CHAPTER 2  
RFID TECHNOLOGY INTRODUCTION

2.1 INTRODUCTION

The objective of this chapter is to unfold the important aspects of the Radio Frequency Identification technology which would help in the improved understanding of the rest of the thesis. Radio Frequency Identification (RFID) is an automated identification technology possessing greater identification capabilities than bar codes. Worldwide, the RFID technology acts as a base in automated data collection, identification and analysis of dynamic systems. RFID has found its importance in a wide range of markets including livestock identification and Automated Vehicle Identification (AVI) systems because of its capability to track moving objects [7,20,23,27,37,47,50,52,71,73,80,83,84,85,99,121,122]. Barcode labels could not survive in certain manufacturing environments where RFID systems are found more robust and reliable than barcode labels in certain manufacturing environment systems. Such examples include but are not limited to the penetration of RFID technology into the bodies of consumers and tagging of mothers with their new borne babies which forbids a later mismatching [53, 60, 103, 108].

In past few recent years, the automatic identification techniques have become quite more than popular and they have also find their places into the core of service industries, manufacturing companies, aviation, clothing, transport systems and much more. And, it’s pretty clear by this point of time that the automated identification technology especially RFID, is highly helpful in providing information regarding the timings, location and even more intense information about people, animals, goods etc. in transit. RFID is responsible for storage of large amount of data and is reprogrammable also as in contrast with its counterpart barcodes automatic identification technology.
In everyday life, the most common form of an electronic data-carrying device is often a smartcard which is probably based upon the contact field. But, this kind of a contact oriented card is normally impractical and less flexible to use. On the contrary, if we think of a contactless card with contactless data transferring capabilities, it would be far more flexible. This communication happens between the data carrying device and its reader. Now, this situation may further appear as ideal if it so happens that the power for the data carrying device comes from the reader by making use of the contactless technology. Because of this specific kind of power transferring and data carrying procedures, the contactless automatic identification systems are termed as Radio frequency Identification Systems. Presently a huge number of companies are actively involved in the development and sales of RFID systems which clearly indicates that this market must be taken seriously. Moreover, in recent years, RFID has grown into an interdisciplinary independent filed which hardly fits in traditional pigeon holes. This is due to the fact that this contactless automatic identification technology uses elements of diverse areas like cryptography, HF technology, telecommunications, semiconductors, data protection and many more.

Provided with the understanding, importance and exposure of present applications of the RFID technology worldwide, a the chapter now ignites a spark towards the details of the technology from various dimensions like the introduction of its umbrella term, introduction of the organization behind the prevalent acceptance of the technology, what technical fronts does RFID posses as a technology. The purpose of this chapter would be defeated without mentioning the relative lucrative benefits of the RFID technology over its competent technology namely barcode, and therefore a complete section in this chapter has been devoted for the same. Apart from that this chapter as well holds the popular standards corresponding to RFID. At the end it presents the expected possible applications of the technology.

Before proceeding towards the history of the RFID technology, a brief overview is presented.
2.1.1 AUTOMATIC IDENTIFICATION (AUTOID)

This section of the thesis primarily revolves around the umbrella term AutoID under which RFID rests. The term AutoID refers to the host of methods which automatically identify objects [164]. This is typically a process of gathering data and then feeding it into computer systems in a beeline. Technologies typically considered as part of AutoID include barcodes, smart cards, OCR and RFID. Barcode can be considered as one of the most widely recognized AutoID systems. To capture data in a fashion that increases operation efficiency and reduces data entry errors are primarily the aims of most AutoID systems. As per the current scenario, in which a number of Auto ID technologies are gaining acceptance, industries are offered a choice to adopt more efficient and accurate standard. This thesis focuses on the RFID (Radio Frequency Identification) technology which is primed to instigate the identification of objects and become the system of adoption in the industries.

2.1.2 AUTOID CENTER

This (AutoID Center) is the organization that bears the credit of the phenomenal adoption of RFID technology. All the recent technical advancements in RFID can be attributed to this organization. This is the reason why this thesis cannot ignore the role it has played and therefore presents the AutoID Center and its objectives.

2.1.3 BRIEF HISTORY

The AutoID Center bears a valuable companionship amongst near about 100 companies across the globe plus six research universities which are amongst the world’s leading ones; the MIT (Massachusetts Institute of Technology) which is in US, the UK university of Cambridge, the Australian University of Adelaide, the Japanese Keio University, the St. Gallen University in Switzerland and at last but not the least the Fudan University in China. Working all together, they are in process of creating the standards and accumulating the elements required to create the so called next generation "Internet of things." It was founded in 1999 at MIT by Sanjay Sarma and David Brock and since then it has become a central hub for RFID information. The name ‘Auto-ID’ suggests that it covers all forms of automatic identification (barcodes, voice
recognition, touch memory, smart cards, etc.), but the Auto-ID Center has decided to focus on RFID and the EPC. The Auto-ID Center believes that RFID and EPC will come up as the future ubiquitous automatic identification system which will offer amplified chances to yield revenue across the value chain and will of course save money.

2.1.3.1 ROLE

By exploiting RFID, a layer on top of the internet is being designed, tested and deployed by the Auto-ID Center. This layer further is expected to make it possible for computers in identification of objects irrespective of their location in real time. The network so formed would offer the existing business applications with a number of ways for feeding accurate, reliable and real-time information. Apart from that, it will pilot a completely novel era heading modernization and opportunity.

It acts as a communication portal for RFID research and development, offering white papers, business cases and even a program to simulate return on investment for supply chains. It is the RFID community that is addressing all issues associated with the technology; tags, readers, software and the establishment of an Electronic Product Code. Key issues such as R&D, performance enhancement, costs, and standards are the central focus.

2.1.3.2 OBJECTIVES

Falling into one of the prime aims of Auto-ID Center that will enable widespread adoption is cost to the end user. The Auto-ID Center is figuring out with its partners for making RFID a feasible alternative for barcodes. This is taken care of by facilitating the design and production of RFID tags which cost pennies when manufactured in large numbers. At the same time they are also following their plan to develop open standards for RFID readers.

The Auto-ID Center is playing a crucial role to help establish standards and promote the adoption of RFID. Key members of the Auto-ID Center backing RFID include Wal-Mart, P&G and Gillette. When and if RFID technology does become the de facto in automatic identification,
the Auto-ID center will have played a substantial role. The future of a tagged world may largely be attributed to this community. Perhaps the greatest influence the Auto-ID Center has in the universe of RFID is the design of EPC (Electronic Product Code), which the following section 2.4 examines. The next section elaborates about what is this RFID technology all about.

2.2 WHAT IS RFID?

The term **RFID** stands for **Radio Frequency Identification**. **Radio** stands for invocation of the wireless transmission and propagation of information or data. For operating RFID devices, **Frequency** defines spectrum, may it be low, high, ultra high and microwave, each with distinguishing characteristics. **Identification** relates to identify the items with the help of various codes present in a data carrier (memory-based) and available via radio frequency reading. The RFID is a term which is used for any device that can be sensed or detected from a distance with few problems of obstruction. The invention of RFID term lies in the origin of tags that reflect or retransmit a radio-frequency signal. RFID makes use of radio frequencies to communicate between two of its components namely RFID tag and the RFID reader. The RFID system can be broadly categorized according to the physical components of frequency and data.

Physical components of the RFID system include, but are not limited to, the following: numerous RFID tags and RFID readers and Computers. The factors associated with the RFID tags are the kind of power source its has, the environment in which it operates, the antenna on the tag for communication with the reader, its corresponding standard, memory, logic applied on the chip and application methods on the tag. The RFID tag refers to a tiny radio device also known as radio barcode, transponder or smart label. This tag is comprised of a simple silicon microchip which is attached to a small flat antenna and mounted on a substrate. The entire device can then be encapsulated in various materials dependent upon its intended usage. The finished RFID tag can then be attached to an object, typically an item, box or pallet. This tag can then be read remotely to ascertain position, identity or state of an item. The application methods of an RFID tag may take the forms attached, removable, embedded or conveyed. Further, the RFID tags
depend upon the power source which may be a battery in case of active-tags and an RFID reader in case of passive tags.

In context of the environment in which the tag operates, the role of temperature range and the humidity range comes into picture. The RFID reader is also referred as interrogator or scanner. Its purpose is to send and receive RF data from tags. The RFID reader factors include its antenna, polarization, protocol, interface and portability. The antenna for communication in case of the RFID reader may be internal or external and its ports may assume the values single or multiple.

