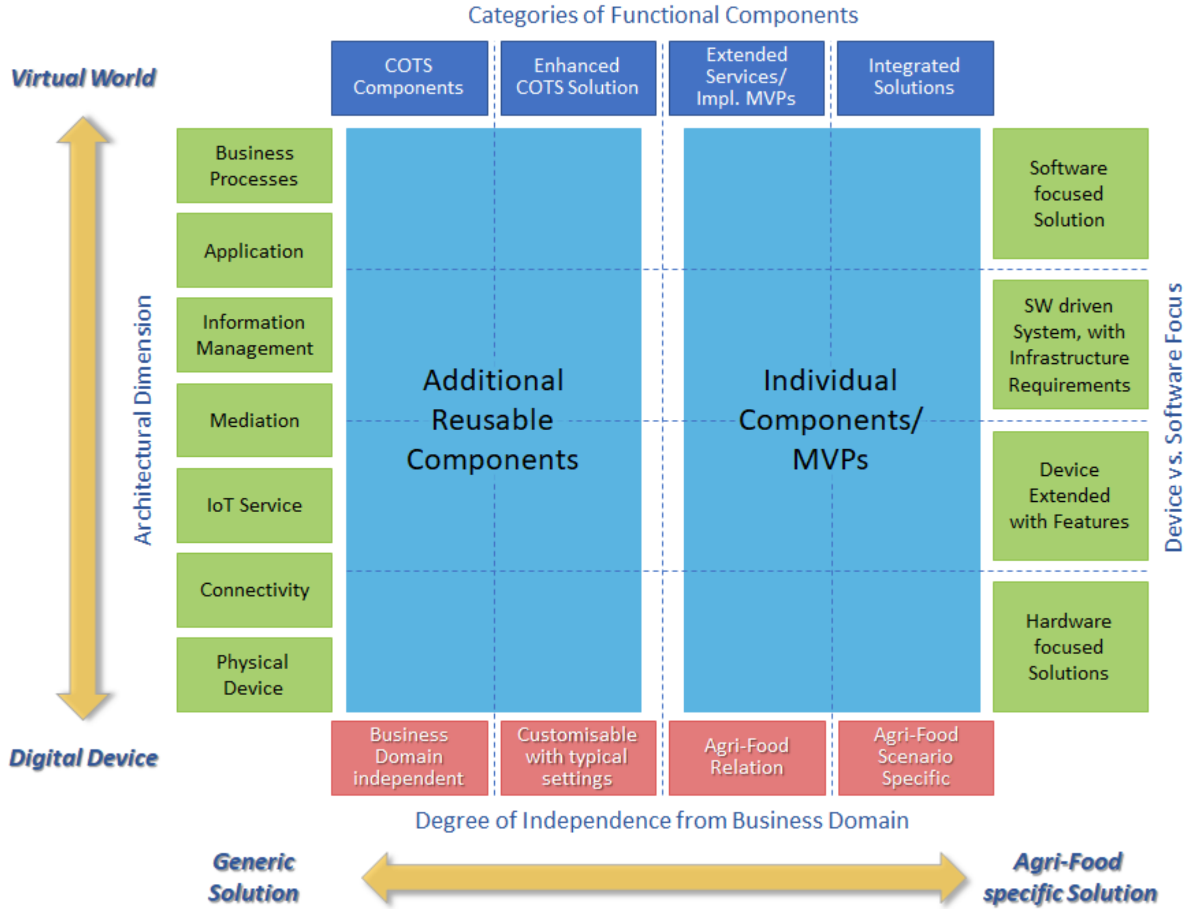

Figure 7: Structure for the classification of IoT related implementations, addressed by IoF2020 use cases.

