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An Inside Look at RFID Technology

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Abstract

RFID (Radio Frequency Identification) is considered one of the "hottest" technologies due to its particular capabilities to track and trace in real-time objects across the extended supply chain. This article gives an inside look at the RFID world in order to improve the level of understanding of this technology and the EPC Network. An introduction to RFID's systems, RFID's potential to improve the efficiency of operations, different areas of application, as well as a roadmap approach to undertake an RFID implementation will be discussed in this article.

Keywords

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AN INSIDE LOOK AT RFID TECHNOLOGY

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Abstract

RFID (Radio Frequency Identification) is considered one of today's "hottest" technologies due to its specialized capacity to track and trace objects across the extended supply chain in real time. This article takes an inside look at the RFID world in order to improve the understanding of this technology and the EPC Network. An introduction to RFID systems, RFID's potential to improve the efficiency of operations, different areas of application, and a roadmap approach to implementing RFID will be discussed in this article.

Keywords: Radio Frequency Identification, EPC Network, RFID applications, RFID projects.

1. Introduction

Radio frequency identification (RFID) is considered as "one of the most pervasive computing technologies in history" (Roberts, 2006). However, the RFID concept is not new but has been around for decades; in fact, it was introduced to the world for the first time during World War II by the British Air Force to distinguish Allied aircraft from enemy aircraft using radar (table 1 provides a brief overview of the history of RFID technology). Since then, this technology has been used for various niche applications such as antitheft systems, luggage tracking systems in airports, electronic toll collection systems, etc. (Smith and Konsynski, 2003). Nevertheless, recent technological advancements, the decrease in RFID infrastructure costs, and efforts to establish standards have renewed the interest in RFID adoption; there was a "boom" in early 2003 due to demands by Wal-Mart and the US Department of Defense (US DOD) that their major suppliers should adopt and implement the technology by the beginning of 2005.

This interest in RFID is highlighted by many recent white papers published by technology providers (e.g. Intermec, 2006; Texas Instruments, 2004), consulting firms (e.g. BearingPoint, 2004; Accenture, 2005), infrastructure providers (e.g. HP, 2005; Sun Microsystems, 2004), enterprise software providers (e.g. SAP, 2005), and solution providers (e.g. IBM, 2003).

In the academic community too, there is rising interest, leading to the publication of several RFID-related research articles in areas such as innovation management (Sheffi, 2004), product life cycle management (Harrison et al., 2005), project management (Bendavid and Bourgault, 2005), decision support systems (Ngai et al., 2005), supply chain management and warehousing (Bendavid et al., 2007; Srivastava, 2004), e-commerce (Lefebvre et al., 2006) and mobile business (Fosso Wamba et al., 2007). Moreover, the RFID market is growing. Indeed, the worldwide market for this technology is expected to expand from US$1.95 billion in 2005 to US$26.9 billion in 2015 as different RFID applications mature (Research and Markets, 2005).

Table 1: RFID's History

Date	Event
1930 - 1940	American navy research laboratories developed a system known as IFF (Identify Friend or Foe).
1940 - 1950	The first application of RFID consisted of identifying Allied or enemy planes during WWII through the use of the IFF system.
1950 - 1960	IFF technology was used to develop the modern air traffic control system. First RFID applications in the military sector, in research laboratories and in major commercial enterprises.
1960-1970	Sensormatic and Checkpoint Systems introduced new applications for RFID, such as electronic article surveillance (EAS) equipment.
1970 - 1980	Technological advancements led to the creation of the passive tag, and the first initiatives for animal tracking and factory automation took place.
1980 - 1990	Many American and European companies started to manufacture RFID tags. First RFID application for automatic toll payment.
1990 - 2000	Standards for RFID equipment interoperability were developed.
2003	The Auto-ID Center from MIT became EPCglobal, an organization whose objective is to promote the use and adoption of EPC technology.
2005	Wal-Mart launched an EPC pilot.

(Source: AIM Publication (2001), Manish (2005), EPCglobalinc.org)

2. RFID system

RFID technology is a wireless Automatic Identification and Data Capture (AIDC) technology (Fosso Wamba et al., 2006b). AIDC technologies include bar coding, optical recognition, biometrics, card technology, touch or contact memory technology, and RFID technology (see figure 1). RFID allows the accurate and automatic identification, tracking and tracing of every product from the factory, through shipping and warehousing, to the retail location without human intervention (Lai and Hutchinson, 2005). An RFID system is composed of three main components: (i) tags, (ii) a reader and its antennas and (iii) a middleware application that is integrated into a host system.

