

Introduction

Technology is an integral part of business and our daily lives in the current information age. It is all around us even if we are not aware of it. One such technology is radio frequency identification or RFID. RFID has in recent years been applied in both business practices and to final commercial products that people buy and use. After discussing the basics of radio frequency identification technology and its history, its many applications, benefits and costs, privacy issues, and future outlook will be shown.

What Is Radio Frequency Identification?

Radio frequency identification is technology for identifying a person or an object by using radio waves. Radio waves are long, electromagnetic waves that can carry coded data. Consequently, radio waves can penetrate many solid objects and materials, including humans. A RFID system and tags take advantage of these properties. A RFID tag contains an antenna and a microchip. The tag comes in with different shapes and sizes, depending on the manufacturer. The microchip on the tag can store typically store two kilobytes of data ([RFID FAQs](#)). This allows a tag to store a serial number or other information about what it is attached to. To read and write the data on the tag, a reader, also called an antenna, emits electromagnetic waves. An antenna can be mounted or could be handheld. Depending on the power output and frequency, the range of the antenna varies from a few inches to hundreds of feet. The tag receives the antenna's radio waves and broadcasts its own waves, which is sent back to the antenna. The antenna decodes the waves to pass to a computer as data to later process ([What is RFID?](#)).

There are many types of RFID tags that are used. The types are passive, semi-passive, and active. Active and semi-passive tags contain an internal battery and generally have more memory. The battery on an active tag boosts its range to be read by a reader. Passive tags do not have internal batteries. They instead rely on the electromagnetic field generated by a reader for

power. Semi-passive tags rely on the electromagnetic field to broadcast back to the reader. Consequently, the range of semi-passive and passive RFID tags is much lower than the active RFID tags. Twenty feet or less is typical range for a passive RFID tag (Gibson).

The Development History of RFID

The history of RFID stretches back to after World War II. Radio and radar technology progressed in the 1930's and 1940's. After the war, in the 1950s, RFID was planned to be used in aircraft in order to determine whether the aircraft was friend or foe. In 1960, commercial applications started to appear with the development of electronic article surveillance or EAS. EAS typically was used with '1 bit' tags to see if the tag was present. The system and tags proved to be a helpful measure to help prevent theft. EAS was the first widespread application of RFID technology. The technology was still very new, however, and needed the integrated circuit, transistor, and microprocessor before RFID would be a success (Landt).

The 1970's and 1980's was a time for development as more and more companies developed their own RFID system. Some of the companies were: General Electric, Westinghouse, Philips, and RCA. The technology was intended to be implemented for tracking animals and vehicles. In 1987, the use of RFID in collecting tolls on toll roads started in Norway. The United States would follow in 1989 with the Dallas North Turnpike. In the same year, vehicles passing through the Lincoln Tunnel, which connects New Jersey and Manhattan, would be charged tolls by a RFID system (Landt).

The 1990's were an important decade for RFID as well. More countries started to adopt RFID technology for toll collecting such as China, Canada, Mexico, and Japan. Research did not stop, for more developments were being made by companies such as Texas Instruments. The TIRIS system developed new applications for vehicles such as starting the engine, dispensing fuel, and locks. Another major advancement was the ability for one tag to be used in multiple

businesses. In Dallas, one tag was used for toll collection on the North Dallas Tollway, access and parking payment at the Dallas-Fort Worth International Airport and at parking garages downtown, and access to gated communities (Landt). RFID started to hit the mainstream and more companies entered the industry.

Applications of RFID

With the inclusion of RFID into the mainstream, many more applications have been developed. RFID technology presently is tracking items such as: animals, library books, luggage, and many more items. Manufacturing companies use RFID tags to track parts and assembly throughout the manufacturing process. Warehouses fitted with a RFID system can keep a real-time inventory of work in process and finished items. Crates and pallets as well contain a RFID tag to track shipments of items when they arrive. Retailers use RFID for supply chain management and for customer payments. The U.S. government and others employ RFID in the military supply chain and for civilian items such as passports ([RFID FAQs](#)). The applications for RFID are nearly in every industry and business around the world.

One of the major benefactors of RFID technology is Wal-Mart. Wal-Mart demanded that by late 2006 that all of its suppliers implement RFID on pallets and crates for shipments to Wal-Mart and Sam's Club stores. RFID readers are now installed in distribution centers and at many stores. The tags store a 96-bit Electronic Product Code (EPC) with a global identification number. The ultimate goal is to improve inventory management. Inventory can be kept in real-time to reduce the amount of excess inventory, errors, shrinkage, theft, and out-of-stocks. The decreased amount of out-of-stocks would increase sales and customer satisfaction. As the whole system becomes more efficient and reduces labor costs, overall, customers can get a better deal compared to the competition ([Wal-Mart](#)). How successful has RFID adoption for Wal-Mart and its suppliers proven? A 29 week study by the University of Arkansas showed that the amount

out-of-stocks decreased by 16%. By having the right product at the right time, sales and customer satisfaction increased.

