Spot by InnerWireless: a Rational Solution for Healthcare Asset Tracking

Executive Summary: "Missing" medical equipment costs hospitals millions of dollars per year; buying or renting excess equipment, losses in productivity and delays in patient care are key factors in the cost. To precisely and economically meet the needs of asset tracking in hospitals, InnerWireless has taken a comprehensive "clean sheet" approach to the design of an RF location system (RFLS) called Spot.

A viable asset-tracking system in hospitals provides direct economic benefits by: reducing equipment costs, improving productivity by making equipment available when needed, increasing equipment utilization and reducing delays in patient care.

However, there are important technical and economic challenges to realizing the potential of tracking assets in hospitals. InnerWireless has started with a "clean sheet," carefully considering the fundamental requirements of location systems, the physical characteristics of the hospital environment and the specific needs of hospital operation. In particular, InnerWireless has concluded that:

- The system should provide a high assurance that the tagged object is in the indicated room (or room-sized space). Higher accuracy at increased cost or with lower assurance is not desirable.
- A relatively large number of "beacons" is essential to meet high assurance and room level location (beacons radiate the RF signal "seen" by the tags which is then used to compute locations).
- Because a large number of beacons is required, they must be low in cost and easy to install and maintain.
- Thousands of items will be tracked in a hospital, so tags must be low in cost. Also, they must be small enough to avoid interference with the equipment operation.
- The technology choices must provide for long battery life for both tags and beacons, as well as simple, low-cost electronics, software and RF elements.
- The radio technology should be efficient and avoid adding congestion to existing wireless networks.
- To realize its full value, location information must be made available to Hospital Information Systems as well as on-demand users.

The InnerWireless design choices for Spot have balanced available, practical technology against these requirements:

- The single most important choice is radio technology, which will largely determine cost, performance, battery life, scalability and device size. Spot is based on the IEEE 802.15.4 standard (the PHY and MAC layer for Zigbee) which has been designed for networks of many devices, small data packets and extremely low power consumption.
- The higher Spot protocol layers have been designed for low data rates, extremely low power consumption and system security.
- Asset tags are small, easily cleaned and have a five-year battery life.
- Beacons require no power or network wiring and are easily installed by hospital maintenance staff in a few minutes; beacon battery life is five to seven years.
- Spot location algorithms have been specifically designed for the hospital environment and take advantage of the large number of beacons.
- Spot includes an intuitive Web-based user interface as well as a fully developed API.

Other alternatives include WiFi (802.11)-based systems that propose the use of existing WiFi infrastructures for locating assets. The reality is that a significant number of additional access points must be added to provide useful location information. Also, WiFi is not designed for large numbers of low power devices. Other approaches require relatively expensive "readers" that demand power and network wiring. In addition, some are emerging entrants with no clear mass market to drive down costs.

InnerWireless is a wireless technology company that provides in-building wireless coverage for a full range of services, including cellular/PCS, paging, two-way radio and WiFi. InnerWireless has concentrated on meeting the rigorous demands for wireless in healthcare, with infrastructure installations in more than 60 hospitals.

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Introduction

In January 2006, InnerWireless announced the creation of Spot, an RF location system (RFLS) designed to locate medical equipment and resources in hospitals. This white paper explains the rationale for the development of this product, including the economic drivers and the specific design choices dictated by the needs of the healthcare market.

Who is InnerWireless?

InnerWireless is a wireless technology company that provides in-building wireless coverage for a full range of services, including cellular/PCS, paging, two-way radio, 802.11/WiFi and specialty services such as medical telemetry. InnerWireless has concentrated on meeting the rigorous demands for wireless in healthcare, with infrastructure installations in more than 60 hospitals.

What is RFLS?

RFLS stands for Radio Frequency (RF) Location System; the term RTLS (Real Time Location System) is also sometimes used to describe this type of system.

An RFLS/RTLS uses wireless technology (radio) to determine the location of an object in a particular space on demand. For example, an RF Location System would allow clinical staff to locate a certain medical device (e.g., an infusion pump) in a hospital when it is needed.

