Radio Frequency Identification Technology: An Overview of its Components, Principles and Applications

Dibyendu Bikash Datta

Abstract - Radio frequency identification (RFID) assists in automatic identification of physical products using radio waves. The technology innovation dates to the mid to late 1940s, is growing rapidly and has the potential to affect many different industries and applications. Today RFID is mostly used as a medium for numerous tasks including managing supply chains, tracking product and livestock, preventing counterfeiting, controlling building access, and supporting automated checkout. Most of the countries are using RFID technology in their private and public sectors. It is important in improving efficiency and visibility, cutting costs, asset utilization, reducing shrinkage and counterfeiting, delivering better, producing higher quality goods, and increasing sales by reducing out-of-stocks. The use of RFID is limited by security concerns and delays in standardization. The paper gives an overview of the current state of the art in the RFID technology, a survey on RFID tags and readers, commonly used frequencies and identifier systems. The paper also discusses on the current and envisaged fields of application, as well as advantages and limitations of use.

Index Terms - RFID, radio frequency identification, electronic article surveillance, sensor networks, RFID benefits, RFID limitations.

I. INTRODUCTION

Radio frequency identification (RFID) is a fastest growing wireless Automatic Data Capture Systems (AIDC) that has the potentiality to make great economic impacts on many industries [1]. While RFID is a relatively contactless old technology and uses RF signals for communication, more recent advancements in chip manufacturing technology are making RFID practical for new applications and settings, chiefly consumer item level tagging. These advancements have the potential to revolutionize supply chain management, enterprise resource planning, inventory control, human resource, logistics and to other areas. Due to technological advancements and development in humans as a result of scientific research and implementations, the need for real-time information storage and processing has become imperative and thus the use of RFID in various fields has become extensive. RFID has also given employees opportunity to channel productive hours to achieve organizational goals while data is being managed through RFID technology. Different objects including humans, goods, vehicles, assets can be easily tracked using RFID technology. The population explosion and the introduction of big data have made RFID technology supreme in every field.

RFID systems is relatively a type of automatic identification system, similar to optical bar codes. Barcode may possibly remain the better solution, particularly in the short to medium term. RFID isn't as cheap as traditional labeling technologies, but it does provide added value and is now at a critical price point that could enable its large-scale adoption for managing consumer retail goods. The major downside at present is the price of individual RFID tags and the system setup costs [2]. Table 1 provides a comparison of the attributes for barcodes and RFID.

Table 1. : Comparison of Barcode vs. RFID

Attribute	Barcode	RFID
Positive	–Low cost –Broad utilization –Human readable	–No line of sight –Large memory: data moves with product /asset –Dynamic data reads
Negative	–Data transfer requires line of sight –Limited data storage –Environmentally sensitive	–Higher costs –Read sensitive to product attributes –Limited adoption

II. RESEARCH OBJECTIVES

The purpose of this research is to improve the understanding of RFID technology and to identify the potential of using RFID to manage various assets and utilities. The scope includes a brief introduction to the principles of the technology, advantages, concerns and limitations of use of RFID technologies.

III. LITERATURE REVIEW

A number of studies show that RFID can be used in different ways to create value. Several world renowned companies use RFID technology to enhance their business performance with immense care of consumers and environmental concerns. Chao-Che Lin and Teh-Hsing Ku demonstrate how participating employees with a systemic view can adopt a better methodology to solve problems in RFID and how performance can be improved through Systems Thinking [3]. A workshop conducted by US Federal Commission brought together RFID proponents, privacy experts, and other interested parties to discuss various RFID's current and possible applications and their implications for consumer privacy. It also emphasized

Manuscript received Feb, 2016

***Dibyendu Bikash Datta**, Department of Fashion Management Studies, National Institute of Fashion Technology,(Ministry of Textiles, Government of India), Salt Lake City, Kolkata, India, Mobile No.:+919433327019,*

ISSN: 2278 – 7798

proposals to address these implications and initiated discussion about the merits of these different approaches [4]. Another study conducted by Mehmet *et al.* explained organizations should consider their corporate responsibility before adopting the true value of RFID and its applications as a new technology [5]. Nemeth *et al.* present modern RFID systems, its challenges and possibilities of integration to supply chains [6]. Chao *et al.* provide a review of the literature on trends and forecast of RFID technologies by a historical review method and bibliometric analysis [7]. They focus on the RFID innovation, deployment by enterprises and market diffusion in supply chain management. Delaunay *et al.* present a survey on the causes of inventory inaccuracy in supply chain management [8]. Dolgui and Proth present a review on the advantages of RFID technologies in inventory management. They also analyze problems related to privacy and authentication properties of RFID technologies [9].

IV. RFID EVOLUTION

RFID technology has passed through many phases over the last few decades. The technology has been used in tracking delivery of goods, in courier services and in baggage handling. Other applications includes automatic toll payments, departmental access control in large buildings, personal and vehicle control in a particular area, security of items which shouldn't leave the area, equipment tracking in engineering firms, hospital filing systems, etc.[10,11]. Table 2 shows RFID evolution over the past few decades.

Table 2: RFID evolution over the past few decades.

