



## The State of RFID: Heading Toward a Wireless Internet of Artifacts

Opinion by Rajit Gadh

AUGUST 11, 2004 (COMPUTERWORLD) - Ever since the announcement of mandates to suppliers of Wal-Mart Stores Inc. and the U.S. Department of Defense to use radio frequency identification (RFID) to track pallets and cartons in the supply chain, RFID has garnered major interest in all corners of the high-tech industry.

These mandates are rapidly driving the technology forward, and I believe they will lead to a wireless Internet of artifacts that allows any artifact -- even human beings -- to become part of the Internet and to eventually be tracked.

While initially Wal-Mart and others were interested in tracking each retail item, pushback from the suppliers on the economic feasibility of placing tags costing 20 to 25 cents on every item resulted in relaxation of this requirement to tagging only pallets and cartons.

Tracking shipments as they move through the supply chain could improve the supply chain by doing the following:

- Reducing the time taken to reorder shipments once they move from a particular warehouse.
- Reducing product shrinkage/theft.
- Improving authentication of shipments.
- Optimizing inventory.

By embedding tags in cartons and pallets, it's possible to track them, read information about their contents and write onto their tags information about their location with appropriate time-stamps of when they passed through the location. Subsequently, companies can better plan and track shipments through warehouses and transportation systems.

While the first application touted to benefit from this technology is the supply chain, other related industrial applications that are being investigated today include asset tracking within an enterprise and border security. Pilot studies are under way in industries such as retail, shipping, warehousing, medical and defense/government.

To help suppliers satisfy the Wal-Mart and Defense Department mandates, systems integrators and IT companies are rapidly offering pilot projects to these suppliers, supply chain software companies are developing RFID extensions to their existing platforms, hardware start-up companies are offering specialized and vertical-industry specific RFID readers and tags, and venture capitalists are funding RFID technology start-ups. While the mandate-driven technologies focus on supply chain and retail areas, this is the start of what I believe to be the wireless Internet of artifacts.

A typical RFID system consists of tags and readers, application software, computing hardware and middleware.

### RFID Tag

An RFID tag is a small radio frequency chip coupled to a microprocessor, which can communicate with an RFID reader. The tag has an ID that it can broadcast upon receiving a request wirelessly from a reader operating with the same frequency and protocol of the tag. If the tag has no battery -- called a passive tag -- it harnesses the RF power from the reader.

A tag may contain memory whose contents can be transmitted to the reader, and tags may be read/write or read-only. Tags can become sophisticated to the point that they can start to appear like Bluetooth or Wi-Fi chips, in which case they are powered and are typically specialized for some application. One of the major reasons for the excitement in this field is that tags can function without batteries and last a long time. Therefore, once they're embedded within a product, they don't need significant maintenance.

## **RFID Readers**

The RFID reader is a powered RF device that communicates with the tags on the wireless side and with one or more computers on the infrastructure side. For industrial and retail applications, the following classes of readers are most commonly used:

- The 13.56-MHz range -- readers operating in this spectrum are called high-frequency (HF) readers.
- The 900-MHz range -- these readers are called ultrahigh-frequency (UHF) readers.

HF readers tend to be lower power with shorter ranges -- typically 10 feet. UHF technology is relatively new, is meant for longer range up to 40 feet and has higher power, but it's perhaps a bit less reliable than the mature HF technology.

A third class of readers is the low-frequency reader that operates at 120 to 140 KHz, which is used primarily for animal tracking because its tag tends to have small data capacity and low read rates.

## **Application Software**

RFID software typically performs a specific function such as keeping track of inventory in a warehouse or reordering inventory based on items removed from a shelf in a retail store. Based on data a computer receives from the tags about the items (whether they be retail products, pallets, cartons, shipments or trucks), the application takes appropriate action.

Based on events within the enterprise, the software would also send information to the readers to write data on individual tags such as the sale of an item or an empty pallet or a shipment that has left a warehouse and is bound for a retail outlet.

The application tends to be specific to a vertical industry, such as supply chain, retail, medical, warehousing, etc. A software engineer typically doesn't and shouldn't need to develop expertise in RFID technology. Thus, groups such as UCLA's RFID@WINMEC research group are developing a systems interface layer that allows programmers to work at the application layer. This systems layer is called the RFID middleware layer.

## **Middleware**

Middleware is the glue that ties hardware components from lower layers with the higher application layers. While in principle it's a horizontal technology, to make it industrially useful, it often has hooks to industry-specific verticals where needed.

