Available online at www.fooddynamics.org

Int. J. Food System Dynamics 4 (4), 2013, 261-272

INTERNATIONAL JOURNAL ON FOOD SYSTEM DYNAMICS

Future Internet as a Driver for Virtualization, Connectivity and Intelligence of Agri-Food Supply Chain Networks

C.N. Verdouw[1], N. Vucic[2], H. Sundmaeker[3], A.J.M. Beulens[4]

[1] *LEI Wageningen UR, The Netherlands*
[2] *HUAWEI TECHNOLOGIES München , Germany*
[3] *ATB Bremen, Germany*
[4] *Logistics, Decision and Information Sciences Wageningen, The Netherlands*
Cor.Verdouw@wur.nl; Nikola.Vucic@huawei.com; Sundmaeker@atb-bremen.de; Adrie.Beulens@wur.nl

Received November 2013 ,accepted January 2014 ,available online February 2014

ABSTRACT

The food and agribusiness is an important sector in European logistics with a share in the EU road transport of about 20%. One of the main logistic challenges in this sector is to deal with the high dynamics and uncertainty in supply and demand. This paper discusses the opportunities of Future Internet (FI) technologies to addresses the specific demands on information systems for logistics in the food and agribusiness domain. More specifically, it presents a Future Internet (FI) based design for smart agri-food logistic information systems. This design aims to enable new types of efficient and responsive logistics networks with flexible chain-encompassing tracking and tracing systems and decision support based on that information. These systems effectively virtualise the logistics flows from farm to fork, support a timely and error-free exchange of logistics information and provide functionality for intelligent analysis and reporting of exchanged data to enable early warning and advanced forecasting.

Keywords: supply chain management, logistics networks, food and agribusiness, information systems, future internet

1 Introduction

The food and agribusiness is an important sector in European logistics with a share in the EU road transport of about 20% (Verweij and Moolen, 2009). The sector faces specific challenges that heavily impact the required information systems. In particular, there is a high uncertainty regarding fresh product quality as well as available volumes due to variations in the natural production process (Verdouw, 2010; Verdouw et al., 2013b). As a consequence, the prediction and planning concept and accompanying logistics system needs to be very flexible, enabling last minutes changes and real-locations, but also provide a robust planning. Due to these characteristics the current state of the art of ICT in the agri-food logistics is characterized by large amounts of available data, but there is a poor level of integration and the support for intelligent use of these data is insufficient (Lehmann et al., 2012; Verdouw et al., 2013b). The complexity of the current solutions is too high and jeopardizes the development and operation of affordable solutions. As a result, there is a mismatch between the state of information technology in agri-food and the high and increasing need for intelligent solutions that combine interoperability with flexibility and that are both sector-specific and suitable for SMEs.

The development towards Internet-based information systems is promising to overcome the above-mentioned mismatch. However, it is widely accepted that the Internet faces a number of shortcomings concerning the processing, storage, transmission and control of data (Zahariadis et al., 2011). In particular, the current internet cannot handle the large amounts of distributed and heterogeneous data in the Internet of Things (Verdouw et al., 2013a). Moreover, there is still no standardized solution to enable a simple and cohesive interoperability among services and stakeholders (Kaloxylos et al., 2012).

The Future Internet (FI) infrastructures are expected to overcome these limitations (Paul et al., 2011; Zahariadis et al., 2011; Lehmann et al., 2012). The FI is a general term that labels the emergence of a new era in the evolution of the Internet (FIWARE, 2013). It combines several trends in internet development into an integrated approach. These trends include:

- the on-going industrialization of IT in the form of cloud computing and open service delivery platforms;
- new wireless networking technologies and the deployment of fibre that are paving the way for new (real-time) applications;
- the breakthrough of the Internet of Things, with the vision of ubiquitously connecting intelligent devices and sensors.

This paper discusses the opportunities of Future Internet (FI) technologies to address the specific demands on information systems for logistics in the food and agribusiness domain. More specifically, the objective is to introduce a Future Internet (FI) based design for smart agri-food logistic information systems.

After a summary of the applied methodology, the remainder of this paper will first introduce main challenges for logistics information systems in the agri-food sector and functional requirements of the system to be designed (specification for experimentation). Subsequently, the design will be introduced, which comprises two parts: key features from a user's perspective and a technical design.

2 Methodology

The research presented in this paper is carried out as a part of the SmartAgri-Food project ("Future Internet for Safe and Healthy Food from Farm to Fork"), which was one of eight use case studies of the "Future Internet Public Private Partnership" (FI-PPP) programme [www.smartagrifood.eu; www.fi-ppp.eu]. Smart Agri-Food has built on the Future Internet Core Platform that is being developed by the FI-PPP programme [www.fi-ware.eu]. The project focussed on three sub systems of the sector: Smart Farming, Smart Agri-Food Logistics and Smart Consumer Awareness. This paper introduces the design of the second sub system: Smart Agri-Food Logistics.

The research started with a specification for experimentation on smart-logistics in agri-food supply chains from a user's point of view and an analysis of user requirements. Based on this specification, case studies has been conducted in two specific sectors, i.e. the Fresh Fruit and Vegetables (FFV) industry and the Plants and Flowers (PF) industry. Both case studies are carried out in close interaction with European-wide acting business partners from the sector. The case studies have focused on complementary issues that i) on the one hand are considered to be a major business challenge in the sector and that ii) on the other hand are challenging from an information technology perspective.

The FFV case study concentrated on the topics transparency and information exchange between agri-food enterprises, which includes the management, tracking and tracing of the product and returnable packaging in order to enable the provision of product quality information from actors to actors in a supply network. It is based on a dual approach concentrating on the 'management of product & information carrier' and the 'provision of product quality information'.