> *"Real-time locating systems are automated systems that continually monitor the locations of assets and personnel. RTLS solutions are gaining popularity in several industries. Typically, they utilize battery-operated radio tags, such as active RFID tags, plus a cellular locating system to detect the presence and location of the tags."*
>
> *Frost & Sullivan*

An RF Location System uses a network of fixed devices (sensors or *beacons*) and small *tags* that are attached to portable objects that are to be located. The system periodically computes the location of a tagged object using information from the tags and ceiling-mounted beacons. The frequency at which locations are determined may range from a few seconds to a few minutes, depending on how often the object is expected to move. The object locations are stored and can be accessed by staff to find a piece of equipment or accessed by hospital applications like asset management.

RFID (RF Identification) is a related technology that senses and identifies an object at or near specific locations – an object moving through a door, for example, or passing a particular point on an assembly line or in a warehouse. RFID systems are often used to verify, validate or report that an object has reached a certain step in a process.

> *("RFID" is also often used as a catch-all term for systems that use radio to sense, identify and/or locate tagged objects. When used in this broad "colloquial" sense, RFID includes RFLS.)*

RFID systems also use sensors (often called "readers" or "interrogators") and tags; a tag must be in fairly close proximity (inches to a few feet) to a reader to be sensed. Because the tag is close to the reader, RFID systems can use "passive" (un-powered) tags that use the RF energy from the reader to respond to the reader's query. In contrast, RFLS systems use "active" (battery-powered) tags because the tag may be many meters from a beacon. Passive tags are relatively cheap; RFID readers and infrastructure are relatively expensive. RFID systems are often used to tag low-cost or consumable items where the inconvenience of close proximity is traded against the low cost of the tagging system.

The familiar bar code systems use optical readers in a manner similar to RFID to read (or scan) printed bar code labels.

Why is InnerWireless offering an RFLS System to healthcare?

Our healthcare customers have told us that asset management in hospitals is a major problem that would quickly produce a large and easily measurable return on investment if a practical, economical solution were available.

The basis for this is easily understood: high-value or life-critical assets in the hectic hospital environment are often misplaced or stolen — this clearly has an economic, as well as a patient-safety impact. Hospital staff often resort to hoarding or hiding equipment to assure availability for their own needs, further reducing the overall utilization of the equipment. As a result, hospitals purchase or rent substantially more equipment than they would otherwise need. (More details on the economic impact of asset tracking are discussed below.)

Patient tracking using RFLS can also yield substantial benefits to the hospital; patient safety and workflow/utilization can be positively impacted. For example, studies in important areas such as emergency departments and surgery show substantially improved throughput and quality of care resulting from careful tracking of patients. Tracking of hospital staff may also offer patient safety and productivity improvements.

And, from InnerWireless' perspective, asset and staff tracking may represent opportunities in other vertical markets.

Finally, InnerWireless believes that existing RFLS solutions and proposals have inherent shortcomings in cost, useful accuracy, scaling and overall viability.

What are the economic drivers for asset tracking in the hospital?

A viable asset tracking system provides direct economic benefits to the hospital in a number of areas:

- **Reduce equipment costs**

  Equipment that is lost or stolen costs hospitals millions per year. Various sources report that hospitals lose between $4,000 and $5,000 per bed, per year in "shrinkage." Theft alone can cost a large hospital more than $1M per year.

  To account for shrinkage, hospitals purchase or rent as much as 50 percent more equipment than they actually need for operations. Reduction in shrinkage would have a direct effect on hospital costs.

  Medical equipment theft is a growing problem. Valuable, usually portable and often poorly protected medical equipment is a prime target for thieves, and developing countries offer a ready market.

  Outbreaks of equipment theft have occurred in Florida, Pennsylvania, California and other areas in the United States. In the United Kingdom, 11 hospitals were hit in the last year; it is suspected that the gear finds its way into Eastern Europe.

- **Improve productivity**

  Missing equipment wastes time; one source estimates that 30 minutes per employee, per shift is spent looking for lost equipment. Up to 40 percent of biomedical technician time may be spent searching for equipment to service. Staff members have reported having to spend more than 20 minutes looking for a wheelchair, while others hoard chairs in their department.

- **Improve equipment utilization**

  The national average for equipment utilization is estimated at only 45 percent; that is, a medical device is used productively only 45 percent of the time. As a result, hospitals not only over-buy, but they do not get full value from their medical equipment investments.

- **Reduce delays in patient care**

  Delays in finding crucial equipment can obviously affect patient care, as well as reduce overall productivity.

