Journal of Studies in Science and Engineering

EngiScience Publisher

Research Article

Design and Application of Agricultural Integrated Management System Based on TLINK

Lijun Guo [1], **Ihsan Mohd Yassin** [2], **Zairi Ismael Rizman** [3,*]

[1] School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, Shah Alam, 40450, Malaysia

[2] Microwave Research Institute, School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, Shah Alam, 40450, Malaysia

*Corresponding Author: Zairi Ismael Rizman, E-mail: zairi576@uitm.edu.my

Article Info

Article History
Received Aug 26, 2024
Revised Dec 12, 2024
Accepted Dec 20, 2024

Keywords
TLINK Cloud platform
ESP8266
Automation
Agricultural Internet of Things
Remote control

Abstract

With the continuous advancement of science and technology, the era of the Internet of Everything has arrived. Agricultural management is becoming more and more intelligent and refined. Agricultural Internet of Things technology is vital in data collection, transmission, user management, etc. To achieve a highly integrated and low-cost smart agriculture with data display. This paper designs an intelligent agricultural management system based on low-cost ESP8266 WIFI Internet of Things technology, aiming to transform traditional agricultural management into a smart, remote, and data-user collaborative mode. The system integrates sensor nodes such as temperature, humidity, light, and carbon dioxide to replace traditional industrial sensors for real-time agricultural environmental data collection, which can realise the automation of irrigation, ventilation, temperature control, lighting, etc. It can start the ecological control system through local voice control. WIFI data transmission, data management through the TLINK cloud platform, PC or mobile phone APP, online remote data viewing and control at any time for agricultural management. The experimental results show that the system has good stability, reliability, high integration, strong environmental adaptability, accurate data, and less packet loss. It dramatically reduces the cost of intelligent agricultural management and construction difficulty, bringing users higher economic benefits.

1. Introduction

Against the backdrop of the rapid expansion of the global technology market, smart agriculture with the Internet of Things (IoT) at its core is expected to become the foundation of future agricultural practices. Table 1 highlights smart agriculture's market size and growth trends in various fields. The rapidly growing market space has promoted the development of intelligent agriculture. Innovative agriculture development is closely related to critical processes such as data collection, transmission, and analysis [1]. High-precision sensors are essential for accurate data collection, while robust IoT systems are essential for efficient data transmission [2]. Practical data analysis and management requires a powerful data management platform. By designing smart agricultural information collection and management systems that meet these requirements, outstanding problems in the implementation of smart agricultural deployment, such as highpower consumption, complex terrain, high cost, and difficulty in networking, can be solved, and the ability to accurately manage the agricultural environment can be improved [1-3].

Table 1. Market size growth trends in various fields of smart agriculture

Field	Market Size or Number of Devices	Growth Forecast	Applications and Uses	Sources
Global Smart Agriculture Market	$1.38 billion (2021)	It is expected to reach $22 billion by 2026, with a CAGR of 9.9%	Overall market growth is driven by IoT devices, drones, precision agriculture technologies , and agricultural robots	Markets and Markets [3]
Agricultural IoT Devices	75 million devices (2020)	Expected to grow to 225 million devices by 2025	Including soil sensors, weather stations, and livestock monitors to improve the intelligence and efficiency of agricultural production	Statista [4]
Agricultural drones	$1.2 billion (2020)	It is expected to reach $5.6 billion by 2025, with a CAGR of 34.5	Used for crop monitoring, soil analysis, and pesticide spraying to improve production accuracy and efficiency	Research and Markets [5]
Precision Agriculture Technology	About 30% of U.S. farmland is used	_____	GPS-guided precision seeding and fertilisation, soil sampling, and crop monitoring to optimise growing conditions and yields	United States Department of Agriculture (USDA) [6]
Smart irrigation system	$1 billion (2021)	It is expected to reach $1.7 billion by 2026, with a CAGR of 10.3%	Use sensors and automation to adjust irrigation based on soil moisture and weather automatically, improving water use efficiency and crop yields	Research and Markets [7]
Agricultural robots	$4.7 billion (2020)	It is expected to reach $20.4 billion by 2027, with a CAGR of 23.1%	Used for planting, harvesting, weeding and monitoring, reducing the need for manual labour and improving agricultural production efficiency	Allied Market Research [8]

Table 2 shows the three main stages of developing smart agricultural Internet of Things. The initial stage is basic monitoring and data collection; no data management platform exists. The intermediate stage focuses on developing key technologies for short-distance communication, and some data management platforms begin to appear. Data can be viewed using mobile terminals, but no data analysis exists. At the current stage, by applying wireless sensor networks such as ZigBee, LoRa, NB-IoT, Bluetooth, and WIFI to the agricultural Internet of Things, there are related smart agriculture and animal husbandries, such as drones for monitoring and pesticide spraying, smart irrigation systems for improving water use efficiency, smart greenhouse control, vertical agricultural management that maximises urban space, agricultural robots for automated tasks, and smart animal husbandry that optimises livestock management through wearable technology and monitoring systems. These related technology applications are inseparable from data management platforms.

Table 2. The three main stages of the development of smart agricultural Internet of Things

Stage	**Characteristics**	**Technologies**
Initial Stage	Deploy simple sensors such as temperature, humidity, and soil moisture sensors for single data collection, and use short-range ZigBee and Bluetooth communications for data collection and concept verification systems.	Basic sensors, short-range protocols (Zigbee, Bluetooth, SMS)
Intermediate Stage	After deploying data collection sensors for data collection and remote data transmission via WIFI and cellular networks, a data management platform emerges, where farmers can view and analyse data through mobile applications or web dashboards and perform automatic control of irrigation and lighting.	WIFI, cellular networks, mobile apps, and web dashboards
Current Stage	The data collection, transmission, and management platform can display real-time data, predict and analyse the agricultural environment through stored historical data, and achieve overall management through data interoperability.	The data management IoT platform fully realises comprehensive data management, environmental prediction, and fully automatic management.

According to a 2015 market study, more than 300 IoT platforms were identified that provide support for IoT to some extent, while more recent estimates indicate that this number exceeds 450 [9-11]. Table 3 compares and analyses the current mainstream open-source IoT platforms with the TLINK IoT platform. By applying these platforms to smart agriculture, the management of smart agricultural terminals becomes more convenient, greatly improving the convenience of fully automated management of agricultural environments. The cloud-based smart agricultural management system is a full-process management system that combines technology with practical applications [12]. It lays a solid foundation for future access to big data and artificial intelligence to achieve agricultural prediction analysis and decision-making. These stages have jointly promoted the transformation of smart agriculture to more efficient, data-driven, and sustainable agricultural practices. Through comparative analysis, we can see that TLINK, as an open-source platform, is adaptable to data processing methods, data visualisation, communication protocols, etc., and is very friendly to developers.

Table 3. Comparison of current mainstream open-source IoT platforms

Platform	Comm. Protocols	Data Processing	Data Visualisation	Integration	Installation Procedure	Documentation
Eclipse Kapua [13]	MQTT	No built-in processing capabilities	No built-in visualisation capabilities	REST APIs, WebSockets, NoSQL persistent storage	Demo installation using dockers; installation from sources using Maven	GitHub repository doc- augmentation, platform website
FIWARE [14]	HTTP, MQTT, LoRa WAN, OPC-UA	Generic Enablers	Different Generic Enablers in dashboards	LWM2M over CoaP, JSON or Ultralight over HTTP/MQTT or OPC-UA, API	Demo installation using dockers; installation from sources	GitHub repository documentation, platform website, dedicated websites for generic enablers
Kaa 0.X [15]	HTTP, MQTT, XMPP, CoAP	No built-in processing capabilities	No built-in visualisation capabilities	Oracle, Apache and MongoDB databases, AWS	Sandbo is ready for execution in a prepackaged virtual machine; local installation using binary packages; installation from sources using Maven	GitHub repository documentation, platform website
Lelylan [16]	HTTP, MQTT, APIs	No built-in processing capabilities	No built-in processing capabilities	Webhooks, WebSocket's	Installation using docker containers; installation from sources	GitHub repository documentation
Macchina.io EDGE [17]	MQTT	No built-in processing capabilities	Web applications	REST API, HTTP	Installation from sources using make	GitHub repository documentation, platform website
OpenMTC [18]	HTTP, HTTPS, MQTT	Dashboard	No built-in processing capabilities	REST API, JSON serialisation	Installation from sources using docker containers	Platform website
TLINK.io [19]	HTTP, MQTT, APIs, CoAP, M ODBUS TCP, UDP	External, through Kafka streams	Dashboards and widgets, Web applications	HTTP/MQTT or REST API or WebSockets or JSON serialisation or WebSockets, NoSQL persistent storage	Installation from sources	platform website

Research has found three major problems facing the development of smart agricultural technology. First, smart agricultural systems are usually composed of multiple devices and platforms, which may lead to poor communication and require standardised protocols to ensure seamless data exchange and interoperability. Second, managing and processing large amounts of data becomes difficult as these systems develop, especially for large farms with more complex sensor acquisition requirements. Data management aspects such as real-time data updates, comprehensive data display, and historical data storage are very important, and achieving scalability without sacrificing performance is crucial. The current data management system has problems such as untimely or slow data updates, insufficient data display, and inability to provide historical data analysis, which cannot help users accurately analyse the agricultural environment. Therefore, a good data management platform is very necessary. Third, IoT devices and sensors are often deployed in remote areas with limited power, so low-power design is required to minimise maintenance requirements.

To solve the above problems, the system integrates ESP8266 and STM32 with separate monolithic sensors to adopt low-power data communication to replace high-power traditional industrial sensors to form sensor nodes. The highly integrated data acquisition module simplifies the layout of data acquisition in the agricultural environment. Each data acquisition module is powered separately, and each integrated data acquisition node independently completes the collection of environmental information such as temperature, humidity, light, and carbon dioxide in the agricultural environment. However, only one power supply port is needed, unlike industrial sensors, where one sensor requires a power supply terminal. Collecting information about the agricultural environment requires countless power supply terminals to connect each industrial sensor, which greatly wastes electricity. In addition, the communication protocols of each sensor are different, and each sensor needs to be arranged in a different position, which makes the layout design process of agricultural environment data acquisition sensors very difficult. For this design system to arrange large-scale agricultural environment data collection, only a few randomly distributed sensor nodes are needed to realise data collection and processing. Power consumption is reduced by combining the sleep mode, and multiple sensor data (such as temperature, humidity, carbon dioxide concentration, soil moisture, and pH value) can be collected and transmitted through a single WIFI node. As shown in Figure 1, the design of the sensor acquisition node integrates each single sensor circuit with ESP8266 to replace the industrial sensor node, greatly reducing power consumption and the difficulty of agricultural environment sensor layout and saving the cost of smart agriculture layout.

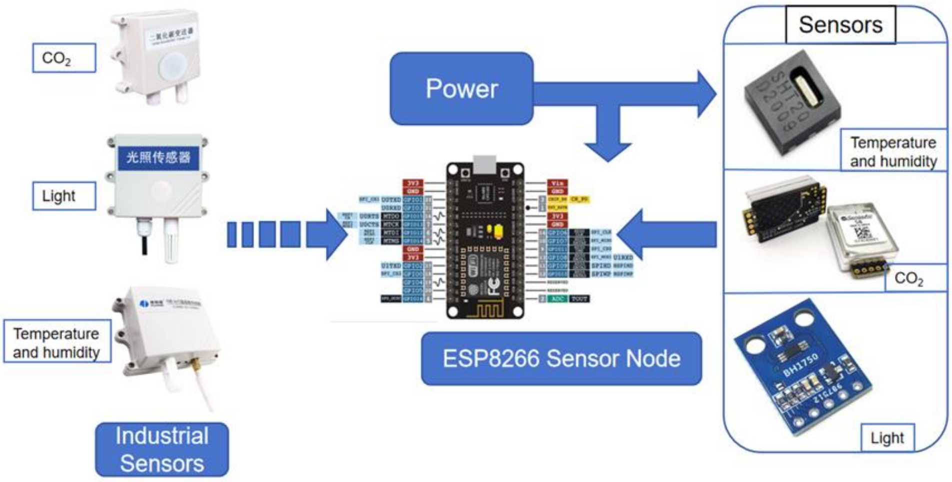


Figure 1. ESP8266 sensor node design replaces industrial sensor node

In addition, the TLINK IoT cloud platform performs one-stop agricultural data management from the data end to the user end, supporting device management, data storage, and display across PC, mobile and Web platforms [20]. The high degree of integration of the data management platform can simplify data management, and cross-device access only requires one account to log in to each data display and analysis platform. From the above solutions, the design system can solve the current smart agricultural technology for multi-device, multi-platform communication problems, scalability of data management and processing, and low-power design requirements of IoT devices in remote areas.

As shown in Figure 2, it is a block diagram of the Internet of Things Agricultural Integrated Management System [21]. It can be seen from the figure that the system integration of this design is high [22]. The sensor acquisition node design system covers various sensors used to collect agricultural environmental information. It uses ESP8266WIFI as a communication link, improving data transmission efficiency and reducing construction costs. After adding nodes, it can be easily and quickly connected to the network, and the operation is simple. When building the Internet of Things, it is only necessary to increase the number of data acquisition nodes for large-scale agricultural environments. In addition, the environmental control system is deployed in a greenhouse environment, and the various control systems (irrigation system, ventilation system, temperature control system, and lighting system) are integrated and controlled through the relay module. The user end uses TLINK to integrate the PC and mobile phone end, view agricultural environmental information data in real-time, and fully automate the agricultural environment through data analysis.

