THE WALMART RFID INITIATIVE

Mechanical and Aerospace Engineering Course 188

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ABSTRACT

The purpose of this paper is to study the implementation effects of Radio Frequency Identification (RFID) on the supply chain industry, specifically Walmart. RFID was first put into practice during World War II as a method to distinguish between the different forces. RFID applications have expanded drastically since then. This new technology will benefit the supply chain industry by improving efficiency and increasing sales. Integrating such technology will require the necessary hardware and software architecture to handle the information. In addition, a timeline containing Walmart's future plans is provided, and some quantified benefits are discussed in this report. Finally, proposals were made to correct the current challenges.

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INTRODUCTION

"Radio Frequency Identification (RFID) is a Wireless Automatic Data Capture (ADC) Technology that uses radio frequency waves…for communications between transponders (tags) and interrogators (readers/scanners)" [1]. Like many of the modern technologies, RFID was first introduced in World War II as a method of identifying the origins of the fighter planes; before returning to base the German pilots would roll their planes to change the reflected radio signal, thus alerting the ground crew [2]. RFID applications have broadened over the years; by the 1970s RFID systems were used to identify assets (see Figure 1). This is the very idea behind today's RFID systems, although the complexities have increased drastically. Currently there are three kinds of tags available in the market: passive, active, and semi-passive tags.

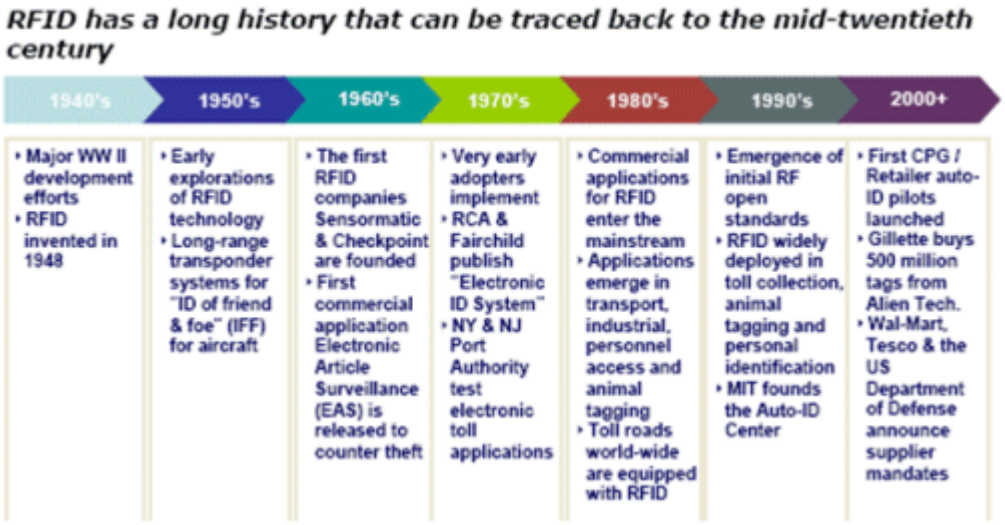

Figure 1 - Brief history of RFID [3]

The main distinctions between the three types of tags are the data storage capabilities, tag size, and transmission range. Due to the fact that passive tags do not have power supplies, they are usually much smaller than active and semi-active tags. Generally, passive tags signal by backscattering, which means they get woken up by the radio frequency from the readers. These tags simultaneously transmit the outbound backscatter signal when they are awake and become

inactive immediately after doing so. Because of this, "passive tags have practical read distance ranging from about 10 cm…up to a few meters…depending on the chosen radio frequency and antenna design" [4]. Active tags, on the other hand, have built-in batteries that allow real-time tracking and longer ranges. Despite these advantages, active tags have limited lifetimes and are generally larger in size due to the battery. Finally, semi-active (also known as semi-passive) tags are hybrids of the passive and active tags, hence the name. Semi-active tags also work on the idea of backscattering, but this does not mean that they behave the same way as passive tags. "The battery-assisted reception circuitry of semi-[active] tags lead to greater sensitivity than passive tags, typically 100 times more" [4]. In addition to heightened sensitivity, the battery is also used for data storage. Table 1 summarizes the differences between passive and active tags while Table 2 discusses the different operating frequencies.

