A Real-Time Monitoring Service based on Industrial Internet of Things to manage agrifood logistics.

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Abstract. Quality and safety in logistic services for Agribusiness requires monitoring services in order to enable the tracing of products from the end consumer back to the field. To this goal, today monitoring is interpreted as a discrete series of simple data collected by actively scanning products; this is not sufficient to pro-actively manage logistics risks and represents an obsolete approach. There are lots of solutions for monitoring and tracking based on dedicated infrastructures but the market is lacking the real solution: real-time monitoring without an infrastructure. Industrial Internet of Things (IIoT) technology can generate an added value to logistics, especially in agribusiness, where waste, cold chain interruption and food contamination generate serious impacts on consumers' health and business continuity. See Your Box Ltd has developed an IIoT based technology able to fill the gap in the sector providing an innovative real-time logistics monitoring service.

Keywords: Monitoring, M2M, SCM, IIoT, Industry4.0.

1 Introduction

Agrifood industry is more and more under pressure from stakeholders which require products quality and safety for end consumer. In a global world, where agrifood goods are produced remotely from the end consumer, the knowledge about conditions of the products during processing and transportation requires systems able to track changes undergone by goods all along the supply chain from producer to the end-users, in order to eventually identify the product which suffered a damage and reconstruct its story from "farm to fork" and back.

Tracking currently requires a discrete series of points where the product is actively scanned (using Barcode, QR code, Smart Labels or Data Loggers), providing often just historical information collected at the moment in which scanning is performed. This cannot be sufficient in agrifood business where maintaining specific conditions (e.g. temperature, humidity, etc.) to prevent the degradation of the goods is essential to guarantee business continuity and reduce supply chain risks.

In scientific literature a lot of paper describes what is intended for "supply chain risks" but there is still no single, agreed definition of the term. For the scope of this paper most interesting is the definition of Zsidisin [1] who proposes a definition of supply risk that relates the occurrence of an incident with the inability of the affected companies to cope with the consequences. Tracing and tracking capabilities can be a first step to limit potential risks and, in the event of an incident, reduce the recovery cost [2], but, in this context, another step is necessary to completely monitoring the shipping.

Some authors proposed specific framework to support supply chain actors and allow them to share information [2], also creating specific ontology [3] with the aim of being connected with a Global Track&Trace Information System.

The framework for traceability of food along the supply chain [3] is characterized by the following elements:

1. Internal systems for registrations: traceability requires data from other management systems;
2. Lack of standardization: actors positioned within different geographical context (UE, USA, Asia, etc.) deal with different implementations of products responsibility and liability, from the regulatory point of view and there is a lack of standards for information encoding and exchange;
3. Financial obstacle: continuously operating information devices, able to regularly transmit information throughout the journey, are currently used based on Radio-Frequency Identification (RFID), Bluetooth, and Near Field Communication (NFC) technologies; these technologies rely yet on dedicated (and often expensive) hardware infrastructure, which needs to be installed as part of the

service; initial investments for the infrastructure can represent an obstacle for the large majority of companies involved in food chains (often SMEs);

4. Implementation issues: the implementation of T&T requires changes in processes and best practices;
5. Privacy and rights problems: the flow of products along the supply chain is associated with information flow among responsible actors and third-party organizations; traceability and quality information are significant for concerned enterprises and they need to be secured, this means a requirement for access and user rights, and data protection (privacy, commercial, and legal protection in case of responsibility).

In table 1 an overview of tools available on the market for no real time tracking without a dedicated infrastructure is reported [4].

Table 1: Current solution offered by the market: NO Real time & NO need for dedicated infrastructure

Characteristics	Bar & QR Code	Smart Labels	Data Loggers
Operational Costs	Low	Low	Medium high
Capital Costs	Low	Low	High
Energy for data maintaining	No	No	No
Energy for data reading/writing	Yes	Yes	Yes
Integration along supply-chain	Yes	Yes	No
Parameter monitoring	No	One parameter	One parameter
Tracking parameters recording	Passive (no real time)	Passive (no real time)	Only time parameters
Information on location	Limited	No	Single trip disposable devices
Transmission range	None	None	None
Need for human interaction	Yes (to scan/record data)	Yes (to read/record data)	Yes (to record/download data)

Within this framework, the Internet of Things (IoT) and, specifically, Industrial IoT, can be the answer.
The Internet of Things is a term introduced in recent years to describe objects equipped with digital functionality that are able to communicate via Internet [5] the scope usually is to monitor or manage the health and/or actions [6] of connected objects (e.g. machines, natural world, people, etc.). In table 2 tools available for real-time monitoring are compared with Industrial Internet of Things systems (i.e. IoT dedicated to business) which is the only technology able to both offer real-time information delivery and no need for a dedicated infrastructure.

