/Theory/In/Practice

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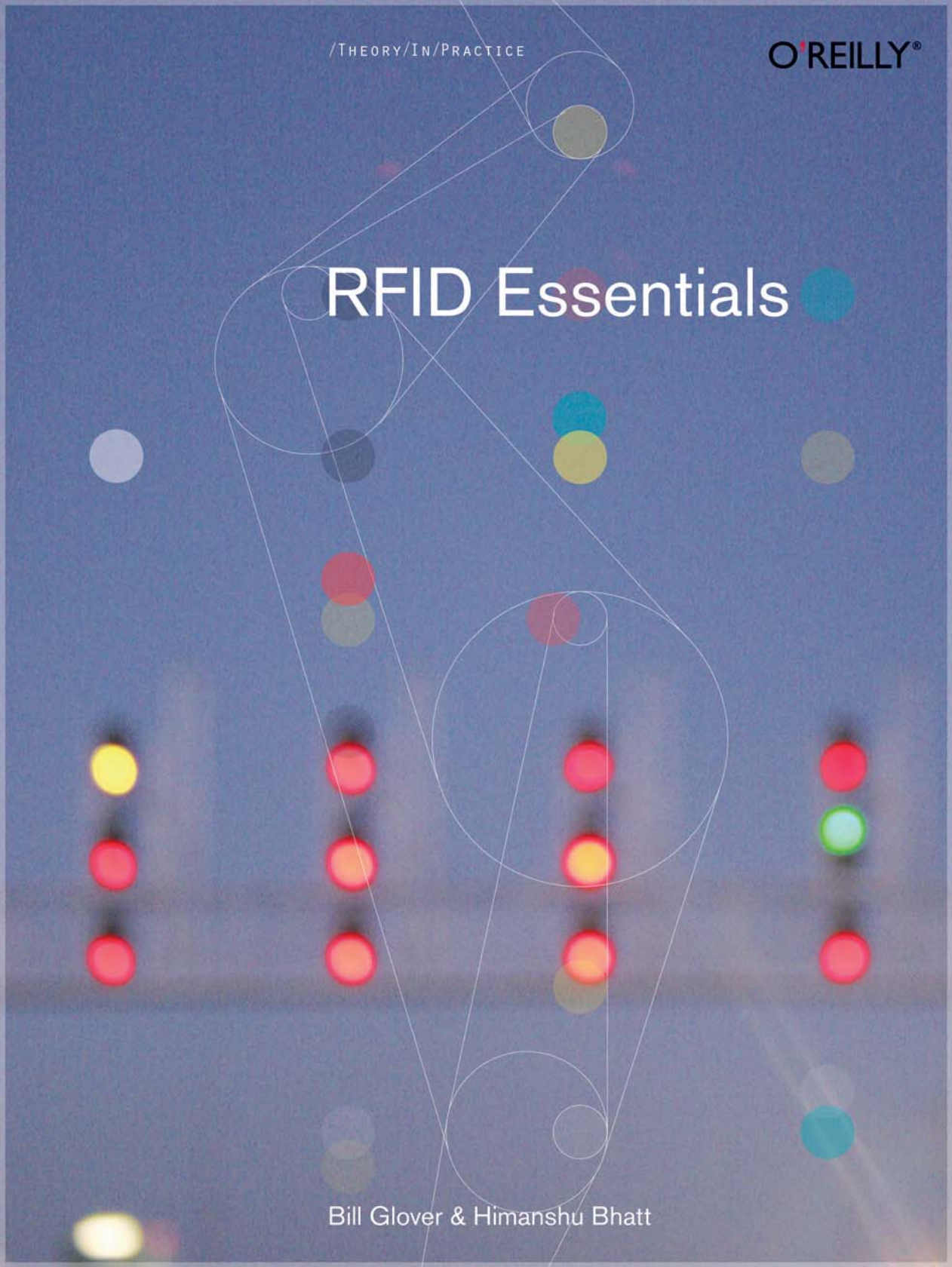
RFID Essentials



Bill Glover & Himanshu Bhatt

CHAPTER ONE

An Introduction to RFID

In Twelfth Night, Shakespeare wrote, "Some are born great, some achieve greatness, and some have greatness thrust upon them." RFID is one of the more recent four-letter abbreviations to have greatness thrust upon it in a flurry of industry mandates, governmental legislation, and hyperbole. RFID stands for Radio Frequency Identification, a term that describes any system of identification wherein an electronic device that uses radio frequency or magnetic field variations to communicate is attached to an item. The two most talked-about components of an RFID system are the *tag*, which is the identification device attached to the item we want to track, and the *reader*, which is a device that can recognize the presence of RFID tags and read the information stored on them. The reader can then inform another system about the presence of the tagged items. The system with which the reader communicates usually runs software that stands between readers and applications. This software is called *RFID middleware*. Figure 1-1 shows how the pieces fit together.

Much of the recent interest surrounding RFID has arisen from mandates and recommendations by government agencies such as the U.S. Department of Defense (DoD) and the Food and Drug Administration (FDA), and from a few private sector megacorporations. For instance, in an effort to improve efficiency, Wal-Mart called for its top 100 suppliers to begin providing RFID tags by early 2005 on pallets shipped to its stores. This mandate caused the companies in Wal-Mart's supply chain to focus on implementing RFID

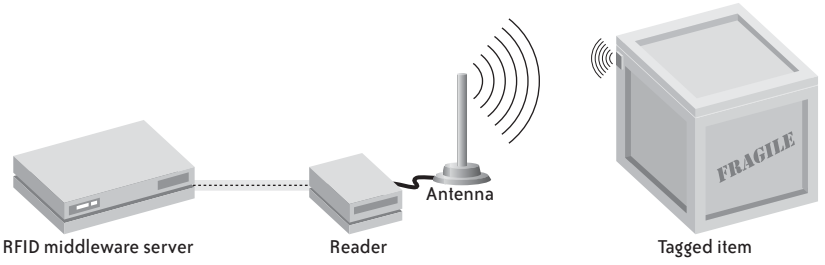


FIGURE 1-1. An RFID system

solutions. Companies worked to decide which tags and readers to use, how to attach tags to (or embed them in) containers or products, and how to test the read rates for RF tags on pallets as they moved through doors and onto trucks. Several companies have announced their support for what are now commonly known as *tag and ship* applications, which tag a product just before shipping it somewhere else, but few of these companies have moved beyond minimum compliance with the mandates to using the information on RFID tags to increase efficiency in their own internal processes.

The mandates have also focused most of these early implementations on tagging, and thus on the physical side of the RFID systems. However, while it is important to both select tags and readers and find just the right arrangement of antennas to recognize tags as they move through docks and conveyor belts, the true benefit (and complexity) of RFID systems doesn't come from reading the tags, but from getting the information from those reads to the right place in a usable form. The first 100 were only the beginning of the Wal-Mart RFID rollout. Many more suppliers will be tagging pallets and cartons and some individual items by the end of 2006. Meanwhile, the biggest news in RFID may surround the ePedigree initiatives aimed at reducing counterfeiting and improving efficiency and safety in the distribution of pharmaceuticals. By then, many more new initiatives will have been launched to apply RFID to other industries in ways we can hardly predict (although we'll try in Chapter 11).

In the pages to come, we explain the essentials of an RFID system, and in order to put these concepts in perspective, we will also briefly discuss the history, current status, and future of the technology. This book will give you the information and understanding you need to take on your first RFID project, but we hope you'll find it just as useful once you become a seasoned veteran in the field.

The Case for RFID

RFID technologies offer practical benefits to almost anyone who needs to keep track of physical assets. Manufacturers improve supply-chain planning and execution by incorporating RFID technologies. Retailers use RFID to control theft, increase efficiency in their supply chains, and improve demand planning. Pharmaceutical manufacturers use RFID systems to combat the counterfeit drug trade and reduce errors in filling prescriptions. Machine shops track their tools with RFID to avoid misplacing tools and to track which

tools touched a piece of work. RFID-enabled smart cards help control perimeter access to buildings. And in the last couple of years, owing in large part to Wal-Mart and DoD mandates, many major retail chains and consumer goods manufacturers have begun testing pallet- and case-level merchandise tagging to improve management of shipments to customers.

Part of what made the growth in RFID technologies possible were the reductions in cost and size of semiconductor components. Some of the earliest RFID tags were as big as microwave ovens, and the earliest readers were buildings with large antennas, as described in Chapter 3. Figure 1-2 shows a modern RFID tag (in the clear applicator) and a reader.

FIGURE 1-2. A tag and reader (image courtesy of Merten G. Pearson, D.V.M.)

Note how the bar code on the applicator matches the code read on the reader. The tag is inside the applicator in this picture and is about the size of a grain of rice. It's very similar to the glass capsule tag shown in Figure 1-3.

FIGURE 1-3. The VeriChip is smaller than a dime (image courtesy of Applied Digital)

Like RFID tags, the size of tag readers is shrinking. While most tag readers are still the size of a large book, smaller and less expensive readers may open up opportunities for many new RFID applications that, over the coming years, could become a normal and mostly unnoticed part of our lives. Figure 1-4 shows one of the smallest readers currently available.

As individuals, we must consider what impact this technology will have on our lives. Such an efficient and unobtrusive tracking mechanism can be used in ways that raise concerns about individual privacy and security. As citizens, we must understand the benefits and

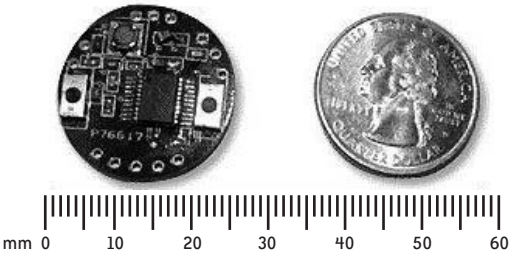


FIGURE 1-4. SkyeTek's SkyeRead M1-mini (image courtesy of SkyeTek)

costs of this technology and its impact on us. Conversely, as developers, we know that "unobtrusive" is a euphemism for "works correctly because a great deal of effort went into design, implementation, and testing." It is our job as managers, architects, and developers to make the technology work so well that it disappears. The following pages will provide an introduction to how RFID works.

Advantages of RFID over Other Technologies

There are many different ways to identify objects, animals, and people. Why use RFID? People have been counting inventories and tracking shipments since the Sumerians invented the lost package. Even some of the earliest uses of writing grew from the need to identify shipments and define contracts for goods shipped between two persons who might never meet.* Written tags and name badges work fine for identifying a few items or a few people, but to identify and direct hundreds of packages an hour, some automation is required.

