RFID Technology Principles, Advantages, Limitations & Its Applications

Mandeep Kaur, Manjeet Sandhu, Neeraj Mohan and Parvinder S. Sandhu

***Abstract*—This paper gives an overview of the current state of radio frequency identification (RFID) technology. Aside from a brief introduction to the principles of the technology, major current and envisaged fields of application, as well as advantages, and limitations of use are discussed. Radio frequency identification (RFID) is a generic term that is used to describe a system that transmits the identity (in the form of a unique serial number) of an object or person wirelessly, using radio waves. It's grouped under the broad category of automatic identification technologies. RFID is increasingly used with biometric technologies for security. In this paper Basic Principles of RFID technology along with its types are discussed.**

***Index Terms*—RFID Technology, RFID Principles, Components of RFID, Benefits , Limitations, Applications.**

I. Introduction

In recent years, radio frequency identification technology has moved from obscurity into mainstream applications that help speed the handling of manufactured goods and materials. RFID(Radio Frequency Identification) enables identification from a distance, and unlike earlier bar-code technology , it does so without requiring a line of sight. RFID tags support a larger set of unique IDs than bar codes and can incorporate additional data such as manufacturer, product type, and even measure environmental factors such as temperature. Furthermore, RFID systems can discern many different tags located in the same general area without human assistance. In contrast, consider a supermarket checkout counter, where you must orient each bar-coded item toward a reader before scanning it. So why has it taken over 50 years for this technology to become mainstream? The primary reason is cost. For electronic identification technologies to compete with the rock-bottom pricing of printed symbols, they must either be equally low-cost or provide enough added value for an organization to recover the cost elsewhere. RFID isn't as cheap as traditional labeling technologies, but it does offer added value and is now at a critical price point that could enable its large-scale adoption for managing consumer retail goods. Here, we introduce the principles of RFID, discuss its primary technologies and applications, and review the challenges organizations will face in deploying this technology.

RFID is used to automatic data capture allowing contact less identification of objects using radio frequency.

RFID compared to BAR CODES

- Similarly - a support tool to automate processes and to improve operations management.
- Reduces labor, eliminates human errors.
- Puts a wealth of data at your fingertips.

Different, in that:

- Tags can be embedded and hidden with no need for line-of-sight. They can be read through wood, plastic, cardboard, any material except metal.
- Tags can reprogrammed on-the-fly.
- Applicable in harsh environments, such as outdoors, around chemicals, moisture and high temperatures.

II. RFID Principles

Many types of RFID exist, but at the highest level, we can divide RFID devices into two classes: active and passive.

Active tags require a power source—they're either connected to a powered infrastructure or use energy stored in an integrated battery. In the latter case, a tag's lifetime is limited by the stored energy, balanced against the number of read operations the device must undergo. One example of an active tag is the transponder attached to an aircraft that identifies its national origin [1].

Passive RFID is of interest because the tags don't require batteries or maintenance. The tags also have an indefinite operational life and are small enough to fit into a practical adhesive label. A passive tag consists of three parts: an antenna, a semi- conductor chip attached to the antenna, and some form of encapsulation. The tag reader is responsible for powering and communicating with a tag. The tag antenna captures energy and transfers the tag's ID (the tag's chip coordinates this process). The encapsulation maintains the tag's integrity and protects the antenna and chip from environmental conditions or reagents [8].

Two fundamentally different RFID design approaches exist for transferring power from the reader to the tag: magnetic induction and electromagnetic (EM) wave capture. These two designs take advantage of the EM properties associated with an RF antenna—the near field and the far field.

Both can transfer enough power to a remote tag to sustain its operation—typically between 10 μW and 1 mW, depending on the tag type. (For comparison, the nominal power an Intel XScale processor consumes is approximately

Manuscript received July 30, 2010.

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500 mW, and an Intel Pentium 4 consumes up to 50 W.) Through various modulation techniques, near- and far-field-based signals can also transmit and receive data [1].

