國立交通大學

科技管理研究所

碩 士 論 文

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一、 RFID Applications and Challenges

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中 華 民 國 九 十 七 年 六 月

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A Thesis
Submitted to Institute of Management of Technology
College of Management
National Chiao Tung University
in partial Fulfillment of the Requirements
for the Degree of
Master of Business Administration
in
Management of Technology

June 2009

Hsinchu, Taiwan, Republic of China

中華民國九十七年六月

FID Applications and Challenges

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Abstract

Since human civilization has stepped in the era of electrical and electronic devices, the pace and magnitude of technological breakthrough has been unprecedented, over any past time period. Ironically, the need and expectations of the society have been a step ahead. At any particular time, there exist few technical fronts where the above two factors exist in equilibrium. Further, the equilibrium is short lived.

RFID stands for Radio Frequency IDentification, it is a technical breakthrough in the challenging field of providing unique identity to a person or thing and being able to monitor it or them. What sets it apart from numerous other short lived breakthroughs is that despite being around for decades, its ramifications with modern technologies are capable of meeting the enormous demand, relevant to its scope, which again is constantly touching new horizons. Despite being such a versatile technology and being adopted by industry giants like Wal-Mart, the technology is still under skepticism in larger proportion.

This literature review paper explores the obstacles or the challenges that prevent the global adoption of this unique and exemplary technology. The challenges are made special by the fact that there are very few technologies that exist in the equilibrium like RFID, and hence are not available for study at all the times. Further they are unique to each technology.

This paper starts with an insight into the history of RFID. Then a concise section on the topic that commands numerous books and research papers to itself, the components of RFID and how they integrate into this technological marvel. The numerous uses of RFID are hard to fit in any paper. Thus we carefully select the areas, relevant to a broader audience, and give a comprehensive account of how RFID has been instrumental in these areas. Next comes the challenges in RFID adoption. The paper presents challenges ranging in duration from the inception of RFID, to the contemporary ones originating from the small material component changes in present day RFID. The paper concludes by giving a brief outline of present scenario and recommendations derived after balancing the challenges against the present and potential scope of RFID technology.

Foreword

This thesis paper is part of my required studies for the completion of my Master of Business Administration in Technology Management at National Chiao Tung University in Taiwan. I chose this topic, as it is a product that has the ability to truly revolutionize the way we conduct our every day lives. I wanted to learn why this amazing technology has been slow to take hold because at first look one would imagine a quick and sweeping integration into society, yet this has not been the case.

I am truly grateful to my thesis advisor Professor Yu and all of the other professors and staff I have come to know here at National Chiao Tung University. Their patience and teachings have been remarkable. The experience has been one that I will never forget and I will always be grateful.

Jeffrey W. Hill

Hsinchu, Taiwan, June 12th, 2009

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1. Introduction

1.1. Overview

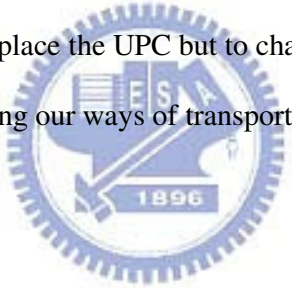
Radio Frequency Identification (RFID) is a new generic technology that refers to the use of radio waves to identify objects (Technology Guide, 2002). It is essentially a wireless transmitter similar in size to a grain of salt. Once this chip is attached to an object, the small radio can send information specifically about that object to a small antenna and then on to a computer network (McGinity, 2004). The chip is powered by the antenna sending out the transmission.

Any technology can be judged by its impact on the present set-up. In that regard RFID fares extremely well. RFID has taken industry by storm. It already has been accepted as a viable alternative to the established and widespread UPC (Universal Product Code), like the bar codes printed on the back of books. This acceptance comes from a number of industries. Its fast growth and huge potential benefits have made it a buzzword in the retail industry with companies trying to upgrade their manufacturing style so that the inclusion of RFID is possible. Leading the charge is Wal-Mart, the world's largest retailer that has shown how off shoring can be made easily manageable through RFID technology. The US Department of Defense (DoD), mandated that their suppliers supply their products with an RFID tag on each individual piece of equipment that is ordered (Office of the Deputy Under Secretary of Defense, n.d.).

Several major computer companies, including Intel, HP, IBM, and Sun, have announced their efforts and future plans to support RFID. The usage of RFID is slowly becoming widespread

ranging from tagging animals and products to use by space satellites to track firefighters and ambulance vehicles back on the planet.

CNN included RFID as one of the "Ten Technologies to Watch" in 2004 (CNN, 2004). ZDNet called RFID one of the ten strategic technologies for 2005 (ZDNet, 2004). The American Institute of Certified Public Accountants (AICPA) announced RFID as one of top 10 major emerging technologies impacting the accountant industry in 2004 (AICPA, 2004) and said that RFID in the near future is 'certain to affect businesses and individuals'. With the recent introduction of the new EPC Gen 2 tag the RFID industry seems poised grow as the overwhelming demand for the chip showed at the time of launch. This paper will show that despite great challenges, RFID is beginning to take hold in the global market and is making great strides to not only replace the UPC but to change delivery and tracking methods of products and people and changing our ways of transportation and even payment in many spectrums of the world.



1.2. History

Harry Stockman first identified RFID technology, in his 1948 paper "Communication by Means of Reflected Power". In his paper he recognized that devices that emit and read radio frequencies could one day communicate with one another and in turn be a mechanism for sophisticated information gathering and exchange. Although Stockman's idea made sense it took several years and many technological advancements before his vision could be realized.

RFID technology is derived from World War II era techniques. The techniques were based on the assumption that aircraft were allowed to identify themselves to other friendly aircraft and commanders on the ground. Before the invention of the transistor and the evolution of

microelectronics, this technology was large, heavy, and consumed exorbitantly high amounts of power.

In the 1970s, Sandia National Laboratories in the United States began incubating commercial applications. From there it went on to launch several businesses. One of them was the Amtech Corporation. Amtech was a pioneer in the field of commercialized animal tagging, and the motor vehicle account tag used on some toll roads beginning in the 1980s. At about the same time, industrial applications in manufacturing automation, warehouse automation, and asset tracking were starting to being deployed.

In the 1992 to 1994 timeframe, the North American rail industry deployed the Amtech technology for tracking rail equipment, tagging over 30,000 locomotives and 1.2 million rail cars and deploying reader devices at key control points along the railroad right-of-way.

From 1998 through 2003, leadership of retail initiatives had been centered at the Massachusetts Institute of Technology (MIT) where in 1999 the Auto-ID Laboratory Center was established. In late 2003, the Auto-ID Laboratory Center at MIT officially closed and transferred its intellectual property to EPCglobal.

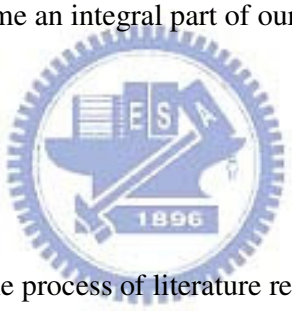
Present day applications of RFID according to one of the world's foremost authorities on the subject and one of the founders of Amtech, Dr. Jeremy Landt, include "preventing theft of automobiles, collecting tolls without stopping, managing traffic, gaining entrance to buildings, controlling access of vehicles to gated communities, automated parking, corporate campuses and airports, dispensing goods, tracking library books, providing ski lift access, buying

hamburgers, and the growing opportunity to track assets in supply chain management." (Landt , 2001).

1.3. Research Methodology

1.3.1. Purpose

The purpose of this paper was to show that despite great challenges and skepticism RFID is beginning to take hold in the global market and is making great strides to not only replace the Universal Product Code (UPC) but to change delivery, tracking and transportation methods in many spectrums of the world. This paper will show that despite these challenges and skepticisms, RFID has truly made great strides in the last few years to overcome these challenges and is truly set to become an integral part of our everyday lives in the very near future.



1.3.2. Design

This paper was conducted using the process of literature review. Research included books, journals, research papers, technology magazines, business magazines, literature from the U.S. Department of Defense, other government web sites, various company web sites and other sources. All efforts were made to get as accurate an account of the current RFID market as possible.

1.3.3. Limitations

In the RFID market there are virtually unlimited applications. An effort was made to look at the most widely used applications globally. Nonetheless, some areas of RFID usage will be left out. It would be impossible to fit all of the applications that RFID is and can be used for into one paper. There was also a limit on current information. While this paper tried to be as

accurate as possible there will be continuous updates and debates as to the technology, its applications, usage, etc. As this is a new immerging technology it is ever evolving and while an effort to obtain the most up to date information was made, it is possible that there is more current information could come to light during the writing of this paper.

2. Literature Research

The literature review section of this paper will analyze some of the findings that other researchers have found while investigating RFID applications. RFID has proven itself to be able to streamline the business process and enable companies to be able to see their assets in real time yet the Warehousing Education and Research Council (2006) found that even with the many positive aspects of RFID most companies continue to implement RFID based on compliance rather than based on ROI.

2.1. Supply Chain and Inventory Control

It has been found that manufacturers and retailers both stand to gain substantially from the benefits of RFID to better maintain their inventory. Much lower inventory levels can be maintained due to the fact that RFID can provide a precise, real-time inventory count at all times. Having this information has also led to out of stock problems to reduce significantly and manufacturers of time sensitive goods such as perishables will know exactly when certain components of their stock are reaching expiration or spoilage dates. Fewer employees are also needed to control, monitor, and process inventory and theft prevention is improved (Kelly and Erickson, 2005).

A paper written by Wamba, Lefebvre, Bendavid (2007), noted many companies that are using RFID to enhance their supply chain and inventory control, one such company is Scottish Courage, a British beverage firm. It is using RFID to track its 2 million kegs throughout the supply chain. As a result the company has eliminated shrinkage, reduced cycle times and improved delivery for outgoing and incoming stock. They also found Marks and Spencer had been seeing significant advantages in RFID by tracking reusable trays and dollies leading to

an 80% reduction in the time taken to read a stack of trays and increasing data accuracy and reliability.

A paper written by Rebecca Angeles (2005) reviewed RFID supply chain applications and implementation issues. In her paper she found information to support the business case for the adoption of RFID based on her research of trade literature. She stated that the technology promised to offer both process freedoms and near perfect information visibility throughout the supply chain across many different industries.

Yet even with the many positive aspects of RFID many companies continue to implement RFID based on compliance rather than based on ROI (Warehousing Education and Research Council, 2006). In a recent study by Vijayaraman (2008) it was found that 24% of the 174 companies surveyed in Europe and the U.S. thought they would never implement RFID technology in their organization for use in their internal supply chain or for integrating with their packaging materials. Lack of customer demand was the most important reason for these companies for not considering RFID implementation. Lack of standards, cost, lack of foreseeable benefits, and lack of understanding were other reasons for not considering RFID technology. The major concerns found for the companies with respect to implementing new RFID technology were cost related, including the cost of implementation, the cost of tags, and the cost of automated label applicators as noted by Vijayaraman, (2008).

2.2. Costs

One of the most major constraints on the growth of RFID are costs. Roberts (2006) states that passive tags with some data storage currently cost between 5 and 10 cents each when purchased in large quantities. High value items such as cartons and pallets are being tagged

with much more expensive tags costing up to $100 each. He claims that at current prices it is not economically viable to incorporate tags into every retail item. Walker (2004) notes that many applications such as RFID-enabled warehouses require specialized hardware such as RFID enabled fork-lifts, conveyor belts, inventory wands and sorting machines that add to the total cost making the price too much for many companies. In May of 2004 AMR Research conducted its Risk Assessment Profile which Evaluates RFID Implementation Risk for Consumer Product Manufacturers. The research found that a conservative cost estimate for RFID implementation for a typical consumer packaged goods manufacturer would be around $13 to $23 million for shipping 50 million cases per year.

A secondary problem is that even with the cheap tags now becoming available at the five cent level, these prices are only available in massive quantities. SmartCode, an Israeli RFID systems provider, offers its customers Gen 2 Electronic Product Code (EPC) RFID inlays for 5 cents each but only in volumes of 100 million or more (Roberti, 2006). Avery Dennison corporation is offering inlays for 7.9 cents in volumes of 1 million or more.

A study conducted in 2008 by Bottani and Rizzi found that using an investment analysis that the introduction of RFID at the pallet tagging level provided positive net present value for all types examined. They found manufacturer's distribution centers (DCs) in particular had the greatest benefits. They found the case level tagging scenarios sometimes had the opposite affect.

Fish and Forrest (2007) found that in the United States the average retailer spends more than $500,000 on RFID hardware and software, including chips, inserts, printers, tags, antennae, readers, data aggregations and filtering systems, middleware, and directory services. Webster

(2008) estimates that smaller companies will have to invest $100,000 to $300,000, while the price tag for a large manufacturer could hit $20 million.

When asked about the time it takes to implement RFID, companies that have started or bagan to test pilot RFID have stated it takes anywhere from 3 months to 6 months (Vijayaraman, 2008) adding to the cost of implementation. Forrester Research believes that optimizing processes, analyzing data, and training workers would cost companies more than the purchase of RFID technology (Walker, 2004). “Firms will incur costs from conversion (including consultants), reallocation of staff, additional hiring, and maintenance contracts” (Smart, 2004).

Wamba (2007) sees RFID as having long term financial benefits. They find that RFID continues to show the promise as an integration tool to aid collaboration with others in the supply chain in an effort to reduce costs throughout the network. Wal-Mart has come forward stating that the changeover offers the retailer major benefits. They estimated that the introduction of RFID technology to their supply chain will save the company up to $8.35 billion annually as well quickly providing important product information.

A recent survey found that high cost remains the primary roadblock to greater RFID implementation in health care (Blair, 2007) yet others are claiming the opposite. The UMass Memorial Medical Center in the United States has lab's stents and balloons that can cost up to $3,000 each. Each of its pacemakers are worth up to $30,000. This is why the center has adopted RFID. Kim Carter, a top administrator at the center, said that their RFID system has helped her bring consigned and paid stock (cash tied up in inventory) down to $100,000,

from about $400,000. As the amount of surplus equipment they need is now much less (Baard, 2008).

While buying RFID chips in large quantities will lead to a reduction in prices researchers at the Georgia Institute of Technology this week announced the development of what they call an "RFID testbed," which allows for the testing of new tag prototypes much more cheaply and effectively than existing tag design processes, therefore allowing companies using the process to spend significantly less on research and development with an end result of lower chip prices (RFID Update, 2008). The system is a chip emulator, which is a piece of hardware that emulates the signals of an RFID tag chip. “An antenna design is attached to the emulator, then stimulated by an RFID reader to generate a signal. That signal, which is the same signal that a real RFID tag with that antenna design would generate, is measured and analyzed, including how it reacts to the physical environment. That process is then repeated for any number of antenna designs, as engineers improve and iterate them in pursuit of a final product.” The process currently used is very costly as prototypes need to be produced by a semiconductor manufacturer for testing.

Gregory Durgin, assistant professor at George Tech's school of electrical and computer engineering says “with our testbed, you don't have to spend $30,000 or $100,000 every time you want to test a new type of signaling protocol."

2.3. Health Care

Health Care has already begun to show the benefits of RFID notes Correa, Gil, and Redin (2005), at Jacobi Medical Center in New York the RFID enabled patient ID system not only enhances patient care and staff working conditions but also saves the center one million US

dollars a year. Lucile Packard Children's Hospital in the US has been using RFID to track new patients to ensure they do not get moved to the wrong location.