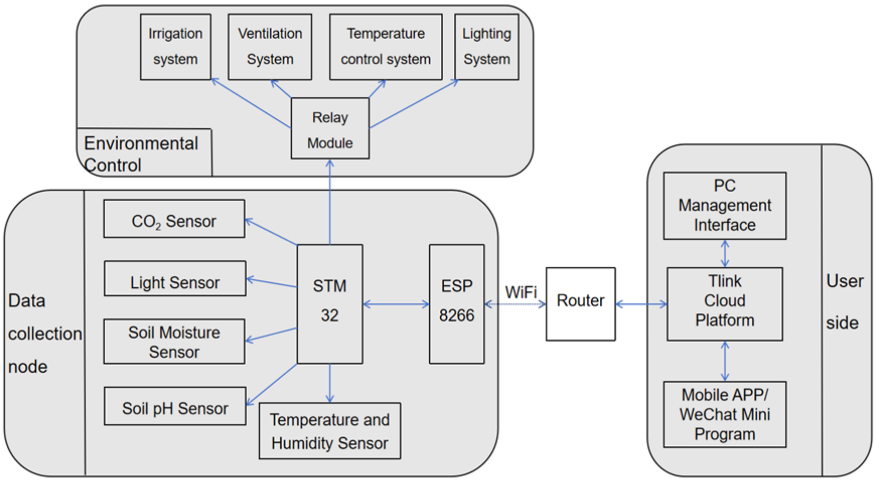


Figure 2. Block diagram of agricultural integrated management system based on the Internet of Things

2. Literature Review

Communication is an indispensable part of data transmission and a bridge between sensor nodes and user terminals. In the literature review, from some recent literature, we will analyse the differences between the application of ESP8266 WIFI in smart agriculture and other communication methods (such as ZigBee, LoRa and other communication technologies). However, for the entire smart agricultural management, the storage, management and display of collected data are indispensable components of the entire user terminal. Through relevant literature research, the advantages and disadvantages of various IoT platforms and the advantages and disadvantages of the TLINK platform are compared, mainly from the following three aspects. First, the IoT platform should be able to display the collected data in real-time and store it historically accurately. It also allows users to view and analyse the agricultural environment anytime. Secondly, when the information on the collected environment is abnormal, the agricultural environment can be automatically adjusted at any time, and the user can be reminded of the abnormal data to manage the agricultural environment status in time. The third aspect is that the mobile phone APP and the computer PC data can be synchronised at any time, which are all essential for the agricultural environment management system.

2.1. Application of LoRa Communication Technology in Smart Agriculture

Ali et al. [23] used LoRa (long-range) communication technology to allow users to remotely control irrigation pumps from 1 km to over 10 km without additional communication towers or associated costs. LoRa-based devices are compact and affordable, allowing remote control and monitoring without large infrastructure investments. Given its low communication cost, LoRa was selected to design and manufacture a remote-control device that manages irrigation pump operations through a mobile application. The technology facilitates smart pump management, improves power efficiency, and simplifies agricultural production.

Dinesh et al. [24] discussed the development of a smart farming system that monitors and controls the agricultural environment using LoRa wireless technology. The system uses various sensors to collect soil moisture, air composition, rainfall, humidity, and temperature data, which are transmitted to a receiving unit via a LoRa module. The receiving unit is typically equipped with an Arduino Nano microcontroller and an OLED display to process and present the collected data for real-time monitoring and management.

Referring to the paper by Elhattab et al. [25], a low-power smart farming system based on LoRa was designed using solar energy, low-power connectivity, and IoT sensors. It consists of two units: the first unit monitors real-time conditions by analysing parameters such as temperature, soil moisture, water level, and pH. The unit tracks soil acidity using a pH sensor, soil moisture using a humidity sensor, climate data using a temperature sensor, and animal intrusion using a PIR sensor. When the parameters fall below optimal levels, the ESP32 microcontroller adjusts the water pump accordingly. The processed data is transmitted via LoRa to the second unit, which relays the information to a cloud server via WIFI. Users can then remotely monitor large agricultural areas through a mobile application connected to the Internet. The system aims to achieve efficient and energy-saving irrigation and intelligent monitoring of agricultural operations.

Studies have shown that LoRa wireless devices are very effective for collecting data in agricultural environments when system complexity is low, data is moderate, and transmission rates are not required [23-25]. Their low power consumption makes them particularly suitable for specific agricultural environments. However, LoRa's dedicated frequency and gateway design can lead to compatibility issues with other devices during data collection, limiting the system to LoRa-only devices. In addition, LoRa-based systems are limited in scalability regarding data display and cloud platform integration, which poses a challenge to expanding from basic data collection to more advanced agricultural management decision-making capabilities. The above systems have found that the management platforms adopted are relatively simple, using mobile terminals [23, 24]or display screens [25] for direct display, without data management, limited management platform selection, and inability to retrieve historical data for agricultural environment analysis.

2.2. Application of Zigbee Communication Technology in Smart Agriculture

Lu Niu [26] discussed the application of ZigBee in smart agriculture big data collection systems, focusing on its role in short-range wireless communications. ZigBee connects environmental sensors (such as temperature and humidity) to a central control unit due to its energy saving, low data rate, and mesh network capabilities. It enables efficient local data collection across agricultural fields, while integration with NB-IoT extends data transmission to longer distances. Despite its short-range limitations, ZigBee's low power consumption and self-healing network characteristics make it an ideal choice for agricultural scenarios. It supports real-time data collection and contributes to the overall IoT ecosystem for smart agriculture.

According to Ünal [27], ZigBee is a key communication technology for data collection and transmission in smart agriculture systems. ZigBee's low power consumption, ease of deployment, and reliable short-range communication make it an ideal choice for integrating GPS receivers into CAN (Controller Area Network) networks for precision agriculture applications. ZigBee facilitates the transmission of real-time data from GPS sensors to centralised agricultural management systems, enabling accurate monitoring of various environmental parameters and vehicle positioning within agricultural fields. This implementation highlights the effectiveness of ZigBee in enhancing the coordination of multiple sensors and devices in agricultural automation, thereby improving the efficiency and precision of agricultural operations while minimising energy consumption and reducing infrastructure costs. This paper demonstrates the key role of ZigBee in addressing the connectivity and data-sharing challenges facing modern precision agriculture.

By consulting relevant literature, ZigBee is very effective in smart agricultural information collection systems due to its low power consumption. It is ideal for single battery-powered sensor networks that need to operate long without frequent battery replacement. ZigBee supports mesh networks, enabling multi-hop transmission and improving network reliability and coverage, especially in large-scale agricultural environments. It can support hundreds or even thousands of nodes, and its automatic rerouting function enhances network stability when nodes fail or new nodes are added. This is especially beneficial in sensor-intensive areas such as greenhouses. Although ZigBee's data rate is limited to around 250kbps and the single-hop communication distance is usually within tens of meters, its spread spectrum technology in the 2.4GHz band has strong anti-interference performance. For applications that require higher data transmission rates, such as large-scale smart agricultural systems, ESP8266 WIFI provides a better solution due to its faster data rate, easier integration with existing WIFI networks, and rich open-source development resources. This makes ESP8266 more suitable for processing large amounts of data and remote monitoring and saves developers time and costs through available SDKs and community support.

2.3. Application of ESP8266 WIFI Technology in Smart Agriculture

Hidayat et al. [28] focused on an IoT-based hydroponic plant monitoring system designed to optimise plant growth and reduce the risk of crop failure. It uses carbon dioxide, light, and nutrient sensors to monitor key environmental parameters, including temperature, humidity, pH, and water level. Using ESP8266, data is transmitted from the sensors to a mobile application, enabling farmers to monitor plant conditions remotely in real-time. The system provides key environmental data such as a temperature range of 24-29℃, pH 6-7, and water level of 8-10 cm. In addition, it transmits the data to a website for real-time monitoring, allowing users to take timely action to resolve any issues.

Sutikno et al. [29] introduced a smart irrigation system design that utilises a NodeMCU ESP8266 microcontroller and the Ubidots cloud platform. The system collects environmental data from a DHT22 temperature/humidity sensor and a soil moisture sensor and transmits the data to Ubidots via WIFI. The Ubidots application receives, stores, and processes sensor data to provide real-time visibility into the condition of agricultural plots. The system can automatically control water pumps based on soil moisture levels. When soil moisture drops below a configurable threshold (e.g., 20%), the water pump automatically starts to begin irrigation. Once soil moisture reaches a stable level, the pump automatically shuts off. Users can remotely access the system through the Ubidots application, view real-time environmental data, and manually control irrigation. This allows farmers to monitor and manage the irrigation process from any location, improving convenience and efficiency.

Halim et al. [30] describe designing and implementing a smart irrigation monitoring system for pepper crops built on an ESP8266 NodeMCU microcontroller. The system consists of a sensor box that includes a DHT11 temperature/humidity sensor and an FC-28 soil moisture sensor. The irrigation system is connected to the water pump via a solid-state relay (FOTEK SSR-25 DA) using an optocoupler motor switch. The entire system can be wirelessly controlled via a NodeMCU connected to a WIFI or 4G network. Mobile and desktop applications have been developed using Blynk and Thinger.io platforms, respectively, enabling users to monitor temperature, humidity, and soil moisture in the pepper growing area and control the irrigation system. The application interface includes a dashboard to display relevant environmental data and a chart to visualise the relationship between humidity and temperature. Users can also use a switch button to start and stop the water pump. The system was deployed and tested in a 0.5-hectare pepper growing area in Kedah, Malaysia, and includes a water pump, a 900-gallon water tank, a filter, a valve, and polyethylene pipes. The tests proved the stability and reliability of the system under various environmental conditions.

According to the literature review, many researchers have designed agricultural data collection systems that collect and transmit sensor data using ESP8266 WIFI modules. On the other hand, in terms of cloud platforms, existing solutions mostly use platforms such as Blynk IoT, Thinger.io, and Ubidots, but they can only display a limited amount of sensor data, cannot customise the data visualisation interface, and the refresh speed is often slow when processing large amounts of data. Some management controls are semi-automatic and require manual activation of the environmental adjustment system. In addition, the various systems are not integrated. If deployed in a large agricultural environment, the positions of the various sensors in the network need to be rearranged, which makes it inconvenient to build a smart agricultural collection system. However, this article proposes an alternative solution: to use the TLINK Internet of Things platform, which has many advantages over the above-mentioned more commonly used platforms.

2.4. Application of IoT Platform in Smart Agriculture

Table 4 compares the three IoT platforms, Blynk IOT, Thinger.io, and Ubidots, in the current research literature with the TLINK IoT platform regarding communication protocol, data visualisation, device management, data processing capability, integration capability, and technical support. By comparing and analysing TLINK's rich data visualisation and integration capabilities and comprehensive communication protocols, developers can continue to develop and build a good bridge for third-party development. First, TLINK can ensure faster data processing speed. The designed system updates data every 3 seconds and realises big data analysis capabilities. When the data is abnormal, it can alarm and automatically regulate the agricultural environment with environmental data, providing more comprehensive support for environmental management. Secondly, the TLINK platform allows more customisation of the data display interface to meet user needs. Finally, by using the TLINK IoT platform to develop intelligent agricultural systems, developers can use the compatibility of the platform API to customise and develop related IoT platforms to support effective decision-making in agricultural, environmental management.

Table 4. Comparison of three IoT platforms: Blynk IoT, Thiner.io, and Ubidot

IoT Platform	Communication Protocol	Device Management	Data processing capabilities	Data Visualization	Integration capabilities and ecosystem	Technical Support and Documentation
Blynk IoT [31]	MQTT, HTTP	Supports simple device registration, status monitoring and control	Moderate processing power, suitable for small and mediumsized IoT projects	Provides a variety of visualisation components (charts, dashboards, maps, etc.) for mobile APPs, suitable for rapid development	Supports RESTful API and can be integrated with other systems	Provide community support, technical forums, and some advanced support requires payment, with detailed documentation and tutorials, including development examples
Thinger.io [32]	HTTP, MQTT, CoAP, WebSockets	Provides device management, remote control, and status monitoring and supports multiple devices	Moderate processing power, supporting real-time data stream analysis	Supports dashboards and charts to display device data in real-time; customisable data panels	Supports integration with thirdparty platforms such as IFTTT; REST API is suitable for system expansion	Community support, paid support plans; provide guidance documents and sample code, detailed documentation, including API references and FAQs
Ubidots [33]	HTTP, MQTT, UDP	Provides advanced device management functions, including batch management, remote control, etc.	High processing power, supporting data streaming analysis and historical data processing	Powerful data visualisation capabilities, support dashboard customisation, provide charts, maps, etc.	Provides a RESTful API that integrates well with third-party systems (such as Zapier IFTTT)	Provides multiple levels of technical support, including paid support plans, suitable for enterprise use, complete documentation and API reference, and supports examples in multiple languages

3. Materials and Methods

The smart agricultural integrated management system is designed through research and analysis with the four modules shown in Figure 3. First, the hardware parts are designed, starting from the selection of each sensor and the connection with STM32, the connection between ESP8266 and STM32, the configuration of relays and the configuration of each sensor, and finally, the functions of each module are displayed through the diagram. Secondly, the ESP8266 software is designed, and the working mode of ESP8266 is configured through Arduino IDE to ensure the system's power consumption. Third, the layout of the TLINK IoT cloud platform. Fourth, the layout of the TLINK cloud platform mobile phone APP.