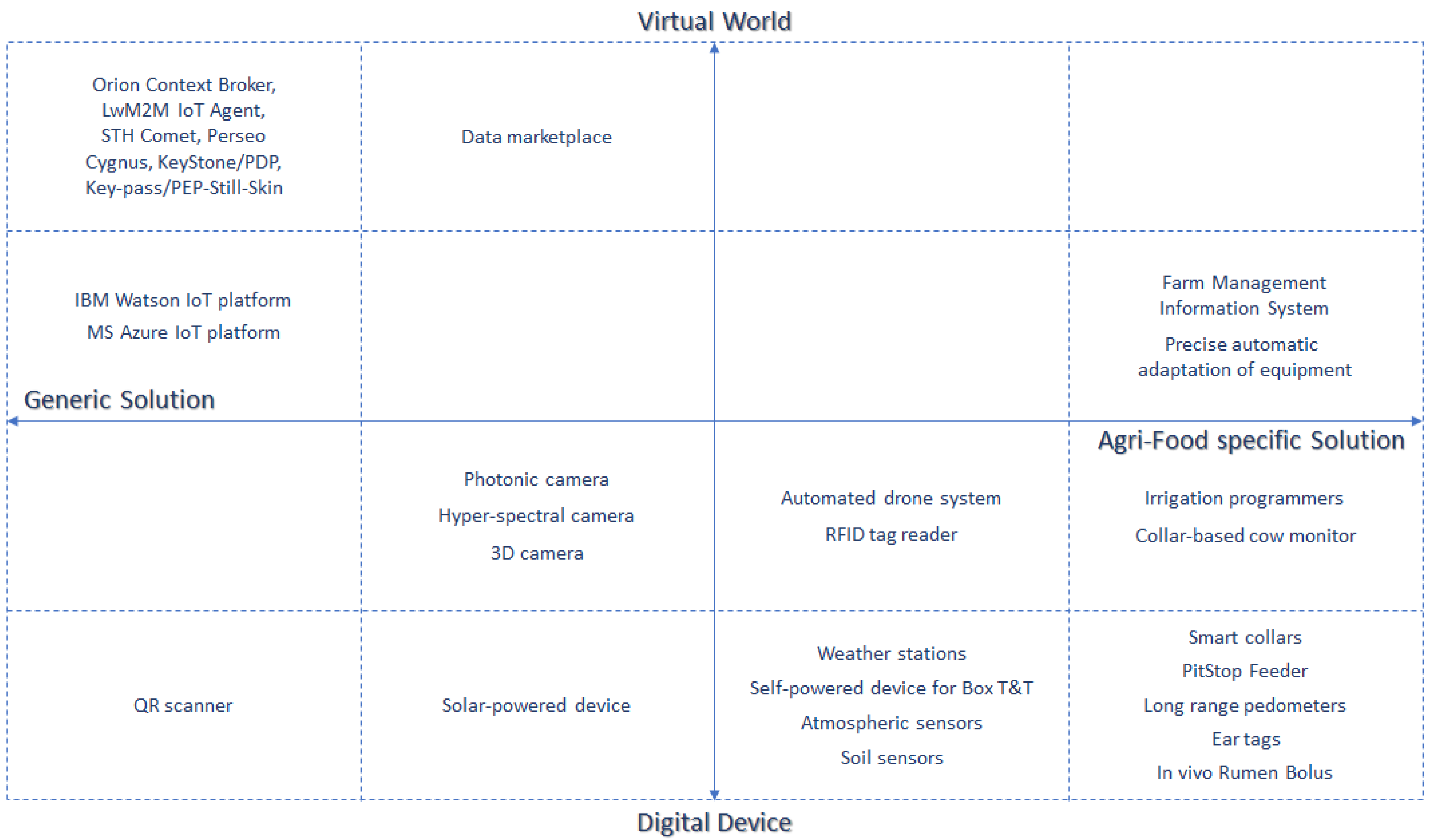

Figure 8: Overview of IoT technology used in the new use cases.

7 Collaboration between Initial and New IoF2020 Use Cases

Since the beginning of the IoF2020 project, the initial use cases fostered the exchange of experience and knowledge to facilitate cooperation. Initially, this cooperation was focussed on trial level, promoted by the trial chairs, and has been evolving to inter-trial collaboration. In the open call, the new use cases were asked to identify potential for collaboration with the initial use cases, in an attempt to re-use relevant results already achieved in the project. All the 14 use cases resulting from the open call have identified at least one use case where possible collaboration is foreseen.

Figure 9 provides a graphical overview on how the new use cases will reuse results from initial use cases, structured by the five trial areas. The overlap of new use cases with different trial areas identifies the usage of results stemming from those different trial areas.

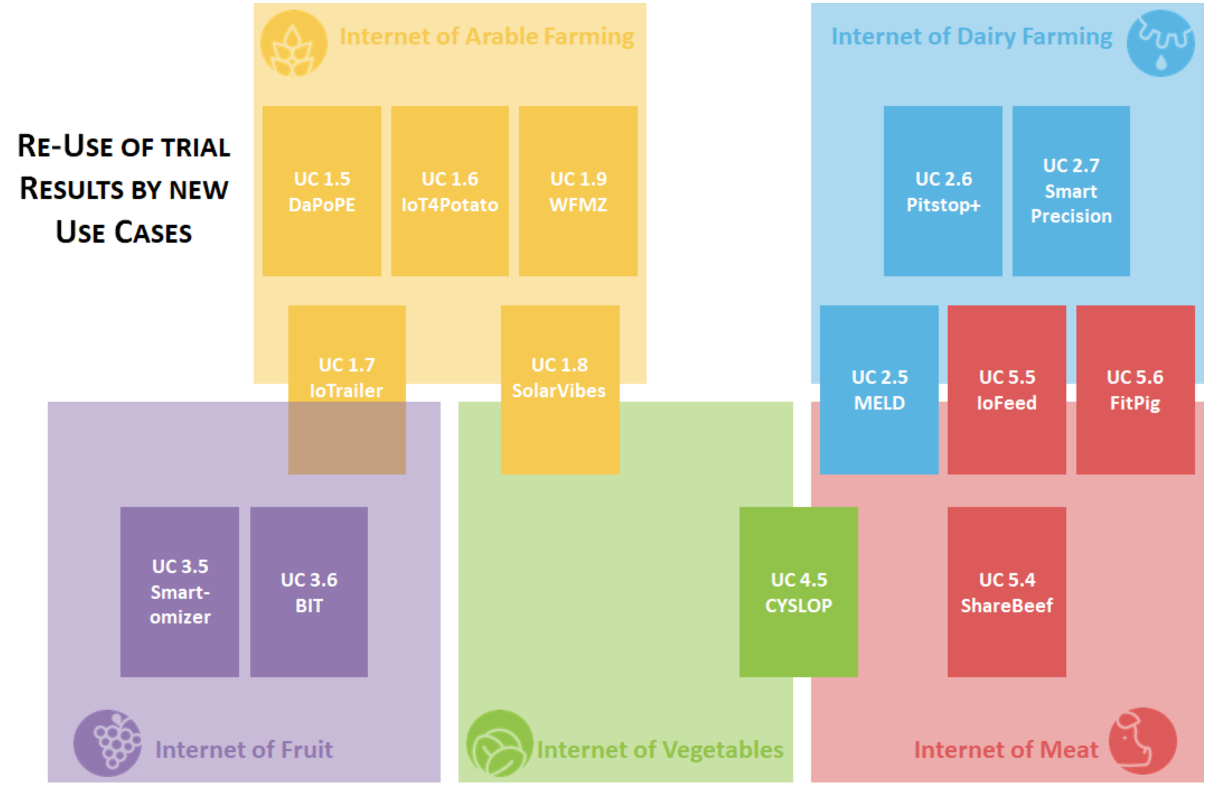

Figure 9: Collaboration among initial and new use cases at trial level.

