HUMAN HEALTH MONITORING USING WIRELESS SENSORS NETWORK (WSN)

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ABSTRACT

Wireless devices have invaded the medical area with a wide range of capability. To monitor the patient details in periodic interval is on overhead using existing technologies. To overcome this we have changed recent wireless sensor technologies. In general six different sensors are used to gather patient medical information without being injecting inside the body by this we are achieving remote monitoring and data gathering of patients. This adds the advantages of mobility. There is no need for a doctor to visit the patient periodically. In this survey paper we discuss advantages of wireless medical devices and challenges involved in this technology. We focus on Wireless Personal Area Network technologies, WiMAX, Wi-Fi and Zigbee. We have also investigated standards being used in wireless medical applications and location of wireless network in a healthcare system. Finally, we identify innovative medical applications of wireless networks developed or being developed in research, projects and research groups on wireless medical application, and commercial products.

Keywords: Medical applications survey, wireless medical applications, wireless networks, sensor networks, wireless applications, wireless homecare, Zigbee, Bluetooth, WPAN, Wi-Fi, patient management, CodeBlue, CIMIT, wireless medical solutions, MobileFi, IEEE 802.20

I. INTRODUCTION

Recently, interest in wireless systems for medical applications has been rapidly increasing. With a number of advantages over wired of 12 alternatives, including: ease of use, reduced risk of infection, reduced risk of failure, reduce patient discomfort, enhance mobility and low cost of care delivery, wireless applications bring forth exciting possibilities for new applications in medical market. Portable devices such as heart rate monitors, pulse ox meters, spirometers and blood pressure monitors are essential instruments in intensive care. Traditionally, the sensors for these instruments are attached to the patient by wires; and the patient sequentially becomes bed-bound. In addition, whenever patient needs to be moved, all monitoring device has to be disconnected and then reconnected later. Nowadays, all of these Time-consuming jobs could be terminated and patients could be liberated from instrumentation and bed by wireless technology. Integrated wireless technology, these wireless devices. Continuous and pervasive medical monitoring is now available with the present of wireless healthcare systems and telemedicine services.

Wireless technology could be the best solution for mass emergency situations like natural or human-included disasters and military conflict where patients’ records such as previous medication history, identification and other vital information are necessary. With the assistant of hand held devices in which wireless network integrated, the amount of time the doctors need to identify the problem, trace back the medication history of the patient and consult fellow doctors will be reduced significantly. Moreover, databases of patients that can be built up by continuous medical monitoring will be accessed and updated easily. As a result, the amount of paper works required and the duplication of patient record will be dropped down. With all of these potentials, wireless systems for medical application are now not only focused by healthcare provider and the government but also by researches and industry. Significant academic and corporate resources are being directed towards researching and development of novel wireless healthcare systems. Several innovative applications based on this technology are developed or being developed in research. In this paper, we will discuss several of these projects, highlighting their architectures and implementation. This paper is organized as follows: We will briefly
discuss the base wireless technologies which current applications are using. We will discuss benefit of wireless healthcare system in detail.

II. BASIC TECHNOLOGIES OF MEDICAL APPLICATIONS

The rapid growth of the technologies extends the potential for exploitation of wireless medical application market. Nowadays, thanks to the large-scale wireless network and mobile computing solutions, such as cellular 3G and beyond, Wi-Fi mesh and WiMAX, caregivers can access into vital information anywhere and at any time within the healthcare networks. The present of pervasive computing, consisting of RFID, Bluetooth, ZigBee and wireless sensor network gives innovative medium for data transmission for medical applications.

A.WiMAX

Based on the IEEE 802.16 standards, so-called Wireless MAN standards, WiMAX is created by the WiMAX Forum, which has strong-security wireless data transmission over long distance, up to 50km, with high data rate, up to 70 Mbps, and high mobile capability, up to 150km/hour. The standard is the incorporation of several advanced radio transmission technologies such as adaptive modulation and coding (AMC), adaptive forward error correction (FEC), well defined quality of service (QoS) framework and orthogonal frequency division multiplexing (OFDM).