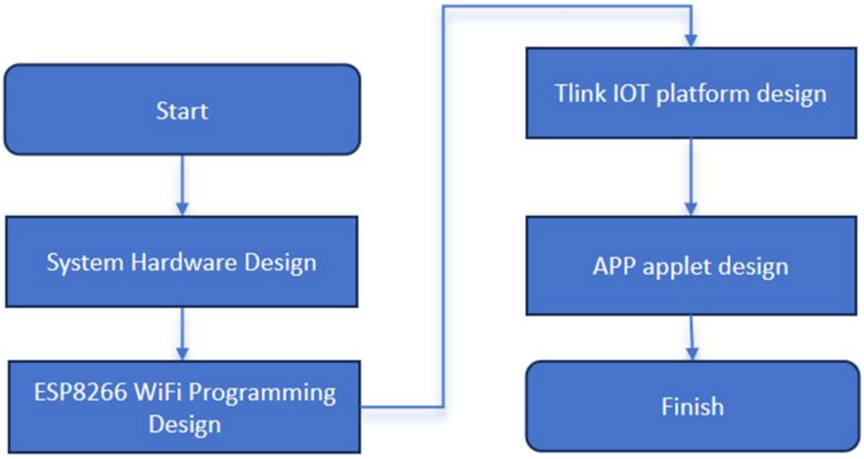


Figure 3. Overall system design process

3.1. System Hardware Design

3.1.1. TFT-LCD Display Interface Circuit

The LCDs are the data collected by each sensor locally in the system. The TFT-LCD display communicates with STM32 via SPI. Interface 1 is GND grounding; Interface 2 is VCC; Interface three is connected to microcontroller PA12; Interface four is connected to microcontroller PA15; Interface five is connected to microcontroller PB3; Interface 6 is connected to microcontroller PB4; and Interface 7 is connected to microcontroller PB5. The collected data is displayed on the TFT-LCD display through the interface connection. Figure 4 shows the interface circuit schematic diagram of the TFT display module and the actual display screen.

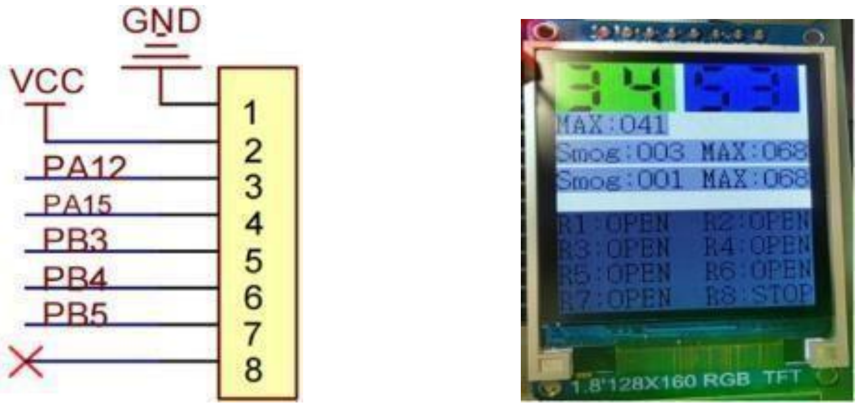


Figure 4. TFT-LCD display module circuit principle and TFT-LCD display screen

3.1.2. DHT11 Interface Circuit

This control system uses the DHT11 sensor as the ambient air temperature and humidity detection module [34]. The DHT11 has a built-in resistive humidity-sensing element and an NTC temperature-measuring element. It has the advantages of strong anti-interference ability, low cost, ultra-small size, and extremely low power consumption. It is widely used in measuring temperature and humidity and is connected to a single-chip microcomputer (inside the DHT11). Figure 5 is the schematic diagram and physical picture of the DHT11 interface circuit.

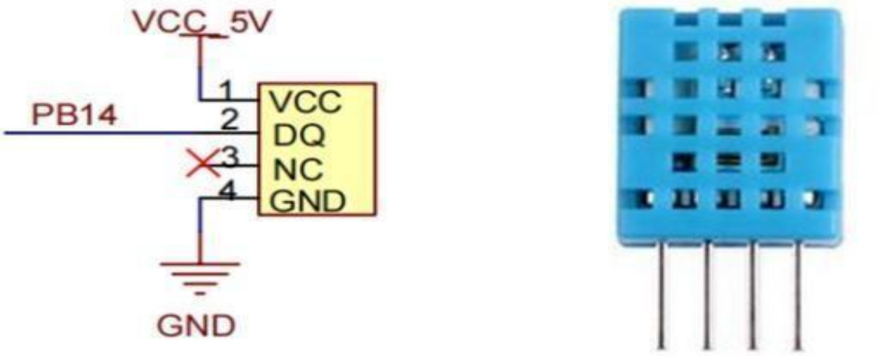


Figure 5. DHT11 temperature and humidity sensor and DHT11 interface circuit principle

3.1.3. Circuit Design of Voice Recognition Module

This control system uses the ASR PRO voice recognition module, which is convenient for users to control the collection system of the agricultural environment control room. The lights, air conditioners, irrigation systems, or ventilation systems can be turned on through the voice recognition function. The intelligent housekeeper can also be awakened to broadcast the current temperature, humidity, air quality, and other information. By shouting "Smart housekeeper turns on the irrigation system" to the module's microphone, the irrigation system switch can be automatically operated, which is convenient for terminal management users to control the environment adjustment system.

The VCC pin is a 5V power pin, and the GND pin is a negative power supply. It is connected to the PA2 and PA3 interfaces of the STM32 microcontroller to realise the voice recognition function; the SPK+ and SPK-interfaces are connected to the speakers to realise voice playback; and the MIC+ and MIC-pins are connected to the microphone. The circuit principle of the voice recognition module is shown in Figure 6.

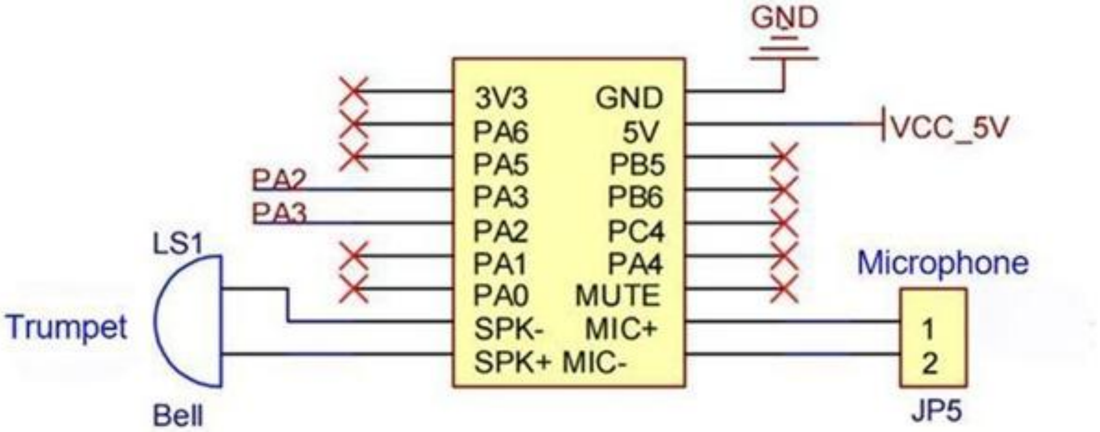


Figure 6. Circuit principle of speech recognition module

3.1.4. Voice Broadcast Module Circuit Design

The voice broadcast module of this control system adopts KT148A. KT148A voice broadcast module is an integrated electronic device designed for voice playback. The audio data stored in the internal memory can be converted into sound output using digital signal processing technology. The designed KT148A module has the advantages of high integration, support for multiple audio formats, high-quality audio output, easy programming control, and robust scalability. Pin 3 of the KT148A module is connected to the PB1 interface of STM32 to realise the simulation of the voice broadcast function; the PB0 interface of the microcontroller is used to download the program. The principle of the voice broadcast circuit is shown in Figure 7.

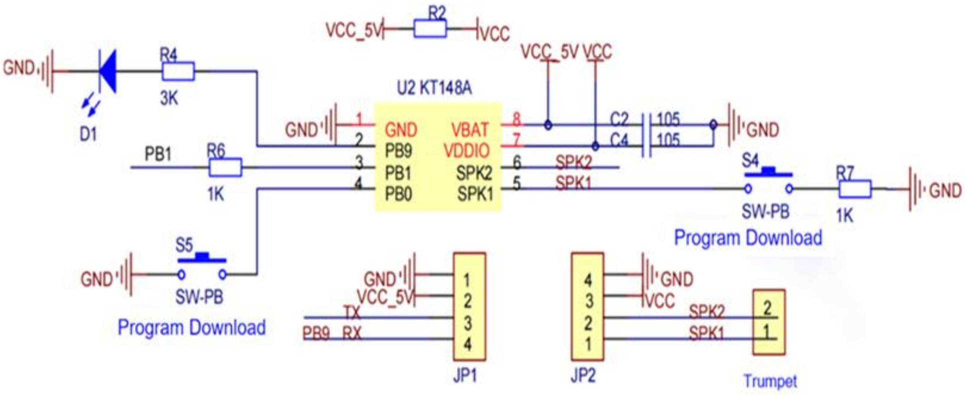


Figure 7. Circuit diagram of voice broadcast module

3.1.5. Circuit Design of Air Quality Detection Module

This control system's air quality detection component uses the MQ135 air quality sensor. This air quality monitoring sensor was selected due to its low cost, long life, and sensitive measurement [35]. As shown in Figure 8, the circuit schematic and hardware diagram of MQ135 are in this design system. MQ135 is mainly used to detect the concentration of gases such as carbon dioxide, alcohol, benzene, nitrogen oxides, and ammonia, providing all-round monitoring for the agricultural environment atmosphere. The VCC interface is the positive power input terminal of the MQ135 sensor, connected to 5V, to ensure that the power supply voltage matches the sensor. The GND interface is the sensor's ground terminal.

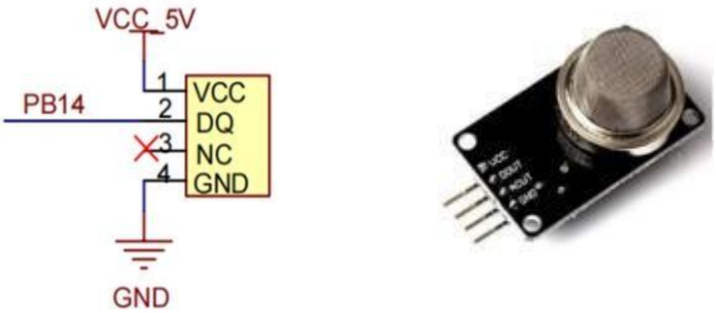


Figure 8. Air quality sensor interface circuit schematic and MQ135 hardware diagram

3.1.6. ESP8266 WIFI Communication Module Circuit Design

The ESP8266 module is a low-cost, low-power, highly integrated WIFI communication chip produced by ESPRESSIF. It integrates TCP/IP protocol stack and microcontroller functions and can provide wireless network connection capabilities for embedded systems.

The circuit interface VCC is the power input terminal, connected to 5V; GND is connected to the negative GND terminal of the power supply; TX is connected to the PA10 interface of STM32, and RX is connected to the PA9 interface of STM32 to realise the communication function. The circuit schematic diagram of the ESP8266 module is shown in Figure 9.

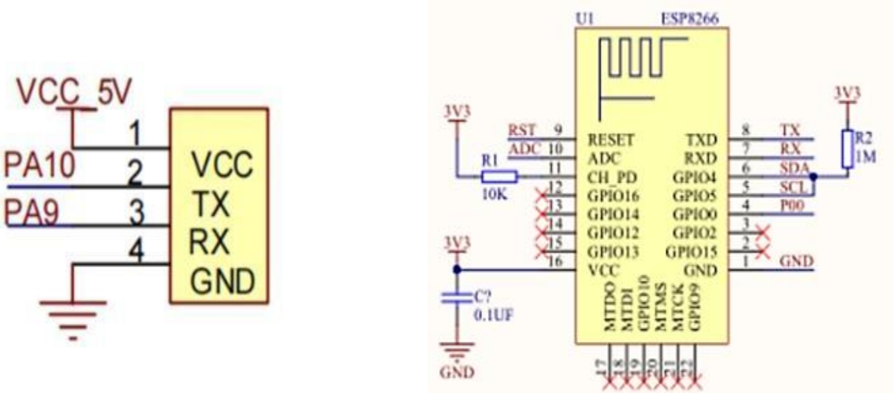


Figure 9. ESP8266 WIFI communication module interface circuit schematic

3.1.7. System Overall Module Circuit

Figure 10 shows the overall circuit module of the smart agricultural management system divided into various modules. Figure 10. The overall circuit module of the smart agriculture management system.

3.2. ESP8266 WIFI Software Design

The ESP8266 WIFI software design uses Arduino IDE as the development platform. Developers must first download the ESP8266 development support package from the IDE official website or GitHub, install the necessary libraries, and then program the ESP8266. In addition, a low-power wake-up mode uses the clock to maintain deep sleep between data transmission intervals. The network connection will be disconnected before entering deep sleep. Suppose the module cannot reconnect after being awakened by the RTC. In that case, it will directly re-enter deep sleep without repeated attempts, dramatically reducing the wireless network power consumption of ESP8266. WIFI programming mainly solves the network connection problem of ESP8266. The official SmartConfig software can configure WIFI with one click, as shown in Figure 11 SmartConfig software interface.