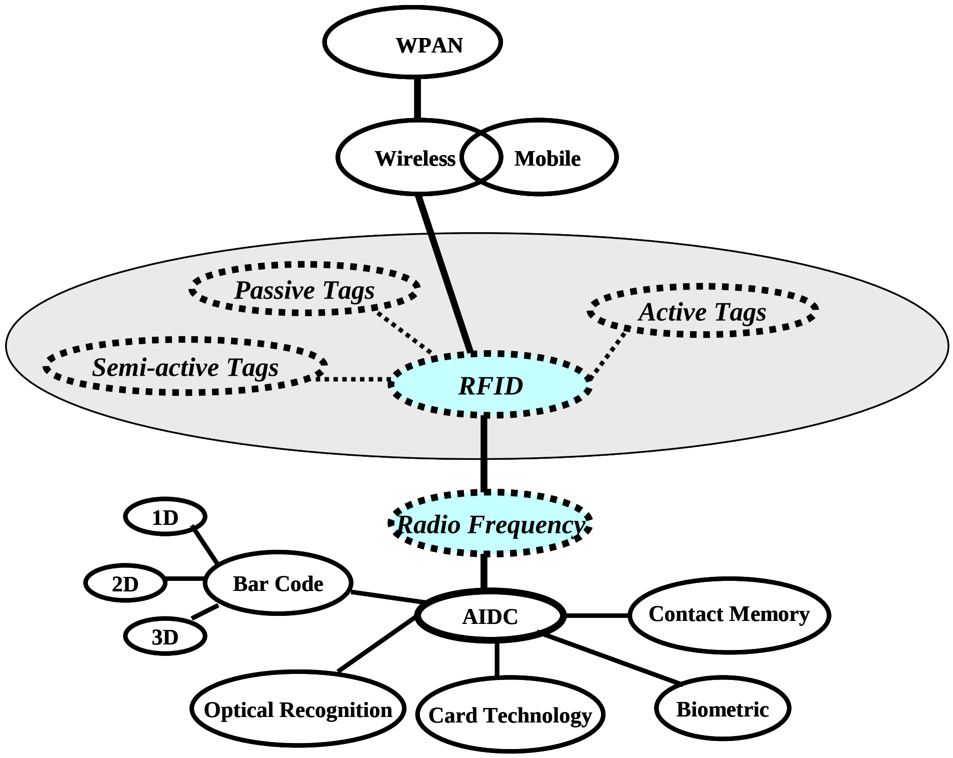

Figure 1: Positioning RFID technology in the AIDC and Wireless technologies landscape
(Source: adapted from Fosso Wamba et al., 2006b)

RFID tags

RFID tags, also known as transponders, contain a chip and an antenna. The latter enables the chip to respond to an interrogation signal transmitted from the RFID reader. RFID tags can be attached to or embedded in a physical object to be identified. They store product-item information such as manufacturer, product lot, size and category, production date, expiration date, final destination, etc. RFID tags have various characteristics such as designs, power source, carrier frequency, communication method, read range, data storage capacity, memory type, size, operational life, and cost. For instance, the tags could be (i) read only, write once/read many times or read/write capable, and (ii) active, passive or semi-active depending on how the operating power is driven. Passive tags do not contain a power source, whereas active tags have a tiny battery from which they draw their power, and thus have greater communication ranges, higher data transmission rates, larger data storage capacity, and higher price tags (Asif and Mandviwalla, 2005; Fosso Wamba et al., 2006a). Figure 2 shows some examples of RFID tags.

Figure 2: Sample of Tags
(Source: Asif and Mandviwalla, 2005)

RFID reader and antennas

RFID readers, also known as interrogators, are electronic devices that emit and receive radio signals through the antennas coupled to them. RFID readers capture data stored in RFID tags and, depending on the technology used, they may also overwrite data on the tags. Readers are responsible for the information flow between the tags and the host system via the RFID middleware. Furthermore, they are able to identify and read a large number of tags per second without any problem. As shown in figure 3, RFID readers come in variety of shapes and sizes and can be classified into the following three main types: fixed reader; hand-held reader; and mobile reader. While fixed readers are usually mounted to walls, dock doors or conveyor belts, mobile readers can be mounted on a forklift or similar equipment and hence increase the flexibility of use of the equipment at various locations in a warehouse.

