RFID Technology and Applications

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Radio frequency identification is a wireless communication technology that lets computers read the identity of inexpensive electronic tags from a distance, without requiring a battery in the tags. In the past, the lack of widely accepted industry standards and resulting market fragmentation limited RFID use to a few applications such as ticketing. "EZ-Pass" highway toll booths are one example of RFID-enabled smart tickets.

However, the situation is now changing, warranting a responsible debate about RFID's merits and implications. As RFID technology matures, it will likely unleash a new wave of applications that will exploit inexpensive and highly available automatic identification.

A new wave of applications

Ticketing, purchasing, and inventory management applications have received a lot of attention in the press. But as the industry converges on standards that enable tags and readers to be reused and as the cost of tags approaches a few pennies per tag, new applications in new areas will develop.

Employing static RFID readers

Looking forward, transportation is just one of the many industries that could benefit from a network of static RFID readers. For example, rental cars with RFID tags fixed to their windshields could store vehicle identification numbers, so rental companies could perform automatic inventories using RFID readers installed in parking lots. This network of readers could also help the companies locate their cars: because the system would have a record of the reader's location, it could approximate the corresponding car's location.

The airline industry could also exploit static readers. Currently, airlines annually transport about a billion checked bags—more than a billion passengers boarded planes in 2004, according to the US Bureau of Transportation Statistics (www.bts.gov) and US Census Bureau (www.census.gov). Only a very small percentage of bags are misrouted (less than 0.5 percent), but airlines still incur a significant cost to recover and deliver misrouted items. Embedding RFID tags in luggage labels could eliminate the need for manual inspection and routing by baggage handlers. A network of readers placed along conveyor belts could read the tags' routing information and provide feedback to a system that could then direct the bags onto the correct path. Automatic routing could reduce the number of misrouted bags, lowering costs and improving customer satisfaction.

Additionally, in the healthcare industry, tags could help reduce operational problems. A nurse could read a patient's tag to learn about his or her medical history and determine the time and dosage for an administered drug. A networked RFID

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reader attached to a hospital bed could also read the tag and, if combined with centralized patient records, display any known drug-induced allergic reactions for the patient. RFID tags could thus eliminate various data entry errors, drug administration mistakes, and incorrect instructions, which occasionally put patients at risk.

Employing mobile readers

The applications described so far highlight static-reader networks that can identify mobile tags within their range. Another way of using an RFID system is to let a mobile RFID reader move close to a tagged object and read its identity. We could embed RFID readers in devices that people usually carry, such as cell phones. Placing a cell phone in front of a tagged product would bring up the price and other product-specific information on its display—for example, nutritional information for food products.

Another possibility is to attach RFID tags to packages to improve postal workers' efficiency. A pickup courier could drive by a mail box, and an RFID reader mounted on the vehicle would determine if there were any packages to pick up so that the courier wouldn't have to stop at an empty box. Similarly, packages in a warehouse could also be labeled with RFID tags so that a robot with a built-in RFID reader could perform a stock check simply by moving through the building.

Also, a cell phone with an embedded RFID reader could read a tag to initiate a transaction with systems accessible through a wireless General Packet Radio Service connection. For example, it could purchase items by scanning an RFID price tag, requesting an electronic payment to be made. The customer's credit card company would receive payment authorization through the cell phone network.

Some retailers are already experimenting with inventory-control and payment systems. Today, people spend a considerable amount of time at checkout counters—removing items from their cart, placing them on a belt for scanning, and then returning them to the cart. Trials are underway to explore a cart integrated with an RFID reader and a wireless mobile computer authorized to make payments as customers add items to the cart. The system displays prices and then authorizes a batch payment when the customer finishes shopping. The productivity gains and cost savings would likely offset the cost of deploying such systems.

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Exploiting actuation

Applications that depend on actuation could also use RFID readers and tags. For example, a hotel could provide automatic check-in for customers who carry phones with embedded RFID tags. As soon as a customer checks in, the hotel could send a room number and secure "key" over-the-air to the customer's cell phone, which would update the information in its own built-in tag. The customer could then go to the assigned room and use the phone to open the electronic lock. Naturally, the hotel would have to design its doors to incorporate an RFID reader and only unlock the room when the right "key" was detected. Of course, if a tag's presence can trigger an action, issues of security and authentication become paramount.

