From A to ZigBee...
The Truth about Sensor Networks

Active radio frequency ID (RFID) - Real-time Location Systems (RTLS) continue to emerge as an important strategic capability for many industries. In hospitals particularly, active RFID-RTLS can play an important role in automation of common tasks - improving operational efficiency, increasing patient flow and enhancing patient safety. Knowing the location, status and movement of equipment and people can provide a rich warehouse of information that can be mined and used to improve hospital business processes and asset utilization, reduce capital expense and rental costs, and improve staff productivity.

To obtain these benefits in a healthcare environment, RFID-RTLS must be fast and inexpensive to deploy, must retrofit easily into existing buildings without patient care disruption and must allow for easy changes and updates to accommodate the ever-changing hospital physical plant. Most importantly, they must co-exist with other hospital infrastructure technologies, such as LAN's, WLAN's (Wi-Fi), and the growing variety of network-enabled and wireless medical equipment.

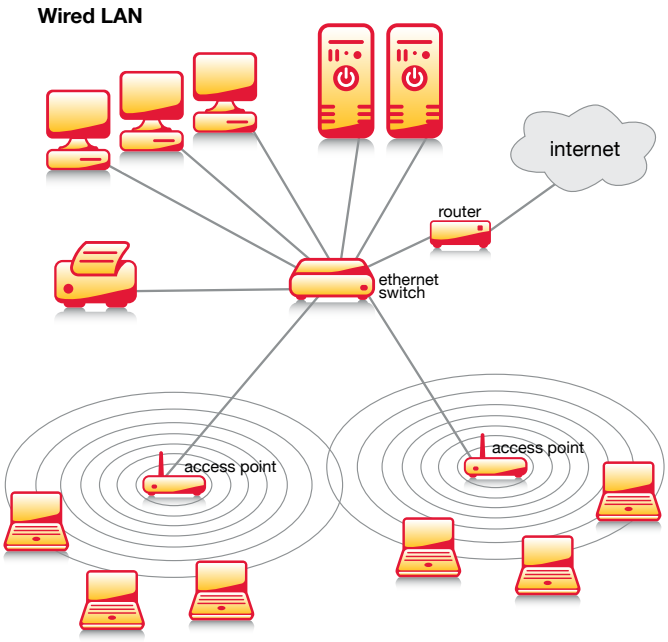
Today, myriad technology options exist each purporting to provide the best RFID-RTLS for the specific needs of the healthcare market.

Oftentimes, when RFID-RTLS are discussed for hospitals, leveraging the existing Wi-Fi network is reviewed as a possible solution. Many hospital administrators look to leverage the Wi-Fi network infrastructure for a positioning system, rather than implementing a separate network. But, the requirements of sensor data collection conflict with the original design goals of Wi-Fi. These conflicts can render Wi-Fi based RTLS impractical and expensive, and can adversely affect mission-critical applications running on the hospital's Wi-Fi infrastructure.

ZigBee® based technology has emerged as an ideal choice for industrial, commercial and home automation markets, where the harshest RF conditions exist. ZigBee was created to address the market need for a cost-effective, standards-based wireless networking solution that supports low data-rates, low-power consumption, security, and reliability. With the ability to install, upgrade and network wireless sensors to monitor a variety of conditions, ZigBee has proven to be the ideal choice for RFID-RTLS in healthcare.

Wired Ethernet Data Networks

Wired data networks, such as the pervasive TCP/IP networks, are designed for high data transmission rates among standard applications. Wired Ethernet data networks provide this speed along with high reliability, and typically form the backbone upon which all other networks and the overall computing infrastructure are built. Cabling costs are a significant part of the overall LAN budget, especially when networks span multiple floors. Even a "wireless" LAN is never totally wireless - it does need to be connected to the wired LAN via access points which provide gateways onto the wired data network.



