Brave New World of

Radio Frequency Identification

ABSTRACT

Radio Frequency Identification (RFID) originates from the transponder technology used during World War II. Recent interest in RFID is spurred by the mandate issued by Wal-Mart and the United States (US) Department of Defense (DoD) that it requires incoming supplies commencing from 2005 to be tagged with Electronic Product Code RFID tags. The paper gives an overview of RFID technology. RFID is a key enabler in the quest by the Singapore Armed Forces to acquire Total Asset Visibility (TAV) capability. Potential benefits that TAV brings are discussed. The challenges faced for future adoption of RFID systems are also highlighted. Experiences gained from the implementation of an RFID pathfinder project are shared in this paper.

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Brave New World of Radio Frequency Identification

INTRODUCTION

Radio Frequency Identification (RFID) originated from transponder technology created by the British for aircraft identification during World War II. Over the next 60 years, the inventions of the transistor, integrated circuits, the computer and the advances in miniaturisation, manufacturing and computer networking have contributed immensely to the evolution of RFID till today, where it stands poised to transform the global supply chain management.

The push from both the US Department of Defence (DoD) and Wal-Mart to use RFID gave this 60-year old technology a boost. In June 2003, Wal-Mart, the leading retailer in the US announced that it would require its top 100 suppliers to use RFID technology on cases and pallets by January 2005 and would expand to include all suppliers by year 2006. Then in October 2003, the DoD announced that it requires suppliers to put RFID tags on cases, pallets and high-value items. The goal is to reduce safety stocks and improve forecasting through better visibility. Both parties require the RFID tags to be based on the Electronic Product Code (EPC) format. The widespread adoption of RFID by both parties as well as other retailers across the US and Europe, has set both the commercial and military sectors abuzz.

The push from both the US DoD and Wal-Mart has also generated great interest in the technology sector. Many of the leading technology companies such as IBM, Microsoft, Texas Instruments, Oracle, Sun Microsystems, HP and Alien Technologies along with many other companies have taken on roles in the research, consultancy, development and support of RFID.

THE TECHNOLOGY

First, it is important to understand how the technology works. The basics of RFID consist of a tiny microchip (or tag) and a small coiled antenna. The RFID microchip and antenna can be attached to almost any object. They can vary in shape, size or form depending on the application such as layering them on a piece of tape or label or placing them between cardboard layers in a carton. The RFID tag would store a unique identification code from which RFID scanners, ranging from handheld units to fixed readers, transmit radio signals to turn on the tag that sends back information to the reader.

There are three types of RFID tags. A passive tag requires no batteries and derives its power from the electromagnetic field created by the signal from the RFID reader. This generates enough power for the tag to respond to the reader with its information in the form of electromagnetic waves. The RFID reader converts the new waves into digital information. While the range is smaller than that for active tags, having no need for a battery makes the passive tag's life virtually unlimited and its size potentially as minute as a grain of rice.

An active tag uses its own battery power to contact the reader. It works over a greater distance than passive tags, but its larger size is its main drawback. Semi-passive tags use a battery to run the chip's circuitry, but communicate by drawing power from the reader. Active and semi-passive tags are useful for tracking high-value goods that need to be scanned over long ranges, because they are too expensive to be placed on low-cost items. The focus is on passive tags, which are a low-cost technology. The read range of passive tags is about a few metres in comparison to active tags that can be read from a longer range.

Another key aspect of an RFID tag is the frequency at which it functions. Depending on the antenna in the chip, readers communicate with tags at various frequencies. There are four different kinds of tags commonly in use, their differences depending on their radio frequencies: low frequency tags (between 125 to 134 kHz), high frequency tags (13.56 MHz), and ultra high frequency (UHF) tags (868 to 956 MHz), and microwave tags (2.45 GHz).

Low-frequency RFID tags are commonly used for identification, and automobile key-and-lock, anti-theft system. High-frequency RFID tags are used in library book or bookstore tracking, pallet tracking, building access control, airline baggage tracking, identification badges and apparel item tracking. RFID tags are commonly used in pallet and tracking, and and tracking, whilst microwave RFID tags are used in long range access control for vehicles.

RFID tags of lower frequencies are better suited for applications that require reading of small amounts of data at low speed. The reading range is also limited to not more than a few metres. Even though they have a shorter range compared to higher frequencies, they are more tolerant of obstacles such as water, tissue, aluminium and wood. They are even moderately tolerant of small amounts of metals in the way. However reading of multiple tags simultaneously is difficult in close proximity as reading collisions can occur. Higher frequencies tags can be used for long range applications. High frequencies also have faster data transfers. However, these high frequency beams are more easily stopped. They have problems with reflections, inability to "see" round corners, and problems with blocking of the beam, even by obstacles transparent to human vision.

RFID DEPLOYMENT

While RFID technology has been available for nearly two decades, costs associated with it have limited RFID to niche uses. These include toll collection, livestock identification, library book monitoring and security access, just to name a few uses. Until quite recently, RFID tags cost at least a few dollars apiece and thus had to be used repeatedly over an extended period of time to justify the investment. Another main issue hindering a quicker proliferation of RFID is the lack of standards or significant initiatives to push for mass adoption.

At present, falling tag costs, emerging open industry standards and new production techniques are spurring wide-scale development and deployment initiatives. A major catalyst has been the collaborative work via the AutoID Center in the US. Here a number of companies and universities have worked together to develop the standards and designs for a range of relatively simple tags that can be manufactured in bulk with the aim to reduce the cost per tag down to below ten cents.

The EPC, a key initiative of AutoID center, is emerging as a global standard for tag specifications. In an EPC-embedded RFID tag, each tag stores a unique 96 bit code that identifies the object and individual serial number. Once the code is read from the tag, the EPC can be linked via a distributed EPC Network to look up databases that can provide detailed information about the item or package such as the manufacturer, characteristics, batch number, shipping history, manufacture date and expiration date. The tags can also be programmed to store additional data. Details of EPC and the EPC Network can be found in Appendix 1.

RFID IN DEFENCE

Previously, the lack of standards and the relatively high cost had led RFID to be implemented in a modest manner in the SAF. Some examples are the Individual Physical Proficiency Test (IPPT) system that uses RFID chips to record the start and finish times of runners for the IPPT, the monitoring of fuel dispensation to authorised SAF vehicles and the signing in and out of weapons.

With falling RFID tag prices and increasing global technical standardization, RFID tags will gradually replace the venerable bar codes, which are currently widely utilised. Defence logistics like the retail industry will exploit various characteristics of RFID to improve supply chain management and processes. Unlike bar codes, RFID tags do not require a direct line of sight for the data to be read. For instance, materiel within a pallet in a truck does not need to be unloaded and unpacked to be scanned by an RFID reader, as the radio waves can penetrate the walls of the pallet and truck. Another feature of RFID technology is the ability of an RFID reader to read hundreds of chips virtually instantaneously, speeding up the loading and delivery processes.

RFID could also be applied to soldier identification, soldier physiological monitoring, casualty evacuation management and recording of casualty vital signs, friend-foe identification systems, and tracking of classified documents. RFID tags can also be used to enhance security such as automatic vehicle identification and ensure that a proper match of authorised drivers to vehicles during heightened security situations. A similar application will be matching authorised soldiers to their assigned weapons to eradicate any unauthorised or unqualified use. RFID deployed for cargo visibility would strengthen maritime and aviation security, while an RFID-based anti-terrorism system with sensor tags to detect radiation, biological or chemical agents would deter smuggling of weapons into the country.

Some RFID technologies include read and write memory that provides an electronic catalogue of the contents that a pallet or container may have held over a period of time. Furthermore, some RFID tags contain other sensors that can transmit valuable data. For example, RFID tags with anti-tamper features could be used to monitor any tampering to a consignment of weapons, ammunitions, hazardous material or other high-value assets. RFID tags with temperature, vibration and humidity monitoring features could also be used to track shelf and environmental conditions under which combat rations are stored to minimise attrition. Opportunities and applications, other than those mentioned, for deploying RFID in the SAF abound.

