RF Code
White Paper

# An Analysis of Active RFID for Asset Tracking

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## Description of RFID

Radio frequency identification (RFID) technology uses radio waves to identify objects. A radio transmitter is attached to the object to be identified. A radio receiver decodes and reports the tag transmissions, over wired or wireless networks, to a software application.

Typical RFID applications include item tracking, inventory control, asset management and physical security. A specific example is the tracking of IT equipment across a multi-campus industrial corporation.

## Technology Choices Available

Vendors of RFID technology typically provide hardware and solutions based on three main types of technology:

### 1. Conventional Active RFID (300-915 MHz/UHF band):

Most active RFID systems make use of a transmitting device to send a unique ID number to a receiver or network of receivers. The most commonly used frequencies are 433 MHz, 868 MHz (Europe) and 915 MHz (USA). 433 MHz is the most freely available and unlicensed UHF frequency worldwide, so many vendors operate there. Most vendors use their own proprietary protocols for transmitting the tag data. The functionality and operation of the hardware differs between vendors, but detection ranges of ~100 meters or longer are often stated. Conventional active RFID tags generally have long battery life and relatively lower costs than the other types of active RFID technology.

### 2. WiFi RFID (2.45 GHz):

In recent years, as WiFi networks have become ubiquitous, some vendors have provided tags that work with the IEEE 802.11 standard. The key advantages are the ability to use existing WiFi infrastructure to implement asset tracking based on WiFi tag technology. Disadvantages include short tag lifespans due to the increased data overhead of using the 802.11 protocol and resultant increase in power consumption. There is also some lack of uniform usage of the 802.11 protocols by vendors and the use of proprietary tag activation systems, so it cannot be assumed that all WiFi-based equipment will operate with complete compatibility. WiFi active RFID offers a maximum range of ~100 meters.

### 3. Ultra Wide Band or UWB RFID (microwave band):

With the release of a broad spectrum of microwave frequencies by the FCC in 2003, UWB technology is now available for deployment with asset tracking systems. The key advantage of UWB is very precise locating of tagged assets within a three dimensional space. The key disadvantage of UWB is the very high cost of the infrastructure as compared against other types of active RFID technology. UWB offers a maximum range of ~50 meters.

### Other Options

In addition to the three technology types listed above, other technology options are emerging in the active RFID arena, such as Zigbee (IEEE 802.15.4), Bluetooth and GPS.

- **Zigbee** offers low power, bi-directional data communications via a mesh network, with range up to around 70 m and thus can be employed in areas where traditional active RFID is used, but the technology has not achieved broad acceptance as yet.
- **Bluetooth**, the short-range wireless networking standard commonly found in mobile phones and computer accessories provides a platform for asset tracking applications. Its shorter range (~ 10 m) and high power consumption mean that it might only be suitable for niche applications where long range and battery life are not critical factors.
- **GPS** is widely employed for vehicle fleet and shipping container tracking. Its relatively high-cost, high power consumption and difficulties indoors make it unsuitable for the large majority of asset tracking and monitoring applications.

- **Barcode** and **Passive RFID** technologies are also sometimes considered for asset management applications, but these types of systems have high recurring labor costs and limited location accuracy because they require manual actions to be taken by personnel with handheld scanners. These technologies have been excluded from this discussion because they do not provide a reasonable solution for use in a dynamic asset environment.

## Choosing a Technology

How does one choose between an RFID solution that uses conventional active RFID versus WiFi versus UWB? The decision-maker who must analyze the best RFID solutions has a difficult job. Currently there are over 100 vendors to choose from, each promising that they offer the leading solution. It is not an easy task to weigh the advantages of each vendor's offering against the business problem at hand to determine which technology and software solution is the best to meet the needs of the project.

For the purposes of this study, we will examine 'Active RFID' and 'WiFi' in great detail. While UWB is also very interesting, the tag price and infrastructure costs to establish the coverage zones are generally economically prohibitive, except for the most specialized of applications

The following discussion focuses on these WiFi solution components: WiFi tags that are compatible with 802.11 wireless networks, access points, and LAN controllers/ location appliances. We also focus on these active RFID solution components: active tags that transmit at 433 MHz and radio receivers (called readers) tuned to decode and report the tag transmissions. Both solutions require a back-end software database with a GUI to show asset location on a map display.

