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A Design of Modern Greenhouse Environmental Monitoring System

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Abstract Based on the problems in the current greenhouse environmental monitoring system such as difficult connection layout, low flexibility and high costs, this paper builds the greenhouse environmental monitoring system based on wireless sensor network, and designs the sensor nodes and gateway nodes. The sensor nodes of this system are responsible for collecting environmental parameters and sending the data to gateway nodes via wireless sensor network. And the gateway nodes transmit the data to the remote monitoring platform. The microprocessor module of node hardware uses MSP430F149 microprocessor for data processing and control; wireless communication module consists of nRF905 RF chip and peripheral circuit, responsible for transmitting and receiving data; sensor module uses AM2301 sensor for data measurement; the power supply module uses the circuit consisting of LT1129 – 3.3, LT1129 – 5 and Max660 to provide 3.3 and ±5V power. The C language development is employed for wireless routing protocol of node and time synchronization algorithm, to achieve node data acquisition and processing, rule forwarding and remote transmission. Remote monitoring software uses NET. ASP, HTML and C# development to provide visual WEB mode remote data management platform for users. The system goes through networking testing in greenhouse in Xining City, and test results show that the system operation is stable and reliable, and the average network packet loss rate is 2.4%, effectively solving the problems in greenhouse environmental monitoring system and meeting the application requirements of greenhouse cultivation environmental monitoring.

Key words Wireless sensor network, Greenhouse environment, Wireless monitoring system, Network performance

1 Introduction

Wireless sensor network technology has been integrated into all areas of people's life and production, and it is listed as one of the most influential technologies in the 21st century. Recently, wireless sensor network has been involved in various fields, and widely used in agriculture[1-5]. Intel Corporation establishes a vineyard wireless sensor network in Oregon and analyzes the performance of the network[6]. Aline Baggio *et al.* establish a WSN system based on T-MAC protocol to monitor potato temperature, humidity and leaf surface temperature[7]. The wireless sensor network system installed in the pasture is designed to collect agricultural information about soil moisture, air temperature and humidity, and soil salinity[8-11]. The nodes installed in the field are used to collect temperature, humidity, soil moisture, light intensity and carbon dioxide concentration[12-15]. Large growing area and high demand on environment are important characteristics for greenhouse cultivation. Maintaining suitable temperature and humidity is the key to crop growth, but the current measurement on greenhouse environment is still dependent on human. Based on the wireless sensor network hardware platform, this paper establishes a wireless sensor monitoring system for greenhouse cultivation.

2 Design of wireless monitoring system

The wireless monitoring system consists of sensor nodes, gateway nodes and remote management platform. Sensor nodes are used for collecting data on greenhouse environment. Gateway nodes use GPRS network to send the network data to remote management platform. The wireless sensor network uses the form of Ad hoc network for single-hop or multi-hop data transmission. The system structure is shown in Fig. 1.

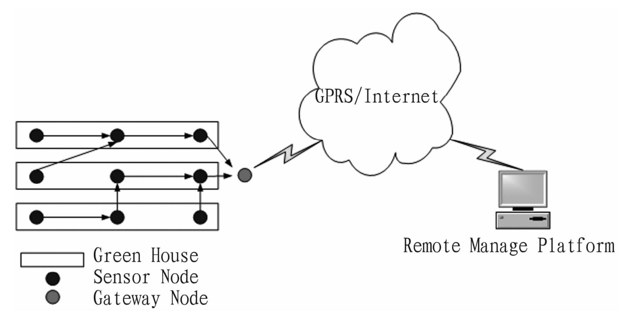

Fig. 1 System structure

2.1 System hardware platform The sensor nodes hardware platform consists of microprocessor module, wireless communication module, sensor module, serial communication module and power supply module. The sensor node can be shown in Fig. 2a. (i) The microprocessor module is the core component. The system chooses AVR series microcontroller MSP430F149 as the master control chip. The microprocessor module can support device management, scheduling, data integration, communication protocol and other functions. (ii) The wireless sensor network has low power demand, so the wireless communication module is a critical part. The wireless communication module must meet low power design, and can change the transmitting power according to different needs. The wireless communication module uses nRF905 RF module, the operating voltage is 1.9 – 3.6 V, and it works in three ISM bands (433/868/915 MHz), with features of strong anti-interference ability, low power consumption and long transmission distance. (iii) The sensor module is responsible for comple-

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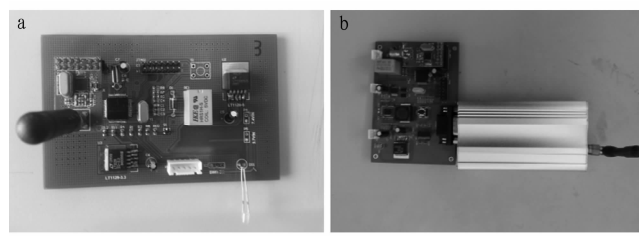
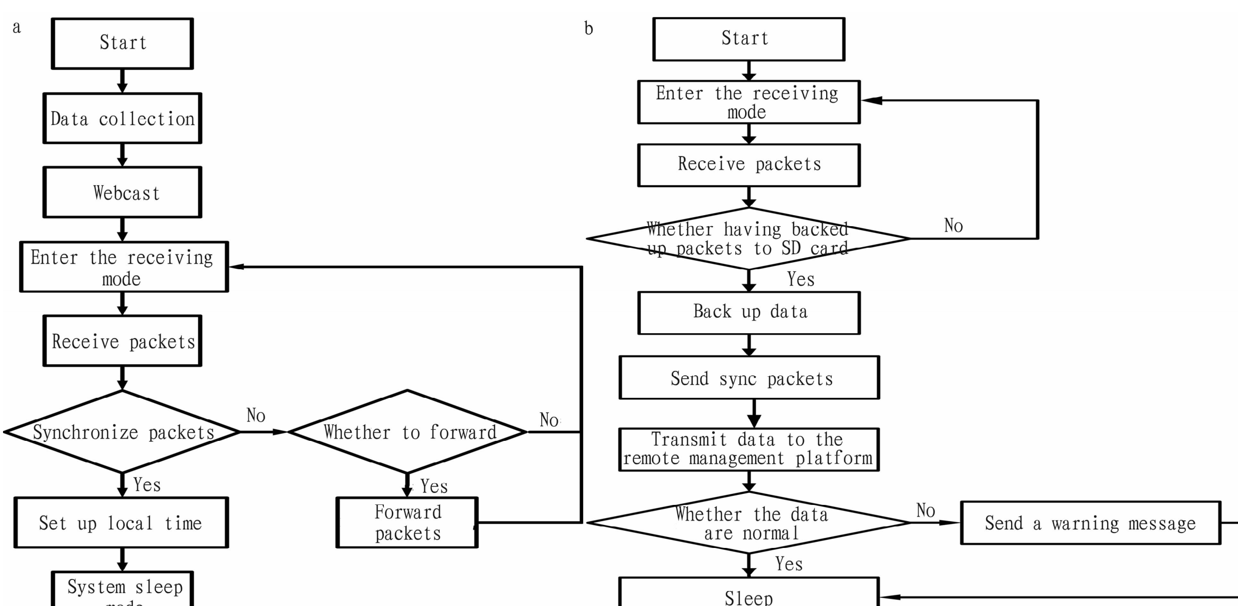
ting the collection of physical parameters. AM2301 sensor mainly collects environment temperature and humidity. (iv) JTAG download module is the program download interface between embedded system and computer. The gateway node hardware platform consists of microprocessor module, wireless communication module, GPRS module, data storage module, serial communication module and power supply module. The gateway node can be shown in Fig. 2b. (i) Like sensor nodes, gateway nodes also use MSP430F149 and nRF905 as the main control chip and RF chip, respectively. (ii) The GPRS module is mainly responsible for data transmission and warning information transmission between gateway nodes and external networks. Gateway nodes use MC55 as the master control chip of GPRS module and communicate with the controller module through the serial port. (iii) Data storage module is used for storing network data to ensure data integrity. Before the data are stored in SD card, data will be transmitted to remote management platform, and managers can obtain data across the network and analyze the variation of greenhouse environment. (iv) Power supply module uses two lithium batteries to provide power to each gateway module. After connection of two lithium batteries in series, it is converted to 3.3 V by the circuit consisting of LT1129-5 and LT1129-3.3, to provide power to processor module and wireless communication module; it is converted to ±5 V by the circuit consisting of LT1129-5 and Max660, to provide power to sensor module; the solar energy is also used to charge batteries, which can help to realize energy self-sufficiency and effectively extend the life of gateway nodes.

2.2 Node software platform The design of the node software platform will directly affect the performance and stability of the node network. In order to make system node effectively complete network task, reduce packet loss and ensure synchronous network, the system software design involves sensor node application and gateway node application. (i) The sensor node application realizes calling of underlying driver program, data collection and dissemination. The greenhouse environment data collected by sensor nodes are broadcast to network when the set time arrives. Then, the sensor node enters reception mode to receive the data packets of other nodes, and judge whether to forward or discard. After receiving the isochronous packet sent by gateway node, sensor node sets the local time and forwards the isochronous packet to the network, and then enters the sleep mode waiting for the next cycle. The flow chart of sensor node application is shown in Fig. 3a. (ii) The gateway node application realizes data remote transmission and data backup and sends a warning message when there is data abnormality. After the system starts, the gateway node first sends synchronization packet to the network to make the entire network into sleep. When the set time arrives, the gateway node enters receiving mode to receive packet from network and back up the data into the SD card. Then, it sends synchronization packets so that the network enters a sleep state and data are transmitted to remote management platform through the GPRS network and the Internet. The flow chart of gateway node application is shown in Fig. 3b.



Note: a. sensor node; b. gateway node.

Fig. 2 System hardware platform



Note: a. sensor node; b. gateway node.

Fig. 3 Flow chart of software

2.3 Design of remote management platform In order to facilitate data management and consulting, the remote management platform is designed based on .NET development platform, SQL Server 2000 and C#. Via computers and mobile phones, users can have access to the Internet or WAP network for remote data management and consulting. The remote management platform mainly includes real-time data display, statistical data analysis, real-time warning system, historical data query and other functions.

3 Networking test and analysis of node performance

The system designed in this paper is arranged in Huifeng vegetable planting base in Xining City for testing, and the environmental temperature and humidity is online monitored in five greenhouses. 1 sensor node is placed in each greenhouse and 3 sensors are installed to measure greenhouse environment indices. The installation of sensor nodes is shown in Fig. 4.

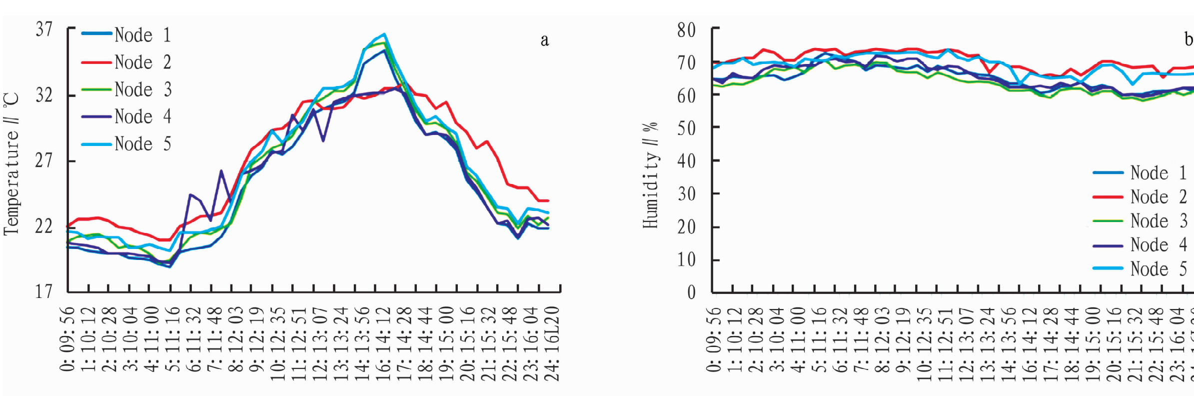
3.1 Networking test This system tests packet loss ratio (PLR) to evaluate the reliability of the network. Data collection period is set to be 30 minutes, and the PLR test time is set to be 168 hours. The PLR test results are shown in Table 1. In Table 1, Local Pakts represents the number of local data packets sent by each node; Forwarding Pakts represents the number of data packets forwarded by node; Rec Pakts represents the number of local data packets received by PC; Lost represents the number of lost data packets for each node. The PLR of system network is calculated: $PLR = \frac{\sum Lost}{\sum Local\_Pakts + \sum Forwarding\_Pakts}(\%)$. The test results show that the system communication is stable and reliable, and the average PLR of the entire network is 2.4%.

Fig. 4 Installation of sensor node

Table 1 The PLR testing statistics

ID	Local Pakts	Forwarding Pakts	Rec Pakts	Lost
Node 1	336	15	345	6
Node 2	336	12	339	9
Node 3	336	7	337	6
Node 4	336	5	329	12
Node 5	336	1	328	9
Total	1680	40	1678	42

3.2 Greenhouse temperature and humidity measurement The greenhouse environmental temperature and humidity are measured by AM2301 sensor, and the average data are collected by Node 1, 2, 3, 4 and 5 and remotely transmitted to server via gateway node. The monitoring data on August 19 can be shown in Fig. 5.



Note: a. temperature; b. humidity.

Fig. 5 Greenhouse monitoring data on August 19

4 Conclusions

The wireless sensor network is an effective tool for measuring environmental parameters. The node designed in this paper has low power and is stable and reliable. It can accurately measure the greenhouse temperature and humidity. The analysis and testing results show that this wireless sensor network can stably operate in application, and accurately transmit the measurement data to remote management platform. The PLR of the network is low, and it can meet the needs of actual operation.

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