Total Assets Visibility

Such intriguing features of RFID position it as a key enabler in realising the vision of Total Assets Visibility (TAV). TAV can be viewed as a capability that provides commanders and warfighters at various echelons with timely and accurate information on the location, movement, status and identity equipment, materiel and supplies from factory to foxhole whether they are in storage, in transit or in process. RFID will bring about some benefits such as:

- Reduced footprint on the battlefield
- Increased accuracy and visibility of inventories
- The optimisation of depot and warehouse operations to meet customer requirements and improve materiel transport
- Accurate supply chain execution
- Better asset management
- Increased availability and readiness of equipment
- Online, real-time, user-driven requisition processing
- Tracking of transaction history associated with each asset
- Reduced manpower for checking inventories
- Checking of assets in and out expeditiously
- Simplified and speedier asset location
- Up-to-date snapshots of the status of fixed assets
- The facilitation of predictive maintenance and shortening maintenance turn-around-time

An RFID-enabled TAV environment would endow the SAF with a logistics system that is able to sense and respond appropriately and in a timely manner to the logistics needs of combat units in the mission theatre. With the information from the ability to track assets, and a knowledge-enabled logistics command and control system assisted by decision-support tools, logisticians would be able to anticipate, predict and plan the right amount of supply materiel to be delivered in a timely manner to where it is needed. This brings about a logistics transformation that shifts away from a 'just in case' paradigm to that of a 'just-in-time' and 'just adequate' approach.

Such a sense-and-respond logistics capability is an integral component of the SAF Integrated Knowledge-enabled Command and Control (IKC2) concept. The SAF IKC2 is conceptualised as network–enabled, knowledge-based warfighting that will enable the SAF to achieve greater force optimisation, self-synchronisation, greater flexibility and efficiency of action as well as to enhance the speed and quality of decision-making. Combat units cannot sustain the attributes of an IKC2 model without a logistics system that shares those attributes. A sense-and-respond logistics capability will allow logisticians to project and sustain combat power with greater speed, accuracy and flexibility and provide the necessary congruency between combat elements and their logistics supply system.

CHALLENGES

Besides cost and standardisation challenges that are being addressed, another key challenge is allaying concerns over privacy. There are concerns that RFID technology makes it possible for our movements to be tracked and allows our personal information to be available to an unprecedented level of detail. The idea of implementing RFID tags sewn into clothes or embedded into a myriad of products has raised the possibility of people being tracked through their possessions. Imagine the RFID tagged items that you have purchased with credit cards would link you to those specific items in the departmental store's or card's databases, down to the colour, size, style and price. Marketers could then make use of the data and surreptitiously identify you for relentless sales pitches. The next time, you walk into the store, advertisements would be flashed on wall-sized screens based on your spending pattern, a scenario played out in the movie 'Minority Report'.

Another disquieting possibility is that future burglars with the appropriate technology would be able to examine contents of nearby wallets, knapsacks and packages to identify valuables and expensive gear before making their moves. Critics also raise Orwellian fears that RFID technology would make it easier for government agencies to track a person's every movement and allow invasion of privacy.

This issue of privacy and the ability to remain anonymous would have to be addressed before RFID become ubiquitous.

RFID IMPLEMENTATION

Every new technology has its set of implementation challenges and RFID is no different. In order to exploit the benefits brought about by RFID, we need to be mindful of a few aspects. Realising cost benefits and understanding the value proposition of RFID is key. The requirements concerning hardware implementation of RFID include the types of tag to be used, the environment they are going to be used in, the number, type and location of readers, the servers and client workstations. There are also other costs incurred in network infrastructure, software applications and also integration with other enterprise information systems.

The cost of investment is closely coupled with the information needs. The adoption of tagging will generate data resulting in very high data volumes that will put pressure on data storage capacity. For example, it is envisaged that Wal-Mart will generate more than seven terabytes of operational RFID data a day. Traditional technology architectures are not prepared to handle volumes of such magnitude. Operational databases, which differ from traditional back-end databases, will be commonplace and necessary for the collection, correlation, filtering and cleansing of data. It is important to think through the data management requirements, strategies and structures to identify the data to be collected and exploit it meaningfully.

The introduction of RFID is likely to bring about changes to some business processes. Automatic data collection and identification of goods may also mean that some roles will be made redundant and new roles created.

While commercial manufacturers will increasingly include EPC in the products that they manufacture, not all military suppliers will follow suit. While the military will exploit the EPC Network to gather information about the supplies that they have acquired from commercial vendors, a separate unique identification numbering system may have to be developed to tag military specific items pertinent to the SAF. The architecture of such a system will have to be harmonised with the EPC construct.

Companies have to examine whether the technology that they put into place today will serve them well down the road as EPC and ISO standards for RFID evolve and new products are introduced. There is also a lack of clear information on the costs associated with upgrading the technology as it advances. Other aspects that need consideration include reliability and performance of the tags, the accuracy of data collected, and the lack of definition on EPC standards and how they will evolve globally.

Given the possible implementation challenges faced, it would be prudent to be an early adopter, albeit on a small scale, to gain experience and understand the issues to be better positioned for future larger scale implementation. The Hospital Movement Tracking System is an early pathfinder project that we have undertaken and its implementation experience is outlined in Appendix 2.

CONCLUSION

While most agree that the benefits of RFID, once harnessed, will bring about major improvements throughout the entire supply chains, logistical processes and other applications, cost efficiency and standardisation are issues to be addressed. One key issue that needs resolution before mass acceptance is privacy concerns, in particular, the potential ability of a government to easily track its citizens as depicted in Aldous Huxley's "Brave New World".

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APPENDIX 1

ELECTRONIC PRODUCT CODE AND EPC NETWORK

Introduction

To facilitate global interoperability and visibility across the global supply chain involving different corporations in the industry ecosystem, there should be a standardised way of uniquely identifying items within the supply chain. Next, there has to be a standardised way of discovering and sharing the data that describes each item.

Electronic Product Code

The Electronic Product Code addresses the first requirement by allowing goods to be identified to the item level. Like many current numbering schemes used in commerce, the EPC is divided into numbers that identify the manufacturer and product type. But the EPC uses an extra set of digits, a serial number, to identify unique items. Using this EPC, one can identify and locate information about the manufacturer, product class and item instance of a particular product.

An EPC is a number that contains:

1. Header, which identifies the length, type, structure, version and generation of EPC
2. Manager Number, which identifies the company or company entity such as "The Coca Cola Company"
3. Object Class, similar to a stock keeping unit such as "Vanilla Coke 330 ml can" Serial Number, which is the specific instance of the Object Class being tagged

016.	37000.	123456.	100000000
Header	EPC Manager	Object Class	Serial Number

Figure 1

In a 96-bit EPC, there are 96 bits of data that can be used to uniquely identify up to 268 million unique companies, each with 16 million different types of products. Each product can contain over 687 billion individual items. Additional fields may also be used as part of the EPC in order to properly encode and decode information from different numbering systems into their native (human-readable) forms. The EPC standards also call for five classes of tags over time to meet different requirements and applications. They are:

- Class 0 : Read Only
- Class 1 Write Once, Read Many
- Class 2 Read / Write
- Class 3 Read / Write Battery Enhanced for Long Range
- Class 4 Read / Write Active Transmitter

EPC Network

For manufacturers, distributors, and retailers to realise the potential of RFID and EPC technology, they need access to comprehensive, real-time product information. The EPC Network provides the open-loop, standards-based environment required for global exchange of EPC information.

The EPC Network is composed of three key elements:

- EPC Information Services (EPC-IS)
- EPC Discovery Services
- Object Name Service (ONS)

When an RFID tag is manufactured with an EPC, the EPC is registered within the ONS. The RFID tag is attached to a product and the EPC becomes a part of that product as it moves through the supply chain. The particular product information is added to the manufacturer's EPC-IS, and the knowledge that this data exists within the manufacturer's EPC-IS is passed to the EPC Discovery Service. When the product leaves the manufacturer's facility, its departure is automatically registered with the EPC-IS. Likewise, when the product arrives at the next point in the supply chain (e.g., a distributor site), it is automatically read and registered with the distributor's EPC-IS and with the EPC Discovery Service.

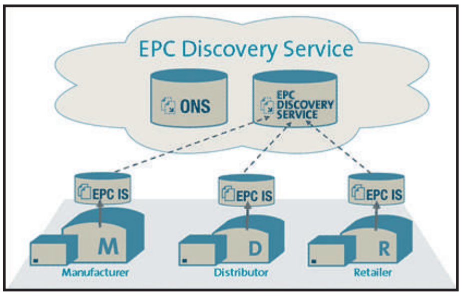

Figure 2

When the distributor needs product information, it asks the ONS for the location of the manufacturer's EPC-IS. The root ONS provides the location of the manufacturer's ONS, which in turn provides the location of the manufacturer's EPC-IS. This query process is transparent to the supply chain member and takes only milliseconds to execute. With the manufacturer's EPC-IS location, the distributor's application can request specific product information.