Period	Developments
1940 - 50	RFID (Long range systems) was first used during World War II to identify rival aeroplanes.
1950 - 60	Early explorations of RFID technology, laboratory experiments.
1960 - 70	Development of the theory of RFID, field trials begin, the first RFID companies Sensormatic & Checkpoint were founded, first Electronic Article Surveillance (EAS) is released to counter theft.
1970 - 80	Explosion of RFID development, Tests of RFID accelerate, very early adopter implementations of RFID, RCA & Fairchild publish "Electronic ID System", New York and New Jersey Port Authority test electronic toll applications
1980 -90	Commercial applications for RFID enter the mainstream, Applications emerge in transport, industrial, personnel access and animal tagging, Toll roads world-wide are equipped with RFID
1990 - 2000	RFID becomes a part of everyday life, RFID widely deployed in toll collection, animal tagging and personal identification Emergence of initial RF open standards, MIT founds the Auto-ID Centre
2000 - 2010	RFID explosion continues, First CPG / Retailer auto ID pilots launched, Gillette buys 500 million tags from Alien Tech., Wal-Mart, Tesco and the US Department of Defense announce supplier mandates, The MIT Auto-ID center became the global in charge of promoting the EPC (Electronic Product Code) standard.
2010 -	RFID technologies are now widely used in almost all industrial sectors such as aerospace, automotive, logistics, health, life and hazardous areas. International Standard Organization (ISO) established technical and applicative standards to have a high degree of interoperability or interchangeability.

V. RFID PRINCIPLES

A basic RFID system consists of three main components:

a) the RFID transponder or tag, which is located on the object to be identified and is the data carrier in the RFID system,
b) the RFID reader, or transceiver, which may be able to both read data from and write data to a transponder, and
c) the data processing subsystem which utilizes the data obtained from the transceiver in some useful manner.

Client Computer | Enterprise application and RFID Middleware | RFID Reader | RFID Antenna | RFID Tag

Figure 1. Basic mechanism of a RFID System

A. *RFID tag*

An RFID tag include a *microprocessor*, *transmitter* and a *radio antenna* that allows data from the tag to be read and written contact-less between the reader and the tag. There are two broad categories of RFID systems: *active* and *passive*. Active tags have its own power source, longer read ranges and are generally expensive than passive tags, which means they can't be used on low-cost items. There are also *semi-passive* and battery-assisted RFID tags, which are suitable for specific applications. Semi-passive tags use a battery to operate the chip's circuitry, but communicate by drawing power from the reader. Active and semi-passive tags continuously broadcast their own signal and are commonly used to accurately track assets in the real-time location or in high speed environments such as tolling. Passive tags are less costly, don't require batteries or maintenance, get their power from the reader's magnetic field, and have short read ranges. The tags also have an indefinite operational life and are small enough to sufficiently fit into a practical adhesive label. The lower price makes employing passive RFID systems economical for many industries. Passive RFID tags have applications including file tracking, access control, supply chain management, smart labels, and more. [12]. RFID tags can be grouped under a number of categories as presented in Table 3.

Two fundamentally different RFID design approaches exist for transferring power from the reader to the tag: *near-field systems* that employ inductive (magnetic) coupling of the transponder tag to the reactive energy circulating around the reader antenna, and *far-field systems* that couple to the real power contained in free space propagating electromagnetic plane waves [13,14]. Both can

ISSN: 2278 – 7798

transfer enough power to a remote tag to sustain its operation - typically between 10 μW and 1 mW, depending on the tag type. Near-field coupling techniques are generally applied to RFID systems operating in the Low Frequency (LF) and High Frequency (HF) bands with relatively short reading distances, whereas far-field coupling is applicable to the potentially longer reading ranges of Ultra-High Frequency (UHF) and microwave RFID systems. Whether or not a tag is in the near or far field depends on how close it is to the field creation system and the operating frequency or wavelength. There is a distance, commonly known as the radian sphere, inside which one is said to be in the near field and outside of which one is said to be in the far field. Because changes in electromagnetic fields occur gradually, the boundary is not exactly defined; the primary magnetic field begins at the antenna and induces electric field lines in space (the near field).

Choosing the technology for a particular application depends on careful consideration of the different capabilities, costs and performance characteristics of the various RFID technologies in relation to the needs of the application. RFID systems only allow relatively low volumes of data to be stored on the tags (typically less than 2k bits of data = 250 characters or as little as only 8 characters in the case of some active tags). As a result the design of the information to be held on the tag is a critical part of the application.

Table 3: Classification of RFID tags

By design and technology used	
Passive	–also called 'pure passive', 'reflective' or 'beam powered' –obtains operating power from the reader –the reader sends electromagnetic waves that induce current in the tag's antenna, the tag reflects the RF signal transmitted and adds information by modulating the reflected signal
Semi-passive	–uses a battery to maintain memory in the tag or power the electronics that enable the tag to modulate the reflected signal –communicates in the same method, as the other passive tags
Active	–powered by an internal battery, used to run the microchip's circuitry and to broadcast a signal to the reader –generally ensures a longer read range than passive tags –more expensive than passive tags (because usually tags are read/write) –the batteries must be replaced periodically
By the tag's memory type	
Class 0	Read Only, preprogrammed passive tag
Class 1	Write Once, Read Many (WORM) passive tag
Class 2	Passive Read-Write tags that can be written to at any point in the supply chain
Class 3	Read-Write with onboard sensors capable of recording parameters like temperature, pressure, and motion; can be Semi-passive or active
Class 4	Read-Write active tags with integrated transmitters; can communicate with other tags and readers
Class 5	Similar to Class 4 tags but with additional functionality; can provide power to other tags and communicate with devices other than readers
By the method of wireless signal used for communication between the tag and reader	
Induction	–Close proximity electromagnetic, or inductive coupling - *near field* –Generally use LF and HF frequency bands
Propagation	–Propagating electromagnetic waves - *far field* –Operate in the UHF and microwaves frequency bands

