

# Wireless Gateway Recorder Supporting Medical Information Exchange between Zigbee Nodes and Bluetooth Devices

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## ABSTRACT

Nowadays more and more wireless technologies are introduced gradually to make health care more intelligent and portable. Particularly, Wireless Body Area Network (WBAN), which can collect and gather physiological data of the human body, plays an important role in realizing real-time monitoring and home health care. However, the single wireless technology inevitably exists shortcomings which may limit the application range of wireless technology in the medical care. Therefore, we designed the wireless gateway recorder which supports medical information exchange between Zigbee nodes and Bluetooth devices. As the hinge of Zigbee network and Bluetooth network, the wireless gateway recorder can take advantages of two kinds of wireless technologies. In this way, the application scope of wireless technology can be expanded in the medical care. In addition, the design provides storage function which means the data from WBAN can be stored in the Micro SD card of wireless gateway recorder. In the paper, we tested the feasibility of the design and applied the wireless gateway recorder in different scenarios of medical care. Test results show that the system works normally.

## Keywords

Zigbee, Bluetooth, WBAN, Gateway function, Storage function

## 1. INTRODUCTION

In recent years, ageing population and health issues are widely concerned around the whole world. More and more people focus on the medical care services. So some novel technologies are introduced into the medical care field, wireless technologies in particular. Wireless sensor network (WSN) is one of the most popular wireless applications. Kinds of sensors are gathered to collect multiple physiological data of human beings in the WSN. Body Sensor Network or the Wireless Body Area Network

(WBAN) <sup>[1]</sup> is a specific application in the health care. In WBAN, small and intelligent medical sensors can be worn on, around or implanted in the human body to monitor human's physiological activities and actions, such as health status and motion pattern.

Zigbee technology is one of the preferred technologies in both wireless sensor network and WBAN. As a new and low power consumption wireless technology, Zigbee has been regarded as the most likely been used wireless technology in industrial monitoring, sensor networks, family monitoring and surveillance security system <sup>[2][3]</sup>. However, since there is no unified standard leading to no mobile terminal with Zigbee function, a wide range of promotion of Zigbee is limited.

While Bluetooth <sup>[4]</sup>, another short distance wireless technology, has been well-developed for years. Mobile terminals with Bluetooth communication function are already used in different fields. But the number of nodes which the Bluetooth network contains is too little to meet the needs of WBAN.

So what if we combine the two technologies together? The benefits are profound if the combination of these two technologies is realized. A gateway which integrates Zigbee and Bluetooth can achieve the goal of combination. In this way, the advantages of two kinds of wireless technologies can be better applied in the medical care. Given the certain condition, there may be no Bluetooth device around to be connected. So the existence of gateway which just implements the physiological data forwarding is meaningless sometimes. In order to adapt to a wider range of application scenarios, adding storage function on the gateway is equally significant.

Hence, we proposed the design of wireless gateway recorder which combines Zigbee and Bluetooth technology. First, the design can realize heterogeneity of Zigbee network and Bluetooth network. This function can make best of two wireless technologies which contributes wireless medical and mobile medical in health care system. Second, it can also store physiological data in the Micro SD card on the basis of the gateway function. Applying to the medical care environment, the wireless gateway recorder acts as the hinge of Zigbee nodes and Bluetooth devices. The physiological data can be transmitted between WBAN and Bluetooth devices wirelessly. In the meantime, the data can also be stored in the wireless gateway recorder as required.

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This paper is organized as follows. In Section 2, the implementation method of wireless gateway recorder is given from gateway function and storage function respectively. In Section 3, we applied wireless gateway recorder into the health care environment completing the test and application. And the future work is referred in Section 4.

## 2. MATERIALS AND METHODS

Figure 1 shows the structure diagram of wireless gateway recorder, which includes Zigbee module, Bluetooth module, storage module and power management module. Zigbee module establishes Zigbee network with Zigbee nodes while Bluetooth module implements Bluetooth connection with the Bluetooth devices. The above two modules communicate with each other in the application layer through UART serial port. Through SPI with Zigbee module, the storage module stores all kinds of physiological data from Zigbee nodes. The power management module powers up the entire wireless gateway recorder and it can fulfill the charging function as well.