## Considerations for Selecting a Solution

### Operating Frequency

Active RFID at 433 MHz versus WiFi at 2.45 GHz. Different radio frequencies have different properties and characteristics. No one frequency will ever be ideal for all the myriad of applications for RFID, so the choice of hardware vendor will have to include analysis of the operating frequencies. Lower frequencies such as 433 MHz operate very well around metals and liquids as well as in crowded environments where objects and people interfere with the line of sight between the tag and reader. Higher frequencies, such as 2.45 GHz, offer higher data transmission speeds but transmit in narrower beams, making them ideal for data intensive tag transmissions and more precise determination of the incoming signal's direction, but are more susceptible to interference by objects in the environment, particularly where things and people move around - offices, hospitals, warehouses, etc.

Another important consideration is the level of competing signals at the frequency used by the system hardware. The more devices there are using the same band, the greater the chance of data loss through transmission collisions and corruptions. Equipment operating in the 2.4 GHz ISM band may occasionally suffer interference from microwave ovens, cordless telephones and Bluetooth devices. Restrictions imposed by ETSI and FCC mean that active RFID tags cannot emit strong signals and could be drowned out by high levels of 'environmental noise' caused by competing signals or other systems.

The off-network vulnerability of physical assets can be reduced or eliminated when their whereabouts are dynamically monitored with a wireless tracking system.

### Communication Protocol and Security

IEEE 802.11 is a set of standards defining wireless local area network (WLAN) computer communication in the 2.4 GHz frequency band. The 802.11 family includes over-the-air modulation techniques that use the same basic protocol, but it is not an explicit RFID protocol. Security was originally purposefully weak due to export requirements of some governments, and was later enhanced via the 802.11i amendment. While standard communication protocols are employed for transmitting WiFi data, not all WiFi equipment is functionally compatible: 1) certain families of WiFi tags are not assigned an IP address and therefore do not support authentication and other information security policies; 2) certain families of WiFi Access Points do not support location-based services; 3) certain vendors offer proprietary hardware that is required for special functions such as tag activation; and, 4) each vendor's own software solution may be the only one capable of working with the technology they provide.

A number of vendors have developed active RFID protocols at 433 MHz. These include bi-directional tags with read/write capabilities using Frequency-Shift Keying (FSK) modulation. These tags work in concert with Interrogators that initiate communications and then listen for a response from a tag. FSK is a disruptive and power hungry protocol with a continuous duty cycle while transmitting; it requires an expensive radio. Other vendors have developed patented technology using the simplest form of Amplitude-Shift Keying (ASK) which is On-Off Keying (OOK). These solutions typically have better costs, battery life, anti-collision performance and read ranges. The very best system security is achieved when the tags are one-way, transmit-only communicators, which broadcast only their 'license plate' type ID. All of the meaningful, sensitive information about the tagged asset resides within the software back-end, it is not stored on the tag or broadcast through the air. Families of tags and readers from competing active RFID vendors typically do not offer operational compatibility. In practical terms, every active RFID vendor is proprietary in one form or another.

### Location Accuracy

If you only need to know that an item is on site, then employing an expensive system to tell where precisely it is on site is a waste of money. Consider carefully how accurately assets must be located to achieve the business objectives and then select the solution that provides that level of accuracy. It is commonly assumed that a true location system must provide tag location data in two or three dimensions, usually by means of triangulating each tag's position using multiple overlapping readers. Much is made of the accuracy of one system over another, but while knowing an asset's location to within a few meters sounds impressive, does the business case truly warrant that level of detail?

A cost effective alternative to triangulation is the use of 'zones' to locate assets. A zone can be defined by logically grouping one or more readers together in the software and it can be as small as a single room or it can cover an entire site. The system will not identify specifically where in the zone the asset is, but merely that it is in there. 'Zonal' systems do not require the dense network of readers or WiFi access points with overlapping read ranges as triangulation systems do, thus significantly reducing the infrastructure costs. If room-level precision is required, certain active RFID vendors offer tags with infrared sensors that report the address of infrared illuminators in the vicinity of the tagged asset. Since infrared light does not pass through walls, these systems can deliver room location data, but if no illuminator is visible to the tag, you are essentially back to zonal precision.

### Up-Front Tag Cost

WiFi tags are generally more expensive than active RFID tags at 433 MHz. For volume tag applications the cost difference may be even more pronounced. Active RFID tag costs less than $22 in moderate volumes, 802.11 tags can cost many times that price. Tag pricing above $50 per piece is not uncommon. This limits the application to only the highest value assets, reducing the practical utility of the system. Some vendors are taking this up-front tag expense out of the equation by giving away the hardware and charging a monthly or annual service fee for the solution.

