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Research of Farmland Information Online Monitoring System based on Wireless Sensor Network

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Abstract

Wireless sensor networks are the main technical means to realize variables information network monitoring in agricultural environment. In order to solve the problem of low-cost, low-power field information, reliable real-time transmission, a farmland information online monitoring based on wireless sensor network has been designed. The overall structure of the system contains sensing layer, transport layer and application layer, which uses the ZigBee wireless communication technology to build wireless sensor networks. Monitoring data of different farmland regions are transmitted through the GPRS network to the monitoring center securely and reliably. The use of data monitoring center is aimed at collecting data for processing. TI's ultra-low-power micro-controller MSP430F149 and ZIGBEE module CC2530F256 work as the core hardware in the designing of wireless sensor network node. With Z-Stack as the protocol stack, software is designed based on the nodes to achieve a gateway node and terminal node functions. The results gained from a set of network communication system tests, inter-node transmission quality tests and remote transmission tests show that: based on wireless sensor network, the online monitoring system of field information can automatically complete the data acquisition and transmission and with the aid of GPRS / Internet network, the data can be sent to the data server with high stability, high reliability, punctuality, meeting the basic requirements of on-line monitoring of farmland information.

Keywords*: Wireless sensor network; ZigBee technology; online monitoring; network structure; the Internet of things*

1. Introduction

The process of implementing precision agriculture includes obtaining field information, management and analysis of field information, the field of decision analysis and decision implementation [1]. The real-time, effectively collecting of field information is an important foundation to achieve precision agriculture. Agricultural information includes geographical environment and soil environment parameter information. Due to the geographical dispersion of agriculture, varied terrain, complex environment and other reasons, farmland information collection usually has features like variable sensors, difficult power supply, real-time collection and so on[2-3]. Therefore, the study of a multi-faceted, networking, fast, and effective variable information collection method of crop-growth environment is one of the important issues of information technology in precision agriculture applications.

Wireless sensor network consists of a large number of low-power, tiny sensor nodes distributed within the scope of monitoring. It is a distributed self-organizing system and its application in the field of precision agriculture has a good advantage which has been used for agricultural irrigation, tillage, fertilization management and so on [4-6]. J. A. Lopez used wireless sensor networks successfully applied in the monitoring of farm soil

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volumetric water content, temperature and salinity[7]; O. Green proposed the use of a wireless sensor network to monitor the feed compartment temperature changes at different locations, according to the monitoring results of different positions within the feed compartment temperature change modeling, forecasting accuracy between 90.0% and 94.3%[8]; R. B. Zhang proposed standard based on the greenhouse frame structure of a dynamic star of wireless sensor networks, from low-cost low-power perspective based on wireless sensor networks greenhouse wireless monitoring system; Z. Li and N. Wang studied when the wireless sensor network node is applied to farmland in the distance, how the transceiver placement height and the height of the three factors affect crop transmission losses[9].

Wireless sensor networks are main technical means to realize the monitoring of variable agricultural information network environment. In order to solve the low cost of field information, low power, reliable real-time transmission problem, we designed a farmland information online monitoring based on wireless sensor network, which is used to realize real-time collection of field information air temperature and humidity, light intensity, rainfall, *etc*[10-11]. By accessing the Internet or the existing mobile network via a wireless gateway, remote monitoring and scientific management of agricultural crop information can be achieved and rational decisions based agricultural information can be made.

2. Hardware Design

2.1. Overall System Architecture

According to the wide coverage of large farmland and many monitoring parameters, combined with the characteristics of the Internet of Things architecture, the structure of farmland information online monitoring system based on wireless sensor network is shown in Figure 1. The system is divided into three layers: the sensing layer, the transport layer and the application layer. The sensing layer mainly uses the ZigBee wireless Communication technology to build wireless sensor network which is a comprehensive coverage of the monitoring area to achieve sensing data acquisition and transmission.

