# Real-time Location for Hospitals

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## Background

Real-time location systems for patient, staff and equipment are on the threshold of becoming a key IT investment in hospitals and other healthcare facilities (Frost & Sullivan market Insight, RFID Unlocking Opportunities in Healthcare Vertical, 19 Jul 2011). In some systems, real-time location is augmented by patient vital sign information allowing the medical staff to be more efficient and provide a higher level of care. These systems rely on a wireless infrastructure.

The most popular solution for localization and tracking, GPS (Global Position System) usually does not work in a hospital environment since satellite signals do not penetrate buildings. This is exacerbated by the growing size of hospital buildings resulting from the trend in hospital consolidation. As an alternate to GPS, early instalments of real-time location systems in hospitals have been using RFID technology (e.g., active battery powered tags and readers), however, such deployments have the following limitations:

- Location is only recorded when the person (patient or nurse) is within a few meters of an installed RFID reader therefore no real-time location can be provided unless RFID readers are installed with very high density.
- Installing multiple RFID readers requires wiring network cable inside the building which usually requires a lot of engineering effort especially for existing buildings (digging the wall etc. for burying the cables).
- Little communication capability is provided by RFID; functions such as vital-sign monitoring and emergency communications cannot be provided.

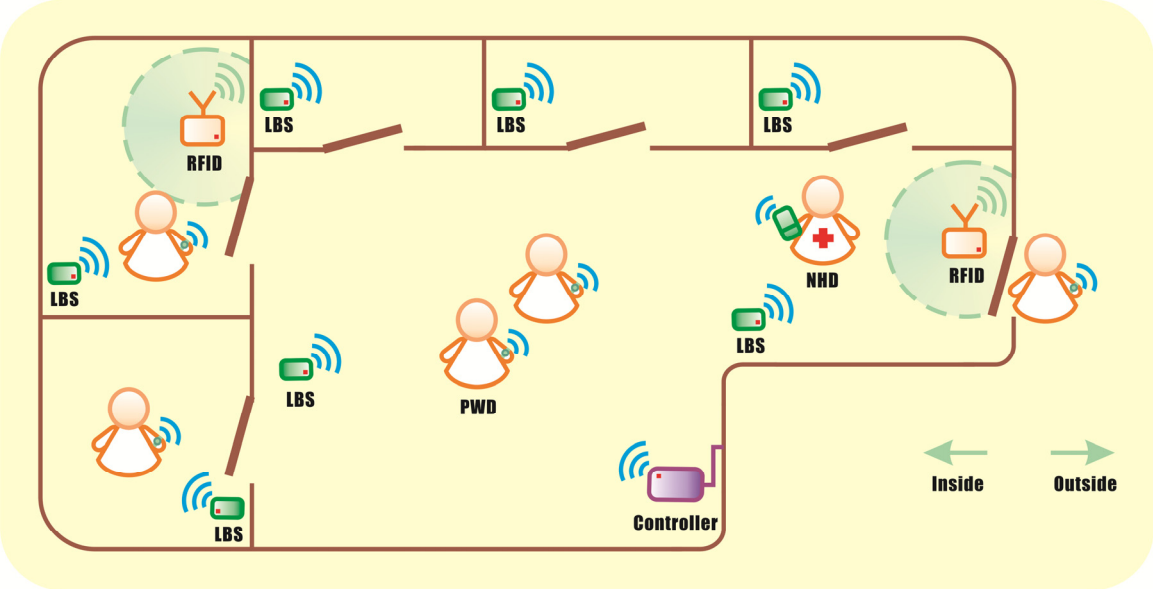
Therefore, although RFID systems have been successfully deployed for asset management in healthcare applications especially in the tracking of pharmaceuticals, their potential for patient/staff real-time location is very limited.

An alternative has been to introduce WiFi (Wireless Local Area Networks) in hospitals which offers good communication capability but is not easily used for location determination. Such initiatives also face issues including the complexity and cost of installation, especially since hotspot density needs to be very high to have wireless location capability (any coordinate in the coverage must be within the range of at least three access points instead of one). Moreover, a WiFi transceiver typically transmits 100-300mW power, which could potentially interfere with medical equipment.