Attribute	Passive	Active
Energy	Induction / Back Scatter	Battery
Frequency	LF (125 KHz), HF (13.56 MHz), UHF (868-930 MHz), Microwave (2.4 GHz)	HF (303, 433 MHz) Microwave (2.4 GHz)
Read Distance	< 25 feet	10 – 1,000 feet
Memory	32 bits – 64 K	64 bits – 128 K
Life	Unlimited	2 – 7 Years
Cost	~$0.10 - $10.00	$10.00 - $100.00
Type (EPC)	Class 0, 1, 2	Class 3, 4, 5

Table 1 - Passive and active tag specifications [1]

Frequency Name	*Frequency Level*	*Range*
Low Frequency (LF)	125 KHz	Up to 20"
High Frequency (HF)	13.56 MHz	Up to 10'
Ultra-High Frequency (UHF)	915 MHz or 2.45 GHz	3' to 20'

Table 2 - Operating frequencies [5]

RFID is a drastic improvement from barcode. RFID not only offers superior accuracy and real-time tracking, Gen 2 Class 1 protocols can also provide a top-speed read rate of 1000

tags per second and write rate of 30 tags per second as opposed to the traditional system [1]. This seems to be the solution in an ever changing society where expediency is one of our top priorities. RFID is currently used in manufacturing, retail, and supply chain industries. Table 3 summarizes the advantages and disadvantages of RFID systems compared to barcode.

	Barcode	RFID
Advantages	• Low Cost • Mature technology and broad adoption • Human readable • Many automated solutions available	• Line of sight not required for operation • Large memory and information moves with the tagged item • Dynamic read and writes • Supposedly long life • Can be very small in size • Multiple tags read
Disadvantages	• Requires line of sight • Minimum information • Durability is suspect • Read/write not possible • One barcode at a time • Manual Handling	• Higher cost • Performance impaired by item and environment attributes • Immature technology

Table 3 - Barcode vs. RFID [1]

This study will focus on Walmart's push for RFID, including the background, motivation, implementation, outlook, and possible changes in the movement.

BACKGROUND AND MOTIVATION

In April 2003, Wal-Mart announced an RFID pilot test with the purpose of increasing efficiency, reducing costs, and improving the customer experience [6]. This is the general consensus within the supply chain management industry. METRO Group, the world's fifth largest retail company, states that RFID can achieve the following benefits [7]:

1. Improve supply chain efficiency (labor reduction, improvement of traceability, reduction of errors)
2. Ensure product freshness
3. Fight against counterfeit products
4. Reduce shrinkage (theft and systematic control of deliveries)
5. Reduce out-of-stock occurrences
6. Improve after-sales operations and planning
7. Management of recycling operations (automation of used package sorting and acceleration of flows)

In addition to these benefits, it seems that the deployment of RFID technology will be easier than other changes that have been implemented in the past. First of all, the maturation of the technology will reduce the associated costs. Second, standards such as EPC and ISO have already been created to ensure that all products will be RFID compatible under different hardware and software. Finally, the maturity of the supply chain industry along with barcode technology will allow the gradual transformation to RFID [7].

For Walmart, the world's supply chain giant who generated $387 billion in revenues last year, the benefits are huge [10]. "Currently, around 2 percent of all lost sales are due to the simple fact a store has run out of an item, but 41 percent of lost sales are due to inventory problems…if RFID can fix just 10 percent of that problem, then Walmart will gain $287 million per year by avoiding lost sales," said Ron Moser, the RFID strategy leader at Walmart [11].

IMPLEMENTATION

For manufacturers and retailers, the decision of implementing a new technology depends on how ready the technology is and how much benefit can be derived from it. An "RFID Opportunity Matrix" can be used as a preliminary analysis (see Figure 2). The figure shows that RFID implementation may not be correct for certain low-cost and low-volume applications due to the high initial cost (large risk) and low return-on-investment (ROI) associated with deployment.