The polarization in case of an RFID reader may be linear or circular and single or multiple protocols may be used. In an RFID reader, Ethernet, serial, Wi-Fi, USB or other interfaces may be used. Regarding portability associated with the reader, it may be fixed or handheld. Apart from the RFID tags and readers, host computers are also amongst the part of the physical components of an RFID system. The data acquired by the RFID readers is passed to the host computer which may further run a specialist RFID software, or middleware to filter the data and route it to the correct application to be processed into useful information [4,5, 22, 55, 113, 119].

Apart from the physical components of an RFID system, the RFID system may be perceived from the frequency perspective. In RFID systems, the frequency may further be classified according to the signal distance, signal range, reader to tag, tag to reader and coupling. The signal distance includes the read range and the write range [95]. The signal range here in case of RFID systems reflects the various frequency bands i.e. LF, HF, UHF and Microwave. Further, the reader to tag frequency may assume single frequency or multiple frequencies. In case of tag to reader frequency, it may be subharmonic, harmonic or an harmonic [21,46, 52].

The data sub classification in RFID systems includes, the security associated with the RFID systems, multi-tag read co-ordination and processing. In the similar context, public algorithm, proprietary algorithm or none are applied for the security associated with the RFID systems [81, 82, 92].
The multi-tag read co-ordination techniques used in the latest RFID systems include SDMA, TDMA, FDMA and CDMA [123]. The processing part is composed of the middleware which further has its own architecture which may assume a single or multi-tier shape and its associated location may be reader or the server [18, 21, 36, 51, 52].

2.2.1 A CLOSER LOOK AT RFID SYSTEM COMPONENTS

An RFID system is basically an integrated combination of various components which work together for detection and identification of objects or persons. These are the components which are primarily responsible for working of any RFID system whether basic or complex. Although there can always be additional components associated with RFID systems like sensors etc. but the following are amongst the key components of these systems:

- RFID Tag (Attached with an object and possess unique identification)
- Antenna (Tag Detector and creates magnetic field)
- RFID Reader (Manipulator and receiver of RFID Tag information)
- Application Software (User or Database or Application and RFID Reader Interface)
- Communication Infrastructure (Enables the RFID system to work and transfer data amongst various components)
2.2.2 RFID TAGS

RFID tags possess unique identification number which is stored inside a microchip of the tag. This microchip is built with an integrated circuit and embedded logic on a silicon chip. This unique identification number called ID is stored in the tag’s memory. This memory chip can be changeable or permanent depending upon its read/write characteristics.

RFID tags come in different sizes and shapes depending upon different environments and application scenarios in which they will be used. Different kinds of diverse materials are integrated on these tags accordingly. Such as, for use in credit cards, small plastic pieces are pasted on the objects and labels. The RFID at present find themselves in clothes, documents,
animals and even human beings. The RFID implanted in human beings normally is of specialized plastic material even smaller than a size of a grain.

### 2.2.3 RFID Reader

RFID reader forms the heart of an RFID system. It is mainly responsible for the functioning and controlling of an RFID system at a particular frequency. It communicates with an RFID tag while making use of an antenna. It reads and RFID tag or perform certain operations on it depending upon the tag type and tag capacity. An RFID reader can be connected to a computer system via RS-485 or RS-232 USB cables in the wired option and via WiFi in the wireless option in order to transfer data to be used for greater purposes.

Having a broader view at almost every aspect of the RFID technology, the next section of this chapter takes a lead in making an abstract comparison of this technology with mainly one of its most talked about competitor technology i.e. barcode.

### 2.3 Comparison with Other Existing Technologies

This section of this chapter on RFID technology focuses on revealing the fact that as compared with the other existing identification and data-carrying technologies like magnetic stripes, barcodes, vision systems and contact memory, RFID has high data capacity, high robustness, low cost and high operating distance. Moreover, specifically, RFID is often positioned as the next-generation barcodes or intelligent barcodes due to its real benefits over other existing competent technologies like barcodes [52].

