A Remote Monitoring System of Logistics Carrier Based on Wireless Sensor Network

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Abstract—To improve the efficiency of the remote monitoring system for logistics transportation, we proposed a remote monitoring system based on wireless sensor network and GPRS communication. The system can collect information from the wireless sensor network and transmit the information to the ZigBee interpreter. The monitoring system mainly includes the following parts: Car terminal, GPRS transmission network and monitoring center. Car terminal mainly consists by the Zigbee microcontroller and peripherals, wireless sensor nodes, RFID reader, GPRS wireless communication module composed of a micro-wireless monitoring network. The information collected by the sensor communicates through the GPRS and the monitoring center on the network coordinator, sends the collected information to the monitoring center, and the monitoring center realizes the information of the logistics vehicle in real time. The system has high applicability, meets the design requirements in the real-time acquisition and information transmission of the information of the logistics transport vehicles and goods, and realizes the function of remote monitoring.

Keywords—logistics, wireless sensor network, ZigBee, GPRS, remote monitoring

1 Introduction

With the rapid development of information technology, the revolution of animal networking technology has been pushed forward. The logistics industry has become an important application field of Internet of things technology. The real-time and effective management of logistics and transportation information and the realization of remote monitoring become the new requirements of modern logistics technology development. This paper presents and designs a remote monitoring system for logistics vehicles. The system can monitor all kinds of related information of the logistics vehicle in real time. Through the wireless network, it is passed to the regulatory center. The intelligent monitoring of logistics information is realized, which ensures the effective operation of logistics vehicles. The remote monitoring of logistics vehicles can effectively and timely grasp the situation of logistics information, strengthen logistics management, improve logistics efficiency, and reduce unnecessary logistics costs.

2 State of art

At present, wireless sensor networks (WSN) have been widely used in the monitoring of logistics and transportation information. Wireless sensor networks are born with the rapid development and maturation of technologies such as integrated circuits, sensors, wireless communications, and microprocessors. It is the result of the development of information acquisition technology from simplification to miniaturization, networking and integration. Wireless sensor networks are used in many fields of logistics industry, such as logistics, warehousing, environmental monitoring, dangerous goods logistics management, cold chain logistics management and so on [1-3].

The wireless sensor network based on ZigBee technology is used to collect the transporter information in the logistics transporter[4-5]. Through the WSN network, the logistics information data is transmitted to the remote monitoring center. The transport vehicle is equipped with a movable sensor node for collecting information of the transporter and the goods[6-7]. Within the coverage of the network, information is transmitted to the monitoring center through routing nodes in the wireless sensor network [8-10].

3 System architecture

Monitoring system includes the following sections: car terminal, GPRS transmission network and monitoring center. The structure is shown in Figure 1. Car terminal is actually a wireless sensor network, which is installed in the transporter. It can be divided into several sensor nodes and a network coordinator. Car terminal is a miniature wireless monitoring network. It is mainly composed of Zigbee MCU and peripherals, wireless sensor nodes, RFID readers, GPRS wireless communication module. The sensor node is used to collect the label information of the goods on the car and monitor the driving information of the car, such as the temperature and humidity inside the car and the information of cargo safety. The tag information of the item is automatically recognized by the RFID reader installed on the collection node. The collected information is communicated to the monitoring center via GPRS on the network coordinator, and the collected information is sent to the monitoring center. According to the received information, the monitoring center grasps the information of the logistics vehicle in real time, and gives the control instructions to the transport vehicle, so as to realize the remote monitoring. The remote monitoring of transport vehicles mainly comes from the information collection, transmission and monitoring of wireless sensor networks. Therefore, this paper focuses on the hardware and software implementation of wireless sensor networks. Remote monitoring system structure is shown in Figure 1.

