ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 6, Issue 8 , August 2019

Review of Current Applications and Future Development of RFID Technology

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ABSTRACT: RFID technology is a fascinating subject that has the ability to create faster, more efficient processes, less prone to error across many industries. The intention in conducting this research is to understand better RFID technology for future advancements that have the potential to impact different enterprises. Throughout the course of this research, the beginnings of RFID technology, the current state of RFID technology, and the potential for the future of RFID technology are all examined. The case studies of companies that have utilized RFID technology in their operations and how this technology has impacted their business are also reviewed. The research shows that the use of RFID will continue to grow across industries in the coming years. As the technology continues to evolve, it will become a more significant fixture in our everyday lives.

KEY WORDS: RFID, supply chain, case studies.

I.BACKGROUND

This research begins with an understanding of what RFID is. Radio frequency identification is a technology that enables large amounts of information to be stored on chips that can be read at a distance by readers without requiring line of sight scanning. RFID technology requires three elements, an RFID tag attached to the object being identified, a RFID reader that collects data from the RFID tag using radio waves, and an information processing unit that can process the information received from the tag via the reader. A typical RFID system is illustrated in Figure 1. In 1948, Harry Stockman realized that it was possible to completely power a mobile transmitter from the strength of a received radio signal and published "Communication by Means of Reflected Power". This paper introduced the concept of passive RFID systems.

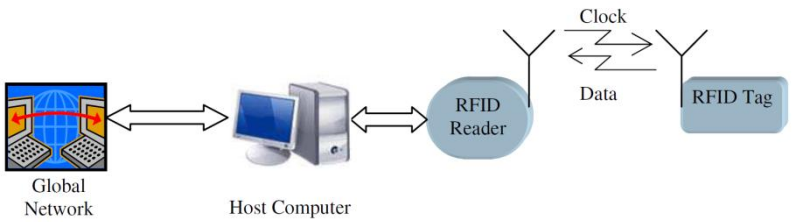

Figure 1 Block diagram of a typical RFID system [Preradovic]

A.HISTORY

The origins of the use of RFID technology date back to World War II where the British, Germans, Japanese, and Americans utilized radar to warn of approaching planes that were still miles away. The issue with only using radar, however, was that there was no way of knowing which planes belonged to the enemy and which planes were a country's own. The Germans were the first to discover that if pilots rolled their planes as they returned to base, it would change the radio signal that was reflected back to the crew on the ground. (Roberti)

By the 1960's the technology was beginning to be used commercially to counter the theft of merchandise. The systems that were utilized could only detect whether or not a tag was present in a piece of merchandise, but were inexpensive and provided effective anti-theft measures. Further development in the 1970's lead to the beginning of completely passive tags with extended operational ranges, while the 1980's gave way to greater implementation. One of the first mainstream uses during this period was for electronic toll collection for buses going through the Lincoln Tunnel by the

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

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Port Authority of New York and New Jersey. The 1990's were significant for RFID technology as over three million RFID tags were installed on rail cars in North America. Aside from tolling and rail operations, the 21st century has brought about rapid expansion of RFID technology in supply chain management. (Landt)

To further understand the background of RFID technology, the research also examines the different types of RFID tags and how they differentiate from each other. There are different types of RFID tags which include active, semi-active, and passive RFID tags. Passive tags do not have an integrated power source and are powered from the signal carried by the RFID reader. Semi-passive tags have an on-board power source, such as a battery, which is used to run the microchip's circuitry. Active tags incorporate a battery to transmit a signal to a reader antenna. As a result of 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. (Antic)

B. RFID PRINCIPLES

The information stored in an RFID chip is defined by its read/write characteristics. Tags can have read-only, write-once, or read-write characteristics. For a read-only tag, the information stored must be recorded during the manufacturing process and cannot typically be modified or erased. For write-once tags, the end-user is able to program the tag's memory that allows for the encoding of information that cannot be erased. For read-write tags, data can be written and erased on demand at the point of application. (Antic) Figure 2 represents the differences in the different type of tags.

