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The Use of Future Internet Technologies in the Agriculture and Food Sectors: Integrating the Supply Chain

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Abstract

The Future Internet is expected to greatly influence how the food and agriculture sector is currently operating. In this paper, we present the specific characteristics of the agri-food sector focusing on how information management in this area will take place under a highly heterogeneous group of actors and services, based on the EU SmartAgriFood project. We also discuss how a new dynamic marketplace will be realized based on the adoption of a number of specialized software modules, called "Generic Enablers" that are currently developed in the context of the EU FI-WARE project. Thus, the paper presents the overall vision for data integration along the supply chain as well as the development and federation of Future Internet services that are expected to revolutionize the agriculture sector.

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Keywords: Supply chain integration; FI-WARE; enablers

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1. Introduction

Over the past thirty years ICT technologies have been introduced in the agriculture and food sectors, improving the food production and its transportation to the end consumers [1, 2]. However, the uptake of these solutions has been slow due to a number of important yet unresolved issues. Some of the key challenges for ICT in the agri-food sector are related to information management, whether within specific domains or across the whole supply chain from farm to fork [3]. The challenges of information management are compounded by specific characteristics of the sector. One of the most significant challenges facing the agriculture and food production sector is the very large number of actors along the supply-chain, their heterogeneity and their dynamically changing business relations due to the nature of food supplies. The consequences of this number and heterogeneity of actors is the very poor information flow that exists along the supply chain. This is compounded by a very conservative "need-to-know" attitude such that essentially information flows only "one-up, one down". For example, the farmer might communicate with the wholesaler or food processor but not directly with the retailer. On the other hand, the retailer communicates with the consumer and wholesaler, but (typically) not many other actors. This is of course even more accentuated in more complex supply chains where food is processed or packaged for longer term storage.

This lack of information flow has been "solved" so far by a combination of government or EC level regulation (food standards, health and safety) and third party certification (organic food certification bodies, GlobalGAP, etc.). Although there is a very large number of such bodies and regulations, the overall result has been a series of either/or categories, i.e. either food is safe or not, either it is organic or not, either it is fair trade or not, with a corresponding dearth of numerical values. No information is available as to how much water was used to produce a pint of beer, and even in the ingredients on packaged goods, they are listed in order of quantity but without details of how much.

The lack of information has been recognized as a critical issue for a long time in the agri-food sector, partly expressed in the need for greater transparency but also in the importance given to tracking and tracing of foods in the context of health and safety, and therefore, in order to both prevent and respond to food emergencies (mad cows disease, and most recently E. Coli). Another major factor is the growing desire on the part of food consumers to know more about their food, a desire for greater food awareness. However, the complexities in reaching transparency are due to complexities in products and processes but also due to the dynamically changing open network organization of the food sector, with its multitude of SMEs, its cultural diversity, its differences in expectations, its differences in the ability to serve transparency needs and its lack of consistent appropriate institutional infrastructure that could support coordinated initiatives towards higher levels of transparency throughout the food value chain. Another factor in the slow adoption of ICT technologies in the agriculture sector is related to the fact that existing market solutions (e.g., farm management information systems, logistics services) have been developed as closed proprietary ones, and their capabilities are directly proportional to their cost. Thus, it is very difficult to achieve interoperability among different system and easily upgrade their functionalities while keeping their cost to an affordable level.

