Wireless Sensor Network for Ubiquitous Health, Cardiovascular Fitness and Activity Monitoring

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***Abstract*: A prototype model for Cardio-vascular activity and fitness monitoring system using IEEE 11073 family, standards addressing the interoperability of personal health devices (PHDs), with a "real-time plug-and-play" wireless sensor network based on Zigbee for telemedicine monitoring system.The system mainly consists of the Body sensor networks for monitoring, acquiring and transmitting the patient's biomedical signals such as ECG, heart rate, blood pressure, temperature, and oxygen saturation, Hospital network, where patient's biomedical signals can be stored and the registered physicians can read the signals and diagnose, and Mobile cellular network, which transmits signals between the body sensor and the hospital network, and now globally available networks are GSM, UMTS, GPRS and 3G networks. To date, with the technological development of wireless technologies and wearable and embedded sensors, it becomes exceptionally easy to collect and transmit individuals' medical without disrupting their normal daily lives. In order to fully utilize these technologies, the real challenge lies in developing another network, wireless body area senor network (WBASN).Here a WBASN based on Zigbee technology is introduced.**

Keywords: Body sensor network, Mobile cellular network, PHDs, WBASN, Zigbee.

Introduction

The idea of Biomedical Sensor Network (BSN) is derived from a thought of mixing wireless technologies and advancements in the field of biosensors for assessment of physiological parameters offering the medical assistance to the person in need. The purpose of BSN, also called Body Sensor Networks, is to provide an integrated hardware and software platform for facilitating the future development of pervasive monitoring systems. It offer prompt feedback for efficient and reliable patient monitoring, disease management and promotes self-care.

Technological developments of sensing and monitoring devices are reshaping the general practice in clinical medicine. Although extensive measurement of biomechanical and biochemical information is available hospitals, the diagnostic and monitoring utility is generally limited to the brief time points and perhaps unrepresentative physiological states such as sedated, or artificially introduced exercise tests. Transient abnormalities, in this case, cannot always be captured. For example, many cardiac diseases are associated with episodic rather than continuous. Important and even life threatening disorders can go undetected because they occur only infrequently and may never be recorded objectively. With the emergence of miniaturised mechanical, electrical, biochemical and genetic sensors, and expansion in biosensor field along with wireless monitoring reduces the death rates.

Wireless Biomedical Sensor Networks (WBSN, for short), the convergence of biosensors, wireless communication and networks technologies, consists of a collective of wireless networked low-power biosensor devices ("motes" or "nodes"), which integrate an embedded microprocessor, radio and a limited amount of storage.

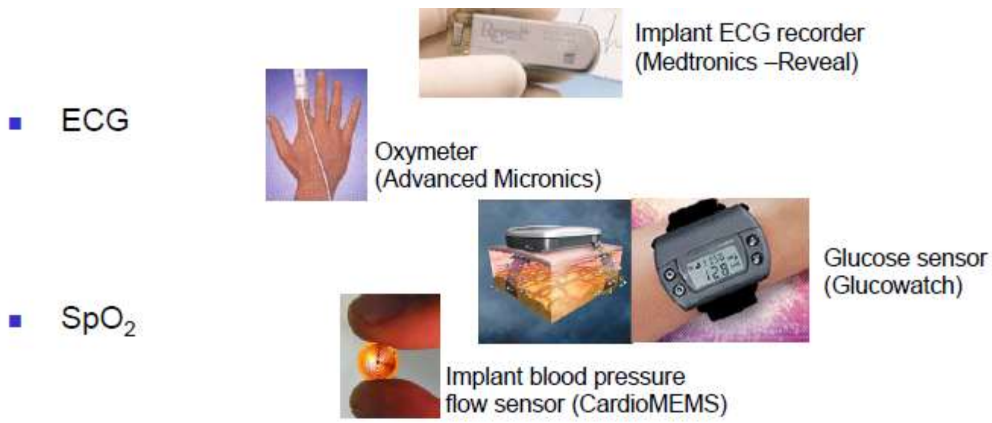
WBSN can wirelessly monitor patients' physiological signals (EEG, ECG, blood pressure, blood flow, pulse oxymeter, glucose level, etc.) by individual node or pill that is worn, carried or swallowed by the patients. It then alerts the healthcare professionals with the abnormal changes of patients' physiological condition, while delivering the data to a database system for long-term storage.

The biomedical sensor devices play a key role in the networks and they can be either external or embedded, either non-invasive or invasive. The development of biosensors compatible with conventional CMOS integrated circuit and non-invasive detection technologies enable the WBSN more feasible. These sensors, very small and inexpensive, lead to many applications in pharmaceuticals and medical care. Typically, there are following several kinds of physiological sensors that would augment WBSN applications:

a) The swallowed pills with wireless transceiver containing sensors that can detect enzymes, nucleic acids, intestinal acidity, pressure, contractions of intestinal muscle and other parameters, allow WBSN involved in the Gastrointestinal diseases monitoring in a non-invasive manner.

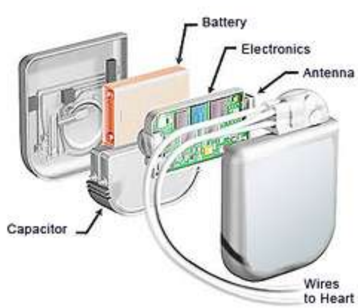
b) Wired sensors plus local wireless device —For instance, *wireless ECG* with several wired electrodes put on the chest to measure the potential drop, is able to continuously radio the patient's electrocardiogram to a sink node located on the arm or a waist-belt.

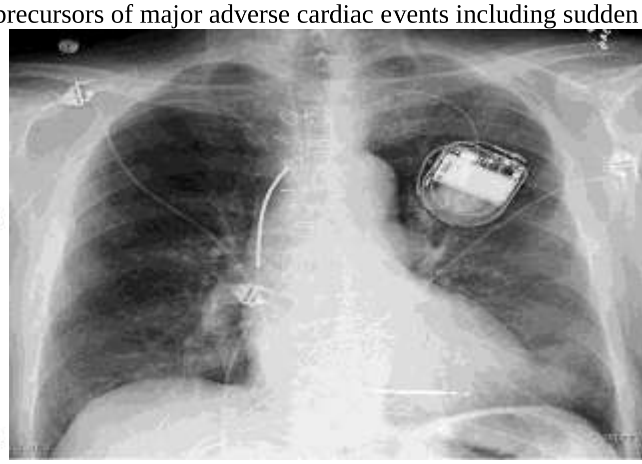
c) Nano-physiological sensors with wireless communication —the futuristic and exciting concepts, nano machines that are biodegradable are able to run through the bloodstream for monitoring physiological changes.



Fig(1)

In cardiology, the value of implantable cardioverter-defibrillator (ICD-Fig(2 &3)) has increasingly been recognized for the effective prevention of sudden cardiac death (SCD).It is possible to envisage a large percentage of the population having permanent implants which would provide continuous monitoring of the most important physiological parameters for identifying the precursors of major adverse cardiac events including sudden death.





Fig(2) ICD

Fig(3) ICD implanted inside patient's body

The primary goals of ISO/IEEE 11073 standards are to, firstly, provide real-time plug-and-play interoperability for citizen-related medical, healthcare and wellness devices; "Real-time" means that data from multiple devices can be retrieved, time correlated, and displayed or processed in fractions of a second."Plug-and-play" means that all a user has to do is make the connection – the systems automatically detect, configure, and communicate without any other human interaction."Efficient exchange of care device data" means that information that is captured at the point-of-care (e.g., personal vital signs data) can be archived, retrieved, and processed by many different types of applications without extensive software and equipment support, and without needless loss of information. Secondly, facilitate efficient exchange of care device data, acquired at the point-of-care, in all care environments.

BASIC CONCEPTS

The traditional concept of telemedicine services is to transmit biomedical information between a patient and hospital using public network Mobile telemedicine system generally consists of three networks: *a)* Body sensor networks for monitoring, acquiring and transmitting the patient's biomedical signals such as ECG, heart rate, blood pressure, temperature, and oxygen saturation, *b)* Hospital network, where patient's biomedical signals can be stored and the registered physicians can read the signals and diagnose, and *c)* Mobile cellular network, which transmits signals between the body sensor and the hospital network, and now globally available networks are GSM, UMTS, GPRS and 3G networks. To date, with the technological development of wireless technologies(wireless personal area network, wireless personal area, WiMAX broadband access and Bluetooth)and wearable and embedded sensors, it becomes more and more easy to collect and transmit individuals' medical data unobtrusively and ubiquitously without disrupting their normal daily lives. In order to fully utilize these technologies, the real challenge lies in developing another network, wireless body area senor network (WBASN).Here a WBASN based on Zigbee technology is introduced.

REQUISITES OF WBASN

In order to make a WBASN useful and practical, some requirements have to be fulfilled. These requirements are closely related to the specific application. ***Length of monitoring:*** The cardiac activity needs to be monitored for an extended period especially for people suffering from cardiac arrhythmia. Long-term analyses on ECGs are required to predict eventual heart attacks. The application must allow continuous monitoring. ***Biocompatibility:*** the shape, size and materials are restricted for the sensors that directly act on the human body. One of the solutions is to package the sensor nodes in biocompatible materials. ***RF radiation safety:*** the electromagnetic radiation must be strictly limited to meet the standards of patient safety. The IEEE and WHO have developed Radio Frequency exposure recommendations specifying near-field restrictions referred to as SAR between 10 MHz and 10 GHz. High power devices need to be tested and it's desired to implement ultra-low power transmission herein. ***Reliability:*** The reliability of measurements and message delivery to healthcare professionals is essential, due to potentially life-threatening episodes. ***Power Management:*** For the purpose of long term monitoring and minimum interference, it is desirable for nodes to minimize their transmit power to achieve acceptable connectivity. Energy aware protocol would allow nodes to negotiate their transmission power to a minimum. ***Time synchronization:*** Each sensor runs at its own clock and has a different sample frequency. Consequently time synchronization between sensors is needed. ***Message delivery:*** vital signs are delivered within a certain time determined by the level of emergency. The architecture should allow real-time delivery of emergency vital signs for both indoor and outdoor environments. Messages carrying emergency vital signs require minimal delays. ***Frequency of signal transmission and the amount of information:*** Important questions are how often data has to be transmitted and how much data. In our application the physiological data is acquired for an extended period (8 hours for example) and downloaded to the base station in real time The system ensures periodic transmission of routine vital signs and immediate transmission of emergency messages. The application data traffic is determined by the sample frequency and digitization method. ***Buffer management:*** In the outdoor environment, the routine vital signs are stored. Buffering data may result in a buffer overflow due to capacity limitations. This may lead to data loss or temporal application termination. ***Scalability:*** The architecture should scale well in terms of the number of patients and the number of sensors on each patient.

ARCHITETURE

The detailed study of working of each major nodes present in the health care monitoring system:

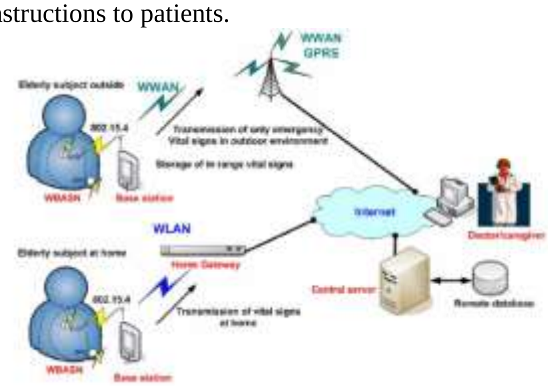
The sensor nodes: Sensor nodes sense[1],process and communicate vital signs. They store acquired data and transmit hem to the base station before their memory fills. The sensors consist of an ECG and a pulse oximeter. The ECG sensor monitors the heart electrical activity. Pulse oximeter accesses blood oxygen saturation and heart rate.These parameters are critical information in emergencies. In such situations, a reduction in blood oxygenation or sudden change in heart rate can indicate a need for urgent intervention. A GPS sensor can also be used outdoor to track the subject location in emergency cases.

The base station or central control node: The base station is a Personal Digital Assistant PDA. It is carried by the patient and communicates with sensor nodes via a Network Coordinator. The wireless communication is based on the IEEE 802.15.4 standard and the Network Coordinator is attached to the base station. To communicate with the central server, the base station employs a WLAN to reach an Internet access point (e.g., a home gateway). The base station acts as a local processor: It allows to collect, present and analyse sensor signals. It can store the collected data before uploading it to the central server. It must ensure periodic transmission of routine physiological data and immediate transmission of emergency data

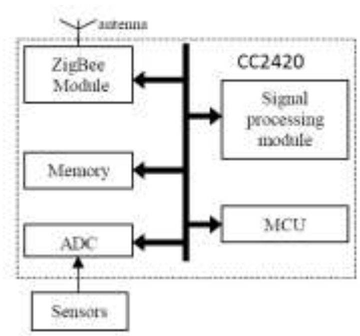
The central control node is implemented by the ZigBee[3] coordinator, which is responsible for managing the sensor nodes within the same WBASN and for transmitting information (includes biomedical information, control information, etc) from the WBASN to a mobile cellular network(such as GSM and 3G networks), or vice versa. The control node can also be regarded as a network access point, acting as a bridge or a router for the WBASN to visit a mobile cellular network. In future development, the central control node can be embedded into a mobile phone. Through the keys on a mobile phone, some control instructions are expediently sent.

When the patient leaves home, the base station detects the absence of WLAN beacons and switches to the outdoor environment operation mode. In such environments, it analyses the collected physiological data, stores the in-range vital signs locally, and initiates uploads when the subject is back within the home network coverage. If an abnormal condition is detected, it sends immediately the emergency vital signs to the central server over a GPRS(g1 gprs sim card) network. The level of emergency is determined by comparing the current values of vital signs to the patient specific thresholds.

The central server: The central server performs central data storage. It receives the sampled physiological data and stores it to the database. As mentioned above, this enables doctors to do long-term analysis and predict heart attacks or other life threatening conditions. The central server keeps also electronic medical records of patients and contacts emergency care givers if a serious health anomaly is recognised. Furthermore, it forwards doctors and caregivers instructions to patients.



Fig(4) Health care monitoring system



Fig(5) block diagram of wireless body sensor node

Wireless Sensor Nodes

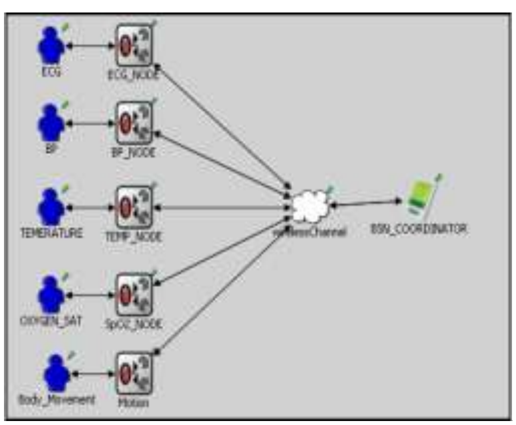
Wireless sensor nodes include the three-lead ECG sensor, and the pulse sensor. With development of micro electro mechanical technology, some of the sensors can being corporated into one sensor collecting several types of biomedical information. The wireless sensor node of the proposed network consists of biosensor, analog to digital converter (ADC) module, signal processing module, microcontroller, memory unit, Zigbee communication module and antenna. Fig(5) describes the major components of the wireless sensor node. Except the biosensor and the antenna are peripheral module, the others are included in CC2420.

The sensors in a node are in charge of collecting original biomedical signal. Commonly the original biomedical signal amplitude and its ratio of signal to noise are too low to satisfy the A/D conversion circuit. Therefore, before being sent into ADC, the biomedical signal is filtered and amplified. For
acquired ECG signal, an operational amplifier is adopted in the network node. The amplifier gain is in the range 500-1000, and its lower and the upper cut-off frequency are respectively 0.5 Hz and 100Hz. A notch filter is used to reduce the 50Hz power line interference.

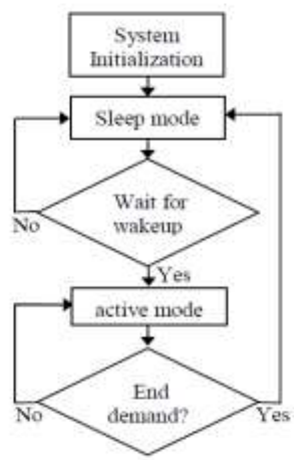
The ADC module of CC2420 has eight analog input pins which can be configured into eight single-ended inputs or four pairs of differential inputs. For the ECG signal, differential
input can perform better than single-ended inputs. The three-lead ECGsignals are digitized by a 12-bit analog to digital convert at 250samples per second. The other two input pins are supplied toheart rate sensor, and the pulse oximeter.

Storage unit has 32, 64 or 128kb flash memory and 10kbRAM to be chosen. Controlled by the MCU, the data from theADC can be temporarily stored in the storage unit and thentransmitted to the central control node through the ZigBee module if necessary. The source codes of control and signalprocessing programs are loaded into the storage unit.

The central processing unit (CPU) of MCU is the enhanced8051 core which uses the standard 8051 instruction set. The CPU has 18 interrupt sources. Each interrupt requested by the corresponding flag can be individually enabled or disabled. interrupts are grouped into a set of priority level groups with selectable priority levels. The signal processing module is designed to check some potential and unconspicuous symptoms (such as hypertension)at the sensor node without physician appearing through body temperature, blood oxygen or the pulse, body temperature, blood pressure. The module is carried out by a set of codes which are programmed in advance and loaded into the CC2420. Once the values of blood oxygen saturation, heart rate or pulse, body temperature, blood pressure collected are beyond normal range, an interrupt signal is automatically produced to the MCU and then wake up the zigbee module. So the biomedical signals including heavy-data ECG signal can be in time sent to a hospital etwork. CC2430 can be used together with various types of antennas. A differential antenna like a dipole would be the easiest to interface.



Fig(6) Wireless sensor nodes



Fig(7) Work flowchart of WBASN

Working Flow

Though the object of the proposed wireless sensor network is to monitor potential patient and to routine check up, it is unnecessary to keep unremittingly transmitting information between the wireless sensor node and the central control node. Therefore,it might reduce much power consumption that ECG signal is not acquired, stored and transmitted if not necessary. CC2420uses different operating modes to allow low-power operation. Using these operating modes, the Zigbee module can work in a way of “Wake up On-demand” in order to reducepower consumption. During most time, the ZigBee module is at sleep condition during which sensor nodes monitor wireless channels at low power consumption. Zigbee module can be activated once one of the following wakeup events appears: *a)* When the patient does not feel well and actively asks for being checked, he/she sends a wake-up instruction to the central control node through which wake-up instruction is transferred to sensor node in the same WBASN; *b)* When the patient’s physician asks to get some biomedical information, he/she sends a wake-up instruction to the

WBASN over cellular network; *c)* When the sign data acquired by sensor is not normal, the signal processing module in wireless sensor node can automatically produce a wake-up instruction. For example, body temperature is beyond the normal value. At the same time, the node produces an alarming message to the patient. *d)* Send any biomedical data to physician at regular time intervals for mentoring patient and routine checkuping. The interval time depends on different patients. For intensive care patient, the period had better be set as a shorter time. The wakeup event can achieve by a sleep timer in CC2420.

In sleep mode, most internal circuits are powered down and external interrupts, 32.768 kHz oscillator and sleep timer peripherals are active. I/O pins retain the I/O mode. ECG signal acquiring circuit is turn off and other acquiring circuits go on working. At the same time, the sensor nodes keep monitoring wireless channels at low power consumption so that the wakeup instructions from the central control node can be received in time. In active mode, all modules are active and the biomedical signals mentioned above are acquired, stored and transmitted. The communicating progress does not stop until the sensor node receives an end demand. The end demand can be produced by: *a)* physician who has gained much biomedical signal enough to diagnose. The physician sends an end demand over cellular network to the WBASN as sending a wakeup instruction; *b)* patient; *c)* an interrupt signal which automatically produce when a fixed and preset time is used up.

CONCLUSION

Currently, there are intensive activities worldwide on applying Information and Communication Technologies in a more active and direct way to support medical and healthcare services. BSN solutions are now ready to enter into the harsher world of commercial applications from the soft academic research environment. It is expected that IEEE standards like Body Area Network (IEEE 802.15.6), ZigBee (IEEE 802.15.4) and Cardiovascular Activity and Fitness Monitor (IEEE 11073-10441) will surely lead to the development of cost effective personal health devices for millions of people.

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