A. Near-field RFID

Faraday's principle of magnetic induction is the basis of near-field coupling between a reader and tag. A reader passes a large alternating current through a reading coil, resulting in an alternating magnetic field in its locality. If you place a tag that incorporates a smaller coil (Fig 1) in this field[23], an alternating voltage will appear across it. If this voltage is rectified and coupled to a capacitor, a reservoir of charge accumulates, which you can then use to power the tag chip. Tags that use near-field coupling send data back to the reader using load modulation. Because any current drawn from the tag coil will give rise to its own small magnetic field—which will oppose the reader's field—the reader coil can detect this as a small increase in current flowing through it. This current is proportional to the load applied to the tag's coil (hence load modulation). This is the same principle used in power transformers found in most homes today—although usually a transformer's primary and secondary coil are wound closely together to ensure efficient power transfer. However, as the magnetic field extends beyond the primary coil, a secondary coil can still acquire some of the energy at a distance, similar to a reader and a tag. The reader can then recover this signal by monitoring the change in current through the reader coil. A variety of modulation encodings are possible depending on the number of ID bits required, the data transfer rate, and additional redundancy bits placed in the code to remove errors resulting from noise in the communication channel. Near-field coupling is the most straightforward approach for implementing a passive RFID system.

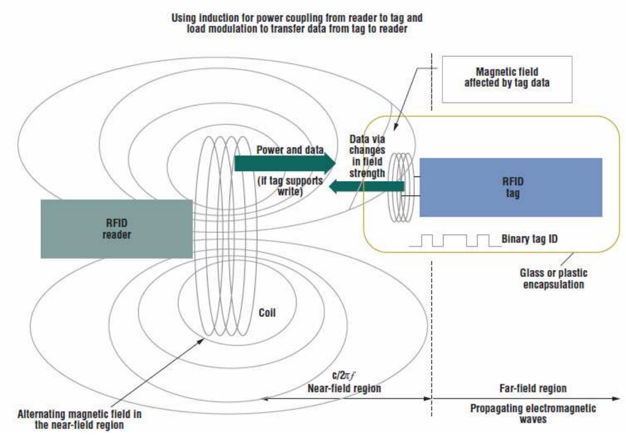

Figure 1. Near-field power/communication mechanism for RFID tags operating at less than 100 MHz.

However, near-field communication has some physical limitations. The range for which we can use magnetic induction approximates to c/2πf, where c is a constant (the speed of light) and f is the frequency. Thus, as the frequency of operation increases, the distance over which near-field coupling can operate decreases. A further limitation is the energy available for induction as a function of distance from the reader coil. The magnetic field drops off at a factor of 1/r3, where r is the separation of the tag and reader, along a center line perpendicular to the coil's plane. So, as applications require more ID bits as well as discrimination between multiple tags in the same locality for a fixed read time, each tag requires a higher data rate and thus a higher operating frequency[1]. These design pressures have led to new passive RFID designs based on far-field communication.

B. Far-field RFID

RFID tags based on far-field emissions capture EM waves propagating from a dipole antenna attached to the reader. A smaller dipole antenna in the tag receives this energy as an alternating potential difference that appears across the arms of the dipole[1]. A diode can rectify this potential and link it to a capacitor, which will result in an accumulation of energy in order to power its electronics. The technique designers use for commercial far-field RFID tags is back scattering (fig 2) [23]. If they design an antenna with precise dimensions, it can be tuned to a particular frequency and absorb most of the energy that reaches it at that frequency. However, if an impedance mismatch occurs at this frequency, the antenna will reflect back some of the energy (as tiny waves) toward the reader, which can then detect the energy using a sensitive radio receiver. By changing the antenna's impedance over time, the tag can reflect back more or less of the incoming signal in a pattern that encodes the tag's ID. In practice, you can detune a tag's antenna for this purpose by placing a transistor across its dipole and then turning it partially on and off. As a rough design guide, tags that use far field principles operate at greater than 100 MHz typically in the ultra high-frequency (UHF) band (such as 2.45 GHz); below this frequency is the domain of RFID based on near-field coupling.

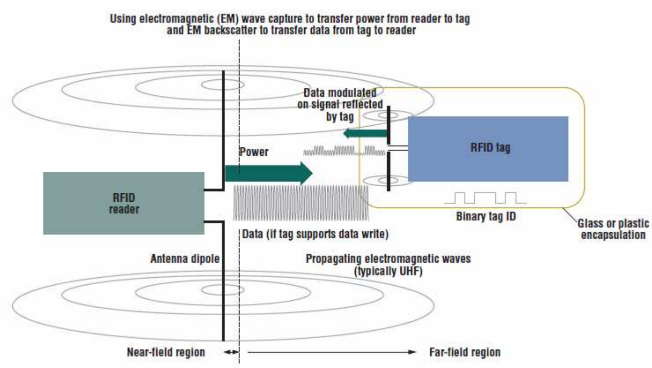

Figure 2. Far-field power/communication mechanism for RFID tags operating at greater than 100 MHz.