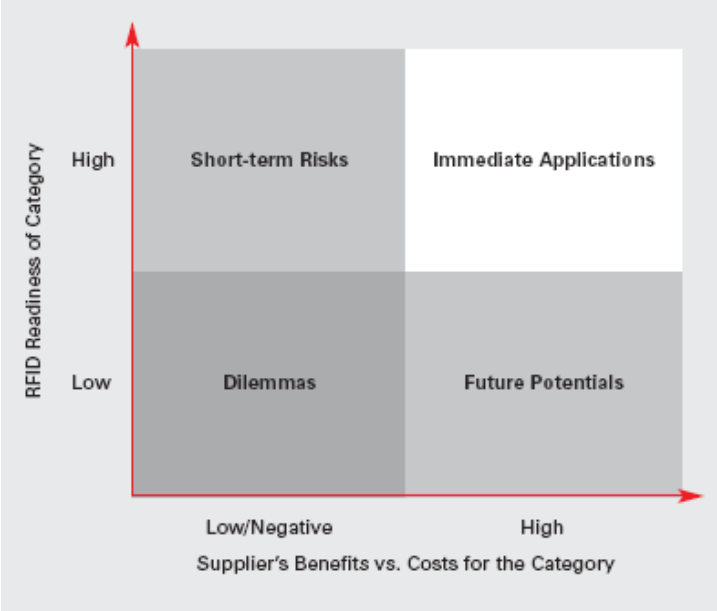

Figure 2 - RFID opportunity matrix [7]

Hardware

Walmart and its suppliers follow the Electronic Product Code (EPC) developed by EPCglobal. EPC is essentially the next generation of product identification, where each item is uniquely identified by the EPC generation, company, product class, and product serial numbers [1]. Figure 3 shows the conversion from barcode to EPC. The tags used in this application are EPC Generation 2, Class 1 Ultra High Frequency (UHF) tags operating between 902 and 928 MHz in the United States. Common tags used today are available in 64-bits or 96-bits. The 96-bit EPC "provides unique identifiers for 268 million companies…each manufacturer can have 16 million object classes and 68 billion serial numbers" [31]. In general, these tags have [12]:

- An EPC identifier

- A tag identifier
- A "kill" function that permanently disables the tag
- 32-bit password-protected access control