Table 2: Current solution offered by the market: Real time & Dedicated infrastructure

Characteristics	RFID	Bluetooth	NFC	IIoT
Operational Costs	Low (for tags)	Low	Low	Low
Capital Costs	Medium (for infrastructure)	Medium	High	Low
Energy for data maintaining	No if passive	No	No if passive	Limited
Energy for data reading/writing	Yes	Yes	Yes	Limited
Integration along supply-chain	No (different organisations use different coding and labelling protocols)	Yes		Full
Parameter monitoring	Yes	Yes	Yes	Yes
Tracking parameters recording	Real-time only passing by barriers	Real-time where a signal exists	Real-time where detectors are installed	Real-time monitoring and transmission

Characteristics	RFID	Bluetooth	NFC	IIoT
Information on location	When passing barriers	No	No	Active tracking down to the single "thing"
Transmission range	Medium	Short	Very short	Long
Need for human interaction	No	No	No	No
Dedicated infrastructure	Yes	Yes	Yes	No

1.1 Industrial Internet of Things (IIoT) technology

In 1999, Ashton proposed the concept of IoT referring to interoperable connected objects with radio-frequency identification (RFID) technology which enable "computers to observe identify and understand the world without the limitations of human-entered data". In recent years, IoT became more and more interesting both for government, academic researcher and industry [7], [8], [9], [10] due to opportunities for transforming business process or enabling new business models (servitization). Very recently, Industrial IoT (IIoT) emerges as a sub-paradigm which focuses more in industrial and operations safety-critical applications [11]. IIoT technology's and data analytics use (record, monitor, manage) real-time data to enable and inform money saving decisions.

According to the analysts [6] the Internet of Things (IoT) has "the potential to fundamentally shift the way we interact with our surroundings" and most benefits are expected for B2B applications with interoperating IoT systems.

It is common a misunderstanding which bases this 'technology revolution' on the hardware devices needed to perform the task, forgetting the complexity of a system (the world of "things") in which about hundreds of trillions of elements could transmit information several time per millisecond. The scale of the challenge is massive and it needs a total rethinking of how to write software, set up servers, use databases in order to manage such a quantity of data being concurrently collected.

The challenge is even bigger when we add the level of criticality that these new services need to face: if an IoT network goes down it might lose control of vital machinery and even few minutes can generate disasters. Software quality insurance and high SLA (Service Level Agreement) levels are reaching a new level of science to provide the robustness, scalability and redundancy needed by the IIoT services.

IIoT architecture and technologies are described in [12], [13] and [14].

1.2 Industrial Internet of Things (IIoT) for agribusiness logistics

IIoT technology adoption has a clear impact on improving efficiencies in logistics, especially in agribusiness, where wastes, cold chain interruptions and food contamination have serious repercussions on consumers' health and on companies' reputation. In agribusiness, IoT-connected sensors can collect data about weather conditions, soil conditions, which allow to regulate the use of water, of pests and chemicals, to reduce waste, increase yield and guarantee compliance with current health and safety regulations. The ability to manage or even better to prevent delays and incidents leads to relevant cost savings, protection of valuable assets and allows more effective planning.

Sensors today are not only physical measuring devices such as thermometers or accelerometers, but they are virtual powerful tools that enable connections between people working in the field through mobile solutions [15], [16]. In the IoT, farm workers can receive real-time notifications from machinery equipped with wireless sensors as issues arise or accessing the weather forecast through the internet can inform the irrigation of a field and therefore optimize use of water and labor. In the wine making industry workers can record crop information from the vines and directly link the data to the company database to plan the harvesting. In livestock management, the cattle temperature can be monitored as an indicator for general health.