Wireless (Wi-Fi) Networks

Wireless data networks provide the very high data rates necessary for mobile users and intelligent, Wi-Fi-enabled equipment. Wi-Fi was developed to replace wired network connections for portable devices, like lap-top computers. Using the Wi-Fi network to collect sensor data for RTLS conflicts with the original design goals of Wi-Fi to support end-users with high data rate networking. The requirements of RFID-RTLS can render Wi-Fi based systems impractical from both a cost and performance perspective. It is important to understand limitations and issues, particularly shared bandwidth and interference that may affect the radio transmission.

Sensor Networks

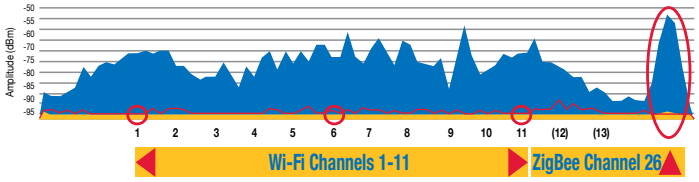
ZigBee is the only standards-based technology that addresses the unique needs of remote monitoring, control and sensor network applications. ZigBee sensor networks require far less throughput but offer even greater flexibility than either of the other network types. Thus, these networks are well suited to applications requiring low data rate transmissions. (In RFID-RTLS implementations, asset tags need only send brief transmissions of approximately 100 bytes.) Lower throughput results in lower complexity, longer battery life, and lower cost. Additionally, with ZigBee sensor networks, RF frequencies are allocated which maintain separation from Wi-Fi and other traffic, preventing the battle for bandwidth that may affect mission-critical applications when converging RFID-RTLS with Wi-Fi.

Complimentary Networks Can Co-Exist

Complementary wireless networks within the healthcare environment can co-exist in order to minimize overall costs, make the best use of available bandwidth, and to partition the use of the available RF spectrum to prevent interference and over-utilization. With the use of clear channel assessment practices, wireless communication protocols such as 802.11 or 802.15.4 (upon which ZigBee is based) include collision avoidance techniques to prevent interference.

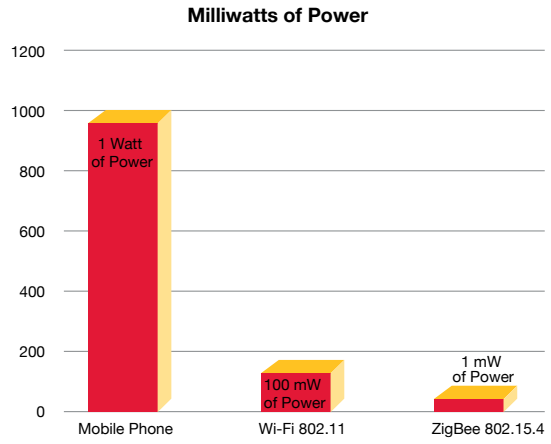
A typical strategy in Wi-Fi deployments is to use channels 1, 6, and 11, which are the three non-overlapping channels available in North America. These channels are allocated such that adjacent access points use different channels so that mobile nodes cleanly associate with one access point in any given area.

ZigBee sensor networks use similar strategies. Frequencies are allocated to sensor networks which maintain separation from Wi-Fi and other traffic. The spectrum analyzer output below shows Wi-Fi activity on channels 1, 6, and 11, and 802.15.4 traffic on channel 26 at the far right, with nice separation above Wi-Fi channel 11.



Transmission Power

Transmission power density is another factor to consider in RFID-RTLS. Transmission power density is regulated by the FCC based on research data studying the effects of RF energy on biological systems like the human body. When implementing new applications, providing reliable communication (as required by the specific application) with transmission power as low as possible should always be considered and is of particular concern in healthcare settings. ZigBee 802.15.4 networks communicate at 1 mW of radiated RF power, compared to 100 mW for nodes within Wi-Fi networks, and 1 watt for mobile phones. These transmission power requirements illustrate sequentially lower overall power consumption of ZigBee 802.15.4 based on matching the transmission needs specifically to active RFID-RTLS applications.



