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The Myths and Realities of RFID

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Abstract

Although radio frequency identification (RFID) has been around more than 50 years, it has only recently received widespread attention, due in large part to its use by large retailers, such as Wal-Mart, and their subsequent requests for suppliers to use it. The resurgence in attention and the increased interest in RFID have spawned many articles and much speculation about its use. Unfortunately, much of what has been written and speculated is misleading or simply not true. It is not uncommon for new technologies (or in this case, rejuvenated technologies) to receive a tremendous amount of hype. Hype can be good, as it draws attention to an important technology. However, hype can also be damaging as people set their expectations based upon exaggerations of reality. These false expectations may lead one to expect the technology to perform at a level to which it is not capable or they may lead people to fear the technology because of what it may do. History would suggest that over-hype leads to disillusionment and disappointment with the technology and can delay or derail its adoption (some examples of hyped technologies include artificial intelligence and electric-powered cars). In an effort to keep the hype in check for RFID, this article examines 10 common myths of RFID and, accordingly, presents the realities of the technology.

Keywords: RFID, radio frequency identification, supply chain

The Myths and Realities of RFID

Introduction

Rarely does a 50-year old technology receive such attention; yet, this is the case with radio frequency identification. Although RFID has been used for many years in devices such as toll passes and employee ID badges, its recent introduction into the consumer packaged goods supply chain has dramatically increased the public's awareness of the technology. Essentially, this old technology has found a new use. The path to this newfound popularity began with a consortium of companies investigating its use for the supply chain in the late 1990's [40] and escalated with Wal-Mart's June 2003 request that the top 100 suppliers use RFID at the pallet and case level by January 2005.

As is the case with many new technologies, there is much hype about what it can and cannot do. Early studies are suggesting that RFID can provide tremendous insight into the supply chain [22] and, subsequently, improve distribution center and store operations (e.g., reducing out of stocks [16]). RFID is not yet widely used in the supply chain, so there is much left to learn about how it can be applied and its subsequent benefits. The excitement over RFID and its potential uses must be tempered by its limitations. Positive hype for a technology may create such high (and unrealistic) expectations that the technology simply never lives up. Artificial intelligence is a good example of a technology that received tremendous hype in the early 1980's (fifth generation computers, etc.), but has been considered a failure because it could never meet the lofty expectations created by the hype [39].

Negative hype should also be recognized. Critics of RFID have been especially vocal about some of the far-fetched uses and potential misuses of RFID [3]. Much of this hype is based on misinformation or false information. The organizational, consumer, and government perceptions and subsequent reactions to such propaganda can be detrimental to a technology's continued development and adoption. For example, several states (e.g., California, New Mexico, and South Dakota) have introduced legislation to control the use of RFID [23]. Much of this legislation is a reaction to speculative, imaginative, or even fictional uses of RFID. The perceptions of the technology, much like expectations, must be grounded in reality.

RFID has the potential to be a great technology for the supply chain. However, unrealistic expectations and misinformed perceptions become confused with reality and transform themselves into myths. These myths, then, begin to be viewed as the truth. RFID has received a tremendous amount of publicity – both positive and negative – in the past few years. While much of it is factual, some of it is not. The purpose of this paper is to separate myth from reality. For this paper, we have selected 10 popular myths (both positive and negative) of RFID. For each myth, a brief discussion is provided followed by an exposition of reality. This should help level-set the expectations and perceptions so that organizations, consumers, and governments have a more realistic understanding of RFID.

An Overview of the Technology

Before discussing the myths, it is important to understand a bit about the technology, although space does not allow for in-depth coverage (for more detail about how RFID works, see, for example [13] [14]).

Much like car radios, cordless phones, and cell phones, RFID works via radio waves. These devices operate in many different frequency ranges, some of the most common being low frequency (LF), high frequency (HF), ultra high frequency (UHF), and microwave [43]. The frequency helps determine such things as range and method of communication (e.g., between transmitter and receiver). In its simplest form, an RFID system consists of a tag (attached to the product to be identified), an interrogator (i.e., reader), one or more antennae attached to the reader, and a computer (to control the reader and capture the data). RFID systems can be classified by the frequency used and whether the system is active or passive. Passive tags are powered by radio waves (an electromagnetic field) created by a reader and transmitted via its antennae. The passive tag will remain powered only while it is within the read field. Once a passive tag leaves a read field, it stops transmitting and is essentially dormant. While in the read field, the powered tag will respond to the reader by reporting the data contained on the tag's chip. This all happens very fast – most readers can now read 1500 tags per second and can read each tag several hundred times per second [38]. The reader then converts all of these returned signals into data that the computer can understand and store. The unique ID stored on the tag is used to determine what is in the box or whatever might be tagged. Unlike passive tags, active tags have an internal battery which powers the tag. Because active tags have their own power source, they do not need a reader to energize them; instead they can initiate the data transmission process. Active tags have a longer read range, can store more data, and can perform some processing functions, but, due to the battery, have limited lifetimes, are larger in size and are more expensive than passive tags [4]. Active tags are most frequently found in defense or military operations, yet also appear in technologies such as EZ Pass, where tags are linked to a prepaid account enabling drivers to pay tolls by driving past a reader rather than stopping to pay at a tollbooth [7].