Pfizer drug company has also been testing RFID to ensure that consumers get the correct drugs and that counterfeit drugs are not obtained by the patient. Parts used in surgery have also benefited from RFID. When parts in a surgery kit are cleaned and sterilized a label is not suitable, but by embedding an RFID device into the tool itself it can confirm whether all the tools in the surgery kit have been cleaned and sterilized properly or not.

The tracking of equipment in the hospital itself has been showing great returns as less equipment needs to be purchased as now equipment can be immediately found. Massachusetts General Hospital in Boston has been looking at RFID as a way to make sure blood slated for transfusion gets to the proper patient. They have found that the risk of transfusion of blood to the wrong patient is more than 100 times greater than the risk of transmitting an infectious disease through a blood transfusion (Bednarz, 2004). Medical errors in hospitals have become a leading cause of death, killing more people each year than AIDS globally. "These medical errors can be classified as poor-decision making, poor communication, inadequate patient monitoring, patient misidentification, inability to respond rapidly and poor patient tracking" (Chao, Jen, Chi, Lin, 2007)

While many benefits have started to be shown in the health care industry, analysis still have many reservations. Chowdhury, B., Chowdhury, M. and D'Souza, (2008) stated in their research that an intruder with unauthorized readers can intercept the communication between the patient tags and RFID readers and can access sensitive patient information such as patient ID, name, drug allergies, etc.

Unauthorized readers are susceptible to gaining access to this information and it is therefore subject to misuse by hackers and criminals. Further, with respect to read and write (reprogrammable) tags, unauthorized alteration of patient data is possible in the hospital information system which could lead to detrimental effects (Chowdhury, B. and D'Souza, 2008). A serious concern related to the Pfizer trial is that once consumers have purchased items from a pharmacy they do not want themselves or the purchased items to be tracked after passing the checkout (Michael and McCathie, 2005).

Frequency and serialization is also a significant issue in healthcare RFID enabled healthcare. Healthcare providers such as hospitals are very concerned as to which tag frequencies to use and where. With the serialization issue, they are concerned about what to include in a patient tag's serial number. Some want the tag serial number to contain intelligence such as patient information; others do not want the tag intelligence information, rather a random serial number (Chowdhury, B. and D'Souza, 2008).

2.4. Retail and Manufacturing

A paper titled "A comparative Analysis of RFID Adoption in Retail and Manufacturing Sectors" published in 2008 found that the potential benefits for retail and manufacturing did not differ statistically but both saw improved operational efficiency and improved visibility throughout. It was found on the manufacturing side that operational efficiency and visibility were the most important while in retail improved inventory management and security were the key issues. The study noted that the growth in retail was exceeding that of manufacturing due to the fact that the scope of use was more widely known, whereas in manufacturing there was a belief that the product could not be as beneficial (Bhattacharya, Chu, Mullen, 2008).

Kelly and Erickson (2005) found that manufacturing will gain from RFID by better inventory control as manufacturers will now be able to track the production process from start to finish. Raw materials and supplies tracking are facilitated and goods in process will are readily identifiable along with backlogs in congestion in various parts of the manufacturing process.

Wells Dairy in the United States found 18 months into their RFID use that, they had enabled the company to both comply with Wal-Mart's RFID mandate and position Wells' Dairy to take advantage of the information gathered by RFID. Improvements included "increased quality control, information gathering, safety and productivity for induction of products into storage. Additionally, the solution has freed up personnel, helped increase accuracy of freezer counts, decreased the number of misshipped pallets and minimized the need for manual reconciliation"(FoodProcessing.com, n.d.).

In a 2005 paper it was said that the use of RFID will demand more flexible processing systems irrespective of whether the packaging is done at the production facility or at a co-packer. This will have a direct impact on the operational efficiency and profitability of the packaging company (Mahna, 2005). For instance, if packaging suppliers were to consider adding tags to their boxes and displays, each tag would have to be individually identified and placed according to a specific product packaging level (Mahna 2005).

In 2005 Jones, Hill, Hillier, and Comfort reviewed the RFID market for retailers in the United Kingdom. Their research found that some retailers did not perceive that the return on investment was significant enough and that the money could be better used in other areas, they cited Woolworth's as one example as a company that had tried RFID and decided to

shelve the application for the time being. Cost of tags were named as the primary deterrent to the usage of the technology. Companies operating on low margins did not see any potential benefit to the new technology. A secondary problem was the lack of international RFID standards for the usage of the tags. Lastly companies cited the cost and process of having to update their current infrastructure to accommodate all the new information as a deterrent.

By adopting RFID technology Wal-mart has assessed it stands to achieve an annual savings of $600 million in out of stock supply chain reductions, $300 million in improved tracking through warehousing and distribution centers, and $180 million in reduced inventory holding and carrying costs (Asif and Mandviwalla, 2005).

2.5. Standard

According to Whitaker, Mithas, & Krishnan (2007), the lack of RFID standards leads to a delay in realizing a return on investment of RFID technology. While standardization of information formats placed on the RFID consumables goods has garnered wide support with the Electronic Product Code (EPC) in the retailing industry; standards dealing with RFID frequency and protocols for the communication of readers and consumables such as tags and labels are continuously evolving. Vijayaraman (2008) found that that the lack of a truly establish global standard is one of the major concerns for companies looking to implement RFID.

Jakovljevic, (2004) stated that a necessary condition for widespread adoption of RFID is the availability of pervasive standards. He warns that early adopters of RFID will be wary of locking into the wrong standards, which could lead to a potentially costly mistake both in terms of time and money. He goes on to say that contemporary supply chains are global and a

consensus on international standards on frequencies is needed. Without such consensus it will be hard for an item using a specific country standard to traverse international supply chains.

In what could be a blow to global standards Madam Zhang Qi, State Council Golden Card National Leader, Chairperson of the Chamber of China Information Industry and Secretary General of the Department of Information Product, Ministry of Information Industry(MII), commented, "China should be big enough to develop and deploy its own standards." Signaling that China may not be willing to follow global standards set by the rest of the world.

In a recent report done on hospitals the lack of standard is cited as an obstacle. "Lack of standards is a major obstacle for the deployment and support for widespread use of RFID system in hospitals. Currently there is no consistent or common standard for the air interface for healthcare industry. Item-level tagging is also necessary for most of the hospital equipment or asset management processes where the payoff occurs. Without clear RFID standards and data ownership policies, investment of RFID system in healthcare has been a difficult task" (Chowdhury, B. and D'Souza, 2008).

As of July 11, 2006 the Gen 2 protocol for passive UHF RFID witnessed the convergence of EPCglobal and International Organization for Standardization (ISO) standards for the first time," says Frost & Sullivan Industry Analyst Priyanka Gouthaman. "Therefore, global acceptance of the Gen 2 standard will encourage end-user confidence and investments in the passive UHF tags market" (Frost and Sullivan, 2007).

The EPC global Gen 2 protocol overcomes the many limitations of EPC global's legacy Class 0 and Class 1 solutions. Seeing the rate at which its popularity and usage is increasing, it can

be said that it is destined to quickly become the leading RFID specification for the UHF band centered around 900 MHz (860 MHz to 960 MHz). For most products this will overcome previous standards barriers, as the new Gen 2 standard works in all countries therefore can be used across the supply chain (O'Connor, 2006).

2.6. Consumers and Privacy

The paper "RFID and the perception of control: the consumer's view" published in 2005 found that consumers feared losing privacy due to the introduction of RFID technology. Even when all of the potential advantages such as enhanced service were well understood the fear overrode nearly all of the perceived benefits. The paper concluded that retailers will have a difficult time addressing these fears with consumers and encouraged more open dialogue about the advantages and disadvantages of the technology with rights groups (Gunther and Spiekermann, 2005). RFID tags contain limited computational resources. Therefore it is a challenge to design adequate cryptographic algorithms for data security (Sarma, Weis, 2002).

Artafact LLC and BIGresearch recently found out that more than 60% of consumers who heard of RFID are very or somewhat concerned about the issues of privacy. The study was based on data collected from over 8000 consumers (Stegeman, 2004).

Ohkubo, Suzuki and Kinoshita found that while RFID tags have the ability to revolutionize society a close examination of personal privacy from both the technical and social aspects must be done. They found that the privacy concerns raised are serious enough to demand a research on comprehensive and effective technique to provide a solution (Ohkubo, Suzuki and Kinoshita, 2003).

Quirchmayr and Wills (2007) concluded that RFID while doubtlessly having many potential benefits still has many problems when it comes to the issue of privacy. They found that new legislation is needed to develop a modern legal framework that is able to cope with the new technologicval developments that will be essential for ensuring growth. They noted that as with all new technologies there will be abuse until legislation can be adopted to control it.

A paper by Spiekermann and Berthold (2005) drew the conclusion that a "disable model" of RFID tag could be implemented to alleviate consumer fears. This could be made mandatory through legislation. They note that RFID is not going to go away, so actions must be taken to ensure privacy protection. An RFID that is disabled upon purchase of an item or after a specific time period cold work to alleviate some consumer fears.

Some feel that the entire privacy issue is being overblown. Jay Cline (2004) of Computer World Security says that "RFID signals are so weak that they're easily blocked by metals and dense liquids. It's infeasible today for someone driving a vehicle down your street to intercept signals from RFID-tagged goods inside your home." This opinion is agreed upon by Evan Schuman of eWeek.com (2004). He says its is all just overblown fear mongering but nonetheless and that "the reality is that RFID does not pose any true privacy threat" but that "if your customers all believe that it does, you must treat their fears with respect."

2.7. Data Collection

Radio Frequency Data Collection (RFDC) is used to communicate information from a mobile location to a host computer in real-time. RF terminals provide a wireless data entry and

display with an RF base station which is connected to a host computer. RFDC provides an accurate, real-time system by allowing the host computer to interactively verify and update data. In addition, it eliminates paperwork, increases customer service, and reduces space requirements. RFDC can substantially improve an operation's efficiency. In the past these systems have been out of the price range for most small to medium size businesses. Recent advances in RFDC technology have started to produce innovative products reducing prices so that smaller companies can begin afford these type of products (OmegaOnline, 2009). Michael (2005) says that "RFID systems uniquely identify every product in real-time across the supply chain to increase efficiency in areas like retail, hospitals, farming, and public transport. They connect suppliers, manufacturers, distributors, retailers and customers and allow them to exchange product and trading partner data." As a result companies can make substantial annual cost savings by reducing inventory levels and lowering distribution and handling costs, increasing security and product integrity, and improving flexibility by the data they gather from these processes.

Some however do not see these new streams of data to be an easy tool to integrate into an existing company's infrastructure. The paper "RFID After Compliance" (2005) says controlling and manipulating the information received from RFID systems, then using it within your enterprise and sharing it with your suppliers is difficult. The amount of data collected with RFID systems may be staggering compared to what is currently collected. Many established information systems are not yet prepared to efficiently accept RFID data. A paper by Jones, Clark-Hill, Shears, Comfort, and Hillier (2004) says "the challenge of RFID implementation comes from integrating RFID systems and the data they generate with other functional databases and applications" A survey by Cap Gemini Ernst & Young of 275

respondents working in the packaging industry revealed that 46 percent of the respondents consider integration as the single biggest concern with RFID (Ferguson, 2004).

2.8. Material Effects

Research conducted in 2008 found that when a metal or liquid item is tagged with RFID, the RF waves are refracted or reflected causing the item to sometimes pass by unread (Moon and Ngai, 2008). Thiesse and Michahelles (2006) also found liquids and metals to be obstacles in the mass deployment of RFID operating at UHF frequencies. They found when on or near these metals and liquids read rates were low. I was shown that at UHF frequencies organic materials absorb the power radiated by the reader, while metallic objects reflect the incident electromagnetic wave leading to a failure to power a tag and therefore a failed detection.

"The presence of products or packaging containing metal components block the RFID signal, or conveyor belts made up of static producing nylon, or glass fiber that produce radio noise may necessitate expensive changes in the physical infrastructure, increasing costs of RFID infrastructure due to the fact that (Margulius, 2004).

Chowdhury, Chowdhury, D'Souza, (2008) had similar findings. They noted that supply chain management is an area of operations that is usually filled with metal, liquid and other harsh environments. They found that the metal objects and other RFID tags that generate electromagnetic energy disrupt the RFID signal and make it challenging for many businesses to tag and track with their RFID enabled system. The RFID tag is also affected by objects surrounding it especially metallic containers/objects. It has been observed that the presence of metal and/water in the RFID tag vicinity causes a failed tag read. As radio waves bounce off metal and are absorbed by water at UHF it distorts the magnetic flux, thus weakening the

energy going to the tag. The same problems were found in healthcare management systems that are found normally teeming with metal, liquid and harsh environments (Banks, 2007).

Some solutions have been forthcoming. While not cheap, they are a solution. In June of 2006 ADASA, Inc., a leading technology company from the U.S. announced the availability of its "Foam Attached Tag" for businesses interested in attaching Gen 2 RFID tags to metal parts and liquid containers in their supply chains. Their new tag gave a convenient and reliable solution for any business wanting to use RFID technology on metals and liquid containers (ADASA Offers Metal Mount RFID Tags, 2006).

In 2008, the leading RFID products producer in China, Daily RFID announced it had developed the HF Metal Tag-08 RFID tag for use in metallic environments (PRLog, 2008).

Another company with a similar solution were GAO Tek Inc. which started offering a series of on-metal Gen 2 RFID Tags in October of 2008. The on-metal RFID tags were developed to withstand harsh environments, providing dependable transmission of data in demanding industry conditions such as changing temperatures and mechanical stress. (GAO Tek Introduces New On-Metal Gen 2 RFID Tags, 2008). In 2008, GAO RFID Asset Tracking has announced its UHF Gen 2 RFID Tag (GAO116501), for containers, pallets, stillages and trolleys tracking. This contactless read and write tag is meant for applications in harsh environments and where long read range is required (Pressreleasepoint).

3. Components and Capabilities

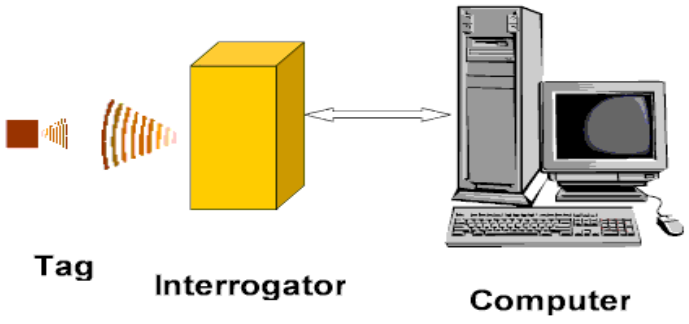
Radio Frequency Identification (RFID) is a technology that combines radio broadcasting and radar. RFID systems are a means of storing and receiving data through electromagnetic transmission to a Radio Frequency compatible circuit.

There are three main physical components in an RFID system:

1. Tag or Transponder
2. Interrogator (Reader)
3. Antenna (attached to reader)

Physical components alone cannot make a device as versatile as RFID. Apart from the physical components there are two more constituents of RFID technology:

1. Software
2. Data Warehousing/Storage



(Figure 1: Taken from HighTechAid.com)

3.1. Tag or Transponder

It is located on the device that is meant to be identified by the RFID system. At its simplest form, a tag is a beacon announcing its presence to a reader. These types of tags are often seen in retail stores used to prevent theft by announcing their presence when taken past a reader. The tag transmits data to the reader and it also has an antenna.