A far-field system's range is limited by the amount of energy that reaches the tag from the reader and by how sensitive the reader's radio receiver is to the reflected signal. The actual return signal is very small, because it's the result of two attenuations, each based on an inverse square law—the first attenuation occurs as EM waves radiate from the reader to the tag, and the second when reflected waves travel back from the tag to the reader. Thus the returning energy is 1/r4 (again, r is the separation of the tag and reader).

Fortunately, thanks to Moore's law and the shrinking feature size of semiconductor manufacturing, the energy required to power a tag at a given frequency continues to decrease (currently as low as a few microwatts). So, with modern semiconductors, we can design tags that can be read at increasingly greater distances than were possible a few years ago. Furthermore, inexpensive radio receivers have been developed with improved sensitivity so they can now detect signals, for a reasonable cost, with power levels on the order of –100 dBm in the 2.4-GHz band. A typical far-field reader can successfully interrogate tags 3 m away, and some RFID companies claim their products have read ranges of up to 6 m.

III. How Radio Frequency Identification (RFID) Works

RFID systems consist of three components in two combinations: a transceiver (transmitter/receiver) and antenna are usually combined as an RFID reader. A transponder (transmitter/responder) and antenna are combined to make an RFID tag[22]. An RFID tag is read when the reader emits a radio signal that activates the transponder, which sends data back to the transceiver.

A basic RFID system consists of three components:

- An antenna or coil
- A transceiver (with decoder)
- A transponder (RF tag) electronically programmed with unique information

There are two types of transponders, which correlate to the two major types of RFID tags.

• Passive transponders and RFID tags have no energy source of their own, relying on the energy given off by the reader for the power to respond. Cheaper, passive RFID tags are the most likely to be used for consumer goods.

• An active transponder or tag has an internal power source, which it uses to generate a signal in response to a reader. Active transponders are more expensive than passive ones. They can communicate over miles like ordinary radio communications. They are commonly used in navigation systems for commercial and private aircraft.

There are many uses of this technology around us today, although they are often invisible to users. You may find that you are already carrying and using a RFID tag, or even several. At its most basic level, RFID is a wireless link to uniquely identify objects or people. It is sometimes called dedicated short range communication (DSRC). RFID systems include electronic devices called transponders or tags, and reader electronics to communicate with the tags. These systems communicate via radio signals that carry data either unidirectional or bidirectional. As the shown in fig 3, [22]when a transponder enters a read zone, its data is captured by the reader and can then be transferred through standard interfaces to a host computer, printer, or programmable logic controller for storage or action.[2].

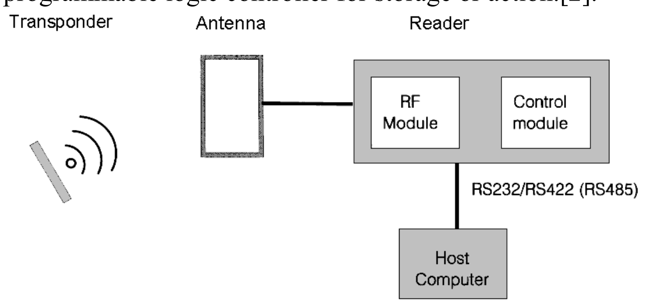

Fig .3.Working of RFID

• The antenna emits radio signals to activate the tag and to read and write data to it.

• The reader emits radio waves in ranges of anywhere from one inch to 100 feet or more, depending upon its power output and the radio frequency used. When an RFID tag passes through the electromagnetic zone, it detects the reader's activation signal.

•The reader decodes the data encoded in the tag's integrated circuit (silicon chip) and the data is passed to the host computer for processing.

The purpose of an RFID system is to enable data to be transmitted by a portable device, called a tag, which is read by an RFID reader and processed according to the needs of a particular application. The data transmitted by the tag may provide identification or location information, or specifics about the product tagged, such as price, color, date of purchase, etc. RFID technology has been used by thousands of companies for a decade or more. . RFID quickly gained attention because of its ability to track moving objects. As the technology is refined, more pervasive - and invasive - uses for RFID tags are in the works.

A typical RFID tag consists of a microchip attached to a radio antenna mounted on a substrate. The chip can store as much as 2 kilobytes of data.