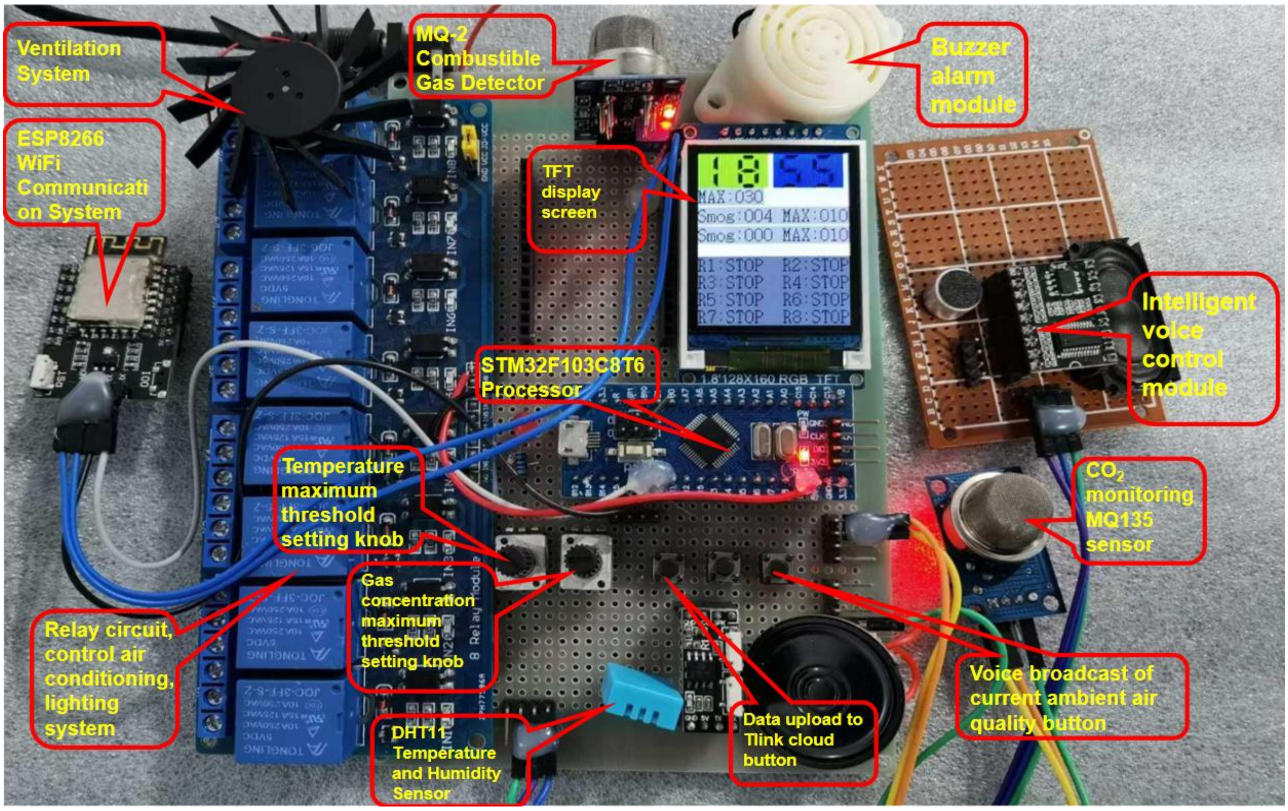


Figure 10. The overall circuit module of the smart agriculture management system


ESP8266 SmartConfig

SSID : NAT.WRTNODE

Password :

SSID is Hidden

Figure 11. SmartConfig one-click network configuration interface

ESP8266 can operate in access point (AP) and station (STA) modes to facilitate data transmission to a remote TLINK server. In AP mode, ESP8266 can host a local server and display a simple web interface created using HTML. Users can connect to the module by accessing the local IP address "192.168.4.1" in a web browser from a PC or mobile device. This interface allows users to switch between AP and STA modes without reprogramming the hardware. In STA mode, ESP8266 connects to a router using predefined parameters and then to a cloud server. Once sensor data (such as temperature, humidity, light intensity, and CO$_2$ levels) is collected, ESP8266 packages it according to the

TLINK platform specification and initiates transmission. Figure 12 illustrates the execution flow of AP and STA modes.

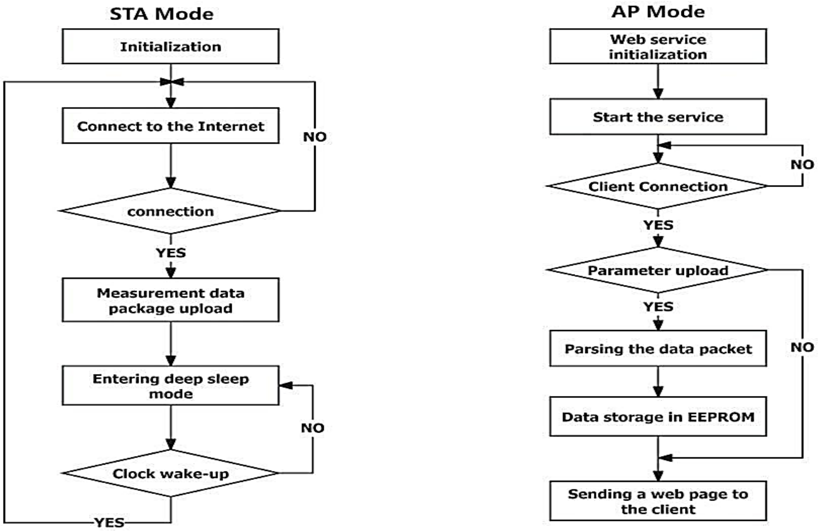


Figure 12. STA vs. AP execution flow comparison

ESP8266 and TLINK usually need to go through the following steps to communicate:

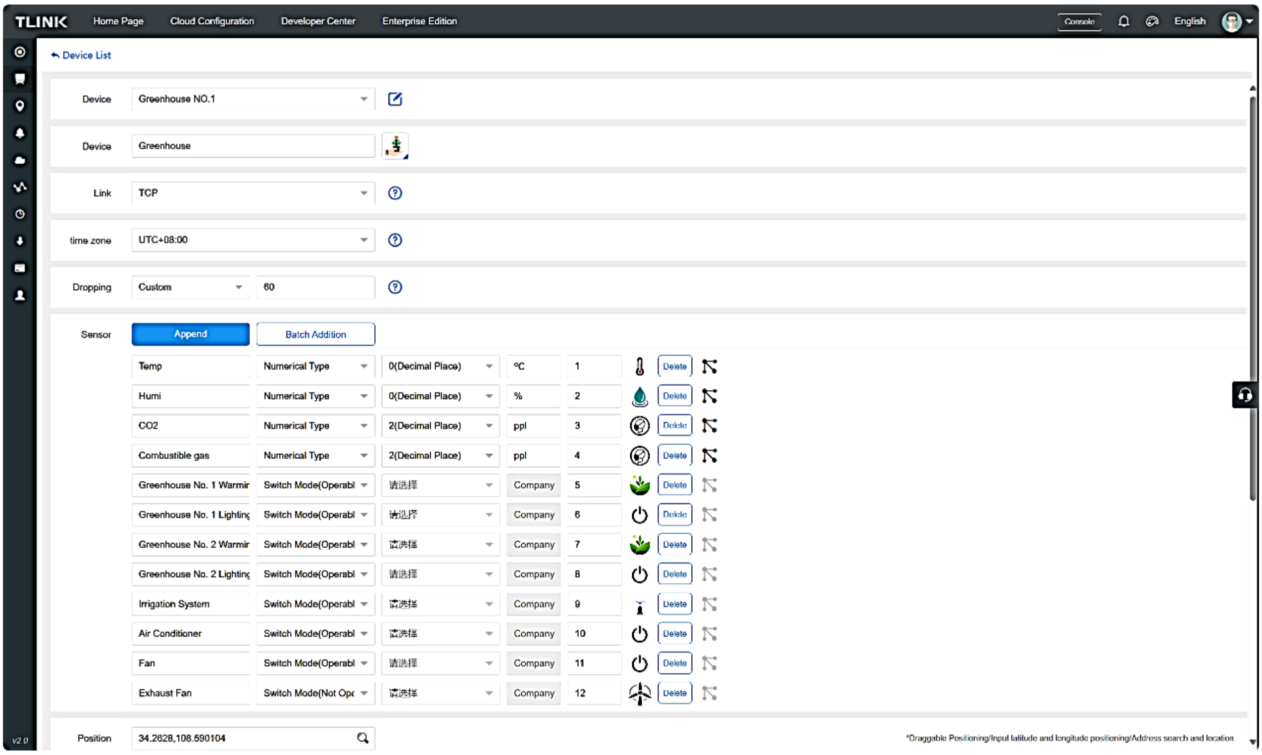
1. Network configuration: Ensure the blue LED on the ESP8266 module is flashing to indicate that the network is being configured. Configure the network through the SmartConfig software. If the network configuration is successful, the LED will not light up, indicating that it has been connected to the WIFI network.
2. Register the device: Register the user ESP8266 device on the TLINK IoT platform and obtain the device ID and API key.
3. ESP8266 program: Use Arduino to write a program to let ESP8266 communicate with the TLINK platform through protocols such as HTTP or MQTT.
4. Data transmission: Write code to send the data collected by ESP8266 to the API endpoint of the TLINK IoT platform through HTTP POST request.
5. Data reception: If you need to receive data from the TLINK platform, write code to process the data received from the platform.
6. Debug test: Test whether the communication between the ESP8266 module and the TLINK platform is daily.

3.3. TLINK Software Design

The study found that the TLINK platform is a cloud platform software for comprehensive management of the entire process of the Internet of Things. The TLINK Internet of Things cloud platform has the characteristics of device interconnection, data security, easy expansion, service integration, sensor terminal access, and user-friendliness. It provides users with efficient, flexible, and secure device connection and management solutions and strong support for the comprehensive management of smart agriculture [31]. As shown in Figure 13, the initial device addition interface of the TLINK Internet of Things cloud platform is shown.

The steps to use the TLINK platform are as follows:

1. Create a device: Start accessing the TLINK Internet of Things platform, complete the "Device Management" according to the platform prompts, select the "Add Device" option on the "Device Management" page, and start adding a new device; fill in all device information according to the page prompts, and then click Create device.
2. Connect the device: Enter the "Device Management" menu, select "Edit Device," find "Link Protocol" in the pop-up submenu and change it to "TCP." Return to "Device Management," click the "Set Connection" option, set the corresponding "Protocol Label," and ensure that the device can successfully connect to the network.
3. Add a trigger: Create a new contact; enter the trigger page and add a trigger.
4. Add cloud configuration: Enter the cloud configuration page and select Create configuration.



Device: Greenhouse NO.1
Device: Greenhouse
Link: TCP
time zone: UTC+08:00
Dropping: Custom 60
Sensor:

Temp	Numerical Type	0(Decimal Place)	°C	1	Delete
Humi	Numerical Type	0(Decimal Place)	%	2	Delete
CO2	Numerical Type	2(Decimal Place)	ppl	3	Delete
Combustible gas	Numerical Type	2(Decimal Place)	ppl	4	Delete
Greenhouse No. 1 Warmir	Switch Mode(Operabl	请选择	Company	5	Delete
Greenhouse No. 1 Lighting	Switch Mode(Operabl	请选择	Company	6	Delete
Greenhouse No. 2 Warmir	Switch Mode(Operabl	请选择	Company	7	Delete
Greenhouse No. 2 Lighting	Switch Mode(Operabl	请选择	Company	8	Delete
Irrigation System	Switch Mode(Operabl	请选择	Company	9	Delete
Air Conditioner	Switch Mode(Operabl	请选择	Company	10	Delete
Fan	Switch Mode(Operabl	请选择	Company	11	Delete
Exhaust Fan	Switch Mode(Not Opc	请选择	Company	12	Delete

Position: 34.2628,108.590104
*Draggable Positioning/Input latitude and longitude positioning/Address search and location

Figure 13. TLINK IoT platform device addition page

As shown in Figure 14, the primary usage of the Web terminal is as follows:

