RFID and Wireless Personal Area Networks for Supply Chain Management

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INTRODUCTION

Efficient supply chain management relies on knowing where products in the supply chain are located. The ability to track items from manufacturing plant to warehouse to distribution center to wholesaler to retailer is currently provided by RFID, radio frequency identification (Weinstein, 2005). Case examples of commercial applications of RFID in supply chain management are evaluated by Jones et al. (2004). A recent development, low power wireless personal area networking, WPAN, can offer advantages over RFID in certain circumstances. It is the purpose of this article to evaluate RFID and wireless personal area networks with respect to each other and to identify the features that give one an advantage over the other. We first describe the two technologies.

RADIO FREQUENCY IDENTIFICATION (RFID)

RFID tags are of two types: passive and active. A passive RFID tag is a chip incorporating memory and a microwave transmitter that is embedded in a product or in the product's packaging. The memory contains the identification number of the tag and may also contain physical specifications of the product using PML, Physical Markup Language (York, 2003). In order to read the tag an RFID reader sends out a burst of microwave energy, which is picked up by the tag and is sufficient to allow the tag to transmit the contents of its memory, which is received by the reader. Since the tag receives power from the reader, it does not need to have its own battery, and is called a passive RFID tag for that reason. Passive tags cost about US$0.20 in large volumes, and are used much more widely than active tags.

Active RFID tags incorporate a battery, cost more than passive tags and can be used to track more expensive products. The price of tags is continuously dropping and increasing usage of active tags can be expected over time.

Some tags are read-only in which case the ID is burnt into the tag at time of manufacture. Others are read/write in which case the memory contains not only the fixed identification number of the tag, but may also contain other information such as a physical description of the product (color, size, etc., in PML format), which is added when the product is manufactured.

Standardization of the identification number, so that it can be read by the many different readers used by organizations in different parts of the supply chain, started at the Auto-ID Center at MIT, and is now being pursued by EPCglobal Inc, an industry consortium that aims to standardize the format of the EPC, electronic product code for use in RFID tags. The current proposal is illustrated in Figure 1 and consists of three parts:

- A 28-bit EPC manager allowing 268 million manufacturers,
- A 24-bit object class allowing 16.8 million products for each manufacturer
- A 36-bit serial number allowing 68.7 billion copies of each product

The specification of the air interface is given by the International Standards Organization (2004). Taken together, the EPC and the air interface are the main standards for RFID.

Automated input of RFID information into a supply chain management system requires RFID readers to be located on shelves in warehouses, distributions centers, and possibly also in retail stores and in delivery trucks. Readers have a range of about one meter so that multiple readers are required. Readers can input information to the supply chain management database via wired connections, for example, using Ethernet, or using a wireless technology such as WiFi or WiMAX (Wright, 2007a, 2007b). The total cost of the system consists of the cost of the tags on each item flowing through the supply chain plus the cost of the readers. Although passive tags cost only US$0.20, readers cost approximately US$250.00.

WIRELESS PERSONAL AREA NETWORKS (WPANs)

An alternative to RFID for supply chain management is a wireless personal area network or WPAN, consisting of devices that communicate with each other instead of with a

Figure 1. 96 bit Standard Electronic Product Code, EPC

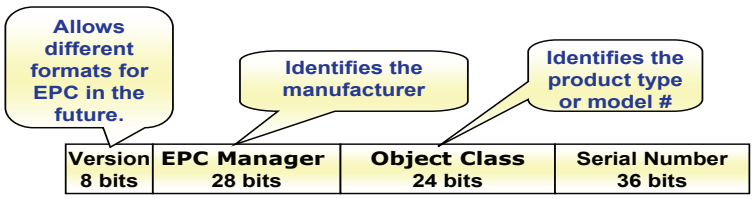
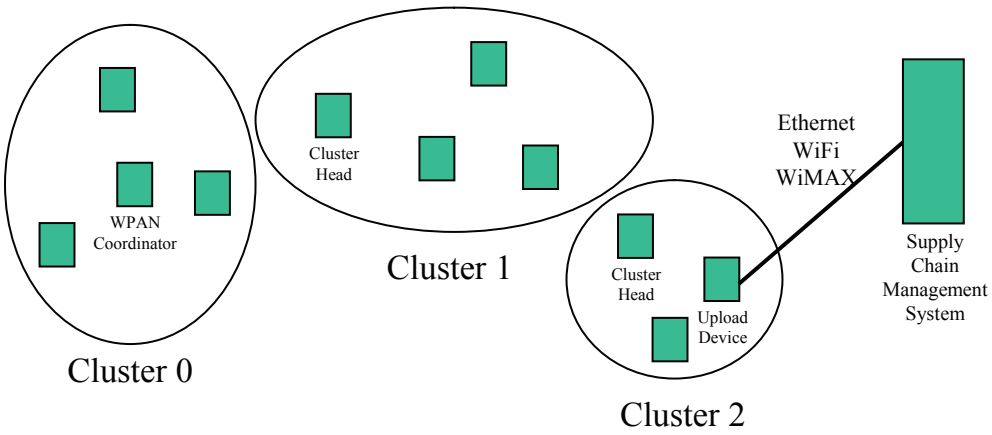


Figure 2. Wireless personal area network



reader. The word "personal" in the title does not mean that there is always a human user, instead it refers to the limited range of the wireless communications: approximately 1 meter from one device to another. WPANs are of various types and here we focus on the low power version that is standardized by IEEE (2003), and is being commercialized by the industry consortium, the Zigbee Alliance, which has developed a specification for wireless personal area network applications (Zigbee, 2006). WPANs require each device to be powered, typically with a battery, but they transmit low data rates at low power so that battery life can exceed a year. Methods for reducing power requirements are described by Liang (2003) and Rajendran et al.(2006); and the system's performance is analyzed by Chin et al. (2003). Initially applications of low power wireless personal area networks include interactive toys and industrial control, in which sensors measure temperature, humidity and position of items in a production facility and use the WPAN to communicate this information to a production control system (Egan, 2005). Supply chain applications include embedding WPAN devices with EPCs in products or their packaging and could also include sensors for measuring temperature and humidity, which are important for perishable items such as produce. WPAN devices can be designed as small as a coin, so as to be easily embedded in products and packaging (Choi, 2003).

The network architecture of a WPAN is illustrated in Figure 2, and is built up of clusters of devices. Each cluster has one device designated as a "cluster head," and one of these cluster heads is the WPAN coordinator. Although the communications range between one device and another is limited to about one meter, networks of clusters can communicate over a much longer distance. Each device uses wireless communications to communicate with its neighbors, and one device can communicate with a supply chain management system using Ethernet, WiFi or WiMAX. This "upload device" is more costly than the others, however only one is required per WPAN. Actual $ costs are not available at the time of writing (1Q06) since WPAN devices are at an early stage of commercialization. Practical methods for designing WPAN networks are described by Minami (2004).

In supply chain management, WPAN devices can be embedded in products or in packaging and can communicate with each other in warehouses and delivery vehicles. As items are added to or removed from a stack of shelves in a warehouse, the clusters reconfigure dynamically, and information about the new products is distributed to the