The PF case study has analyzed and demonstrated the possibilities of Future Internet technologies for dynamic Quality Controlled Logistics in floricultural supply chains, i.e. advanced logistics decision making in the supply chain taking real-time information on product quality behavior into account (van der Vorst et al., 2011). In this approach, logistic processes throughout the supply chain are continuously monitored, planned and optimized based on real-time information of the relevant quality parameters (such as temperature, humidity, light, water).

Based on the specification for experimentation, the research has designed an overall architecture for Smart Agri-Logistics based on the FI-PPP Core Platform architecture. This overall design served as a common base for the design and implementation of specific architectures in the case studies that demonstrate the possibilities of Future Internet technologies for the selected business issues in both sectors.

The remainder of this paper first introduces the specification for experimentation and user requirements and subsequently it presents the addressed key features and a technical design.

3 Basic demands on logistics information systems in agri-food

3.1 Main ICT challenges for agri-food logistics

The special characteristics of the agri-food industry heavily impact logistics in this sector. Important sector-specific challenges from a logistic perspective include:

- *High supply uncertainty due to natural production*: unpredictable variations in quality and quantity of supply, which demands for flexibility in logistic processes, planning, early warning and pro-active control mechanisms;
- *High perishability of fresh food products*, which demand for temperature-conditioned transportation and storage (cold chains) and very short order-to-delivery lead-times;
- *Seasonable growing*, which demands for global sourcing to ensure year-round availability;
- *High demands on food safety, quality and (environmental) legislation*, which among others demands for the ability to trace production information of products in transit and track the origin of food products in case of incidents;
- *High flow complexities*, due to a combination of continuous and discrete product flows, diverging and converging processes and by-products; this demands for advanced tracking and tracing and logistic planning capabilities;
- *Important role of import/export*, including additional phytosanitary and veterinary inspections;
- *Complex network structure* where small and medium enterprises trade with huge multinationals in the input and retail sector; this demands for proper collection and regional orchestration in logistic mainports and proper allocation mechanisms to connect aggregated demand with fragmented supply.

Due to these characteristics the application of existing ICT solutions is not always obvious and it is less straightforward than it might be in other industries. For example: there is a high need for interoperability but this should be accompanied by flexibility to deal with the high dynamics in agri-food logistics. Furthermore, the need for sector-specific ICT solutions is high, but at the same time the possibilities for investments are low due to the large number of small and medium enterprises (SMEs). Consequently, the current state of the art of ICT in the agri-food logistics is characterized by large amounts of available data, but there is a poor level of integration, and the support for intelligent use of these data is insufficient. The complexity of current solutions is too high and jeopardizes the development and operation of affordable solutions. As a result, the adoption of internet for basic information services is high, but the use for more advanced functionalities is limited.

These complexities contrast with the high and constantly increasing need for better information, control and transparency in the agri-food sector. Consequently, there is a mismatch between the state of information technology in agri-food and the high and increasing need for intelligent solutions that combine interoperability with flexibility and that are both sector-specific and suitable for SMEs. More specifically, key challenges concerning ICT include:

- Timely and flexible availability of product and quality information to a variable network of downstream and upstream partners;
- Seamless interoperability of enterprise and supply chain systems, allowing for hybrid cloud and decentralised approaches and for the usage of heterogeneous standards concerning identification, frequencies, data interchange, etc.;
- Dynamic logistic planning and scheduling systems enabling last minutes changes and reallocations based on early warning and (quality) simulation capabilities;
- Information security (privacy, authentication, integrity) and data quality;
- Affordable solutions which can be utilised by SMEs that lack significant resources and specialised competences.

3.2 Functional requirements

The specification for experimentation is used to define an initial set of functional and non-functional requirements for smart agri-food logistics. These requirements are later updated based on the stakeholder analysis in both case studies. In total 55 functional requirements and 11 non-functional requirements are defined (Vucic et al., 2012; Verdouw et al., 2013b). The functional requirements are grouped into 14 functional blocks. Some 30% of the requirements are addressing blocks related to data analysis, collection and management. About 20% of the defined requirements are addressing the configuration and communication functionalities and some 15% are addressing service based architecture and loose coupling principles. Also requirements related to e.g. the Internet of Things (IoT), interoperability and immediate user notification are identified. Examples of the defined requirements include: access of advanced sensor data on-line via the internet, communication of quality alerts about products in transit, calculating the impact and consequences of incidents, easy configuration of a personalised supply chain cockpit profiles, search capabilities to find companies certified by the relevant standards and authentication of objects/actors for specific tasks.

4 Key features Smart Agri-Food Logistics

4.1 Key features

In order to address the user demands as defined in the previous section, the designed architecture for Smart Agri-Food Logistics aims to enable of new types of efficient and responsive logistics networks with flexible chain-encompassing tracking and tracing systems and decision support based on that information. These systems effectively virtualise the logistics flows from farm to fork, support a timely and error-free exchange of logistics information and provide functionality for intelligent analysis and reporting of exchanged data to enable early warning and advanced forecasting. Three critical features of these systems are distinguished, as illustrated in Figure 1 (Verdouw et al., 2013a; Verdouw et al., 2013b):

i) *Real-time virtualization*: decoupling of the physical flows of products and logistics resources (objects), and the information flows for planning, control and coordination/orchestration;

ii) *Logistics connectivity*: timely and error free exchange of the information about (lots of) products and logistic resources with other organizations and additional services in order to enable quick response;

iii) *Logistics intelligence*: intelligent analysis and reporting of the exchanged data to enable early warning and advanced forecasting.