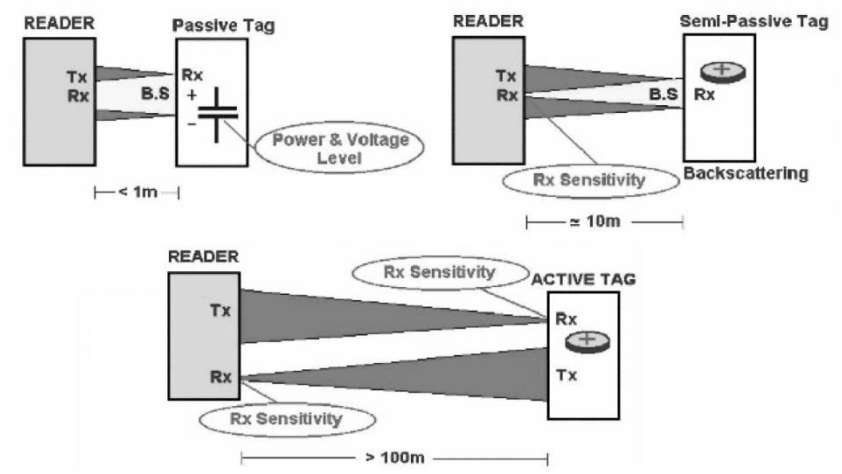

Figure 2 Differences in the different type of tags [Antic]

The following section will further examine the current state of RFID technology including a look into the RFID Lab at Auburn University, and the present state of affairs of the warehousing and analyzation of large data sets that are collected.

II. TECHNOLOGY

A. RFID LAB

One of the most exciting recent developments concerning RFID technology was the opening of the RFID Lab at Auburn University in May of 2015. Although the concept originated in 2005 at the University of Arkansas under Bill Hardgrave, once he moved on to Auburn University, the RFID Lab soon followed. The RFID Lab specializes in the business case and technical implementation of RFID in retail, supply chain, and manufacturing settings. The RFID Lab is an important part of the present and future of RFID technology as it is constantly working on business cases for different companies within these various industries. In its most recently released State of RFID adoption among US Apparel Retailers in July of 2016, the authors detail the current growth rate of RFID implementation across the industry.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
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Figure 3 shows the percentage increase between 2015 and 2016 in specific areas of the RFID adoption phase. The feasibility assessment stage is an early stage assessment by a retailer as to whether or not RFID is a viable technology. The proof of concept stage typically involves a small number of a company's stores, and a limited number of merchandise categories to demonstrate RFID's effectiveness in the retailer's environment. This leads to the pilot phase which generally involves more test stores, merchandise categories, and the use of matched control stores to help isolate the RFID effect. If the pilot proves to be successful, the next step is phased deployment. Since it is typically not possible for a retailer to RFID-enable all items, in all stores, all at one time, companies will phase in the technology over a period. Full deployment is reached when all items in all stores are RFID enabled. (Hardgrave, etc)

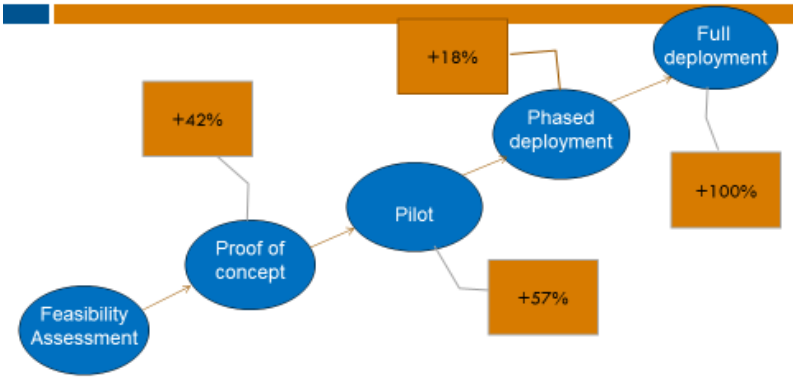

Figure 3 Adoption of RFID technology [Hardgrave]

Although this study focuses on apparel retailers, the data backs up that RFID growth is increasing throughout the industry, and that RFID technology is progressively becoming more commonplace in our everyday lives.