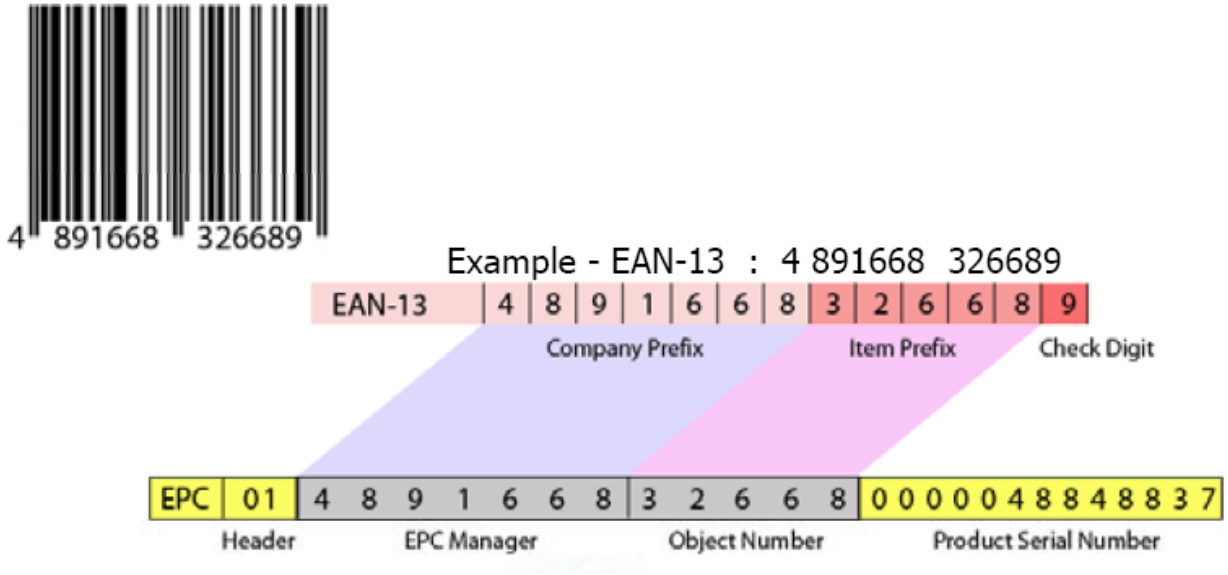

Figure 3 - Barcode to EPC conversion [1]

Although these EPC compatible tags can still be as expensive as 50 cents per tag on a small scale, when purchased in bulk, their prices can drop drastically [13]. SmartCode, an RFID systems provider that helps companies become Walmart-compliant, "says it will sell Class 1 EPC tags for 5 to 10 cents in volumes of 1 billion or more." Alien Technology, another RFID manufacturer, was able to provide Gillette with 500 million tags in 2003 for "well under 10 cents" [14].

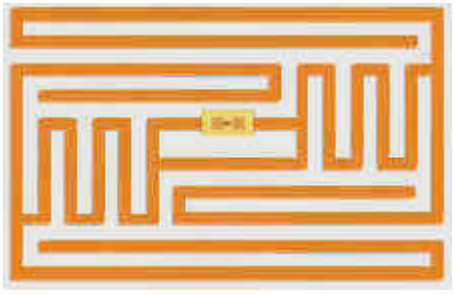

Figure 4 - EPC tag used by Walmart from SmartCode [4]

According to Alien Technology, the prices of RFID equipment have fallen by 70 percent since 2005 [18]. Despite the drop in prices, deploying RFID readers on both the store and distribution levels can still cost a significant amount. Typical readers such as the Alien Technology ALR-9900 or the Motorola XR400 are capable of supporting more than four read points, which means the read ranges are much greater than the typical 30 ft [16]. In addition to readers, RFID portals must be installed at the incoming and outgoing points for tracking

purposes. Like their reader counterpart, RFID portals can also cost anywhere from $1000 to $3000, such as the Alien Technology ALX-9010 [16].

Although the technology is only reading 66 percent of the individual cases on fully loaded pallets, it has proven to be effective on the pallet level [24]. Simon Langford, Walmart's manager of global RFID strategy, says Walmart has been reading the pallets at 98 percent accuracy [25]. A supply chain model is simulated in the Information Technology Research Institute at the University of Arkansas, where RFID readers are installed at the dock doors, conveyors, impact doors, forklifts, and pallet wrappers [17]. Figure 5 shows the reader locations at different points in the supply chain. Using this model of 5 reader points per distributor and 6 read points per retail store, Walmart, with 937 stores, 2527 Supercenters, 138 Neighborhood Markets, 129 distribution centers, and 566 Sam's Clubs stores, would spend approximately $6.4 million in readers alone if each reader costs $1000 and is capable of handling 4 read points [19].