The next sections will introduce these features in more detail.

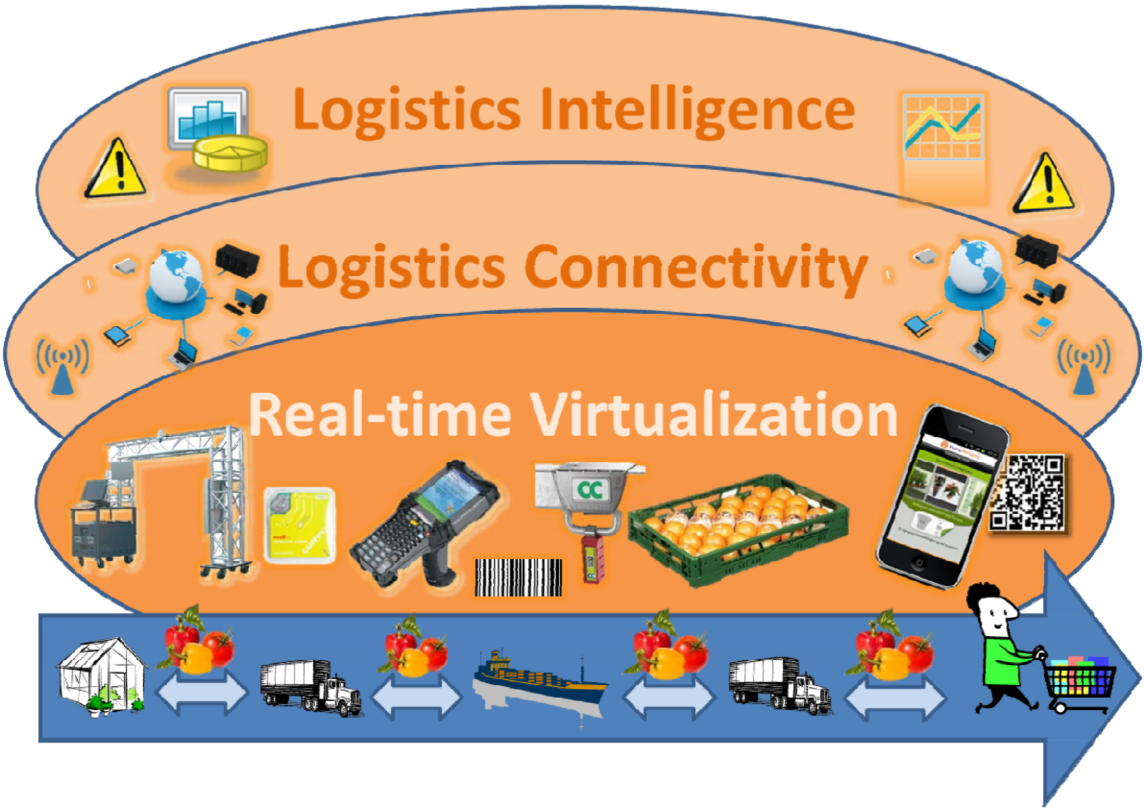

Figure 1. Key features of Smart Agri-Food Logistics

4.2 Real-time Virtualization

The interaction between real/physical and digital/virtual objects as apparent in the Internet of Things (IoT) is an essential concept of virtual logistic networks. In the IoT, physical entities have digital counterparts and virtual representations; things become context aware and they can sense, communicate, interact, exchange data, information and knowledge (Guillemin and Friess, 2009). In other words, each physical object is accompanied by a rich, globally accessible virtual object that contains both current and historical information on that object's physical properties, origin, ownership, and sensory context (Welbourne et al., 2009). Geographically dispersed physical objects have to be tied to and continuously update a virtual representation of the object, i.e. (lots of) products and logistic resources such as containers. The virtual objects must 'adequately' represent the identity, place and (dynamic) properties of the (physical) objects of interest, they must be 'reliable' for different purposes of usage, they must be timely available and the security and privacy must be unquestionable. The enabling technologies are mainly related to the IoT and include RFID, real-time logging, and sensor and actuator networks.

A complicating factor in the food and agri-business is that the properties of agri-food products are highly dynamic because they are living products. Furthermore, virtual objects must provide multiple views for different users, having distinct purposes of usage. Visualisation plays an important role to create views that are experienced by human users as reality. Promising enabling technologies include advanced visioning technologies (including high-speed/low-cost solutions, 3D, and internal features such as ripeness), the mixture of real and virtual objects in augmented reality (including mobile applications) and in particular the combination of both technologies.

4.3 Logistics Connectivity

The Internet acts as a storage and communication infrastructure that holds a virtual representation of things linking relevant information with the object (Uckelmann et al., 2011). As such, virtual objects serve as central hubs of object information that combine and continuously update data from a wide range of sources. Logistics connectivity is of vital importance to enable timely, reliable, secure and flexible data communication. This in particular requires i) solid infrastructures to communicate information of objects while safeguarding property, access and usage rights, and ii) standards for a seamless identification and exchange of product/logistics data. An important underlying challenge in virtual networks is to find solutions to support rapid configuration and the combination of federated and centralized solutions. The enabling technologies are mainly related to the Internet of Services and include Service-Oriented-Architecture (SOA)-based interoperability platforms, business process management systems, data exchange standards, trust/identity capabilities and cloud technologies.