To retrieve the data stored on an RFID tag, you need a reader. A typical reader is a device that has one or more antennas that emit radio waves and receive signals back from the tag. The reader then passes the information in digital form to a computer system.

Once a link is established with a unique ID on an item, then automation of an assortment of processes ensures.

IV. Benefits Of RFID

Though RFID is not likely to entirely replace commonly used barcodes in the near future, the following advantages suggest to additionally apply RFID for added value of identification:

• Tag detection not requiring human intervention reduces employment costs and eliminates human errors from data collection,

• As no line-of-sight is required, tag placement is less constrained,

• RFID tags have a longer read range than, e. g., barcodes,

• Tags can have read/write memory capability, while barcodes do not,

• An RFID tag can store large amounts of data additionally to a unique identifier,

• Unique item identification is easier to implement with RFID than with barcodes,

• Its ability to identify items individually rather than generically.

• Tags are less sensitive to adverse conditions (dust, chemicals, physical damage etc.),

• Many tags can be read simultaneously,

• RFID tags can be combined with sensors,

• Automatic reading at several places reduces time lags and inaccuracies in an inventory,

• Tags can locally store additional information; such distributed data storage may increase fault tolerance of the entire system,

- Reduces inventory control and provisioning costs,
- Reduces warranty claim processing costs.

V. Limitations Of RFID

Although many RFID implementation cases have been reported, the widespread diffusion of the technology and the maximum exploitation of its potential still require technical, process and security issues to be solved ahead of time. Today's limitations of the technology are foreseen to be overcome and specialists are already working on several of these issues.

A. Standardization

Though the characteristics of the application and the environment of use determine the appropriate tag, the sparse standards still leave much freedom in the choice of communication protocols and the format and amount of information stored in the tag. Companies transcending a closed-loop solution and wishing to share their application with others may encounter conflicts as cooperating partners need to agree in standards concerning communication protocols, signal modulation types, data transmission rates, data encoding and frames, and collision handling algorithms.

B. Cost

The cost of tags depends on their type. In the 2003 report 'RFID Systems in the Manufacturing Supply Chain' [11], ARC This predicted decrease is still deemed insufficient, as economic use of tags—taking the associated 5–35% decrease of labor costs and zero tag information generation costs into account as well—would require a maximum of 25 cents per tag for high-end products, and 5 cents for common item-level tagging.

Prices of active or semi-passive tags (at least $1 per tag) are even more of a hindrance, allowing their economic application only for scanning high-value goods over long ranges.

C. Collision

Attempting to read several tags at a time may result in signal collision and ultimately to data loss. To prevent this, anti-collision algorithms (most of them are patented or patent pending) can be applied at an extra cost. The development of these methods, aimed at reducing overall read time and maximizing the number of tags simultaneously read, still goes on [12][9].

D. Frequency

The optimal choice of frequency depends on several factors, such as:

a) Transmission mode. RFID tags basically use two kinds of data transmission, depending on the behavior of electromagnetic fields at the frequency used. In lower frequencies (such as 125–134kHz in the LF band or 13.56MHz in the HF band), inductive coupling is used, while in frequency bands above (UHF with typical frequency ranges of 433MHz, 865–956MHz and 2.45GHz), wave backscattering is the main means of transmission. This also affects the safe reading range, as it is easier to build direction-selective devices with a longer read range in higher frequencies. This may restrict design freedom if either reading range or spatial selectivity are an important issue [6].

b) Behavior of tagged goods and environment. Properties of some materials may be an obstacle to RFID application at a given frequency, as they may corrupt data transmission either by absorption or by ambient reflection of the signals. Typically, conductive materials such as goods containing water, or metal surfaces may be the source of problems. However, absorption and reflection being frequency-dependent, failure at one frequency does not rule out applicability at other frequencies. Electromagnetic disturbance can also have external sources, which is also a common though also frequency dependent problem in an industrial environment [8].

c) International standards in frequency allocation. Due to historic reasons, the world is divided into three large regions of frequency allocation for various purposes, region 1 containing Europe, Africa, the Middle East and former SU member states, region 2 with North and South America and the part of the Pacific east of the date line, and region 3 with Asia, Australia and the Pacific west of the date line. The industry exerts pressure towards an uniformization of frequencies allowed for RFID, yet there still are notable differences between the three regions, forcing companies planning to employ tags in several regions to restricting themselves to bands shared by all regions concerned. A compromise for tags only modulating the reader signal without actively producing a carrier wave on their own may be their ability to work in a wider frequency range than nominally specified, allowing their usage even in regions where RFID bands are 'close enough'.