B.DATA-WAREHOUSING

One of the current issues with collecting information from RFID-enabled devices is the warehousing and analyzation of the massive data sets that are generated. Woo explains that data warehousing is the process of designing, constructing, and using a data warehouse. A data warehouse is constructed by integrating data from multiple heterogeneous sources that support analytical reporting, complex ad-hoc queries, and decision-making. Many industries that have been collecting digital data are having difficulties scaling up their systems because of the large size of the data. Since the data sets are so large and complex, it becomes difficult and expensive to process using traditional database management tools and data processing applications. Cloud computing services and big data platforms can scale to handle much larger data sets. (Woo)

As businesses further understand that the amount of data is growing every year, systems that are able to analyze larger data sets more efficiently in time and cost are becoming more important. A RFID data warehouse helps to integrate the massive amounts of information that is generated and store it historically so that users can analyze different aspects of the business. The data is stored in a format that is optimized for intensive queries and reporting so businesses can use data warehouses for performance analysis, trend analysis, and making educated predictions. (Woo)

Companies that produce RFID data warehousing solutions are recognizing the need for high accuracy, low hardware cost, secure connections, and protected access for customers. As more information will be continued to be gathered as RFID technology becomes more prevalent in the future, the use of smart data warehousing solutions continuing to evolve are an important part of RFID usage moving forward.

ISSN: 2350-0328

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Now that an understanding of where RFID technology originated, and how the different types of tags differentiate from one another has been established, the research will examine applications that RFID technology is currently being utilized in, and how various industries have implemented the technology into their business practices.

III. CURRENT APPLICATIONS

A. SUPPLY CHAIN INDUSTRY

Supply chain management is the active management of supply chain functions to maximize customer value and achieve a competitive advantage. Since a supply chain involves many different processes including suppliers, manufacturers, warehouses, and retailers, RFID technology can have a dramatic impact. The relationships between all of these entities become crucial in the efforts to improve supply chain performance. Utilizing RFID technology within these processes can help a company to have visibility to accurate, real time information that can lead to improved efficiency and accuracy across the supply chain.

According to Wisner, Tan, and Leong, "RFID is a valuable technology for tracking inventory in the supply chain. It can synchronize information and physical flow of goods across the supply chain from manufacturers to retail outlets and to the consumers at the right place at the right time. Likewise, RFID can track returned goods through the supply chain and prevent counterfeit. It also helps to reduce out-of-stock items. There is no doubt that RFID is invaluable for improving inventory management and supply chain efficiency" (Wisner, Tan and Leong).

One of the main challenges to implementing RFID technology across an entire supply chain is cost. According to the RFID Journal, RFID tags can range in cost from $.07 to $.15 for passive tags and $25.00 and up for active tags. Companies need to fully commit to understanding the overall cost of implementation of the system compared to the potential reward value. As the costs of equipment and tags continue to decrease the longer that RFID technology is available in the market, it will become more economical for companies to implement RFID technology into their supply chains.

Another challenge is the integration of systems with supply partners. As more companies better understand the value that integrating a supply chain with RFID technology can bring including reducing costs, better inventory tracking, and increased accuracy, there is more of a chance that integration can be successful. Forrest and Fish outline the seven steps to help ensure successful implementation of RFID technology. These steps begin with a company developing a clear strategy with clear management support and conducting a small project with RFID technology. The next step is to start gradually to implement RFID technology, followed by continually improving the procedures, along with negotiating and building trust among supply chain partners. The final steps are to develop a cross-functional team to help plan and implement the processes, followed by expanding the technology throughout the entire supply chain. (Forrest, Fish)

There are many barriers to completing all seven steps to successful implementation but having clear management support in the first step clears a large hurdle. From my professional experience working in the industry, many times a new system can be talked about and introduced, but if it does not have the support of management, it has an exponentially greater chance to fail. Negotiating with and building trust among supply chain partners is also an important step. Determining what costs will be absorbed by each company and the extent to which RFID technology will be utilized are a big part of the negotiation. Long standing partners may or may not be ready for the potential change as they may be set in their ways, or they could be looking to evolve as a company and improve their processes as well. New partners may be willing to participate in the implementation as a show of good faith to establish a long-lasting business relationship. The following section will illustrate companies who have already adopted RFID technology into their operations and some emerging industries who are recently introducing RFID technology into their processes as well.

B.OTHER INDUSTRIES

Discussed in greater detail earlier in the research, the opening of the RFID Lab at Auburn University ties in to various application cases with the amount of interest it has generated from corporate partners including Amazon, Fed Ex, and Delta Air Lines. Dave Clark, Amazon's Vice President of Worldwide Operations and Customer Service

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exclaimed that "We are partnering with the lab to develop new solutions for implementing RFID in our supply chain, specifically focused on tagging and driving inbound items through our fulfillment process. We fully expect to be inventing new processes, new technology and new uses of RFID as we allow customers to experience faster delivery, lower cost and greater selection." Clark also reported, "Amazon is in the early stages of working on RFID programs, but the company believes that the technology holds great promise for matters that are central to its competitive advantage." (Roberti) As evidence by the companies that are teaming up with the RFID Lab, it is clear to see the role that these companies envision RFID technology plying a part of in their long-term plans.

Although RFID technology has been around since World War II, it has not been until the twenty first century that companies have truly begun to start implementing the technology into their operations. In the following paragraphs, the research will further examine what companies were the forerunners in pioneering RFID technology into their operations, what these companies have learned, and what the future holds for RFID technology within their industries.

Once of the first major proponents of utilizing RFID technology was Wal-Mart. As a company that recognized that their distribution system is an integral part of their success, the company has continually been at the forefront of new supply chain initiatives. In June of 2003, the company announced that it was requiring its top hundred suppliers to be able to apply RFID tags to cases and pallets by January 2005. While suppliers were apprehensive about the mandate, Wal-Mart anticipated that the initiative would reduce inventory by five percent, reduce the rate of stock-outs with an increase in sales, and reduce store and warehouse labor costs. (Seidman) The suppliers viewed the mandate as an increase in their costs without any corresponding benefit. While the aggressive mandate by the company was thought to be very progressive at the time, it did not accomplish what it originally set out to do because of costs associated with implementation, and the fact that even though RFID technology did not require line-of-sight to be read, it could not penetrate liquids and metal. By 2009, Wal-Mart had scaled back on its mandate to its suppliers, but as the company continued to learn about the best ways to use RFID, the technology continued to be utilized within its supply chain and inside stores to further expand its usage to the levels that we are currently seeing today.

Other retailers such as Macy's and Target have recently taken the item level tagging approach as well. While Wal-Mart's original RFID mandate to its suppliers may have been ahead of its time, it is clear to see that other retailers and industries have moved forward with utilizing the technology as well. As time moves on and there is a show of demonstrated success with item-level tagging, retailers and other industries will once again look at the original case-level tagging concept that Wal-Mart had originally intended to implement.

The pharmaceutical and health care industries are examples of other industries that have adopted RFID technology. One of the main reasons for this adoption in the pharmaceutical industry is the persistent threat of counterfeit medicine. Counterfeit medicine can carry the same brand names as medicines from legitimate drug manufacturing companies but may not contain the same ingredients or wrong doses of ingredients that the drugs that are sold under a brand name contain. Adding RFID technology to the supply chains of these industries can help to provide more precise inventory management and reliable tracking from inception to delivery by increasing oversight and accountability. In the health care industry, RFID technology has been used in identifying lab specimens, tracking medical devices and monitoring patients.

One of the more recent companies to implement RFID technology is Delta Air Lines. In May of 2016, Delta invested $50 million into baggage tracking technology to be able to provide their customers with real-time tracking for their luggage. Delta teams have deployed 4,600 scanners, installed 3,800 RFID bag tag printers and integrated 600 readers to enable hands-free scanning of baggage throughout the handling process. The baggage is being identified at four points along a passenger's journey: the handover of baggage to the airline, the loading of luggage onto aircraft, and the subsequent delivery to a transfer area at the destination airport and the bags' return to passengers. "With a $50 million investment in RFID at 344 stations around the globe, we aim to reliably deliver every bag on every flight," Bill Lentsch, Delta's Senior Vice President of Airport Customer Service and Cargo Operations, explained. "This innovative application of technology gives us greater data and more precise information throughout the bag's journey." (Kang)

In May of 2017, Delta won the Best Radio Frequency Identification Technology Implementation award from the RFID Journal and in November of 2017 the company gifted Auburn University's RFID Lab $2 million to build a

ISSN: 2350-0328
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bay dedicated to aviation-based RFID technology. This gift shows that Delta is serious about the RFID technology that it has already embraced as part of its operations, as well as the future benefit of the technology for the company to separate itself from its competition.