Figure 3: Types of RFID readers
(Source: www.symbol.com)

RFID middleware

The RFID middleware is at the core of any RFID system. It is responsible for monitoring readers, managing, filtering, processing and aggregating all the data collected from products by readers and then routing the data to the dedicated information systems (e.g. enterprise resource planning (ERP) system, warehouse management system (WMS), manufacturing execution systems (MES), etc.) (Liard, 2004). In addition, the RFID middleware can be used to manage and control RFID readers' infrastructure. It can be considered as the nervous system of RFID technology since it provides key functionalities, such as the efficient management of the data produced by the RFID system (Liard, 2004; Sandip, 2005).

While RFID infrastructure comes in a large variety of designs, the choice of the appropriate tags, readers, antennas and middleware will depend on the requirements of each particular application. For instance, passive tags are frequently used for high-volume, low-cost products in the retail industry; semi-active tags are typically used for retail tracking; finally, active tags are used to track high-value products such as car engines in the automotive industry.

Despite the lively interest in RFID adoption, there are some limitations in terms of lack of standards or technical expertise and the high cost of the hardware and systems necessary to deploy RFID (e.g. tags, middleware). Furthermore, security and privacy concerns, and issues related to the specific industry in which deployment will take place are other obstacles that should be taken into consideration. Finally, technical challenges such as RFID integration with existing intra- and inter-organizational information system infrastructures as well as the management of the high volume of data generated by RFID systems should be calculated prior to implementation. As noted by John Fontanella (Bacheldor, 2006a), when integrating RFID in their operations, firms need to "rethink business processes, IT integration and even RFID middleware, as well as illuminate the need for data reliability and integrity."

To overcome standardization issues, some widely accepted standards such as the EPC network are emerging. Section 2 will explain in detail the EPC network and its components.

3. The EPC Network

The EPC (Electronic Product Code) network is an RFID networking standard proposed and developed by the Auto-ID Center (Leong et al., 2005). Essentially, this network leveraged on the first three components of a RFID system, and extended this infrastructure by adding a unique product-item identification through the EPC code (see figure 4), the local ONS (Object Name Service) and the EPC-IS (EPC Information Service), which provide a means of sharing information more easily in a given supply chain.

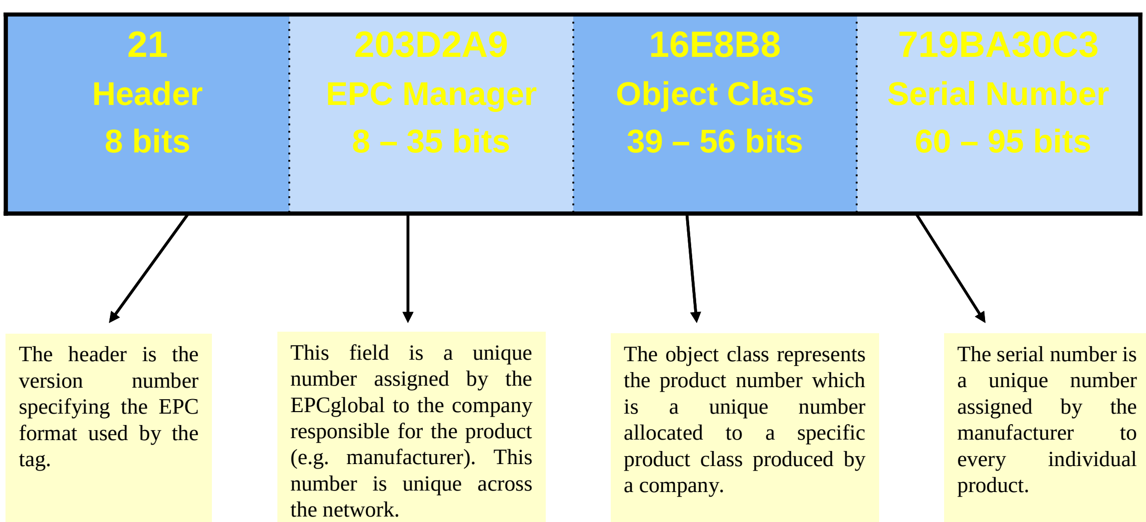

Figure 4: The Electronic Product Code (EPC): example of a 96 bit EPC tag
(Adapted from Leong et al., 2005; Harrison et al, 2005)

