RFID in Healthcare

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Abstract Radio Frequency Identification, better known as RFID, is an emerging non-contact identification technology which is designed to enhance the bar code technology. The demand for RFID has grown due to the benefits that embedded RFID in stationary and mobile devices offer. The technology has proven to be promising to the healthcare industry in that it can improve efficiency and safety of patient care. RFID also helps to mitigate drug counterfeiting, eases inventory management, streamlines patient tracking, and prevents medications errors, and helps surgical procedures. This paper describes various applications of RFID technology in healthcare.

Keywords Radio frequency identification, RFID technology, healthcare, hospital

Introduction

RFID stands for Radio Frequency Identification. It refers to technologies that use radio waves to identify objects, animals, or people. It is more efficient than standard barcode technology by reading multiple tags at once. Due to its low energy consumption and adaptability to different environments, RFID has found applications in various fields such supply chain management, transportation, manufacturing, agriculture, pharmaceutical industry, healthcare, and libraries [1]. RFID technology can save organizations time and money by providing real-time traceability, identification, and location data for people and resources.

Historically, the healthcare industry has considered itself as being operationally different from other industries. The healthcare industry in the United States is gigantic and an inefficient mess. Although there is no magic bullet for those inefficiencies, RFID technology may help to tackle some of the inefficiencies. The simple yet powerful technology is poised to revolutionize healthcare industry. RFID is all about organization, efficiency, and speed, the three things healthcare system lacks [2]. RFID offers several opportunities and challenges for healthcare transformation. The healthcare industry is becoming more and more invested in RFID technology due to the sheer number of applications that can benefit, from tracking of surgical tools to tracking patients and staff.

What is RFID?

Radio Frequency Identification (RFID) was the first explored in the 1940s as a means of identifying allied airplanes. It is a new technology which enables wireless labeling and identification of objects, humans, and animals. It serves the same purpose as a bar code or magnetic strip on a credit card or ATM card. It may work with or replace bar codes. The advantages of RFID systems over bar codes include [3]: (1) physical line-of-sight scanning is not needed, (2) several RFID tags can be read simultaneously, (3) information on the tags is dynamic, (4) can endure harsh environment, (5) has a faster response time and process time. Just as the bar code must be scanned to retrieve information, the RFID card needs scanning to get the identifying information.

RFID uses radio frequency waves to identity and track tags connected to objects. A typical RFID system consists of three main components, which as illustrated in Figure 1 [4] and explained as follows [5,6].
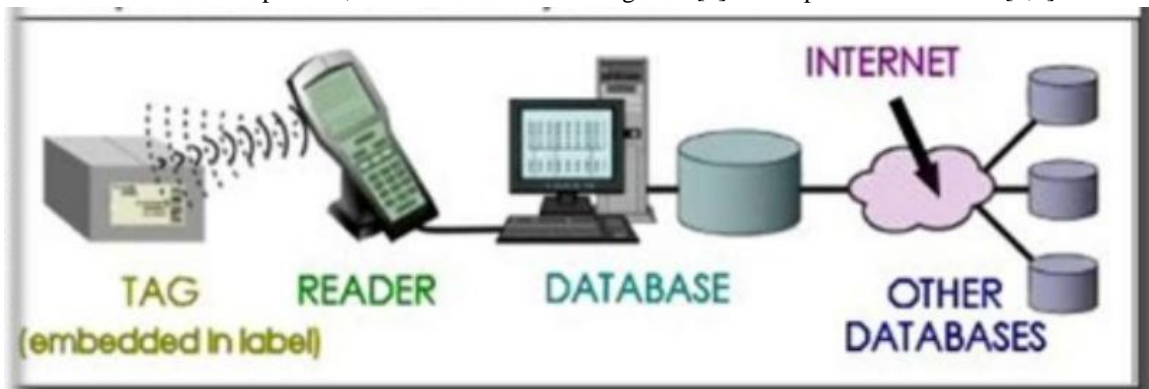