- **Recover lost charges**

  Manual procedures are usually required to record that a medical device is being used so that the patient's bill includes those charges. One study estimates that charges are filed for only 50 percent of the infusion pumps actually being used.

  By using equipment location technology in combination with other information, hospitals can improve charge accuracy. It is estimated that a 900-bed hospital can recover $8M per year in lost charges using equipment location records.

- **Improve safety**

  JCAHO reports that “Equipment moving from patient to patient without going through decontamination in between has become a significant issue to JCAHO in regard to infection control in hospitals.” Staff is under pressure to use whatever equipment they can find, potentially without being aware of the maintenance or decontamination status.

  This situation is exacerbated because maintainers cannot find equipment an estimated 20 percent of the time; handling of potentially dangerous equipment failures or recalls may also be compromised.

Clearly, investment in asset tracking in hospitals can have clear, short-term payoffs; we expect these systems to pay for themselves within the first year. However, there are important technical and procedural challenges to realizing the huge potential of asset management.

What are the challenges in the design of Spot?

InnerWireless believes that its overall expertise in wireless systems engineering, especially in the demanding in-building environment, brings a unique perspective to the challenges of RFLS systems. Our understanding of the specific requirements of healthcare adds to our credentials for undertaking this design.

InnerWireless has started with a "clean sheet," considering the fundamental requirements of location systems, the characteristics of the physical environment inside hospitals, and the specific needs of hospital operation. Subsequent design choices are based on these considerations and not on the restraints of an existing architecture. Following are some of the key considerations:

- **Accuracy and assurance**

  RF location systems are often touted for their "accuracy," sometimes claiming to locate objects within a few inches without considering location assurance or cost. This has given rise to a "horsepower race" among technology providers, where quality is measured by "accuracy" alone.

  However, when asked, healthcare workers say that they simply want to know the room where the equipment can be found; finer resolution of the predicted location is not important, especially if such resolution adds uncertainty or is costly. On the other hand, assurance that the equipment is actually at the predicted location is highly valued. Finding equipment in a room-sized area is not a burden, if there is a high likelihood that the device is actually in the indicated room.

  The rational way to set the performance criteria for a location system is a combination of accuracy and the probability ("assurance") that the object is located within the specified accuracy. For example, a requirement might be that an object be found within one meter of the indicated location 70 percent of the time. Given such criteria, a design can make trade-offs between accuracy and assurance.

  The conclusion is that, for hospital asset tracking, the design should provide a high assurance (90 percent or greater) that the tagged object is in the predicted room (or room-sized area).

- **Beacon density**

  RF location systems generally work by measuring the characteristics of RF signals generated by beacon as "seen" by a tag and computing the tag location from this information. Because the measured characteristics are disturbed by the surroundings, especially in an indoor environment, and other uncontrollable factors, the computed location will not be precise. Although the choice of algorithms used can influence the quality of the result, any algorithm will work better with more information; that is, by increasing the number of beacons that can be "seen" by the tag. The design criterion is to deliver high assurance, so data from more beacons should increase the likelihood that the tag is in the indicated room.

  The clear conclusion is that a high beacon density is essential to meet the required accuracy and assurance level.

  It is worth observing that there is a significant difference between location systems and systems designed for wireless communications. In a communications system (e.g., WLAN), the device (e.g., laptop) need only "see" one access point to operate properly. In fact, there is an obvious economic benefit to minimizing the number of access points required in a WLAN for data connectivity.

- **Beacon and tag cost**

  High assurance RFLS requires a high beacon density, so beacons must be economical. The cost of the beacon itself is a factor, along with the cost to install and maintain a large number of beacons in the hospital.

  The cost of wiring to connect the beacons to network resources could be a cost issue, especially because a large number of beacons is required. This suggests that beacons that connect wirelessly to the network would be an advantage. Easy, tool-free, minimally disruptive installation, ideally by hospital maintenance staff, will reduce installation and maintenance costs. Of course, if beacons are "cordless," they must be battery-powered; a battery life of several years will help keep maintenance costs low.

  Because the asset tracking application will require that thousands of items be tagged, a low-cost tag is an obvious requirement.

  The need for low cost beacons and tags drives a number of technology decisions.

