RFID Technology in Business Systems and Supply Chain Management

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ABSTRACT

In today's fast-changing competition environment, companies and organizations need to renew their services and products, and change and replace their business processes with new ones continuously to benefit more from time and resources. Therefore, data capturing, gathering and management technologies are always needed by companies and organizations to support their decision-making and plans, and develop their strategies. One of the technologies that could help companies to handle data is RFID (Radio Frequency Identification). Many organizations are slow in warming up to the idea of using RFID to conduct more effective and efficient business processes, data mining applications, and cost savings. In this study, RFID technology and its system structure are proposed. The paper introduces a middleware for business models including RFID technology. Information about the advantages of RFID over today's data gathering and Auto-ID (Automatic Identification) technologies is given. The impacts of RFID technology on business systems, especially supply chain management, are presented.

Keywords: *Radio Frequency Identification; Data Gathering; Item Tracking/monitoring; Process Management; Supply Chain Management*

Introduction

Technological innovations and their consequences are becoming indispensable parts of our daily lives. RFID, as one of these innovations, is a system that provides easy, secure and quick data entry, storage and transmission. It is used in many places such as shops, stores, hospitals, pharmaceuticals companies, logistic services etc. where real time data should be used (Brown, 2007, Miles et al., 2008). At its core, RFID is an enabling technology that has the potential to help retailers provide the right product at the right place at the right time, thus maximizing sales and profits. It builds a basis for coding, storage and transmission systems. It improves the data management capabilities and resolves the problems caused by lack of information. It provides contactless and wireless technology to identify objects that are uniquely manufactured, shipped and sold, such as container, pallet, case and item, thus it provides the building blocks for increased visibility throughout the supply chain. It is important in improving efficiency and visibility, cutting costs, delivering better asset utilization, producing higher quality goods, reducing shrinkage and counterfeiting, and increasing sales by reducing out-of-stocks (Angeles, 2005, Brazeal, 2009). It helps in gathering data and improves the security of information about the objects. RFID has vast applications as it is relevant to any organization engaged in the production, movement or sale of goods. This technology includes retailers, distributors, logistics service providers, manufacturers and their suppliers, hospitals, pharmaceuticals companies, and the entire supply chain applications.

RFID is an emerging technology consisting of data gathering, distribution, and management systems that has the ability to identify or scan information with increased speed and accuracy (Ahson & Ilyas, 2008). Although implementing RFID technology is a complicated process, the right planning and development of an RFID strategy can offer important advantages to business systems for efficient and successful supply chain management. While RFID technology has received a fair amount of attention in media recently, many are still unfamiliar with RFID and the benefits it can offer. In the face of the need for clear, extensive information about RFID and its benefits, this paper presents the opportunities offered by the technology for any organization involved in the production, management, or sale of goods.

RFID Systems and System Components

RFID is a wireless automatic identification (Auto-ID) and data capturing technology that gives the opportunity to monitor objects by using a tag that carries information. In RFID systems, there are different software and hardware requirements for data gathering and management. One of the most important components of RFID systems is tag. A tag can be identified as a microchip that has an electronic circuit and antenna on it. For the purpose of tracking the movement of goods, tags can be placed anywhere, such as containers, pallets, materials handling equipment, cases or even on individual products. Tags can be classified as passive (no battery), active (with battery) or semi-passive according to their power supply (Khan et al., 2009, Klaus, 2010). While active tags use an energy source that is integrated to a tag physically, passive tags obtain this energy from the readers in the communication field. Today, semi-passive tags that have some properties of both active and passive

tags can be also used. The other component of RFID is reader which connects the tags to external world. Although readers can be classified as portable and mobile (Klaus, 2010), all of them consist of same components. In every reader, there are some parts that read tags, gather data and handle communication. While the reader antenna receives/sends the radio waves, it builds the signal and decrypts the signal which is sent from tags.

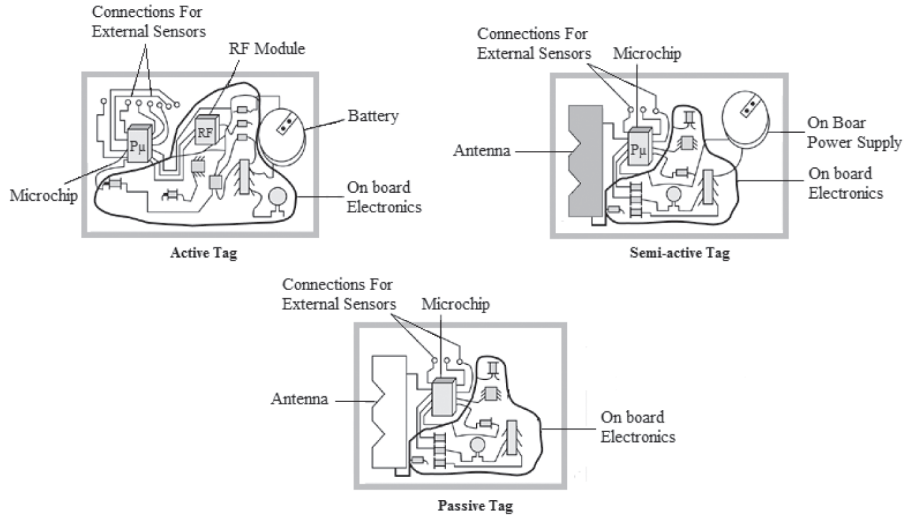
There are eight main components for building RFID systems in a supply chain management:

1. RFID Tag
2. Antenna
3. Reader
4. Controller
5. Interrogator
6. Sensors
7. Software System (ERP/MRP)
8. Communication Infrastructre
9. Annuciators/Actuators