Figure 1: Components of an RFID system [4]

(1) Tags: A tag usually consists of a chip and an antenna. The antenna is usually in the form of spiral metal coil. The tag stores information such as serial number, manufacturer code, assembly location, date of installation, country of origin, and other data. It can store information from 64 bit to 8 MB. It can assume a variety of shapes and sizes. It may be passive, active, or intelligent, indicating the three types of tags. Each type serves a different purpose in the healthcare industry. A passive tag is smaller and cheaper because it does not use a power source such as a battery. A typical passive RFID tag is shown in Figure 2 [7]. An active tag is battery-assisted to power up its circuitry and periodically transmits its signal. An intelligent tag is similar to active RFID tag in that it uses battery-powered sensors. The tags are attached to objects or persons. RFID tags do not have chips are called chipless tags. The implementation of chipless tags can significantly reduce the tag price. There are billions of tags in circulation and the number increases yearly. The tags are becoming part of the infrastructure of the Internet of things.

Figure 2: A typical passive RFID tag [7].

(2) Readers: These are also known as interrogators. They read and write data on the tags. Readers can be real-only, write-only or read-write. RFID does not require a line of sight to read data on the tags. The tag and reader exchange information wirelessly. An RFID system may consist of several readers. A reader can communicate with more than one tag at the same time. This may require anticollision algorithms.

(3) *Controller*: This is a host computer to host data. It may take the form of a PC or workstation and control application software. It is the brain of the RFID system. It connects multiple readers and centrally processes information that is collected by the readers. RFID systems operate at different frequency bands. In the United States, the FCC has allocated four different bands:

- Low frequency (LF), between 30 kHz and 300 kHz
- High frequency (HF), between 3 MHz and 30 MHz
- Ultra-high frequency (UHF), between 300 MHz and 1 GHz
- Microwave, between 1 GHz and 5.8 GHz

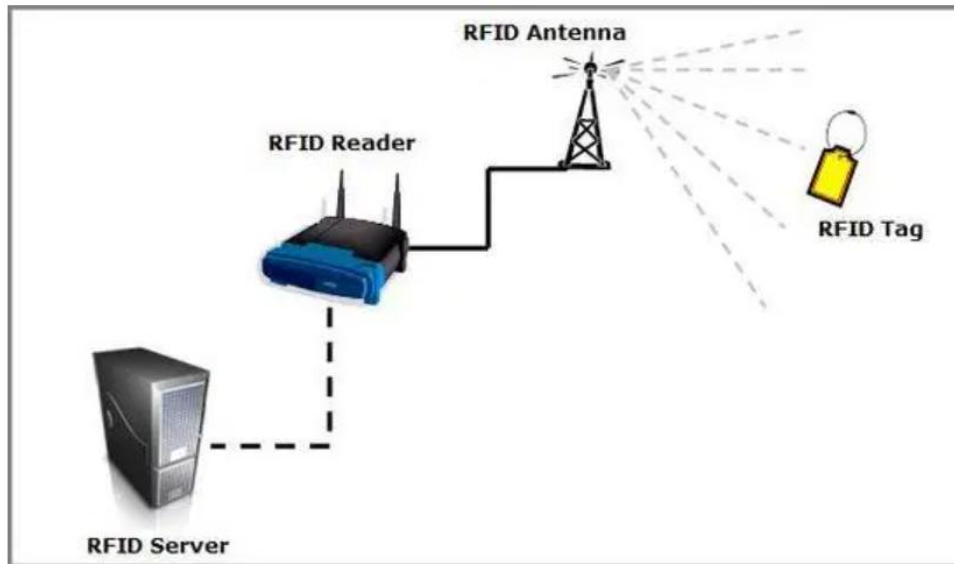Figure 3 shows a typical RFID system [8].

