A Proposed RFID Wireless Body Sensor Mesh Network using Intelligent Agents and Cloud-based Architecture

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ABSTRACT

Every year, thousands of patients in Caribbean are admitted to hospitals and kept under medical observation. Patient monitoring is done manually and or by using Wireless Body Sensor Networks (WBSN), which are pyhsically monitored by medical staff. In this paper, we propose a system for patient monitoring using Wireless Body Sensor Mesh Networks (WBSMN), which utilize Radio Frequency Identification (RFID) sensors for reading physiological parameters and positive patient identification. Intelligent Agents are proposed for querying sensor nodes, data aggregation and alerting medical staff of anomalous readings. A Cloud-based architecture is also proposed for supporting a community of healthcare centers and remote/mobile patient monitoring.

Keywords: Patient Monitoring, Wireless Body Sensor Mesh Network, Radio Frequency Identification, Agent Technology, Cloud Computing

1. INTRODUCTION

Over the past few years, healthcare has been the focus of many research initiatives. Many of these projects have focused on the use of Information and Computing Technology (ICT) to improve efficiency in administrative, medical, and technical processes. There are many more problems within the sector; and the issue of patient monitoring has attracted a lot of attention over the last ten years.

Patient monitoring is a critical function, since the condition of a patient under medical observation can change in the blink of an eye. In critical cases, ICT enables significant reduction of the possibility of human error. However, manual patient monitoring requires that medical staff make routine checks on a patient under observation, to capture the physiological conditions of the patient such as temperature, blood pressure, pulse rate, etc. The readings are recorded on the patient's medical chart and the captured data is used to determine the patient's treatment plan. ICT innovations not only make the automation of the patient monitoring process possible, but may also significantly improve the process.

In this paper, we propose a solution to this problem, which we will deploy in Jamaica. Given the generic nature of the solution, we understand that it can be applied in many other contexts. We start by surveying the related work in the space, then present our solution and then conclude.

2. RELATED WORK

This work intersects the areas of Wireless Sensor Networks (WSNs), Radio Frequency Identification (RFID) Technology, Agent Technology and Cloud Computing.

2.1 WIRELESS SENSOR NETWORKS (WSN)

Wireless Sensor Networks (WSN) (Singh et al., 2010) were initially developed for military applications, such as battlefield monitoring, and have been successfully retargetted for patient monitoring. Researchers have found that wireless sensors when operated in ad-hoc environments are susceptible to frequent network failures and are also unreliable (Sankaranarayanan and Ganesan, 2009). Failures are not acceptable in a healthcare setting, where critical information about the patient is being transmitted. To provide a more relaible network, researchers have proposed the use of Wireless Mesh Networks (WMN) (Sankaranarayanan, 2008, Sankaranarayanan and Ganesan, 2009), which are an extension of Local Area Networks (LANs). WMNs have a far better range and also use a limited amount of cabling (Akyildiz et al., 2005). WMNs enables the sensing of vital information emerging from wireless sensors connected to the backbone network, creating a Wireless Sensor Mesh Network (WSMN) (Sankaranarayanan, 2008, Sankaranarayanan and Ganesan, 2009), which is an integration of wireless sensors and mesh networks and provide different functionalities to improve the monitoring of the environment where the network is deployed. All WSNs are controlled by software that implement the various routing protocols used by the network. The software that controls the interaction between the sensors in the network is another area of ongoing research. The Internet of Things (IoT) (Castellani et el., 2010) is the natural progression of WSNs, where many physical objects are connected to the Internet via wireless technologies, such as Near Field Communication (NFC) and Radio Frequency Identification (RFID).

2.2 RADIO FREQUENCY IDENTIFICATION (RFID)

In addition to being used for monitoring of patients' physiological parameters, Radio Frequency Identification (RFID) (Ahsan et al., 2010, Korkmaz et al., 2010, Lefebvre et al., 2011, Mitrokotsa and Douligeris, 2009, Rantzau et al., 2006) may also be used to manage medical equipment, dangerous medical substances and drugs, inventory control, and to identify and locate patients. Morak and Schrer (2012) describe a RFID chip enabled card that allows patients to have their medical information read and even written to by physicians even if the patient has undergone medical treatment in another hospital. Fifah (2013) presents a RFID solution used for piority-based patient appointment management.

