Ubiquitous Computing Technologies to Manage a Transport Monitoring System

Pino Caballero-Gil, Cándido Caballero-Gil and Francisco Martín-Fernández
Department of Computer Engineering
University of La Laguna
38271 La Laguna Tenerife, Spain
Email: {pcaballe, ccabgil, fmartinf}@ull.edu.es

***Abstract*—Management of transportation and logistics includes delivering, movement and collection of goods through roads, ports and airports. In general, many different actors are involved in the actions, what makes more complex the administration and reduces efficiency and effectiveness. Some of the critical aspects that must be covered by a supply chain system are time, space and interdependencies. Added to them, there are several security challenges due to non-intentional or intentional errors. With this in mind, technologies such as RFID, GPS, WiFi Direct and LTE/3G can have the potential to automate product authentication and tracking of merchandise, solving or at least reducing, most of the negative effects caused by mismanagement or attacks against the weakest link in the process of the supply chain. Thus, this type of management can be considered a part of the Internet of Things useful to improve demand management, customization, and automatic replenishment of out-of-stock goods while reducing inventory and distribution costs, and counterfeit versions of name-brand items. Furthermore, it can be used to create safer and more efficient schemes that help enterprises and organizations to improve quality of service and traceability of transported merchandise. In this work, a new system is designed to be integrated in the transport of merchandise, enabling its follow-up through the cloud. The results of the implemented tool show that the combination of ubiquitous technologies provides a more complete and efficient service than existing services.**

I. Introduction

In transportation and logistics industry, automation in product monitoring and control, inventory, customer relationship management, fleet tracking, etc., is a typical issue dealt by companies who offer solutions for the individual problems. The main goal of this paper is to improve such solutions by making use of the Internet of Things (IoT) through the management of ubiquitous information about the transported goods with different types of communications and devices [1] integrated in the Smart Cities [2].

Secure real-time information is a must for the proper operation of any organization involved in the transportation and logistics sector. Particularly, tracking and tracing merchandise must cover current and past locations of every single item, including report of the arrival or departure, and record of the identification of objects, location, time and status. Such information can be very helpful for both owners and customers. Firstly, it helps to design and manage the Supply Chain (SC), adding security and interesting added information useful for the management of products, and establishing an new customer service. Secondly, internally, it allows examining how customers obtain benefit by improving the use of resources, reducing storage costs, risk of loss or theft, etc.

New entrepreneurial systems are paying more attention to the performance, design and analysis of the SC in order to reduce cost, improve efficiency and effectiveness, and launch new products with bigger benefits. Enterprise managers know that the competitiveness of their products is achieved not only by optimizing the manufacturing lines, but also by improving the SC.

The RAPEX report [3] indicates that the traceability of consumer goods would reduce fraud in Europe and allow taking action against unsafe products. This would be possible through a control of the merchandize that reaches countries borders, including details such as date and place of entry as well as origin and destination of goods. Furthermore, it stresses the importance of monitoring and control at any time and place, what would help to decrease the effects of dangerous goods that could enter the borders and decrease thefts that may arise. In addition, in some specific non-commercial situations such as disasters and emergencies, an effective SC for essential goods can mean the difference between life and death.

The study [4] estimates that in the U.S. excess inventories in 2004 were of more than $117 billion and many companies lost $83 billion due to coordination problems between elements of the chain. In order to have an efficient SC, a fast supply system must be responsive to customer demand shifts, and alert about any disruption. Besides, it must include the planning of the distribution, management of the warehouse and transportation fleet, and planning sales, operations, schedule and production. The collection of real- time data of the SC allows both better data management and planning.

In the industry of transportation and logistics, the automation in monitoring and control of goods, inventory, customer relationship management, fleet tracking, etc., is a typical issue that must be dealt by the enterprises that works with individual problems. The objective of this research is to improve these solutions by making use of the IoT, through managing information about the transport merchandise from the ubiquitous system that includes different types of communications and devices [1], [5]. The current expansion of the IoT is possible due to three different issues. The first factor is the miniaturization of computer components, because since they are getting smaller, it is easier to connect virtually anything, anywhere, at anytime. The second factor is the overcoming of the limitation of the mobile telephone infrastructure. Finally, the third factor is the proliferation of applications and services that use the wealth of information created from the IoT.