Incorporating sensor technologies

The use cases highlighted so far assume that tags can only store and communicate static data. Interesting possibilities arise when RFID tags incorporate a sensor to obtain information about the physical world. A tag could return dynamic environmental data along with an object's identity. For example, an RFID sensor tag attached to an airplane part could record the stress and shock experienced during the flight. A maintenance crew could read this information using a handheld reader and dynamically update the plane's maintenance schedule, depending on its condition.

Integrating sensors with RFID tags could also provide a snapshot of wide-area environmental factors found in our physical surroundings. If we could efficiently network together tag readers that could communicate with RFID sensors in their locality, we could make real-time queries about the physical world and measure environmental effects at a finer resolution than ever before. This could lead to better forecasts, new business models, and improved management techniques.

Deployment issues

With the remarkable progress in microelectronics and low-power semiconductor technologies, inexpensive RFID tags are becoming a reality. In the near future, the price of RFID will fall below a critical threshold and these tags will become commonplace—attached to almost every manufactured item.

However, for many of the potential RFID applications we've discussed to become a reality, developers will need to consider a host of commercial and engineering issues. These range from designing affordable RFID tags to under-

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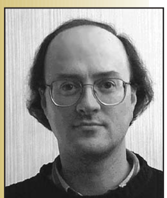

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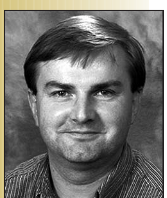

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standing how RF propagates in complex environments such as a shopping car. At the system level, managing and validating the vast amount of data collected can also be a difficult task. Furthermore, the challenges extend to the important social issue of protecting personal data and user privacy as the tags become pervasive in our daily lives. Effective solutions for collecting and managing electronic identities will, to a large extent, determine the success of future RFID applications.

In this Issue

We had an enthusiastic response to the call for papers and, out of the many submissions we received, accepted six articles. We hope that you find their ideas provocative and that the articles guide further research and provide lessons for successful deployment of this nascent technology.

In "An Introduction to RFID Technology," Roy Want provides an in-depth overview of RFID technology. He gives examples of various types of tags, including devices that employ sensors and memory, and he discusses novel reader technologies that can be integrated into cell phones. He also considers privacy issues related to RFID deployment and examines how to mitigate such concerns.

"RFID-Based Maintenance at Frankfurt Airport," by Christine Legner and Frédéric Thiesse, is a case study of RFID deployment in an asset management application at Europe's second largest airport. The study describes how RFID can improve the efficiency of the airport's routine maintenance operations. It also discusses how to comply with strict government standards designed to improve safety in public areas.

In "Requesting Pervasive Services by Touching RFID Tags," Jukka Riekki, Timo Salminen, and Ismo Alakärppä present a middleware architecture for providing touch-based interfaces for pervasive services using RFID tags. The authors also document a usability study and their experience in using touch-based interfaces.

"LotTrack: RFID-Based Process Control in the Semiconductor Industry," by Frédéric Thiesse, Markus Dierkes, and Elgar Fleisch, presents a system design for RFID deployment that is also in use to support semiconductor fabrication. The authors study the ability of a hybrid RFID system to track the movement and location of semiconductor wafers during production. They describe the tracking system's architecture, provide details of their custom long-range active RFID tags, and summarize the lessons learned.

In "Self-Powered Wireless Temperature Sensors Exploit RFID Technology," Karn Opasjumruskit, Thaweesak Thanthipwan, Ohmmarin Sathusen, Pairote Sirinamarattana, Prachanart Gadmanee, Eakkaphob Pootarapan, Naiyavud Wongkomet, Apinunt Thanachayanont, and Manop Thamsirianunt describe the technology behind integrating a temperature sensor into a passive RFID tag. They describe the chip's architectural plan and the sensor's implementation.

Finally, "The Evolution of RFID Security," by Melanie R. Rieback, Bruno Crispo, and Andrew S. Tanenbaum, provides a historical perspective of RFID technology in the context of security. They also track the evolution of security and privacy threats from RFID's inception to the present day.

The potential to obtain instant detailed information about the physical world through RFID's mass deployment presents opportunities for research and technology development as well as new challenges. We hope this special issue provides a glimpse into RFID's future, inspires your own work, and helps extend the scope of RFID applications in the field of pervasive computing.