An IIoT system makes a lot of data to be available to improve agricultural processes performances and at the same time provides enhanced supply chain visibility, allowing the effective implementation of the famous slogan 'from farm to fork' which could grant a better food traceability and help stakeholders (people, farmers, distributers, governments) to have a higher level of confidence in the origin, safety and nutritional quality of food. IIoT technologies and data analytics can be used as an integrated tool to help food producers in the global market with growing population, limited resources and greater demand for social responsibility.

2 An innovative real-time logistics monitoring service: See Your Box Ltd

What See Your Box Ltd (SYB) [17] has developed is a technology able to close the gap in the sector.
SYB delivers a business to business real time monitoring service that provides a wide array of environmental and geo information to users without need for any dedicated infrastructure. SYB service ultimately allows merging the concept of tracking with that of monitoring.
Founded in 2013, SYB is a dedicated B2B service; it uses an Industrial Internet of Things based solution to provide a real-time monitoring service for goods shipped and stored internationally.
SYB service provides the integration of four technologies, a hardware device the size of a pack of cigarettes, an international communication network with dedicated transmission protocol a fully owned cloud server system and an easy way to integrate all information collected inside the companies' servers, as reported in Table 3.

Table 3: SYB Integrated solution

Device	Communication	Cloud system	Full Company System Integration
Operates both indoors and outdoors (with triple location technology) Months of rechargeable battery autonomy Programmable and re-programmable remotely from any web-enabled device Internal array of sensors	GSM network Dedicated globally available encrypted communication channel	Dedicated secured client area with 24/7 data access Data processing with on-going alert system Different rights driven account management Routing, map display Client dashboard view	API calls to allow integration with company IT server Possibility to transfer sensible data to the company server

The device powered with a standard mobile battery of 1500 mA can provide up to 3 month monitoring service depending from transmitting frequencies. The device guarantees a peak transmitting consumption of less than 20 mA. It can be configured in low power and ultra low power mode in order to consume no more than 5 µA. The device operates on GSM network and in a dedicated globally available communication channel, avoiding roaming charges (which are still prohibitive).
The main features of the server are the following:
- *scalability*: the system is easily scalable, being created inside a XenServer hypervisor; if more horsepower is needed, a consumer grade PC could be added in the server farm, and VMs replicate in the matter of minutes;
- *security and privacy*: each single data sent by the device is encrypted and directed over a secure channel; the data is stored inside a private own server and its backup is stored on another private owned machine, both secured;
- *customization*: extensive APIs will be provided in order to enable customer to easily integrate the service inside the client IT infrastructure; there is also the possibility to provide a website responsive and compatible with almost every HTML5 capable browser website for the client needs.
In Figure 1 the dimensions of the SYB device are compared to common objects.

Figure 1: SYB device dimensions compared to a pen and a smartphone

The way SYB interprets the word "monitoring" is that a wide array of environmental parameters such as shock, acceleration, light, temperature, sound, humidity and more are constantly integrated and enriched with data provided by the internet, such as rainfall, wind intensity and route conditions. Ultimately the monitoring information is "welded" together with proper geo-location data and represents the basis for future predictive statistical analysis, the big-data reporting.
The device is programmed over the air in order to work in different conditions, e.g.:
- On Call (Pull system) when a request is sent by the server, the device will reply with location (using antennas triangulation) and/or sensor reading (temperature, battery, accelerometer …);
- At discrete intervals (Simple push): the device antenna registration can be accessed at discrete intervals through a call to the international GSM network;
- On Alarm (Push): the device will spontaneously send and SMS and/or dial a number with required data when one or multiple sensor thresholds are infringed. On alarmed the device can also trigger an action (on/off relay to enter fly mode, kill car engine, start external siren…).
The real challenge for SYB is to make such a service a one stop solution, Simple, Secure and Smart at the same time so that final users do not deal with all the three complex technologies involved. In Figure 2 it is show how SYB works.

Figure 2: See Your Box system (Source: See Your Box, *How it works*, in: http://www.seeyourbox.com/index.html#/#howitworkssection, accessed 2016 April 8th).