RFID Tag

An RFID tag consists of a microchip where the information about the object is stored, an antenna connected to the chip, on-board electronics, and a protecting film layer that covers these components. It is used as an electronic data carrier, and different information can be written and read in its environment. The microchip in the RFID tag can store information from 64 bit to 8 MB (Klaus, 2010), which means that the tag can carry some important information such as shipping history, order number, customer information, company/staff information and serial number (Ahson & Ilyas, 2008). There are several kinds of tags in different forms and sizes. A common way of categorizing tags is by their power source. This is also one of the main determining factors for the cost and longevity of a tag. There are three types of RFID tags: passive, active, and semi-passive. A passive tag does not contain a battery; it obtains all of its energy from the reader by using different transmission methods. It uses the signal received from the reader to power the IC, and changes the signal level to transmit information back to the reader. Passive tags are the most common ones in cost-sensitive applications because they have no battery, no transmitter, and they are also very cheap. An active tag is a full-featured radio device with its own transmitting capability independent of the reader (Shepard, 2005, Roberts, 2006). It uses an on-board battery to power on-board electronics, microprocessor, memory, and external sensors for communication. Tags that use battery power for some functions but still allow the reader to power communications have been termed "active" as well. They are not only capable of supplying power for themselves but also they are able to initiate communications with other tags of their own kind without the aid of a reader. These tags are called two-way tags, battery-assisted passive tags or semi-passive tags (Shepard, 2005, Xiao et al., 2007). They use a battery to power the on-board electronics and microchip, and the passiveness of semi-passive tags depends on required signal levels between the tag and the reader.

Table 5. Marketing Management Factor and its variables



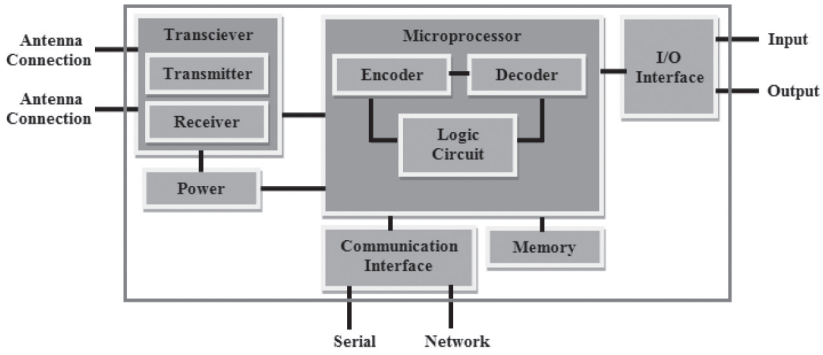
Although having an onboard battery makes RFID chips more expensive, semi-passive and active tags have several advantages over passive tags. In semi-passive systems, the reading range may be longer because the passive communications can use all of the power provided by the reader for data transmission rather than sharing some of the power with the chip. Active tags have an extremely long reading range and perform some functions in the absence of a reader (e.g., using battery power for environmental sensors). This capability can be very useful for tags to identify items such as perishable goods. These varieties of RFID tags can dynamically store data. Active RFID tags have large read/write data storage, almost 128 kilobytes, and sophisticated data search/access capabilities. In a passive RFID, the data storage is less than 128 bytes with no search capabilities or data manipulation features (Klaus, 2010, Glover & Bhatt, 2006).

RFID Reader

An RFID reader is a specialized radio transmitter and receiver. It generates signals at the carrier frequency and modulates these carrier signals to convey information to the tags (Klaus, 2010). It must selectively receive and amplify responses from the tags, and convert the signal from the carrier frequency down to much lower frequencies. It is designed for fast and easy system integration without losing performance, functionality and security. Fig. 2 shows the components of an RFID reader. An RFID reader consists of a real time processor, operating system, virtual portable memory, and a transmitter/receiver unit in one small self-contained module that is easily installed in the ceiling or in any other convenient location. The reader is usually classified into two types (Klaus, 2010, Shepard, 2005). The portable reader is set to a definite place. It is the reader type that RF tags go through and by which they make communication. The mobile RFID reader includes a wireless interface, precisely Bluetooth (IEEE 802.15.1), ZigBee (IEEE 802.15.4) or Wi-Fi (IEEE 802.11b/g/n). This device uses

short or long range radio links. Therefore, it can identify, read/write, remotely control and monitor RFID tags over wireless communication. It contains some software tools for communication with other mobile RFID readers, PDAs, laptops, etc. The mobile RFID reader facilitates the identification of the tags that are in dangerous fields where the reading process is difficult (Roberts, 2006, Xiao et al., 2007, Glover & Bhatt, 2006).

Figure 2: The Components of a Reader



RFID Controller

An RFID controller is a machine such as computer, server, workstation etc. on which database or application softwares work. It also can be a network system which includes computers, servers and workstations connected to each other. The RFID Controller is the brain of an RFID system. It controls RFID middlewares, applications and database sytems (Brown, 2007, Shepard, 2005, Fosso Wamba et al., 2007). It is also used for connecting multi-queriers in a network and processing information centrally. The controller uses information that is collected by readers. It has some properties such as monitoring RFID sytem, rerouting data about items if necessary, remote controlling and managing devices, validating and authorizing identities, creating and managing accounts, stock analysis for products, coordination with ERP/MRP systems, informing suppliers when new product stock is required, etc. (Angeles, 2005, Brazeal, 2009, Glover & Bhatt, 2006).

RFID Antenna

It is the hardware that provides communication among readers and tags. In many situations, the use of an antenna is very important because tag reading ranges are very small. Although the antenna has a very simple structure according to its concept, it must receive the best signals in low power and adapt to special conditions. Antenna must be designed in different sizes, shapes and frequency intervals according to the properties and distances of the environment where the application will be implemented in (Klaus, 2010, Hossain & Karmakar, 2006).

