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Orchard Irrigation System Based on NB-IoT

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ABSTRACT:

In this paper, through the systematic analysis of the traditional orchard irrigation system, a new type of IoT intelligent orchard irrigation system is proposed. The system uses the STM32F103 embedded chip as the microcontroller, and uses the temperature and humidity sensor to collect the temperature and humidity data of the orchard environment. After being processed by the microcontroller, it can not only realize the automatic control of irrigation by the terminal node, but also transmit it to MQTT through the NB-IoT wireless communication network. The server is displayed on the connected OneNET IoT cloud platform in real time, and at the same time, the human-computer interaction is carried out with the help of the OneNET IoT cloud platform, so as to realize the remote control of the orchard irrigation system, aiming to reduce the irrigation cost of the orchard and improve the utilization rate of water resources. Meet the precise, scientific and intelligent needs of orchard irrigation. Experiments show that the remote control of orchard irrigation realized by the combination of NB-IoT wireless communication technology and OneNET Internet of Things cloud platform complements the terminal automatic irrigation control. While realizing flexible and intelligent irrigation, it not only completely overcomes traditional orchard irrigation The disadvantages of the method, and to a certain extent, improve the efficiency of orchard irrigation.

Key words: Orchard, NB-IoT, Temperature and humidity sensor, Intelligent irrigation, OneNET Cloud Platform

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1. INTRODUCTION

In the traditional agricultural development model, orchard irrigation is mainly at the expense of consuming a lot of human resources. Whether it is the manual collection of soil-related temperature and humidity parameters or the artificial irrigation of large-scale orchards, there are low irrigation efficiency, irrigation time and irrigation. The amount of water is difficult to control and other disadvantages [1]. Secondly, my country has a dazzling array of fruit products. Different regions not only have large differences in climate, but also have complex and varied topography. The same species of fruit trees in different growth environments will show different shapes, which also lead to their growth requiring different irrigation conditions [2]. It can be seen that how to abandon rough irrigation based on traditional artificial cultivation experience and realize modern irrigation with high efficiency, high precision and low cost is very important.

With the rapid development of the Internet of Things technology, new wireless communication technologies such as NB-IoT and LoRa (Long Range Radio) continue to sprout, and gradually burst out their tenacious scientific and technological vitality. In particular, NB-IoT, as an IoT technology that has just been developed in recent years and has far-reaching influence, has the advantages of low cost, wide coverage, low power consumption, and large capacity. It can not only serve a large number of information collection nodes and upload them To the Internet of Things cloud platform, it can also ensure that the data transmission distance is up to about 10km. It can be seen that NB-IoT technology can provide real massive throughput capability and provide relatively mature technical support for the development and innovation of IoT technology.

According to the development status of my country's agricultural Internet of Things technology, and relying on the advantages of the relatively mature agricultural Internet of Things technology, this paper adopts the NB-IoT technology with the advantages of low power consumption, wide coverage and large capacity to realize the wireless sensing of Internet of Things data. On the basis of the acquisition system, an intelligent orchard irrigation system integrating intelligent monitoring, auxiliary decision-making and intelligent control functions is explored and designed.

The system design will start from the existing problems of orchard irrigation, and integrate NB-IoT technology on the basis of the existing technology of orchard irrigation control system, that is, use various sensors to collect relevant data such as soil temperature and humidity and equipment operation status, and use NB-IoT to collect relevant data. The module is sent to the OneNET IoT cloud platform, and the OneNET IoT cloud platform stores, analyzes, displays and makes decisions on the data, thereby realizing remote monitoring of the environmental conditions of fruit tree growth [4]. At the same time, relying on the data analysis function of the microcontroller, through the intelligent control of the orchard irrigation system at the terminal node, the precise irrigation of the orchard can be realized, the refinement level of irrigation can be improved, and the effect of simplifying the network layout, saving costs and intelligent irrigation can be achieved.

2. OVERALL SYSTEM SCHEME DESIGN

1.System functional requirements

The goal of this system is to design an intelligent irrigation system for orchards. It is necessary to consider the functional needs of the system from a practical point of view, and at the same time take into account the concepts of rational selection of materials and scientific design, so as to enhance the reliability and practicability of the intelligent irrigation system. The system design mainly needs to focus on the functional requirements of the soil temperature and humidity parameter acquisition module and the NB-IoT communication module. First of all, the orchard is used as the data collection source, and the environmental temperature and humidity sensor is used to collect the environmental data of the orchard, which not only has high requirements on the accuracy of the sensor, but also needs to meet the requirements for the sensor to adapt to the complex data collection environment. In addition, the data acquisition node is required to be small in size and easy to install and maintain. Secondly, the communication method selected for data is required to have the advantages of low power consumption, low cost, and fast response. Obviously, NB-IoT wireless communication technology has irreplaceable advantages. effect.

The specific functional requirements that the intelligent irrigation system needs to have are as follows:

(1) The stability requirements of the environmental temperature and humidity parameter collection node: the soil humidity sensor is easily affected by the soil salinity and fertilizer corrosion, which can easily affect the measurement accuracy, resulting in certain errors. Therefore, the soil moisture data acquisition sensor must have the characteristics of high precision, corrosion resistance and long life.

(2) Intelligent irrigation control system with data analysis function: use intelligent algorithms to intelligently analyze the received data and make scientific decisions, so that the control system can play the role of autonomous decision-making or replacing manual control.

(3) Stability requirements for data transmission: At present, the communication modules used for modern agricultural data transmission are mainly ZigBee modules, LoRa modules, Wi-Fi modules and Bluetooth modules, etc., but the working frequency bands of these data transmission modules are all unlicensed frequency bands , has certain limitations in data security and system upgrades. In addition, these modules are not fully suitable for agricultural production, nor can they play their respective advantages in the field of orchard irrigation. Therefore, choosing the NB-IoT communication technology with the advantages of low power consumption and low cost is of great significance to ensure the accuracy of data and promote the integration and development of IoT technology and the orchard industry.

(4) Application design of the IoT cloud platform: With the help of the OneNET IoT cloud platform to build a client application platform, the orchard administrator can log in on the PC side and view the received data and intelligent processing results at any time, and can also retrieve the history as needed. data [5]. The control of the entire orchard irrigation system is divided into two parts: the terminal intelligent automatic processing and the OneNET IoT cloud platform manual control. The orchard administrator can choose the remote manual control method according to the actual needs.

2.Overall system design

The intelligent orchard irrigation system based on NB-IoT technology is mainly based on sensor data acquisition technology, server development technology, NB-IoT communication technology, IoT cloud platform construction technology and computer control technology, forming a set of perception layer, transmission layer and application. Layer three layers in one IoT architecture. The hardware system of the intelligent orchard irrigation system is mainly composed of microcontroller module, node environmental data acquisition module, NB-IoT wireless communication module and irrigation control module; the software system is mainly composed of temperature and humidity data processing system, MQTT (Message Queuing Telemetry Transport) server System, real-time data monitoring system and OneNET IoT cloud platform system are composed of four systems.

The theoretical core of the design of the intelligent orchard irrigation system is the embedded chip STM32F103 as the control core, and the temperature and humidity environment-related data of fruit tree growth are collected through the environmental temperature and humidity sensing technology, and transmitted to the OneNET IoT cloud platform through the NB-IoT technology [6]. After the analysis of the OneNET IoT cloud platform, the real-time monitoring of the orchard tree growth environment is realized. Once the cloud platform issues the control instruction information, it will be transmitted to the terminal node by the NB-IoT network, and the orchard irrigation system can be controlled remotely. In addition, the relevant data can also be processed by STM32F103 to realize automatic control of orchard irrigation directly at the terminal node. The two irrigation methods of remote control and automatic control complement each other, making the management of the orchard irrigation system more economical, professional and intelligent.

The intelligent orchard irrigation system can monitor the environmental data such as temperature and humidity around the fruit trees in the orchard in real time. Through the data visualization processing of the OneNET IoT cloud platform, it is convenient for users to conduct environmental monitoring and remote irrigation at any time. Using the interconnection of the NB-IoT network, real-time monitoring and management of large-scale orchards can be realized. The overall system design architecture of the Internet of Things integrates the three layers of the transport layer and the application layer. The overall theoretical framework of the system is shown in Figure 1.

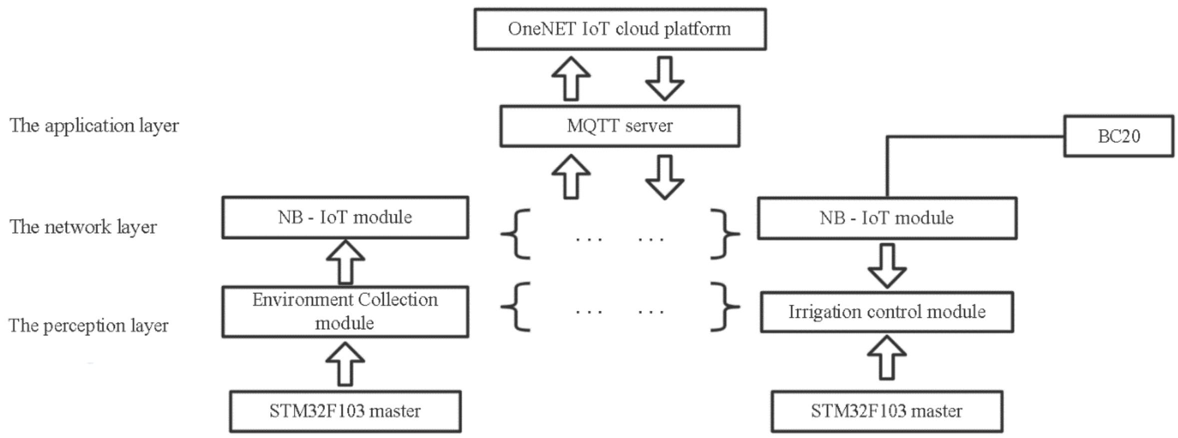


Fig. 1 The overall theoretical framework of the system

The perception layer mainly includes a microcontroller and various sensors, and the sensor obtains the ambient temperature and humidity information sensed in real time under the control of the microcontroller. Through various sensors arranged in the soil around the fruit trees, the real-time monitoring of the soil temperature and humidity environment in the orchard is carried out.

This system uses STM32F103 as a microcontroller to realize the functions of real-time control of various sensors, data processing and data transmission. The ambient temperature and humidity sensor determines whether it is suitable for irrigation under the current environment by monitoring the temperature and humidity of the air, while the soil humidity sensor determines whether irrigation is required or whether the irrigation water amount meets the standard by collecting the water content in the soil, so as to achieve a more suitable irrigation effect.

The microcontroller compares and analyzes the ambient temperature and humidity data collected by the sensor with the preset temperature and humidity thresholds, generates an instruction to control the opening or closing of the irrigation module, and sends it to the irrigation module to intelligently control the on-off of the electromagnetic relay. The role of independent decision-making to realize intelligent irrigation of orchards.

Since the NB-IoT module is connected to the USART (Universal Synchronous/Asynchronous Receiver/Transmitter) is connected to the microcontroller, then the transport layer can upload various environmental data obtained to the MQTT database center through the gateway of the NB-IOT communication network, and send it to the OneNET IoT cloud platform after analysis and processing. By selecting the NB-IoT module, the real-time transmission of data collected by the nodes of the orchard irrigation system and the issuance of irrigation control instructions on the OneNET Internet of Things cloud platform can be realized at the same time, forming a reasonable adjustment mechanism.

In the orchard intelligent irrigation system, the application layer is mainly composed of two modules: MQTT server and OneNET IoT cloud platform.

The MQTT server mainly provides management data services. The ambient temperature and humidity data saved by the MQTT database server supports the invocation of the OneNET IoT cloud platform management system in real time. As the core of the application layer, the OneNET IoT cloud platform can collect and process various data received, and store, classify, organize and analyze the orchard environmental data. By visualizing the environmental temperature and humidity data collected and uploaded by the sensor, it is convenient for users Make decisions about whether to turn the irrigation control switch on or off. Once the command to control the opening or closing of the irrigation module is generated, it can be sent to the irrigation module to control the on-off of the electromagnetic relay, which plays the role of auxiliary decision-making and realizes the remote control of irrigation for the orchard. This also provides a reliable data and empirical basis for orchard irrigation to guide orchard farmers to carry out scientific irrigation.

3. SYSTEM HARDWARE DESIGN AND IMPLEMENTATION

The hardware part of the intelligent orchard irrigation system is mainly composed of the core control module, the sensor parameter acquisition module, the NB-IoT communication module, the power supply module and the irrigation control module [7]. Among them, the sensor parameter acquisition module mainly detects the soil humidity environment and air temperature and humidity environment of the orchard; the irrigation control module includes the OneNET IoT cloud platform irrigation control module and the electromagnetic relay irrigation control module. The former is located at the application layer, and the latter is the control terminal. , at the perception layer.

1.Microcontroller Module Design and Implementation

The intelligent orchard irrigation system uses the STM32F103C8T6 embedded chip as the MCU main control unit. The actual STM32F103C8T6 microcontroller is shown in Figure 2 [8]. The chip is a 32-bit microcontroller based on the ARMv7 architecture, as shown in Figure 3, using a 48-pin LQFP (Low-profile Quad Flat Package) package with a maximum transfer rate of 72MHz. 11 timers and 51 general-purpose I/O interfaces, as well as DAC (Distributed Autonomous Corporation), USART, SPI (Serial Peripheral Interface) and IIS (Internet Information Services), etc., together with reset circuit, power supply circuit and clock circuit A minimal system of single-chip microcomputers with abundant on-chip resources is realized. In addition, STM32F103C8T6 has its own analog-to-digital conversion function, which does not require additional design of analog-to-digital conversion related circuits.

Fig. 2 STM32F103C8T6 physical map

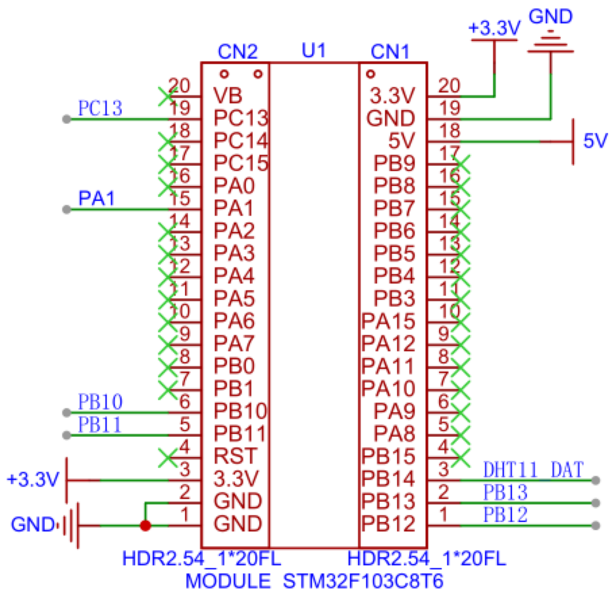


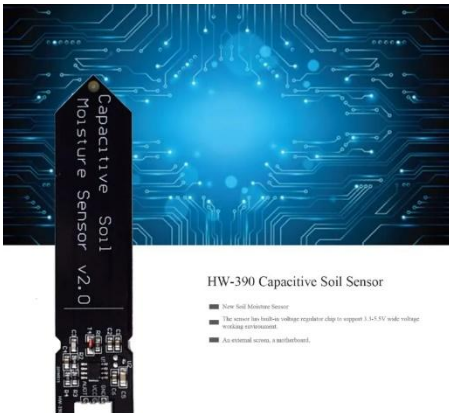
Fig. 3 STM32F103C8T6 core board schematic

2.Design and Implementation of Ambient Temperature and Humidity Parameter Acquisition Module

The environmental temperature and humidity data acquisition module of the intelligent orchard irrigation system mainly uses the environmental temperature and humidity sensor and soil humidity sensor to collect the growth environment data such as the soil temperature and humidity of the orchard and the environmental temperature and humidity, and the corresponding environmental condition data in the OneNET IoT cloud platform Under the reference of , it has played an important role in the intelligent decision-making of the orchard irrigation system [9].
The soil moisture sensor Moisture Sensor v2.0, as a part of the ambient temperature and humidity parameter

acquisition module, is made by COMS (Complementary Metal Oxide Semiconductor) micro-processing technology, which can well ensure that the sensor has strong stability and high reliability. The Moisture Sensor v2.0 in Figure 4 adopts a single-leaf arrow-shaped design to facilitate its placement in the soil. The acquisition circuit is shown in Figure 5. The soil moisture sensor mainly uses the principle that the triode can amplify the current under certain conditions. After it is placed in the soil, as the soil environmental humidity increases, its output voltage will subsequently increased. When the water content in the soil is just enough to make the voltage source and base of the triode conduct forward, a rated current will be generated between the emitter and the base of the triode [9]. According to the amplification principle of the triode, a beam of current several times the current size will be formed between the emitter and the collector of the triode at this time [9]. According to the voltage division principle of the circuit, when the current flows through the resistor of the emitter, a corresponding voltage is generated for the AD converter to collect soil moisture data. Therefore, the sensor has the characteristics of strong anti-interference and high sensitivity, and is suitable for the design of orchard irrigation systems.

The temperature and humidity sensor model used by the ambient temperature and humidity data acquisition module is DHT11 (Figure 6) [9]. As shown in Figure 7, it is a single-bus digital temperature sensor, and the output temperature and humidity digital signal has been calibrated [17]. It consists of an NTC (Negative Temperature Coefficient) temperature sensing component and a resistive humidity sensing device, together with an 8-bit microcontroller, the rated voltage is 3.3V, and the testable temperature range is -20℃~+60℃ , the humidity range is 5%RH~95%RH.



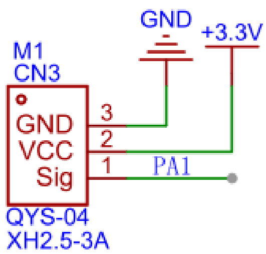


Fig. 4 Physical map of soil moisture sensor **Fig. 5 Soil moisture acquisition circuit diagram**

Fig. 6 Physical map of temperature and humidity sensor

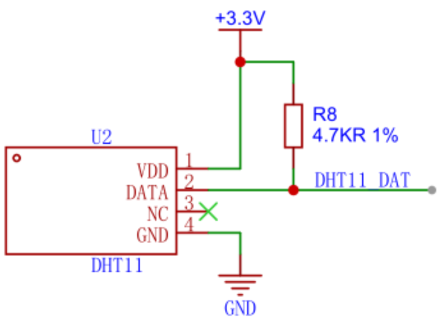


Fig. 7 Temperature and humidity acquisition circuit diagram

DHT11 digital temperature and humidity sensor can make it have permanent stability and strong reliability by combining data module acquisition technology and temperature and humidity sensing technology [10]. The reason why the integration is simple and fast is that the DHT11 digital temperature and humidity sensing system uses a single-wire method to realize the serial interface [10]. The sensor has the characteristics of strong anti-interference ability, low hardware cost, high stability, small size and low power consumption.

After the microcontroller is powered on, its processor starts to work to collect ambient temperature and humidity values. First, the microcontroller executes the digital-to-analog conversion instruction to convert the relevant data values monitored by the ambient temperature and humidity parameter acquisition module into the corresponding voltage values, and then the microcontroller obtains the voltage signal to obtain the real soil moisture data [11] . In addition, the LED indicator light of the sensor circuit can be used to judge whether the soil moisture value meets the irrigation requirements. If the LED flashes, it means that the humidity exceeds the predetermined range, and the irrigation should be stopped immediately.

3. Communication technology networking

(1)Communication methods and protocols

As we all know, communication methods are mainly divided into traditional wired communication methods and wireless communication methods that are more common today [12]. Wired communication uses coaxial cables, twisted pairs, optical cables, etc. for data transmission. The data transmission is not only fast, but also has strong anti-interference and high stability [13]. However, the cost of network deployment is relatively high, while wireless communication uses radio waves to transmit data in wireless transmission media, mainly including satellite communication, short-wave communication and medium-wave communication [14]. Not only is the cost of transmitting information via wireless communication relatively low, but it is also very simple to deploy. Although its practicability is strong, its anti-interference is weak, so the signal is easily affected by the external environment in the process of data transmission.

As a low-power wide area network, NB-IoT has become an indispensable branch of the Internet of Things technology development in the era of the Internet of Everything. Under the premise of consuming 180 kHz bandwidth, NB-loT can be directly deployed in networks such as LTE, UMTS (Universal Mobile Telecommunications System) and GSM (Global System for Mobile Communications). By comparing the four communication methods in Table 1 below, we can see that compared with traditional Bluetooth, Wi-Fi, and ZigBee, NB-IoT has created a wide range of New functions for area coverage and free movement. It can be seen that NB-IoT technology is the best choice for the network deployment requirements of wireless communication methods with large range and throughput.

The wireless communication method that the intelligent orchard irrigation system should adopt is NB-IoT technology, that is, the communication method between the terminal node in this system and the OneNET IoT cloud platform server MQTT is NB-IoT communication.

Table(1). Performance comparison of four common communication methods.

Type	NB-IoT	Bluetooth	Wi-Fi	ZigBee
Single point coverage	Over 10 km	10 m	100 m	50~300 m
Power consumption	10 years/AA battery	1~100mW	1mW or more	1mW or less
Transmission rate	250Kb/s	1Mb/s	11Mb/s	250kb/s
Frequency band	Carrier frequency band	2.4GHz	2.4GHz	868MHz~2.4GHz
Number of network nodes	200000	8	50	65000
Time required to connect to the Internet	6~10s	10s	3s	30ms
Network scalability	None	None	None	Auto-scaling
Complexity	Simple	Complex	Very complicated	Simple
Safety	High	High	Low	Higher
Terminal equipment fee	Middle	Low	High	Low
Integration reliability	High	High	Generally	High

(2)NB-IoT wireless communication module design

The communication protocol of the orchard irrigation system refers to the application layer communication protocol between the NB-IoT module and the OneNET IoT cloud platform. In the TCP/IP layered model corresponding to the OSI (Open System Interconnection Reference Model) reference model, HTTP (Hyper Text

Transfer Protocol), MQTT, CoAP (The Constrained Application Protocol) and other protocols are the main protocols of the IoT application layer. It can be applied to the design of this system.

The MQTT protocol and the CoAP protocol are both commonly used IoT communication protocols, but there are great differences between the two protocols. From the perspective of practical application, the client of the MQTT protocol must know the data format in advance, while the CoAP protocol has no restrictions on the data format. From the comparison in Table 2, it can be seen that the CoAP protocol is a one-to-one protocol that realizes the transmission of status data between the client and the server, and the essence of the MQTT protocol is to realize the data transmission by transmitting the data to the server. MQTT It is the communication bus for real-time data transmission [15]. It can be seen that the MQTT protocol is a many-to-many protocol. Compared with the CoAP protocol, the MQTT protocol also has the advantages of openness and ease of implementation. Therefore, according to the requirements of the intelligent orchard irrigation system, the MQTT communication protocol is used for data transmission between the PC and the server.

Table(2). Performance comparison between MQTT and CoAP

Properties	MQTT	CoAP
Communication mechanism	Asynchronous	Synchronize
Connection method	TCP	UDP
Communication mode	Many-to-many	One-to-one
Application scenarios	Works with push and IM	Internet of Things
Power consumption	Low	Low
Reverse control	Reversible control	No reverse control

The wireless communication module is the NB-IoT communication module, which is the key component to realize the communication between the microprocessor and the OneNET IoT cloud platform [16]. The intelligent orchard irrigation system uses the Quectel BC20 shown in Figure 8 as the wireless communication module. It is a multi-band NB-IoT wireless data transmission module specially designed and developed by China Mobile. The BC20 module adopts the UDP (User Datagram Protocol) application layer communication protocol, uses the patch package and the circuit is connected to the IOT card to realize the communication. The circuit diagram is shown in Figure 9.

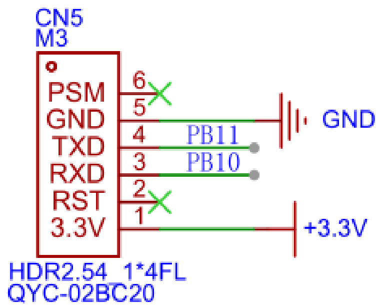


Fig. 8 Physical map of NB-IoT module **Fig. 9 NB-IoT module circuit diagram**

Before the wireless communication module communicates, it will initialize each serial port and module, and the microcontroller will issue an instruction to determine whether the wireless communication module BC20 is successfully connected to the network. If the BC20 module fails to connect to the network, it will be reminded through the OLED display and reconnect to the network. Otherwise, perform the next step, that is, monitor whether the irrigation control instruction information sent by the OneNET IoT cloud platform is received or whether the communication time is specified for the module. If the irrigation control instruction information sent by the OneNET IoT cloud platform is received, it is allowed to send this information to the microcontroller, and the microcontroller executes the corresponding instructions to control the closing or opening of the solenoid valve of the irrigation control module; The set fixed sending time allows the sensor to upload the collected ambient temperature and humidity data to the OneNET IoT cloud platform. It can be seen that the NB-IoT wireless communication module is the key bridge for uploading and issuing instructions, and plays the role of a central hub in the entire irrigation system.

4.Irrigation Control Module Design

When the microcontroller receives the irrigation control decision-making instructions fed back by the OneNET IoT cloud platform, it will control the irrigation control module to execute the corresponding instructions. In view of the realistic operability limitation of irrigation system design, the on-off control of orchard irrigation water pump is simulated in this system by the on-off control of electromagnetic relay.
The electromagnetic relay used in the irrigation control module is the Hongfa (HF) JZC-32F series 005-HS3 solid state relay (Figure 10) developed by Shenzhen Jimei Company. In order to facilitate the judgment of whether the electromagnetic relay is in working state, here is the electromagnetic relay module equipped with An LED work indicator, in addition, as shown in the schematic diagram of the irrigation control module circuit shown in Figure 11, an optocoupler needs to be added between the electromagnetic relay and the microcontroller to improve the anti-interference ability of the irrigation control module.

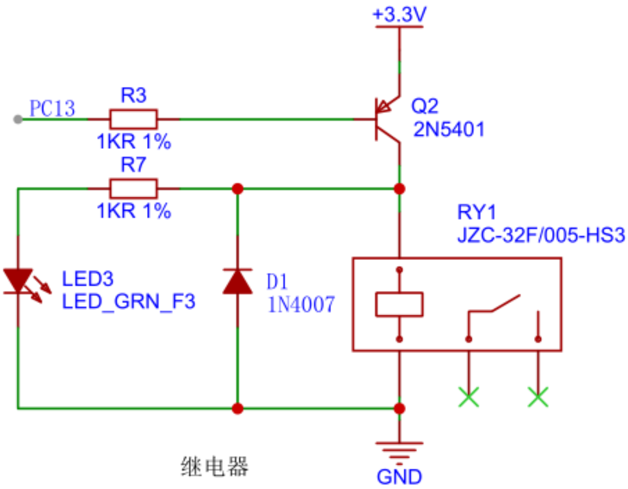


Fig. 10 Hongfa relay physical map **Fig. 11 Irrigation Control Module Circuit Diagram**

This system adopts two irrigation control methods, remote control and intelligent control [17]. Remote control means that the user performs the operation of the electromagnetic relay by operating the irrigation button on the user interface of the OneNET IoT cloud platform. Intelligent control is that when the environmental temperature and humidity data of the orchard is uploaded to the OneNET IoT cloud platform, after each terminal node uses the microcontroller to compare the collected environmental temperature and humidity data with the set relevant thresholds, when the environmental temperature and humidity values are within the Within the preset threshold range or outside the preset threshold range, the control program is automatically executed to control the on-off operation of the electromagnetic relay.
After receiving the control command from the OneNET IoT cloud platform, the microcontroller realizes the irrigation function of the orchard irrigation system by controlling the on-off of the electromagnetic relay. After receiving an instruction to start or stop irrigation, the microcontroller controls the on-off of the electromagnetic relay accordingly; if no irrigation-related instruction is received, the irrigation control module enters a low-power sleep mode.

4. SYSTEM SOFTWARE DESIGN AND IMPLEMENTATION

The software architecture of the orchard irrigation system is mainly divided into system main program design, node data acquisition module program design, server module program design and IoT cloud platform monitoring interface design. The software design of the NB-IoT node data acquisition module is to realize the functions of the entire system core.

1.System main program design
The microcontroller STM32F103 of the hardware module of the orchard irrigation system needs to implement the specific functions of the entire hardware module by orderly controlling the peripheral equipment irrigation control module, NB-IoT wireless communication module and ambient temperature and humidity data acquisition module. It can be seen that the design of the main program of the system is The key and core of the entire terminal node software programming. As shown in Figure 12 is the flow chart of the main program of STM32F103.

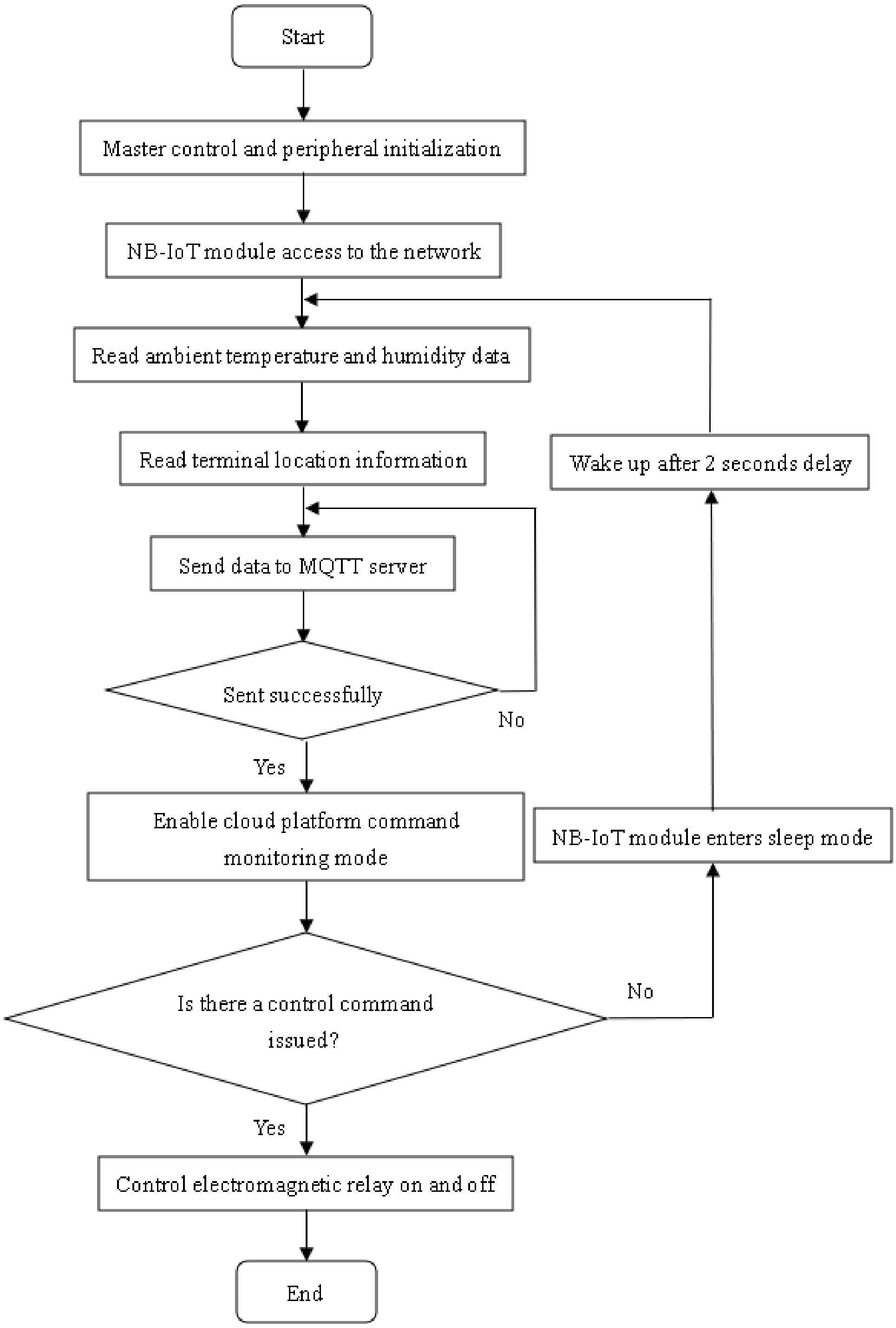


Fig. 12 Main program flow chart

Keil uVision5 is the development software used for the design, compilation and debugging of the mainprogram of the system, and it is implemented by C language program [19]. The main program of the system needs to logically and reasonably call the special function functions and execute the corresponding system call instructions, so as to control the coordination and mutual assistance of each module of the orchard irrigation system in an orderly manner, and purposefully realize the initialization of the hardware system and the collection of ambient temperature and humidity data. , processing, transmission and monitoring of related instructions of the OneNET IoT cloud platform.

The following is a detailed introduction to the software design of this part according to the control logic of each module executed by the main program of the system.

(1) Hardware system initialization. First, after powering the system, the microcontroller will initialize the entire system, mainly the initialization of its own memory, crystal oscillator module and underlying hardware modules. The initialization of underlying hardware modules includes system GPIO interface, environmental data acquisition module, NB -Initialization of IoT wireless communication module and serial communication commands [20]. Finally, initialize the port of the MQTT server and the NB-IoT interface.
(2) The hardware terminal is connected to the OneNET IoT cloud platform. After the NB-IoT module is initialized by the hardware terminal, on the premise of logging in to the OneNET IoT cloud platform in advance, the microcontroller will call the corresponding function to realize the NB-IoT module trying to connect with the OneNET IoT cloud platform. After docking the results, the NB-IoT module starts to receive the data processed by the terminal and prepares for data transmission.
(3) Read the temperature and humidity data of the orchard environment. After the initialization is completed, the algorithm process of the system main program is started. First, the data reading function needs to be called to wake up the soil humidity sensor and the temperature and humidity sensor to collect data from the ambient temperature and humidity data acquisition module, and send the data to the microcontroller through the corresponding serial port [21]; The residual data is cleaned up to avoid affecting the current data transmission; finally, after the data to be transmitted is stored in the newly defined structure, the string conversion function is called to convert the temperature and humidity data stored in it. is the corresponding string [22]. Then it is placed in the waiting queue of the NB-IoT wireless communication module, that is, the temperature and humidity data of the orchard environment is transmitted to the NB-IoT module.
(4) The terminal node positioning information is read. After the ambient temperature and humidity data is collected, the acquisition of the location information of the terminal node begins. First, the NB-IoT module sends an application for writing data to the microcontroller, and after passing the application, the microcontroller obtains the corresponding location information through the communication serial port; then, the location data analysis function is called to write data to the microcontroller. After analyzing the location information of the terminal, the microcontroller obtains the latitude and longitude data of the terminal node; finally, the obtained relevant location information is judged. If the location information obtained by the terminal satisfies the conditions, the calling function will need to send the information containing the location information. The structure is converted into a string, waiting to be uploaded to the OneNET IoT cloud platform [23].
(5) Send data to the MQTT server. After the above two kinds of data are obtained, the function of connecting strings should be called, and the above two kinds of corresponding data that have been converted into strings should be connected together to form a new string of information [24]. Then, after the data sending function of the wireless communication module is called by the microcontroller, the generated message is uploaded to the cloud platform. After this program is executed, the terminal node completes the process of data acquisition and transmission, and then the hardware system will enter the command monitoring and delay mode.
(6) OneNET IoT cloud platform command monitoring. After uploading the ambient temperature and humidity data and hardware module location information to the MQTT server, the hardware module enters the command monitoring mode, and judges in real time whether the MQTT server has issued orchard irrigation control commands. When listening to a control command issued, the microcontroller prepares to execute the electromagnetic relay control command to implement irrigation operations on the orchard.
(7) Terminal node wake-up mechanism. Considering the system power consumption and data transmission pressure, which are mainly generated by the NB-IoT wireless communication module, the NB-IoT module can be woken up every 2 seconds through the design of the main program. After each wake-up, the hardware system will repeat Execute the process of data collection and transmission once, and complete the terminal automatic irrigation control program when irrigation is required.

2.Node Data Acquisition Module Program Design

Since the data acquisition nodes of the node data (environmental temperature and humidity parameters) acquisition module must work in the orchard (outdoor) environment for a long time, the use of wiring for power supply is not only expensive, but also greatly hinders the loosening and fertilization of the orchard. Consider adopting the method of sub-nodes to install solar power for each data acquisition node. Secondly, too frequent uploading of data collected in the orchard environment will increase the pressure of data processing and cause the paralysis of the NB-IoT wireless communication network. At the same time, due to the increase in the amount of data transmitted by the NB-IoT wireless communication network, high traffic costs will be incurred.
Combining the above actual background situation, and taking into account the power consumption of the hardware module of the orchard irrigation system, each data acquisition node is set to sleep and wake-up modes to ensure that each node is in a dormant state for a long time during its service life. The program design flow chart is as follows 13 shown.

Most of the energy consumption of the entire hardware module of the orchard irrigation system is generated by the NB-IoT wireless communication module. When it is in the wake-up mode, its rated current is about 30mA, and when the sleep mode is turned on for a long time, its rated current is 2μA, that is, when the data When the acquisition node is in sleep mode, its current rating is 2 μA [25]. Under normal circumstances, each data acquisition node is in sleep mode. The interrupt mode of the serial port and the timer can cooperate with each other to start the wake-up mode at regular intervals to wake up the nodes in the sleep mode, so as to achieve the design purpose of regularly uploading environmental data.

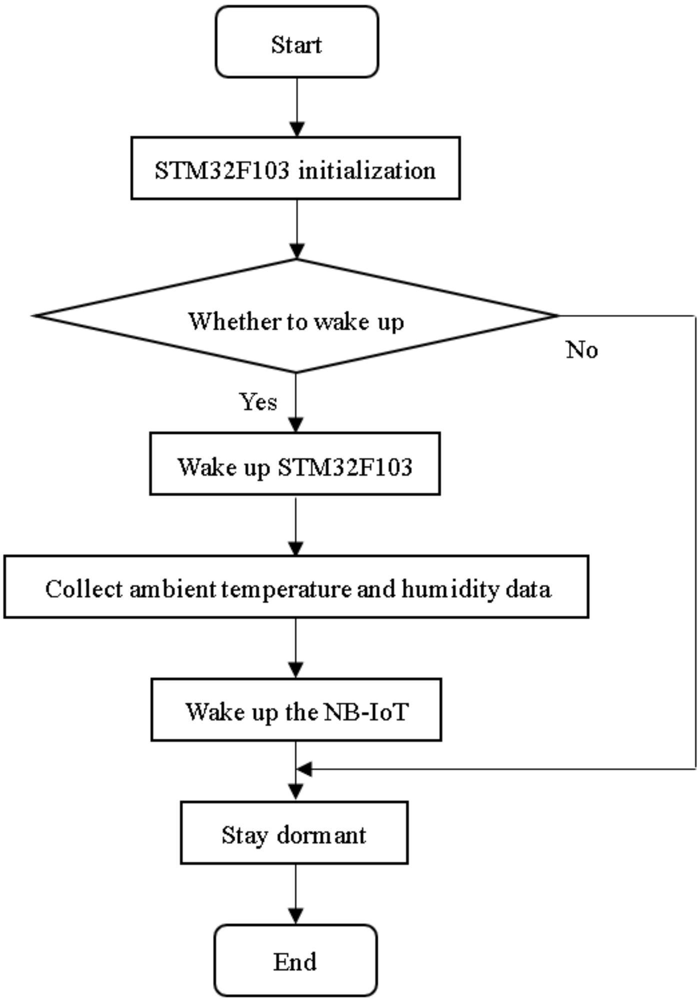


Fig. 13 Flow chart of data acquisition node program design

3.Server Module Program Design

The MQTT protocol adopted by the intelligent orchard irrigation server module is a relatively simple communication protocol developed by the IBM (International Business Machines Corporation) research team for data transmission between the client and the server [26]. It can be seen from Figure 17 that a complete MQTT communication system consists of a single server and several clients [26]. As shown in Figure 14 and Figure 15, the core of the entire communication establishment lies in the client's subscription and publication of the topic. Before communication, the corresponding topic is agreed through the MQTT protocol server. If the client needs to obtain (Figure 16), it is related to the topic The information can be subscribed to the server side [27]. After the subscription is completed, if other clients send subscription information to the topic, the server will also send corresponding information for the subscribing client [27].
In addition, in order to ensure that the system can maintain high communication efficiency in various complex communication environments, the MQTT protocol also has various functions such as QoS (Quality of Service) mechanism, persistent connection, information cache and will [28].

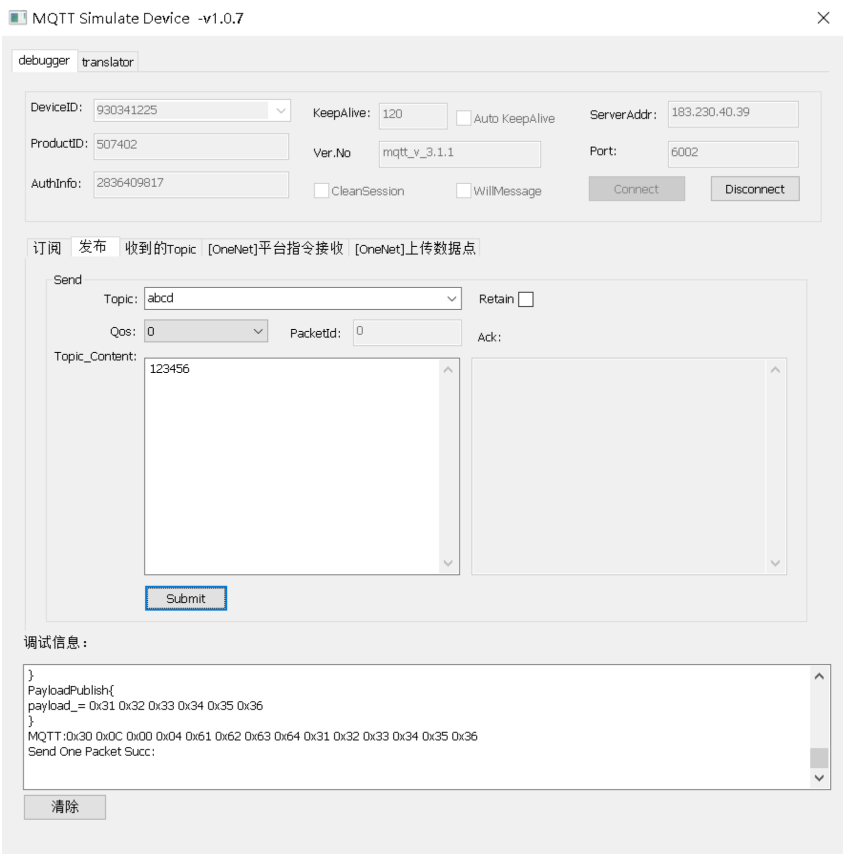


Fig. 14 Publishing of MQTT protocol topics

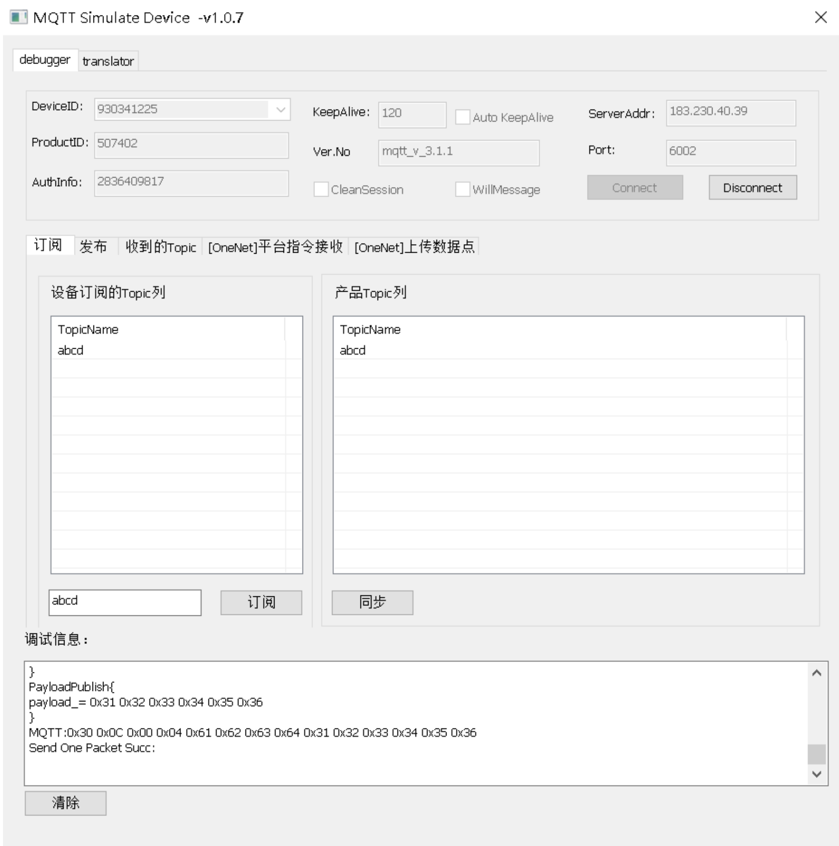


Fig. 15 Subscriptions to MQTT protocol topics

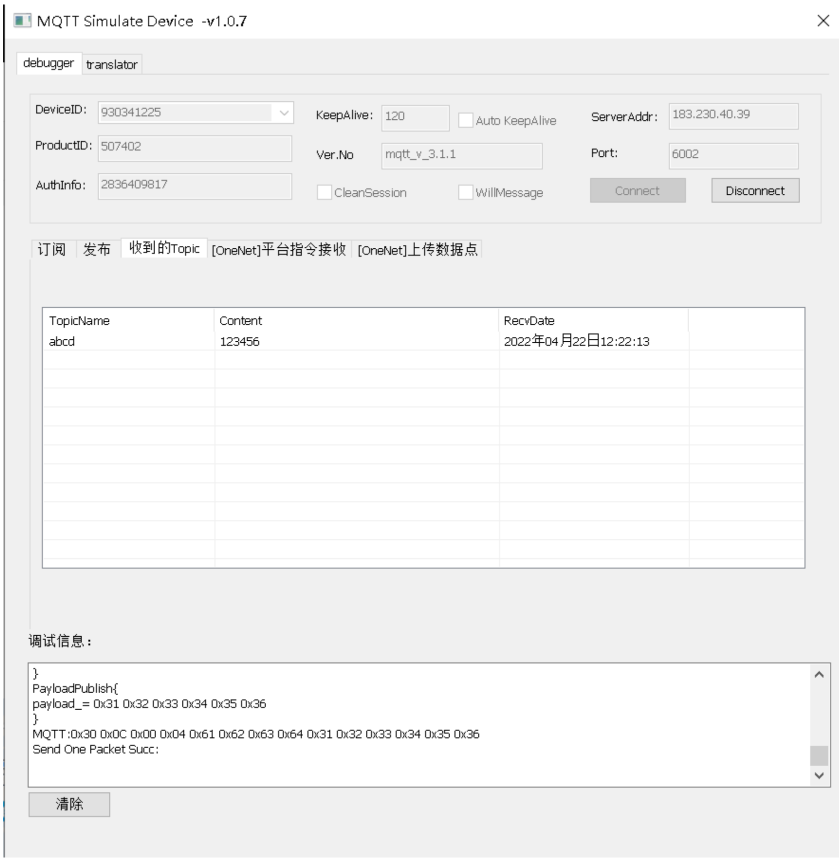


Fig. 16 Reception of MQTT protocol topics

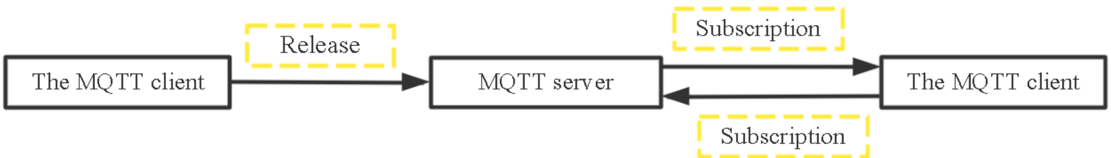


Fig. 17 Schematic diagram of MQTT protocol communication

(1) The QoS mechanism of the MQTT protocol is its very practical special function. The working mechanism is that the client can set the QoS level according to the actual needs to ensure the accuracy of information transmission. In the QoS mechanism, it is mainly divided into three different levels: 0, 1, and 2, which are used to represent three different ways of transmitting information. If the information is transmitted only once and whether errors occur during the transmission process is not considered, it is represented by level 0; if the information needs to be sent multiple times before being received without errors, it is represented by level 1; if the two ends of the communication only A message that can be received without errors after being sent once is denoted by level 2 [29].

(2) The MQTT protocol has the function of storing topic information. Under the premise that the topic information has the information cache mode enabled, when a new client connects or disconnects and reconnects, they will monitor and save the information from this topic.

(3) The MQTT protocol has the important function of long-term connection. This function is mainly to prevent the loss of historical information data. If the mechanism enables long-term connection mode, the server and client will be in a persistent connection state. In this case, even if the data transfer is abruptly terminated, the data related to the topic is still noted on the server side. After the data transmission is established again, the client can still receive the historical information sent by the topic [30].

(4) The Wills function is similar to the long-term connection function, in order to avoid sudden suspension of data transmission. With this feature, if the data transfer between the server and the client suddenly stops, the server can still publish it based on the Wills message sent by the client.

4.Design and implementation of monitoring interface of IoT cloud platform

Based on the consideration of the cost of the Internet of Things cloud platform, the intelligent orchard irrigation system uses the OneNET Internet of Things cloud platform with relatively low cost and high reliability. The OneNET IoT cloud platform is developed by China Mobile to assist development users to more easily access IoT devices and to receive, analyze, store, forward and display IoT device-related data, as well as to solve practical problems. IoT issues provide a cloud platform for intelligent decision-making solutions.

First, before the development of the IoT cloud platform, it is necessary to apply for registration and create a personal account on the official website of the OneNET IoT cloud platform, as shown in Figure 18. After logging in (Figure 19), the environmental data collection device model and environmental data collection node device to bind. The design of the intelligent irrigation system also needs to connect the NB-IoT network to the OneNET IoT cloud platform. However, the perfect adaptation of the BC20 selected by the NB-IoT wireless transmission module and the OneNET IoT cloud platform protocol enables the system to have higher communication capabilities. Efficiency, shorter development cycles and more reliable stability guarantees.

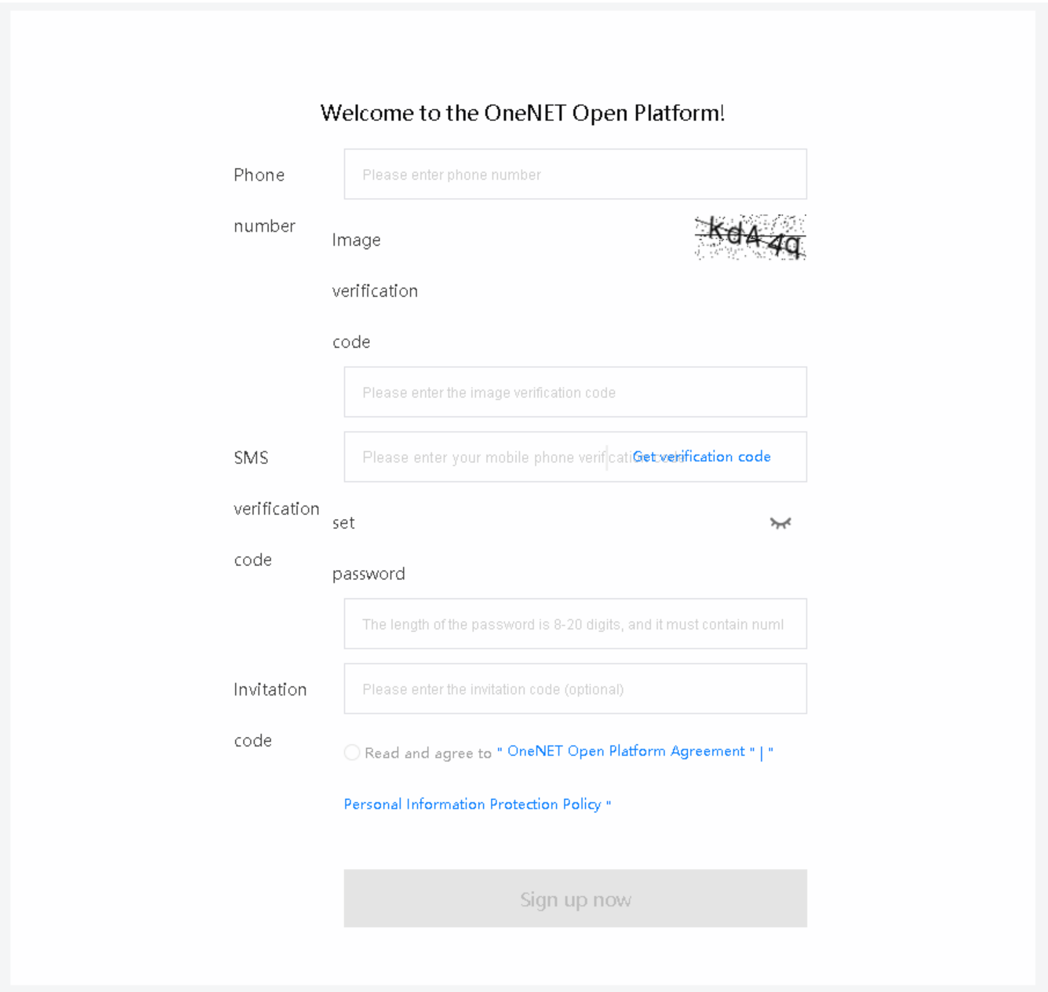


Fig. 18 OneNET IoT cloud platform registration account

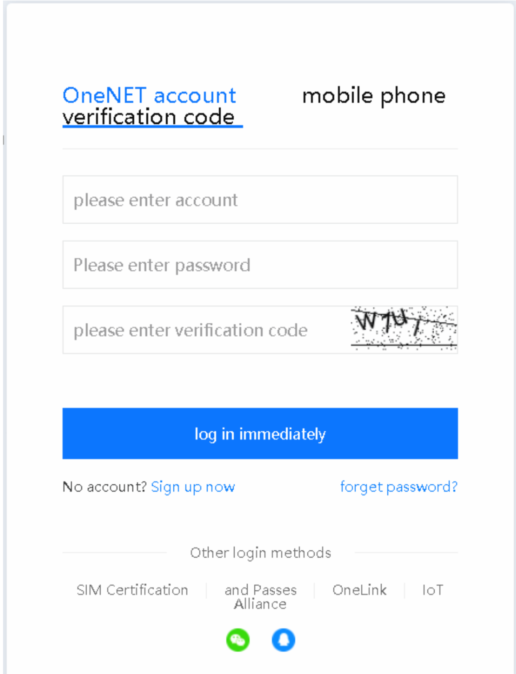


Fig. 19 Login interface of OneNET IoT cloud platform

The ambient temperature and humidity data transmitted to the MQTT server by the NB-IoT wireless communication module needs to be processed by the OneNET IoT cloud platform before it can be seen by the orchard administrator. The BC20 module is downloaded from the OneNET IoT cloud platform official website and transplanted SDK (Software Development Kit) to the microcontroller to achieve perfect docking with the OneNET IoT cloud platform, as shown in Figure 20. After the SDK development kit is implanted into the microcontroller chip for connection, the ambient temperature and humidity data can be uploaded to the OneNET IoT cloud platform through the following steps:

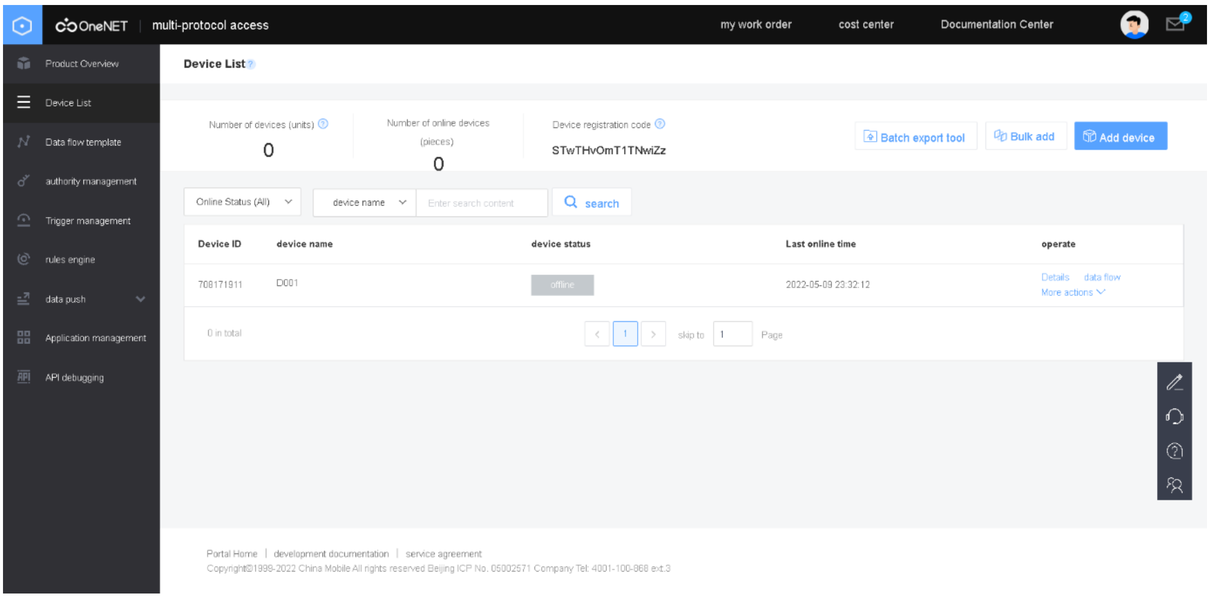


Fig. 20 OneNET IoT cloud platform and system hardware module complete connection diagram

(1) Download the SDK software development kit and implant its source code into the microcontroller.
(2) While accessing the OneNET IoT cloud platform, reasonably allocate resources to the data information exchanged with it, such as current value, temperature and humidity, etc.
(3) When the device is initialized, the heartbeat packet will be set and the data information will be uploaded to

the MQTT server. The SDK will also periodically send Update information to the server MQTT, otherwise the MQTT server will send RST (Rapid Storage Technology) data to the microcontroller.
(4) When it is detected that the resource data has changed, the nbiot_device_notify function is called to send a notification. If it is suitable to be called at this time, the SDK source code is called to transmit the relevant information to the OneNET IoT cloud platform.
(5) The command information issued by the OneNET IoT cloud platform is that the platform first uses the MQTT protocol to send the relevant commands to the microcontroller [31]. Then, the microcontroller processes the relevant execution commands or read and write commands by calling the execute function.

5. SYSTEM IMPLEMENTATION AND TESTING

After the hardware development and software design of the intelligent orchard irrigation system based on NB-IoT are completed, the ambient temperature and humidity data acquisition module program and the NB-IoT wireless communication module program need to be compiled and programmed into the microcontroller STM32F103C8T6, in order to test the environment The accuracy of temperature and humidity data collection and the stability of NB-IoT wireless communication are now being tested for practical applications of the smart orchard irrigation system.
During the test, each ambient temperature and humidity data collection node and irrigation control hardware module (Figure 21) can be randomly placed within 2.5km of the NB-IoT wireless communication gateway, and not only can the 0.96-inch OLED equipped with each data collection node be installed. The original ambient temperature and humidity data collected are observed on the display screen, and the temperature and humidity data sent through the NB-IoT network can also be displayed on the OneNET IoT cloud platform. Start the OneNET IoT cloud platform first, as shown in Figure 22. After debugging, you can view the received ambient temperature and humidity data, and compare it with the original ambient temperature and humidity data on the OLED display in real time. On the premise that the data collected by the test environment data node can be correctly received by the OneNET IoT cloud platform, the sensitivity and accuracy of the intelligent orchard irrigation system are monitored.
First, the soil moisture sensor Moisture Sensor v2.0 was tested. After the ambient temperature and humidity data collection node was powered on, by changing the soil moisture conditions, it was observed that the OLED display and the related data received by the OneNET IoT cloud platform also produced errors. The change of the approximate amplitude within the range, as shown in Figure 23 and Figure 24, indicates that the environmental temperature and humidity data collection node successfully collected data. Inserting the Moisture Sensor v2.0 into a beaker filled with water, and it was fully submerged, showed a noticeable change in soil moisture data, fluctuating around 70% RH. The fluctuation of the related data of the OLED display and the OneNET IoT cloud platform not only indicates that the collected soil moisture data can be sent to the OneNET IoT cloud platform using the NB-IoT network, but also indicates that the soil moisture sensor can work normally. The soil moisture test results are shown in Figure 25.

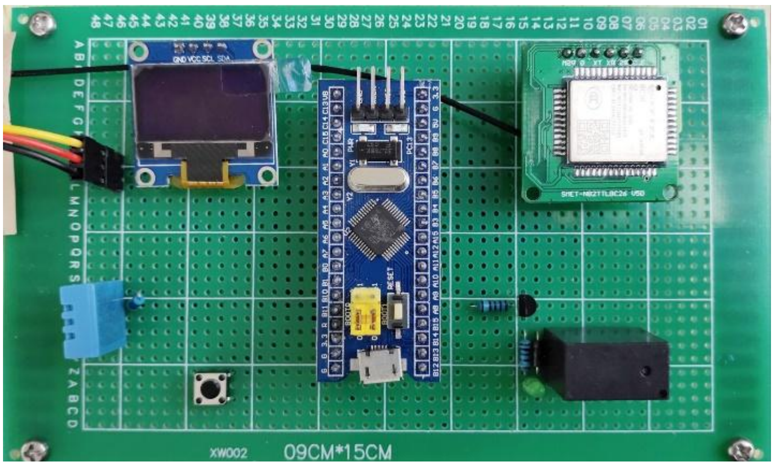


Fig. 21 Physical map of environmental data acquisition nodes and irrigation control hardware modules

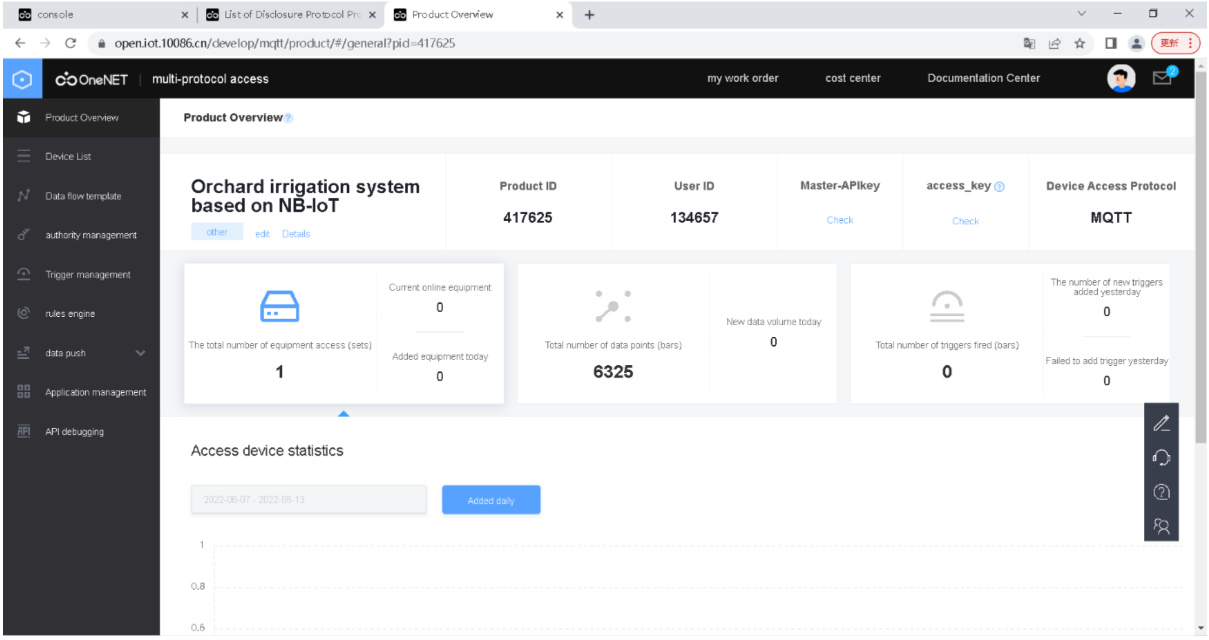


Fig. 22 OneNET IoT cloud platform product main interface

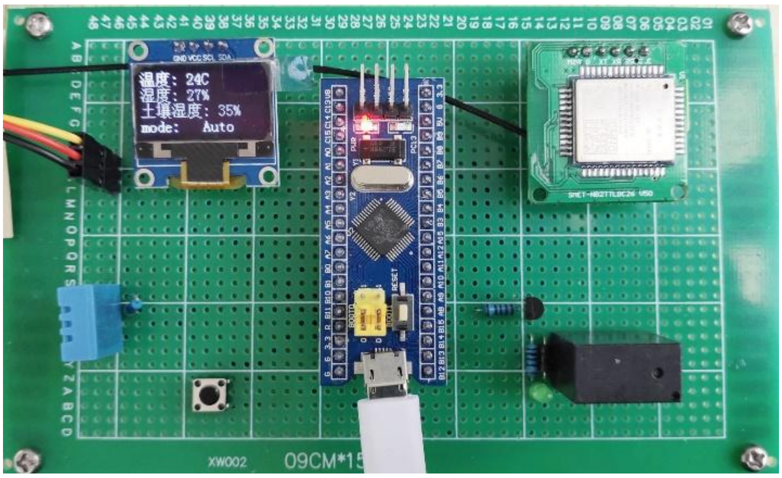


Fig. 23 Environmental data acquisition node OLED display data display diagram

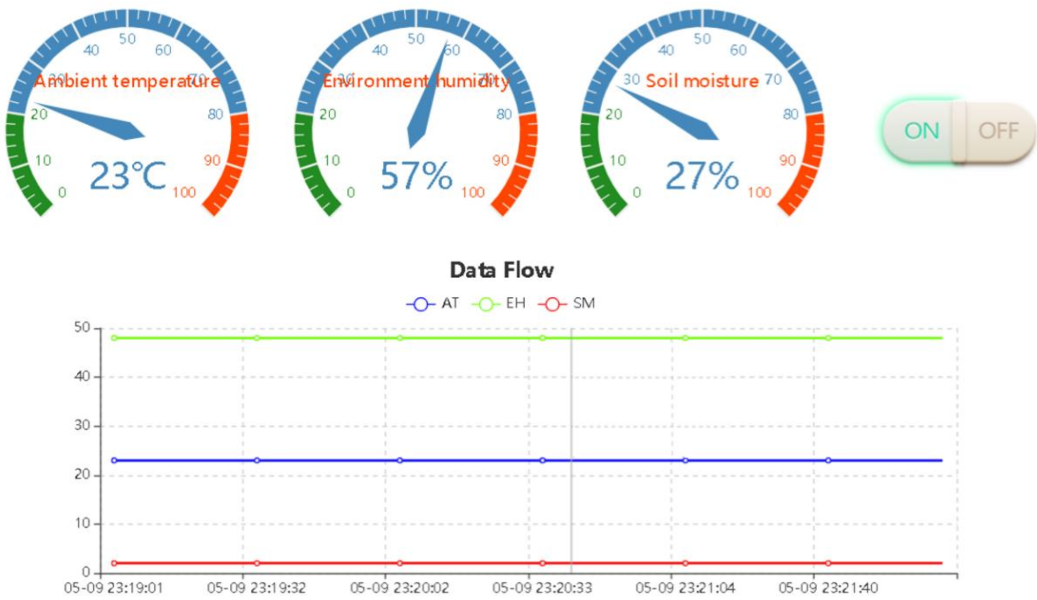


Fig. 24 OneNET IoT cloud platform product data display interface

Then use the control variable method to test the DHT11 temperature and humidity sensor. First, place the DHT11 temperature and humidity sensor in different humidity environments at the same room temperature, and observe that the humidity changes from about 0% RH to about 36% RH. Then, the DHT11 temperature and humidity sensor was placed in two environments with large temperature differences under the same drying conditions, and it was easy to observe that the temperature suddenly jumped from about 19 °C to about 32 °C [32]. The change of ambient temperature and humidity data proves that the DHT11 temperature and humidity sensor can collect data normally. As shown in Figure 25, air temperature and humidity data can be viewed on both the OneNET IoT cloud platform interface and the OLED display. This test once again verifies that the temperature and humidity data can be accurately transmitted to the OneNET IoT cloud platform.

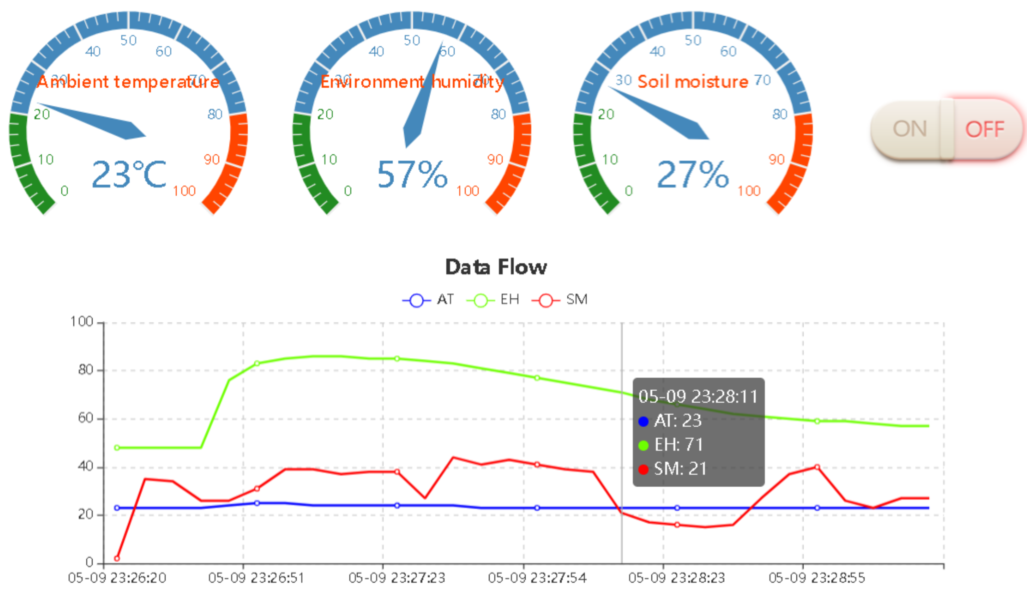


Fig. 25 OneNET IoT cloud platform system test result chart

The test of intelligent orchard irrigation system control includes two parts: automatic control test and remote-control test. Control mode switching buttons are designed in the two channels where the terminal node microcontroller is located. Whenever the button is pressed, the system alternately connects one of the corresponding channels and turns on the corresponding control mode. Test automation and remote control.

When the button is pressed, and the information of the Mode item displayed on the OLED display is Auto, it indicates that the automatic control mode is entered at this time. If the ambient temperature and humidity data collected by the node is not within the preset range, after being analyzed by the microcontroller, an instruction to turn on or turn off the irrigation control module will be generated and executed. By observing whether the LED indicator light of the irrigation control module works, it can be judged whether the automatic control of the orchard irrigation system is realized; through the real-time changes of the relevant data of the OneNET Internet of Things cloud platform, the specific effect of the automatic control can be detected.
When the button is pressed, and the information of Mode displayed on the OLED display is Manual, it indicates that the remote-control mode is entered at this time. When the OneNET IoT cloud platform detects that the temperature and humidity data is lower than the preset range, the user can turn on the remote irrigation control switch, and the OneNET IoT cloud platform will send irrigation commands to the irrigation control module.
After the received irrigation command is analyzed by the microcontroller of the irrigation control module, all peripheral devices are initialized first, and then the electromagnetic relay is controlled to start simulating orchard irrigation. At the same time, wake up the environmental temperature and humidity data acquisition module, collect soil temperature and humidity data in real time and send it to the OneNET IoT cloud platform in real time. The OneNET IoT cloud platform monitors the irrigation effect in real time based on the uploaded soil moisture data. Once the soil moisture data of a certain depth of soil layer reaches the preset value, the remote irrigation control switch is turned off, and the irrigation termination command can be sent to the irrigation control module [33].The microcontroller of the irrigation control module controls the disconnection of the electromagnetic relay, thus completing the irrigation task within a period of time.

6. CONCLUSION

This paper develops an intelligent orchard irrigation system based on the new NB-IoT wireless communication technology combined with the three-tier architecture of the Internet of Things system. The main architecture of this system design is to periodically collect ambient temperature and humidity data by controlling the sensing layer temperature and humidity sensor, and send it to the application layer MQTT server in real time through the transport layer NB-IoT communication network. The OneNET IoT cloud platform at the application layer visualizes the real-time ambient temperature and humidity data. Users can independently select control modes such as terminal automatic control or remote manual control based on the visualized data to control the on-off of the electromagnetic relay, thereby greatly improving the flexibility of irrigation. On the basis of realizing the purpose of intelligent irrigation of orchards.
This system combines advanced IoT technology and adopts BC20 module with low power consumption and wide coverage for NB-IoT communication technology networking, which not only has low hardware cost but also simple communication networking, which conforms to the development trend of the Internet of Everything. Real-time monitoring and periodic collection of ambient temperature and humidity greatly improves the stability of the irrigation system. Secondly, the orchard administrator can selectively control the irrigation system remotely according to the ambient temperature and humidity data, which further enhances the flexibility of the irrigation system control. Experiments show that the system has the advantages of low cost, simple networking, high stability, good flexibility, and high degree of intelligence. At the same time, the irrigation cost is reduced, which is in line with the modern development trend of the agricultural Internet of Things and can meet the modernization needs of orchard intelligent irrigation.

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