HISTORY AND EVOLUTION OF RFID TECHNOLOGY

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"History is more or less bunk. It's tradition. We don't want tradition. We want to live in the present and the only history that is worth a tinker's dam is the history we made today".
Henry Ford, U.S. automobile industrialist (1863-1947),
Interview in ***Chicago Tribune,*** May 25,1916

"Those who cannot remember the past are condemned to repeat it."
George Sautayana, U.S. (Spanish-born) philosopher (1863-1952),
The Life of Reason, Vol. 1,1905

INTRODUCTION

The quotes above describes how history is important to us so we can learn from it. Though many people believe that RFID is a new technology, it has an extensive history. A more accurate describtion of **RFID is an emerging wireless communication technology, that is used to uniquely identify tagged objects or people by means of electric or magnetic fields at radio frequencies to transmit information. RFID consists of three basic core components : a tag, an interrogator and a controller.** It´s emergence is best understood by evaluating the history of RFID. It can be said that to manage something effectively one must first understand it. RFID systems are complex entities that can be utilized in many ways. Managers will have to use insight to make sound decisions on how and when to use these systems. Perspective is an organizing framework. that supports effective decisions and can be gained by reviewing historical events.

A sense of history in RFID is important for the following reasons. Some RFID technologies have stood the test of time and have become more pervasive in the supply chain. Other RFID technologies have been utilized in other industries, such as animal tracking, and present unique advantages. The convergence of RFID systems has been theorized to create innovations in current industries and to lead to the creation of new industries. Given that the history of RFID is integrated with the history of other automatic data capture devices such as bar codes, we approach chronicling RFID history in the following ways. [1]

It is difficult to trace the history of RFID technology back to a well-defined starting point; there is no clear progression of RFID developments over time that ultimately arrives at the present state of matters. Rather, the history of RFID technology is intertwined with that of the many other communications technologies developed throughout the 20th century. These technologies include computers, information technology, mobile phones, wireless LANs, satellite communications, GPS, etc.

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With RFID just beginning to emerge as a separate technology, it is only in hindsight that we know many of the developments made in these other technologies to have also been developments in RFID technology research, development, and deployment.

1.1 THE CONVERGENCE OF THREE TECHNOLOGIES

Research and advances in the following three areas have given rise to commercially viable RFID:

- ***Radio Frequency Electronics***—Research in this field, as applied to RFID, was begun during WWII and continued through the 1970s. The antenna systems and RF electronics employed by RFID interrogators and tags have been made possible because of radio frequency electronic research and development.
- ***Information Technology***—Research in this field began in the mid-1970s and continued through the mid-1990s roughly. The host computer and the interrogator both employ this technology. The networking of RFID interrogators and the networking of RFID systems (the EPC Network for example) has also been made possible by research in this area.
- ***Materials Science***—Breakthroughs in materials science technology in the 1990s finally made RFID tags cheap to manufacture and, at present, $0.05 tags are on the horizon. Overcoming this cost barrier has gone a long way to making RFID technology commercially viable. [2]

1.2 MILESTONES IN RFID AND THE SPEED OF ADOPTION

In order to better define the development of RFID technology the following time-based development summaries are shown below.

1.2.1 Pre-1940s

The last half of the 19th century saw many advances in our understanding of electromagnetic energy. By the turn of that century, the works of Faraday. Maxwell, Hertz, and others had yielded a complete set of laws describing its nature. Beginning in 1896, Marconi, Alexanderson, Baird, Watson, and many others sought to apply these laws in radio communications and radar. The work done in this era form the building blocks upon which many technologies have been built, including RFID.

1.2.2 1940s—WWII

WWII brought about many advancements in radio frequency communications and radar. Following the war, scientists and engineers continued their research in these areas and increasingly sought civilian uses for it. In October of 1948, Harry Stockman published a paper in the *Proceedings of the IRE* titled "Communications by Means of Reflected Power," which in hindsight may be the closest thing to the birth of RFID technology.

1.2.3 1950s—Early Exploration of RFID Technology

During the 1950s, many of the technologies related to RFID were explored by researchers. A couple of important papers were published, notably FX. Vernon's "Applications of the Microwave Homodyne" and D.B. Harris's "Radio Transmission Systems with Modulatable Passive Responders." The U.S. military began to implement an early form of aircraft RFID technology called Identification, Friend or Foe, or IFF.