Antennas have two kinds of broadcasting: planarly or circularly. An antenna that broadcasts planarly

concentrates on a unique axial for maximum income in the longest reading distance. An antenna that broadcasts circularly distributes the UHF energy generated by the reader to a longer distance equally. Therefore, with circular diffusion, it is possible that the antenna reads all surrounding tags.

An antenna can be designed as to several factors, such as the following:

- Reading distance
- Particular product types
- Known orientation
- Arbitrary orientation
- Specific operating conditions
- Reader/controller
- Antenna polarization
- Environmental changes
- Speed of the tagged objects

RFID Interrogator

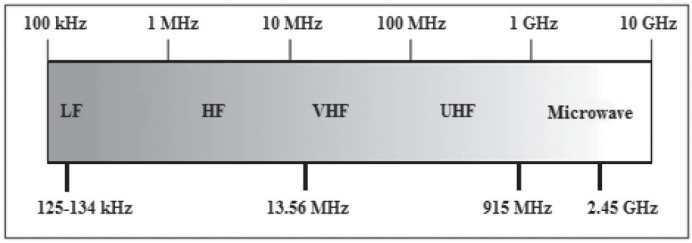
An RFID interrogator is essentially a small computer. It has three basic parts: an antenna, an RF electronic module that is responsible for reading RFID tags, and a microcontroller module that is responsible for communication with controllers or readers. The interrogator acts as a bridge between the tag and the controller (or reader). It has just a few critical functions (Brown, 2007, Angeles, 2005, Ahson & Ilyas, 2008):

- ✓ Reading data contents of an RFID tag.
- ✓ Writing data to the tag, if required.
- ✓ Relaying data from/to the controller.
- ✓ Powering the tag, if required (for passive systems).
- ✓ Implementing anti-collision measures to ensure simultaneous RW communication with many tags.
- ✓ Authenticating tags to prevent fraud or unauthorized access to the RFID system.
- ✓ Data encryption to protect the integrity of RFID data.

Operating Frequencies in RFID Systems

Operating frequency is the electromagnetic frequency which the tag uses to communicate or obtain power. The electromagnetic spectrum in the range in which RFID typically operates is usually broken up into low frequency (LF), high frequency (HF), ultra-high frequency (UHF), and microwave. Because of the fact that RFID systems broadcast electromagnetic waves, they are regulated as radio devices (Glover & Bhatt, 2006).

Figure 3: Radio Frequency Spectrum



Low Frequency (LF)

Frequencies between 30 KHz and 300 KHz are considered as low. RFID systems commonly operate at the frequency range from 125 KHz to 134 KHz. LF RFID systems generally use passive tags, have low data-transfer rates from tag to reader, and are especially good if the operating environment contains metals, liquids, dirt, snow, or mud (a very important characteristic of LF systems). In LF RFID systems, active LF tags are also available from vendors (Lahiri, 2005).

High Frequency (HF)

High frequency RFID systems operate between 3 MHz and 30 MHz ranges. 13.56 MHz is the typical operating frequency used for HF RFID systems. A HF RFID system that uses passive tags, has a slow data-transfer rate from tag to reader, and offers fair performance in the presence of metals and liquids. The other frequency range is very high frequency (VHF) and lies between 30 and 300 MHz. Although there are applications for VHF systems such as FM radio/TV broadcasts, land mobile stations, marine and air traffic control communications, air navigation systems, etc., none of the current RFID systems operate in this range.

Ultra High Frequency (UHF)

UHF RFID systems operate between 300 MHz to 1 GHz ranges, and they can use both active and passive tags. These systems have fast data-transfer rates between tags and readers, but perform poorly in the presence of metals and liquids.

Microwave

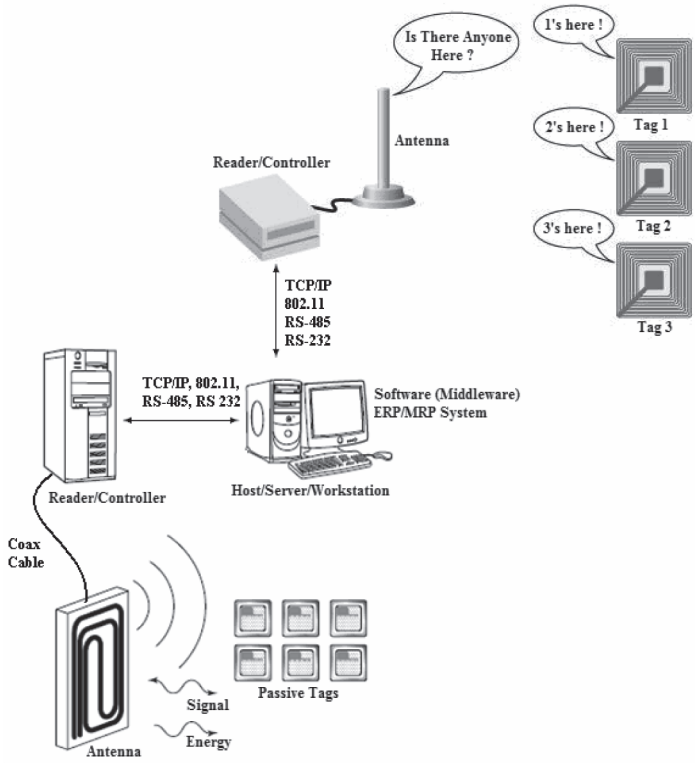
Microwave RFID sytems that operate from 1 GHz upto 5.8 GHz. 2.4 GHz frequency are called Industry, Scientific, and Medical (ISM) band and accepted worldwide (Lahiri, 2005). Microwave RFID systems can be used for active, semi-active and passive tags. They have the fastest data-transfer rates between tags and readers. Because of the fact that antenna length is inversely proportional to the frequency, the antenna of a passive tag operating in the microwave range has the smallest length

(which results in a small tag size because the tag microchip can also be made very small).