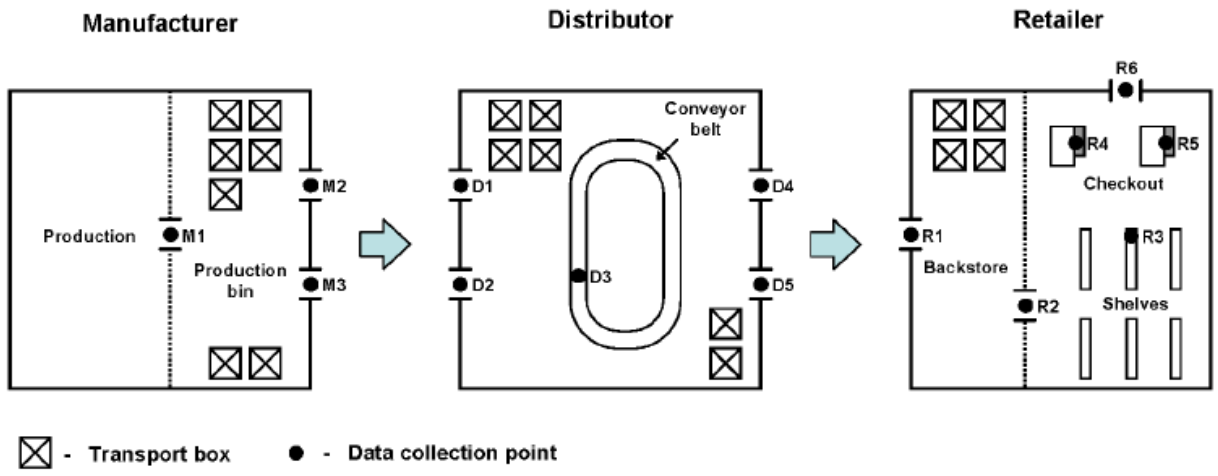

Figure 5 - Supply chain with RFID data collection points [15]

Software and Data Management

The proper operation of the hardware requires the correct software architecture. There are three ways to store data in a supply chain: to have data in a central database, in distributed databases, or on the transponders. Having data in a central database allows for simple architecture and data management. Having data in distributed databases, on the other hand, is essentially the same as having many "central" databases, thus eliminating the single point of

failure. Finally, while storing the data on the tags also permits a simple architecture, the tag prices increase dramatically due to its additional storage capacity. Figure 6 sums up all the pros and cons of having different ways of managing data. Because of the increase in data quantity in all of the cases when compared to barcodes, these data are compressed without loss of information before storage. Walmart utilizes the distributed database architecture, where individual databases are stored at each corresponding store and distribution center and uploaded online [15].

In this type of system, the basic layer consists of RFID transponders, which are read by the second layer of tag readers. The data collected by the readers then move on to the third layer, the middleware, where filtering and sorting occurs. At the fourth level each individual EPC code is matched up and identified via manufacturer and product names. The final component is called the Object Name Service (ONS) where the service maps an EPC to a URL describing the item. [20]. Figure 7 shows this structure as a tree diagram.

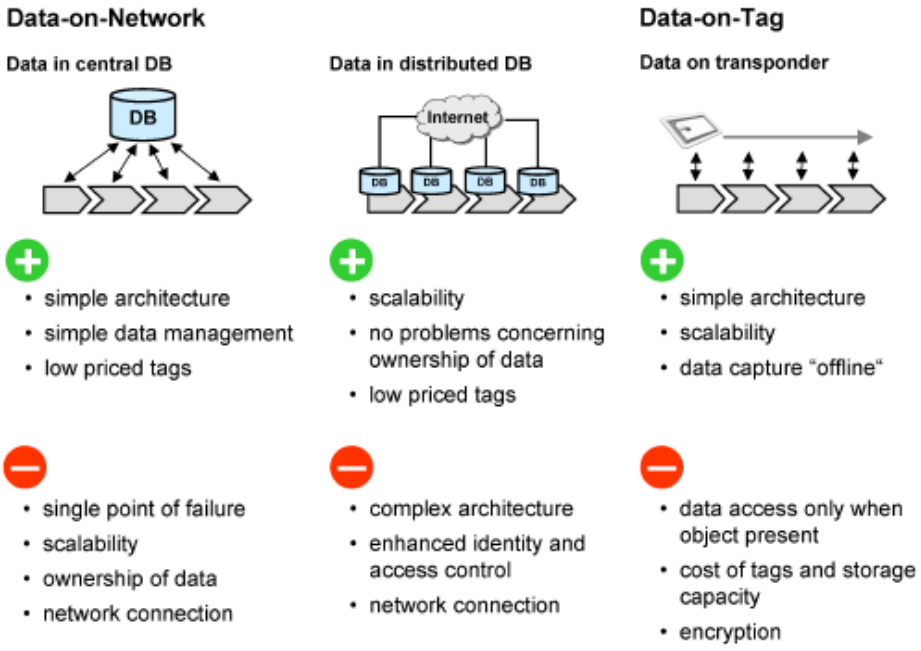

Figure 6 - Concepts of data organization [15]