The cross-trial collaboration indicates that the reuse or replication of IoT based solutions or at least of components seems feasible over the boundaries of agri-food sectors. Of course, the close relation e.g. between dairy and meat are possibly facilitating the reuse, due to similarities in the live-stock sectors. The intended reuse is further indicated in the following Table 2, presenting all planned interactions between new and initial use cases. For informative purpose, a description of the initial use cases was added to chapter 9 with a listing of the 19 initial use cases.

Abstracts of all the planned collaboration actions between the new and initial use cases are presented from Table 3 to Table 7, grouped by trial areas.

Table 2: Intended collaboration between new and initial use cases in IoF2020.

Tria l	Initial Use Cases / New Use Cases	Arable			Dairy			Fruit				Veget.	Meat		
		UC1.1 Within-Field Management Zoning	**UC1.2 Precision Crop Management**	**UC1.4 Farm Machine Interoperability**	**UC2.1 Grazing Cow Monitor**	**UC2.2 Happy Cow**	**UC2.3 Herdsman**	**UC3.1 Fresh Table Grapes Chain**	**UC3.2 Big Wine ‘Optimization**	**UC3.3 Automated Olive Chain**	**UC3.4 Intelligent Fruit Logistics**	**UC4.4 Enhanced Quality Certification System**	**UC5.1 Pig Farm Management**	**UC5.3 Meat Transparency and Traceability**	**External Use Cases to be further detailed**
Arable	DaPoPE			X											
	IoT4Potato	X													
	IoTrailer	X									X				
	Solarvibes	X	X									X			
	WFMZ	X													
Dairy	MELD						X							X	
	Pitstop+						X								
	Smart Prec.				(X)	(X)	(X)								
Fruit	Smartomizer							X	X	X					
	BIT								X						
Veg.	CYSLOP													X	X
Meat	ShareBeef													X	
	IOFeed						X								
	FitPig								X				X		

Table 3: Collaboration among new use cases in trial area 1 (arable) with the initial use cases.

Use Case	UC1.1 Within-Field Management Zones	UC1.2 Precision Crop Management	UC1.4 Farm Machine Interoperability	UC3.4 Intelligent Fruit Logistics	UC4.4 Enhanced Quality Certification System
UC 1.5 DaPoPE			Data exchanges via standards		
UC 1.6 IoT4Potato	IoT4Potato can benefit from know-how on how to use Sentinel 1 and 2 data in North European Countries.				
UC 1.7 IoTrailer	Exchanging expertise related to Lora network usage			Expertise related to TAG and RFID readers	
UC 1.8 SolarVibes	Within field management zoning have tested and worked on similar crops and there is good potential for data integration to develop AI models for potatoes and implement using SolarVibes FMIS to improve farming efficiency.	Using camera-based sensing in wheat farms could be interesting to collaborate and study the data.			Develop more effective quality analysis algorithms, by using crop quality certification to enhance export/import opportunity for farmers.
UC 1.9 WFMZ	Extend capabilities of UC1.1 by providing additional data on plant nutrient contents that increases amount and precision of data for better management zoning and decision making. Both solutions should be integrated and managed by the same FMIS with common software functionality. Both use cases extend each other for a common goal, sensor data and hyperspectral image data should be integrated in a single more effective solution.				

Table 4: Collaboration among new use cases in trial area 2 (dairy) with the initial use cases.

Use Case	UC2.3 Herdsman	UC5.3 Meat Transparency and Traceability
UC 2.5 MELD	There is a potential to incorporate data from UC2.3 with the early lameness detection algorithm. There is also a potential to integrate alerts from MELD UC with other on-farm data to test the value of analysing multiple integrated streams.	Possibility to adapt some results from UC5.3 obtained in pigs and adapt them for beef market. Europe has the 2nd most valuable beef market in the world, with undoubtable the highest standard of regulation. This study potentially shares some synergy with UC5.3 and could verify if a larger beef study is warranted for EU Beef.
UC 2.6 Pitstop+	Share approaches and data, as both systems have algorithms to assign the status “Alarm” or “Observation” to cows showing abnormal behaviour. It is possible to enhance the precision of assigning the status “Alarm” or “Observation” to cows by equipping them with the same systems and sharing logged data.	
UC 2.7 Smart Precision	Analysing potential to reuse hardware and software components as well as collected data during the UC validation and the built algorithm. This will be checked for the following three use cases from trial 2: • UC2.1 Grazing Cow Monitor • UC2.2 Happy Cow • UC2.3 Herdsman	

Table 5: Collaboration among new use cases in trial area 3 (fruit) with the initial use cases.

Use Case	UC3.1 Fresh Table Grapes Chain	UC3.2 Big Wine Optimization	UC3.3 Automated Olive Chain
UC 3.5 Smartomizer	Potential to include data from sensors installed (crop and field sensors and weather data). Possible inclusion of Smartomizer in the solution of UC3.1.	Potential to include data collected from sensors in vineyards (weather conditions, vine phenological conditions). Possible inclusion of Smartomizer with the sensiNact platform.	Potential to include data collected from IoT boxes (soil sensors, probes, air and plants sensors).

Use Case	UC3.1 Fresh Table Grapes Chain	UC3.2 Big Wine Optimization	UC3.3 Automated Olive Chain
UC 3.6 BIT		Adapt device for scalability and usability purposes and modify the platform user interface. Leverage on the deep knowledge on tracking systems from UC3.2. Data on temperature trends recorded during wine shipment in UC 3.2 tests will be integrated in the database.	

