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# Radio Frequency Identification: An Apparatus Instrumental in Smart ID Applications

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**Abstract**

Optical Character Groups (OCG), optical character recognition, bar codes, security tags, Electronic Artificial Surveillance (EAS), magnetic stripes: Radio frequency identification (RFID) is also just another form of this technology. The major difference of RFID compared to other technologies is that it does not require a direct line of sight to operate. The distance from which it can be read is also relatively longer. The coverage of nature of data to support the RFID tags is relatively much wider than barcodes and includes environmental factors like humidity and temperature, apart from carrying the product information of what prototype or which manufacturer it belongs to. This technology facilitates real-time positioning and has received interest from numerous sectors such as logistics, manufacturing, and healthcare. The durability of an RFID chip varies and can be effectively used for more than ten years with very lower maintenance expenditure. The memory capacity of current RFID tags is much larger than the traditional barcodes and amounts to 16-64 Kbytes. At the same time, the read/write time is also drastically improved.

*Keywords*: RFID Tags; barcode; Zigbee; UHF RFID; smart card; Internet of Things (IoT); tracking; real time location system; ISO; line of sight

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## 1. Background

It was during World War II when conceptual RFID was first used. The British employed it for the identification of their own and enemies aircraft and for the gunning down of allied planes. The cost factor had impeded the use of RFID at that time for exploitation beyond defense productions. It was more than 50 years until RFID as a technology could be amalgamated with the mainstream. The commercial value of electronic products is defined by either their extreme lower prizes or what they can offer in return monitory value to the user organization. RFID had not been so cheap compared with other available labeling technologies. However, it does extend a value addition at a reasonable price with continuous upgrades of technology. It has come a long way since then, transitioning from a potential ID apparatus to a large-scale commercial utility for precisely locating and tracking a moving object.

Defence productions found this technology handy by manufacturing a tracking system that could tack mobile objects like armored vehicles in real time by combining wireless positioning sensors and active RFID tags. Then, a Real Time Location System (RTLS) was introduced through Wi-Fi by combining it with RFID to improve the inventory management and its automation. It revolutionized the manufacturing industry by providing real-time information of processed products and their locations to enable dynamic production scheduling [1]. The arrangement contributed effectively to resolving the issue of physical supervision by applying huge resources in goods delivery and offered great flexibility in economizing human and material resources.

## 2. Introduction

Traditionally, there has been number of auto identifier technologies (Auto ID), including Optical Character Groups (OCG), optical character recognition, bar codes, security tags, Electronic Artificial Surveillance (EAS), and magnetic stripes. RFID

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is also just another form of this technology. The major difference of RFID compared with other technologies is that it does not require a direct line of sight to operate. The distance from which it can be read is also relatively longer. The coverage of nature of data to support the RFID tags is relatively much wider than barcodes and includes environmental factors like humidity and temperature, apart from carrying the product information of what prototype or which manufacturer it belongs to. This technology facilitates real-time positioning and has received interest from numerous sectors such as logistics, manufacturing, and healthcare. The durability of an RFID chip varies and can be effectively for more than ten years with very lower maintenance expenditure. The memory capacity of RFID tags is much larger than the traditional barcodes and amount to 16-64 Kbytes. At the same time, the read/write time is also drastically improved [2].

Its ability to discern all other RFID tags in the vicinity within the equipment range and without any human efforts distinguishes it from other such applications. Data acquisition through RFID is speedier, more reliable, and mostly acquired at lower costs. The flexibility to integrate it with many other modern technologies including GPRS provides much better connectivity. However, it is still beleaguered with apprehensions of security of being read by low-cost RFID readers and consequent alteration of its data. The tracking of mobile resources with accurate positioning, real-time monitoring of objects, and dynamic adjustments of existing resources are now possible through RFID. Different frequency ranges including Ultra Wide Band (UWB) are being used to address the navigational requirements and accurate positioning of mobile objects. An appropriate antenna for the desired system is also a contentious issue. The type of material used for fabrication and corresponding structure with relative costs are certain factors that dictate the large-scale productions of RFID [3]. The tracking of objects by RFID tags must consider many features such as beam tilting and grating lobes, which characterize the configuration and scalability of the required RFID antenna.

