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Analysis of UHF ISO/IEC 14443 Gen 2 RFID Technology

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Abstract
ISO/IEC 14443 is an International Standard for identification cards, contactless integrated circuit chips. Radio Frequency Identification (RFID) is an ISO/IEC 14443 proximity card; integrating Radio Frequency (RF) power and signal interface. RFID is a wireless communication which is used to record the presence of an article using radio waves. Analysis of RFID technology elaborates on the concepts evolving RFID, components of the RF network, understanding the fundamentals of how the data travels in waves into the framework. The exploration of the system such as architecture, characteristics, the classes of RF tags and the diversity of low- , high- , ultra high- , microwave frequency ranges are deliberated. Pros and cons of electromagnetic field identification – near field and far field communication are also identified. Applications of Ultra High Frequency (UHF) ISO/IEC 14443 RFID technology are analyzed.

Keywords: *Communication, far field, near field, RF spectrum, RFID, RFID system*

I. Introduction

ISO/IEC 14443 an acronym developed by Working Group 8 of Subcommittee 17 in ISO/IEC Joint Technical Committee 1 [1], is a standard that defines circuits used in identification and transmission protocols utilized for communication. Radio frequency identification (RFID) is an ISO/IEC 14443 Integrated Circuit (IC), is a technology where information stored on a microchip can be remotely transmitted, without physical contact using RF spectrum. RFID does not use Line of Sight (LoS) communication with the middleware and simultaneously reads/writes with the various transponders. The core units of the RFID system are logic circuit (transponder), base station (interrogator) and the application software (operating systems).

In the primary elements, logic circuit (RF tag) has two different classes namely, Active and Passive. RFID tags are termed as active or passive based on the way the Integrated Circuits (IC) are powered [2]. Active ICs are battery powered and transmits signals actively. Passive ICs have no battery power source embedded on the chip. The energy to activate the circuit is solely derived from the incoming wave from the middleware. The several frequency spectrums of RFID network communication include Low Frequency (LF). High Frequency (HF), Ultra High Frequency (UHF), Microwave differs in ranges of intercommunication. The orbit of each frequency band varies by MHz to GHz. Some modes can be used globally (HF) whereas UHF has to obtain license in some regions.

The electromagnetic field that surrounds an RFID antenna is divided into two segments as Near Field Communication (NFC) and Far Field Communication (FFC). NFC is described as the area around the antenna to one wavelength (λ) away (approximately up to 35 centimeters). The RFID tag used outside the one wavelength away, it is termed as FFC. Utilizing the electromagnetic communication, RFID technology is helping organizations across industries world-wide to address the issues of automating the product visibility and asset management process.

II. Constituents of RFID Framework

The constituents of RFID framework are composed of a programmable RFID tag and reader to interrogate the RFID inlay. A programmable RFID tag/inlay incorporates an RFID chip for data storage, power source and signal receiver to facilitate connection with the RFID chip. The silicon circuit is capable of caching 1.25 megabits of info. A transponder is programmed information that uniquely identifies itself, thus the concept of automatic identification is achieved.

A reader/ antenna system acts has the signal receiver portrays to interrogate the RFID inlay. An antenna system is composed of a modulator/demodulator, coder/encoder and control [3]. The reader handles the radio communication through antennas and transfers the tag information to the end system using the application programs. An antenna is attached to the reader to communicate with the transponders. The reader interface layer (middleware) comprises of thousands to tag signals into a single identification and also acts as a conduit between the RFID hardware elements to the end user. The software operating the framework is composed of networking software and programming codes. Radio Frequency or the RF field is an electromagnetic field where the communication between transponder-interrogator communications takes place.

III. Principles of RFID System

RFID system is a low cost identification system with the applications of practical way to identify and trace wildlife, personnel to goods in a warehouse. The RFID principles commute data from the reader to the tag. Two fundamental approaches that are employed in the transferral of data are magnetic induction and electromagnetic (EM) wave capture. The EM wave capture is associated with an RF antenna in two types such as the near field and far field communications. Commonly both can transfer enough power to a remote tag to sustain the energy- typically between 10 μ W and 1 mW based on the size of the tag. With the implementation of various modulation schemes both near field and far field communications can send and receive data.

