Intelligent and Converged Networks
2023, 4(4): 342−354

ISSN 2708-6240
DOI: 10.23919/ICN.2023.0028

Development of the Internet of smart orchard Things based on multi-sensors and LoRa technology

Pingchuan Zhang*, Xu Chen, Shan Li, Caihong Zhang, and Yanjun Hu

Abstract: With the rapid growth of science and technology, the Internet of Things (IoT) technology has matured and attracted the attention of many researchers. The development of agricultural modernization leads to the gradual emergence of intelligent management gradually taking root in agricultural production. Among many technologies in the IoT technologies, low-power Wide Area Network (WAN) technology has the characteristics of reliable and stable transmission with long distance and low power consumption. This is very useful for data transmission in special environments, especially for orchards in mountainous areas. This paper proposed a new agricultural Internet of Things in orchard management based on multi-sensors, such as DHT11 for temperature/humidity and GY-30 for illumination, the Long Range (LoRa) technology for transmitting the collected data or control command between the terminal and data cloud center, etc. Setting a low-power IoT sensor network in the orchard can remotely measure the parameters in the orchard. LoRa WAN is used to transmit data to the central node. In order to reduce power consumption and cost, a single monitoring node selects two power supplies, a solar power supply and a power supply, and the power supply can be turned on remotely by users in special circumstances. Experiments in different environments in the peach orchard show that the monitoring system has enough reliability and accuracy, and is suitable for environmental monitoring in orchards in remote areas or areas with complex terrain.

Key words: Internet of Things; LoRa; smart orchard; sensor network; multi-sensors

1 Introduction

The spectrum of applications for Internet of Things (IoT) technology in production and life has grown as the technology has matured. Using the IoT technology to intelligently monitor and scientifically manage the agricultural environment has become an unavoidable trend and a critical component of current agricultural development[1]. Agricultural IoT technology is a new type of agriculture that combines the IoT with agricultural production, and is a new trend in global agricultural development[2, 3]. The purpose of an intelligent orchard is to keep track of environmental temperature and humidity, light intensity, soil humidity, and other factors that affect fruit tree growth, and to realize the monitoring, collection, transmission, and regulation of data.

The fruit business contributes significantly to economic growth. Today, people pay special attention to quality of life, and the demand for fruit is a remarkable manifestation. Each season, the market demand for fruit increases continuously, which requires fruit farmers to increase the production of orchards and expand the scale of orchards. At the same time, the problems are gradually exposed. According to the traditional management mode, large-scale orchards need a lot of labor and financial resources[4]. Only when all factors (meteorological factors, geographical factors, and human factors) are kept normal can we ensure the output and income of the orchard. However, if there is no early prevention and control of sudden weather information such as continuous rainstorms and

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• Pingchuan Zhang, Xu Chen, Shan Li, Caihong Zhang, and Yanjun Hu are with School of Computer Science and Technology, Henan Institute of Science and Technology, Xinxiang 453000, China. E-mail: zhangpingc@hist.edu.cn; 2928992341@qq.com; 2842567720@qq.com; 419002350@qq.com; 13622572@qq.com.

* To whom correspondence should be addressed.

Manuscript received: 2023-03-29; accepted: 2023-09-04

droughts and other meteorological factors, there is a great chance that the orchard will reduce production, increase the loss of fruit farmers, and fail to meet the demand for fruits[5].

China's agricultural IoT started later and developed slowly, and it has been in a backward state due to unbalanced industrial development and other factors. However, Chinese scientists have not stopped researching related aspects, and some of them are of outstanding significance, which can be recorded and have good enlightenment and leading role. In the late 1990s, Mao et al.[6] developed the first generation of automatic irrigation system on Intel 8031, the originator of 51 single chip microcomputer. This system not only realizes the function of regular irrigation, but also has the function of measuring soil moisture.

High-quality fruits have many benefits for people. Only by grasping the growing environment of fruits at any time can we cultivate high-quality fruits. For orchard managers, it is most effective to provide solutions with low cost, low maintenance, and low power consumption[7]. Based on Long Range (LoRa) technology, fog computing and other means, this paper uses advanced energy efficiency and IoT wireless sensor network to monitor the orchard environment, which puts forward a technical framework to meet these requirements and can improve the overall performance of the ecosystem[8, 9].

LoRa is a low power long-distance communication technology that belongs to the Low Power Wide Area Network (LPWAN)[10]. LoRa is widely used in medical treatment, environment, military affairs, precision agriculture, etc., and its application fields are constantly expanded by research and technological progress[11]. Meanwhile, orchard is a multi-parameter environment, and the main environmental parameters include air temperature and humidity, light illumination, soil temperature and humidity, and meteorological parameters. Therefore, the orchard IoT needs multi-class sensors to collect the above parameters as the data basis for realizing smart orchard.

Fog computing cloud services are being extended to the edge. They aim to improve low latency, mobility, network bandwidth, security, and privacy by bringing computation, communication, and storage closer to edge devices and end users[12]. Another layer, called the fog layer, is introduced between the fog computing cloud and terminal equipment. Terminal devices, also known as IoT nodes, are located at the endpoint layer. According to the definition, IoT nodes must be connected to the network, and they usually contain various sensors or actuators that interact with the physical world[13]. Specifically, in the fog computing of orchard environmental monitoring, IoT nodes can be connected to the gateway device of orchard management, which provides cloud services. Practice has proved that applying LoRa technology and fog computing to orchard monitoring system can effectively guide fruit farmers to manage orchards scientifically and improve yield and quality.

2 Material and method

The monitoring system of IoT introduced in this paper, although specially tested in peach garden, can be applied to any kind of fruit tree or nut tree park for monitoring application. Therefore, this section briefly introduces the monitoring factors needed by peach garden and the growing environment conditions of peach trees, which prepares for choosing which components to arrange later, and deeply studies all the sensors and methods mostly used for each hardware component. The overall structure of the orchard IoT-based surveillance system is shown in Fig. 1.

2.1 Peach garden environment

In this section, some details of peach garden are introduced. There are many factors that affect orchard growth including light intensity, temperature, humidity, soil temperature and humidity, soil pH, etc., which will affect the growth of fruit trees and fruit development. Among them, temperature is an extremely important energy factor for peach tree growth and development. It directly affects the photosynthesis, transpiration, and respiration of fruit trees. Peach tree is a warm-loving tree species, which prefers dry and cool climate during its development. Peach trees have a wide temperature adaptation range and strong cold tolerance, but winter

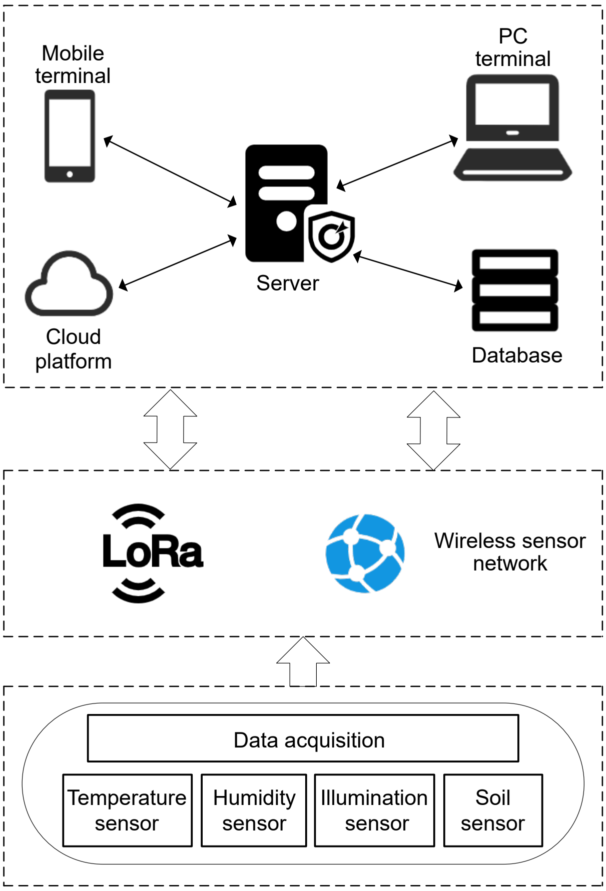

Fig. 1 Overall structure of the orchard monitoring system.

temperatures below −25–−23 ℃ are prone to freezing damage, Therefore, peach grows best in cool and mild climate, with 10–17 ℃ for southern varieties and 4–8 ℃ for northern varieties[14]. The cold tolerance of peach buds belongs to the weak category in temperate fruit trees. In winter, the tolerance of buds gradually increases with decreasing temperature during natural dormancy. The peach blossom buds can withstand the low temperature of −18–−16 ℃ during the dormancy period, and the freezing temperature of the buds after germination is from −1 ℃ to 2 ℃ during the discoloration period. After the natural dormancy of flower buds ends, the short-term high temperature suddenly leads to a significant decrease in tolerance to cold. When the temperature drops again, even if it does not reach the critical temperature for freezing, it is extremely vulnerable to freezing damage. The relationship between root growth and temperature is also very close. The soil temperature at the beginning of the growth of the roots of peach trees is 4–12 ℃, and the optimal soil temperature is 18 ℃[15]. The cold tolerance of peach root system is weak. It can resist −11–−10 ℃ in dormant period, but it can withstand low temperature above −9 ℃ in active period. After the root system of peach suffers from freezing damage, it will soon wither in spring. It will die after a few years of mild freezing, or in the year of severe freezing. Furthermore, peaches trees are more suitable for weakly acidic soil, and the pH of suitable soil for peach trees is 6.0–6.5[16]. Peaches trees grow well in slightly acidic to slightly alkaline soil. If planted in alkaline soil, yellow leaf disease is more likely to occur. When the salt content of the soil reaches more than 0.28%, it will hinder the growth of peach trees, and even lead to dead plants[17, 18]. Sensor technology, wireless communication technology, and other forms of technology are all being used in new ways, and other related technologies in the field of IoT to orchard management will greatly address the above problems. The first thing to study is the effort of labor and energy. At the same time, it also solves the problems of traditional environmental monitoring methods, such as difficult collection, low monitoring data efficiency, difficult data processing, and high maintenance and management costs.

2.2 Multi-sensor’s modules

Taking into account the automation of the orchard monitoring system and the fact that the environment in which the orchard is located is different from the greenhouse environment, where many factors are beyond human control and are affected by weather, such as rainstorm, light, wind erosion, etc., the equipment selection in the orchard should consider this influence and should pay attention to some corrosion-resistant devices or shells to protect the components[19]. When building a transmission network, because there are many branches in the orchard, it is not easy to conduct wiring by conventional wired transmission. If leaves and fruits fall off without timely treatment, the soil will become acidic, which has a great influence on wired transmission, not only shortening service life, but also increasing the frequency of device replacement frequency, thus increasing labor input and cost.

The orchard IoT system can transmit the collected environmental factors and meteorological factors such as temperature, air humidity, light intensity, soil humidity, and soil pH to the host computer through wireless network communication and display them to users[20].

Wireless communication can be carried out between the collecting node and 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. The information collected can cross the distance barrier and be collected from the upper computer in a lossless and real-time way.

At present, there are many types of Supply Chain Management (SCM) on the market, each with its own advantages and disadvantages in function. The STM32 series SCM is not only small and low in cost, but also has many I/O ports, comprehensive internal modules, and flexible and simple operation. In this design, STM32F103C8T6 is the primary control chip of the orchard IoT system.

2.2.1 Temperature and humidity sensor

Through the analysis and research of the existing sensors, this sensor is designed to monitor the internal and external parameters of peach trees in peach garden, i.e., the growth environment parameters of peach trees, and at the same time, it analyzes the most suitable method for supplying power to the intelligent sensing devices efficiently. Two temperature and humidity sensors are selected, because the environment and the temperature inside the trees, as well as the air and soil humidity have different effects on fruit trees. The DHT11 sensor composed of the Negative Temperature Coefficient (NTC) thermistor and humidity sensor is used to monitor atmospheric temperature and humidity. A sensor with an NTC thermistor and a hygrometer sensor are selected for internal temperature measurement and soil moisture monitoring, respectively. The above sensors are easy to arrange in orchards, and their power consumption is very low, thus achieving low power consumption. The working standard of the thermistor consists of a temperature sensitive resistor, which is inversely proportional to temperature. The hygrometer sensor detects the change of soil moisture according to the principle of electrical conductivity[21]. Figure 2 shows the physical drawing of DHT11. It is a sensor that combines temperature and humidity to measure. The circuit diagram is shown in Fig. 3. The description of DHT11 pin is shown in Table 1.

The two types of optical fiber temperature sensors are type 1 in which the optical fiber only serves to transmit light, and other sensitive elements must be installed on the end face of the optical fiber to form the new sensor's transmission sensor; and type 2 in which the sensitive function of the optical fiber itself is used to make the optical fiber measure the temperature, which belongs to the functional type, and the optical fiber not only serves to transmit light but also to measure the temperature. Figure 4 depicts the

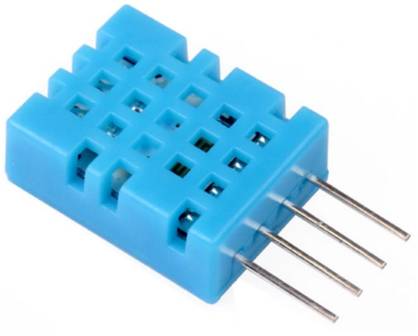

Fig. 2 Temperature and humidity sensor DHT11.

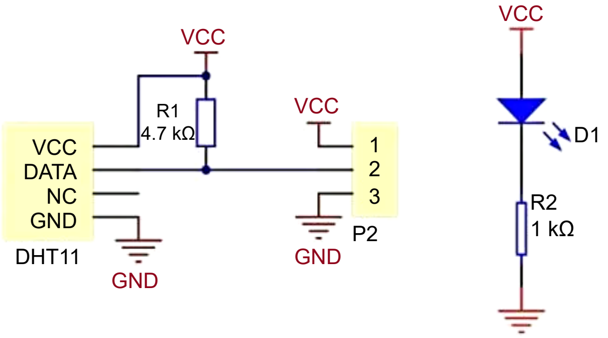

Fig. 3 Circuit diagram of DHT11.

Table 1 Description of DHT11 pin.

Pin	Name	Annotate
1	VCC	3.5–5 V direct current
2	DATA	Serial data, single bus
3	NC	Empty
4	GND	Ground, negative power supply

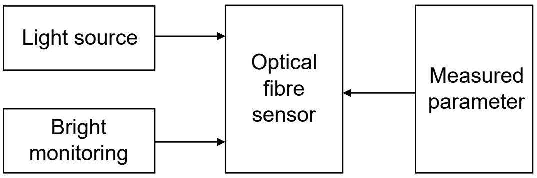

Fig. 4 Basic system structure.

fundamental system structure of an optical fiber temperature sensor.

Optical fiber sensors are classified as functional optical fiber sensors or non-functional optical fiber sensors based on their sensing principles. The transmission equation in an optical fiber is Eq. (1).

$$E = E_0\cos(wt+\varphi) \tag{1}$$

where E_0 is the initial amplitude, w is the optical frequency, φ is the initial phase of the incident light, and E_0, ω, and φ are the characteristic parameters of optical transmission in the optical fiber.

The power supply voltage for DHT11 is 3.5–5 V. For decoupling and filtering, a 100 nF capacitor can be inserted between the power supply pins (VCC, GND). To improve the signal's anti-interference capacity, a pull-up resistor of more than 5 kΩ is connected in parallel to the DATA pin. Wait 1 second after the sensor is turned on to get out of the unstable state, during which no instructions should be sent. Figure 5 shows how the circuit is commonly used.

2.2.2 Illumination sensor

In this design, GY-30 is selected as the illumination sensor module, and the internal integration of the module utilizes BH1750FVI illumination sensor. The internal photosensitive diode of BH1750 is responsible for light sensitivity. The operational amplifier is used to obtain analog value for weak current change, and the digital signal is obtained through the AD converter. The internal crystal oscillator is also selected to provide the reference frequency. The description diagram, physical diagram, and circuit diagram of the GY-30 module are shown in Figs. 6–8.

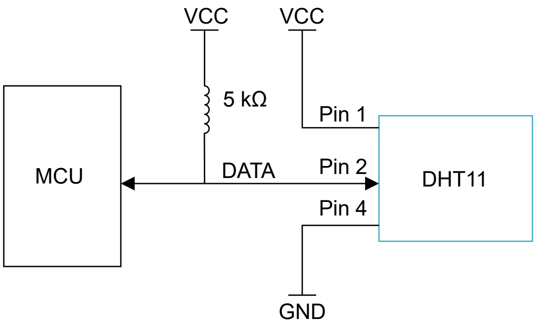

Fig. 5 DHT11 in the circuit.

The photodiode, operational amplifier, ADC acquisition, crystal oscillator, and other components of BH1750 are depicted in Fig. 9. The photovoltaic effect converts the input optical signal into an electrical signal, which is amplified by the operational amplifier circuit, collected by the ADC, and then converted into a 16-bit binary number by the logic circuit and stored in the internal register. Note that the stronger the light entering the optical window, the larger the photocurrent, the larger the voltage, so the magnitude

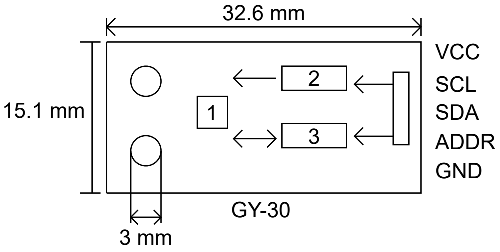

Fig. 6 GY-30 module description diagram.

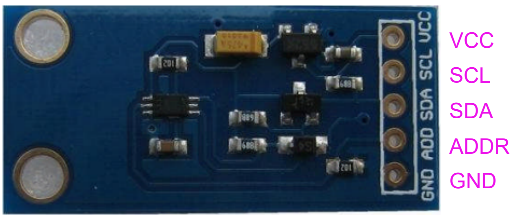

Fig. 7 GY-30 module.

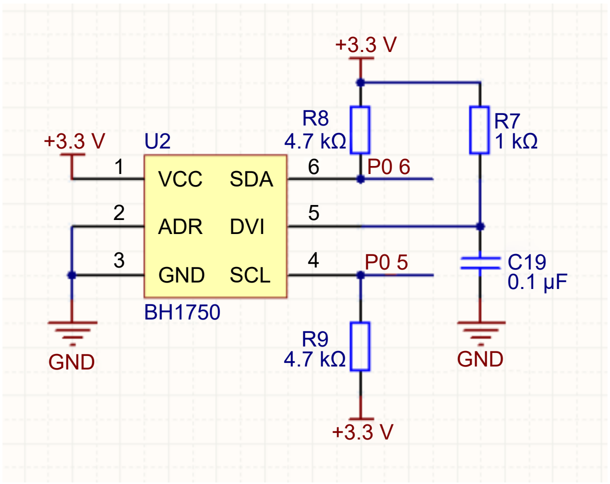

Fig. 8 Circuit diagram of BH1750.

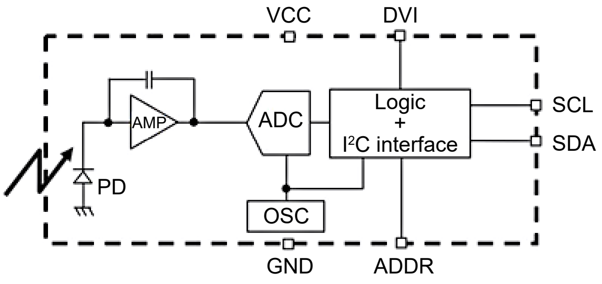

Fig. 9 BH1750 internal structure.

of illumination can be judged by the voltage instead of the photocurrent, but from BH1750, the clock and data lines are led out. The Microcontroller Unit (MCU) may use the Inter-Integrated Circuit (I^2C) protocol to connect with the BH1750 module, select the BH1750's working mode, and collect the BH1750 register's illumination data. The definitions of each pin can be found in Table 2.

In the design, it is necessary to ensure the timing relationship between DVI and VCC. Generally, there are two schemes that can be realized:

(1) MCU controls DVI signal, as shown in Fig. 10.

(2) Implementation of an embedded RC circuit between VCC and DVI, as shown in Fig. 11.

2.2.3 Soil moisture sensor

The soil moisture sensor is made up of two parts. One is the waterproof probe that has been treated with waterproof and the other part is the probe that has been treated with rust prevention probe. It can be widely laid in orchard soil, and it can measure the moisture and humidity of shallow soil and deep soil. The soil moisture sensor is shown in Fig. 12, and the circuit diagram is shown in Fig. 13.

Table 2 Definition of each pin.

Pin	Name	Annotate
1	VCC	Power supply pin
2	ADDR	ADDR=H (⩾0.7×VCC)，slave address is “1 011 100”; ADDR=L (⩽0.3×VCC)，slave address is “0 100 011”. Circuit structure is 3 state buffers
3	GND	Ground
4	SDA	I^2C serial data interface
5	DVI	I^2C trunk reference level of trunk；Internal register asynchronous reset：DVI⩽0.4 V, at least 1 μs. BH1750FVI is pulled down by 150 kΩ, while DVI=L
6	SCL	I^2C Serial clock interface

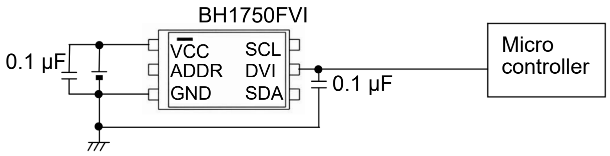

Fig. 10 MCU controlling DVI signal.

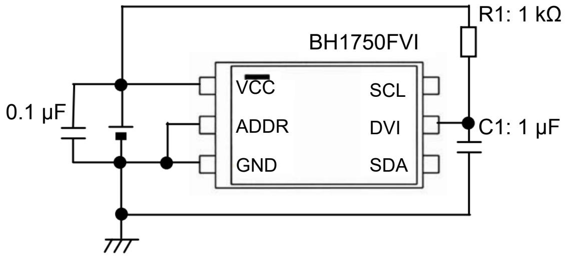

Fig. 11 RC circuit between VCC and DVI.

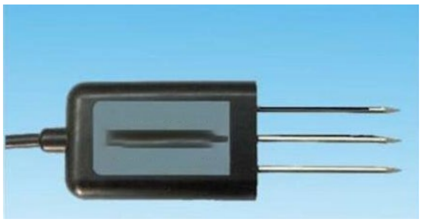

Fig. 12 Soil moisture sensor

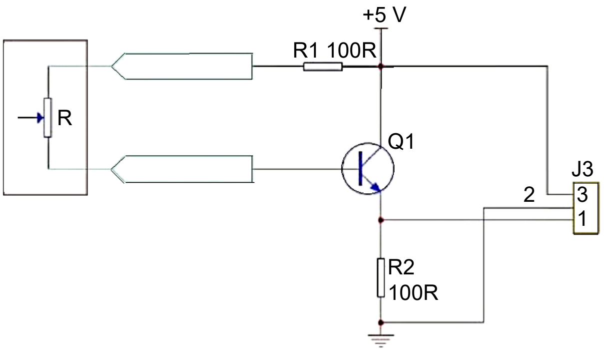

Fig. 13 Circuit diagram of the soil moisture sensor.

Through the work and data monitoring of soil temperature and humidity sensors in the surface and deep layers of soil, we can obtain the latest soil temperature and humidity data in real time, which is convenient for us to monitor the soil environment in orchards, so that orchard managers can observe in time, improve the soil quality in orchards, and increase the output. At this time, there is a variety of soil moisture measuring methods available both at home and abroad, as well as a variety of soil moisture sensors. Soil moisture measuring methods includes Time Domain Reflection (TDR), gypsum method, infrared remote sensing method, Frequency Domain Reflection/ Frequency Domain method (FDR/FD method), titration method, capacitance method, resistance method, microwave method, neutron method, Karl Fischer method, nuclear magnetic resonance method, and so on.

2.3 LoRa technology

His design adopts from LoRa point-to-point communication[22, 23]. For orchard production, a low-power, low-cost long-distance transmission scheme is the key consideration. It is of great significance to arrange all kinds of information collection sensors in the orchard to increase output and reduce resource consumption. These sensors will upload data regularly and send the data wirelessly to the remote user center to realize remote real-time data acquisition.

There are numerous new network protocols and gadgets, according to the information. Many of them, such as Wi-Fi, Bluetooth, ZigBee, and 2G/3G/4G cellular networks, are commonly used in daily life, but there are some new emerging network alternatives, such as Narrow Band (NB)-IoT, LoRa, and Sigfox. The best communication choices are chosen based on the scope of the application, the data requirements, the safety, and the battery life. The primary communication protocols in the IoT technology are summarized in Table 3.

Large-scale planting in orchards, due to the lush branches and leaves of fruit trees, has a certain influence on signal transmission, and it is extremely cumbersome and difficult to pull the power lines. Therefore, when selecting communication modules, the characteristics of low power consumption and long-distance transmission should be met at the same time[24], i.e., LPWAN needs to be built. The main purpose of LPWAN is the long-distance communication between power supply devices through low bit rate transmission. Choosing LPWAN can reduce labor investment, equipment investment, line construction investment, and power consumption, and meet the environmental protection requirements of low cost and low power consumption.

Table 3 Main communication protocols in IoT technology.

	Frequency (MHz)	Scope of action (m)	Transmission speed (bit/s)
Bluetooth	2400	0.5–100	1×10^6
ZigBee	2400	10–100	2.50×10^5
Sigfox	868	30 000–50 000	100 or 600
LoRa	433/868	15 000–20 000	300–50 000

The LoRa technology is a superior option for monitoring the orchard environment. LoRa is a physical layer technology that uses commercial proprietary spread spectrum technology to modulate industries below gigahertz and provides two-way communication via special linear frequency modulation spread spectrum technology that expands narrowband input signals to a wider channel bandwidth[25]. The resulting signal has noise-like qualities, making detection and blocking more challenging. With a maximum payload length of 256 bytes, the processing gain can improve the capacity to resist interference and noise while also providing an adaptable data rate function. LoRa’s communication frequencies are primarily within unlicensed Industrial, Scientific, and Medical (ISM) radio frequency band, while it can work at any frequency below 1 GHz[26]. This is the main factor behind low-cost worldwide deployment and interoperability.

