A Comparison of Radio Frequency Identification Technologies and TeraHop Movable Wireless Sensor Networks

This Application Note compares and contrasts Radio Frequency Identification systems, commonly referred to as "RFID" and the technology employed by TeraHop Networks, Inc., Each of the three systems described meet the needs of certain applications. Rather than competing technologies, the three systems can complement each other.

Both RFID and TeraHop technology are wireless data technologies that are incorporated into devices that are attached to objects that move or that are moved from place to place, to enable tracking/monitoring. Beyond this commonality, there are significant differences that make RFID appropriate for some applications and TeraHop technology appropriate for others. Within the overall RFID space, there are many variations; some based on international standards while many others are based on proprietary approaches. Unfortunately, attributes in certain approaches and products are assumed to be present in others. To help clarify this situation, this application note divides RFID into two commonly accepted categories; Passive RFID and Active RFID.

Passive RFID

Passive (or "ordinary") RFID systems consist of very small/simple devices ("tags") that can be placed on assets, and "readers" that are used to collect data from those tags. The data collected by the readers is then forwarded to application systems. The tags typically comprise an antenna and a single-chip transceiver. They do not have a battery. The readers are usually PDA-like devices or are cigar-box-size units that are mounted to buildings, posts, or are placed along conveyor belts or near shipping doors to read tags as they pass by.

In operation, a reader and a tag are brought into mutual proximity, and the reader transmits a radio signal that the tag's antenna receives and converts to energy to power the tag's chip transceiver just enough to transmit a unique stream of bits back to the reader. The stream of bits uniquely identifies the tag and, by inference, the asset to which it is attached. The tag's bit sequence is assigned by the manufacturer and is unique and never re-used.

RFID systems are very simple; a tag "talks" directly to a reader, then another tag talks directly to the same reader. This simple but effective system has been designed to be a replacement for barcodes. The use of broadcasted radio energy to activate (or "excite") the RFID "tags" is very inefficient, however. Therefore, the read-range between a tag and a reader is very limited. Typical ranges are from a few inches to a few feet. Refer to Figure 1.

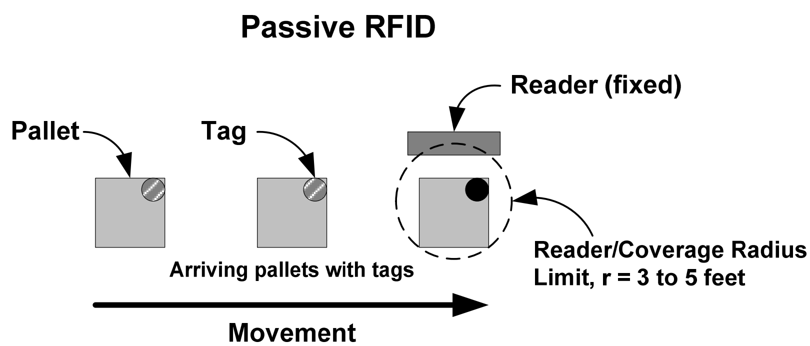

Figure 1.

Two different modes of operation are typically used. In one mode, readers are portable, usually carried by people, and are moved to the assets with RFID tags. This mode is commonly used for checking inventory stock levels. In the other mode, readers are stationary, and the assets with RFID tags are brought into close proximity to the readers.

A common example of the second mode is the use of stationary readers at retail store doors to help reduce theft. Similarly, some seaports have stationary readers at the port's gates to read tags that may be attached to containers. RFID systems that use the latter mode are commonly referred to as "portal" or "choke-point" systems since the tagged assets must pass through a portal (or choke point) for the system to read the tags.

The cost of an RFID tag can be as little as fifteen cents. RFID's major advantage over bar-coding is its ability to read tags without requiring direct line-of-sight, as is required with barcodes. Also, RFID tags can be read much faster than barcodes. RFID systems are covered by international standards with many vendors providing interoperable components.