Figure 3: RFID system [8]

Historically, RFID technology has been used extensively in supply chain management to track goods in warehouses. Since 1887 when Heinrich Hertz experimentally discovered radio waves, they have been used to detect and track entities on land, in space, and in the air. RFID is used for real-time location services, along with other wireless technologies. Encryption is supported on RFID.

Applications of RFID in Healthcare

RFID technology is a favorable asset to healthcare. Due to the flexibility and small size of RFID tags, a vast number of applications already use RFID-based technology in the healthcare industry. Here are the top common ways RFID technology is being used in healthcare [9,10].

- *Tracking:* The primary use of RFID in healthcare is tracking equipment, tracking patients, and tracking staff. RFID can be utilized for real-time tracking of staff, patients, medications, equipment, perishable products, supply chain, and inventory management. Accurate patient tracking using RFID technology can improve patient safety, especially tracking vulnerable patients such as the elderly, dementia patients, children, and matching of newborns to their mothers. Real-time continuous automatic hand hygiene tracking give healthcare organizations the ability to record compliance and prevent hospital-acquired infections. The asset tracking capability of the RFID system helps users find tagged equipment. Waste can be minimized through inventory tracking and this may increase accountability and supply efficiency. Figure 4 depicts a tracking system in healthcare using RFID [11].
- *Validation:* Like tracking, being able to validate through the RFID can reduce medical errors, check productivity, and help construct necessary documentation for administrative and audit purposes. The validation is an effective method of ensuring quality in a healthcare setting. Medical errors constitute the third-leading cause of death in the US. The RFID technology can reduce medical errors which can be classified into five categories: poor decision making, poor communication, inadequate patient

monitoring, patient misidentification, inability to respond rapidly, and poor patient tracking. Most of the medical errors caused by misidentifications are preventable. The RFID makes the prevention about human error in medicine easy and fast.

Figure 4: Tracking in healthcare via RFID [11]

- *Hospital Management:* There are many benefits in using RFID technology in the hospital. These include the ability to provide real-time traceability of medical equipment. RFID tags are used in the hospitals to verify patient information, reduce wait times and bottlenecks, and to locate staff and patients. Since RFID tags are cheap and small, a hospital can use them to track almost everything. Hospitals are known to have an ever-changing medical supply that must be tracked. The moment an item is brought into the hospital, it is tagged with an RFID smart label and put into the hospital's database. Keeping track of high-value items in hospitals is critical in hospitals because the replacement cost is very high. Recently, the RFID has been applied in hospital management. The application of RFID can bring hospitals towards the integration of technology benefits. When integrated with hospital information systems (HIS) and electronic health records (EHRs), RFID facilitates processes and reduce medical, medication and diagnosis errors. Textile used in hospitals must be equipped with RFID tags to realize digitization. RFID technology allows hospitals to monitor the interactions between staff and patients and services provided in order to bill more accurately. Figure 5 shows the use of RFID in hospitals [12].

Figure 5: RFID in hospitals [12]

- *Inventory Management:* This is the most important aspect of managing an organization. It is a complex process that asks what is in stock, how much is it, who has it, where is it, and when to reorder. The RFID helps manage patient inventories so that the right assets are available when and where they are needed.
- *Pharmaceutics:* RFID has been used in the pharmaceutical sector where it has been adopted to prevent counterfeit pharmaceuticals from entering the marketplace. Using RFID can reduce the amount of time spent counting, ensuring accurate data, and informing the amounts of drugs that are on hand. Tracking drugs from creation to receipt can alleviate drug counterfeiting, theft, and misuse of medications.

Other areas of application of RFID in healthcare include sensing, interventions, parking, medication tray restocking accuracy, patient identification, equipment identification, clinical workflow, drug safety, laundry, and real time locating systems (RTLS).

Benefits

RFID technology is used for tracking staff, patients, and medical devices using radio waves, requiring no line of sight and no contact. Common benefits of the implementation of RFID in healthcare include patient safety, patient and asset tracking, efficiencies in patient care, and provider satisfaction [9,13].