3.1 Near Field Communication

Magnetic Induction technique stated by the Faraday's principle is the source for near-field coupling between reader and the tag. The reader passes under high alternating current through a reading coil, resulting in alternating magnetic field in the region. For example (Figure 1), if the tags with small coil are placed in a field, an alternating voltage appears across it. If the said voltage is rectified and coupled with to a capacitor then the charge gets accumulated and thus powering the tag is powered and data can be transferred.

Load modulation is the technique which the circuits use to transfer the data to the middleware, as the power drawn from the tag coil can detect and will increase the own magnetic field. The reader will be able to identify the current flowing through it. The power source is proportional to the load applied on it. Furthermore, as the magnetic field induction extends beyond the primary coil, a secondary coil can still acquire some energy at a distance and similarly the reader and the tag. The middleware can still improve the signal by monitoring the change in the power through the reader coil. Passive RFID system uses the near field communication system.

The physical limitations of the near field communication systems are the range and the power availability. The range with the implementation of magnetic inductions approximates to c/2πf, where c a constant with the specification of speed of light and f is the frequency [4]. Therefore, with the increase in the frequency f, there happens to be a drop in the near field communication. Secondly, the power availability for induction as a function of distance from the reader coils. The decrease in the magnetic field induction happens at the factor of 1/r3, where r is the separation from the plane of the coil [4]. Therefore, for the implementation of the near field communication requires more identification bits and tags have fixed read time. The tags operating at higher data rates have higher read time and higher operating frequency. The difficulties have lead to design of the Far field communication system.

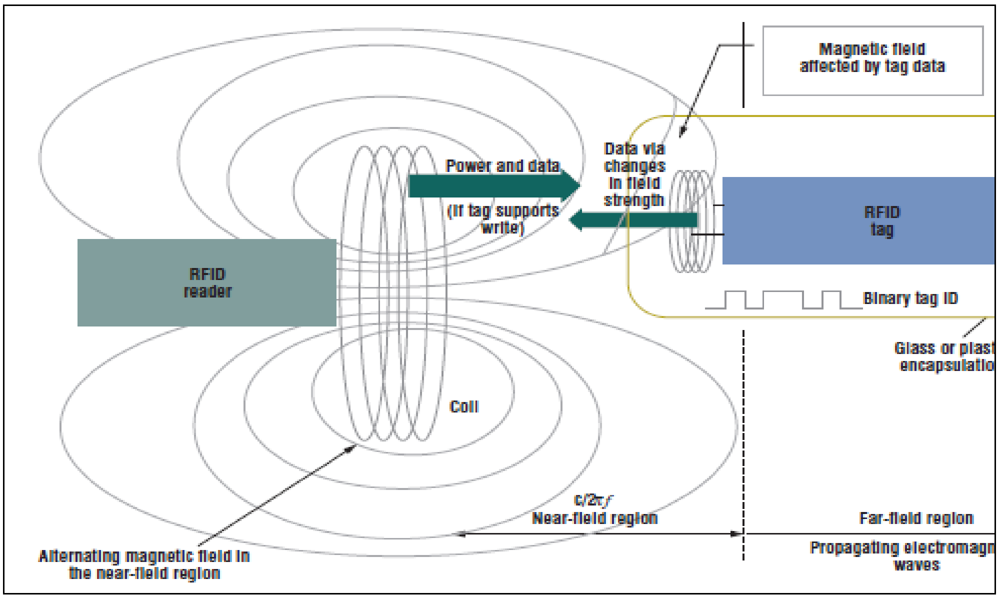

Figure 1. Block Diagram of Near Field Communication

3. 2 Far Field Communication

Far field communication systems capture the Electromagnetic (EM) waves propagating from dipole antenna attached to the reader. The dipole antenna in the tag receives energy as an alternating potential difference that appears in the midst of the dipole. The rectification of the potential and linking it to another capacitor results in the accumulation of the energy to circuits. Back scattering techniques are used in far field communications. For instance (Figure 2), if the antennas are designed with precise dimensions, it can be tuned to receive a particular frequency. If a mismatch occurs, the antenna will reflect energy as small waves, towards the middleware and detect the energy using radio waves. The change in the impedance of the antenna, the tag can reflect back the signal pattern that encodes the identification code of the tag. The tag can be tag detuned by placing a transistor and switching on and off. Far field coupling are used between 100 MHz i.e. the ultra high frequency. Near field communication is used below the specified frequency.