Cost of Implementation

With the success of RFID, it is natural to wonder what has stopped it from being implemented by mid-size businesses. One of the major factors hindering RFID adoption is cost. The total cost of ownership depends on the company's application and implementation. However, each implementation shares similar parts. Each implementation involves readers, tags, and middleware. Ultra high frequency readers range from \$500-3,000. The difference in cost comes from the different functions. Readers that perform additional functions like data filtering and storage are consequently more expensive to those that perform less. The cost of tags is very variable. The cost depends on the tag's frequency, memory, and packaging. Simple, passive tags cost around five cents each while those with plastic packaging for protection can be a few dollars each. Active tags can cost between \$10 to \$50 due to the battery size, memory, and plastic packaging. Middleware is tasked with filtering data and sending it to the business' database or other applications. Some also manage the reader's software. Cost of middleware varies due to complexity and amount of install locations. Servers to run the middleware also have to be purchased, which increases the total cost of ownership more ([RFID FAQs](#)).

Hardware and software is not the only costs to be considered when implementing a RFID system. There are also costs to install the readers, test tags, and train employees. To install readers and determine tag product placement, companies typically hire a system integrator. Passive tags need to be tested and if defective disposed of and replaced. Employees to maintain RFID readers and data need to be trained and can be costly to do so ([RFID FAQs](#)). All of the startup costs can impede a mid-size business from adopting. However, as price for the technology falls, more companies can justify the costs of RFID adoption.

Privacy Issues

With the success of RFID technology, concerns are being raised about consumer privacy being compromised. Like other types of technology, measures need to be considered to counter hackers or unintended recipients of information. The main concern is that RFID tags are used to track a person's movements or gather personal information such as buying behaviors. This is supposedly due to possessing an item with a RFID tag. Unlike traditional bar codes, RFID tags do not require a line of sight to be read and tags can be read more than one at a time. Also, the read range is far greater for a RFID tag than a bar code reader (McIver).

The specific issues are unwanted parties intercepting radio waves from readers and tags and also reading tags without consent. A big worry is that customers who buy an item with a RFID tag and pay with a credit card or smart card could be tied together to track them. In theory, that information could be read without the customer's knowledge or consent and ultimately sold to other companies to market their products to that customer. Many customers would consider that method of data gathering to be intrusive. RFID critics also argue that RFID tags can leave people open to identity theft and "Big Brother" watching over them (McIver).

Are the concerns well-founded? The answer is that some concerns are illegitimate and others are. First, the read rate of tags is not 100%. Radio waves, like other types of waves, can exhibit reflection and interference. At ultrahigh frequencies, radio waves are reflected from metals, in turn lowering the read rate. Water can absorb radio waves at ultrahigh frequencies, which also makes it more difficult for readers to interrogate tags and for tags to respond at long distances ([RFID FAQs](#)). As for tracking a person's movements at all times, this concern comes from confusion by thinking RFID and GPS are the same. Unlike GPS, passive RFID tags cannot read satellite data or transmit waves strong enough even with the aid of a battery or reader

(Brito). Also, since human beings are mostly water, the radio waves from a tag can possibly be absorbed.

Despite the real world problems with RFID, there are some legitimate privacy concerns surrounding RFID systems. One major legitimate concern is that RFID tags can be read without consent or knowledge. RFID readers can be easily concealed and an item can be tagged and read without a person knowing it. These issues are worrisome because an increasing number of government documents, like a U.S. e-passport, contain personal data. The personal data for a U.S. e-passport, for instance, is name, date of birth, nationality, and biometric information via a photograph (Juels 2). If this information is leaked, it has the potential for identity theft. Another concern is that RFID tags with unique EPC serial numbers can be linked with personal information. If a tag is linked with an online database, there is the possibility of the database being hacked and personal data being compromised. This assumes that retailers will connect EPC serial numbers to individual customers in a database, however.

RFID's Place in the Future

Even with physical limitations and privacy concerns, the future outlook for RFID technology is promising. One of the greatest goals is for RFID to replace bar codes. However, this will take some time. Bar codes are legacy technology and cost less than implementing a RFID system. Costs will have to decrease for tags and technology limitations have to be mitigated in order for a complete phasing out of bar code on an item level. Another future application is to combine RFID tags with sensors. With sensors, tags can tell the condition of an item due to environmental changes like temperature. For instance, if an item is spoiled or otherwise unfit for use. This has many applications, especially in the health care, pharmaceutical, and food industries because the items are sensitive to the environment and have

short shelf lives (Gouthaman). If RFID technology keeps decreasing in cost and becomes more standardized, customers should see better quality products and less recalls.

Conclusion

In conclusion, RFID technology is and will continue to be a part of people's daily lives. The basis of the technology originated as far back as 1930. However, it wasn't until much later until the technology became a viable business tool. Wal-Mart is a big supporter of RFID technology along with the U.S. Department of Defense for use in efficient supply chain management. Other applications that have RFID technology include: payment systems, access control, and tracking animals, luggage, library, and more.

However, like other types of technology, RFID has concerns over privacy. Because the read range of RFID tags is longer than that of traditional bar codes, tags can be read without a person's knowledge or consent. If the tag contains personal data and is intercepted by an unauthorized party, people fear it will result in identity theft. Another major concern is that if RFID tagged items are purchased with a credit card or smart card, that information could be combined for targeted marketing. Even worse, some people believe that RFID tags can be used to track a person's every move. However, this claim is false because RFID tags are not 100% reliable. This is because radio waves are reflected by metal and absorbed by water at ultra high frequencies.

The future for RFID technology is bright. As tags continue to drop in price, more companies can justify implementing a RFID system. Standardization and the increased protection of consumer privacy will also help companies adopt RFID systems. It will take more time for RFID to completely replace bar codes, however. The development of RFID sensors to track condition of short lived items appears to be promising. Other applications not conceived yet will likely appear in the future as the world is made even more aware of the technology.

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