Environment Monitoring and Early Warning System of Facility Agriculture Based on Heterogeneous Wireless Networks

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***Abstract*—This paper presents a distributed heterogeneous wireless sensor network for facility agriculture environmental monitoring and early warning system based on Internet of Things technologies, namely using the ZigBee wireless sensor network technology in real-time monitoring of facility agriculture environmental parameters, such as temperature and humidity. In exceptional case, GSM SMS will notify the user to take appropriate environmental regulation measures. The system includes a ZigBee coordinator node, multiple ZigBee sensor nodes, multiple ZigBee routing nodes, a GSM SMS module, and the management software based on SQL running on the remote control center PC. The real-time collection and early warning from facility agriculture environmental parameters enhance the level of facility agricultural management, thus improving the yield of the crop.**

Keywords—distributed; heterogeneous network; facility agriculture; ZigBee

I. INTRODUCTION

Facility agriculture is an important part of modern agriculture, which makes agriculture production gradually get rid of the dependence on the natural environment, thus steadily picking up the output of agricultural products with high quality. Facility agriculture has a variety of modes of agricultural production, and Plastic Greenhouse is the most common one. Since the environmental parameters such as temperature and CO2 concentration in Plastic Greenhouse can be artificially controlled, the crop can achieve the best growing conditions by making proper adjustment to those parameters. Considering the environmental parameters of the Greenhouse directly affect the growth of crops, it’s of great important to monitor the environmental parameters and more importantly early warn of the environment can be obtained in time. Therefore, in order to strengthen the ability to monitor and adjust the environment, agricultural greenhouse environmental parameters monitoring and early warning system was fast developed.

Internet of Things (IoT) technology has being fast developed in recent years. In 2005, a report of the International Telecommunication Union (ITU) on IoT, proposed that any objects can exchange information and communicate at any moment and any place, thus extending the concept of IoT [1]. Even though the core technology of the IoT is still the Internet, the client of the Internet has extended and expanded to objects and then realize the exchange of information and communication between objects. The IoT makes it possible to access remote sensor data and control physical things from a distance, thus building a bridge between physical and digital world [2][3].

According to the service types and functionality, the IoT architecture can be divided into 4 layers, namely perception layer, access layer, network layer and application layer. The perception layer provides the functional and procedural means to collect physical information with using RFID tags, various types of sensors, cameras, etc. The access layer mainly delivers the data from the perception layer to the Internet. The network layer provides the functional and procedural means of transferring data sequences from a source host to a destination host. The application layer, the closest layer to the end user, integrates the underlying functionality of the system and then builds a practical application for the users.

IoT technologies include many technologies, such as ZigBee technology and RFID technology. During the past few years, ZigBee wireless sensor network technology has shown a broad application prospects in the facility agriculture due to its unique advantages, which are low-cost equipment , self-organization of the network, flexible network sensor node ,reliable data transfer, low power consumption, etc.

ZigBee wireless sensor nodes can collect soil moisture, nitrogen concentration, pH value, precipitation, temperature, air humidity and CO2 concentration, and then deliver them the central control device by wireless sensor network for the user to make decision and reference, so that the user can timely know the problems and take effective measures to improve the survival rate of crops per unit of production.

IoT technology used in Facility agriculture has interested some research groups. Morais proposed a smart irrigation and environmental monitoring system in 2005. The wireless network in the system has a top-down hierarchy structure [4]. Hui Liu has presented a wireless sensor network prototype for environmental monitoring in Greenhouses. In the system, A mesh network is build for data acquisition and routing the data to a special designed sink node. And then the sink node sends them to a remote PC through GSM network. As the author shows, the network prototype could meet the goal of providing real-time data on environment monitoring and remote querying [5].

In order to strengthen the system's ability to interact with the users, GSM network can be integrated into the system for early warning notification via SMS, so the function of the GSM network is different from Liu's results.

II. SYESTEM INTRODUCTION

In this paper, a distributed heterogeneous wireless sensor network used for monitoring facility agriculture environmental parameters is presented. (See Fig. 1)The network adopts distributed network architecture, and the entire network includes multiple wireless sensor nodes, multiple wireless routing nodes, a wireless coordinator node and a GSM SMS alarm module for early warning. Fig. 2 is the system flow chart and its module function.

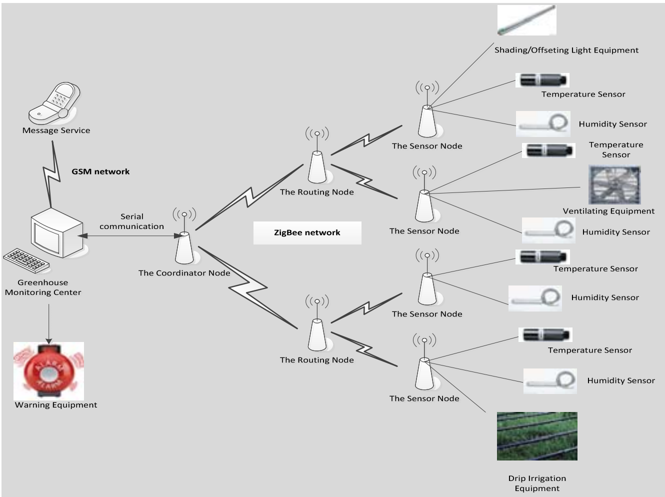

Figure 1. System framework

Wireless sensor nodes containing different kinds of digital sensors, which are used to collect the data of various environmental factors, are the terminals of the network. They can join or exit the wireless monitoring network freely.

Wireless routing nodes are responsible for the whole network's routing work, and multiple wireless routing nodes make up a wireless mesh network. Wireless routing nodes can also join or exit the wireless monitoring network freely.

The wireless coordinator node, namely the central control node of the network, is responsible for receiving and analyzing the data sent by the sensor nodes. All nodes receive and send data in accordance with the priority level of data types. When the PC gets the data from the sensor nodes, it will analyze them according to the crops growth factor database analysis. When the data are consistent with the alarm requirements, GSM SMS alarm module will send a alarm message to the user via GSM network. The user can send control Instruction through the GSM network to the PC, and then operate facilities to adjust the environment.

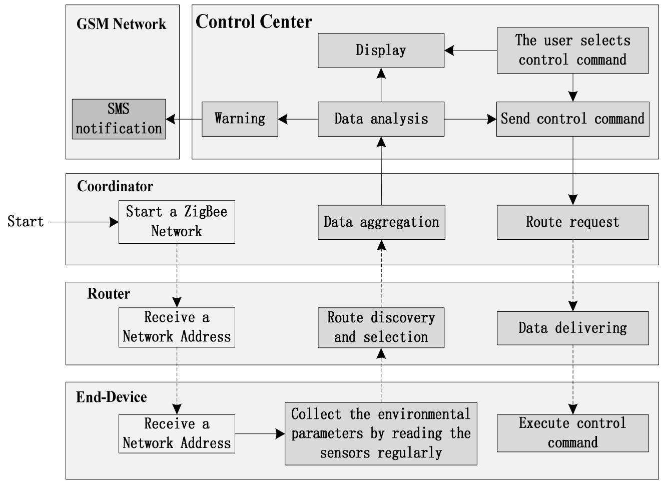

Figure 2. System flow chart

III. TECHNICAL ROUTE

A. *The Coordinator Node*

The coordinator node is the device that "starts" a ZigBee network. The main software implementation process of the coordinator is shown below: After initialization of system's hardware and software, the coordinator node scans the RF environment for existing networks, and chooses an idle channel. Then the coordinator will select a network identifier (also called PAN ID) for the new network. At last, the coordinator will enter a loop process in which it monitor and handle other devices' request to join the network, receive network data and deliver them to the PC, detect whether the PC has control command to transmit and send control commands to the other nodes.

B. *The Routing Node*

The wireless routing node performs functions for allowing other devices to join the network and multi-hop routing. Due to the multi-hop routing function, two devices can depend on other intermediate devices to exchange data in a ZigBee network, and if a particular wireless link is down, a new route will be found to avoid that particular broken link. These greatly enhance the reliability of the wireless network. Next, we will show the detailed description of a routing node's working.

After initialization of system hardware and software, the router looks round for existing networks. And then it will evaluate their ZigBee channel energy. If the energy level on that channel is above a threshold value, the router can join the network; otherwise it has to continue to scan for a available network. In order to join the selected wireless network, the router will send beacon frames to the router and coordinator on that network. If the router can receive the returned super frame, then it will continue to send request to join the network, otherwise terminate the joining process.