B. RFID Reader

The RFID Reader, also known as an "interrogator," is a data capture device responsible for powering and communicating with tags, application and computer networks. The reader is equipped with antennas for sending and receiving signals, a transceiver, and a processor to code/decode data. In a passive system, the RFID reader transmits an energy field that wakes up the tag and powers its chip, enabling it to transmit or store data. Active tags may periodically transmit a signal so that data can be captured by multiple readers distributed throughout a facility. Readers may be portable handheld terminals or fixed devices positioned at strategic points, such as a store entrance, assembly line, or toll booth (gate readers.) Readers can have PCMCIA (Personal Computer Memory Card International Association) cards to connect to laptop PCs, usually powered from their own power source (battery) or by the vehicle they are mounted on, and typically have wireless connectivity. Readers typically operate at one radio frequency, so if tags from three different manufacturers used three different frequencies, a retailer might have to have multiple readers in some locations, increasing the costs further. The classification RFID readers is presented in Table 4.

Table 4: Classification of RFID readers

By design and technology used	
Read	–only reads data from the tag –usually a micro-controller-based unit with a wound output coil, peak detector hardware, comparators, and firmware designed to transmit energy to a tag and read information back from it by detecting the backscatter modulation –different types for different protocols, frequencies and standards exist
Read/write	–reads and writes data from/on the tag
By fixation of the device	
Stationary	–The device is attached in a fixed way, for example at the entrance gate, respectively at the exit gate of products
Mobile	–The reader is a handy, movable device.

C. RFID Frequencies Range

The range of the RFID tags depends on their frequency. Most RFID systems operate in the Industrial - Scientific -

ISSN: 2278 – 7798

Medical (ISM) bands, which are freely available to low-power, short-range systems [15]. These bands are defined by the International Telecommunications Union (ITU). Devices operating in each band are subject to different power and bandwidth regulations. The RFID operating frequencies and performance characteristics are mentioned in Table 5.

This frequency determines the resistance to interference and other performance attributes. The selection of RFID tag depends on the application; different frequencies are used on different RFID tags [10]. EPCglobal and ISO are the major organizations working to develop international standards for RFID technologies in the UHF band [16]. In order to avoid the use of different radio frequencies standards, most of the international communities are obligated to comply with the ITU standards.

Table 5: Operating Frequencies and Performance Characteristics

Description	**Low Frequency**	**High Frequency**	**Ultra-High Frequency**		**Microwave**	
Frequency range	125-134 KHz	13.56 MHz	850-950 MHz		2.45 or 5.8 GHz	
Tag type	Passive	Passive	Active and passive		Active and passive	
Read range	0 - 0.5m	< 1.5 m	Active	Passive	Active	Passive
			3-10m	> 10m	3-10m	> 10m
Tag size	Larger	Larger	Smaller		Smaller	
Data transfer rate	Slow	Medium	Fast		Fastest	
Ability to read near metal or wet surface	Best	Better	Worse		Worst	
Tag cost	High	Lower than LF tags	Lowest		High	
Typical application	Livestock tracking, Beer Kegs, Auto Key & Lock, Library Books	Item level tracking, Airline baggage, Building access	Supply chain tracking, Warehouse management, Case, pallet, truck and trailer tracking		Electronic toll collection, Railroad monitoring	
Advantage	Work well around liquids and metals, global standards, no radiation / reflection problems	Larger memory, global standards, tolerant of fluids and metals	Longer read range, write extensive amount of data, lower cost readers, high data transmission rates (read more tags at one time)		Longer read range potential, growing commercial use	
Disadvantage	Very short read range, limited memory, low data transmission rate (read very few tags at one time), high production cost, impractical for warehouse operations	High read rate compared to LF, low data transmission rate (read fewer tags at one time) does not work near metal	Very high tag cost, complex software may be necessary, does not work in moist environments		Complex systems development, Most expensive	

D.Electronic Product Code (EPC)

With so much trade being conducted globally, standards and regulations are important to ensure safety and the interoperability of tags and readers across national boundaries and between trading partners. EPC is one common type of data stored in a tag. EPC are encoded on RFID tags as a license plate, indexed to a store of related information. which can be used to track all kinds of objects including: trade items, fixed assets, documents, or reusable transport items. This new identification system has the characteristics of interoperability and open standards backed by EPCglobal, a partnership of the Uniform Code Council and European Article Numbering International (EAN). When written into the tag by an RFID printer, the tag contains a 96-bit string of data. The first eight bits are a header which identifies the version of the protocol. The next 28 bits identify the organization that manages the data for this tag; the organization number is assigned by the EPCglobal consortium. The next 24 bits are an object class, identifying the kind of product; the last 36 bits are a unique serial number for a particular tag. These last two fields are set by the organization that issued the tag. Rather like a Uniform Resource Locator, the total electronic product code number can be used as a key into a global database to uniquely identify a particular product.

VI. ADVANTAGES OF RFID

RFID has many advantages over barcodes, but barcodes have become a standard in many industries for many worthwhile reasons. Depending on the application, either system will have its strengths and weaknesses. When it comes time for you to make a decision between either system, keep the initial and recurring costs in mind, as well as the potential return on your investments. In years past, implementing a full-scale RFID system was cost prohibitive for small to mid-size companies, but today, the difference in the cost of a new barcode system versus an RFID system may be minimal in certain applications. Also, investing in an RFID system may pay for itself over time due to potential increases in efficiency and decreases in errors. With an RFID system, several benefits that can be achieved with RFID solutions:

RFID doesn't need line of sight. : For a barcode to be read, the scanner must be placed directly in front of each label, and both need to be oriented in a very specific position in order to work properly. RFID tags on the other hand, don't need to be directly in sight of an RFID reader. Because RFID

ISSN: 2278 – 7798

uses radio waves to communicate, RFID tags only need to be within the read range of the reader, which will vary depending on the equipment.

An RFID tag is read/write : A barcode can only be read, and the data can never be changed once it has been printed onto a label. RFID tags can be read, and the data on the tag can be rewritten or modified as needed.

RFID tags are durable and reusable : Because barcodes are typically printed on paper labels or other unprotected surfaces, they are easily damaged and rendered unreadable. Depending on your application, you can find RFID tags specifically designed to work in harsh conditions. A durable hardcase protects these RFID tags from impacts, heat, moisture, and changing weather conditions. As we mentioned previously, since RFID tags are updatable, they can be reused, which will cut costs in your deployments.

Data is encrypted. **:** Barcodes are easily counterfeited, and the data itself is always readable. With RFID tags, your data is much more secure as the information has the ability to be encrypted. Also, it's much more difficult to replicate RFID tags recognized in your system.

RFID tags are capable of storing more data.: Standard barcodes are limited in the amount of information they are capable of representing. An RFID tag actually stores data in non-volatile memory and is capable of storing up to 8 kilobytes of data in certain tags.

Read rate is greatly increased.: Each barcode must be individually scanned in order to be entered into the system. RFID systems can read multiple tags at the same time, and do not need line of sight. Since RFID readers are capable of reading hundreds of tags at once, the increase in read rate saves you time that can be spent elsewhere.

RFID tags can be printed with a barcode : If you have a bar-coding system in place, but would like to make the switch to RFID, or perhaps you have need of both barcodes and RFID, you may find using RFID tags with printable paper labels to be quite advantageous. Overall, RFID systems have many more features than simple bar-coding systems, but both RFID and barcodes are good fits for certain applications. Each situation must be analyzed on its own in order to determine if RFID is the right call.

Reduce warehouse and distribution labor costs : Replace the point and read labor-intensive operation of tracking pallets, cases, cartons and individual products with sensors that can track these items anywhere in the facility with pin-point accuracy. This can reduce the high labor costs and service fees of regular stock management and store shelf inventory.

Reduce point-of-sale labor costs : With RFID-enabled products, checkout can be completed with a quick scan of all items in cart helping to reduce point-of-sale labor costs. The current scan-it-yourself component of self-service checkout can be improved, helping to improve adoption, reduce self-service checkout times and reduce fraud.

Reduce inventory : Inventory accuracy is important to helping eliminate excess/missing inventory, losses and write downs. With RFID, inventory errors can be reduced so that the company can be assured that the inventory indicated is the actual inventory available.

Improve forecasting and planning: The supply chain is becoming smarter. Visibility improvements throughout the supply-chain can help to improve the forecasting capabilities to help better track where inventory is and what is happening to it throughout the supply chain. RFID has already made its mark with companies like Wal-Mart, Tesco, and Gillette using it to track inventory and improve stock replenishment. Pilot RFID projects in these areas are already saving money and improving efficiency. RFID has the potential to dramatically improve forecast accuracy.

Reduce theft : RFID technology provides item-level visibility throughout the supply chain, and improves inventory accuracy. The item-level visibility gives the location and date-stamps of goods as it moves throughout the distribution process. Products can be tracked through the supply chain to pinpoint where a product is and eliminate inventory errors that can cause shipments to go missing, or to better find where and when in the process the product was lost. Within the retail store, RFID can be successfully deployed, particularly on higher margin items, to help combat theft by shoplifters and employees.

Reduce out-of stock conditions :

When an item is out-of-stock, 20 percent of the time the customer either does not buy it or else buys a competitive product. In grocery stores, as much as 8.3 percent of revenue is lost each year due to out-of-stock conditions [17].

Eliminating out-of-stock conditions via better RFID product tracking and inventory visibility and forecasting, such as alerting the store staff immediately when the last item leaves the shelf, can have an immediate top-line revenue impact and have residual effects by improving customer service and satisfaction. Similarly, taking advantage of the serial number associated with each tag, the manufacturer can monitor the aging of specific pallets, cases or containers of inventory in the customer's premises and potentially head-off product spoilage or product-aging claims.

Improve customer experience :With RFID, items in a cart can be tracked and if a high-tech cart or kiosks are part of the shopping experience, offers can be made automatically related to the items - such as dynamic up-sell/cross-sell of useful or necessary accessories.

VII. RFID APPLICATIONS IN THE WORLD

Early commercial examples of RFID applications include automatic tracking of train cars, shipping containers, and automobiles. Railroad cars were originally labeled with optical bar code labels for tracking. These labels began to deteriorate and be obscured by dirt, causing reads to fail. As a solution, railroad companies began to tag railcars with RFID devices. By 1994, these devices were mandatory and nearly every railcar in the United States was tagged. RFID devices began to be used for automated toll collection in the late 1980s and early 1990s. Electronic toll systems have since been adopted around the world. Like railway and shipping applications, electronic toll systems may use sturdy, self-powered RFID devices. Automobiles, railcars, and shipping containers are all high-value items, with ample

ISSN: 2278 – 7798

physical space that can accommodate more expensive and bulky RFID devices. These types of tags could offer much more functionality than simple identification. For example, shipping containers might have accelerometer sensors, tamper alarms, or satellite tracking integrated into an identification device.