- **Tag size and packaging**

  Some medical devices are relatively small; the asset tag should be sized to avoid interfering with the use or handling of the device. The rigors of the hospital environment also require that the tag be easily cleaned.

  The tag size requirement impacts technology choices, including the battery.

- **Battery life**

  Long battery life means that tags and beacons require battery changes less frequently. Changing the battery puts the tag out of operation (making the asset "invisible") and frequent changes add to maintenance costs. Beacons are ceiling mounted, so beacon battery changes are disruptive to clinical spaces and also increase maintenance costs.

  The key to long battery life is the design of the communications protocol and power management within the devices. Obtaining the accurate location of tags can be accomplished by milliseconds of communications activity, separated by minutes of inactivity. Designing the protocol so that devices can "sleep" in very low-power mode during the relatively long periods of inactivity and "wake up" when communications are scheduled will minimize power consumption and lengthen battery life.

  The choice of specific batteries involves trade-offs between battery power density, life, cost and size.

- **Radio communications technology**

  The economic requirements and the nature of the application set the following criteria for the radio technology:

  - *Standards-based.* A standard technology that has wide application will assure that chip sets will be available, produced in high volume and, consequently, low costs. Other elements (design tools, protocol stacks, etc.) will also be available.
  - *Low power consumption*. Arranging for devices to "sleep" will conserve power and minimize maintenance cost. Avoiding device “collisions” with retries and acknowledgements will help conserve power.
  - *Low data rate requirements; frequent transmissions.* Heavy weight protocols designed for large transmissions would reduce the overall efficiency in this application.
  - *Simple electronics and RF requirements.* This will reduce the size, complexity and cost of devices.
  - *Scalable.* Thousands of tags are required. The technology should deliver low complexity and sufficient capacity.
  - *Relatively uncrowded frequency band.* Avoiding bands that are heavily used will minimize problems of congestion and interference.

- **Usage**

  The location data gathered by the RFLS system only has value when it is made available to the staff and systems in the hospital. There are two requirements:

  - An intuitive, easy-to-use tool for locating assets by clinical staff — this addresses the problem of on-demand locating of misplaced clinical equipment.
  - Integration of RFLS with other information systems in the hospital — a well-designed application program interface (API) allows other applications to access and use the location data. Workflow analysis, equipment maintenance and servicing, and asset utilization and requirements analysis are processes that can benefit from equipment tracking.

What are the key design choices for Spot?

InnerWireless has taken a clean-sheet approach to the design of Spot; design choices have balanced available, practical technology against the specific requirements of locating and tracking in the hospital environment.

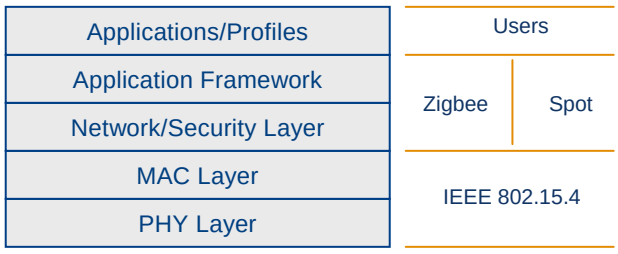
- **Radio technology and implementation**

  The single most important decision is the radio technology – the radio technology will largely determine cost, performance, battery life, scalability and device size. InnerWireless is not constrained by commitment to one particular standard, so we have been able to select a technology that is specifically designed to meet the requirements outlined in the previous section, rather than trying to adapt a technology intended for other purposes.

  Spot is based on the IEEE 802.15.4 standard. This is a lower level protocol designed for remote controls and sensors. This standard uses small data packets and has an extremely low power consumption, which helps lengthen battery life.

  A standards-based technology helps assure the availability of low-cost components, software and development tools.

  IEEE 802.15.4 comprises the Physical (PHY) layer and the Media Access Control (MAC) layer of the overall protocol stack. Network, security and application framework details are specified by the Spot protocol or, in the case of Zigbee, the Zigbee standard.



  The Spot radio technology has the following characteristics:

  - Designed for systems consisting of large device quantities that have low data rates, consume very low power and are thus characterized by long battery life.
  - Designed to accommodate highly integrated single-chip implementations using few analog stages and digital circuits wherever possible.
  - Requires minimum memory resulting in a less expensive integrated circuit.
  - Requires 2 percent to 10 percent of the software required for a typical Bluetooth or WiFi node.
  - Uses a single chip implementation of the transceiver and a very low-power microcontroller.

