Intelligent Temperature Control System Based on Cloud Platform

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***Abstract*—The design of this project starts from the Internet of Things technology, integrating short-range wireless communication with network wireless communication technology. Starting from sensor technology, wireless communication technology, and cloud platform technology, an intelligent temperature control system based on cloud platform is proposed. The system consists of an indoor temperature control terminal and an outdoor window household terminal. The two ends are wireless networked through ZigBee modules, and the temperature control terminal is network through WiFi modules to achieve single device networking and control of non networked devices. CC2530 is used as the main control chip at both ends to control temperature monitoring, smoke alarm, gateway control mode, automatic control, device linkage, data cloud command issuance, and other functions.**

Keywords—ZigBee: Intelligent temperature control; OneNet; Equipment linkage; Gateway control mode

I. INTRODUCTION

With the development of society and the advancement of technology, people's quality of life continues to improve. Temperature control devices, as an essential part of indoor environments with unstable and uncomfortable temperatures, are not only used in households, but also have a wide range of applications in industry, communication, and medical fields. Therefore, the requirements for the intelligence and informatization of temperature control systems are gradually increasing, and the flexibility of control, the convenience and diversity of information feedback, and the addition of monitoring information need to be further improved.

Under the background of country's vigorous development of new infrastructure, with the development of communication technology and the demand for diversified equipment control methods[1], system linkage has become the development trend of IoT devices.

Some domestic enterprises or institutions have developed products or solutions for smart home linkage. The greenhouse temperature control system based on single-chip micro-controller and Zigbee[2], which realizes the detection and control of N greenhouses. And a smart aquaculture environment monitoring system based on ZigBee and cloud platform[3], which can upload aquaculture environment data and achieve real-time detection and management. There is also a mountain road natural disaster monitoring system based on ZigBee[4], which uses heterogeneous networking and MQTT protocol[5] to prevent disasters in advance. A research team from the University of California, Berkeley has developed a deep learning based smart home control system that can automatically adjust devices such as lighting, temperature, music, etc. based on user behavior and preferences, and provide personalized suggestions and services.

The linkage of IoT devices has broad application prospects, such as combining with artificial intelligence to create more intelligent IoT systems[6]. At present, China has made certain progress in the linkage of the Internet of Things, but there are still some problems and challenges, such as security, standardization, interoperability[7], etc. In the future, with the gradual maturity and popularization of technologies such as the Internet of Things and 5G[8][9], as well as the increasing demand and awareness of smart living among consumers[10], smart home linkage will face more opportunities and challenges, requiring continuous innovation and optimization[11].

This design develop an intelligent temperature control system that combines the temperature control end and the window end. We plan to adopt this intelligent temperature control system by linking the temperature control end and the window end, which can automatically adjust the air conditioning switch, as well as the window switch, angle, etc. according to indoor temperature, humidity, air quality and other conditions. For users, they can view indoor and outdoor temperatures in real-time through a mobile app and manually control the device. From a safety perspective, it can monitor indoor smoke and hazardous gas conditions in real time. When smoke and other fire risks or toxic gases are detected, windows can be opened for ventilation and an alarm can be triggered to achieve early warning and response, reducing the risk of casualties and expansion.

II. System Hardware Design

A. Hardware architecture design

In this work, hardware mainly starts from control systems, environmental data collection, IoT platforms, wireless network and automatic control. Using CC2530F256 as the main control core, environmental data is collected through temperature and humidity modules, gas monitoring modules, and raindrop sensor modules; Control the air conditioning and windows through servos and brushless motors. The overall control mode realizes manual control, automatic control, and remote control, which can meet the control requirements in various situations.

Figure 1 is the architecture diagram of the system hardware, Figure 2 is the actual hardware diagram of the temperature control end and window end.