Power Consumption and Battery Life

For RFID-RTLS, power consumption and battery life of the actual asset tags are key considerations in choosing the type of network to deploy. In RFID-RTLS for example, low power ZigBee sensor networks provide a cost-effective communications medium that is sufficient for communicating sensor data and requires no maintenance. These networks can be designed to communicate small amounts of data very infrequently, with most asset data residing on the server, indexed by unique ID's associated with the tagged asset. The low transmission power of 802.15.4 ZigBee networks results in both overall lower power consumption and longer battery life.

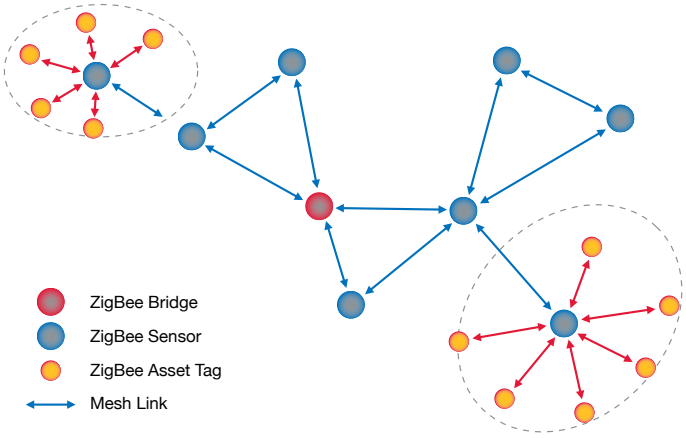
Conversely, 802.11 Wi-Fi networks require significant power due to their higher data rates and the associated higher complexity. Many devices connected to Wi-Fi networks are AC-powered and have large, high-capacity batteries to offset these power requirements, such as laptops and VoIP phones that are easily recharged.

Low data rate wireless sensor networks consume less power to operate simply because they don't have the same data rate requirements. In addition, the nodes within these networks can be electronically simpler and cheaper. They are designed to provide for a large number of nodes, and for nodes which can run on a single battery for several years without re-charging or changing the battery.

ZigBee RF Mesh Network

Unlike Wi-Fi, ZigBee devices have the ability to form an RF mesh network between nodes. Each node is self routing and able to connect to other nodes as needed. ZigBee sensor networks leverage this mesh network to route data among the sensors themselves to collection points or to bridges onto the LAN. The network of sensors communicates wirelessly with each other along with wireless communication from the battery-powered tags to the sensors.

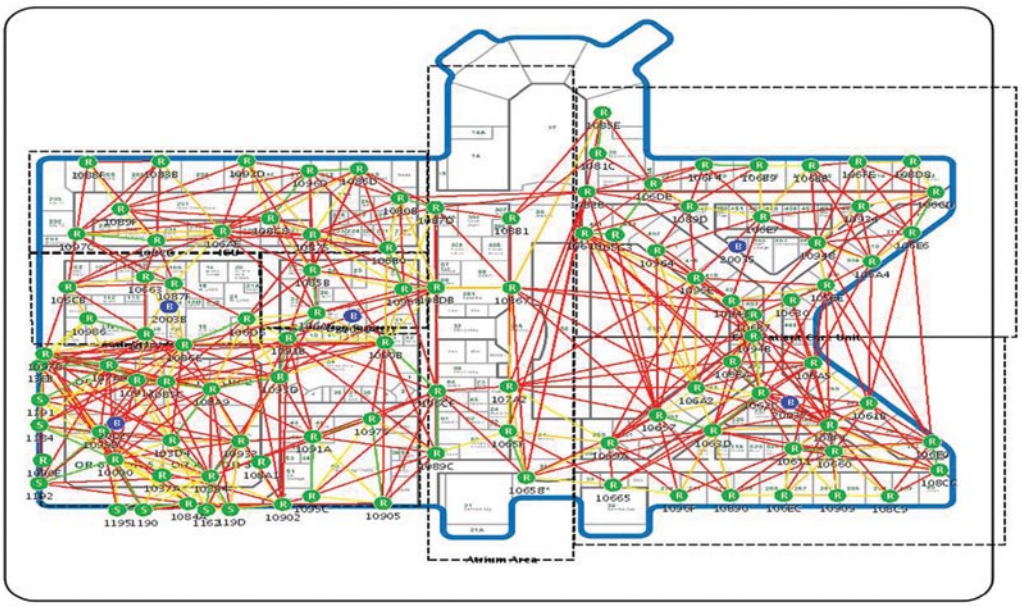
As the diagram below shows, this type of ad-hoc network formation is much like the internet itself, and provides tremendous flexibility and fault tolerance.



