IoT Application in the Supply Chain Logistics*

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Abstract. Using existing technology, nowadays it is possible to solve, or at least to reduce, most of the possible negative effects caused by the mismanagement of the supply chain process. In such industry, automation in product monitoring and control, inventory, customer relationship management, fleet tracking, etc., is a typical issue dealt by the companies who offer solutions for the individual problems. Transportation and logistics involves the delivery, movement and collection of goods through roads, and in the international case also through ports and airports. Consequently, it usually includes many actors, what complicates their management, efficiency and effectiveness. Therefore, time, boundaries, and interdependencies are the main difficulties in a chain supply. Besides, it raises several security challenges due to unintentional errors or intentional attacks. This paper presents a secure system to control the goods from their manufacture until their delivery to the end customer, which makes the work easier for custom authorities and all people responsible for goods in transit. In particular, we describe an innovative solution for the management of the complete supply chain process, which makes use of many different current IoT technologies such as RFID, EPC, Wi-Fi, GPS, QR codes, etc. in a safe and efficient way.

Keywords: Ubiquitous, IoT, QR Codes, Wi-Fi Direct, RFID, supply chain, distribution, logistic, transportation, tracking.

1 Introduction

Managers of companies know that competitiveness is not only achieved by optimizing the manufacturing lines, but also it is important to improve the supply chain, enhancing the productivity growth. Robust real time information is primordial for the operation of any organization. In particular, track and trace of goods, knowing where each thing is at any time, can be helpful to reduce storage

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costs, risk of loss or theft, etc. For this reason, it has increased attention placed on the performance, design, and analysis of the supply chain in order to struggle for efficiency and effectiveness.

According to the RAPEX report [1], the traceability of consumer products would improve Europe's ability to fight fraud and take action against unsafe products. This would be possible through a comprehensive control of the goods that reaches our borders, including details such as date and place of entry as well as the origin and destination of the imports. It also stresses the importance of monitoring and control of the goods at any time and place, since this would decrease the effects of dangerous goods that could enter our borders or thefts that may arise. For other possibilities in non-commercial situations such as disasters and emergencies, an effective supply chain for essential goods can mean the difference between life and death. Particularly, tracking and tracing goods as a process of determining the current and past locations of a unique item or property, reporting the arrival or departure of the object and recording the identification of the object, the location, the time, and the status, is a typical company's issue. In this line, Internet of Things (IoT) technology can help to improve every aspect of supply chain management, improving demand management, customization, and automatic replenishment of goods. Besides, it allows creating new safe and efficient schemes that add QoS and management traceability of transported goods. IoT permits to manage ubiquitous information about the transported goods through different types of communications and devices [2] integrated in the Smart Cities [3]. IoT expansion has been possible due to three existing issues:

1. Computer components miniaturization. They are getting smaller, making it easier to connect virtually anything, anywhere, at anytime.
2. Overcoming the limitation of the mobile telephone infrastructure.
3. Proliferation of applications and services that use the wealth of information created from the IoT.

This paper proposes the application of IoT to compare the transported goods with the delivery note, determine their origin and destination, and track and trace them from the distance. Such information will benefit not only the authorities but also the exporters and importers, who can control their merchandise, ensure its reliability, optimize its transportation through adaptive travel route assignment, and provide added value to the customers. Here we describe an innovative solution for the management of the complete supply chain process, which makes use of many different current IoT technologies such as RFID, EPC, Wi-Fi, GPS, QR codes, etc. in a safe and efficient way.

The rest of the paper is organized as follows. Related work is overviewed in Section 2. The security aspects are analyzed in section 3. Section 4 presents our proposed solution based on a ubiquitous system. Finally, conclusions and future works are given in Section 5.

2 Related Work

IoT in the transportation and logistics sector [4] and the supply chain management [5], [6] requires dealing with several problems related to the reliability and security of the used technologies. There are different works that describes solutions for the management of the complete supply chain process [7], which makes use of many different IoT technologies such as RFID, EPC, Wi-Fi, GPS, QR codes, etc. in a safe and efficient way. In [8] the author classifies different existing models to improve the supply chain and introduce different works for every model. [9] performs an analysis of efficiency and effectiveness of applying different strategies to improve the supply chain.