In the specific context of RFID, the middleware layer performs additional functions such as making read/write more reliable, pulling and pushing data through a network of readers to the correct location (much like a router), controlling and monitoring readers, allowing secure read/write operations, reducing RF interference, handling tag-based and reader-based events, notifying an application, accepting and forwarding interrupt commands from an application and alerting a user due to exceptions.

Architecturally, the RFID middleware layer would typically be divided into sublayers, with the lower layers focusing on functions relating to reading from and writing to the tag with reliability, robustness and security.

The upper layers are linked to the applications and therefore would typically provide hooks to databases including functionality such as product shipment tables; product routing and planning tables; tag tables; reader tables; portal tables (a portal is a point through which shipments passing are monitored, such as an entrance door to a warehouse); enterprise IT systems such as billing, ERP, SCM and CRM; and handling tag code standards such as the Electronic Product Code.

One of the major advantages of middleware is that it simplifies software development. The lower middleware layers create abstract classes for readers, tags, the RFID network, etc. When new technology such as a reader with new protocols is available, its characteristics can be incorporated into the middleware, thereby requiring minimal structural or even code-level changes to the software.

The upper middleware layers, in addition to having hooks to databases, also include additional data functionality such as cross-referencing tag IDs with shipment IDs, or shipment IDs with location IDs, or tag time-stamps with expected time of arrival of a shipment. They can store/retrieve such information from the database, so RFID applications could typically refer to the database IDs instead of the tag IDs, which may be specific to a vendor.

This means programmers can focus on developing the business logic for applications instead of having to understand different kinds of hardware. Within a given application, an enterprise might need to support readers and tags from different manufacturers, active as well as passive tags, tags operating at different frequencies/protocols or tags with different read/write reliability and specifications. This is something the middleware enables. Eventually, middleware might be able to greatly reduce the time it takes to integrate RFID hardware into existing applications.

During the development of the RFID@WINMEC middleware layer -- the target applications for which are supply chain, warehousing, asset tracking and security -- we have found several technical challenges that an RFID middleware needs to address.

Reading and writing of tags are rarely 100% reliable, especially when the spatial density of tags within the field of view of the reader is high. This is caused by a variety of reasons, one of them being RF interference due to closely spaced tags. Also, reliability of read/write operations is reduced with increasing relative velocity of tags within the reader field (because it reduces the amount of time available for the read/write). A host of such issues are being investigated, and subsequent to our current research, a technical report is planned for release by UCLA-WINMEC during the RFID Forum in October.

Before creating an application, IT managers need to consider the characteristics of the applications, because they would affect reader and tag selection. For example, if a longer range of reading is required for pallets flowing through a supply chain, a UHF reader/tag combination is needed.

For shorter-range applications such as mobile payments by tags, HF technology might become more relevant. If the application must operate in harsh environments such as keeping track of machine tools on a factory floor, then the tags recommended might be active tags to guarantee signal strength. For in-warehouse location finding, a reader that can determine direction and distance is desirable (although not commercially available). For applications that tag animals and are perhaps read by a mobile reader, power restrictions might force the use of low-frequency technology.

Tag selection must be done at the same time as the selection of the reader. At the most basic level, a decision between active versus passive tags needs to be made. This decision is based on requirements such as range of reading capability, availability of battery if tag is active, life of tag, security needs, data transfer and read/write rate.

Active tags tend to be significantly more expensive (typically by 1.5 to 2 orders of magnitude per tag), and therefore most large-scale applications today use passive tags. Decisions on the selection among passive tags rest on the kind of data to be stored in the tag, the amount of memory required, size, directional antenna needs, desired frequency of operation, desired range of operation and so on.

While there exist technical, business, economic and sociological challenges in deploying RFID system, the touted potential benefits are so significant that this field has generated tremendous excitement. I believe that the wireless Internet of artifacts is a phenomenon that's going to become increasingly ubiquitous in some shape or form since it allows any artifact to become part of the Internet and to eventually be tracked.

Industry is expected to be a significant driver of this wireless Internet of artifacts, with the first genre of applications coming in the areas where inanimate objects are identified and tracked, such as supply chains, goods/shipment tracking and securing of moving goods within and across an enterprise.

The second genre of applications will include tags on living beings, which are already beginning to emerge -- for example, tagged wristbands on patients in a hospital.

Just as in the case of the Internet and the wireless Internet, privacy and security issues will become crucial for the wireless Internet of artifacts, and technologists and businesses will gradually find a way to solve them.

*Rajit Gadh is a professor at the Henry Samueli School of Engineering and Applied Science at UCLA, where he heads the Wireless Internet for Mobile Enterprise Consortium.*