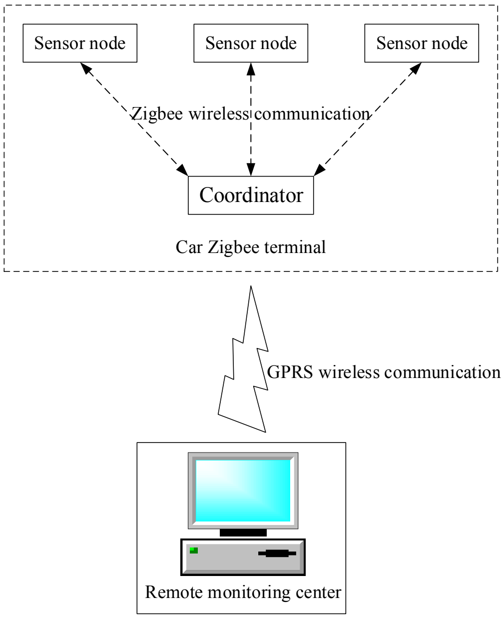

Fig. 1. Remote monitoring system structure

4 Hardware design of wireless sensor networks

Wireless sensor node is a miniaturized embedded system, which forms the basic support platform of wireless sensor network. Nodes of different functions require different hardware fundamentals. In the system's hardware design, the most important is the low-power design. This is determined by the nature of the wireless sensor network. In sensor networks, the location of sensor nodes is not fixed. It requires as long as possible to operate in small volume. Therefore, it has high requirements for power consumption and stability. The low power design of the system hardware platform mainly includes three aspects: simplifying the hardware structure and selecting the components with low power consumption and small size.

4.1 Design of sensor nodes

Sensor nodes are placed in the monitoring area to complete the collection and wireless transmission of environmental temperature and humidity parameters. According to the design requirements of low cost, low power consumption and small size, the sensor node adopts Chipcon's System On Chip (SOC) chip CC2530 [11]. The node consists of three parts: sensor module, microprocessor and power management module. The power supply module provides stable 3.3V voltage for the sensor nodes through the voltage regulator. The sensor module transfers the parameter data through the GPIO port of the processor. CC2530 is the core of the node hardware. The whole hardware block diagram is shown in Figure 2.

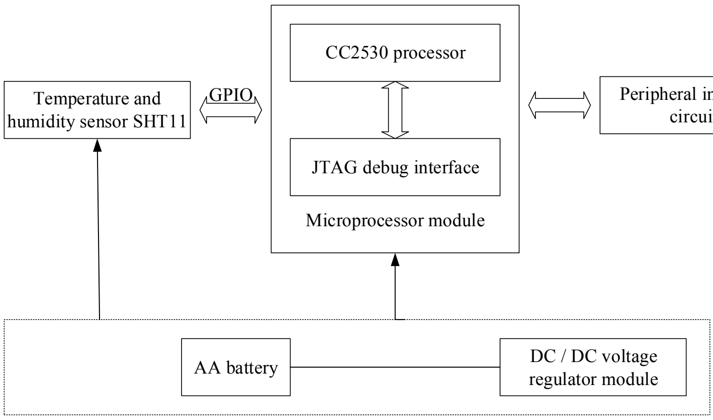

Fig. 2. Wireless sensor network sensor node structure

Wireless sensor network wireless communication technology can use ZigBee technology, Bluetooth, Wi-Fi and infrared and other technologies. ZigBee technology is a short-range, low complexity, low power consumption, low data rate, low-cost two-way wireless communication technology or wireless network technology. It is a set of communication technologies based on IEEE802.15.4 wireless standards related to networking, security and application software [3]. Therefore, the sensor node adopts the Zigbee module which integrates microprocessor and RF module together with a number of peripheral devices. Among them, the Zigbee module contains data processing and transmission functions, such as processor, memory and wireless transceiver, etc. it is the core module of wireless sensor network. Peripheral equipment includes sensor module, RFID module, power module and so on. The microprocessor in the Zigbee module stores the information collected by sensors and RFID into the memory, and then transmits the data through the wireless transceiver.

Wireless Zigbee module uses TI's latest ZigBee2007 / PRO standard chip CC2530F256. It complies with IEEE802.15.4 / ZigBee standards. The band range is 2045M-2483.5M, which is free to switch between 16 bands. Wireless data transfer rate up to 250kb / s, which has an on-chip 256K of programmable Flash and 8K of RAM. It offers a comprehensive set of peripherals - including two USARTs, an 8-channel 12-bit ADC, and 21 general-purpose GPIOs and more with the official Z-Stack2007 / Pro stack from TI, which makes secondary development quick and easy. CC2530F256 can be operated with only a few external components. The sensor on the wireless sensor network node can choose the suitable device according to the information collected by the transporter. This paper mainly detects the temperature and humidity of the freight car and the safety of the cargo in the carriage.