Currently, the emphasis is on the use of UHF passive RFID in the retail supply chain. It is important to note the frequency (UHF) and passive nature of the system. UHF passive systems typically have a read range of 10 to 30 feet (although read ranges can vary slightly due to localized conditions) and have difficulty with products containing water (which absorbs the radio waves) and metal (which reflects the radio waves) [13] [14]. Throughout this paper, we will be referring to passive UHF RFID, unless otherwise noted.

Myth #1: RFID is new – or -- RFID technology is mature and stable

The Myth

Due to the recent interest in passive RFID, brought on by its use in the consumer packaged goods (CPG) supply chain, many believe RFID to be a new technology. Thus, a portion of Myth #1 suggests that RFID is new. However, early versions of RFID have been used since World War II when the Allies equipped their aircraft with transponders to prevent friendly fire accidents. Hence, the source of the second portion of Myth #1, namely that RFID is mature and stable. Interestingly, the two portions of this myth, while somewhat based in reality are, in fact, contradictory (the technology cannot be new *and* mature).

The Reality

RFID, using the term broadly, has been around for many years; as indicated, one of the first uses of the technology was to identify aircraft during World War II. This early version of the technology was called IFF for Identify Friend or Foe [40]. Since World War II, RFID has

found limited, but successful, use in several niche areas. In fact, most people have used RFID without even realizing it. Popular uses of RFID include: toll road passes (a device usually attached to the windshield that allows one to keep driving past a toll booth rather than stopping to pay the toll) and employee ID badges (the type that requires the user to 'wave' the ID badge near a reader device). Most of the uses, to date, have employed *active* RFID (requires a battery), or passive RFID in lower frequencies (e.g., ID badges usually operate in the LF or HF range) [26].

Passive (UHF) RFID is a relatively new technology. This particular type of RFID technology was created at IBM in early 1990's [40] and experienced limited use until the Auto-ID Lab at MIT, along with a consortium of companies, began exploring its use more broadly (but specifically in the CPG supply chain) in 1999 [40]. Therefore, the use of passive RFID in the supply chain is new. Passive RFID is also far from mature and stable. Since its initial deployment by such retailers as Wal-Mart, the technology has evolved rapidly: devices are getting more powerful, more reliable, and more portable. Also, until December 2004, there was no accepted standard for passive RFID communication. EPCglobal adopted the Generation 2 standard in December 2004 and has since submitted it to the International Organization for Standards (ISO) for consideration (it appears that the ISO will adopt it as a global standard in the very near future). Standardization is a huge first step toward maturity. With the Generation 2 standard in place, tag and reader manufacturers can produce technology that is truly interoperable and end users can purchase the technology with interoperability assurance. As the technology is deployed in many different settings (various retailers, suppliers, manufacturing environments, etc.), the user community is gaining valuable insights into the proper uses of the technology.

Myth #2: RFID can be used to continuously track people/objects wherever they go – anywhere

The Myth

One of the concerns often expressed about RFID is that, due to its ability to 'track' things, one's privacy can and will be easily violated [3]. Essentially, some believe that RFID will be used to track people or their belongings wherever they are or wherever they go. This myth makes two key assumptions: (1) an RFID tag can be used as a real-time worldwide location device; and (2) that people and their belongings will contain RFID tags.

The Reality

It is true that passive RFID can be used to "track and trace" (track = where is it? trace = where has it been?) products. However, track and trace only works within certain very restrictive conditions. As indicated earlier, an electromagnetic field is needed to power a passive tag to allow it to respond to the reader. This field typically only reaches about 10 to 30 feet. Therefore, unless a tag enters this field, the reader has no idea the tag exists. When a tag enters the field, it can be "tracked" (i.e., the reader knows where the tag is because it is within the read zone) and once it leaves the field, one would know where the tag has been (i.e., traced). Outside of the read zones, however, the tag does not emit a signal nor can a reader locate the tag – a passive tag can only be recognized when it is within the electromagnetic field. Therefore, *continuous* tracking of people/objects anywhere in the world would require millions of readers and antennae located in very close proximity to produce the necessary overlapping

electromagnetic fields. Even on a smaller scale, to continuously track a box within a 20 acre warehouse would take thousands of readers and antennae – a situation that is simply not economically justified. Instead of continuous tracking, RFID can be used to effectively determine the movement of products through the supply chain by using discrete read points at key areas. Figures 1 and 2 illustrate potential read points in a distribution center and retail store, respectively. By establishing key read points in the supply chain, products can be tracked (e.g., the product is now at the store inbound door) and traced (e.g., the box was last seen at the sales floor door at 8:23am on February 23). As a case moves from the supplier, to the retail distribution center (DC), and then on to the retail outlet, it passes through a number of RFID read fields (Figure 1). Readers capture and record the case's tag data as it passes through these points. As product is delivered to the distribution center, read portals (created by stationary readers and antennae on each side of the delivery door) capture the pallet and case data. The product is stored in the distribution center for an indeterminate amount of time, then individual cases are put on the conveyor system to begin the sorting process; the conveyor system may contain multiple read points. Finally, the individual cases are sorted and shipped out the shipping doors which contain read portals similar to the receiving doors. The actual reads for a single case may vary depending on the type of product (e.g., bagged pet foods are not placed on conveyors) and the type of DC it enters (refrigerated/grocery DCs are different from general merchandise; e.g., grocery DCs have stretch wrap machines where readers can be placed, but do not have conveyors).