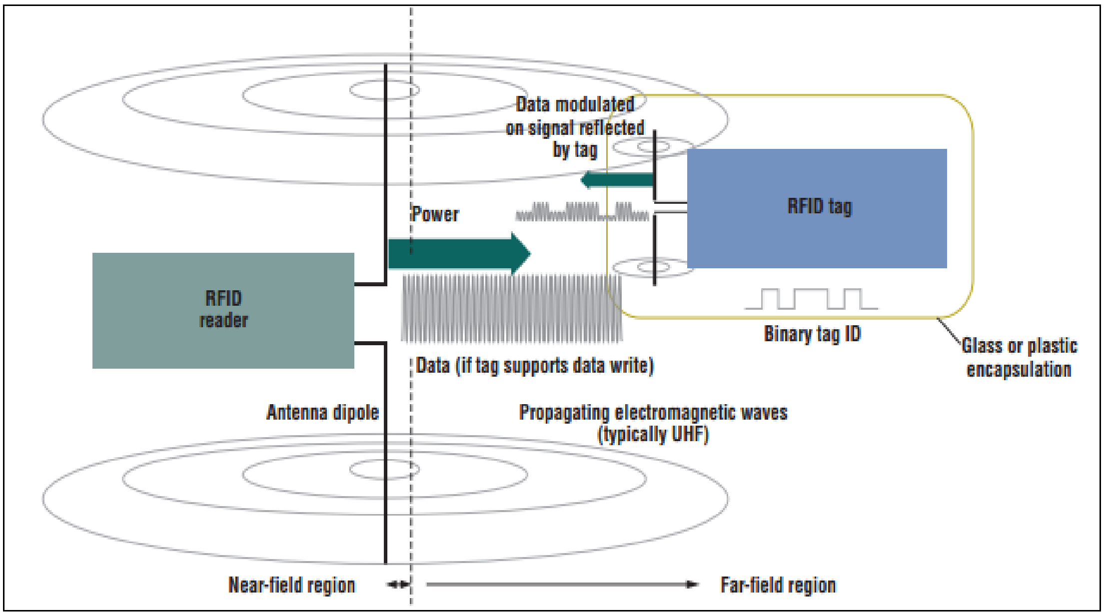

Figure 2. Block Diagram of Far Field Communication

IV. Classification of RFID Integrated Circuits

4.1 Characteristics of RFID System

The characteristics of the RFID system will evolve the classes of RFID transponders, the frequency ranges of the RFID transmission and the modes of communication. RFID transponders differ on the way the ICs retrieve the energy [5].

4. 2 Active Tags Specifications

Active tags have built-in power source. With the built in battery, active tags can operate at a greater distance and at higher data rates in return for limited life driven by the longevity of the built-in battery and higher costs. Active tags send signals without being queried are termed as beacons. An active tag ranges from tens to meters and making it ideal for locating objects or serving as landmark points. An average life span of an active tag is from 2 days to 7 years.

4.3 Passive Tags Specifications

Passive tags do not have an internal power source and rely on the powers source induced by the reader. The reader has to supply the power required until the transaction is completed. Due to the lack of energy, Passive ICs are the small and cost-effective. The reading range of the Passive tags is between 2mm and a few metres. The benefits of no in-power supply tag is that can be produced by printing and the lifespan is unlimited since the ICs do not depend on internal power supply.

4.4 Semi-Passive Tags Specifications

Semi-Passive tags are sub-classified from Passive tags. Semi Passive ICs have an internal power source that keeps the micro chip powered at all times. Advantages of Semi passive ICs are numerous. As the chip is always on battery, the responds to requests, increasing the number of tags that can be queried based on time. Since the antenna is not required for collecting power, the same can be used for optimizing back scattering and subsequently increasing the reading range. The tags which do not apply the energy from the field the back scattered signal is stronger, increasing the range even further. With all the advantages, semi-passive tags have a larger read range than passive tags. Semi-Passive tags are also called as Battery Assisted Passive tags (BAP).

V. Frequency Spectrums of RFID Integrated Circuits

RFID tags fall into three regions of frequency spectrum [6]. The Low Frequency (LF) ranges from (30 – 500 kHz), High Frequency (HF) ranges from (10 – 15 MHz), Ultra High Frequency (UHF) ranges from (860 – 960 MHz) and Microwave ranges from (2.4 GHz to 5.8 GHz).