As manufacturing costs dropped, RFID systems began to be used for lower-value items in industries besides transport. An example is in animal identification of both pets and livestock. Glass-encapsulated RFID devices have been implanted in millions of pets throughout the United States. These tags allow lost animals to be identified and returned to their rightful owners. These tags have a very short read range.

Livestock, particularly cattle, are often labeled with a RFID device that is clamped or pierced through their ear, attached to a collar, or swallowed. Unlike implanted pet tags, these RFID devices are rugged and able to be read from greater distances.

Other widespread applications of RFID systems include contactless payment, access control, or stored-value systems. Since 1997, ExxonMobil gasoline stations have offered a system called SpeedPass that allows customers to make purchases with an RFID "fob", typically a keychain-sized form factor [15]. In 2005, American Express launched a credit card enhanced with RFID that allows customers to make purchases without swiping a card.

RFID proximity cards or "prox cards" are commonly used for building access control at many companies and universities throughout the world. Similar systems have been used for ski-lift access control at ski resorts around the world. Many subway and bus systems around the world, for example in Singapore, use stored-value RFID proximity cards.

There are several applications that use RFID as an anti-counterfeiting measure. In 2005, the Wynn Casino in Las Vegas first opened and deployed RFID-integrated gaming tables and gambling tokens. These "chips-in-chips" are designed to frustrate counterfeiting, prevent theft, detect fraud, and to offer enhanced games or service. Besides stored-value tokens like casino chips or event tickets, there have also been proposals to tag currency [18]. In 2005, a controversial proposal to attach tags carrying biometric identification data to United States passports began to be implemented.

While RFID continues to lower the costs of tracking high-value items, an untapped and lucrative market lies in tracking cheap, everyday consumer goods. Companies like Proctor & Gamble, Coca-Cola, and Wal-Mart have hundreds of billions of products and components in their supply chains. Tracking and managing the flow of goods through these supply chains is a complex and expensive enterprise. Wal-Mart and the Department of Defense of US told their top suppliers to begin tagging cases and pallets with RFID tags by January of 2005. Most enterprises will be forced to redesign their value chain processes as a result of RFID changing the storage, collection, and use of data concerning goods in the supply chain. [19].

In response to the growing problem of counterfeit drugs, the United States Food and Drug Administration recommended that all wholesale prescription drug shipments be labeled with RFID pedigrees. The goal of these pedigrees is to both attest to the authenticity of a drug shipment and to detect simply theft in the supply chain. In 2003, razor manufacturer Gillette placed a single order of five hundred million low-cost RFID tags from a manufacturer named Alien Technologies. Gillette disposable razor blade cartridges are relatively expensive, costing US $1-2 per blade or more [15].

Because these items are small, easily concealable, and there is a constantly growing resale market, Gillette blades were one of the most frequently shoplifted consumer items. Somewhere between 15-20% of Gillette's blades are stolen (or "shrink") between manufacturer and the consumer point of sale. The high costs of "shrinkage" justified incorporating RFID tags into every razor blade package that Gillette sells.

The fashion industry has also been an early RFID-adopter. Several fashion makers like Swatch watch, Ecco shoes, Prada, and Benetton have all tagged clothing with RFID labels. These tags are typically for retail inventory control, since retail clothing stores often face a high level of "shrinkage", as well a lot of legitimate movement of inventory by customers trying on clothing. RFID tags have also been used as a pedigree for high-fashion items or to enhance the consumer shopping experience. For example, Prada's retail store in New York City offers an RFID-enhanced dressing room that displays product information and suggests matching apparel.

Clothing is particularly suited for RFID, since it does not contain metals or liquids that interfere with some types of RFID systems. Retail stores also typically do not have sensitive electronics, like medical equipment, that some RFID operating frequencies may interfere with. Clothing's relatively high per-unit value also justifies the use of RFID tags, which could be removed and recycled at purchase-time. The clothing industry was an early-adopter of simple EAS systems in the 1960s for these very reasons. It will likely be a leader in RFID adoption as well.

The next step in RFID for clothing may be to integrate tags directly in the product at the time of manufacture, rather than manually attaching temporary tags. This greatly lowers RFID handling costs. Directly incorporating RFID into products or packaging will likely become commonplace once the proper technology becomes economical [20]. A promising direction is to print RFID labels directly into paper products during manufacturing time. This would lower the handling and processing costs of integrating RFID with consumer products.

The public sector is an important user of RFID technology in addition to rapidly increasing use of RFID in the private sector. Seven main application areas in the public sector are listed below:

E-passports and identity credentials *:* E-passports combine the traditional paper document with an RFID tag where the critical information is stored. The RFID tag often contains biometric data such as data for facial recognition and fingerprints. The format of the biometric data and

ISSN: 2278 – 7798

communication protocols is defined in a standard adopted by the International Civil Aviation Organization to ensure international inter- operability. RFID technologies are also planned for national identity credentials or other official documents such as driving licences, residence permits, social security cards, etc.