1.2.4 1960s—Development of RFID Theory and Early Field Trials

The 1960s were a prelude to an RFID explosion that would come later, in the 1970s. R.F. Harrington did a great deal of research in the field of electromagnetic theory as it applied to RFID, as

described in "Field Measurements Using Active Scatterers" and "Theory of Loaded Scatterers." RFID inventors and inventions began to emerge also. Examples include Robert Richardson's "Remotely Activated Radio Frequency Powered Devices," Otto Rittenback's "Communication by Radar Beams," J.H. Vogelman's "Passive Data Transmission Techniques Utilizing Radar Beams," and J.P. Vinding's "Interrogator-Responder Identification System."

Some commercial activities began in the late 1960s, too. Sensormatic and Checkpoint were founded to develop electronic article surveillance (EAS) equipment for anti-theft and security applications. (Anti-theft gates placed at the doors to department stores for instance.) Their systems were simple, 1-bit systems, meaning they could only detect the presence of RFID tags, rather than identify them. EAS later became the first widespread commercial use of RFID.

1.2.5 1970s—An RFID Explosion and Early-Adopter Applications

The 1970s witnessed a great deal of growth in RFID technology. Companies, academic institutions, and government laboratories became increasingly involved in RFID.

Notable advances were made in research. In 1975, Los Alamos Scientific Laboratory released a great deal of its RFID research to the public in a paper titled "Short-Range Radio-telemetry for Electronic Identification Using Modulated Backscatter," written by Allied Koelle, Steven Depp and Robert Freyman.

Large companies such as Raytheon, RCA and Fairchild began to develop electronic identification system technology, too. By 1978, a passive microwave transponder had been accomplished.

Several government agencies began to show interest in the technology also. The Port Authority of New York and New Jersey experimented with transportation applications developed by GE, Westinghouse, Philips, and Glenayre, though the technology was not adopted. The U.S. Federal Highway Administration convened a conference to explore the use of electronic identification technology in vehicles and transportation applications as well.

Numerous small companies focused on RFID technology began to emerge in the late 1970s. By the end of the decade, much of the research in RF electronics and electromagnetics, as applied to RFID, was complete and research computers and information technology, crucial to the development of RFID hosts, networks and interrogators, had begun, as evidenced by the birth of the PC and the ARPANET, predecessor to the internet.

1.2.6 1980s—Commercialization

The 1980s brought about the first widespread commercial RFID systems. The systems were simple ones. Examples include livestock management, keyless entry, and personnel access systems. The Association of American Railroads and the Container Handling Cooperative Program became active in RFID initiatives, with the aim of RFID-enabling railroad cars. Transportation applications emerged late in the decade. The world's first toll application was implemented in Norway in 1987, followed by Dallas in 1989. The Port Authority of New York and New Jersey implemented a commercial project for buses passing through the Lincoln Tunnel.

All of the RFID systems implemented in the 1980s were proprietary systems. There was no interoperability between systems and little competition in the RFID industry as a result, which kept costs high and impeded industry growth.

1.2.7 1990s—RFID Enters the Mainstream

The 1990s were significant in that RFID finally began to enter the mainstream of business and technology. By the middle of the decade, RFID toll systems could operate at highway speeds, meaning drivers could pass through toll points unimpeded by plazas or barriers. In addition, it became possible to enforce tolls with video cameras. Deployment of RFID toll systems became widespread in the

United States as a result. Regional toll agencies took tie technology one step further and began to integrate their RFID systems too, enabling drivers to pay multiple tolls through the same account. Examples include the E-Z Pass Interagency Group, located in the northeastern United States, a project in the Houston area, a project linking toll systems in Kansas and Oklahoma, as well as a project in Georgia.

Texas Instruments began its TIRIS system in the 1990s also. This system developed new RFID applications for dispensing fuel, such as ExxonMobil's Speedpass, as well as ski pass systems and vehicle access systems. In fact, many companies in the United States and Europe became involved in RFID during the 1990s; examples include Philips, Mikron, Alcatel, and Bosch.

Research in information technology was well developed by the early 1990s, as evidenced by the proliferation of PC's and internet. This left the RFID industry with only the problem of expensive tags to overcome, in order to realize commercially viable systems. Advances in materials technology during the 1990s, many of them related to the work of semiconductor chip makers such as IBM, Intel, AMD, and Motorola, finally put cost-effective tags on the horizon. Investment capital began to flow towards RFID and many venture capital projects got underway as a result. Large-scale "smart label" tests had begun by the end of the decade.