4.4 Logistics Intelligence

The usage of dynamic virtualization data for intelligent decision support is an important future challenge. The shared information needs to be appropriate for planning, coordination, orchestration and control of the logistics network. Therefore, information systems must support the intelligent analysis and reporting of exchanged data. These functionalities enable early warning in case of disruptions or unexpected deviations (e.g. in lead time, temperature, etc.) and advanced forecasting about consequences of detected changes by the time the product reaches destination. Using such application requires big changes of business processes and supply chain cooperation. Enabling technologies include Business Intelligence, Business Process Management, Decision Support Tools, Configurators, Event Management Systems, Fuzzy Logic and Data Mining.

As argued in the previous section, current solutions do not sufficiently provide these features. The Future Internet (FI) offers a realistic scenario to solve this because it aims at a provision of an integrated architecture that overcomes the basic limitations of current information systems for agri-food logistics. The next section will introduce a Technical Design based on the Future Internet Core Platform that is being developed by the FI-PPP programme.

5 Technical design for Smart Agri-Food Logistics systems

5.1 Role of the Future Internet Core Platform

The Smart Agri-Food Logistics design, as presented in this paper, builds on the Core Platform that is being developed by the FI-WARE project of the FI-PPP programme (EuropeanCommission, 2012; FIWARE, 2013). This platform aims at a provision of an innovative infrastructure for cost-effective creation and delivery of versatile digital services, providing high Quality of Service and security guarantees. The basic underlying approach is that the Core Platform will offer reusable and commonly shared capabilities and functionalities (Generic Enablers, GE's) which can be flexibly customized, used and combined for many different Usage Areas (pick, plug and play). Thus, the GE can be defined as functional building blocks of the Core Platform. Any implementation of a GE is made up of a set of components which together support a concrete set of functions and provide a set of Application Programming Interfaces (APIs) that are in compliance with open specifications published for that GE.

Figure 2 shows that products implementing the Generic Enablers can be selected and plugged together with complementary products (Domain-Specific Enablers, DSE's) in order to build domain-specific instances (EuropeanCommission, 2012). Smart Agri-Food Logistics is intended to be one of those instances (as part of the Smart Agri-Food Use Case Trial).

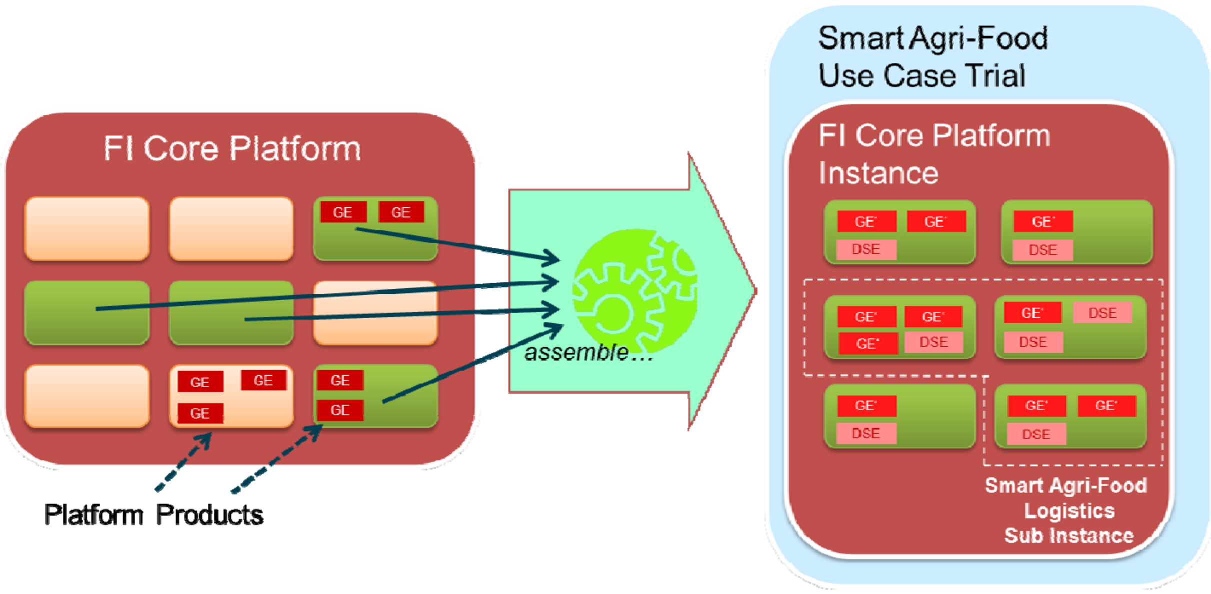

Figure 2. Smart Agri-Food Logistics sub instance of the FI Core Platform (based on FIWARE, 2013)

5.2 Technical design

The technical design to realize the Future Internet services for Smart Agri-Logistics is depicted in Figure 3.