The simplicity and low cost of RFID, however, brings a number of limitations. Those limitations include:

- difficulty in accurately reading individual tags when there are large quantities of densely packed assets (known as the "mixed pallet" problem);
- difficulty reading tags on liquid assets and/or that include packaging foil;
- the need for close proximity between the tag and reader;
- the very limited data (only the identity) that can be read;
- although very low cost, RFID tags are far more expensive than the barcodes that they are intended to replace.

RFID has been in use for well over a decade and has been much hyped. There is a common tongue-in-cheek comment made in the industry that RFID is the oldest, new technology available! Much of the hype was generated by the mandate of a major retailer that required RFID tagging by the larger suppliers to that retailer. That requirement has since been significantly reduced due to both technical and economic considerations.

Despite its limitations, RFID technology is very useful and works well when appropriately applied. The most appropriate applications of RFID are those for which one wishes to track the movement of large volumes of small, relatively low-value consumables that move along predictable and controlled paths. Refer to Table 1 for a summary comparison of RFID and TeraHop technologies.

Active RFID

Active RFID (A-RFID) systems are very similar to ordinary or Passive RFID with three major differences:

- A-RFID tags have an internal battery power source that dramatically increases the tag-to-reader range.
- There is no global standard for A-RFID, and, consequently, capabilities vary significantly from one supplier to another.
- The cost of A-RFID tags is typically orders of magnitude higher than Passive RFID systems due to their increased complexity and lower volumes.

A common example of an A-RFID application is automated toll collection, which has been implemented on many toll roads. In these systems, a vehicle equipped with an A-RFID tag passes by a toll booth or through a designated traffic lane that is equipped with a reader. The constantly broadcasted signal from the reader is received by the tag, which, in turn, responds by transmitting its unit identification back to the reader. The working distance between the reader and the tag can be as much as 100+ feet, depending on vehicle speed, vehicle density, the radio frequency band used, and radio protocol supported.

Having an internal power source enables increased capabilities other than just longer range, which has resulted in many variations of A-RFID-based systems. One variation allows the tag's data transmission to include more than just the device's identity. The batteries in these tags can last for years. Another variation includes "chirping" or "beaconing" operation, in which the tag periodically broadcasts its identity, independent of being queried by a reader. Further, some tags have internal processors and intelligence that permit the integration of on-board sensors and autonomous decision-making regarding data transmissions. However, these more-capable, more-complex tags typically exhibit greatly diminished battery lives, usually measured in weeks or months, depending on the particular design and usage.

Consequently, there is considerable confusion in the marketplace regarding battery life and features of the non-standard A-RFID systems. Quite often people assume that the "full featured" systems that support sensors, localized processing, and very long range have the same low cost and long battery life of the simpler battery-assisted devices.

A-RFID tags are much more expensive than ordinary RFID tags; they are typically priced between $20.00 and $100.00. Given the cost (and diminished battery life), A-RFID is most appropriately applied to assets that are somewhat larger and more costly than those associated with ordinary RFID, but which move similarly or more quickly.

As in ordinary RFID-based systems, in A-RFID-based systems, a tag "talks" directly to a reader, then another tag talks directly to the same reader. So, for purposes of this discussion, it is important to note that both passive and active RFID tags are *not part of a network*. Rather, the tags communicate *with* a network that comprises one or more readers, and those readers may be further interconnected to a communications network to which users can connect. This not-part-of-the-network distinction is a major difference from the TeraHop system described below, and it has major implications for system capabilities, performance, and utility. Refer to Figure 2 and to Table 1.