The modernization process of orchards makes modern orchards have the characteristics of large area, complex geographical factors, long fruit cultivation period, etc., which results in the requirements of orchard IoT, such as many detection factors, long monitoring period, deployment of monitoring points, and so on. 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[27, 28].

The ATK-LORA-01 wireless serial port module selected in this system is a LoRa wireless serial port module introduced by ALIENTEK. It has the characteristics of small size, low power consumption, high performance, and long communication distance. The physical drawing of ATK-LORA-01 is shown in Fig. 14.

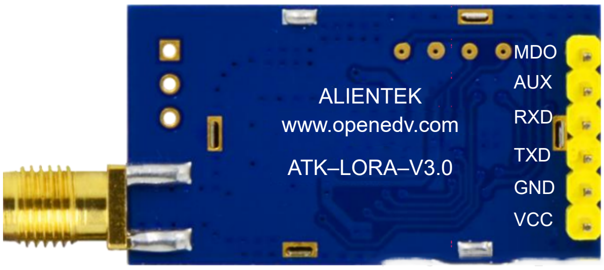

Fig. 14 ATK-LORA-01 wireless serial port module.

Using simplified interface for connecting to this module, all functions can be completed with only 4 I/O, and it is simple and convenient to use 1×6 rows of needles to connect with the outside.

When the module is electrically connected to MCU/ARM equipment, attention should be paid:

(1) The wireless serial port module is TTL level (high level >2.4 V; low level <0.4 V).

(2) The pin level of the module is 3.3 V, and the level conversion adaptation is needed to communicate with the 5 V MCU.

(3) The MD0 and AUX pins are low when suspended.

The Received Signal Strength Indicate (RSSI) algorithm can divided into two categories, propagation model modeling method and fingerprint database matching method. Here the RSSI propagation model is used.

RSSI propagation model estimation method first calculates the signal propagation loss by using the received signal strength, then converts the transmission loss into distance by using theoretical and empirical models, and then calculates the location of nodes.

The traditional RSSI estimation method usually carries out many measurement experiments on the positioning environment, obtains the relationship between the signal propagation distance and the path loss in this environment, and establishes the “distance-loss” model, which is generally as follows:

$$P = P_{r0} + 10n\lg\left(\frac{d}{d_0}\right) + \xi \qquad (2)$$

where d_0 is the distance between the reference point and the signal source, P_{r0} is the RSSI of the received signal source when the distance is d_0, d is the real distance, $\xi \sim N(0, \delta^2)$ is the masking factor, P is the RSSI of the signal source received by the point under test, and n is path loss coefficient. When the path loss system is known, the propagation distance of the signal can be calculated according to the received signal strength.

The RSSI positioning algorithm is based on distance[29], and the accuracy of distance estimation directly affects the accuracy of the final positioning. After estimating the distance between the terminal equipment and the three anchor nodes, the location of the target can be estimated by the trilateral positioning model shown in Fig. 15. There is always an error in the distance estimation value obtained by RSSI, so that the three circles in Fig. 15 do not intersect at one point, but form an area.

2.4 Software architecture

The overall functional flow framework is shown in Fig. 16.

This system consists of four parts, information collection, information transmission, PC interaction, and downlink command execution, and these four parts can be classified into terminal node, gateway terminal, and PC terminal. Information transmission is an essential carrier for all other functions. If the information transmission function is compared to the body, then the information collection function and the down command execution are two hands, one for getting data and the other for doing things. Simply put, it is one body with two wings, and the upper computer is the brain.

In this design, the terminal module is divided into two parts. The first part is to collect the environmental information from the orchards at regular intervals

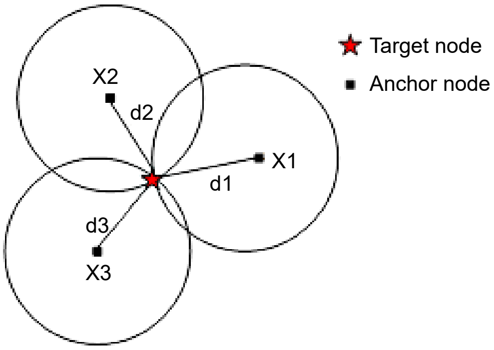

Fig. 15 Trilateral positioning model.

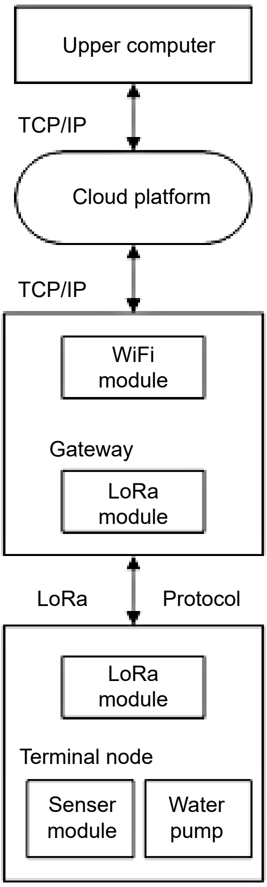

Fig. 16 Overall functional flow chart.

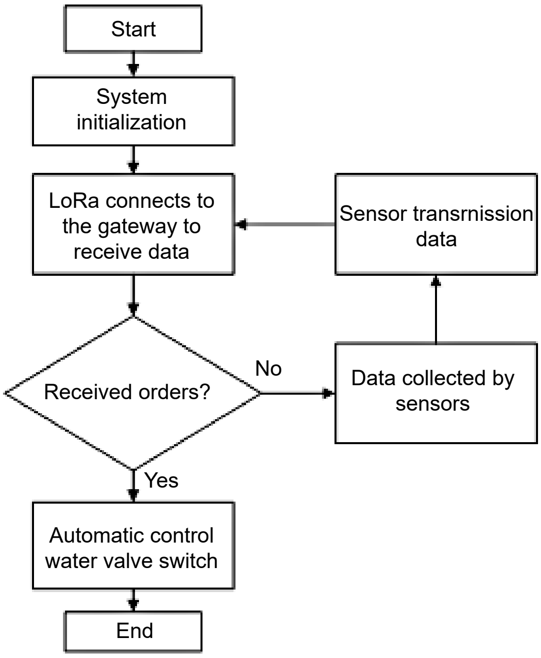

Fig. 17 Workflow of the whole terminal node.

through sensors. The sensor relates to the acquisition module through the I/O interface, and is mainly responsible for monitoring the environment of the park within a set time (500 ms) and collecting primary data.

The working flow of the entire terminal node is shown in Fig. 17.

On the other hand, the serial port 2 (USART2) of the STM32 microprocessor is connected to the LoRa module to receive the downlink command. If the command from the upper computer is received, the judgment is made by the IF statement to open/close the water pump relay.

2.5 Decision on irrigation

The main purpose of irrigation decision is to calculate the irrigation time, i.e., the time of each irrigation activity[30]. In each period, intelligent irrigation calculates the irrigation time for each region according to the measured soil humidity and temperature.

Fuzzy Logic Control (FLC) is an intelligent algorithm for dealing with uncertain information. FLC mainly consists of four parts, fuzzification interface, knowledge base, jamming engine, and defuzzification interface. The fuzzy interface converts the input quantity into a fuzzy set. The knowledge base is the main system of FSC, which stores fuzzy rules. In the interference engine, fuzzy rules are evaluated according to the input variables of the membership function. The defuzzification interface is to forward the fuzzy set to the output.

The system model of Fuzzy logic Input-based Decision Algorithm for Irrigation Time (FI-DAIT) algorithm is shown in Fig. 18. The change rate of soil temperature and soil humidity is taken as the input of fuzzy logic controller, and the output is irrigation time.

First, take the soil moisture decrease rate $\Delta M(k)$ as the input of the fuzzy logic system, and its definition is shown in Eq. (3).

$$\Delta M(k) = M(k) - M(k-1) \tag{3}$$

where $M(k)$ is the current soil humidity, $M(k-1)$ is the soil humidity at the last moment, $\Delta t = t(k) - t(k-1)$ represents the time interval between two consecutive sampling values. Another input is the soil temperature $T(k)$. $\Delta M(k)$ and $T(k)$ are two inputs to the system inputs, and the output $P(k)$ represents the irrigation

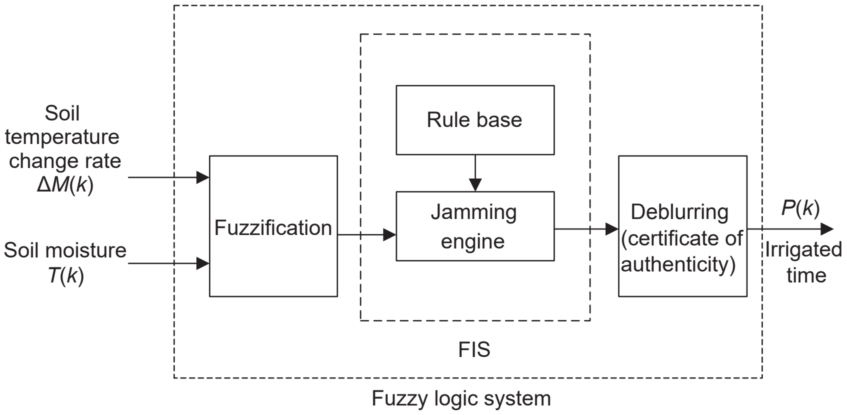

Fig. 18 FI-DAIT algorithm model based on FLC.

time.

By inputting the acquired data parameters into the model, we can get the irrigation time required by the soil in this area and set the value of $P(k)$ to judge, and the system will need to complete irrigation at the corresponding time. The arrangement of automatic irrigation pipes is shown in Fig. 19.

The arrangement of water pipes in the whole orchard is linearly distributed, which not only saves the cost, but also allows peach trees to be irrigated scientifically.

3 Result and discussion

Through monitoring and summarizing the data, the reliability of LoRa's network transmission is tested, and the results are shown in Table 4.

After the orchard IoT system's software and hardware have been configured, it is placed in the orchard IoT model for actual testing. As indicated in Table 5, three time points of morning, noon, and night are chosen for this study, and three sets of temperature and humidity data are chosen for each time point. The temperature and humidity data collected by the sensors are essentially the same as those measured manually, according to the experimental data, and the system fits the predicted design requirements.