Public services (e.g. waste management/waste control) : Public services include services such as the management of parking facilities and waste management. In waste management RFID is used for two main purposes: for tracking (hazardous) waste to protect the environment and to allocate costs according to the amount of waste. Currently applications can, for example be found in Korea where pilot projects in the field of hazardous waste tracking were conducted as well as in Germany where costs of waste are calculated according to the waste's volume or quantity.

Health (e.g. applications in hospitals) : A significant number of public sector RFID projects are implemented in healthcare. One area where multiple projects are already at the implementation stage is the hospital sector. RFID is used to track assets such as beds or containers, to identify patients for medication control and to track babies and dementia patients to increase their security. Other applications include health insurance cards which have already been introduced in Mexico, for example. Information such as username and prescribed drugs are stored on the embedded RFID chip.

Document administration/postal services : The public sector also uses RFID technology for the administration of documents. In this field, RFID tags are attached to documents to improve the location of documents and thus to increase process efficiency and quality. RFID is also used for postal services in distribution centres to facilitate the sorting of mail items.

Defence : RFID technology in the area of defence is mainly used to streamline supply- chains and procurement processes. The most prominent example of a department relying intensively on RFID technology is the US Department of Defense. Both active and passive tags are attached to inbound and outgoing shipments at the case and pallet level.

Education/Cultural institutions/Science : The public sector also relies on RFID at its cultural institutions. Examples include lending systems at libraries and newer applications can be found in museums where artworks are presented via RFID technology via automatic display of information.

Logistics/Transport (e.g. toll collect systems) : Finally, RFID is used by the public sector in the fields of logistics and public transports. Toll collect systems were early applications of RFID technology. Newer applications are access cards for public transport, RFID-based bus schedules as well as particular location-based services. Table 6 gives a non-exhaustive overview of RFID applications used by countries indicating that applications are very diverse.

Overall, governments are currently developing and using RFID in a variety of different areas. To be an important user of RFID technology has a number of important effects both for further RFID suppliers and users. On the supply side, government projects can have significant effects. Pilot projects contribute to further development and testing of different components of RFID systems, and are seen as an important means to spur innovation. Moreover, important implementation projects support the formation of an RFID market at national and international level. These effects on the supplier side enhance a more reliable and sophisticated supply of different components of RFID systems.

On the user side, pilot projects conducted by governments provide pilot experiences for new RFID applications. Both the public and the private sector profit from technology feasibility studies and testing results. A further characteristic of government projects is their ability to generate valuable experience and robust results on a large scale. Furthermore, many of the governments' RFID projects may trigger wider applications.

Government projects are usually designed to disseminate results widely. A wide range of stakeholders involved in RFID technology benefit from these projects and results are usually made broadly available. If this process is organized in a highly efficient way, spill-over benefits of public sector RFID projects can be considerable.

Table 6: Selected RFID applications in the public sector

Country	Project Category	Project Description
Austria	Health	Tests by the municipal administration of Vienna on the applicability of RFID in the health care system
	Public services	Tests in the Viennese parking facility management
Denmark	Education	Lending systems in libraries
	E-passport	E-passport available since mid-2006; biometric passport relying on RFID embedded fingerprint technology to be introduced mid-2009
Germany	E-passport	E-passport (available since the end of 2005), electronic ID card (to be introduced at the end of 2009)
	Public services	Waste management in different communities
	Education	Lending systems in libraries
Japan	Logistics/Transport	Set-up of the "Free Mobility Assistance System" based on ubiquitous network technology including RFID tags, to provide information for seamless movement (e.g. transfer routes and transport modes)

ISSN: 2278 – 7798

Korea	Public services, health, defence, logistics/ transport	Pilot projects in the fields of procurement, baggage handling, container management, ammunition management, tracking hazardous waste, museums, air cargo, etc.
Mexico	Health	Health insurance card: RFID technology is integrated in the "popular insurance" card where the username, information on doctors as well as prescribed drugs are stored
Netherlands	E-passport	E-passport
	Health	RFID technology used in hospitals
	Education	Libraries
	Logistics/Transport	Payment cards for public transport
Portugal	E-passport	E-passport and e-passport control systems at Portuguese airports (e.g. Lisbon, Faro)
Spain	Document administration/ postal services	The Spanish postal service uses RFID technology in 15 distribution centres in different locations in Spain (e.g. Madrid, Barcelona)
United Kingdom	E-passport	Biometric passport relying on RFID technology
United States	Defence	Use of passive and active RFID tags for inbound and outgoing shipments along the supply chain
Singapore	Logistics/Transport	Nationwide Electronic Road Pricing (ERP) system to control and manage traffic volume; payment of road usage charges. The ERP is applied to all of Singapore's 840000 vehicles
	Public services	RFID tags replace paper season parking tickets at car parks in public housing estates
	Education	Lending systems in all national and community libraries

VIII. CHALLENGES IN RFID IMPLEMENTATION IN INDIA

RFID technology adoption in India will require great effort and sustained attention for a few more years. In April 2005, RFID Association of India was founded to promote awareness and adoption of RFID technology, standards and applications across industry, government and among academia in the country. The radio frequency band allocated for RFID in India is 865 - 867 MHz. The power has been set to 4W. In India the governing bodies monitoring the implementation of RFID are Wireless Planning & Coordination Wing, Ministry of Communications and Information Technology, and Department of Telecommunications. Despite numerous benefits over manual practices as well as computerized bar-code systems, RFID is yet to fully take off in India.