Table 6: Collaboration among new use cases in trial area 4 (vegetables) with the initial use cases.

Use Case	UC4.2 Chain-Integrated Greenhouse Production	UC4.3 Added Value Weeding Data	UC5.3 Meat Transparency and Traceability	Other
UC 4.5 CYSLOP			On-field sensors, common software features (shared EPCIS). Potential for a CYSLOP agent to integrate UC5.3 data services to its data marketplace and enable data-sharing.	Any other use case that shares the concept of multi-stakeholder community that exchanges paid or free information services. Exploitation of the marketplace components.

Table 7: Collaboration among new use cases in trial area 5 (meat) with the initial use cases.

Use Case	UC2.3 Herdsman	UC3.2 Big Wine Optimization	UC5.1 Pig Farm Management	UC5.3 Meat Transparency and Traceability
UC 5.4 ShareBeef				Possible reuse of some software elements that enable data transparency. According with the UC 5.3 "The transparency system is generic and can be applied in any one of the UCs involved in production, and transportation of goods”. Some of the IoT devices could be used to improve data transparency.

Use Case	UC2.3 Herdsman	UC3.2 Big Wine Optimization	UC5.1 Pig Farm Management	UC5.3 Meat Transparency and Traceability
UC 5.5 IOFeed	Potential synergies detected with feed measurement. Feed consumption data could be integrated into IO-Feed project.			
UC 5.6 FitPig		Possible reuse of a device to monitor and control the environmental conditions, being used in UC3.2 in the vineyards and cellars. The data integration is being done with FIWARE platform due to its interoperability so in our case it will also be reused.	Exchange experience and results on ear tags used in the trial. Cooperation of data integration for the PLF study commission of the EAAP (http://www.eaap.org/presentation/scientific-structure/scientific-commissions/commission-on-precision-livestock-farming-plf/).	

As presented in the tables before, the use cases proposed to use existing results and validate their IoT based solutions with the help of the initial use cases. Based on the proposals evaluated by independent external experts, the use cases were asked to describe their planned work in a further detailed work plan. The preparation of the work plans had also to take into account the comments of the external experts to clarify open questions or to improve the use case realisation. Each work plan had to identify the specific deliverables to be elaborated and the timing towards so called minimum viable products that shall serve for an end-user driven test and validation.

The new use cases will be further analysed and supported by work packages 2, 3 and 4 to create further synergies by outlining experience gained and lessons learnt with respect to the end-user driven implementation, reuse of technology and the development of specific agri-food related business models, helping both the solution providers as well as the end-users to realise the intended benefits.

8 Conclusions

The overall objective of IoF2020 is to foster the deployment of IoT solutions in Europe through integration of advanced IoT technologies across the value chain. This shall be achieved by demonstration of multiple IoT applications at scale and in a usage context. Key is also the test and validation as close as possible to operational conditions, while being aware that there are several roadblocks as e.g. IoT device operation at large scale, real-life driven requirements with respect to security privacy and trust as well as making sure to aim at a working business model – guaranteeing sustainable usage of the realised IoT based solutions.

The initial set of 19 IoF2020 use cases started in the beginning of the project in early 2017. They are validating a complimentary set of IoT based solutions in different stages of the agri-food chain, involving diverse combinations of related agri-food stakeholders. The regional distribution of those stakeholders is concentrated in the Western part of Europe, leaving some white spots in Eastern as well as Northern Europe. At the same time, the initial set had a realisation focus on the earlier steps in the agri-food chain, while enabling future potentials by the realisation of IoT based solutions gathering data, information and knowledge that could also have an added value for later steps in the chain. Therefore, the open call for new use cases asked for teams to cover additional regions, also aiming at later stages in the agri-food chain and focusing on the involvement of a large group of end-users, while also directly involving large number of farmers.

At the same time, IoF2020 in cooperation with the other four large scale pilot (LSP) projects harmonised the timing, key aspects and potentials for cross LSP collaboration in the scope of the different open calls. Based on this, the LSP projects agreed on general requirements with respect to interoperability, replicability and reuse. Hence, the idea was to ask for general objectives of the proposed use cases that facilitate an understanding by different stakeholders on how IoT and related technologies can be applied in the food and farming industry, with a view of creating interoperable and portable solutions. Therefore, identified “interoperability points” had to be mapped to the use cases’ architectures. This can also help to identify cross business domain synergies, avoiding to reinvent the wheel when e.g. food is approaching the city and demands for new ways of transport, logistics and consumer interaction are coming up. This clearly indicates relations towards the SynchroniCity LSP project on smart cities and the AutoPilot project on autonomous vehicles and possibly future food transport in connected environments. Nevertheless, the impact of food on consumers’ health and related information from the agri-food chain might also add value to solutions developed for smart living environments for ageing well (i.e. Activage LSP project).

IoF2020 received nearly 100 proposals from all over Europe that were evaluated by a team of independent external evaluators. Taking into account the excellence of the submitted use case proposals as well as the requested funding, IoF2020 was able to select 14 new use cases for funding. Those 14 new use cases are addressing all 5 trial areas (i.e. arable, dairy, fruits, vegetables and meat) that were already used to group the 19 initial IoF2020 use cases. On top of that, most of the new use cases have already clear plans for collaborating with the initial use cases and re-using specific solutions, experience gained and lessons learnt. This is not limited to a “trial-internal” collaboration, but already identifying cross-trial synergies, asking for reuse of results across trial borders. From a technological and IoT perspective, this shall also help to further validate the reusability of components that are not bound to a specific context.

