IOF2020: Fostering business and software ecosystems for large-scale uptake of IoT in food and farming

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Abstract

The Internet of Things (IoT) is expected to be a real game changer that will drastically improve productivity and sustainability in food and farming. However, current IoT applications in this domain are still fragmentary and mainly used by a small group of early adopters. The Internet of Food and Farm 2020 Large-Scale Pilot (IoF2020) addresses the organizational and technological challenges to overcome this situation by fostering a large-scale uptake of IoT in the European food and farming domain. The heart of the project is formed by a balanced set of multi-actor trials that reflect the diversity of the food and farming domain. Each trial is composed of well-delineated use cases developing IoT solutions for the most relevant challenges of the concerned subsector. The project conducts 5 trials with a total of 19 use cases in arable, dairy, fruits, vegetables and meat production. IoF2020 embraces a lean multi-actor approach that combines the development of Minimal Viable Products (MVPs) in short iterations with the active involvement of various stakeholders. The architectural approach supports interoperability of multiple use case systems and reuse of IoT components across them. Use cases are also supported in developing business and solving governance issues. The IoF2020 ecosystem and collaboration space is established to boost the uptake of IoT in Food and Farming and pave the way for new innovations.

Introduction

The Internet of Things (IoT) is a powerful driver that is expected to transform the entire farming and food domain into smart webs of connected objects that are context-sensitive and can be identified, sensed and controlled remotely (Sundmaeker et al., 2016; Verdouw et al., 2016a; Verdouw et al., 2016b). IoT will be a real game changer in agriculture that drastically improves productivity and sustainability. This vision is illustrated by the story in Text Box 1, which is an example for arable farming, but it is exemplary for other subsectors such as dairy, meat, vegetables, and fruits including wine and olives.

To make this vision come true much technology is already available, although there are specific IoT challenges in this sector. Agri-Food 'things' are often living objects and attached devices have to work in harsh environments, while network connectivity in rural areas can be challenging. In fact, a large-scale uptake of IoT in agriculture is in particular prevented by a lack of interoperability, user concerns about data ownership, privacy and security, and by appropriate business models that are also suitable for (very) small companies (EIP-AGRI, 2015; Pérez Freire et al., 2015). Consequently, current IoT applications in farming and food are still fragmentary and mainly used by a small group of early adopters, despite the great world-wide interest of IoT technology providers and investors.

IoF2020 is a European Large Scale Pilot (LSP) on IoT for Smart Farming and Food Security. Its main objective is to foster a large-scale uptake of IoT in the European farming and food domain. This will contribute to a next huge innovation boost and consequently to a drastically improved productivity and sustainability in the agri-food domain. More specifically, IoF2020 aims to:

- Demonstrate the business case of IoT for a large number of application areas in farming and food;

- Integrate and reuse available IoT technologies by exploiting open architectures and standards;
- Ensure user acceptability of IoT solutions in farming and food by addressing user needs, including security, privacy and trust;
- Ensure the sustainability of IoT solutions beyond the project by validating the related business models and setting up an IoT Ecosystem for large scale uptake.

The IoF2020 consortium consists of 71 public and private partners from 16 different countries and has a total budget of 35 M€. The project started in January 2017 and will last for 4 years.

March 2020, a field somewhere in Europe
The morning mist soaks into thick shreds across the country, above the sun rises and turns the horizon red. From the fog a soft humming sound, two tractors emerge. When he spots me, the driver of the second tractor steps out, but where is the driver of the first tractor? There is none, says the farmer, I operate both machines. How? Well, that strange vehicle you saw here last week has mapped the whole field and this map is now instructing the board computers of the two tractors how to drive. The first tractor exactly follows pre-programmed lines and carries out soil cultivation, based on soil composition. My tractor with a sowing machine automatically follows the same lines and automatically adjusts distance, quantity and variety of potato seed. Incredible, isn't it?

