Enhancing the Information Transmission for Pharmaceutical Supply Chain Based on Radio Frequency Identification (RFID) and Internet of Things

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***Abstract*— Information transmission is one of the important features desired in pharmaceutical supply chain. But, at the same time, it is a challenge task as there is an information transmission lag in the existing model of supply chain management. The need of supply chain visibility and transparency in pharmaceutical industry has increased tremendously with the emerging auto-identification technologies. The motivation to introduce auto-identification technologies could be to gain rapid benefits in visualization of supply chain information. Radio Frequency Identification (RFID) and EPC can be used to meet this attempt. With the advent of accurate and reliable information transmission, various supply chain concepts, such as adaptive logistics management, virtual warehouse, and counterfeit combat can be achieved. The main aim of this paper is to outline the possibility of applying RFID and Internet of Things in enhancing the pharmaceutical supply chain information transmission. Based on the study, benefits and issues related to such technologies integration are discussed.**

Keywords-information transmission; supply chain information; radio frequency identification (RFID); internet of things; electronic product code (EPC); pharmaceutical industry

I. INTRODUCTION

Pharmaceutical industry is one of the major and rapid growing industries in the world, which deals directly with the health care. Unlike other industries like textile and electronic component manufacturing, defective and sub-standard medicines, cannot be sold in the market as it may cause danger to the life of human beings and even animals. All the medicinal products must achieve the certain universally accepted quality standards before they are sold. Thus, as discussed by [1], the quality considerations are the main objectives of pharmaceutical industry. In order to guarantee the quality of the medicines, numerous studies have currently been focused on monitoring the medicines' manufacturing process as well as its distribution process [2][3][4]. However, although numerous quality regulations are taken to ensure the manufacturing process of medicine, 5 to 7% of pharmaceutical products worldwide are estimated to be counterfeit goods [5]. Such deficiency is mainly due to the insufficient information transmission capability among the supply chain parties.

To enhance the information transmission capability, auto-identification technologies serve as a promising tool in visualizing the information between enterprises in the supply chain. Among of these technologies, radio frequency identification (RFID) has been widely adopted in supply chain management for better track-and-trace the product movement. Numerous studies have shown that RFID can significantly improve the problems mentioned for the domain industry [2][6]. RFID is a technology that uses radio frequency waves to communicate between a reading device and a small electronic transponder (also known as a tag) without human intervention. Communication takes place when the tags fall within the interrogation zone of fixed or portable RFID readers. Using this technology, unique tagged-object information encoded in a microchip integrated with antenna, can be captured and transmitted automatically.

To further extend the monitoring capability of RFID, Kwok et al. [7] proposed to integrate the RFID and Electronic Product Code (EPC) technologies for creating an "Internet of things" that enables automatic information acquisition and effective information sharing in a supply chain. They developed a Mobile EPC-RFID based Self-validation System (MESS) to visualize the RFID data transaction associated with EPCglobal Network. EPC is a collection of interrelated standards for hardware, software, and data interfaces, together with core services operated by the EPCglobal. All the EPC are shared and transmitted under the umbrella of EPCglobal Network. Therefore, in theory, with the Internet of things in place it is possible to track every tagged item on earth. When applied to supply chain information transmission, RFID can be deployed to track mobile equipment and movable assets, such as pallets and vehicles, and even combating the counterfeit problems encountered in the product transmission.

The purpose of this research study is to first, investigate the problems faced in supply chain information transmission in pharmaceutical industry, and study the current and existing approaches and strategies to tackle the information transmission problems. Second, explain the basic of RFID technology and Internet of Things. Third, discuss the benefits and issues when applying RFID and Internet of Things in supply chain information transmission enhancement. And finally, draw conclusion on adopting RFID and Internet of Things in supply chain information transmission.

II. INFORMATION TRANSMISSION IN PHARMACEUTICAL INDUSTRY

Supply chain networks reflect the concept in networking relationships between internal units of organizations as well as external exchange among the organizations [8][9]. In today's business world, the supply chain of pharmaceutical industry

has a tendency to get complex as the medicine follows a disjointed supply chain [10]. Generally, there are two existing practices for the medicine transaction in the pharmaceutical industry. The first one is a direct transaction process, in which the medicinal products are flowed from manufacturers to customers through the channel of retailers (such as clinic, hospital, and drug store); whereas another one is a wholesale transaction process, in which the products are flowed through wholesalers and retailers. Fig. 1 depicts the entire pharmaceutical supply chain process from the raw material receipt to the end of purchase of customers. It is found that the movement of the product from the manufacturers to the end-users is a long chain, in which the information transparency is critical to enhance the operational practice of the company. With the advent of higher information visualization, medicine recall, correct inventory control, stock management, as well as replenishment can be significantly enhanced.