Radio tags are small devices that range in size from several inches to a tiny microchip. They come in a variety of appearances and are made by a number of different companies but they share some basic characteristics. They are generally very thin allowing them to be placed unobtrusively in many different kinds of products and goods from clothing, to cattle, to library books. The tiny chip that stores the information is surrounded by an antenna. On many devices it looks like a spider or octopus with an extremely small head surrounded by legs or tentacles which are the antenna.

RFID tag capabilities, however, extend well beyond a simple beacon. Tags can hold a unique identity (UID) of 8 bytes in length and can be used for inventory management on a global scale, such as a UPC. More than just an UID, a tag can carry re-writeable persistent, storage and is accessible via a reader (Ahson and Ilyas, 2008).

RFID tags are classified by its energy source as:

- Passive
- Semi-Active (or Semi-Passive)
- Active.

Passive

Passive tags do not have a battery to power their signal but may have a battery to maintain memory in the tag or power its electronics. When a passive tag comes within range of the reader, the antenna of the reader powers the passive tag temporarily which causes it to reflect the RF signal, modulating it to transmit information from itself to the reader. Their range is much more limited than an active tag.

Semi-Active

A semi-active tag has the characteristics of both the active and passive tags. It uses its own battery power for some functions but, like the passive tag, uses the radio waves of the reader as an energy source for its own transmission.

Active

Active tags contain a battery powered radio transceiver. Having a radio transceiver greatly increases the range of the active tag to at least 300 feet (Chiesa, 2002).

3.2. Reader and Antenna

A reader includes an antenna and is the device that is used to read or send data to the tag. RFID technology has numerous ranges and frequencies. The common RFID frequencies used today are:

- low frequency (LF)
- high frequency (HF)
- ultra high frequency (UHF)
- microwave

- Low frequency tags are often used with CD, books, and DVD sales to prevent theft.

- High frequency tags have common uses in library books, pallet tracking, bookstore tracking, access control for buildings, airline baggage tracking, as well as for apparel and even the tracking of pharmaceuticals.
- Ultra high frequency tags are used commercially. Most companies will used the UHF tags to track their trucks, certain pallets, trailers, and other large items.
- Microwave tags are used in long range access control for vehicles, an example being General Motors' OnStar system.

Most commonly used frequencies by RFID readers are high frequency (HF) and ultra-high frequency (UHF). Currently HF RFID systems adhere to the ISO standard while UHF RFID systems have yet to become standardized globally.

RFID systems start at the 100khz frequency band and go to a high of 5.8ghz. The higher the frequency the longer range the device can read the tag. With higher frequencies comes faster reading times. RFID readers employ tag reading algorithms that are capable of identifying hundreds of tags per second. Once identified, a reader may read data from or write to tag memory, depending on the permissions granted by the tag (Ahson and Ilyas, 2008)..

Table 1: Comparison of HF and UHF frequencies in RFID technology

	HF	**UHF**
Frequency	13.56 MHZ	860 – 950 Mhz (Divided among Continents)
Memory	64-256 bits	64-2048 bits
Read range	10 - 20 cm	3 – 6 m
Read Rate	50 tags/sec	400 tags/sec

An example of high frequency RFID in action is toll collection from cars that can drive at close to highway speeds through toll booths to pay their tolls. As the frequency increases so does the price (Chiesa, 2002).

The second-generation UHF standard has been getting a lot of attention because UHF is considered most suitable for warehouse environments, where many adopters of RFID in the supply chain have been focusing their efforts.

Thus, researchers came up with a technological breakthrough when they presented the EPCglobal UHF Generation 2 (EPC G2) standard. It is the first royalty-free, global standard that will allow companies to harness the power of radio frequency identification (RFID) to provide greater product visibility in their supply chains worldwide. The first EPCglobal UHF Generation 2 RFID tags were manufactured in 2005.

3.3. Software

Once elemental data from the RFID has been received and validated, additional information can be added including time, temperature, location, and similar indicators. This extension of data surrounding RFID messages is being called “sensor-based computing” by practitioners at Oracle (Seeley, 2004).

Now there exists numerous complex software and software models, tailored according to the various industries that RFID may be put in use to. As RFID becomes pervasive and is integrated with other sensor information, opportunities may arise to use this richer information to create innovative new business models. Vendors such as SAP, Oracle, Sun, Peoplesoft, IBM, and Microsoft are currently deploying various middleware approaches toward the integration of RFID with their existing product offerings.

For example, SAP is reported to have developed a middleware layer, named the Auto-ID Infrastructure, that routes data from readers to applications (including multiple communication and sensing devices such as RFID readers and printers, Bluetooth devices, embedded systems, and bar-code devices) and triggers appropriate events using a rules engine (RFID Journal, 2004). This approach is likely to emphasize reformatting incoming data for use with legacy systems of various types.

According to the software providing company AbsoluteSky (2007), while automatically tracking the inventory, the tracker software performs a range of functions including: on-hand status and search, automated receiving, inventory status changes, as well as zone differentiation and shrink reduction. The RFID Journal categorizes middleware technologies into three levels:

- software applications which solve connectivity problems and monitoring in specific vertical industries,
- application managers that connect disparate applications within an enterprise, and
- device brokers that connect applications to devices like shop-floor machines and RFID readers (Rockwell, 2004).

3.4. Data Warehouse/Management

The RFID data warehouse must maintain a significant amount of data for decision making. Historical and current data is required from supply chain partners and from various functional areas within the firm in order to support decision making in regard to planning, sourcing, production, and product delivery. Supply chains are dynamic in nature. In a supply chain environment it may be desirable to learn from an archived history of temporal data that often contains some information that is less than optimal.

Though there is cost associated with storing this data, there is potential value as a raw material for knowledge creation, decision support, and data mining. The nature of this data is can be identified at finer levels of individuality; there are many more business events for an item. Not just 20 items leaving a warehouse and 10 arriving at another location, but which items arrived, by what route, and how long they were stored (Eckfeldt, 2005).

Although the motivation for using RFID in large part revolves around streamlining operations, Shapiro estimates that 80% of the data in a transactional database that supports supply chain management is irrelevant to decision making, and that data aggregations and other analyses are needed to transform the other 20% into useful information (Shapiro, 2001).

From a technology infrastructure perspective, issues will involve selecting and implementing the right set of decision support systems and knowledge support tools as well as organizing the data to maximize the trade-off between capturing all possible data and retaining a size that is manageable for ad hoc as well as programmed queries (Eckfeldt, 2005).

The value of the data warehouse and the collection of RFID process will primarily be in the discovery of new relationships and opportunities for process redesign. Specifically within the supply chain context, this information can aid in logistics network design, supply chain planning, and vehicle routing and scheduling (Simchi-Levi, 2000).

3.5. Recent Positive Developments in Global Adoption

RFID has been established as a very reliable technology for use in various fields like tagging animals, goods, etc. Recently there have been positive developments in the global adoption. We are taking the following four fields to be the indicators of the positive developments in RFID technology adoption by the global community:

1. Materials transmission ability
2. Generation 2 tags
3. Readers
4. Tag Costs
5. Intel and Microsoft Involvement
6. Standards
7. Data Sharing

The above fields are chosen since they bear a direct correlation with trends in global adoption. Any increase or decrease in one of them will lead to a corresponding increase or decrease in the global adoption of RFID technology.

3.5.1. Materials Effects on Transmission

RFID tags have had trouble reading through and around products that contain metal or liquid, this has caused problems for companies wanting to implement RFID into their systems. In recent years companies have been working hard at developing solutions to this. In 2005, AICA Kogyo Company and Toppan Forms Co., Ltd. of Japan developed RFID labels that could be directly pasted on metal surfaces like a sticker.

In June of 2006 ADASA, Inc., a leading technology company from the U.S. specializing in the development of advanced mobile RFID systems, announced the availability of its "Foam Attached Tag" for businesses interested in attaching Gen 2 RFID tags to metal parts and liquid containers in their supply chains. The Foam Attached Tag or "FAT" tag gave a convenient and reliable solution for any business wanting to use RFID technology on metals and liquid containers (ADASA Offers Metal Mount RFID Tags, 2006).

In 2008, the leading RFID products producer in China, Daily RFID announced it had developed the HF Metal Tag-08 RFID tag for use in metallic environments. This passive RFID tag is designed in a very small size, having only a diameter of 13mm round and suitable for on-metal tagging, with a reading range of up to 3cm.The price is approximately 1.0 USD (PRLog, 2008).

In October of 2008 GAO Tek Inc. started offering a series of on-metal Gen 2 RFID Tags. The on-metal RFID tags were developed to withstand harsh. These passive RFID tags set the bar in providing dependable transmission of data in demanding industry conditions such as

changing temperatures and mechanical stress. They have been successfully used in asset tracking applications such as railway and warehousing solutions, and it has successfully passed the rigorous testing requirements for Aerospace standard AS5678 specification (GAO Tek Introduces New On-Metal Gen 2 RFID Tags, 2008).

In 2008, GAO RFID Asset Tracking announced its UHF Gen 2 RFID Tag (GAO116501), for containers, pallets, stillages and other types of tracking. This contactless read and write tag is suited for applications in harsh environments and where long read range is required. The UHF 902MHz Gen 2 RFID Tag is compliant with ISO 18000-6C and offers a maximum read quantity of 500tags/s. Its rugged design makes the tag waterproof and dustproof and is resistant to immersion in salt water, alcohol, oil, 10% HCl and ammonia for as long as 100 hours (Pressreleasepoint).

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3.5.2. Gen 2 RFID Tags

For RFID technology to be adopted globally, it is crucial that the components are designed to cater a wide variety of needs ranging from low cost robust to high cost very sensitive tags. One such substantial development in this field has been the Gen 2 RFID tags, which is outlined below.

The invention that has aggressively promoted the use of RFID technology in recent times is the Gen 2 RFID tag. That is why we need to include a brief overview of it in the paper. EPC Gen 2 tag can be used in all global UHF frequencies.

The EPC global Gen 2 protocol overcomes the many limitations of EPC global's legacy Class 0 and Class 1 solutions. Seeing the rate at which its popularity and usage is increasing, it can

be said that it is destined to quickly become the leading RFID specification for the UHF band centered around 900 MHz.

It provides a comprehensive framework with enhanced features and an enormously improved performance over its predecessors such as:

- Operation in high-density reader environments,
- Compliance with global regulations,
- Superior tag readability,
- Fast read rates, field re-write ability, and
- Enhanced security and privacy

The above mentioned are the advantages of the Gen 2 RFID tags over its ancestors. The technology has even numerically advantages over its counterparts, both in terms of statistics and innovation. Gen 2 RFID:

- Has the theoretical potential to read over 1000 tags per second during top speed
- Are writeable at a minimum rate of about 5per sec. to allow RFID tag integration and programming on most high-speed assembly and packaging lines.
- Combination of "Q" protocol & symmetry are expected to deliver regenerated read robustness in numerous applications
- Multiple manufacturers of tags and readers
- Interoperable system components
- Writable, Verifiable, "Killable" tags
- Possess a 32-bit password to be used for activating kill commands to infinitely shutdown tags, similarly for accessing and relocking a tag's memory
- Unlimited user memory (Unless the chip is damaged)

- Read rates ten times faster than Class 0 and Class 1 and a 50-fold improvement in fighting the spectrum interference that can plague RFID readers in various environments. (RFIDProductNews, 2005)

3.5.3. RFID Readers

With few exceptions, RFID readers were comprised of multiple electronic components from many different manufacturers. These components are purchased by the reader manufacturer, then assembled into a cohesive whole to create the final reader product.

Intel introduced its first RFID reader chip, the R1000, in 2007. The chip consolidates several RFID reading and data processing functions that had historically been performed by multiple processors connected together on a circuit board. What Intel has done in the R1000 is design a single chip that provides most of the same functionality, but is cheaper and smaller. "If you crack open any of the leading readers," Intel's Krause explains, "you see a very complex and expensive design. The R1000 integrates about 90 percent of all those discrete components onto a single chip" (RFIDUpdate, 2007).

Drew Nathanson, director of RFID research at Venture Development Corporations stated that “today's UHF readers are relatively large, the size of a tablet PC or corporate wired phone and cost as much as $2,000 due in part to a bill of materials of as much as $200 for transceiver modules made from more than a hundred discretes. Using the new Intel chip, readers could cost as little as $500.”

The Intel release is significant for following reasons:

1. It reduces the components, complexity, and cost necessary to produce a Gen 2 UHF RFID reader. Intel estimated the chip could lead to reader costs falling by half. A bold prediction to be sure, but less so when one considers Intel's role in the history of PC development.

2. The second reason the R1000 is significant is that Intel's investment to develop and produce the RFID chip suggests the company has confidence in the strength and growth of RFID technology (RFIDUpdate, 2007).

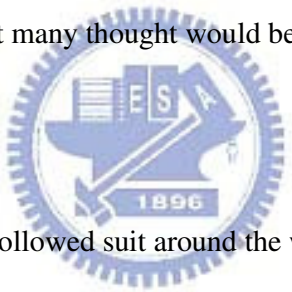
GAO RFID has recently produced a Gen 2 RFID reader which is a small, easy to use, low cost EPC compliant reader for the operating in the 860 to 960MHz frequency band that is suitable for easily customized for use in asset tracking, healthcare, supply chain & logistics, event management, access control, livestock tracking, inventory control & management, field service maintenance and document authentication. The RFID reader features an enhanced interference rejection, a small footprint and high read rate (ArticlesBase, 2009).

On May 22 of 2009 DAILY RFID launched a low cost RFID card reader operating in 125KHz or 13.56MHz frequency. The RFID card reader is a cost effective choice to read passive RFID tags. The RFID reader, designed as a plug-and-play device, is approximately the size of a business card, and features has low power consumption. It is ideal for close quarter checking, basing on a read range from up to 100mm. The reader is ideal for various applications such as industrial tracking, access control, time and attendance, and supply chain management. (PR-Inside, 2009)

3.5.4. Tag Costs

Cost is undoubtedly the prime factor for any technology to succeed in the market. No matter how many innovations may have been produced for a particular technology it can be rendered useless and shelved if it is not within the cost barrier for the masses. Initially RFID was costly and hence only few large firms came forward to embrace its potential. But over time as the cost has declined, the global adoption has increased.

In 1999 tags costs were set between approximately 30 cents and $1.00 US. By the start of 2006 the price for tags had dropped to between 10 and 30 cents. Then in May of 2006 it was announced that SmartCode, an Israeli RFID systems provider, would offer its customers Gen 2 Electronic Product Code (EPC) RFID inlays for 5 cents each in volumes of 100 million or more (Roberti, 2006). A price that many thought would be the real beginning of RFID worldwide.



Since then other companies have followed suit around the world. Chinese RFID tag and reader company Invengo, announced entry in the US market with a new EPC compliant inlay at a price of just 5.8 cents each on smaller purchase volumes of only five million or more. The inlay is available for 6.0 cents on orders of just one million (Bacheldor, 2009).