In summary, all the selected new use cases are addressing the farm production, where six of those fourteen have a focus on farm production itself. Three use cases are addressing farm asset production, somehow considering the farmer also as a type of end-consumer of key assets required for the farm operation. Those cases validate customer-supplier relations, as the use cases covering post-farm steps also do. Eight use cases are addressing more than one step in the agri-food value chain, usually aiming at the validation of a horizontal interaction along the chain, where also vertical interaction in single steps of the chain are addressed. Only three use cases are reaching up to the retailer and end-consumer.

In parallel to the design of agri-food chains or better to say networks, the quality and quantitative performance of agri-food networks directly relates to the location of farming (e.g. due to weather, soil, water supplies, available equipment, education of farmers, size of farms, available private and public ICT infrastructure, Internet connectivity in rural areas). This was also the reason to attract additional regions by the open call not yet covered by the initial 19 IoF2020 use cases. This evolution offers the opportunity to test and validate IoT based solutions already successfully deployed in the initial region or in a local setting involving a specific setting of required stakeholders. The new use cases successfully achieved this objective, by adding diverse testbeds in around 22 regions – especially towards Eastern European regions.

Finally, when analysing the scope of IoT technology used in the new use cases, one can identify an innovation tendency towards agri-food solutions incorporating usage of required digital devices. On the application layer towards the "virtual world", new use cases are mainly using generic solutions not necessarily stemming from agri-food environments. However, this indicates that the collection and aggregation of agri-food related data requires specific technological expertise in the realisation of agri-food related devices. Processing and usage of data, information and knowledge seem to benefit from numerous available components and platforms that are offering cross-sectorial and cross-domain synergies.

As soon as the new use cases will validate their first results in real-world test scenarios, IoF2020 will add further information about the deployed IoT based solutions to the IoF2020 section in the IoT catalogue (www.iot-catalogue.com). A first description is already available at the IoF2020 website, identifying specific goals, expected results and contact points (www.iof2020.eu/trials). Further inquiries can be directed to the IoF2020 team also via the IoF2020 website (www.iof2020.eu/contact).

9 Annex 1 – IoF2020 Use Cases Overview

9.1 IoF2020 Use Cases Description and Areas Addressed

The following Table 8 provides and overview of the 33 use cases, sorted by the five trials. It shortly outlines the application areas addressed, the agri-food chain roles and the countries involved. The countries with test beds are indicated in bold, while other countries refer to the partners involved (see also http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Country_codes). More information about the use cases can be found at the IoF2020 website (https://iof2020.eu/trials).

Table 8 The IoF2020 Trials and Use Cases divided over several EU countries

Trial	Nr.	Name	Short Description	Application Areas Addressed	Chain Roles	Countries
The Internet of Arable Farming						
T1 Arable	1.1	Within-field management zoning	Defining specific field management zones by developing and linking sensing- and actuating devices with external data.	Management zoning of arable fields; Crop protection; Yield prediction	Farming, Logistics	**NL**, DE, BE
	1.2	Precision Crop Management	Smart wheat crop management by sensors data embedded in a low-power, long-range network infrastructure.	Nitrogen and water monitoring; Precision irrigation control; Crop growth optimization	Farming	**FR**
	1.3	Soya Protein Management	Improving protein production by combining sensor data and translate them into effective machine task operations.	Protein monitoring & forecasting; Rational water usage (irrigation); Mechanical weeding	Farming	**IT** + Danube countries (CH, RS, **AT**, SK, HR, RO, CZ, UA)
	1.4	Farm Machine Interoperability	Data exchange between field machinery and farm management information systems for supporting cross-over pilot machine communication.	Sustainable soil tillage; Machine to machine communication for application of task maps; Farm equipment data sharing	Farming	**NL**, DK, DE, BE
	1.5	DaPoPE	Data exchange between field and potato processing industry to optimise logistical and quality processes.	Yield prediction, Yield calibre management, Traceability from field to shed after harvesting	Farming, Processing	**BE**, NL, **PL**
	1.6	IoT4Potato	Smart farming-based services for fertilization, irrigation and pest management, using data from telemetric IoT stations.	Rational water usage (irrigation); Precision fertilization; Pest management; Crop growth optimization	Farming, Processing	**CY, PL, UA**

Trial	Nr.	Name	Short Description	Application Areas Addressed	Chain Roles	Countries
	1.7	IoTrailer	Secure and authenticate transport of bulk goods in the agri-food chain guaranteeing a fully traceable delivery of animal feed and human food.	Automatic silo detection; Data exchange between silo, trailer and load stations	Farm Asset Production, Farming	**BE**, NL, **PL**, FR, BG, RO, ES, SI
	1.8	SolarVibes	Sensor-based farm management for predictive analysis of diseases, and smart community sensor network to help farmers adopt sustainable farm practices and improve overall agricultural efficiency.	Soil conditions monitoring; climate monitoring; Crop growth optimization; Crop disease recognition	Farming	**DE, RO, HU**
	1.9	WFMZ	Determine macro- and micro-nutritional elements at different stages of plant growth using hyperspectral imaging to increase productivity of plants.	Plant micro- and macro nutrient characterisation; Precision fertilization; Early plant stress detection; Crop management; Yield prediction	Farming	**LT, LV**
			The Internet of Dairy Farming			
T2 Dairy	2.1	Grazing Cow Monitor	Monitoring and managing the outdoor grazing of cows by GPS tracking within ultra-narrow band communication networks.	Cow Tracking and Tracing; Pasture Time Monitoring	Farming	**BE, NL** *(future)*
	2.2	Happy Cow	Improving dairy farm productivity through 3D cow activity sensing and cloud machine learning technologies.	Real-time 3D monitoring of dairy cow activity; Animal Health Management; Cow Fertility Management	Farming	**NL**
	2.3	Silent Herdsman	Herd alert management by a high node count distributed sensor network and a cloud-based platform for decision-making.	Monitoring of animal behaviour (motion); Early detection of livestock diseases	Farming	**UK**
	2.4	Remote Milk Quality	Remote quality assurance of accurate instruments and analysis & pro-active control in the dairy chain.	Remote quality monitoring of raw-, half- and end-products; Validation/calibration quality info; Product composition analysis (incl. fresh-grazed grass & cow pregnancy indicators)	Processing, Consumption	**NL**
	2.5	MELD	Provide lame detection as a service using leg mounted sensors and collars in cattle.	Early detection of anomalies in pasture-based cattle herds; Monitoring of animal behaviour (motion)	Farming	**IE, PT, IL, ZA**