RFID Applications

RFID systems can be divided into two major groups, as mobile and immobile applications. Immobile RFID systems include RFID readers, antennas (usually 2 or 4 antennas for each reader), hosts, servers, middleware and external units such as light and sensors. These systems are also called RFID gates. In these systems, readers serve as gates, receive information from tagged objects and send these information to servers or controllers. Mobile systems use wireless communication to gather data and monitor objects. They are similar to fixed systems due to RFID system structure. They provide advantages such as data gathering and managing, reading/writing ranges and communication technologies. Reading/writing data from/to RFID tags is done by radio frequencies. Passive tags, which are widely used, are activated by the energy that is generated by RFID readers, and send their information to readers. RFID readers receive information and transfer this information to controllers, servers, database systems or RRP/ERP/MRP systems in supply chains. Fig. 4 shows an RFID system model in a supply chain management, and provides information about how RFID systems work.

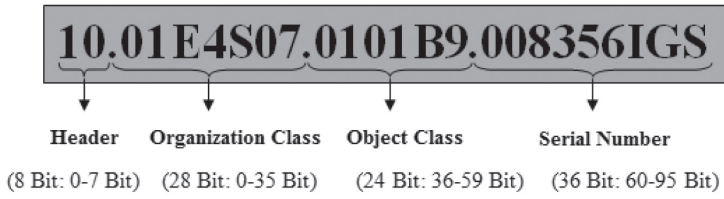
Figure 4: An RFID System Model



RFID Data Model Used in a Supply Chain

RFID data can be classified into two categories: the event data and the master data. The event data keeps real-time (or dynamic) information which is about RFID tagged objects such as containers, pallets, materials handling equipment, cases, automobiles, textiles, animals, and etc. The master data provides conditional information and verification about the event data. Fig. 5 shows an example of an RFID data model that contains 96 bit EPC code in a supply chain management, and provides information about how RFID data is structured.

Figure 5: An RFID Data Model



Event Data

Event data is related to a definite time, and it provides the communication about RFID tagged objects during supply chain processes. It is created whenever some sort of transaction occurs. It is captured in distributed data repositories, and only the relevant event data has to be sent to the monitoring for further processing (Miles et al., 2008, Angeles, 2005, Brazeal, 2009). The processing and matching of automatically generated monitoring instructions with the event data gathered from distributed data repositories has to be performed by an appropriate event processing engine (Veronneau & Roy, 2009, Kwak et al., 2010). Event data creates information which is about investigating the existence of items somewhere at some time. It stores the identity, location and time information. Event data can be illustrated like this: "EPC X is observed at location L at 4:15 p.m. 28 June 2010". Event data is currently used for tracking and tracing applications to monitor items associated with transportation processes and transported goods (Ferrer et al., 2010). The combination of new technologies provides the potential to use RFID based on event data for the automatic and near real time monitoring of processes in supply chain networks to detect anomalies according to specified objectives. By using RFID widely, applications may need more information and more sensor observations (Werner & Schill, 2009).

Master Data

Master data, also called reference data, describes an item and its general properties. It includes useful data about customers, products, employees, materials, suppliers, manufacturers etc. in a supply chain. It contains information such as source verification, product definition referenced by EPC (Electronic Product Code), manufacturer information, details about the object which event data is caught from, and storage information. It can define transactional processes and operations (Glover & Bhatt, 2006,

Kwak et al., 2010, Tajima, 2007). Master data is a key information for quality-assurance, persisting demands, business operations and data-mining applications. It provides processes for collecting, aggregating, consolidating, matching, and distributing such data throughout a company to ensure control and consistency in the ongoing maintenance and application of this information (Chuang & Shaw, 2005). Master data is used in data management systems to define characteristics of an item that are used within other data centric processes. It is stored in different data systems across a company, and it may or may not be referenced centrally. Therefore, the possibility exists for duplicate and/or inaccurate master data. Usually, master data can't grow as fast as event data.

Data Size

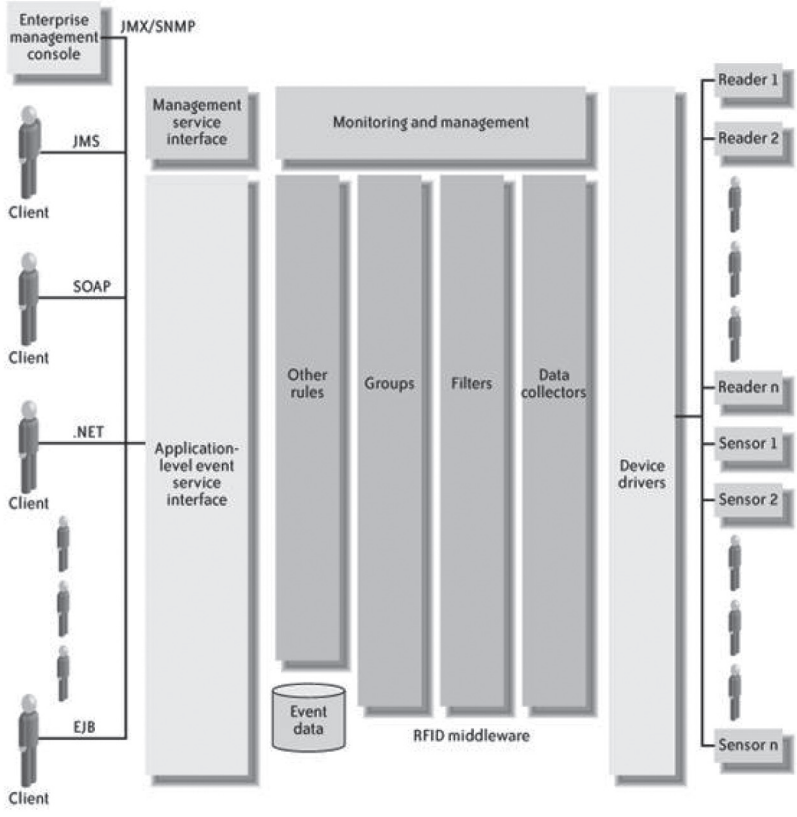
The effect of RFID on data gathering and management systems in a supply chain is related to which data will be collected by using RFID, how often it will be collected, and what will be done with RFID data. Due to the necessity of RFID system and network infrastructure, RFID data volume can overload the storage fields and supply chain network. Therefore, data size can be changed as a function that is dependent on the number of processes executed by the RFID system.