2.3 INTELLIGENT AGENT

Intelligent Agent Technology (IAT) was born from the field of Artificial Intelligence. An agent is defined as "anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors" (Edwards and Sankaranarayanan, 2011). The authors proposed IAT for searching and making appointments at various healthcare facilities based on the patients current health condition. In their paper, intelligent agents were created using the Java Agent DEvelpoment platform (JADE), enhanced with the Lightweight Extensible Agent Platform (LEAP) add-on and deployed on mobile devices (e.g. smart phones, PDAs) in the Jamaican healthcare environment.

2.4 CLOUD COMPUTING

Cloud computing presents Information Technology (IT) resources to users as "Pay-Per-Use" services. Currently, there are three (3) primary services available via the Cloud, namely Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). Given this, a health care service only needs a good Internet connection and REST-like infrastructure to leverage Cloud technology. This enables small healthcare clinics to multi-specialty hospital to pay per (cloud) service, similar to paying for Internet service. Pior research on a cloud-based electronic hospital management system (Horowitz, 2012) uses an application program interface (API) that connects emergency department (ED) workers with pre-hospital data from Boston EMS ambulances. Doctors at Beth Israel Deaconess Medical Center (BIDMC) are allowed to see vital data collected in ambulances via the hospital's ED Dashboard and import it into patient's Electronic Health Record (EHR). Before this project, the ED doctors had to fax the patient data manually to the BIDMC every day.

3. THE PROPOSED SYSTEM

We propose integrating RFID Wireless Body Sensor Integrated Mesh Network technology with Cloud-based intelligent agents to enable seamless and more efficient patient monitoring.