In the context of the SmartAgriFood project (http://www.smartagrifood.eu), we address the challenge of applying ICT to the agriculture production and logistics sector, while at the same time improving the food awareness for the end consumers. It is a project embedded in the Future Internet Public Private Partnership (FI-PPP), supported by the EU FP7 programme. FI-PPP aims to ease the access of SMEs to a wide range of powerful software functionalities, the so called Generic Enablers, to enhance their competitiveness in the global market though the improvement of their currently available solutions or the development of new ones. In the context of our project we have designed and partially implemented an architecture that tackles these issues. Our aim was to enable the integration amongst different systems, (i) to allow easy and secure access to necessary information along the agriculture and food supply chain, (ii) to simplify the discovery of stakeholders and services, (iii) to simplify the publishing of data to other stakeholders, (iv) to host a great many software modules on the cloud to reduce the cost for the end users, and (v) to enable the service composition/mash up to enhance the functionalities of offered applications. Our work is going to be continued in a new project called cSpace, also within the context of FI-PPP. To bring this vision into reality we are adopting the latest technological advances in the ICT sector, and more specifically the technologies that are currently designed in the context of the FI-WARE project [4]. The objective of this paper is to give an overview of the architecture developed in the SmartAgriFood project, which aims to enhance smooth information exchange across the supply chain and to offer new business opportunities by enhancing supply chain cooperation, developing and maintaining trusted business relations and full control over own data. The methodology to develop this architecture was to involve a diverse set of stakeholder in the supply to chain, to provide us with ICT functional and non-functional requirements to be covered by the new architecture. Next, these requirements were analyzed and grouped to build the functional architecture of the system. A significant part of this architecture was implemented and evaluated by end users in a number of different pilots.

The structure of this paper is as follows. In Section 2 the specific challenges are presented focusing on the three sub-use cases. Section 3 discusses the FI Generic Enablers and their role in facilitating the SmartAgriFood overall vision. In Section 4, we present our architecture and discuss the designed modules and the information exchanged among them. Section 5 presents an example on how the overall system operates in a specific event. Finally, section 6 concludes the paper.

2. Challenges of the agricultural sector and our vision

To improve the operations and services along the whole food supply chain via the use of ICT technologies it is needed to deal with three main areas, namely farming, logistics and retail. The first area concerns the techniques of agriculture that may be automated and improved to assist farmers in their tasks [1, 5]. The present state-of-the-art in the application of ICT to farming is called "precision agriculture". A generic definition provided by [6] is ''that kind of agriculture that increases the number of (correct) decisions per unit area of land per unit time with associated net benefit". The realization of this concept involves computerized systems that assist farmers to collect, process, store and even disseminate data in order to automate the control of farm operations and improve their results. Although this concept has been around since the 80's and has already proved its value, existing systems either provide limited functionality or are complex and fairly expensive proprietary solutions with limited or none interoperability with other systems.

The second area along the food chain (i.e., logistics) involves a large number of stakeholders dealing with logistics services (e.g. product auto-identification, conditioned transport using sensors and control systems, remote-controlled early warning systems). "Logistics is that part of the supply chain process that plans, implements and controls the efficient, effective flow and storage of goods, services and related information from the point-of-origin to the point-of-consumption in order to meet customer requirements and satisfies the requirements imposed by other stakeholders such as the government and the retail community" [7]. Since the agriculture and food sectors deal with perishable goods, affecting public health, particular requirements are set in logistics to improve the conditions of transportation and storage, especially asking for information in real-time to avoid harmful consequences and waste. Nowadays, logistics is seen as an important process that is directly associated with an organization's competitiveness. Solutions used in this area are always under constant improvement, since their operation depends on the capabilities offered by the underlying network communication infrastructure, their ability to link with other systems and the tools used to handle efficiently the highly dynamic nature and uncertainty of supply and demand.

The third area involves the retailers and their infrastructure and the end consumers that want to have access to a diverse set of information related to health and safety issues, availability, environmental impact, animal welfare, etc. Although much information is available at the sales points and in distributors' and producers' systems, this information is not easily accessible for those who are interested in it, e.g. the supermarket costumer. Currently there are a small number of simple applications where the bar code of a product can be read by a smartphone and some information about the type of product is accessible over the Internet or additional information and discount is provided by customer loyalty programs. There exist certain websites where some subsets of relevant information are available (nutritional information, or environmental information, or country of origin) with varying degrees of sophistication in different countries. However, there are hardly any examples of product related information tailored to consumers, and there are not related information about all processing stages of product (i.e., from seed to shelf) and integrating multiple data sources.