In [10] there is a review with more than 40 articles about simulation in the supply chain. There are also some apps in Google play store that helps and facilitate the tracking in the supply chain. One of them is Package Buddy [11]. This app allows tracking packages, from many carriers with a phone or tablet. This tool is not developed to control the supply chain but it can provide useful information to improve the timetable.

According to Dr. H. James Harrington [12] who has been involved in quality and performance improvement projects since the 1950s, 'Measurement is the first step that leads to control and eventually to improvement. To measure something allows understanding possible problems, at this way it is possible to control and improve. The theory is that improvements in quality lead to lower costs and higher productivity because they result in less rework, fewer mistakes, fewer delays, and better use of time and materials.

The Japanese philosophy, Just In Time (JIT) [13] is a production strategy that strives to improve a business return on investment by reducing in-process inventory and associated carrying costs. To meet JIT objectives, the process relies on signals or Kanban between different points in the process, which tell production when to make the next part. Kanban are usually 'tickets' but can be simple visual signals, such as the presence or absence of a part on a shelf. Implemented correctly, JIT focuses on continuous improvement and can improve a manufacturing organization's return on investment, quality and efficiency.

Companies without centralized supply chain governance can negatively impact procurement, manufacturing and time to market processes in supply chain, which can impact company's financial strategy. Supply chain risk management is an essential part of the supply chain governance system to ensure that risks are identified in the entire value chain and mitigated to deliver financial goals.

3 Security Aspects

The secure system proposed uses IoT to control the goods from their manufacture until their delivery to the end customer, which makes the work easier for custom authorities and all people responsible for goods in transit. However, the different technologies involved in the system for the supply chain are wireless and do not have a dedicated channel. Hence, it could allow getting information

about collected goods, delivery process, full history of the goods transportation and so on therefore, communication security is an important problem to be solve. In particular, our system has to protect authenticity, confidentiality, privacy and integrity in order to avoid the risk of penetration that could result in unauthorized goods tracking, data interception, modification or system access.

On the one hand, regarding authenticity and confidentiality, it must be ensured that only authorized users can access the system and the information about transported goods. This is solved in the proposal through the use of convenient access control and encryption systems. On the other hand, regarding privacy and integrity, it must be ensured that no information about transported goods can be accessed or modified by unauthorized users. In particular, in this work we use a standardized labelling with information about the goods origin and destination, which involves the possibility of unauthorized tracking and modification of such information. In order to avoid it, our approach includes several cryptographic algorithms to detect counterfeit information and to avoid unauthorized reading, writing or modification of labelling goods; besides, the information that demands privacy is ciphered. During the transportation, all the information is saved in the smartphone, and could be shared with other devices or sent to the cloud. Hence, accessing to this information requires credentials. The proposed labelling is designed to avoid the possibility of unauthorized tracking and modification of such information, however the cloning is another problem inherent of this technology [14] that allows tampering goods. For this reason, we also analyse it and propose a solution based on zero knowledge proofs [15].

Other security problems related to the supply chain [16] are physical aspects like tracking trains along a route, special situations that can happen at rail stations, fencing, urban areas, pit stops, or trucking routes. But physical problems are out of the scope of this paper.

4 Ubiquitous System Proposed

This paper proposes a system that, using existing technologies, allows having more information in real time and setting up alarms to detect changes in the container, it reduces risks of loss or theft. People involved and getting benefit of this proposal are suppliers, manufacturers, distributors, retailers, and customers. This secure and ubiquitous system enable the control of goods from their manufacture until their delivery to the end customer, which makes the work easier for custom authorities and all people responsible of goods in transit. In particular, it allows checking whether the collected goods are correct by detecting any error in the delivery process, providing on-line checking mechanisms and keeping a complete historical of goods transported, all of this, taking into account the safety and security needs required during the supply chain process. Furthermore, it includes several cryptographic algorithms to detect counterfeit information and to avoid unauthorized reading, writing or modification of goods labelled. The proposal implies minimum cost because it is based on affordable and usual devices such as RFID and smartphones, so it not only seeks to minimize economic

costs by using cheap passive tags, but it also reduces the effort to learn new technologies because people are familiar with smartphones.