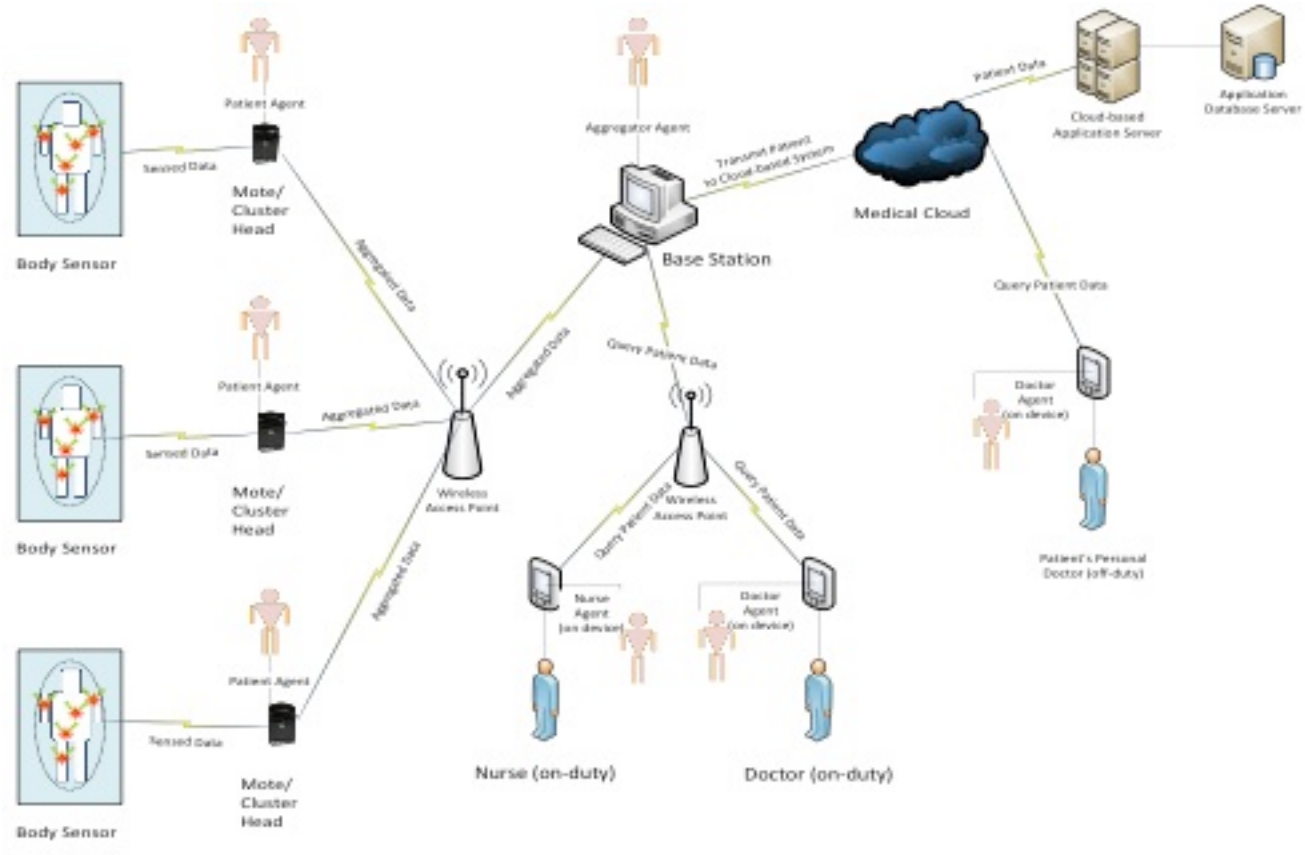

Figure 1: Proposed System Architecture

Based on our literature review, healthcare facilities currently use Wireless Body Sensor Networks (WBSNs) to monitor patients and these WBSNs are normally formed in an ad-hoc fashion, which is prone to failure. We propose to use a Wireless Body Sensor Mesh Networks (WBSMN) (Figure 1) to provide far better range and bandwidth as posited by Sankaranarayanan (2008). An additional advantage of our system will be that the performance will be acceptable or marginally better than WSBNs. This is supported by Benjamin and Sankaranarayanan (2009) experiments using the Opnet Simulator.

Another contribution of this work lies in the integration of WBSMN and RFID technologies to create a RFID Wireless Body Sensor Mesh Network (RFID-WBSMN), which would see the RFID Tag and Interrogator technologies enhanced with sensors for monitoring the physiological parameters of the patient and positive patient identification.

We also propose using intelligent agents at the mesh node in the RFID-WBSMN to query the sensors and make intelligent decisions; reporting to medical staffs' smart handheld devices in case of anomalous readings. The literature has reported on the increased performance of wireless sensor networks (WSN) when agent technology is used as supporting middleware, since the agent can be programmed to perform some processing work on the sensed data, which can lead to a reduction in the network traffic therefore reducing network latency.

We propose the use of policy-driven agents. The policies define the operational parameters of the agent and will be created by the patient's assigned doctor and propagated throughout the system by a policy agent. The system will support patient monitoring models defined using Bayesian classifiers, which will allow the training of agents

to make decisions by reasoning over the variations in expected readings of monitored parameters, and the actual readings.

The processing of physiological parameters by using intelligent agent middleware requires the use of powerful computer systems with memory, processing power and software. Therefore a Cloud-based architecture is proposed, which would represent a Community Cloud. The Community cloud is under the control of multiple organizations that share some common interest, e.g. health care facilitates. The infrastructure, platform and software for the proposed system will be managed by the Cloud Service Provider (CSP), which can be accessed and used by a range of healthcare entities.

Figure 1 shows the proposed system and its various components. The system has four intelligent agents, namely the Patient Agent (PA), Aggregator Agent (AA), Nurse Agent (NA) and Doctor Agent (DA). The PA is located at the cluster head of the RFID-WBSMN of the patient and queries the sensors for data and transmits to the AA. The AA is located at the Base Station, i.e. a workstation connected to the wired network with Internet connection The AA checks for indications of anomalous readings sent by the PA, then initiates alerts to the NA and DA of the on-duty medical staff and also the DA of the patient's assigned doctor (who may not be on duty). The AA transmits the patient's data to the Cloud-based application server for final processing and storage in the database server. The NA and DA are located on the smart handheld device for the on-duty nurse and doctor respectively (and also the patient's assigned doctor who may not be on duty). The NA and DA provide alerts to the medical staff and also allow the querying of patient's status, which includes current and past sensor readings.

The proposed system will be extended to support mobile or remote patients, using PAs located on smart handheld devices capable of receiving and transmitting readings for the sensors monitoring the patient's physiological condition. Using the Cloud services, the data from the mobile or remote patient will be processed and the monitoring healthcare facility and medical staff alerted of abnormal conditions. This proposed system can be viewed as a Medical Internet of Things (IoT-Med), as it is possible to uniquely identify, track and monitor all the "things" connected to the system over the Internet.

4. CONCLUSION

We propose the integration of RFID with the WBSMN to develop a sensing network that can uniquely identify the patient and the data collected from the patient, in addition to determining the patient's location within the network and monitoring the patient's condition. This research will leverage Cloud Technology to address the concerns surrounding the feasibility of system implementation for healthcare information systems, the dissemination of patient's data via the Internet, and the remote monitoring of patients by any healthcare service. This research will introduce the use of intelligent agents within the Cloud for the intelligent autonomous management of health care applications for patient monitoring through a Cloud-based infrastructure, platform and software to be accessed and used as a pay per service. This research seeks to provide a ubiquitous system for patient monitoring both within the health care facility and at remote locations. We propose to test this system in a hospital in Kingston, Jamaica.

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