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Water resources data acquisition and monitoring system based on internet of things

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ABSTRACT

Based on the limitations of water resource data acquisition and monitoring, such as technology and other problems, manual recording can only be used. The method has high cost, poor real time and low accuracy, and it does not play an important role in the prevention and control of flood disaster and water resources protection. On this basis, the method of combining Zigbee technology with General Packet Radio Service technology is proposed to collect and monitor the data of water resources. The water resources data acquisition and monitoring system designed in this paper is mainly composed of three parts: water resources data acquisition, coordinator part, and remote control center. The water resource data acquisition and monitoring system based on the Internet of things technology is simple in structure and convenient for installation and maintenance. It is suitable for remote area to collect and monitor water resources data, which overcomes the defects and shortcomings of the previous water resource data acquisition and monitoring system. In addition, it realizes the data collection of water resources and long-distance transmission and monitoring of data, which provides a theoretical basis for the work of water conservancy department.

Keywords: Water resources data acquisition; Detection system; Internet of things; Zigbee technology; GPRS technology

1. Introduction

There are great differences in climate, terrain, and geological characteristics in all parts of China. Affected by the monsoon climate, flood and flood disasters often occur. In 1954, there were heavy rain and flood in the Yangtze-Huaihe area. The affected population around the Yangtze river was more than 18,800,000 people, and the affected area of farmland was more than 47,000,000 mu, causing heavy losses. In 1963, a huge flood disaster occurred in the Haihe River, and the Hebei Plain became a sea of vast ocean. The farmland suffered a serious disaster. The grain output was reduced by 6 billion kg, and the direct economic loss was over 6 billion Yuan. In the rainy season of 1991, there was heavy rainfall in the Yangtze-Huaihe and Taihu Lake areas. According to statistics from relevant departments, over 4 million houses collapsed in Zhejiang, Jiangsu, Anhui, Hunan, Henan, and Shanghai during the entire rainy period, affecting 130 million people. The catastrophic floods that occurred in 1998 have affected 29 provinces, autonomous regions, and municipalities directly under the central government. According to the statistics of relevant departments of various provinces, the affected area of farmland is 334 million mu, a large number of houses collapsed, and the direct economic loss reached as high as 255.1 billion Yuan. Among them, the disaster in Heilongjiang, Inner Mongolia, Hubei, Hunan, Jiangxi, and Jilin is the most serious. The origin of these disasters is mainly because the news is not accurate and timely. The uncertainty of the water situation has aggravated the difficulties of disaster rescue and relief, and further expanded the losses caused by the flood disaster.

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In this context, it is very important to build a data acquisition and monitoring system for water resources. The traditional water resource data acquisition and monitoring system mostly adopts manual recording and wired transmission. This method has high cost and complex structure, while it is difficult to maintain. Therefore, the difficulty of collecting data information of water resources is increased. In view of the characteristics of water resource data acquisition and monitoring system, a research method of water resource data acquisition and monitoring system based on the technology of Internet of things (IoT) is proposed.

2. Brief introduction of related technology

2.1. IoT technology

IoT technology is defined as a technology to connect items to the Internet and interact with each other to achieve intelligent identification, location, tracking, monitoring, and management through the information-sensing equipment such as radio frequency identification (RFID), infrared sensor, global positioning system, and laser scanner in accordance with the provisions of the agreement.

The network structure of the IoT is mainly composed of three levels: the perception layer, the network layer, and the application layer [1]. The perception layer includes data acquisition, sensor network, and collaborative information processing, which mainly completes the overall perception and acquisition of the underlying information. The data acquisition part is divided into four parts: sensor, two-dimensional bar code, RFID, and multimedia information. Sensor network and collaborative information processing mainly include four parts: low-speed and high-speed short distance transmission technology, self-organizing networking technology, collaborative information processing technology, and sensor middleware technology. The convergence, fusion, and transmission of information are realized.

Network layer is the core bearing network, which mainly includes mobile communication network, Internet, and other special networks. It can determine the quality of service and efficiency of the entire IoT system, and realize the interconnection between the perception layer and the application layer of the IoT.

The top layer is the application layer, including the IoT application and the IoT application support sublayer. This layer mainly provides the corresponding service for user. It is the purpose of the research of the IoT technology to realize its social value. It is the purpose of studying IoT technology, where it is the part of realizing its social value.

2.2. Zigbee technology

Zigbee technology is a technical means suitable for near distance wireless communication, which has been developed gradually in recent years. Under the background of the rapid development of communication technology in the world today, with its low power consumption, low cost, short time delay on data transmission, flexibility, and reliable networking, it has been widely applied to the field of industrial control, home automation, medical care, and agricultural remote intelligent control.

The development of Zigbee technology is only a few years. It was first composed of Motorola, Mitsubishi electric group, Inwensys, and Philips company in 2002. The Zigbee1.0 version was formally proposed at the end of 2005. By the end of 2006, the Zigbee alliance has joined more than 150 well-known manufacturers all over the world, showing a flourishing development trend. The name origin of Zigbee is also interesting. When the bee finds pollen, it tells the companion where the pollen location is by the zig dance. In this way, the honeybee group realizes the internal "wireless transmission." It coincides with the low cost, low rate, high reliability, and flexible network of wireless communication networks that people are pursuing. People have named this new wireless communication technology "Zigbee" technology (transliteration as "purple bee" technology).

3. System scheme design

3.1. An overview of data collection and monitoring system for water resources

The data acquisition and monitoring of water resources is a basic cause which is related to the national economy and the people's livelihood and social development. It mainly includes the development and utilization of water resources, the management and protection of water resources, the prevention and control of flood disasters, and so on, which provides a theoretical basis for the water sector to work more accurately. Water resources data collection and monitoring technology is a kind of technology used to collect, transmit, and process the parameters from river, lake, and water level of reservoir and rainfall (snow), water quality, water flow rate, and temperature by computer technology, wireless communication technology, sensor technology, and automatic control technology. The traditional data acquisition and monitoring of water resources mainly depends on the manual measurement. For remote areas and dangerous areas, it is difficult to collect and process the data acquisition parameters in real time so that managers can make deployment conveniently. In this context, the implementation of water resource data acquisition and monitoring system is of great significance [2].

3.2. Design principles of data acquisition and monitoring system for water resources

According to the specific requirements of the water resource data acquisition and monitoring department, the water resource data acquisition and monitoring system should meet the following characteristics:

3.2.1. Reliability

Water resource data acquisition and monitoring technology is a project related to the national economy and the people's livelihood. It requires that the system must be able to collect, transmit, and process data in real time and reliably. The device can work without interruption, so that the staff working in monitoring center can make corresponding deployment, so as to reduce the losses caused by flood disasters.

3.2.2. Practicability

This requires that the designed system is easy to operate, install, and maintain. The software design of the system adopts an object-oriented interface design method to improve the operability of the system.

3.2.3. Adaptability

The installation range of water resource data acquisition and monitoring system is wide, and the climate and terrain conditions are not the same everywhere. This requires that the system must have strong adaptability and can run steadily in a variety of different environments.

3.2.4. Networking

The system can not only collect data, but also perform real-time monitoring, scientific processing, accurate analysis, and quick upload according to the corresponding requirements, so that managers can query data conveniently.

3.3. The composition of data acquisition and monitoring system for water resources

The water resource data acquisition and monitoring system designed by the system is shown in Fig. 1. It includes three parts: remote monitoring center, General Packet Radio Service (GPRS) network, and Zigbee wireless sensor network [3].

3.3.1. Remote monitoring center

The software platform is built mainly by computer technology and database technology to realize the remote management and display of the water resources collection data of the monitoring area. The monitoring center can set parameters for the monitoring terminal in operation.