From the above discussion it is clear that the agri-food supply chain is very complex and consists of heterogeneous processes and systems. Nowadays, the systems in all three areas are largely proprietary monolithic solutions that were built as isolated solutions and function as information silos. They provide useful functionalities but this usefulness is usually directly linked to their cost. Although they produce a significant amount of data to perform specifically designed tasks, this data cannot be linked together across silos to develop new functionalities or to address new social, business or policy objectives. These characteristics obviously limit the capabilities and hinder their wider adoption by stakeholders.

To tackle the above mentioned issues we need to design ways that will allow users to make their data more easily accessible to other interested stakeholders, or even to advertise their usage possibly connected with related revenue models. Also, we need to provide an automated way to integrate information produced by different systems and to enable simple communication means between these systems. Therefore, we would be able to produce far more advanced services in a simpler and cheaper way. For example, stakeholders in the food chain should be able to discover, subscribe to and combine data from services offered by different parties. This automatic service discovery and services composition, along with data correlation, is expected to enhance the functionalities offered to the end users, combined with an end-user determined level for secure and authorised access. Moreover, an actor in the agri-food supply chain should be able to discover other stakeholders all over the world and to establish with them business relationships in a simple way [8].

In order to turn this into reality in the context of a dynamic business ecosystem that already consists of a vast number of real players, Future Internet technologies need to provide a number of advanced yet generic services along the whole food supply chain. For example, the Future Internet is expected to enable the attachment and accessing of end devices (e.g., sensors, tracking devices) and machinery (e.g., tractors). Additionally, the Future Internet is expected to allow cloud implementation of services that will facilitate the effective accessing, processing, and analyzing of massive streams of data from these end systems. It will also provide the means for service developers to build sophisticated services that will use libraries of software modules dealing with opinion mining techniques, real time recommendations to end users, location based services etc. It will also provide the means to use expert systems that will improve the "intelligence" of control processes, possibly using distributed schemes. Finally, it is expected that generic interfaces among the services located in the cloud, the underlying network infrastructure and the end devices will improve considerably the QoE of end users. As mentioned in the introduction, all these issues are handled by the FI-WARE project that builds the Future Internet Core Platform. This is further described in Section 3.

Fig 1 presents the overall vision that is a fully integrated and virtualized agri-food supply chain where stakeholders and services from all over the world can inter-operate. With the advent of the Future Internet we will witness a number of service providers along the food chain (e.g., Farm Management System Providers, Logistics services providers, Food information providers) that will supply end users with advanced Future Internet services. These providers will allow, in a simple way, the integration of a number of services offered by external parties as well. These providers will fully operate inside the cloud or using proxies to cater for network traffic optimization or for handling unstable or low bandwidth Internet links. These proxies can also have additional functions, like aggregating at a first level all data collected by local Internet of Things (IoT) environments consisting of sensors, tracking devices, farming machinery, lorries, and sales points, etc. For an end user to discover and select among a vast number of services or even stakeholders, he may consult his associated service provider (e.g., a farmer will use his farm management system provider) or he will be able to contact directly a Public Registry (or broker) that will play the role of a yellow pages service. The result of this vision is that we can establish a direct link among all the stakeholders in the food chain, and have potential access to any information we may need to perform a task (e.g., plan an optimum itinerary for a logistics company), or to simply have full transparency for food products information (e.g., for handling food health alerts).