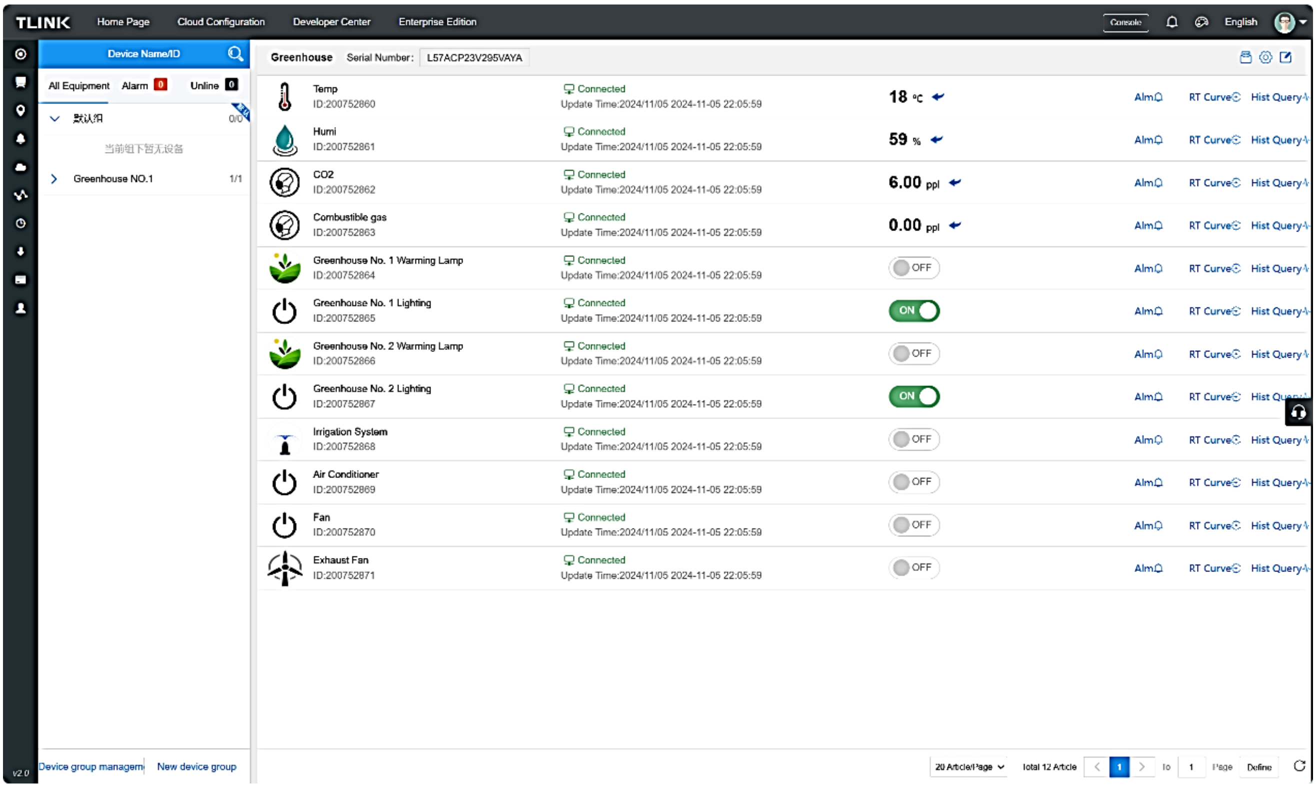
1. Visit the official website: Enter the TLINK IoT platform official website address https://www.TLINK.io/user/userIndex.htm in the computer browser.
2. Register/login account: Open the TLINK IoT platform client. You must register for a new account if you don't have one. If you already have an account, you can log in directly.
3. Open the interface: Open the console option at the top of the interface. To communicate with the control system, you need to connect to WIFI. The TLINK IoT platform interface will display a successful connection message.
4. Related data settings: add greenhouse name, serial number and ID, set serial number to L57ACP23V295VAYA, set temperature ID to 200752860, humidity ID to 200752861, smoke concentration ID to 200752862, MQ135 air quality detection ID to 200752863, greenhouse No. 1 heating lamp ID to 200752864, greenhouse No. 1 lighting ID to 200752865, greenhouse No. 2 heating lamp ID to 200752866, greenhouse No. 2 lighting ID to 200752867, irrigation system ID to 200752868, air conditioning system ID to 200752869.
5. View data: The MQ135 data on temperature, humidity, and the agricultural environment in the greenhouse can be viewed on the web interface. You can use the smart agricultural environment control button based on the feedback.
6. Control equipment: The interface allows for controlling each part of the room's lighting, air conditioning, and ventilation systems.

3.4. Mobile APP Applet Design

As shown in Figure 15, the steps for the mobile software data visualisation interface are as follows:

1. Download and install: Download the official mobile client of the TLINK IoT platform.
2. Register and log in: After opening the mobile client, you must register a new account or log in with an existing one.
3. Open the interface: After ensuring that the designed ESP8266 WIFI hardware is successfully connected to the router network, the mobile interface will display a successful connection signal.
4. Data setting: Add the serial number L57ACP23V295VAYA of the greenhouse equipment.
5. Data display: Use the communication module to upload each module's monitoring data to the TLINK IoT cloud platform, which can monitor environmental temperature and humidity, MQ135 air quality,

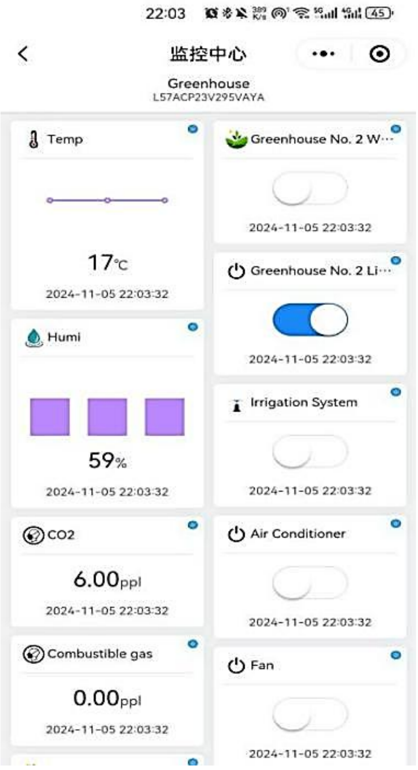
and other data in real-time. 6. Remote control: The greenhouse can be remotely controlled, allowing users to control the agricultural environment more conveniently.



Greenhouse Serial Number: L57ACP23V295VAYA

Temp ID:200752860	Connected Update Time:2024/11/05 2024-11-05 22:05:59	18 ℃	Alm	RT Curve Hist Query
Humi ID:200752861	Connected Update Time:2024/11/05 2024-11-05 22:05:59	59 %	Alm	RT Curve Hist Query
CO2 ID:200752862	Connected Update Time:2024/11/05 2024-11-05 22:05:59	6.00 ppl	Alm	RT Curve Hist Query
Combustible gas ID:200752863	Connected Update Time:2024/11/05 2024-11-05 22:05:59	0.00 ppl	Alm	RT Curve Hist Query
Greenhouse No. 1 Warming Lamp ID:200752864	Connected Update Time:2024/11/05 2024-11-05 22:05:59	OFF	Alm	RT Curve Hist Query
Greenhouse No. 1 Lighting ID:200752865	Connected Update Time:2024/11/05 2024-11-05 22:05:59	ON	Alm	RT Curve Hist Query
Greenhouse No. 2 Warming Lamp ID:200752866	Connected Update Time:2024/11/05 2024-11-05 22:05:59	OFF	Alm	RT Curve Hist Query
Greenhouse No. 2 Lighting ID:200752867	Connected Update Time:2024/11/05 2024-11-05 22:05:59	ON	Alm	RT Curve Hist Query
Irrigation System ID:200752868	Connected Update Time:2024/11/05 2024-11-05 22:05:59	OFF	Alm	RT Curve Hist Query
Air Conditioner ID:200752869	Connected Update Time:2024/11/05 2024-11-05 22:05:59	OFF	Alm	RT Curve Hist Query
Fan ID:200752870	Connected Update Time:2024/11/05 2024-11-05 22:05:59	OFF	Alm	RT Curve Hist Query
Exhaust Fan ID:200752871	Connected Update Time:2024/11/05 2024-11-05 22:05:59	OFF	Alm	RT Curve Hist Query

Figure 14. Sensor data interface of the web client of the TLINK IoT platform



Temp
17℃
2024-11-05 22:03:32

Humi
59%
2024-11-05 22:03:32

CO2
6.00ppl
2024-11-05 22:03:32

Combustible gas
0.00ppl
2024-11-05 22:03:32

Greenhouse No. 2 W···
2024-11-05 22:03:32

Greenhouse No. 2 Li···
2024-11-05 22:03:32

Irrigation System
2024-11-05 22:03:32

Air Conditioner
2024-11-05 22:03:32

Fan
2024-11-05 22:03:32

Figure 15. TLINK IoT platform mobile APP data visualisation interface

4. Results and Discussion

4.1. Temperature and Humidity Detection Function Experiment

As shown in Figure 16, when using the DHT11 temperature and humidity sensor to detect the temperature module, blow air to the DHT11 sensor to detect different temperatures. Use the knob to set the threshold of the sound and light alarm to 30°C. At the beginning, the temperature detected by the sensor was 17°C. When blowing air to the DHT11 temperature and humidity sensor, the temperature rose to 30°C on the TFT-LCD display, reaching the set parameters [36]. The system began to issue sound and light alarms and turned on the exhaust fan to ventilate and cool the agricultural environment so that the photosynthetic temperature of the plants is stable to ensure the plant growth environment; when the temperature and humidity sensor is stopped, the temperature can be seen to return to a stable state gradually.

When performing a functional test on humidity, blow air to the sensor so that the temperature and humidity sensor detects different humidity. Initially, the humidity detected by the DHT11 sensor was 72%. When blowing air to the sensor, the humidity value can be seen on the display slowly rising to 98%; when blowing air to the DHT11 temperature and humidity sensor is stopped, the humidity value on the display slowly decreases. Multiple functional tests confirmed that the temperature and humidity monitoring system was operating normally and that the data could be displayed in real-time on the display screen. The test results showed that the function met expectations.

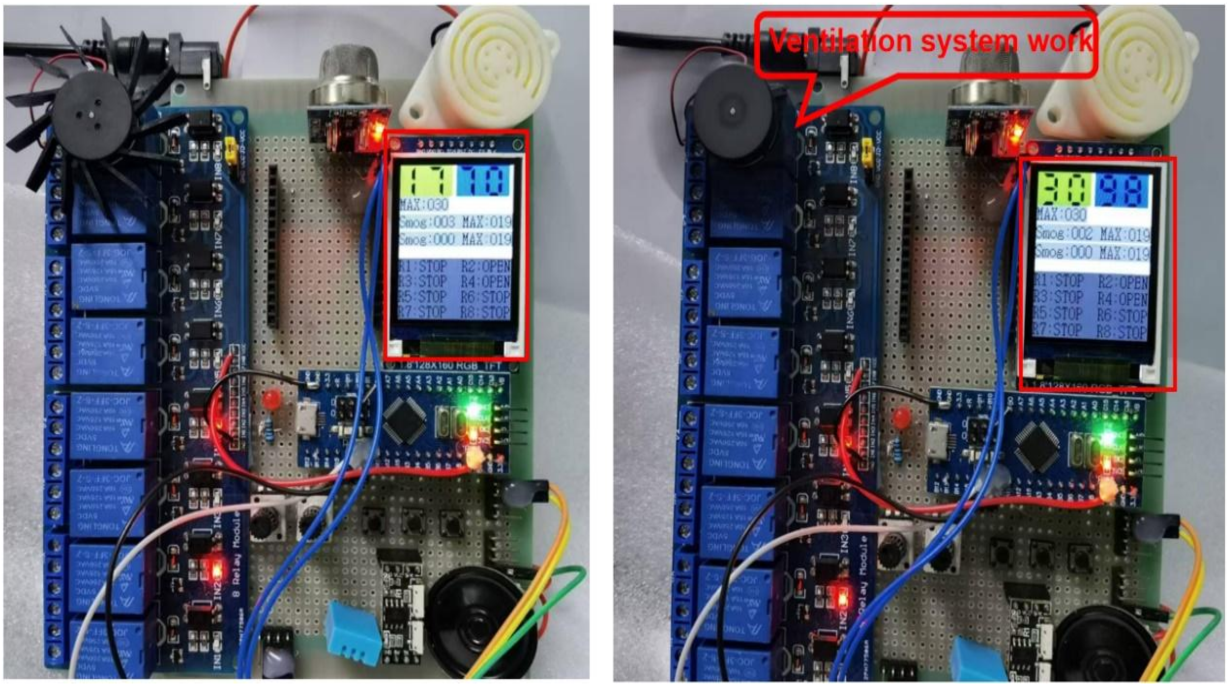
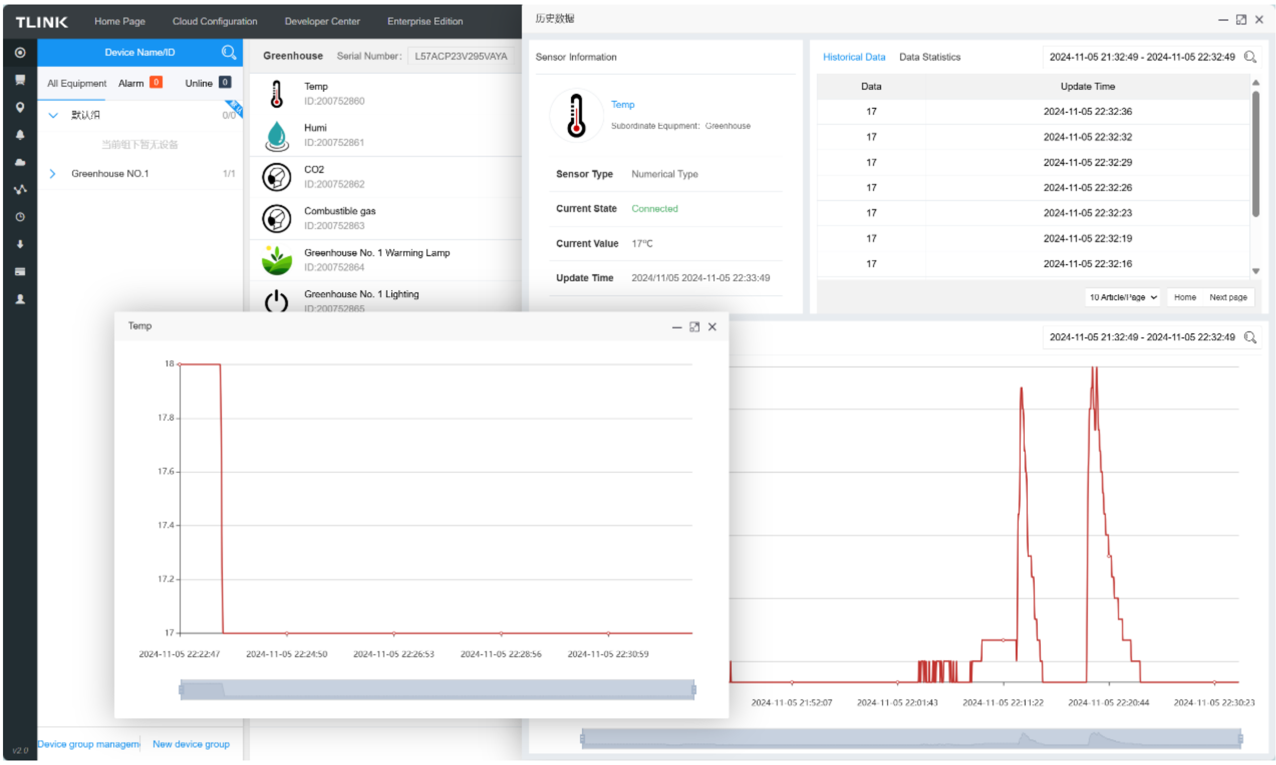


Figure 16. Temperature and humidity detection function test

From the TLINK IoT platform, we can see that the sensor data will be saved to the cloud, and the temperature and humidity data collected by the sensor can be retrieved at any time. Figure 17 shows the TLINK.io Web data visualisation interface; the current time is 22:30 on November 5, 2024. The network is normal, and the data is updated every three seconds. The figure shows that clicking on the history query retrieves the temperature and humidity historical data collected by the sensor from 22:01 to 22:30. From the figure, we can see the maximum and minimum values of the data from 22:01 to 22:30, the amount of data collected, and other information. Click the real-time curve on the interface to observe the real-time data changes. The data is stably transmitted and updated every 3 seconds. The line chart can clearly show the changes in temperature and humidity data.