  The IEEE 802.15.4 standard defines three license-free frequency bands that include 16 channels at 2.4 GHz, 10 channels at 902 to 928 MHz, and one channel at 868 to 870 MHz. Because no manufacturer has committed to a single-chip implementation in the other bands, Spot uses one 802.15.4 channel in the 2.4 GHz band. Note that a channel used by Spot does not overlap with the WiFi (802.11bg) channels.

> *"By the year 2008, annual shipments for ZigBee chipsets into the home automation segment alone will exceed 339 million units," and will show up in "light switches, fire and smoke detectors, thermostats, appliances in the kitchen, video and audio remote controls, landscaping, and security systems."*
>
> *-- West Technology Research Solutions*

- **Communications protocol**

  InnerWireless has carefully designed the higher level Spot communications protocol to meet the specific requirements for the RFLS application. One of the keys is scheduling communications activity – providing long "sleep" periods of low battery drain. The protocol allows flexible scheduling, which allows the battery life to be balanced against the rate at which locations are updated (moving tags may require a faster rate).

  In addition, the Spot protocol is synchronous and deterministic, eliminating random device-to-device "collisions" along with the resulting acknowledgements and retries. This is a shortcoming of Zigbee-derived systems when battery life is a premium.

  The combination of technologies selected for Spot allows a five-year battery life for tags and five to seven years for beacons.

- **Location algorithm**

  As indicated above, high beacon density improves the likelihood that a tagged object is in the location indicated by the RFLS (location assurance). Spot implements a relatively large number of inexpensive beacons, and the location algorithm is designed to take advantage of the additional information available.

  The Spot location algorithm processes signal strength measurements from 10 beacons in the vicinity of the tag. The location algorithm uses neither triangulation nor RF fingerprinting to determine location, but it rather processes the measured data by geometrically weighting and adjusting the measured data to determine the tag's "location zone" (room or room-sized space). The details of the patent-pending algorithm are based on InnerWireless' experience and deep understanding of the in-building radio propagation environment.

- **User/application interfaces**

  The value of asset location information is only realized when it is made available to staff or other hospital information systems. Spot includes an easy-to-use Web-based interface for on-demand locating of equipment by staff and

a fully developed, standards-based application program interface (API) and developer's toolkit (DTK) for integration with hospital information systems.

- **Packaging**

  Spot asset tags are small for convenient attachment to medical equipment and designed for easy cleaning.

  Spot beacons are easily installed by regular hospital maintenance staff in a matter of minutes and do not require tools or wiring – a task equivalent to changing a light bulb. Staff require less than five minutes of training. This reduces installation cost and minimizes disruption in the clinical, working spaces of the hospital.

What about WiFi-based RFLS?

The most commonly proposed RFLS alternative is based on using WiFi for location. The promise of WiFi-based RFLS is that an existing 802.11 infrastructure can be leveraged to provide location, as well as data and voice. Additionally, the hope is that 802.11-enabled assets, such as laptop computers, can "automatically" be tracked without the requirement for a tag.

The reality is quite different. 802.11 location systems have severe limitations and are expensive to implement and maintain. The limitations are particularly significant for "real world" challenges like asset tracking in hospitals. Following are some of the common myths and realities of 802.11-based RFLS, which are based on the requirements we have developed above:

- **Use of "existing" infrastructure**

  The idea of using an existing (paid for) 802.11 infrastructure for locating is very attractive. However, wireless data networks are set up by maximizing the area each access point device covers to keep network infrastructure cost low. Even if more access points are deployed to provide more capacity, the design is still dictated on the premise that a device need only "see" one access point. In fact, interference issues require that the power levels be set so that access point coverage areas have minimal overlap.

  Unfortunately, this kind of deployment is fatal for high assurance RFLS. As we have noted, any reliable RFLS will require information from several access points. In fact, 802.11 location systems typically rely on data from a minimum of three, but typically five to seven, access points. Thus, an existing infrastructure requires the addition of a significant number of access points for location, along with the resulting networking, wiring and maintenance burden.

  Experiments have shown that an 802.11 RFLS will, in some cases, produce a false location if the tag is not physically surrounded by access points. This indicates that additional access point deployment around the periphery of floors is required, exacerbating the access point overbuild problem.