OMESH Networks proposes a wireless location system is based on OPM (Opportunistic Mesh) technology, which can gracefully resolve all the above issues of existing systems.

## Proposed System

The proposed system topology illustrated in the figure below:




The system is composed of the following elements: 1) Location Base-Station (LBS), 2) Patient-Worn Device (PWD), 3) Nurse-Held Device (NHD), and 4) Controller.

- Location Base-Station: can be installed without network-cable wiring. It collects location/sensor information of PWDs and NHDs, and sends the information to the Controller over multiple wireless hops (relaying over other LBSs). LBSs are installed as required to provide wireless coverage. One single station covers about 100 meters with line of sight; and the actual range varies depending on the building and wall structures. The multi-hop wireless mesh networking over LBSs and the controller is dynamic and self-organizing.

- Patient-Worn Device: is a wearable tag device periodically broadcasting the patient identification to neighboring LBSs, which is then forwarded to the Controller for location estimation. A PWD can optionally integrate vital sign sensors including heart rate and acceleration. The sensor information is also streamed to the Controller, via the LBSs.

- Nurse-Held Device: is a PDA device which can retrieve patient location and sensor record from the Controller, via the LBSs. A NHD also periodically broadcasts the nurse identification to neighboring LBSs, so that the nurse location can be acquired by the Controller.

- Controller: can interconnect with the LBSs to retrieve location/sensor information of PWDs and NHDs. The location of PWDs and NHDs is acquired by the radio signal strength from multiple LBSs. The Controller is connected directly to hospital's internal network (e.g., LAN), and provides a configuration interface to the operator. The operator can assign patients to nurses, so that the Controller can provide patient location and sensor records to an authorized NHD via the LBSs.

Traditional passive RFID tags and readers can also be supported in the proposed system for legacy asset management. The proposed system can provide backhaul communications for RFID Readers so that network cabling can be replaced by wireless in reducing the installation complexity.

## Networking Technology and System Spec

The wireless networking technology of this proposed system is OPM (Opportunistic Mesh) Networks. OPM can dynamically establish large wireless networks without predetermined topology constraint and spectrum allocation, facilitating the deployment of location base-stations. It also uniquely provides reliable and real-time (multi-hop) wireless communications. In the event of sudden changes in networking environment, for example incurred by moving facilities or accidents, the negative impact on the network operation is minimized. More specifically in the target applications, the technology advantages of OPM are:

- Dynamic drop-and-play location base-stations to facilitate fast deployment;
- Guaranteed real-time wireless over unlimited number of hops for delivering location/sensor information and alert signals;
- Low power consumption and small footprint; being adaptable to interference in unlicensed bands.
- Compatible with established network layer standards, providing easy and interface to existing IT networks.

The system elements, LBSs, PWDs, NHDs and the Controller, are all using the OPM15 radio module for the wireless communication and networking. The physical specifications of the proposed system are tabled in what follows:

| | |
|---|---|
| LBS/Controller Coverage | 100 meters with line of sight |
| Transmission Power | 0.1-3mW (100 times less than WiFi) |
| Real-time Location Accuracy | up to 1 meter |
| Frequency Band | 2.4GHz |
| Maximal Number of Wireless Hop | unlimited |
| Maximal Communication Latency | typically 20ms per hop |
| Sensor Application Bandwidth | up to 100kbps |
| Power Consumption (Sleep) | ~4uW |
| Power Consumption (Active) | ~60mW |

The PWDs and NHDs in the proposed system are powered by batteries. The battery lifetime depends on the system customization (additional vital-sign sensors etc.) and configuration (information update interval), which could range from one week to over one year.

## User Interfaces

The user interfaces include the nurse interface on NHDs and the operator interface on the Controller. The interfaces can be customized according to the hospital requirement. The following figures provide an interface example for NHDs: