© 2016 IJSRSET | Volume 2 | Issue 2 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Healthcare Analysis via Wireless Sensor Network

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ABSTRACT

Wireless body area networks (WBANs) are emerging as important networks, applicable in various fields. Development in low-power integrated circuits, ultra-low-power RF (radio frequency) technology, wireless communications and micro sensors permitted the realization of Wireless Body Area Networks (WBANs). It is one of the latest approaches in medical identification, management and also key building block for future intentional networks and Internet. WSNs have been under rapid development and has become essential in such domains as industrial operations (factory, production, supply chains), health care (home monitoring, biomedical, food safety), environmental (agriculture, habitat preservation), infrastructure (energy, traffic and transportation, flood gauges, bridge stress, power grids, water distribution), and military, as well as for research and development. Advances in wireless sensor networking have opened up new opportunities in healthcare systems. Sensor-based technology has invaded medical devices to replace thousands of wires connected to these devices found in hospitals. This technology has the capability of providing reliability in addition to enhanced mobility. In the future, we will see the integration of a vast array of wireless networks into existing specialized medical technology. This paper will investigate the application of current state-of-the-art of wireless sensor networks in health care systems and will address how WSN concepts are integrated in our computer engineering program.

Keywords: Wireless body area network, WSN, IEEE 802.15.4, healthcare, WBAN survey

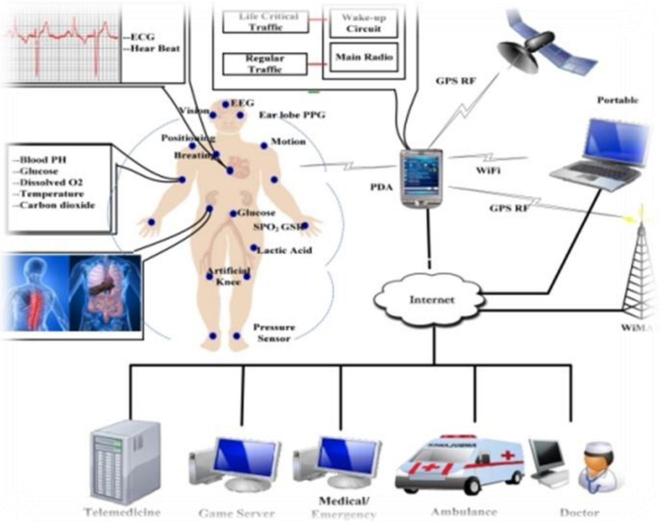
I. INTRODUCTION

Wireless sensor networks comprises of vast number of nodes , small sensors appropriate in specially appointed way and have the capacity to correspond with one another remotely. Wireless sensor network in healthcare monitoring provides independent life with quality care, helping chronically ill & elderly people. Recent technological advances in sensors, low-power microelectronics and wireless networking have enabled the design and proliferation of wireless sensor networks capable autonomously monitoring and controlling environments. One of the most promising applications of sensor networks is human health monitoring. A number of tiny wireless Sensors, strategically placed on the human body, create a Wireless Body Area Network (WBAN) that can monitor various vital signs, providing real-time feedback to the user and medical personnel. Generally speaking, three types of devices can be distinguished in WBAN: sensors, actuators and personal device.

The sensors are used to measure certain parameters of the human body, either externally or internally. Examples include measuring the heartbeat, body temperature or recording a prolonged electrocardiogram (ECG). The figure 1 represents the placement and purpose of sensor nodes in human body. The actuators (or actors) on the other hand take some specific actions according to the data they receive from the sensors or through interaction with the user, e.g., an actuator equipped with a built-in reservoir and pump administers the correct dose of insulin to give to diabetics based on the glucose level measurements. Interaction with the user or other persons is usually handled by a personal device, e.g. a PDA or a smart phone which acts as a sink for data of the wireless devices. In order to realize communication between these devices, techniques from Wireless Sensor Networks (WSNs) and ad hoc networks could be used. However, because of the typical properties of a WBAN, current protocols designed for these networks are not always well suited to support a WBAN.

II. SYSTEM ARCHITECTURE

The proposed wireless body area sensor network for health monitoring integrated into a broader multitier telemedicine system is illustrated in Figure 1. The tele medical system spans a network comprised of individual health monitoring systems that connect through the Internet to a medical server tier that resides at the top of this hierarchy. The top tier, centered on a medical server, is optimized to service hundreds or thousands of individual users, and encompasses a complex network of interconnected services, medical personnel, and healthcare professionals. Each user wears a number of sensor nodes that are strategically placed on her body. The primary functions of these sensor nodes are to unobtrusively sample vital signs and transfer the relevant data to a personal server through wireless personal network implemented using ZigBee (802.15.4) or Bluetooth (802.15.1). The personal server, implemented on a personal digital assistant (PDA), cell phone, or home personal computer, sets up and controls the WBAN, provides graphical or audio interface to the user, and transfers the information about health status to the medical server through the Internet or mobile telephone networks (e.g., GPRS, 3G). The medical server keeps electronic medical records of registered users and provides various services to the users, medical personnel, and informal caregivers. It is the responsibility of the medical server to authenticate users, accept health monitoring session uploads, format and insert this session data into corresponding medical records, analyze the data patterns, recognize serious health anomalies in order to contact emergency care givers, and forward new instructions to the users, such as physician prescribed exercises. The patient’s physician can access the data from his/her office via the Internet and examine it to ensure the patient is within expected health metrics (heart rate, blood pressure, activity), ensure that the patient is responding to a given treatment or that a patient has been performing the given exercises. A server agent may inspect the uploaded data and create an alert in the case of a potential medical condition. The large amount of data collected through these services can also be utilized for knowledge discovery through data mining. Integration of the collected data into research databases and quantitative analysis of conditions and patterns could prove invaluable to researchers trying to link symptoms and diagnoses with historical changes in health status, physiological data, or other parameters (e.g., gender, age, weight).



In a similar way this infrastructure could significantly contribute to monitoring and studying of drug therapy effects. The second tier is the personal server that interfaces WBAN sensor nodes, provides the graphical user interface, and communicates with services at the top tier. The personal server is typically 310 System Architecture of WBAN for Ubiquitous Health Monitoring implemented on a PDA or a cell phone, but alternatively can run on a home personal computer. This is particularly convenient for in-home monitoring of elderly patients. The personal server interfaces the WBAN nodes through a network coordinator (nc) that implements ZigBee or Bluetooth connectivity. To communicate to the medical server, the personal server employs mobile telephone networks (2G, GPRS, 3G) or WLANs to reach an Internet access point. Internet Tier 1: WBASN Tier 2: PS Tier 3: MS WBAN (ZigBee, Bluetooth) WWAN (GPRS) Emergency Informal caregiver Healthcare provider User1 User N Medical Server WWAN WLAN (Wi-Fi) Figure 1 shows Health Monitoring System Network Architecture. The interface to the WBAN includes the network configuration and management. The network configuration encompasses the following tasks: sensor node registration (type and number of sensors), initialization (e.g., specify sampling frequency and mode of operation), customization (e.g., run userspecific calibration or user-specific signal processing procedure upload), and setup of a secure communication (key exchange). Once the WBAN network is configured, the personal server manages the network, taking care of channel sharing, time synchronization, data retrieval and processing, and fusion of the data. Based on synergy of information from multiple medical sensors the PS application should determine the user's state and his or her health status and provide feedback through a user friendly and intuitive graphical or audio user interface. The personal server holds patient authentication information and is configured with the medical server IP address in order to interface the medical services. If the communication channel to the medical server is available, the PS establishes a secure communication to the medical server and sends reports that can be integrated into the user's medical record. However, if a link between the PS and the medical server is not available, the PS should be able to store the data locally and initiate data C. Otto, A. Milen kovic, C. Sanders, and E. Jovanov 311 uploads when a link becomes available. This organization allows full mobility of users with secure and near real time health information uploads. A pivotal part of the tele medical system is tier 1 – wireless body area sensor network. It comprises a number of intelligent nodes, each capable of sensing, sampling, processing, and communicating of physiological signals. For example, an ECG sensor can be used for monitoring heart activity, an EMG sensor for monitoring muscle activity, an EEG sensor for monitoring brain electrical activity, a blood pressure sensor for monitoring blood pressure, a tilt sensor for monitoring trunk position, and a breathing sensor for monitoring respiration, while the motion sensors can be used to discriminate the user's status and estimate her or his level of activity. Each sensor node receives initialization commands and responds to queries from the personal server. WBAN nodes must satisfy requirements for minimal weight, miniature form-factor, lowpower consumption to permit prolonged ubiquitous monitoring; seamless integration into a WBAN, standards based interface protocols, and patient-specific calibration, tuning, and customization. The wireless network nodes can be implemented as tiny patches or incorporated into clothes or shoes. The network nodes continuously collect and process raw information, store them locally, and send processed event notifications to the personal server. The type and nature of a healthcare application will determine the frequency of relevant events (sampling, processing, storing, and communicating). Ideally, sensors periodically transmit their status and events, therefore significantly reducing power consumption and extending battery life. When local analysis of data is inconclusive or indicates an emergency situation, the upper level in the hierarchy can issue a request to transfer raw signals to the next tier of the network. Patient privacy, an outstanding issue and a requirement by law, must be addressed at all tiers in the healthcare system. Data transfers between a user's personal server and the medical server require encryption of all sensitive information related to the personal health [2]. Before possible integration of the data into research databases, all records must be stripped of all information that can tie it to a particular user. The limited range of wireless communications partially addresses security within WBAN; however, the messages can be encrypted using either software or hardware techniques. Some wireless sensor platforms have already provided a low power hardware encryption solution for ZigBee communications

III. APPLICATION OF WIRELESS NETWORK IN HEALTH CARE

The integration of existing specialized medical technology with pervasive wireless networks will be seen in the near future. Medical applications benefit from wireless sensor networks in many ways. The recent advances in miniaturization of smart biosensors will open up new opportunities for continuous monitoring of patients. Unobtrusive, tiny wearable sensors will allow collection of vast amounts of data automatically, reducing the cost and inconvenience of regular visits to the physician. Thus, many more researchers may be enrolled, benefiting all research peers [2]. In [3] the authors present an approach to enable plug and play-like simplicity for wireless medical body sensors (WMBSs), by enabling body-worn sensors to recognize the body they are deployed on. By confining the smart sensor communication to on-body sensors, no interference is generated between WMBSs. These authors refer in-body communication by body-coupled communication (BCC). Each person must place the appropriate smart sensor array and a "personal identifier", as shown in figure 4. Following, medical applications will be described by are of interest.

A. Cancer Detection

Represents one of the major concerns in healthcare. Nowadays, one of biggest treat for human life is cancer. Cancer is the second leading cause of death in US with rising numbers each year: currently 9 million people had a cancer diagnosis, with 1,221,800 new cases in 1999. Although, there is no conclusive evidence on how to prevent cancer and early detection is crucial. Studies have shown that cancer cells exude nitric oxide, which affects the blood in the area surrounding a tumor. A sensor with the ability to detect these changes in the blood can be placed in suspect locations. Research is also being conducted on placing sensors on a needle, enabling physicians to diagnose tumors without having to do a biopsy. Sensors used in this device have the ability to differentiate between different types of cells, identifying cancerous ones.

B. Glucose Level Monitoring

Glucose Level Monitoring is essential for controlling another emerging disease: diabetes. The US national institute of health (NIH), US national institute of diabetes, and digestive and kidney disease reported 15.7 million people had diabetes in 1999 in the US. Complications that can arise from diabetes include heart disease, stroke, high blood pressure, blindness, kidney disease, and amputations. Characteristic treatment for diabetes includes a strict diet, exercise, insulin injections, and blood monitoring. Wireless biomedical sensors may present a more effective way to treat diabetes, by providing a more consistent, accurate, and less invasive method for monitoring glucose levels. The current constant pricking on the finger for blood, several times a day over a period of years can damage the tissue and blood vessels in that area. A biosensor could be implanted in the patient once. The sensor would monitor the glucose levels and transmit the results to a wristwatch display for instance. This approach leads to fewer invasions, more accuracy due to multiple readings, and anticipation to insulin needs. Furthermore, insulin could automatically be injected when a certain threshold glucose level is reached. Asthma For millions of patients suffering from asthma in the world, sudden allergic morbidity may cause severe threat to their lives. They require administration of Terbutaline in minutes, in order to ease symptoms of rapid-onset asthma attacks, or the attacks may become fatal. A wireless sensor network can help them by having sensor nodes that can sense the allergic agents in the air and report the status continuously to the physician and/or to the patient himself. Hsueh-Ting Chu et al, developed a portable GPS-based device that continuously consults a remote server and reports whether the current air condition will threaten user's health. The server also collects information from the network of national air quality monitoring stations. Then, if it finds anything allergic to the patient, an alarm to the patient and/or physician can be triggered.