E. Faulty manufacture of tags

Manufacturing of tags is not yet 100% failure-free today; about 20–30% of tags used in early RFID pilots have been defective [13].

F. Faulty or deficient detection of tags

a) Tags may be damaged during usage. A wide range of application challenges can be answered by the multitude of suitable tags, yet none of them is completely invulnerable and the causes of damage may vary from type to type. The result is a read failure which is, in many cases difficult to detect, as is the fact of the damage itself for a hidden tag. This becomes a business issue when, for example, the payment for goods is calculated by the number of detected tags and no measures are taken to compensate for read failures.

b) Adverse conditions of the environment and improper placement may corrupt reading. As mentioned before, absorption, ambient reflection of the signal and external signal sources (such as security systems, cordless phones, barcode scanners) may introduce read errors. Similarly, improper orientation of tags may impair reading efficiency as most antennas used in tags are direction-sensitive [13].

c) Registration of data from tags which pass within range of an RFID reader accidentally.

d) Reader malfunction. This eventuality cannot be predicted or completely avoided, making alter-native fallback measures (such as barcodes) necessary for the case of reader failure.

G. *Quick technology obsolescence*

One of the common concerns of companies implementing RFID today is the rapid obsolescence of the technology, especially in view of the investment cost. Technology is continuously evolving and new protocol standards, faster and more fault-tolerant readers quickly outdate their predecessors.

H. *Security and privacy Issues*

Depending on the field of application—and in some cases, prescribed by law—it may become necessary to prevent unauthorized persons from reading or writing data stored on or transmitted from tags. To this end, encryption must be ensured at all interfaces where data could be intercepted or transmitted (on the medium itself, as well as tag–reader and reader–host communication) [13].

I. *Possible virus attacks*

Although not widely reported so far, a study of the Vrije Universities Amsterdam [14] has shed light on potential vulnerability of current RFID software if used together with a backend database. Similarly to previously known attacks against SQL systems (such as the Slammer virus), intentionally effected buffer overflow, false end-of-row characters and camouflaged comments can lead to un-verified data being interpreted as SQL commands which can perform malicious operations on the database contents or prompt the system to copy the infected data to further tags.

VI. Applications Of RFID

Current and proposed uses of RFID span a wide spectrum of application areas shown in fig 4, and a fully comprehensive overview would certainly surpass the limits of this paper [4]. It is, however, easy to see that the nature of a given:

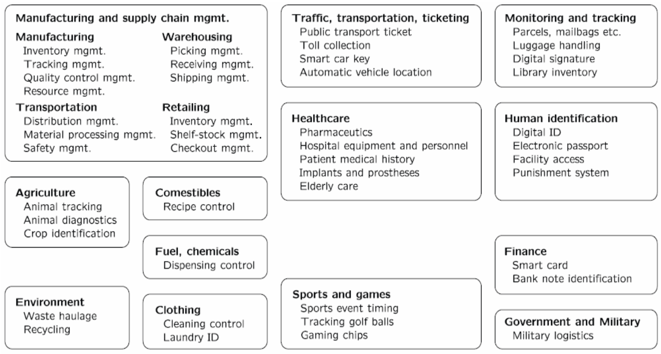

Figure 4. Application of RFID

The following are uses of RFID:

A. *Instance or class identification*

If RFID tags are only used for the purpose of item type or instance identification, usually, a data-base is maintained in the background to provide or receive the additional information needed. Augmented with this support, destination or way of handling can be determined for the given item, an already proven concept in a number of logistics solutions (several shipping and postal services, such as UPS, FedEx, USPS and Finland Post [15].

B. *Location identification*

If a given reader is assigned to a known location, it is possible to track the current place of a given uniquely identifiable item. Numerous logistics companies and some postal services have already integrated such RFID-based features into their tracking services (several shipping and postal ser-vices, such as UPS, FedEx, USPS and Finland Post [15]; automatic vehicle location systems in public transport control in Vejle, Denmark [16]; location of rolling stock at the Swiss Federal Railways), and similarly, the physical location of work pieces is being kept track of in several manufacturing facilities, too (e.g.: in Dell's facility in Xiamen, China [17]).

