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Environmental monitoring of intelligent granary in grain storage relying on radio frequency wireless WSN nodes

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Abstract

The safety of grain storage has always been a relatively complicated problem. With the rapid development of science and technology and the improvement of agricultural automation in my country, the technology for granary management has been further improved. In view of the shortcomings of low efficiency and poor accuracy of manual point-by-point measurement in China's grain storage process, this paper proposes a granary monitoring system based on wireless sensor network to collect various data on temperature, humidity, and insect pest through sensor, and transmit them to the remote monitoring center with GPRS in order to reduce the loss during grain storage. This paper proposed a granary monitoring system based on the wireless sensor network (WSN). Various data on temperature, humidity, and pests are collected by sensors and transmitted to the remote monitoring center through WSN. The monitoring management software completes the real-time query of the uploaded data and issues alarms on parameters that have exceeded the standard. It has not only ensured grain quality but also reduced labor intensity, which complies with the real-time and intelligent requirements of the granary monitoring system.

Keywords: *Wireless Sensor Network, Granary Monitoring, Intelligent Granary;*

1. Introduction

Our country is a major grain-growing country and a major grain-consuming country. The grain storage is related to both military supplies and civilian food and national security and social stability [1-2]. The safety of grain storage has always been a relatively complicated issue. With the rapid development of science and technology and the improvement of agricultural automation in our country, the granary management technology has been further improved [3-5]. Temperature and humidity have always been the main factors affecting the quality of the grain storage process [6-8]. How to design a granary monitoring system to monitor the temperature, humidity, and rat damage in the granary in real-time is an issue worthy of our study [9]. Currently, a wire transmission system composed of multiple sensors, multi-channel analog switches, A/D converters, and single-chip microcomputers is applied to most of the grain condition detection systems used in grain storage [10]. This collection system requires a large number of cables to be installed in the warehouse, which is complicated to be installed and removed. At the same time, the measurement error is relatively large due to the influence of wire resistance and distributed capacitance. In addition, many grain warehousing units in China still apply the traditional method that combines temperature measuring instruments with manual transcription and management, which has low efficiency and poor accuracy. Hence, the identification of effective granary temperature and humidity measurement methods and corresponding intelligent control has always been an essential issue in the development of grain warehousing technology. The intelligent information management system of the granary has now become a significant development trend of grain storage technology.[11]

Wireless Sensor Networks(WSNs) are a special Ad Hoc network organized jointly by a large number of multi-functional miniature wireless sensors with low power consumption [12]. It meets the IEEE802. 15.4 wireless transmission standard and features low complexity, low rate, low power consumption, and low cost. Compared with other wireless networks, wireless sensor networks as a new generation of sensor networks have higher reliability of data transmission, simple and flexible networking, and vast application prospects, such as military reconnaissance, environmental monitoring, medical monitoring, space exploration, urban traffic management, warehousing management, etc. [13]. Randomly distributed tiny nodes integrated with sensors, data processing units and communication modules in the network form a network through self-organization, detect temperature, humidity, noise, light intensity, pressure, as well as size, speed, and direction of the moving objects and many other physical phenomena of our interest through various sensors set in the nodes, and transmit information through wireless communication [14]. Data-centric, orientating at obtaining information, without wiring, the network system has high node density and high accuracy in data collection [15].

2. Overall design of the monitoring system

To monitor and manage the granary accurately and effectively, we use the wireless sensor network technology to collect various data on temperature, humidity, pests, and so on. The software is used to establish an early warning mechanism, which has not only guaranteed grain quality but also lowered labor intensity, compliant with the real-time and intelligent requirements for granary monitoring system data.

The granary monitoring system based on wireless sensor network is composed of a large number of inexpensive micro-sensor nodes, wireless gateways and monitoring centers deployed in the monitoring area.

The wireless sensor network topology includes star, cluster, and mesh topology. In order to reduce energy loss and data packet loss, this paper uses star network topology. The system structure is shown in Figure 1.