More specifically, the EPC network is composed of five components (refer to figure 5): (i) the EPC code starts as a 64-bit to 256-bit identifier (Leong et al., 2005). (ii) The RFID reader identifies any EPC tag within its interrogating field, reads the EPC tag and forwards information to the SAVANT. (iii) The SAVANT, which is the middleware system located between readers and the enterprise information systems, is responsible for data filtering, aggregation and routing to the dedicated information system. The SAVANT also interacts with the EPC-IS and the local ONS. (iv) The EPC-IS is the gateway between any requester of information and the firm's information systems. (v) Finally, the local ONS is the authoritative directory of information sources available to describe all EPC tags used in a supply chain (Srivastava, 2004; EPCglobal, 2004; Floerkemeier et al., 2003; Fosso Wamba et al., 2006a).

The EPC code offers the means for unique identification of any object throughout a supply chain. Indeed, once an EPC code is incorporated into an RFID chip (also called an EPC tag) and attached to a physical object, the object become "unique" in the world.

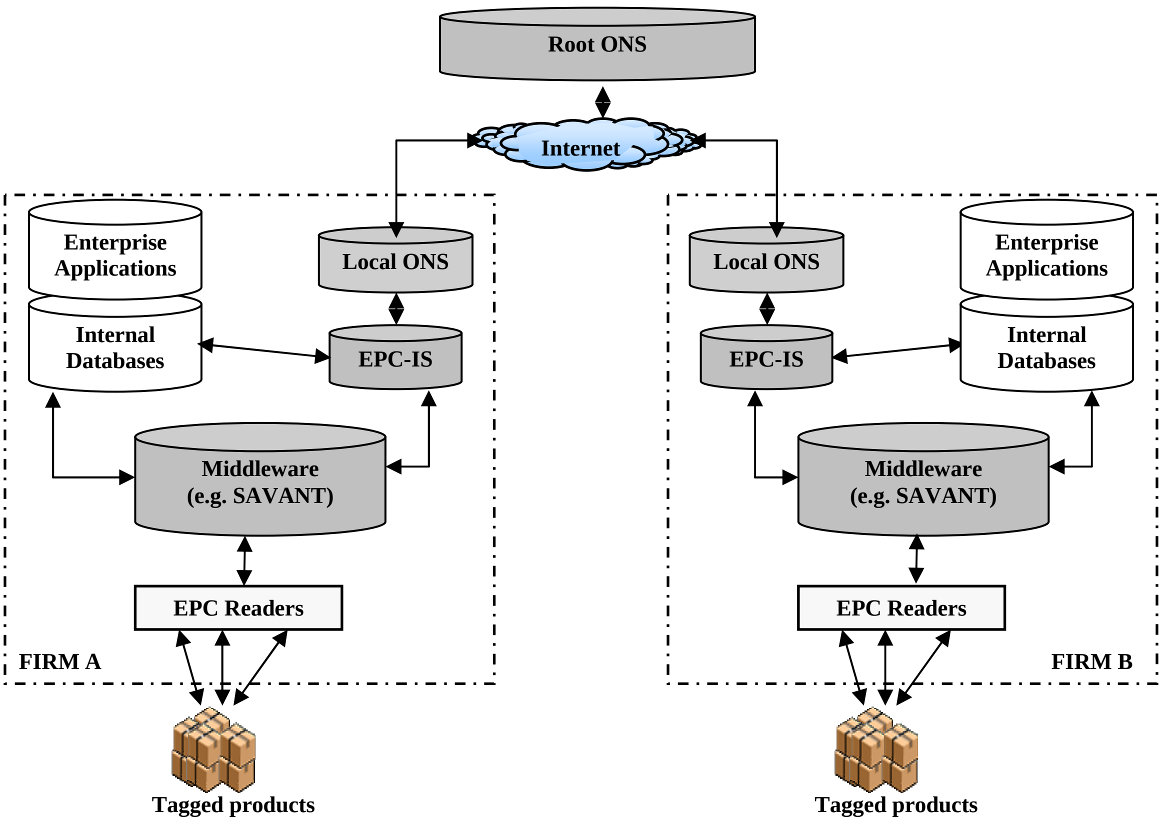

Figure 3: Information flow in the EPC Network

4. RFID Applications

In order to remain competitive, organizations from different industrial sectors have started to evaluate the potential of RFID technology to improve supply chain visibility, asset management, information/product management flow and product visibility. RFID applications in the retail, manufacturing, healthcare and pharmaceutical, transport and logistics, and industries will be discussed in this section.

Retail and consumer goods

The retail industry is considered as a primary driver of RFID adoption (Poirier and McCollum, 2006). Indeed, the recent renewed interest in RFID technology was driven by influential retail organizations such as Wal-Mart, Tesco, Metro, Procter & Gamble, etc., in early 2003. Since then, various pilots and real-life projects have been conducted in order to evaluate the potential of RFID technology. For example, in 2003, Metro Group was the first retailer to use RFID technology in its "Extra Future Store," for various applications throughout the supply chain (Collins, 2004). Other retailers such as Zara and Prada are using RFID technology to enhance their fashion supply chain

management and thus respond faster to consumer preferences.

RFID technology has the potential to optimize supply chain processes in the retail industry. This technology has the ability to allow all supply chain members to identify, trace and manage each product (depending on the desired level of granularity: product, box, pallet, etc.) in a flexible way, by providing product information in real time. Indeed, in a business case study, Lefebvre et al. (2006) show that RFID technology has the potential to improve warehouse activities such as receiving, put-away, picking and shipping by (i) automating almost all information-based processes, (ii) eliminating human intervention for activities such as data entry, validation and verification, and (iii) merging some processes. As a result, all warehouse processes are optimized, and consequently processes along the entire supply-chain are as well. Moreover, RFID technology has the ability to automatically trigger certain business processes.

The use of RFID technology implies the optimization of processes. For example, it allows the elimination of manual and visual verification of each product received, thereby avoiding errors due to the human factor. Furthermore, this technology can make various improvements in the storage, picking and shipping of products. For example, it allows instant access to information concerning the location (e.g. rack) of each product, accelerating the storage process and avoiding bottlenecks at distribution centers and stores.

Manufacturing

Handling goods in production facilities seems to be a very costly and time-consuming activity for manufacturers; indeed, it may account for up to 50% of the overall product cost. Consequently, it is a priority for manufacturers to implement technologies that improve the management of materials and the efficiency of the production process within their facilities (Lu et al., 2006). According to Lu et al. (2006), RFID's unique capabilities have the potential to:

- Facilitate the dynamic planning of production activities
- Improve the tracking of materials, tools or spare parts
- Ensure the efficiency of the maintenance process
- Enhance the management of reusable assets
- Reduce labor cost
- Minimize human related errors, etc.

Furthermore, RFID is an enabling technology that has the ability to improve the manufacturing supply chain's performance; for instance, the integration of RFID allows one to reduce inventory levels of work in progress, control inventory in real time, improve customer relationship management, and automate parts tracking. Hence, RFID has great potential to improve demand planning and forecasting; to boost labor productivity, quality control activities and production agility; to accelerate the cash-to-cash cycle; and finally to streamline the management of reverse logistics (Ranky, 2006; BearingPoint, 2005). Some current RFID applications in the manufacturing industry are highlighted in table 2 below.

Table 2: Example of RFID applications in manufacturing

Firm	Applications	Source
Toyota (South Africa)	• Transporters tagged to streamline manufacturing and vehicle tracking • The tags are intended to remain with the vehicle throughout its life and hold its maintenance history	Baudin and Rao (2005)
Harley Davidson (USA)	• Process automation through tagging bins carrying parts to provide instructions to employees at each stage of the process	
Johnson Controls (USA)	• Tracking of car and truck seats through the assembly process	
The Gap (United Kingdom)	• Denim apparel tracking to improve customer service through better inventory management	
Michelin (North America)	• Tire tagging to comply with the TREAD (Transportation, Recall, Enhancement, Accountability and Documentation) act and recall management	(Baudin and Rao, 2005; RFIDJournal, 2003)
HP (Brazil)	• Printers tagged at a Brazilian factory to track them through shipping and reverse logistics	Roberti (2006)
NISSAN (North America)	• Using active RFID tags to track auto parts, manufacturing processes and finished vehicles	Bacheldor (2006b)