C. *Transfer of further data*

In the third application group, not only an identity is extracted from the tag but also auxiliary data are read or written. Data read from the tag usually contains information which would be difficult impractical or impossible to obtain from a remote or pre-recorded database, or measurement results. Some products may provide instructions for proper handling this way (envisaged are cases where tags in food packaging would instruct an oven about the optimal cooking time [18], or tags in clothing would select the right program for a washing machine [19]), while in a number of already implemented uses, tags provide medical measurement data e.g., about eye-ball pressure (sensor and transmitter integrated into artificial lens implant [20]). Writing data to a tag usually adds information about the processing of the given item (or delivery progress in transportation), and in a few cases, a new identity is assigned to the tag by rewriting (such as for reusable containers, pallets etc., as in a pilot project at the Finnish Post [21]). An interesting application is envisaged for washing machines where read-write tags in clothes also record how many times the given piece has been washed and select the proper washing program to adapt to aging of the fabric.

D. Asset Tracking

It's no surprise that asset tracking is one of the most common uses of RFID. Companies can put RFID tags on assets that are lost or stolen often, that are underutilized or that are just hard to locate at the time they are needed. Just about every type of RFID system is used for asset management. NYK Logistics, a third-party logistics provider based in Secaucus, N.J., needed to track containers at its Long Beach, Calif., distribution center. It chose a real-time locating system that uses active RFID beacons to locate container to within 10 feet.

E. Manufacturing

RFID has been used in manufacturing plants for more than a decade. It's used to track parts and work in process and to reduce defects, increase throughput and manage the production of different versions of the same product.

F. Supply chain management

RFID technology has been used in closed loop supply chains or to automate parts of the supply chain within a company's control for years. As standards emerge, companies are increasingly turning to RFID to track shipments among supply chain partners [14][18].

G. Retailing

Retailers such as Best Buy, Metro, Target, Tesco and Wal-Mart are in the forefront of RFID adoption. These retailers are currently focused on improving supply chain efficiency and making sure product is on the shelf when customers want to buy it.

H. Payment systems

RFID is all the rage in the supply chain world, but the technology is also catching on as a convenient payment mechanism. One of the most popular uses of RFID today is to pay for road tolls without stopping. These active systems have caught on in many countries, and quick service restaurants are experimenting with using the same active RFID tags to pay for meals at drive-through windows.

I. Security and access control

RFID has long been used as an electronic key to control who has access to office buildings or areas within office buildings. The first access control systems used low-frequency RFID tags. Recently, vendors have introduced 13.56 MHz systems that offer longer read range. The advantage of RFID is it is convenient (an employee can hold up a badge to unlock a door, rather than looking for a key or swiping a magnetic stripe card) and because there is no contact between the card and reader, there is less wear and tear, and therefore less maintenance. As RFID technology evolves and becomes less expensive and more robust, it's likely that companies and RFID vendors will develop many new applications to solve common and unique business problems [5][20].

a) Use of RFID Technology in a Port

The primary advantage to RFID in a port/terminal application is that it is an 'automatic' data collection technology. That is, no operator intervention or action is required. Whereas other forms of data collection, whether bar code or manual methods, depend on employees to record information, RFID relieves them from this time-consuming and error-prone process. The two direct benefits of this are:

- Accurate and complete data collection; and
- Better utilization of employees' time.
- There are five major areas where RFID can be effectively used in a port cargo terminal:
- Access Control;
- Container Security;
- Container Identification and Location;
- Activity Tracking;
- Regulatory Compliance.
- Some of these applications offer benefits to the terminal/port operator; either directly or as added services for shippers. Other benefits must be seen more as a means of simplifying compliance with increasing governmental security regulations and record keeping requirements.

b) Use of RFID Technology in distribution and manufacturing

- *Picking and Sortation System Within a Warehouse:*

To get the most from RFID, there is a need for an advanced enterprise-wide information management infrastructure. The application may be designed around a centralized database or use a decentralized approach, maintaining and updating the data directly on the tag, or a combination. In any event, the IMS needs to be prepared to handle real time data quickly, and to pass it to other systems in the chain that can also use the information [10].

- *Beer Barrel Tracking at Uerige Brewery:*

In addition to the big international breweries, in Germany there are many smaller but successful breweries that remain competitive through ingenuity. Uerige Brewery is one of these that has put auto ID to work for asset management and supply chain automation. Barrels are expensive assets of a brewery's business. In this application the barrels each contain an embedded Read/Write tag that uniquely identifies them and whose memory is partitioned and can be encoded by individual page with new data along the cycle of travel from factory to customer and back to factory. Barrels are handled by several entities: factory, distributors, and pubs.