As more and more companies come towards the 5 cent tag price this will go a long way to larger orders and greater production, over time this will lead to an even cheaper tag. When the time comes that tags are 1 cent or less we will begin to see mass item tracking. Rafi Nave, vice president and CTO of Tower Semiconductor, an Israeli chip foundry that specializes in making radio chips says he sees that time coming in the next few years but says for now they are just to expensive to be putting on cereal boxes (Kanellos, 2007).

3.5.5. Intel and Microsoft Involvement

One of the most important factors of success is the involvement of big business. Recently Intel and Microsoft have started to invest substantially in RFID. Microsoft, which is playing in the middleware space with its BizTalk R2, is working with partners to deliver applications designed to address specific business problems (Roberti, 2007). Its approach is to provide a foundational layer upon which partners can build applications. Some partners might be focused on retail software and develop applications to reduce out-of-stocks, for instance, while others might be strong in manufacturing and develop systems for tracking work-in-process. In 2008, Microsoft invested NT$ 5.5 hundred million (17 million US$) into their Taiwan RFID Excellence Center.

The Microsoft BizTalk server when compared with competing RFID software solutions, "is cheaper by a factor of ten," John Fontanella of AMR Research said. "It's around five grand, compared to 50 to 100 grand. This puts RFID into reach of every organization." Cost is of course a factor in every purchasing decision, but even more so when it comes to RFID adoption. "We've seen how sensitive the RFID market is to price," Fontanella noted. (RFID Update, 2007)

Another very important move in the RFID reader market has been that of Intel, with its Gen 2 RFID reader chips R1000, in March of 2007. The cost and size reduction of the R1000 could have dramatic consequences for RFID readers, according to Kerry Krause, Intel's Marketing Director. For example, the standard fixed Gen 2 readers commonly deployed in distribution centers and retail back rooms currently sell for roughly $1,000, depending on volume. Krause expects that the savings provided by the R1000 could cut that cost in half. "I expect to see that those high performance Gen 2 UHF readers will be $500 or below by the end of the year" (RFID Update, 2007).

Revenues from RFID transponders, readers, software and services will reach $5.6 billion in 2009, according to the latest market data ("RFID Annual Market Overview") from ABI Research and have been growing each year, showing that for some industries RFID is slowly expanding.

3.5.6. Standards

A technology such as RFID is meant to be used globally. Further RFID equipment needs to be compatible with some global standards so that they can be interoperable among themselves and among any region of the world.

RFID technology has had a hard time in getting any global standard and consequently it was popular in some pockets of the world while all together non-existent in others. International companies ended up making their own standards to overcome regional limitations. It has only been in very recent times that fruitful efforts have been made at a national level and by the companies to produce unified standards. Perhaps the most promising development for RFID deployment is adoption of a standard RFID technology.

In July 2006, the International Standards Organization approved EPCglobal"s second generation, Class 1 protocol standard for RFID devices operating in the UHF band (Quirk, 2007). When Gen 2 was ratified by EPCglobal in 2004, it impressed experts in the field, who enthusiastically touted it as the first truly worldwide standard for RFID. The ISO ratification confirms that view.

Gen 2 has the capacity to store large amounts of information on a tag and permits customization of content. This enables supply chain trading partners to encode and read UHF tags in a similar manner. Gen 2 also allows supply chain entities to share an interoperable reading and software infrastructure.

Gen 2 conforms to the UHF radio regulations of the FCC and European and Asian telecommunications regulatory bodies. Consequently, Gen 2 tags and equipment can be used nearly universally, which allows manufacturers, distributors and vendors from all over the world to seamlessly coordinate their supply chains via RFID. Gen 2's positive impact on the deployment of RFID is illustrated by the recent decisions by Wal-Mart and the Defense Department to require their suppliers to use it exclusively.

Gen 2 RFID readers and tags enable global corporations to use a common RFID reader hardware platform and software in the North American, European, and Asia-Pacific regions. Similarly, UPM Raflatac, a Finnish-based tag manufacturer, is supplying a similar tag to the Advanced Logistics Asia project. As part of this project, Metro plans on using a common platform to track all of its Chinese-manufactured supplies from China to its German warehouses.

China's approval of two UHF bands in 2007, says Craig K. Harmon, president and CEO of standards development organization Q.E.D. Systems, can be viewed as good news for U.S. and European companies. China's 920 to 925 MHz band overlaps the 902 to 928 MHz band used in the United States, so U.S. RFID tags will be readable by interrogators approved for use in China. Although China's 840.25 to 844.75 MHz band is lower than Europe's UHF RFID band, European RFID tags should still be readable in China as well.

A huge impetus is expected to come from the introduction of Gen 2 RFID reader chips by Intel, R1000. These will ultimately result in the improved compatibility of core reader functionality across vendors. As RFID reader companies base their products on the R1000, the core reader technology and functionality will be the same, not unlike how Dell, HP, IBM, and Sony computers use the same Pentium based chip technology. This sort of competitive landscape provides a level playing field for RFID reader vendors to focus on added value, rather than low-level reader processor design for competitive differentiation (RFIDUpdate 2007).

The Microsoft BizTalk Server 2006 R2, Microsoft Corp.'s core service-oriented architecture (SOA) and business process management (BPM) technology is now available. This product includes advancements for radio frequency identification (RFID) and electronic data interchange (EDI), and extended interoperability such as Enterprise Service Bus (ESB) Guidance and Line of Business Adapters. Together, these capabilities make it easier for companies to connect systems within their own organizations and across those of trading partners (Microsoft Presspass, 2009).

The product has been a long time coming, and some in the industry believe it could have a materially positive effect on RFID adoption as it makes sophisticated RFID data capture and management capabilities affordable and accessible to smaller enterprises. Microsoft itself is pushing that angle. "By entering the market with its own BizTalk RFID software, Microsoft could help kick off a wave of adoption, by helping to standardize technology and reduce costs for RFID on the Windows platform," said B. Robert Helm, director of research at independent research firm Directions on Microsoft (RFIDUpdate, 2007).

Also a great positive step forward in the area of patent sharing was the RFID Consortium formed in 2006, a group of RFID industry companies holding patents for technologies essential to EPCglobal and ISO/IEC standards for UHF RFID. It is a joint licensing program that allows manufacturers easy access to the patents necessary to comply to industry standards. This easy access works to both keep costs down and speed up the pace of RFID adoption. Among the members of the group are 3M, Zebra Technologies, Motorola, and ThingMagic

3.5.7. Data Sharing

Since the RFID tags need to function globally anywhere, so should be the data stored by them. The data carried by an RFID tag may be need to be read by a reader manufactured by a company different than the tag's manufacturer. So companies need to share the formatting of data done by them in order to make the RFID devices truly operable anywhere in the world.

Initially, companies were skeptical of sharing any data storage methodology used by them due to copyright issues and distrust among themselves. But with the growth of open standards in the software community, RFID companies have started to share their methods of storing data.

The EPCglobal Network comprises Internet-based technologies that provide for business integration and collaboration by enabling the storage and retrieval of electronic real-time Electronic product codes (RFID data) in safe and secure, databases on the Internet. The electronic product code (EPC) unambiguously identifies objects in the supply chain and includes data on the source of the information, the company, and the stock-keeping unit (SKU) number.

The standards body EPCglobal, supported and applied by U.S. and European companies, is advocating data sharing through the registry of companies that it maintains. In April of 2007 EPCglobal announced the ratification of Electronic Product Code Information Services (EPCIS), a secure, real-time standard for data sharing among trusted organizations. The ratification marks a key milestone in the effort to enable RFID based supply chain visibility across trading partners, industries, and even nations. The ratification was the result of years of effort by more than 150 companies and organizations participating in the EPCIS working group.

European and U.S. companies, including IBM, Microsoft, Wal-Mart, and Tesco, agreed on code standardization and supported a modified EPCglobal UHF Generation 2 standard (Gen 2 [ISO 18000-6]), which was approved by ISO, the international standards body, in July 2006 (RFID Journal, 2007)

Technical organizations such as EPCglobal, are developing standards for the Electronic Product Code, including its *Guidelines on EPC for Consumer Products.* This is one of the biggest steps, both in terms of magnitude and consequences, taken in history of RFID technology to promote data sharing globally.

In April 2007, EPCglobal ratified the Low Level Reader Protocol (LLRP) standard, a specification for the network interface between the reader and its controlling software or hardware. Having already standardized the tag and reader radio frequency (RF) air interface protocol with the UHF Gen 2 standard, this specification was the practical, logical next step in facilitating the adoption of EPC and RFID technology. (LLRP.org, 2009)

For example, a developer that is building a dock door RFID reading application today might have to program separate code to interface with each RFID reader vendor, one piece of code for Impinj's readers, one for Alien's readers, one for Motorola, etc. With LLRP, by contrast, the developer can program a single piece of software that can then work with any reader that supports the interface. The result is better interoperability (RFIDUpdate 2007).

The standards development process is ongoing. GRIFS, the EU funded project promoting closer co-operation between RFID standards organizations, announced in May of 2009, the launch of the first comprehensive online database of international RFID standards. (EPCglobal, 2009)

4. RFID Applications

The uses to which RFID systems are being put today will need a paper of their own. So we select a small subset of application areas where RFID systems are being used. We first present an even smaller and most precisely chosen subset of scientific RFID research areas, which have and can, revolutionize society as a whole. Then we dive into the main uses of RFID, classified on the basis of domains, which though having benefited enormously from RFID technology, are the areas, in which RFID finds itself confronted with a lot of challenges for adoption.

4.1. Scientific Avenues

These applications of RFID are useful and a decade ago would have been considered amazing. However, this pales in comparison to what the future of RFID could hold. RFID could truly revolutionize the world with an enormous amount of applications. The ability for RFID devices to communicate with one another and the improvement of the size, durability and range of these devices have opened the door to much more than providing access and paying for snacks. Let us have a look at them:

DoD

A few DoD sectors are also using RFID with integrated sensor networks. The U.S. Navy, working with Georgia Tech, has developed an RFID sensor network that monitors the temperature, humidity, and air pressure in containers where aircraft parts are stored. The U.S. Military's Combat Feeding Program pilot uses active RFID tag based sensor networks to provide real-time visibility of rations as they move from the manufacturer to units in the filed. (RFID Journal, 2004)

BP Oil

The BP oil company uses RFID and sensor network to monitor assets and react quickly to changes in environmental conditions. (RFID Journal, 2004)

Elder Care

A joint project called "*Caregiver's Assistant* and *CareNet Display,"* developed by Intel Research Seattle and University of Washington, aims to provide elder care by monitoring elders' activities. (Intel Research Seattle, 2009)

HP Labs: Smart Rack

HP opened its USRFID Demo Center in HP Labs on Oct 2004. A major research prototype is Smart Rack. Smart Rack uses thermal sensors and HF RFID readers to identify and monitor the temperature of servers sitting in large metal server cabinets. These sensors and readers are networked and the collected data are used to show, in real time, an inventory of the cabinets and temperature profile of each cabinet. It may become a commercial product and offered within HP's OpenView network management system. (RFID Journal, 2004)

NASA

The project has the objective that instead of reporting to an external control system, sensed data can be shared throughout the network and be used by the embedded intelligence to act directly on any detected changes. RFID tagged objects, such as firefighters or astronauts, may be sensed and be guided by the intelligent sensor web; or product components and production flow may be sensed and be guided to slow down or to speed up. (RFID Journal, 2005)

The Space Shuttle surfaces typically experience very high temperatures during reentry (1000s of degrees F) therefore they require a form of a thermal protection to prevent the vehicles from burning up. SRI International has developed a series of wireless sensors for monitoring these temperatures. The shuttle's surface is covered by 4-inch thick light-weight ceramic tiles that are attached to the underlying metal skin by a high temperature adhesive. However, sometimes hot gases penetrate the narrow gaps between the tiles and char the underlying adhesive. Hence all of these tiles must be inspected after each flight, and any tiles that are in danger of coming off must be replaced. This procedure is labor-intensive and time-consuming. Special RFID tags coupled with temperature sensors automate this job by signaling vulnerable tiles eliminating the need to manually inspect all of them (Watters and Jayaweera, 2002).

Vitacraft

One company already using RFID in its cookware is Vita Craft with their RFIQin. Their pan reads the card you show and "tells" the cooktop what to do sixteen times per second to perfectly monitor each cooking step and perfectly reproduce the most difficult recipes. Each pan handle is embedded with an RFID chip that uses a proprietary signal to communicate with coordinated chips in the cooktop and special recipe cards that monitor each cooking step for a particular dish (Vita Craft, 2009).

4.2. Main Uses

These are the specific areas where RFID is being put to use, and from where arise some of the most appalling challenges in adoption of RFID. So to understand the nature of challenges

that these systems put in path of adoption of RFID, it is indispensable to look into how they use RFID.

Enumerating these areas:

Product tracking, inventory systems and distribution centers

- US
- Europe
- Canada
- Australia
- Asia
- Latin America

Logistics and Transportation

- Airports
- Yard Management
- Shipping and Freight
- Railway
- Transportation Payments

Passports

Race Timing

Hospitals

Human Implants

Asset Management

Animal Identification

Museums

Libraries

Schools

Prisons

Access Cards

4.2.1. Product tracking, inventory systems & distribution centers

4.2.1.1. USA

Perhaps the only nation where both the United States Government and the huge private sector are taking equal interest and making investment in the adoption of RFID tag. For example, the United States Department of Defense (DoD) as well as large retail leaders in the US such as Albertsons, Target, Best Buy, Wal-Mart and Sam's Club (which is owned by Wal-Mart) are attempting to become 100% RFID compliant for case and pallet tagging by their suppliers. "Wal-Mart wants to be able to read 100 percent of the pallet tags coming through its dock doors (RFID Journal, 2003)." As of April of 2008 "over a third of Wal-Mart's approximately 3,600 stores have implemented the technology (RFID News, 2008)."

RFID has played a huge role in phenomenal success of Wal-Mart. It can be comprehended from the fact that Wal-Mart's top 600 suppliers, which count for over 70% of its product, now affix RFID smart tags to all shipped pallets and cases. Wal-Mart has been so much impressed by the technology that according to RFID News (2008) Wal-Mart will now require RFID tagging on all shipments from its Chinese suppliers as of January 2009. The standards will affect all of Wal-Mart's more than 1,000 Chinese suppliers with the rules becoming much stricter in early 2010. All suppliers that fail to meet the new information standards will be dropped from Wal-Mart's supply chain. Another good example is Sam's Club which will

charge fee from suppliers for non-tagging. The fees start at $2 and escalate based on how long the supplier is out of compliance, capping at $3 according to CIO Magazine (2008).

Recognition of technology became visible in July of 2004, when the United States Department of Defense (DoD) issued a policy requiring passive RFID tagging at the case, pallet and item packaging level. The only excluded items were sand, concrete, wood, liquids, and coal. Munitions and explosives were also excluded until electromagnetic testing can be completed to ensure that the scanning will not cause an explosion of any kind.