The frequency spectrums do not require license if the transmitted power is limited. Low-frequency tags are physically used for access control and security, manufacturing process, harsh environments and animal identification applications and in various industries that require short read ranges. The low frequency spectrum is the highly adaptive to metal environments and with the loss of performance. High-frequency tags were developed as a low cost and as an alternative to low-frequency tags with the ability to be printed or embedded in substrates such as paper. The applications of HF tags include library tracking and identification, patient health care, access control and laundry identification, item level tracking etc. Metal presents interference issues and requires special considerations for mounting on particles.

Ultra High-frequency tags boast greater reading distances and superior anti-collision capabilities, increasing the ability to detect multiple tags at an instance [7]. The primary application envisioned for UHF tags is supply chain tracking. The UHF spectrum is has to obtain transmission license for communication in United States (US), Europe (EU) and Japan. Microwave tags are mostly used in active RFID systems. With the operating long range and high data transfer speeds increases the price of the tags. UHF tags are employed in railroad car tracking, container tracking and automated toll collection as a reusable asset. Though the tags have different kinds of frequency spectrums, the modes of communication remain the same.

VI. Modes of Communication in RFID System

The modes of communications are termed as coupling. Coupling is the methodology used to link the tag and the reader. Coupling is classified into two forms namely – inductive coupling and capacitive coupling. Inductive coupling involves the reader emitting a magnetic field [8]. When a transponder enters the field, the chip will vary its antennas response which will result in perturbation of the magnetic field which can be detected by the reader. The strength of the magnetic field drops sharply by with the distance from the emitter and hence inductive coupling are inherently short range. The mode of operation is transmitted using HF.

Capacitive coupling involves the reader emitting a propagating electromagnetic wave. When the wave impinges the tag, the chip modifies the antenna radar cross section in such a way that the reflected signal containing the information on the chip can be detected by the reader. This is the primary mode of operation at UHF and in the microwave region. The frequency spectrums, modes of communication vary in the reading ranges of the transponders. The working principles of the transponders diverge only with the classes of the transponders. Active and passive tags use discrete mechanisms to communicate data to the middleware and to the end system.

VII. Working Principle of RFID System

The working mechanism of the RFID technology initializes with the RF tag (Figure 3). The transponder (tag) is activated when it passes through radio frequency field, which has been generated by an antenna and reader. The silicon chip sends out a programmed response. The antenna that generated the field originality and is attached to the reader detects that response. The transceiver (or reader) sends the data to the middleware. The middleware sends the information transmitted from the transponder to the end system [9].

Active RFID is equipped with an internal power with which the signal is generated in response to the reader [10]. Active RFIDs are expensive when compared to the passive RFIDs. The frequency range of an active tag is more to the passive tag.

Passive RFID is not equipped with an internal power source. The energy to activate the passive tag is passed by the reader. The read range of the passive tags is lesser and subsequently less priced.

VIII. Benefits of RFID System

RFIDs were not invented just to replace the exiting the barcodes system. The advantages of the RFID system are many more. The following are the advantages of RFID

- Identification of articles or objects by using RFID transponders reduces labor work, erroneous data and saves time.

- Line of Sight (LoS) technology is not used as it is replaced with near field or far field communications.
- The read/write capability of the transponder is added advantage when compared to the barcode system.
- The range of the transponder is high whereas in barcode system closest contact is required for data transmission.
- Large amounts of data are stored on the tag on a transponder and can be identified by the unique identification number.
- Products are identified with unique identification number rather than broad classification.
- RFID transponders are less sensitive adverse conditions like climatic changes, chemicals, physical damages etc.,
- Multiple transponders can be communicated simultaneously.
- RFID can be further advanced with the combination of sensors.
- Automatic reading reduces time lags and inaccuracy in data.

IX. Limitations of RFID

Many supply chain companies are moving towards the implementation of RFID technology. However, RFID has limitations based on tracking and exploitation of the potential skills requires privacy and security schemes to be implemented for the necessary system accordingly.

The limitations have foreseen based on the implementations done based on the characteristics on the existing systems of RFID. The following are considered to be the constraints of the technology

- Transponder standardization
- Transponder collision
- Transponder manufacturing issues
- Frequency range restrictions
- Privacy and security issues
- RFID technology obsolescence

9.1 Transponder Standardization

The transponder standardization is accomplished based on three criteria [11] such as individual reading distance, close coupling or long range coupling systems, energy supply namely passive, semi-passive and active transponders. The storage structures are defined as write once/read multiple (WORM), read write and complex data structures.

The transponder usually saves 96 bit (max) identification number [11]. The identification number can formatted using widely used number formats, the Universal Product Code (UPC), the European article number (EAN) or the serialized shipping container code (SSCC). The Electronic Product Code (EPC) comprises a new RFID technology-based product identification.

ISO has also implemented standards on RFID transponders for automatic identification and item management. The standard is known as ISO 18000 series, covers the air interface protocol for the systems used in tracking goods in supply chain. The major frequencies used in systems in the world are

- 18000-1: Generic parameters for air interfaces for globally accepted frequencies.
- 18000 -2: Air interface for 135 KHz
- 18000-3: Air interface for 13.56 MHz 4
- 18000-4: Air interface for 2.45 GHz
- 18000-5: Air interface for 5.8 GHz
- 18000-6: Air interface for 860 MHz to 930 MHz
- 18000-7: Air interface at 433.92 MHz

The tags must meet the standards to achieve the transponder standardization.

9.2 Transponder Collision

Transponder collision occurs when one or more tags are energized simultaneously by RFID tag reader and reflect back to the reader at the same time. The problem occurs when large volumes of tags are read in the RF field. The reader is unable to differentiate the signals as tag collision confuses the reader.

Different technologies have been implemented to differentiate the individual tags and it might vary from one RFID model to another. For example, when the reader recognizes that the tag collision has occurred, it sends a signal called as 'gap pulse'. Upon receiving the signal, each tag consults a random number to determine the interval to wait before the data transmission. Through the said method, each tag gets unique number interval and start the data transmission different intervals.

9.3 Transponder Manufacturing Issues

The cost of the RFID chips is high because of the manufacturing yield. The customers have to pay for the good chips along with the defectives ones that has never made out of the fabrication facility, intensive labour separation of the good ones from the defective ones. A recent study of the RFID vendors portrays that the 30 percent are damaged during production that is when chips attached to the antennas and additional of 10-15 percent become inoperative in the printing process [12].

Due to the redundancy built in the RFID tags, manufacturing defects are ignored. Some of the tags might be defective while other tags fail in the RF field but by attaching multiple tags for an object probably will reduce the error rate. This considerably increases the overall reliability of the multi-tag RFID system and also decreases the tag manufacturing costs.

The failure rate of the RFID tags in the RF field is estimated as 20 percent [13]. Failure rate induces an additional cost pressure on RFID tag manufacturing as individual tags must be reliable and tested after production but after packaging, tags may become defective. The property of multi-tag system helps to improve overall reliability and cost of deployed multi-tag system.

9.4 Frequency Range Restrictions

RFID system uses a number of frequency ranges. The frequency range used, determines the characteristics of the system operation. Determination of the correct frequency range is important in the early stages of the development process.

As discussed in Section V, Frequency spectrums in RFID integrated circuits, there are 4 different spectrums. The Low Frequency (LF) ranges from (30 – 500 kHz), High Frequency (HF) ranges from (10 – 15 MHz), Ultra High Frequency (UHF) ranges from (860 – 960 MHz) and Microwave ranges from (2.4 GHz to 5.8 GHz).

LF can be used globally with license. The frequency is used for vehicle identification and is of 0.5 metres range. MF is used for inductive coupling in the RF field and has the range about 1 metre. HF is used for electronic ticketing, contactless payment, access control and the range is about 1 metre. UHF is used with backscatter coupling and cannot be used globally and there are significant restrictions on the same. When the same is used, it is used for asset management and in tracking of container, baggage, parcels and many more. UHF range is about 1 to 10 metres.

9.5 Privacy and Security Issues

Privacy and security issues affect the system based on the fields of application. By prescribed law, unauthorized persons might be objected from reading or writing the data stored or transmitted from the tags [13]. Encryption must be ensured at all interfaces where data could be intercepted or transmitted from the tag-reader and the vice versa.

Privacy threats include the complications such as challenges in transponder authentication, data interception and host based encryption. Inclusion of Active jamming, Blocker tag algorithms, Faraday cage, Hash lock techniques and Kill command can be implemented as the solutions to prevent privacy threats [14].