RFID Middleware for Business Operations and Supply Chain Models

RFID middleware is a software that bridges RFID system and enterprise IT applications. It helps data gathering and management for any RFID deployment in a supply chain. It consists of a set of services that allow multiple processes running on one or more RFID system to interact. RFID middleware assists with the filtering, aggregation, and routing of RFID data. It has built-in business rules that monitor the data stream and direct data to appropriate enterprise systems. It is used to manage data flow between the RFID networks and the IT systems within an organization (Sarac et al., 2010, Chuang & Shaw, 2005, Asif & Mandviwalla, 2005).

Fig. 6 shows a sofware architecture in a supply chain management. RFID middleware can be integrated to the ERP/MRP system of a company. This integration helps RFID services to write the correct data to the desired places in time. The integration provides varying degrees of management and monitoring capabilities, service-oriented architecture integration capabilities, and built-in adapters to various ERP packages (Glover & Bhatt, 2006). The company which hosts the RFID service provides this integration by working with its trading partners which use current systems (Saygin et al., 2007, Gaukler & Seifert, 2007). RFID middleware provides connectivity with RFID devices while encapsulating the applications from the device interface and interconnections. It lowers the volume of information that applications need to process by filtering and grouping raw RFID observations captured by readers and sensors. It provides an application-level interface for querying RFID observations and managing RFID devices such as readers, controllers, interrogators and servers (Chuang & Shaw, 2007, Chen et al. 2008).

Figure 6: An RFID Software Architecture For A Business Model (Glover & Bhatt, 2006).



RFID middleware has four main functions for data management in business applications:

1. **Data Gathering:** Middleware is responsible for the extraction, aggregation, smoothing, and filtering of data from multiple RFID readers throughout an RFID network. It serves as a buffer between the volumes of raw data that are collected by RFID readers and the relatively small amount of data that is required by enterprise IT systems in the decision-making process. Without this middleware buffer, enterprise IT systems could quickly become overwhelmed by the flow of data (Hunt et al., 2007).
2. **Data Routing and Management:** Middleware facilitates the integration of RFID networks with enterprise systems. It determines which data must go where. It does this by routing data to appropriate enterprise systems within an organization (Saygin, 2007).
3. **Process Management:** RFID middleware is an application of knowledge, skills, tools, techniques and systems to define, visualize, measure, control, report and improve supply chain processes with the goal of meeting customer requirements profitably. It is the ensemble

of activities of planning and monitoring the performance of a business process (Gaukler & Seifert, 2007, Bagchi et al., 2007). Middleware can be used to trigger events based on business rules. For example, an order is created on a company's website, and a pallet lies at a dock door in a distant warehouse as though waiting for its marching orders. The enterprise IT system that is responsible for initiating this shipment would pass the purchase order to the middleware system. Middleware locates the specific dock door where the pallet is stored, and writes the delivery information on the pallet's tag. Other events and processes such as unauthorized shipment and unexpected inventory, low stock, and stock cut can be managed by middleware.

4. **Device Management:** Middleware must contain technologies, protocols and standards used to allow the remote management of RFID devices, and involve updates of firmwares or other middlewares over the air. For example, the employer or the end-user can use middleware via a web portal to update the firmware, install middleware applications and fix bugs, as wireless and contactless. Thus, large numbers of RFID devices can be managed with middleware, and the end-user is freed from the technical service requirement to refresh or update the RFID system. For supply chain management and business applications, RFID device management means better control, update, safety, and management as well as increased efficiency, decreased possibility for device downtime. Middleware is used to monitor and coordinate devices such as readers, hosts, controllers, servers. Large organizations might have hundreds or thousands of different types and brands of readers to spread across their networks. Networking and monitoring RFID sytem devices, and keeping track of these devices` health and status, would be a major job and most efficiently done at the middleware level. Remote management of an RFID network could also be made possible through middleware (Sarma, 2004, Prabakar et al., 2006, Minli et al. 2008).

Discussion

The main feature of RFID technology is its ability to identify, locate, track, and monitor objects without a clear line of sight between the tag and the reader. Addressing all of the functional capabilities of RFID systems ultimately defines the RFID applications to be developed in a variety of industry, commerce, and service where data need to be gathered. The effectiveness of an RFID application in addressing desired functionality depends on several important factors:

- *Contactless:* An RFID tag can be read without any physical contact between the tag and the reader.
- *Writable data:* The data of a read-write (RW) RFID tag can be rewritten several times.
- *Absence of line of sight:* A line of sight is generally not required for an RFID reader to read a tag.
- *Variety of reading ranges:* An RFID tag can have a reading range from as small as a few inches to as large as more than 100 feet.
- *Wide data-capacity range:* A tag can store from a few bytes of data to virtually any amount of data.