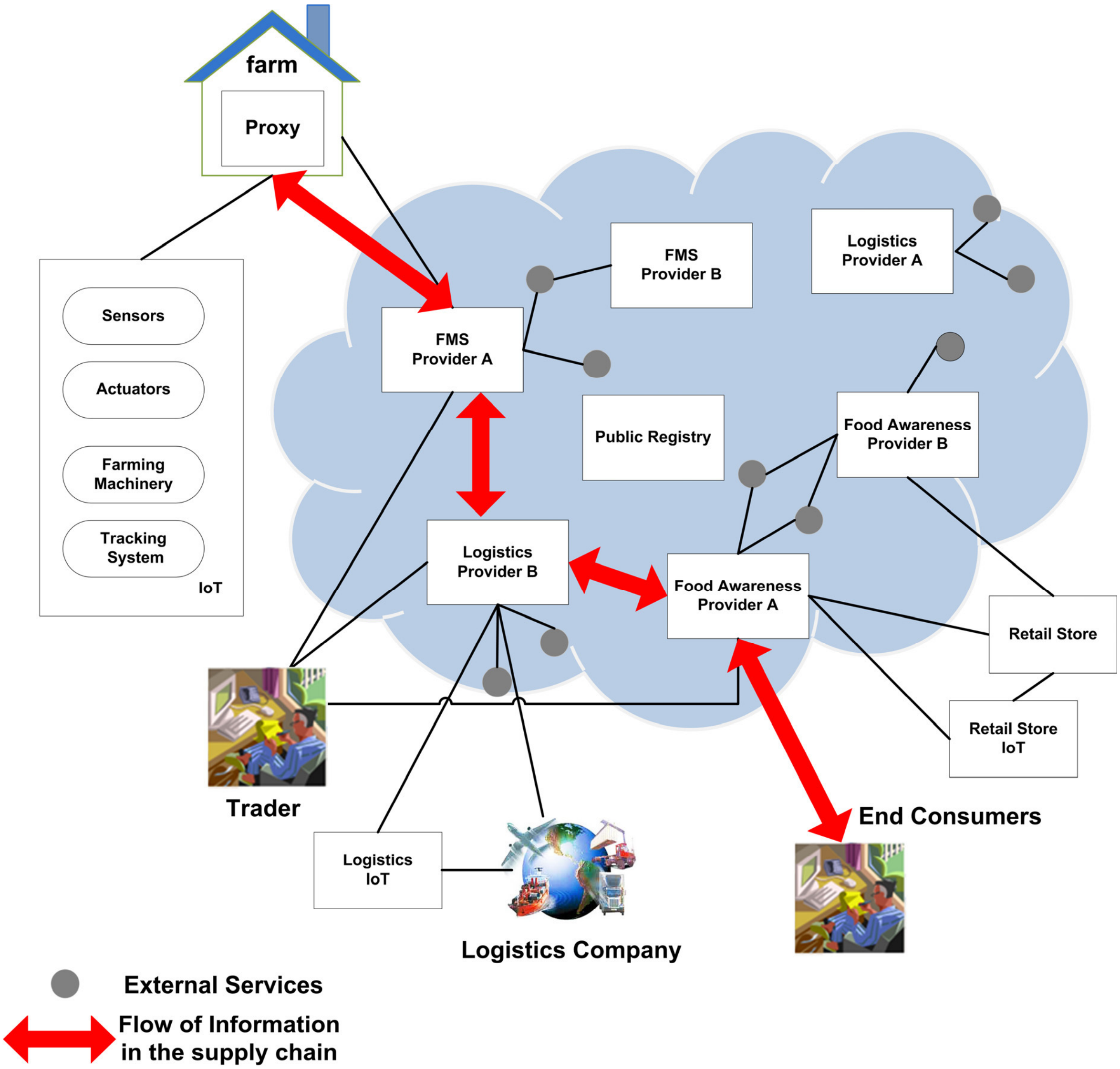

Fig. 1: A fully integrated agri-chain vision

3. Generic Enablers in the Future Internet

Within Phase 1 of the FI-PPP programme, eight use case areas are currently defining requirements for what a Future Internet Architecture should support and provide. In this context, "Future Internet" is more than just a bit pipe of IP packets: it will provide solutions at service level for today's shortcomings of the Internet (e.g. address features like security, performance, service integration and scalability). Every use case is organized as a single project, where "SmartAgriFood" is one of the eight use case projects to provide requirements derived from the smart farming, the smart logistics and food awareness sub-domains. FI-WARE defines a set of "Generic Enablers" (i.e., appropriate software modules) common to all future Internet applications. All FI-PPP requirements are handled in the FI-WARE project to enhance and improve the Generic Enablers. The latter are catalogued into chapters [4]:

- Cloud Hosting – the fundamental layer that provides the computation, storage and network resources, upon which services are provisioned and managed.
- Data/Context Management Services – the facilities for effective accessing, processing, and analyzing massive streams of data, and semantically classifying them into valuable knowledge.
- Service Delivery Framework – the infrastructure to create, publish, manage and consume Future Internet services across their life cycle, addressing all technical and business aspects.
- IoT Services Enablement – the bridge whereby Future Internet services interface and leverage the ubiquity of heterogeneous, resource-constrained devices in the Internet of Things.
- Interface to the Network and Devices – open interfaces to networks and devices, providing the connectivity needs of services delivered across the platform.
- Security – the mechanisms that ensure that the delivery and usage of services is trustworthy and meets security and privacy requirements.

One of the main challenges in realizing the fully integrated agri-food-chain is the definition of an open, standardized infrastructure that supports the integration of vendor independent solutions and services. In the context of the SmartAgriFood project apart from the "generic enablers" we define a set of "domain specific enablers". These are software modules that are applicable in the agricultural sector. These enablers may be totally independent from the generic enablers (e.g., coordinating the execution of external services) or base their operation on the functionality offered by the generic enablers, as described in Fig 2 for the case of smart farming (identical principles are followed for the logistics and the food-awareness domains). The lower layer consists of the generic enablers as these are specified by FI-WARE. These generic enablers could be libraries of generic functions or general purpose software modules. The intermediate layer contains software modules that make use of the generic enablers (e.g., Farm statistical analysis, Farm data acquisition and Farm Execution module) or are totally independent from them (e.g. Service Coordination module).

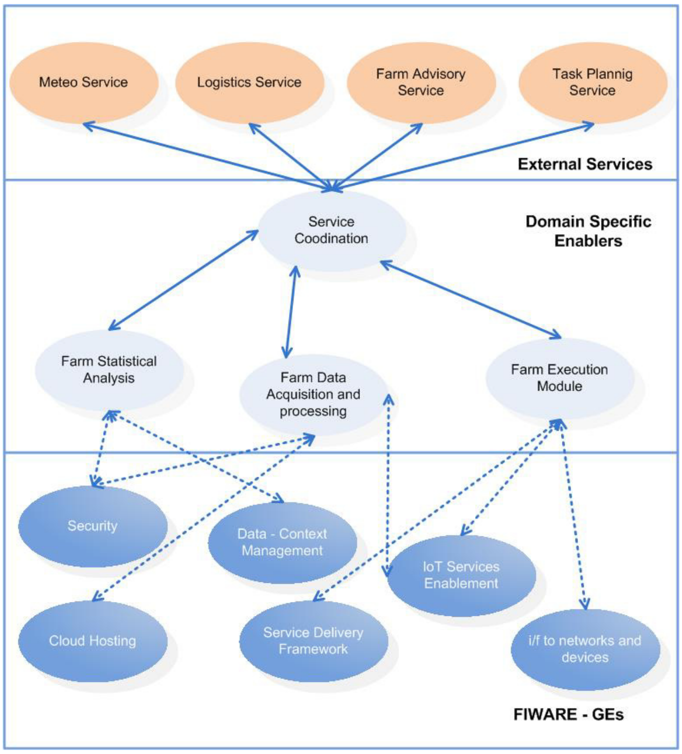

Fig. 2: Using generic and domain specific enablers to provide an advanced cooperating services' environment (farm centric example)

