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Design and implementation of orchard IoT based on LoRa

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ABSTRACT:

With the rapid development of agricultural and rural modernization. The development of Agricultural Internet of things in agricultural information monitoring is in full swing. This article focuses on the development and application of Agricultural Internet of things in orchard management, and tries to put forward a novel, practical and highly technical technology. A wide range of portability and wide range of Internet of things for orchard.
1. In view of the development status of Internet of things technology in orchard management and the technical bottlenecks of the popular orchard Internet of things technology, the strategy of applying the new generation of wireless communication technology LoRa to orchard Internet of things is put forward.
2. Based on content one, connecting with the actual demand and key factors of agricultural production, we have designed a practical system function including information collection, downlink command execution and host computer interaction. It abstracts three layers of structure and has three function modules to drive function.
3. according to the actual application needs of the system, the system is designed with PC host computers to interact with users. In order to achieve the goal of remote interaction, the system considers the use of cloud platforms to break through the distance barriers and achieve real long-distance interaction.
The design of LoRa based orchard Internet of things system has strong advantages such as portability, low energy consumption, long distance communication and strong interactivity. It has a good application prospect in the field of orchard Internet of things monitoring.

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I. INTRODUCTION

With the development of the Internet of Things technology and the gradual application of the Internet of Things industry in production and life, it has become an inevitable trend and an important means to build a modern agricultural grain, fruit and vegetable industry by using the Internet of Things technology to intelligently monitor and scientifically manage the agricultural environment. The goal of intelligent orchard is to monitor the environmental temperature and humidity, light intensity, soil humidity and other parameters that are closely related to the growth of fruit trees, to realize data monitoring, collection, transmission, and regulation [1]. By this means, information resources are transformed into productive forces, which changes the industrial structure of orchard production, from the present situation of labor-intensive and environment-dependent agricultural production mode to a modern orchard industry that can be monitored, measured, prevented, and controlled by human beings. From the perspective of orchard management, this not only reduces the management cost, enhances the important position of controllability in orchard management, but also makes scientific management evidence-based. From the field of agricultural production, the improvement of fruit quality and the increase of orchard yield provide a stepping stone for science and data. In recent years, with the increasing market of fresh fruits and vegetables, the planting area of orchards continues to grow, which is bound to put forward higher requirements for the coverage of orchard monitoring and sensor deployment network. Facing various present situations and bottlenecks encountered in the development of large orchards, the task of designing a set of orchard Internet of Things system with wide coverage and large planting scale has become an urgent production demand.
When designing the Internet of Things system, we should consider its hierarchical architecture. A good architecture can make the division of labor among modules clear, and the system is light and convenient to use. Modern orchard Internet of Things system is usually divided into three layers, which are information perception layer, data transmission layer and interactive application layer from bottom to top [2].
In the traditional cable communication transmission, it has been eliminated by history because of the price, deployment, and security of cable. And because mobile communication technologies such as GSM and GPRS are paid communication methods, they are also not applicable to large-scale orchard Internet of Things. Short-distance communication technologies such as WIFI and ZigBee are quite mature and have been used in various

Internet of Things systems. However, due to the limitation of their communication distance, they are not suitable for the large-scale orchard monitoring communication requirements mentioned in this paper. In addition, in the node network of sensor networking, a part of energy will be consumed, so the energy consumption in the networking network will be the key point to determine the quality of the monitoring system. While pursuing low power consumption, the new generation of orchard sensor network also puts forward high requirements for communication distance. LoRa (long range) [3] wireless communication technology is a new generation of low-power wide area network [4] (low-power-wide-area network, LPWAN) technology that has been mature and applied abroad. Compared with several existing communication methods just mentioned, it has the advantages of strong robustness, long communication distance, low energy loss, etc. It is very suitable for deployment in agriculture and rural areas. LoRa communication scheme has obvious advantages in the design of Internet of Things system in large orchards.