Mesh network routing permits path formation from any source device to any destination device.

For RFID-RTLS applications, ZigBee sensors are deployed with sufficient density to "cover" a building (or possibly some subset of a building). This coverage also provides a sufficient density of network nodes for routing data, even at low transmission power. With the sensors themselves providing the backbone for wirelessly collecting sensor data, the overall solution becomes both simple to deploy and very low cost.

The diagram below outlines a mesh network deployment for a typical hospital floor plan:



• Green = Sensor (receiver) • Blue = Bridge

ZigBee-Based Active RFID-RTLS

RFID-RTLS systems based on underlying ZigBee technology are getting a lot of attention, particularly in the healthcare market. A ZigBee mesh network is self configuring and self healing, maximizing reliability and minimizing the cost of network deployment and maintenance.

Awarepoint of San Diego, California has patented ZigBee-enabled sensors that are plugged into standard wall outlets and associated with known positions on building floor plans. Bridges connect the wireless ZigBee network of sensors to the enterprise LAN (via either wired Ethernet or Wi-Fi). Active RFID tags are attached to assets (equipment or people), sending brief transmissions every 5 seconds (for tags in motion) and every 10 minutes (for tags not in motion). Sensors transmit every 60 seconds to measure RF variability in the area under observation and calibrate the system. The frequency of these updates is key in minimizing environmental variables and maximizing positioning reliability. Analysis by a positioning engine results in the precise tag location, which is viewable on a web-based search application.

Using underlying ZigBee technology and patented computational algorithms, Awarepoint's Real-time Awareness Solution returns asset location within 1-3 meters, providing room level accuracy. The configuration of the Awarepoint Awarenet™ sensor network further eliminates "floor hopping" which can be an issue with Wi-Fi based deployments.

ZigBee network technology is the best suited underlying technology for active RFID-RTLS deployments for a variety of reasons. Purpose-built ZigBee networks based on the IEEE 802.15.4 standard provide the lowest-cost implementation of sensor networks. The Awarepoint RFID-RTLS ZigBee based solution requires no cabling infrastructure, offering a truly dust-free installation; and provides the longest battery life for mobile tag nodes, due to low-complexity, low transmission power, and low data rates. This low data rate ZigBee wireless sensor network is complementary to other networks deployed in healthcare, cost-effectively delivering real-time location, status and movement of equipment and people into the overall environment.

When considering active RFID-RTLS, hospital administrators *do not have to choose* between a Wi-Fi data network and a sensor network - they should select each for the right reasons. Each is designed for specific applications and should be chosen to leverage the particular strengths for which it was developed.

A technology visionary with over 20 years' leadership experience, Ronald Hegli serves as chief technology officer and vice president of engineering for Awarepoint. Previously Hegli was vice president of engineering and chief architect at Websense, Inc. Among his many accomplishments. Prior, Hegli served as director of product programs for Nuera Communications, Inc., a carrier-class IP telephony solutions provider. Hegli was also vice president of engineering for TriTeal, Inc. and served as VP of engineering for Akonix Systems and WebSideStory.

Hegli started his career with General Electric Company as an Edison engineer, and was a principal engineer with Digital Equipment Corporation. Hegli holds a Bachelor of Science in Nuclear Engineering from Oregon State University and a Masters in Science in Engineering from the University of California, Berkeley.

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