

## The Evolution of RFID Networks: The Potential for Disruptive Innovation

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In some cases by design, but mostly by accident, numerous advances in technology have been highly disruptive. The personal computer and the Internet are instructive examples that empower new and smaller players to innovate and challenge the entrenched economic and technological interests.

RFID offers the possibility of an explosion of nodes at the edge of the network with billions of devices added each year. But the question is still open as to whether RFID will join the personal computer and the Internet in the disruption hall of fame. The recent rise of RFID seems carefully choreographed for improving supply chain management through the efforts of EPCglobal. Wal-Mart, the United States Department of Defense (DoD), and other big players treat RFID as a technology that will sustain their market power through incremental innovation. However, the scope and style of RFID extends far beyond this key initiative. This brief report examines the latest phase in RFID's history, including the EPCglobal initiative and several other recent trends in tagging technology that together, are expanding the RFID roadmap beyond the EPC thrust and may lead to more disruptive scenarios.

### Tagging Trends

The major driver for developing RFID technology has been the tagging of physical objects with microchips so they can interface with computers. Although it has recently entered the mainstream, RFID technology has been available for several decades. The 21st century has, however, marked the beginning of a new era in RFID. In general, the size and cost of computing devices has decreased while

computing power has increased, and the Internet has made it easier to store and share object data. More specific to RFID, we have observed several key trends. First is the evolution of standards for the various components of an RFID system including the transmission technology (the "RF" part) and unique identifiers (the "ID" part). Second, outside the realm of dedicated RFID systems, short-range radio-based communication networks like WiFi and Bluetooth have emerged which are increasingly used in RFID applications, while optical tagging solutions (using light rather than RF as the transmission medium) are being developed that may compete with certain RFID applications, particularly those aimed at consumers. Lastly, both RFID and other tagging technologies are making their way to the edges of the network and into the hands of end-users, significantly increasing the potential for disruptive rather than incremental innovation.

Before examining these trends and their implications in more detail, let us review the basics of RFID technology.

### Technology Basics

An RFID system comprises a transponder and receiver, more commonly known as a tag and reader. Tags can be passive, semi-passive, or active. Passive tags are activated when they enter the range of the reader's signal whereas active tags operate on batteries and generate their own power source. Semi-passive tags have a battery that runs the circuitry of the chip, but does not power transmission of data to the reader. Active tags contain their own power source, and can transmit their signal up to several hundred feet, compared to a passive tag's read range of a few inches to several meters.

Information related to a given object is stored on an affixed tag and transmitted to a reader over a radio frequency (RF) connection. The information is usually in the form of a unique identifier (ID) or code, which resolves to a database containing detailed information about the tagged object. The reader in turn connects via wired or wireless networks to servers hosting RFID applications that make use of the object data, and, in the case of supply chain applications, middleware manages the

flow of RFID data between readers and enterprise applications. Figure 1 shows the key components of an RFID system.

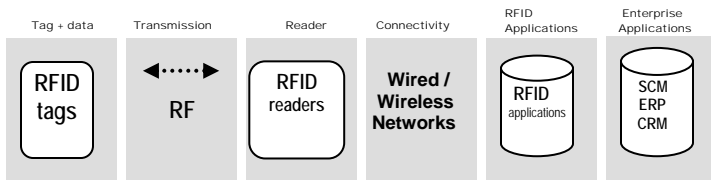


Figure 1: Key components of an RFID system.

Each of the key components operates on the basis of standards. Tag and reader standards include the transmission frequency as well as the communication interface protocol between tag and reader. ID standards define the tag data format or coding system, as well as the ID resolution mechanism (the process for matching IDs to data).

### The Evolution of Standards

Traditional RFID systems and many of today's experiments are highly-specialized, closed-loop applications that use proprietary technology. In other words, the various hardware and software components are tightly integrated and specific to a particular application. Consequently, today's RFID landscape is comprised of many islands of custom-built networks. Many efforts to standardize the various components of an RFID system, from the industrial to international level, are leading towards interoperable RFID technology and applications.

The EPCglobal Network is the most comprehensive and significant standardization effort to date. It is essentially an RFID system based on universal standards for all components of an RFID application. The vision is to have trading partners around the world adopt EPC-compliant technology to enable global data synchronization.