The system, Fig.1, has different parts according to the step where the goods are in the supply chain. These parts are detailed below and can be summarized in: generation of the container receipt, read the QR information with the smartphone, check information of goods in the smartphone against the one located into the container, track and trace goods, send information by P2P for the authorities.

Fig. 1. Complete ubiquitous system

4.1 First Step: QR Container Receipt

The first step in our system is the container receipt generation with the products that will be available into the container and create a QR code corresponding to this container receipt. This container receipt has a known format consisting on: receipt ID, number of products, product code, the date, the source and destination of the goods, information about enterprises and carriers. The product code consists of 13 digits divided into four areas: The number system: two digits which identify the country, the manufacturer code: 6 digits assigned to each manufacturer, the product code: 3 digits assigned by the manufacturer, and the check digit: an additional digit used to verify that a bar code has been scanned correctly.

In order to protect the container receipt generation the content of the QR code can be cipher [17]. This ensures that the authorized person to read the content of the receipt note is who has the key. Alternatively to this step, it is also possible to keep the information of the commodity in the cloud and access it with an ID and password.

4.2 Second Step: Data Generation into the Smartphone

The second step corresponds to the driver who will transport the goods to the next place. To do this, the driver uses his/her smartphone to read the QR code with Transport Tracking app. If the QR code is cyphered, he/she has to write the key to decipher the content. After reading this code, the driver will have in his/her smartphone a list of products he/she has to transport, a container ID,

the date, the source and destination place they have to be transported and all the associated information. Alternatively, the driver can put only the container ID and download all information about the container from the cloud.

4.3 Third Step: RFID Validation

After having the list of products that will be carried on, downloaded on the smartphone the device tries to read the RFID reader that the container has. Fig.2 This RFID reader has a Wi-Fi interface to communicate with the smartphone. After reading, the smartphone checks every product in the list against the container. This is especially interesting not only in the charge moment but also, in every goods delivery to ensure that there is not any error. To protect the data privacy, the connection between the Wi-Fi interface of the RFID reader and the smartphone must be ciphered using WPA-2.

Fig. 2. RFID validation

4.4 Fourth Step: Web Service Fleet Tracking and Traceability

Nowadays two very important things are the traceability and fleet tracking. For this reason, the proposed system allows both of them but also to check if the goods are in the place they have to be at every moment.

The on demand request Fig. 3 allows asking the driver's smartphone to read the RFID container in order to know if everything is correct at this moment. The driver smartphone returns the answer where the possible responses are success or error. In case of error, it shows the detail of the problem. The user, who wants to request, has to be authenticated in the system and ask to the driver's smartphone.

Another possibility that this system allows is the configuration of goods reception alert. The system can be set up to send an alert when the container is near to the reception place. The driver's smartphone will send automatically a notification to the responsible of reception for everything to be prepared on his/her arrival. To ensure the privacy and security of data, the server in the cloud must be secure.

4.5 Fifth Step: Wi-Fi P2P Request

In order to facilitate the authorities work and help them to manage the commodity faster, there is an authority interface Fig. 4. This interface allows agents

Fig. 3. Monitoring and on demand request

to examine the content of every container without looking inside it. In this way, agents can check easily the sign, keys, date and all information about the enterprises and carriers of the content. If they find something strange or suspicious, they can carry out a thorough.

This interface must be secure and with access restricted to authorities therefore, a lightweight p2p authentication method like the one presented in [18] is required.

Fig. 4. P2P request

5 Conclusion and Future Research

In this work, a new logistic system that combines different technologies to facilitate the complete supply chain has been presented. The system allows checking in a quite flexible way the location of the commodities. It allows checking the merchandize during the charge or delivery where most of the problems happen. In addition, the system has an interface for authorities, which allows control of merchandise information. This tool reduces the authorities' work in order to perform the merchandise management in travels and custom areas.

Since it is a work in progress, there are many open questions to solve. For example, determine if the proposed encryption mechanisms for the different kind of communications are the most appropriate, analyse the time and risks in the supply chain, as well as compare the degree of improvement of our proposal against other existing tools.

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