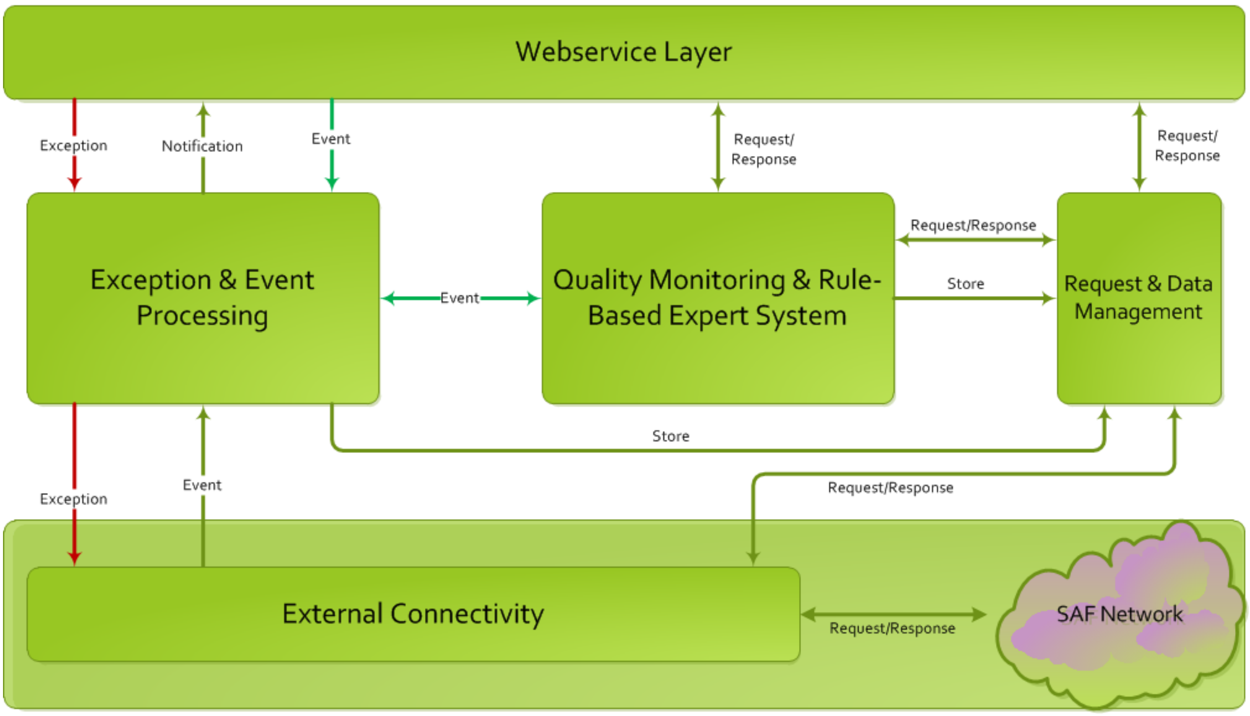

Figure 3. Overall technical design Smart Agri-Food Logistics

The enhanced logistics information system comprises five basic functional blocks:

a. *External Connectivity*: this module connects devices, resources and other systems to local systems for communication and data exchange. By connecting systems a network will be built which will be used to transfer data and messages through the supply chain, called “SAF Network” in the Figure.
b. *Web service Layer*: this layer serves as point of user interaction where users get or provide data from and to the system or other users. This user interface includes features like: controlling several system functions, creation and receipt of events and messages, using product monitoring and receipt of Expert System recommendations and request and provide product data/ events.
c. *Request & Data Management*: this module enables the correct provision and storage of data a set of compatible data bases as well as interfaces to legacy systems need to be set up. It serves as abstraction layer to several kinds of information systems, e.g. legacy and local systems as well as remote databases (for example from other actors).
d. *Exception & Event Handling*: this module provides basic information processing capabilities for the exchange of event-related information. It is a composition of three sub-modules:
    - *Event Analyzer & Handler* receives events from both the Web service Layer and the External Connectivity module to analyze and handle them. This process can result in a User Notification and/or an Exception Propagation.
    - *User Notification* receives events to handle by notifying specific users. The resulting notifications will be directed over the Web service Layer to the respective users.
    - Similar to the User Notification the *Exception Propagation* receives events but not only from the Event Handler. Exceptions can also be created from users and sent over the Web service Layer. This special kind of event is not intended for notifying users of the local system but rather to notify other actors of the supply chain about the recognized exception.
e. *Quality Monitoring & Rule-Based Expert System:* this module supports the monitoring of highly dynamic product data like status, location and quality. It consists of three development sub modules as well:
    - *Rule Engine* contains a set of relevant expert system rules for the products of interest. Currently supported rules are threshold-based and fuzzy logic, and the module is extendable for other types of rules.
    - *Quality Monitoring* module is in charge of collecting the necessary information for the expert system. This typically includes measurements of environmental parameters, business steps, location-based information, etc.
    - *Expert System* gives prediction results (e.g., product quality decay forecast), recommendations, and alarms.

5.3 Underlying architectural dimensions

It is important to notice that there are some important architectural issues behind the overall design that are addressed in the specific architectures of both case studies. These additional dimensions of complexity include i) the level of intelligence, ii) location of data storage, iii) location of application services and user interfaces and iv) routing of information (Vucic et al., 2012; Verdouw et al., 2013a):

Level of intelligence: the modules include services of different levels of intelligence, which can be classified into information handling, problem notification and decision making services (Meyer et al., 2009). *Information handling* is concerned with basic operations with data such as collecting, storing, and delivering (e.g. to legacy information systems of the different supply chain actors). *Problem notification* assumes informing the relevant stakeholders and users if something is wrong (e.g. temperature too high) or if there are any events causing deviations from the plan. This functionality is often coupled with certain rules which are applied to filter the collected data and extract the exception message. Finally, *decision making* assumes the involvement of information systems (decision support systems) for assisting or completely replacing humans in performing sophisticated decisions and triggering certain actions. This presents the highest level of intelligence in the envisioned agri-food logistics information system. The input data in this case can have various representations including the (exception) notification messages.

Location of data storage: Figure 3 may suggest that data are all stored as virtual objects in the internet (cloud). However, data are usually also stored on intermediary platforms or on physical objects, among others to ensure availability in case of communication breaks (Verdouw et al., 2013b). As a consequence, the architecture should include advanced capabilities to synchronise local and cloud data. The architecture should allow asynchronous communication, enabling to send data without waiting for immediate response, in order to compensate disconnects from the internet on mobile devices.

Location of application services and user interfaces: Also the application services are not all located in the cloud. They usually are also available on mobile devices and local computers or on the object itself, e.g. board computers of vehicles or smart containers. As a result the architecture must allow both cloud and local user interfaces.