The innovative solution for the management of the SC described in this work makes use of many different IoT technologies such as QR codes, 3G/GPRS/LTE, RFID, EPC, Wi-Fi Direct, GPS, etc. all of then in a secure system. First, it enables to compare the transported merchandise with the delivery note. In addition to this, it allows to observe, trace and check via cloud, the transported goods from the source to the destination. Besides, the system includes an interface that allows fast checking of information relevant for authorities. Such information will benefit not only the authorities but also the carrier, who can reduce time, control their goods, ensure their reliability, optimize the transportation through adaptive travel route assignment, and provide added value to customers.

This work is organized as follows. A brief survey of some related works is provided in section II. The methodology used to deal with security aspects and risk factors in the SC is included in section III. Section IV provides a description of the proposed ubiquitous system. Finally, Section V closes the paper with some conclusions and future works.

II. Related Work

It can be foreseen that the IoT will be more and more important in the transportation and logistics sector and the SC management [6] [7], because these areas require dealing with several problems related to reliability and security.

The author of [8] classifies several existing models to improve the SC and explains the studied approaches for each model.

As explained in [9], most security issues in the SC are related to physical problems happening along the path, such as regular scheduled stops, long stops at night, breaks in fencing, stops near residential areas, unmanned trains and unlocked containers.

As aforementioned, the main aim of this research is to improve productivity and security of the SC by using the more advanced technologies of nowadays. Related with the main aim of this research, which is to improve productivity and security of the SC by using the more advanced technologies, [10] provides an analysis of the efficiency and effectiveness after applying several strategies to enhance the SC. The work [11] covers a review of more than two hundred papers related to green SC management.

The present work has taken into account the cloning problem of the used technology [12], consisting in tampering merchandise. In order to avoid it, the use of an ad-hoc solution to authentication based on Zero-Knowledge-Proofs [13] is proposed.

We can find in the Google Play Store, several apps to facilitate the tracking of goods in the SC [14] [15], which share some of the characteristics proposed in this work. However, the app here proposed allows tracking information from many carriers via web with any device like a laptop, phone, tablet, etc., starting from the delivery note, and tracing the merchandise in a secure way till the destination, combining different advanced technologies.

III. Methodology

In this research, a combination of international security standards, industry best practice, regional legislative documentation and related experience has been taken into account. With all this in mind, the proposed solutions provide security in the SC, and increase visibility and efficiency, by preventing and limiting the amount of cargo theft.

Several recommendations to secure SC systems exist, such as a set of minimal security requirements that are provided to all logistics partners. Some of them are: seal containers with highly secure locks, wrap all products with non-descriptive plastic in order to confuse potential criminals, and implement information security system to ensure that product information and transportation routes are not accessible to unauthorized personnel.

The aforementioned theoretical recommendations must be applied in practice. Therefore, the security of the proposed system is also based on their application. While applying them, the proposed system allows improving the SC by providing information in real time, and setting up alarms in case of changes in goods containers in order to reduce thefts.

The proposed system allows facing the control and improvement of the SC, so 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 goods. Hence, measuring the performance allows setting aims and evaluating the progress, by identifying the main aspects to refine, analyse the effects of the refinements, and solve possible issues. Particularly, in the SC, in order to develop an improvement of any sector, it is pertinent to know the starting situation, establish a realistic aim, decide how to measure the development in the system and set an action plan. This has been the method followed when designing the approach of this work. The Japanese philosophy known as Just In Time (JIT) 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 has to rely on signals between different points in the process, which tell production when to make the next part. Implemented correctly, JIT focuses on continuous improvement, so our proposal can be a useful tool to reach such a goal.