Viper Motorcyles (USA)	• Using RFID to track the movement of subassembly parts throughout the factory to find out the status of motorcycles in the production process • Tagging of all parts valued at $75 or more in order to reduce shrinkage and theft.	Li et al. (2006)
Scottish Courage (UK)	• Using low-frequency RFID tags to track 1.9 million kegs, allowing a reduction in distribution overhead and in keg losses	
Volkswagen (Germany)	• Tracking of finished vehicles to improve vehicles location process	Lu et al. (2006)
Boeing (USA)	• Maintenance activities optimization through the use of RFID tags on airplane parts to speed up access to information regarding maintenance history, parts pedigree, etc	
Chevrolet Creative services (USA)	• Tracking and controlling reception and shipping of crates at the warehouse facility	
Ford Motor Co (USA)	• Improvement of labor productivity through the use of RFID technology at the manufacturing plant	
Herding (Germany)	• Using RFID technology to track production, quality control and shipment of new and reconditioned filters	Wessel (2006a)

Healthcare and pharmaceutical

While most attention has centered on RFID applications in the retail industry, RFID opportunities in the healthcare and pharmaceutical field have started to attract a lot of interest from technology leaders (e.g. Ekahau, Radianse) as well as medical organizations (table 3). In 2005, Aventyn, a technology consulting firm, reported that in the healthcare industry inefficient medical supply management, multiple proprietary systems, and the lack of technology standards had led to a rise in operating costs and a decrease in the quality of care. RFID technology offers key benefits to enhance the quality and reliability of operations in the healthcare industry.

RFID applications in this sector are numerous. For instance, RFID technology makes it possible to track medical equipment and devices in hospitals (e.g. wheelchairs, ECG machines) facilitating their location, identification and confirmation of their availability in real time while preventing shrinkage. This is considered a critical zone of opportunity for RFID since doctors spend an estimated 90 minutes per day searching for medical instruments necessary to perform their work and in the US alone more than $11 billion was spent between 2003 and 2004 due to inefficiencies related to the supply of medical assets (Aberdeen Group, 2006; Aventyn, 2005). Furthermore, between 44,000 and 98,000 deaths in the US every year are caused by preventable medical errors; hence, the accurate management of medications administered to patients represents a challenge to be overcome (Aventyn, 2005). The use of RFID-enabled wristbands could help hospitals to comply with patient safety requirements; medical staff could read patients' RFID wristbands with an RFID-enabled device (e.g. PDA, Tablet PC) to be able to uniquely identify each patient (e.g. name, age, sex) and instantaneously get access to their health record information such as allergy history, medications prescribed, medication dosage and strength, and lab results. Correct drug administration, patient status follow-up and elimination of patient identity mix-ups are some of the benefits that RFID technology can offer to this sector (Alvin Systems, 2005).

For the pharmaceutical supply chain, the US Food and Drug Administration (FDA) has recommended the use of RFID tags by the year 2007 in order to better integrate the US medical supply chain (Spekman and Sweeney, 2006). Given that the pharmaceutical industry loses between $10 and $30 billion per year to counterfeit versions of drugs such as Viagra®, increasing the safety and visibility of pharmaceutical products is a priority (Spekman and Sweeney, 2006). RFID is a promising technology that can improve operating efficiency and increase the safety and visibility of pharmaceutical products from raw materials, through manufacturing to patient consumption ("medication pedigree"). Pfizer, a leading pharmaceutical company, is using high-frequency (HF) and ultra-high-frequency (UHF) RFID tags on bottles, cases and pallets containing Viagra® to fight counterfeiting. In late 2006, Pfizer found counterfeits of its products in no fewer than 69 countries, a situation that is pushing this company to pursue its first electronic pedigree (e-pedigree) trial, which will document

the movement of RFID-tagged bottles of Viagra® as they leave Pfizer's facilities for delivery to distributors, wholesalers, etc. (Bacheldor, 2007a). RFID's unique capabilities allow the tracking and tracing of medications at the item level at each stage of the value chain, preventing theft and counterfeiting and facilitating the management of product recalls in order to assure the integrity of drugs administered to patients. Many pilot deployments have taken place already in the healthcare environment (table 3).