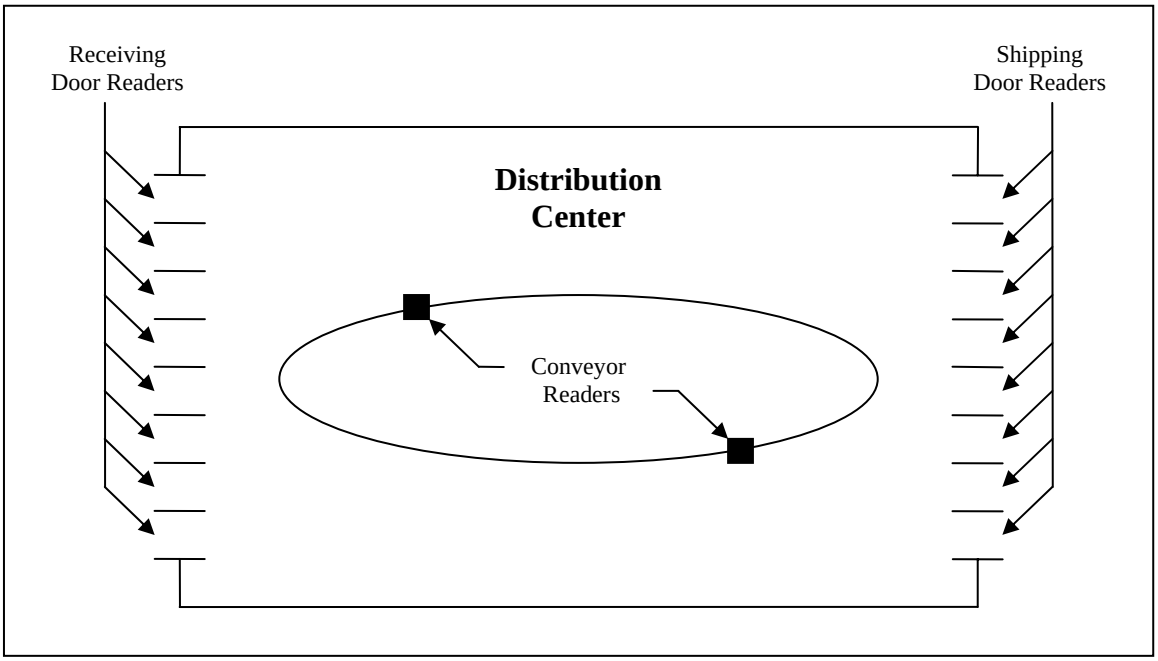

Figure 1. Generic Distribution Center Read Points

At the store level, the readers are confined to the backroom area – no readers are on the sales floor (see Figure 2). Receiving doors have read portals similar to those found at the DC dock doors and capture reads from the individual cases as they are unloaded from the truck. The product then moves immediately to the sales floor (where readers are placed next to the doors

going to the sales floor) or onto backroom shelving. Eventually, all products should be moved to the sales floor and the empty cases returned through the sales floor doors (a second read is captured at this point) and placed into the box crusher for disposal (the last read point).