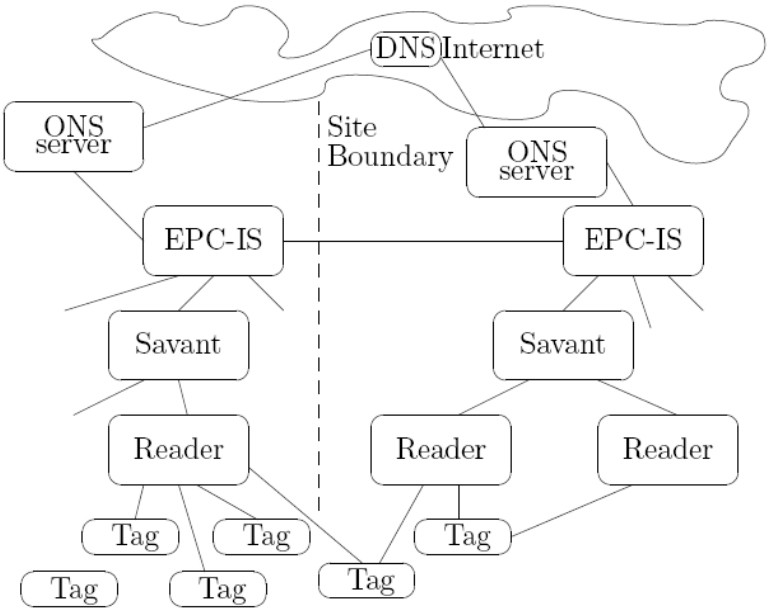

Figure 7 - EPC system architecture [20]

As previously stated, the middleware handles the data from the reader side and translates it to the server side. "It extracts data from the RFID interrogators (readers), filters it, aggregates it and routes it to enterprise applications such as a warehouse management system (WMS), enterprise resource planning (ERP) software or a manufacturing execution system (MES)" [21]. Without the middleware, the data infrastructure would fall apart. RFID middle can be purchased between the ranges of $5,000 to $20,000 as of 2006 as opposed to the $125,000 license a few years prior to that. Some of the popular RFID middleware include services from SAP, Microsoft, Sun Microsystems, and Oracle [21]. The company epcSolutions, Inc. claims that it is the leading provider of RFID compliant software to Walmart suppliers [22].

Timeline

2003 – Announced RFID implementation [11]

2004 – Pilot test with 8 manufacturers and 7 stores [25]

- Mandate for top 100 suppliers [11]

2005 - RFID in 104 Walmart stores, 35 Sam's Clubs, 3 distribution centers [24]

2006 - Additional 200 suppliers compliant [23]

2007 - RFID in 975 enabled stores [11]

2008 - RFID in over 1000 locations [19]

- $2 fee for each untagged pallet to Sam's Club [26]

- Case and mixed pallet level tagging for 5 distribution centers [26]

2009 - Case and mixed pallet level tagging for remaining 17 distribution centers [26]

- Unit level tagging for 1 Texas distribution center [26]

2010 - Unit tagging for all distribution centers [26]

Benefits

The strongest motivations driving the RFID movement are the derived benefits from implementing the system, mainly the increase in sales and the improvement in efficiency. Because inventory inaccuracy is often unavoidable, it is in one's best interest to minimize it. In his study, Dr. Bill Hardgrave from the University of Arkansas showed that there is a 13 percent decrease in perpetual inventory inaccuracy after RFID deployment [27]. By reducing inventory inaccuracies, one can lower the chances of making incorrect management decisions (excess inventory, etc) and potentially increase overall sales. As mentioned before, Walmart can gain $287 million a year by avoiding lost sales [11].

