IoT –Based Information Systems in Seed-to-Fork Food Production

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***Abstract*— Agribusiness industry and food production are dealing with perishable products, unpredictable production and supply chain management variations, tendency to maximize waste reduction and adherence to strict regulations related to food safety. The Internet of Things (IoT) includes several technologies that can be put into practice, in order to respond to all these demands and resolve challenges, as it allows remote control of the production conditions and distribution of products. In this paper, an architecture for IoT-based information systems in seed-to-fork food production is proposed. The architecture includes IoT from the first to the last phase of production, distribution and even feedback consumers. The authors propose a hybrid solution that combines the IoT and Future Internet.**

I. INTRODUCTION

Freshness of products is one of the most important attributes of food products for consumers. Therefore, when purchasing food products, consumers always tend to buy products which are fresher, due to the fact tgat the fresher the product, the higher its nutritional value. In order to determine the freshness of a product, it is common to use detection of visual characteristics of the product, or observe the expiration date to get an idea of the freshness. This traditional method of determining the freshness of the product is not completely reliable. Namely, when the food product is kept for a long time in a cooling storage and brought to the point of sale, the buyer can think that the product can retain freshness for several days. Probably, this could happen if the product was stored correctly. However, at that moment the buyer does not have any data if the product was stored correctly or not. He/she can only evaluate the freshness of the product based on its visual characteristics and make a conclusion how the product was stored. Therefore, it is very important that every customer has an opportunity to get the data from the complete product life cycle. One solution is to use IoT (Internet of Things) for product tracking during its life cycle.

The Internet of Things (IoT) is a network of devices, equipment, and machines capable of interacting with each other [1]. Among many definitions of IoT, the following are most common:

- The interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data [2].
- IoT is a recent communication paradigm that envisions a near future, in which the objects of everyday life will be equipped with microcontrollers, transceivers for digital communication, and suitable protocol stacks that will make them able to communicate with each other and with the users, becoming an integral part of the Internet [3].
- IoT is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment [4].

The IoT can be used in everyday life [5], in health-care applications [6], military applications [7], rescue operations [8], and other application for monitoring, tracking, control systems [9] - [12].

Having in mind such a wide range IoT applications, it is not a surprise that the usage of IoT in monitoring of agricultural products is also well-developed and adopted. Most consumers are aware that, using their mobile devices (and connection to Internet), they can easily reach important information about a product. Based on this information, in many cases, the consumer will make final decisions about buying a product. This behaviour of consumers is becoming a global trend. In order to facilitate and accelerate the applications that will make up the future work on the Internet, the European Union supported the development of FIWARE. FIWARE is a platform for the development and global deployment of applications for Future Internet.

This platform can be very helpful in putting information, collected by IoT, in practice. FIWARE provides an enhanced, OpenStack-based, cloud environment, plus a rich set of open standard APIs, that make it easier to connect to the IoT, process and analyse Big data and real-time media or incorporate advanced features for user interaction [9].

In this paper, a reference architecture of an IoT based information system in seed-to-fork food production through FIWARE application is presented.

II. INTEROPERABILITY OF IOT AND FIWARE

Internet of Things has been identified as one of the emerging technologies in IT, as noted in [10] Hype Cycle (Fig. 1). Hype Cycle is a way to represent the emergence, adoption, maturity, and impact on applications of specific technologies. It has been forecast that IoT will take 5–10 years for market adoption [10].

Gartner also forecasts [11] that the IoT will reach 26 billion units by 2020, up from 0.9 billion in 2009, and will impact the information available to supply chain partners and how the supply chain operates.

IoT is built on three pillars, related to the ability of smart objects to [12]:

1. be identifiable (anything identifies itself),
2. to communicate (anything communicates) and
3. to interact (anything interacts) – either among them-selves, building networks of interconnected objects, or with end-users or other entities in the network.