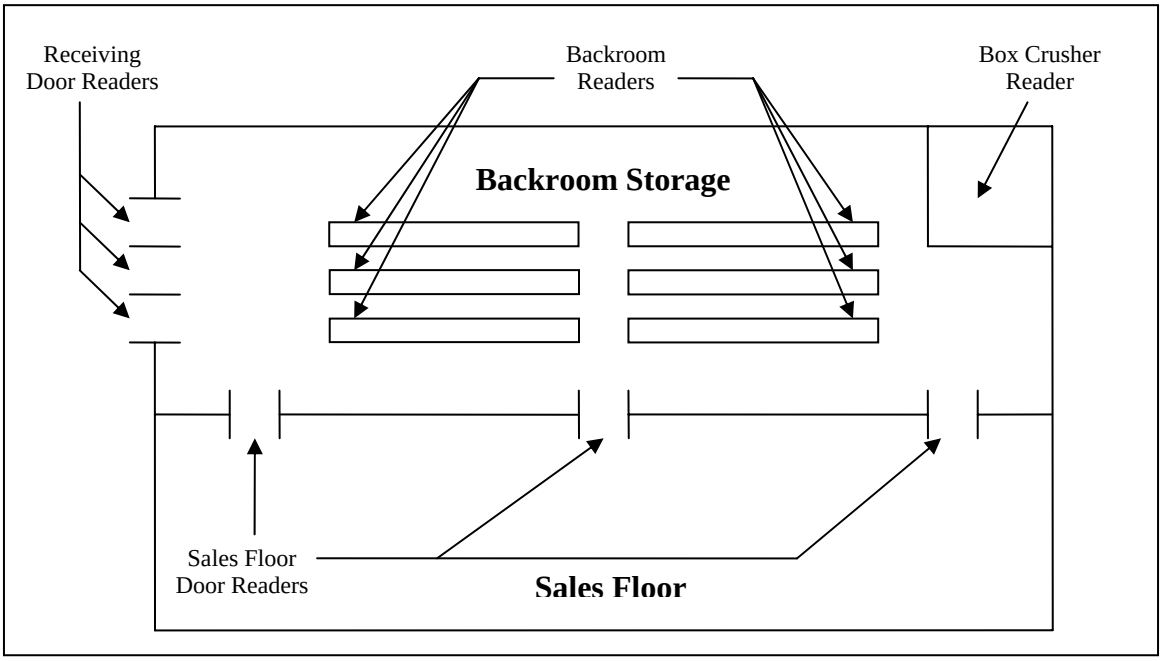

Figure 2. Generic Retail Store Read Points

Table 1 follows the movements of a single case of product from its arrival at the distribution center to its end of life at the box crusher. This particular case of product arrived at distribution center 123 on August 4, was put on the conveyor system on August 9, and departed shortly thereafter. It arrived at store 987 about 12 hours after leaving the DC, went almost immediately to the sales floor, returned from the sales floor about 4 hours later and was put in the box crusher for ultimate disposal. To understand the movement of products and to gain visibility into the supply chain, it is not necessary, nor is it economically feasible, to continuously track products as they move through the supply chain.

Facility	EPC	Date/time	Reader
DC 123	0023800.341813.500000024	08-04-05 23:15	inbound
DC 123	0023800.341813.500000024	08-09-05 7:54	conveyor
DC 123	0023800.341813.500000024	08-09-05 8:23	outbound
ST 987	0023800.341813.500000024	08-09-05 20:31	inbound
ST 987	0023800.341813.500000024	08-09-05 20:54	sales floor
ST 987	0023800.341813.500000024	08-10-05 1:10	sales floor
ST 987	0023800.341813.500000024	08-10-05 1:12	box crusher

Table 1. Sample RFID Data

Myth #2, in addition to assuming that a tag can be used as a real-time location device, assumes that people and their possessions will have an RFID tag. Currently, the emphasis is on tagging pallets and cases as they move through the retail supply chain. Technology does exist to allow a person to be implanted with a subdermal RFID tag. To date, these efforts have been focused on using the tag data for medical purposes [10] or to gain entry to doors, documents, etc. as a replacement for ID badges [8] [42]. Given discrete read points (such as those used in a retail supply chain), it is possible to track and trace a person as they move through the read zones. However, this type of track and trace is no different than the current use of employee ID badges to gain entry to buildings, for example – RFID simply represents a different (and totally voluntary) medium for doing so.

Overall, RFID can be used for tracking and tracing, but only within defined read zones. Continuous tracking everywhere is not feasible.

Myth #3: People can drive down the street and read RFID tags inside your home, thus knowing everything about you and your stuff

The Myth

With the ability to read tags without having a direct line of sight (i.e., reading through walls, boxes, etc.), some people are concerned that others will drive down the street with a portable RFID reader and detect the products you have in your home [18]. According to this myth, burglars are going to love RFID. Using the technology, they can simply cruise down the street and identify the house with the best stuff to steal. Certainly, this covert reading of tags constitutes a blatant violation of privacy.

The Reality

It is possible to read data from an RFID tag without direct line of sight – in fact, this is one of the key advantages of RFID. To read tags inside a home while driving down the street, however, is not likely for several reasons. First, recall that the read range for passive UHF RFID is typically about 10 to 30 feet. Thus, a car or person with an RFID reader would have to be extremely close to the house to read the RFID tags. And, since the signal can only penetrate about 10 to 30 feet, they would have to encircle your house. Anything more than about 10 feet from an exterior wall would probably be safely outside the read zone. Second, RFID is affected by water and metal. Not only would the reader have to be very close, but there could be no RF interference from water or metal. Third, currently, only pallets and cases are tagged. Since the majority of these pallets and cases are discarded at the store, or distribution center, there are few tags to be read inside the home. (Note: there are exceptions – some products with a case pack size of 1 would be tagged and taken home by the consumer; that is, the case becomes the item, such as a television or printer). It is likely that, within the next few years, more item level tagging will occur. If so, the occurrence of tagged products actually being in the home will increase. When RFID tagging becomes ubiquitous at the item level, evil doers may be enticed to attempt to identify products within the home. However, unless they drive very slowly within a few feet of the house (and, they would have to drive around the house) and there is no water or metal to interfere with the RF, then the likelihood is very small that this sort of thing will occur. In short, current technology simply does not allow one to drive down the street and read

everything inside someone else's home. Now, suppose for a moment that the technology did exist, what type of information would you obtain from an RFID tag? This information is the subject of Myth #4.

Myth #4: RFID tags contain information about anything and everything, including sensitive personal information

The Myth

In a recent episode of a popular television drama, a person implanted with a subdermal RFID tag was murdered. The detective working the case recognized the use of RFID and, via an RFID reader (that just happened to be readily available), was able to retrieve a picture of the person's driver's license, work history, college transcripts, etc. – all of this available from one tiny RFID tag. Identity theft is on the rise [11] and consumer concerns with privacy are at an all time high [34]. According to the proponents of this myth, RFID provides one more mechanism for invading one's privacy [3].