Security threats occur with access control and encryption factors. The solution for security threats are cryptography, data encryption algorithm and authentication protocols [14]. With the inclusions of the said solutions in the implementation of the RFID system will reduce the complications of privacy and security issues.

9.6 RFID Technology Obsolescence

Technology obsolescence is the concern of companies implementing RFID along with the investment cost. Like computer technology-based systems, RFID system is changing rapidly. RFID is a most powerful data collection tool and some challenges must be met before the technological benefits are recognized. Obsolescence standardization is one of the critical challenges that affect the uses of RFID.

Technologies are constantly evolving and new protocols standards, faster and more fault-tolerant readers may quickly outdate the predecessors. The advancement in RFID systems might incorporate current technologies standards along with the new principles. New capabilities can be enforced in Active RFID tags to address obsolescence.

X. Applications of RFID

RFID proposes a span of application areas and full comprehensive view can surpass the limits of the paper. RFID applications can split in to three groups by its implementation such as

- Object recognition
- Location identification
- Data communication

10.1 Object Recognition

RFID technology – a wireless technology provides efficient mechanisms to enhance supply chain processes. RFID tag can used to identify as unique identifier for a physical object. Therefore reduces administrator error, labour cost such as data entry and barcode scanning. RFID system is also called as 'Smart Labels' as the object could be read with the distinctive tags placed on them. RFID replaced barcodes, which needs Line of Sight (LoS) communication. RFID system is robust and the tags can be programmed, holding information such as current destination, expected weight and time stamps [15].

RFID tags enable automation throughout the supply chain, including optimisation of warehouse space, reduced shrinkage, goods tracking and thus creating a platform for cost reduction and improved customer service.

10.2 Location Identification

Location identification comprises what the system is actually going to achieve and the nature of the system involved. The consideration for choosing proper radio frequency identification system is required. The solutions vary from location accuracy, positioning systems, frequency range and the type of the object to be tracked. Active ultra-wideband (UWB) RFID system will be able to determine where the tagged object is located within few inches. UWB tags can be very expensive when the system involves large number of objects to be tracked.

Passive ultrahigh-frequency (UHF) RFID solutions will provide about 15 to 30 feet of read range, depending on which tags and readers are deployed in the process. UHF systems can typically tell that a tag is within a defined read field, but not specifically where in that field. Applications can be programmed to detect the tag where it is located and some companies have developed applications that deliver greater location accuracy.

Passive systems utilize Received Signal Strength Indicator (RSSI) to determine the distance between the object and the RFID interrogator. RSSI will not possible point out the tag's exact distance because of the signal strength can be affected by waves bouncing off the floor or ceiling, but can indicate whether the tag is getting closer for further away. RSSI for an object closer to the reader within the same environment will be stronger than the one located further away. The disadvantage of the RSSI is to distinguish the difference in location of tags spaced in inch apart.

10.3 Data Communication

Software communication protocols can be divided into two categories – Application Programming Interface (API) and the Transmission Control Protocol /Internet Protocol (TCP/IP). The communication protocol addressed in the presentation layer focuses on the application layer protocol layer, e.g. API at a handheld reader device. A Common Interface (CI) can be created by installing APIs to different readers. Common Interface can provide the readers to access the same tag. CI can give consistent application interface for RFID operations with increased operation efficiency, reduced operation errors and training costs. Secondly, reduce software development and maintenance costs.

XI. Conclusion

Analysis of UHF ISO/IEC 14443 Gen 2 RFID Technology has indicated current state and trends of RFID technology. The limitations and unresolved issues of RFID lead to development of the technology and hinder to the development of the technology. Along with the challenges, RFID continuous to make into systems like smart card, Just in Time (JIT), inventory controls. RFID technology has been developed as an advancement of barcodes and low cost components makes RFID as a technological evolution. High level engineering efforts are under way to overcome current technical limitations and build accurate and reliable tag recognition systems.

RFID potential benefits are immense and lead way to novel applications. The components which are integrated into RFID ICs such as readers and tags communicate with radio frequency. The size and broad deployment enhances the power and increases the privacy and effects of the mechanism. Deployment of appropriate tools, mechanisms and approaches along with necessary confidentiality and safety protocols should be incorporated for the RFID deployment. It is necessary to consider the tools and methods available before the stationing the equipment. The development leads to the evolution of a secured environment for every individual to live.

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