In order to reduce the workload of software design, sensors select modular circuits, which can reduce the programming of AD. In addition, it can directly add the digital information collected by the sensor module to the I/O interface of the microprocessor module. The temperature and humidity sensor is a digital temperature and humidity sensor chip SHT11, which was launched by Sensirion company of switzerland. It is an intelligent temperature and humidity sensor developed using CMOSens patented technology (a combination of CMOS and sensor technology). The SHT11 integrates functions such as temperature sensing, humidity sensing, signal conversion, heater and A / D conversion into a single chip [10]. The chip measurement principle is as follows. First, humidity and temperature are converted into electrical signals, respectively, by a capacitive polymer humidity sensor and a temperature sensitive element made of energy gap material. Then, the electrical signal is entered into the weak signal amplifier for amplification. Next, it enters a 14-bit A/D converter. Finally, the digital signal [4] is output through the two-wire serial digital interface. The chip has the advantages of high precision, small size and simple interface.

To determine whether the goods in the carriage are safe, to judge whether the door is open and whether someone enters the carriage, the information can be collected by detecting the brightness and the infrared ray of the human body. Therefore, the sensor selects the brightness sensor and the human pyroelectric infrared sensor. On wireless sensor network node, RFID module is installed. It can not only automatically gathering and transporting car models, license plate number, driver information, but also can read different items on the transport vehicle. Then, through the Zigbee network and the GPRS network, the information is transmitted to the monitoring center [5]. The RFID module is divided into two parts: an electronic tag and a reader. The electronic tag is mounted on the article and the carriage door. The reader is connected to the Zigbee module, which is equivalent to collecting the sensor on the node for information collection. RFID selects the MS-J300 read / write module, which uses 3V-3.6V power supply. It can recognize 200 electronic tags simultaneously.

4.2 Hardware design of Sink node

Sink nodes need to complete the creation and maintenance of sensor networks, data aggregation and command sending function [6]. The overall hardware diagram of the node is shown in Figure 3. It can be seen that the Sink node is composed of microprocessor module, power management module, peripheral interface circuit module and serial port circuit module. The microprocessor module and the peripheral interface circuit are the same as the sensor nodes. Sink node transfers data through serial port circuit and ARM board. Because the Sink node has the largest energy consumption in the sensor network, its power module needs to be compatible with two methods of external power supply and battery power supply.

5 The main function software design of the system

This section will be based on the system hardware node circuit designed in the third chapter. According to the total functional requirements of the system, the software function and workflow of sensor nodes and sink nodes are determined. The writing and debugging of the intelligent sensor node driver is introduced in detail, in order to realize the wireless transmission of temperature and humidity sensor data. At the same time, the wireless transceiver process of Sink node node and the communication module with gateway through serial port are introduced.

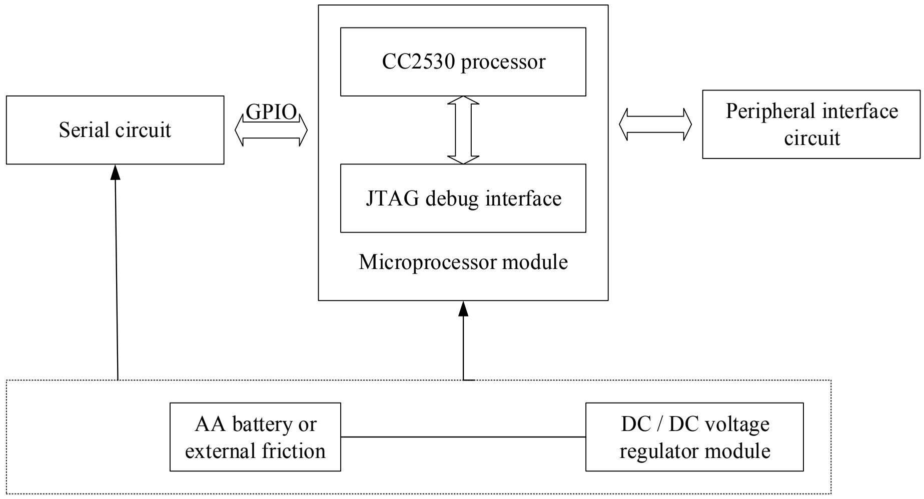

Fig. 3. The overall hardware diagram of the node

5.1 Sensor driver

SHT11 two-wire serial interface is different from the standard I2C bus. Therefore, it must work strictly in accordance with SHT11 communication timing. When using SHT11 to read and write data, it should be noted that the SCK used for synchronization does not have the lowest clock frequency due to the fully static logic design inside SHT11. The DATA data line only changes after the SCK falling edge and ensures that the data bit is valid at SCK high [8]. Communication timing includes: send command timing, measurement timing (read and write timing), reset timing [7].