Table 3: Example of RFID applications in healthcare

Firm	Applications	Source
Harmon Hospital (USA)	• Tracking of medical assets using an RFID-based real-time location system (RTLS) to locate assets seamlessly	Bacheldor (2006c)
PinnacleHealth (USA)	• Using active RFID tags to track surgical patients, providing hospital staff with real-time information about their status • Tracking of about 2,500 assets to improve their accessibility through the use of active RFID tags	Bacheldor (2007 b,c,d)
Chang-Gung Hospital (Taiwan)	• Using RFID-enabled passive wristbands to identify surgical patients and track their operations to improve patient care and safety • System allows medical staff to save an average of 4.3 minutes per patient in performing patient identification and verification processes	
Washington Hospital Center (USA)	• Using ultra-wideband (UWB) RFID systems to track and locate medical assets • Future applications: patient tracking	
St. Luke's Health System (USA)	• Future implementation of RFID for bedside applications to reduce medical errors and track ambulatory patients at a new hospital	Li et al. (2006)
Cardinal Health Inc. (USA)	• Using RFID tags on surgical equipment to ensure that all tools used during an operation have been removed from the patient's body	
Purdue Pharma (USA)	• Using RFID to comply with Wal-Mart's mandate and prevent drug theft and counterfeiting	
Hamilton Health Sciences (Canada)	• Using active RFID tags on nursing wards to track IV pumps and other high-value mobile equipment	O'Connor (2006)
St. Olav's Hospital (Norway)	• Tracking of 130,000 work garments by using an RFID-based system, resulting in reduction of inventory space and labor costs	O'Connor (2007)
Jena University Hospital (Germany)	• Deploying a pilot RFID system to track medication to ensure that patients get the correct doses of the right drugs • Implementing the RFID system to improve the efficiency of the treatment process and enhance drug-handling safety	Wessel (2006b)

Transport and Logistics

The potential for RFID applications in transportation and logistics is vast. According to a recent report from Aberdeen Group (Belkin, 2006), the main incentive for companies to adopt RFID is this technology's potential to leverage the performance of internal operations, including *logistics asset management*. A growing number of companies report the loss of at least 10% of their pallets

and shipping containers, contributing to a multimillion-dollar problem that affects operating performance (Aberdeen Group, 2006). RFID tags embedded in cases or pallets can indicate the designated truck to ensure that orders are placed in the right vehicle, thus avoiding inconsistencies and misplaced orders. In addition, RFID technology can be coupled with GPS (Global Positioning System) technology in order track and trace high value merchandise in real time while in transit, from the moment it is shipped to the moment it is received; this is a very promising application since each year in the US about $10 billion worth of goods are stolen, damaged, or lost in transit (Aberdeen Group, 2006). In order to comply with market demand, some applications for tracking and tracing while in transit have emerged; for instance, Mikoh Corporation has developed the SecureContainer system, which features a passive tag designed to alert an RFID interrogator if a sealed container has been opened while passing through the supply chain (Swedberg, 2007a). Safeway, a US supermarket chain, is using active RFID tags and readers to track cargo containers transporting groceries as they leave distribution centers in Washington State and travel across Alaska to the chain's stores and distribution centers (Swedberg, 2007b). Unipart Logistics, a 3PL (third party logistics) supplier from the UK, is offering its global costumers a new service that combines active RFID, GSM/GPRS and GPS technologies for tracking containers of goods and fleets of trucks and trailers (Bacheldor, 2007e). Furthermore, real-time information on product condition is especially important in the food industry supply chain, since short shelf-life products such as fruits and dairy products need to be stored at specific temperatures throughout the supply chain, including during transportation, and require strict traceability (Kärkkäinen, 2003). Sensor-enabled active RFID tags could be used to ensure that products are maintained at the appropriate temperature, notify of any environmental change (e.g. humidity levels) and advise of any mishandling during transportation.