If the router continue to receive the acknowledgement frame returned by the network, it will send request for network address, otherwise terminate the joining process. If the router can receive a network address returned by the network, it shows that the router join the network successful, otherwise terminate the joining process. At last, the router will also enter a loop process in which it monitor and handle other devices' request to join the network and transmit the network data.

C. The Sensor Node

The wireless sensor nodes are end-devices of the wireless network, mainly being responsible for collecting environmental parameters like temperature, humidity and light etc. Moreover, it boots the illumination adjusting equipment. The detailed software implementation process of the sensor node is shown in Fig. 3.

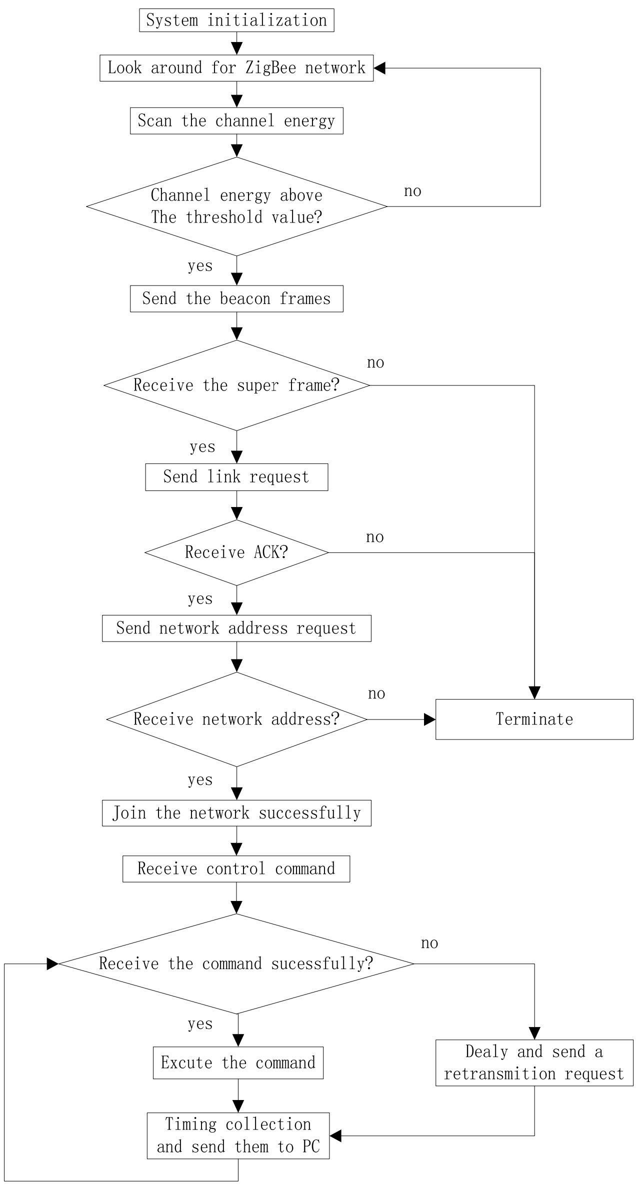

Figure 3. The wireless senor node flow chart

The process for joining the network of the wireless sensor node is similar to that of the router. The difference between the two types nodes is that the sensor node will read the temperature, humidity and light sensor and then transmit them to the PC in a multi-hop way. What's more, if the network control command is received, the sensor node will determine the status of the command. And if it's success, the command will be executed, otherwise the sensor node will send a retransmission request after a certain time delay.

IV. THE THE RESULTS OF OUR PROJECT

The upper computer software is the main control part of the entire data acquisition and analysis system, developed by Microsoft Visual C++2008 and using Microsoft Office Access 2003 as its database. The interface of the software is shown in Fig. 4. By choose the related parameters for the software; we can realize functions including a remote control, data acquisition, data storage, data display, etc. Data analysis mainly processes the various types of data provided by the sensor nodes, including temperature, humidity, and remaining capacity of the node etc. Besides, it can take the initiative to control the system to collect environmental factors, and then display them. As soon as abnormalities are detected by analyzing the environmental factors, early warning function will be enabled, and GSM warning messages will be sent to the system user.

Figure 4. Data service and analysis interface

V. CONCLUSIONS

We have proposed an environmental parameter monitoring and early warning system for facility agriculture, and then show the detailed development process and functions of the main parts of the system. When applying the system to a real facility agriculture environment, the upper computer software receives the timing collecting data from the sensor nodes with high stability and accuracy. And the reliability and timeliness of the warning function reach a good level.

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