- *Support for multiple tag readings:* It is possible to use an RFID reader to automatically read several RFID tags in its reading zone within a short period of time.
- *Durable:* RFID tags and readers can easily operate under difficult conditions.
- *Perform smart tasks:* In addition to the tasks of carrying and transmitting of data, an RFID system can be designed to perform some other tasks (e.g., acculturation to environmental conditions, operating at high or low temperature and pressure).
- *Extreme reading accuracy:* Thanks to extreme reading accuracy advantage, RFID is an accurate and secure technology for data gathering and management.

The advantages listed above are generic for any type of RFID sytems. Some additional factors are needed to be considered for applications such as data gathering, item monitoring, automatic identification, and access control mechanisms. These may include privacy and security concerns, data mining, and the integration of the RFID with other technologies such as biometric systems, Global Positioning Systems (GPS) and wireless communication technologies. In the near-feature, commercial applications of RFID technology in supply chain management will continue to develop and grow. Therefore, RFID industry must focus on applications that increase the volume of usage, lower the costs and develop effective business models.

Companies gain competitive advantage over other companies by offering consumers greater values. These values can be provided by means of lower prices, investment or better services. New business strategies should be developed and new technologies should be adopted in order to compete with rival companies in industry. For the companies who will use RFID systems, a question arises: "Can RFID deliver a competitive advantage?"

Firms who are the earlier adopters of RFID technology will gain a competitive advantage through business innovation and differentiation. Companies with supply chains have already begun to explore how to apply RFID technology with the goal of improving supply chain management and collaboration. Leader retailers around the world and national organizations have begun to suggest and insist that manufacturers and suppliers should attach RFID tags to products before shipment.

A good example of a company who is an earlier adopter of RFID with the help of IBM is American Power Conversion. According to Rich Morrissey, APC's director of eBusiness, APC has a better position with customers and RFID helped the company to achieve a competitive advantage through business innovation, differentiation and an established technological leadership position. In addition to these, the company protected its revenue streams, won customer loyalty, speeded up its decision-making and gained greater supply chain visibility.

Another example is Wal-Mart, which is one of the largest American public organizations and runs a chain of large discount department stores and a chain of membership required warehouse stores. The company extended its existing edge and saw RFID as a way to reduce the cost of handling goods. Therefore, a firm who adopts the RFID technology saves billions of dollars and reduces the cost of its supply chain operations and can translate these savings into increased profit margins at the

point of sale. Additionally, a firm can also cut prices that helps to gain low-cost advantage against its competitors.

During supply chain processes, several data such as "which products use which parts" or "who assembles the product in what time" can be stored in database management systems. Therefore, products in which related parts are used can be automatically determined and applied to necessary operations. RFID systems give an opportunity to create a database with data on customers' needs. By the use of RFID, information in database systems is updated and correct information that is necessary for reporting and analysis is obtained on time. RFID has many potential activities such as billing and delivering products, physical stock and identity account tracking. Information/data is easily accessed and updated dynamically in real-time, stocks are tracked and controlled, and storehouse and selling control can be done. Products that are taken from stock or that have remained in stock can be monitored with their costs and efficient stock management can be done.

By using RFID data (e.g, EPC), correct information is obtained from the production line and used in different stages of the supply chain without human intervention. The products are directed to a definite route automatically and defective products are also prevented in the production line. Some critical processes during business operations such as stock management, item tracking/monitoring, transportation, delivery, device management, and software update are planned automatically. In this way, lost time and manpower can be decreased.

There are several advantages of RFID applications in supply chain management. RFID technology provides collaborative business commerce solutions, enables more efficient and effective buying, selling, and cash management. Companies can control costs, increase sales, minimize risks, and enhance cash flow by using RFID systems. As a result of the real time item monitoring, RFID provides effective logistic management, and effective purchase and supplier/procurement management. In addition to these, RFID applications decrease repeating jobs and faults caused by using automation instead of manpower, decrease manpower costs and prevent problems by obtaining detailed information.

An RFID tag has a unique identification code and data is protected with cryptographic algorithms. Advanced encryption methods prevent unauthorized access to the information in the RFID chip. The tag can be locked and becomes unusable if necessary. The security of RFID improves the delivery and control of goods, decreases theft and faults, increases anti-forgery, eliminates wrong data entry and prevents complications between similar products or the products that have similar codes. In this way, RFID data processing accuracy and sensitivity enable the proper verification of object data (Ahson & Ilyas, 2008, Hunt et al., 2007).

RFID data contains a unique code (e.g., EPC) that provides the unique identification of each item. RFID contributes to supply chains and business operations in different ways through its advanced unique identification and real-time communication properties. Through the unique code of each tag and the easiness of scanning, RFID improves the accuracy, the speed of processes, the traceability and the visibility of products throughout supply chains. It also reduces handling and distribution

costs and increases sales by reducing stock-outs. RFID ameliorates the efficiency of current supply chains, but it also supports the reorganization of supply chains to drastically enhance their overall performances.

RFID is also used to minimize human faults and increase process speed in a scope like selling, storing, production, etc. In RFID systems, processes are executed faster than manual systems because information is transferred with electronic methods. With the speed increasing in the data entrance, work efficiency also increases and employees are shifted to more suitable locations. Another advantage of using RFID, is its being economic. With correct data entrance and increased speed of data entrance, the number of employees is reduced, leading the system to become more economic.

An RFID application reduces the stationer and stores costs by eliminating data entry forms. Because it is not necessary to use complicated equipment – stationer for RFID tag, data recording/storing process becomes simpler and has less cost than other automatic identification (autoid) technologies. RFID is more durable, and can be applied more simply than other autoid when the factors like damage, frazzling, being torn during its usage are taken into account.