4.2.1.2. Europe

While the big US chains have been focusing on pallet and case tagging the Europeans have been leading efforts to use item level tagging. Also, European companies have chosen to concentrate on tagging products where the theft rate is high in relation to the product value. Simultaneously they also have been generally more successful in educating consumers about any concerns over information data privacy

Metro, the world's fifth-largest retailer and Germany's largest retailer, has clearly articulated a mandate that is very similar to Wal-Mart's for RFID but at item level. According to Trebilcock (2007), it is launching, what is the first of its kind, end to end RFID-UHF item level shopping experience. The focus is not on pallets and cases, but on individual items in a retail store, not just high-value items but all items in the store. In addition, METRO has installed smart shelves with built in RFID readers that monitor the merchandise on the shelves. Bill Colleran, President and CEO of Impinj Corporation, the company that is providing the Gen 2 tags that will be used, gave an useful insight, "in certain areas of the men's department, there's a flat panel screen that will tell you everything that's on that

shelf…that way, you don't have to sort through everything only to find out the size you're looking for isn't there".

The METRO store chain is equipping two hundred of its prime locations with RFID technology. It has mandated to 650 of its biggest suppliers to start shipping RFID tagged product. The suppliers will be expected to tag their goods, failing which they will be charged a fee for non-compliance. Further Metro has stated that it will pass on the additional handling cost of an untagged pallet to suppliers that do not comply (Smith, 2007).

Other companies that have come forward are Marks & Spencer, the fourth-largest retailer in the United Kingdom, and Tesco, another large retailer in the U.K. Marks & Spencer, is already using item level RFID apparel tracking at 42 of its stores. This was incorporated after the successful trial using RFID in tracking men's apparel.

Tesco has been using item level tagging, to instantaneously check stock availability and preventing theft of DVDs, electronic games and cosmetics. Tesco has a different strategy for using RFID. It has not focused on tagging cartons and containers, rather it puts a passive RFID tag on reusable roll cages. According to Trebilcock (2007) containers are loaded onto the cages, which are then rolled through the store, as inventory is put away on shelves. The RFID tag on the roll cage acts like an electronic license plate, which identifies each specific roll cage. The system is designed for the cage to know the destination store it is going to. If the wrong cage is loaded onto the wrong truck, the RFID system will catch it at which time a display system alerts a warehouse operator who can then fix the problem and ensure the product goes to the right place.

4.2.1.3. Canada

In Canada, the implementation and usage is different from that in the US. For example, Staples Business Depot has implemented a tagging strategy where they tag and track thousands of items in real-time, at long range. The tagging and hence tracking starts as early as entering the item in the store inventory, to the store shelves, and continuing through to the completion of the sale. Addressing privacy and cost concerns, the RFID tags are not hidden on the items and are re-usable by the store as they are physically detached from the product at the checkout when the item is sold to the customer.

4.2.1.4. Australia

In Australia, the usage of RFID technology is on similar lines as in the UK, that is for item level tagging. Leading Australian companies like Capilano Honey, P&G, ACCO and MasterFoods have been using a pallet counting program similar to what is being used in the UK at Tesco. Each pallet has a unique number encoded into it with RFID, so that each pallet can be accounted for individually. When put in use, each pallet of product passes a fixed RFID reader, its tag information is sent to an Adaptive Asset Manager (AAM). This information is then relayed via general packet radio service (GPRS) to the driver's personal digital assistant (PDA). At this point, an indicator light on the PDA shows that the pallets are being read for that particular order. Once all the pallets have been read, the PDA indicator turns to green. Then the driver departs to deliver the pallets to the customer (Bacheldor, 2007).

Fixed RFID readers put at the customer sites read the tagged pallets as they are unloaded. By this mechanism the system confirms individual pallets for the store. Once again, the AAM system passes on the information to the driver's PDA. Once all pallet tags have been read, the

PDA indicator turns to green. The driver can then close the order as it has been confirmed. This process allows for any discrepancy to be resolve immediately, rather than waiting for the long and time consuming reconciliation process. As stated by Bacheldor (2007), “with accurate reads showing 100 percent of the time, the system has been able to show successful electronic proof of deliveries (ePODs).”

4.2.1.5. Asia and India

Asian retail in general has been slower at adopting the use of RFID than its western counterparts. India has also shown slow growth in the technology. Prasad (2007) notes “in the world's second most populous nation, RFID continues to be a concept--waiting to be put to practice.” That being said however, there has been some trying the technology. In 2005, one of Japan's largest electrical and electronic stores, Yodobashi, asked its suppliers to use UHF EPC tags on their products at the item level. A major Chinese retailer named Gome, which sells appliances and consumer electronics, opened the first RFID based trial store in China in 2004.

4.2.1.6. Latin America

The technology is still to take roots there, though few of the retail sector giants have started the vogue. One of the largest department stores in Latin America, Falabella, did a pilot project investigating how using RFID might improve its tracking of products at the item level, yielding an inventory accuracy of 98.4 percent and a 25 percent reduction in out-of-stocks (O'Connor, 2004). Thus the technology was embraced as a part of the store. Over the time more stores followed the lead. But the adoption is not as rapid as USA or Europe.

4.2.2. Logistics and Transportation

4.2.2.1. Airports

Many airports have been working with airlines to introduce RFID at their terminals. Let us explore the cause. According to Geneva-based aviation IT specialist SITA (formerly known as Société Internationale de Télécommunications Aéronautiques), every piece of mishandled passenger baggage cost carriers US$90 each. Luggage lost by airlines cost $3.8 billion total in 2007, representing approximately 42 million bags. This accounted for 2% of all luggage (Jones, 2008). Aside from the disappointment of customers it is obvious why airlines wish to reduce this number by every little bit possible.

One of the first airports to introduce RFID technology was Hong Kong International Airport. The system here operates in parallel with the legacy barcode system. Henry Ma, Airport Authority Hong Kong's General Manager of Terminal Business, stated in 2008 "We've seen significant performance improvements, and we believe there will be further efficiency and reliability gains when the rollout is completed later this year," This is attributed to the unique property of RFID tags that they can be read at any angle and from a distance this means tags can be read faster, contain more data and are more reliable, with read rates of 97% versus an average of 80% for the barcode only tags.

In 2005 McCarran Airport in Las Vegas Nevada changed to an RFID luggage tracking with an aim to reduce the number of lost bags. Airport officials in 2006 claimed that the system had been 99.5 percent accurate (Cheung, 2005). Milan's Malpensa Airport served 21.7 million passengers in 2006. It was in an urgent need of a system for baggage tracking as part of an effort to reduce the cost of baggage handling. The airport signed a contract with

Denmark's Lyngsoe Systems to install and integrate a system in Milan that is nearly identical to one used at Hong Kong International Airport. This resulted in the implementation of RFID system at the airport in 2007.

The International Air Transport Association (IATA) has endorsed RFID based baggage handling as a way of simplifying airport procedures. It has predicted that global implementation of RFID, in controlled baggage handling, can lead to an annual saving of US$760 million for the airline industry. Several international airports have now implemented or have started implementing RFID technology in their baggage handling systems.

Heathrow, the UK's busiest airport, began a six-month trial of RFID tags in 2008 for use in tracking passengers' baggage. The RFID tags contain data that includes the passenger's name and route. They are attached by airport personnel in specially equipped Emirates check-in counters. The trial will be tagging approximately 50,000 bags each month for passengers traveling or transferring on Emirates Airline between Heathrow and Dubai. The project is expected to save Heathrow around 400 million pounds in reduced luggage losses and replacing existing messaging systems (McCarter, 2007).

4.2.2.2. Yard Management

Though shipping sector was initially skeptical about the benefits of RFID when applied to yard management but after seeing the successful incorporation and working of RFID in so many industries, many companies in this sector have turned to RFID for yard management.

One example of a provider of yard management solutions is PINC Solutions based in Berkeley, California, USA. They offer an asset visibility solution for distribution center yards

using passive RFID. Ruggedly designed Gen 2 RFID tags are attached to a yard's mobile and movable assets such as trailers. Their ruggedness has been a crucial feature in use of RFID in yard management. The tow trucks that move the trailers from one location on the premises to another are equipped with RFID readers. These readers are able to calculate their own locations. As the truck is moving the trailer, its reader records the event and relays the activity and location data back to a central server via a standard wireless LAN connection. Then that information is incorporated into computer graphical representation of the yard, allowing the yard manager to see in real-time the location of all trailers and trucks (RFID Update, 2007).

4.2.2.3. Shipping and Freight

Shipping and freight service companies have begun to use RFID in their operations. Schenker is one of the world's leading providers of integrated logistics services. It offers land operation, air and sea freight as well as comprehensive logistics solutions and global supply chain management. It incorporated RFID as part of a system for its shipping in 2006. In shipping, goods need to be tracked as they are exchanged since it is at that time that the goods are lost mostly. The container RFID tag is automatically registered at points where liability changes hands. That means the shipment becomes immediately visible at important transitional milestones in the transport chain. The first phase initiates with the partners on the packing stations at the port. The second phase involves the container terminals. Schenker also tested the 'e-seal', an electronic seal that documents any opening and closing of the container (Oracle, 2007).

In 2004 Kuhne & Nagel (K&N) and Siemens Business Services began implementing a pilot transatlantic RFID project, to test for the first time across a supply chain from Munich to

New York under real conditions. The pilot was executed together with printing systems manufacturer Oce and Lufthansa Cargo. The pilot went on to be a success and in 2005 K&N announced that they now provide “rapidly implementable, cost-effective radio-frequency identification (RFID) solutions for its customers” (K&N, 2005). They went on to say “we believe that RFID will be an integral part of next generation supply chains”.

4.2.2.4. Railway

Railways around the world have also implemented RFID. This provides solution to some of the worst problems that railways face without the use of RFID, to eliminate bad information that can come from:

- From mistakes that are made manually when entering into the database
- During the process when railcars are switched onto different tracks.

Pertinent information can also be written onto the tags. This encompasses information such as what the railcar contains, any hazardous materials that might be on board and other important information (Bacheldor, 2007). A company called TransCore produces a variant of RFID technology that is already in use at numerous railways throughout the world. They have installed more than 6.5 million tags and 20,000 readers throughout the world's rail and intermodal freight industry.

The North American railroad industry operates an automatic equipment identification system based on RFID. The Association of American Railroads (AAR) adopted TransCore's Amtech RFID technology as the standard for automatic equipment identification. This has resulted in 100 percent of all railcars in interchange service being equipped with TransCore's tags in North America (Bacheldor, 2007).

4.2.2.5. Transportation Payments

In today's fast paced society speed and ease of movement are becoming more essential. Road pricing is an effective tool for traffic demand management policies. In general, road pricing is implemented either for revenue maximization or for regulating transportation demand (Tezcan, 2006). Regionally RFID has been becoming a very effective tool in speeding up the time it takes to pay for transportation in many formats.

RFID provides following benefits over the traditional systems:

- Much quicker and easier collection of road tolls
- With RFID no stopping is required
- Less staff is needed to work at toll booths.

An example is EZPass on the New Jersey turnpike to pay a toll without stopping. This is done by providing the Passenger person an RFID device, the EZPass, which communicates with the tollbooth (West Virginia Department of Transportation, 2009). Likewise, when someone uses their Speedpass in the US, this is a very small nation wide chain of Exxon and Mobil gas stations, where one can quickly pay for gas without having to use any cash. Speedpass can simply be swiped and will debit the funds from your account. Thereby letting your fill up your car very quickly and getting back on the road without having to wait in long lines.

In Singapore, public transportation buses and trains employ passive RFID cards known as EZ-Link cards. They have integrated the same card across different domains. People are able to pay for bus and train rides with it, as well as purchase items from shops. A similar service has been available in Taipei, Taiwan since 2002. In Taiwan the transportation system uses

RFID operated cards as fare collection. The Easy Card is charged at local convenience stores and metro stations (MRT).

In Toronto, Canada and surrounding areas, RFID pricing systems are used to collect toll payments on Highway 407 (Industry Canada, 2009). The RFID devices have been installed in the vehicles of frequent users since 1997. Similar RFID systems are used for electronic freeway tolling in Pakistan as well as Norway where all public toll roads are equipped with the RFID payment system that is known as AutoPass (ITS Decision, 2009).

4.2.3. Passports

Malaysia became the first country in the world to issue RFID passports in 1998. In December 2002, thumbprint data was added to the data on their passport chip. Presently, the data included on the Malaysian passport comprises of a digital photograph of the bearer's face, and images of their two thumbprints. Many more countries have followed the lead set by Malaysia. As of today the United States, United Kingdom, Australia, Russia, and nearly all European Union countries have put some type of RFID device in their passports.

The first phase of issuing US passports implanted with RFID technology happened in 2006. The US government has affirmed that the passports are tamper proof despite concerns otherwise. The passports contain the person's name, sex, date of birth, nationality, digitized photographs and as well as blood type and medical considerations. Government officials have constantly assured that the passports are tamper proof due to a metallic anti-skimming material on the front cover and the spine of the passport, plus a cryptographic technique to keep new codes from being programmed (Financial Wire, 2006).

The British government began issuing RFID passports in 2006 and wants to incorporate fingerprints and other biometric data on the chips in the near future, although privacy activists are concerned over how data will be stored and handled. Currently, the chip contains the printed details on the passports, the person's photograph and security technology to detect if those files have been altered (Kirk 2007).

4.2.4. Race Timing

This is not a technical term here. The race timing refers to the motorcycle race timing. It is really exhilarating to see the wide spectrum of fields that RFID can be applied to. Recently large events have been implementing RFID into race timing. In August of 2008, the Zoomius Titan RFID race management system were used to completely manage, time and score a motorcycle race weekend at the Reno-Fernley circuit near Reno, Nevada in the US. The event comprised of practice sessions, qualifying sessions, sprint races and an endurance race. Live timing and scoring, results and lap-times were available to all racers with a Wi-Fi enabled computer.

"The race weekend was a complete success," said Chris Keane, CEO of Zoomius Inc. "Our long-term research and development has paid off with a great result. Our receivers at start and finish, pit-in and pit-out gave everyone , staff and racers alike, a complete and accurate picture of everything that was happening at any moment" (Keane, 2008).

"RFID is absolutely the best way to manage races, the timing system makes life easier for race organizers and more interesting to participants. We can deliver real-time splits during the race which the athletes appreciate and our software allows friends and family to get updates with times, photos, and videos. In addition, because our timing chips are inexpensive and

disposable, the race organizer doesn't have to worry about collecting them at the end of a race." said Kurt Hansen, founder and President of Innovative Timing Systems.

In February of 2009 RFID made its debut at the New Orleans Mardi Gras Marathon. The 7500 runners all wore RFID Race Timing Systems bracelets and their times were streamed live to the internet. Race Director of the race, Mike Cambre and the Executive Race Director of the New Orleans Track Club, Chuck George said they were very happy with the timing services of the system (RFID Race Timing Systems, 2009).

4.2.5. Hospitals

About five years ago, some hospitals began to use real-time tracking of equipment to save money. This was possible because it cut out much of the over purchasing or leasing of equipment. “The RFID tracking allowed staff to find equipment when it's needed”, said Gregg Malkary, managing director of Spyglass Consulting Group, so the tracking systems have been paying for themselves.

The Healthcare industry has begun to completely embrace RFID. The Food and Drug Administration in the US has been advising pharmaceutical companies and distributors to begin to tag their products to combat drug counterfeiting. Within hospitals, RFID is used to track physical assets, such as expensive medical equipment, and organic supplies.

Massachusetts General Hospital in Boston is looking at RFID as a way to make sure blood slated for transfusion gets to the proper patient. According to the co-director of blood transfusion service at the hospital, Dr. Dzik, the risk of transfusion of blood to the wrong patient is more than 100 times greater than the risk of transmitting an infectious disease

through a blood transfusion. The hospital is working with wristband supplier Precision Dynamics and software maker Lattice to develop an RFID based solution to the problem of transfusion error in operating rooms (Bednarz, 2004).

