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# Greenhouse Environment Monitoring System Based on Wireless Sensor Network

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**Abstract:** This paper aims to solve the defects of the existing greenhouse environmental monitoring system, and proposes a monitoring scheme relying on the ZigBee wireless sensor network, which realizes the real-time tracking of greenhouse environmental data with the help of hardware and software cooperation. At the hardware level, the ZigBee wireless sensor network architecture is built with a CC2530 chip as the center, covering the sensor node and the sink node. The software level involves the data collection and transmission of the sensor node, the data receiving and forwarding of the sink node, and the monitoring and management of the host computer. After testing and verification, the system is stable and reliable, the overall structure is simple, the layout is flexible, and can effectively achieve the goal of wireless monitoring of greenhouse environmental data.

**Keywords:** ZigBee; CC2530; Greenhouse; Wireless sensor networks; Environmental monitoring

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## 1. Introduction

Recently, the field of agricultural technology has developed rapidly in the country, and greenhouse cultivation technology has been widely adopted. Environmental factors such as temperature, humidity, light intensity, and carbon dioxide concentration in the greenhouse play a key role in the growth of crops. Real-time monitoring of these factors is conducive to improving the greenhouse environment. At present, China adopts the wired connection method in greenhouse environmental monitoring, but this method has shortcomings such as cumbersome wiring, weak anti-interference, high cost, and complex maintenance. With the continuous progress of wireless communication technology, the ZigBee wireless network has many advantages, such as short-distance communication, low cost, and low energy consumption, and its application in the field of agricultural greenhouse is gradually increasing. The greenhouse environmental monitoring system designed in this paper introduces ZigBee technology, takes the CC2530 chip as the core, and designs a sink node and sensor node [1]. The sensor node collects the greenhouse environmental parameters, sends the data to the sink node through the ZigBee network, and then uploads the data to the monitoring center through the RS-232 serial port for storage, display, and query [2]. In addition, the monitoring center can send control instructions to the sensor node to complete the collection and adjustment of environmental indicators, to reduce system expenses and energy consumption, enhance the expansion of the monitoring network and the maintenance efficiency of the equipment, and then improve the performance of the entire monitoring system.

# 2. The design goal of the work

## 2.1. Build an accurate and stable greenhouse environmental monitoring system

The system focuses on the continuous detection of key environmental indicators such as temperature, humidity, and light intensity in the greenhouse, and is equipped with a remote operation function to achieve the purpose of accurate adjustment of the greenhouse environment.

## 2.2. Continuous detection of greenhouse environmental indicators

With the help of wireless sensor network technology, a large number of high-precision and stable performance sensing units are deployed in the greenhouse to collect environmental information continuously and send it to the core control node for processing and analysis.

## 2.3. Realize the remote control function

With the help of mobile phone or computer client software, it is convenient for greenhouse managers to remotely view and adjust the greenhouse environment, such as adjusting the temperature, humidity, light intensity, and other factors, to meet the growth needs of different crops, so that greenhouse management becomes easier and more efficient.

# 3. Analysis of relevant status quo

The greenhouse environmental monitoring system has evolved from the previous wired sensing mode to the wireless sensing unit, overcoming the problems of cumbersome wiring and high costs, and enhancing the flexibility and expansibility of the system.

The vigorous development of the Internet of Things technology has promoted the wide use of real-time observation and remote control functions, and managers can monitor and adjust the greenhouse without time and space restrictions, thus significantly improving management efficiency and convenience.

The system will accumulate massive data in the operation process, and data processing and analysis methods such as data mining and machine learning are deeply integrated into it, providing strong support for scientific decision-making.

# 4. Technical scheme and analysis

## 4.1. Overall system structure

This system is mainly used for monitoring farmland environmental information, and its overall structure design is shown in **Figure 1**. It consists of three parts: a data information collection module, an information transmission module, and a remote monitoring module.

Data acquisition unit: Composed of many soil temperature and humidity sensor nodes and a multi-functional wireless sensor network, with the help of sensor probes to obtain the soil temperature and humidity, air temperature and humidity, carbon dioxide concentration, and other environmental data.

Information transmission module: The use of ZigBee wireless communication technology to build a collection network. The ZigBee coordinator module will be the sensor node data convergence, through the GPRS/4G/WIFI module uploaded to the remote monitoring terminal [3].

Remote monitoring unit: Based on WEB technology to create a monitoring website and background SQL database, to complete the collection of data storage, management, and query display functions.

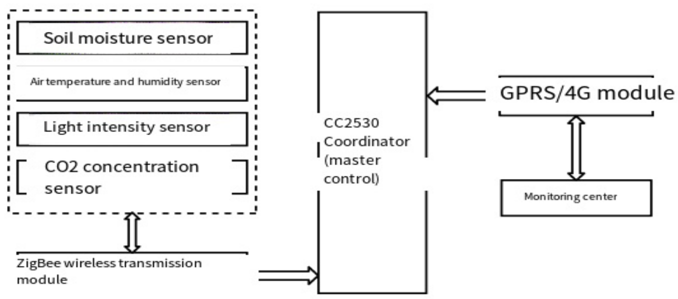


**Figure 1**. The overall design of the monitoring system

## 4.2. Network topology

This system adopts the star network topology [4]. A large number of wireless sensing units are uniformly distributed in the greenhouse. These units act as end nodes and the main task is to collect environment-related data. In addition, a summary node is also set up to act as a core node, which is installed outside the greenhouse to receive the data transmitted from the sensor units and transmit this data to the back-end processing system by other means. This architecture is concise and easy to expand and maintain management.

## 4.3. System hardware design

### 4.3.1. Main control module

The main control module adopts CC2530 as the core processor. CC2530 supports multiple channel selection and ZigBee 2007/PRO protocol stack [5]. This makes the node based on the design of CC2530 reach a farther communication range, have a more stable networking efficiency, and meet the requirements of the system. Selecting CC2530 as the central processing unit of the main control module can complete the data collection, transmission, and processing of the sensor node. Its low energy consumption also makes the system durable and reduces the frequency of battery change. Through the programming of the CC2530 digital I/O interface and built-in peripherals, the interaction and control with the sensor nodes can be realized. In addition, the wireless communication function of CC2530 can ensure stable wireless data interaction with sensor nodes.

### 4.3.2. Sensor selection

Temperature sensor: The DS18B20 temperature sensor was chosen, and the DS18B20 is a digital temperature detector with excellent accuracy and stability [6]. It can be connected to ZigBee sensor nodes through a single data cable and communicate with digital signals. The sensor has a wide operating voltage range of 3V to 5.5V, and the temperature measurement accuracy reaches ±0.5°C, which is very suitable for the temperature detection work in the greenhouse.

Humidity sensor. The DHT22 humidity sensor was selected, and the DHT22 sensor combines humidity and temperature detection in one [7]. It excels in measurement accuracy and stability, being able to measure a wide range of relative humidity from 0% to 100%. The DHT22 sensor utilizes digital signals for data transmission with ZigBee sensing nodes, making it ideal for greenhouse humidity monitoring.

Light sensor: This project selected BH1750 as the light detection element, BH1750 is a digital light intensity detector. It has high sensitivity and a wide range of light intensity detection, measuring from 0 to 65535 lux, and communicates with ZigBee sensor nodes through the I2C interface [8]. The BH1750 sensor is suitable for light monitoring in greenhouses.

CO2 sensor: MG811 is selected as the system CO2 concentration sensor in this paper [9]. The MG811 sensor uses NDIR (non-distributed infrared) technology to achieve more accurate CO2 concentration detection, with a wide detection range, generally covering hundreds to thousands of ppm (some models can detect even higher concentrations) and has excellent long-term stability, even if long-term use can maintain more accurate measurement results [10].

Soil moisture sensor. The capacitive soil moisture sensor was selected, a volumetric soil moisture sensor that measures the moisture of the soil [11]. For example, the SEN0114 soil moisture sensor can output soil moisture values through analog signals. It can be connected to the analog input interface of ZigBee sensor nodes and is suitable for monitoring soil moisture in greenhouses.

#### 4.3.3. Design schematic diagram

The design schematic diagram is shown in **Figure 2**.

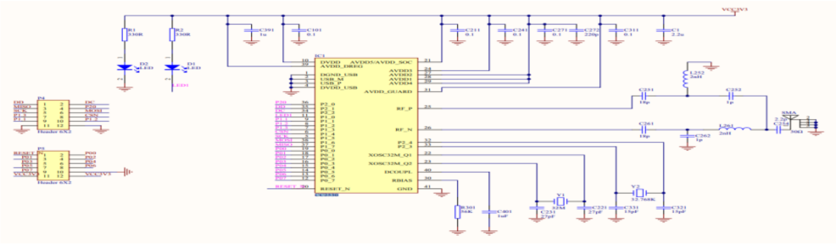

**Figure 2**. Schematic diagram of CC2530 Zigbee RF module

### 4.4. System software design

#### 4.4.1. Zigbee protocol

The Zigbee protocol uses IEEE 802.15.4 physical layer communication technology as its underlying communication standard [12]. IEEE 802.15.4 is a standard designed for low energy consumption, low transmission rate, and short-distance wireless communication scenarios, and is widely used in the construction of wireless sensor networks and personal local area networks (pans). It specifies the related technical requirements of the physical layer and MAC layer in detail, thus providing a solid foundation for the stable physical layer communication of the Zigbee protocol.

#### 4.4.2. Routing protocol

Given the star topology architecture of the Zigbee network, each sensor node only needs to transmit data to the coordinator, without performing multi-hop forwarding. Therefore, each sensor node sends data directly to the coordinator, eliminating the tedious routing decision process. As the root node, the coordinator adopts the table alternative routing strategy to maintain the network topological relationship table and simplify the route search process. It uploads the collected data to the monitoring terminal through TCP/IP to achieve stable and reliable data transmission [13].

### 4.5. PC software design

#### 4.5.1. Website interface development

The use of HTML and CSS technology to build the front end of the website, covering the login registration, data presentation, system configuration, and other core functional plate pages.

### 4.5.2. Build back-end database

Database architecture planning: Build a variety of data tables to store the collected data and system-related information.

Data interaction interface: Using Flask to develop a web service interface to realize the data communication between the background system, the database, and the equipment [14].

Periodic acquisition task: The design acquisition thread regularly captures real-time data from the device and inserts it into the database.

### 4.5.3. Design of data display module

Report display: Using Echarts/Highcharts to achieve a variety of dynamic reports such as charts, tables, and so on [15].

GIS positioning: Display real-time location of collection points in reports combined with open-source map API

Data query: Design time and condition query interface to achieve multi-dimensional filtering query function.

## 4.6. Test and result analysis

The system uses 4 data collection nodes to realize the comprehensive network monitoring of the greenhouse, transmits the data obtained by the sensor to the upper computer, and then presents the collected data by logging in to the web interface, thus obtaining the following results (**Figure 3**).

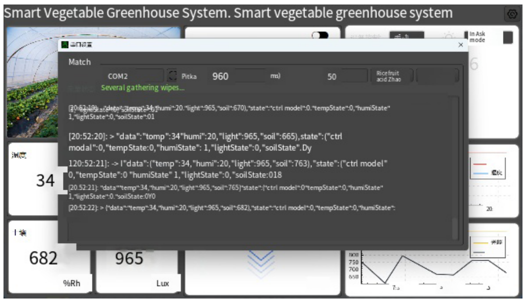


**Figure 3**. Collected data

It can be found that the temperature, humidity, and light data in the greenhouse have been effectively collected and displayed on the web interface.

This study developed a set of greenhouse environment monitoring systems relying on a wireless sensor network, which can achieve real-time monitoring and data collection of the greenhouse environment, supply accurate environmental data for greenhouse managers, help them improve the planting environment, and then improve the yield and quality of crops.

## 5. Conclusion

The system has many advantages: Relying on wireless sensor network technology, the system shows high flexibility and expansibility, which can fit the layout and scale of various greenhouses; The use of low-power wireless communication protocol, ensures that the system can be durable and stable operation, reduce energy consumption; With the help of remote terminal equipment, managers can obtain environmental information of the greenhouse at any time, which is easy to monitor and adjust the growth environment. The experimental results show that the system is effective and feasible. It can collect and transmit data in real-time and accurately, and provide decision reference for managers to optimize the growth conditions of plants.


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## Disclosure statement

The authors declare no conflict of interest.

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