The Reality

While this mythical scenario makes for good television, RFID tags have very limited storage and cannot hold all of the information suggested. Most tags currently have only 96 to 256 bits of information [21]. In the supply chain, RFID tags contain an electronic product code (EPC) consisting of 96 bits of identifier information [9]. The EPC, much like the Universal Product Code (UPC), is a family of codes. A common EPC is the serialized global trade identification number (SGTIN). The EPC generally consists of a series of numbers that identify the manufacturer, the product (in some instances, such as the SGTIN), and a unique serial number for the tagged unit (pallet or case, for example). Figure 3 illustrates a sample EPC (specifically, an SGTIN) as it would appear on the tag and translated into human readable form. As shown in Figure 3, tag data, in its purest form, is a series of binary digits. This set of binary digits can then be converted to hex and the SGTIN decimal equivalent. As shown, an SGTIN is essentially a 14-digit UPC (for shipping container identification) with a serial number. The serial number is the most important difference between the 14-digit UPC used today and the SGTIN contained on an RFID tag. With UPCs, companies can identify the product family to which a case belongs (e.g., Paper Towels 2-pk), but they cannot distinguish one case from another. With an SGTIN, each case is uniquely identified. This provides visibility at the case level, rather than the product family level. Note, however, the absence of the 'mythical' information thought to be contained on an RFID tag – pictures of the product, names / addresses of key supply chain partners, key dates, etc. It is, however, possible to find much of this information by using the EPC (in this case, the SGTIN) to look up the information in a secure, proprietary database – no different than what is currently done today with UPCs.

RFID tags, in reality, contain only limited information – not vast databases of sensitive, personal information. As used within the supply chain, the EPCs can be used as 'license plates' to uniquely identify a product. Additional information about the product would have to be retrieved from an alternative data source.

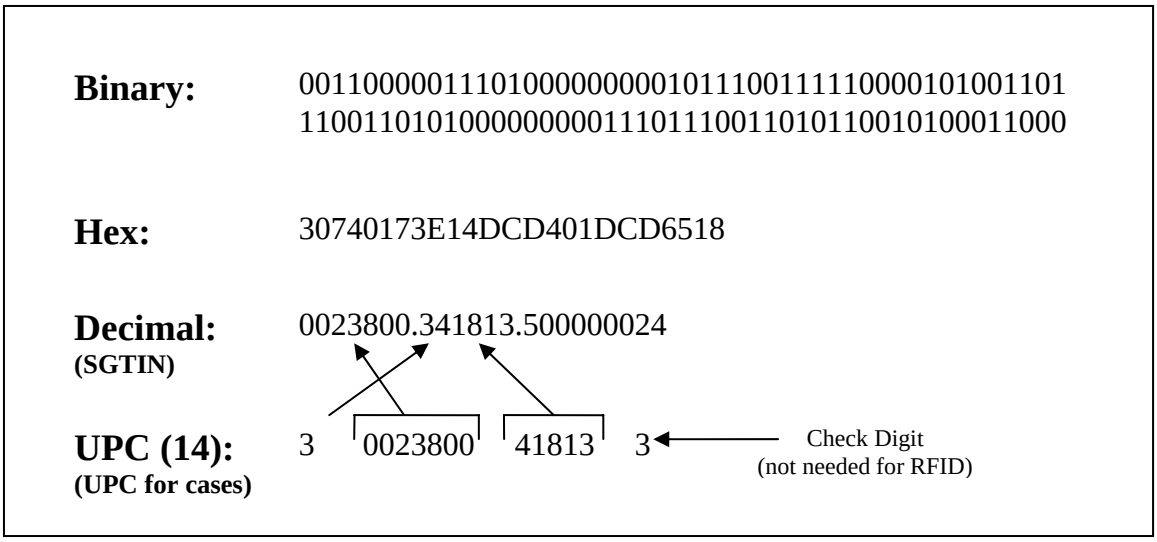

Figure 3: Tag Data

Myth #5: RFID is generating millions of terabytes of data

The Myth

Several estimates suggest that Wal-Mart's RFID, at full deployment, could generate more than 7 terabytes of data per day (e.g., [30]). Millions of products pass through supply chains such as Wal-Mart's on a daily basis. Capturing data at key read points for the associated pallets and cases will surely generate much more data than is currently collected via barcode (after all, that is one of the benefits of RFID – the visibility it provides compared to barcode). If RFID generates terabytes of data per day, companies will suffocate under an avalanche of data.