4. The overall Smart Agrifood architecture

The goal of the SmartAgrifood Project (SAF) is to link the different areas by integrating FI-WARE's GEs and introducing appropriate tools and services that are specialized to perform specific tasks (e.g., monitoring and advising greenhouse owners for their crop, monitoring and recording the environmental conditions of fruits and vegetables, providing tailored information to end consumers). In SAF, we have defined three subsystems, one per each already described sub-domain. The first one, called Farm Management System (FMS), deals with management and control of tasks undertaken by farmers [9]. The second one deals mainly with logistics issues as well as business relations and product information, and it is called Product Information System. The third one, called Tailored Information System (TIS), undertakes the task to provide food awareness information to the end consumers. These systems are illustrated in Fig 3. These systems provide solution for specific functionalities to their users in the food chain. However, to build a fully integrated chain we have also identified four generic services, namely the Certification service, the Product Information Service, the Business Relations Service and the Identification Service, which can be used by different subsystems along the food-chain linking the three sub-domains.

More specifically, all actors in the food chain need to identify each other and be able to discover available ICT services, performed by the identification service. All food and production mechanisms need to be certified; these certificates are maintained by the certification service. The information about the life cycle of the produce, the type of production, the area and other information which may be required by the end-consumer or by the various intermediaries handling the produce to ensure the correct type and proper quality, is maintained by the product information service. The business relations service identifies the relationship between the various actors in the end-to-end "farm to fork" process to facilitate their interaction. All aforementioned services are expected to communicate with the three previously mentioned systems and help them realize the end-to-end vision. Also, these services allow external service providers and stakeholders to create and participate in a virtual marketplace where end-users (e.g., farmers, logistics firms, traders, end consumers) can discover, post or process information that is required to perform their tasks or even automate the operation of their business.

Fig 3 presents this framework together with a number of interfaces between all the involved entities that are specified in the following subsections. Note, that the message dispatcher is not an additional service but rather an implementation detail that helps to keep the number of interfaces between the platforms and the services at a small number (i.e., without the dispatcher we would require 12 distinct interfaces). These interfaces need at certain point to be standardized in order to allow the vision of a fully integrated chain.

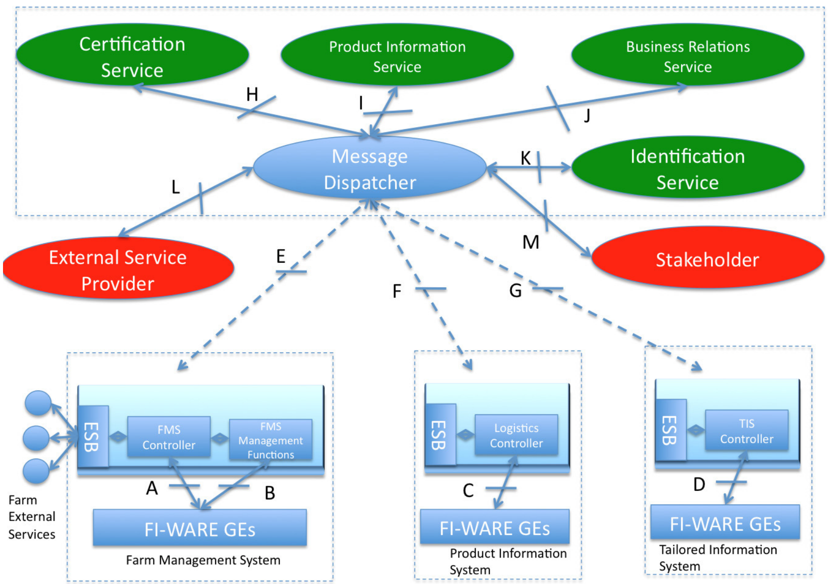

Fig. 3: The overall architectural picture of SAF

The information to be exchanged with the **Certification Service** indicatively includes information related to: *Standard Used (e.g., GS1), Legal, Entity/Location (e.g., GLN), Logistics Unit ID (e.g., SSCC), Certificate number, Type of certificate, Issued date, Expiration date, Responsible person, Certificate authority.*