In addition to the increase in sales, improvements in efficiency will lead to lower operating costs. METRO Group showed that RFID can reduce the time spent at different stages of "replenishing the shelves" by up to 60 percent at the item level [7]. Less time spent means more efficient workers, and efficient workers means lowered effective labor costs.

Sales Front Office	Time Spent per Pallet		RFID Impact	
Replenishment of Shelves	Min	Max	Case Level	Item Level
Remove plastic foil from pallet	0.5	0.75		
Sort cases by product category	6*	9*	30%	30%
Put in shopping trolley	1*	2*		
Move goods with shopping trolley to correct shelf	1*	3*	10%	10%
Unload trolley and put cases next to relevant shelf	2*	4*		
Open cases	1*	4*		
Search for product on the shelf	2*	10*	10%	60%
Check expiry dates of products in shelf	12*	20*		60%

*Estimates

Table 4 - RFID time reduction at sales office [7]

The summary of results from METRO Group's study is shown in the table below. Their estimated 9 to 14 percent reduction of out-of-shelves is consistent with the results obtained by Dr. Bill Hardgrave. It is also shown that RFID can reduce labor by 17 percent at the case level and reduce theft by 11 to 18 percent [7].

Retailer-only Benefits		Joint Benefits	Manufacturer Benefits
Supply Chain Efficiency in Store	Theft Reduction	Improvement of Product Availability	To be selected among potential benefits
17% Labor Reduction at Case Level	11 to 18% Reduction of Theft	9 to 14% Reduction of Out-of-shelves	To be calculated individually

Table 5 - RFID benefits in supply chain [7]

Challenges and Proposals

According to research conducted by AMR Research, many of Walmart's suppliers are slow with the transformation due to high costs and little return on investment. As a consequence, according to the same study, each supplier has only spent $1 million to $3 million each as opposed to the $13 million to $23 million required to see significant benefits [8]. For Walmart, this number jumps up to $35 million to $40 million for system integration, and as much as $100,000 per store and $400,000 per distribution center. These costs, however, are fixed, one-time costs associated with infrastructure setup [9]. As of March 2008, only 600 of Walmart's 60,000 suppliers use RFID technology [27]. Due to this low percentage, Walmart announced in

January of 2008 that it will charge a $2 fee for each untagged pallet that enters a Texas distribution center for Sam's Club, its wholesale subsidiary [26].

Data storage can also pose a problem for the supply chain giant. When item-level tagging becomes effective, 2 terabytes per day would be generated for a 1,000 store chain with 150,000 items per store. With more than 7,000 stores worldwide, this number would translate into 14 terabytes per day [28]. As of now the processed data go through a compression process via "aggregation methods" to reduce the data quantity without loss of information. "In addition, suitable archiving methods should be implemented as a means of separating old, as well as obsolete, data from data being presently used" [15]. This issue will require further investigation when item-level tagging becomes a reality.

Security is another concern that many RFID users have. Class 1 Generation 2 tags have two key security features [32]:

- **Kill command –** the tags can be permanently disabled, but to do so, one must enter a tag-specific 32-bit password
- **Disguised EPC number –** the product information is somewhat hidden since it is "translated" via an EPC database (see Figure 7)

Despite these features, Gen 2 tags are still seen as vulnerable due to weak data encryption, weak password protection, and no tag or reader authentication. In hostile situations, these weaknesses can subject users to hacks and unauthorized copies of the tags. As of now, consumers and manufacturers can only shield themselves from attack by not putting confidential information on the tags and using information pointers rather than actual information, like EPC. Future protocols will have to address these issues [32].