Routing of information: Figure 3 may suggest a centralized routing approach in which all clients are connected to a single server that is capable to redirect/proxy the request from one node to another. However, the architecture should enable an hybrid routing approach i.e. a combination of centralized and peer-to-peer (P2P) in which all clients are directly connected to each other. The advantages of hybrid routing are confidentiality of direct communication, low data traffic via the central server, decentralised management of access rights is possible and a single entity in the network for look-up of information (Vucic et al., 2012; Verdouw et al., 2013b).

5.4 Generic Enablers addressed in the design

The modules as introduced above build on a combination of Generic Enablers (GEs) and Domain Specific Enablers (DSEs) of the Future Internet PPP (see Figure 2). The FI Core Platform contains Generic Enablers in five categories (FIWARE, 2013):

- *Cloud Hosting*: the fundamental layer that provides the computation, storage and network resources, upon which services are provisioned and managed,
- *Data / Context Management*: the facilities for effective accessing, processing, and analysing massive volume of data, transforming them into valuable knowledge available to applications;
- *Applications / Services Ecosystem and Delivery Framework*: the infrastructure to create, publish, manage and consume FI services across their life cycle, addressing all technical and business aspects;
- *Internet of Things (IoT) Services Enablement*: the bridge whereby FI services interface and leverage the ubiquity of heterogeneous, resource-constrained devices in the Internet of Things;
- *Interface to Networks and Devices (I2ND)*: open interfaces to networks and devices, providing the connectivity needs of services delivered across the platform;
- *Security*: the mechanisms which ensure that the delivery and usage of services is trustworthy and meets security and privacy requirements.

The Smart Agri-Logistics design exploits the following Generic Enablers (GEs): Mediator and Mashup GEs, Complex Event Processing GE, Publish / Subscribe Broker GE, Location GE, Identity Management GE and the GEs of the Internet of Things chapter (see Table 1).

Table 1.
Main Future Internet Generic Enablers as addressed in the Smart Agri-Food Logistics design

Generic Enabler	Case study	Exploited in module
Applications / Services Ecosystem and Delivery Framework Chapter		
Mediator GE	FFV	Web service Layer
Mashup GE	PF	Web service Layer
Data / Context Management Services Chapter		
Complex Event Processing GE	FFV, PF	Exception & Event Handling, Quality Monitoring & Rule-Based Expert System
Publish / Subscribe Broker GE	FFV, PF	Request & Data Management, Web service Layer
Location GE	FFV, PF	Connected Device Handler, Cloud Dashboard
Security Chapter		
Identity Management GE	FFV	Request & Data Management, Web service Layer
Internet of Things Services Enablement Chapter IoT		
Complete IoT Framework	PF	External Connectivity, Request & Data Management, Exception & Event Handling

5.5 Domain Specific Enablers addressed in the design

The addressed Domain Specific Enablers (DSEs) are twofold.

First, the architecture utilises the generic DSEs of Smart Agri-Food, which are common for all sub-use cases within the agri-food domain. These DSEs provide the common services required by all entities that enable the tracking and tracing of food from farm to fork and vice versa. Four main services have been identified as the fundamental components of the system architecture:

i) *Identification service*: stores verified identities of all actors in the end-to-end process; this DSE provides services for Authentication, Identity Management (IdM) and Service Contract Orchestration and Retrieval;
ii) *Certification service*: piece of functionality that helps determining whether information about any given product is reliable and can be trusted; this DSE includes a certification validation service; a logo validation service and a service which provides other independent sources of information that can be used for validation;
iii) *Product information service*: maintains 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; this DSE is composed of information look-up services and requesting/updating services;
iv) *Business relations service*: identifies the relationship between the various actors in the end-to-end farm to fork process to facilitate their interaction; this DSE operates in the philosophy of a service life cycle and includes services for requirements, capabilities, recommendations, matchmaking and feed-back.

Second, within the case studies specific DSEs have been developed. The main DSEs as developed in the Fresh Fruit and Vegetables (FFV) case study are a web service layer, to feed the user Interface (UI) and to communicate with the user; an external connectivity module, to connect with external system; a data management service, which provides an abstraction layer to handle different kind of data; and an exception propagation module, improving the reaction time and quality on possible harmful food problems. The main DSEs as developed in the Plants and Flowers (PF) case study are an Event Platform, in which the scanning events are stored and processed; an Expert System that predicts the quality decay of products related to the events in the platform; and a Cloud Dashboard, which is the User Interface and the related web services that integrates the event platform and the expert system.

6 Discussion and conclusions

This paper has discussed the opportunities of Future Internet (FI) technologies to addresses the specific demands on information systems for logistics in the food and agribusiness domain. It in particular has introduced a Future Internet (FI) based design for smart agri-food logistic information systems. In order to addresses the specific demands in the food and agribusiness domain, the design aims to enhance of new types of efficient and responsive logistics networks with flexible chain-encompassing tracking and tracing systems and decision support based on that information. These systems effectively virtualise the logistics flows from farm to fork, support a timely and error-free exchange of logistics information and provide functionality for intelligent analysis and reporting of exchanged data to enable early warning and advanced forecasting. Consequently, three basic features are distinguished:

- *Real-time virtualization*: decoupling of the physical flows of products and logistics resources (objects), and the information flows for planning, control and coordination/orchestration;
- *Logistics connectivity*: timely and error free exchange of the information about (lots of) products and logistic resources with other organizations and additional services in order to enable quick response;
- *Logistics intelligence*: intelligent analysis and reporting of the exchanged data to enable early warning and advanced forecasting.

The technical design builds on the Future Internet Core Platform, that is being developed by the FI-PPP programme. This Core Platform will offer reusable and commonly shared capabilities and functionalities (Generic Enablers) which can be flexibly customized, used and combined for many different Usage Areas. Products implementing these Generic Enablers can be picked and plugged together with complementary products (Specific Enablers) in order to build domain-specific instances.

The overall design of the enhanced logistics information system comprises five basic functional blocks: i) External Connectivity, ii) Web service Layer, iii) Request & Data Management, iv) Exception & Event Handling and v) Quality Monitoring & Rule-Based Expert System. There are some important architectural issues behind the overall design that are addressed in the specific architectures of both case studies. These additional dimensions of complexity include i) the level of intelligence, ii) location of data storage, iii) location of application services and user interfaces and iv) routing of information.

The design system builds on a combination of Generic Enablers (GEs) and Domain Specific Enablers (DSEs) of the Future Internet PPP. The addressed GEs are Mediator and Mashup GEs, Complex Event Processing GE, Publish / Subscribe Broker GE, Location GE, Identity Management GE and GEs of the Internet of Things chapter. The architecture utilises the generic DSEs of Smart Agri-Food, i.e. the identification service, certification service, product information service and business relations service. Furthermore, within the case studies specific DSEs have been developed.

It can be concluded that the designed system has effectively addressed the specific demands in the food and agribusiness domain. For example: the architecture is designed to enable actors in the chain to continuously monitor the quality of incoming and outgoing products and advanced sensor data can be accessed timely via the internet and peer-to-peer. This enables actors to react on quality and safety issues in a timely manner. The architecture also allows for decentralised approaches, which supports a high variety and variability of supply chain networks. Table 2 further discusses the contribution of the Smart Agri-Food Logistics design to specific logistic challenges in the food and agribusiness.

To conclude, the main contribution of the Smart Agri-Logistics design as presented in this paper is that it utilizes a generic and standardized internet platform to instantiate specific solutions for logistics information systems in the agri-food sector. As a result, it can overcome current bottlenecks and enables the development and operation of affordable solutions that independent from geographic locations and independent from specific implementation choices. This potentially will boost the application of intelligent information systems for logistics management in agri-food supply chains.

The main added value of such systems for the end users in the agri-food business is the improvement of the efficiency and responsiveness by the real-time management of logistic flows from farm to fork. More specific benefits include:

- Less waste, better decay management;
- Surgical response in case of food alert, for quick and precise recall/withdrawal of products;
- Better security of food products, avoiding fake products, illicit traffic or threats using food as vector;
- Lead-time reduction;
- Better service levels;
- Lower inventory levels;
- Better utilization of logistics capacity;
- Reduction of GHG emissions and carbon footprint, e.g. decrease of transport kilometres or empty vehicles;
- Enhanced regulation enforcement control of non-European imported products.
- Better competitive position of European agri-food industry;

Table 2.
Contribution of the Smart Agri-Food Logistics design to specific logistic challenges in the food and agribusiness

Key agri-logistics specific characteristics	Contribution of the designed system
Agricultural production is depending on natural conditions, such as climate (day length and temperature), soil, pests and diseases and weather. This results in unpredictable variations in quality and quantity of supply (unpredictable yields in primary production and uncertain output of food industry processes, e.g. sugar or fat content)	• The architecture is designed in such a way that intermediates can have continuous insight in current and expected supply of produce from growers and planned and actual demand of retail stores. This enables supply chain participants to plan dynamically. • The architecture is designed to enable actors in the chain to continuously monitor the quality of incoming and outgoing products and advanced sensor data can be accessed timely via the internet and peer-to-peer. This enables actors to react on quality and safety issues in a timely manner. • Expert quality assessments and certifications are an essential element of the designed architecture to calibrate and check calculated product quality. • Based on quality events the products can be reallocated to alternative buyers if the quality parameters do no longer match the requirements of the original buyer. • Based on the current state of products in the supply chain, flexible logistic

Key agri-logistics specific characteristics	Contribution of the designed system
	interventions are supported as well as forwarding exception notifications in critical situations (e.g. unsafe products, unexpected product quality) to involved actors is assured. • The feedback of remaining quality and shelf-life of products backwards to growers is supported.
Agri-food products are natural products with a high perishability (in particular fresh food)	• Temperature conditions are monitored throughout the supply chain. • Exception notifications are generated in case of actual or expected incidents that decrease shelf life. • Planning is done according to anticipated demand/supply developments, but the scheduling is carried out according to the latest information updates.
Seasonal growing: primary production is often limited to a specific period, dependent on the climate, weather conditions and variety. This results in an unpredictable supply of produce in a short period of time.	• The design of the architecture enables that the information can be shared irrespective of specific locations. • In the designed architecture the flexibility to use different varieties with similar properties is supported. In this way intermediaries have more flexibility to match supply and demand than when having to find specific varieties on order of the retailer.
High demands from consumers and society, including food safety legislation and quality standards (food is something that is directly affecting the human body)	• The availability of advanced product information including certification information throughout the supply chain is an important part of the designed architecture. • Functionalities for product logo recognition are addressed. • In the designed architecture the information of the current and expected quality of the product is available to the consumer.
High volume distribution combined with frequent delivery and increasingly fine-mesh distribution	• In the designed architecture all relevant objects are uniquely identified using standards. Furthermore, the control systems are highly automated, particularly with UHF RFID technology, which reduces human errors. This is presumed to be more robust that manual control measures.
High flow complexities, in particular: - Sequential continuous (bulk, volumes/weight) and discrete (countable) product flows - Alternating diverging and converging processes and by-products	• The facilitation of EPCglobal standards in the architecture enable to use different identification technologies as well as aggregation and disaggregation events to handle different traceability schemes in the sector.
Important role of import/export, including phytosanitary and veterinary inspections	• The information exchange with authorities concerning trade and phytosanitary/veterinary documents is envisaged to be included in future work.
Complex network structure where small and medium enterprises (farms and parts of the processing industry) trade with huge multinationals in the input and retail sector.	• The architecture allows for decentralised approaches, which supports a high variety and variability of supply chain networks. • The designed architecture assigns a supply chain coordinative role to the trader in order to match the multinational demand of a big retailer with the fragmented supply of many different growers of flowers and plants. • The architecture enables all agri-logistics companies to participate independently from their size. • The approach includes cloud-based solutions to ensure participation of SMEs without sophisticated IT infrastructures. • The use of Generic Enablers support a rapid development of customized solutions at minimal costs