## 3. RFID as a Technology: An Overview

At a basic conceptual level, RFID is a technology that establishes the wireless link for identification of objects with a unique identity. It is sometimes referred to as dedicated short range communication. An RFID system is comprised of three major components: a transponder that is programmed electronically and is commonly known as the RF tag, a transceiver, and an antenna. A transponder is combined with an antenna to form an RFID tag, and a transceiver and an antenna form an RFID reader. A transponder is activated when a radio signal is emitted by a reader and data is reverted to the transceiver. The information is transmitted then to a computer in digital form. A particular ID is granted for transmission of that data, and a link is considered to be established [4].

A typical RFID tag is a device that consists of a microchip and an antenna that are combined together and mounted on a substrate. We require a reader to retrieve back the stored data in an RFID tag. There are two types of RFID tags that co-relate with two different types of transponders, as explained below:

- *Passive transponders.* These transponders do not have their own energy sources. They are dependent on the reader to provide the required power. These are relatively cheaper and utilized in smaller consumer applications.
- *Active transponders.* These transponders have their own power source to generate signals. They are expensive and able to communicate over longer distances up to miles in navigational applications like commercial aircrafts.

An RFID tag is activated when the antenna associated with the tag emits the radio signal to read/write the data on it. The distance covered by the radio signal depends on its radio frequency and the power output. A reader's activation signal is detected by the RFID tag whenever it passes through an electromagnetic zone. The RFID tag has an integrated circuit that possesses the encoded data. The reader passes this data after decoding it to the computer for processing. A simplified block diagram to explain this processing of data is shown in Figure 1. An RFID reader is comprised of one Control module consisting of a microcontroller chip to process the data and a radio frequency module. It is connected to a computer that has a database with respect to a particular application. The RFID reader is also connected to an antenna that emits the associated radio frequency in conjunction with the RF module. The motive of an RFID system is to transmit the data by a portable tag read by an RFID reader, and then data is processed according to the particular application involved. The transmitted data may provide location information, product specific information like its price/size/date of manufacturing, etc.

### *3.1. Principles of an RFID System*

The basic principal that governs an RFID tag functions is as follows: a current is induced in an antenna when a magnetic field is generated by its associated reader. The microprocessor chip is powered by this current. Along with the chip, a condenser is charged by the current to extend uninterrupted power in a Passive tag. However, in an active tag, a battery is used to power the chip instead of a condenser. A command is received by the RFID tag on activation from the reader, which in turn replies the request by forwarding its serial number [5]. The reader requires extending continuous power to the RFID tag during its reading cycle. The major components involved in the RFID technology are explained in the succeeding paragraphs.

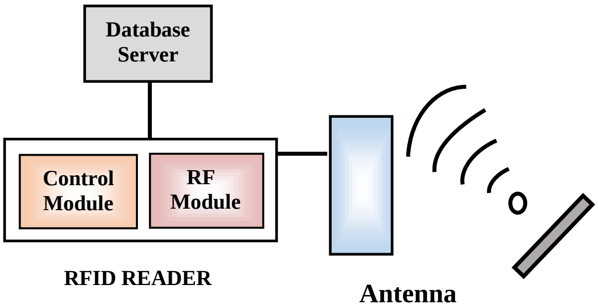


Figure 1. A simplified block diagram of RFID

*3.2. The RFID System*

In order to have a complete RFID system, a reader and a few tags would be insufficient. Information about the serial number of a product alone does not help much to keep track of an object. The real strength of the RFID system is to have additional information fetched from the backend with product details and comprised of a database and an interface where the RFID tag is scanned and computation is performed.