Barcodes specifically when compared with RFID possess hardly any write or read facility, i.e. there cannot be any addition to the information already available on a barcode which is printed. Moreover, barcodes specifically require line of sight, the barcode must be carried on the outside of the product, where it is subject to wear and tear. This further imposes a limitation on the
ruggedness of barcodes as compared to RFID. Reading barcodes is much more time consuming in the sense that since if the item is not properly oriented, then it may take seconds to read an individual tag.

![Barcode](image)

**Figure 2.2** Barcode

The real attractive features of the RFID technology precisely include:

1) No line of sight required
2) Higher Range
3) Greater Durability
4) Multiple-Read speed
5) Read/Write-Update
6) Robustness
7) High Reliability
8) Low cost

More specifically, in context of the above highlighted features associated with the RFID technology, the number of items scanned in a given moment of time in barcode systems is one whereas it may be multiple in case of RFID hence leading to a fast inventory scan as an example. Also, in the barcodes there exists a possibility of manual read errors and are prone to miss-scanning whereas RFID systems are fully automated and posses greater accuracy.
In terms of the identification specification of the two technologies, there exists only one series or type in case of the barcode systems as compared with unique item level identification in case of RFID systems [129]. For example, in a given scenario, if a barcode indicates “this packet contains 500g of XYZ brand containing 70% soap”, then in a similar situation, an RFID tag would bear a step further and would as well emit a unique serial number which distinguishes among those many billions of identically manufactured soap bars and indicates that “this packet contains 500g of XYZ brand containing 70% soap, serial number 987654321”.

2.3.1 SOME OTHER ALLIED AUTOMATIC IDENTIFICATION SYSTEMS

2.3.1.1 MICROPROCESSOR CARDS

Microprocessor cards are those which have a microprocessor in them, as their name as well implies. It is connected to RAM, ROM and EEPROM segments and hence in other words, it can be said that it is connected to a segmented memory. The operating system for the microprocessor is placed on the mask programmed ROM and this procedure is accomplished at the time of manufacturing. The ROM contents cannot be overwritten and must be decided and burnt at the time of manufacturing. For the same production batch, these contents on ROM are identical for all microchips of that batch.

The application related data and application related programs are stored on the microchip’s EEPROM memory. The operating system of the microprocessor card bears the responsibility of reading or writing data on this part of memory. As in computer systems, the RAM is temporarily working memory and its contents are erased when the supply of voltage is disconnected.

Some of the microprocessor cards provide a lot of flexibility also. For example, in the modern smart cards, multi-application facility is associated and hence it becomes possible to integrate many applications in a single smart card. The application areas of microprocessor cards include
but are not limited to security sensitive applications. The SM mobile phones and new Electronic
Cash cards are some of the examples belonging to this category.

2.3.1.2 MEMORY CARDS

The card in which the memory (EEPROM) is accessed using a state machine or sequential logic
is normally referred to as a memory card. The incorporation of the basic security procedures is
possible in these cards.

The memory card for use in a specific scenario is designed for that specific application or
dedicated functionality. The flexibility is quite limited in these cards but on the positive side of
the coin, these cards are highly cost effective. For the above said reason, these cards are used in
large scale and cost effective regions. The example of memory card includes the German state
pension system insurance card.

2.3.1.3 BIOMETRIC PROCEDURES

The term biometric involving living being refers to the mechanism of measuring and counting
procedures. In relation with identification systems, this term refers to all the mechanisms or
techniques or may be procedures which identify people with the help of comparing individual
and unmistakable physical characteristics.

Examples of biometric procedures include hand printing, fingerprinting and voice identification
techniques. Less commonly, retina identification is also incorporated in the same category.
2.3.1.4 FINGERPRINTING

Since the beginning of twentieth century, criminology has been using the fingerprinting identification technology for the good purpose of identification of criminals. The comparison between dermal and papillae ridges of fingertips leads to the working mechanism of this process of fingerprinting. This comparison can not only be obtained from the respective fingers but also in combination with the object which the individual might have touched.

The process of fingerprinting involves the placement of finger on a reader and getting scanned, especially when used for personal identification purposes. The data pattern then so obtained is compared with a stored pattern to establish a match.
The present fingerprinting systems take even lesser than half of a second to recognize a fingerprint. In addition to this, the advancement in these systems have attained a level at which it can be checked whether the finger which is kept on the reader is that of a living person or belongs to dead.