Acknowledgments

The research leading to these results has received funding from the European Community's 7th Framework Programme (FP7/2007-2013) under grant agreement n° 285 326.

References

EuropeanCommission, (2012). ICT Work Programme 2013. Publications Office of the European Union, Luxembourg, p. 170.

FIWARE, (2013). Overall FI-WARE Vision. Project Wiki, http://forge.fi-ware.eu/plugins/mediawiki/wiki/fiware/index.php/Overall_FI-WARE_Vision.

Guillemin, P., Friess, P. (2009). Internet of Things – Strategic Research Roadmap. European Commission Information Society and Media.

Kaloxylos, A., Eigenmann, R., Teye, F., Politopoulou, Z., Wolfert, S., Shrank, C., Dillinger, M., Lampropoulou, I., Antoniou, E., Pesonen, L., Nicole, H., Thomas, F., Alonistioti, N., and Kormentzas, G. (2012). Farm management systems and the Future Internet era. *Computers and Electronics in Agriculture*, **89**, 0:130-144.

Lehmann, R.J., Reiche, R., and Schiefer, G. (2012). Future internet and the agri-food sector: State-of-the-art in literature and research. *Computers and Electronics in Agriculture*, **89**, 0:158-174.

Meyer, G.G., Främling, K., andHolmström, J. (2009). Intelligent Products: A survey. *Computers in Industry*, **60**, 3:137-148.

Paul, S., Pan, J., and Jain, R. (2011). Architectures for the future networks and the next generation Internet: A survey. *Computer Communications*, **34**, 1:2-42.

Uckelmann, D., Harrison, M., and Michahelles, F. (2011). An Architectural Approach Towards the Future Internet of Things, In: Uckelmann, D., Harrison, M., Michahelles, F. (Eds.), Architecting the Internet of Things. Springer-Verlag, Berlin Heidelberg: 1-24.

van der Vorst, J.G.A.J., Kooten, O.v., and Luning, P.A. (2011). Towards a Diagnostic Instrument to Identify Improvement Opportunities for Quality Controlled Logistics in Agrifood Supply Chain Networks. *International Journal on Food System Dynamics*, **2**, 1:94-105.

Verdouw, C.N. (2010). Business Process Modelling in Demand-Driven Supply Chains: A Reference Framework. Ph.D. Thesis, Information Technology Group, Wageningen University, Wageningen.

Verdouw, C.N., Beulens, A.J.M., and van der Vorst, J.G.A.J. (2013a). Virtualisation of floricultural supply chains: A review from an Internet of Things perspective. *Computers and Electronics in Agriculture*, **99**, 1:160-175.

Verdouw, C.N., Sundmaeker, H., Meyer, F., Wolfert, J., and Verhoosel, J. (2013b). Smart Agri-Food Logistics: Requirements for the Future Internet, In: Kreowski, H.-J., Scholz-Reiter, B., Thoben, K.-D. (Eds.), Dynamics in Logistics. Springer Berlin Heidelberg: 247-257.

Verweij, C.A., Moolen, B.J.v.d. (2009). De agrologistieke kracht van Nederland. Nederland Distributieland (NDL/HIDC), Platform Agrologistiek, TNO, p. 38.

Vucic, N., Reiche, R., Sundmaeker, H., Verdouw, C.N., Robbemond, R.M., Koenderink, N.J.J.P., Meyer, F., Gülcü, N., Hernandez, J.G., Pimentel, D.Q., van Bekkum, M., Brewster, C., Tröger, R., Kläser, S., Cassing, Y., Lehmann, R., and Schiefer, G. (2012). Smart-Logistics Generic Enablers and Architectural Requirements, In: Wolfert, J. (Ed.), Smart Agri-Food. EU: 134.

Welbourne, E., Battle, L., Cole, G., Gould, K., Rector, K., Raymer, S., Balazinska, M., and Borriello, G. (2009). Building the Internet of Things Using RFID: The RFID Ecosystem Experience. *IEEE Internet Computing,* **13**, 3:1089-7801.

Zahariadis, T., Papadimitriou, D., Tschofenig, H., Haller, S., Daras, P., Stamoulis, G.D., Hauswirth, M., (2011.) Towards a Future Internet Architecture, In: Domingue, J.G., A.; Gavras, A.; Zahariadis, T.; Lambert, D.; Cleary, F.; Daras, P.; Krco, S.; Müller, H.; Li, M.-S.; Schaffers, H.; Lotz, V.; Alvarez, F.; Stiller, B.; Karnouskos, S.; Avessta, S.;and Nilsson, M. (Ed.), The Future Internet: Future Internet Assembly 2011: Achievements and Technological Promises, Vol. 6656 ed. Springer: 7–18.