### Recurring Tag Costs

Calculate the expected lifetime of the tag versus asset lifetime and any further costs associated with retagging assets in future. Much of the value proposition of the asset tracking system comes from a tag that lasts for the life of the asset being tracked. If the battery life is shorter than the asset life, then battery maintenance is needed. Recovering the asset to refresh the battery drives up the cost of tagging the asset. Non-WiFi based active RFID tags can last up to 7 years, even at a 10-second beacon rate. This translates into a one-time installation for most assets, with no further service required. By contrast, 802.11 tags may require a trade-off decision based on the application. They can either have a very long period between beacons (problematic for workflow, security, mobile, or highly-valuable items) or have a battery life measured in months. One company requires that tags be re-charged at the end of each shift - meaning that for each tag out of service re-charging, there must be a second replacement tag that can take its place, doubling the expenditure on tags.

### Tag Size and Form Factors

The best of the active RFID tags have a form factor of approximately 1 cubic inch. WiFi tags typically range from 2.6 to 4 cubic inches. Bulky tags cannot be used for applications such as tracking IT servers and mobile equipment, such as laptops, where a small form factor is essential. Even manufacturers of the smallest tags are under pressure to reduce size without impacting performance or battery life.

Ideally, tags would be very small, flat, and work consistently irrespective of environment and orientation. In reality, until electronic and battery technology improves significantly, the tags will be relatively large, expensive and only suitable for use with assets that can accommodate them. Mounting tags directly on large metal objects can diminish the signal strength and quality of the tag transmissions. Try to select a vendor that offers a range of tags that have the right shape and sizes to be attached to your specific types of assets. No vendor may be able to offer tags that conform to all your requirements, so their ability and willingness to customize the tags to suit your environment and industry-specific requirements is another consideration.

### Number of Items to be Tracked

The more tagged items there are in any one area, the greater the number of transmissions that will be emitted per second. These transmissions add to the 'noise' levels in the environment, and can interfere or 'collide' with each other. All major RFID vendors implement anti-collision methods to reduce the chances and effect of these collisions, but there are limits to the number of tag messages that can get through to a reader in any one second.

Again the transmission capabilities and frequency used by the RFID hardware must be considered. For systems tagging thousands or tens of thousands of assets, it is crucial that the tag signals are kept as short as possible to enable regular transmissions as often as every few seconds, or else the transmit rate must be reduced to help preserve a useful battery life. Where possible the tags should use a frequency least affected by other devices in the environment itself to minimize the effects of RF noise.

### System Throughput and Expansion

Active RFID applications are typically designed to manage a large numbers of tagged assets in a confined area. Whether they are stacked in a staging area, or distributed throughout a warehouse, the nature of these applications requires the ability to handle a hundred or more tags per second per reader. This is not possible for WiFi tags both because of weak anti-collision performance and because of the compounding effect on the network's data throughput. This is a natural limitation of a technology that was not originally designed for RFID.

Active RFID systems are designed for expansion and scalability. The best of the active RFID solutions can handle dense tag environments and do it without burdening the wireless data network. This means that scalability is built in from the beginning. The worst time to find out about system limitations is during a period of growth. Active RFID tags operate in other bands of the ISM spectrum that do not degrade wireless data traffic. The tag transmission protocols are typically sparse; the readers can monitor hundreds of tags simultaneously and run in exception mode, with an on-board state engine that monitors tag status, and only reports an event if there is a change of state.

WiFi based systems do not recognize the inherent power of change states. They report every beacon regardless of condition. Since the access point is not an intelligent point of collection, there exists no method to filter extraneous beacons; this adds to the amount of traffic being placed on the network. Wireless LANs are designed to maximize data throughput. WiFi tags generate a large volume of small packets with identification data. For example, a location network with 10,000 tags sending a beacon every 10 seconds generates 60,000 wireless data packets every minute—over and above the ordinary data traffic on the same network; this problem is compounded when overlapping access points are processing the same tag transmissions. Interference is created, reducing the data handling capabilities of the network. Some vendors look to longer beacon rates (and therefore less-frequent packets) to solve this, as well as to increase battery life, but this requires a compromise in terms of the timeliness of information.

### Location Data Timelines

A tag that signals every few minutes or hours cannot truly provide 'realtime' data. However, not all asset tracking systems require 'realtime' data - an item in a warehouse, or an IT server installed in a rack, may not move for weeks or months and the only time the tag must signal is when it does move. The integration of motion sensors into RFID tags can enable them to transmit infrequently when at rest, but rapidly when on the move, thus lengthening battery life but still ensuring rapid detection when changing location.