II. SYSTEM DESIGN SCHEME

OVERALL SYSTEM DESIGN

The basic function of this design is to monitor and collect the environmental factors of orchards-temperature, air humidity, light intensity and soil humidity in real time, and the information collection layer communicates through wireless network, and the collected information will finally be transmitted to the upper computer and displayed to users [3]. Users can monitor orchard information in real time, conveniently and remotely, compare the collected information with the preset threshold, and automatically or manually control the switch of water pump system for irrigation. Specific requirements of system functions are as follows:
(1) The information perception layer is the collection of environmental information and the basis for judging whether irrigation is carried out or not. Real-time acquisition of the parameters of fruit tree growth environment is the premise of realizing intelligent orchard. The task of information collection is completed by deploying various sensors to collect information in the orchard.
(2) The acquisition node can communicate wirelessly with the uploading node. At this time, the wireless transmission mode between nodes is required to have the characteristics of long communication distance, low power consumption, high security, and stable signal.
(3) The collected information can break through the distance barrier and be collected to the upper computer in real time and remotely.
(4) The core of this design is to realize the irrigation function of the orchard automatically or manually by using the collected orchard environmental data, which requires that the system can realize the downward command and control the water pump terminal.
After analyzing the system functions, the design of the orchard Internet of Things system is based on the hierarchical structure of the intelligent Internet of Things system, including the hardware and electrical design of the sensing layer, the wireless transmission protocol of the transmission layer and the upper computer software design of the application layer [4]. Its hierarchical structure is shown in Figure 1.

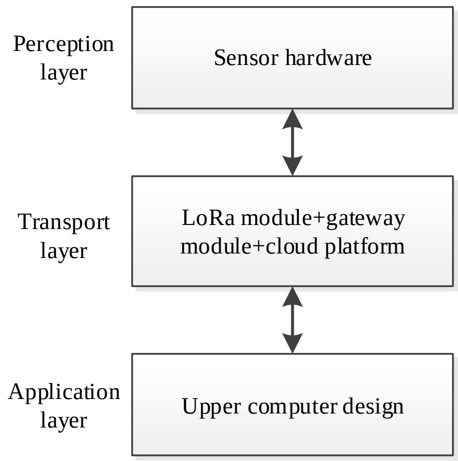

Fig.1 System hierarchy analysis diagram

In this design, STM32 is used as the main control chip of the orchard IoT system, which consists of air temperature and humidity sensor, soil humidity sensor, light intensity sensor, water pump switch controller, wireless communication module (Lora), WIFI gateway module, cloud platform, host computer, etc., and realizes the information collection and intelligent management of IoT orchard. The specific functions and working principles are as follows:

LoRa technology is adopted in wireless communication between nodes to transmit data, and then the node data is transmitted to the host computer through the transmission layer. The information layer is the terminal of orchard environmental information acquisition, which is composed of sensors, STM32 single chip microcomputer, etc. Sensors arranged in the park collect environmental information of the park at certain intervals, and the collected analog signals are converted into digital signals by A/D converters in MCU for further transmission. The sensing layer collects the data collected by the sensor, and when the set time is reached, the microprocessor sends the data to the gateway module through LoRa protocol; The gateway consists of STM32 microprocessor, LoRa module, WIFI module and cloud platform, and is mainly responsible for wireless communication with the perception layer and the host computer. LoRa of the transport layer receives the data from the sensor, processes the received data by microprocessor, then packages the data to the cloud through WIFI module, and the upper computer connects to the cloud. After the matching is successful, the upper computer of the PC receives the data, processes the data and shows it to users. According to the collected data, users can choose the automatic or manual mode independently, control the water pump switch, and carry out orchard irrigation. In the automatic mode, the collected soil moisture data is compared with the preset soil moisture threshold value. If the collected data value is lower than the preset threshold value, then the upper computer will automatically send the water pump on instruction for irrigation operation.
The system mainly includes the following parts: terminal module, gateway module and upper computer module. The overall hardware structure is shown in Figure 2. Among them, the terminal module is divided into two job functions: information acquisition and downlink command execution. By investigating and analyzing the relationship between fruit trees and environmental factors, it is determined that the main park environmental information that the system needs to collect mainly includes: soil information, meteorological information, and soil information includes soil moisture; Meteorological information includes air humidity, air temperature and light intensity. The terminal collects this environmental information, and transmits it to the information handing-in module through LoRa wireless fidelity. The information handing-in module then tells the information to be transmitted to the upper computer through WIFI connection to the cloud.

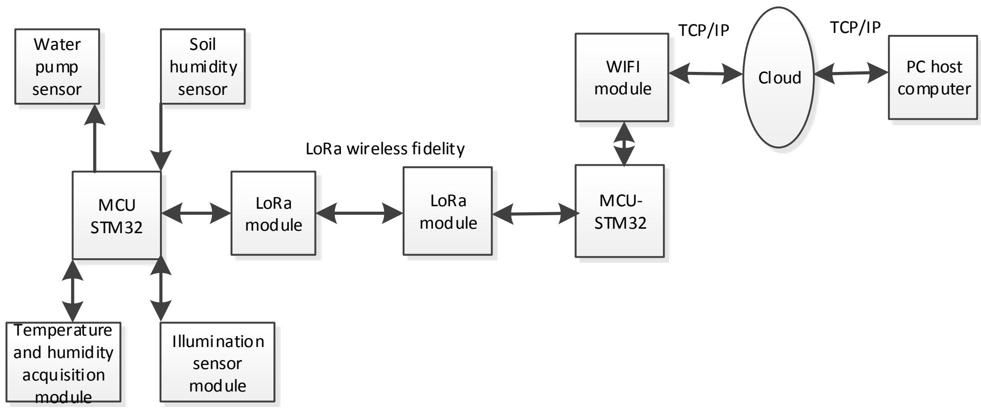

Fig.2 Integral module frame

In the hardware design, light intensity sensor, soil humidity sensor and air temperature and humidity sensor are set, and these sensor nodes are used to detect and collect information of orchard environment, among which a single-chip microprocessor is used, which is responsible for processing data and controlling the normal work of each module, and is the core of the system operation.
In the design of information handing-in module, lora is used to receive the data information from the terminal, which is processed by MCU, connected to the cloud by WIFI module, and the cloud platform is used to transmit the data to the host computer. Finally, the data collected from the sensor terminal is transmitted to the client of the host computer, thus realizing remote control.

SYSTEM MODULE SELECTION SCHEME

(1) Scheme selection of single chip microcomputer
At present, there are many types of single-chip microcomputers popular in the market, each with its own advantages and disadvantages in function. Considering that I am familiar with STM32 series single-chip

microcomputers, it is not only small and low in cost, but also has many attached I/O ports, and its internal modules are comprehensive, so it is flexible and simple to operate. In this design, STM32F103C8T6 is used as the main control chip of the orchard Internet of Things system [5,6].

(2) Communication scheme selection

LoRa point-to-point communication is adopted in this design [7,8]. For orchard production and application, low-power and low-cost long-distance transmission scheme is the key consideration. It is of great significance to increase the output and reduce the resource consumption by arranging all kinds of information acquisition sensors in the park. These sensors will upload data regularly and send the data to the remote user center wirelessly to realize remote real-time data acquisition [10,11].

Wireless communication has many technical types. Bluetooth technology, which is often used in our life, is one of them. Bluetooth technology is based on IEEE802.15.1 protocol, and has a long history of application [12-14]. It mainly transmits data by packet switching. At present, it is mainly used for short-distance transmission, such as Bluetooth headset. Theoretically, it can keep communication within about 100 meters. However, in daily life, the distance between two rooms greatly reduces the communication quality, and even leads to disconnection. WIFI technology is a kind of communication technology that people can get at their fingertips at present, but the vitality of WIFI facilities is fragile, which requires high deployment environment, and it is likely to be maliciously cracked in terms of security, which will affect the normal communication requirements. ZigBee technology is not common in life, but it has been well applied in the field of near-field industrial communication. Nowadays, most of the large-scale fruit tree planting areas are in rural suburbs or even some mountainous areas, which are remote [15,16]. All the above technologies are constrained by various factors such as low signal coverage, unstable quality, inconvenient equipment deployment and difficult equipment maintenance, which can't guarantee the normal operation of the system and stable data transmission. The traditional cellular network is not suitable for networking systems that work continuously all day and have a small amount of data transmission, which will not only waste a lot of network resources, increase the system load, but also greatly increase the system cost.

The modernization process of orchards makes modern orchards have the characteristics of large area, complex geographical factors, long fruit cultivation period, etc., which makes the Internet of Things in orchards need to consider many factors for detection, long monitoring period, and deployment of monitoring points in place. LoRa technology is suitable for such application scenarios. LoRa technology considers the balance between long-distance transmission and transmission power consumption, and has the advantages of low cost, low power consumption and long-distance transmission.

(3) Cloud platform scheme selection

Grain Rain Cloud Transmission Platform provides an easy-to-use and free remote network debugging assistant. And provide simple transparent transmission function. As we all know, the Socket communication mode adopts the communication mechanism between the client and the server, and the client can establish a connection with the server only by checking two parameters [17]. One parameter is the IP address of the server, and the other parameter is the port number for communication. Therefore, when the facilities are connected to Grain Rain Cloud Transparent Transmission System as clients, in order to identify the data source and whether the client devices are legal, the system adopts a verification method called registration packet. After each connection, a packet of data is sent, which must be written and sent according to the system rules. The cloud uses the contents of this packet to identify the client device. The format of the registration package is: EP = device id & pw = device id where device id (device number) and device id (device password) are two variables. Users can customize these two variables individually, or they can use the variable definitions generated by the system by default. In this paper, the serial number of the host computer equipment is D4UT9UZF83FM7XN5 gateway module, and the serial number of the gateway module is LKXTAU3CDSMPPYSL, and the passwords are all 123456.

INTRODUCTION OF SYSTEM HARDWARE CIRCUIT DEVICES

(1) Introduction of STM32F103C8T6 chip

An important part of a single-chip microcomputer is its internal chips, which are generally relatively small [18], and are internally integrated with arithmetic units, controllers, memories, input and output ports and other logic components. Traditional single-chip microcomputers are small, low in power consumption and high in operation speed. This system uses STM32F103C8t6, a chip in STM 32F103 series, as the main controller. The circuit diagram and physical diagram of STM32F103C8T6 are shown in Figure 3 and Figure 4 respectively.

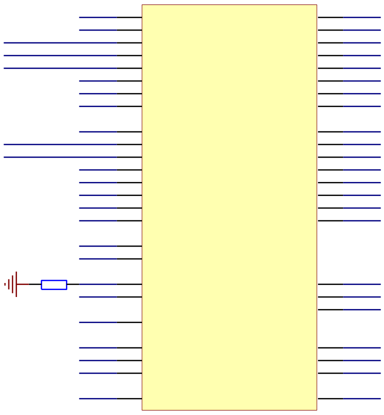

Fig.3 circuit diagram of stm32f103c8t6

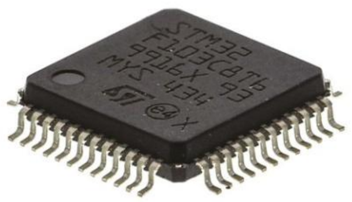

Fig.4 STM32F103C8T6 microcontroller physical diagram

(2) Introduction of WIFI module

ATK-ESP8266 is a high-performance serial port-wireless (UART-WIFI) module [19]. It can carry software applications by itself, and can format all WIFI functions by using an AP interface. ESP8266 is shown in Figure 5. ESP8266 can be started directly from external flash memory. In other cases, when undertaking the task of Wi-Fi adapter, such as the development of embedded system, it can be added to the module unit containing MCU, and the connection is convenient and fast. ESP8266 has high on-chip integration, and its package is also very suitable for development. It can be realized by simple external circuit packaging when in use. ESP8266 is a WIFI solution with highly integrated on-chip system and perfect self-system. As shown in the circuit diagram of Figure 6.

Fig.5 WIFI module ESP8266

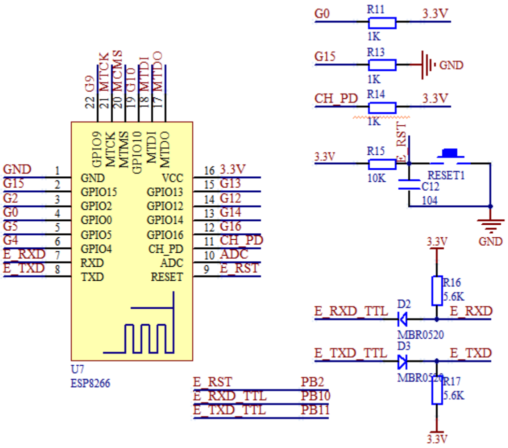

Fig.6 Circuit diagram of WIFI module

The basic principle of this system using WIFI module to realize remote control is as follows: the collecting node wirelessly transmits the collected environmental data to the information handing-in module through LoRa, and the information handing-in module is connected to the cloud platform through WIFI module, and the cloud platform sends the data to the remote client in real time, and the remote client understands and controls the orchard environment through the upper computer.

(3) Introduction of LoRa module

The ATK-LORA-01 wireless serial port module selected by this system is a LORA wireless serial port module introduced by ALIENTEK [20]. It has the characteristics of small size, low power consumption, high performance, and long communication distance. The physical diagram of ATK-LORA-01 is shown in Figure 7.

Fig.7 Front of atk-lora-01 wireless serial port module

SX1278 spread spectrum chip is used in the module, which belongs to ISM frequency band. It has the advantages of long communication distance, stable signal, high safety, and efficiency. There are 32 channels in the module, and the working mode, serial port rate and other parameter settings can be modified by AT instruction. Operating frequency is 410Mhz-441Mhz, in which the stepping channel adopts 1Mhz frequency as the standard, and supports firmware upgrade function [21,22]. The internal chip of the module has its own filter circuit to stabilize the signal and eliminate the interference. The electrical parameters of the module are shown in Table 1.

Table1. ATK-LORA-01 Module Parameters

Project	Explain
Module size	36*20mm（SMA connector and antenna are not included）
Modulation system	LoRa spread spectrum
Operating voltage	3.3~5V
Emission current	118ma（20dbm 100mw voltage 5V）
Receiving current	17ma（Mode 0, Mode 1）， The minimum is about 2.3uA (mode 2+2S wake-up)
Antenna form	SMA antenna
Working temperature	-40~+85℃
Storage temperature	-40~+125℃

The ATK-LORA-01 module uses simplified interface connection. Only 4 IO's are needed to complete all functions, and 1*6 rows of needles are used to connect with the outside, which is simple and convenient. The detailed description of each pin is shown in Table 2.

Table2. ATK-LoRa-01

Serial number	Name	Pin direction	Explain
1	RXD	input	TTL serial input, connected to external TXD output pin
2	TDX	output	TTL serial output, connected to external RXD input pin

3	GND	Earth wire
4	VCC	3.3V~5V Power input

(4) Introduction of temperature and humidity sensor
The temperature and humidity sensor of this system is DHT11, which is easy to learn and familiar to everyone, as shown in Figure 8. It is a sensor that combines temperature and humidity to measure [23]. The description of DHT11 pin is shown in Table 3.

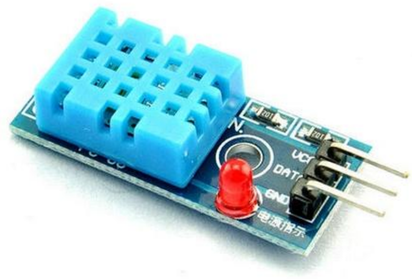

Fig.8Temperature and humidity sensor DHT11

Table3.DHT11 Pin Description

Pin	Name	Annotate
1	VDD	Power supply 3-5.5VDC
2	DATA	Serial data, single bus
3	NC	Empty feet, please hang up.
4	GND	Grounding, negative power supply

(5) Introduction of light sensor
GY-30 is selected as the light sensor module in this system, and BH1750FVI light sensor is integrated in the module. There is a photodiode in BH1750 which is responsible for light sensitivity. The analog value of weak current change is obtained by operational amplifier, and the digital signal is obtained by AD converter. There is also a crystal oscillator in BH 1750 to provide the reference frequency. The explanatory diagram and physical diagram of GY-30 module are shown in Figure 9 and Figure 10.

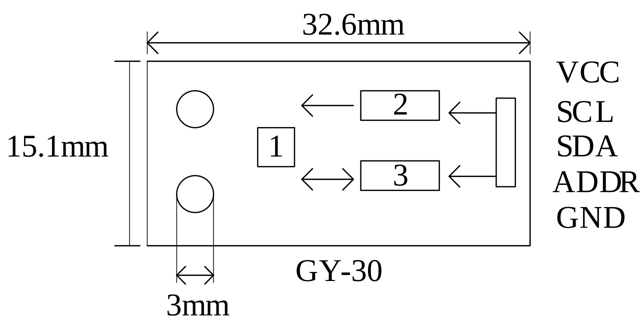

Fig.9 GY-30 module description diagram

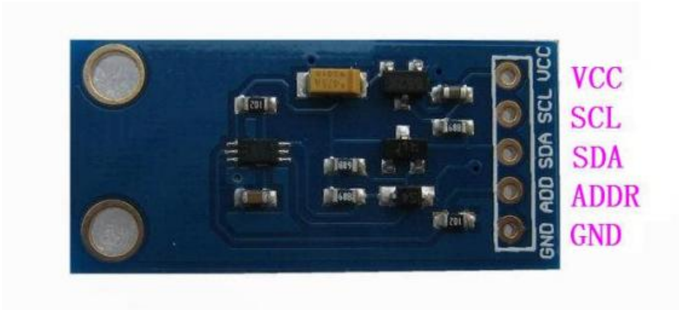

Fig.10GY-30 physical drawing

(6) Introduction of Soil Humidity Sensor

The soil humidity sensor is divided into two parts, one is a waterproof probe, and the other is a rust-proof steel probe [24]. It can be laid in orchard soil in an adult way, and it can measure the moisture content of shallow soil and deep soil. The output sensor model of this system is YL-69. The physical diagram and circuit diagram are shown in Figure 11 and Figure 12 respectively.

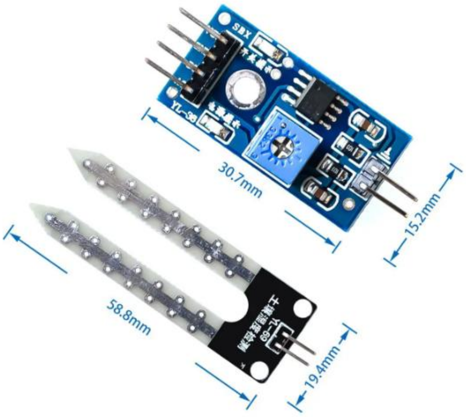

Fig.11 Soil moisture sensor YL-69

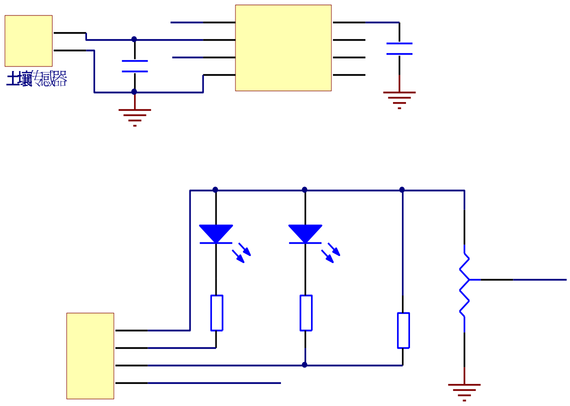

Fig.12YL-69 Circuit Diagram

(7) Introduction of water pump

The water pump relay module used in this system is an optocoupler isolation relay drive module [25,26]. The working voltage of the module is 5V, and the module can be triggered at high level by jumper. This method can also be used to set the low-level trigger when the actual work requires it. As shown in figure 13.

Fig.13 Physical diagram of driving module of one-way optocoupler isolation real

III. SYSTEM PROGRAMMING

OVERALL PROGRAM FLOW DESIGN

The analysis of this system includes four functions: information collection, information transmission, host computer interaction and downlink command execution, which are divided into node terminal, gateway terminal and host computer terminal. Among them, information transmission is an indispensable carrier for all other functions. The overall functional process framework is shown in Figure 14.

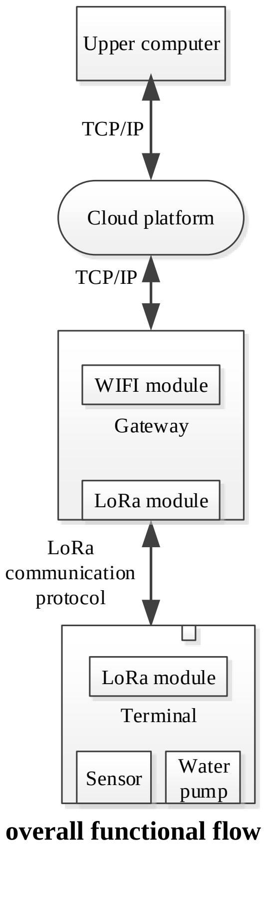

Fig.14 overall functional flow framework

GATEWAY MODULE DESIGN

The gateway module is an important link connecting the host computer and the terminal node, and it is the core of the whole system. On the one hand, the gateway terminal communicates with the node terminal through Lora module; on the other hand, the gateway terminal connects to the cloud through WIFI module, and then keeps communication with the host computer through the cloud, which ensures the possibility of remote monitoring and control of the system. LoRa module transfers data with WIFI module through STM32 microprocessor, and

WIFI module transfers data with host computer through transparent transmission function of cloud platform. First, after power-on, the WIFI module will automatically connect to WIFI according to the service set identifier –SSID (Service Set Identifier) and password burned in the module in advance. This function is realized by atk_8266_WIFIsta_test () function. The gateway module connected to the network will log in to the cloud platform through the WIFI _ register _ cloud () function, and then communicate with the host computer through the cloud platform. See appendix for specific codes of atk_8266_WIFIsta_test () function and WIFI _ register _ cloud () function. After connecting to the cloud, the gateway starts to work. The workflow of the gateway is shown in Figure 15:

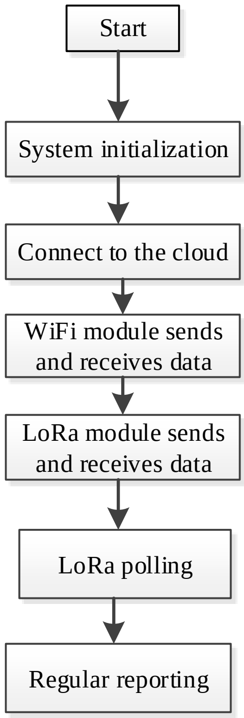

Fig.15 working flow chart of gateway

PROGRAM DESIGN OF UPPER COMPUTER MODULE

(1) Function design of upper computer
The host computer is the main embodiment of the client and user interface of the whole software system. It provides an interactive interface, so that users can intuitively and clearly see the data collected from the node terminals. According to the sensors used in this system, it can be known that the interface of the upper computer should have the display of sensor parameters. According to the functions set by this system, the water pump switch can be controlled automatically or manually. Therefore, there should be an automatic and manual mode selection module, and a module for setting the soil moisture threshold to realize the automatic control function. In addition, as the main tool of remote control, the upper computer should have the function of accessing the Internet by connecting the specified IP and port, and it should also have the function of sending commands to the terminal, to realize the function of real-time interaction. The upper computer interface is shown in Figure 17.

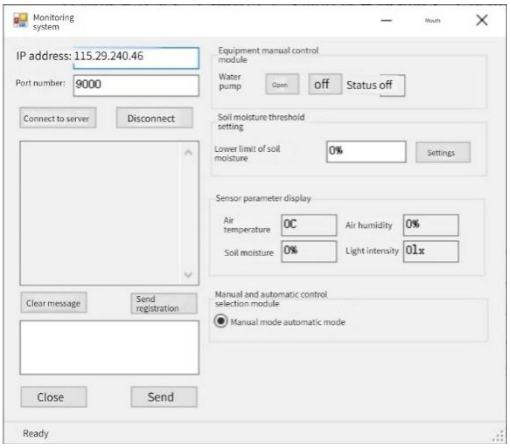

Fig.16 Upper computer interface

(2) Upper computer function realization

The upper computer is developed in C++ language based on Microsoft Visual Studio2013 environment, and an. exe executable file is generated, which is named TCPClient.exe. It has been introduced before that this system realizes the connection between the gateway module and the upper computer with the help of Grain Rain cloud platform. Users can access the network and own the PC with this executable file, and they can open the TCPClient.exe executable file anytime and anywhere to connect to the cloud transparent transmission system and view the monitoring data sent by the node terminal. This software is mainly connected to the cloud through TCP protocol. By inputting the IP address and port number of the cloud server for connection, and then manually sending the device ID and password distributed in the cloud platform to the server, the gateway can be connected to the cloud server, and the information can be exchanged with the node terminals. The upper computer cooperates with the background program on the computer and the bottom program on the node terminal microprocessor to detect the orchard environment, control the running state of irrigation equipment, and set the running parameters of irrigation equipment. The upper computer module mainly includes the functions of connecting to the cloud server, sending and registering, displaying sensor parameters, setting irrigation mode, controlling water pump switch, setting off-line threshold of soil moisture, etc. Connect the upper computer to the cloud registration interface as shown in Figure 18.

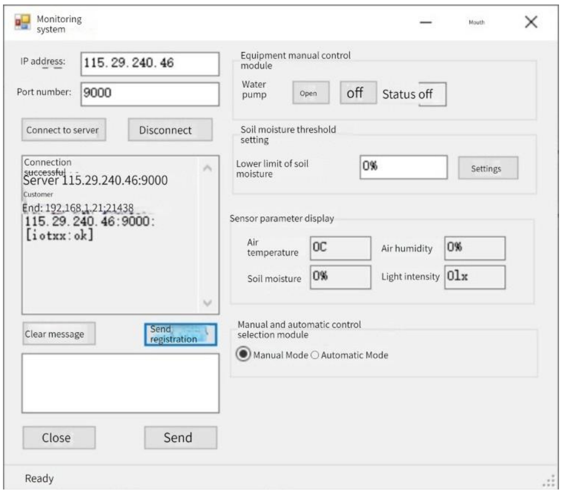

Fig.17 The upper computer connects to the cloud registration interface

IV. SYSTEM IMPLEMENTATION AND DEBUGGING

SYSTEM INTEGRATION

System integration refers to the use of hardware devices to connect all subsystems or independent physical devices, so that they have smooth and accessible electrical characteristics. System integration of this system is the assembly and welding of the electrical components needed by this system. The physical diagram of the welded terminal node module is shown in Figure 18 and the physical diagram of the gateway module is shown

in Figure 19In this paper, the hardware circuit PCB design is completed by using Altium Designer Summer09 software. The system integration process is as follows:
1.cording to the circuit schematic diagram and the functional design of the system, buy the corresponding components on the e-commerce platform, and draw the PCB diagram of the system according to the packaging of each component.
2.Make the circuit board according to the PCB diagram of the system.
3.According to the implementation scheme, solder the components on the circuit board. In order to ensure the accuracy of welding debugging, the following points need special attention:
1.Pay attention to safety.
2.Welding should be carried out in a modular way.

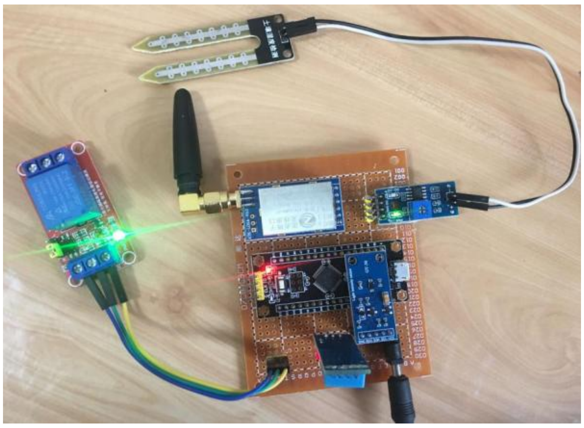

Fig.18 Physical diagram of terminal node module

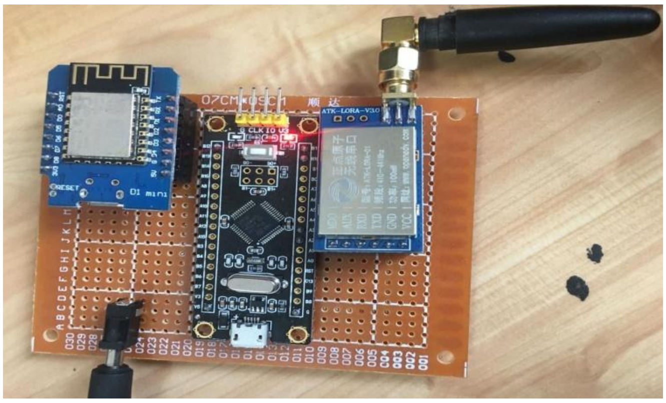

Fig.19 Physical diagram of gateway module

TESTING AND DEBUGGING

In order to verify the realization of the function of this system, I came to the orchard for field test. The equipment used in this test is a charging treasure, which is used to supply power to the terminal module, a notebook computer, which is used to test the realization of the upper computer function and supply power to the gateway module, and a networked mobile phone which is used to provide hotspot WIFI to the gateway module and computer.
Test in the orchard. Deploy the terminal module in the orchard, insert the soil humidity sensor into the orchard soil, and power on through the charging treasure.
Plug the USB power cord of the gateway module into the computer, the gateway module will automatically connect to the hotspot of the mobile phone, and at the same time, connect the computer to the Internet, then open the upper computer on the computer to connect to the cloud, and receive the data detected by the terminal module after registration. As shown in Figure 20.

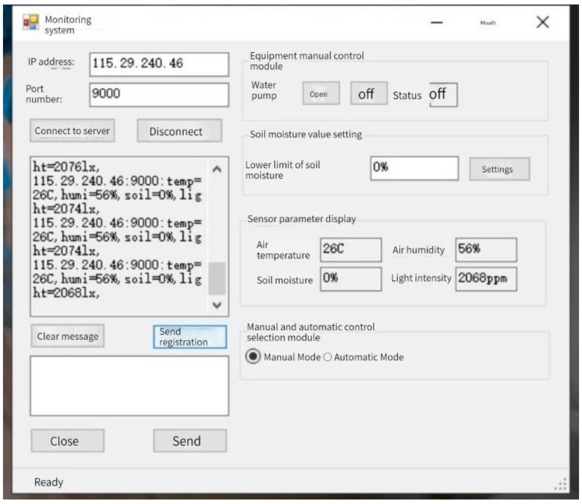

Fig.20 Upper computer number

RESULT ANALYSIS

In the process of system debugging and testing, we should do the following: First, check whether the design principle of the hardware circuit is correct, whether the desired results can be achieved in advance, whether the implementation mode is too complicated, and so on; Secondly, the model of the device should be calculated and selected. If the selection is not reasonable enough, the light one will weaken the efficiency of the system and fail to achieve the expected effect, or the heavy one will damage the device and cause the system to fail to run. Thirdly, after the hardware welding is finished, it is necessary to carefully check whether the welding of the circuit is accurate and whether there is open circuit or short circuit.

In the process of testing, the problem that the soil moisture field of the upper computer has no indicator occurred. After the test of changing the location, it was confirmed that it was only a long-term bare leakage of orchard-land, which lacked effective management. When the soil was dry, the system integration and program design all worked normally.

From the actual test results, this system can realize the remote monitoring of the environment and the control of the water pump by the Internet of Things in orchards, and meet the original design requirements.

V. CONCLUSION

In this paper, the research status, development trend and related technologies of the orchard Internet of Things system are analyzed thoroughly, and the open cloud platform and the emerging LoRa technology are selected to design and implement the orchard environment monitoring and irrigation Internet of Things system. The system has the advantages of high-cost performance, strong portability, long communication distance and low energy loss. The system is mainly divided into three parts: terminal node module, gateway module and host computer. This paper mainly studies the hardware circuit design and driver programming of terminal node module and gateway node module, focusing on the design and implementation process of orchard Internet of Things system based on LoRa.

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