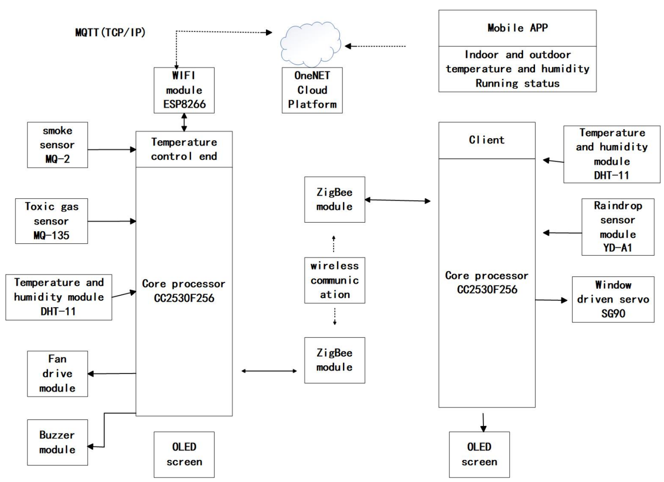

Fig. 1. System Hardware Architecture

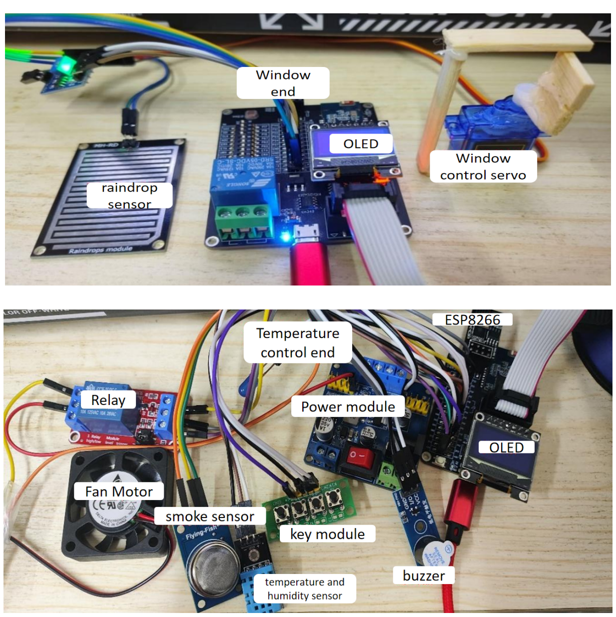

Fig. 2. Figure of temperature control hardware for both side

B. Design of various hardware module components

1) Control System Design

The intelligent temperature control system in this design uses CC2530F256 as the main control core at both ends. In this system, CC2530 is used as the core controller for initialization control of IO ports, wireless point-to-point communication, and implementation of various functions.

The temperature control end and window end of this system both use ZigBee development boards for networking and wireless transmission and reception functions. The ZigBee module on the temperature control end is used to receive outdoor temperature, humidity, and window switch status sent from the window end, and send control instructions to the window end; The ZigBee module on the window side is used to send outdoor temperature and humidity, as well as window status, to the temperature control end while receiving instructions from the temperature control end.

2) Raindrop Detection Module

In this system, the raindrop sensor is connected to the P1_2 port at the window end, and the servo is connected to the P1-0 pin of the micro-controller timer 1 channel 2. It is designed to output a digital signal through the raindrop detection module. When the rainfall exceeds the set threshold, the window will automatically close.

3) Temperature and Humidity acquisition module

The temperature and humidity acquisition module consists of two DHT11 temperature and humidity sensors and a fan motor. It is paired with a microcontroller through a specific protocol, and after pairing, it sends a high level to represent data 0 and 1, and outputs temperature and humidity digital signals.

In this system, two sensors are located at the temperature control end and the window end respectively. The temperature and humidity sensors on the temperature control end are used to collect indoor temperature and humidity, while the temperature and humidity sensors on the window end are used to collect outdoor temperature and humidity.

4) Smoke Detection Module

In this module, the MQ-7 smoke sensor is used to detect smoke information in the environment. When the smoke concentration is too high, the active buzzer will be activated with a high level to generate an alarm. At the same time, the system will open the window servo, start the fan motor, and upload the alarm to the cloud platform.