Trial	Nr.	Name	Short Description	Application Areas Addressed	Chain Roles	Countries
	2.6	Pitstop+	Precision livestock farming mineral supplementation at dairy farms to improve animal welfare, resource usage and reduce environmental impact.	Animal Health Management; Precision feeding (mineral supplementation); Dairy production optimization; Cattle performance monitoring (health, production and reproduction)	Farming	LV, LT, DE
	2.7	Smart Precision	Smart multi-sensor devices equipped with long range low power communication technology for precision dairy and beef cattle monitoring	Animal welfare monitoring; Optimize use of medication; Traceability; Accurate heat detection and calving alert	Farming, Processing	HU, CZ, PL, SVK
			The Internet of Fruits			
T3 Fruit	3.1	Fresh table grapes chain	Real-time monitoring and control of water supply and crop protection of table grapes and predicting shelf life.	Smart Irrigation; Variable Rate Spraying; Smart Post-Harvest Processing & Packaging	Farming, Packaging	IT, EL, BE
	3.2	Big wine optimization	Optimizing cultivation and processing of wine by sensor-actuator networks and big data analysis within a cloud framework.	Pest Management; Selective Harvesting; Wine Cellar Monitoring	Farming, Processing	FR, IT
	3.3	Automated olive chain	Automated field control, product segmentation, processing and commercialisation of olives and olive oil.	Fertigation; Harvesting Logistics; Smart Mill Processing	Farming, Processing	ES, EL
	3.4	Intelligent fruit logistics	Fresh fruit logistics through virtualization of fruit products by intelligent trays within a low-power long-range network infrastructure.	Returnable Transport Items (RTI) for Fruits packaging and transporting; Field to Fork logistics; Super Market Placing and Monitoring	Logistics, Consumption	DE, NL
	3.5	Smartomizer	Use air blast atomizing sprayers to significantly reduce amount of plant production product used in three agricultural subsectors (cherry, apple and almond).	Farm resource job optimization; Specialty crops precise spraying; Machine to machine communication	Farming	HU, PL, PT
	3.6	BIT	Monitor the whole wine and beverage distribution channel, from producer to consumer, to prevent damages during shipping and storage.	Beverage integrity tracker; Product state-of-health assessment; Beverage box monitoring	Farming, Processing, Packaging, Logistics, Consumption	IT, PT, RO, CH, FR, HU, ES,

Trial	Nr.	Name	Short Description	Application Areas Addressed	Chain Roles	Countries
The Internet of Vegetables						
T4 Vegetables	**4.1**	City farming leafy vegetables	Value chain innovation for leafy vegetables in convenience foods by integrated indoor climate control and logistics.	Advanced sensing of crop conditions in indoor farming; Automatic execution of growth recipes; Integrate production with processing & distribution	(City) Farming, Logistics	**NL**
	4.2	Chain-integrated greenhouse production	Integrating the value chain and quality innovation by developing a full sensor-actuator-based system in tomato greenhouses.	Traceability and monitoring ambient conditions of fresh tomatoes along value chains; Pesticide residue management; Energy efficiency management	Farming, Logistics, Consumption	**ES**, IT
	4.3	Added value weeding data	Boosting the value chain by harvesting weeding data of organic vegetables obtained by advanced visioning systems.	Automated weed control; Crop monitoring and harvest prediction based on weeding data; Optimizing weeding efficiency	Farming	**NL**, AT
	4.4	Enhanced quality certification system	Enhanced trust and simplification of quality certification systems by use of sensors, RFID tags and intelligent chain analysis.	Compliance to PDO, organic and GlobalGap certification; tracking and tracing, verification of product origin and production method	Farming, Logistics, Consumption	**IT**, ES
	4.5	CYSLOP	Increase total farm productivity by delivering tailored information to farmers based on data acquired by IoT devices.	Crop optimization; Plant protection; Irrigation scheduling; Product traceability	Farming, Processing, Logistics, Consumption	**GR**, **CY**, **SI**
The Internet of Meat						
T5 Meat	**5.1**	Pig farm management	Optimise pig production management by interoperable on-farm sensors and slaughter house data.	Pig production monitoring and early warning; Boar taint detection; Informing consumers about production conditions	Farming, Processing, Consumption	**BE, NL**, IT
	5.2	Poultry chain management	Optimize production, transport and processing of poultry meat by automated ambient monitoring & control and data analysis.	Poultry growth monitoring and weight prediction; Monitoring of picking & logistics; Poultry category assessment slaughterhouse	Farming, Logistics, Processing	**ES**, BE
	5.3	Meat Transparency and Traceability	Enhancing transparency and traceability of meat based on a monitored chain event data in an EPCIS-infrastructure.	Transparency food safety and quality information; Cold chain monitoring; Quality decay prediction and pro-active alerts	Farming, Logistics, Processing, Consumption	**NL**, DE