According to the report, active RFID applications in hospitals, which can be tracked on an RFID network, were much more popular than passive RFID networks, which require a nearby reader.

4.2.6. Human Implants

In August 1998 Kevin Warwick from the Department of Cybernetics at the University of Reading, implanted himself with an RFID chip. This was the first time ever that a human was implanted. He used the implant for nine days and was able to get it to open doors and turn on lights automatically for him (Warwick, 2000).

In 2004, the U.S. Food and Drug Administration approved the first human implantable chip, made by VeriChip Corporation of Delray Beach, Florida, USA. It can be put to numerous uses including information storage, personal identification, medical history, medications, allergies, and contact information. According to VeriChip, 2,000 RFID chips have been sold for implantation in humans as of January 2008. About 400 patients, including those with Alzheimer's disease, have RFIDs implanted.

VeriChip human implants have also been used by a Spanish nightclub to allow VIPs with implanted chips to bypass entrance lines and by the Mexico attorney general's staff to safeguard identity information at a time when the kidnapping of government officials there is not uncommon (Shtuhl, 2008). Some customers are simply using them as high-tech keys.

One of the medical uses is for patients who are unconscious. The RFID implant links the chip to their medical record in a way that allows them to be treated without anyone being there to tell the doctors what is wrong. Indonesia's Papua province has passed a bylaw that requires some HIV/AIDS patients to be implanted with RFID chips in a bid to prevent them from infecting others.

4.2.7. Asset Management

Many companies have started to use RFID in asset management. The RFID system for asset management can be built and designed to:

- Track people or assets, control their movements
- Restrict access to unauthorized areas
- Record reporting time and attendance as well as report violations in real time
- Immediate stock keeping of inventory

This benefits the business in many ways:

- Using the tags to monitor attendance of staff and contractors ensures facilities meet employee needs and provide them with sufficient resources.
- Staff can use ID tags to sign in to use machinery and access restricted areas. This can help to comply with Health and Safety regulations.
- RFID tags are also a very useful security tool as it can be known at all times how many people are in the building and where they are located.

These systems have been used by Accor Hotels, Heerema Marine Contractors, Plukon Poultry Manufacturing, Thames Valley University, and Heathrow airport among others (Moy, 2006).

Airlines have also moved to RFID for asset management to track parts and improve safety. The two airplane manufacturing giants, Airbus and Boeing, have been working together since 2003 to use RFID to support the process of maintenance and repair of aircraft parts. This resulted in the inclusion of RFID in the manufacturing process itself, attaching a RFID to each part used. Each tagged part carries key information about its ownership and maintenance history. This has helped speed up aircraft repairs, reduce delays, and improve the overall safety of each aircraft (Mari, 2008). "These tags will allow ground crews to check the remaining life span of parts without having to open access panels or do visual inspection," said Kenneth Porad, program manager, automated identification program at Boeing. In the past airline ground crew members had to inspect parts and check serial numbers visually. To find out when a certain part was last inspected, personnel had to look up written records. This process has become extremely efficient now due to RFID.

4.2.8. Animal Identification

Electronic animal identification is crucial in identifying animals for

- Management
- Food safety
- Disease control
- Recovery purposes

Mandatory identification is in place in the more progressive countries throughout the world, and is evolving in other countries, as the impact of food safety and traceability starts to impact them (BusinessWire, 2007).

Inventory management has been the motivating factor behind animal tracking with RFID technology. Having exact data of the number and location of stock at all times, allows livestock producers like ranchers to optimize the livestock's value. RFID technology helps ranchers round up stock more efficiently, provide feed and water at optimal locations when necessary, and even handle some basic health monitoring such as the frequency with which animals visit feeding stations. For example a decrease in frequency can be interpreted as indication of illness in the animal (Texas Instruments, 2009).

RFID technology is being vastly deployed at automated feeding stations and in slaughterhouses. So now the animal's carcass can be accounted for well down in the segments of the retail chain. Import and export considerations can also be monitored to assure customs authorities that the animal did not suffer from a disease.

RFID technology is a valuable wildlife conservation tool. By attaching RFID tags to animals and birds, agencies can:

- Track migration patterns
- Monitor population growth or decline
- Evaluate breeding locations.

Even domesticated pets can benefit from RFID tags that make the chances of a happy return to its family much greater when a pet is lost (RFID Tribe, 2009).

The US Secretary of the Department of Agriculture (USDA) announced plans for the universal tagging of livestock in the US with RFID chips in 2007. This also encompassed

implementation of various databases. It has been voluntary up until recently, but it is expected to be universal by the end of 2009.

The USDA has also started their 'Animal Trace Processing System', commonly known as the 'metadata system'. This system allows state and federal animal health officials to query the National Animal Identification System (NAIS) and private databases during a disease investigation. The animal tracking databases will record and store animal movement tracking information for livestock that state and federal animal health officials will query for animals of interest in a disease investigation (USDA, 2007).

4.2.9. Museums

Museums are home to some of the priceless and very costly artifacts from the beginning of human civilization. Till now it took numerous security guards and a combination of sensors to keep artifacts safe. But with RFID sensor technology, museums have been able to eliminate a substantial amount of overhead staff and security systems, thus saving a lot of money.

A perfect example of an RFID pilot is at the Museo delle Origini (Museum of the Origins of Man) in Rome. The museum has implemented this technology in collaboration with Oracle and Intel to create an environment it calls Wi-Art. The need for museum guides no longer exists as information about its exhibits is automatically transferred to visitors' handheld PDAs as they approach. Relevant information is stored in an RFID tag attached to each exhibit, and is automatically displayed on the screen of a PDA equipped with an RFID tag reader when the PDA comes into range (Holloway, 2007).

Text to speech technology allows information to be 'spoken' to visitors with impaired vision. The information ranges from descriptive text profiles to audio and video clips. All the data had been previously compiled by the museum and stored in an Oracle database. The new system allows the museum to make more information accessible to visitors than had been unavailable previously, enhancing the quality and educational capacity of each museum visit. The system improves the accuracy of the classification process of archaeological finds.

A similar system is also being used in Germany at Mulenhof Museum in Munich, it now features an interactive multimedia exhibit based on RFID technology, thanks to a partnership between the Munster School of Business Administration and Economics and electronics producer Elatec. When someone approaches a reader using a museum issued PDA with an integrated RFID reader, the PDA plays multimedia content associated with the exhibit. In addition to offering visitors an enhanced museum experience, system allows the museum to compile and analyze data such as how long a visitor spends at each exhibit. This data can help the museum plan future exhibits to better suit their audience's interest (RFID News, 2008).

RFID are being used to track and trace collections when they are moved and also to protect them when in storage. Art security is now a major issue for RFID, and so ISIS corportation a maker of RFID has worked with one of the world's leading galleries to develop a wireless, real-time, automated tracking, audit and art alarm system specifically for the art market. The application is active during the day when intruder alarm systems are deactivated. Tags, attached to works of art, are in constant radio communication with sensors located out of sight on visitors in the protected areas. The tags have different functionality depending on the piece and its location. Tags for art on display contain vibration sensors, giving security

controllers specific user-configurable information about any incident as it happens. The software can be programmed to trigger any number of third party devices via the ISIS I/O unit, such as CCTV, audio-visual alarms, alpha-numeric pagers, door control or off-site monitoring (Holloway, 2007).

The Tech Museum of Innovation (The Tech) in San Jose, California implemented low cost RFID wristbands manufactured by Hitachi on March 29, 2005. It is the first museum to use disposable RFID wristbands as part of its interactive exhibits. Visitors receive TechTags, pre-encoded readable wristbands, upon entering the museum's galleries. During their experience in the museum, visitors wave their wristbands in front of RFID readers at select exhibits to trigger various interactive experiences (Hitachi, 2005).

4.2.10. Libraries

The adoption of RFID technology by libraries promises a solution that could drastically lessen the time taken by libraries for activities ranging from adding a book to the library to issuing and depositing it. By using RFID it is possible to inventory hundreds of thousands of items in their collections in days instead of months. In addition, it would allow library goers to check out and return library property automatically at any time of the day. Besides better keeping collections in order and speeding up checkouts, RFID promises to provide a better control on no returns, theft, and misfilings in the library (Singh, Brar, Fong, 2006).

3M has built a state-of-the-art RFID based collection management system for the business library. They have named it the "electronic self-checkout system". The system places "tags" inside each book. Now, students and faculty can check books with a single swipe of their RFID enabled Library cards. According to 3M, 2% of libraries in the U.S. use some form of

RFID, and 8% worldwide. One such library is at the University of Guelph, in Ontario, Canada, which has had their books tagged since at least 1991 (RFID Gazette, 2006).

TAGSYS corporation of the United States has designed a WiFi enabled handheld, item-level RFID reader to for inventory tracking and management for libraries. The new reader provides fast, accurate and secure tracking of books, periodicals, DVDs, CDs, documents, and other media. The WiFi supported item level RFID reader all together interrogates multiple items very quickly. The library's host computer or PDA receives data via WiFi. The reader is portable and can be easily carried with a shoulder belt.

Bentley College in the United States has spent $16 million on renovating its business library. One of the renovations included adding an RFID component to the system in 2006. Bentley College is one of the few academic libraries in the United States, which has converted its entire collection to RFID (RFID Gazette, 2006).

The New Orleans Public Library had all of its branches damaged by Hurricane Katrina in late 2005. The Alvar branch was completely rebuilt, out of necessity. Its reopening was marked by RFID tags on all of its CDs, DVDs and books. The new system allows customers to check out items at new checkout stations by themselves.

New Orlean's RFID implementation is small in comparison to Shenzhen's new public library in China. The huge library is over half a million square feet and has 2 million books tagged. Tagsys was also involved in this project, as well as for Seattle's Public Library. Seattle's RFID library project is the largest in the world, with Shenzhen's second.

The Twin Lakes Public Library in central Georgia has deployed the RFID based Intelligent Library System developed by Checkpoint Systems. This system has improved collection security and registers 99% of the books exiting the library doors as against the previous system which registered only 33% of the books that were taken out of the library (RFID Gazette, 2006).

4.2.11. Schools

One of the most important uses that RFID is being put to is in school. RFID tags are used to keep track of the children who are prone to harms way. Thus putting RFID tags on each child's dress as part of school identification card can be used to monitor the location of children at all times. This presented an ideal solution to the schools concerned with student's security. Now they can track the student from the time he leaves home or enters the school to time he reaches back home or leaves the school. More and more schools are implementing it.

Enterprise Charter School in Buffalo New York started using RFID to track students in 2003. The charter school's 422 students wear small plastic cards around their necks that have their photos, name and grade printed, along with an embedded RFID chip. As the children enter the school, they approach a kiosk where a reader activates the chip's signal and displays their photograph. The students touch their picture, and the time of their entry into the building is recorded in a database. A school staffer oversees the check-in process. The school spent $25,000 on the ID system. The $3 ID tags students wear around their necks at all times (Scheeres, 2003).

In 2005, at Brittan Elementary School officials in Sutter, a rural farming community, the tags have been implemented to simplify attendance-taking and reduce vandalism. In addition to

tracking students in classrooms, the school's principal wants them tracked in bathrooms and locker rooms (Perton, 2005).

In 2007 a pilot program started with ten schoolchildren enrolled at Hungerhill School in Edenthorpe, England, a secondary school for ages 11 to 16 are being tracked by RFID chips in their school uniforms as part of a pilot program. The program proved successful as a way to hasten registration, simplify data entry for the school's behavioral reporting system, and ensure attendance (Claburn, 2007).

Seattle based Zonar Systems is providing RFID technology to the school bus industry. The drivers are issued a unique RFID card that can be kept anywhere on their person, such as in a backpack, purse or wallet-it need not be visible. As the student passes the card reader upon entering or exiting the bus, the time, date, and location are logged and transmitted to a secure database. The school system can then access the information from any web browser. John Harris, Transportation Supervisor for the Quincy, WA school system said, "It's all about the safety of the children entrusted to our care. We are installing it now in our buses and the initial experience has been good. It builds extra confidence and parents like it."

Ray Trejo, Director of Transportation for the Demming, New Mexico public schools said about their RFID system, "ZPass complements the security that already exists inside the school building by making sure we know where students are from the time they are picked up at their bus stop until they are dropped off at the end of the school day." (RFID News, 2008).

4.2.12. Prisons

Managing correctional populations is challenging and expensive. One promising approach to assist in cost reduction is using active RFID technology. Using RFID tagged wrist or ankle bands, RFID technology has also been introduced into correctional institutions. The technology provides real-time, centralized monitoring of inmate locations and movements throughout correctional institutions. Parameters can be set for each individual wrist or ankle band to trigger an alert when its wearer moves into an unauthorized area or comes near inmates wearing specifically designated wrist or ankle bands. RFID devices may also be worn by correctional officers and staff. These units allow real time monitoring of staff location and come enabled with a manual alarm function that staff can use to alert a central monitoring station of an immediate need for assistance (Reza, 2004).

RFID inmate tracking is already used in a many European countries including Sweden and Holland, as well as U.S. institutions in Michigan, California, and Illinois. As of 2008 all of the Australian Capital Territory has outfitted their prisons with RFID inmate tracking (Browne, 2008).

RFID was first used in the US in 1997 at California State Prison at Corcoran to track staff whereabouts and increase their safety (NIJ, 2007). In the year 2000, California's Calipatria State Prison was the first jail in the United States to install an RFID tracking system for inmate use. Since then, jails in in other states have followed with bracelets for approximately 3,000 inmates nationwide. The RFID bracelet is encoded with the same ID number used on the bracelet's bar code. The inmate's ID number and personal information is entered into the database along with a particular profile that would then restricts them to certain parts of the jail. No inmates have attempted to escape or tamper with their bracelets in the jails where the system has been deployed (Swedberg, 2005). Knowing that an alarm would be activated if

the bracelet is removed or destroyed has worked as a deterrent for inmates. Swedberg (2005) notes that the bracelet includes several built in tamper-proof safeguards. The braided stainless steel wire that runs the length of the bracelet will cause the RFID tag to stop transmitting it is cut. The device also has a sensor that is designed to set off an alarm in 15 seconds if it loses contact to skin.

In November of 2008 a study was done by the National Institute of Justice in the US and the findings noted that RFID in prisons has been able to:

- Improve Monitoring and Control of Inmates/Reduced Staff Time
- Reduce Actual and Attempted Escapes
- Reduce Number of Investigations and Improve Investigative Capabilities
- Reduce Inmate Grievances, Disciplinary Actions, and Lawsuits

Expansion of RFID usage has continued, in June of 2008, it was announced that Alanco/TSI Prism, a provider of real-time RFID tracking technologies, had won a $3.3 million contract to create an RFID based inmate tracking system for the Washington D.C. Department of Corrections. The system, which will be installed at a Washington DC jail complex housing over 2,000 prisoners and staffed by 450 Department of Corrections employees. (Reuters, 2008)

4.2.13. Access Cards

Some of the applications of RFID are found in devices that many people use on a daily basis almost unknowingly. The access card that employees use to gain access to their work place,

a restricted area, or ones apartment building employs RFID technology. Its ubiquity can be estimated by finding inclusion of RFID in the most trivial daily activities. When one uses the EZPass on the New Jersey turnpike to pay a toll without stopping, that person is using an RFID device, which communicates with the tollbooth. When someone uses their Speedpass, a small tag on their key chain, to pay for gas and/or snacks at Exxon and Mobil gas stations, Stop and Shop or McDonalds in the United States, they are using RFID.