Greenhouse Serial Number: L57ACP23V295VAYA

Temp ID:200752860
Humi ID:200752861
CO2 ID:200752862
Combustible gas ID:200752863
Greenhouse No. 1 Warming Lamp ID:200752864
Greenhouse No. 1 Lighting ID:200752865

Sensor Information

Temp
Subordinate Equipment: Greenhouse

Sensor Type: Numerical Type
Current State: Connected
Current Value: 17°C
Update Time: 2024/11/05 2024-11-05 22:33:49

Historical Data | Data Statistics | 2024-11-05 21:32:49 - 2024-11-05 22:32:49

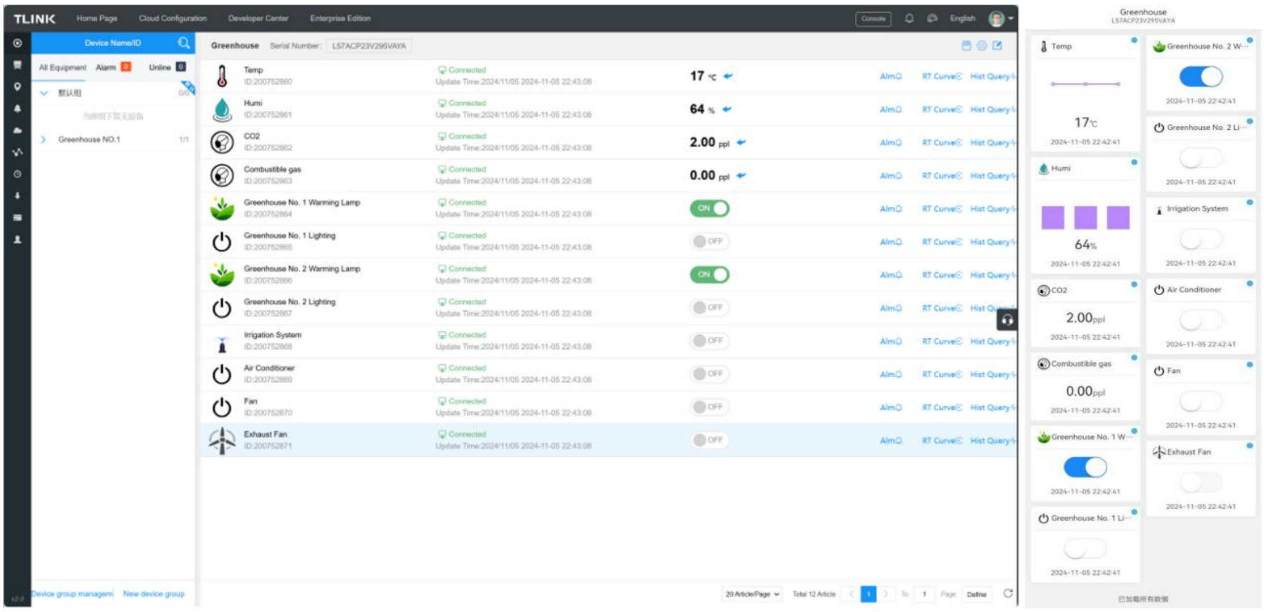
Data	Update Time
17	2024-11-05 22:32:36
17	2024-11-05 22:32:32
17	2024-11-05 22:32:29
17	2024-11-05 22:32:26
17	2024-11-05 22:32:23
17	2024-11-05 22:32:19
17	2024-11-05 22:32:16

2024-11-05 21:32:49 - 2024-11-05 22:32:49

Figure 17. TLINK real-time data visualisation interface and TLINK historical data viewing interface

4.2. System Automatic Control Function Experiment

Figure 18 shows that the left picture is the mobile phone APP switch status interface, and the right is the Web switch status interface. The intelligent environment control system can control intelligent lighting, air conditioning, and ventilation equipment. It can be interactively controlled through voice recognition technology or operated through remote control functions. Tell the system that the smart housekeeper turns on greenhouse warming lamp No. 1 and greenhouse warming lamp No. 2. You can see that the relay action LED lights corresponding to greenhouse warming lamp No. 1 and greenhouse warming lamp No. 2 light up. The data can be seen in the mobile phone APP data visualisation interface or a Web interface. Feedback, switch on status. In addition, the corresponding switch control can also be performed through the Web client or mobile phone APP client, and the switch button can be used to control the relay state to turn on or off the corresponding lighting, air conditioning, and fan switches to control the switch of the agricultural environment system.



Greenhouse Serial Number: L57ACP23V295VAYA

Temp ID:200752860	Connected Update Time:2024/11/05 2024-11-05 22:43:08	17 ℃	Alm	RT Curve Hist Query
Humi ID:200752861	Connected Update Time:2024/11/05 2024-11-05 22:43:08	64 %	Alm	RT Curve Hist Query
CO2 ID:200752862	Connected Update Time:2024/11/05 2024-11-05 22:43:08	2.00 ppl	Alm	RT Curve Hist Query
Combustible gas ID:200752863	Connected Update Time:2024/11/05 2024-11-05 22:43:08	0.00 ppl	Alm	RT Curve Hist Query
Greenhouse No. 1 Warming Lamp ID:200752864	Connected Update Time:2024/11/05 2024-11-05 22:43:08	ON	Alm	RT Curve Hist Query
Greenhouse No. 1 Lighting ID:200752865	Connected Update Time:2024/11/05 2024-11-05 22:43:08	OFF	Alm	RT Curve Hist Query
Greenhouse No. 2 Warming Lamp ID:200752866	Connected Update Time:2024/11/05 2024-11-05 22:43:08	ON	Alm	RT Curve Hist Query
Greenhouse No. 2 Lighting ID:200752867	Connected Update Time:2024/11/05 2024-11-05 22:43:08	OFF	Alm	RT Curve Hist Query
Irrigation System ID:200752868	Connected Update Time:2024/11/05 2024-11-05 22:43:08	OFF	Alm	RT Curve Hist Query
Air Conditioner ID:200752869	Connected Update Time:2024/11/05 2024-11-05 22:43:08	OFF	Alm	RT Curve Hist Query
Fan ID:200752870	Connected Update Time:2024/11/05 2024-11-05 22:43:08	OFF	Alm	RT Curve Hist Query
Exhaust Fan ID:200752871	Connected Update Time:2024/11/05 2024-11-05 22:43:08	OFF	Alm	RT Curve Hist Query

Greenhouse
L57ACP23V295VAYA

Temp	17℃	2024-11-05 22:42:41
Humi	64%	2024-11-05 22:42:41
CO2	2.00ppl	2024-11-05 22:42:41
Combustible gas	0.00ppl	2024-11-05 22:42:41
Greenhouse No. 1 W···	ON	2024-11-05 22:42:41
Greenhouse No. 1 Li···	OFF	2024-11-05 22:42:41
Greenhouse No. 2 W···	ON	2024-11-05 22:42:41
Greenhouse No. 2 Li···	OFF	2024-11-05 22:42:41
Irrigation System	OFF	2024-11-05 22:42:41
Air Conditioner	OFF	2024-11-05 22:42:41
Fan	OFF	2024-11-05 22:42:41
Exhaust Fan	OFF	2024-11-05 22:42:41

已加载所有数据

Figure 18. The mobile APP switch status interface is on the left side, and the Web switch status interface is on the right

4.3. Air Quality Detection Function Experiment

MQ135 gas sensor module is widely used in air quality detection devices. This design is mainly used to detect carbon dioxide in agricultural environments. The control system uses the built-in analog-to-digital conversion ADC module of the STM32F103C8T6 microcontroller to convert the air quality [37]. The collected analogue signal is converted, processed, and displayed intuitively on the TFT-LCD screen. Since there are no harmful gases under experimental conditions, the presence of a large amount of CO_2 gas is simulated by exhalation. As shown in Figure 19, the threshold of the air quality alarm is set by adjusting the knob. When the real-time monitoring value exceeds the preset threshold, the STM32F103C8T6 microcontroller will start the buzzer and LED light for sound and light alarm. When the MQ135 sensor collects values and displays the current display value of 4 on the TFT screen, it does not reach the set threshold of 10, so the control system does not start the alarm; when the display value rises to 12, exceeding the threshold of 10, the control system issues an audible and visual alarm and automatically turns on the exhaust fan to discharge harmful gases in the agricultural environment. Normally, CO_2 benefits plants, but the plant's photosynthesis is slow when the content continues for a certain period. The leaves may turn yellow and must be supplemented with fertiliser in time. Therefore, the health of plant growth is analysed by CO_2 content.

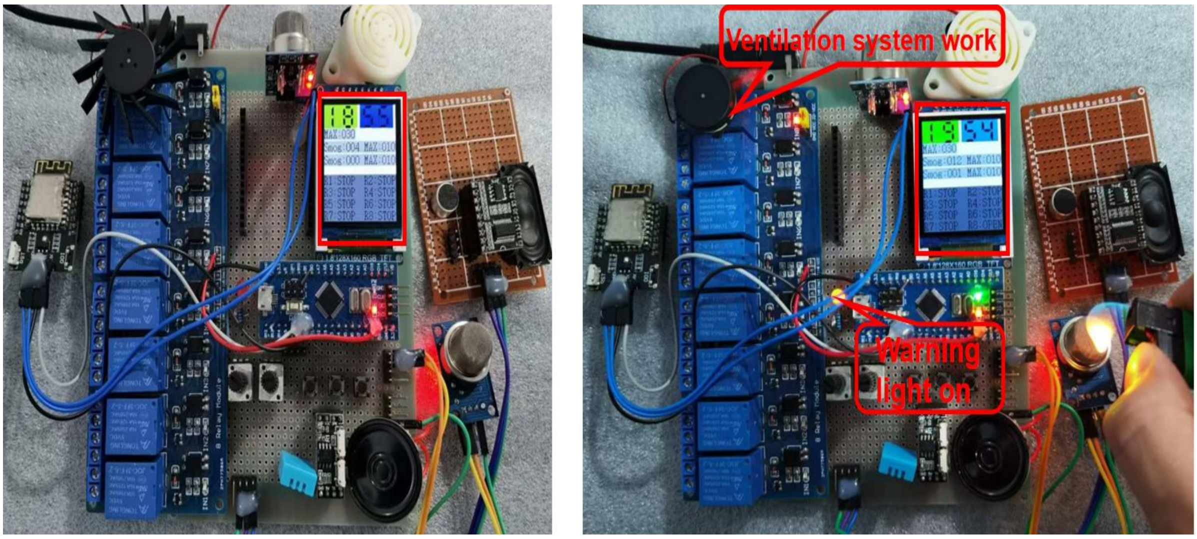
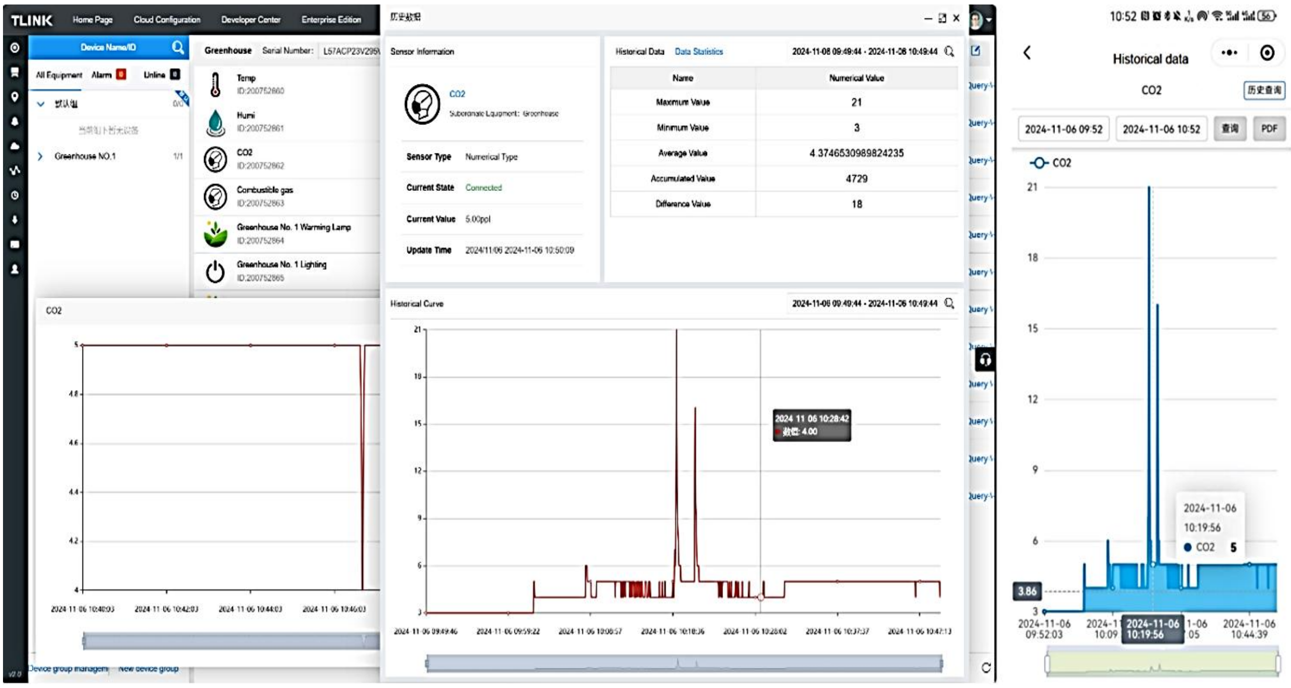


Figure 19. CO_2 concentration test

Figure 20 shows the historical data retrieved from TLINK. The historical data collected by MQ135 is saved in the TLINK cloud platform. During the data display test, when the collected data value is 15, the maximum value is set to 10. As shown in Figure 19, the fan will start to rotate, the ventilation system will start automatically, and the system will remind the user of an alarm.



CO2

Subordinate Equipment: Greenhouse

Sensor Type Numerical Type

Current State Connected

Current Value 5.00ppl

Update Time 2024/11/06 2024-11-06 10:50:09

Historical Data Data Statistics 2024-11-06 09:49:44 - 2024-11-06 10:49:44

Name	Numerical Value
Maximum Value	21
Minimum Value	3
Average Value	4.3746530989824235
Accumulated Value	4729
Difference Value	18

Figure 20. Visualisation of historical data line chart of air quality monitoring Web and mobile APP data collected by MQ135

4.4. Data Collection and Analysis

Place the system in a simulated environment, connect to the wireless network with network name: 123888, password: 1122334455 through ESP8266, press the data upload button of the system and the data collected by the system is uploaded to the TLINK cloud platform of the Internet of Things platform. The data updates the environment's temperature, humidity, and CO_2 concentration values every 3 seconds. Place the collected data in an environment without interference from other factors, as shown in Figure 21. The collected real-time and historical data can be viewed on the TLINK Web and mobile APP interfaces.

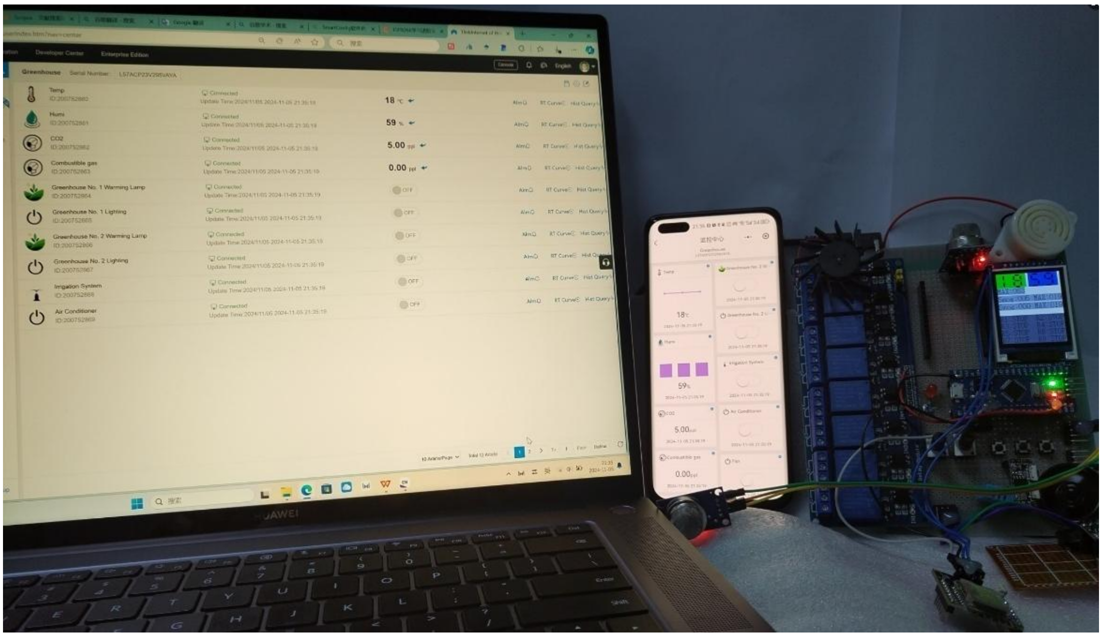


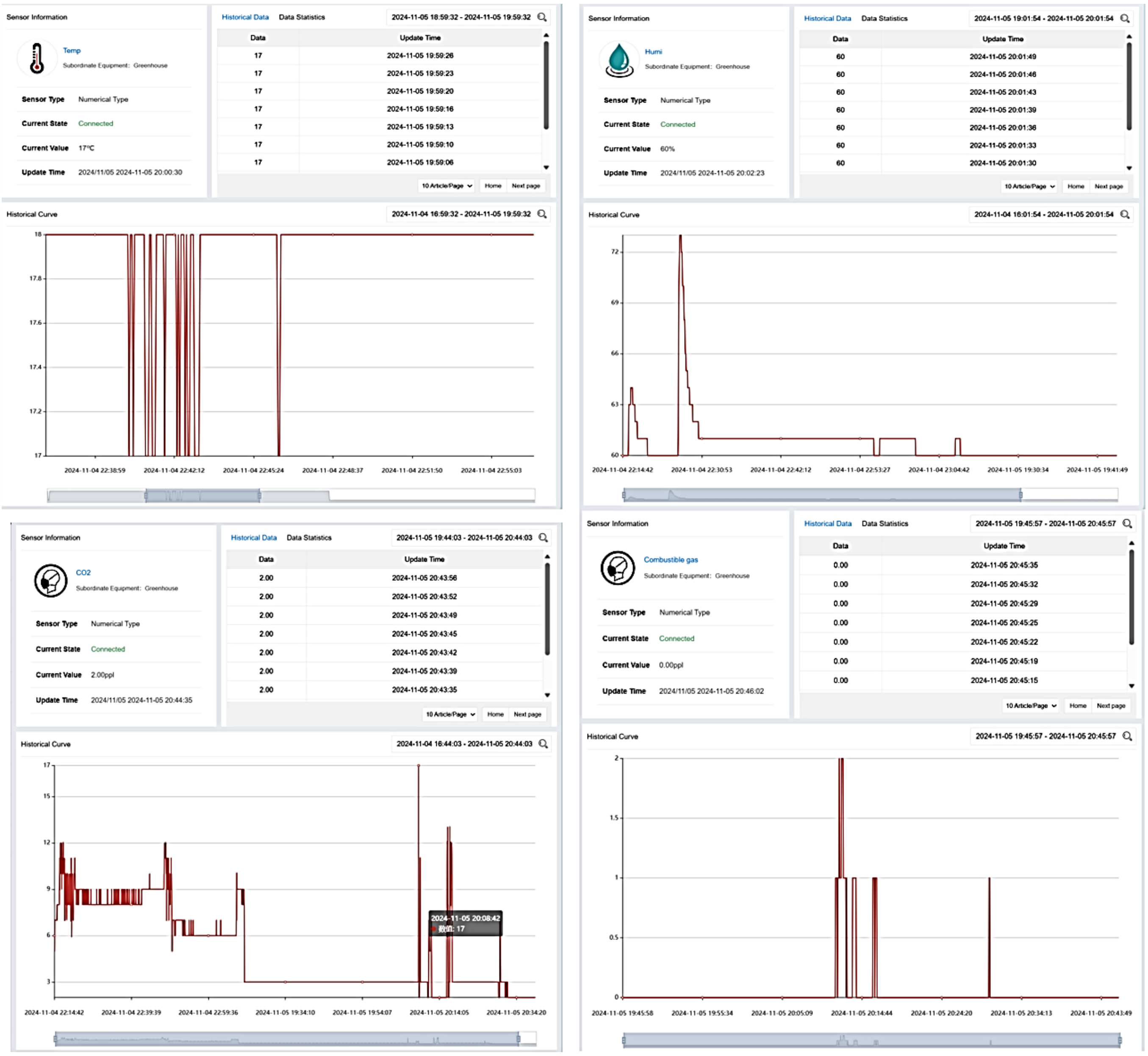
Figure 21. TLINK's web and mobile app interface can view collected real-time and historical data.

Figure 22 shows TLINK's data visualisation interface automatically draws a data line chart with data points every 3 seconds. Historical data can be retrieved with one click, and historical data files can be exported by entering historical data on the mobile phone APP. In addition, the various modules used in the design system to replace industrial sensor modules greatly reduce the cost required for the construction of smart agriculture. Table 5 shows the cost comparison between traditional industrial sensors and module circuits of this design system. The integrated design nodes of the system modules make it easier to expand the system acquisition and bring better economic benefits to users.

An industrial temperature and humidity sensor requires MYR51, while a DHT11 temperature and humidity sensor only requires MYR3. In addition, a router can connect up to 64 nodes of this design system, and the node uploading data does not require high router speed, which greatly saves users the cost of building this design system.

Table 5. Comparison of circuit costs of traditional industrial sensors and TLINK smart agriculture management system modules

Industrial sensor name	**Temperature and humidity sensor**	**GPRS**	
Cost Unit Price	MYR51	MYR50	
Smart agriculture management system module circuit name	DHT11 Temperature and Humidity Sensor	ESP8266	Router
Cost Unit Price	MYR3	MYR5	MYR90



Sensor Information

Temp
Subordinate Equipment: Greenhouse

Sensor Type	Numerical Type
Current State	Connected
Current Value	17°C
Update Time	2024/11/05 2024-11-05 20:00:30

2024-11-05 18:59:32 - 2024-11-05 19:59:32

Data	Update Time
17	2024-11-05 19:59:26
17	2024-11-05 19:59:23
17	2024-11-05 19:59:20
17	2024-11-05 19:59:16
17	2024-11-05 19:59:13
17	2024-11-05 19:59:10
17	2024-11-05 19:59:06

Sensor Information

Humi
Subordinate Equipment: Greenhouse

Sensor Type	Numerical Type
Current State	Connected
Current Value	60%
Update Time	2024/11/05 2024-11-05 20:02:23

2024-11-05 19:01:54 - 2024-11-05 20:01:54

Data	Update Time
60	2024-11-05 20:01:49
60	2024-11-05 20:01:46
60	2024-11-05 20:01:43
60	2024-11-05 20:01:39
60	2024-11-05 20:01:36
60	2024-11-05 20:01:33
60	2024-11-05 20:01:30

Sensor Information

CO2
Subordinate Equipment: Greenhouse

Sensor Type	Numerical Type
Current State	Connected
Current Value	2.00ppl
Update Time	2024/11/05 2024-11-05 20:44:35

2024-11-05 19:44:03 - 2024-11-05 20:44:03

Data	Update Time
2.00	2024-11-05 20:43:56
2.00	2024-11-05 20:43:52
2.00	2024-11-05 20:43:49
2.00	2024-11-05 20:43:45
2.00	2024-11-05 20:43:42
2.00	2024-11-05 20:43:39
2.00	2024-11-05 20:43:35

Sensor Information

Combustible gas
Subordinate Equipment: Greenhouse

Sensor Type	Numerical Type
Current State	Connected
Current Value	0.00ppl
Update Time	2024/11/05 2024-11-05 20:46:02

2024-11-05 19:45:57 - 2024-11-05 20:45:57

Data	Update Time
0.00	2024-11-05 20:45:35
0.00	2024-11-05 20:45:32
0.00	2024-11-05 20:45:29
0.00	2024-11-05 20:45:25
0.00	2024-11-05 20:45:22
0.00	2024-11-05 20:45:19
0.00	2024-11-05 20:45:15

Figure 22. Historical data collected by the system

The data transmission performance of the smart agriculture management system is shown in Figure 23. The data is updated every 3 seconds between 2024-11-05 19:24:00 and 2024-11-05 23:11:00. There are 5740 data points in this period. The line graph below shows no data breakpoints, and the system runs stably.