Finally, the current read-rate of 66 percent of the individual cases on fully loaded pallets is not anything close to ideal. One must also solve the issue of current read accuracy on RF-challenged materials such as metals and liquids [24]. Mojix, a Los Angeles based company, says that they have found the solution. The company claims that the Mojix STAR System can achieve the following performance through field testing [29]:

- Read range: **600 ft**

- Area coverage: **250,000 ft^2**
- Receiver sensitivity: **50db**
- Read rate: 700 tags/sec
- Read reliability: 99.9% (pallet, carton, or item level), 100% (RF-challenged goods)

Companies such as Procter & Gamble and Kraft Foods participated in the trials and verified these numbers. Kim Zimmer, EPC Operations and Technology Leader of Procter & Gamble said, "Our testing of Mojix system has provided a new perspective on the possibility of outfitting a distribution center with RFID capability…[it] has demonstrated its potential to perform in challenging real world warehouse scenarios" [30]. This is made possible because a single system can manage up to 512 eNodes, which are points of excitation, thus increasing the area coverage by 100 times (as opposed to the traditional monostatic systems, see Figure 8). Despite the optimism for this new technology, further investigation and research must be performed to see if Mojix is really a viable business plan for the industry.

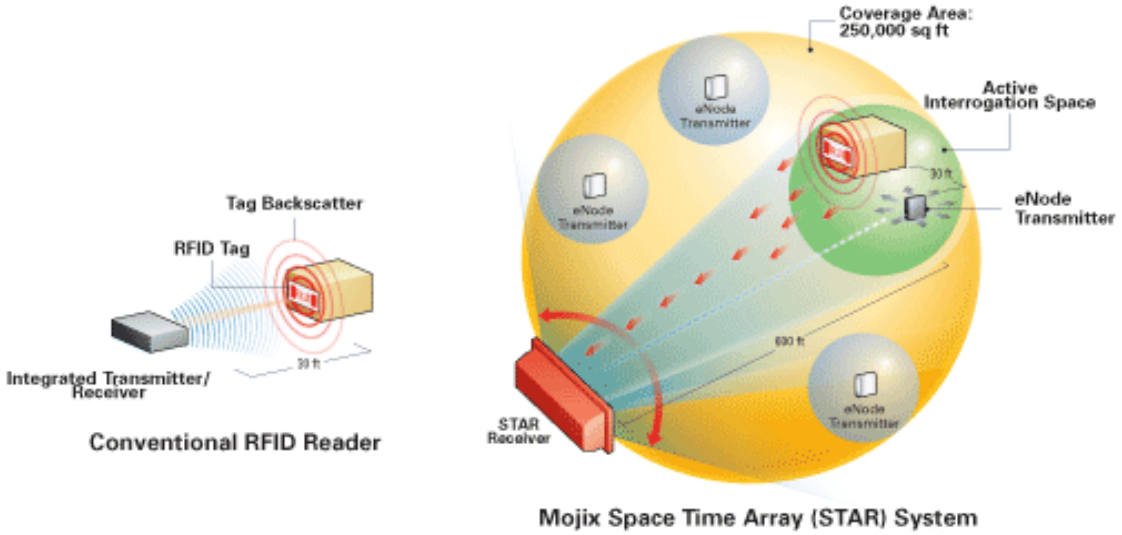

Figure 8 - Mojix vs. conventional technology [29]

CONCLUSION

Walmart announced its plans for RFID in 2003. Despite its mandate over 5 years ago, only 1 percent of its current suppliers are RFID-ready. Although it has been proven by many studies that benefits from RFID are realizable by both the manufacturers and suppliers, many businesses are still slow with integration due to the low return-on-investment. RFID suppliers and users are currently at a standstill: users will implement RFID technology when the costs are lower while suppliers will be able to provide cheaper services with increase in demand. Walmart, a firm believer in technological transformations, is pushing hard for RFID. "A bar code standard was approved in 1973, but by 1984 only 15,000 suppliers were using codes on their products. Wal-Mart threw its weight behind bar codes in 1984, and by 1987 there were 75,000 suppliers using bar codes, according to AMR Research" [33]. Since RFID requires a much more complicated integration process, it is expected that the transformation will take longer. Like with barcodes, Walmart's supplier mandate will most likely kick into full gear once Walmart implements stricter requirements, thus lowering costs of RFID investments. One should expect RFID to become a household name in the years to come.

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