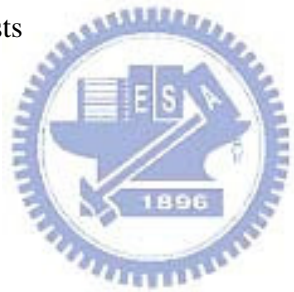
When accessing university buildings, such as National Chiao Tung University, after hours, that person can only gain entry with an RFID enabled card. There are so many RFID chips in use for access cards that one computer hack alone in 2008 on the Mifare Classic RFID chip algorithm caused concern for one billion access cards to be updated for security (Mah, 2008).

As of April 2005 1.8 billion RFID tags had been sold worldwide, with the heaviest volume applications for the technology being in markets such as access cards for the financial, security and safety markets, and for the automotive and passenger transport sector (UsingRFID.com, 2005). Since then sales have accelerated even faster. By early 2007 a total of 3.752 billion RFID tags have been sold worldwide, 27 percent in 2006 alone, that figure is expected to soar to 33 billion reports InStat (Mumford, 2006)which equates to 1.02 billion with 35 percent being those being RFID access cards (Electrical Contractor, 2007)

5. RFID Challenges - Problems in RFID Adoption

After going through the uses that RFID systems have been applied to and can be applied is compelling enough to make the whole world welcome RFID. But this technology becomes dangerous whenever the binding between the tag and its context of use is in doubt. This situation is identical to Social Security numbers, which are themselves useful as identifiers but not as authenticators, with a wide range of proven abuses. As done throughout the paper, we first enumerate the problems and then take them one at a time and present a detailed analysis. The problems are:

1. Tag Frequency
2. Tagging Strategies
3. Tag and Infrastructure Costs
4. Consumer Fears
5. Standards
6. Data Sharing
7. Distribution-Network Alignments
8. Patent Challenges
9. Material Effects on transmission



5.1. Tag Frequency

Difference between radio transmission frequencies is significant hurdle to broader RFID implementation worldwide. The United States favors UHF at 915 MHz, while Europeans favor UHF at 868 MHz. But in China, the government did not accepted UHF bands until 2007 when China's State Radio Regulation Committee (SRRC) approved bandwidth in the

840.25 to 844.75 MHz and 920.25 to 924.75 MHz ranges for use by UHF RFID tags and interrogators in that country (Swedberg, 2007)

In Japan, the standard for UHF is at 950-956 MHz, a frequency that can often create interference with cell phone operation, and is higher than the bands allotted in the United States and Europe (Fish and Forrest, 2007).

As mentioned UHF RFID operates in 902-928 MHz in the United States. This is primarily because the GSM range on the United States is not in this range. On the other hand it operates in 860-868 MHz in Europe and 920 to 926 MHz in Australia. Thus, in order to achieve a globally visible supply chain the tags should operate well across all the UHF RFID frequencies notes Ramakrishnan (2005).

Compromise solutions appear to still be many years away. Earlier, the diverging concepts meant that companies were looking at installing additional readers, platforms, middleware, software, and potentially at costlier tags to handle the different frequencies as products and their associated tags crossed borders (Fish and Forrest, 2007).

The problem deepens with the technical implications of variations in frequency. For example- a 2.45 GHz interrogator in the US operates at a power level that is a hundred times more than what is legally permissible in Europe. This affects the read range of the reader. In Japan, tags used for freight tracking can only operate with a frequency of 2.45 GHz; this gives them a range of several meters. A 900 MHz UHF tag used for tracking purposes in the US has a read range of 10 meters (RFID Gazette, 2008)

Part 15 of the FCC's rules for low-powered devices deals with RFID regulations. RFID devices are referred to as "intentional radiators". RFID devices have to meet the RF emissions limitations and power restrictions as laid down by the FCC (RFID Gazette, 2005).

5.2. Tagging Strategies

In the consumer products market, tagging worldwide has shown decisively different focuses of use by varying regions of the world. This difference in focus and well as frequency operation differences has continued to hamper the ability to focus on RFID as a global alternative to the UPC code.

Even though RFID has still to gain wide currency, a number of bills have been introduced by the U.S. federal government concerning consumer privacy. In Europe, several laws have already been passed that need RFID-tagged products to carry a label informing this fact and that consumer data can be gathered only after the consumer has been informed and their consent is necessary for using that data (RFID Gazette, 2008)

Further before initiating business abroad, RFID vendors should understand the regulatory implications from the concerned agencies; these are the European Radio Communications Office (ERO) and the European Telecommunications Standard Institute (ETSI) in Europe, the Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT) in Japan, and the Standardization Administration of China (SAC) in China. This leads to a chaotic scenario for any company willing to enter on a global or inter-regional scale (RFID Gazette, 2005).

In the United States the very way products are tagged differs from that of other countries. The United States Department of Defense (DoD) as well as large retail leaders in the US such as Albertsons, Target, Best Buy, Wal-Mart and Sam's Club (which is owned by Wal-Mart) are focusied on becoming compliant for case and pallet tagging by their suppliers (RFID News, 2008). Whereas Europeans have been working to use RFID for item level tagging. Also, European companies have chosen to concentrate on tagging products where the theft rate is high in relation to the product value. They have been able to do this as they have been generally more successful in educating consumers about any concerns over information data privacy. Metro, the world's fifth-largest retailer and Germany's largest retailer, has clearly articulated a mandate that is very similar to Wal-Mart's for RFID but at item level (Trebilcock, 2007). The problem with the various tagging strategies is that many of these retailers share the same suppliers thereby making the process extremely complicated.

5.3 Tag and Infrastructure Costs

One of the most significant impediments to a quicker adoption worldwide of RFID tags and systems have been the cost. Tag costs are typically not quoted by manufacturers since the total cost depends upon volumes purchased and on the capability and reach of the tags themselves. Yet, with the lowering of costs over the past decade RFID tagging is still expected to cost the suppliers roughly 20 times more than the bar coding system now in place, according to RFID News (2008).

According to Fish and Forrest (2007), in the U.S., the average retailer spends more than $500,000 for RFID hardware and software, including chips, inserts, printers, tags, antennae, readers, data aggregations and filtering systems, middleware, and directory services. Webster (2008) estimates that smaller companies will have to invest $100,000 to $300,000, while the

price tag for a large manufacturer could hit $20 million. However, the changeover offers the retailer major benefits. It is estimated that the introduction of RFID technology to Wal-Mart's supply chain will save the company up to $8.35 billion annually as well quickly providing important product information. As for consumer packaged goods, the lower margins and higher volume of most consumer packaged goods do not easily allow for the expense of RFID on an item-level basis.

Most UHF readers cost from $500 to $2,000, depending on the features in the device. Companies may also have to buy each antenna separately, along with cables. Antennae are about $250 and up. The price of readers is expected to fall as companies purchase them in large volumes. Low and high frequency readers range in price, depending on different factors. A low frequency reader model (a circuit board that can be put into another device) can be under $100, while a fully functional standalone reader can be $750. High frequency reader modules are typically $200 to $300. A standalone reader can be about $500 (RFID Journal, 2009).

At present, RFID tags cost anywhere from about 5 cents to $40, possibly more, depending on tag type and use. However, to get the cheaper tags, which are typically passive and suited to item-level tagging, they have to be purchased in massive volumes due to costs of manufacturing tags. So at present, most retailers and suppliers feel no need to adopt this technology that will likely eat their margins. This is true even in the pharmaceutical industry, where specific drugs are supposed to now be item-level tagged by law in the United States (RFID Gazette, 2007). The chief question is whether businesses are ready to spend big on new technology again, after reining in budgets in recent years and watching flaky dot-coms go under, according to Sarah Friar, vice president of Goldman Sachs (Gilbert, 2004).

5.4 Distribution-Network Alignments

Various regions possess markedly different distribution-network strategies, which can dramatically impact stock levels and result in mismatch in global manufacturing chain. European producers use more direct shipments to stores than their American counterparts do. Asian retailers possess networks of suppliers that enable them to source great portions of their commodity from local suppliers. China struggles with dispersing shipments inland, and the price of property continues to drive the type of distribution networks originated in Japan and on China's coastline.

North American companies face the greatest challenges in reducing stockouts, because their supply chains are lengthy, and their producers are generally located outside of the continent. This can simply be seen statistically. In 2007, China became the largest importer of goods into the U.S. surpassing Canada. Chinese imports were $325 billion in 2007 and are expected to be $728 billion by 2012 (Turner, 2008).

Merchandise is first shipped to large distribution centers and then to local stores. For example, Wal-Mart's Chinese suppliers, which supply sixty-five percent of the retailer's non-food merchandise, ship across the Pacific Ocean to centralized DCs (Johnson and Hall 2007). Compounding their distribution network issues, North American companies normally receive scheduled deliveries. In the future, U.S. retailers may be required to switch from daily delivery schedules to more flexible schedules, possibly using smaller DCs and enlarging their cross-docking initiatives.

RFID technology is still in a nascent stage as far as the retail marketplace is concerned. Supply chain managers will need to assess their distribution networks. Managers are expected to balance the costs connected with their distribution networks against customer satisfaction. This is crucial in order to render the correct goods at the correct places in the correct quantities at the correct times.

5.5. Consumer Fears

RFID also comes with some potential dangers. Juels, Rivest, Szydlo (2003) state that the impending ubiquity of RFID tags also poses a potentially widespread threat to consumer privacy. The privacy concern is especially a concern in the wealthy American market. Subduing these concerns remains to large hurdle for RFID advocates.

The simplest RFID tag would broadcast its ID serial number, that is, its electronic product code to any nearby reader. Industry analyst say RFID would infringe on customers' privacy by broadcasting. For example, clothing designer Benetton plans to weave radio frequency ID chips into its garments to track its clothes worldwide (Batista, 2003). “Benetton has thousands of retail outlets worldwide and therefore wanted to put in place a future-proof technology to bring clear cost benefits to the business whilst seamlessly enabling garments to be tracked throughout their lifetime," said Terry Phipps, electronic data processing director at the Benetton Group (RFID News, 2003).

Privacy advocates fear that consumers will be bombarded with intrusive advertising since a history of customers' purchases and their identities, along with other information would be linked with the tag even after they leave the store (Batista, 2003). These fears of privacy invasion have made many people weary of the idea of introducing this technology.

In 2006, Juels and Weis examined several published systems of RFID that failed to fulfill their privacy definition. In doing so, they were able to highlight potential design flaws with current RFID chips, which could lead to easily stolen information.

Consumer advocates, including the Electronic Frontier Foundation, the Electronic Privacy Information Center, and CASPIAN, jointly released the *Position Statement on the Use of RFID on Consumer Products* in 2003 (Privacy Rights ClearingHouse, 2003). A bill that would impose strict limits on California's use of tags in state-issued identity documents has also been proposed (ZDNet, 2007).

The current generation of RFID technology is vulnerable to eavesdropping, cloning and forging. Consumer advocates claim the "privacy implications are too dangerous to ignore. Imagine a world in which every item you purchase has an embedded RFID tag," the report said. "When you buy the item, your entire inventory of purchases can be stored in a central database. Advertisers could track your spending habits. When you wear the tagged clothing, you can be tracked and profiled as you travel through strategically placed scanners," it said. (McAfee, 2007)

Corporations and governments also have found that private citizens are not the only ones that need to have some concern. In March of 2008 it was confirmed by two independent research teams that there had been hacks of the Mifare Classic RFID chip algorithm, which possibly could have security effects on up to one billion RFID chips used for access cards. The Dutch government issued a public warning about the security of access keys based on it. The minister of interior affairs, in a letter to parliament, wrote that there are plans for government

institutions to take “additional security measures to safeguard security.” The hack was a very serious matter as the technology is used by transit operators in London, Boston, and the Netherlands. It is also used in access cards in numerous other organizations around the world (Mah, 2008).

5.6 Standards

The United States and Europe have long worked jointly on a common RFID standard; while China and Japan each developed their own standards within their country. International standards have however been adopted for some very specific applications, such as for tracking animals and for smart cards, which require encryption to keep the data secure.

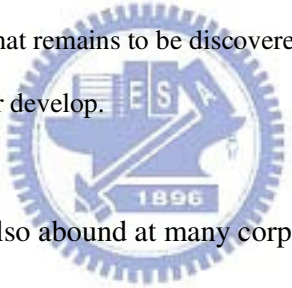
EPCglobal, a joint venture set up to commercialize Electronic Product Code technologies, has its own standards process, which was used to create bar code standards. The EPCglobal standard, which was designed with the end users' performance requirements in mind, is a short but unique number that allows for global interoperability and enables supply chain members to encode data in a similar manner.

According to the industry watchers, the absence of a global standard for RFID deployment has resulted in interoperability issues and a technology that is still too expensive to acquire. For the retail sector, it seems, while RFID may generate a lot of enthusiasm, it doesn't seem to be generating many concrete rollout plans. Only 5 percent of retail companies surveyed are planning to implement the technology within the next three to six months.
(CNET, 2007)

5.7 Data Sharing

While U.S. and European companies favor ongoing use of EPCglobal's Network, it is improbable that China will grant foreign companies access to RFID data because administrative officials there believe that anyone could analyze factors such as China's industrialized production, capability, and merchandise manufacturing locations in real-time. According to Harmon and Downey (2005) statements and actions by Chinese officials indicate that China intends to chart its own course, not necessarily in line with the recently developed "international" standards. Given China's growing economic clout and cohesion with other East Asian countries, nonconformity may lead to a proliferation of regional standards that limit the use of RFID or force the creation of a complicated set of translating interfaces between different "standards."

Companies have found a way around the data-sharing subject by arranging dedicated common platforms between trading bodies. What remains to be discovered is whether a truly common global database that includes China will ever develop.



Technical questions about RFID also abound at many corporations. What do companies need to do to handle the onslaught of data RFID systems are expected to generate and how can companies incorporate RFID with other business systems that monitor inventory? Goldman Sachs' Friar said many big names in computer technology have yet to figure it out, despite pitching new RFID products and services. IBM, Hewlett-Packard, Microsoft and Sun Microsystems all unveiled new RFID efforts this week in conjunction with the conference. (CNETNews, 2006)

5.8 Patent Issues

The idea of a patent pool has been around since August 2002, when the Auto-ID Center published an executive briefing paper that proposed the creation of a patent pool as a way to

reduce the chance that adoption of Electronic Product Code technologies would be slowed by law suits over patents. There has been a tremendous amount of confusion about what the decision by Intermec Technologies to charge royalties for the use of its more than 140 RFID patents might mean for the future of Electronic Product Code technologies (RFID Journal, 2007).

Intermec, based in Everett, Wash., says it has contributed technology protected by a dozen patents, and does not intend to provide all of the intellectual property royalty-free. "It's not our intention to give away our innovation and IP," Mike Wills, vice president and general manager of Intermec, said.

The possibility of having to license technology used in the Gen 2 standard is significant because vendors have been struggling to reduce the per-unit cost of electronic tags, a key component of RFID, or radio-frequency identification, technology. The price of electronic tags used to track supply-chain goods could swell if a key standard in RFID, winds up including royalties (Gonsalves, 2009).