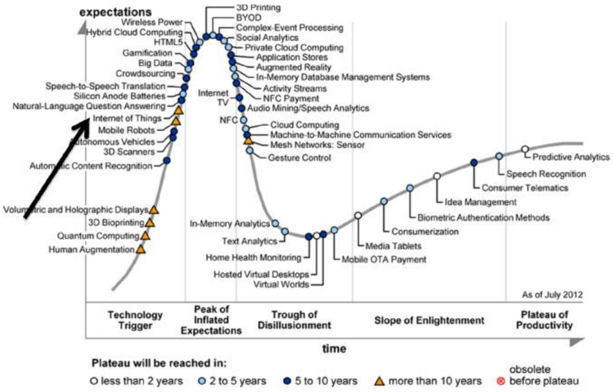

Figure 1. Hype Cycle of emerging technologies [10]

Basically, there are four IoT technologies that support these three pillars:

1. Radio Frequency Identification (RFID);
2. Wireless sensor networks (WSN);
3. Middleware and cloud computing; and
4. IoT application software.

RFID is a system for automated data acquisition, which allows acquisition and wireless (radio wave) transfer of enterprise/business-related data. RFID technology is suitable for usage on plastic product/parts [13], but also on other kind of products that are in packages made of paper, plastic etc. RFID technology allows real-time identification during production, storage, delivery, or any other process taking place within a production, distribution and retail management system. Data about the processes and products are acquired and transferred in wireless mode between production and business processes in real time. Using RFID technology, it is possible to track products and equipment (trucks, tools, truck, pallet, etc.), with minimum human intervention. This can potentially cut back operating costs and increase real-time visibility during the complete product life cycle.

Wireless sensor networks (WSN) consist of spatially distributed autonomous sensor-equipped devices to monitor physical or environmental conditions and can cooperate with RFID systems to better track the status of things, such as their location, temperature, and movements [14]. WSN allow different network topologies and multihop communication. Recent technological advances in low-power integrated circuits and wireless communications have made available efficient, low-cost, low-power miniature devices for use in WSN applications [8].

Middleware is a software layer between software applications, which helps software developers to perform communication and input/ output. It hides the details of different IoT technologies in order to free IoT developers from software services that are not directly relevant to the specific IoT application.

On the other hand, cloud computing is a model for on demand access to a number of configurable resources (e.g., smart devices, networks, servers, storage, applications, services, software), that can be provisioned as Internet as a Service (IoS). One of the most important outcomes of the IoT is an enormous amount of data generated from devices connected to the Internet [8] which must be available in an adequate way.

The IoT application software can be developed for different kinds of agribusiness applications. Wherever there are a number of devices, equipment and machines, capable of interacting with each other, IoT applications can enable reliable and robust data/messages receival and appropriate action in a timely manner.

For example, applications for monitoring the status of fresh food products, such as fruit, fresh-cut products, meat and dairy products. During transportation, the conservation status (e.g., temperature, humidity, shake (causing Mechanical damage), gas), can be monitored constantly and appropriate actions taken automatically to avoid spoilage when the connection is out of range. For example, Kroger's IoT temperature monitoring system cuts down on the number of cold products that go bad and have to be thrown out, reduces labor and saves energy. On the other hand, happy customers enjoy better ice cream and other cold and frozen foods. A typical Kroger store's temperature monitoring system has more than 220 tags connected to a network that uses the ZigBee low-bandwidth wireless network protocol. Nearly half of the chain's 2,600 stores have the technology; a complete rollout is expected by early 2016 [15].

Another example is customer service like Amazon Go. Amazon Go service lets customers walk in, grab food from the shelves and walk out again, without ever having to stand in a checkout line. This service uses machine learning, sensors and artificial intelligence to track items customers pick up. These are then added to the virtual cart on their application. If they pick up an item they later decide they don't want, putting it back on the shelf removes it from their cart [16].

FIWARE provides a cloud platform (named as FI-LAB) based on the Datacentre Resource Management System (DCRM) Generic Enablers (GE) and offers interfaces for future developments (e.g. for developing an intercloud). Each GE is a software block offered as cloud service, followed by an open specification and flexible API, as introduced by FIWARE. FIContent is a set of APIs within FIWARE, specifically targeting the media sector. It offers ready-made components for developers in areas relevant to smart city services. It includes functions like: user tracking and privacy; contextualisation; live information; live sharing and communication; augmented reality, blending real and virtual worlds and many more. FIWARE is closely connected to cloud computing. In this platform, various cloud service providers deploy and offer cloud services in the context of the FI-PPP (Future Internet Public-Private Partnership) programme [17].