Two weeks later…
The same field. An unmanned small tractor drives with a high speed along the same invisible straight lines. With surgical precision, a hoe eliminates every weed in the field, the farmer says. This saves a lot of chemicals and labour in comparison to earlier days where we had to spray the full field with a heavy tractor. So this is good for the environment and I have much less costs! Within a few weeks the fertilizer will follow the same lines again and by a pre-defined task map it knows exactly where and what to put different types of fertilizer for optimal growth of the plants. That map was generated on the basis of big data analysis and calculations in the cloud involving relevant data from the market, weather and public regulations. Additional cameras are checking the crop and, if necessary, make corrections. Again, the plants just get enough nutrients to grow optimally and nothing is spoiled to the environment. Wow, amazing! Come, I'll show you how it works in the office. Don't you have to stay with your tractor? Oh no, it knows what it is doing.

At the office with a good old-fashioned cup of coffee…
Of course we farmers are still in charge of our own farm but most of the field operations are carried out automatically by autonomous objects. Now we can focus on the market choices and take care of communication with our customers and last but not least citizens who are very much involved in farming nowadays. After execution of the field work, the measured data is automatically returned from the machine to the office through the cloud. This is the basis for subsequent tasks. But I also provide it to research institutes, which feed these data into computer models for further improvement. The same holds for public legislation and certification bodies. They use the same data to check for compliance to their rules. Every organisation has access to a specific set of our data in the cloud. Of course, this is subject to strict security and privacy rules. No, no, I don't want leave my data lying around. Oh yes, by the way, food safety and traceability is not an issue anymore; it is highly guaranteed by all kind of sensors and in case something might go wrong early warning systems alert me in time.

Text Box 1. Illustrative story of the vision on IoT in agriculture

Trials and Use cases

The heart of the project is formed by a balanced set of multi-actor trials that reflect the diversity of the food and farming domain, including different agricultural sub sectors, conventional and organic farming, early adopters and early majority farmers, SMEs and large industrial companies, and different supply chain roles including logistics and consumption. Each trial is composed of well-delineated use cases that together address the most relevant challenges for the concerned subsector. The use cases follow a demand-driven philosophy in which IoT solutions for specific business needs are developed by a dedicated team of agri-food end users and IoT companies (integrators, app/service developers, infrastructure/technology providers) with a clear commercial drive, supported by R&D organisations. IoF2020 conducts 5 trials with a total of 19 use cases in arable, dairy, fruits, vegetables and meat production (see Figure 1).

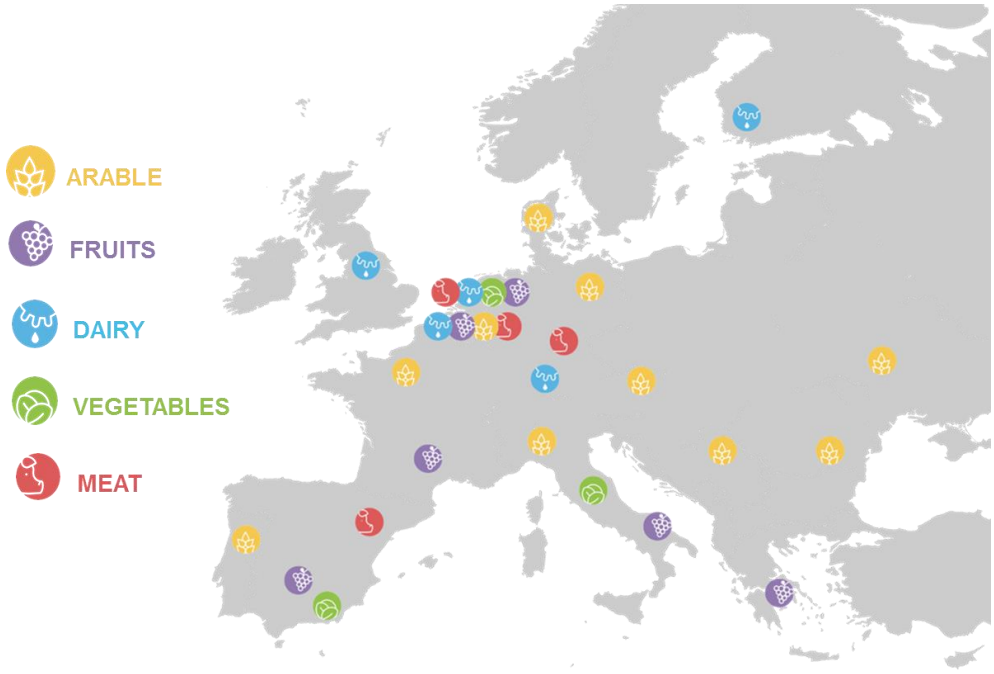

Figure 1. Geographical coverage of the IoF2020 trials and use cases

The ***Internet of Arable Farming (trial 1)*** integrates operations across the entire arable cropping cycle combining IoT technologies, data acquisition (soil, crop, climate) in growing and storage of arable crops (potatoes, wheat and soya beans). These will be linked to existing sensor networks, earth observation systems, crop growth models and yield gap analysis tools and external databases (e.g. economic/environmental impact) and translated into farm management systems. The trial will result in increasing yields, less environmental impact, easier cross-compliance and product traceability and more use of technology by farmers. The trial consists of 4 use cases:

1.1. *Within-field management zoning*: defining specific field management zones by developing and linking sensing- and actuating devices with external data;

1.2. *Precision Crop Management*: smart wheat crop management by sensors data embedded in a low-power, long-range network infrastructure;

1.3. *Soya Protein Management*: improving protein production by combining sensor data and translate them into effective machine task operations;

1.4. *Farm Machine Interoperability*: data exchange between field machinery and farm management information systems for supporting cross-over pilot machine communication.

The ***Internet of Dairy Farming (trial 2)*** implements, experiences and demonstrates the use of real-time sensor data (e.g. neck collar) together with GPS location data to create value in the chain from 'grass to glass', resulting in more efficient use of resources and production of quality foods, combined with a better animal health, welfare and environment implementation. The trial focuses on feeding and reproduction of cows through early warning systems and quality data that can be used for remote calibration and validation of sensors and consists of 4 use cases:

2.1 *Grazing Cow Monitor*: monitoring and managing the outdoor grazing of cows by GPS tracking within ultra-narrow band communication networks;

2.2 *Happy Cow*: improving dairy farm productivity through 3D cow activity sensing and cloud machine learning technologies;

2.3 *Silent Herdsman*: herd alert management by a high node count distributed sensor network and a cloud-based platform for decision-making;

2.4 *Remote Milk Quality*: remote quality assurance of accurate instruments and analysis & pro-active control in the dairy chain.

The ***Internet of Fruits (trial 3)*** demonstrates IoT technology that is integrated throughout the whole supply chain from the field, logistics, processing to the retailer. Sensors in orchards and vineyards (incl. weather stations, multispectral/thermal cameras) will be connected through the cloud and used for monitoring, early warning of pests and diseases and control (e.g. variable rate spraying, selective harvesting). Traceability devices (incl. RFID, multidimensional barcodes) and smart packaging allows for condition monitoring during storage, processing, transportation and on the shelves. Big data analyses will further optimize all processes in the whole chain. This will result in reduced pre- and post-harvest losses, less inputs, higher (fresh) quality and better traceable products (incl. protected designation of origin, PDO). The trial consists of 4 coherent use cases:

3.1 *Fresh table grapes chain*: real-time monitoring and control of water supply and crop protection of table grapes and predicting shelf life;

3.2 *Big wine optimization*: optimizing cultivation and processing of wine by sensor-actuator networks and big data analysis within a cloud framework;

3.3 *Automated olive chain*: automated field control, product segmentation, processing and commercialisation of olives and olive oil;

3.4 *Intelligent fruit logistics*: fresh fruit logistics through virtualization of fruit products by intelligent trays within a low-power long-range network infrastructure.

The ***Internet of Vegetables (trial 4)*** focuses on a combination of environmental control levels: full-controlled indoor growing with an artificial lighting system, semi-controlled greenhouse production and non-regulated ambient conditions in open-air cultivation of vegetables. It demonstrates the automatic execution of growth recipes by the intelligent combination of sensors that measure crop conditions and control processes (incl. lighting, climate, irrigation and logistics) and analysis of big data that is collected through these sensors and advanced visioning systems with location specification. This will result in improved production control and better communication throughout the supply chain (incl. harvest prediction, consumer information). The trial consists of 4 use cases:

4.1 *City farming*: value chain innovation for leafy vegetables in convenience foods by integrated indoor climate control and logistics;

4.2 *Chain-integrated greenhouse production*: integrating the value chain and quality innovation by developing a full sensor-actuator-based system in tomato greenhouses;

4.3 *Added value weeding data*: boosting the value chain by harvesting weeding data of organic vegetables obtained by advanced visioning systems;

4.4 *Enhanced quality certification system*: enhanced trust and simplification of quality certification systems by use of sensors, RFID tags and intelligent chain analyses.

The ***Internet of Meat (trial 5)*** demonstrates how the growth of animals (individual and group level) can be optimized and communication throughout the whole supply chain can be improved based on automated monitoring and control of advanced sensor-actuator systems. The data generated by events will also be used for early warning (e.g. on health status) and improve the transparency and traceability of meat throughout the whole supply chain. This will assure meat quality, reduce mortality, optimize labour and improve animal health and welfare leading to reduction of antibiotics. The trial consists of 3 use cases:

5.1 *Pig farm management*: optimise pig production management by interoperable on-farm sensors and slaughter house data;

5.2 *Poultry chain management*: optimize production, transport and processing of poultry meat by automated ambient monitoring & control and data analyses;

5.3 *Meat Transparency and Traceability*: enhancing transparency and traceability of meat based on an monitored chain event data in an EPCIS-infrastructure.

Technical architectural approach
Each use case will be an autonomous implementation of an IoT system, which provides a dedicated solution for a specific domain challenge. However, for a large scale uptake it is important to maximize synergies across multiple use case systems. Therefore, a core concept of IoF2020 is that the use case systems function as nodes in a software ecosystem (Kruize et al., 2016). As a consequence, much attention is paid to ensuring the interoperability of multiple use case systems and the reuse of IoT components across them. Figure 2 shows the architectural approach to achieve this during design, development, implementation and deployment.

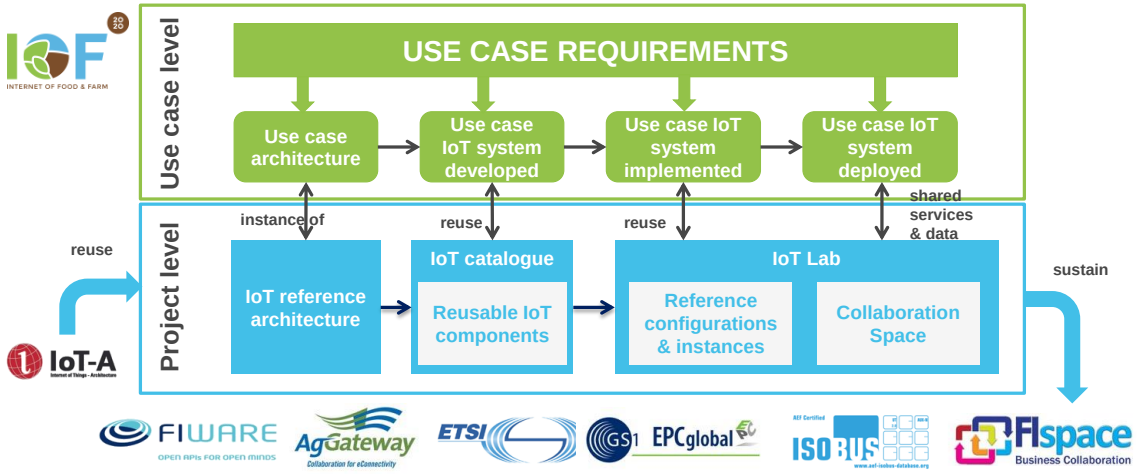

Figure 2. IoF2020 architectural process ensuring reuse and interoperability of IoT systems