Fig. 19 Layout of automatic irrigation pipeline.

Table 4 Test results of network communication reliability.

Node spacing (m)	Sending data packet	Receiving data packet	Packet loss rate (%)
10	500	500	0
30	500	500	0
50	500	500	0
80	500	498	0.4
100	500	496	0.8
110	500	491	1.8
120	500	478	4.4
130	500	436	12.8

Table 5 Experimental data of orchard.

Time	Temperature (℃)		Humidity (%RH)	
	Sensor	Manual	Sensor	Manual
8:10	18.36	18.3	81	80
8:20	18.69	18.7	79	79
8:30	18.55	18.6	79	80
12:10	24.00	24.1	57	57
12:20	24.05	24.4	59	60
12:30	24.66	24.2	59	60
20:10	20.85	21.3	90	91
20:20	20.36	20.3	91	90
20:30	20.65	20.6	92	92

Make the measured data change into a line chart as shown in Fig. 20.

Through image analysis, it is concluded that the temperature change of the orchard soil is relatively stable in one day, and regular irrigation is needed to maintain sufficient soil moisture, so that peach trees can grow normally.

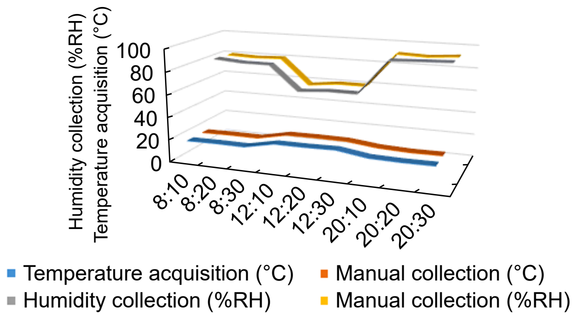

Fig. 20 Chart of temperature and humidity change.

In the process of system debugging and testing, the following considerations are considered. First, it should be checked whether the design principle of the hardware circuit is correct, whether the desired results can be achieved in advance, and whether the implementation method is too complicated. Second, the model of the device should be calculated and selected. If selection is not reasonable enough, it will weaken the efficacy of the system and fail to achieve the expected effect, or it will damage the device and cause the system to fail to operate. Third, after the hardware welding is finished, it is necessary to carefully check whether the circuit welding is accurate and whether there is any open circuit or short circuit.

During the test, there is a problem that the soil moisture field of the upper computer does not have an indication. After the test of changing the location, it is confirmed that the orchard is exposed for a long time, lacking effective management, and the system integration and program design are working normally due to the drought of the soil.

According to the actual test results, this system can realize the task of remote environment monitoring and water pump controlling in orchard IoT, which meets the original design requirements.

4 Conclusion

In this document, we discuss the use of IoT technology in orchard monitoring, which includes data collection of environmental temperature, humidity, soil temperature, and humidity, and orchard irrigation decisions. The main communication protocol of the system is LoRa technology, which has characteristics of long range, low power consumption, and reliable transmission. It is used to continuously monitor the temperature readings of different spots in the needed area. Users can see parameters related to network operation in addition to temperature, monitor the growth environment parameters of peach garden by intelligent equipment and the surrounding environment by video monitoring equipment, and make scientific decisions in orchard irrigation. On the one hand, it can reduce manual management and cost; on the other hand, it can improve the yield and fruit quality through scientific irrigation and planting.

Acknowledgment

This work was supported by the Science and Technology Department of Henan Province (Nos. 212102310553 and 222102210116), and Ministry of Education Industry-University Cooperation Collaborative Education Projects (HENAN CHENYUNYANG Electronics Technology Co., Ltd. (No. 221001221014436) and WUHAN MaiSiWei (No. 202101346001)).

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Pingchuan Zhang received the BS degree from Chengdu University of Technology, China in 1991, the MS degree in computer software and theory from University of Zhengzhou, China in 2005, and the PhD degree in microelectronics and solid physics from Huazhong University of Science and Technology, China in 2012. Since 2013, he has been an associate professor at Henan Institute of Science and Technology. In spring 2023, he was appointed as a distinguished professor teaching in IoT, and master's supervisor of agriculture engineering and information technology. He is the author of 12 books, more than 40 articles, and more than 10 inventions. His research interests include IoT and physical agriculture, intelligent systems, and sensing technology.

Xu Chen received the bachelor degree from Henan Institute of Science and Technology, China in 2021. He is now pursuing the master degree of agricultural engineering and information technology at Henan Institute of Science and Technology, China. His research interests are computer vision and agricultural Internet of Things.

Shan Li obtained the bachelor degree in Internet of Things engineering and technology from Henan University of Science and Technology, China in 2022. She is currently pursuing the master degree in agricultural engineering and information technology at Henan Institute of Science and Technology, China. Her research focuses on artificial intelligence and agricultural Internet of Things.

Caihong Zhang received the bachelor degree in computer science and technology from Zhengzhou Aviation Industry Management College, China, in 2006. She is now studying in Henan Institute of Science and Technology with a master's degree in agricultural engineering and information technology. Her research interests are computer vision, agriculture, and Internet of Things.

Yanjun Hu received the bachelor degree in computer information management from Xi'an University of Electronic Science and Technology, China in 2005. He is now studying in Henan Institute of Science and Technology with a master's degree in agricultural engineering and information technology. His research interests are computer vision, agriculture, and Internet of Things.