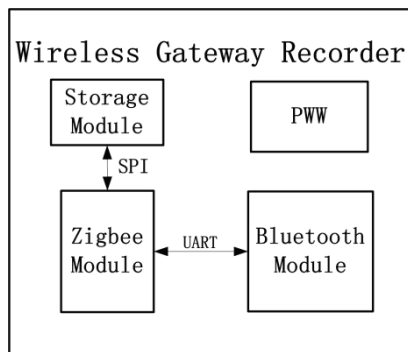


Figure1 Structure diagram of wireless gateway recorder

The wireless gateway recorder has two main features. First is the gateway function, which can convert protocols between Zigbee and Bluetooth. Second is the storage function, which can store physiological data in the Micro SD card. In this paper, we implanted the FAT32 file system to achieve the sorted storage.

### 2.1 Gateway Function

When it comes to the gateway function, Zigbee function and Bluetooth function must be achieved separately in the first place. Here we illustrated the two functions from two aspects: hardware and software.

#### 2.1.1 Hardware Implementation

Zigbee function is realized by Zigbee module. Zigbee module is achieved by CC2530 which is a new generation system-on-chip (SOC) chip launched by Texas instruments (TI). As a real SOC solution, CC2530 is integrated with industry standard 8051 MCU, high-performance RF transceiver, system programmable flash memory, 8 KB RAM and 32/64 KB optional flash version. CC2530 still supports other powerful functions and peripherals including two USARTs, 12 bit ADC and 21 general GPIOs [5]. It can be widely used in remote control, consumer electronics and home control, measurement and intelligent energy, building automation, medical care, etc [6][7]. In addition, the peripheral circuit of CC2530 chip is simple which includes the filter circuits, crystal circuits and RF circuits. In RF circuits, balun matching circuit must be introduced when using the non-equilibrium F antenna. Considering the stability and size, this paper used the TI company's 2450BM15A0002 chip which is specially used to

implement CC253x series RF chip input and output matching.

As to the Bluetooth function, it is realized by BlueCore4 chip from CSR company. The chip provides 48 KB RAM and three times faster data transmission rate than the v1.2 Bluetooth device and it makes the Bluetooth mobile phone's power consumption much lower. Besides, BlueCore4 is fully compatible with the existing Bluetooth v1.1 and v1.2 device. As Bluetooth technology has been very mature now, many commercially standard Bluetooth modules are available. In order to shorten the development cycle, the design used BTM0604C2P [8] standard Bluetooth module to realize the Bluetooth function.

The gateway function is achieved through Bluetooth module and Zigbee module communicating with each other via the UART serial port. Because standard Bluetooth module is chosen in the paper, we only need to configure Zigbee module's UART serial port. The design chose CC2530 USART1Alt1 and the corresponding specific I/Os are P0.2 (CTS), P0.3 (RTS), P0.4 (TXD) and P0.5 (RXD) respectively.

#### 2.1.2 Software Implementation

Software implementation should be finished separately as well as hardware implementation.

First is the Zigbee function on the basis of hardware. Zigbee network has three types of logical devices including coordinators, routers and end devices. Among them, the coordinator is the exactly one which is responsible for establishing and maintaining the network. The router has relay function which can select data transmission path and then forward data. It is relatively simple of the end device which just sends and receives data.

In the wireless gateway recorder, Zigbee module acts as the coordinator to construct WBAN. In the paper, Z-stack from TI is embedded into CC2530 chip to reach the goals including establishment and maintenance of network, division of time slot, channel access control, collecting and forwarding data to the Bluetooth module. Zigbee coordinator flow chart is shown in figure 2. After completing the system initialization, the Zigbee coordinator constructs a new Zigbee network. Then the network enters into the state of wireless monitoring to check if any wireless signal exists. If there is one Zigbee node applying to enter the network, the coordinator will assign the short address to the node. When the coordinator receives the physiological data from the Zigbee node, the AF\_INCOMING\_MSG\_CMD event will be triggered. And then the coordinator starts to deal with these data in the zb\_ReceiveDataIndication function. The data has two directions: transmission via UART serial port to the Bluetooth module and storage via SPI to the Micro SD card.

In the design, the Bluetooth module is implemented by a standard module. We just need to configure the module in according to the manual provided by the company. The configuration includes device name, device type, serial port parameters, energy saving parameters, etc.

The software implementation of gateway function is mainly achieved in the application layer via UART serial port in the program. In the paper, we chose interrupt mode and set baud rate to 38400 to realize the serial communication.

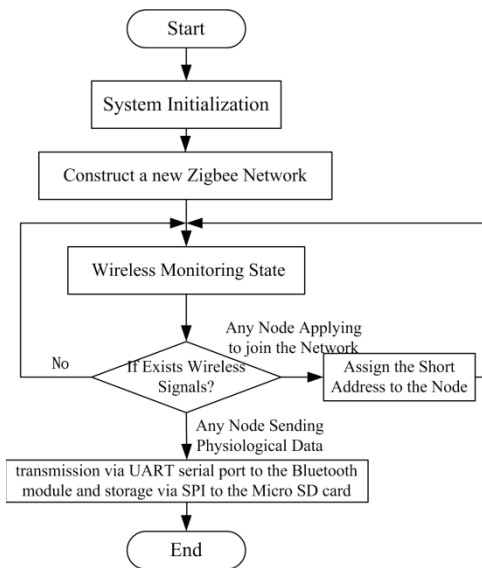


Figure2 Flow chart of Zigbee coordinator

## 2.2 Storage Function

2G Kingston Micro SD card is picked up to realize the storage module. The Micro SD card connects with CC2530 chip via SPI port. The design chose four-wire<sup>[9]</sup> connection which is USART0 SPI Alt2<sup>[10]</sup> of CC2530. The corresponding I/Os are P1.2 (SS), P1.3 (CS), P1.4 (MISO), P1.5 (MOSI) respectively. FAT32 file system is also implanted to sort and store data.

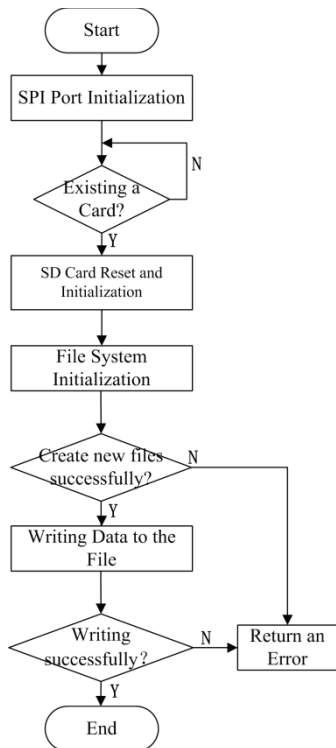


Figure3 Flow chart of file system

After configuring the SPI port, resetting and initializing Micro SD card, the file system can be initialized. File system initialization includes loading device number, sector numbers occupied by FAT table, the root cluster number, bytes per sector, sectors per cluster, etc. when initialization is finished, physiological data can be stored in different documents. As shown in figure 3 is the file

system implementation flow chart.

The file system can achieve the following functions: opening the root directory of the SD card, opening deep directories of the SD card, generating the file, writing data to the file, reading data in the file and closing the file. When the wireless gateway recorder applies to medical care, users can implement classified storage of data according to their needs. They can store the data based on patient type or physiological data type.

## 3. RESULTS

### 3.1 Performance test

#### 3.1.1 Transmission distance test

Since both Zigbee technology and Bluetooth technology are short-range wireless communication technologies, normal communication should be conducted within a certain distance. Before applying the design to specific application environment, the transmission distance has to be tested to ensure the normal work.

The method to test the transmission distance of Zigbee is fixing the wireless gateway recorder in one place and moving another Zigbee node. Through the button-and-light way to observe the Zigbee wireless communication, thus determine the transmission distance. For the way of Bluetooth transmission distance test, we insert a Bluetooth adapter on the PC, move wireless gateway recorder and observe the light which indicates the wireless connection between the wireless gateway recorder and PC.

In the condition of barrier-free laboratory, Bluetooth transmission distance is about 10 meters which is up to the Bluetooth transmission standard. However, Zigbee transmission distance is only 10 meters which is far shorter than the Zigbee transmission standard. The main reason may be that the PCB antenna is hand-painted, so there must be a certain deviation. However, since the design is applied to WBAN which is always around the patient, 10-meter distance can meet the demand.

#### 3.1.2 Maximum transmission rate test

The wireless gateway recorder mixes Zigbee network and Bluetooth network. The transmission rate of Bluetooth network can reach to 2Mbps which could completely meet the needs of medical care. Therefore, the test is mainly in view of the Zigbee network. The specific test methods are as follows: one Zigbee node collecting data through ADC establishes Zigbee connection with wireless gateway recorder. The Zigbee node sends the collected data to the wireless gateway recorder and the recorder stores the data into the Micro SD card. The maximum transmission rate of Zigbee network is tested through changing sampling rate in the program. Experimental results show that when the ADC sampling rate is 200 Hz and the transmission rate is 1.6 Kbps, observing data in the Micro SD card that no data is lost. When the ADC sampling rate is 250 Hz and the transmission rate is 2Kbps, no data is lost as well. When the sampling rate is up to 500 Hz, data lost is found as shown in the figure 4. The transmission rate is relatively low. Analyzing the reason, the wireless gateway recorder is inserted Micro SD card and implanted FAT32 file system. The processing capacity of CC2530 in the wireless gateway recorder is occupied, thus limiting the Zigbee transmission rate. But the current transmission rate basically meets the requirement of dealing with a single node transmitting data.

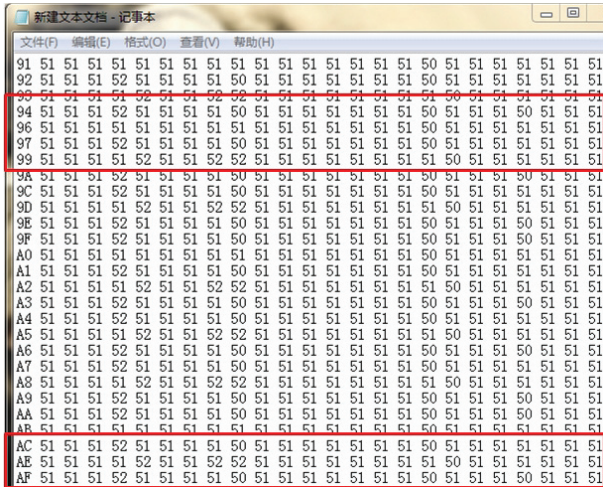


Figure 4 Micro SD card data capture when sampling rate is 500 Hz

### 3.2 Application scenarios

The design of wireless gateway recorder aims to better use wireless technology in medical care applications. Hence, we chose blood oxygen node, ECG node and thermometer node as Zigbee end devices, Zigbee module in wireless gateway recorder as Zigbee coordinator to form the Zigbee star network. As shown in Figure 5 is the real objects of above. The star network which realizes WBAN must exist to realize physiological data acquisition. While Bluetooth devices are not always available in the system under some situation. So this paper presents two kinds of application scenarios: Bluetooth connection is not established and Bluetooth connection is established.

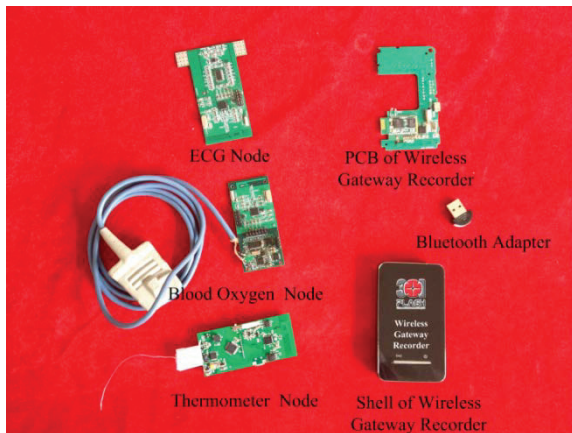


Figure5 Real objects of system

#### 3.2.1 Bluetooth connection is not established

The Bluetooth module in wireless gateway recorder wirelessly connects with Bluetooth devices. The Bluetooth devices can be personal computers (PC), the personal digital assistants (PDA) and smart phones. In the paper, the PC is chosen to achieve Bluetooth connection with the wireless gateway recorder. When the Bluetooth device is not available as shown in figure 6, the wireless gateway recorder doesn't need to implement the Bluetooth connection. In this situation, the wireless gateway recorder just gathers and stores data without realizing gateway function. Zigbee end devices collect physiological data and send it to the wireless gateway recorder through Zigbee technology wirelessly. All the

data including data from the ECG node, blood oxygen node and thermometer node is stored in the Micro SD card of wireless gateway recorder.

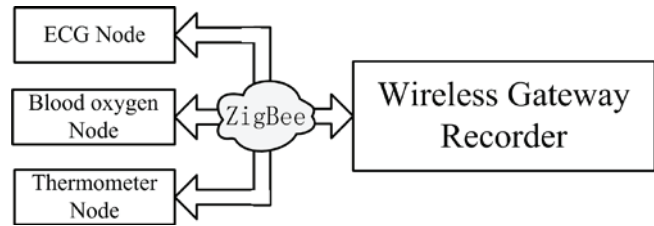


Figure 6 Block diagram when Bluetooth connection is not established

#### 3.2.2 Bluetooth connection is established

When the PC is available as shown in figure 7, there are two choices when using the wireless gateway recorder. First, wireless gateway recorder can only realize gateway function which just forward the data from Zigbee nodes of WBAN to the PC. Second, both gateway function and storage function can be implemented, which means the wireless gateway recorder forwarding data to PC and storing data into the Micro SD card in the meantime.

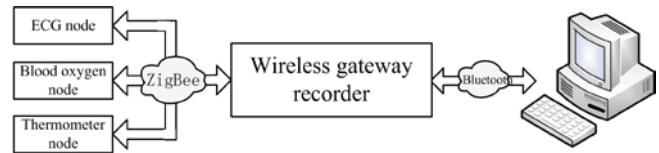
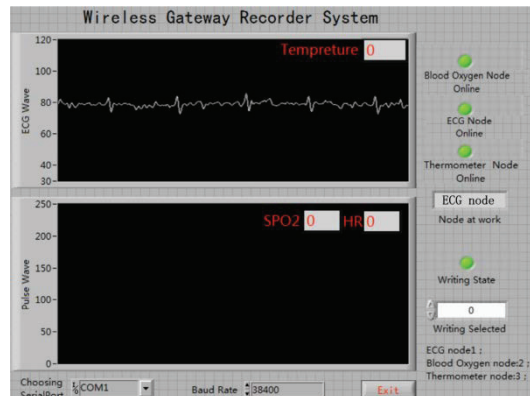


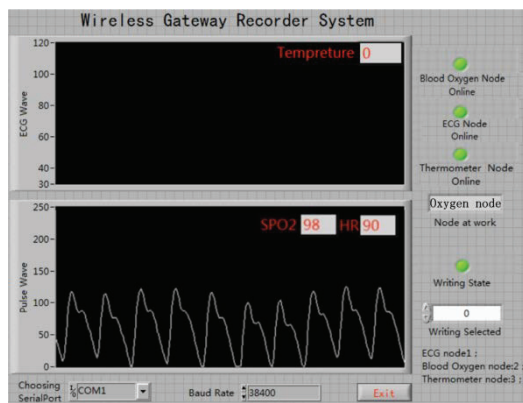
Figure 7 Block diagram when Bluetooth connection is established

The PC builds the display and storage platform of physiological data through LabVIEW. The platform can display the ECG waveform from ECG node, pulse wave, blood oxygen saturation and heart rate from blood oxygen node, temperature from thermometer node separately. In addition, the PC can control the Zigbee nodes through the platform.

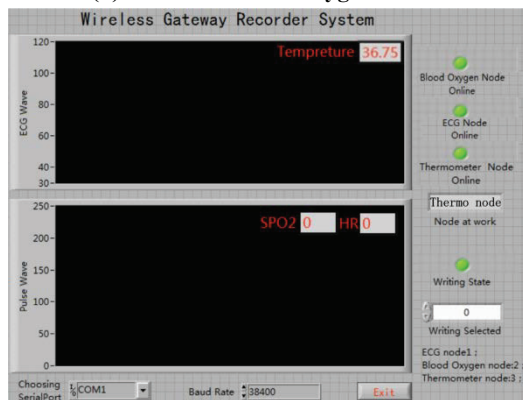
When the three nodes and wireless gateway recorder form star network successfully, the nodes upload their own information to the PC and PC shows the online status of the nodes. Then fill in the "writing select" the corresponding number to start a node to collect physiological data according to the user's need. After receiving the control command, the node begins to collect data and upload it. Figure 8 shows the physiological data from the three nodes separately.



(a) Data from ECG node



(b) Data from blood oxygen node



(c) Data from thermometer node

Figure 8 Data display interface on PC

#### 4. DISCUSSION

The design has realized the wireless gateway recorder which is applied to the medical care, specifically WBAN in health care. The wireless gateway recorder integrates Zigbee and Bluetooth technology. On one hand, the wireless gateway recorder forms a Zigbee star network to realize WBAN in which the Zigbee nodes collect and upload the physiological data and the wireless gateway recorder stores it. On the other hand, the wireless gateway recorder connects with the Bluetooth device through Bluetooth technology which means the data from WBAN can be uploaded to the Bluetooth devices wirelessly. After testing, the system works normally. In conclusion, the design is significant in promoting the application of wireless technology, especially the better use of WBAN in the medical care.

However, current design is not perfect which needs continuing study and improvement in many aspects. 1) Now multiple nodes form star network with wireless gateway recorder but cannot upload data simultaneously, otherwise data will be lost. Therefore, more powerful MCU should be introduced in the wireless gateway recorder to enhance the processing capacity. 2) PC is chosen to be the Bluetooth device in the system now because it is easier to test the system. In order to achieve the goals of portability and mobilization, the PDA or the smart phone can be the better choice. 3) Application of this design can also be expanded. The physiological data is uploaded on the Bluetooth devices which can be expanded to realize the remote medical care through uploading data on the Internet.

#### 5. ACKNOWLEDGMENTS

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