As products progress through the supply chain, they are in constant communication with the EPC-IS. The result is real-time full visibility of the supply chain.

The AutoID Center has assigned continuing commercial development of the EPC Network to EPCGlobal Inc., a non-profit organisation formed by European Article Numbering International and the Uniform Code Council.

APPENDIX 2

HOSPITAL MOVEMENT TRACKING SYSTEM

During the Severe Acute Respiratory Syndrome (SARS) Emergency Response in 2003, DSTA spearheaded the design, development and implementation of two pilot Hospital Movement Tracking Systems (HMTS) at Alexandra Hospital and National University Hospital.

The system automatically tracks the movement of hospital staff, patients and visitors at the Accident and Emergency (A&E) department within the hospitals leveraging RFID tags, readers and custom application running on servers to capture information.

System Overview

All patients and visitors entering the A&E department were each issued a radio frequency identification tag (about the size of an identity card), in exchange for their identity cards at the registration counter. Hospital staff carry permanent tags. Each tag is encoded with a unique identity, and is associated with a person's identity card number.

As a person moves around the A&E department, the radio frequency energy emitted from the tags is detected by the readers installed in the ceiling. The back end servers will record the date and time information that the person enters or leaves a certain area. Different coloured lanyards are issued together with the tags for ease of tracking and testing – blue for hospital staff, green for patients and pink for visitors. The system deployment diagram is depicted in Figure 3.

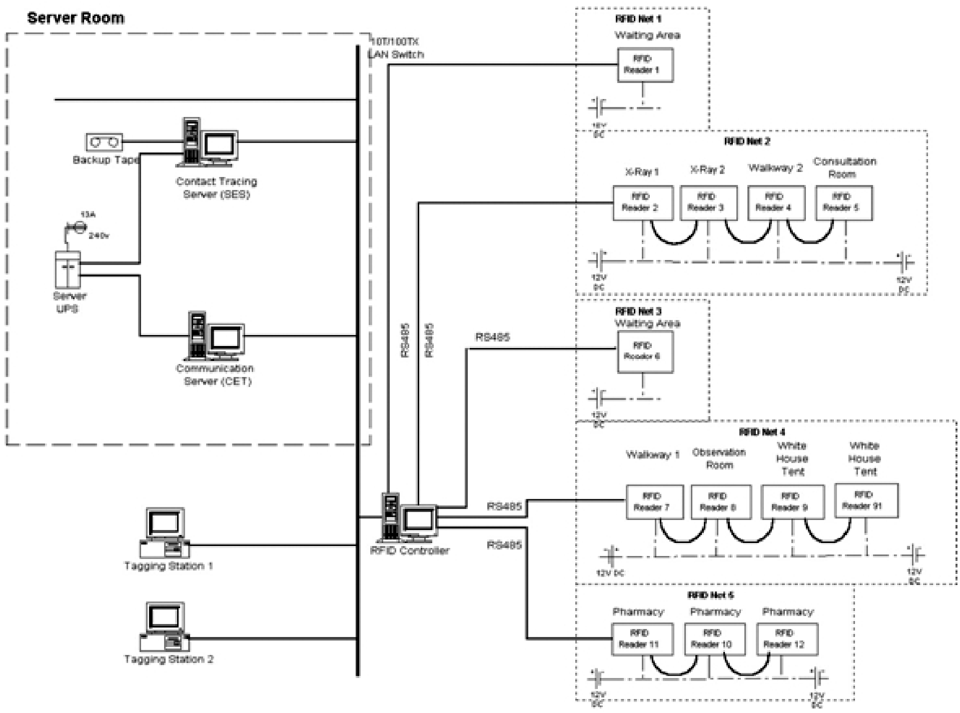

Figure 3. System deployment diagram

Benefits

Previously, Alexandra Hospital manually recorded the entry and exit timings of patients and visitors. If a suspect SARS case was discovered, it took about two days to track all contacts, given the high traffic flow of the hospital. The patient had to recall where and when he has been to in the hospital. The hospital has to check through the duty rosters of its staff to see if they had been to those areas at that time.