RFID includes some technological features such as security, identification and authorization for commercial applications. Due to identification and authorization functions, RFID increases visibility, and develops effectiveness of communication among objects by matching entities automatically. For instance, RFID identification and authorization features in medical applications enable the identification, positioning and tracing of patients and related medical equipment consistently at the right time. In this way, double-checking in medical treatment services, workload and resources in advanced processes are decreased.

RFID, integrated into wireless network systems, brings mobility to any tagged object by increasing the capacity of data communication. In this way, efficient use and management of goods is improved. For instance, the use of RFID with wireless network system enables the enumeration of medical equipment in a hospital from a fixed location. This dramatically decreases the search time. Moreover, by the use of RFID tags for patients, medical equipment, and patient registers in a hospital, data about entities can be traced fast. RFID integration enhances tracing of goods use, and provides current and the best sourcing use by decreasing loss or misplacement of goods. In this way, it improves the efficiency of material inventory.

Due to RFID and wireless sensor network environment built with EPC global, aims and limits about location, storage space and time can be changed; RFID enables services existing in innovative ways or new services to be created. Standardized RFID network software architecture, which uses RFID system to enable the constant, temporaneous, direct identification, positioning and tracing of objects such as pallet, container, goods, medicines, and patients is used to transform data collected by RFID into information. This information is processed as useful information that can be used with back-end system in a company's decision-making period (Smith, 2005). For instance, through the effective use of RFID and EPCglobal network in medical institutions (especially data processes with

intensive workload such as search, data entry, comparison and verification), not only is medical error dramatically reduced, but treatment quality of the medical institution is also improved effectively, which enhances operational performance and capacity of hospital.

Conclusion

RFID is the general name of the systems that use radio waves in automatic object identification. It transmits the identification information of objects as a numerical serial number dynamically. These wireless systems give the opportunity to read without contact and being visibility. This property provides simplicity in difficult environments, as compared to conventional technologies such as barcode. Today, RFID technology with its different applications provides many advantages in the industry. Invention of new technologies decreases the operational costs of firms and companies and increases the efficiency and profitability. By using RFID technology, the changes in the working process can be analyzed and planned. The RFID system can set with the most suitable tag design and be started to be managed.

Large scale applications with integrated databases such as inventory tracking, production band automation, stock management, staff and data tracking can be developed. RFID is a technology that is not limited to only product identification and tracking, but also it has large application fields for supply chain management and applications. It is very suitable for the companies and firms who need dynamic systems to control their entities, data and information regularly. The people who want to invest in RFID must investigate the RFID gains properly. It can be said that discovery duration about RFID is current, and to apply a system based RFID is both a science and an art.

RFID improves the effectiveness of supply chain and provides the opportunity to collect various data about customer behaviours. It presents enterprise innovations that result in high performance on behalf of company value and applications that increase business operations. It has the structural features that activate business processes planning and management. Thanks to tracking of any object tagged with RFID and the intelligent management of data about the object, value-added operations of companies improve.

RFID significantly alters companies' capacity of obtaining real-time data about the locations and characteristics of tagged objects. When various processes related to business operations are used with RFID, companies can observe the location, history and changing situations of tagged objects more easily. When RFID is used with a company`s general communication infrastructure, it provides wide-ranging location and knowledge of goods to the company.

RFID systems can be assessed both strategically and operationally. Strategical systems aim at integration of RFID technology and company processes, development of better business models by companies, customer satisfaction and development of new business opportunities. Besides, it leads an effective supply-chain system in order to coordinate companies' members from overseas. Operational systems focus on effectiveness and flexibility in process redesign. RFID has an effective

and competitive role in all stages of supply-chain management such as business value, organizational business strategies, cost, quality, service and speed, etc. Thanks to intelligent tracking of objects and automation of business processes, RFID decreases the costs of data collection, increases the effectiveness in business processes, and creates competitiveness among companies by interactive working with BPR, MRP, ERP, and SCM applications. Adoption of RFID by enterprises results in great changes for both business processes and company employees. RFID aims at activated restructuring studies, optimization of business processes, and providing effective business integration. In the near future, the adoption of sensor-based Radio Frequency Identification (RFID) technology will allow the creation of the real-time, sensor-connected manufacturing plant. By adding RFID tags to every product, tool, resource and item of materials handling equipment, manufacturers will be able to get better demand signals from customers and the market.

References

Brown, D. E., (2007). *RFID Implementation,* McGraw Hill Companies, NY, USA, ISBN: 978-0-07-226324-4.

Miles, S. B., Sarma, S. E., and Williams, J. R., (2008). *RFID Technology and Applications,* Cambridge University Press, NY, USA, ISBN: 978-0-521-88093-0.

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

Brazeal, M., (2009). RFID: *Improving the Customer Experience,* Paramount Market Publishing, Inc., NY, USA, ISBN: 978-0-9801745-3-3.

Ahson, S. A., & Ilyas, M., (2008). *RFID Handbook, Applications, Technology, Security, and Privacy,* CRC Press, FL, USA, ISBN: 978-1-4200-5499-6.

Khan, M. A., Sharma M., and Prabhu R, B., (2009). A Survey of RFID Tags, *International Journal of Recent Trends in Engineering,* Vol. 1, No. 4, pp. 68-71.

Klaus, F., (2010). *RFID Handbook: Fundamentals and Applications in Contactless Smart Cards, Radio Frequency Identification and Near-Field Communication, Third Edition,* John Wiley & Sons Ltd., West Sussex, UK, ISBN:978-0-470-69506-7.