It could possibly lead to patent wars and ultimately the curve of RFID growth would be rendered flat. This patent problem has recently hit the RFID industry after its rapid growth. Thus it is one of the recent problems for which solutions are yet to be found by the RFID manufacturers.

RFID security device manufacturer HID is using threats of patent infringement to stifle a Black Hat Federal presentation by Chris Paget on the threat of RFID card cloning. The risks of RFID card cloning are real and are nothing new. The details of the technology have been

publicly available for years. What is new is the visceral demonstration that a device can provide. HID is scared that people will stop purchasing their technology once it is widely known that it is not secure. This shows the power of security researchers to get the word out where more academic presentations and low profile websites have failed (Granick, 2007).

5.9 Material Effects on Transmission

These are the inherited limitations in the RFID devices on the account of raw material used in their components. They pose a threat to the universally usability of the RFID device since RFID devices fabricated out of same material cannot work everywhere for the same range.

It is a well-known fact that conventional electric dipole RFID label antennas will not work when placed against a metal or liquid surface. So some vendors have introduced metal and water friendly RFID tags, but they tend to be expensive and bulky or are designed for a particular application (Code and Hu, 2009).

Freshpatents (2008) states "RFID tags in the presence of metals and liquids may experience detuning due to absorption or parasitic capacitance provided by these materials. So tags for shipping and freight and metal containers are needed to be made of a robust material or better technology that can overcome the effect of metals and liquids."

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While RFID systems have become quite common in everyday life, metal poses a unique challenge to their effective operation. RFID tags are designed to efficiently receive energy transmitted from the reader. Since a passive RFID tag has no power source, it must derive all its power from the incoming wave. If this energy is not transferred to the chip efficiently, the chip will not power up and the tag won't be read (MicrWave Journal, 2008).

DoD Explosives Safety Board (DDESB) has limited the use of RFID for explosives and munitions transport due to DoD Ammunition and Explosives Safety Standards having not been 100% met (MERC Online, 2009). More testing will be needed before it can be assured that the radio frequencies will not ignite the material.

6. Conclusions and Recommendations

RFID was first identified in 1948. Then it was a topic of research, a technology that holds some unidentified future prospects. In 1970 it was given first commercial usage in form of animal tagging and vehicle tracking on selective toll roads. Still it was futuristic and researchers were still wondering where it could be used and what purposes it could serve.

It took the revolution in the computer industry and the advent concept of embedded devices to develop the technology which further developed software that could tap the potential of RFID hardware. Finally, the usage of RFID technology by a market giant like Wal-Mart took the world by storm. Since then RFID technology has seen a rapid rise in usage and the number of areas in which RFID technology can be used.

The primary reason for the popularity of RFID is that it is a very simple device in terms of hardware. It has just three components namely tag or transponder, interrogator or reader and antenna. It is only through tag that information can be stored to or retrieved from the RFID. The reader is a device to read information from the tag. It knows how to access and convert data stored on the reader in some representable format. The antenna is the medium by which reader is able to detect a tag and read data from the tag.

Apart from the physical components, RFID devices are rendered versatile by software from companies like Oracle, SAP and now Microsoft that make RFID store more data both in terms of content and amount, as well as make RFID readers more powerful. With the advent of a separate field of data warehousing RFID can be used to manage and track large quantities of product dispersed as far as the opposite corners of globe.

The uses that RFID has been put to are numerous across vast numbers of domains. On one hand, the access cards enable a passenger to access trains, or an office without having to carry cash or papers. On the other, the U.S. Navy uses them to monitor the temperature, humidity and pressure of containers storing aircraft parts, HP labs uses them to monitor the temperature of the servers and NASA aims to guide firefighters and astronauts from space to their needed places.

The growth in usage has been distributed over various regions of globe. In the USA both the government and private sector have used and mandated the use of RFID tags in certain areas. Be it WalMart or DoD, both have been active proponents of the technology by adopting it. Europe has seen the popularity of item level tagging. Metro, Germany's largest and world's fifth largest retailer, Mark and Spencer, and Tesco have been leading the revolution in the European industrial marketplace which is rapidly absorbing item level tagging, as a core infrastructure. Australia has emulated the path of Europe. Leading Australian companies like Capilano Honey, P&G, ACCO and MasterFoods have been using pallet and item counting programs. Canada has been successfully using RFID for real time tracking. Asia and Latin America have been slow in using RFID but now at both places are beginning. Its popularity is increasing.

Coming to Logistics and Transportation, the RFID tags have been used by airports like Heathrow and McCarran The IATA has adopted RFID and are successfully using it for luggage tracking. Shipping freight and yard management started to use RFID after the development of RFID devices that can withstand rough handling. Railways and transportation payment have seen rise in the usage of RFID to track goods, vehicles, etc.

Countries like Malaysia, USA and Britain have successfully launched RFID based passports. RFID has been helped in monitoring precise race finish times. Hospitals have used RFID to do real time tracking of their equipment and to ensure proper blood transfusions. Human implants of RFID chips are being used for personal identification for medical records, entrance into clubs, etc.

As we have seen the adoption of RFID has been widespread and balanced across some regions of globe while others have yet to really begin testing. The uses range from commonplace smart cards relieving people of the need to carry cash and other documents to monitoring temperatures in oil factories and server rooms. Logistics and transportation have used RFID to significantly reduce their cost of operation and maintenance. Same hold true for asset management, museums, libraries and prisons. RFID technology, due to easing ability of deployment and maintenance has been the primary choice to keep track of location of both the important assets in asset management and animal tracking or important persons through human implants or tags for children going to school.

Despite being such a versatile technology in terms of number of application areas, RFID has had tough time in being as widely accepted as any other similar contemporary technology could have been. The difference is tag frequency standards (Swedberg, 2007) worldwide have continuously thwarted the attempts to globalize standards for an RFID device. Adding to the woes of RFID are the further different tagging strategies being followed by different regions, like America going for case level tagging (DoD), while the focus in Europe and Australia is on item level tagging.

Though a lot of progress has been made to lower the cost of RFID readers and tags, the UHF reader still cost between $500 to $2000 (RFID Magazine, 2009). RFID tags still cost anywhere from about 5 cents to $40 with the restriction that the cheaper tags have to be purchased in massive volumes due to the costs of manufacturing tags (RFID Gazette, 2007).

The problem of regional variations in strategies and usage of RFID hampers its global adoption at various levels. Another area where the variations in global standards resurface as a major challenge is distribution-network alignments. European producers use more direct shipments to stores than their American counterparts, while China struggles in dispersing shipments inland. China has now became largest importer of goods to USA (Turner, 2008) and will need to use RFID to optimize long supply chain procedures.

Yet another major challenge coincides with a test in 2006, Juels and Weis were able to highlight potential design flaws with current RFID chips, which could lead to easily stolen information. Tagged clothing introduced by Benetton (Batista, 2003) could be used to track and profile you as you travel through strategically placed scanners (McAfee, 2007). Absence of any universal standards among the nations has never allowed RFID to truly expand its horizon. The absence of a global standard for RFID deployment has resulted in interoperability issues and a technology that is still too expensive to acquire (CNET, 2007).

China's stubbornness to have its own course if it so chooses (Harmon and Downey 2005), could lead to regional data standards with complex translation rules. Goldman Sachs' Friar says that many big names in computer technology have yet to figure it out, despite pitching new RFID products and services (CNET, 2007).

The patent wars have been initiated with the decision of Intermec to patent its 140 odd technologies being used in RFID (RFID Journal, 2005) and refusing to join the consortium of patent sharing companies. It could lead to an increase in already high price of RFID components (Gonsalves, 2009). Further an implicit limitation is tag material to have different read ranges in different environments. RFID material made RFID tags universally usable with the Gen 2 harsh environment tags. Now tags could be put even in salt water, alcohol, oil, 10% HCl and ammonia for as long as 100 hours (Pressreleasepoint, 2009).

The good part is that despite all these challenges, the potential of RFID technology continues to bring in giants like Microsoft, Oracle and SAP to develop software and specialized components of the technology. Their name alone vouches for the technology. Some quoted the entrance of Microsoft in the field of RFID with its Biztalk server in 2007 as a 'Watershed Moment in history of RFID (RFID Update, 2008). "By entering the market with its own BizTalk RFID software, Microsoft could help kick off a wave of adoption, by helping to standardize technology and reduce cost," said B. Robert Helm (RFID Update, 2007).

The RFID devices have seen a steep fall in price and a vertical rise in performance in a short time. Gen 2 RFID tags revolutionized the capabilities of RFID tags over its ancestors. They were in demand as soon as they were launched (Fish and Forrest, 2007). "The reader chips had their field day when Intel introduced their reader chip R1000, in 2007" (RFID Update, 2007). It integrated 90 percent of components on one chip, hence smaller and much cheaper, as put by Intel's Krause.

The cost of RFID which had been a large challenge went for a nose dive with entry of Intel's R1000 and Microsoft's BizTalk Server. It is predicted that the savings provided by the R1000

could cut the cost in half or more for reader and software prices (RFID Update, 2007). "The Microsoft BizTalk server being cheaper by a factor of ten puts RFID into reach of every organization", as quoted from Fontanella (RFID Update, 2007). On top of this the Georgia Institute of Technology has come up with a new test bed which allows RFID tags to be tested much faster, cheaply, and more efficiently than ever before, this new process should help lead the development of cheaper tags.

Regional standards always impeded RFID technology to reach its potential at global level. But since July 2006 when the International Standards Organization approved EPCglobal"s second generation, Class 1 protocol standard for RFID devices operating in the UHF band, Gen 2 has become a near global standard (RFID Journal, 2007). Gen-2 RFID readers and tags enable global corporations to use a common RFID reader hardware platform and software in the North American, European, and Asia-Pacific regions (Fish and Forrest, 2007).

China's approval of the two UHF bands, says Craig K. Harmon, can mean it is finally opening its gates to global standards. As RFID reader companies base their products on the Intel's R1000, the core reader technology and functionality will be the same providing a competitive landscape (RFID Update, 2007).

Data sharing among vendors and manufacturers has also been on the rise. European and U.S. companies, including IBM, Microsoft, Wal-Mart, and Tesco, agreed on code standardization and supported a modified EPCglobal UHF Generation 2 standard (RFID Journal, 2007). The RFID Consortium formed in 2006, a group of RFID industry companies holding patents for technologies essential to EPCglobal and ISO/IEC standards has some heavy backers in

companies like 3M and Motorola, this consortium although recent will prove to be a valuable part of the lowering cost of RFID

In April 2007, EPCglobal ratified the Low Level Reader Protocol (LLRP) standard, which would result in is better interoperability (RFIDUpdate, 2007). GRIFS announced in May of 2009, the launch of the first comprehensive online database of international RFID standards.

Thus we find that despite so many hurdles in the way of global adoption, the ubiquity of RFID devices is on the rise. The entry of the Gen 2 tag and Intel's reader chip along with the Microsoft BizTalk server could finally be the push that RFID needed to take off in the global marketplace. Time will only tell if Intel and Microsoft can do for RFID what they did for the PC market but not many are betting against them. While it is not expected that RFID will become immensely popular overnight we can conclude that it has certainly taken hold and will continue to grow at a steady and healthy past. With over 3 billion RFID chips now in circulation the world is just beginning to see the capabilities of this great technology. As it now becomes increasingly streamlined and cheaper to implement we are sure to see further deployment across many industries. Further research is recommended in the following areas:

6.1. Standards and Patents

The RFID standards are progressively becoming globalised and hence interoperable, be it for the components such as tags and readers or data sharing or standards. Various nations and companies are realizing the vast untapped potential that RFID technology can be put to. Progressive steps towards globalization are being taken by both alike. EPCglobal and ISO have worked together to create what appears to be emerging as the global standard for UHF,

then Gen 2 tag. It is important that these two bodies continue to work together to see that RFID continues to gain fluidity globally.

China has been manufacturing tags for the Gen 2 standard and has come around themselves to allocating frequency space in China for the Gen 2 tag, pushing to near certainty that the Gen 2 chip is the new standard globally..

Companies need to be encouraged to promote open standards. Charging royalty for patents, in yet the nascent stages of global adoption of RFID, could lead to a chaotic future and may impede the adoption of RFID. This can be estimated from the fact that the decision of Intermec company to charge royalty for its 140 technologies led to a great confusion in the market among new entrants (RFID Journal, 2007). The RFID Consortium however is currently well positioned to overcome this obstacle.

In this case of patents the Gen 2 chip appears to have overcome most of the barriers imposed by this challenge. Further questions arise as to who will continue to hold the patents for all of the other RFID frequencies and whether or not this will put limitations on the adoption of RFID outside of the UHF spectrum.

6.2. Costs

Costs appear to be finally approaching mass scale prices. The first to begin this trend was the tags themselves. The industry has just started to see the 5 cent tag but in less than a decade that price is now only 10% of what it was in 1999. Over time this price will continue to drop and quality and read rates will go up. The injection of the Intel R1000 and the Microsoft BizTalk server may finally be the push that the industry has been waiting for as these two

giants look to do for the RFID industry what they did for the computer industry which is streamline components and systems, easing interoperability and dramatically lowering prices. It will be important to see over the next few years how corporations have adopted the Intel and Microsoft brands. It will also be important to watch over the coming years to see if companies have adapted the process discovered by the Georgia Institute of Technology with their new test bed for testing tags more cheaply and efficiently than ever before.

6.3. Privacy Concerns

Anything that has been perceived by a human as a threat to its safety and security has been either tamed and controlled in case of natural things or made defunct in case of technology.

Comprehensive countermeasures must combine a variety of viewpoints, legal, social, and technological to address the many potential security threats to the personal data of tens of millions of consumers worldwide (Okhubu and Suzuki, 2005). In order to increase consumer acceptance of RFID technology, RFID advocates must promote and implement comprehensive security measures, along with consumer education, enforcement guidelines, and research in and development of practical security technologies (Levi, 2000). Questions arise as to how consumers will take to RFID if it has a “kill switch” or other methods to try to alleviate fears and whether or not these methods will work.

6.4. Case and Pallet Tagging

Around the globe suppliers will have a difficult task to fill if Wal-Mart wants case and pallet tagging and Metro wants item level tagging if they have overlapping suppliers. Roberts (2006) claims that “at current prices it is not economically viable to incorporate tags into every retail

item" For RFID to grow case and pallet tagging should be introduced first, as tags become cheaper item level can be introduced.

The paper by Rebecca Angeles (2005) reviewed RFID supply chain applications and implementation issues. Her paper found information to support the business case for the adoption of RFID based on her research of trade literature. She stated that the technology promised to offer both process freedoms and near perfect information visibility throughout the supply chain across many different industries. The study by Bottani and Rizzi (2008) found that using an investment analysis that the introduction of RFID at the pallet tagging level provided positive net present value for all types examined. They found manufacturer's distribution centers had the greatest benefits. They found the case level tagging scenarios sometimes had the opposite affect.

This study shows that if pallet tagging can be profitable while case tagging is only profitable sometimes, it is reasonable to conclude that item level tagging would never provide a positive net value. In order to streamline RFID shipping worldwide retail and manufacturers should focus on pallet and case tagging to start and then make the natural progression to item level tagging as it becomes economically viable.

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