2.3.1.5 VOICE IDENTIFICATION

Identifying individuals using speaker recognition is achieved by specialized systems for voice identification. Here, in these systems, a user is connected via a computer and speaks on a microphone. Then the spoken words are converted into digital signals. These signals are further evaluated by the identification software. The purpose of voice identification system is to identify a person based on his/her voice input. Here, the speech characteristics are matched against stored reference patterns.

2.3.1.6 SMART CARD

Smart card refers to electronic data storage with surplus computational capabilities. The microprocessor in the smart card is embedded into a plastic card for convenience. This card is normally the size of a credit card. The readers for smart cards establish a galvanic connection to the contact surfaces of these cards and intakes the smartcards. Clock pulse and energy is supplied to the smart card by the reader.

One of the crucial advantages associated with the smartcard is that if required, it can be protected against undesired access and is cheaper. The smart card industry as a reason is one of the fastest growing sectors of the microelectronics industry.
One of the disadvantages of smart cards is the vulnerability of its contacts to dirt, wear and tear hence resulting in their tendency to malfunction.

RFID systems are closely related to the smart cards which are mentioned above. Here also, the data is stored on an electronic data carrying device called transponder.

But, in contrast with smart cards, here in RFID systems, the galvanic contact is not used in order to provide power supply to the data carrying device and the data exchange amongst the reader and the data carrying device.

Instead magnetic or electromagnetic fields are used for that purpose.
The mechanism on which RFID systems work is drawn from the radar and radio engineering fields. Here, the information is carried by radio waves. Due to numerous advantages of the Radio Frequency Identification systems over its existing counterparts, it is expected soon to take over mass markets in near future.

In continuation of the introduction of the technological aspects of the RFID technology, the subsequent section of this chapter presents an overview of the various standards associated with RFID.

2.4 STANDARDIZATION

As far as standards of RFID are concerned, an RFID system can use a few standards. Reason behind this being that there is no one universally accepted standard at the moment. Since years, competing standards have been one of the crucial challenges for RFID. The specifications and standards may be decided and composed at the national, international, industry or trade association level. The individual organizations may call their own specifications as “standard”. When these individual organizations set various industry standards and specifications, normally
they are based on international standards in order to make implementation and support easier. Apart from this, there comes an added advantage of providing a wider choice of available products.

These standards can be applied to include the content and format of the codes placed on the tags, the frequencies and protocols that will be used by the tags and readers to transmit the RFID data, the applications use, and the security and tamper-resistance of tags on packaging and freight containers. Currently, Wal-Mart and the Department of Defense (DoD) are the two largest drivers of RFID [94]. Both the Department of Defense (DoD) and Wal-Mart have issued mandates for their top suppliers to use RFID technology when shipping products to their distribution centers. With a slightly different long-term outlook, they are both looking to accomplish the same thing [13].

In the above mentioned RFID standards debate, the ISO (International Standards Organization) and the EPC Global have both been leading figures. The ISO has their 18000 standard and the EPC standard has been introduced by the EPC Global Center. Both of these standards are further detailed below.

2.4.1 ELECTRONIC PRODUCT CODE (EPC) STANDARDS

The Auto-ID Center has proposed Electronic Product Code as the next standard for identifying products. The EPC, like the barcode, is divided into numbers and letters that identify the manufacturer, product, version and serial number. EPC uses an extra set of digits to identify unique objects [11]. To keep the RFID tag costs down and due to limited memory, the EPC is the only information stored on the RFID tag’s microchip. Readers can then access an infinite amount of dynamic data associated with that individual object in a database via the internet [12].

The development of a standard specification for item level tagging in the consumer goods industry called the Electronic Product Code (EPC) has been a driving force at the Auto-ID
Center at MIT. This has further led to a new group called EPCglobal, which is a joint venture between the EAN International and Uniform Code Council (UCC). EPCglobal maintains bar code system amongst others. The primary goal of EPCglobal, as stated in its name, is to make the final EPC standard an official global standard [12].

2.4.2 EPC TAG CLASSES

Several classes of the RFID tags fall under the EPCglobal umbrella. Class 0, Class 1, Class 2, Class 3 and Class 4 are amongst the EPC Class type categories. If Class 0 and Class 1 are considered, then the difference arises from the data structure and operational perspective. The Class 0 RFID tags are passive read only tags. The Class 1 RFID tags are passive and one-time write able. The Class 2 (Gen2) tags are also passive but supports read and write features. The Class 3 semi active tags posses the enhanced range capabilities with the help of battery. The Class 4 active RFID tags have read write features with active transmitter [11].

2.4.3 EPC CODE STRUCTURE

The Electronic Product Code (EPC) is a globally unique serial number that identifies an item in numerous number of items. This precisely allows inquiries to be made about a single instance of an item, wherever it is within the supply chain. The EPC is a number made up of a header and three sets of data. The header is useful in identifying the EPC’s version number, and it further allows for different lengths or types of EPC’s later on. EPC Manager is identified by the second part of the number, and generally it is the manufacturer of the product. The third, called object class, directly refers to the exact type of the product. It most often specifies the Stock Keeping Unit (SKU). The fourth part is the serial number unique to the specific item. In general terms, currently, the 96-bit EPC is the most prevailing version and contains information about the manufacturer, the type of object and a specific serial number that relates to the specific object being monitored. Due to the fact that EPC can hold such detailed information, it is central to the RFID compliance initiatives set in motion by many leading retailers and the DoD. Moreover, it is
not only that specific company can track its offerings down to the item level under this scheme, but the trading partners can also more precisely track inventory and supplies that spans across global borders. It is of utmost importance to note that once the EPC has been embedded on a RFID tag and read by the reader, it still only provides as much information as a random series of numbers does. Therefore, it demands for the computers for a way to associate the information on the tag to its corresponding information stored elsewhere. Moreover, software is required to source the information about the unique object and communicate it back to the user to make use of the data.

2.4.4 INTERNATIONAL STANDARDS ORGANIZATION (ISO) STANDARDS

The International Organization for Standardization (ISO) is based in Geneva, and its standards carry the weight of law in some countries. All ISO standards are required to be available for use around the world. Therefore, users of ISO RFID standards need not to worry if their systems comply with the different regulations on frequencies and power output for each country where they do business. Moreover, the ISO has created many standards for RFID that deal with both the air-interface protocol and applications for RFID [13].

2.4.5 ISO STANDARDS FOR RFID AIR INTERFACE

The ISO 18000 series is a set of proposed RFID specifications for item management that could be ratified as standards during 2004. The series includes different specifications that cover all popular frequencies, including 135 KHz, 13.56 MHz, 860-930 MHz and 2.45 GHz. This series is classified from ISO standards 18000-1 through 18000-7 as per the ISO standard. The ISO 18000 – 1 Part1 corresponds to the Generic Parameters for Air Interface Communication for Globally Accepted Frequencies. The 18000 - Part 2 supports the Parameters for Air Interface Communications below 135 KHz. It is primarily the ISO standard for Low Frequency.
Following next is the 18000 - Part 3 ISO Standard, which allows the Parameters for Air Interface Communications at 13.56 MHz. It is the ISO standard for High Frequency and supports the Read \ Write capability. The ISO 18000 - Part 4 standard is designed to support Parameters for Air Interface Communications at 2.45 GHz which is an ISO standard for Microwave Frequency and supports the Read \ Write capability.

The next standard in the series which is the ISO 18000 - Part 5 supports the Parameters for Air Interface Communications at 5.8 GHz. The ISO 18000 - Part 6 standard allows Parameters for Air Interface Communications at 860 – 930 MHz. It is the ISO standard for UHF Frequency and has Read \ Write capability. It is also targeted for same markets as EPC standards. Lastly, the ISO 18000 – Part 7 supports the Parameters for Air Interface Communications at 433.92 MHz. It is the Manifest tag for Department of Defense (DoD) [14,163].

The next section of this chapter now further unfolds the RFID related applications.

2.5 RFID APPLICATIONS

In spite of the fact that the RFID is still in its adoption phase, presently there exists diverse spectrum of applications of RFID [1,2,3,8,9,10,19,25,26,29,30,32,33,34,35,37, 38,40,42,46,59, 60,66,69,70,74,76,77,93,104,129,130,132,133]. In such a scenario, the purpose of this chapter would be defeated without presenting what does a electrifying technology like RFID really holds for the future? To explain things better, let us take an example from the real life application.

Consider a scenario as per the present (2011) situation which may arise as a result of shopping in any of the malls. A shopper visits the grocery store and purchases some products and puts them into a cart spending his/her valuable time. In such a scenario, queuing in long checkout lines, (especially longer than that on the weekend days) at these grocery stores become one of the visible grievance regarding the shopping date as part of wasting more of one’s valuable time waiting in those heavy queues.
Now, consider an imagination of visiting the grocery store, filling up the trolley and simply walking right out of the door. How does that sound? No lines and no waiting! No longer will one have to wait as some salesperson rings up each item in the cart one at a time. Soon, these lines could disappear when the RFID tags are used instead of the barcodes. This is based on the fact that the RFID tags have the capability to interact with an interconnected system which can track every product that has been placed in the shopping cart. These RFID tags further aims to communicate with an RFID interrogator that will detect every item in the cart and beeps corresponding to each of the items almost immediately. The electronic RFID interrogator will of course be connected to a huge network which is capable to send the related information on the products that the customer purchases, to the product manufacturers and the retailers. After that, the customer’s bank is expected to be notified by deducting the amount of bill from his/her accounts directly.

Consider another scenario where there are a huge number of multi-national companies, large factories, chemical processing plants, oil refineries, steel plants etc. In such a situation, there exit a large number of various kinds of people, who come in and go out during the day at all such places. These kinds of facilities operate around the clock with contractors, employees and other visitors like vendor representatives entering and leaving these organizations. In the similar context, today (2011), as a part of general practice, most places either issue a dead badge along with a photo to its employees and a “visitor” badge to all other associated people. As of now, a manual recording of such kinds of entries and exits are performed. Normally, a security guard at the entrances of these organizations enters it into a personal computer and therefore these entries appear as “electronic” but actually this bears no difference than a paper record. To support this fact, consider the situation of an evacuation or emergency in an organization, where, by using this mechanism, though it is possible to figure out the number of people inside, but there exists no way to determine the exact locations of these persons. A typical site may be about 100 acres or more.

The problems figured out with the existing system are listed ahead. Firstly, even within a vicinity of few hundred feet, there is no system to really locate a person. This may become a big problem
in case of a fire or other disaster while grasping the fact that one still has to carry out a physical head count. Secondly, in the above mentioned scenario, given a badge, a person can freely access any part of a large site which is not desirable because of safety, security and confidentiality reasons. If RFID comes into picture in the future similar kind of a scenario then the solution may include the replacement of the dumb photo badges with the RFID proximity cards. In such situations, these RFID embedded cards would need to be held close enough to the access control devices. Here, the requirement associated with these access control devices would be to be connected to a computer to accumulate data on tracking of which card followed the trajectory through which doors.

Now, although the above described RFID solution is a viable solution for an office complex, it is really not factual for a chemical plant, since the majority of the equipment at such locations, like, storage tanks or plants are elephantine hardly have any “doors” or “gates” to be accessed. Incorporating doors at such areas would be bottleneck as the work of regular plant operations personnel cannot can get cumbered as they can’t move about freely.

Hence in such areas, the effective use of a Real Time Location System can be made. By such system, an employee must be automatically logged in once he comes in the range of a reader (say near a storage tank farm). He must be logged out when moved out of the range until spotted by another RFID reader. The overall benefits associated with the described scheme include giving a real time status of all the employees, visitors and contractors etc. Moreover, more semantically intense information may be drawn by which visitor movement can be tracked, or, it may be seen if a contractor has unauthorized accessed to another area, or, in case of an emergency evacuation, one can pinpoint the figures and identities of staff at precise locations, therefore directing the emergency efforts correctly, or, if conducting a practical drill, one can actually log people movements to see if the drill was done correctly, so on and so forth.

Similar kind of situations may come across diverse domains like health industry, automobile industry etc and hence this technology may be used to draw intense benefits in concerning time, security, money and of course in making our lives much more comfortable.
The next few sections of this chapter are going to throw light on the public transit system in various countries across the globe, which are presently making use of RFID technology.