5) Window Driver Module

The window drive module consists of an SG90 servo and a relay. In this system, the SG90 servo is used to open and close the windows. The servo signal receiver is connected to the P1-0 pin on the window side, and a timer is used to output PWM waves. The output angle is set through pulse signals of different widths. When the window side receives temperature control or manual control instructions, it will perform the corresponding window opening/closing operation.

6) WiFi module design

This system connects devices to the internet through the ESP8266 WiFi module. It is connected to the temperature control terminal, and AT commands are sent and messages are received through the serial port 0 of the temperature control terminal.

The function of the WiFi module is to connect the temperature control terminal to the network, which is used to upload indoor and outdoor temperature and humidity, as well as the operating status of windows and fans to the cloud platform. At the same time, it receives instructions issued by the cloud platform and sends them back to the micro controller for instruction processing.

III. System Software Design

A. Software architecture design

The system program is written in C language to initialize the pins of each module. First connecting the I/O ports of each module to initialize settings, Interrupt service functions such as serial port interruption. Then set key interruption to switch OLED screen display. ADC sampling monitors rainfall levels, smoke and toxic gas concentrations. Control the switch of the window motor through timer output. Using SPI to drive OLED screens to control the display content of OLED screens, and displaying Chinese, images, and special symbols by importing a font library. Set millisecond delay at 32MHz clock; The functions of each functional module are separately written in the functional function for easy modification and debugging, referenced in the main function, and designed with different priorities for each function to ensure that the system prioritizes handling emergency situations and special situations, enabling the system to operate stably and achieve the expected functions; In the temperature control end, use the serial port UART0 to send AT commands to the WiFi networking module to connect it to the cloud platform, and set the format message to achieve data upload to the cloud platform. At the same time, use the serial port UART0 to receive the instructions received by the ESP8266 module, and recognize and run the instructions through programming. If a window closing instruction is received, the temperature control end will send the window closing instruction to the window end through ZigBee, and the window will be closed.

B. Design of ZigBee Wireless Communication Function Subroutine

The temperature control end and the window end communicate with each other through ZigBee wireless communication function. The window end will send the temperature, humidity, and window status of the window end to the temperature control end within each set time interval. All information is stored in an array, which only needs to be sent to the temperature control end and extracted. When the window receives an instruction, it performs the operation of opening/closing the window. The temperature control end receives outdoor temperature, humidity, and window status from the window end through ZigBee, and sends an open/close window command to the window end upon receiving the command.

C. Data upload and instruction issuance

The data upload and command issuance function subroutine is implemented through the ESP8266 module. In the program, AT commands are sent to the ESP8266 through the CC2530 serial port UART0. Simply modify the WiFi name and password connected to the WiFi module in the program, connect the ESP8266 to the internet, burn the MQTT firmware of the OneNET cloud platform into the WiFi module, and set the corresponding TOKEN and connection properties through the AT command to connect to the OneNET cloud platform. After collecting all data on the temperature control end, including indoor and outdoor temperature and humidity, smoke concentration, toxic gas concentration, fan operation status, and window operation status, all data is uploaded to the cloud platform. The cloud platform synchronizes the data to the mobile APP through the MQTT protocol, thus achieving data upload.

There are two ways to issue commands: cloud platform command issuance and APP control. The cloud platform sends command packets as soon as the command is issued. After receiving the command, ESP8266 sends it to CC2530 through the serial port for parsing, processing, and corresponding operations. APP control is achieved through the MQTT subscription function, using the APP to send command packets. The MQTT subscription data is synchronized to ESP8266, which receives the command and sends it to CC2530 through the serial port for parsing, processing, and corresponding operations.

The flowchart of da the ta upload and instruction issuance program is shown in Figure 3.

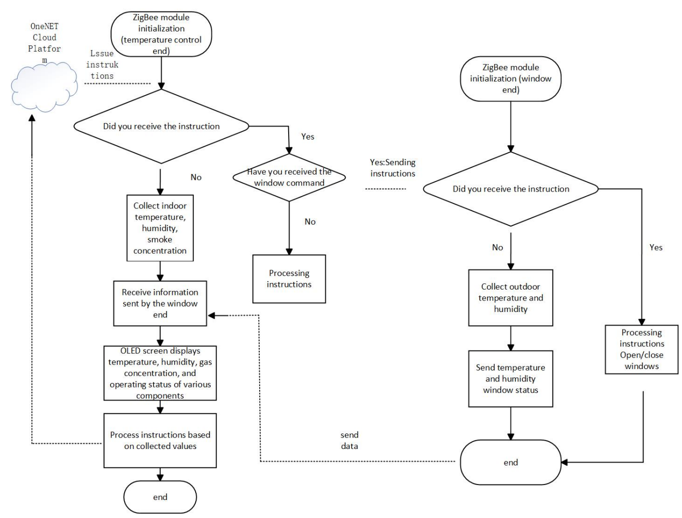

Fig. 3. Flow Chart for Data Upload and Instruction Issuance

IV. Functional Testing and Implementation

By setting temperature values and handling various abnormal situations, automatic control of the system is achieved, which includes temperature and humidity monitoring control, smoke monitoring and alarm control, and raindrop detection control. The priority is divided into smoke monitoring and alarm control > raindrop detection control > temperature and humidity monitoring control.

A. Temperature and humidity monitoring and control function

By using temperature and humidity sensors to collect temperature and humidity data, the output digital signals are converted into temperature and humidity values and sent to the computer. The detected values are correct, and then the temperature and humidity are displayed through OLED. Automatic temperature control, by setting the expected temperature value, the temperature control end combines the collected indoor and outdoor temperatures, and intelligently adjusts them through temperature control devices and window switches to reach the set temperature value. For example, when the indoor temperature is greater than the set value and the outdoor temperature is greater than the indoor temperature, the fan will be started to cool down and the windows will be closed to ensure stable indoor temperature.

B. Smoke monitoring and alarm function

Smoke monitoring and control mainly involves monitoring indoor temperature and concentration through smoke sensors, and displaying the collected values on OLED screens. Firstly, observe the smoke concentration and toxic gas concentration under normal conditions and the smoke concentration and toxic gas concentration under the condition of burning objects or containing toxic gases. Compare the simulated signal values and set a threshold for smoke concentration. When the smoke concentration exceeds the threshold, the system will open the window and start the fan to disperse harmful gases, ensuring air circulation and personal safety in dangerous situations. The following Table I shows a testing process during the smoke collection function test.

TABLE I. SMOKE COLLECTION TEST PROCESS

Collection times	**smoke sensor concentration (%)**	**alarm status**	**window status**	**Fan status (on/off)**
1^{st}	12%	no alarm	turn off	turn off
2^{nd}	33%	no alarm	closed	closed
3^{rd}	72%	alarm	activated	activated
4^{th}	86%	alarm	on	on
5^{th}	99%	alarm	closed	closed
6^{th}	65%	no alarm	open	open
7^{th}	53%	no alarm	turned on	turned on

C. Raindrop detection and control function

Rainwater detection control, which detects rainfall through a raindrop sensor, continuously adjusts the number of water droplets on the raindrop sensing pad to find the rainfall threshold when it rains. In the program, when the rainfall exceeds the threshold, the system will close the windows to prevent rainwater from entering the room, ensure indoor dryness, and prevent items from getting wet. Thus, automatic control processing under rainy conditions has been completed.

D. Data upload OneNet platform

Use ESP8266 module to view the firmware required for OneNet, burn the required firmware for OneNET and MQTT protocol into ESP8266 module, and then add devices to OneNet. ESP8266 displays online, as shown in Figure 4.

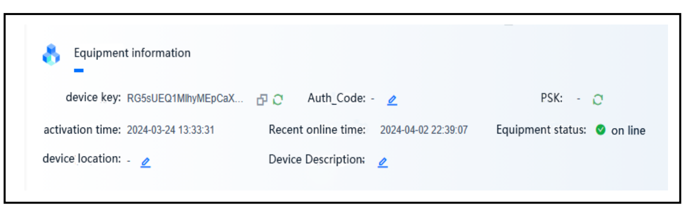

Fig. 4. ESP8266 successfully connected to OneNET cloud platform

After successful upload, the uploaded data can be observed on the OneNET platform. The cloud platform receives data shown as in Figure 5,

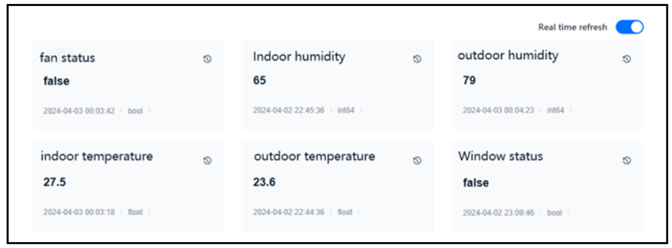

Fig. 5. Upload data to OneNET cloud platform

After receiving the instructions, the microcontroller will parse and execute the corresponding processing.

V. CONCLUSION

This article analyzes and studies the background and current situation of the application of IoT device linkage control in current intelligent temperature control systems. In order to solve the problems of manual window closing and gas leakage in closed environments in various scenarios, a cloud based intelligent temperature control system is proposed. Compared with traditional smart air conditioners and smart windows, the innovation of this design lies in linking temperature control devices with windows. By simply networking the temperature control devices, multiple windows that are not connected to the network can be controlled, making the control more flexible and personalized. It can be used in various scenarios, such as opening the air conditioner in advance and automatically closing the windows when no one is at home; Activate central air conditioning in large buildings and automatically control all windows to close; At the same time, it can monitor and warn of harmful gases and automatically handle them. When harmful gases are detected, ventilation can be activated and windows can be opened.

ACKNOWLEDGMENT

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REFERENCES

[1] Huang Xiaobin. A Multi-functional Smart Home Control System Based on STM32 Microcontroller [D]. Xidian University, 2022.

[2] Chen Muze. Research and Implementation of a Smart Home Central Control System Based on OneNET Cloud Platform and AI [D]. Yangzhou University, 2024.

[3] Qin, Kai. Design and Implementation of a Wireless Smart Home System Based on IoT Technology [D]. Zhejiang University of Science and Technology, 2024.

[4] Yao, Zipeng. Research on Temperature Control System for Greenhouse Based on the Integration of Single-Chip Microcomputer and ZigBee Technology [J]. Modern Industrial Economy and Informationization, 2023, 13(03): 106-107+111.

[5] Xue, Hongmin, and Wang, Weizhuo. Design of an Intelligent Breeding Environment Monitoring System Based on ZigBee and Cloud Platform [J]. Modern Information Technology, 2022, 6(05): 164-167+171.

[6] Mu, Wenyang. Design of a Natural Disaster Monitoring System for Mountainous Highways Based on ZigBee-WiFi Technology [D]. Beijing Jiaotong University, 2023.

[7] Shih M L, Tsai L H, Tsai Y C. Design and Evaluation of Wireless DYU Air Box for Environment-Monitoring IoT System on Da-Yeh University Campus [J]. Applied Sciences, 2024,14 (5).

[8] Anees S A ,A A A S .Design of a smart hydroponics monitoring system using an ESP32 microcontroller and the Internet of Things. [J]. MethodsX, 2023,11 P102401-102401.

[9] Jain K R, Mukherjee A, Karmakar P, et al. Experimental performance of soil monitoring system using IoT technique for automatic drip irrigation [J]. International Journal of Communication Systems, 2023,36 (18).

[10] George R, Ioanna R. Low Power IoT Electronics in Precision Irrigation [J]. Smart Agricultural Technology,2023,5

[11] Chouhan S K, Moud R .Intelligent Security Monitoring System Using Zigbee [J]. Journal of Research in Science and Engineering,2023,5 (11).