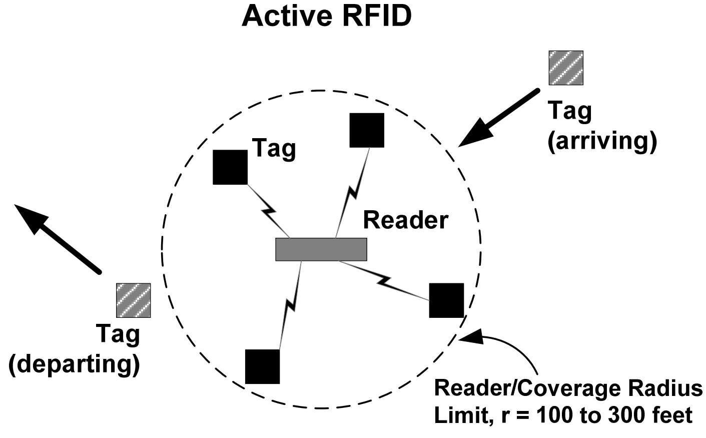

Figure 2.
Tag messages pass directly to/from only the reader, limiting coverage area to that of just the reader.

TeraHop

TeraHop refers to its asset-mounted tags as Remote Sensor Nodes or RSNs. These devices are far more sophisticated than either passive or active RFID tags, and that sophistication greatly increases capabilities, performance, and utility. The most notable networking capability that comes with this sophistication is that TeraHop RSNs become *part of a network* rather than merely communicate with one, as is the case for both types of RFID-based systems.

By being part of a network, any TeraHop RSN can communicate with any other proximate RSN and, when appropriate, relay messages from one RSN to another and eventually to a Gateway that connects to the outside world. In the TeraHop system, Gateways provide functionality comparable to RFID readers in that they convey RSN messages to other network components and to user applications. Unlike most RFID readers, TeraHop Gateways are multi-function, multi-radio, control elements that provide far more functionality than merely reading and forwarding tag data.

The sophistication of TeraHop RSNs derives from having an internal microprocessor, internal sensors, and higher-power radios, all of which are supported by very effective power-control circuitry. So, despite having features that would ordinarily limit battery life to weeks or months, RSN battery life is typically 2+ years, in a package about the size of a deck of cards, and offering far more capabilities than either type of RFID system.

In normal industrial environments (as opposed to ideal conditions), the radio range of a TeraHop RSN is 300 feet. Coupling this range with the ability of RSNs to relay messages - a process that TeraHop refers to as "hopping" – network range can be extended to almost one mile. Similarly, network penetration (into a building or out of a stack of shipping containers) is far deeper than with RFID-based systems. Refer to Figure 3.