While RFID technology has already been applied effectively, it has certain technological barriers that still need to be overcome to optimize its application. Costs, interoperability and security are technical issues that all companies worldwide face in adopting RFID. These issues can be easily overcome once the adoption rate picks up. Following are some of the reasons for the status of scenario.

High Cost : RFID technologies has a great potential but the determining factor in rolling out RFID in any business has always been the cost of the RFID tag, which is higher as compared to barcode system. The RFID deployments in the country are few as compared to the hype that was created. In transition from bar-coding to RFID, cost turned out to be a big hurdle. Industrial leaders are unable to justify the return on investment and net profit by investing the extra cost in the existing system. Active tags are very expensive but cost of relatively inexpensive passive RFID tags added with the cost of reader, software, and infrastructure may not be affordable to organization as well as end customers. Apart from the initial cost, there is involvement of cost involved in maintenance and upkeeping of the system. But, with gradual decline in the cost of RFID tags, the technology is becoming more affordable and are expected to completely replace the barcode system in future.

Small scale: Compared to bigger corporate houses of western world, Indian businesses lack scale to justify return on investment from RFID. Small and medium size organizations cannot afford the cost of implementing the entire technology. Manual labor savings from RFID deployment are not attractive enough in India where labor costs are already low.

Lack of standardization: The standards for RFID technology are still evolving and there are many hurdles ahead of it. RFID has been implemented in different ways by different manufacturers; global standards are still being worked on. Many versions of RFID exits that operate at different frequencies and need different software and readers. Therefore, the need is to be agreed upon one or group of frequencies to provide interoperability between the manufacturers, retailers and distributors. There are well developed standards for low and high frequency RFID systems, but most companies want to use UHF in the supply chain because it offers longer read range up to 20 feet under good under good conditions. UHF tags are a relatively newer technology than LF or HF, and reader costs are typically higher than the lower bandwidth readers. A major disadvantage of UHF tags is that they experience interference in proximity to liquids or metals. Many applications like animal tracking, metal container tracking, or even many access control systems are infeasible with UHF tags. Some materials have been developed that may shield UHF tags from metal-related distortion, but these may be cost prohibitive to use in practice. UHF readers may also interfere with sensitive electronics like medical equipment.

Lack of mandates: Unlike western countries, India does not have any mandates from retailers or government to drive the adoption of RFID. Exporters that do not have any man-date from buyers such as Wal-Mart in the United States and Metro Group in Germany or regulatory bodies such as the U.S. Food and Drug Administration (FDA) to implement

ISSN: 2278 – 7798

RFID do not feel any motivation to implement RFID. Even other global retail giants like Tesco, Marks & Spencer and Carrefour of UK have also mandated the use of RFID for its major vendors. It appears that India's adoption of RFID technology may very well be imminent, especially since the country is gradually becoming a sourcing destination for global supply chains. This will push Indian companies exporting their products to an international market, to adopt technologies such as RFID to comply with overseas mandates. To sustain their competitive edge, these companies will also have to leverage RFID to meet customer requirements back home. For example - Ranbaxy Laboratories Limited has chosen Acsis to implement a RFID tracking system to meet Wal-Mart's RFID mandate for its Class 2 pharmaceutical suppliers

Lack of Optimal Readability: Accuracy in the case of RFID depends on three factors: signal strength, frequency, and the surrounding environment. Most tags have limited readability in RF impaired environments or when placed near metals or liquids. Researches have shown that RFID scanners successfully read tags 85 to 90 percent of the time. Some RFID tags cannot be detected by the antennas if they are shielded by the hand or the body. A solution suggested is that the RFID label should be integrated in the package or the product itself so the exact location of the tag is not known.

Privacy Issues in RFID: The impending ubiquity of RFID tags, however, also poses a potentially widespread threat to consumer privacy. The simplest RFID tag will broadcast its unique serial number – that is, its EPC to any nearby reader. Each product can get identified through its tags which can be read even if they are kept in the cars or homes of the customer. The security and privacy of the RFID against unauthorized readers is in debate from the very beginning. This presents a clear potential for privacy violations. The size of a women's dress can be publicly readable or a person gets his location tracked and recorded based on the unique ID number in shoes or other clothing by any nearby scanner. Due to this problem the clothing retailer Benetton withdraw plans for embedding RFID tags in its apparel products [21].

Researchers have recognized the RFID privacy problem for some time, and are continuing to devise better approaches. No single approach is likely to be completely satisfactory, however; a combination of methods may prove to be best. The simplest is the "Kill Tag" approach in which the tag is electronically deactivated after the item is being sold out. The tag also can be removed physically from the product before they are handed over to the consumers. The other approaches are Cryptographic approach, Hash Function approach, Faraday Cage approach, Randomized Hash Lock, backward channel XORing, Active Jamming approach, Regulation approach, etc.[21,22]

Short on Skilled Workers: Despite the potential of RFID technologies eliminated some jobs for clerks and warehouse laborers, they also created new jobs by creating new capabilities. However, these new jobs require specialized skills among both the managers and technicians, who typically have college degrees, as well as among the less educated operational occupations. Workers who have these skills, often learned on the job, are actually in short supply. Moreover, other aspects of the technology, such as mass personalization, will require levels of operational flexibility that can only be handled by a skilled and creative workforce and people will continue to be vital to the industry.

IX. CONCLUSION

In an increasingly liberated and uncertain business environment, RFID technology has potential to provide businesses, governments, and consumers a safe, private, and unobtrusive way to keep track of its product and business. RFID tag that can be read instantly without manual intervention through packaging, without direct line of sight between object (in presence of dirt, heat, moisture and contaminants), which is very valuable for production facility as well as supply chain systems. The efficient uses of RFID as demonstrated in the model, enable fast-tracking, shorten production time, relocation and distribution time, which facilitate competitive business advantages and lower product prices. In addition to advantage of prompt production time, consumers are also benefited from shorter delivery time and high level services due to the fast and accurate tracking using RFID. Results of simulated case study indicate that RFID tracking improves the efficiency of assembly production in terms of resource, time utilization and output. If RFID is implemented in the existing business processes, and databases, it will continue to improve manufacturing shop floor efficiency as well as quality of supply chain business globally.

REFERENCES

[1]. Roberti M, 2007, "The history of RFID technology" *RFID Journal* http: //www.rfidjournal.com/article/ view/1338

[2]. Lodgher, A. H., Texas., Texas Transportation Institute., & Prairie View A & M University. (2010). *Feasibility and applications of RFID technologies to support right-of-way functions: Technical report*. College Station, Tex: Texas Transportation Institute, Texas A & M University System.

[3]. Lin, C. C., & Ku, T. H. (2009). The Impact of RFID Application to Business Performance: Towards a Systemic View. *IJEBM*, *7*(1), 12-25.

[4]. Choi, Y., Kang, D., Chae, H., & Kim, K. (2008). An enterprise architecture framework for collaboration of virtual enterprise chains. *The International Journal of Advanced Manufacturing Technology*, *35*(11-12), 1065-1078.

[5]. Barut, M., Brown, R., Freund, N., May, J., & Reinhart, E. (2006). RFID and corporate responsibility: hidden costs in RFID implementation. *Business and Society Review*, *111*(3), 287-303.

[6]. Németh, P., Tóth, L., & Hartványi, T. (2006, July). Adopting RFID in supply chains. In *Mechatronics, 2006 IEEE International Conference on* (263-266). IEEE.

[7]. Chao, C. C., Yang, J. M., & Jen, W. Y. (2007). Determining technology trends and forecasts of RFID by a historical review and bibliometric analysis from 1991 to 2005. *Technovation*, *27*(5), 268-279.

[8]. Delaunay, C., Sahin, E., & Dallery, Y. (2007, September). A literature review on investigations dealing with inventory management with data inaccuracies. In *RFID Eurasia, 2007 1st Annual* (1-7). IEEE.

[9]. Dolgui, A., & Proth, J. M. (2008). RFID technology in supply chain management: state of the art and perspectives. In *IFAC World Congress. Seoul, Korea*, 4465-4475.

[10]. Ahsan, K., Shah, H., & Kingston, P. (2010). RFID applications: An introductory and exploratory study. *arXiv preprint arXiv:1002.1179*.

[11]. Garfinkel, S., & Rosenberg, B. (2006). *RFID: Applications, security, and privacy*. Pearson Education India.

[12]. Angeles, R. (2005). RFID technologies: supply-chain applications and implementation issues. *Information systems management*, *22*(1), 51-65.

ISSN: 2278 – 7798

[13]. Flores, J. L. M., Srikant, S. S., Sareen, B., & Vagga, A. (2005, January). Performance of RFID tags in near and far field. In *Personal Wireless Communications, 2005. ICPWC 2005. 2005 IEEE International Conference on* (353-357). IEEE.
[14]. Kaur, M., Sandhu, M., Mohan, N., & Sandhu, P. S. (2011). RFID technology principles, advantages, limitations & its applications. *International Journal of Computer and Electrical Engineering*, *3*(1), 151.
[15]. Weis, S. A. (2007). RFID: Principles and applications. *System*, *2*, 3Principles.
[16]. Wu, N. C., Nystrom, M. A., Lin, T. R., & Yu, H. C. (2006). Challenges to global RFID adoption. *Technovation*, *26*(12), 1317-1323.
[17]. Michael, K., & McCathie, L. (2005, July). The pros and cons of RFID in supply chain management. In *Mobile Business, 2005. ICMB 2005. International Conference on* (pp. 623-629). IEEE.
[18]. Beysenbi, M. A. (2014). *Saparkhojayev Nurbek Pazharbekovich* (Doctoral dissertation, State University of New York at Binghamton, USA).
[19]. Sullivan, M., & Happek, S. (2005). Demystifying RFID in the Supply Chain: An Overview of the Promise and Pitfalls. *United Parcel Service of America*,*1*(11).
[20]. Shin, S., & Eksioglu, B. (2015). An empirical study of RFID productivity in the US retail supply chain. *International Journal of Production Economics*,*163*, 89-96.
[21]. Juels, A., Rivest, R. L., & Szydlo, M. (2003, October). The blocker tag: Selective blocking of RFID tags for consumer privacy. In *Proceedings of the 10th ACM conference on Computer and communications security* (103-111). ACM.
[22]. Sarma, S. E., Weis, S. A., & Engels, D. (2003). Radio - frequency - identification security risks and challenges. *Cryptobytes*, *6*(1).

Author

Dibyendu Bikash Datta
Associate Professor
Department of Fashion Management Studies
National Institute of Fashion Technology
(Ministry of Textiles, Government of India)
NIFT Campus, Plot-3B, Block-LA, Sector III,
Salt Lake City, Kolkata - 700 098, India

ISSN: 2278 – 7798