Wireless Body Area Networks for Health-Care Systems

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Abstract

Body Area Network (BAN) development has been driven by pressure to reduce health care costs and by an increased focus on prevention and early risk BANs are highly localized wireless networks that can potentially support a variety of medical applications. Our final paper deals with all aspects involved in Wireless BAN (WBAN) in health care arena.

Keywords: *Body sensor networks (BSN), medium access control (MAC), multi hopping network technique, sensor nodes, wireless body area networks (WBAN)*

INTRODUCTION

Sensor network has grown significantly supporting a range of applications including medical and health care systems. WBAN is a special purpose sensor network designed to operate autonomously to connect various medical sensors and appliances, located inside and outside of human body [1]. The advantages of WBAN includes mobility of patients due to the use of portable monitoring devices, location independent monitoring facility and it will connect itself to the internet to transmit data in a non-invasive manner. It consists of number of tiny sensor nodes and a gateway node to connect to external data base server. Health care sector is increasingly looking forward for Advanced ICT (Information and Communication Technology). Sensor nodes which are attached or implanted into a human body include miniaturized, low power devices. These detect medical signals such as ECG (Electrocardiogram), PPG (Photoplethysmogram), EEG (Electro encephalography), pulse rate, blood flow, pressure, temperature. Popular wireless technologies used for medical monitoring are Zigbee/IEEE 802.15.4, WLAN, GSM, and Bluetooth (802.15.1). Bands involved in this wireless communication are ISM (Instrumentation scientific and medical), MICS (medical impact communication service), WMTS (Wireless medical telemetry service), UWB (Ultra-wide band) [2]. Pieces of software involved are Residing at local PC GATEWAY and Residing at remote PC BSN. BSN plays a main role in collecting data from local pc to be analyzed later by health professionals. Multihopping network technique involves 3 networking levels. Sensor node design involves where sensor nodes collect raw signals from the human body. A CCU and gateway design plays a prominent role in this wireless communications related to medical applications. MAC (medium access control protocol and monitoring) involves medical wireless sensor networks. Requirements of WBAN includes types of devices, data rates, energy, quality of service and reliability, usability, security, privacy, traffic heterogeneities and topology and good quality of service.

BODY SENSOR NETWORK

Body Sensor Networks (BSNs) enable continuous, non-intrusive, and remote health monitoring, and are widely considered as the next generation of healthcare technology. One of the main challenges in engineering BSNs is ensuring that communication is prompt, reliable, and energy-efficient. The objective of our project is to develop communication protocols to meet these stringent requirements of BSNs. As a past work, an optimized handover strategy with user movement trend awareness has been proposed for BSNs with significant performance improvement shown by simulation results. Now we are investigating the inter-user interference issues in BSNs in Figure 1. Inter-user interference refers to the interference in desired communication when several BSNs operate in the same vicinity.

As BSNs will be commonly utilized in aggregated places like hospitals, the inter-user interference exists widely and severely. We are trying to provide a solution to this problem with minimum cost. The receiver station is capable of displaying all received data on user display graphic (GUI) and is capable of storing all the data in database system of medical centers [3]. BSN application

***Fig. 1:** Health-Care Monitoring System.*

collects data from local pc, converts and stores them onto remote pc to be analyzed later by health professionals.

The observations by Hippocrates, the Greek founder of modern medicine, that audible sounds emanating from the chest were produced by the heart, ultimately led to the development of the stethoscope in 1816. Since then, diagnostic tools have continued to evolve and have revolutionised medical practice, allowing doctors to extract more and more important information about their patients' physiological states. This increased level of sophistication is perfectly illustrated by the stethoscope, which has evolved from a simple tube, into a device has been carefully engineered to accurately relay heart and chest sounds, allowing clinicians to recognise disease processes. The most advanced stethoscopes can also digitally filter and enhance this sound quality. Whilst these diagnostic tools continue to develop, they still offer information that is nothing more than a "snapshot in time". The next great challenge for diagnostic devices lies in their ability to monitor a patient's physical and biochemical parameters continuously, under natural physiological status of the patient, and in any environment in Figure 2.

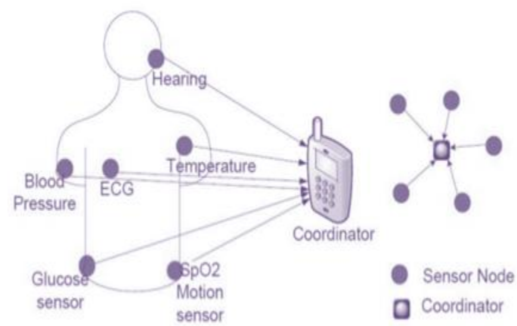

***Fig. 2:** BAN Network Topology.*

The development of wireless BSNs offers a platform to establish such a health monitoring system, and represents the latest evolution of diagnostic tools. BSN patient monitoring systems will provide information that is likely to be as important, dramatic and revolutionary as those initial observations made by Hippocrates himself.

Technical Challenges Facing BSN
Although the BSN platform aims to provide the ideal wireless setting for the networking of human body sensors and the setting up of pervasive health monitoring systems, there are a number of technical challenges that lie ahead. These include the need for better sensor design, MEMS integration, biocompatibility, power source miniaturisation, low power wireless transmission, context awareness, secure data transfer, and integration with therapeutic systems.

Medium Access Control

A MAC protocol provides slightly different functionality depending on the network, device capability, and upper layer requirements, but several functions exist in most MAC protocols. In general, a MAC protocol provides:
Framing – Define the frame format and perform data encapsulation and decapsulation for communication between devices. Medium Access – Control which devices participate in communication at any time. Medium access becomes a main function of wireless MAC protocols since broadcasts easily cause data corruption through collisions. Reliability – Ensure successful transmission between devices. Most commonly accomplished through acknowledgement (ACK) messages and retransmissions when necessary. Flow Control – Prevent frame loss through overloaded recipient buffers. Error Control – Use error detection or error correction codes to control the amount of errors present in frames delivered to upper layers. Networks include:

- TDMA (Time division multiple access)
- Polling Protocol
- Random Access Protocol.

Multi Hopping Network: Involves 3 networking levels: between sensors and CCU, between CCU and base station, between base stations in medical centres. First wireless link: less than 10 m. Second wireless link: greater than 100 m Distribution of data to remote destinations is sent via internet. A low cost and reliable approach is preferred for transmission of data from sensor nodes to health care centre. Multi-hop transmission means that transmission of data through different hop to the main coordinator in Figure 3.

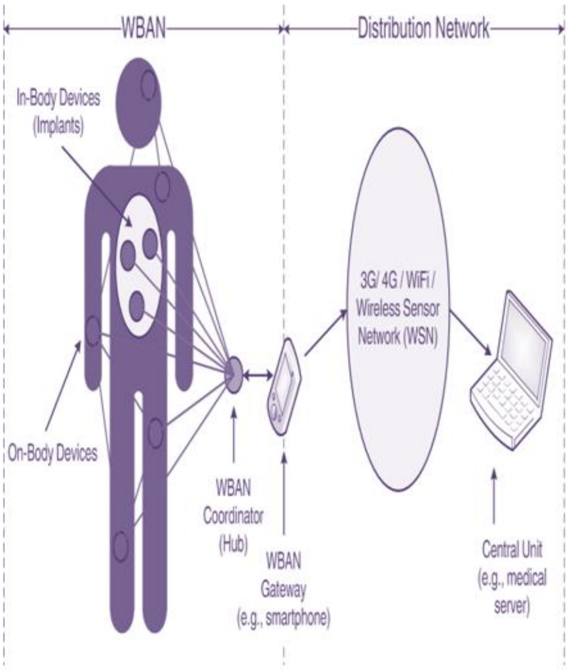

Fig. 3: *BAN Monitoring System.*

Sensor Node Design

Sensor nodes mainly undergo 3 tasks. They are detecting signal via front end, digitizing/coding/controlling, wireless transmission via radio transceiver technology.

First signal goes through amplification process to increase signal strength.

Second signal is passed through filtering stage to remove unwanted signal and noise.

Third signal goes through analog to digital conversion foe digital processing.

Now, digital signal is then processed and stored in microprocessor (microcontroller even). Micro controller will then pack that data and transmit over the air via transceiver.

Sensor nodes and CCU hardware designs: We develop our individual sensor nodes to detect and transmit the physiological signals. Characteristics of these physiological signals are obtained from the public domain available on the Internet. Most physiological signals have low amplitudes and frequencies in nature, and occupy a small information bandwidth [4–7]. At such low frequencies and low amplitudes, some problems inherent to circuits need additional attention. For a reliable information transfer it is necessary that the interface electronics in the sensor nodes detect the physiological signals in the presence of noise and increase the signal-to-noise ratio (SNR) of the detected signal for a better processing by the subsequent blocks of the sensor nodes. Sensor nodes are designed to be small and power efficient so that their battery can last for a long time. They collect the signals from a human body which are usually weak and coupled with noise. An amplification/filtering process is utilized first to increase the signal strength and to remove the unwanted signals and noise. Then an Analog to Digital conversion (ADC) stage is employed to convert the analog body signals into digital for a digital signal processing [8]. The digitized signal is processed and stored in a microcontroller. The microcontroller will then pack the data and transmit over the air via a wireless transceiver. Figure 4 shows the hardware implementation of our sensor nodes and the block diagram. In our system we designed sensor nodes that can measure up to four body signals for a single patient. One node is dedicated to one of continuous physiological signals such as ECC, EEG or EMG. Four sensor nodes electronics (i.e., 4-channel) are built on a common PCB board so that some electronics can be used interchangeably used for multiple patients monitoring, the first CCU type (CCU-1) can also be useful for private usage at patients' home or for a single patient monitoring in a hospital. It can receive the physiological signals directly from sensors without using the gateway CCU. The hardware for CCUs requires a microcontroller and a wireless transceiver to coordinate all the activities, similar to the sensor boards. The CCU-1/sensor nodes consist of a transceiver (AMI52100 IC) from AMI semiconductor used for the MICS band generation (we also used CC1000 in some sensor nodes to generate 433 MHz ISM and WMTS bands for sensors-CCU wireless connections) and the microcontroller-PIC16F887. In addition to these chips, we use another transceiver-the CC1010 chip from Chipcon (this chip contains CC1000 and a microcontroller built-in) on the intermediate CCU board (CCU-2) to obtain a wireless transmission and networking with the WMTS band [6, 8]. The CC1010 and CC1000 transceiver chips can be configured to transmit anywhere within 300 and 1000 MHz frequencies. They have been programmed to operate with one of WMTS bands in our prototype system. The wireless chips AMI52100 IC and CC1000 are selected in the project because of the following reasons: overall cost saving, low-power consumption, size, and the suitability of operating at the MICS, WMTS, and 433 MHz ISM bands. AMIS has a data rate capability of 19 kbps while device can connect with Internet wirelessly and thus will able to send data to the medical center for remote monitoring [4]. Meanwhile, the patient will have the opportunity to continue with his social activities.

REQUIREMENTS OF WBAN

- Types of devices (sensor node, actuator node, PD)
- Data rates
- Energy consumption
- Quality of service and reliability
- Usability
- Security and privacy
- Number of nodes
- Scalability (10kbps-10Mbps)
- Traffic heterogenties
- Topology
- Improving network lifetime parameters
- Range of 3 m at lowest mandatory rate
- Human safety

Data Rates

Due to strong heterogeneity of applications, data rates will vary strongly, ranging from simple data at few K bits to M bits.

Fitness Monitoring

ECG, pulse rate, blood pressure, respiration rate, body temperature

Insulin Pumps

Glucose level, bio-sensor, blood pH level, body temperature, humidity.

Energy Consumption

Sensing, Communication, Data Processing.

CONCLUSION AND FUTURE SCOPE

The workshop on body area networks is the latest in a long series of workshops and symposia organized by CWINS that have brought together leading figures in wireless technology to help shape the wireless industry at key points in its evolution. These began in 1991 with the world's first workshop on wireless local area networks (LANs), and include some of the earliest meetings on cell phone technology, Wi-Fi, and wireless geolocation. This will place a remark in medical applications and health care centers in future.

ACKNOWLEDGEMENT

The authors would like to thank the Management of MLR Institute of Technology and Global Academy of Technology for their support.

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