*3.3. Use of Frequency Bands in RFID*

There are mainly three types of frequency bands that are utilized in RFID applications: Low Frequency (LF), High Frequency (HF), and Ultra High Frequency (UHF). Frequency ranges for these bands vary from 30KHz-5.8GHz and 30-500KHz for LF, 10-15MHz and 850 – 950MHz for HF, 2.4-2.5GHz and 5.8GHz for UHF. The LF application tag is faster and cheaper and used in relatively smaller applications. These low frequency tags have the advantage of being least affected when operating in fluids or metal. HF tags offer better ranges but are costlier. UHF tags have the best ranges up to more than 30 meters and higher transmission rates, but they are the most expensive. They differ in frequency ranges in applications in different countries and, unlike LF and HF applications, require licenses from those countries for their use.

*3.4. Power Requirements in RFID*

Power or energy requirements for passive, semi passive, and active RFID tags vary. Passive tags are dependent on power provided by the reader, and they do not have their own internal energy source. Therefore, without any need of a battery, they are cheapest and smallest and have the longest lifespan, but their ranges are limited to just few meters. Active RFID tags have an internal energy source to extend power to microchip and for the antenna to produce a signal. These tags have the best ranges compared with other types of RFID tags, up to tens of meters with a lifetime of up to five years.

*3.5. RFID Standards*

The utility of RFID applications has a very wide range, with varying requirements of users. There are specific international standards for particular type of applications. Some of these standards are ISO 10536, ISO 11784, ISO 14223, ISO 15693, and ISO 18000. At present, there are more than 1800 RFID patent standards covering more than 5700 RFID system applications.

## 4. A Brief Comparison with Similar Technologies

Traditionally, there are many identification technologies that have found an important place amongst users in their personal and commercial applications. The most prominent ones are barcodes, smartcards, and the RFID system. These technologies have distinct characteristics and offer a particular type of application. Operational management of applications use by these technologies differs due to different processing. The read rate, memory, line of sight ranges, and reusability are just a few factors that distinguish these technologies from one another [6]. Table 1 below depicts some of the basic differences between barcodes, smartcards, and the RFID system:

Table 1. Comparison with other identification technologies

| | Bluetooth | WiFi | ZigBee | Wibree |
|---|---|---|---|---|
| **Power consumption** | Medium | High | Low | Low |
| **Frequency** | 2.4GHz | 2.4GHz | 2.4GHz | 2.4GHz |
| **Cost** | Low | High | Low | Low |
| **Data rate** | 1Mbps | 11-54Mbps | 250kbps | 1Mbps |
| **Range** | 30-300ft | 100-150ft | 30m-1.6km | Up to 10ft |
| **Modulation/ Protocol** | FHSS | DSSS/CCK, OFDM | DSSS, CSMA/CA | FHSS |

Apart from the RFID system, there are many other wireless communication technologies that are prevalent including Zigbee, Wi-Fi, Wibree, and Bluetooth. All these technologies have different characteristics with different capabilities. They have different standards and communication protocols to follow. Their power requirements, coverage, costs, data transmission rates, and restrictions like requirement of line of sight and security specifications differ from one another. Their consumer related and commercial applications also differ in nature in terms of the suitability for a particular need, which can be fulfilled by a specific communication technology only. A brief comparison of these technologies is given in Table 2.

Table 2. Comparison with other communication technologies

| | Barcode | Smart card | RFID |
|---|---|---|---|
| **Read rate** | One at a time | One at a time | Multiple simultaneously |
| **Range** | Inches to feet | Inches | Inches to 100's of feet |
| **Memory** | No memory | Large | Small |
| **Security** | Very low (Coding) | High (Encryption) | Medium (Authentication) |
| **Line of sight** | Required | Required (exposed to reader) | Not required (in most cases) |
| **Reusability** | No | No | Yes |
| **Cost** | Low | High | Medium |

The major difference of such technologies as compared with RFID lies in the object tracking, conservation of power, and nature of security they offer. The mechanism put in place with respect to the RFID system tracking with automation is qualitative in nature and unlike other similar prevalent technologies that can only be quantified after a prolonged use. Various components associated in system designing of all these technologies are scalable and evaluated with the progress of many evolving smart applications [6]. The rate of power consumption of processors in these technologies is directly linked to the requirement of data communication rates, which is associated with the design trade-offs of microcontroller chips extending support to complex security algorithms.

