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WIRELESS COMMUNICATION SENSOR NETWORKS FOR REMOTE HEALTH MONITORING

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ZigBee, wireless sensor networks, e-Health, remote vital signs monitoring.

ABSTRACT

ZigBee-based wireless sensor networks (WSNs) are a promising alternative to cabled systems for patient monitoring in hospitals. However, the low data rate protocols provided by IEEE 802.15.4 poses several challenges, mainly because its protocols were primarily designed to operate in low traffic load scenarios and some vital signs sensors generate a large volume of data. This work aims on understanding the potential offered by low power radio technologies applied to patient health monitoring under several scenarios and, additionally, examine usability, financial, ethical and social issues related to the interaction of different actors (hospital managers, caregivers, patients and their families) in the medical environment and the system.

INTRODUCTION

There are commercial solutions to remotely monitor in-patients and most are used for cardiac monitoring. The majority of these systems are costly and employ patient units that are relatively obtrusive and have small power autonomy what restricts their use to acute in-patients who require mobility to recover from their conditions. However, some research teams have proposed systems that can solve these issues (Curtis el al. 2008).

We have proposed HM4All, a monitoring system based on wireless sensor network (WSN) technologies and standard-based protocols, designed to allow remote monitoring of ECG (electrocardiography), HR (heart rate), SpO2 (oxygen saturation in the blood), and skin temperature. It is based on ZigBee, an open protocol whose MAC and PHY layers are supported by the IEEE 802.15.4 protocol. A prototype system was developed and commissioned in one of the internment floors of Guimarães Private Hospital, in Portugal (Fernández-López et al. 2010).

Several tests have been done in laboratory to determine the adequability of using WSN technologies to monitor patients. Additionally, the prototype system has been used to evaluate the benefits it creates, detect the usability issues, measure its performance, discuss the technological limitations, and propose improvements.

SYSTEM ARCHITECTURE

The prototype system architecture is shown in Figure 1. ZigBee-based wearable sensors used by in-patients associate to one of the WSNs in operation in the hospital floor to continuously send vital sign data to one of the network coordinators (only one WSN is shown, but several can coexist). Data is sent through a serial interface to the ZigBee-to-Wi-Fi Gateway, where they are processed and sent, through the Wi-Fi infrastructure to the Data Server. Patients' vital signs can be presented by any Web browser running in any computer (monitoring station). More than one monitoring station can be used to visualize data. Out-patients, recovering at home, can have their vital signs monitored as well, provided they have the ZigBee infrastructure and the required applications running on a personal computer with access to the Internet. Healthcare providers can observe patients' vital signs anywhere using an application running in a PDA and, in the future, they will be able to receive alerts.

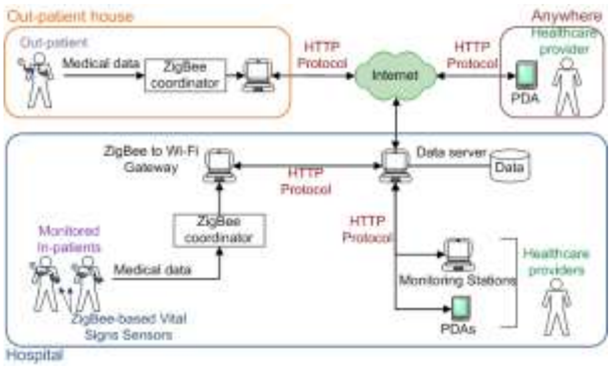

Figure 1: HM4All Architecture

WIRELESS SENSORS

HM4All specifications included ECG waveform, heart rate, SpO2, and skin temperature monitoring. ECG and temperature sensors are already prototyped and are shown in Figure 2. A SpO2 sensor is being designed. All sensors are based in the JN5139-M01 ZigBee module from Jennic (Jennic 2008), are relatively small and have good power autonomy.

Figure 2: Sensors Prototypes: ECG (left) and Temperature (right)

SOFTWARE APPLICATIONS

Several applications were developed, namely, a ZigBee-to-Wi-Fi Gateway, a Data Visualization Application and a Web site. The ZigBee-to-Wi-Fi Gateway establishes a serial connection, verifies the integrity and correctness of the data and process data. Additionally, it is responsible for establishing HTTP connections to send the processed data to the database as well as exhibiting relevant sensor related information, to the system administrator.

The Data Visualization Application that runs in the Data Server (see Figure 1) is a Web-based application and consists of two servlets: the Data Reception Service (DRS) and the Data Dispatch Service (DDS). The DRS receives and validates processed data received from the gateway. It also stores data on the database. The DDS is responsible for serving data to authenticated clients. Both applications are supported by the Apache Tomcat Web server and the MySQL database.

The Web site allows patient data visualization and provide several additional functionalities to authenticated users, such as:
• Patient registration, sensor insertion, and association between patients and sensors;
• Individual alarm configuration; and
• Historical data presentation in graphical format.

RESULTS AND FUTURE WORK

Laboratory tests and simulation results indicate that star networks operating in the unslotted CSMA-CA mode can relay all the traffic generated by at least 12 ECG nodes. In tree topologies, the increase of the network traffic load imposes a reduction in the number of devices, but they still can reliably relay the traffic of a considerable number of ECG nodes (Fernández-López et al. 2009a, b).

The prototype system was designed to monitor up to six patients simultaneously. The packet delivery ratio observed in tests using six ECG and six temperature sensors in the hospital floor is close to 100%, what is promising.

Future work includes more tests in the hospital environment, where several sources of interference and fading are present.

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HELENA FERNÁNDEZ LÓPEZ was born in Rio de Janeiro, Brazil and went to Rio de Janeiro State University (UERJ) where she obtained her degree in Electronics Engineering and to Rio de Janeiro Federal University (UFRJ) where she obtained her Master degree in Electrical Engeneering. She worked for several years for the Brazilian Navy before moving in 2007 to the University of Minho, Portugal, where she is now a PhD candidate. Her e-mail address is: `hlopez@uminho.pt`.