  Spot is designed to support a high density of low-cost wireless beacons to provide high location assurance at the room-level.

- **Use of WiFi for locating**

  WiFi is a wireless LAN implementation; like LANs, WiFi is designed for relatively large data transfers in an environment of relatively few devices per access point.

  Because data transfers are large, there is very little penalty involved in a relatively large "overhead" (control and addressing information) per packet. However, the information reported by RFLS tags is small (less than 100 bytes) so that the overhead per packet is comparable in size to the "payload." As a result, using WiFi for location information is inefficient, adding inordinate traffic to a WiFi network that may already be heavily used.

  WiFi, like a LAN, is contention based: when traffic is heavy, additional bandwidth is consumed by "collisions" and re-try attempts. For a properly engineered WiFi deployment where there are a few devices per access point, this is acceptable. However, for medical asset tracking where there may be hundreds of devices that send small packets with high overhead every few minutes, the capacity of WiFi may be overcome. As a result, other critical applications using WiFi may become unusable. In particular, voice-over-WiFi is especially vulnerable because it requires high capacity, and delays or uncertain timing in packet delivery can seriously impact usability.

  As a LAN implementation, WiFi requires an IP address per device. Because the RFLS application will use hundreds of beacons and tens of thousands of tags, administering IP addresses for a WiFi-based RFLS can be an unmanageable burden.

  Spot is designed for low power with efficient communications among a large number of devices that transmit short bursts of information. Spot does not operate on WiFi channels, so existing WiFi applications are not impacted. In addition, Spot device identifiers are managed separately.

- **WiFi "beacons" and tags**

  WiFi RFLS uses access points to implement the beacon function. As noted above, more access points will be required, including perimeter access points, than is the case for a wireless LAN. Access points are wired and require expert installation. There is no opportunity to implement a dense, and at the same time, low-cost beacon infrastructure.

  The high overhead and contention resolution scheme of WiFi also will make small, low-cost battery-powered tags untenable because the basic nature of 802.11 communications requires significant amounts of power. Either large batteries, similar to those used in laptops would be required, or if smaller batteries are used, battery life will be problematic.

  Spot implements a low-cost, dense beacon infrastructure for high-assurance locating. Spot is purpose-designed for RFLS, so we can offer small, low-cost tags suitable for hospital access management.

What are the other RFLS alternatives?

There are a few other purpose-built RFLS alternatives.

Some systems use infra-red either alone or in combination with radio. In the latter case, the radio link is used to identify the tag, and infra-red is the primary means to achieve room-level location.

Infra-red signals are blocked by any opaque object, including walls, doors, people and equipment, as anyone who has used a TV remote control can testify. Blockage of the signal seriously degrades the location performance. Readers are always wired due to power requirements.

Another radio-based system is built off an ultra-wideband (UWB) technology and promises very accurate location capability (within inches), but early chips to support readers and tags have been expensive with limited capability. This is an early-stage technology with no clear “mass market” to drive down the cost of chips. Readers are always wired due to power consumption.

Regardless of technological differences among alternatives, producing high-assurance location information depends on a dense network of beacon devices. As we have pointed out above, the quality of location information is degraded when only a few beacons are involved. Thus, providing high-quality location with an RFLS beacon wired for power and/or for network connections will be expensive. Spot's unique approach implements a dense beacon network economically to provide high-assurance room-level location.

Conclusion

InnerWireless has designed Spot specifically for the indoor location application. Not constrained by an existing radio technology, InnerWireless has made design decisions based on a careful analysis of the requirements and its deep understanding of the in-building environment.

Spot delivers room-level accuracy (as required in healthcare) with a high degree of assurance that the tagged asset is in the room-sized space indicated. By selecting the IEEE 802.15.4 standard as the basic radio technology, InnerWireless assures low cost and long battery life. Spot's unique high-density, low-cost beacon deployment is easily installed by hospital personnel and requires no communications or power wiring. A Web-based user interface is provided, along with a fully developed API for integration with hospital information systems from multiple vendors.