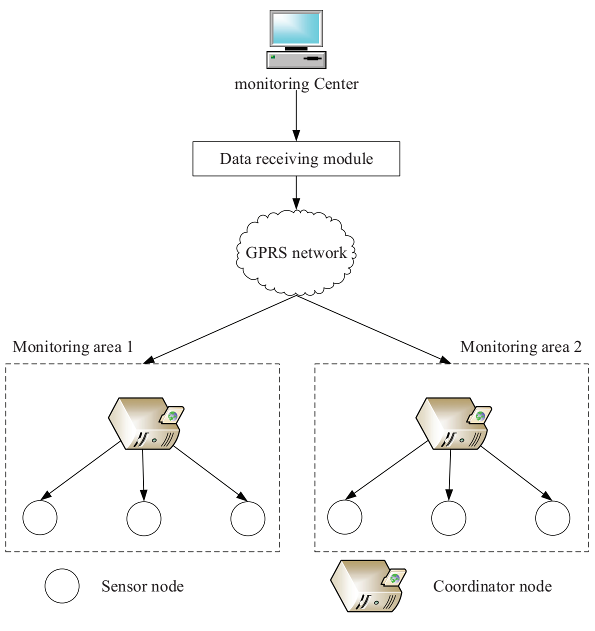

Fig. 1. System block diagram.

In addition, the monitoring center can process, store, and analyze the collection data of water resources, so that it is convenient for the water conservancy department staff to conduct real-time analysis of the monitoring area.

3.3.2. GPRS network

This part is composed of the GPRS communication module and the existing GPRS communication network. The data collection data of water resources are uploaded to Internet through the GPRS network, and the data are finally sent to the remote control centre. The GPRS communication module uses the GTM900B produced by Huawei company.

3.3.3. Zigbee wireless sensor network

It is mainly composed of sensor nodes and coordinators as well as related system software, such as various water level sensors, rainfall sensors, and temperature sensors. This part is responsible for the collection data of water resources, and the data are uploaded to the network coordinator node after processing. The micro control unit (MCU) of the coordinator selects the MSP430F149 chip with high performance and low power consumption and uses the CC2430 chip produced by Chipcon company as its radio frequency (RF) transceiver module. The coordinator node can communicate with multiple sensor nodes. After all of the triggering events are processed, the system will automatically enter into sleep state, so as to better save energy.

4. The hardware design of the system

The hardware part of water resources data collection and monitoring system mainly includes the following aspects: water resource data acquisition sensor node, coordinator node, and data monitoring center. Water resources data acquisition sensor node is mainly to collect the water resources data acquisition information parameters (including water level, rainfall, and temperature). The collected data of water resources are uploaded to the corresponding coordinator node, and the data information is finally transferred to the monitoring center. The staff in the monitoring center will make corresponding instructions for each part according to the safety range of the collected water resources data, so as to ensure the safety of each river basin.

4.1. Block diagram of water level sensor node

The design of the water level information wireless sensor acquisition node is mainly composed of the total controller, the data transceiver module, the wireless sensor, and the power supply part. Because the system is made up of a large number of sensor nodes, the performance of the system depends on the performance of the sensor nodes. The key of the design is data acquisition sensor nodes. This section mainly introduces the collection of water level information. This system uses the CC2430 chip produced by Chipcon company as the MCU [4]. The chip has an 8051 microcontroller kernel, and a series of functional modules such as RF front end and battery monitoring are integrated in the chip. The water level information acquisition terminal also includes the water

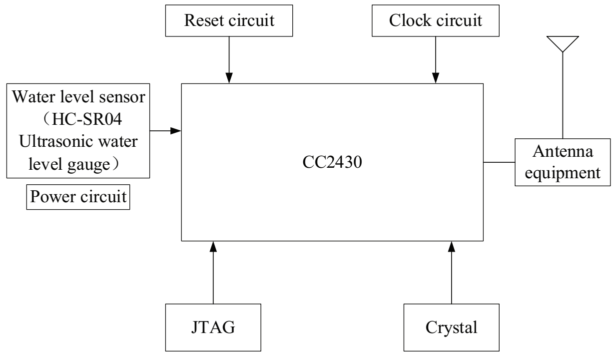

Fig. 2. Water-level sensor node block diagram.

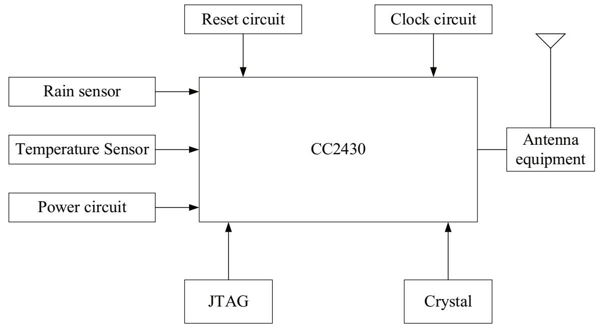

Fig. 3. Rainfall and temperature data acquisition node block diagram.

level sensor module, the power supply, the crystal oscillator, the Joint Test Action Group (JTAG), the clock circuit, and so on. The block diagram of the sensor node of the water level acquisition terminal is shown in Fig. 2.

The system chooses CC2430 chip as MCU. It is the first system on chip that conforms to the Zigbee protocol launched by the Chipcon company (acquired by TI in 2006) in Norway. This system also supports the IEEE802.15.4 protocol with 2.4GHz.

The water level information collection system of this paper uses HC-SR04 as the ultrasonic distance measuring module, which has the advantages of stable performance and high accuracy [5]. It is developed according to the characteristics of the collection of water level system in China. Because of its technical advantages, it is listed as the key promotion product of the national water conservancy system.

Because the data acquisition and monitoring points of various water resources are scattered and widely distributed, mostly in harsh environment areas. The system works in the way of unattended field, so there is no guarantee of AC power supply at any time. In order to meet the monitoring requirements of water resource data acquisition and monitoring system and the demand of monitoring network, the solar power supply mode is selected in this paper. Solar power supply system uses solar cell module to convert light energy into electric energy during the day. It supplies power to MCU and its peripheral circuits, and charges battery. At night and continuous rainy weather, battery is used to supply power for the system.

The operating voltage of the single chip microcomputer CC2430 is +3.3V, and the operating voltage of the water level sensor HC-SR04 is +5V. To ensure that the system can work normally, the module needs the DC voltage of +5V and +3.3V. The +5V voltage is obtained by the conversion chip B1205LD-1W, and the +3.3V voltage is obtained by the B1203LD-1W.

4.2. Design of hardware circuit for sensor nodes of rainfall and temperature

The design of the wireless sensor acquisition node for rainfall and temperature data is mainly composed of the total controller, the data transceiver module, the wireless sensor, and the power supply. This system uses the CC2430 chip produced by Chipcon company as MCU. The chip has an 8051 microcontroller kernel, and a series of functional modules such as RF front end and battery monitoring are integrated in the chip. The block diagram of the sensor node of the rainfall and temperature acquisition terminal is shown in Fig. 3. Because its working principle is similar to the working principle of water level data acquisition sensor node, there is no more about it here. The working principle of rain sensor and temperature sensor is simply introduced.

The internal integration of C2430 has a temperature sensor, but the measured temperature difference is larger, and in some cases it can reach ±2°C. It cannot meet the requirements of the system's temperature measurement precision, so this system uses DS18B20 as its temperature acquisition sensor.

According to the high-precision requirement of rainfall information collection in water resources data acquisition monitoring, the system uses capacitive rain gauge sex-determining region of Y (SRY-1) developed by domestic Wenzhou Huayun instrument and Equipment Co., Ltd, Zhejiang, China. Its patent certificate number is 99252318.4, and the Meteorological Technical Equipment License (XZ-06-2002) issued by the State Meteorological Administration has been obtained. According to the working principle of the capacitive grating sensor, the rainfall is measured by the displacement value of the capacitive grid. The performance is stable and the measurement is accurate. The output of rain gauge is a pulse signal. The signal can be directly connected with the wireless module to transmit the rainfall data in remote way.

4.3. Hardware circuit design of coordinator node

The network structure of the Zigbee coordinator node is relatively complex. The requirement of communication is high, and the hardware circuit diagram of the coordinator node is shown in Fig. 4.

The requirements of the power resource requirements, the system memory capacity requirements and the chip power consumption of the water resource data acquisition and monitoring system are considered. The MSP430F149 chip is selected as the MCU of Zigbee coordinator. MSP430F149 is the most typical one of the MSP430 series single chip. It is widely used in many fields because of its low power consumption, high integration, and rich peripheral equipment.

At present, there are many kinds of GPRS modules commonly used in the market, such as TC35i, TC45, MC35i, MC39i of SIEMENS, 18 and G20 of Motorola, GR47 and GR48 of Sony Corp, and GTM900 series of Huawei. According

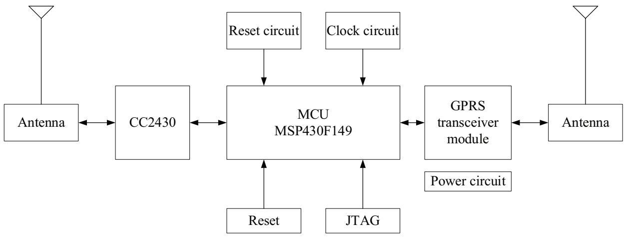

Fig. 4. Coordinator module diagram.

to the characteristics of the water resource data acquisition and monitoring system, through the comprehensive comparison, this system selects the GTM900B produced by Huawei company as the GPRS communication module.

4.4. The hardware design of the total control center

The hardware of the data monitoring center is composed of a GPRS communication module, a data server, and a number of management terminals. The GPRS communication module performs a series of communication tasks such as receiving the data sent by the coordinator and sending the corresponding instructions to the Zigbee network. The function of the data server is more powerful and needs to be served by a server with high performance and large capacity. In addition to receiving the communication data from the GPRS communication module, it also has the functions of data storage, processing, program management, and so on. It is convenient for managers to query, analyze, and print corresponding monitoring data through management terminals. The management terminal is used to complete the connection with the data server. Using the client/server mode, the manager queries and prints monitoring information to the data server by processing terminals.

5. Software design of the system

The functions of the system are complex. In order to better combine the software and hardware, the modular software design idea is adopted in this system, and the idea is clear. The efficiency and development cycle of the system have been improved. The overall structure of the system, the node of the data acquisition sensor, the node of the coordinator and the software design of the control center are analyzed.

5.1. The software structure of the system

In the water resource data acquisition and monitoring system, a complete and efficient work system is constructed to coordinate the work between different modules. In order to meet the requirements, this paper makes a reasonable design for each node. It mainly includes the design of data acquisition sensor node, the node design of coordinator, and the software design of monitoring center. The specific block diagram of the software is shown in Fig. 5.

The software design of the system is the core of the whole system, and the software design of the sensor node is considered in this paper. In order to avoid the interference in collecting, processing, and transmitting data acquisition information of water resources, multiple sensors use timer

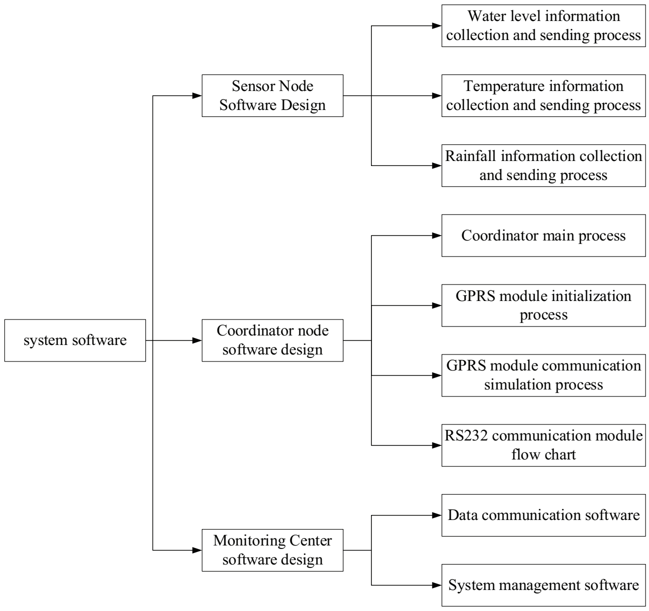

Fig. 5. System software block diagram.

interrupt to drive the acquisition command. In order to save energy, the system will remain in the dormant state when it is not working. Only when the time arrives, the system starts to collect, process, and send data. The process can be summarized as shown in Fig. 6.

5.2. Software design of data acquisition sensor node

The software design of data acquisition sensor node mainly includes two parts: data acquisition and data transmission. The data of water level, rainfall, and water temperature are collected by the system in different time. Therefore, in order to avoid the interference in collecting, processing, and transmitting data acquisition information of water resources, multiple sensors use timer interrupt to drive the acquisition command. In order to save energy, the system will remain in the dormant state when it is not working. Only when the time arrives, the system starts to collect, process, and send data.

5.2.1. Water level information collection process

The measurement of water level information mainly depends on the principle of ultrasonic distance measurement. The software part of ultrasonic ranging mainly includes the main program, the ultrasonic generation subroutine, and the receiving subroutine. When the ultrasonic wave is sent, the timer T0 inside the CC2430 single chip is started. When the ultrasonic touches the water, it is reflected back, and the receiving signal end receives the reflected ultrasonic wave after the voltage jump. The interrupt request signal is generated at the INT0 end, and the MCU responds to the external interrupt request, and a time difference is obtained. The height of the water level is obtained according to the calculation formula of the propagation distance of the ultrasonic wave in the air. The flow chart of the water level sensor and the working flow chart of the ultrasonic distance measuring module are illustrated in Figs. 7 and 8.

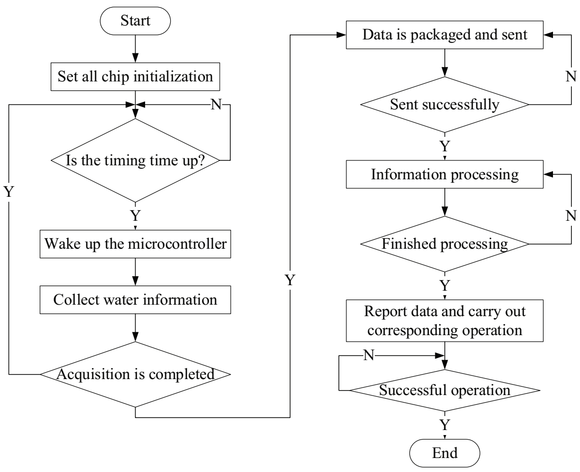

Fig. 6. The total system flow chart.

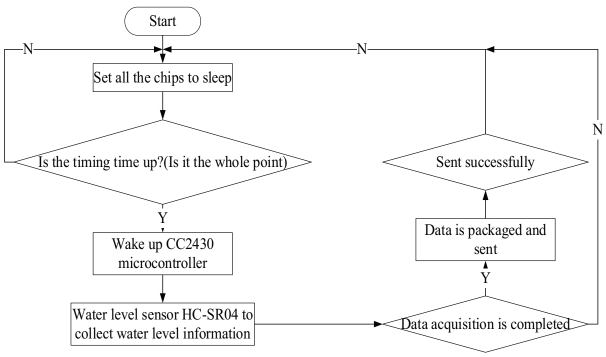

Fig. 7. Water level information collection flow chart.

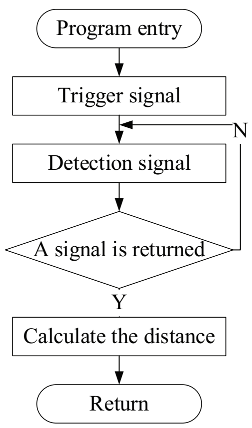

Fig. 8. Ultrasonic ranging program flow.

Usually, the ultrasonic rangefinder set a minimum measurable distance. Because the time is too short, the ultrasonic wave is transmitted directly from the transmitter to the receiver, causing the measurement error. Therefore, the general ultrasonic rangefinder needs to delay about 0.1 ms when working.

5.2.2. Temperature information and rainfall information collection process

The temperature collection chip of water resource data acquisition and monitoring system is selected by DS18B20, and the single-chip microcomputer selects CC2430. When the temperature is collected, the CC2430 sends instructions to the DS18B20, and the DS18B20 receives the instructions and begins to collect the temperature. After the acquisition is completed, the data are sent to the single-chip microcomputer CC2430. If the outside temperature is 0 or below 0, it will reach the freezing point of water. Then, the water surface will freeze. In this way, there is no need to monitor the water level again. The system automatically enters the dormancy state, which can better save the cost. The flow chart of its temperature data acquisition is shown in Fig. 9.

The temperature sensor DS18B20 controls the initialization of the chip according to its own communication protocol program. In the initialization stage of the chip, MCU launches a low-level pulse of 480–960 µs. After that, the total control line of single line changes to a high level. The system determines whether there is a device response by the presence of a low level. The temperature sensor DS18B20 detects the low level of 480–960µs on the total control line. After the total control line changes to a high level, the delay is 15–60µs. The response exists pulse, and the initialization of DS18B20 is over. If the DS18B20 does not detect the low level, it will always be in the waiting state. The reason for the delay is that the data transmission mode of DS18B20 is bus, and the time sequence of reading and writing is strict. In order to ensure the accurate timing of the I/O, a delay time is needed. According to the characteristics of DS18B20, the reasonable delay time is 15×N. Its initialization sequence diagram is shown in Fig. 10.

The rainfall sensor of water resources data acquisition monitoring system adopts SRY-1 rain gauge and CC2430 single-chip microcomputer. When the rain begins, CC2430

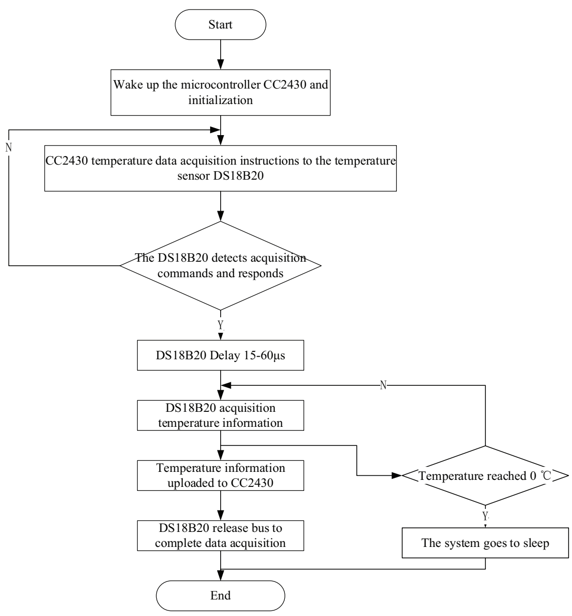

Fig. 9. Temperature acquisition flow chart.

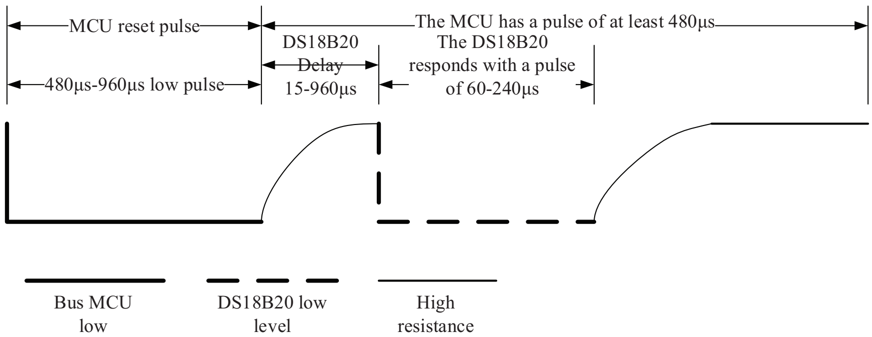

Fig. 10. DS18B20 initialization timing diagram.

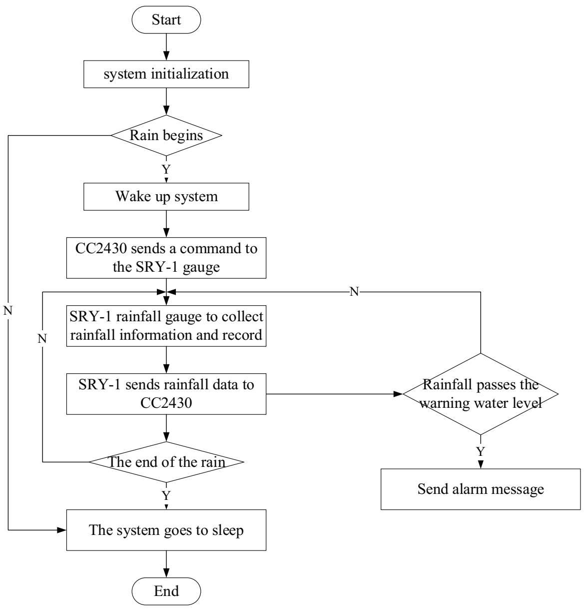

Fig. 11. Rainfall data acquisition flow chart.