Shepard, S., (2005). *RFID: Radio Frequency Identification,* McGraw-Hill Companies, NY, USA, ISBN:0-07-144299-5.

Roberts, C.M., (2006). Radio frequency identification (RFID), *computers&security,* Vol. 25, pp. 18–26.

Xiao, Y., Yu, S., Wu, K., Ni, Q., Janecek, C., and Nordstad, J., (2007), Radio frequency identification: technologies, applications, and research issues, *Wireless Communications And Mobile Computing,* Vol. 7, No. 4, pp. 457–472.

Glover, B., & Bhatt, H., (2006). *RFID Essentials,* O'Reilly Publishing, Sebastopol, CA, USA, ISBN: 978-0-596-00944-1.

Fosso Wamba, S., Lefebvre, L. A., and Lefebvre, E., (2007). Integrating RFID Technology and EPC Network into a B2B Retail Supply Chain: a Step toward Intelligent Business Processes. *Journal of Technology Management & Innovation,* Vol. 2, No. 2, pp. 114-124.

Hossain, S. S., & Karmakar, N., (2006). An Overview On RFID Frequency Regulations And Antennas, *4th International Conference on Electrical and Computer Engineering (ICECE),* Dhaka, Bangladesh, pp. 424-427.

Lahiri, S., (2005). *RFID Sourcebook,* Pearson Education, IBM Press, Indiana, USA, ISBN: 978-0-13-185137-5.

Veronneau, S., & Roy, J., (2009). RFID benefits, costs, and possibilities: The economical analysis of RFID deployment in a cruise corporation global service supply chain, *International Journal of Production Economics, Elseiver,* Vol. 122, No. 2, pp. 692-702.

Kwak, C., Cho, Y., Ko, J. M., and Kim, C. O., (2011). Adaptive Product Tracking in RFID-Enabled Large-Scale Supply Chain, *Expert Systems with Applications, Elseiver,* Vol. 38, No. 3.

Ferrer, G., Dew, N., and Apte, U., (2010). When is RFID right for your service?, *International Journal of Production Economics, Elsevier,* Vol. 124, No. 2, pp. 414-425.

Werner, K., & Schill, A., (2009), Automatic Monitoring of Logistics Processes Using Distributed RFID based Event Data, *International Workshop on RFID Technology (IWRT),* Milan, Italy, pp. 101-108.

Tajima, M., (2007). Strategic value of RFID in supply chain management, *Journal of Purchasing and Supply Management, Elseiver,* Vol. 13, No. 4, pp. 261-273.

Chuang, M.-L., & Shaw, W. H., (2005). How RFID Will Impact Supply Chain Networks, *IEEE International Engineering Management Conference (IEMC 2005),* Newfoundland, Canada, pp. 231-235.

Sarac, A., Absi, N., and Dauzere-Peres, S., (2010). A literature review on the impact of RFID technologies on supply chain management, *International Journal of Production Economics, Elsevier,* Vol. 128, No. 1, pp. 77- 95.

Asif, Z., & Mandviwalla, M., (2005). Integrating the supply chain with RFID: a technical and business analysis, *Communications of the Association for Information Systems,* Vol. 15, No. 24, pp. 393–427.

Saygin, C., Sarangapani, J., and Grasman, S. E., (2007). A Systems Approach to Viable RFID Implementation in the Supply Chain, *Trends in Supply Chain Design and Management Technologies and Methodologies, Springer series in advanced manufacturing, Part 1,* pp. 3-27.

Gaukler, G. M., & Seifert, R. W., (2007). Applications of RFID in Supply Chains, *Trends in Supply Chain Design and Management Technologies and Methodologies, Springer series in advanced manufacturing, Part 1,* pp. 29-48.

Bagchi, U., Guiffrida, A., O'Neill, L., and Hayya, J., (2007). The Effect of RFID On Inventory Management and Control, *Trends in Supply Chain Design and Management Technologies and Methodologies, Springer series in advanced manufacturing, Part 1,* pp. 71-92.

Chuang, M.-L., & Shaw, W. H., (2007). RFID: Integration Stages in Supply Chain Management, *IEEE Engineering Management Review,* Vol. 35, No. 2, pp. 80-87.

Chen, N.-K., Chen, J.-L., Chang, T.-H., and Lu, H.-F., (2008). Reliable ALE middleware for RFID network applications, International Journal Of Network Management, John Wiley & Sons, Vol. 19, No. 3, pp. 203-216

Hunt, V. D., Puglia, A., and Puglia, M., (2007). RFID: *A Guide to Radio Frequency Identification,* John Wiley & Sons Inc., New Jersey, USA, ISBN: 978-0-470-10764-5.

Saygin, C., (2007). Adaptive inventory management using RFID data. *The International Journal of Advanced Manufacturing Technology,* Springer, Vol. 32, No. 9-10, pp. 1045-1051.

Sarma, S., (2004). Integrating RFID, *Queue,* ACMDL, NY, USA, Vol. 2, No. 7, pp. 50-57.

Prabakar, V., Kumar, B.V., and Subrahmanya, S.V., (2006). Management of RFID-centric business networks using Web Services, *Advanced International Conference on Telecommunications and International Conference on Internet and Web Applications and Services (AICT-ICIW'06),* Guadeloupe, French Caribbean, pp. 133.

Minli, W., Gang, W., and Dajun, H. (2008). Device Management in RFID Public Service Platform, *3rd International Conference on Convergence and Hybrid Information Technology,* Busan, Korea, Vol. 01, pp. 1133-1136.

Smith, A. D. (2005). Exploring Radio Frequency Identification Technology and Its Impact on Business Systems, *Information Management & Computer Security,* Vol. 13, No. 1, pp. 16-28.