B.WLAN

The standards of WLAN was3 of 12 first introduced in 1997, namely IEEE 802.11. The capacities of IEEE 802.11 standards evolved from 1- 2Mbps in the initial version to 54Mbps in IEEE 802.11a and IEEE 802.11b. IEEE 802.11a has a range of 100 feet and 802.11b has coverage of 350feet outdoors and 150 feet indoor. After the introducing of 802.11a and 802.11b, Wi-Fi alliance formed and started its work certifying wireless based devices. Since that time, 802.11 have been developed much further. Many extensions of 802.11 were released, including 802.11g, added in 2003 with capacities of 54Mbps transmission working on 2.4GHz band at range of 350ft outdoors and 150 feet indoors; 802.11n with higher throughput of up to 200Mbps; 802.11i, added in 2004 with enhanced security; and 802.11s added for Mesh Network.

C.WPAN

WPANs using ZigBee or Bluetooth standards are gaining in popularity, with wireless motes available from industry. A number of physiological monitoring systems based on the motes have been proposed and deployed in real clinical settings. In addition to patient monitoring these systems can be used for patient tracking in situations where location information is essential, such as mass casualty incidents. Another technology using in WPANs is ZigBee, a so-called IEEE 802.15.4. The standard is an ultra-low power, low-data rate which is used for monitoring and controlling applications. Devices using ZigBee has less than 1% life time in active status. In most of the life, the devices are in sleep mode to save device’s power.

D.WBAN

Recent technological developments in low-power integrated circuits, wireless communications and physiological sensors promote the development of tiny, lightweight, ultra-low-power monitoring devices. A body-integratable network, so-called WBAN, can be formed by integrating these devices. WBAN with sensors consuming extremely low power is used to monitor patients in critical conditions inside hospital. Outside the hospital, the network can transmit patients’ vital signs to their physicians over internet in real-time. WBAN usually uses ZigBee, or UWB standard.

![Fig.2 WWBAN deployment scenarios](image)

One of many applications of WBAN in medical domain is computer assisted physical rehabilitation. Intelligent sensors wearing by patients transmit vital signs to personal server, which is running on a PDA, laptop or 3G cell phone. Sequentially, the data is transmitted from personal server to servers of the healthcare system, such as weather forecast, medical database or emergency server over Internet. Algorithms may be executed on the healthcare system servers to give instant and patient-specific recommendations.

E.Other technologies

Many other standards, technologies are applied to medical applications, including RFID, sensor network, 3G, 4G, and so on. In this section of the paper, we will identify briefly these technologies. The first RFID chips were approved by Food and Drug Administration in October 2004[RFID], which opens the door for applying RFID in 4 of 12 medical applications. Since that time, a number of U.S. hospitals have begun implanting RFID tags into their patients to identify them. RFID is not only the efficient method to keep track medical equipments but also have potential in positioning...
patients and hospital staffs. Sensor networks have been applying in various aspects of medical care. By equipping patients with tiny, wearable vital sign sensors, physiological status of patients can be obtained easily.

Cellular systems (2.5G, 3G and beyond 3G) have the potential to greatly improve telemedicine services by extending the range of healthcare system, enhance the flexibility and heterogeneous network with an end-to-end telemedicine framework. The system consists of a cellular network platform, which gathers the information from wearable sensors, monitoring devices and server platform.

III. SYSTEM ARCHITECTURE

A. Overview of system architecture

The whole system architecture is shown in figure. It is composed of medical sensor nodes, a hand-held personal server, a hospital server and related services. In this system, medical sensor nodes are used to collect physiological signals including bio-signals, medical images, and voice signals. These obtained signals are fed into the personal server through wireless personal area network (WPAN). The wireless communication between the sensor nodes and the hand-held personal server uses IEEE 820.15.4/Zigbee standard. After arriving at the hospital server, the data are either stored in the clinical data base, or available to a clinician through a hospital’s local area network (LAN). Then clinicians can analyze the physiological data and give diagnosis advices accordingly.