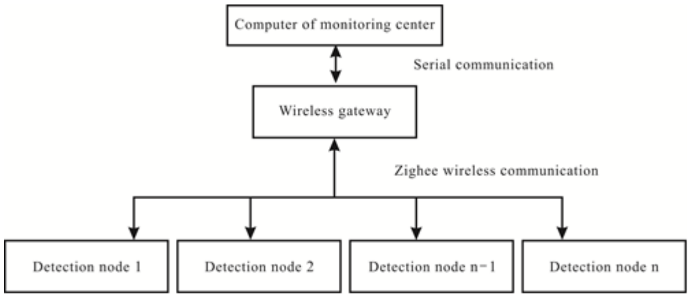

Figure 1. Schematic diagram of the system structure

The data perception and collection of temperature and humidity, audio, smoke, water immersion, infrared, etc. are completed at the detection node, and the collected data is sent to the wireless gateway through the routing protocol regularly; the wireless gateway is mainly responsible for the establishment of the network and transmitting the collected data to the monitoring center through the serial communication; the monitoring center completes the collection, processing, monitoring and display of wireless sensor node data with Lab VIEW graphical programming environment, and supports remote access to the information query terminal.

The wireless sensor network is used to monitor the temperature, humidity, rat damages, insect pests, and fire at various points of the granary in this paper. The GPRS network communication technology is combined to implemented centralized monitoring of each granary. In the remote monitoring center, the corresponding alarm thresholds are set for various food situations according to the requirements of various food preservation indicators. When the collected grain condition exceeds the standard, the monitoring system will issue the corresponding alarm promptly. The management staff can learn about the grain condition of the granary through the monitoring interface to make relevant decisions timely and accurately.

The hierarchically clustered tree topology is a multi-hop routing, low-cost, and low-power network

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structure. Its advantage is the relatively simple routing, which is easy to expand, simplifying the connection with the Internet. It can effectively balance the load at each network node to use this structure, avoid the flooding problem occurring when the route is established, and can also be connected to industrial Ethernet, making the network easier to connect with the existing security monitoring system.

The specific method is as follows: all sensor nodes in the monitoring area are divided into several clusters, the sensor nodes in each granary are divided into one cluster, and each cluster acts as a fixed self-organizing network. They are divided into four types: sensor end nodes (cluster nodes), cluster-head nodes, network coordinator, and gateway nodes according to the function of sensor nodes in the network. The end node is responsible for collecting sensor information and sending it to the corresponding cluster-head node. After the cluster-head node de-redundantly processes the data, it forwards the data to the nearby network coordinator, which then forwards the data to the gateway node and transmits it to the remote monitoring center via GPRS. Meanwhile, the control commands of the remote monitoring center are transmitted to each end node in layers through the GPRS gateway, network coordinator, and cluster-head node. The cluster nodes of each cluster are arranged at the center of the cluster, making the difference of transmission distance from each end node from it not large, and the power consumption of each node evenly distributed, which avoids the consumption of more energy of some nodes due to the long communication distance, thus extending the life of the entire network. The overall system design structure is shown in Figure 2.

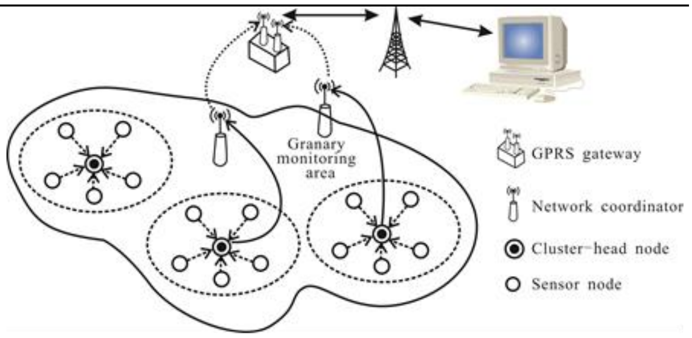

Figure 2. The overall structure of the granary monitoring system

3. Monitoring system hardware design

3.1. Structural drawing of system design

As the scale of the node network in the entire network is excessively large, a clustering hierarchy development model is adopted when designing the system. The whole system can be divided into a data collection layer, a system service layer, and an application management layer.