Systems used for security purposes will need a response to unauthorized events within seconds, not minutes. Assets passing through an exit door have just a few seconds to register that they are leaving the area. The options for reading tags in real time, particularly those that can move at speed past the reader, require either beacon tags which transmit repeatedly or receive and respond to a 'beacon-now' signal from a special tag activator. There is inevitably reduced battery life if the tag must respond or transmit its data with rapid repetitions.

One hope for WiFi location systems is that WiFi-enabled devices will work automatically on the network, with no need to tag a WiFi device separately in order to locate it. While this is true for a powered WiFi enabled device, it is not true for most applications that require asset tagging. A WiFi enabled laptop can be tracked by an 802.11 location system while the laptop is turned on—usually only when it is stationary. If a user closes the laptop, putting it into sleep mode, 802.11 communication ceases and the system location data is no longer valid.

### Access Point / Reader Cost

For rough calculations, figure on $1,000 per reader or access point. To determine the number of readers required, divide the total physical square footage by the reader's coverage zone square footage. With a read range of ~100 meters, a circular reader zone should theoretically cover Pi x R x R = 31,400 square meters. In practice, the reliable coverage zone is a much smaller area; some vendor guidelines specify coverage zones of only 12,000 to 20,000 square feet. In buildings with multiple floors, estimating the required number of readers can get complicated, as RF signals readily propagate through most non-metal construction materials (e.g., floors, ceilings).

For WiFi based location systems to work effectively, it is recommended that access points be installed in a staggered fashion in hallways and at the perimeter of the coverage area. Consider whether WiFi triangulation based on signal strength indications will be needed.

Some vendors offer location services only if the tagged asset is read simultaneously by three or more readers. Statistical algorithms are applied to determine the "predicted" location of the asset, but if there is insufficient reader coverage, the true location can vary significantly. Additional access points will add extra cost to implementation. Some vendors recommend that access points be installed every 70 feet. For precision location, Cisco Systems recommends that access points are placed every 15 meters (~50 feet).

### Hardware Installation

The reader infrastructure is typically installed above the ceiling tiles. Power drops and internet connectivity may not be available in the preferred reader locations. Location system precision can be improved if there is line of sight, or near line of sight, from the tags to the readers. Most environments are crowded with obstructions, making this difficult or impossible to achieve. Installing and re-positioning readers and access points can be labor intensive and therefore costly. Based on the density of readers and the way in which their locations were determined, the precision of the system location resolution can vary due to environmental factors. Appropriate placement of access points is vital to an effective wireless architecture and to proper RF calibration.

Some WiFi vendors propose that the existing wireless infrastructure can be used to deliver location information in addition to a wireless data connection. Be aware that significant and costly additional hardware infrastructure may be required to accommodate asset tracking applications. As a practical matter, an active RFID location infrastructure may be less costly to install and maintain than the incremental infrastructure required for a WiFi-based tracking system.

The installation environment plays a crucial role in determining how the system's infrastructure must be configured to meet the operational requirements demanded of it. Access point radio angle and the orientation of the antennae are important factors for obtaining accurate and consistent proximity data from the WLAN. Proper calibration of RF signals is critical for enabling location-based services to deliver close and consistent proximity data. RF calibration must be performed carefully across all facilities and floors and repeated if the floor layout changes. In some cases, it may not be physically possible to achieve the required level of performance; such is the nature of radio signals.

### Calculating the Total Cost of Ownership:

The lifespan and transmit rate of the tags offered by e vendor of choice are important considerations when calculating the overall system costs. Add to that the up-front costs of attaching tags to assets. If there is schedule for conducting a periodic physical inventory, that may be the best time to attach the tags. If the assets will need to be retagged, or tag batteries replaced after a few years, the costs in hardware and manpower to achieve this must be considered as part of the total cost of ownership. Most tags have a transmission pattern that can flag a low battery condition; this needs to trigger a system alert condition, as it may become increasingly difficult to locate tagged assets after the batteries have died.

Many persuasive cost saving arguments for each vendor exist: WiFi tags offer the chance to use an existing WiFi network access point infrastructure, thus minimizing infrastructure costs when compared to active RFID systems. However, conventional active RFID vendors offer tags that are as much as one fifth of the cost of WiFi tags, with battery life spans up to three times longer than WiFi tags.

Long battery life dramatically reduces the total cost of ownership. Understanding where one's assets are and, in some cases, what their condition is, can unlock cost savings that enable an asset tracking system to deliver a return on the original investment in one to two years.

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