✚ Technical Overview of the LEAF◇ Patient Monitoring System

A high-level technical review of a new wireless monitoring system

Abstract

This paper presents a brief overview of the technical attributes of the LEAF Patient Monitoring System. The LEAF System enables hospitals, long term care facilities (LTC), and nursing homes to wirelessly monitor the realtime orientation and activity of patients susceptible to pressure injuries; and to provide alerts when patient orientation or activity deviates from individualized turn management protocols set by the healthcare provider.

Basic System Architecture

The LEAF° Patient Monitoring System is a distributed, wireless system comprised of four main components:

1) LEAF Patient Sensors

2) LEAF Wireless Mesh Network (WMN) of LEAF Relay Antennas

3) LEAF Bridges, LEAF Mesh Network Server Software, and LEAF Database

4) LEAF Patient Monitoring Software

A disposable and wireless LEAF Patient Sensor is affixed adhesively to the patient's upper torso. The sensor takes measurements of the patient's orientation and communicates this data wirelessly to the mesh network of LEAF Relay Antennas that had previously been setup in the facility. The mesh network relays data from the LEAF Sensors to a LEAF Bridge using an RF to USB transceiver. The LEAF WNM collects the patient data from the LEAF USB Transceiver and sends the data to a SQL database for subsequent analysis. The LEAF Patient Monitoring Software displays each patient's turn history, current status, alerts staff if any patient requires a caregiver assisted turn, and automatically documents the patient's turn history.

LEAF Patient Sensor

The LEAF Patient Sensor is a single-use, disposable, wireless device that is adhesively affixed to a patient's skin. The sensor itself is comprised of several key components: a 3-axis accelerometer to measure patient orientation and activity; a phototransistor that measures ambient light levels and turns on the device when the packaging and/or adhesive liner is removed; a capacitive contact sensor that enables the device to sense when it is attached to skin and sense when it is removed from skin; a microcontroller for automated data collection, analysis, and storage; an RF radio for transmitting and receiving messages; and a coin-cell battery for providing electrical power.

Each LEAF Sensor has a unique 64-bit serial number that is assigned to the device during the manufacturing process. When the sensor is turned on and joins the LEAF WMN, it is assigned a much shorter network address by which it is subsequently addressed. Since the sensor knows no patient identifying data (such as patient name or patient electronic medical record number), the data transmitted by the sensor is anonymous and obviates any concern about data security on the wireless network.

Mesh Network of Relay Antennas

The LEAF Patient Monitoring System uses a proprietary wireless local area network (WLAN) to relay messages between the Patient Sensors and the LEAF Bridges running the LEAF Mesh Network Server Software. The proprietary WLAN is distinct from the facility's Wi-Fi network and is comprised of many LEAF Relay Antennas that are plugged into available power outlets within the facility where patients are being monitored. Each Relay Antenna communicates with multiple nearby LEAF Relay Antennas to form a mesh, or web-like, connection of antennas. Messages sent to or from LEAF Patient Sensors over the mesh network are relayed from the source to the destination by sequentially hopping from one LEAF Relay Antenna to the next. A single LEAF Wireless Mesh Network can be composed of hundreds of LEAF Relay Antennas. Further, multiple LEAF Wireless Mesh Networks can be configured within a single facility. The web-like architecture of the mesh network ensures there are redundant pathways between the sensor and server.

The network over which the LEAF Sensors and LEAF Relay Antennas communicate is conformant with the physical layer specifications prescribed by the 802.15.4 wireless standard.[1] The 802.15.4 wireless standard defines a low-power wireless network architecture especially well-suited for battery powered devices and is the network on which the more commonly referenced Zigbee communication protocol is based.

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LEAF° Bridges, MeshNet Software, and SQL Database

Messages sent by the LEAF Patient Sensors are relayed by the LEAF Wireless Mesh Network to one of multiple LEAF Bridges running the MeshNet Software. The LEAF Network Bridge is a small form factor Windows PC with a LEAF USB RF Transceiver attached. The LEAF Bridge serves as the access point between the LEAF Wireless Mesh Network and the LEAF SQL database running on a server computer.

The LEAF MeshNet Server Software is a Microsoft Windows-compatible application that has been tested to work on computers and servers running Windows server 2012/2016, and Windows 8/10 operating systems. The server software runs equally well on a dedicated Windows server or on hardware more typical of desktop systems or even laptop computers. Multiple instances of the LEAF MeshNet Software can be run on multiple computers, ensuring data relayed from LEAF Patient Sensors have multiple, redundant means of being collected and entered into the SQL database. The LEAF SQL database may reside on the same computer on which the MeshNet Software is running, though is more typically running on a dedicated virtualized server located onsite at the healthcare facility or offsite at the customer's datacenter.

Data exchanged between the LEAF MeshNet Software and the LEAF Database contain no patient identifying data such as patient name or patient electronic medical record number which obviates any concern about data security on any network links between the LEAF Bridges and LEAF Database.

LEAF Patient Monitoring Software

A user interface to the system is provided by the LEAF Patient Monitoring Software. The LEAF Patient Monitoring Software accesses the LEAF Database, processes the data, and displays in near real-time the relevant information. Caregivers using the system can customize a turn protocol for each patient being monitored. The software alerts caregivers when a patient has been in an orientation for a duration longer than was specified by the individualized turn protocol.