Existing some of the RFID applications in Asia include the “Octopus card” in Hong Kong, in which RFID technology is implemented and which is used almost exclusively for the purpose of mass transit payments. It was designed and launched in 1997 in the month of September exclusively for the goal of transit fare collection. This card can be read several centimeters from the RFID interrogator and can be recharged at add-value. A similar kind of thing applies to India, New Delhi Metro, which is the rapid transit system. In Dubai, tolls through Garhoud bridge and Sheikh Zayed Road make use of the RFID technology, it is called “Salik” and it means toll road. For use in Waterbus, metro and buses in Dubai, a public transportation card named “Nol!” which means “fare” in Arabic is also introduced. It was introduced in 2009 in the month of September. “SUICa” which meant Super Urban Intelligent card was introduced by Japan in its railway transportation service for transport service for payment. SUICa was introduced much earlier in 2001 in the month of November. Similar technology was used in Singapore’s “EZ-Link” card. “T-money” cards in South Korea are used for public transit. Most of the cabs in Seoul accept card payment including T-money cards. In Shanghai, the Shanghai public transportation cards are used for advance credit money or debit money in accordance with the distance traveled. This is recognized by the check-in and check out stations. Taiwan also makes use of RFID technology in their transport systems and which hence responsible for fare collection. “EasyCard” is the name given to the RFID card and it is charged at metro stations and various local stores. This idea there is now being extended for the local convenience stores and other chain stores and groceries.

In Europe, in UK, RFID technology has been extensively used for operating systems designed for pre-paying of public transport which is unlimited. This design is incorporated in a pass which resembles credit card which on scanning reveals the details of the validation of the pass and the duration of validation of that pass. They make use of something called “Oyster cards” in London, which is a way of electronic ticketing and is mostly used in the Greater London Area. It
is a blue contact less smart card which allows the pay as you go kind of a service associated along with the association of the facility of various places and lengths of times. This card is specially designed to exponentially reduce the number of transaction at ticketing offices leading to saving of efforts, time, paper and money. Its use is motivated by offering cheaper fares as compared with payment with cash. This card was first introduced in the month of July in 2003 with quite a limited spectrum of features but since then there continues to be a structured and phased incorporation of more functions. In 1998, Moscow Metro was formally the first system in Europe to implement the RFID smart cards. It is the world’s second busiest Metro. In Finland, the RFID smart card system has official been in use since 2001. In Dublin the same technology has been in use in similar kind of system since the year of 2005.

Talking of North America, in the year 1999, the Washington Metro used “smartTrip” card and it became the first US-urban mass transit system. In Atlanta, something called MARTA is responsible for making a transition from its rail and bus lines from coin tokens used earlier to “Breeze cards”. These Breeze cards in Atlanta, makes use of the RFID technology imbibed in the paper tickets. Here, the plastic cards are used for more permanent users. The New York City Metropolitan Transportation authority used “PayPass by MasterCard” for a trial which used the RFID technology. In Canada, in St. John’s, the Metrobus was gifted with the RFID technology in the year of 2006. In 2009, in Seattle a card namely “Orca Card” was implemented using the same technology. In Chicago, similar kind of technology use is being made since 2002 in rail systems.

In Australia, Western Australia makes use of “SmartRider” ticketing system which again makes use of the RFID technology for the purpose. It provides features to automatically tag-on or tag-off for passengers and to be automatically charged according to the number of zones they have traveled so far.

In South America, “Civica” is the name of a recently implemented card system at Medellin. Apart from that, the transportation system in Santiago an RFID contact less smart card has been used in the subway system metro and it is named as “Bip”. In south amerce in Cali, MIO
(Masivo Integrado de Occidente) system is introduced which makes use of the RFID technology for public transit systems.

The next section presents, the conclusion for the chapter.

**2.6 CONCLUSIONS**

This chapter presented a brief real-time picture of the RFID technology. It introduced the RFID technology which will be helpful in understanding the capabilities and constraints of the technology. It also gave an idea about the history, role and objectives of the organization responsible for its widespread use. A brief comparison with the other existing identification technologies in terms of technical properties of RFID was made. This had effectively taken out RFID with its embedded benefits over other existing identification technologies. Apart from that, the ISO and EPC standards and their importance were made apparent in RFID. Lastly, this chapter was closed with the present and possible futuristic RFID applications. Now, with this background, the thesis can proceed with a detailed description of RFID research literature.