In this system, the collected data are transmitted to the system monitoring center by GSM. The system service layer processes the received data. The system application management layer manages and monitors the entire system according to the processed data to ensure the safety of the entire granary. Based on the above analysis, this paper uses the system architecture shown in Figure 3.

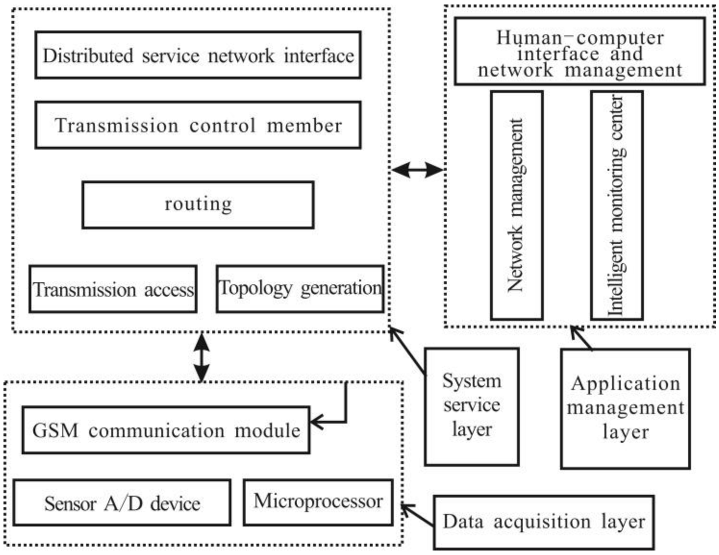

Figure 3. Architecture of monitoring system

The data acquisition layer shields the bottom layer hardware details for the upper layer through the abstraction of the hardware platform (power

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supply, data acquisition, data processing, and wireless communication unit), simplifies the porting of the system platform. The main functions of this layer implement data acquisition and transmission tasks of wireless network nodes. The system service layer includes channel access, sensor service, and network topology generation. In this layer, it will also complete the implementation of various routing and security algorithms and support various communication transmission protocols in addition to implementing kernel services such as task scheduling and semaphores of the operating system. Given that the amount of data collected in the system is relatively large, a special component is designed in the architecture design of the system, which is mainly used for congestion detection, feedback, and control of system data. The introduction of this component can significantly improve the reliability of the entire wireless monitoring network. The application layer is defined by users according to the needs of specific applications, and the upper layer software can be conveniently designed by using the interface provided by the system service layer. The monitored granary is controlled intelligently according to the requirements of the system to ensure its safety.

3.2. Zig Bee protocol overview

Zig Bee is a wireless network protocol developed by Zig Bee Alliance. It is a two-way wireless access technology with a close range, low power consumption, low data rate, low complexity, and low cost, and mainly suitable for automatic control and remote monitoring The IEEE802. 15.4 specification is taken as the medium access layer (MAC) and physical layer (PHY). Compared with other wireless network technologies, Zig Bee's typical transmission data types include periodic data, intermittent data, and low response time data. This wireless communication technology has the following characteristics: 1) low data transmission rate, only 10-250kbps; 2) low power consumption, 2 dry batteries of No. 5 in sleep mode can be used for 6 to 24 months; 3) reliable data transmission;) Large network capacity, the entire network can support up to 65000 Zig Bee network nodes; 5) automatic dynamic networking, autonomous routing; 6) high security; 7) low implementation cost.