Simple means you press a button and everything else happens automatically.
Secure means that while IoT of things is the ultimate "social network" where all personal information are shared, IIoT needs a high level of security where all the data are protected and encrypted all along their trip from the device to the company servers.
Smart means that goods are constantly monitored from 'from farm to fork' disregard the means of transportation, the kind of goods moved and the supplier chosen. But transporting eggs is not the same as transporting pineapples, therefore the system needs to self adapt and identify the right storage parameters that apply to the specific good.
SYB challenge is making the most of the potential of IoT technology to disrupt the existing markets and ensuring the integrity of quality assurance in transit, logistics risk management and the traceability of goods.
In Industrial Internet of things the solution is a service NOT a product. Relates your experience to what happens today when companies buy a car. They want a lease firm to take care of everything, maintenance, tires, insurance, gasoline and even highway tools disregard from the model of the car; same for Industrial Internet of Things.
Finally companies today have complex internal IT, ERP systems with different accounting permissions linked to the different responsibilities of their key employees. Such an extensive and powerful network of data needs to integrate with the existing system and to be available to the right individuals at the right time. Basically IIoT needs to make your box "*intelligent*".
Leveraging its experience with 4 international corporations, more than 5,000 hours of uninterrupted service and more than 1.5 million of data points collected over the three continents, SYB its launching its service on a big international scale. Based on test already performed in operational environment with successful outcomes, SYB device is positioned at TRL7 (Technology Readiness Level, [18]), that means that technology maturity corresponds to an actual system prototype demonstration in a space environment, at the scale of the planned operational system. This level of maturity can be obtained only assuring system engineering and developing management confidence over the purpose of technology

R&D. The device is capable to work in extreme conditions in the range [-35; +80] °C as required in the toughest cold-chain processes.

3.1 Experimental data

The qualitative and quantitative benefits coming from the adoption of SYB in agribusiness can be classified in two categories, as reported in Table 4.

Table 4: Benefits of SYB adoption in agribusiness

Quantitative (economics)	Qualitative (performance)
Higher revenues for high quality products	Prevention of deterioration
Reduction of cost for wastes due to deteriorated goods	Continuous monitoring of environmental/operational data
Improved production efficiencies	Improvement of logistics performance indicators
Improvement of inventory management and turnover	Early identification of ruptures of safety measures
Antitheft	Brand image protection
Reduction of insurance premiums	Process improvement based on analytics

Among qualitative benefits particularly relevant is the availability of data all across the supply chain and owned by the company directly responsible of food delivering to the consumer: this will generate a higher visibility for the agrifood company and consumer awareness of food safety responsibility. More, the continuous monitoring of environmental/operational data allows the companies to have the full record of important parameters (i.e. temperature and humidity) along supply chain even if several service providers are involved. The real-time monitoring allows also to early identify ruptures of safety measures along the cold-chain that could trigger deterioration and contamination and identify responsibility. The direct connection to a server allows to add a great deal of value to the collected information by analyzing big quantity of data to prevent new adverse events and improve the logistic process during a shipment., even in real time if needed. Shipment is the single most important measurement unit of SYB service; it last for a predefined period and is equipped with a specific set of features associated to the SYB device.
A shipment recently operated in Australia just showed how a huge quantity of eggs was having serious problems due to a several breaches in the cold chain process. The system was in “On Call” configuration, as requested by the customer. In Table 5 an extract of the analysis is provided.

Table 5: Parameter and Data Points

Parameter	Data Point 1	Data Point 2	Data Point 3
Temperature	8.5	24.3	8.5
Humidity	44.6	45	44.8
Shock	0	0	0
Unexpected opened box	0	0	TRUE
Route	Lat: -27.5 Long:151.96	Lat: -29.5 Long 149.87	Lat: -37.78 Long: 144.78

Data Point 1 is the starting point of the shipment, near to Brisbane (Australia), Data Point 3 is an intermediate point of the shipment in Melbourne (Australia), at a distance of about 1,500 km. The transported load (eggs) has to be maintained at a controlled temperature of 8.5 C (±1.5°C) and controlled humidity (maximum 50%). Moreover, the load, due to its fragility, should not undergo shock due to impact and unexpected opens of the box have to be avoided. SYB device is able to monitor all the requested parameters.
In Figure 3 the routing map display with data points.

