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Investigation on Healthcare Monitoring Systems:
Innovative Services and Applications

Audace Manirabona, University of Burundi, Faculty of Engineering Sciences, Bujumbura, Burundi
Lamia Chaari Fourati, University of Sfax, Sfax, Tunisia
Saâdi Boudjit, University of Paris 13, Villetaneuse, France

ABSTRACT

Wireless Body Area Networks (WBANs) services and applications have emerged as one of the most attractive research areas and have become more and more widespread especially for healthcare use. Lots of researches have been carried out to specify innovative services and applications using healthcare monitoring systems (HMS). However, the WBAN requirements vary from one application/service to another. Furthermore, HMSs are expected to reduce healthcare costs by enabling the continuous remote monitoring of patients' health even during their daily activities and thus reduce the frequency of the patient's visits at hospital. From a medical point of view, the WBAN will emerge as a key technology by providing real-time health monitoring and diagnosis of many life-threatening diseases. In this paper, the authors outline the WBAN applications and services requirements for healthcare and review them with emphasis on their strength, limitations and design challenges. In addition, HMS architecture and its applications are deeply studied and some case studies are discussed.

KEYWORDS

Applications, Health Monitoring Systems, Healthcare, Services, WBAN

INTRODUCTION

With the current trend in communication, networking and computing technologies coexist with people in a ubiquitous and pervasive way. The WBANs meet many needs for the market in a variety of innovating and interesting applications, it promises to revolutionize many domains such as ubiquitous healthcare applications (Jae-Myeong, et al. 2008; Huan-Bang, et al. 2008; Huan-Bang, et al. 2009; Dante, et al. 2010), military and aerospace (Tufail, et al. 2009), safety, interactive gaming, entertainment, animal managements and emergency (Jobs, et al. 2009). In the field of medical services (Gao, et al. 2008), the WBANs aim to facilitate health monitoring (Jobs, et al., 2009), medical care (Virone, G. et al.2006), and healthcare delivery in ambulances (Pomalaza-Rez, et al. 2007) and in emergency rooms (Otto, et al. 2006) and assistance to people with disabilities.

A WBAN is a collection of miniaturized wireless nodes deployed on or implanted in the body to supervise the human body functions and its environment. These nodes include sensors that sense physiological data and actuators that execute commands such as injection.

The sensors in turn can be categorized into wearable and implantable devices. Thus, the WBAN nodes for medical applications can be wearable (Pervez, et al. 2009) and/or just implants (Hung, et al. 2004). Wearable nodes are considered for both medical and non-medical applications; however, the WBAN implants are mainly considered for medical and healthcare applications. Wearable devices are those that can be used on a human body surface while implantable medical devices are those

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inserted inside human body. Non-medical applications include real-time audio/video streaming, data wave, stream delivery, etc.

A WBAN can include a large number of physiological sensors, which can be used as a bridge between the human body and a remote monitoring system or electronic systems such as household appliances, in order to generate all the information regarding the subject under observation and control. Nowadays, many kinds of sensors and actuators are already commercially available such as:

- *ECG (electrocardiogram)* sensor is used for monitoring heart activity. In order to obtain an ECG signal, several electrodes are attached at specific sites on the skin (e.g., arms, and chest), and the potential differences between these electrodes are measured;
- *EEG (electroencephalography)* sensor is used for monitoring brain electrical activity by attaching small electrodes to the body scalp at multiple locations. Then information on the brain's electrical activities sensed by the electrodes is forwarded to an amplifier to produce a pattern of tracings.
- *EMG (electromyography*) sensor used for monitoring muscle activity during contractions or at rest. Nerve conduction studies are often done while measuring the electrical activity in muscles. Since nerves control the muscles in the body by electrical signals (impulses) and these impulses make the muscles react in specific ways. Nerve and muscle disorders cause the muscles to react in abnormal ways.
- *Glucose sensor* is an optical meter (glucometer) which is used to analyze the blood sample and gives a numerical glucose reading.
- *The blood pressure sensor* is designed to measure systolic and diastolic human blood pressure.
- *Gyroscope and accelerometer* for monitoring trunk position and movement: the accelerometer is used to recognize and monitor body posture, such as sitting, kneeling, crawling, laying and standing, walking and running. The gyroscope used for measuring or maintaining orientation, based on the principle of conservation of angular momentum. Gyroscopes can be used with accelerometers for physical movement monitoring.
- *Breathing sensor* for monitoring respiration;
- *Infrared or diode-based sensors* for monitoring temperature;
- *Pulse oximeter* used for cardio-respiratory monitoring. It measures oxygen saturation;
- *Humidity and temperature sensors* used for measuring the temperature of the human body and/or the humidity of the immediate environment around a person. An alarm signal can be issued if a certain threshold value is exceeded.
- *Gas sensor* used to monitor oxygen concentration during human respiration.
- *Implantable Neural Stimulators* that send electrical impulses into the brain or spinal cord to treat for instance Parkinson disease, intractable epilepsy and chronic pain. An example of such a device is given by Pravin, et al. (2012).

In Table 1, sensors and actuators that could be used for wearable BAN and those that could be used for BAN implants are specified. Table 2 highlights WBAN services and applications.

The rest of this paper is organized as follows: The next section outlines WBAN applications and services followed by a section presenting related works focused on WBAN services and applications and also examining some HMS projects and real case studies. And then follows a section presenting HMS architecture including HMS challenges, existing architecture and a four-tier healthcare architecture (4tHMS) for monitoring system with its modules. Finally, a section discussing the HMS improvements and issues is presented before a section that concludes the paper and gives directions for our future works.