The benefits are:

- Manages barrel loss.
- Isolates damage to barrels.
- Compiles complete, automatic records of customer service and generates invoices.

VII. CONCLUSION

The paper gave an overview of the current state and trends of RFID technology. Even though numerous limitations and unresolved issues still hinder the widespread application of RFID. Despite these challenges, RFID continues to make inroads into inventory control systems, and it’s only a matter of time before the component costs fall low enough to make RFID an attractive economic proposition. Furthermore, extensive engineering efforts are under way to overcome current technical limitations and to build accurate and reliable tag reading systems. We might also start to see economic pressure from the larger distributors to modify product packaging and its associated materials to more effectively integrate RFID. Finally, at this delicate stage, while major corporations are trialing the technology, media reaction and outspoken privacy groups can influence the rules by which we use the technology.

RFID’s potential benefits are large, and we’re sure to see many novel applications n the future—some of which we can’t even begin to imagine. The components that go into RFID readers and tags are simple radio communications, but their smaller size and broad deployment enhance the power of the technology and raise concerns about the privacy effects of RFID deployment. These concerns are often premised on unlikely assumptions about where the technology will go and how it will be used.

REFERENCES

[1] K. Finkelzeller, The RFID Handbook, 2nd ed., John Wiley & Sons, 2003.
[2] R. Want et al., “Bridging Real and Virtual Worlds with Electronic Tags,” Proc. ACM SIGCHI, ACM Press, 1999, pp. 370–377.
[3] M. Weiser, “The Computer for the 21st Century,” Scientific Am., vol. 265, no. 3, 1991, pp. 94–104.
[4] T. Kindberg et al., “People, Places, and Things: Web Presence of the Real World,” ACM Mobile Networks & Applications J., 2002, pp. 365–376.
[5] R. Want, “Enabling Ubiquitous Sensing with RFID,” Computer, vol. 37, no. 4, 2004, pp. 84–86.
[6] E. Batista, “‘Step Back’ for Wireless ID Tech?” Wired News, 8 Apr. 2003; www. wired.com/news/wireless/0,1382,58385, 00.html.
[7] R. Singel, “American Passports to GetvChipped,” Wired News, 19 Oct. 2004;vwww.wired.com/news/privacy/0,1848,v65412,00.html.
[8] A. Juels, R.L. Rivest, and M. Szydlo, “ThevBlocker Tag: Selective Blocking of RFIDvTags for Consumer Privacy,” Proc. 8thvACM Conf. Computer and Comm. Security, ACM Press, 2003, pp. 103–111.
[9] D.W. Engels and S.E. Sarma, “The Reader Collision Problem,” white paper MITAUTOID- WH-007, Auto-ID Center, Nov. 2001.
[10] S. Garfinkel, “An RFID Bill of Rights,” Technology Rev., Oct. 2002, p. 35.
[11] http://www.rfidjournal.com/article/articleview/1098/1/1/.
[12] Burdet, L. A., 2004: Smart Environments, Seminar, Zürich.
[13] Lewis, S., 2004: A basic introduction to RFID technology and its use in the supply chain, Laran RFID, White paper.
[14] Shutzberg L., 2004: Radio Frequency Identification (RFID) In the Consumer Goods Supply Chain, Rock-Tenn Company, www.packagingdigest.com/newsite/Online/RFID_IWP.pdf
[15] http://RFID.nordic.se.
[16] http://www.aimglobal.org/members/news/templates/casestudies.asp?articleid=166&zoneid=25.
[17] http://www.aimuk.org/pdfs/RFIDcomp04.pdf.
[18] Almirall, E., Brito, I., Silisque, A., Cortés, U., 2003: From Supply Chains to Demand Networks, pg. 13.
[19] http://www.rfidjournal.com/article/articleview/1332/2/129/
[20] Finkenzeller, Klaus, 2003: RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification, Second Edition. John Wiley & Sonspg. 399.
[21] http://www.rfidinternational.com.
[22] Susy d’Hont, “The cutting edge of RFID Technology and Applications for manufacturing and Distribution” , Texas Instrument TIRIS, 2002.
[23] Roy Want, “An Introduction to RFID Technology”, IEEE Pervasive Computing, vol. 5, no. 1, pp. 25-33, Jan.-Mar. 2006.