The software flow chart for parameter reading of SHT11 is shown in Figure 4. After the initialization of the hardware is completed, if the sampling cycle is reached, the CC2530 first resets the communication to synchronize with the SHT11 clock, and then sends the temperature acquisition and humidity acquisition commands respectively. Next, the CC2530 continuously queries the level state of the DATA. If it is low level, it means that the acquisition is finished. Then, the 12 bit parameter data is read according to the time sequence diagram. Finally, the output conversion is carried out to inform the master program to complete the acquisition.

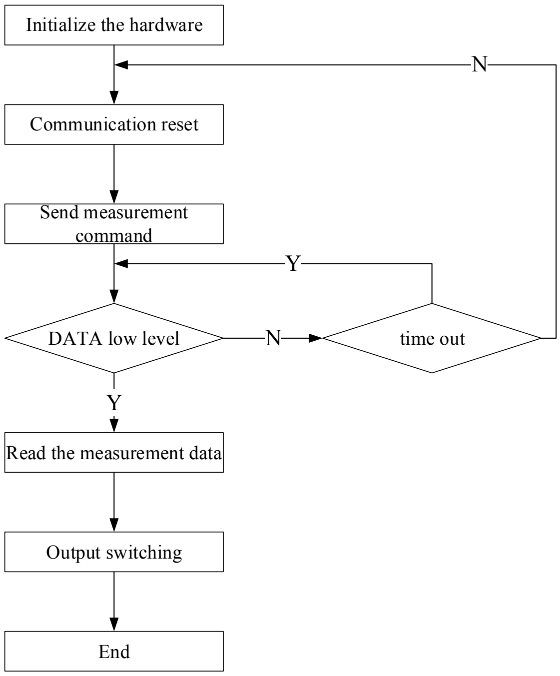

Fig. 4. SHT11 sensor parameter reading software flow chart

After reading the temperature and humidity data, conversion and nonlinear compensation are required. For the temperature data, because the energy gap material of the SHT11 has good linearity, the temperature value can be obtained by using the formula (1). Among them, SOT is the temperature measurement. d_1, d_2 is the T temperature conversion coefficient, they are respectively related to the supply voltage and conversion accuracy. In the paper, $d_1 = -39.66$, $d_2 = 0.02$.

$$T = d_1 + d_2 \times SO_T \tag{1}$$

For humidity data, non-linear compensation is required to obtain accurate humidity values. Formula (2) is corrected to calculate the humidity. Among them, SO_{RH} is a measure of humidity. C_1, C_2, C_3 are humidity conversion coefficients. It is related to the measurement accuracy. $C_1 = -4$, $C_2 = 0.0405$, $C_3 = -2.8 \times 10^{-6}$.

$$RH = C_1 + C_2 \times SO_{RH} + C_3 \times SO_{RH}^2 \tag{2}$$

5.2 Software design of sensor nodes

After the sensor network is successfully created by the Sink node, the sensor node is added to the network with the terminal node device type. Zigbee sensor nodes first do some initialization after power on, such as setting the clock frequency, setting the

IO port, set the timer and so on. The Zigbee network is then scanned and attempted to join a network that receives the strongest signals. The ZigBee Device Object (ZDO) indicates that a node has joined the network by sending a "ZDO_STATE_CHANGE" message to all already registered tasks in the application framework. The status of the message indicates the status of the current network. The main program enters the event monitoring state. The corresponding action is performed when sensor data is received via the I / O port or when a wireless command is received via the RF antenna. The work flow of sensor acquisition node is shown in Figure 5.