3.3. Basic introduction of hardware modules

3.3.1. Network node module of RF sensor

The RF sensor node is the basic unit of the wireless sensor network. The stable operation of the node is the fundamental guarantee of the reliability of the entire network. The sensor node is composed of Zig Bee end nodes and routing nodes, and the sink node is served by the Zig Bee coordinator. This paper designs the sensor node and its peripheral interface circuit based on the Freescale second-generation Zig Bee development platform MC13213 chip. MC13213 integrates the low low-power- consumption 2. 4GHz RF transceiver MC13192 and 8-bit microcontroller HCS08, HCS08 has 60KB of FLASH and 4KB of RAM, enough to store the Zig Bee protocol stack and run simple applications. The RF transceiver of M13213 supports the 802.15.4 standard, working in the 2. 4GHz ISM band, and can provide a data throughput rate of 250kb/s and 16 optional channels. The transceiver includes a low-noise amplifier (LNA), power amplifier(PA) of 1mW output power with VCO, integrated transmit/receive switch, on-board power regulator, and full spread-spectrum encoding and decoding. HCS08 series MCUs have high operating performance, low power consumption, and 4 working modes, which greatly extend the battery life.

The sensor network node is composed of a sensor module, a processor module, a wireless communication module, and a power module. The hardware structure of the sensor node is shown in Figure 4.

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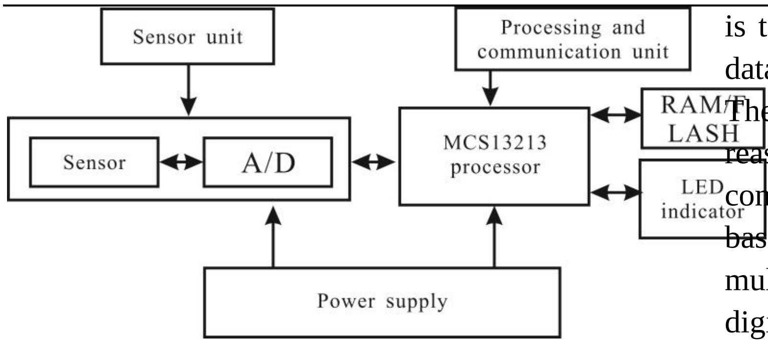

Figure 4. Hardware structure of the sensor node

The sensor module is responsible for the collection and data conversion of the information in the monitoring area; the processor module is responsible for controlling the work of the entire sensor node, storing and processing the data collected by this node and the data sent by other nodes; the wireless communication module is responsible for wirelessly communicating with other sensor nodes to exchange control information and send and receive data. The power module provides the energy required for the operation of the sensor node, usually using a miniaturized battery.

3.3.2. Design of Zig Bee sink node

The distributed cluster-head node accepts the data report from the sensor node, and after a simple fusion, sends the data to the sink node from the first-level cluster head, and then through the Siemens MC39i data module, transmitting the data to the monitoring center via GPRS/GSM. It is composed of the Zig-bee module, GSM/GPRS data module, and microcontroller, as shown in Figure 5. The connection between them is achieved through an asynchronous serial port. As multiple cluster-head nodes are distributed in the sensor network, the controller must implement data polling and scan for different ID nodes to upload with software interruption, making the node data be transmitted sequentially and completely after being processed by the microcontroller.

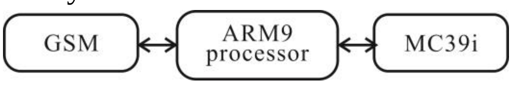

Figure 5. Sink node structure

3.3.3. Module design of multifunctional sensor board

The main purpose of the sensor network node is to obtain various physical data, and the physical data must be obtained by the sensor board. Therefore, it is very important to select sensors reasonably in accordance with the power consumption and volume requirements of the nodes based on ensuring data accuracy and reliability. The multifunctional sensor board is designed by using a digital sensor with a simple peripheral circuit, which can collect data on temperature, humidity, infrared and other signals.

According to the requirements of grain condition monitoring indicators, we collected relevant information through temperature and humidity, infrared, insect pest sound, smoke sensors selected.

1) Temperature and humidity sensor: Temperature and humidity are the most basic indicators in grain storage. The temperature and humidity are measured by selecting SHT11 temperature and humidity dew point sensor launched from the Swiss Sentrion. It has relative humidity and temperature measurement, all calibration, excellent long-term stability, ultra-low energy consumption, ultra-small size, auto sleep, debugging free, calibration-free, free of the peripheral circuit and full interchangeability;

2) Insect pest sound sensor: Stored-grain insects are also one of the harmful factors of food. The ADE-2010 insect sound detector made by Beijing Channel Scientific Instrument Co., Ltd.. is used to determine the occurrence of insect pests by listening to the sounds emitted during insect activity;

3) Infra-red sensor: SNS-303 high-performance curtain passive infrared intrusion detector made by Kunshan Ni Cela Electronic Equipment Co., Ltd can detect rats invading the granary;

4) Smoke sensor: The fire hazard also poses a considerable threat to the granary. In this paper, the MS5100 smoke sensor is selected to determine whether a fire has occurred according to the detected smoke density so that the fire can be monitored in time.

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3.3.4. GSM wireless communication module

In the WSN-based granary monitoring system, the network is centered on data transmission, and the GSM wireless communication module is a relay station for the wireless sensor network to exchange control information and data with the monitoring center. Its hardware structure is shown in Figure 4.

The STMCOM's GSM/GPRS dual-frequency module-SIM100 is adopted for GSM module, which integrates a complete radio frequency circuit and GSM baseband processor, and has a standard RS-232 interface, and provides an AT command interface to the user to support digital, language, short message, GPRS and fax services. The SIM100 and peripheral circuits are connected by a 60-pin system connector. Its peripheral circuits are: power supply; standard RS-232 serial port l analog audio output interface; radio frequency interface tSIM card interface; control interface; general input and output interface and network indicator ISPI interface, etc.

4. Software design of monitoring system

In this paper, the network layer and application layer are developed. Combined with the GPRS gateway, the function of the monitoring center is implemented. Acquisition commands are sent to each node to upload data at the sensor nodes.

4.1. Software design of RF wireless WSN node

RF wireless WSN nodes (including ordinary sensor nodes and cluster-head nodes) follow the working mode of sleep, wake-up, and normal operation. After the system is initialized, it enters the low-power sleep mode, waits for the wake-up by the interruption and executes the interruption program. After the interruption is executed, the system returns to the state before the interruption and continues to execute the low-power mode. The main program flow of the sensor node is shown in Figure 6.

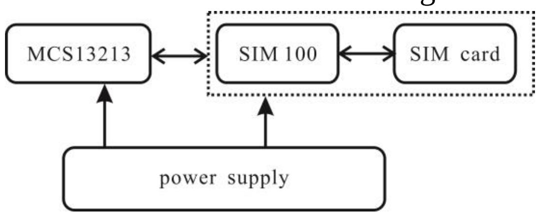

Figure 6. GSM hardware structure of the communication module

After the sensor node is powered on, it first completes the initial setting of each parameter, then broadcasts the granary number in its address information, and starts searching for the network of its own cluster accordingly. Once the sensor node searches out the network, it immediately sends a request to establish the network. After the network is built, it enters a low-power and energy-saving state and waits for an interruption command.

4.2. Work process

When the gateway node is powered on or reset, it first initializes and establishes a new network, gives network information such as the ID number and channel number of the network, and then establishes a connection with the monitoring center. Then it enters the wireless monitoring state, if a wireless signal exists in the air, and it is a detection node to join the network, then the network number and ID shall be assigned to the joining node. After the detection node is powered on or reset, it initializes and sends a network access request to the gateway node. After joining successfully, it shall enter the sleep state. Environmental data shall be collected at the set time, and then the data sent to the gateway. Figure 7 shows the program flow of the detection node.

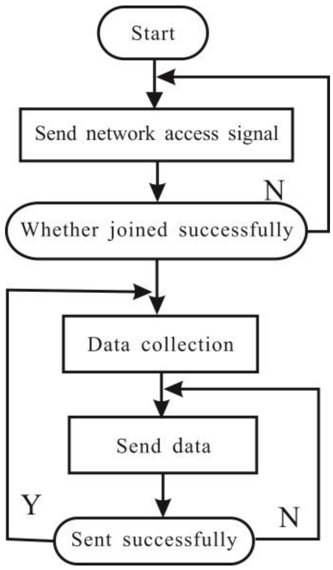

Figure 7. Flow chart of the gateway node program

4.3. System design of monitoring center

The monitoring center management software is

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designed using Visual C++ language. The system consists of data collection, query display, alarm setting, and user management module. The data collection module is responsible for collection and storage of the data; the query display module can directly retrieve the historical data of the specified sensor from the database and display it in a graphic manner. The temperature and humidity alarm thresholds are set to 20°C and 5%RH, respectively, when data collected at a node is greater than the temperature and humidity threshold or when rat damage, insect damage or fire hazard occurs, the corresponding node status shall turn into a red warning; the user management module is used to set the visitor authority. The data processing flow of the monitoring center is shown in Figure 8.

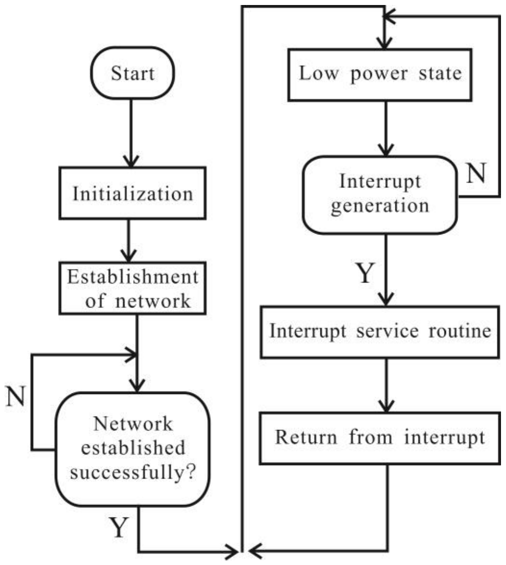

Figure 8. The main program flow of the sensor node

5. Experimental results

In the experiment, 200 cluster head nodes, 20 temperature and humidity sensors, infrared sensors, detectors (pest sounds), and sensors (smoke) are randomly arranged in a hexagonal honeycomb area with a side length of 400 m. To connect these sensor nodes, we arranged a network coordinator and WSN gateway. Firstly, data are collected based on the monitoring system and transmitted to the monitoring center through WSN. After processing and analysis, the data are presented on the monitoring interface in real-time. In the system, red and green colors are used to indicate the status. When an index is abnormal, a red alarm is issued; otherwise, it is considered to have no problem. Green color indicates that the status is normal. The gravity center of the granary is shown in Figure 9:

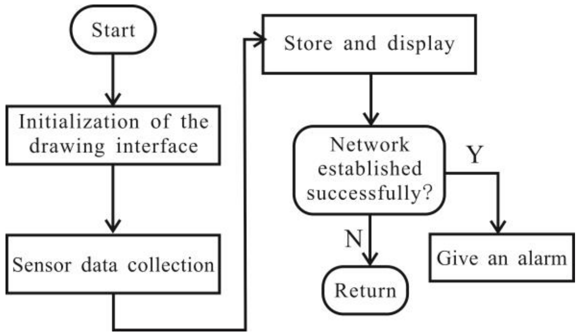

Figure 9. Data display processing flow

6. Conclusions

In this paper, granaries are monitored intelligently through wireless RF WSN nodes. Various data on temperature, humidity, and pests are collected by sensors and sent to the remote monitoring center through WSN. The monitoring management software completes the real-time query of uploaded data and issues alarms on the parameters exceeding the standard. It has not only guaranteed grain quality but also lowered labor intensity, which complies with the real-time and intelligent requirements of the granary monitoring system.

The intelligent monitoring of granaries is conducive to fast processing and analysis of information so that leaders can make scientific decisions without causing significant losses. Hence, intelligent granary monitoring through wireless RF WSN nodes has promoted business integration, improved efficiency, and reduced labor costs.

Acknowledgement

1.Access control technology in Henan key R & D and extension special (science and technology)182102210324 SSL VPN system. 2. research and application of dynamic authorization model A413009 key scientific research project plan 19 in Henan Province in SSL VPN system. 3. the study of security control of the national natural science foundation 61703146 event-triggered networked system. Research 4.Wireless Sensor

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