The bar code is probably the most familiar computer-readable tag, but the light used to scan a laser over a bar code imposes some limitations. Most importantly, it requires a direct "line of sight," so the item has to be right side up and facing in the right direction, with nothing blocking the beam between the laser and the bar code. Most other forms of ID, such as magnetic strips on credit cards, also must line up correctly with the card reader or be inserted into the card reader in a particular way. Whether you are tracking boxes on a conveyor or children on a ski trip, lining things up costs time. Biometrics can work for identifying people, but optical and fingerprint recognition each require careful alignment, similar to magnetic strips. Facial capillary scans require you to at least face the camera, and even voice recognition works better if you aren't calling your passphrase over your shoulder. RFID tags provide a mechanism for identifying an item at a distance, with much less sensitivity to the orientation of the item and reader. A reader can "see" through the item to the tag even if the tag is facing away from the reader.

RFID has additional qualities that make it better suited than other technologies (such as bar codes or magnetic strips) for creating the predicted "Internet of Things."† One cannot,

* Lawrence K. Lo, "AncientScripts.com: Sumerian," *http://www.ancientscripts.com/sumerian.html*.

† This term was originally attributed to the Auto-ID Center. We will discuss both this term and the Auto-ID Center in more detail later in this book.

for instance, easily add information to a bar code after it is printed, whereas some types of RFID tags can be written and rewritten many times. Also, because RFID eliminates the need to align objects for tracking, it is less obtrusive. It "just works" behind the scenes, enabling data about the relationships between objects, location, and time to quietly aggregate without overt intervention by the user or operator.

To summarize, some of the benefits of RFID include the following:

Alignment is not necessary
: A scan does not require line of sight. This can save time in processing that would otherwise be spent lining up items.

High inventory speeds
: Multiple items can be scanned at the same time. As a result, the time taken to count items drops substantially.

Variety of form factors
: RFID tags range in size from blast-proof tags the size of lunch boxes to tiny passive tags smaller than a grain of rice. These different form factors allow RFID technologies to be used in a wide variety of environments.

Item-level tracking
: Ninety-six-bit RFID tags provide the capability to uniquely identify billions of items (more about this in Chapter 3).

Rewritability
: Some types of tags can be written and rewritten many times. In the case of a reusable container, this can be a big advantage. For an item on a store shelf, however, this type of tag might be a security liability, so write-once tags are also available.

The Promise of RFID

As previously mentioned, the capability to attach an electronic identity to a physical object effectively extends the Internet into the physical world, turning physical objects into an "Internet of Things." Rather than requiring human interaction to track assets, products, or even goods in our homes, applications will be able to "see" items on the network due to their electronic IDs and wireless RF connections.

For businesses, this can mean faster order automation, tighter control of processes, and continuous and precise inventories. Business partners will finally be able to share information about goods end to end through the supply chain and, just as importantly, to instantly identify the current location and status of items. For example, pharmacists will be able to track how long perishables have been out of refrigeration.

Military personnel, law enforcement officers, and rescue workers may soon use RFID tags to help build and configure complex equipment based on rules enforced by tag readers. RFID already tracks expensive and sensitive assets used in each of these fields.

For individuals, RFID could provide more effortless user interfaces—so-called "smart" systems that could tell you, for example, which clothes in your closet match. Smart medicine cabinets could warn you against taking two drugs that might interact negatively. It's even conceivable that supermarkets of the future may not have checkout stands—you may fill your cart with goods that a reader in the cart will scan and add to your total. Video monitors on the shelves will offer specials on complementary products; they may even offer to guide you to all of the ingredients for a recipe, based on some of the items you've already chosen. As you walk out the door, you will place your thumb on a pad on the cart handle to approve payment. A shoplifter, however, wouldn't make it very far before the readers recognized unpurchased items passing beyond the sales floor.

Some of these applications are already running in pilot stages. Libraries and video stores use RFID to thwart theft. Some shoppers in Japan use RFID-enabled cell phones to make purchases from vending machines. Businesses use RFID to track goods, and animal tracking has been around for years.

RFID will enter the home and the supermarket aisle when the prices of readers and tags become low enough and when the information infrastructure to use and maintain the new technology is in place. Some of these applications may seem far-fetched, but they are things we know we can do with a bit of engineering. What RFID promises most is to surprise us with uses we can't even imagine at this stage of adoption.

> NOTE
> **For more on the future of RFID, see Chapter 11.**

The Eras of RFID

The progress of RFID adoption divides naturally into eras: the Proprietary era, the Compliance era, the RFID-Enabled Enterprise era, the RFID-Enabled Industries era, and the Internet of Things era. In Figure 1-5, you can see when some of the capabilities of RFID technology became, or will become, available.

In the beginning, during the Proprietary era, businesses and governmental entities created systems designed to track one particular type of item, and this tracking information typically remained within the same business or governmental entity. In the Compliance era (the present era), businesses implement RFID to meet mandates for interoperability with important customers or regulatory agencies but often don't use the RFID data themselves. The future will bring the era of the RFID-Enabled Enterprise, where organizations will use RFID information to improve their own processes. The era of RFID-Enabled Industries will see RFID information shared among partners over robust and secure networks according to well-established standards. The final RFID era that is currently foreseeable is the era of the Internet of Things. By this time, the ubiquity of RFID technology and other enabling technologies, combined with high standards and customer demand for unique products based on this infrastructure, will lead to a revolutionary change in the way we perceive the relationship between information and physical objects and locations. More and more,

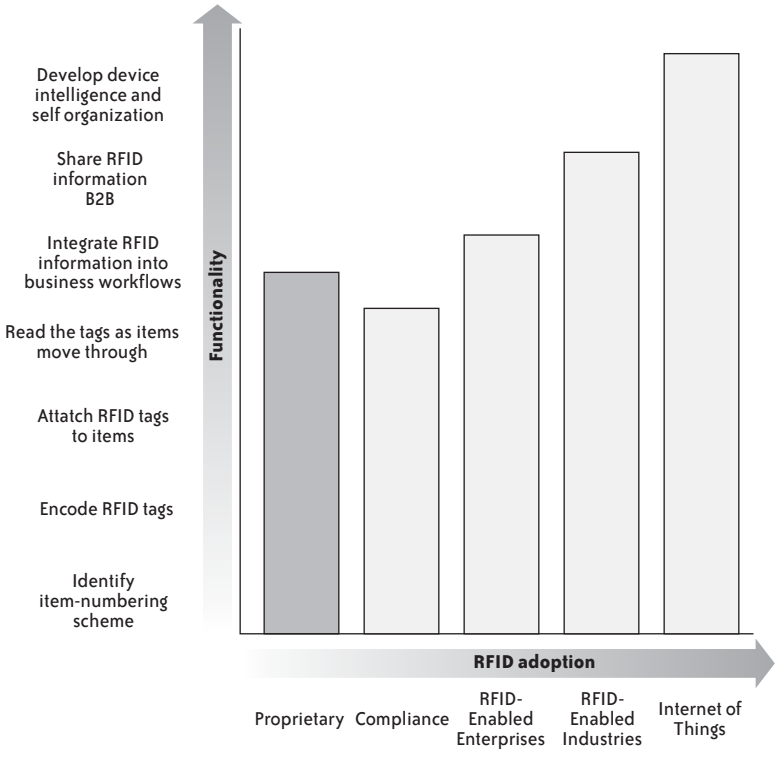


FIGURE 1-5. New capabilities will come with deeper adoption

we will expect most objects in our daily lives to exist both in a particular place, with particular properties, and in the information spaces we inhabit. For instance, a park bench has a particular shape, color, and location, but with a tag, it can also have a list of notes left by people who have stopped there to rest. The list is just as real as the color of the paint, and just as much an attribute of the bench. This is now a green metal bench on the north end of Shaker Park with "a great view of the sunrise," according to "pigeon-guy."

Companies, regions, and even individuals will move through these eras at different paces. Even now, some users of RFID are touching on the RFID-Enabled Industries era as emerging standards make this possible, while others are still in the Proprietary era. In many other areas, RFID has not been adopted at all.

The Proprietary Era

For almost 60 years now (triggered by the development of transistors in 1947), businesses and governmental entities have used RFID to track items and provide access control to facilities. The smaller size and greater durability of transistors made it possible to attach transmitters to valuable items, and over time developments such as improved batteries, integrated circuits, and microchips reduced the cost of the transmitters (tags), allowing tracking of less valuable items. Some of the applications in this era included the tags used to track rail cars and the chassis tags that have been used since the 1980s to track

automobiles through an assembly line. In the 1970s and 1980s, RFID was used for tracking dairy cattle. In the 1990s, the beef industry began tracking cattle using $5.00 ear tags. Expensive, proprietary RFID tags, which were usually recycled, were a major characteristic of this era. The reuse spread the cost out, such that a single use might cost only a few cents. Some of the systems developed during this era were technically advanced and tightly integrated into business processes, but they were characterized by both poor support for sharing information between trading partners (incompatible IDs, for instance) and costly reader and tag components.

The Compliance Era

The steep drop in semiconductor prices and widespread adoption of broadband networking at the end of the 20th century triggered an era we call the Compliance era. In this era, the U.S. DoD and large retailers such as Wal-Mart and Tesco began asking their suppliers to tag pallets (and sometimes individual items) with RFID tags. Their mandates required that the tags conform to emerging standards. The anticipated volume of tags that will be purchased to meet these mandates has pushed these same standards much closer to universal adoption, which has greatly reduced the cost of components.

Because this tagging effort has arisen from efforts to comply with a mandate rather than a perceived business opportunity for suppliers, many suppliers have implemented so-called tag and ship applications, which apply RFID tags to pallets or cartons as they leave the supplier's control and ship to a retailer or government customer. The supplier then uses the information on the tag to fill out an advanced shipment notification (ASN), notifying the recipient to expect goods tagged with particular identifiers. The supplier does not tag the goods early enough in its own cycle to take advantage of tracking to improve its processes.

In short, some of these suppliers currently may see RFID as an added expense and burden. They are driven almost entirely by cost efficiency in complying with the mandates, and we do not see applications that integrate RFID into internal business processes or extensive sharing of RFID information between partners in this era. Also, the new, less expensive tag technology is still prone to manufacturing defects, and, due in part to early implementation of the tag standards, often Compliance-era tags do not perform as well in practice as the tags in the Proprietary-era systems. Thus, while adoption of RFID is on the rise, there has actually been a slight slump in its capabilities (in the sense of how the technology is used, if not the purposes to which it is applied). Fortunately, new, more efficient standards and rapid improvement in both tag quality and throughput are quickly closing the gap.

The RFID-Enabled Enterprise Era

As standards stabilize and component costs fall, many organizations will begin to implement RFID tracking within their internal processes. This will allow them to measure the pulse of their distribution systems for materials, assets, and products and to keep real-time inventories of items, such as the location and age of perishable goods. During this era, declining costs will inspire a steady transition from tracking shipping units to tracking individual items. Other types of sensors will join RFID to monitor information such as the

highest temperature to which an item has been exposed or whether gases produced by spoilage are present. Labor-intensive bar code inventories will, in many cases, be replaced with scan-by inventories, allowing someone simply to walk down the aisle with a hand-held reader. Similarly, portal readers at the door will record the entry and exit of every item in a shop or warehouse.

In response to demand, more manufacturers will begin tagging items with standards-compliant tags at the point of origin, taking over from the suppliers and distributors who performed this role in the Compliance era. Business integration products and inventory tools will begin to fully support individual item tracking.

However, even with widespread internal adoption and tagging at the origin of the supply chain, it will take time for businesses to develop the agreements and security to allow organizations to share RFID information with one another (so-called business-to-business, or B2B, communication). While businesses will continue to share whatever B2B information they have shared in the past, the new RFID information will be used largely within the enterprise.

The RFID-Enabled Industries Era

In this era, RFID standards, RFID information networks, business agreements, and comprehensive security and privacy policies will solidify to the point where entire industries and supply chains can share appropriate information reliably, trusting that only authorized users can see any sensitive information. This will probably include a redefinition of what constitutes sensitive information, as unexpected revelations are likely to arise from the study of detailed instance data (where only aggregates and estimates were available before). Safety overstock inventories will drop, along with fulfillment times and costs, due to theft and error. Simply knowing "what was where when" provides a powerful tool for applications that we have only begun to realize. Expect to see new products, partnerships, and even whole cottage industries develop by harnessing the advantages of this new flow of information.

For many years, pundits have predicted that businesses will begin to share information much more freely, but it hasn't yet happened on the scale they predicted. Why might RFID information be different? The key is that RFID information is very concrete. It can be difficult for partners to agree on what an item description should contain, but RFID information can be as simple as a universally standardized ID code, a timestamp, and a universally standardized location code. (For more information on ID and location codes, see Chapter 4.)

While we will realize all of these advantages, significant challenges will also arise as managing all of this information, including the sensors and software that produce it, becomes more difficult. Ad hoc or dated architectures will creak and even fail under the load.

The Internet of Things Era

This final era will be triggered by widespread adoption of RFID technology and the associated demand for easier management of distributed sensor networks, as well as by a reduction in the cost of smart devices and tags. Lower costs and greater demand for information will commercialize existing technologies already in use so that military and manufacturing applications can create self-organizing networks of cheap, expendable components with extremely low incremental maintenance and management costs. This technology will finally make it possible to adopt RFID technology on retail floors, in farm fields, and in homes. It will expand the group of businesses adopting the technology to include even the smallest entrepreneurs. RFID tags will cease to simply be labels applied to items and will more often be added as integral parts at the time of manufacture or as part of the packaging. At this stage of development, the idea that an item has a digital identity will become as basic as the idea that an item has a color or weight or size.

In this era, physical objects will be tied to the Internet through their digital identities. Just as we expect to be able to do a quick Internet search to find the answer to an obscure trivia question, we will expect to be able to wave a soda bottle past a cell phone and find out where and at what specific time the soda was manufactured and, if we like, the last known location of every other bottle of that soft drink manufactured within the same hour at a particular location. Invisible digital graffiti associated with identities attached to physical objects will surround us in the form of messages posted to the Internet. But this could go far beyond messages like "Joey was here"—for example, a how-to video for using a piece of equipment could be associated on the Internet with the equipment's tagged ID. By this era, we probably won't think about RFID technology any more than we think about electrical technology today. We will simply expect it to work.

Application Types

Certain broad types of RFID applications characterize whole approaches to this technology and are different enough in considerations and implementation to warrant a separate discussion. The tree in Figure 1-6 shows RFID's relationship to other identity systems, as well as the relationships between different types of RFID.

The term "autoid," short for automatic ID, describes any automated system for attaching an identity to an item. Real-Time Location Systems (RTLSs) are automated systems for tracking the location of an item. Notice that RFID is related only indirectly to RTLSs and that RFID is only one type of automated identity system. We will discuss RTLSs and how they can complement RFID in Chapter 11.

Obviously, we can't fit all of the possible uses of RFID into five simple categories, so we've left out a few applications. For example, while we don't directly discuss payment systems, pay-at-the-pump systems based on RFID raise some (but not all) of the same concerns as access control systems. Refer to the "Access Control" section for information on considerations and implementation; although payment systems don't always have issues with

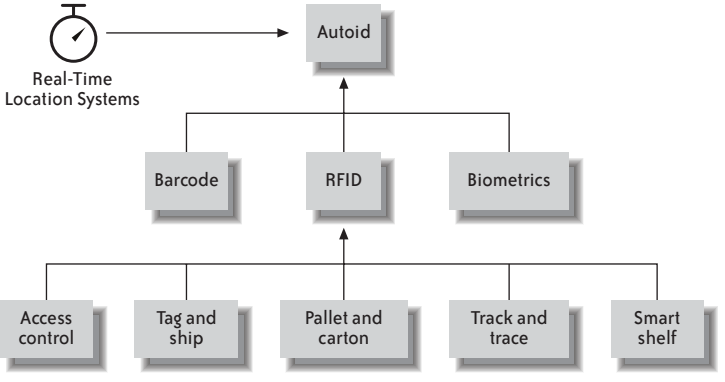


FIGURE 1-6. Relationships among the various types of RFID applications

tailgating, both types of system must overcome counterfeiting and require strong audit procedures. We've also left out some unique applications, such as using RFID tags on compatible pieces of equipment to coordinate assembly of mobile structures in the field for military deployments and trade shows. However, these five categories are inclusive enough to provide at least some sense of the issues and considerations involved in typical RFID applications. The future will bring even more varied applications, but they will raise many of the same concerns as the applications in these categories.

Access Control

Access control applications are RFID systems used to selectively grant access to certain areas—for example, RFID tags attached to an automobile or held in a person's hand as a card, key chain, or wristband may allow access to a road, building, or secure area.

Considerations

Primary considerations for this type of application are:

Anti-counterfeiting
: Counterfeit tags must be recognized and attempts to use or manufacture them discouraged.

Tailgating
: Tailgating occurs when an unauthorized person or vehicle enters just behind an authorized person or vehicle before the gate or door can close.

Emergency access
: In an emergency, the access control system must allow emergency personnel or vehicles access to secured locations. It must also allow nonemergency personnel to evacuate without getting in the way of the emergency response team. Yet emergency access provisions must not provide an attractive "exploit" that allows unauthorized persons to defeat the system by staging a false emergency.

Implementation

To address tailgating and emergency access considerations, most access control implementations include a barrier to entry such as a gate or door. The timing of the door and additional sensors can "singulate" vehicles or persons who enter, restricting access to one at a time.

The anticounterfeiting consideration is the most difficult to address. Many existing systems try to keep the construction and programming of their tags a secret in hopes that no one will reverse-engineer them, but several of these systems have already proven vulnerable to such attacks. Fortunately, most of these systems were noncritical or were backed by audit procedures that caught reverse-engineering attempts. Strong encryption of both a randomly generated challenge message and digital signatures might reduce the opportunity for counterfeiting in cases where the added cost of more complex tags is acceptable, but in general, a human guard, video camera, or police interceptor vehicle is sufficient to discourage all but the most incorrigible. The lesson is that RFID systems do not operate in a vacuum, and effective systems often involve supporting automation, other sensors, and manual processes to ensure success.

Tag and Ship

Tag and ship applications are minimal RFID systems that allow a user to associate an RFID tag with an item, apply the physical tag to the item, and then verify that the tag operates properly while attached to the item. In some cases, these systems even use pre-encoded tags to further reduce cost (see the "Implementation" section for a warning about this practice).

Considerations

Primary considerations for this type of application are:

Cost
: Because the drivers for this sort of application typically comply with a mandate, keeping cost low is the primary concern of the end user. This includes initial cost and the total cost of ownership (TCO) over time, from upgrades and repairs to monitoring and maintenance.

Isolation
: Tag and ship systems are in some cases the first automated system to be deployed at a given location. The support and maintenance infrastructure needed for such systems, and even the floor space they take up at the dock or shipping area, often aren't readily available.

Tag failure
: Manufacturing defect rates are still high for the smart labels (paper tags with embedded RFID antennas and chips) used in this type of application. Since the logistics of trying to reorder missing numbers would be difficult, the system may have to discard one or more labels before finding a functioning label to apply to the item. For pre-encoded labels, this means discarding serial numbers.

Impact on processes

Because this type of application is typically implemented in response to an external mandate rather than a perceived internal need, the application's impact on the throughput of what may be a finely tuned manual process can be an important issue. RFID labels appear as only an added cost from this perspective, and each extra second spent attaching labels raises that cost.

Implementation

To implement a tag and ship system, the first requirement is to create or purchase a tag and ship device with a low TCO. A self-contained appliance that operates as simply and reliably as possible should be the best fit. Repairs and maintenance should be no more difficult than changing a light bulb. This means it is often cheaper to buy a few spare devices than to maintain and manage a single device or pair of devices. Owning spare devices can, for example, lower the costs of maintaining and supporting the device in harsh environments where visits from IT personnel are rare.

For the device to resolve the other primary considerations, it should operate simply and quickly and impact manual processes as little as possible. This means there cannot be a complex workaround for failed labels or a multistep process for applying the labels. The simplest way to implement this system is to use labels that are encoded by the appliance itself rather than those pre-encoded by a tag vendor. This enables you to simply skip a failed label and write the same identity to successive new labels until one succeeds. Wherever possible, a tag and ship system should also use an automated "print and apply" device that encodes the label, prints human-readable and bar code information in ink on the surface of the label, and either presses the adhesive label onto the item or blows it on with compressed air. When items are too awkwardly shaped for this approach, the system should provide a visual prompt to indicate how the tag should be applied manually (position and orientation) to reduce errors by the operator.

Pallet and Carton Tracking

One of the most commonly mentioned forms of RFID, pallet and carton tracking, essentially puts a "license plate" on a shipping unit made up of one or more individual items.

Considerations

Primary considerations for this type of application are:

Pallet or carton integrity

This type of tracking works best with a shrink-wrapped pallet that contains only one type of item; the pallet ID is then associated with a simple item count. It also works well with a mixed pallet that has a more complex manifest, describing counts for more than one item. Pallet and carton tracking can be ineffective if there is a possibility that the pallet or carton may be broken down and reconstituted. In this case, the counts or manifest may become invalid.

Pallet orientation

Pallets have six sides. Given that the bottom is typically inaccessible, we still have five choices when deciding where to attach the tag. Because most dock doors are roll-ups, placing a reader overhead can be difficult, so few implementations tag the top of the pallet. Most pallets have an orientation, and shippers typically place pallets with a certain side facing out, so in most cases it isn't necessary to put tags on all four sides. Even if putting a tag on each side seems reasonable, this means creating and reading a whole set of duplicate tags, which can cause problems for both printers and readers. The front of a pallet is blocked by the forklift, although it is possible to place a reader there. (We talk more about antenna placement in general and forklift pitfalls in particular in Chapter 5.) The back of the pallet is blocked from the readers by the pallet itself and then by the forklift upon passing through the portal. This leaves the left and right sides available for tagging. No strong consensus exists on which to use, so most implementations place readers on each side but tag only one side of the pallet.

Interfering contents

You might expect that a tag on the outside of a box would be easily visible to a reader, regardless of its contents, but this is not so. Imagine the reader as a bright light and the tag as a small mirror. Could you see a small mirror attached to a larger mirror, even if the light of a 300-watt floodlight illuminated it? A tag on a box of metal cans can be just as difficult for a reader to distinguish. If the product contains metal, have mercy and put the tag on a thin foam backing. The added distance will usually create enough space between the tag and the reflected signal to greatly improve read rates.

Implementation

Because the considerations for pallet and carton tracking have to do with implementation, we have already covered several implementation ideas in the preceding section. To sum things up:

- Track wrapped pallets with known contents.
- Place tags on the left or right side (as seen from the forklift) but not on both sides.
- Put a foam backing on the tag to raise it a bit if the contents of your pallet are high in metals or liquids.
- Check Chapter 5 for antenna alignment tips and warnings about forklifts.

Track and Trace

One of the earliest uses of RFID was to track dairy cattle. Now, companion animals and livestock of all types are routinely tagged with injectable glass capsules or button ear tags. These tags are used to identify lost pets and to sort, care for, and track the history of livestock. In recent years, RFID has also been increasingly used to track produce and pharmaceuticals. Information from livestock, produce, or pharmaceutical tracking can be critical in the event of a public health threat.

Considerations

Primary considerations for this type of application are:

Information sharing

By definition, track and trace applications require information sharing. One of the key requirements when merging information is coordinated identification. If one producer claims this flat of strawberries should be called 12345 and another claims that a different flat of strawberries should be called 12345, how can the inconsistency be reconciled? What if one producer reuses numbers and sends a flat 12345 this week and another flat 12345 next week? In any track and trace system, each identity must be unique across all producers and for as long a period as the information must be maintained. This can be accomplished in several ways, but the simplest method is either to assign a prefix to each producer to put at the beginning of their identities or to assign blocks of identities to each producer from a central authority (which accomplishes the same thing). Whatever method is used must be universally enforced—otherwise, the integrity of the data in the system will be suspect.

Role- and instance-based access control

Sharing information includes pooling information with competitors. Track and trace systems must have a provision for role- and instance-based control over access to information. In simplest terms, a role is a job, such as veterinarian or retailer, while an instance is a particular person. For example, a retailer may need general information but should not be able to view sensitive information about individual producers or manufacturers. A veterinarian should be able to view detailed information, but only for clients with whom she has a professional relationship. A government inspector should be able to see which animals or produce might have been commingled with a certain suspect lot, but might not need to see any other information.

Implementation

Rather than "rolling your own" identity management system ("identity" meaning user identity for role- and instance-based access control), when implementing a track and trace system you should buy an off-the-shelf identity management and access control solution in the form of an integrated software stack. Several enterprise software vendors offer these. Likewise, you should not create a completely new and proprietary system for provisioning identities. Because so many entities need to share track and trace information, you should ensure that your system makes use of the emerging identity standards (such as those described in Chapters 2 through 9).

Smart Shelf

A smart shelf system is a set of shelves, or some other container (such as a refrigerator), that constantly keeps track of the individual items it contains. If an item is removed or added, the shelf immediately updates the inventory. By tying the identity of an item to its attributes, such as expiration date or lot number, a system using smart shelves can immediately locate all expired products and products from a certain lot. An example of a smart

shelf system is a system that contains indicators such as horns or lights that warn users if a product has been removed from refrigeration for too long and should therefore be discarded. Similarly, if the user removes two drugs at the same time that are known to interact negatively, the system signals a warning.

Considerations

Primary considerations for this type of application are:

Item-level inventory support
: The most important consideration in a smart shelf system is the necessity of resolving inconsistencies between existing applications and a system that handles individual inventory. Most inventory systems currently deal only with tuples made up of stock keeping unit (SKU) codes and a count.

Physics and hardware
: Developing a reliable smart shelf system from readers, antennas, and standard shelving is a daunting task due to the complexity of choosing components, placing antennas, and modeling the possible side effects.

Handling spurious reads
: A reader may sometimes fail to recognize a tag. This can be due to interference or absorption of the RF signal. For instance, someone may reach for one item and briefly block the signal response of several others. Also, passing carts full of items by the reader at once may cause false positives to appear on a shelf. The systems must be able to deal with these reads in a manageable way.

Implementation

Several vendors provide prebuilt smart shelf units. Such units are expensive, but the cost may be justified when compared to the TCO of creating your own version. To handle spurious and intermittent reads, many readers can perform "smoothing," in which the reader configuration sets a threshold number of reads to which a tag must fail to respond before the reader marks its absence. A similar threshold can require several reads before an item is added to a shelf, so tags in a passing cart have a smaller chance of being around long enough to cause confusion. With this kind of threshold in place, tags will likely have weaker signals, which could alternatively cause them to be ignored.

Interfacing with existing inventory systems can be complicated; however, you can greatly simplify things by using middleware to handle individual item events and sending inventory changes only to backend systems. Again, you should compare the TCO of custom middleware to the cost of buying a commercial product.

Challenges

Any new technology introduces both costs and benefits, and RFID is no exception. Let's begin with the challenges it presents:

Cost

The most-discussed cost element for RFID systems is the cost of individual tags. However, this is just a part of the overall cost. Successful adoption of RFID will require changes to business processes and information systems, personnel training, and, in some cases, customer education.

Accuracy

Many of today's RFID systems are far from robust. Most of the projects we surveyed in early 2005 reported a read accuracy rate of between 80 and 99 percent. What this means is that if we move a pallet carrying 100 tagged boxes past an RFID reader, the reader will fail to recognize anywhere from 1 to 20 tags. There are many reasons for this, but most stem from the inherent challenges in moving liquids and metals using RF communications.

Implementation

Introducing RFID will invariably change your business processes, from how items are labeled to how they are selected, palletized, cycle counted, and so on. For each step in the business process, you will need to incorporate capabilities for exception processing—that is, what to do if the RFID technologies are not working properly. For example, if an RFID reader stops working or a label falls off, how will you continue? Apart from the RF side, there are many challenges to overcome in integrating the RFID data and procedures into your existing systems and the business processes they support.

RFID Adoption Guidelines

With things changing so quickly, it can be difficult for organizations to decide where, when, and how much to commit to any particular RFID product or standard. The following guidelines offer a strategy for approaching RFID. Simple as the steps may seem, ignoring any one of them can lead to lost opportunities at best, and failure at worst.

Determine the business need.

The current process exists for a reason. Before you even think about changing it, make sure you know its strengths, weaknesses, and reasons for being. Don't start from the premise, "Where can I use RFID?" Instead, start by asking, "How can I improve this process?"

Evaluate potential changes.

Carefully assess the costs and benefits of any potential changes. For example, if you want to automate a manual process, ask yourself a few questions about the change. Would a bar code work better than the manual procedure? Could the process be changed in some way to take more advantage of RFID, or conversely, to eliminate it from your process? How will you handle equipment failures or other types of failure? Note that RFID is sometimes mistakenly referred to as a "replacement for bar codes." Bar codes are actually better than RFID for some applications, and they're considerably less expensive. Also, with RFID there is a temptation to develop automated systems with minimal human oversight. But what happens if someone puts a box full of RFID tags on a pallet and accidentally runs it through the reader? Will your systems believe

you've shipped 100 pallets? With bar codes, someone would probably scan each pallet manually, which would prevent this error.

Develop a long-term roadmap.

Instead of implementing RFID systems in an ad hoc manner, develop a long-term business justification for adopting RFID and formulate a vision of how your business processes will look in an RFID world. Follow this up by developing a master plan that shows which systems will need to change and how. Show what your application and infrastructure architecture will look like after deploying RFID. Doing the design up front will give you a clear goal and will also promote the necessary discussions between you and your business units, end users, operations staff, IT staff, and business partners. Don't underestimate how much RFID will impact these stakeholders.

Start small.

Develop a proof of concept (prototype) to validate your assumptions. It's better to fail small and learn early than to fail large and have to recover. Don't be afraid to revise the roadmap and architecture based on mistakes in your prototype, and be ready to start the cycle over again, learning more each time and managing risk as you progress.

Run in parallel with existing systems.

Take a lesson from mountain climbers—don't let go of the last toehold until you are sure the new one won't crumble away beneath you. Not only is it more responsible to run the new system in parallel with the old system for a while, but it can also lead to valuable insights that were invisible when looking at either system in isolation. Don't forget to test the workarounds and recovery strategies you identified earlier. You might be surprised to discover that all of the RFID readers in the building fail when you turn on the exhaust fan for the first time. Only when everything runs smoothly should you begin to depend on the new technology.

Be flexible.

Now that you've made these changes, you have a brand new process. The old process took time to develop, and the new one will take time to mature. While this is happening, be ready to take advantage of new capabilities. Readers with new features and smarter controllers will come out; meanwhile, your personnel should be looking for innovative ways to make use of the new equipment. Watching carefully how people use a piece of equipment can provide important clues for streamlining the process.

Share with partners.

You have a great system in place, but your suppliers are still sending signals by carrier pigeon. Work with your less-enlightened trading partners and show them how to improve their own processes. RFID is an evolving technology, so taking a leadership role will allow you to define the agenda and the standards for future integration. Wal-Mart is an example of a company that has approached a potentially disruptive technology by choosing to lead in its development. As Dr. Alan Kay said, "The best way to predict the future is to invent it." If you keep it all to yourself, you'll just have to change your system when one of your partners chooses a completely different approach.

Summary

In this chapter, we discussed the following:

- RFID is a technology that allows a small radio device attached to an item to carry an identity for that item.
- RFID has been around a while—long enough that we can divide its history into eras and begin to predict future trends.
- In the current era (Compliance), cheap semiconductors and fast Internet connections have encouraged retailers and governmental agencies to require suppliers to place RFID tags on shipping units such as pallets and cartons. However, most suppliers are just tagging pallets and shipping them without using the information internally, and even retailers are simply breaking down the pallets on receipt.
- As the components get cheaper and the information infrastructure becomes more defined and robust, RFID will be used for an increasingly broad array of tasks.
- There are five main categories of RFID applications. Knowing the type of application in question can tell us quite a bit about special considerations and implementation.
- This is a volatile time for RFID, so we must take a disciplined approach to both acquiring knowledge about it and adopting the technology within our organizations. Keep an eye on key players and standards as we move through this era to see which way the technology will shift.