C. OTHER APPLICATIONS

Manufacturers, retailers and airlines are not the only industries currently adopting RFID technology. The National Football League utilized tags in every football used during the 2017 season. While originally tested in player's shoulder pads in 2013, Zebra Technologies and Wilson Sporting Goods teamed up to test the technology at the 2015 Pro Bowl. In 2016, tagged game balls were used during the preseason and Thursday Night Football games, and in 2017 every ball in every single game was tracked. (Taylor) The data will enable the collection of real-time location, speed, and ball rotation data, enabling advanced statistics for broadcasters and viewers.

The full potential of RFID tags is still far from tapped, but the possibilities for the technology are nearly endless. For starters, the measurement of location could be used to take the subjectivity out of spot measurements, depending on where and how the tags are implemented. As Zebra Technologies continues its partnership with the NFL it's possible and even likely that the technology play a significantly larger role in the future of the NFL. (Skiver) With the NFL's use of RFID technology leading the way in the sports world, it will be interesting to see if other sports such as hockey, soccer, basketball, and baseball will start to implement the technology in their games in the future. As teams within individual sports leagues will always try to gain a competitive edge over their opponents, and the leagues themselves trying to provide the best customer experience for their fans, RFID technology is sure to have a growing impact on sports in the years to come.

While RFID technology has impacted certain industries for longer periods, new industries are always emerging as potentially being able to benefit from RFID technology as well. From simple tracking purposes through the supply chain, inventory management for retailers, or analytical data for sports leagues, the uses and impact of RFID is ever growing. With Delta now pioneering RFID technology in the airline industry, other airlines will begin to follow suit as customers will expect the same level of technology across the various airlines that they will encounter in their travels. In the following section, the research will explore chip-less RFID technology and how this segment of RFID technology has the potential to grow exponentially in the coming years.

IV. CHALLENGES AND FUTURE DEVELOPMENT

A. PRIVACY AND SECURITY

Two of the main concerns regarding RFID technology are security and privacy. In the following section, the research will further examine these concerns to understand them better and how they are currently being addressed, along with improvements that are being made to help alleviate these concerns. The research will also look further into the two main international RFID standards bodies and the differences between the two organizations.

While the benefits of RFID technology are seemingly endless across many different industries, there are concerns about the security and privacy of all of the data that is being collected. The concerns include if the data is only being utilized for its intended purpose, and if people who are not affiliated with organizations who are collecting the data are able to access it for other intentions. Another issue that could also lead to concern is the invasion of personal privacy as RDID tags could potentially be attached to items that the general public is unaware of. One of the more famous instances of this happening is referred to as the Broken Arrow Affair in 2003. In this instance, Wal-Mart equipped the lip-stick shelves of a store in Broken Arrow, OK with RFID technology. When one of the lipstick containers was removed, a video monitor was triggered in Cincinnati, OH where Proctor and Gamble employees were able to view the consumers as they handled the lipstick. (Hildner)

Khattab explains that RFID security attacks can be categorized into two main categories: privacy violations and security violations. In privacy violations, the attacker tries to harvest information from the objects by eavesdropping to the communications between the object and the reader or by tracking them. In security violations, an adversary counterfeits the behavior of a tag or a reader for making undesirable communications. Such security attacks

ISSN: 2350-0328
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may target the physical tag, the communication channel between the tag and the reader, or the application or the system which employs the RFID technology. (Khattab)

Garfinkel provides an excellent graphic that illustrates the potential areas of security concern. The labels in white illustrate threats to corporate data security, while labels in yellow represent threats to personal privacy.

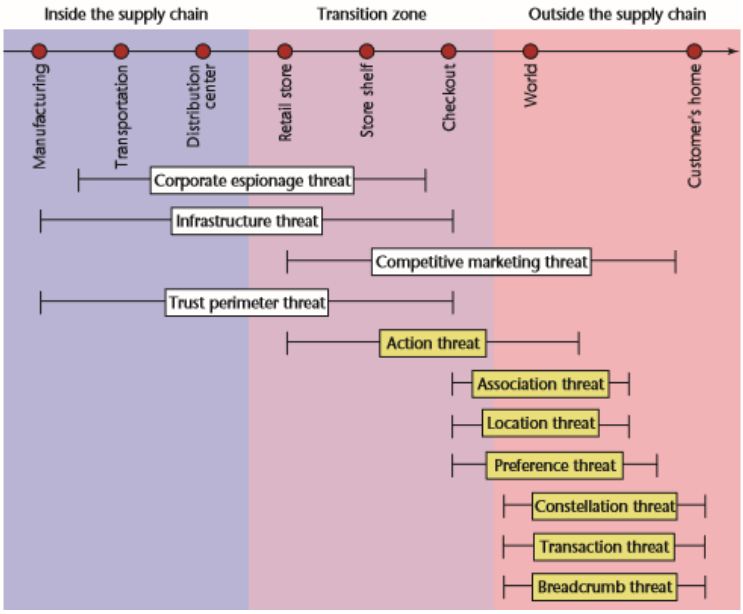

Figure 4 Illustration of potential areas of security concern [Garfinkel]

To understand Figure 4further, the inside the supply chain column refers to where tagged objects are manufactured, transportation systems, and retail store stock room. The transition zone refers to where tagged items change hands from the vendor to the customer, while the outside the supply chain zone refers to all locations up to and including the customer's homes that are not a part of the supply chain. The threats to corporate data security include espionage threat, infrastructure threat, competitive marketing threat and trust perimeter threat. The espionage threat could include a scenario where a competitor could place orders from multiple store locations to learn the dynamics of how the stock is replenished. The competitive marketing threat could potentially allow competitors to gain unauthorized access to customer preferences, while the infrastructure and trust perimeter threats could allow for the breach of data storage systems.

Personal privacy threats include action, association, location, preference, constellation, transaction, and breadcrumb threats. Action and association threats pertain to the monitoring of the action of a group of tags and associating a customer's identity from a tagged item. Location and preference threats pertain to unauthorized readers being placed at different sites to collect information while identifying customer preferences. Constellation, transaction, and breadcrumb threats refer to being able to track people without knowing their identity, while building an item database about the items that a customer has purchased.

B.POTENTIAL SOLUTIONS TO PRIVACY CONCERNS

There are a number of options to help protect the privacy of RFID tags against possible attacks. Killing tags, sleeping tags, and blocker tags are all viable options. Killing tags relates to the deactivation of a tag after an item has been purchased by a customer. The downside to this method is that the lifespan of the tag is limited and it cannot be utilized after deactivation.

Sleeping tags refer to the reader sending a command and password to the tag to make it temporarily inactive. This method allows the tag to be active again as soon as it receives another command from the reader. Blocker tags are

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
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able to block readers from identifying tags that exist within the blocker tag's range. The blocker tag intends to confuse the reader in to believing that there are many tags in the vicinity. The drawback to this method is that blocker tags may not be applicable to some industries that need to have frequent communication with authorized readers. (Khattab)

There are many environments, however, in which simple measures like use of kill or sleep commands are unworkable or undesirable for privacy enforcement. Consumers may wish RFID tags in their possession to remain active or may simply find it inconvenient to manage their wake/sleep patterns. Businesses may have concerns about unauthorized monitoring of tags before they are killed. (Juels) One of the non-physical technologies to help provide security and privacy to RFID technology is cryptography. Cryptography is based on algorithms between tags and readers, and while standard cryptosystems provide a more secure option than the physical solutions mentioned previously, they also require more resources than what is available to many tags. While cryptography technology is continually being developed to make RFID tags more secure, we likely will not see them on the majority of future tags until the costs associated to implement the technology are brought down.

Figure 4 shows that there are a few scenarios that exist where the privacy and security of RFID technology can be compromised. There are options to help overcome some of these issues, including blocker tags that confuse a reader into thinking that there are many tags in the vicinity, kill switches that allow for the deactivation of the tag, tag and passwords that would enable the tag to send out information only if it receives the right password form the reader. As the technology continues to grow and become more scrutinized, companies and individuals will need to be more conscientious about decisions that they make in regard to RFID security and privacy. As more industries adopt RFID technology into their operations, the demand for secure systems will continue to grow as well.

C. STANDARDIZATION

RFID technology has multiple standards as most are specific to a given application. The two main international RFID standards bodies are the International Standards Organization and Electronics Product Code Global Incorporated. Standards are important because they establish the quality, safety, compatibility, reliability, productivity, and efficiency levels of the products. By the use of standards, trade among different industries and countries is possible. (Aguirre) Although regulations in each country can dictate transmission power levels, transmission channels, frequency use, and type approval, Electronics Product Code Global Incorporated is focused on creating a worldwide standard for RFID.

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CLASS 0	***Read Only* Tags** • Read - Only Memory • Passive Tags (Passive Tags do not use batteries)
CLASS 1	***Identity* Tags** • Read - Only Memory • Passive Tags (Passive Tags do not use batteries)
CLASS 2	***Higher Functionality* Tags** • Read & Write Memory (up to 65 KB)
CLASS 3	***Semi - Passive* Tags** • Read & Write Memory (up to 65 KB) • Built-in battery to Support Increased Read Range
CLASS 4	***Active* Tags** • Allows Active Communication • Built-in battery to Support Increased Read Range • Allows Tags to be Networked with Each Other
CLASS 5	***Active RFID* Tags** • Allows communication with **Class 4** & **5** tags and/or other devices

Figure 5 Tab Classes [Smiley]

Smiley also shows the differences between EPC classes and ISO codes, see Figure 5. While there are many ISO standards that cover different areas of RFID technology such as ISO 15693 for vicinity cards, and ISO 14443 for proximity systems, the ISO 18000 series covers general frequency bands as detailed in Figure 6.

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STANDARD CODE	DESCRIPTION
ISO 18000-V1	Generic parameter for air interfaces globally accepted frequencies
ISO 18000-V2	Air Interface 135 KHz
ISO 18000-V3	Air Interface 13.56 MHz
ISO 18000-V4	Air Interface 2.45 GHz
ISO 18000-V5	Air Interface 5.8 GHz
ISO 18000-V6 Part A, B, C, D	Air Interface 860 MHz – 960 MHz
ISO 18000-V7	Air Interface 433.92 MHz

Figure 6 ISO 1800 Standards [Smiley]

D. CHIP-LESS RFID TECHNOLOGY

Chip-less RFID technology allows for many additional uses than tags with electronic circuitry, as they are able to work over a wider temperature range and are less sensitive to radio frequency interference. The research will further explore the functionality of these systems, what industries the technology may be best suited for, and the development and deployment of the technology.

As Perret explains, chip-less tags most often offer mechanical and thermal reliabilities superior to chipped tags and require a lower power transmitted by the reader to capture information. Chip-less tags are generally lower priced and smaller compared to chipped tags, however, they generally have a lower data capacity. In addition to cost, another advantage of chip-less RFID is its sensing capability. Since the information is encoded and detected at a physical layer level, any factor that can alter the signal like coupling to adjacent materials or changes in the near environment of the tag can be detected by the reader. (Martinez) Since chip-less tags do not have a power source and silicone microchip, the cost is less expensive to manufacture than a chipped tag. This is very appealing to companies, as the cost of RFID technology is certainly one of the main concerns about its widespread implementation as was discussed earlier in this paper.

Like various existing RFID technologies, chip-less RFID tags are associated with a specific radio frequency reader, which questions the tag and recovers the information contained in it. However, chip-less tags are fundamentally different from RFID tags as they function without a communication protocol. Standard RFID tags work by the reader sending a signal toward the tag, the tag processing the request for information, and sends back a response. Chip-less RFID tags can be viewed as radar targets possessing a specific, stationary temporal or frequential signature. With this technology, the remote reading of an identifier consists of analyzing the radar signature of the tag. (Perret) Figure 7 illustrates a basic chip-less RFID system.