The Reality

RFID will produce more data. At issue, however, is how much more? A New York Times article states that Wal-Mart's *total* database size to date is about 460 terabytes [17]. Thus, it is hard to imagine a scenario that would produce multiple terabytes daily. Exactly how much data will be generated from the widespread deployment of RFID is difficult to determine, but a rough estimate can be made. As shown in Table 1, there are four key pieces of information needed for each read: (1) the facility (such as distribution center, store, etc.); (2) the EPC; (3) the date / time; and (4) the reader location. Now, if we liberally assign a storage size of 10, 25, 15, and 15 bytes to the facility, EPC, date/time, and reader location, respectively, then the total size per record is about 65 bytes. Next, let us assume that 1 million units (pallets and cases) move through the supply chain each day. Finally, Figures 1 and 2, suggest about nine different read points. To establish a liberal estimate, we will further assume that a unit can make it through all nine read points in one day (in reality, a single unit could not make it through all nine read points in a day; thus, our estimate may be high). Thus, the estimate of the daily database size becomes:

Record size X number of units moving through system daily X number of reads per unit per day (1)

Equation 1 assumes, of course, that a company does not keep thousands of reads per reader per tag (recall that readers are capable of reading each tag several hundred times per second). Rather, the vast majority of these 'duplicate' reads must either be filtered at the reader or at the server-level via specialized middleware. A company would not want or need to store thousands of reads for each tag at each read point.

Given the aforementioned assumptions, and equation 1, the estimated daily database size would be 585,000,000 bytes (65 x 1 million x 9); slightly more than one-half gigabyte of data. As mentioned, this is a very liberal estimate. Companies can plug their own numbers into this simple equation to determine their estimated database size. Thus, storage is not an issue since one-half gigabyte of data is relatively small. The real issue is the number of records generated (in this example, 9 million records are generated daily) and how one manages those records. In summary, it is not a question of terabytes, but a question of records. Yes, RFID will generate much more data. The challenge is not how to store it, but how to mine it for business value.

Myth #6: You must have 100% reads at 100% of the read points for RFID to be useful

The Myth

For RFID to be effective, every tagged unit must be seen at every potential read point in the supply chain. A 'missed' read on a pallet or case, for example, will cause inventory counts to be inaccurate. Thus, if RFID cannot guarantee that 100% of the tagged units will be seen at 100% of the read points, then why bother? And, since RFID is not a perfect technology (e.g., water and metal cause problems for UHF RF devices), achieving perfection (100%) is not possible. Some have used these arguments to suggest that RFID is not an appropriate technology for the supply chain because the read rates will be less than 100%.

The Reality

Is it possible to read 100% of tagged units at 100% of the read points? Theoretically, yes. Practically, no. There are many things that could cause a read to be missed, such as: a person walking in front of a reader as a case passes by could cause the reader to miss the case, and two cases passing through a read point side by side could cause one to be missed, among many others. We refer to the notion of seeing 100% of tagged units at 100% of read points as the "theoretical 100%" read. Although possible, it is unlikely that every tagged unit will be seen at every possible read point.

However, it is highly likely that a tagged unit will be seen at one or more read points. Although retailers expect to see 100% of the tagged units as they pass through the supply chain, they do not expect to see 100% of the units at 100% of the read points. Instead, they expect to see 100% of the tagged pallets as they pass through an appropriate read point (such as inbound doors at a distribution center) and 100% of the cases after they are removed from the pallet; it is not expected to see 100% of the cases on a pallet. Rather than concentrating on achieving the "theoretical 100%", it is more realistic to ask the questions: (1) was the tagged unit seen somewhere and (2) can a life cycle be constructed from the points at which it was seen?

Refer to Figures 1 and 2 which show typical read points at a distribution center and store. What is the probability that a case was seen somewhere in the supply chain? Assume that the chances of reading any given case are 50% at the DC inbound and 90% at the following read points: conveyor read 1, conveyor read 2, store inbound, out to the sales floor, in from the sales floor, box crusher. Then, the probability of seeing that case somewhere in the supply chain is:

1 – [(1-50%) x (1-90%) x (1-90%) x (1-90%) x (1-90%) x (1-90%) x (1-90%)] =
1 – [.0000005] =
99.99995%

Thus, the chances of seeing it at one of the read points is 99.99995% -- not 100%, but very, very close. We refer to the probability of seeing a unit somewhere in the supply chain as the "practical 100%". The above calculation assumes, of course, that the tag on the case is not defective. Obviously, a case with a defective tag will not be seen at any of the read points. The tagging source should verify the tag before releasing.

As a further exercise, one can examine the probability of seeing a case at various facilities, such as a store. Using the above parameters, the probability of seeing a case at the store (considering the store inbound, out to sales floor, in from sales floor, and box crusher readers at 90% each) is:

1 – [(1-90%) x (1-90%) x (1-90%) x (1-90%)] =
1 – [.0001] =
99.99%

The chances of seeing a case at the store is 99.99%. Obviously, as the read percentage at individual read points improves, the chances of seeing a case at least at one point also improves. According to public statements by Linda Dillman, CIO of Wal-Mart, read rates at the conveyor system and store box crusher are about 95% and 98%, respectively (as of January 2005) [33]. Thus, the examples provided suggest a conservative estimate for seeing a case somewhere in the supply chain.

A second expectation with read rates is the ability to construct a life cycle from the reads. For example, if a case is seen at conveyor read point 1 and the outbound (DC) door, then it must have passed by conveyor read point 2. Thus, conveyor read point 2 becomes an "implied" read, based on seeing it at the other two read points. Although it would be preferable to see the case at every read point, it is not necessary. A life cycle can be constructed by a combination of actual and implied reads.

Overall, it is possible – and highly likely – that one can achieve a "practical 100%" read rate (i.e., see 100% of tagged units somewhere in the supply chain"); a "theoretical 100%" (i.e., see 100% of tagged units at 100% of the read points) is much less likely.

Myth #7: Major retailers have mandated that all suppliers tag all products for all stores

The Myth

In June 2003, Wal-Mart asked its top 100 suppliers to begin using RFID tags on products by January 2005 [19]. The Department of Defense (DOD), Target, Albertson's and Best Buy have also started their own RFID initiatives [24] and, subsequently, have asked their suppliers to participate. Many believe that these "mandates" require that all products from all vendors (or, at least, the mandated supplier group) be tagged for all stores.

The Reality

The reality is that, currently, a relatively small group of suppliers is tagging a relatively small group of products going to a relatively small group of stores. Take, for example, Wal-

Mart's RFID initiative. The top 100 suppliers were to be ready to send tagged products through the Wal-Mart supply chain by January 2005. In addition to these 100, 37 suppliers *volunteered* to tag some products [19]. Of course, the top 100 suppliers represent several thousand products. Some companies tagged almost all of their products; others tagged only a few [29]. Suppliers were encouraged to develop a tagging strategy and work with Wal-Mart to determine what should be tagged during the early implementation phases. As of January 2005, Wal-Mart had RFID-enabled 104 stores, 36 Sam's Clubs, and 3 distribution centers (all in the Dallas, Texas area) [5]. Next, Wal-Mart asked their next 200 largest suppliers to begin tagging by January 2006 and the next 300 by January 2007 [27]. At the same time, they continued to increase the number of stores and distribution centers (approximately 500 stores by October 2005; an estimated 1000 stores by October 2006). Overall, Wal-Mart used a two-pronged implementation strategy: (1) groups of suppliers and (2) a geographic roll out.

The DOD, Target, Albertson's, Best Buy and others have followed similar strategies. For example, the DOD has required its suppliers, beginning in 2005, to tag items going to two depots [37]. The tagged items fall into four categories: rations, clothing, weapons repair parts, and personal demand items. In 2006, the number of tagged item categories is to increase to seven and the number of depots is to increase to 16. Target started its RFID implementation with just 10 stores and 1 distribution center (also in the Dallas, Texas area) in the fall of 2004 [35]. The company initially asked only a handful of vendors to tag three products each [1]. While Target plans to involve more vendors and more products, the company has kept a low profile and has stated that its interests lie primarily in the backroom (implying an RFID deployment more limited than Wal-Mart's) [32]. Albertson's issued a mandate to its top 100 suppliers in March 2004 requiring that they start tagging products at the pallet and case level by April 2005 [2]. Best Buy issued a similar mandate to their major suppliers in August 2004. The company does not expect to complete the process of having all pallets and cases from all suppliers tagged until May 2007 [28].

Eventually, if RFID continues to be adopted, all vendors will need to tag all products for all stores. In fact, to get the full value of RFID, it must be used widely (across stores and products) (perhaps this is the source of the myth?). However, contrary to what many believe, retailers (such as Wal-Mart) did not employ a "Big Bang" implementation strategy where all suppliers had to start tagging all products for all stores at one time. Rather, each is employing a phased roll-out (primarily geographic and groups of suppliers) to gradually enable the entire network (stores and suppliers).

Myth #8: RFID is costing the average Wal-Mart vendor $23 million annually

The Myth

AMR Research estimated that Wal-Mart's top 100 suppliers would each spend approximately $13 million to $23 million preparing to meet the retailer's initial January 2005 mandate [15]. Of this $13-23 million, $5-10 million was to be spent for tags and readers, $3-5 million for integration, $3-5 million for changes to legacy applications, and $2-3 million for storage and analytics [15].

The Reality

Incucomm surveyed 137 of Wal-Mart's suppliers after the initial implementation and found the median actual cost of implementation to be about $200,000 with an average of about

$500,000 [41]. The reality, then, represents a cost much less than the $13-23 million estimate. Why such a dramatic difference between AMR's estimate and Incucomm's actual? First, the scope of the implementation could affect the estimate. Many suppliers followed a 'slap and ship' strategy in which they simply put a tag on cases going to the designated Wal-Mart distribution centers. Second, technology prices continue to decline, which would reduce the total cost. Tag prices have seen the most dramatic decrease and represent the variable cost in the estimate provided by AMR. Third, the deployment of RFID is not as difficult as originally thought, thus reducing the integration costs. Finally, as suggested in Myth #4, the storage requirements for RFID data are much less than originally anticipated.

Overall, suppliers are spending much less on their RFID implementations than suggested by AMR Research. This initial estimate was cause for alarm in the industry (costs were much too high and no potential business case) and may have caused many to modify or delay their implementation plans. One way in which suppliers may have modified their strategy was to simply buy the cheapest tag possible, rather than purchasing a tag that was appropriate for their product. By doing so, they may have lowered their cost, but they have also reduced their ability to gain potential benefits from the tagging effort (as explained in Myth #9). Technology prices will continue to decline as the use of RFID expands (tags, readers, antennae), thus reducing the overall cost of implementation.