Companies without centralized SC management can negatively hit procurement, manufacturing and time to market course in SC, which can produce problems in the company's financial strategy. The management of the security risk is a fundamental part of the SC management system to guarantee that risks are identified in the whole value chain and mitigated to deliver financial aims. Particularly, the phases of the SC that must be covered by the system are specially manufacturing and distribution, suppliers, transportation, retailers, arrivals to the central warehouse, tracking of containers in docks, cranes or boats and wholesale and retail distribution centre.

In order to improve the SC logistics, we can define a set of goals like to reduce costs and maximize profits, improve reliability, minimize inventory, reduce delivery time, maximize equipment utilization, increase flexibility, improve simulation, reduce work in process, and reuse previous products.

Several tools exist to process the development of a dynamic SC model that allows having important insights and analysing the conduct and features of a SC. Most existing models and tools have been designed to address special issues that can be classified into one of the following categories:

- Optimization: The objective is to find the optimal operational guidelines that maximize or minimize a factor, such as cost, risk or profit.
- Decision Analysis: Typically involves the quantitative evaluation and comparison of two or more alternatives.
- Diagnostic Evaluation: In general, it is conducted when the cause of a particular problem is unknown.
- Risk Management: SC dynamics can be severely impacted by unanticipated disruptive events.
- Project Planning: Alterations in parts eventually produce disruptions, and short-term/long-term inefficiencies.

IV. Monitoring Transport System

The secure and ubiquitous system to control the goods from their manufacture until their delivery to the end customer here presented makes the work easier for custom authorities and all people involved in the transit of goods.

Particularly, the new system allows checking whether the collected merchandise is correct by detecting possible errors in the delivery process. Furthermore, it provides an on-line checking mechanism and stores a complete history of the transportation of merchandise. All this process is done taking into account the security requirements involved in the SC process by using cryptographic algorithms to detect counterfeit information and to prevent unauthorized reading, writing or modification of labelling merchandise.

The approach involves a minimum cost as it is based on affordable and usual devices such as low-cost RFID and smartphones, so not only reduces economic costs by using inexpensive passive tags, but also minimizes the effort to learn the use of new technology because most of people are familiar with smartphones.

Most of the companies related to SC logistic take advantage of RFID technology because it allows them validate information about goods and locate them easily and quickly inside the container [16] [17].

The typical SC is normally composed by five players: supplier, manufacturer, distributor, retailer and customer. The proposed scheme has different parts according to the five stages in the SC where the merchandise can be:

- generation and extraction of QR data of container goods
- RFID validation of goods
- web service for fleet tracking and traceability
- Wi-Fi P2P request for customs check

Each one of the different types of relationships in the SC has its own characteristics. For this reason they must be dealt with in different ways. The different technologies here proposed are shown in Fig. 1. These technologies have been proposed to reach the best solutions for these relationships.

A. QR Bill of Goods

The first stage in the operation of the designed system is the generation of the bill of goods, which includes relevant information about the products that are inside the container, apart from other relevant information. This receipt has a specific format consisting on:

- related enterprises and carriers
- origin and destination places and corresponding dates
- receipt ID, 13-character codes identifying the products and quantity of each product
- other relevant information

The tool generates the QR code containing all the formatted information of the bill of goods, and encrypts it so that the only way to read its content is by using the shared secret key. The resulting QR code is copied in the same data sheet of the bill of goods.

The way to generate the QR code about the information is with an on-line service [18], but the information is encrypted before creating the QR code.

B. QR Information Extraction

The carrier executes the second stage through the transport-tracking app. The smartphone reads the QR code using the app (see Stage 1 in Fig. 2), and its content is decrypted with the shared key that was previously stored in the device. After reading the code, the driver has all the data of the QR bill of goods stored in his/her smartphone.

The development of the reading of QR codes in the Android platform was done by using a library called Zxing (see working in first smartphone in Fig. 3). Later, information is stored in the local device into an SQL database. All the information related to origin and destinations can be also seen in the device by using Google Maps Android API v2.