- *Patient Safety*: Patient safety is a global public health concern. RFID has the potential to help to improve patient safety. RFID tags provide the ability to reduce misidentification problems. The RFID system correctly identifies and recognizes medical staff, patient ID, and blood sampling data in real time. It also prevents medication errors.
- *Stored Information:* RFID technology can store, transfer, and house large amounts of data regarding patients, staff, and equipment. RFID data can be stored, managed and shared online. Data showing potential problems can be quickly retrieved. Big data can be leveraged from the stored information in RFID technology.
- *Improved Medical Process:* With automatic data capturing and storage capability of RFID, manual processes can be automated. RFID has the potential to significantly improve operations by actively monitoring asset. RFID provides real-time tracking of staff, patients, and properties. It is applied to real-time traceability, identification, location of assets, preventing counterfeiting of drugs, saving nurse time in locating medical equipment, reducing medical errors in laboratory tests and improving security of a hospital.

Other benefits include improving staff productivity, decreasing equipment rental, improving regulatory compliance, protecting drug supply, improving resource utilization, and enhancing patient satisfaction.

Barriers

There are many barriers that impede the implementation of RFID technology in the healthcare industry. These include economic, technical, organizational, privacy, electromagnetic interference, legal issues, security challenges, monitoring and tracking limitations due to human error, lack of information, insufficient budget available, and the complexity of technology [9,14,15].

- *Cost:* Cost is one of the major challenges facing RFID technology. A typical RFID system requires tags, readers, antennas, communication infrastructure, and so on, and can cost an organization millions of dollars. Tags can be reusable or disposable, with reusable tags having higher price. RFID readers can be ten times more expensive than barcode scanners. The economic impact of RFID implementation must be analyzed to overcome cost concerns that must be kept on hand. Using high-cost RFID tags to track single-use, low-cost inventory items in hospitals is not feasible.
- *Technical Limitations:* These impede adoption of RFID. The limitations include system errors, RFID tag readability, electromagnetic interference with medical devices, interoperability with other health information technology, wireless network connectivity, lack of staff knowledge of detection areas, and the inability of the radio frequency waves to reach some of the tags. Testing of the RFID technology must be thoroughly done prior to widespread implementation so that unforeseen technical issues can be addressed.

- *Material Limitations:* RFID tags are sensitive to the material size of your assets. It is difficult to apply RFID tags on metals and fluids, which tend to reflect the radio waves. Metals will deactivate the RFID antenna and the tag will not transmit. Fluids can also affect the reliability of the RFID signal. Nevertheless, RFID tags can be read through a variety of materials such as ice, snow, paint, fog, and other visually environmentally challenging conditions.
- *Tag and Reader Collision*: This is a common problem with RFID. Tag collision occurs when numerous tags are present in a confined area and the RFID reader fails to differentiate between incoming data. RFID reader collision results when the coverage area managed by one RFID reader overlaps with the coverage area of another reader, thereby causing signal interference.
- *Electromagnetic Interference* (EMI): The interference of RFID with other wireless equipment, especially operation and intensive care wards, remains the single biggest obstacle to RFID roll-out in healthcare.
- *Education about the Technology:* There is a lack of education on the RFID technology and how it works. Education on technology prior to adoption is highly recommended to ensure staff can use the technology properly. Educating and training healthcare professionals on RFID can help decrease negative perceptions.

Other barriers include technology incompatibilities, interoperability, and lack of RFID standards, and lack of government support. RFID is harder to understand. Building an RFID system in a hospital environment is difficult. Ethical issues in tracing and tracking of individuals and equipment is a major concern. These barriers must be addressed in full transparency before successful implementation of an RFID technology system can take place. With more research, the barriers can be removed or minimized.