The information exchanged with the **Product Information Service** indicatively includes: *Standard Used (e.g., GS1), Logistics Unit ID (e.g., SSCC), Company Unique identifier (e.g., GLN - Global location number), Field or plot of harvest, Date of harvest, Commodity variety, Trading Partner/Buying Part (e.g., GLN - Global location number), Date of Dispatch/Shipment, Ship from Location (e.g., GLN - Global location number), Ship to Location (e.g., GLN - Global location number), Link to additional crop information (pointers to FMS), List of Access rights to data (GLN, data variables), Employer's id for managing data entry, Date of uploading information*. The information exchanged with the **Business Relations Service** indicatively includes: *Business_Service_id, Business_Service information, Pricing scheme Store_Id, Offering, Category, negotiationCallback*. The information exchanged with the **Identification Service** indicatively includes: *User Id, Credentials, Type of Service, List of keywords, Tariffing scheme, Charging_record.*

5. Operation Example

In this section we present an operational example of our architecture. Fig 4 has been created using the Archimate tool providing in a single picture not only the interworking of functional modules but also the corresponding business actions and events. For the scenario we are addressing the timely notification of actors in the food chain about producing related exceptions (e.g. bacteria, pesticides, contamination) and to finally avoid the consumption of harmful produce. It includes the detection of a critical event or situation in the distribution process (e.g. a laboratory result indicating the harmfulness of a product) as well as identification of relevant product batches. The system targets at the provision of this exception information to all relevant actors in the supply network, which handled the product or are about to receive the product. This exception notification is transferred to different systems and networked devices to increase the possibility of detection and to separate safe from unsafe products in order to remove harmful products from the process.

On the Archimate business level this scenario starts when a stakeholder reports (registers) an exception. This registration is provided through a "Health hazard exception reporting service", especially to entities that are not a direct member of a chain, which is or could be affected by an exception/ crisis. This shall open a communication channel for e.g. food laboratories, consumer protection agencies, logistics service providers, health care entities, certification providers or public authorities as soon as they identify a potential hazard. Each exception needs to be combined with one or more unique IDs that can be propagated in the food chain. The information that is reported includes a transaction id, a logistics unit id, a timestamp, the detail description of the exception, the current delivery status, the location, the impact on consumers, the urgency the consequences to the chain, the potential side effects to other deliveries and possible contingency measures.

The exception reporting service communicates with the SAF generic services to obtain access to the full product chain and manage to identify the suppliers and receivers of a produce to inform them. For this purpose it triggers the identification service (authentication purposes) which collects data from the product information and the business relations service to identify the related suppliers and receivers in the food chain, so as to propagate to them the information about the exception. This information will be transferred through the FMS, the Product Information System and the TIS to the end users. Any actions that are executed for treating this exception will be transferred back to the exception reporting service that will record the actions and close the incident.

