The Design of Spatiotemporal Data Transmission System in Digital Watershed With the Integration of ZigBee and GPRS

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ABSTRACT

Digital watershed construction and application is the basis and foreland of water conservancy information, while temporal and special continuous real-time data transmissions becomes a big problem for the construction of digital watershed. In order to resolve this problem, watershed data transmission system is constructed based on ZigBee and GPRS after analyzing these disadvantage and advantage. Data collection, transmission and management of temporal and special continuous real-time data are realized in this data transmission system, which have a broad application prospects in digital watershed construction.1

INTRODUCTION

Digital watershed is not only an important part of the Integrated River Basin Management (IRBM), but also is the foundation of digital earth[1]. One book, <The bud and prospects of digital hydrology> written by Rui Xiao-fang, pointed out that digital technology is making hydrological elements of the collection, transmission, storage, processing and display a fundamental change. In the course of construction of digital watershed, information acquisition device should be installed and deployed
in the watershed critical control node[2]. However, some notes that can collect basic information such as precipitation and evaporation are mostly situated on the outskirts, and data collection has the characteristic of the space-time continuum, multivariate distribution and large amount. So how to transmit and process the data quickly becomes a difficulty for the construction of digital watershed.

With the rapid development of the Internet of things technology, the application of wireless sensor network (WSN) provides technical basis for the establishment of data acquisition and transmission system for fast and efficiently, and leads the future development trend of water information system[3]. ZigBee technology with its low power consumption, low cost, low transfer rates, flexible networking features, the formation of a large number of network nodes in the field of WSN have been widely applied[4-8], but the biggest problem we faced is that the transmission distance is limited, we can’t achieve long distance transmission. The GPRS technology that is not limited transmission distance can solve this problem[9-11]. Accordingly, in order to meet the continuous space-time multiple information transmission to the application in the construction of Digital Watershed, this paper designs an integrated ZigBee and GPRS technology transfer system.

1 ZIGBEE-GPRS WIRELESS ACQUISITION AND TRANSMISSION NETWORK DESIGN

1.1 Frame Structure

ZigBee wireless acquisition network consists of sensor acquisition nodes, the network coordinator node and GPRS transmit module. Each ZigBee network that interconnected by a coordinator node of the network and a GPRS module has a separate network number and transmits data transparently. Network coordinator node can achieve remote information transmission between the control center and the Internet by ZigBee-GPRS ways. The frame structure is shown in Figure1.
1.2 ZigBee Network

1.2.1 SENSOR NODE

As a network terminal device, ZigBee sensor nodes are only responsible for collecting and transmitting data to a network coordinator or a routing node. Sensor nodes do not need to maintain the network structure, so when it is not required to collect or transmit data, it can enter a dormant state to save battery power and then improve utilization.

(1) The hardware

In the sensor terminal node hardware design, the design of processor module, ZigBee wireless communication module and power module is the same with the following network coordinator node, including the processor, radio frequency modules and other hardware selection and various parts of the same hardware circuit.

In the actual application process, since the type of sensor output signal varies, universal analog interface circuit needs to be designed for the acquisition of analog signals. Universal analog interface circuit mainly deals with the sensor output signal whether its voltage and current signals (1~5V, 0~10V, 4~20mA, 0~10mA) is standard or not, and it is possible to amplify the weak signal, and make the appropriate conversion process. The design uses the STM32 processor in a way 12 A
/ D conversion, Microchip company's programmable gain amplifier (PGA), MCP6S28 and simple filtering protection circuit. Universal analog interface circuit can capture 8-channel analog signal. In addition, in order to enable the system to measure the differential signal, the circuit utilizes optocouplers TLP521-2 to switch quantity and frequency signal amount conversion, and then put the signal after shaping into processor I/O port by shaping the Schmitt trigger SN74LVCZG14. Frequency signal can pass through the processor input capture function to calculate the frequency value.