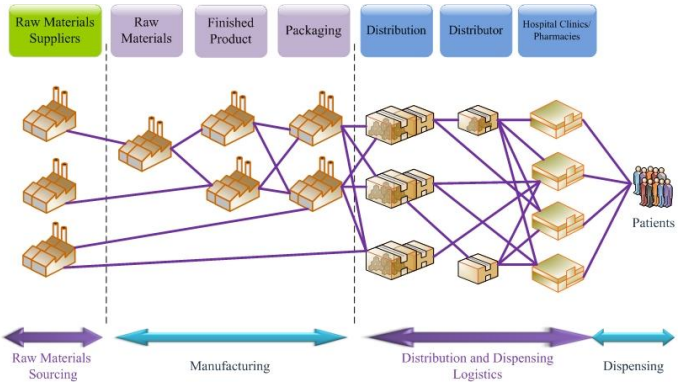

Figure 1. Supply Chain in Pharmaceutical Industry

Furthermore, another major problem caused by the lower information transmission is the counterfeiting issue. Although Good Manufacturing Practice (GMP) regulations [11] are used to govern the control and management of manufacturing and quality control testing of pharmaceutical products, the influx of unacceptable medicine is constantly revoking. According to the study conducted by ICC Counterfeiting Intelligence Bureau [12], counterfeiting issues are now constantly one of the serious issues in today's manufacturing industry. The insufficient information transmission among supply chain parties make them difficult in assuring the product lifecycle safety, especially the product authentication problems [13].

Throughout the visualizing the supply chain information, parties within the chain can share and access the product movement information for improving their responsiveness, planning, decision making; and quality of products [9]. For example, when such concept is applied in counterfeiting, these supply chain information can form a location-based authentication measure in determining whether the product is moved through an agreed pattern, which has been widely highlighted and discussed in [7]. At present, Mitra and Singhal [14] summarizes the alternative of supply chain information sharing mechanism which includes Electronic Data Interchange (EDI), Extensible Markup Language (XML), extranet, private marketplace, industry exchange, neutral exchange, and so on. However, all these mechanisms require lot of human involvement, which may be resulted in human errors; thus an auto-identification and sharing framework are the new means of enhancing information transmission.

III. RFID AND INTERNET OF THINGS

RFID technology has the potential to replace barcode, the traditional scan-based data collection technology, as RFID provides significant improvement in product identification and tracking [15][16]. The main differences between barcodes and RFID are summarized in Table 1. The distinctive capability of RFID is its ability to operate at higher data communication speeds with large data storage capacity, and it supports automatic retrieval of data without physical contact. In particular, RFID has three important features that make it better than barcodes when applied to information transmission:

- *Read Range and Interference*. One of the important advantages of RFID technology is its long read range. An item with a barcode must be scanned directly by a laser beam with no obstacle between the scanner and the label. In RFID, the read range is longer and tags can be read even when blocked by an obstacle.
- *Visibility*. Barcode technology has been widely used in supply chain management in the past 30 years as barcodes can contain information about manufacturers, product families and type, which has increased the effectiveness of supply chain operations. However, barcode technology is limited to information at the Stock Keeping Unit (SKU) level, where different items with the same SKU share the same ID. This is a disadvantage for lots of businesses including those in the retail industry, as shop managers are unable to identify the specific items of a given SKU that have been sold. RFID technology can be applied at the item level as each product can be assigned a unique ID. This enables specific items in the supply chain to be tracked, which enhances the visibility of the supply chain operation.
- *Read/Write Tag Data*. Barcode data is fixed once it is printed. It cannot be altered unless replaced by a new label. RFID tags, on the other hand, can be reprogrammed to store updated information, which provides users with greater flexibility.

An RFID system has three major components: the tags, which store the unique identification information of tagged-objects; the readers, which detect and communicate with tags to extract information; and the antennas, which transmit the data as radio signals. Fig. 2 shows how the technology works. The item is attached with an RFID tag that stores its unique identification number. When the reader sends out a radio signal, the tag responds to identify itself. The reader then converts the radio waves returned from the tag into data that can be passed on to an RFID middleware (i.e. a piece of software that facilitates communication between different channels) for filtering and analyzing the identification information. The wide range of printers and readers, each with a different interface, available in the market around the world makes interoperability of systems difficult to achieve. Thus,

middleware is needed to convert the scanned information into standardized format for better communication with the enterprise software (like warehouse management system and enterprise resources planning system) that already exists in the company, and storage of all the information in databases for future use and analysis.