Defense and others industries

The US Department of Defense (US DOD) has been one of the principal drivers towards worldwide RFID adoption. The US DOD required its major suppliers to adopt RFID and start tagging their cases and pallets, as well as any item valued at $5,000 or more, by the beginning of 2005 to increase inventory visibility (Li et al., 2006). Last year, 69 facilities within 19 Defense Distribution Centers across the United States were equipped with RFID readers in order to start receiving RFID-enabled shipments. This important initiative is expected to push more RFID deployments within government institutions, for instance Air Force, Marines, Navy and Army (DC Velocity Staff, 2006).

There are several applications for RFID technology in other industries. For instance, these days RFID tags are commonly used, among other things, for:

- Livestock-animal control: RFID is used to identify each animal and retrieve relevant information such as vaccination records (Smith, 2005);
- Human tracking: at an amusement park in Denmark children can wear an RFID-enabled wristband, so that parents can easily find them if they get lost (Li et al., 2006). Also, the Mexican government has implanted RFID chips into its top judicial officials in order to be able to track them in case of kidnapping (Roberts, 2006);
- Airline baggage management: Delta Airlines is planning to adopt RFID to locate lost luggage. Delta currently misplaces 4 out of every 1,000 bags; it costs this company about US$100 million per year to recover, deliver or replace this luggage (Li et al., 2006; Roberts, 2006);
- Asset tracking: Star City Casino in Sydney has tagged 80,000 employee uniforms in an effort to curb the theft of uniforms (Roberts, 2006).

As RFID technology continues to mature and the cost of systems and hardware decreases, RFID applications will become widespread in other industries. In the following section, a methodology for RFID adoption is presented.

5. Roadmap to RFID adoption

As the adoption of RFID technology is moving more and more from mandatory to voluntary, firms are looking for tools, frameworks and methodologies to enable them to evaluate the real impact of RFID technology on their business processes. The following three-phase methodology has been developed at the ePoly Research Center (Lefebvre et al., 2006) as a detailed blueprint for executing an RFID implementation from the definition of the business case to deployment.

Phase 1: Opportunity-seeking phase

The opportunity-seeking phase is the starting point for any RFID technology business case. During this phase, researchers determine all supply chain members' primary motivation for adopting RFID technology (WHY?). Through focus groups, supply chain members should agree on which Product Value Chain (PVC) the study will be conducted on. Then, the selected PVC will be analyzed in order to (i) understand the specific activities within the PVC and (ii) identify all critical activities in the PVC that

will be targeted by the implementation of this technology (WHICH? and WHY?). The next step consists of the mapping of the intra- and inter-organizational business processes of the supply chain network supporting the PVC in order to understand how they are carried out now ("As is") and highlight the link between firms in the network (WHO and WITH WHOM?).

Phase 2: Scenario building

In this phase, the main objective is to evaluate specific RFID opportunities within the supply chain for a given product value chain. First of all, IT and business staff involved in the project need to answer questions such as: What are the strategic activities in the supply chain? Which supply chain members are going to be involved in the project? At what level? How will firms in the network handle their respective activities? What would change in terms of activities, processes and organizational structure? Which product or family of products should be targeted? What are the characteristics of the product to be tagged? What information should be captured concerning the product (pallet, box or item level)? What are the issues and guidelines for RFID data access and use? How should information be shared at the supply chain level? How will the existing IT infrastructure be impacted? How easy will it be to integrate the RFID infrastructure into existing IT infrastructure (firm level and supply chain level)? Which RFID infrastructure will be used (i.e. (i) read/write tags, (ii) mobile or fixed readers, (iii) traditional network (e.g. EDI) or EPC network, etc.)? Based on the answers to these questions, several scenarios for integrating RFID technology should be built.

Phase 3: Scenario Validation and Proof-of-Concept

In the third and final phase, all scenarios for integrating RFID technology are evaluated and discussed at the various firms and the supply chain level in order to choose one "preferred" scenario. This final selection is based on technological and business requirements for an RFID-enabled business process at the firm level and the supply chain level.

Finally, the "preferred" scenario is simulated in a laboratory setting (proof of concept), simulating the actual physical environment and interface between supply chain players, allowing a feasibility analysis and evaluation of the challenges. Depending on the results obtained during the proof of concept, supply chain members will be able to decide whether or not to continue with the Beta Test (pilot) in a real-life setting.

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