C. Artificial Retina

Loss of vision clearly deteriorates a person's quality of life. Wireless sensor network technology can also help blind people. Loren et al. propose a biomedical application, called artificial retina. In the smart sensors and integrated microsystems (SSIM) project, retina prosthesis chips that consist of 100 micro-sensors are built and implanted within a human eye. This solution allows patients with no vision or limited vision to see at an acceptable level. The wireless communication is used to suit the need for feedback control, image identification and validation. Sensors in the eye produce electrical signals, then the underlying tissue converts signals into a chemical response, mimicking the normal operating behavior of the retina from light stimulation. The chemical response is digital (binary), essentially producing chemical serial communication. Home monitoring. Examples of areas in which future medical systems can benefit the most from wireless sensor networks are in-home assistance, smart nursing homes, clinical trial and research augmentation. Patients gain benefits such as privacy, dignity, and convenience, and are supported and enhanced by the ability to provide services at home. Family members and the smart homecare network itself become part of the healthcare team. Memory aids and other patient-assistance services can restore some lost independence, while preserving safety

D. Heart Rate Monitoring

Heart rate is a research domain that it will save many lives. It is well known that every year 40% to 45% of firefighters die of heart attacks compared to 25% for the normal population. Monitoring the firefighter's vital signs and the environment could revolutionize the way they train, are selected for each job assignment, and allowed to work on a high-risk assignment. Current heart rate monitors require time and attention for their placement such as the chest straps with electrodes that need moist skin contact. There are also wrist watches with electrodes that take non-continuous measures and act only when triggered, or photoplethysmograph sensors for the finger that are very sensitive to motion artifacts and loose accuracy specially when doing manual work. However there is no practical monitoring system a person can easily wear while on the job. In the challenges and the difficulties of placing heart rate sensors in the worker's uniforms are presented. Some real systems employing wireless sensor network technology can be used today.

IV. CONCLUSION

Today, there is an increasing interest in developing technical solutions, by academia and industry alike, to address problems with healthcare delivery. While it is difficult to accurately predict the future of any field, the global aging population presents steep challenges for the healthcare industry to deliver services to all who need it while adapting to a new environment that demands cutting costs of healthcare services. In fact, the future of healthcare in our increasingly aging world will oblige ubiquitous monitoring of health with minimal physical interaction of doctors with their patients. Low-cost technologies are expected to aid in the delivery of services while simultaneously reducing costs. Wireless sensor networks have the potential to assist in meeting some of these future challenges, by simplifying use of medical equipment, advancing at-home medical care, and displaying health and wellness information to both providers and patients. The design of better wireless medical sensor networks seems to be a good solution to part of the problem. As a result, wireless sensor networks are becoming increasingly important for monitoring patients both in the clinical settings as well as home. This paper studied the application of WSNs in the healthcare system. The application of the Wireless Sensor Networks in healthcare systems was divided into three categories: monitoring of patients in clinical settings, home and elderly care center monitoring for chronic and elderly patients, and collection of long-term databases of clinical data. This study revealed that the existing application of WMSNs in the healthcare system have some shortcomings that need to be addressed. The WSN research community has done an admirable job of addressing some of the limitations that currently exist for healthcare-related applications; however, improvements are still needed regarding security and privacy issues in addition to further upgrades to wireless communication. As educators in the field of engineering and computer science, it is essential to expose our students to the emerging field of WSNs. As the industry is constantly involved in the development of technology and products to solve issues with WSNs, tomorrow's computer. Scientists and engineers must be educated on the Wireless Sensor concepts. It is our job to integrate these concepts into the undergraduate curriculum of these fields. Wireless Sensor Networks applications in healthcare are being researched and deployed all over world. With the rise of these applications, implications will also arise.

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