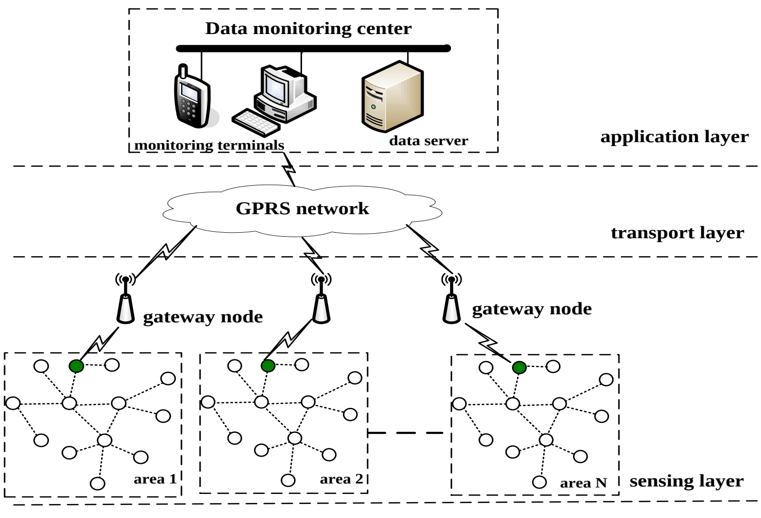

Figure 1. The Structure of System

The main function of the transport layer is the data information from different farmland monitoring region are safely and reliably transmitted to the data monitoring center through GPRS network. Because data transmission protocol of the GPRS network and data transmission protocol of wireless sensor network are not compatible, the communication bridge between the sensing layer and the transport layer through the gateway node must be built. In order to reduce the size of the hardware, the gateway node also has a coordinator node function that is responsible for wireless sensor network control and maintenance, and achieves the conversion of two kinds of communication protocols.

The main function of the application layer is to use the data collected from the monitoring center for processing. The data monitoring centre consists of the data server and monitoring terminal. With the use of the PC monitoring software, farmland information with real-time graphical display, alarm monitoring, maintenance, printing and other functions can be completed. Users can access the data center monitoring by the monitoring terminal, accessing crop growth in real-time tracking and analysis, and taking appropriate measures in accordance with changes in the environment to achieve accurate water-saving irrigation requirements.

2.2. Design of Gateway Node Hardware

ZigBee wireless sensor network consists of a large number of monitoring nodes in a communication network in self-organization, where there is the only one gateway node with both the coordinator and a gateway functions. The gateway node not only collects the farmland data information from the wireless sensor network, but also sends them through the GPRS module to the remote data monitoring center and receives the control commands from the data monitoring center. Therefore, the data processing tasks is arduous accomplished by the gateway node requires a mature network protocol support and high hardware resource. In addition, in order to reduce the power consumption of the gateway node, TI's ultra-low-power microcontroller MSP430F149, the module CC2530F256 supporting protocol ZigBee2007 stack and the GPRS module SIM900 supporting TCP / IP protocol from the SIMCOM company are selected[12]. The specific hardware interface circuit is shown in Figure 2.

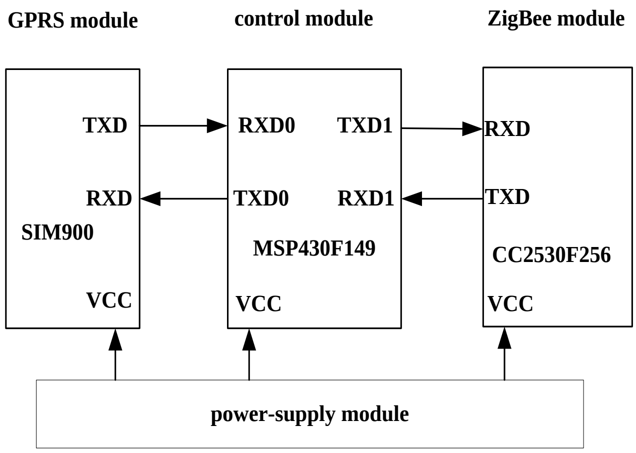

Figure 2. Gateway Node Hardware Interface Circuit

The gateway node is composed of the control module, GPRS module and ZigBee module. The control module is the MSP430F149 microcontroller which has two serial ports, respectively serial port 0 and 1, to meet the communication needs of the actual hardware. The MSP430F149 microcontroller communicates with the GPRS module SIM900 by serial port 0. The SIM900 module accesses the network via SIM card information to transmit data. The MSP430F149 microcontroller communicates with the ZigBee module CC2530F256 by serial port 1. The CC2530F256 module realizes the farmland data collecting. The MSP430F149 achieves the conversion of TCP/IP protocol and ZigBee2007 protocol, and implements corresponding packing and unpacking in accordance with the protocol specification.

2.3. Design of the Terminal Node Hardware

The terminal node of the ZigBee network mainly uses the sensors to collect farmland data information with a simple preprocessing by processor unit and transmits them by the wireless transceiver module to the router nodes. According to its features, the hardware configuration of the terminal node is shown in Figure 3. The terminal node is made up of ZigBee unit and sensor unit. ZigBee unit is a key part of network communication, mainly composed of the CC2530F256 module and RF power amplifier modules. The CC2530F256 module completes the protocol stack data processing and wireless transceiver function. The RF power amplifier module further amplifies the signal power for increasing the signal transmission distance.

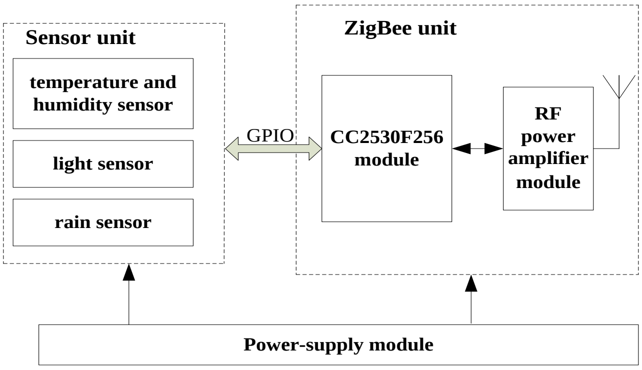

Figure 3. Hardware Structure Diagram of the Terminal Node

The sensor unit is composed of temperature and humidity sensors, light intensity sensor and rain sensor. The sensor unit communicates with CC2530F256 module by the simple GPIO buses. Under the control of the CC2530F256 module, the sensor unit acquires temperature and humidity sensors, light radiation intensity, rainfall data information. They are transferred according to a certain data format combination coding and transmitted by the ZigBee monitoring network.

In order to reduce the difficulty of collecting data, the sensor unit is selected as follows: the temperature and humidity sensor DHT11 is selected, which uses a single-bus serial interface to achieve synchronous communication with the microprocessor and has a strong anti-interference ability, fast response, cost-effective advantages; The light intensity sensor BH1750 with the IIC bus is selected ,which supports a wide range of light intensity measurement and precision and has low current technology and direct digital output; The rain sensor JDZ02-1 is selected, which converts the rainfall amount to a digital information as the switch form and can be connected directly to the microprocessor interface.

The router node is mainly responsible for the terminal node to achieve information routing within the network, and has the functions of allowing the terminal nodes to join or leave the network. According to its features, the hardware configuration of the router nodes is easier than the hardware configuration of the terminal node, router nodes is direct composed of the ZigBee unit.

3. Design of System Software

3.1. Design of Gateway Node Software

The gateway node mainly achieves data conversion of ZigBee network and the GPRS module, so the key is coding of the control module MSP430F149 of. Because MSP430F149 communicates respectively with GPRS module, ZigBee module through the serial port UART0, UART1, the serial communications requires proper management. The control module MSP430F149 has two ways to receive data for serial communication: One way is to check the serial status register data flag, if one is set to determine the serial receive new data, then it can read data; Another method is enable the serial port to receive data interrupt, when new data is received, it will generate an interrupt, indicating that you can receive new data. In order to timely receive new data, the processor has better interrupt response handling mechanism, selecting the interrupt method to complete reading the serial data. In addition, their priorities are determined based on two serial interrupt received and the amount important information data. In the course of the entire system, the gateway node receives the GPRS module data transmission which is remote data monitoring center control commands, these control commands are very important data information and a smaller amount of data; received ZigBee gateway node module preclude the collection of data is a wireless sensor network node. Therefore, set the serial port UART0 interrupt priority than UART1 interrupt.

The control module MSP430F149 uses the idea of modular programming, the main program flow chart of the gateway node is shown in Figure 4. The main program is a big cycle, according to the priority order, GPRS communication module interrupt things before ZigBee communication interrupt events precedence. When GPRS communication interrupt response, the processor receives from the command center to monitor the data transmission, and the appropriate action in accordance with the command data; when the ZigBee communication module interrupts, the processor receives the ZigBee network to transmit data collected and uploaded to the Data Monitoring perform to the appropriate processing center.

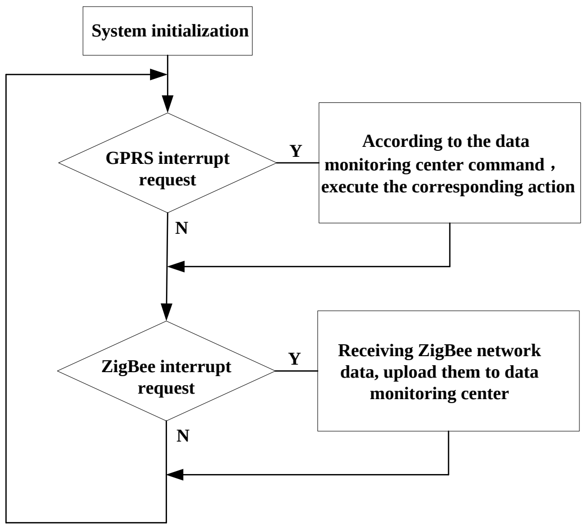

Figure 4. Main Program Flow Chart of the Gateway Node

The control module MSP430F149 completes the communication with the GPRS module by sending different AT commands [13]. GPRS module perform the appropriate tasks differ according to the received AT command and TCP/IP protocol encapsulated data and then access the Internet so that the data is sent to the data server monitoring. After completion of data transmission, GPRS modules continue to send heartbeat packets to maintain GPRS link. Because internal GPRS module has been embedded TCP / IP protocol, so long as the rational allocation can be achieved through AT commands, Internet data exchange can be achieved. GPRS module initial configuration process is as follows:

(1) AT \ r, the system power, check the serial communication is still working;
(2) AT + IPR = 9600 \ r, set the serial communication baud rate is 9600bps;
(3) AT + CSQ \ r, the detection signal intensity, the return value is determined by the signal strength whether the requirements of the environment in which the connection;
(4) AT + CGDCONT = 1, "IP", "CMNET" \ r, set the access point parameters, support for data protocol type for IP, access to the Internet access point network name for CMNET.
(5) AT + CGCLASS = "B" \ r, the GPRS module for single mode operation GPRS services;
(6) AT + CGDCONT = "TCP", "218.195.108.234", 1008 \ r, establish a TCP / IP link, where the parameter "TCP" indicates that the link type is TCP, rather than UDP; Parameters "218.195.108.234", said need to link the IP address; parameter 1008, compared with the corresponding need to connect to the IP port number.

3.2. Design of Terminal Node Software

After the gateway node starts, initialize the hardware and the protocol, select the appropriate channel to create a ZigBee network. When a node applies to join the network, the gateway node is responsible for the allocation of a 16-bit short address and allows it to join the network. The software program flow chart of the terminal node is shown in Figure 5.

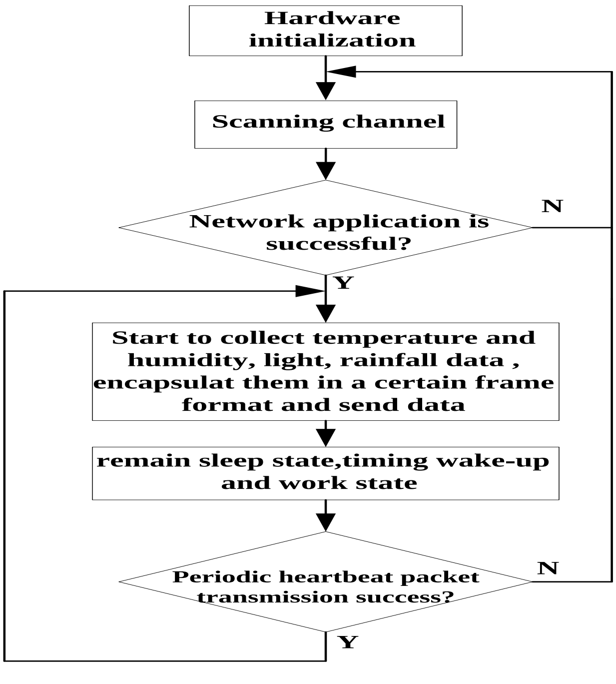

Figure 5. Software Program Flow Chart of the Terminal Node

After the terminal node starts, initialize the hardware and protocols, then circulates scanning channel ZigBee network to send a request to join until the application succeeds. When the terminal node joins the network, the terminal node is assigned with a unique 16-bit network address, and the 16-bit address gets registered with the network terminal node bound coordinator. The terminal nodes sequentially acquires farmland temperature and humidity, light intensity, rainfall data, packs and sends them to a gateway node according to a certain frame format. Then terminal nodes enter into sleep mode, wake terminal node timing mode, put it into working condition. Finally, send a periodic heartbeat packet to determine whether the terminal nodes is in the net, if it is, repeat the data collection and transmission process, otherwise re-apply the net.

3.3. Design of Data Monitoring Center Software

The monitoring data center management software was designed by VB6.0 and uses the Winsock control monitoring function LocalPort to monitor TCP connection requests from the network. When monitoring a connection request to establish a SOCKET connection, TCP / IP protocol data communication will be achieved. Database uses SQL SERVER 2003 and ACCESS2003 build connections between ACCESS database is connected to the software by ADO, DATAGRID bounding manner, to achieve data management.

The monitoring terminal software includes modules for three main parts of the user management module: data manipulation module, data management module, each module functions: user management module can realize the user identity and rights management; data operations management modules: data queries, stored, printing and other functions; data management module: monitoring data classification display (show farmland temperature, humidity, light intensity, rainfall data), data deletion and early warning capabilities.

4. System Experiments and Results Analysis

4.1. Network Communication Test

To simplify the test difficulty, the system network test uses a gateway node, two router nodes and a terminal node. Gateway node, router nodes and end nodes constitute a tree ZigBee network. Temperature and humidity data collection will be forwarded through the router node to the gateway node by terminal nodes, use LCD12864 to display the results. According to the given effective RF communication distance of 150 meters and 20 meters by the ZigBee module, communication distance selects network testing system, whose results are shown in Figure 6. Terminal nodes are assigned network addresses F193, collected at 28 ° C, humidity of 38%; data source address of the gateway node of received F193, a temperature of 28 ° C, humidity of 38%, the gateway node receives the data and data collection terminal nodes are exactly the same, networking systems is successful and network communication is good.

(a) Hardware of terminal node (b) Hardware of gateway node

Figure 6. Network Test Results

4.2. Inter-Node Transmission Quality Test

Experimental tests consist of a ZigBee network gateway node, two nodes and a router terminal nodes and the distance between adjacent nodes is less than 50 m. Setting terminal node sends data to the gateway node every 10 minutes, the continuous transmission interval is 1000, a single transmission packet size is denoted by N bytes, the gateway node number of correctly received data packets are denoted as M, the average intensity of the received signal between is recorded as W dBm, packet error rates between nodes are referred to as Y, 50A represents the environment in the open area, the distance between adjacent nodes is less than 50 meters, 50B represents an environment under obstructions, neighboring nodes the distance is less than 50 m, the terminal node at the transmission power at 0 dBm, the transmission quality measurement results with terminal nodes and the gateway nodes are shown in Table 1.

Table 1. Node Transmission Quality Test Results with 0dbm Transmission Power

Communication environment	N/bytes	W/dBm	Y/%
50A	3	-75	0
100A	3	-63	0.1
50B	3	-60	0.5
100B	3	-38	1.5
50A	10	-72	0
100A	10	-62	0.3
50B	10	-57	2.6
100B	10	-32	10.5

Test results show that different communication environments and the size of a single packet on the system will affect the communication quality. In more complex communication environment conditions, in order to reduce the packet error rate, the distance between nodes can be reduced or the packet size can be reduced according to some coding scheme. According to the statistical test result, the distance between adjacent nodes in a ZigBee network is within 50 meters, when the node transmits data packets are small, reliable transmission of data between nodes ca be achieved, reducing system power consumption and prolonging the network life cycle.

4.3. Remote Data Transmission Test

System test selects 100m * 100m flat region as an experimental test site, the test time is 10 hours, ambient temperature is between 14 ~ 20 ° C, relative humidity of 40% to 60%. The test is based on whether the acquisition and verification from wireless sensor network transmission errors of farmland temperature and humidity data can meet the needs, that is to say, it depends on the correctness data acquisition and transmission. Temperature and humidity test data comparing the data monitoring center management software and standard instrument display monitoring results are shown in Table 2, Table 3.

Table 2. Farmland Temperature Test Data

time	Standard value	monitoring value	Absolute deviation
10:15	16.01	15.90	0.11
10:30	16.10	15.92	0.18
10:45	16.25	16.01	0.24
11:00	16.40	16.30	0.10
11:15	16.80	16.52	0.28

Table 3. Farmland Humidity Test Data

time	Standard humidity value	Humidity monitoring value	Absolute deviation
10:15	55.10	54.28	0.92
10:30	55.24	54.52	0.72

10:45	55.30	54.70	0.60
11:00	55.52	55.12	0.40
11:15	55.73	55.45	0.28

A simple calculation shows that the average temperature of the test data farmland absolute error is 0.18, the average absolute error is 0.58 humidity test data, the temperature error of the system is within ± 0.2% range, humidity error is within ± 1.0% range, indicating that based on wireless transmission field information, online monitoring system can automatically sense the network to complete data acquisition and transmission and can aid GPRS / Internet network, and send data to the data server. The data transmission if of stability, high reliability, real-time and the on-line monitoring of field information can meet basic requirements.

5. Conclusions

The farmland information monitoring generally has the characteristics of complex environment, more monitoring point and wide coverage. In order to solve the problem of low-cost, low-power field information, reliable real-time transmission, a farmland information online monitoring based on wireless sensor network has been designed. The results gained from a set of network communication system tests, inter-node transmission quality tests and remote transmission tests show that: based on wireless sensor network, the online monitoring system of field information can automatically complete the data acquisition and transmission and with the aid of GPRS / Internet network, the data can be sent to the data server with high stability, high reliability, punctuality, meeting the basic requirements of on-line monitoring of farmland information.

Conflict of Interest

The authors confirm that this article content has no conflicts of interest.

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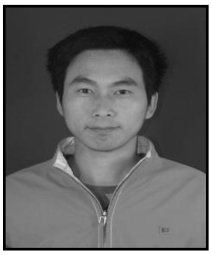

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