The above text shows interoperability of IoT and FIWARE technologies with their enormous potential, which can be used in different kind of applications [18]-[19]. In the next chapter, a reference architecture of information systems in seed-to-fork food production is presented.

III. Designed Reference Architecture

The system described in this paper allows traceability of agricultural products and all its lifecycle phases from seed to fork. This allows final users to get safe, high quality products, for best price. Also, other entities involved receive data which allow them to improve their business and optimize their services, resulting in higher income and more satisfied clients. The proposed system can be divided into three main groups: seed to fork stakeholders, seed to fork service and IoT devices. Along with these three groups, the system also contains two connectors: web user interface for connection between stakeholders and seed to fork service and device manager for connection between IoT devices and seed to fork service. The reference architecture of implemented system is shown on Fig. 2.

Seed to fork stakeholders represent different users of the system. Stakeholders can be: seed suppliers, farmers, logistics services, warehouse management services, production services, laboratories, auction services, retailers, customers and authorities. Seed suppliers can track yield of their products (seed) in various conditions and get feedback for their product from other users of the system (most often: farmers, laboratories, customers, etc.). Farmers have all needed information about their business on one place, can easily print out reports, get feedback from customers, organize transport and storage of their products, and get professional advice and training. Logistic and warehouse management services allow easy organization of transportation and storage for agricultural products for all involved users. The system allows logistic and warehouse management services to utilize their capacities to the maximum. Production services enable transformation of raw products to products that are ready to be used by the final customer. The service allows production to get cheapest and best quality product, as well as receive feedback for their output products. Laboratories enable the tracking of agricultural product quality, as well as the quality of the whole product lifecycle. In case that the product is not in its desired quality boundaries, the system allows detection of problematic links in the product lifecycle and notifies all stakeholders related to the problematic product. Auction services enable buyers to have access to all needed information about products they are buying, and allows sellers to have estimated sell price, so they can easily plan their budget. Retailers can choose best products for their customers, based on feedback left by customers and by information about product. Customers can find products that fit best their needs, ensuring that they have safe, quality product for the best price. Authorities can easily track every link in product lifecycle, ensuring that whole system is functioning according to regulations and informing all involved entities with relevant information, such as change in regulations.

Seed to fork service allows collecting and processing data about agricultural products and its lifecycle phases. Seed to fork services include the following: sensor data, seed purchase, farmer production and monitoring, production planning and monitoring, production analysis, product quality forecast, warehouse management, transport planning and monitoring, delivery planning, quality monitoring (process and product), return product, problem handling. Sensor data enables collection of all relevant data for product and its lifecycle phases, as well as storage of the collected data into relevant databases. Seed purchase enables purchasing best quality seeds from proven and reliable seed suppliers. Farmer production and monitoring provides tracking of all relevant information about farmer's production, as well as planning of future production. Production planning and monitoring provides tracking of all information related to production and planning of future production, based on other available information. Production analysis enables detection of potential problems and bottlenecks, and its results are used to increase the production capacities, reducte costs and provide better management of resources. Product quality forecast is used to dynamically calculates expiration date and quality of product, based on information from production, transportation and storage. Warehouse management and transport planning and monitoring enables optimal usage of warehouse and transportation capacities and finding optimal storage and transportation for producst, based on conditions required for the specific product. Delivery planning enables cheapest and fastest delivery of products to its final customers, based on timetables defined by both suppliers and final customers. Quality monitoring (process and product) enables feedback from all related entities in product's lifecycle, analysis of data from laboratories, and thus assessing quality of both product itself, and whole seed to fork process (complete product lifecycle). Return product enables the final user to return products with unsatisfactory quality, as well as receive refund. Return product also allows identification of the problem source and notification of all problem related stakeholders in the product's lifecycle. Problem handling allows defining strategies and procedures in case of problems or issues, for example, withdrawal of a product from market because of high pesticide contamination.

For implementation of seed to fork service FIWARE platform is used. The Fig. 3 shows FIWARE architecture of implemented system.