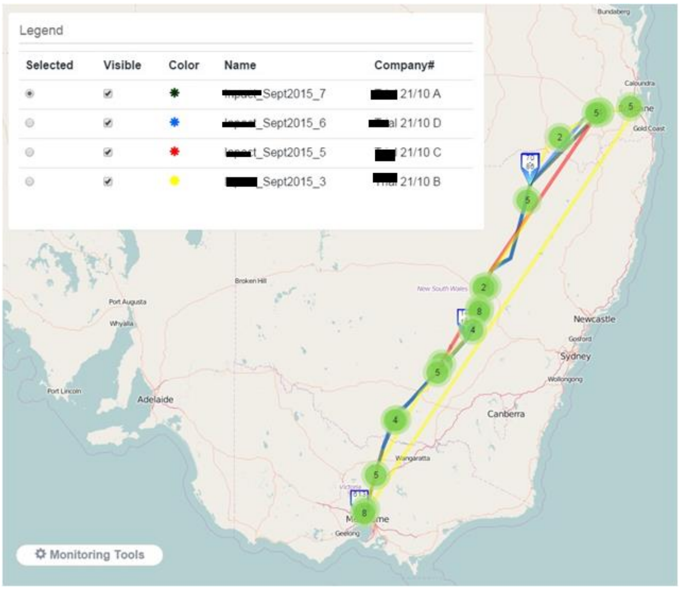

Figure 3: Data Point in See Your Box system

As shown in Table 5, at Data Point 2 a rapid increase of temperature was registered, due to a failure in the refrigerated transport system (as verified ex-post). The customer provided to fix the failure without opening the box and initially decided to prosecute with the shipment. When the load arrived in Melbourne (Data Point 3), the customer decided to open the container in order to verify the state of the load that had suffered a significant interruption in the cold chain (this action is registered using TRUE in the parameter "Unexpected opened box"), avoiding to sustain other costs for damaged products.
SYB system is then able to guarantee a "continuous" quality control on shipment, that is both product quality control, based on condition monitoring, and process control, also when the shipment process is managed by different companies along the supply chain, improving customer knowledge about partner reliability and responsibility in case of wastes.
The system can also be used as antitheft and to reduce insurance premiums.
About quantitative benefits it was assessed a reduction in variable costs in the range of 2%, while new products based on the service are to be launched.

3 Conclusion

According to the forecasts, the global population is expected to reach 9,6 billion of humans by 2050. Intensive farming practices due to increasing food demand have lead to scarcity of land and water resources dropping. In order to grow enough food and feed an ever rising population, farming industry must find a way to address declining yields, improve efficiency and mitigate the impacts of climate change.
The solution is embracing the Industrial Internet of Things (IIoT) technology, which will enable a full and complete control on all the steps of the food supply chain, efficient from a wastage point of view and transparent to the consumers' eyes.
'Smart farming' (as it has been called) will allow farmers and growers to improve productivity and reduce waste, ranging from the quantity of fertilizer used to the number of journeys made by farm vehicles.
IoT technology will be a key enabler for transforming the agricultural sector and creating the smart farming vision. In the next few months SYB will introduce the real-time monitoring logistics service for a variety of specific uses in the agribusiness sector. Operational system data will be used to inform new publications.
The ultimate aim of the research is to provide quantitative proof of the advantages to the food sector from using this technology to monitor the condition of goods in transit. Analysis of the operational data will enable us to evaluate the impact of real-time monitoring tools in this sector in terms of quality and efficiency.

Current research developments include:

- Transportation of premium water and wine and spirits: long distance cargo transportation may have a significant impact on the quality of goods at the point of use most related to temperature and light exposure, contamination and bottle breaking.
- Cold chain monitoring: monitoring of different stages of the journey during the frozen food process from producer to customers, large distribution or restaurants; SYB make it possible to avoid this lack of information and preserve the quality of products (via temperature and humidity monitoring) in the frozen food transportation process.
- Exotics fruits and vegetables: transportation by boat from South and Central America to Europe is a well established process, but there is a strong need for supply chain efficiency. For those companies, one of the main sources of additional cost is the charging of penalty fees for late delivery to large distribution clients (empty shelves). Adoption of SYB could provide advanced notice of product deterioration during cargo and boat transportation.

The technology developed is the perfect tool to optimize levels of production and reduce waste, providing a 100% control on all production. Exploiting IIoT at best is what SYB has been doing in the last two years.

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