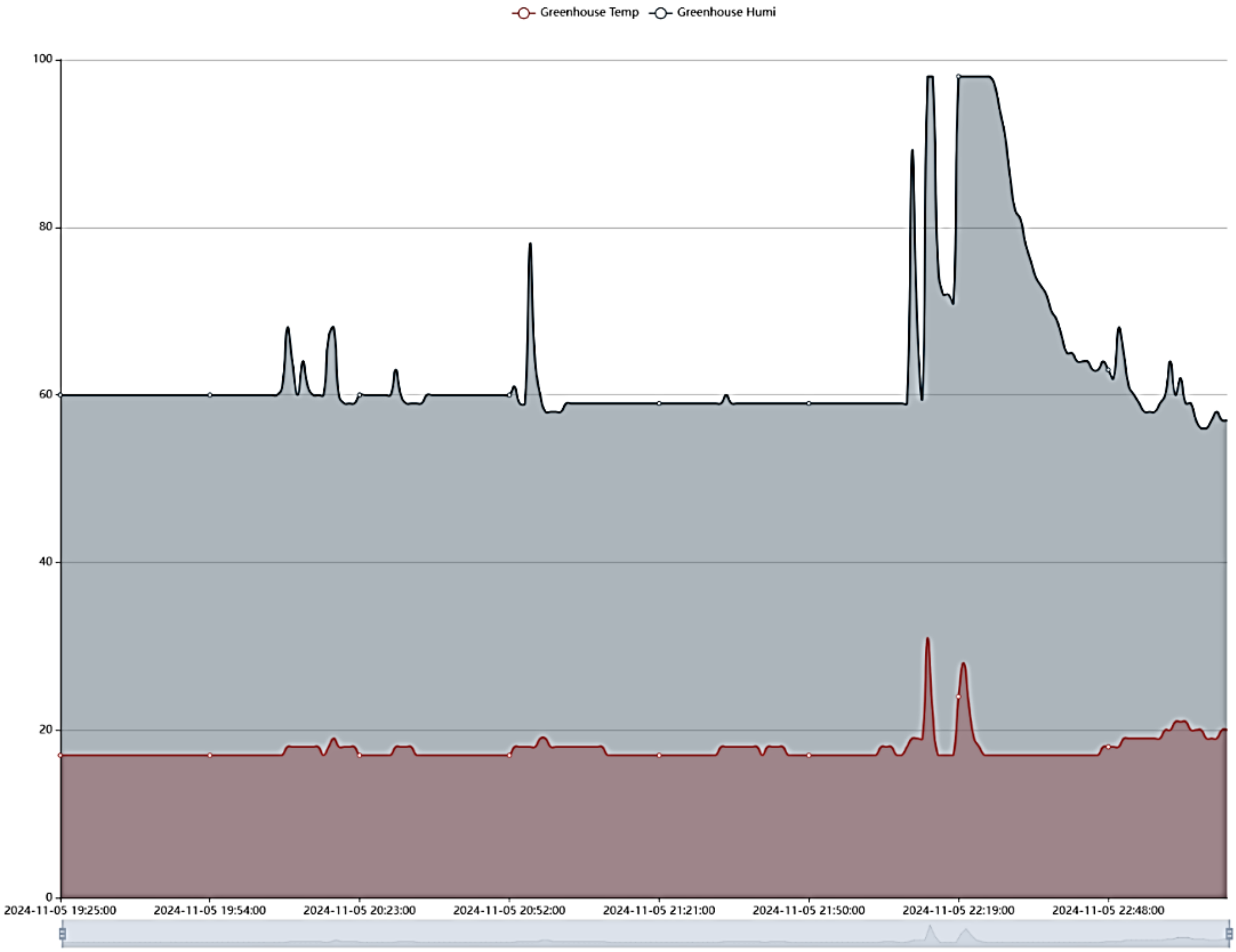


Figure 23. Temperature and humidity data line chart between 2024-11-05 19:24:00 - 2024-11-05 23:11:00

5. Conclusion

This study mainly designs a smart agricultural management system based on TLINK. Through experimental verification, it is found that the system can realise the relevant functions of agricultural environment monitoring and control. The design uses low-cost ESP8266 for data transmission and STM32F103C8T6 for data processing. It integrates a powerful TLINK cloud platform with a mobile phone APP and Web data visualisation interface to simplify user login and device binding. The system realises information collection and control from sensors to the cloud and the user end, focusing on simplicity, cost-effectiveness, and stability. The system is developed based on the Arduino platform. Through a tailored acquisition program and WIFI configuration through SmartConfig, it can significantly shorten the development cycle while efficiently managing sensor data.

The system integrates various cheap sensor circuits into one piece, replacing traditional expensive industrial sensors to facilitate the layout of large agricultural environments. The sensors store data (such as temperature, humidity, and CO_2 concentration) in the TLINK cloud, which is convenient for retrieving and viewing historical data. The design is streamlined and effective. It can reconnect within three seconds after the WIFI is disconnected to ensure the continuity of data collection. At the application layer, the TLINK clou2d platform provides support for the control interface of the smart agriculture information collection system, which can be monitored online via PC and remotely controlled via mobile phone applications. The system records and monitors greenhouse environmental parameters without data loss or anomalies. The user interface supports real-time monitoring, historical data visualisation, local data file output, and data management. The solution emphasises low-cost hardware, rapid development, and user-centered design. The integrated and modular design makes it a practical choice for DIY IoT smart agriculture systems, reducing costs and increasing economic benefits for users in building smart agriculture.

Declaration of Competing Interest: The authors declare they have no known competing interests.

References

[1] A. Soussi, E. Zero, R. Sacile, D. Trinchero, and M. Fossa, "Smart Sensors and Smart Data for Precision Agriculture: A Review," *Sensors,* vol. 24, no. 8, p. 2647, 2024.

[2] M. S. Farooq, S. Riaz, A. Abid, K. Abid, and M. A. Naeem, "A Survey on the Role of IoT in Agriculture for the Implementation of Smart Farming," *Ieee Access,* vol. 7, pp. 156237-156271, 2019.

[3] M. Ayaz, M. Ammad-Uddin, Z. Sharif, A. Mansour, and E.-H. M. Aggoune, "Internet-of-Things (IoT)-based smart agriculture: Toward making the fields talk," *IEEE access,* vol. 7, pp. 129551-129583, 2019.

[4] P. Kumar *et al.*, "Role of artificial intelligence, sensor technology, big data in agriculture: next-generation farming," in *Bioinformatics in agriculture*: Elsevier, 2022, pp. 625-639.

[5] Y. Lan, S. J. Thomson, Y. Huang, W. C. Hoffmann, and H. Zhang, "Current status and future directions of precision aerial application for site-specific crop management in the USA," *Computers and electronics in agriculture,* vol. 74, no. 1, pp. 34-38, 2010.

[6] B. Kasenzu, "Role of Precision Agriculture Technologies in Enhancing Farm Productivity in Kenya," *American Journal of Agriculture,* vol. 6, no. 2, pp. 1-12, 2024.

[7] R. K. Sidhu, R. Kumar, P. S. Rana, and M. Jat, "Automation in drip irrigation for enhancing water use efficiency in cereal systems of South Asia: Status and prospects," *Advances in agronomy,* vol. 167, pp. 247-300, 2021.

[8] A. Monteiro and S. Santos, "Sustainable approach to weed management: The role of precision weed management," *Agronomy,* vol. 12, no. 1, p. 118, 2022.

[9] M. A. Muhammad, Y. Panuju, H. Prayitno, R. A. Pradipta, and G. I. Akbar, "Internet of Things Ultraviolet Sterilizer Receiver Box: How to Design and Construct?," *International Journal of Electronics and Communications System,* vol. 1, no. 2, 2021.

[10] S. S. Shareef and H. L. Rauf, "Integrating Internet of Things Technologies for Dynamic Sustainability in Architectural Design," *Emerging Technologies and Engineering Journal,* vol. 1, no. 1, pp. 26-42, 2024.

[11] L. De Nardis, A. Mohammadpour, G. Caso, U. Ali, and M.-G. Di Benedetto, "Internet of things platforms for academic

Research and Development: A critical review," *Applied Sciences,* vol. 12, no. 4, p. 2172, 2022.

[12] M. Junaid *et al.*, "Smart agriculture cloud using AI based techniques," *Energies,* vol. 14, no. 16, p. 5129, 2021.

[13] E. Kapua. (2024, 06 November). *Eclipse Kapua Platform*. Available: https://projects.eclipse.org/projects/iot.kapua

[14] FIWARE. (2024, 12 January). *FIWARE*. Available: https://www.fiware.org/

[15] K. Project. (2024, 06 November). *Kaa 0.10 Open Source Platform*. Available: https://www.kaaiot.com/kaa-open-source

[16] Lelylan. (2024, 06 November). *Lelylan. Open Source Internet of Things*. Available: https://github.com/lelylan/lelylan

[17] Macchina.io. (2024, 06 November). *Macchina. io—IoT Edge Device Software Development and Secure Remote Access Solutions*. Available: https://macchina.io/index.html

[18] OpenMTC. (2024, 06 November). *OpenMTC*. Available: http://www.open-mtc.org/

[19] TLINK.io. (2024, 06 November). *TLINK.io Tutorial*. Available: https://www.tlink.io/help.htm?menu=2

[20] M. S. Mekala and P. Viswanathan, "A Survey: Smart agriculture IoT with cloud computing," in *2017 international conference on microelectronic devices, circuits and systems (ICMDCS)*, 2017, pp. 1-7: IEEE.

[21] Z. Xu, W. Wu, Y. Cai, X. Liu, and Y. Jiang, " A New Wearable Brace Monitoring Multiple Physiological Parameters Based on the Nb-Iot Technique," *Journal of Mechanics in Medicine and Biology,* vol. 22, no. 08, p. 2240041, 2022.

[22] X. Zhao, B. Li, L. Zhang, Y. Wang, Y. Zhang, and R. Chen, "FPGA implementation of high-efficiency ECC point multiplication circuit," *Electronics,* vol. 10, no. 11, p. 1252, 2021.

[23] A. H. Ali, R. F. Chisab, and M. J. Mnati, "A smart monitoring and controlling for agricultural pumps using LoRa IOT technology," *Indonesian Journal of Electrical Engineering and Computer Science,* vol. 13, no. 1, pp. 286-292, 2019.

[24] G. Dinesh, A. K. Gupta, M. Nagaseshireddy, P. D. Prasanna, M. S. Varshini, and K. Gowtham, "LoRa-Powered Smart Agriculture System for Monitoring and Controlling," in *2024 IEEE Wireless Antenna and Microwave Symposium (WAMS),* 2024, pp. 1-6: IEEE.

[25] K. Elhattab and K. Abouelmehdi, "Intelligent agriculture system using low energy and based on the use of the internet of things," *Bulletin of Electrical Engineering and Informatics,* vol. 13, no. 2, pp. 1286-1297, 2024.

[26] L. Niu, "Design of intelligent agricultural environmental big data collection system based on ZigBee and NB-IoT," in *2023 IEEE 2nd International Conference on Electrical Engineering, Big Data and Algorithms (EEBDA)*, 2023, pp. 1299-1304: IEEE.

[27] İ. Ünal, "Integration of ZigBee based GPS receiver to CAN network for precision farming applications," *Peer-to-Peer Networking and Applications,* vol. 13, no. 5, pp. 1394-1405, 2020.

[28] M. A. J. Hidayat and A. Z. Amrullah, "Sistem kontrol dan monitoring tanaman hidroponik berbasis Internet of things (IoT) menggunakan NodeMCU ESP32," *Jurnal Saintekom: Sains, Teknologi, Komputer Dan Manajemen,* vol. 12, no. 1, pp. 23-32, 2022.

[29] T. Sutikno, A. N. Wahyudi, T. Wahono, W. Arsadiando, and H. S. Purnama, "Smart irrigation system using node microcontroller unit ESP8266 and Ubidots cloud platform," *Computer Science and Information Technologies,* vol. 5, no. 2, pp. 168-175, 2024.

[30] A. A. Abd Halim, R. Mohamad, F. Y. A. Rahman, H. Harun, and N. M. Anas, "IoT based smart irrigation, control, and monitoring system for chilli plants using NodeMCU-ESP8266," *Bulletin of Electrical Engineering and Informatics,* vol. 12, no. 5, pp. 3053-3060, 2023.

[31] A. Buxoo and A. P. Murdan, "A Smart Approach to Parking Management using LoRa Communication," in *2024 1st International Conference on Smart Energy Systems and Artificial Intelligence (SESAI)*, 2024, pp. 1-6: IEEE.

[32] M. S. A. Alrubaye, A. As'arry, M. A. Azman, M. Z. M. Yusoff, K. A. M. Rezali, and A. Zolfagharian, "Monitoring and Prediction of Air Quality System using Internet of Things (IoT)," *Journal of Advanced Research in Applied Sciences and Engineering Technology,* vol. 48, no. 1, pp. 61-76, 2024.

[33] N. S. Mohammed and N. H. Selman, "Home energy management and monitoring using ubidots platform," *Al-Furat*

Journal of Innovations in Electronics and Computer Engineering, vol. 1, no. 3, pp. 14 - 21, 2023.

[34] A. K. Singh, "Smart Farming: Applications of IoT in Agriculture," in *Handbook of Smart Materials, Technologies, and Devices: Applications of Industry 4.0*: Springer, 2022, pp. 1655-1687.

[35] A. A. Rahim, R. Mohamad, N. I. Shuhaimi, and W. C. Buclatin, "Real-time soil monitoring and irrigation system for taro yam cultivation," *Indonesian Journal of Electrical Engineering and Computer Science,* vol. 32, no. 2, pp. 1042-1049, 2023.

[36] S. Çeven, E. Küçükkülahli, A. Albayrak, and Y. Biçen, "Development of IoT Based Battery Management System," in *2021 2nd International Informatics and Software Engineering Conference (IISEC)*, 2021, pp. 1-5: IEEE.

[37] L. Meili and B. Yankang, "Embedded automatic control system for temperature, humidity and light intensity in agricultural greenhouses," in *Proceedings of the 2nd International Symposium on Computer Science and Intelligent Control*, 2018, pp. 1-5.