ISSN: 2710-0588

Zigbee Based Monitoring System for Shiitake Mushroom Growing Environment

Lei Pan[1], Yuhua Fang[1], Jiale Qian[1], Ziqing Li[1], Zhenghua Shen[2,*]

[1]Zhejiang Mingrui Intelligent Equipment Technology Co., LTD, Wenzhou, China

[2]Department of Intelligent Manufacturing, Wenzhou Polytechnic, Wenzhou, CO 325035, China

[*] Corresponding Author: Zhenghua Shen

Abstract

In response to the complex terrain and climate, the wide distribution of shiitake mushroom greenhouses, and the difficulty in collecting data in Qingyuan, China Mushroom City, and considering the difficulty of wiring in cultivation bases, a zigbee based monitoring system for shiitake mushroom growing environment was designed. Combined with the advantages of Internet of Things technology, multi-sensor technology, computer processing technology, it can precisely measure and record environmental factors data in mushroom growing greenhouses, providing monitoring conditions for precise cultivation strategies of shiitake mushroom and effectively improving the intelligent and precise production process of edible mushroom factories.

Keywords

Shiitake Mushroom; Environmental Factor; Monitoring System.

1. Introduction

Qingyuan County, China's mushroom city, is located in the southwestern mountainous area of Zhejiang Province, with diverse ecological environments and a subtropical monsoon climate. It has a short frost free period and a large temperature difference between day and night, making it the most suitable for the growth of mushrooms and other fungi. But the terrain is complex, with various landforms such as valleys, basins, hills, low mountains, and middle mountains. Mushroom cultivation greenhouses are usually built according to the characteristics of the terrain, with water habitats. The environmental factors inside each cultivation greenhouse are slightly different.

The application of Internet of Things technology has solved the problems of poor real-time performance and low production efficiency in traditional agricultural production, saving manpower consumption, and eliminating the need for people to obtain production information through manual monitoring[1]. As one of the important scientific technologies for realizing smart agriculture, IoT technology can accurately measure crop growth environment data and achieve modern intelligent monitoring that traditional agriculture does not possess[2,3]. At the same time, IoT technology plays a positive role in improving agricultural production efficiency, enhancing resource-saving agricultural management, and accelerating the transformation of backward agricultural industries[4].

Based on ZigBee and OneNET cloud platform, IoT technology was applied to design a shiitake mushroom greenhouse monitoring system. Users only need to log in to the OneNET client to remotely view the changing trends of various environmental factors.

ISSN: 2710-0588

2. Analysis of System

2.1. Analysis of Environmental Factors During the Fruiting Stage of Shiitake Mushrooms

2.1.1. Temperature

Temperature is one of the important environmental factors affecting edible fungi. The fruiting temperature of shiitake mushrooms is 8-20℃, the optimal temperature is 14-18 ℃. The differentiation of their fruiting bodies requires a temperature difference of 6-8 ℃ between day and night.

2.1.2. Humidity

Higher air humidity can help to improve the quality of mushroom production, and a relative humidity of 55% to 65% should be maintained during the mushroom production stage. Low humidity can help to inhibit the development of hyphae and the formation of primordia, and the surface evaporation rate of mushroom will also increase with decreasing environmental humidity. If the environmental humidity is higher than 85%, it provides a basis for the occurrence of pests and diseases, and ultimately decrease the edible quality of mushrooms, so the shape will be smaller and the aesthetics will be poor.

2.1.3. Illumination

The different growth stages of shiitake mushrooms require different levels of illumination. During the mycelial growth stage, a dark growth environment is needed without excessive light. A higher light scattering environment during the growth and development stage of the fruiting body can help to cultivate plump and shiny fruiting bodies. The suitable intensity of illumination for the developmental stage of the fruiting body is 500-1100LX. When the illumination intensity is higher than 1100LX, the color of the fruiting body is significantly darker and the aesthetics are extremely poor, while when it is lower than 500LX, the color of the fruiting body is whiter and the stem is longer, with low nutritional value.

2.1.4. CO_2 Concentration

Moderate CO_2 concentration can promote the growth and development of shiitake mushrooms, and increase their yield and quality. When the CO_2 concentration in the environment is too low, the growth rate of shiitake mushrooms will be affected, and both yield and quality will decrease; When the CO_2 concentration in the environment is too high, it can cause the growth rate of shiitake mushrooms to be too fast, affecting their quality and taste. The optimal concentration range for CO_2 during the differentiation stage of primordia formation is 2500-3500ppm; The concentration range of CO_2 during the growth stage of fruiting bodies should be higher than that during the differentiation stage of primordia.

2.2. Analysis of Shiitake Mushroom Greenhouse

Each mushroom greenhouse needs to collect environmental factors that affect mushroom growth, such as temperature, humidity, illumination, CO2 concentration, etc. At the same time, it is necessary to control the operating conditions of environmental control equipment such as ventilation fans and lighting inside each greenhouse. If single machine control is adopted, the investment cost and later operation cost are relatively high, so network control should be adopted.

Considering that various types of sensors placed in mushroom greenhouses require a significant amount of funds to purchase cables when using wired transmission methods, especially in mountainous fields with complex terrain. There are also problems such as high construction costs and difficult maintenance in the later stage. Therefore, wireless transmission is required to achieve environmental monitoring of mushroom greenhouses. And using software design to achieve the purpose of system networking and transmission, each sensor

ISSN: 2710-0588

acquisition node adopts battery power supply, thereby eliminating cable connections between sensor nodes.

In addition, the distance between the system operation room and the mushroom greenhouse is relatively far, making it difficult and costly to install cables between the data aggregation node and the machine room. Therefore, the data aggregation node of this system and the operating machine room also adopted wireless communication transmission. This not only realizes the intelligence and unmanned cultivation stage of shiitake mushrooms, but also reduces production input costs.

3. Design of System Architecture

Internet of Things was applied, and ZigBee and cloud platform technologies was effectively integrated in this monitoring system. ZigBee technology has characteristics such as low power consumption and self-organizing networks, making it very suitable for use in mushroom greenhouses[5]. The system is divided into three parts: data collection layer, data wireless transmission layer, and upper computer monitoring layer[6]. The system block diagram of ZigBee based monitoring system for shiitake mushrooms fruiting environmental factor is shown in Figure 1.

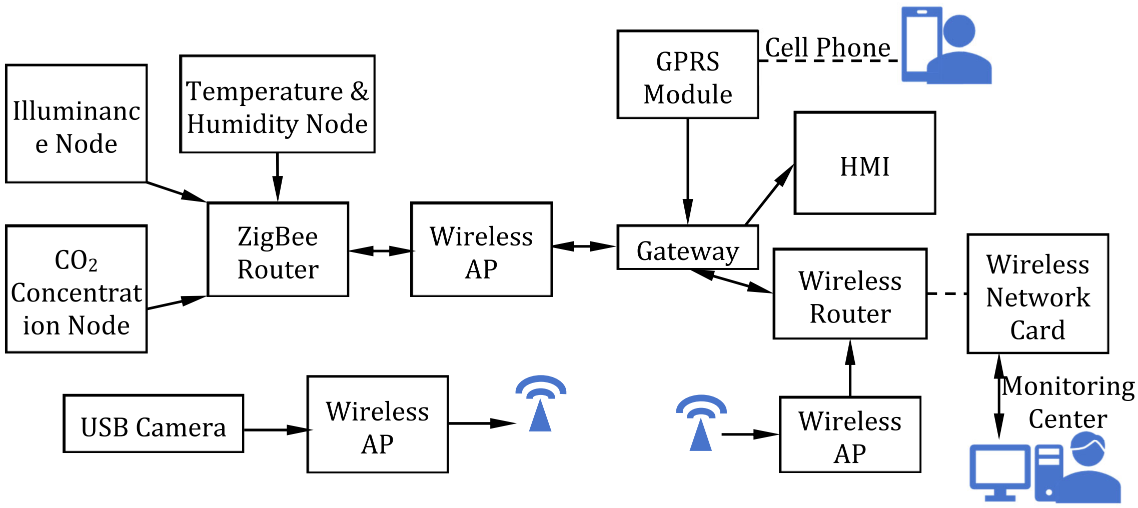

Figure 1. System Block Diagram of ZigBee Based Monitoring System for Shiitake Mushrooms Fruiting Environmental Factor

3.1. Data Collection Layer

Collecting environmental factor data for mushroom greenhouses requires temperature sensors, humidity sensors, CO_2 concentration sensors, and illuminance sensors. Each sensor was installed on the ZigBee terminal node, and the collected data is further transmitted to the ZigBee coordinator after AD conversion by the ZigBee terminal node, so as to achieve long-distance wireless transmission of data[7].

3.2. Wireless Transmission Layer

It was centered around a ZigBee coordinator and ESP8266 controller. The ZigBee coordinator is the most important node in the ZigBee network, with only one coordinator in each ZigBee network. This node is responsible for network establishment, channel selection and maintenance, as well as data aggregation. It receives data collected by ZigBee terminal nodes during each transmission cycle and transmits the data to the system's upper computer monitoring layer through the ESP8266 controller via the Internet.

ISSN: 2710-0588

3.3. Upper Computer Monitoring Layer

It includes a mushroom greenhouse monitoring interface and cloud platform remote PC and APP access methods. The upper computer was designed based on the interface development tool provided by the cloud platform, which can intuitively display real-time data values and trends, and has a good human-computer interaction interface, making it convenient for operators to control the system. After ESP8266 transferring the data to the OneNET cloud platform, it is only needed to complete the data flow compilation of the cloud platform to achieve real-time data monitoring, information warning and other function settings for mushroom greenhouses. So PC login to the cloud platform or mobile device cloud APP can be remotely accessed to realize remote intelligent production of mushroom greenhouses.

4. Hardware Design of Data Collection Layer

4.1. Temperature and Humidity Sensor

Based on the actual environmental characteristics of the mushroom greenhouse and the suitable temperature and humidity range for mushroom cultivation, the temperature and humidity sensor DHT22 was selected for this design. The DHT22 temperature and humidity sensor can simultaneous measure temperature and humidity. It obtains environmental temperature and humidity through built-in measuring components, and sends digital signals to the microcontroller measurement values through the Data pin. DHT22 has fast response speed and strong anti-interference ability, and its signal transmission distance is far superior to similar products.

4.2. CO_2 Concentration Sensor

The CO_2 concentration sensor CDM4161 was selected, with a range of 50~8000ppm and an accuracy of 20%. It adopts a semiconductor temperature measurement module, which has the characteristics of wide detection range and high sensitivity. CDM4161 not only meets the measurement range requirements, but also satisfies the requirement that the CC2530 chip at the node terminal cannot convert high analog voltage.

4.3. Illuminance Sensor

The light demand during the fruiting stage of shiitake mushrooms is divided into two stages: (1) no light demand stage. At this stage, mycelium needs to grow in a dark environment and therefore does not require light. (2) High light demand stage. The growth stage of the fruiting body requires a high lighting environment, and the use of uniformly scattered light sources can meet the requirements. The BH1750FVI illuminance sensor has a range of 1~60000LX and is a sensor with fast response and strong anti-interference ability.

4.4. Relay Module

The relay module in this system is responsible for controlling the operating status of environmental control devices such as ventilation fans and humidifiers. The ZigBee node control chip CC2530 drives the closure of relay contacts through high- and low-level conversion through the IO port to achieve the setting function.

5. Hardware Design of Network Transport Layer

Based on ZigBee wireless transmission technology, a wireless sensor network was designed for the system. The data collection layer and data transmission layer are composed of ZigBee terminal nodes, routing nodes, and coordinator nodes. The data measured by sensors is transmitted to the upper computer through wireless networks.

ISSN: 2710-0588

5.1. ZigBee System Chip

As a controller, the CC2530 chip has been widely used in various fields such as smart homes and health monitoring. It's functionality, reliability and comprehensive usability have been verified by market applications. The CC2530 chip consists of three main modules: CPU memory series module, external device and power clock management module, and wireless signal transceiver module. Because the ZigBee terminal nodes in this design system require real-time data collection, the CC2530 F256 high-capacity version chip was selected. The multiple operating modes of CC2530 chip increase the flexibility of use, and can meet the needs of different industries and occasions. The conversion delay between chip operating modes is very short, it can effectively reduce chip energy consumption and meet the low-power requirements of ZigBee terminal nodes.

5.2. System Gateway Chip

The ESP8266 chip was chosen as the gateway control chip ,it is powered by a 3.3V DC power supply and can be used in conjunction with the CC2530 chip. It also supports transparent transmission protocol and is suitable for use in semi enclosed environments such as mushroom greenhouses. The volume of ESP8266 chip is smaller than that of ARM11, Raspberry Pi and other chips, and it is characterized as small size, flexible layout, low power consumption, and low price. The ESP8266 chip has strong on-chip storage and computing processing capabilities, which can not only achieve data transmission, but also serve as a WiFi client to connect to designated servers.

5.3. ZigBee Node

The ZigBee network adopted a mesh topology structure, consisting of three types of nodes, which are terminal nodes, routing nodes, and coordinator nodes. A total of 12 terminal nodes were designed to collect environmental factors for each mushroom greenhouse. Two routing nodes were designed to be responsible for summarizing and transmitting terminal node information within the region. The coordinator node was designed to be responsible for establishing and managing the network, as well as aggregating and managing the received data.

6. Software Design

6.1. Design of Sensor Acquisition Software

The temperature and humidity sensor DHT22 communicates with CC2530 through SPI single bus protocol. CC2530 supports hardware SPI protocol and can drive DHT22 to work normally using IO port. The temperature T and relative humidity RH detected by the temperature and humidity sensor are respectively

$$RH = 6 + 125 * \frac{S_{RH}}{2^{16}} \tag{1}$$

$$T = -46.85 + 175.72 * \frac{S_T}{2^{16}} \tag{2}$$

Which S_T and S_{RH} are the temperature and humidity signals returned by the sensor, respectively. The illumination sensor BH1750FVI communicates with the CC2530 chip through the IIC bus. As CC2530 itself does not support the hardware IIC protocol, an IO port is required to simulate the IIC driver. The ZigBee terminal node control chip will send measurement value commands to the illumination sensor BH1750FVI, and then send 8-bit reading commands. The terminal

ISSN: 2710-0588

node will periodically report the illumination data of the mushroom greenhouse at 30 second intervals and upload the obtained measurement data to the coordinator node.

The CO_2 concentration sensor CDM4161 communicates with the CC2530 chip through the IIC bus, and the CC2530 needs to use an I/O port to simulate the IIC driving of the CDM4161 sensor. After the CO_2 concentration sensor CDM4161 starts working, the CC2530 chip sends a start measurement command and then sends a reading command to obtain CO_2 concentration data from the mushroom greenhouse. The terminal node initializes the ZStack protocol stack and sends a network access request to the coordinator node. After obtaining the coordinator's assigned address, the node uploads the measured greenhouse CO_2 concentration data at intervals of half a minute.

6.2. Software Design of ZigBee networking

The coordinator node of a ZigBee network is responsible for establishing the entire network, and only one coordinator node is needed in the system to network building and other functions. There are multiple routing nodes and terminal nodes depending on the functional requirements. The coordinator node is connected to the gateway through an IO serial port and packages the received information to be transmitted to the gateway. At the same time, the coordinator node communicates with routing nodes and terminal nodes through wireless networks. The data transmission process of the ZigBee coordinator node is shown in Figure 2.

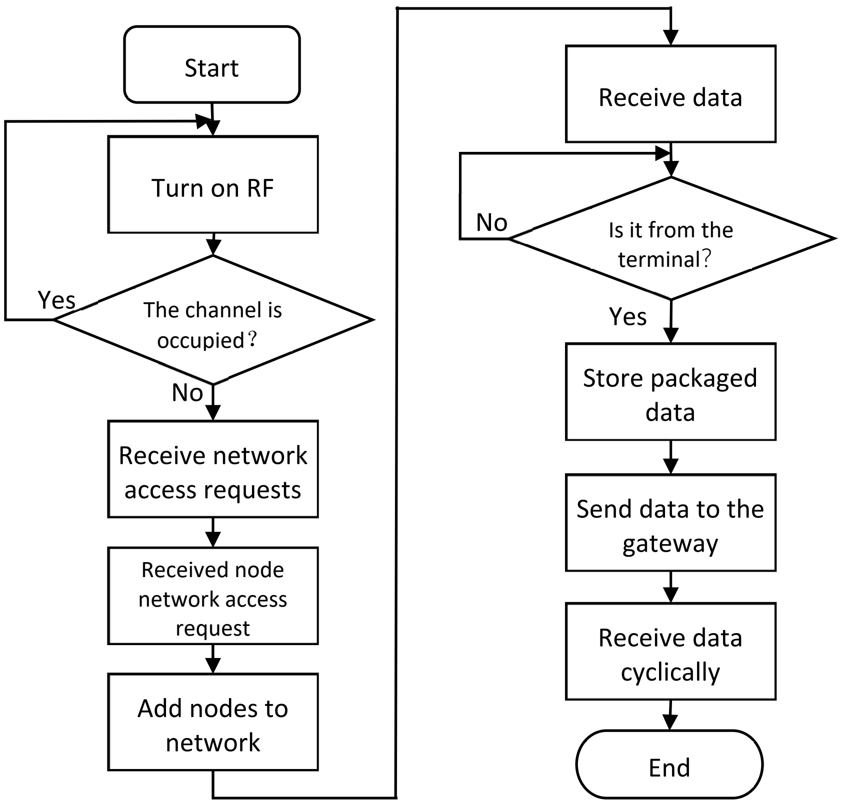

Figure 2. Coordinator Network Building Process

6.3. Software Design of Gateway

The gateway is the data communication link between the wireless transmission network and the cloud platform. As the information transmission hub of the entire system, it is responsible for transmitting data instructions between the cloud platform and the local ZigBee network. The gateway chip communicates with the ZigBee coordinator through a serial port, and

ISSN: 2710-0588

communicates with the cloud server through the ESP8266 module. The flowchart of the gateway program is shown in Figure 3.

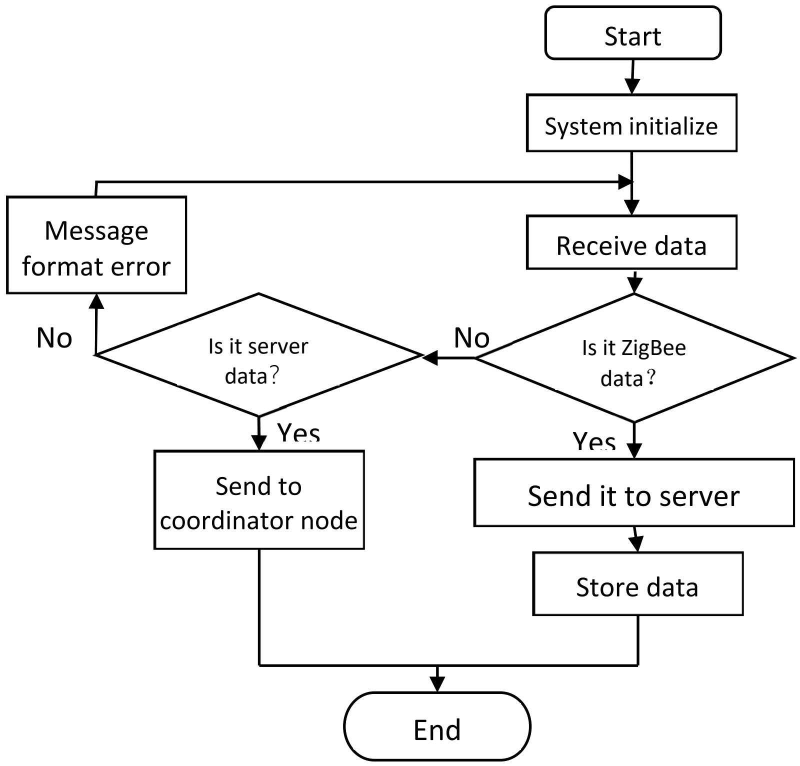

Figure 3. Gateway program flow

6.4. Design of Cloud Platform

The mushroom greenhouse equipment needs to report measurement data to the platform in real time, and receive control instructions from the platform in real time, and the platform needs to store the data reported by the equipment and issue real-time application data to the mushroom greenhouse equipment. Based on the characteristics and requirements of the mushroom greenhouse equipment end and cloud platform[8] end of the system, EDP access protocol within a multi-protocol framework was selected to achieve equipment access.

7. System Testing

System functionality and wireless communication capabilities were tested at the mushroom planting base, with two collection nodes set up to collect environmental factor data every 15 minutes starting from 8am. Figure 4 shows the monitoring data of nodes 1 and 2. It can be seen that the remote and local data of temperature, humidity, light, and CO_2 concentration are basically consistent. In addition, out of 800 sets of environmental factor data measured by the two nodes, only 5 sets have slight deviations, with an error rate of 0.625%.

The system testing and experimental results show that this environmental monitoring system can work normally at different times throughout the day. The system is characterized as accurate data collection, stable signal transmission, and reliable wireless network communication, achieving the expected remote monitoring of environmental factors in mushroom greenhouses.

ISSN: 2710-0588

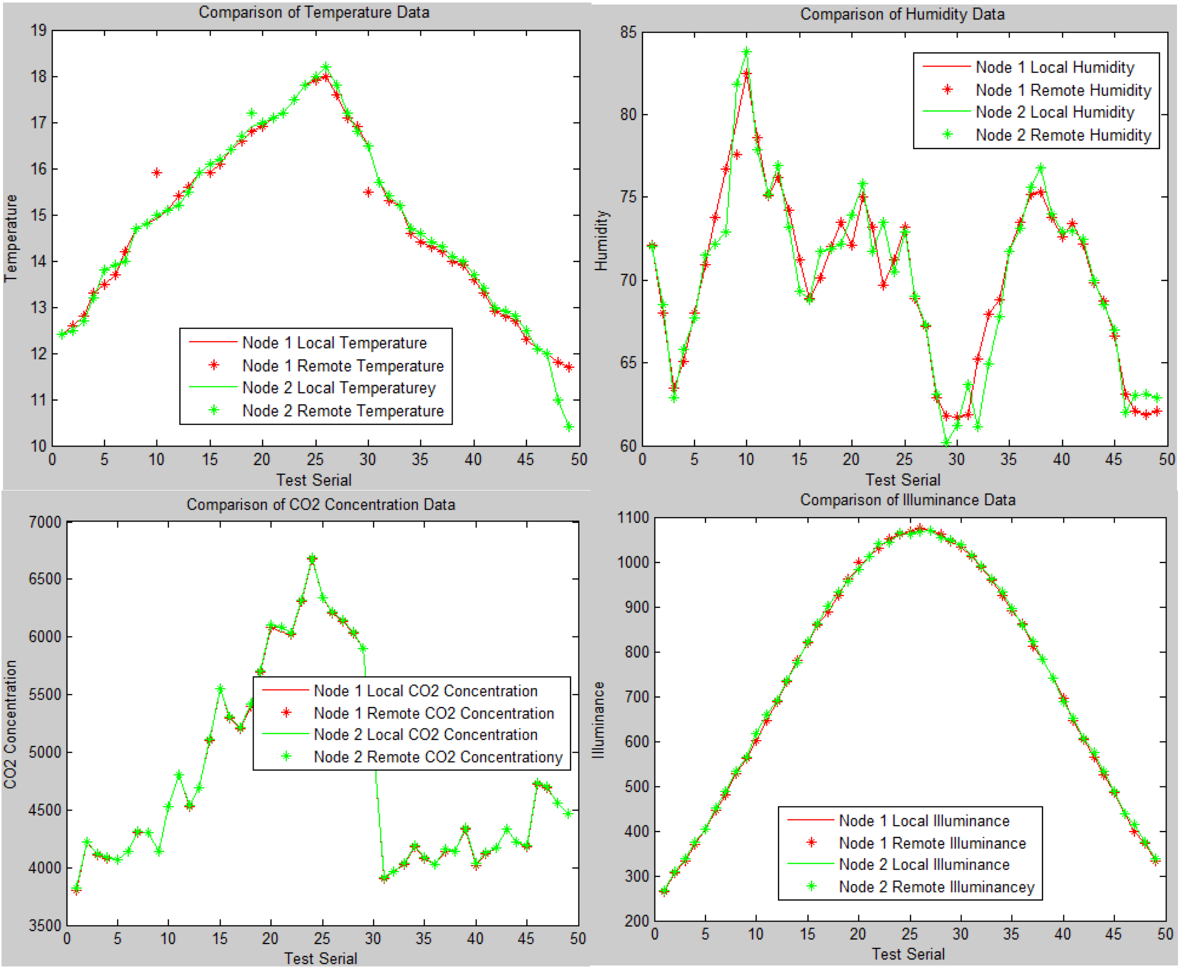

Figure 4. Comparison of Local and Remote Environmental Factor Data of Node 1 and Node 2

8. Conclusion

Based on ZigBee technology, combined with multi-sensor fusion technology and IoT cloud platform, a digital monitoring system for shiitake mushroom growing greenhouse was designed. The system uses the CC2530 chip as the controller, utilizes multiple sensors to detect environmental factors such as temperature, humidity, CO_2 concentration, and illumination, and constructs a mesh topology structure using ZigBee wireless transmission technology. The upper computer monitoring center has been developed on the OneNET cloud platform, integrating multiple functions such as local information collection and control, cloud transmission, and remote monitoring.

The digital monitoring system provides real-time query, alarm, control, and automatic adjustment of various environmental parameters for mushroom farmers. It mainly helps mushroom greenhouses achieve intelligent management of the greenhouse without reconstruction or large-scale modifications, thereby releasing more manpower and material resources, allowing for larger scale planting with limited manpower.

References

[1] W.Y. Gao. Application of Sensor Network Technology in Smart Agriculture, South China Agriculture, vol. 14(2020), No.28, 77-79.

[2] P.F. Yang and R.J. Yang. The Application of Agricultural Internet of Things, Big Data, and Cloud Platform Management Technologies in Agriculture, Agricultural Development and Equipment, (2019), No.2,41

ISSN: 2710-0588

[3] X.F. Guan, L.F. Lu, et al. Construction and Application of Zhejiang Province Smart Agriculture Cloud Platform, Zhejiang Agricultural Science, vol. 61(2020), No.3, 595-597.

[4] Y.F. Li, Y.H. Lin. Thoughts on the Development of Smart Agriculture Based on Accelerating Agricultural Modernization Construction, Journal of Green Science and Technology, vol. 24(2020), No.3, 177-180.

[5] Yige WANG， Xia HE， et al. Soil Temperature and Humidity Monitoring System based on LabVIEW and ZigBee Wireless Sensor Network, Industrial Instrumentation and Automation, (2020), No.4, 29-33.

[6] J.X. Chen, L. N. Wang: Sensor Network Application Development (China Machine Press, China 2019)

[7] CHAI XiLin, ZHANG Jin, et al. Design of Smart Agricultural Greenhouse Monitoring System based on Wireless Sensor Network and Edge Gateway, Industrial Instrumentation and Automation, (2024), No.1, 13-18.

[8] L. Zheng, H.J. Li, et al. Design and Implementation of Precision Control Platform for Installment Agriculture Based on the IoT, Software Guide, vol. 24 (2023), No.8, 138-143.