Until the 1990s the RFID systems on the market were proprietary systems. Many in the industry recognized this as a barrier to growth and an effort to standardize the technology began. Several standards organizations got to work on publishing guidelines, including the European Conference of Postal and Telecommunications Administrations (CEPT) and the International Organization of Standards (ISO). The Auto-ID Center at M.I.T. was established in 1999 for that purpose also. Currently, all of these organizations are working on standards for RFID technology, particularly supply chain and asset management applications.

1.2.8 2000s—RFID Deployment

By the early 2000s it had become clear that $0.05 tags would be possible and that RFID technology could someday replace bar code systems. The implications this had for the product distribution and retail industries, and the dollar figures involved, garnered a lot of attention for the industry. The year 2003 in particular was an eventful one for RFID. Both Wal-Mart and the DoD, the world's largest retailer and the world's largest supply chain, respectively, issued RFID mandates requiring suppliers to begin employing RFID technology by 2005. The combined size of their operations constitute an enormous market for RFID. Other retailers and many manufacturers, such as Target, Proctor & Gamble and Gillette have followed suit.

Furthermore, in 2003, the Auto-ID Center was merged into EPCglobal, a joint venture between the Uniform Product Code Council, makers of the UPC barcode symbol and EAN. EPC's technology has been adopted by both Wal-Mart and DoD und the RFID industry. It appears that RFID finally has a common platform from which to move forward. The standards developed by EPC were adopted by the ISO in 2006, giving the RFID industry a single source to go to for guidance. The convergence of all standards to one will serve to increase competition amongst players in the industry, lower the costs of RFID and quicken the deployment of RFID technology.

As of 2007, it was obvious that numerous applications for RFID across a number of industries would soon emerge. In the coming years, RFID technology would grow further and further into the mainstream and become another part of everyday life, just as television, PC's and mobile phones already had.

1.3 RFID IN THE FUTURE

With big companies such as Wal-Mart, Proctor & Gamble, Target and Gillette investing heavily in the technology, RFID has a very promising future. There is little doubt that the technology can bring numerous advantages to these industries. Success in deploying RFID technology, however, will depend heavily on resolving a number of obstacles and impediments before ubiquitous

deployment becomes a reality. It is probably fair to say that, at some point, RFID technology will be widely used but it is going to take time. Moreover, while the potential uses of RFID technology may be limitless, it may never reach the expected acceptance level or delivery of its full economic potential due to privacy and ethical concerns. Despite these caveats, 2005 was the year that the leading global retailers triggered the full-scale propagation of RFID technology. Adopters of RFID technology can be divided in three categories:

- ***Early movers,***
- ***fast followers,***
- ***and slow adopters.***

Early movers are the companies or industries that are leading their industry in terms of RFID adoption and are able to drive major RFID programs that influence their particular industry. They are able to gain the greatest knowledge, have the ability to influence standards, are ready to make significant investments and take risks.

Fast followers are companies or industries that hesitate to invest in the technology, but aim to gain knowledge and target specific areas at points in time where the cost/benefit can be justified.

Slow adopters are companies or industries that start to implement RFID technology once costs and practices have been stabilized. They will not make any risky investments but are ready to increase speed of implementation based on learning from others in their industry.

1.3.1 A Simplified RFID Technology Roll-out Timeline

In 2004, the number of RFID technology pilot projects by early movers increased rapidly and participants gained experience with the technology. Late in the year, EPC standard Class I Generation 2 was published and European legislation on UHF was amended, solving two important problems.

2005

- EPCglobal becomes fully operational.
- Reliable UHF products become available.
- Vendors offer pallets and crates fitted with RFID tags.
- Early movers, such as Wal-Mart, start large scale roll out throughout the organization, at least at the crate- and -pallet level.
- The number of fast followers starting pilot projects increases quickly.

2006

- EPCglobal standards adopted by ISO.
- Early movers of RFID technology are fully occupied with implementation and system integration.
- Fast followers start their implementation programs.
- Slow adopters of the technology slowly start their initial RFID pilot projects.

2007

- Price of a passive RFID tag continues to fall and begins to approach the 5 cents per tag benchmark price (on large volume purchase).
- RFID technology implementation programs of fast followers continues.
- Early movers complete their RFID implementation programs with logistical applications.

2008 and Beyond

- In the years after 2007, interest will shift towards item-level tagging, but it will be some time before this is implemented. (According to one industry representative, it will be at least 10 years before there is a "no checkout scenario" at large supermarkets. High-value, high-risk

goods would be the first to benefit from item-level tagging; goods such as pharmaceuticals and firearms, for example.) Smart shelves for select categories of products begin to appear and "smart" appliances with embedded RFID technology come into the market place. [3]

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