C. RFID Validation

Once the list of transported products is in the device, the smartphone may be used with an RFID reader to consult the tags inside the container. To do that, the RFID reader must have a Wi-Fi interface to exchange information with it. Later, the smartphone has all the information to check whether every product in the list is inside the container (see Stage 2 in Fig. 2). This stage is especially interesting not only in the loading of merchandise in the container, but also in every delivery of merchandise to reduce possible errors. Furthermore, by using RFID readers in the container it is also possible to know the approximate position where a product is. In order to protect data privacy, the connection between the Wi-Fi interface of the RFID reader and the smartphone is encrypted using WPA-2.

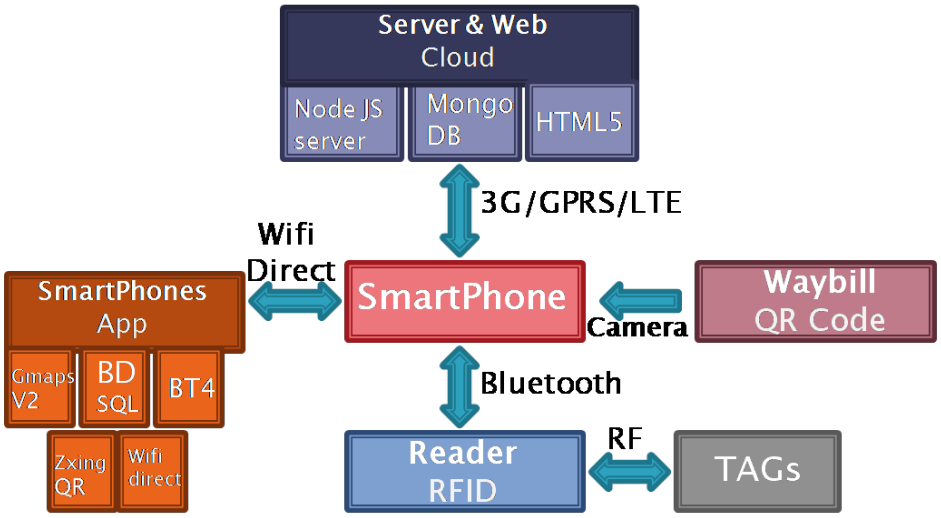

Fig. 1. Relationship between technologies for the ubiquitous SC system

D. Web Service for Fleet Tracking and Traceability

Firstly, fleet tracking allows checking whether the merchandise is in the place that it is supposed to be at every moment (see Stage 3 in Fig. 2). Secondly, specific details about the path of the merchandise can be discovered with traceability, allowing the detection of possible bottlenecks to improve the next parts of the route. The option on-demand-request enables asking the driver's smartphone, which recovers information from the RFID reader about the content of the container at that moment. The driver's device sends the answer that can be either OK or Error, and in this latter case the details about the problem are attached. In order to keep privacy, only users with privileges can see this information.

The tool has other additional features, such as possible configuration of alarms in case of good reception or when the carrier is next to the reception place. In this way, the driver's smartphone will send automatically a message to the responsible of reception.

The server in the cloud is secured to to guarantee data privacy and security. The Web Platform has been implemented by using a Node JS server with Mongo DB for data and Express framework to create the web services for Node JS. For the responsive front-end, Bootstrap framework and GMaps API have been used.

Fig. 2. Functionalities of the ubiquitous system for the SC

E. Wi-Fi Direct Request

Another interesting option of the system is a short-distance interface to facilitate authorities work and merchandise management. In order to do that, the app has an interface that identified agents can use to examine the content of every container without looking inside (see Stage 4 in Fig. 2). Thus, they can check quickly and easily whether all the information about companies, carriers and merchandise is correct before further actions. In case of suspicious information, they can proceed to a physical control so that they can check the content and see whether it corresponds to the information the system provides. This interface is secured as only authorized people can access to the information through it. In particular, a lightweight P2P authentication method similar to the one presented in [19] is used. The implementation of this interface has been performed by using the Wi-Fi Direct APIs for Android (see Fig. 3).