(2) The software part

Software design of the sensor terminal node includes network equipment, data collection procedures, data transmission and routing functions to achieve other modules, so function of the sensor nodes is relatively simple. In order to reduce the power consumption of the sensor nodes, when finished collecting data and send out, the node enters a low-power or sleep mode. Until timed interval, the node will wake up and start the data acquisition and transmission of the next cycle. Using its own 12 for A / D converter, STM32 is employed to collect the hydrological information.

![Data Acquisition flowchart](image)

Figure 2. Data Acquisition flowchart.
1.2.2 NETWORK COORDINATOR

As the control center of ZigBee wireless data acquisition network, the network coordinator is the only one that can initiate to establish a new network equipment. Not only does it need to have to realize the entire network management functions, but also need to have scalable features for the computer or other equipment reserved connection interface etc.

(1) The hardware part

According to the functional classification, the network coordinator node hardware structure mainly has the following several parts: the processor module, wireless communication module, GPRS communication module, power module, the reserved interface module and other peripheral circuit etc.

Considering the node power consumption and processing speed, processor module use STM32 series embedded processor of ST company as the main control microprocessor unit. Considering the node power, communication distance, volume and the development cycle, we use TI's CC2420 as the wireless transceiver chip of wireless communication module. The design of power supply circuit module selects 3.3V and 5V two kinds of voltage level. In addition, we design a battery charging interface circuit and a switching circuit of two power supply.

(2) The software part

According to the functional and logic of network coordinator, using the software design idea of hierarchical modular, the design of software architecture for network coordinator node is divided into three layers: hardware driver layer, system service layer and application layer. This three layers contact each other through certain interface functions.

Hardware driver layer is mainly responsible for the processor hardware drivers, for which the resource is initialized, parameter configuration, activation, etc. The hardware resources can be used by directly accessing to hardware resources register in the application.

System service layer is designed mainly for UC/OS-II embedded real-time operating system (RTOS) and ZigBee protocol stack transplantation. UC / OS-II RTOS’s main task is to build and manage the various modules, to achieve inter task’s communication, scheduling and synchronization, and provide the task scheduling, message queues, semaphores, time management, interrupt system and other services for the application of each module. ZigBee protocol stack mainly transplants the physical layer, media access layer, network layer and application layer ported to the processor, so that it can provide protection for data security and reliable transmission.

Based on UC / OS-II RTOS and ZigBee protocol stack, the application layer establishes different tasks depending on the user's specific application requirements, and implements ZigBee network management and data transceiver tasks by using interface functions they provided.
1.2.3 ROUTER NODES

The router which located in the middle position of ZigBee network, is a full-featured device node and the executor of the routing function. Its features include route discovery, route maintenance, routing and forwarding, etc. The router can correctly forward the information to the destination node by looking its best path to extend the coverage of the entire network. Here are the router design ideas. The router nodes are initialized, and then scan the network to find whether there is a new network. Once found a new network, then it sends a join request to the network coordinator to confirm whether the added successfully. If the join is successful, the router should always monitor whether there is data to the nodes on the network, or whether there is a terminal equipment request to join the network, and then make the appropriate response based on the listened message.

1.3 GPRS Transmission Network

1.3.1 GPRS NETWORK NODE DESIGN

(1) Hardware platform design

1）GPRS module selection

Using of Tian tong company’s W-801G and SMT package types, GPRS communication module enables GSM and GPRS function.W-801G, an industrial grade GPRS wireless module, can provide standard RS232/485/422 data interface and SIM card interface, and can also easily connect to other devices with serial port. User device can establish a connection with the server through the GPRS wireless network and Internet network, and can realize data transmission.

2) GPRS module circuit

Operating voltage is SIMVCC pin, SIMRST is reset pin, SIMCLK is the clock frequency of the input pins, SIMI/O is responsible for the data interaction I/O pin, LED display the working status of GPRS.