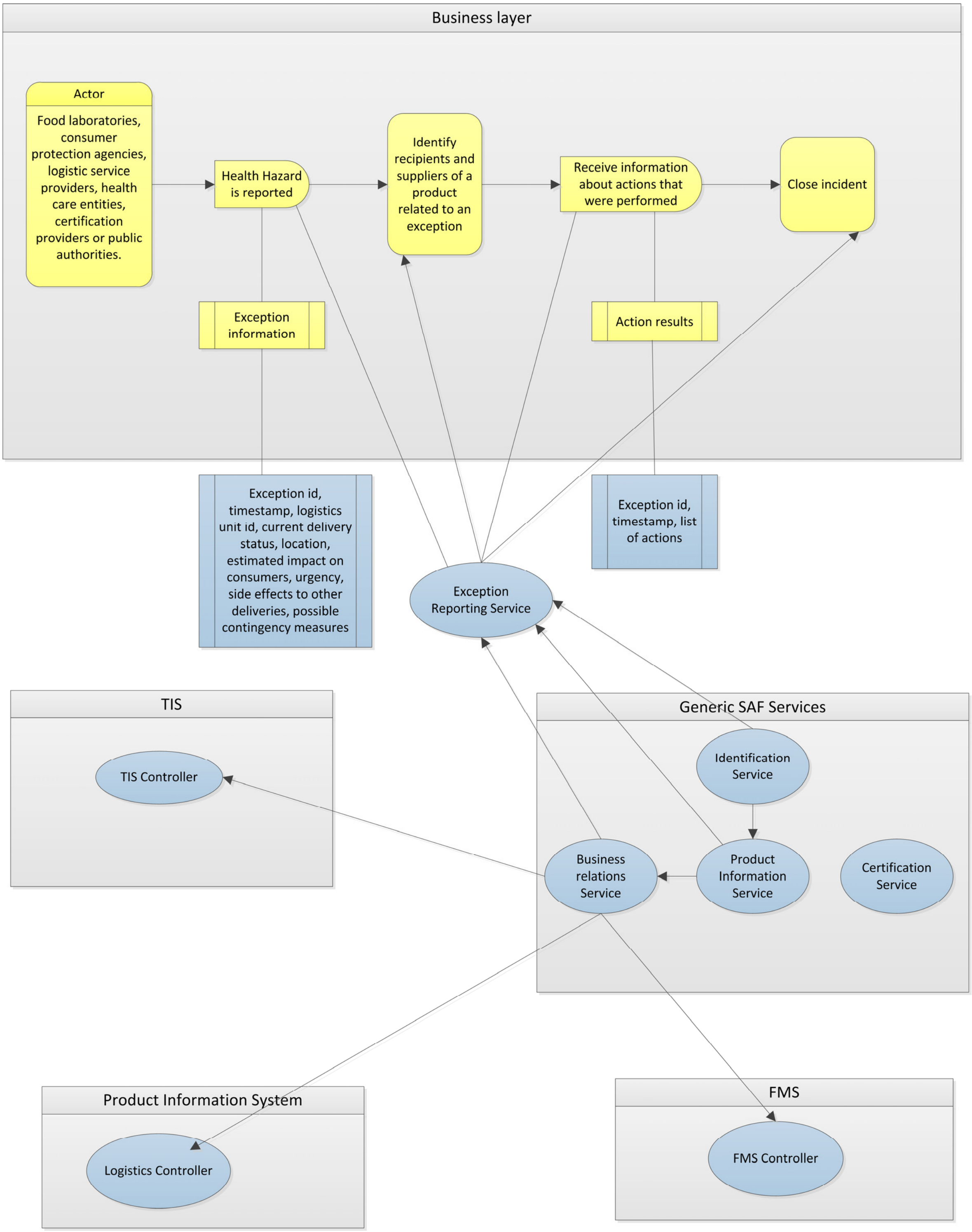

Fig. 4: Representation of a health hazard reporting service handled by the SAF architecture

6. Conclusions

In this paper we have presented the SmartAgrifood architecture that aims at building an integrated food chain that will allow data to be transferred bi-directionally in an automatic and simple way. An additional goal of the architecture is to enable stakeholders to communicate and also discover services provided by different service providers. This is expected to create a market place similar to the one of Google Play or Apple Store. The main difference is that these services are not stored locally on an end device but rather they have access to the same data (e.g., farmer's data) stored in the cloud. This way, end users will be able to build their own tailor cut environment in an affordable way. The concepts will be tested in real life in the context of a new ambitious project, in the context of FI-PPP, called cSpace that is starting in April 2013.

Acknowledgements

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