Trial	Nr.	Name	Short Description	Application Areas Addressed	Chain Roles	Countries
	5.4	ShareBeef	Shared value system to integrate and share data along the food supply chain to improve resource efficiency and customer satisfaction.	Animal welfare monitoring; Crop monitoring and optimization; Product certification; Traceability; Data sharing	Farm Asset Production, Farming, Processing, Logistics, Consumption	BG, HR, IE, IT, PT, ES
	5.5	IoFeed	Integral feedstock management system based on 3D camera technology used to monitor stock levels in farms' silos.	Animal feed delivery optimization; Monitor silo content; Logistics optimization	Farm Asset Production, Farming	ES, UK, DE
	5.6	FitPig	Context-based alarm and decision support using data collected from monitoring physiological signs from pigs.	Monitor pig welfare; Optimize use of medication; Food safety; Piglet mortality management	Farming	SE, ES, CH

9.2 IoF2020 Use Cases IoT Infrastructure

Table 9 is generally structured according to an underlying architectural model, mainly differentiating the technology in three main layers. The IoT device layer is grouping all the hardware that is mainly used for sensing and actuating, usually deployed in the end-user related environment. The IoT integration and communication layer is listing those components that are usually kind of third party systems or platforms taking care for data gathering as well as data aggregation and storage. The IoT application layer is listing the software that is providing key features for envisaged end-user related solutions. It should be noted that the presented infrastructure reflects the initial results for test and validation, while this will be further extended along the realisation of the IoF2020 project.

Table 9: *Overview of the IoT components of the Use cases and size of deployment in test beds.*

Trial	UC	IoT Device Layer	IoT Integration/ Communication Layer	IoT Application Layer
T1 Arable	1.1	30 sensors for soil moisture, Veris soil scanner, machine control, yield sensors, indoor climate, crop quality, 4 weather stations, 3 GEO-localization units	Lora Network, 365FarmNet, Zoner, Crop-R and Akkerweb platforms, Cloudfarm FMIS	Weather forecast service, Akkerweb agro-eco algorithms; GIS, zoning and T&T modules
	1.2	120 sensors for water potential, soil temperature, reflectance and leaf area index, 3 weather stations (wind speed, solar radiation, air temperature, air humidity, rain)	30 gateways, Arvalis IoT platform; 365FarmNet; Atland FMIS	Weather forecast service, Arvalis agro-eco algorithms
	1.3	20 soil moisture and crop quality sensors; accurate GNSS receivers; cameras for weed detection, 4 weather stations, 2 soil scanners	Platform 365FarmNet, FMIS	Weather forecast; Agronomic models of extension services
	1.4	Soil and yield sensors on 2 tractors, 2 soil tillage implements and on 1 combine; 10 stations for precipitation, humidity, air and soil temperature, soil moisture and 1 weather station	365FarmNet, ThingWorx IoT platforms	Soil-plant-atmospheric algorithms; Weather forecast; GIS and zoning tool; Traffic optimization modules
	1.5	AVR, Aura imaging, Visualization module for AVR	Microsoft Platform, API for data exchange between AVR & Aura, API for ERP integration	Potato growth model
	1.6	9-10 telemetric stations (gaiatrons)	Gaiasense platform (Gaiacloud and dashboard), Orion Context Broker, Cygnus, NGSIv2 translator	Models for evaluating cultivation conditions and estimate risks, pest prediction models, irrigation models, context-aware decision support
	1.7	8 trailer base stations, 8 wireless readers, 1500 TAG (for each silo)	Bulk load station	Central control system, silo traceability

Trial	UC	IoT Device Layer	IoT Integration/ Communication Layer	IoT Application Layer
	1.8	2000 Agrisensors	10-15 AgriModule (gateway), PI endpoint between devices and AWS	Vibes Protocol (crop analyser and health analyser), 1 AWS (cloud service)
	1.9	1 UAV, 1 hyperspectral imager, 2 GPS	AgroSmart	Hyperspectral image processing software, plant growing models, yield prediction
T2 Dairy	2.1	75-100 stickntrack GPS-trackers, BLE tags	UNB (Sigfox and LoRa) IoT platform 365FarmNet	Grazing Cow Monitor app + API
	2.2	500-700 neck/leg transmitters with accelerometer RF sensors for dairy cow activity in 3D space 50-60 intelligent routers	Base Station Device, Data, Connecterra IoT platform, connection to 365FarmNet	Cloud-based decision support system, analytics cow centric behaviour, prediction algorithm
	2.3	150-200 Afimilk Silent Herdsman devices	Hypercat, connection to 365Farmnet	Collar-based analytics, early illness detection
	2.4	20-30 InfraRed sensors (FTIR) to measure milk quality composition	Qlip platform for automatic calibration and validation, connection to 365Farmnet	QA data visualization, remote alerts, interventions harmonization, milk composition/quality analytics
	2.5	1200 cattle pedometers, 600 collar-based monitors	Fog node	1 IBM cloud-based machine platform, lame detection algorithm
	2.6	1240 ear tags, 24 mineral feeders	5 master units to handle communication between feeders and cloud	1 Microsoft Azure platform, Pitstop+ Manager, algorithm for cattle status monitoring
	2.7	In vivo rumen bolus, combining sensors for temperature, acceleration, ph level with communication via NB-IoT or LoRa.	NB-IoT or LoRa layer for long range communication and geo localisation	Cloud-based server environment offering datamining and machine learning based forecasts, alerts, and predictions.
T3 Fruit	3.1	30 sensors/ measurement devices for crop evapotransp. (ETc); soil water content (VWC); Stem Water Potential; Berry Growth Rate; Sap-flow meter, Dendrometer, Stem psychometer sensors. 30 irrigation systems controlling 90 solenoid valves and hydrometers. 100 BLOW gas sensors	GPRS/4G and long RF communication; cloud IoT data management based on state of the art platform (e.g. Cassandra) and processing using state of the art technologies such as Apache Flink & Spark	Crop and post-harvest monitoring (irrigation, pest and quality alarms); Irrigation DSS, Prediction software for crop management and the harvest period, Shelf-life prediction tool
	3.2	150 Multi-Sensor/ actuator smart nodes, 10 Video Sensors, 300 sensors for detecting IR and VIS absorbance and temperature (cellar)	5 Gateways, SensiNact IoT platform; wine cloud system (cellar)	Management software for Wine Production from process to wine