3) GPRS module power supply design

The coordinator is located in the center of the network and we need to often open on it for long power supply, therefore the coordinator uses switching power supply, and the lithium batteries as a backup power supply. As the GPRS power supply chip, LM2596 fixed output voltage have three types: 3.3V volts, 5 volts and 15 volts.

4) GPRS module and ZigBee module hardware design

GPRS module requires ZigBee network coordinator for data communication via serial UART interface where can achieve connection between the module CC2420 and W-801G.In this design, the W-801G GPRS module mainly uses VSIM, SIMCLK, SIMIO, SIMRST, GND, UTXD1, URXD1 pins etc. The UTXD1, URXD1 two pins is responsible for sending and receiving data, and the UART interface is for serial communication with the outside world. VSIM to SIMRST is a SIM card interface circuit which can be used with a specific number of SIM card.
(2) The software platform design

The GPRS module is an important component of space-time continuum multivariate data transmission network of the digital watershed water resources, which is responsible for data transmission between ZigBee network coordinator and monitoring center. Because GPRS communication based on IP address, we must first know the IP address of the GPRS module. Using a fixed IP address, the monitoring center makes the terminal number correspond with IP addresses to maintain communication links so smooth. After the serial port initialization, we must first set the GPRS mode to determine whether it is text mode or a wireless data transmission mode, and then began to communicate.

1.3.2 GPRS COMMUNICATION MODULE

(1) The hardware part

Using the Tian Tong Cheng Ye company’s W-801G, the GPRS communication module can achieve GSM and GPRS function by using SMT package. It uses an external 3.3V ~ 4.2V DC power supply, providing UART, SIM card, ADC interface. In addition to support GPRS and AT command set, it can also provide a wealth of features such as voice and data services. As an industrial grade GPRS wireless module, W-801G provides a standard RS232 / 485/422 data interface and a standard SIM card interface, so it can easily connect to other devices with serial port. User equipment can connect the server and realize the data transmission through the GPRS wireless network and Internet network. The SIMVCC pin provides working voltage, the SIMRST pin is reset pin, SIMCLK is the clock frequency of the input pins, SIMI/O is responsible for the data interaction I/O pins, LED display GPRS working condition.

(2) The software part

GPRS data transmission module is responsible for ZigBee network coordinator and data monitoring center. Because GPRS communication based on IP address, we must first know the IP address of the GPRS module. Using a fixed IP address, the monitoring center makes the terminal number correspond with IP addresses to maintain communication links so smooth. After the serial port initialization, we must first set the GPRS mode to determine whether it is text mode or a wireless data transmission mode, and then began to communicate.

1.3.3 COMMUNICATION PROTOCOL

Communication protocol is strictly necessary for the agreement to maintain communication, that is a set of information transmission, format and content of the contract. Based on the TCP/IP protocol, digital river basin water resources continuous space-time multivariate data transmission network can realize data transmission by combining wireless Internet communication and ZigBee-GPRS. The design of communication protocol integrates response type protocol (Polling) and the
Cyclic Digital Transmission (CDT) protocol characteristics. The following is the system communication protocol design. Under normal circumstances, the monitoring center timing acquisition terminal operating data information or remote control terminal device and circuit switch, at this time is the use of polling method. In order to improve the real-time interaction of the monitoring center and the terminal, when the equipment operation of terminal site is not normal or switch jump, setting terminal FTU will automatically upload the change information, and this is the use of CDT method. To prevent data loss, if the command is issued no answer, again the command, if still no response, they think communication failures, communication failures prompt pops up.

2 MONITORING CENTER DESIGN

2.1 Layered Structure

Using Java JSF + SPRING + HIBERNATE framework, monitoring platform software according to the level of internal structure can be divided into the presentation layer, control layer, business logic layer and data access layer. Business entity is accomplished the transmission of data between the layers. Software hierarchy and MVC design pattern, "Model-View-Controller" correspondence shown in Table 1. Each layer can implement application logic functions in one respect by the interaction between the layers to form application architecture, and then achieves functional complex applications.

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(1) Interface layer design

Interface layer uses Rich Faces components drawing format for XHTML documents, and uses FLEX to develop the SWF file. Online monitoring and
historical data query rules are basically the same in digital river basin water resources continuous space-time multivariate data monitoring.

(2) Control layer design

Control layer’s monitoring platform is mainly designed Faces Servlet hosted Action Bean. Similar to the MVP’s Presenter, it will be packaged and converted of data and methods in Action Bean between the interface layer and service layer to improve the interface reusability. Control layer consists of a base class called Base Pages and several concrete classes inherit the class composition. Base Pages completes pagination, navigation and other public methods, while concrete class completes control interface specific business by calling SERVICE interface.

(3) The business layer design

The business layer, also known as Services layer, is the MVC design pattern in the model layer. Calls for data access layer is to call the data access interface in the business logic layer, and then use dependency injection to obtain specific data objects. This layer consists of a template class called Generic-Manager-Impl and several service interfaces and concrete classes that implements the interface.

(4) Data Access Layer Design

The data access layer, also known as DAO layer, is the model layer in MVC model, whose responsibility is responsible for database access. The data access layer has three parts: a template class called Generic Dao Hibernate du, several data access interface and concrete classes that implement the interface. Generic Dao Hibernate has established a number of template method, such as get all(), exists(), remove(), save(), for design and implementation of monitoring platform in data access, which used to query, delete, duplicate determination, preservation operation. Data access interface defines data the business layer required and the relevant agreement of data operation. Data access class is to achieve a data access interface, and bind and extend the template class.

(5) Physical layer design

Physical layer includes: an abstract class called Base Object and inherit the implementation of this class. Base Object includes entity object comparison, serialization and other public methods, while the implementation class contains attributes, GET and SET method that described object required.

2.2 Functional Modules

Monitoring platform has five subsystems: Digital Watershed basic information management, online monitoring data (including time and space continuous multivariate data receiving), integrated statistics, water resource information service and management system. The function of the structure is shown in Figure 3.
1) Basic information management
It completes maintenance and queries some watershed information, such as Rivers basic information, information on water sources, surface water intake port information, water user information, groundwater water well information, information into the river outfall, sewage treatment plant information, basic information about irrigation and water information.

2) Online monitoring system
Online monitoring system can provide various types of online information services, including comprehensive health monitoring, early warning and statistical analysis. It not only can real-time master the water source, water intake, emission cross section information in water resources development process, but also can grasp the dynamic change rule of water quality and quantity continuum of multivariate data. Finally, it can realize the quantitative management.

3) Comprehensive statistics
The system management object is subjected to a secondary processing and analysis. In addition, it can provide data to support management decisions. Monitoring historical data is analyzed to generate a variety of statistical reports, such as analysis of water statistics, water quality trend analysis, comprehensive socio-economic situation in the region, the base report recording and reporting.

4) Information service
After multivariate data space-time continuum of water monitoring information through audit, human intervention, we would release them to the public.
5) Management system
It can complete organization management, security policy setting, provide safe and auxiliary function for the whole system.

3 CONCLUSION

Based on the need of digital basin continuum multiple information transmission, construct the data transmission system of internet of things technology, which analyzes the ZigBee and GPRS technology in depth. ZigBee wireless sensor network can access information from multiple nodes, such as the information of natural water cycle process including multiple nodes precipitation, evaporation, runoff, soil moisture, and the information of social water cycle process including water extraction, transmission, use, consumption, drainage. Information transmitted via a gateway to the GPRS network, and initially realized the rapid transmission of remote data. In the terminal monitoring center, data can be detected management, statistical analysis and information service. This system successfully solves the difficulties of digital multi-temporal watershed continuous transmission of information, and will be more widely used in the construction of digital watershed.

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