With this system, exact information on when a person enters or leaves a certain area as well as the persons he could have been in contact with, can be recorded. Such information can be obtained quickly when needed, through the query and search capabilities of the system.

This allows for faster and easier tracking of contacts, easing the workload of the hospital staff. Under the manual contact tracing effort, it takes six staff about 350 minutes to generate the list of contacts when a suspected SARS case is discovered. Using HMTS, only one person is required to perform the task and the list can be generated in 31 minutes or less.

Information Processing

The back-end server processes the information. It consists of a database of all the movement data captured via the tracking system, and an access terminal.

Access to the database is through a web-based portal in the hospital intranet, and is granted only to authorised hospital personnel.

The portal has a very powerful query and search capability. Should a suspect SARS case be found at the A&E department, a check can be made immediately to find out who has had contact with the suspect SARS case, in which zone and at what time. The information is kept confidential and will be destroyed after 21 days.

Challenges

Several challenges were encountered during the implementation process:

- A clear understanding of the operational processes within A&E was needed to allow for the installation to determine the system deployment diagram for the capture of the relevant information needed for the contact tracing effort (such as contact numbers, installation of readers to cover the various zones patients are likely to visit).

- The site had to be surveyed to determine the location of hardware to be installed as well as site peculiar requirements. The registration counter had intermittent connection to the servers because the Wi-Fi connection was unstable due to the lack of line of sight (heavy human traffic).

- Difficulties were experienced in the tuning of the reader capture zone, as the coverage diagram is probabilistic instead of deterministic. Several rounds of measurements were conducted to give the best coverage. The readers were tuned to balance the reader zone coverage overlap and the blind areas (where there is no reader coverage).

- There were safety concerns with electromagnetic interference (EMI) and electromagnetic compatibility (EMC) with medical equipment. Extensive EMI/EMC measurements were carried out to determine the ambient RF signature at the emission frequency (433.92 MHz) before and after the introduction of the HMTS. Furthermore tests were carried out with all the medical equipment used in A&E department to ensure that it was not susceptible to malfunction resulting from the interference of the RF emissions of the group of 50 tags. Testing was carried by the Productivity and Standards Board to ensure that the tags were safe to be worn by the patient, visitor and staff. The tags passed the Specific Absorption Rate test.

- Extensive testing was carried out to verify the data reliability. The use of active RFID technology for movement tracking is relatively new. The contact tracing team was originally sceptical on the results obtained from the system. The behaviour of the HMTS had to be understood before the results obtained could be explained. Due to the anti-collision algorithm used by the reader to read a large number of tags, the system was only able to read 100% of all tags within its coverage zone only after one minute after 100 tags are introduced. Tests conducted showed that system contact lists generate were more than 98% accurate compared with the manual testing. The difference can be attributed to manual capturing errors and problems encountered when staff left tags within A&E department after work (resulting in errors being introduced to the data captured).

- Innovative solutions to filter tag data, had to be introduced when staff leave the A&E department at the end of the shift but left their tags in the lockers (located within the A&E department). The active tags selected for HMTS operate in the UHF band (433 MHz). At this frequency, RF energy can be blocked by human tissue. During testing, patients occasionally 'disappear' from the HMTS when the patients lie over the tags. An extendable lanyard was introduced to extend the tags and attached to the bed to overcome this limitation.

BIOGRAPHY

Lai Ying Cheung is Division Manager (Joint/Army Tactical C2 Solutions Centre and Communications Experimentation Centre). He obtained an MSc in Eletrical Engineering from the National University of Singapore in 1990 and an MBA from the Nanyang Technological University in 1997. He was also a member of the Integrated Communication System programme that won the Defence Technology Prize in 1992.

Joshua Lee Yuan Horng is Programme Manager (Joint/Army Tactical C2 Solutions Centre). He manages work plan objectives for the Sustenance C2 programme that includes process study, experimentation and solutions for the Army Combat Support Service Domain. This responsibility also entails keeping abreast of best practices in relevant commercial logistics, and the technology development of RFID and its application. Besides having implemented the HMTS, he also managed the Asset Tracking System trial for the Army.