Trial	UC	IoT Device Layer	IoT Integration/ Communication Layer	IoT Application Layer
	3.3	12 soil/air sensors for water, temp. nitrates, conductivity, humidity, radiation; 12 data logging units, 12 autonomous solar energy units, 12 fertigation actuators, 6 ISOBUS on-board sensors; 3 temperature/pressure sensors and 3 electronic noses (oil mill), Product barcodes/QR, RFID	12 wireless sensors networks (HSPDA, UMTS, GPRS, GSM), 12 gateways, 1 global SIM data comm., 1 integration service bus	Application Modules (3 implementations): Field Operations and Machinery Control; Field decision support (alerts, models); Olive mill Control; Traceability; Warehouse Logistics
	3.4	1000 passive RFID transponders with environmental sensors (temperature, relative humidity, illumination and methane) in trays, handheld and fixed RFID readers	EPCIS and V-Track AutoID middleware system, LORA and package sensor platforms for data access	V-Track application layer, Jesper business rule engine (open source and Cassandra big data database (open source); Reader-based application
	3.5	6 sprayer control systems, 36 soil and climate sensors	6 specialty crop gateways, 6 H3O protocol gateways, 1 ADAPT gateway, Orion context broker	IoT cloud platform, field management services, spraying job optimization algorithms
	3.6	60 data loggers	Gateway	Web platform, historical data analysis, prescriptive planning, blockchain environment
T4 Vegetables	4.1	Advanced crop sensors (100x each) for temperature, humidity, CO2, pH, nutrition, air flow, plant observers, electrical conductivity, 15000 LED lighting devices	30 wired and/or ZIgbee connections from sensors to city farming system	1 production control, 1 "Green Cloud" climate control (incl. irrigation) system
	4.2	35 sensors for temp. & moisture, humidity, CO2, water supply, soil water; leaf wetness, and nutrients; 13 actuators for pulverization, dehumification, artificial light actuator, irrigation, CO2 enrichment actuator and biomass heating; 4 IP cameras and 4 weight devices	1 web-based IoT platform, 3 WIFI networks, 3 Gateway NI CompactFieldpoints	Web Application for DSS: DSS production managing; DSS Deceases early-warning system DSS pest control; DSS for handling & transport managing
	4.3	6 RGB Cameras, GPS, timestamp Handheld (Smartphone), 1-2 GUI (Touchscreen in tractor), 12 Weed actuators	1-2 local data storage & image pre-processing syst., 3-4 gateways, 2 WIFI networks, cloud IoT platform	Web application and smartphone app, 3 DSSs for Growth, Weed, Soil Monitoring
	4.4	35 sensors of volume, moisture and chemicals (in the field-min. 15); 100 digital traceability tags (100), QRs	Web certification data platform	3 apps for data upload, query & aggregation app, traceability app for buyers/consumers

Trial	UC	IoT Device Layer	IoT Integration/ Communication Layer	IoT Application Layer
	4.5	soil/air sensors, irrigation actuators (electrovalves), IoT powered irrigation controllers	Orion context broker, Cygnus, IoT gateway, IoT2EPCIS, IoT Agent	PEP Proxy, QUHOMA, data marketplace, plant protection services, irrigation scheduling algorithm
T5 Meat	5.1	50 sensors for water & feed consumption, daily growth, cough monitoring and stable climate control; PigWise sensor; 8 RFID Readers (FEIG/DTE), 500 RFID Tags (HID Global); slaughterhouse recordings of 2000 pigs	1 IoT Data platform 1 Virtus Middleware + LinkSmart Middleware components 1 ebbits Adaptation Layer	Early Warning System Application; Boar Taint presence report linking with preventive measures; Data Analytics & Visualization
	5.2	110 sensors for temperature, humidity, luminosity, CO2, noise and ammonia (farms, trucks); 8 scales with integrated sensors & camera); 12 silo weight cells, 10 Sony SmartBands	GPRS/WIFI WSNs: 4 farms (TIBUCON) and 10 trucks WSNs, Bluetooth 4.0 SmartBands, Google Fit LiveLog, 1 IoT Data Platform & Middleware	Early Warning System, Birds Manipulation Assistant, Environmental Assistant, Production Management DSS, Data Visualization
	5.3	30 barcode/QR readers; 5-10 RFID gates at slaughterhouse and meat processor, about 100 temperature sensors and 5-10 cooling actuators at transport; temperature sensors and shop shelve actuators at test shop	2 EPCIS repositories – IoT Data platform 1 Discovery server	2 Connectors, 1 Discovery App, 1 Aggregation App
	5.4	335 smart collars, 910 ear tags, 4 soil stations, 4 weather stations, 2 IoT automatic weight control, 2 IoT multi sensor station	Device management, Orion context broker, IoT Agent, API mediation	Decision support system, blockchain services, data analytics, animal welfare algorithms, slaughter welfare algorithms
	5.5	325 volumetric sensors (3D camera)	1 monitoring platform, Orion context broker, Cygnus	1 smart logistics platform, feed demand forecast, automatic restocking process, logistics optimisation
	5.6	2 weather stations, 50 ear tags	10 smart spot (gateways), device management platform	FIWARE IoT platform, hear rate estimation algorithms, animal health monitoring