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

Developing business and software ecosystems by a lean multi-actor approach
IoF2020 embraces a demand-driven methodology in which end-users from the agri-food are actively involved during the entire development process aiming at cross-fertilisation, co-creation and co-ownership of results (see Figure 3).

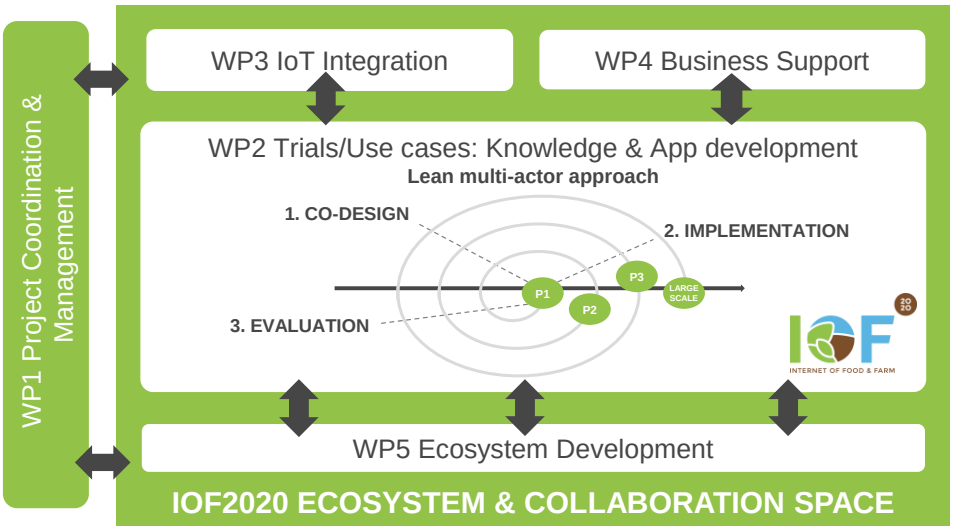

Figure 3. IoF2020 Project approach and structure

The approach for the use cases is a combination of the *lean start-up methodology* that focuses on the development of Minimal Viable Products (MVPs) in short iterations and the *multi-actor approach* that stresses the active involvement of various stakeholders. The use cases will actively be supported by three other work packages (WPs). WP3 facilitates sharing, reuse and finally integration of IoT components as described in the previous section. WP4 provides business support in terms of monitoring KPIs, business models, market studies and governance aspects (incl. security, data ownership, privacy, liability and ethical issues). WP5 facilitates the development and expansion of the various ecosystems on use case and project level and beyond amongst others by communication, dissemination, organizing workshops and events and by active involvement of European and national communities from the demand- and supply-side of IoT, including industry associations and cooperatives, European Innovation Partnerships, Technology Platforms and ERAnets. A mid-term open call of 6 M€ will be used to further accelerate these developments. This approach establishes a large IoF2020 ecosystem and collaboration space that is expected to sustain after the project.

Conclusion and outlook

IoF2020 aims to boost the uptake of IoT in European Food and Farming. This will be realized through a balanced set of multi-actor trials and use cases in several subsectors. The use cases are developed in a scalable manner through an open technical architecture and infrastructure with components that can be shared and reused by stakeholders outside the project. This development is leveraged by activities that build-up and extend the total ecosystem, defining attractive and successful business models and solving governance issues. In this way IoF2020 will pave the way for data-driven farming, autonomous operations, virtual food chains and personalized nutrition for European citizens.

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