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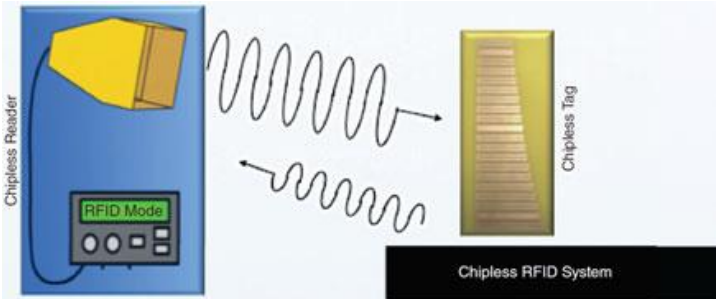

Figure 7 A basic chip-less RFID system [Forouzandeh]

The two main approaches to chip-less RFID at a system level are time domain-based approach and frequency domain-based approach. The first approach relies on time domain reflectometry. A short pulse with a wideband spectral content is transmitted by the reader, and the reflection of this pulse created by the chip-less tag is detected by the receiver. An advantage of this approach is longer reading ranges are achieved, but at a cost of lower bit coding capacity. The second approach is a frequency domain approach. In this approach, a single frequency signal is swept through the bandwidth of interest and the reflection produced by the tag is coherently detected by the receiver. (Martinez)

One of the main developments of chip-less RFID technology is the ability to print tags. Developing printable chip-less RFID tags is a very intriguing subject, as it would drive down the costs associated with the normal tag manufacturing process. With the innovative printing technologies that are now available, the ability to print electronics is becoming a viable option.

One of the companies leading the way in printable RFID tags is Zebra Technologies Corporation. Zebra introduced the first integrated, on-demand RFID smart label printer/encoder in 2001 and has continually worked on advancing the technology since. According to Zebra, printable RFID tags contain a low-power integrated circuit attached to an antenna and are enclosed with a protective material as determined by the application. Smart label printers use media that contains an RFID inlay embedded within the label material.

The ability for companies to utilize chip-less RFID technology at a fraction of the cost of standard RFID technology opens up the possibilities that RFID could be even more largely implemented in the future as technologies continue to evolve. As printing technology improves, it will inevitably lead to more companies being able to print and employ RFID technology more efficiently. As companies such as Zebra Technologies continue to research and manufacture printing solutions, the chip-less segment of RFID technology is an exciting area that has the potential to grow exponentially within the coming years.

V. CONCLUSION

The intention for this research was to understand RFID technologybetter, from its inception to future advancements that have the potential to have an impact across many different industries. In addition, the real-world case studies of companies that have adopted RFID technology in their operations helped to provide more clarity on how this technology has had an impact on their business. While gaining a better understanding for these subjects, new subjects emerged such as security and privacy that proved to require more in-depth analysis. Although RFID technology is not a new concept, it is poised to expand greatly in the coming years across many industries.

The future growth of RFID will partially depend on how much companies are willing to invest in the technology. The research indicated that price point is a significant factor when companies decide to utilize the technology in their business. As RFID technology continues to become most cost effective for solving real-world business challenges, more companies will become more apt to integrate the technology into their operations. It is likely that costs and privacy will continue to be monitored, but as some of the world's best-known companies across a variety of industries continue to invest in RFID technology, it is apparent that the technology will continue to be a focal point in the years to come.

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 6, Issue 8 , August 2019

The research concludes that RFID technology is here to stay, and that exciting new developments will be available for widespread use in the not so distant future. Ideally, we will likely see a printable chip-less RFID tag available that only costs a few cents to produce, is small in stature, has a wide read range, contains high data capacity and is resistant to conditions such as noise and temperature. The research shows that chip-less RFID technology is poised for widespread use and will have a substantial impact in the near future.

As RFID technology not only has the potential to impact business, but the daily way of life for millions of people around the world, continued efforts will have to be made in the areas of security and privacy. For consumers RFID technology will continue to increase in everyday lives for thigs such as refrigerators recognizing expiration dates on tagged items, and laundry machines having the ability to recognize the best way to wash a load of tagged items. In order for this to happen consumers will need to feel secure and confident about the personal information that RFID technology is able to gather and utilize.

This research allows for follow-up data collection such as checking in on how current RFID technology is being utilized in the present day, what companies in certain industries are integrating the technology into their business, and what new developments in RFID technology will have the largest impact in its future, as well as security and privacy concerns for everyday consumer usage. The research has greatly expanded my knowledge and understanding of RFID technology and will have a lasting effect on my professional and personal experiences moving forward. I look forward to continuing to learn about RFID technology as it constantly evolves and new developments are discovered and implemented.

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