Fig. 3. Android implementation of the tool for the SC

V. Conclusion and Future Research

This paper has proposed a new system to improve efficiency and security of logistic management in Supply Chain, which combines different technologies. In particular, it allows checking the cargo not only in the loading and delivery moments, which are the places where most problems usually happen, but also at any time and place, as it offers a system for tracking and tracing merchandise on demand. In addition, the system interface to control the goods allows a fast and easier control of goods by authorities in custom areas.

Both, the tool implemented in the Android platform, and the Web service are in Beta version and will be soon available in the Google play store and online, respectively. Since this is a work in progress, many open questions exist, such as the choice of the most appropriate encryption mechanisms for the ubiquitous communications, the analysis of the time and risks involved in the proposed SC tool, and a comparison between the improvement degree of the proposal and other systems.

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References

[1] D. Giusto, A. Iera, G. Morabito, and L. Atzori, The Internet of Things, 20th Tyrrhenian Workshop on Digital Communications. Springer, 2010.

[2] J.M. Shapiro: Smart Cities: Quality Of Life, Productivity, And The Growth Effects Of Human Capital. Review of Economics and Statistics 88(2), pp. 324-335, 2006.

[3] European Rapex Reports. Available at http://ec.europa.eu/consumers/safety/rapex/ [retrieved: May, 2014]

[4] C investment hot. U.S. companies have begun to attack the more than $117 billion in excess inventory and $83 billion in lost sales. Material Handling Management, 2004.

[5] R. Angeles, RFID Technologies: Supply-Chain Applications and Implementation Issues. Information Systems Management 22(1), pp. 51-65, 2005.

[6] D. Simchi-Levi, Designing and managing the supply chain, Mcgraw-Hill College, 2005.

[7] M. Christopher, Logistics And Supply Chain Management: Creating Value-Adding Networks, Pearson Education, 2005.

[8] B.M. Beamon, Supply Chain Design and Analysis: Models and Methods, International Journal of Production Economics 55(3), pp. 281-294, 1998.

[9] H.L. Lee, S. Whang, Higher supply chain security with lower cost: Lessons from total quality management, International Journal of production economics 96(3), pp.289-300, 2005.

[10] D. Turker, C. Altuntas, Sustainable supply chain management in the fast fashion industry, An analysis of corporate reports, European Management Journal 32(5), pp. 837-849, 2014.

[11] S.K. Srivastava, Green supply chain management: a state-of-the-art literature review, International Journal of Management Reviews 9(1), pp. 53-80, 2007.

[12] D.C. Ranasinghe, S. Devadas, P.H. Cole, A Low Cost Solution to Cloning and Authentication Based on a Lightweight Primitive, Networked RFID Systems and Lightweight Cryptography, Part IV, Springer, pp. 289-309, 2008.

[13] P. Caballero-Gil, C. Caballero-Gil, J. Molina-Gil, C. Hernandez-Goya, Self-Organized Authentication Architecture for Mobile Ad-hoc Networks, 6th International Symposium on Modeling and Optimization in Mobile, Ad-Hoc, and Wireless Networks, pp. 217-224, 2008.

[14] Package Buddy, Available at play.google.com, [retrieved: May, 2015].

[15] Package Tracker Pro, Available at play.google.com, [retrieved: May, 2015].

[16] M. Bouet, A.L. Dos Santos, RFID Tags: Positioning Principles and Localization Techniques, Wireless Days, pp. 1-5, 2008.

[17] B. King, X. Zhang, Securing the pharmaceutical supply chain using RFID, International Conference on Multimedia and Ubiquitous Engineering, pp 26-28, 2007.

[18] QR Code Generator, https://www.the-qrcode-generator.com/, [retrieved: May, 2015]

[19] C. Caballero-Gil, P. Caballero-Gil, A. Peinado-Dominguez, J. Molina-Gil, Lightweight Authentication for RFID Used in VANETs, Lecture Notes in Computer Science 6928, pp. 493-500, 2012.