So far, EPCglobal has issued standards for the tag data (the EPC or electronic product code), the tag + reader interface (the latest version being Generation II, or Gen II), and most recently for the middleware that manages the incoming data from readers. EPCglobal runs the registry for the system, assigning EPCs to subscribing manufacturers.

Wal-Mart and the U.S. Department of Defense issued the first round of EPC mandates in 2003, followed by several other large retailers in the U.S. and Europe. This handful of mandates has driven

most of the recent hype and innovation related to RFID. Their scope and scale is enormous; the DoD initiative alone addresses 60,000 suppliers handling \$29 billion worth of items a year.<sup>1</sup>

Although the EPC initiative has gained the support of many leading firms, it is not clear if or how it will succeed. While mandates require that cases and pallets of certain goods be shipped with EPC tags, the centralized ID resolution system that enables the information network itself has not been adopted primarily because trading partners are wary of security breaches as well as sharing their data. Other adoption issues include lack of proven ROI for suppliers, premature technology, an inadequate supply of tags and readers, and unresolved political issues between industry groups and nations. Furthermore, the EPC vision, and therefore its growth potential, is limited to supply chain applications, particularly those geared to the needs of the consumer packaged goods industry.

In addition to the EPC effort, other ID systems and tag + reader networks are being developed. In terms of ID systems, Japan's Ubiquitous ID Center has developed the uCode, which may compete with EPC standards for supply chain applications in Asia. Other ID schemes have used URLs or IP addresses as the tag's unique identifier with the existing DNS as the ID resolution mechanism and ICANN as the registry. Additionally, plenty of applications use proprietary coding systems and databases. Enterprises for example may use their own unique identifiers, resulting in a closed-loop application (a situation the EPCglobal Network seeks to remedy). Another common example is pet tracking applications, which currently use several databases or registries. In these cases, each database of objects comprises a unique naming context, or namespace.

### Converging and Competing Technologies

RFID systems are essentially short-range, low frequency, low-bit rate wireless networks. Since their origins in the late 1940s, they have been developed specifically to exchange small amounts of data over relatively short distances using tags and readers based on proprietary air interface protocols, and more recently ISO and EPC standards. Up until now, these dedicated RFID networks, including the EPCglobal Network, have evolved independently of the new generation of short-range wireless data

<sup>1</sup> "Effect of RFID mandates," *RFID Gazette*, November 21, 2005.

networks like Bluetooth, Zigbee, WiFi, and NFC (near field communication). But these old and new trajectories have begun to converge, and the “RF” component of RFID has expanded to include these newer wireless technologies. In other words, RFID applications are starting to “piggy back” onto today’s established WPANs and WLANs using *active* tags that communicate with these networks’ air interface protocols. In this sense, active RFID tags are a subset of more common communication devices like cell-phones, PDAs, and WiFi-enabled laptops, only with fewer input/output features (like keypads, screens, etc.) and transmitting less data.<sup>2</sup> Similarly, RFID networks are a subset of today’s broad menu of wireless networks, as shown in Figure 2<sup>3</sup>.

Technology	Frequency	Typical Range	Data Rate
Traditional RFID	125-134kHz (LF) 13.56 MHz (HF) 400-930 MHz (UHF) 2.5 GHz & 5GHz (microwave)	20' (passive) 400' (active)	1-200 kbps
Near field communication (NFC)	13.56	0-20 centimeters	106, 212, 424 kbps
Zigbee 802.15.4	2.4 GHz	70 meters	250 kbps
Bluetooth 1.1 802.15.1	2.4 GHz	10 meters	780 kbps
Bluetooth 2.0	2.4 GHz	10 meters	3 Mbps
Ultra-Wideband 802.15.3a	3.1 GHz	10 meters, 2 meters	110, 480 Mbps
802.11a	5 GHz	100 meters	54 Mbps
802.11b/g	2.4 GHz	100 meters	54 Mbps
802.16 WiMAX	10-66 GHz	1-3 miles	134 Mbps
802.16a WiMAX	2-11 GHz	30 miles	75 Mbps
802.16e WiMAX	6 GHz	1-3 miles	15 Mbps
GPRS	900, 1800, 1900 MHz	National network	160 kbps
EDGE	900, 1800, 1900 MHz	National network	473.6 kbps
UMTS	900, 1800, 1900 MHz	In selected cities	2 Mbps
CDMA2000/ 1XRTT	1900 MHz, others	National network	156-307.2 kbps
CDMA2000/ 1xEV-DO	1900 MHz, others	In selected cities	2.4 Mbps

Figure 2: Wireless technologies

While dedicated RFID systems will continue to develop, we will see more active RFID applications that exploit the growing base of Bluetooth modules

<sup>2</sup> Raj Bridgelall, Symbol Technologies Inc., IEEE, 2003.

<sup>3</sup> Table adapted from Craig Mathias and Lisa Phifer, “The Evolving Wireless Landscape,” *Business Communications Review*, pp. 18-23, April 2005.

in consumer devices,<sup>4</sup> while ZigBee-enabled RFID will use wireless sensor networks to track mobile assets.<sup>5</sup>

Similarly, WiFi-enabled RFID allows organizations to leverage existing WLAN investments or choose to invest in a wireless infrastructure that will have multiple purposes, rather than building separate networks. Several WiFi-enabled child-tracking applications currently exist including KidSpotter, set up in Denmark’s Legoland Theme Park, and a trial in a Japanese school that uses similar network technology.

NFC is a more recent wireless technology used in combination with RFID. NFC is essentially a WPAN technology with an even shorter range – about 20 centimeters – and lower data rates than Bluetooth. The technology supports a “touch paradigm,” where devices (including smart cards or mobile phones and PDAs with embedded tags and readers) are brought very close together, or actually touch, to intuitively create a connection between tag and reader. NFC-based RFID may be used to automatically configure a higher-bandwidth connection like Bluetooth or WiFi between two devices. Another typical application involves tapping a concert poster with a cell phone to automatically connect to a Web site over the mobile phone network to buy a concert ticket or download a song. NFC technology is compatible with the established smart-card infrastructure for contactless smart cards (wave or tap instead of swipe), which enables NFC phones to function as the smart card for mobile payment applications.<sup>6</sup> Mobile payment using cell phones is already very popular in Japan. NFC technology is aimed primarily at consumer applications and analysts predict that 50% of mobile phones will be NFC-enabled by 2009.<sup>7</sup>

<sup>4</sup> Frank Seigemund and Christian Florkemeier, “Interaction in Pervasive Computing Settings using Bluetooth-enabled Active Tags and Passive RFID Technology together with Mobile Phones,” Institute for Pervasive Computing, Department of Computer Science, ETH Zurich, Switzerland.

<sup>5</sup> Mary Catherine O’Connor, “RFID’s Urge to Converge,” *RFID Journal*, January 23, 2006.

<sup>6</sup> A competing technology, R2R, recently renamed eNFC integrates additional smartcard standards.

<sup>7</sup> Claire Swedbert, “Developing RFID-Enabled Phones,” *RFID Journal*, July, 9, 2004,

<http://www.rfidjournal.com/article/articleview/1020/1/1>

More intelligent – and more expensive – active RFID chips are generally required for these types of applications (compared to the envisioned 5¢ EPC passive tag for example), but they enable richer and potentially higher revenue-per-transaction services.

In this sense, RFID is becoming less a distinct wireless technology and more integrated into today's wider wireless landscape. But also, as a tagging solution in general, traditional, dedicated RFID is not only converging with other radio-based wireless technologies, it may also compete with *optical* tagging solutions – but not the barcode technology it intended to surpass. Despite the important advantages RFID offers over barcodes and infrared (IR) scanners -- no line of sight required, automatic detection, tags can be as large or as small, as complex or simple, as expensive or cheap as necessary, and with read/write tags, data can be changed -- there are many cases where newer optical tagging systems could compete with RFID. This is particularly true for consumer-oriented applications involving mobile phone readers where performance, cost and ease of use factors outweigh RF's advantages as the data capture and transmission technology.

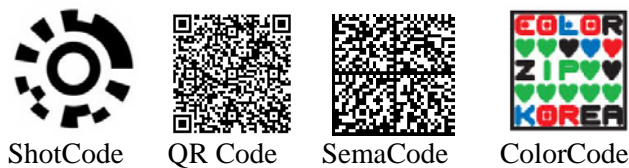


Figure 3 : Examples of 2D matrix codes

Several automatic identification applications have emerged in the last few years using 2D symbols called matrix codes and camera phones, shown in Figure 3. Matrix codes are essentially complex barcodes, capable of storing a far greater amount of information. The transmission technology used is plain old “visible light.” Examples include Semacodes, Shotcodes, QR Codes, and ColorCodes. The phone's built-in camera essentially takes a picture of a unique symbol, which is usually printed on paper (although they can also be printed on t-shirts, burned into wood, tattooed onto skin, etc.) which is then decoded using software installed in the phone. The application then uses the mobile phone network to connect to a server on the Internet, similar to an NFC application described above. One key difference between these “visible-light-ID”

systems and both RFID and “IRID”, is that they are driven by an existing -- and fast growing -- user base of camera phones and an unregulated (although not always available) supply of light for transmission. Rather than relying on the integration of RFID or IR readers into cell phones, software transforms the existing camera into a scanner or reader. Mobile operators in Japan like DoCoMo and Vodafone have installed the necessary software on most of their new phones, increasing the popularity of these applications in Asia over the last couple of years.

A dedicated RFID tagging solution therefore must be weighed in terms of cost, performance, ease of use, potential for adoption and ROI, process changes, etc. against other short-range wireless networks as well as other machine-readable systems including those based on infrared (e.g., barcodes) and visible light (e.g., Semacode).

### Explosion at the Edge

This broader scope of RFID activity and tagging stands in contrast to the EPCglobal vision. And yet the EPC effort has driven much of the hype surrounding RFID in the last few years, and largely defined the agenda. It has in the process accelerated the RFID technology market, and for the big players, supply chain efficiency has and will continue to improve, as will associated profitability. Studies have shown that Wal-Mart can achieve savings of more than \$8 billion every year, and reports were issued last fall showing a 16% reduction in stock.<sup>8</sup> And more suppliers are looking beyond “slap and ship” compliance to experiment with innovative ways to integrate EPC data into their operations.

However, within the narrower context of supply chain applications, RFID innovation has largely been incremental, rather than disruptive. EPCglobal is creating an infrastructure for the larger players, most of which is focused on the supply chain. Unresolved privacy concerns further confine these efforts to back end processes as some of the more innovative point-of-sale and product lifecycle applications have been held back by consumer groups. A true “Internet of Things,” is unlikely to spring forth from these efforts alone.

But, the potential to tag “everything” and create billions of “objects that talk” is a tempting vision to those who view greater connectivity and ubiquitous

<sup>8</sup> “Effect of RFID mandates”, *RFID Gazette*. November 21, 2005.

network elements as the handmaidens of innovation. At some point, we speculate, a community of users, or a small competitor will figure out a unique killer application for objects that talk. As RFID and other tagging technologies increasingly find themselves in the hands of consumers, it is more likely that grassroots tagging will emerge as end users start reading tags with their personal devices, and more so when they start creating their own data relating to an object code, and their own tags.

One useful analogy exists in the world of tagging *digital* objects, namely Gracenote's CDDB (compact disc database) online CD database. The database was essentially created by users for free, where the key enabler was the huge installed base of PCs with built-in CD players. (The database was later privatized and licensed to software developers for a fee.) As tag reading and writing technologies become available at the edge, RFID and competing technologies like visible-light-ID (VLID), may enable similar edge-based innovation. The Semapedia application for example, links objects tagged with Semacodes to Wikipedia entries. A user could create a Semacode symbol that encodes the URL for the Wikipedia entry for a historical building on their PC, print it out on a piece of paper using a regular printer, and tape the code to the building. Semacodes are both created and read using consumer equipment, and read by a camera phone, while Wikipedia is a user-created online resource. The system is completely edge-based. The example is rather primitive, and raises interesting issues regarding the tagging of public space, but it illustrates the potential for edge innovation.

In this way grassroots projects could develop that would provide a counterbalance to more centralized efforts such as EPCglobal. Such a process is well adapted to the creation of technology to meet shared needs but also is good at accommodating differences by spinning off related projects. We await such developments with great anticipation.

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