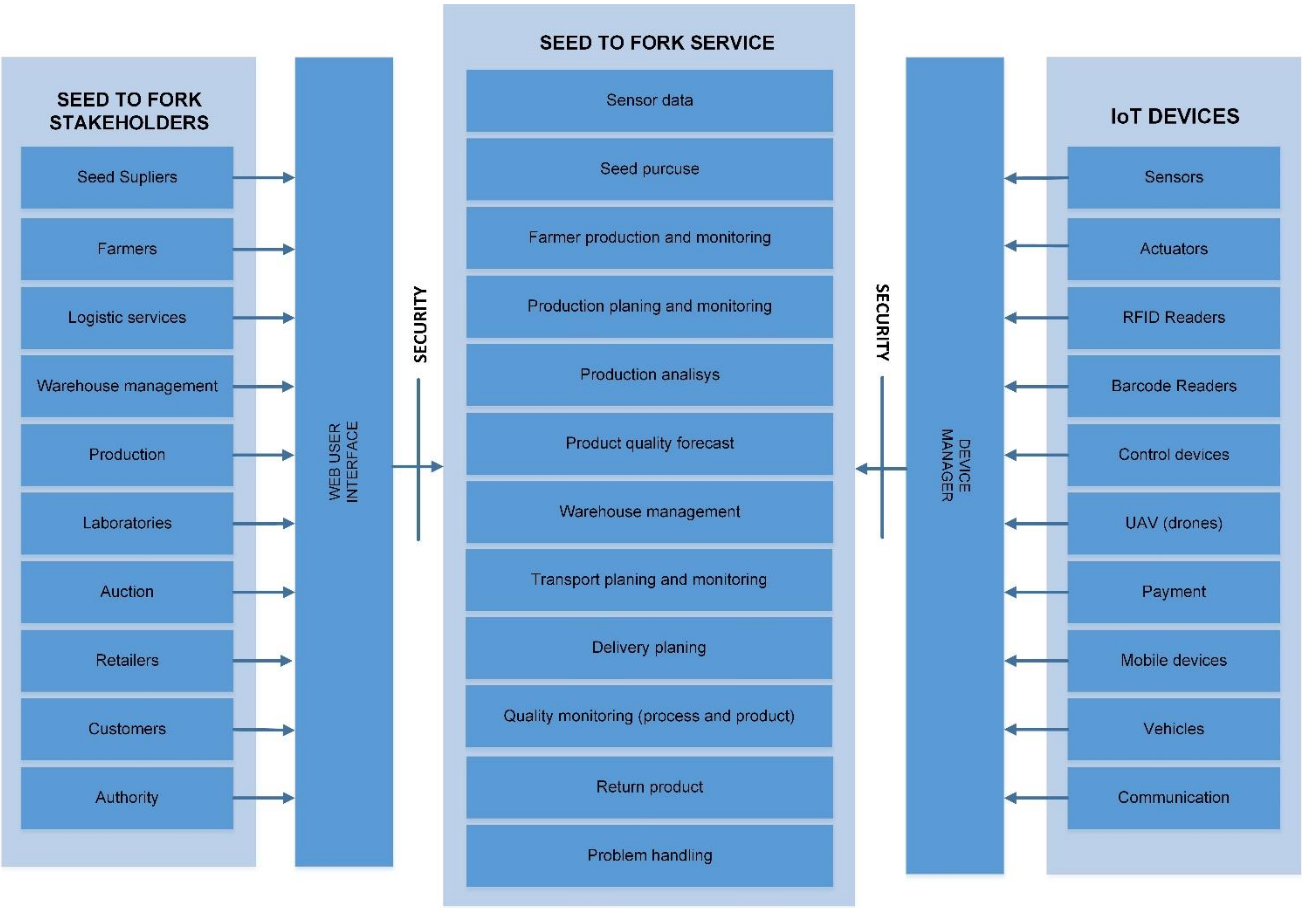

Figure 2. Reference architecture

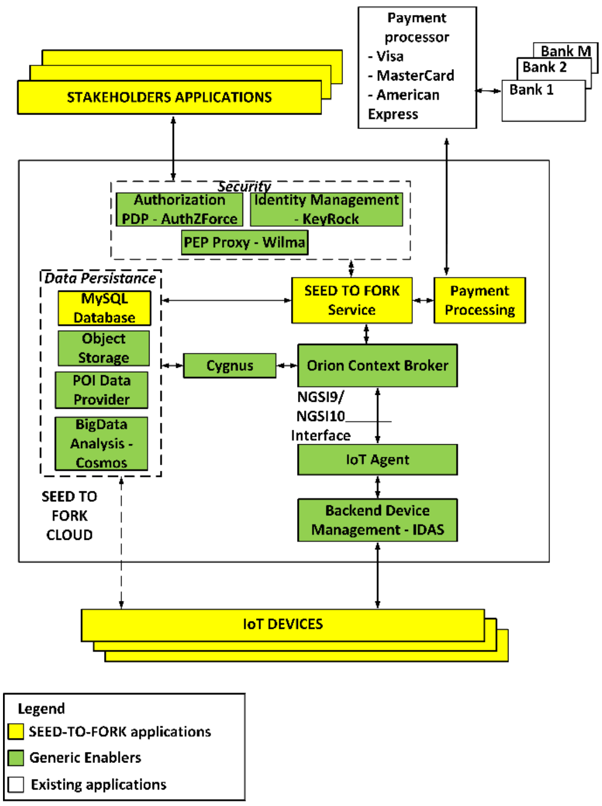

Figure 3. FIWARE architecture of implemented system

In order to enable the collection of data from a large number of remote sensors, Backend Device Management – IDAS is used. Backend Device Management – IDAS collects and manages data from a large number of sensors and transmits data to the IoT enabled Context Broker through NGSI9/NGSI10 interface by using IoT Agents. Orion Context Broker provides context awareness for data that comes from sensors (context producers). It provides an easy way for context consumers to use data (Android application, web application) in a context aware manner. It is an implementation of the publish/subscribe model, so the data transfer is optimal. Collected data is transferred from Orion Context Broker further to the big data storage and analysis component – Cosmos Big Data (Hadoop). Here, the data is stored and algorithms for analyzing data are implemented. Cygnus plays the role of a connector between Orion Context Broker (which is a NGSI source of data) and Cosmos Big Data (Hadoop). The Object Storage is used for storing file data in flexible and robust way, as well as storing different types of metadata associated with these files. For example, images from drones for crop analysis can be stored in the Object Storage, together with spatial and temporal information. For security purposes, a combination of PEP Proxy, Authorization PDP and Identity Management is used. Identity Management component provides a system for account management. Identity Management is used for creating different types of users with different roles (farmer, transporter, consumer, etc.) in order to provide sign-on (SSO) platform. Authorization PDP provides externalized authorization logic and provides an advantage of flexible access control features depending on the type of users and roles. PEP Proxy - Wilma is completely integrated with FIWARE ecosystem and FIWARE account and together with Authorization PDP and Identity management gives a complete and robust security system for the application. The PEP Proxy represents a secure wrapper for implemented web services, which provides access control for these services based on the data from the previous two security components.

Application block represents web and mobile applications that can be developed to meet the needs of specific users (farmer, transporter, consumer, etc.).

IV. Conlusion

In this paper an architecture for IoT-based information systems in seed-to-fork food production is presented. Described architecture allows collection of data related to food products through whole product's lifecycle, from production of seeds, sowing, cultivation, harvest, processing, storage, and distribution to the final customer. All stakeholders can easily exchange data with each other, in order to facilitate and accelerate data processing. This is especially important for enterprises that consist of independent entities, and for association of several independent enterprises. Enterprises can improve their business by analyzing data in the system, which can decrease the cost of production, storage, delivery and decrease waste generation. On the other side, final customers can buy quality and safe food products at reasonable prices, with the possibility of returning the food products if they are not satisfied with the quality of that product.

In future work, a further development of the service for seed-to-fork food production is planned. This means implementation of different methods for data processing, data classification and artificial intelligence methods for prediction. Another option is to enable enterprises integration of third party components in order to further improve its business by adapting service for the seed-to-fork food production service to their specific needs.

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