Global RFID in Healthcare

The global implementation of RFID technology has impacted many industries. Companies around the world are using RFID to improve productivity, efficiency, and decision-making, The healthcare industry is one of the largest sectors in most nations and The global healthcare sector faces some severe challenges such as escalating operating costs, the ageing population, the high level of medical errors, the complexity of the healthcare value chain, the poor costing system, and mandates for increasing patient safety [16]. RFID has the potential to revolutionize and transform the industry. The global radio frequency identification (RFID) market for healthcare is expected to soar due to the value and efficiency the technology promises to bring to healthcare industry. North America held the largest market share of about 45% in 2018. The factors driving the growth of RFID technology market in healthcare include price, capability, and size. The RFID technology offers potentially limitless applications for driving accuracy and value for the healthcare industry. As hospitals, labs, pharmaceutics, supply chains, and labels adopt RFID technologies, they become smarter. RFID could also address the issue of medical errors, which is the third-leading cause of death in the US [17]. It can play a significant role for improving hospital core processes at the clinical and non-clinical levels.

The RFID in Healthcare Consortium (RHCC) is a non-profit, global organization founded to elevate awareness and to educate science community on the adoption of new technologies. The RHCC is an educationally focused, vendor neutral association dedicated to promoting the use and adoption of auto-ID, NFC, RFID, RTLS, sensors and wireless technologies in the healthcare. For more information, please visit their website: www.rfidinhealthcare.org/rhcc/rfid-healthcare [18]. We now consider how RFID is used in healthcare systems of different nations.

- *United States*: The healthcare system in the US is overloaded. This calls for the need of intelligent hospitals, which integrate diverse technologies to provide a seamless exchange of information. To deal with the complexity of patient care workflows, enhance patient diagnosis, treatment, care, safety and satisfaction has driven hospitals to integrate RFID into a variety of hospital operations and processes [19]. Stanford University Medical Center and New York Presbyterian Hospital have used RFID technology to monitor patient location. FDA requested RFID manufacturers to provide information about the effect of RFID energy on drugs as part of an overall private-sector study of electronic track-and-trace systems. Sun Microsystems is studying how to use RFID to track investigational new drugs

[20]. The US government uses RFID technology to track employees. The technology can increase patient safety, speed critical treatments, and provide better tracking of patient drug-treatment compliance. Medical equipment can be tagged to monitor usage, improve billing accuracy, and schedule maintenance [21].

- *Europe:* The potential use of RFID within healthcare industry in Europe is great. RFID is regarded as complementary, increasingly used in combination with WiFi. It needs to be integrated in pre-existing technological environments. Physical constraints like tag size, ability to attach tags, and the hospital environment still impede the implementation of certain RFID applications. Negative perceptions among users still exist and need to be taken seriously [22]. For example, a packaging supplier for an Italian coffee producer affixes a passive RFID tag to each pallet.
- *Taiwan:* RFID is popular in Taiwan and is used for different kinds of applications in healthcare industry.   Some of them will be the killer application. Taiwan has utilized RFID in semiconductor design, memory design, and specialized wafer production, electronic fabrication, software development, and system integration. RFID   in the healthcare industry is just at the initial deployment stage in Taiwan. RFID can offer some benefits to hospitals in Taiwan: they can possess best return on investment (ROI), make patients safer, and acquire competitive advantage [23].

Conclusion

RFID is a technology that allows storing and retrieving a huge amount of data through electromagnetic transmission using radio waves. RFID technology is revolutionizing the way hospitals manage inventory and track assets. It is increasing efficiency, improving the patient experience, and changing the bottom line for the healthcare supply chain [24].

In coming years, using of the RFID will be a requirement in the healthcare industry.

RFID is a disruptive technology that is here to stay. It will be the next generation innovation for automatic data collection and asset tracking. More information about the use of RFID in healthcare can be found in the books in [25-33] and the following related journals:

- *RFID Journal*
- *Journal of Medical Systems*
- *Hospital Topics*

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