B. Medical sensors & wireless personal area network

The main tasks of the medical sensors are to collect physiological signals and send them to the personal server. Typical medical sensors and characteristics of the signals are shown in Table 1. In this system, the type and number of medical sensors are scalable depending on applications. Several commonly used medical sensors are briefly introduced as follows:

<table>
<thead>
<tr>
<th>Signal</th>
<th>Frequency Range</th>
<th>Signal Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrocardiograph</td>
<td>0.05–100 Hz</td>
<td>0.01–5 mV</td>
</tr>
<tr>
<td>Electroencephalograph</td>
<td>0.5–60 Hz</td>
<td>15–100 mV</td>
</tr>
<tr>
<td>Electroocculogram</td>
<td>0.5–50 Hz</td>
<td>N/A</td>
</tr>
<tr>
<td>Electromyogram</td>
<td>0.5–60 Hz</td>
<td>N/A</td>
</tr>
<tr>
<td>Heart Rate</td>
<td>45–200 beats/min</td>
<td>N/A</td>
</tr>
<tr>
<td>Breathing Rate</td>
<td>12–40 breaths/min</td>
<td>N/A</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>dc–60 Hz</td>
<td>40–300 mmHg</td>
</tr>
</tbody>
</table>
C. The personal server
Previous descriptions show that the personal server plays an important role in overall telemedicine system. It is designed as a hand-held unit which can be used to communicate parallels with a series of scalable medical sensor nodes as well as a remote hospital server. It maintains a communication bridge between patients and the hospital and data may be sent to the remote hospital server for further processing if necessary. In general, the personal server performs the following tasks:
1) Initialization and configuration of medical sensor nodes.
2) Collecting data from medical sensors.
3) Processing physiological data and displaying results.
4) Keeping reliable communication with remote hospital server.
5) Providing a graphic user interface.

IV. SENSOR NODES AND CCU HARDWARE DESIGNS
Sensor nodes are designed to collect raw signals from a human body. The signal from a human body is usually weak and coupled with noise. First, the signal should go through amplification and filtering process to increase the signal strength, and to remove unwanted signals and noise. After which, it will go through an Analog to Digital conversion (ADC) stage to be converted into digital for digital processing. The digitized signal is then processed and stored in the microprocessor. The microprocessor will then pack those data and transmit over the air via a transmitter. The overview of a Pulse Rate Sensor Node is shown in Figure.

![Block diagram of a pulse rate sensor node.](Fig.5)

![Hardware design of sensor node.](Fig.6)

The CCU also requires a micro-controller and a wireless transceiver chip to coordinate all activities similar to the sensor nodes. The CCU hardware is made of the same transceiver chip from AMI semiconductor (AMI52100 IC) and the microcontroller PIC16F877 [14]. The targeted wireless distance between sensors and the CCU (the MICS link) is 1-10 meters. The CCU can thus be located at the waist of the patient or at an easily accessible place.

V. POTENTIALS AND CHALLENGES OF WIRELESS MEDICAL APPLICATIONS
With the advancement of wireless technology, wireless devices can be used to reduce medical errors, increase medical care quality, improve the efficiency of caregivers, lessen the caregiver-lacking situation, and improve the comfort of patients. Although the technology has found ways into various fields, medical domain has very strict quality and assurance requirements, which causes many challenges that are faced when implementing and operating the systems. The following part of the paper will be reserved to identify potentials and challenges of healthcare system using wireless technology.

A. Potentials of wireless technology in medical application
Wireless inside-body monitoring is a hot application of wireless network in patients’ monitoring. Using WBAN technologies to transmit data from monitoring devices, such as Capsule Endoscope, to outside body, these applications used to monitor the digestive organs such as the small intestine by video or successive image data. The system uses IEEE 802.15.6 and wearable WBAN to guarantee the quality of system. Details about Capsule Endoscope will be given in the later section of paper. Operation assisting is very new application of wireless network [CIMIT]. In an operation, doctors have to monitor the patient’s vital signs to have timely actions. These signs can be obtained by applying to the patient adhesive electrodes so that the signs are transmitted over wires to display monitors. The large number of wires used around the operation table prevents the medical team’s access to the patient. Moreover, the adhesive can be detached from
patient what is caused by strong enough impact to the wires. To help surgeons and medical teams operate more freely, the Smart pad [CIMIT] is presented. A device displays patient’s signals without adhesives or wires. Although real-time patient monitoring field is not a new topic in wireless medical applications, researchers and industries are investing a lot of effort and money to it. These applications basically use biomedical sensors monitor the physiological signals of patients such as electro-cardiogram (ECG), blood oxygen level, blood pressures, blood glucose, coagulation, body weight, heart rate, EMG, ECG, oxygen saturation, etc. 5 of 12 Home monitoring systems for chronic and elderly patients is rapidly growing up in quantity and quality. Using the system can reduce the hospital stay of patient and increase patient safety and mobility.

B. Challenges of wireless technology in medical application

The use of wireless technologies in medical environments is bringing major advantages to the existing healthcare services. However, these have several key research challenges such as various types of network communication infrastructure, fault-tolerance, data integrity, low-power consumption, transmission delay, node failure, etc. Reliability is one of the most important factors in a successful healthcare system. To ensure this factor, system designers have to care about adaptation of nodes when its location, connection and link quality is changed. Different network communications infrastructure should be used in appropriate situation. For example, with high-risk patients, the services with higher QoS should be used. The mentioned challenges are associated with technical implementation. However, there are many other challenges associated with deployment of a new technology. Specifically, the new system should be low cost and not interfere with existing infrastructure. So managing interference between the old system and the new one and using spectrum properly are challenges of wireless technology applied to medical applications. From patient’s aspect, one of the most important issues is how comfortable they feel when using these new applications. Therefore, the applications must be not only helpful but also unobtrusive, specifically small, lightweight, etc. Last but not least, patients’ information must be private and secure, but remain accessible to authorized persons.

VI. STANDARDS USED IN WIRELESS MEDICAL APPLICATIONS

Coming along with a rapid increase of wireless systems for medical applications, significant academic and corporate resources are being directed towards development of standards. Significant progress in issuing industrial standards has been made by organizations, such as IEEE, Bluetooth SIG, ISO, ASTM, etc.

A. IEEE standards

A set of standards, so-called ISO/IEEE 11073 or X73, identifies nomenclature, abstract data models, service models, and transport specifications for interoperable bedside devices. The standards’ primary goals are “providing interoperability for patient-connected medical devices and facilitating the efficient exchange of vital signs and medical device data in all health care environments”.

| ACSE: Association Control Service Element |
| AL: Alarm (Channel) |
| CDDISE: Common Medical Device Information Service Element |
| MDIB: Medical Data Information Base |
| MDSS: Medical Device System |
| NG: Numeric (Channel) |
| ROSE: Remote Operation Service Element |
| SA: Sample Array (Channel) |
| VMD: Virtual Medical Device |

Fig.7 IEEE Standards

B. ISO Standard

Many standards issued by ISO to provide guidance for implementation, use and management of wireless communication and computing equipment in healthcare facilities “The recommendations given recognize the different resources, needs, concerns and environments of healthcare organizations around the world, and provide detailed management guidelines for healthcare organizations that desire full deployment of mobile wireless communication and computing technology throughout their facilities”.

C. Bluetooth SIG standards

The Bluetooth Special Interest Group (SIG) issued the Medical Device Profile for Bluetooth wireless technology at Medical, the 39th World Forum for Medicine in Düsseldorf (14-17 November 2007) [Bluetooth]. A Bluetooth profile provides guideline of how different applications use Bluetooth wireless technology to set up a connection and exchange data. The profile is developed by the Medical Devices Working Group to ensure that devices used in medical, health and fitness applications can transfer data between devices in a secure and well defined way via Bluetooth wireless technology.

D. ASTM standards

ASTM issued ASTM F1220-95(2006), a standard guide for emergency medical services system (EMSS) [ASTM F1220]. The standard and its sub-standards provide guide for telecommunication practices, required performance standards to support all of the functions of community EMSS. In addition, the standards identify state planning goals and objectives for EMSS communications.
VII. PROJECTS AND RESEARCH ON WIRELESS MEDICAL APPLICATION

In this part of the survey, we will discuss groups and projects researching on medical applications.

A. CIMIT
CIMIT is a center conducting research in order to improve patient care [CIMIT]. CIMIT teams have produced truly novel, cost-effective healthcare solutions, many of them are networked sensor solutions, wireless monitoring, and tracking systems. These novel solutions will be implemented in real-world in the near future from hospital to home. CIMIT teams have been designing and constructing “Operating Room of the Future, a fully functioning operating room in which novel, integrated technologies and new processes are introduced, evaluated, and improved, and through which patients move with far greater comfort, speed and safety”.

![Fig.8 Smart Pad - A Wireless, Sticker less EKG System](image)

![Fig.9 Future clinical system](image)

B. Code Blue
Code Blue is the project of Harvard University trying to develop novel applications of wireless sensor network technology to medical applications. Many products of the project have great potential to apply to practice such as: Intel SHIMMER motes, UVa/AID-N "eTag" wireless triage tags, UVa/AID-N wireless blood pressure cuff, Limb movement in stroke patient rehabilitation monitoring system.

![Fig.10 Intel SHIMMER motes](image)

![Fig.11 UVa/AID-N wireless blood pressure cuff](image)
C. Capsule endoscope
Capsule endoscopy is a way to record images of the digestive tract for use in medicine. The capsule is the size and shape of a pill and contains a tiny camera. After a patient swallows the capsule, it takes pictures of the inside of the gastrointestinal tract. The primary use of capsule endoscopy is to examine areas of the small intestine that cannot be seen by other types of endoscopy such as colonoscopy or esophagogastroduodenoscopy (EGD). The technique was invented in Israel. It was approved by the U.S. Food and Drug Administration in 2001. This is a novel application of wireless technology into in-body patient monitoring. It is a result of collaboration among NICT, Olympus Medical Systems Corp., FUJIFILM Corp., Yokohama City University, and Yokohama National University. Capsule endoscopy can be used to monitor digestive organs by video and images transmitted from inside body to the outside over WBAN. Capsule endoscopy is used to examine parts of the gastrointestinal tract that cannot be seen with other types of endoscopy. Upper endoscopy, also called EGD, uses a camera attached to a long flexible tube to view the esophagus, the stomach and the beginning of the first part of the small intestine called the duodenum.

A colonoscopy, inserted through the rectum, can view the colon and the distal portion of the small intestine, the terminal ileum. These two types of endoscopy cannot visualize the majority of the middle portion of the gastrointestinal tract, the small intestine.

VIII. CONCLUSIONS
This paper demonstrates the use of WSNs as a key infrastructure enabling unobtrusive, continual, ambulatory health monitoring. This new technology has potential to offer a wide range of benefits to patients, medical personnel, and society through continuous monitoring in the ambulatory setting, early detection of abnormal conditions, supervised rehabilitation, and potential knowledge discovery through data mining of all gathered information.

We have described a general WWBAN architecture, important implementation issues, and our prototype WWBAN based on off-the-shelf wireless sensor platforms and custom-designed ECG and motion sensors. We have addressed several key technical issues such as sensor node hardware architecture, software architecture, network time synchronization, and energy conservation. Further efforts are necessary to improve QoS of wireless communication,
reliability of sensor nodes, security, and standardization of interfaces and interoperability. In addition, further studies of different medical conditions in clinical and ambulatory settings are necessary to determine specific limitations and possible new applications of this technology.

REFERENCES


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