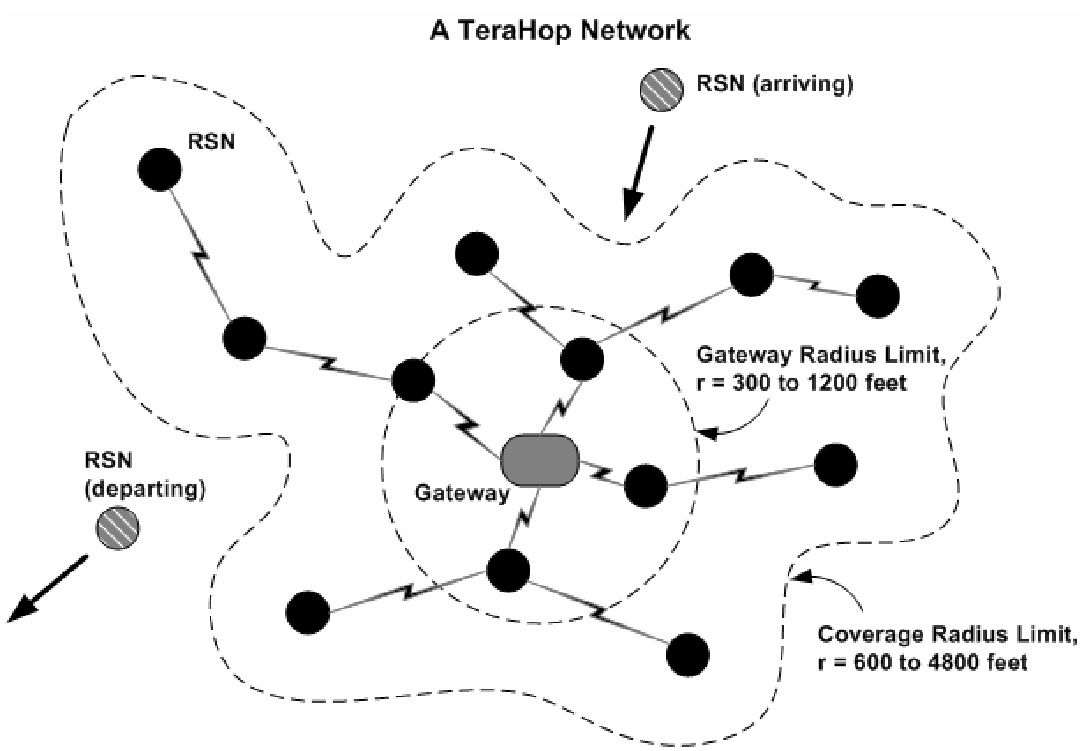

Figure 3.
RSN Messages can hop to/from other RSNs to/from the Gateway, greatly extending the coverage area.

The range magnitude of the THN system enables area coverage of an entire site with minimal site infrastructure. A single Gateway at minimum range covers over six acres. RSNs can communicate with a Gateway if they are anywhere within the range of the Gateway or of any RSNs that are already networked with that Gateway, thereby expanding that coverage area. This so-called “area-coverage” obviates portals, choke-points, and special lanes to make an asset’s presence known and to transfer data and messages. Those data and messages can include data about the asset and its condition (from sensor data), and can automatically change the RSN's behavior depending on location, sensor inputs, and its internally programmed logic.

The combination of wide/deep coverage and the use of Class-Based Networking further reduces the amount of infrastructure required to cover a TeraHop site and enable different entities to share that infrastructure. Class-Based Networking can be thought of as assigning RSNs to groups, and only RSNs that share groups use each other for hopping. So, RSNs on assets from ABC Company might be configured to hop with only other ABC Company RSNs, even when there may be RSNs belonging to XYZ, Inc., also on the same site. Yet, both groups of RSNs could use the same Gateway infrastructure to connect to their own respective user applications. So, total infrastructure is minimized, and the corresponding minimized cost of that infrastructure is shared among all.

The extensive and flexible capabilities of the THN system make it most appropriate for tracking and monitoring high-value, medium-to-large assets. These are usually assets that move within a site and that change sites frequently and unpredictably, that dwell at sites temporarily, and that do not have an always-on power source. These assets include cargo containers, construction equipment, and first responder personnel and equipment.

	P-RFID	A-RFID	TeraHop
Tag/Device Cost	< $1	$10-100	$200
Infrastructure Cost	Low (1 gate) Very high (a site)	Med. (1 zone) Very high (a site)	Medium
Tag/Device Size	Postage stamp	ID badge to paperback book	Deck of cards
Internal Battery Life	NA	Months-years, depending on features	2 years, minimum
Location Precision	At a gate	Zone presence	Site presence
Range Radius	3-5 feet	100-300 feet	300-4800 feet
Sensor Monitoring	None	None-limited	Standard
Query Capability	None	Limited	Standard
Data Storage	None	None - limited	Standard
Site Device Density	Unlimited	Limited	High
Use at Temporary Sites	Limited	Limited	Unlimited
Infrastructure Complexity	Low	Low	Low
Tags Are Networked	No	No	Yes
Tags Hop Messages	No	No	Yes
Tags Auto-Adjust to Site	No	No	Yes
Asset Appropriateness	Small-size, low-value consumables	Medium-size, medium-value	Medium-large size high-value

Table 1.
Summary comparison of the three technologies.

Summary

Understanding the differences of the three technologies is crucial to deciding which, if any, of these technologies to apply in an asset tracking or monitoring application. Due to the differences of the technologies, there is little overlap in their application appropriateness, and which one to use will usually be unique and obvious. None of the technologies makes a good substitute for the others.

*****

Document No. 27001038

For additional information, please visit TeraHop online at ***www.terahop.com.***