Myth #9: RFID is the panacea for creating the perfect supply chain

The Myth

RFID will solve all problems in an organization's supply chain. RFID-enabled supply chains will be free from process inefficiencies and process breakdowns, and all human touch points will be removed; thus, providing a totally automated supply chain. Overall, if one's supply chain is broken, RFID will fix it. Unfortunately, several companies have approached RFID believing all of the above to be true.

The Reality

RFID can improve the supply chain. Companies can use RFID to improve either the efficiency or effectiveness of various existing processes (e.g., make the receiving process more efficient by cutting down on the time needed to verify receipt of the product; with visibility of the product at case level, product rotation can be better monitored and managed). Companies can also use RFID to radically change the way they are either manufacturing or distributing their products. RFID provides the ability to reduce human touch points (such as scanning product for a barcode) and to "see" products as they move along the supply chain – visibility that is not currently available in most retail supply chains. However, simply putting a tag on a box and installing a reader at a dock door is not going to solve supply chain issues. Rather, the technology must be deployed properly and the data used to drive process improvements.

Although current uses of RFID are relatively limited (not yet widespread), early results of its benefits are encouraging. In a study using RFID to track promotional items, Gillette found that 38% of the stores did not get the product to the shelf in the time window provided (e.g., if something is on sale for the week of February 27, did it make it to the sales floor during that week) and, not surprisingly, sales were 48% higher in those stores where the product did make it to the sales floor in a timely manner [22]. Wal-Mart reported the results of a study conducted by the University of Arkansas that showed a 26% reduction in out of stocks after RFID was

deployed in several stores [16] [36]. Other benefits such as better recall management and tracing the pedigree of products have also been touted and demonstrated [6].

RFID offers many advantages over existing barcode technology (see Myth #10) and many potential opportunities to improve the supply chain. RFID can reduce product out-of-stocks, make product movement more efficient, and provide unbelievable visibility into the supply chain. That said, it is not a panacea for all supply chain problems. Companies must realistically deploy RFID and identify those areas where benefits may occur. Simply putting the technology in place without an identified need or understanding of the data it provides will limit the potential benefits.

Myth #10: RFID is replacing the barcode

The Myth

Barcode technology is old and outmoded. RFID is a mature and stable technology (myth #1) that offers the ability to solve all of one's supply chain problems (myth #9). Thus, RFID is moving rapidly to replace the barcode. To bolster the RFID industry, at the expense of the barcode industry, some would lead you to believe that the barcode will soon disappear.

The Reality

RFID does offer several advantages over barcodes. Examples of these advantages include [25] [31]:

- RFID tags do not require a clear "line-of-sight" with the reader's antenna; barcodes requires line of sight.
- Many RFID tags can be read simultaneously; for barcodes it's one at a time.
- RFID tags contain more information than most barcodes, specifically a serial number used to identify the tagged unit; barcodes primarily identify product families. (Note: some industries, such as perishable foods, use a barcode that contains additional information such as weight, date, and serial number and some specialized barcodes contain several thousand bits of information.)
- RFID tags are resistant to heat, dirt, and solvents and are not easily damaged.
- RFID tags can potentially be written multiple times, making them reusable data containers.

However, barcodes offer several advantages over RFID:

- Barcodes are less expensive than RFID tags.
- In certain circumstances (such as around water and metal), they are more reliable to read and provide more accurate read rates.
- Barcodes work with virtually any products (whereas current RFID tags are not suitable for some container types).
- Barcodes can be printed before production or can be printed directly on the items.

Currently, RFID is predominately used at the pallet and case level. Cases contain a 14-digit UPC and could be replaced with RFID as its use spreads globally. However, it will be several years before RFID will reach the individual item level (e.g., a bottle of mustard). First,

barcodes are much less expensive to produce for item level identification (barcodes cost 1/10 of 1 cent [12]). RFID tags, although declining in cost, are much more expensive. RFID uses silicon chips which will keep the costs high (compared with barcodes). Second, barcodes are integrated into the item level packaging (e.g., the barcode is part of the mustard bottle). RFID tags are currently difficult to integrate since they require a silicon chip. Recently, Philips Research Laboratories has announced alternative types of 'chipless' tags that do not require a silicon chip but, instead, use polymer film circuits [20]. Companies like Fuji, MXT, and the British Technology Group are also experimenting with magnetic wire and fiber systems for chipless RFID [20]. Thus, RFID and barcode will serve as complementary technologies in the near term, each serving a different purpose in the supply chain. RFID is a data carrier, much like barcode; therefore, it is possible that it will replace the barcode at some point.

Conclusion

RFID is an exciting technology and offers many potential benefits for the supply chain. However, for RFID's continued development and adoption, there must be a clear understanding of what it can and cannot do within the supply chain. Positive hype tends to create unrealistic expectations and negative hype creates false perceptions of the dangers of the technology – both types of hype are harmful. Hype manifests itself as myths, which begin to be viewed as the truth. In this paper, we have identified 10 popular myths of RFID (both positive and negative) and elucidated the corresponding realities. Many of the myths discussed in this paper may, at some point, become reality as the technology advances and its uses become more sophisticated. At this time, however, the myths may have a kernel of truth, but are mostly false. Separating myth from reality should help provide rational expectations and perceptions so that organizations, consumers, and governments have a more realistic understanding of RFID.

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