Appendix: Spot Architecture and Operation

Spot consists of:

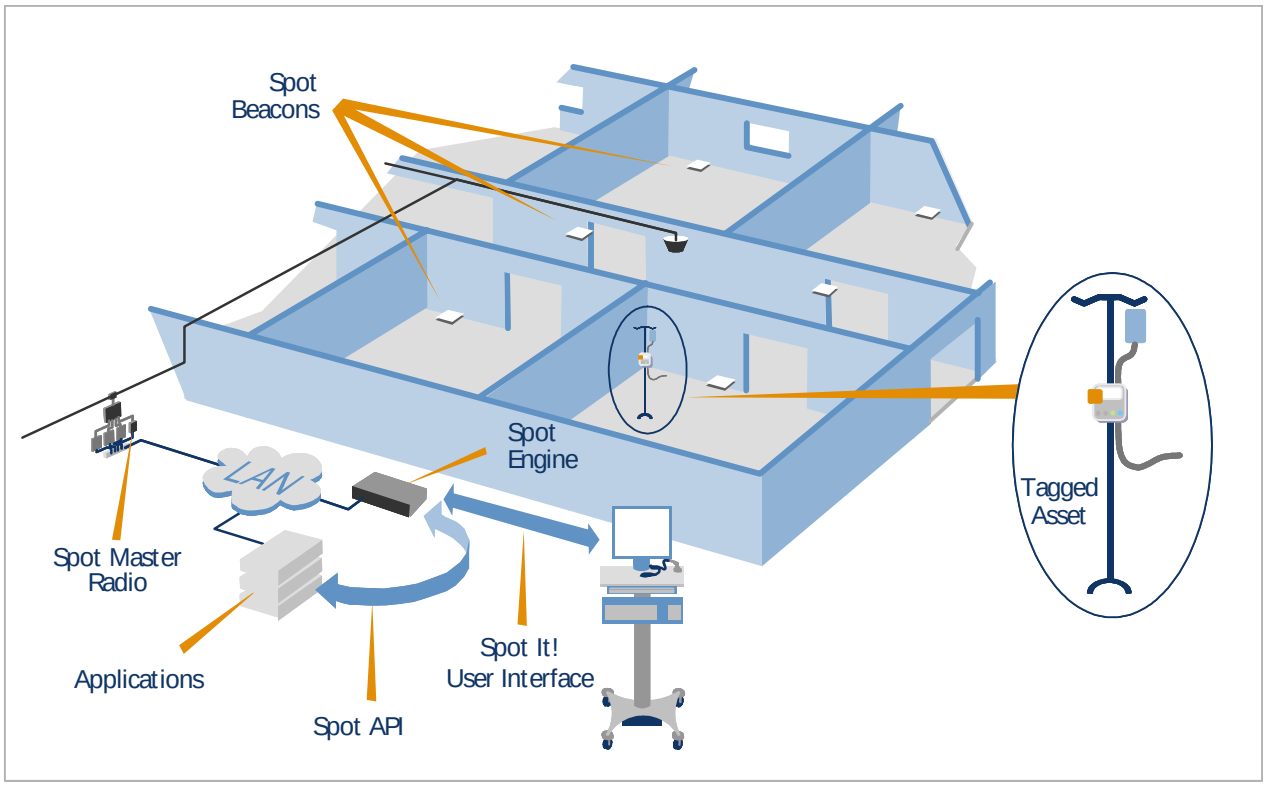
- A network of wireless, battery-powered beacons, usually attached to the ceiling.
- Tags attached to objects to be tracked.
- Master radio(s) that wirelessly connect beacons and tags to the enterprise network.
- Spot Engine – an appliance attached to the enterprise network that calculates and logs tag locations and provides configuring and administrative tools. The Spot Engine also implements the Application Program Interface (API) that allows access to asset location data from other hospital information systems.
- "Spot It!" – a Web-based graphical user interface that allows staff to locate assets (or classes of assets) on-demand.

Spot Beacon and Tag

Spot operation is outlined below:

- The Spot Engine configures tags, beacons and master radio(s), including scheduling of operations (e.g., how often a particular tag will "wake up").
- At scheduled intervals, tags "wake up" and collect signal information from surrounding beacons.
- Tags send beacon signal information to the Spot Engine via the master radio (in the figure, the master radio is connected via the InnerWireless wireless distribution system).
- The Spot Engine calculates and logs the location of the tag and makes that information available to the "Spot It!" user interface and to other hospital applications.

Spot Master Radio



Spot System