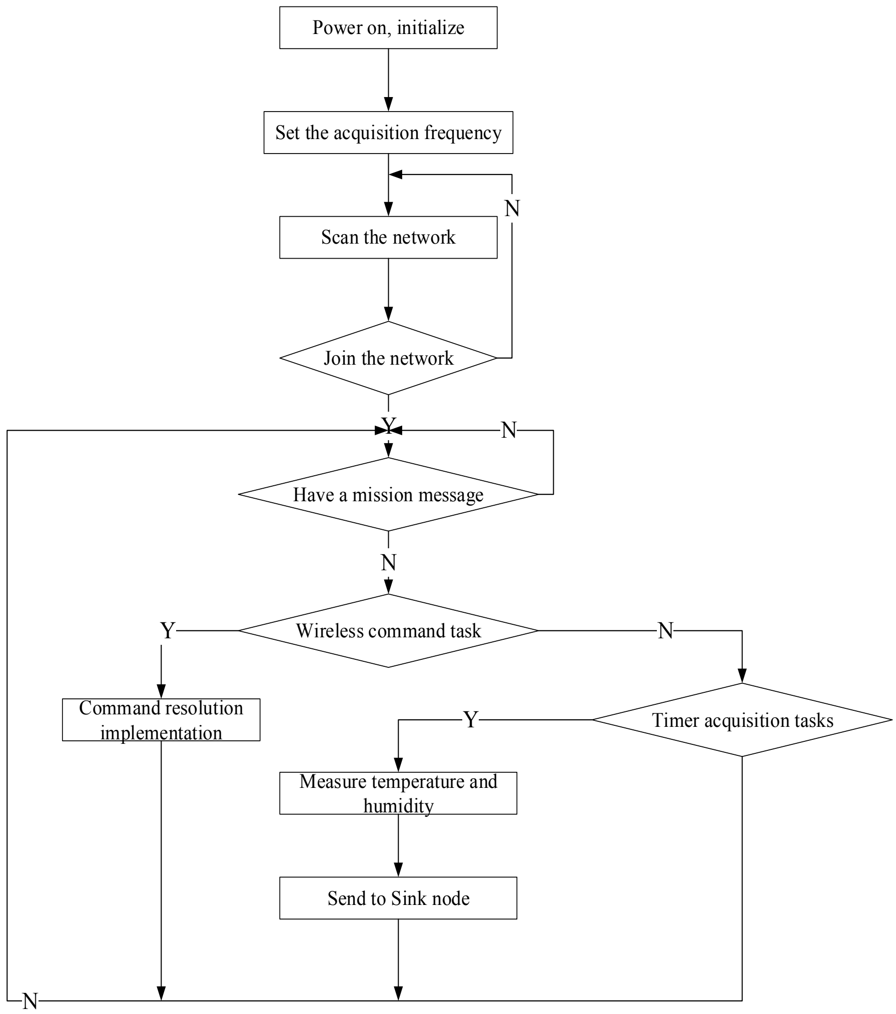

Fig. 5. The work flow of sensor acquisition node

According to the development framework of OSAL, sensor data monitoring and wireless command monitoring are set as a task. The several key programs are designed and implemented as follows.

Set sampling period: in OSAL, the function osal_start_timer Ex (byte task ID, UINT16 event_id, UINT16 timeout_value) is a timer whose task corresponds to a task whose timeout_value (ms) is turned on by a unit of ms. With osal Add Timer (), a "timed task" has been added to the soft timer list. When this timer overflows, the osalTimerUpdate () function will set an event_id for the task that corresponds to taskID, so that this task will be run in the following main loop. The sensor acquisition task get_sensor_data () timeout_value should be set to the sampling period T. After the sampling period timer overflows, the event handler sensor_process Event () reads the temperature and humidity environment parameters into the parameter buffer sensor_buff [] through the read_sensor () operation SHT11.

The wireless transceiver data sends sensor data through AF_DataRequest () to the Sink node after the sensor data is collected. There are several important parameters in AF_DataRequest (): dstAddr contains 16 bit short address and endpoint number of Sink node. srcEP needs to fill in the address and endpoint information of sensor nodes. len indicates the size of the transmitted tactile data, and the specific data is stored in the data buffer sensor_buff[].It can get the short address information of the node by calling the function NLME_Get Short Add R ().

The wireless command monitoring task receives the commands of Sink nodes wirelessly, and then parses them. When the wireless command monitoring task is registered in the ZigBee application framework, AF_DATA_CONFIRM_CMD messages are received when there is wireless data. Then the message is parsed and processed accordingly.

5.3 Software design of Sink node

The main tasks of the Sink node are as follows. The network is started and created. The terminal device is allowed to be added. The acquisition data of sensor nodes are received. Through the serial port, it is sent to the ARM board to monitor the user command of the serial port [9].

The specific soft flow of Sink node is as follows. First, the Sink node is set to the Sink node device. ZDAPP_CONFIG_PAN_ID 0xFFFF is set, so that the Sink node will be able to establish a random PAN_ID as its network ID based on its own IEEE address. After the sensor network is established, the sensor data is received by listening to the AF_DATA_CONFIRM_CMD message. After that, it immediately sent to the ARM development board through the serial port. At the same time, it also receives commands from users through the serial port. After parsing, the data is sent to the relevant sensor node. The specific software flow chart is shown in Figure 6.

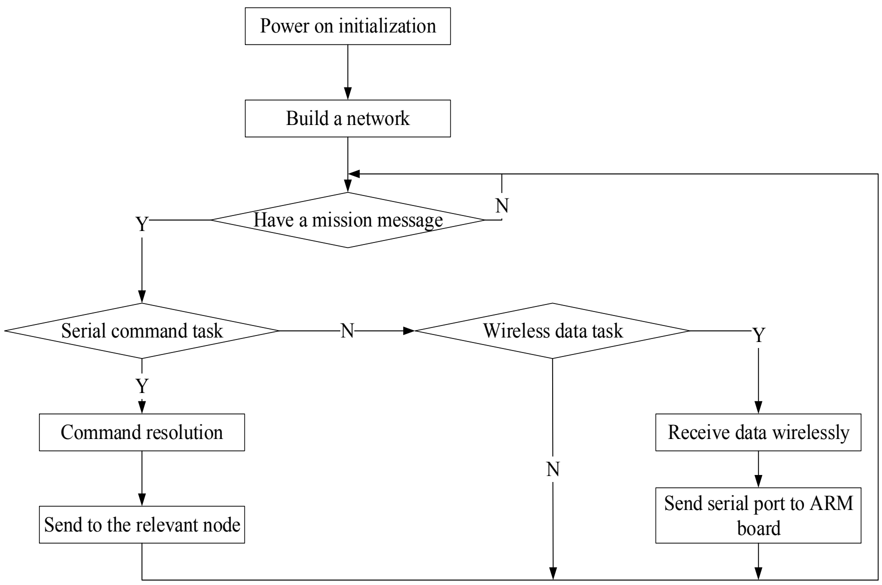

Fig. 6. The specific software flow chart

It can be seen in the OSAL framework, Sink node also includes two tasks: wireless data monitoring task and serial command monitoring task. Since the wireless transceiver has been introduced in the previous, the following briefly describes the Sink node serial transceiver.

There are two serial communication interfaces in CC2530, which are UART0 and UART1 respectively. There are two ways to send and receive data by serial port. One is the interrupt mode, and the other is the DMA (Directory Memory Access) mode. In this paper, serial port 0 interrupt mode is used to send and receive serial data. In the OSAL framework, HalDriverInit () is used to configure the pins, baud rates, stop bits of the serial port. When the interrupt is generated, the command sent by the serial port is put into the buffer to ser_buf[] by operating the UxBUF register. Then, the task processing function is sent to the serial port to send the message, and the data sending process is similar to the acceptance, and no more details are given here.

6 Design of monitoring center

Monitoring center is the core of intelligent management of remote monitoring system. It consists of a database server and a Web server. The system requires the database to be less redundant and faster. Web server response speed is fast. The user interface is simple, friendly and easy to use. It needs to have the function of query, historical curve display and user login control. In this chapter, the overall organization data flow diagram of the monitoring center is given. The data transfer module for database server and gateway interaction is designed. Linux under the MySQL database table operation is realized. Then, according to the system requirements, the database table is designed. Finally, the Web server based on AJAX and the interface with database server are designed, so as to realize the real-time monitoring of the client.

6.1 Overall design of monitoring center

The monitoring center is a distributed system based on B/S mode, including database server and Web server. The database server and gateway are connected by Ethernet, which has two main functions. The sensor data and equipment information are stored in the database and waiting for the Web server to request the data. The user command issued by the Web server is forwarded to the gateway. The Web server acts as the server of Http to respond to the requests of various pages and scripts of the client. The data flow diagram of the monitoring center is shown in Figure 7.

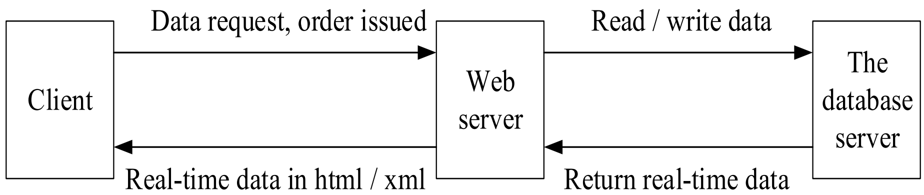

Fig. 7. The data flow diagram of the monitoring center

6.2 Detailed design of monitoring center

The database system is the core part of the remote monitoring system. Data is taken from the monitoring unit at the sensor site. After analysis and processing, the data is transmitted to the database server, and stored in the corresponding table in the background database for remote monitoring personnel query, analysis, record. The Web server sends user commands to the database server, which then forwards it to the gateways to execute the commands. As a remote monitoring system for data and command storage part, the performance of the database directly affects the performance of the entire monitoring system.

The database server mainly consists of Web server data response module, database operation interface and gateway interaction module. The gateway interaction module completes the sensor data reception and command issuance. Web server data response module to accept legitimate users of the database connection, and respond to Web server data requests. As the Web's data response is built-in interface, it only needs to develop database operations interface and gateway interaction module. The structure of the database server block diagram is shown in Figure 8.

The Web server mainly obtains the latest sensor data by connecting to the database server. The data is displayed to the user through the Html page or XML file. It also accepts user control commands. The command is written to the command table of the database server, and then forwarded to the gateway. Finally, the command is executed. The AJAX client requests the latest data once every second, and the Web server

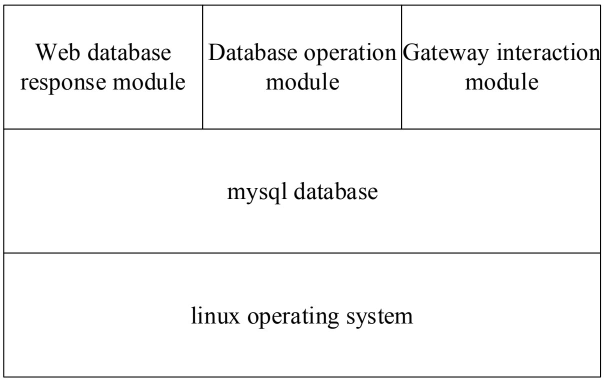

Fig. 8. The structure of the database server block diagram

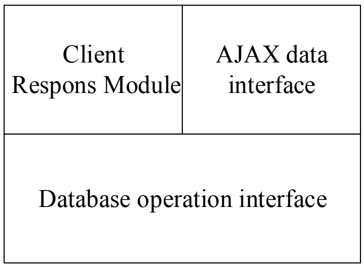

Fig. 9. The block diagram of the Web server

encapsulates the latest data as the XML file and returns it to the client's AJAX object to achieve dynamic real-time refresh. The block diagram of the Web server is shown in Figure 9. Web server mainly consists of client response module, AJAX data service interface and database operation interface. The client response module mainly responds to the Http request of the browser. The database operation interface is completed, and the database server requests the data. The AJAX data service interface responds to the XML file of the AJAX object of the client.

7 Conclusions

A remote monitoring system of logistics vehicle based on wireless sensor network and wireless data transmission technology is proposed and designed. This system is mainly composed of three parts: vehicle terminal, GPRS transmission network and monitoring center. The implementation process of each part is described. The hardware and software implementation process of the wireless sensor network is introduced. The modular design method is used in the system, and each module can be reduced and upgraded according to the actual situation. Through the remote wireless monitoring of logistics vehicles and goods, the system can obtain the required information quickly and accurately, so as to provide help for the effective operation of logistics vehicles.

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