The implementation of the LEAF Patient Monitoring System is highly configurable. In a "thick client" configuration, the LEAF User Interface Software may be installed on Windows-based computers as needed throughout a monitored unit, either on dedicated LEAF All-in-One computers, the facility's existing "workstations on wheels", or both. Alternatively, in a "thin client" configuration, an application delivery service such as Citrix XenApp or an alternative Virtual Desktop Infrastructure (VDI) can be used to deliver a server-hosted instance of the LEAF Patient Monitoing Software to client devices. By leveraging a facility's existing deployment system, the LEAF User Interface Software can be centrally managed and maintained just like any other server-hosted Windows application the facility currently supports. In either thick or thin client configurations, user permissions can be administered and maintained through Active Directory Domain Services to ensure compliance with a facility's security policies.

The high degree of configurability of the LEAF System gives the IT and nursing staff of the facility the flexibility to decide how best to implement the system. A status board and/or computing device may be positioned at the central nursing station to give caregivers access to the LEAF User Interface. Additionally, a display device providing caregiver access to the LEAF User Interface can be positioned in each patient's room. The use of mobile computing devices such as laptops or tablet computers can enable dedicated turning teams to easily check which patients are due or soon due for an assisted turn.

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Typical installations of the LEAF Patient Monitoring System use Citrix XenApp to serve the LEAF User Interface Software to virtually all common desktop or mobile computing devices, including Microsoft Windows and Apple desktop systems, iPads, and Android tablets.

Summary and Additional Information Source

The LEAF° Patient Monitoring System architecture is flexible, allowing the healthcare facility to configure the system to best accommodate existing nursing workflow and IT infrastructure. A more detailed and comprehensive technical description white paper on the LEAF System is available by contacting Smith+Nephew at LeafIT.Support@smith-nephew.com.

High level schematic representation of the LEAF Wireless Network
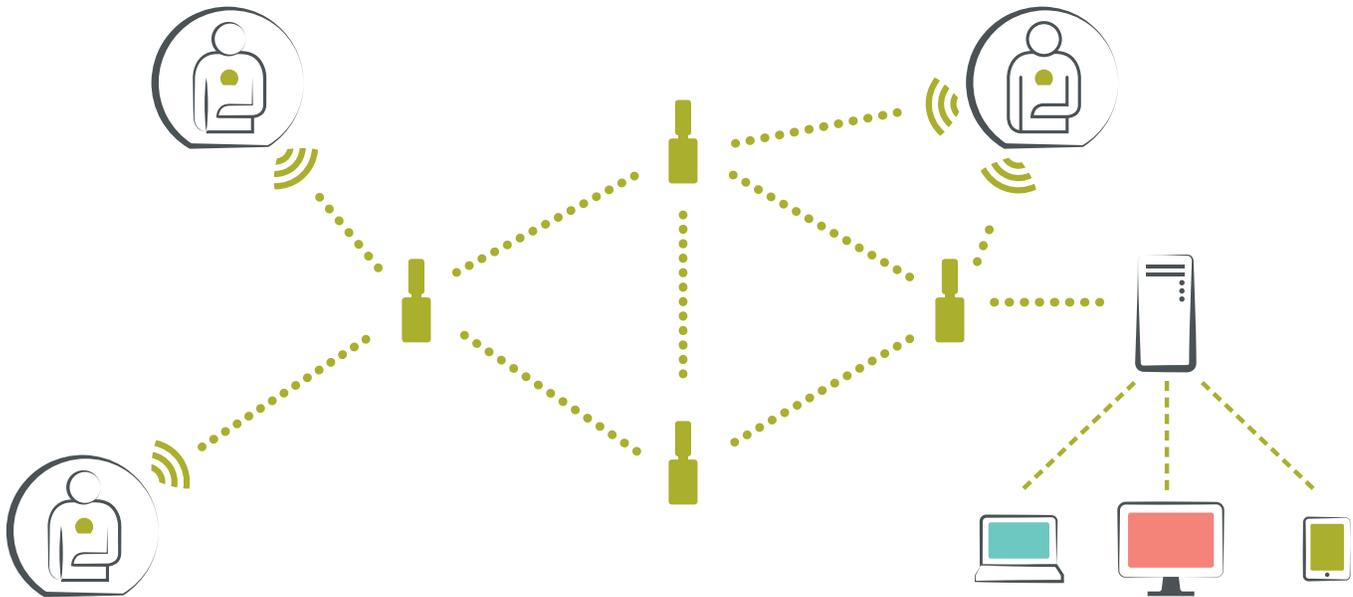
Continuous Monitoring

Patient position and activity data is automatically routed to the nearest LEAF Relay Antenna. As a patient moves about the unit or hospital, their data is seamlessly transmitted through the LEAF WMN in order to provide uninterrupted patient monitoring throughout the care environment.

Secure and Redundant

A series of relay antennas forms the basis of the LEAF WMN. This mesh network provides a highly redundant data transmission that is fault-tolerant. Data is transmitted using a proprietary wireless protocol.

Flexible Viewing Options

Patient data can easily be viewed at a central monitoring station or on mobile platforms (i.e. tablets). System administrators can view data for specific patients, individual units, or even the entire hospital from virtually any web-enabled computing device.

Reference 1. IEEE Std 802.15.4-2003, Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs)