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The Development of Wireless Sensor Network for ECG Monitoring

Jun-Liang Lin, Hsien-Chieh Liu, Yu-Ting Tai, Hsin-Hsien Wu, Shuo-Jen Hsu, Fu-Shan Jaw, You-Yin Chen*

Abstract— **The main problem we want to solve contains two subjects: The first one is the patient's pressure due to wired physiological signal estimation. With wireless sensor network technique, patients only need to carry a few small nodes, and then the physiological signal can be transmitted in the air. The other subject of the vital problem is that some protocols, like Bluetooth, provide a peer to peer wireless communication technique, but such peer to peer network may need a complex algorithm to find the best data transmission path. In this study, we use the hierarchy routing as network topology that three-layer architecture contains PAN coordinator, router and device. The study focuses on implementation of a prototype electrocardiography (ECG) system which replaces wired connections between sensor points and a central node with wireless links. Successful implementation of the final system would be of benefit to all involved in the use of ECG as access to and movement of the patient would not be impeded by the physical constraints imposed by the cables. Most aspects of the design would also be portable to other sensor applications, making the work relevant to a vast range of systems where movement of sensors is desirable and constrained by hard-wired links.**

I. INTRODUCTION

Due to progress of the time is so fast, everyone has very high pressure on life or job. The pressure will affect the quality of health. The barrier of sleep contains a lot of factors that contains pressure, posture of sleep and others. These are good issue for researching and analyzing. Recently, heart monitors are used to determine existing and to help predict impending problems of health. They are also being used in hospitals or home for monitoring patients during sleeping. With the increasing use of electrocardiograph (ECG) monitors, it is anticipated that such instruments will be used in determining other health related issues. However, existing ECG monitoring systems are relatively bulky and hence are less portable. This bulkiness is due to electronics involved in obtaining high quality signals from the confounding effects of patient movement and electrode attachment artifacts. Also, patients are confined to remaining near the ECG Monitoring machine as they are attached to the ECG monitor via the leads. The entire process of obtaining ECG signals from patients can be greatly eased with the use of portable system that allows remote monitoring. As a result, a wireless ECG monitoring system solution is required where the system would be used without compromising functionality or quality. The idea is to replace the leads used in normal ECG monitoring system with a wireless solution.

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*Y. -Y. Chen is with the Department of Electrical and Control Engineering, National Chiao-Tung University, Hsinchu, 300 Taiwan, R.O.C (corresponding author to provide phone: 886-3-513-1233; fax: 886-3-571-5998; e-mail: irradiance@so-net.net.tw).
H. -C. Liu and F. -S. Jaw are with Institute of Biomedical Engineering, National Taiwan University, Taipei 106, Taiwan, R.O.C.
J. -L. Lin, Y. -T Tai, H. -H. Wu and S. -J. Hsu are with the Department of Electrical and Control Engineering, National Chiao-Tung University, Hsinchu 300, Taiwan, R.O.C.

II. MATERIALS AND METHODS

The proposal system acquires ECG data from the sensor nodes and sends this over a wireless link to the PC and displays the ECG signal on an application program designed by the team. The system is divided into three parts, ECG sensor with wireless transmission device, CMX real time operating system, and implementation of ZigBee protocol stack.

A. System Design

We develop a wireless sensor network system using ZigBee that is under IEEE 802.15.4 wireless protocol [1], which focus on sensor network, control and health-care related applications. The wireless sensor network is to use tree layers of network architecture and hierarchy routing as shown in Fig.1. The sensor node, which contains an ECG sensor, micro-controller unit (TI MSP430, USA) and a RF chip (UBEC UZ2400, Taiwan), will select the shortest distance in personal operation space (POS) and the minimum number of associated device of router to join automatically. When device has joined a router, it will convert analog signal to digital with analog-digital converter (ADC) and store the result of conversion to ring buffer. In order to reduce transmission overhead of RF chip, we do not send result to router immediately when conversion has been completed. Instead, we store result in ring buffer immediately when conversion has completed, the device will send result of conversion to associated router when timer has expired. When router receives a data from device, it will send data to associated PAN coordinator immediately

and the PAN coordinator will send it to UART. The UART of PAN coordinator is connected with UART of personal computer (PC). We develop an application program to receive data from UART and store it to database (SOL server, MS, USA) using open database connectivity application interface (ODBC API). The system structure is shown in Fig. 1, which contains 3 patients in a net, the user (professional medical personnel) can monitor the ECG waveform vie the internet.

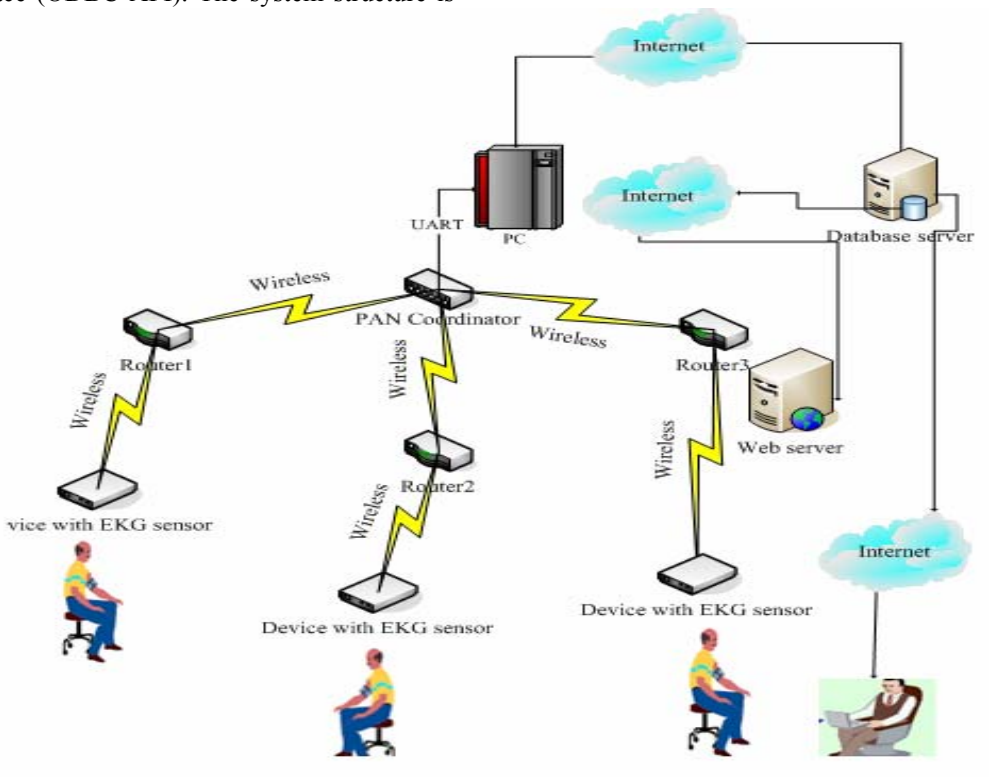

Fig. 1. Topology for wireless ECG sensor network

B. ECG sensor

Electrocardiogram (ECG) is the electrical activity of heart. Because ECG is very small signal, at the range of a few mV (usually less than 10), it is often interfered by the 60 Hz noise induced by the power line or human body. In this case, we know that signal conditioning is very important for bio-potential measuring the best-fitting conditioning for the bio- potential signal can make it very simple to do the further signal processing. Therefore, it is necessary to employ an instrumentation amplifier which is performed as a differential input stage [2], to reduce he 60 Hz noise and to amplify the ECG signal we are interested in. Then, we filtered the low frequency DC noise by a low pass filter and amplify the signal by a gain and filter stage. Faults often occurs that the output waveform is very sensitive to the motion like breathing and even slightly moving of human body, so it is necessary to add an anti motion-artifact stage to avoid the signal from motion artifact. For the need of clearer signal with fewer 60 Hz noise interference on the baseline of ECG waveform, we apply a Driven Right Leg circuit [3], [4] to lower the 60 Hz noise. These four stages mentioned above are shown in Fig. 2.

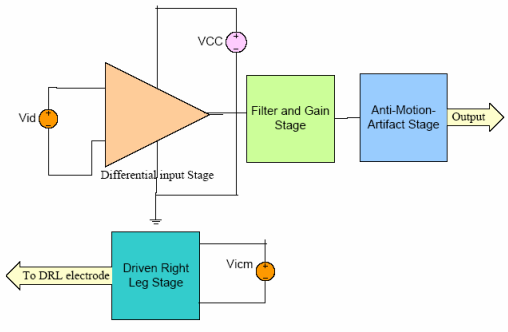

Fig. 2. System block diagram of ECG Sensor

C. Introduction and implementation of ZigBee

The ZigBee protocol stack is shown in Fig. 3, the IEEE 802.15.4 standard defines the lower two layer: physical (PHY) layer, and the medium access control (MAC) layer. The PHY layer operates in two separate frequency ranges: 868/915 MHz and 2.4 GHz. We use the 2.4 GHz in this paper. And medium access control (MAC) layer is responsible for accessing to the radio channel using a CSMA-CA mechanism, transmitting beacon frame, synchronization and providing a reliable transmission mechanism. The ZigBee alliance builds on this foundation by providing network (NWK) layer, and application (APP) layer. The NWK layer is responsible for implementing a mechanism, which is used to join and leave a network, it also provide discovery and maintenance of routes between devices devolve to the NWK Layer. And the last one is application (APP) Layer."

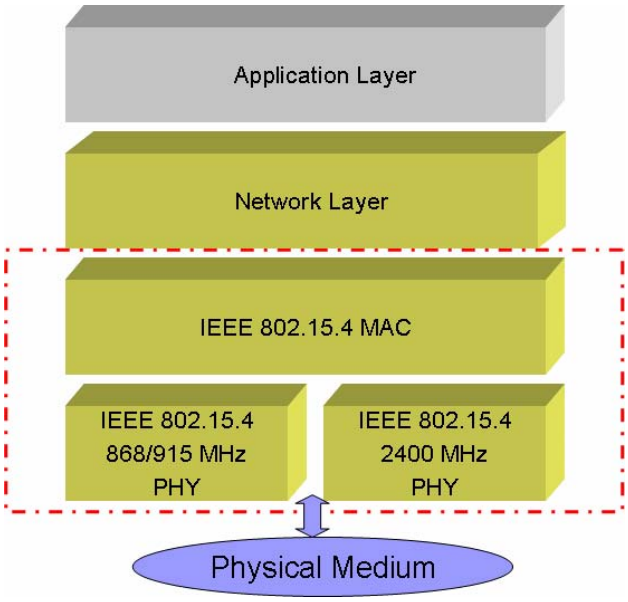

Fig. 3. ZigBee protocol stack

The system uses an Operating System (OS) named CMX Tiny real time multi-tasking operating system, which is to provide a true preemptive operating system and wide range of functions and to use little RAM as possible. We ported CMX Tiny real time multi-tasking operating system on the TI MSP430 platform and the RTOS supports a lot of kernel functions to handles interrupt, timer, task schedule and resources management of hardware (Fig. 4). First of all, the firmware system will do initialization of Universal Asynchronous Receiver/Transmitter (UART), serial peripheral interface (SPI), micro-controller unit (MCU) and medium access control (MAC) and then create three task, timer task, ISR task and system task. Finally, start these tasks.

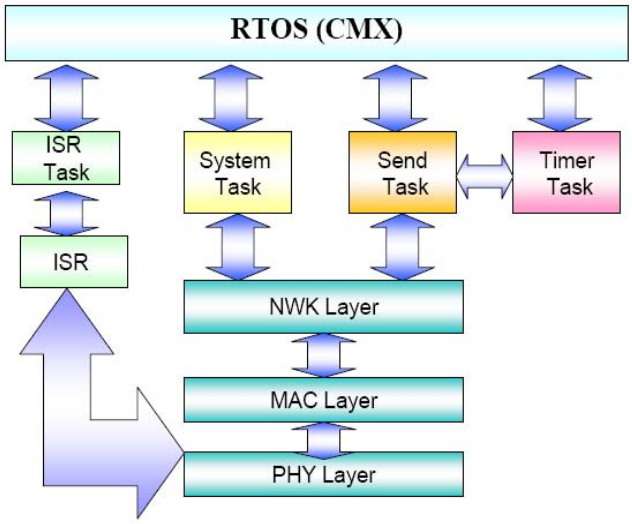

Fig. 4. Firmware architecture based on CMX tiny real time multi-tasking operating system.

III. RESULTS

The design of the ECG sensor circuit was successful as can be seen in Fig. 5 which shows an ECG signal on the oscilloscope. Filtering and Compression techniques were used to remove unwanted noise. The size of the wireless ECG sensor node is acceptable as it can easily be placed on a patient without too much discomfort.

The ZigBee protocol stack implementation on the TI MSP430 is functioning properly with the packet format. Furthermore the system has been created using the Operating System (CMX real time operating system). This not only provided the platform by which our threads can execute, but it also is very useful in performing the requirements of the ZigBee protocol.

We have implemented a wireless sensor network which can be used to do remote ECG monitoring. We can view the patients' ECG data from the remote webpage (Fig. 6), this achieves the essence of telemedicine. In the prototype of our system as shown in Fig. 7, the result waveform viewed from the webpage is identity form the waveform of the ECG sensor, there is a comparison between the oscilloscope waveform and the webpage waveform in Fig. 5 and Fig. 6. This illustrates the reliability and correctness of our system. This system can provide convenient interface for the end user (professional medical personnel or even the patient) to monitor the physical situation.

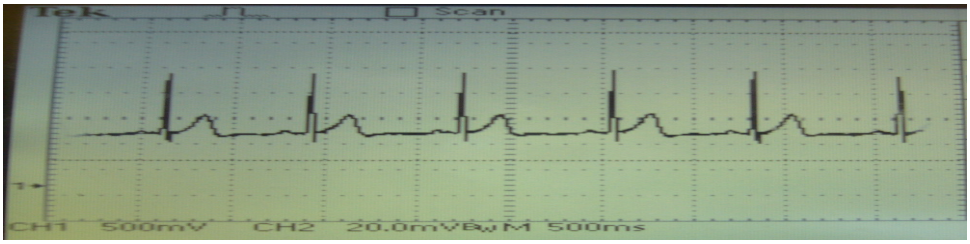

Fig. 5. ECG waveform shown by using oscilloscope

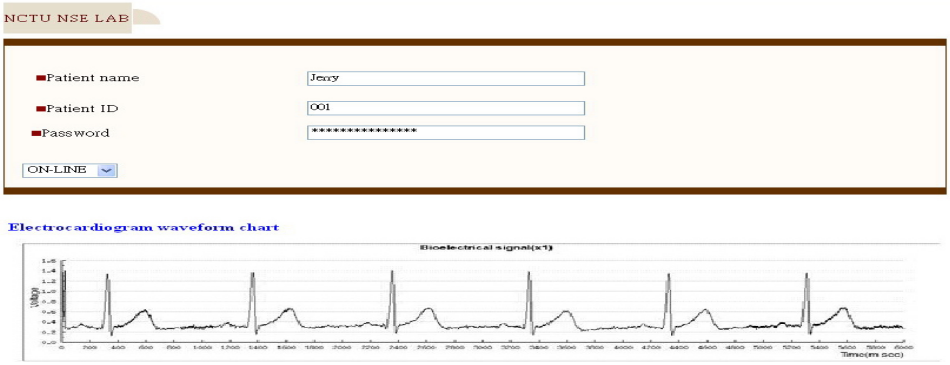

Fig. 6. The ECG result shown on the remote webpage

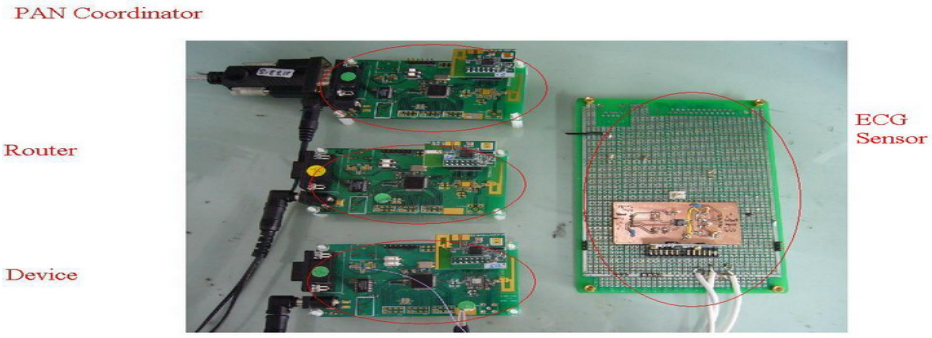

Fig. 7. The completed prototype of wireless ECG monitoring system.

IV. DISCUSSIONS AND CONCLUSIONS

The wireless sensor network can be used in health-care, and home-care related applications. The system supports self-network capability, remote monitoring and controlling. It also allow additional sensor node to join the wireless sensor network, such as SPO_2 sensor, blood pressure (BP), heart rate (HR) and related sensors. In router part, when wireless sensor network become larger, data transmission and receiving through router will also be larger, and data may stuck at router. In future, we can develop a bridge which contains two RF chips, one for receiving only and the other for transmission only to solve stuck problem. Also, we can apply relative location estimation technology in our system in order to get position of patient indoor. The doctor will get more information about patient for health-care.

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