## 5. Implementation of the Technology

In this section, our endeavor is to discuss the implementation of RFID technology as an application in a small campus of an organization that may be a commercial, academic, medical, or any other type of similar institution. In order to establish the identity of all the individuals and track their movement, a tagged identity card is issued in that organization. Then, each office, department, or store will be provided an RFID label. The unique ID given to all the individuals will be stored in the RFID reader, which will be placed at all the prominent entrances including the main entrance/exit on the campus.

Now, let us hypothetically assume a case of the above-mentioned campus, which employs a Zigbee module against an RFID application. Zigbee is a low cost wireless network standard that operates worldwide in 2.4GHz radio band with a minimal power requirement in wireless monitoring and control applications. The complete operation cycle of the control circuit of the RFID tag is illustrated in Figure 2. The system will work as described: the microcontroller first receives the ID forwarded by the reader. It assigns a specific code after authentication to each ID [6]. This code is further transmitted to the Zigbee transceiver by a serial link to broadcast it to all the receiving nodes including a database server that maintains the complete log of proceedings. Simultaneously, the broadcast is also received by control circuit node that automates the RFID object tracking. This profile of all the individual objects can be modified by a re-writable memory [7].

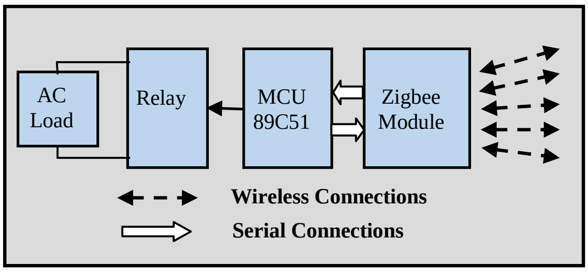


Figure 2. Block diagram for control circuit

In the RFID system, there are two major segments where the RFID tag contributes to the processing to run the entire system, as shown in Figure 3.

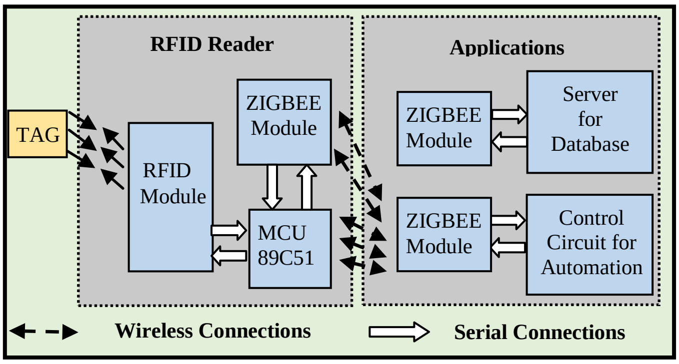


Figure 3. Block diagram for RFID system

### *5.1. RFID Reader*

This segment consists of a microcontroller and an RFID module. The moment RFID tag carried by an object comes into contact with the RFID reader while passing through its range, and it is detected by the reader. The microcontroller out of the pre-stored data in the microcontroller ROM verifies and compares the tag ID. If the tag ID is valid, it is further broadcasted after storing it in the microcontroller RAM.

### *5.2. RFID Application*

In this segment, a Zigbee Module with RS232 standard is used for serial communication with a database server. Data transmission to the database server and control circuit from the RFID reader are processed through wireless communication. Simultaneously, the control circuit receives the mapped tag ID from the database server. All the objects tracked by the RFID tag with respect to the valid tag ID of a particular tag holder are then automated by the control circuit on a predefined profile.

The central database server operates in conjunction with the associated front end RFID application, which maintains the log in the database and updates all the records of RFID tags. It also facilitates the updating of user profiles in the RAM of the control circuit. The user profile of an individual may include his/her personal details, such as tag ID, name, date of birth, department name, and phone number. The system can offer search profiles with a query mechanism to support the tracking of individuals in different circumstances. There are many checks and balances provisioned in the system to ensure adequate security. As an example, it will prevent someone trying to access at two or more places simultaneously with the same tag ID. It can be further explained by the proposed workflow diagram in Figure 4.

The processing of the proposed system is illustrated in the work flow. It commences when the administrator exercises his/her option of login after the initiation of the RFID reader. The RFID tag is detected by the reader the moment it comes within range. The tag information with respect to the user is read by the RFID tag after referring it to the database. Simultaneously, the biometric print of the user is taken by the biometric device to authenticate the identity of a user for cross-examination. If the RFID reader and biometric detections confirm the match, the system is updated and the access time of the user is displayed accordingly. However, if there is any mismatch of the user identity with respect to the RFID tag and biometric database, the user must go through the same exercise to verify his/her identity. During this ID authentication process, users' access time is recorded and a report is forwarded. If there is any delay to establish the users' ID, a message is forwarded by the system.

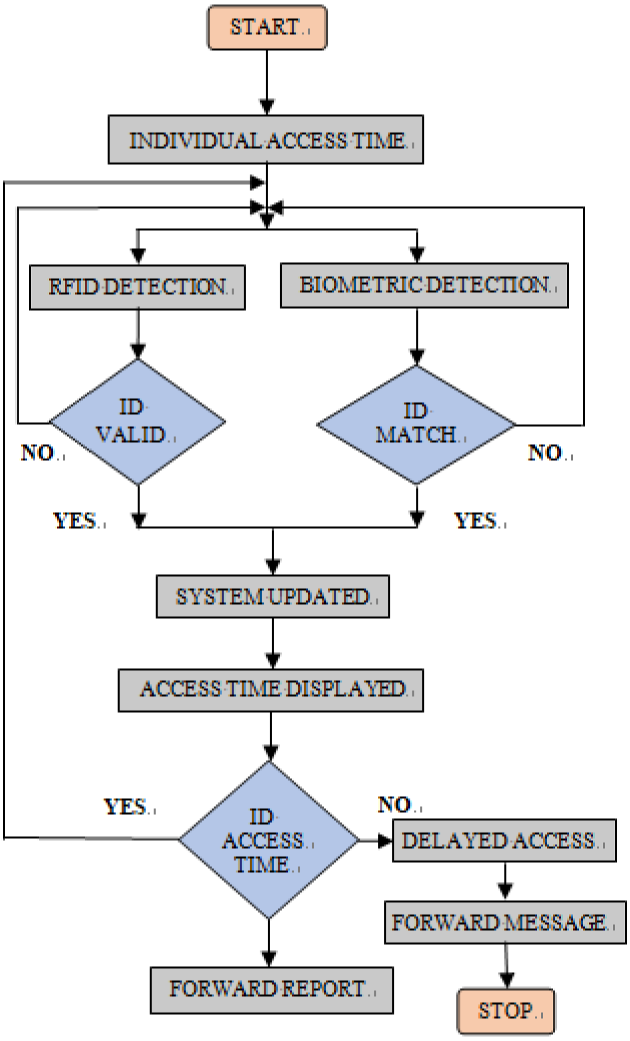


Figure 4. Workflow diagram of proposed system

The proposed system can convert any user organization with several user personals and departmental assets into an RFID enable campus. All the individual users and assets of that campus will be tagged with a unique Tag ID. These tags will be affixed in the users' smart identity cards. Different user departments will be tagged with unique RFID labels. The details of these tag IDs and labels will be stored in the RFID reader unit. Apart from this logical control by using the RFID application, the physical control of the premises using such applications also holds due importance. Any losses or theft of the RFID equipment that is installed in the users' premises must be reported to administration controllers with immediate effect. The database server available with the administration will assist in their investigation by providing the information about the last known location of loss assets. The placement of reader units is also an important aspect that will dictate the success of the installation of the RFID system; therefore, it must be very carefully chosen by the user organizations.

**6. Applications of RFID**

Coverage of RFID applications is spread to a broad range in nature over many walks of life. There are numerous chores, such as the management of supply chains, animal tracking, control of physical access of a premise, thwarting of any type of counterfeiting, and RFID toll gates [8].

The spectrum covered by the RFID applications is quite wide in nature and surpasses the scope of this paper. Some major promising applications are discussed as follows:

### *6.1. Data Transfer*

Every RFID tag is fed with a data required to provide authentic information about a person or object. The auxiliary data that assists in extraction of the identity from the tag are read and written over it. This data is fed with RFID tags mainly in consumer goods for their uses, which facilitate all the users using it at remote locations.

### *6.2. Authentication and Security of Physical Access*

Control of access of several campuses has been supported by the RFID. Initially, LF RFID tags were used for such requirements. However, 13.56MHz frequency tags with longer ranges have been introduced in the market. They offer more convenience for users who want to simply hold the tag instead of get physically involved in other kinds of applications to unlock the key or swipe a magnetic stripe card.

### *6.3. Identification of Locations*

A location that is required to be tracked will be assigned by the reader provided that it is a pre-known location and information about this location has already been fed in the RFID tag. Postal services and logistic companies are already using such applications in tracking their goods. In a public transportation system, automatic location systems for vehicles are another example of such an application.

### *6.4. Management of Supply Chain*

A closed loop supply chain for the automation of supply is generally employed by food supplier companies. RFID technology becomes an asset to such an arrangement, as it can track the supply and shipments for better delivery control [9].

### *6.5. Tracking of an Asset*

This is the most notable, prominent, and commonly used application of RFID technology. An RFID tag is put on a particular asset that is required to be tracked. This is done mainly to prevent its loss or theft or even for those assets that are difficult to be located in the normal circumstances. It assists the administration in locating such assets or resources that are underutilized and in general difficult to be located [10].

### *6.6. Payment Arrangements*

There are certain resentments over the uses of RFID in the supply chain; however, it has generally lauded the payment mechanism of many services and provided a great convenience to users. The most popular application is the payment of road tolls. It enables users to pay tolls without having to stop.

### *6.7. Manufacturing and Retailing*

In the manufacturing sector, RFID is being used to track the progress of work in the process of manufacturing products. It reduces the possibility of defective products and increases the manufacturing efficiency. All the present big retailers across the world, like Wal-Mart, Metro, and Tesco, are major consumers of RFID technology.

### *6.8. Regulatory Compliance*

The effective governance of a system relies on the regulatory compliance of that system by its users. The compliance of all users associated with the RFID tags can be ensured through effective monitoring by the administrators. The constant tracking of individuals ensures that all the regulations imposed by the administration are being adhered to [5].

In a major transformation of modern technologies, RFID applications have a reach in even human implantation. RFID wristbands and RFID tag-embedded clothes are examples of such applications. Health care is a field that finds itself as a major user of RFID tags [11]. In addition to medical transactions, medical histories of patients can be ascertained by tags in which entire medical records are stored and updated. The airline industry uses RFID tags to track passengers' baggage. Visual tracking is an application that recognizes the importance of RFID tags. There are many more RFID applications that not only contribute to add value, but also assist in the administration of services employed by such applications [12].

## 7. Issues and Challenges with RFID

Like many other technologies, RFID is not devoid of certain limitations. Recognizing these challenges enhances the scope of progress against the drawbacks that plague the current technology. Understanding the basic RFID technology is key to formulating the required changes in the system. This may include database usage, security, interoperability, reliability, operational management, or any other issue that needs to be addressed for any transformation [11].

There are many limitations of RFID implementations that need effective diffusion to exploit the overall potential of the technology [13]. Many such foreseen challenges must be overcome, and some prominent ones are discussed as follows:

### *7.1. Manufacturing of RFID Tags*

It has been observed that the entire fraction of manufacturing is not defect-free. There are cases in which almost up to 20%-30% RFID tags have been detected with defects by quality control departments.

### *7.2. Optimization of Frequency*

There is a number of factors that dictate the optimal choice of chosen frequency like international standards, environment requirements as per the behavioral pattern of RFID tags, and transmission mode. As far as international standards are concerned, frequency allocation is performed by dividing the world into three major regions due to distinct differences in such regions. This leads to the restriction of tags with only reader signals being modulated and no carrier wave being produced by their own, which can enable operations in wider frequency ranges.

The ambient reflection of a signal, electromagnetic disturbances, and data absorption for a particular material is frequency-dependent, which may result in data being corrupted for a particular frequency. Thus, choosing an appropriate frequency is key for a particular application. There are two types of data transmission being used. The first is inductive coupling in LF and HF frequency bands, and the second is wave backscattering in the UHF frequency bands. Caution is needed with direction selective devices, which may restrict the design for reading ranges.

### *7.3. Rapid Obsolescence of Technology*

The production of RFID tags at a large scale demands a high investment by the manufacturing industry along with the support infrastructure. The rate of obsolescence becomes the hurdle in adopting the evolving technology at a large scale.

### *7.4. Fault Detection of RFID Tags*

There can be many causes of fault detections of tags including prolong usage, adverse environmental conditions, improper placement, error occurred by ambient reflection of signals, and readers' malfunctioning. The reasons of the damage may vary, and they may not be predicted or avoided.

### *7.5. Standardization of RFID*

Picking up an appropriate RFID tag depends upon the nature of usage and the type of application to be used. Communication protocols and the amount of data to be stored may determine the type of standard that will be adopted by the RFID system. The other compelling factors for a particular standard may include the rate of data transmission, type of algorithms for collision handling, and type of signal modulation.

### *7.6. Signal Collision*

Simultaneous reading of multi tags by a reader may produce signal collision and a resultant data loss. Numbers of anti collision algorithms are prevalent and are available at an additional price. Patents of such algorithms are uncertain.

### *7.7. Privacy and Security*

The prevention of any unauthorized access is the primary aim of any technology. Different measures including data encryption are provisioned to enable read/write of data transmitted to only authentic users by RFID tags. Denial of access to those other than authorized users by cloning of RFID tags or preventing hackers is difficult to ensure because there is no restriction of line of sight. There have been reports of attacks by SQL injection and code insertion. To meet such challenges, tag passwords and crypto techniques are one of the few possible solutions in practice.

### *7.8. Interoperability*

To gain the benefits of RFID technology, interoperability must be ensured amongst users. Almost all the vendors employing larger applications prefer to have open standards. However, interests of user states must be protected while balancing the requirements. Presently, Electronic Product Code (EPC) global and ISO standards are common standards that are prevalent worldwide. The main challenge is global acceptability due to various regional interests.

RFID is an evolving technology that requires a high degree of application to absorb changes with contemporary technologies [14]. Apart from the challenges discussed above, there are still various issues like database management, testing, electromagnetic compatibility, relative costs, and certification [12]. Developing suitable antenna architecture and determining the exact amount of antenna required for a particular portal have always been contentious points. A careful and calibrated approach is needed to plan the antenna architecture for RFID [15].

## 8. Conclusions

This paper presents an overview, conceptual implementation, and current trends of RFID technology by bringing out certain existing limitations. The inherent mechanism of this technology in locating and tracking moving objects makes it a very attractive tool for almost all smart applications. Inventory control has witnessed yawning inroads with effective use of RFID tags in logistic management. Constant improvement in technology in various aspects of the tags is likely to result in better economic proposition with cost effective applications by overcoming numerous limitations. However, privacy issues and some genuine security concerns do require adequate intervention [7]. The proposed case of a smart premise by using RFID technology exemplifies its advantages in the context of any organization that operates in a closed campus environment. Apart from the object tracking, room automation, power conservation, and prevention of theft are the other features against which the RFID system can be utilized effectively. Exploiting the full potential of RFID technology requires a calibrated approach with an excellent understanding of the system. At the same time, an endeavor must be made to pick a lightweight, UV/chemical-impact-resistant, non-water absorbent, and durable antenna as per the associated application. Incorporating appropriate solution providers and system integrators is key for the successful accomplishment of this technology [16].

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