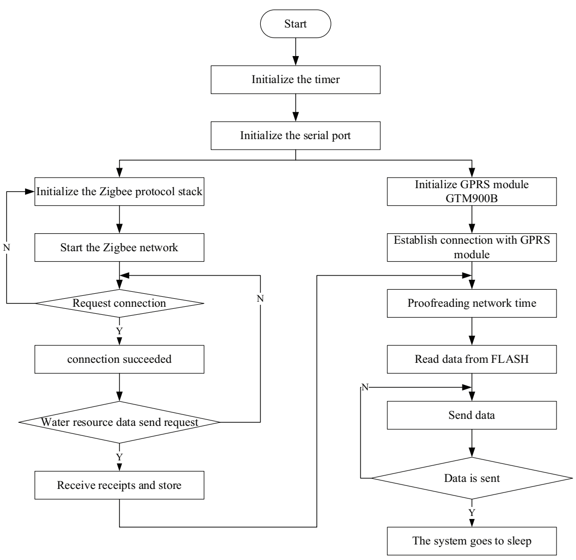

Fig. 12. Coordinator main program flow chart.

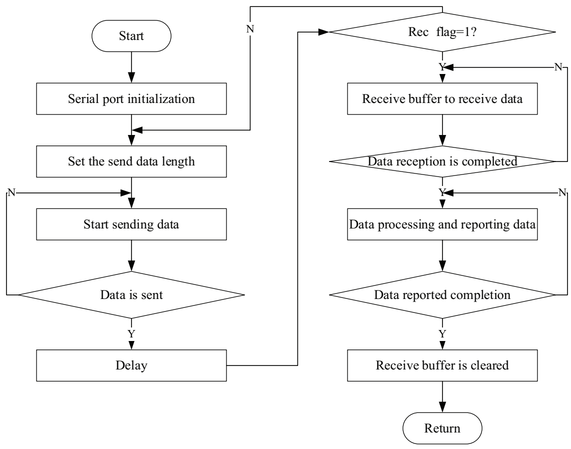

Fig. 13. RS232 communication module program flow chart.

sends commands to SRY-1 rain gauge. After receiving the instruction, the rain gauge starts to collect rainfall information. After the acquisition is completed, the data are sent to the single-chip microcomputer CC2430. In the process of rainfall collection, if the collected information shows that the rainfall exceeds the warning value, the system will send the alarm information automatically. Therefore, the staff can make relevant decisions and prevent the occurrence of flood disasters. After the rain is over, the system automatically enters the dormancy state in order to save energy. The flow chart of its data acquisition is shown in Fig. 11.

5.3. Design of coordinator node software

The software design of coordinator mainly includes the main program flow of coordinator, Zigbee communication module software, GPRS module GTM900B initialization process, GTM900B module fast communication, program flow, and RS232 communication module flow. The master program flowchart of the coordinator is shown in Fig. 12.

The computer of the monitoring center is generally different from the high and low level of the transistor–transistor logic (TTL) circuit defined by the GPRS module GTM900B. To complete the serial communication function, the level conversion must be carried out, and the TTL level needs to be converted to the RS232 level. First, the serial port UART0 of MSP430 single-chip microcomputer is initialized, and a receiving buffer is created to store the remaining data. After the data processing is completed, the buffer zone is cleared. The program flow diagram is shown in Fig. 13.

The software design of the monitoring center is composed of data communication processing software and system management software. The task of data communication processing software is to complete data communication with coordinator and realize long-distance transmission of water resources collection data, so as to facilitate staff to query, observe, and calculate data. In addition, the corresponding deployment for water resources data collection and monitoring field is planned. The system management software is mainly used to control the operation of the whole network and set the system parameters in the network.

6. Conclusion

According to the characteristics of data acquisition and monitoring system of water resources, Zigbee technology and GPRS technology are combined to monitor remote water resources data acquisition information. The data acquisition and remote data transmission of the water resource data acquisition and monitoring system are realized. The hardware design of each component node of water resources data acquisition and monitoring system is introduced, including the hardware design of data acquisition sensor node, coordinator node, and general control center. The software design of each node of water resources data acquisition and monitoring system is introduced, including water resources data acquisition, coordinator node, and remote control center node. The design process of each part is described, and the collection and transmission of water level information, rainfall information, and temperature information are introduced. The system uses modular design ideas to reduce the development cycle of the system.

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