TABLE I. COMPARISON BETWEEN RFID AND TRADITIONAL DATA COLLECTION TECHNOLOGY

	RFID	**Traditional Technology (e.g. barcode)**
Function	Identify unique individual items	Identify types of products
Data Communication	Does not require line-of-sight	Requires line-of-sight
Data Type	Dynamic data – read/write and rewritable	Static data – read only
Human Intervention	Hands free operation	Needs hand-held scanners to read information
Speed	Fast – one-to-many (up to 300 reads/sec)	Depends on of the operator – one-to-one
Tag Life	Long	Will wear out quickly with use
Data Storage	Large	Limited – only stores numeric codes
Security	High	Low

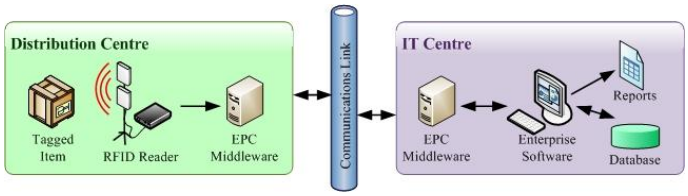

Figure 2. A Schematic Diagram of an RFID System

To leverage the autonomous data capturing supported by the RFID technology, an effective product information sharing platform helps to disseminate and improve the information sharing among parties involved in the supply-chain. Due to Wal-Mart's mandate, the Electronic Product Code (EPC) standard is probably the most popular RFID standard. Currently managed by the EPCglobal Inc., a subsidiary of GS1, was the creation of the MIT Auto-ID Center, a consortium of over 120 global corporations and university labs. The EPC architecture is a family of interrelated standards for hardware, software, and data interfaces, together with core services. It is designed to meet the needs of various industries, while guaranteeing uniqueness and interpretability for all EPC-compliant tags. As shown in Fig. 3, some of the key technologies regarding the exchange of production information are:

- *EPC Information Services (EPCIS).* The EPCIS is the primary vehicle for data exchange between supply chain parties in the EPC network. It functions as the data repository that provides standardized interfaces for handling queries and returning results, and it is also responsible for authenticating the parties involved in the data exchange to ensure security.
- *Object Naming Service (ONS).* Similar to the mechanism for locating resources in the Internet by domain name service (DNS), the ONS server returns a list of network addresses and redirects queries to different parties containing the actual data associated with a given EPC.

Incorporating RFID technology and EPCglobal network, the so-called "Internet of Things" allows autonomous information acquisition and effective information sharing. With the ratification of the EPCIS standard in April 2007, Bacheldor [17] stated that the EPCIS standard will unlock the full potential of EPC communications and this is expected to have a big impact on RFID adoption. Perfect information transparency will be achieved throughout the supply chain network. Fig. 4 summarizes how RFID technology and Internet of Things can improve the pharmaceutical industry.

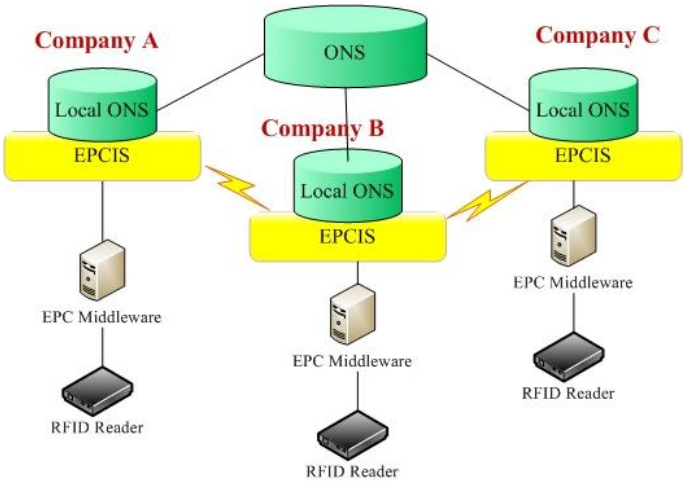

Figure 3. Architecture of EPC

IV. APPLICATION OF RFID AND INTERNET OF THINGS IN PHARMACEUTICAL SUPPLY CHAIN INFORMATION TRANSMISSION

Pharmaceutical industry is a special industry that has always been highly concerned by governments and customers, as the number of crimes on counterfeit drugs has greatly increased in recent year. Since many counterfeit goods, especially those in the health and safety categories, are of inferior quality, such products had been the cause of a number of major public health and safety incidents; thus counterfeiting is a global problem that produces financial losses as well as public health and safety threats [7]. In order to promote a healthy environment for the pharmaceutical industry, new technologies must be employed to realize the information visualization of the medicinal products (like the product movement within the supply chain).

As above mentioned, integration of RFID and EPC holds the promise of unprecedented supply chain visibility, so as to facilitate the information transmission among the supply chain

parties. With correct implementation of such system in place, accurate and reliable supply chain information can be visualized for improving the supply chain concepts like adaptive logistics management, virtual warehouse, and counterfeit combat. It is expected that such integration is a promising approach to address the problems in pharmaceutical supply chain, especially the issues of insufficient information transmission. Fig. 5 shows the architectural model of how RFID and EPC can be applied in the pharmaceutical industry.

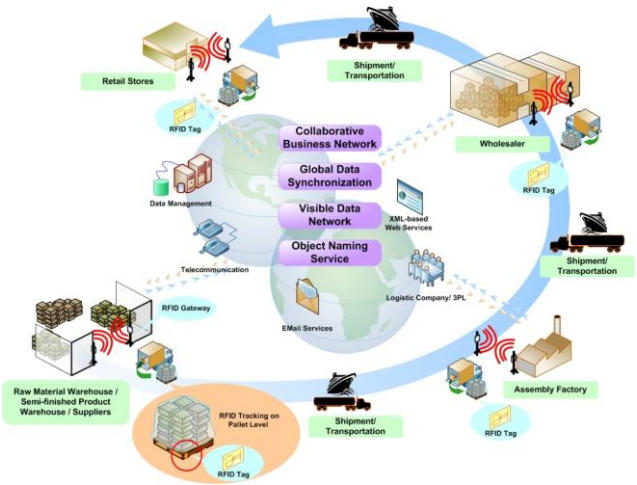

Figure 4. Adoption of RFID and Internet of Things in Pharmaceutical Supply Chain

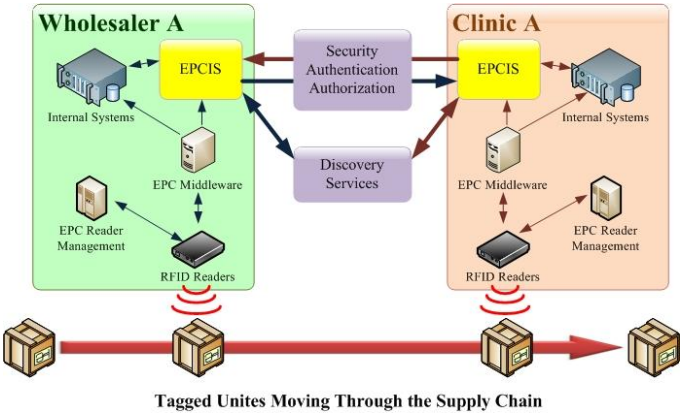

Figure 5. Architectural Model of RFID and EPC in Pharmaceutical Industry

As shown in Fig. 5, each medicinal product is attached an EPC tag (RFID coded with a unique EPC) for identification propose. In particular, 96-bit EPC tags are the most commonly used in industry because their data capacity is sufficient for most applications. With the large capacity provided by the EPCglobal Inc., each company has up to 68 billion unique serial numbers for each product. Other than the identification number, other product related information (like the production date, manufacture information, and shipment date) are stored in the EPCIS. With the help of the automatic capturing capability of RFID, the product information can be updated from point to point. Furthermore, users can even simply visualize particular product information by enquiring the unique identification code provided in EPC, as shown in Fig. 6. As a result, all the parties (i.e. from manufacturers to the end of customers) within the supply chain can be benefited by the implementation of Internet of Things.

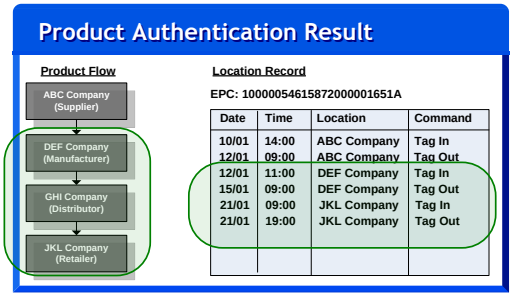

Figure 6. Example of Supply Chain Information Visualization

With the enhancement of supply chain information visualization, several benefits can be achieved in the pharmaceutical industry. For example, the higher information transmission can enhance the productivity in shipping and receiving, accuracy in shipping and dispensing, and even the product recall when the products are problematic. Furthermore, it goes well in the case of fighting against medicine counterfeiting problems, as depicted in [2][6][7].

V. CONCLUSION

Benefits of the application of RFID and EPC in enhancing the pharmaceutical supply chain information transmission are obvious. In this paper, we discussed that information sharing is a basic condition for a successful supply chain management, especially for medicine counterfeiting. It is possible to observe that the supply chain information can be captured automatically and visualized smoothly. According to the practical problems encountered in pharmaceutical supply chain information transmission, this paper has reviewed and discussed the current applications and their related issues of RFID and EPC integration in supply chain information transmission.

However, since the adoption of RFID and EPC is still in the infancy stage, this paper also discusses its development has experienced explosive growth. This provides support and considerations for pharmaceutical company and other healthcare services providers to further adopt the application in global and standardized fashion, so as to realize its full potential as a higher information transmission solution and supply chain analyzer.

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