IoT enabled Smart Lighting System using STM32 microcontroller with high performance ARM® Cortex®-M3 core

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***Abstract*: Green technology for economically viable engineering designs and sustainable environment is highly desirable for future smart city applications. An intelligent system for operating and controlling lighting in order to save energy is developed and presented in this article. The system is implemented on Alibaba Cloud IoT platform on STM32 development board using STM32 medium-density performing microcontroller with high performance ARM® Cortex®-M3 RISC core. It includes communication between wireless sensors and actuators, and control of light sources. The HC-SR501 human infrared sensor is also used for detecting people and BH170 photosensitive sensor for synthetic brightness detection. The system includes indicators to represent three orders of magnitude of temperature sensor reading. The system developed in this work also features (i) an OLED display unit enabling users to view sensed data easily and (ii) Web platform-based User Interface (dashboard) for allowing users to easily interact with the system. The overall system provides a practical and interactive solution for data visualization and to remotely control light sources.**

Keywords: Alibaba Cloud IoT platform, STM32, Smart lighting, Wi-Fi module, MQTT

I. INTRODUCTION

Now that people have entered the Internet era, many traditional life devices have been eliminated one by one. In the future, traditional wired home devices will be gradually replaced by smart home systems integrated by the network. The smart home can connect various devices in the home through the Internet of Things technology to provide users with services such as lighting, home appliance control, anti-theft alarm, and environmental monitoring. Compared with ordinary households, smart homes can allow users to obtain more efficient and smart life experiences while retaining their original working habits. For example, the network communication function of smart homes allows users to detect the situation of the house thousands of miles away. (Power consumption, personnel situation, surrounding environment, etc.), and then perform remote control. Smart homes with machine learning functions can also provide users with an interactive experience, enable room facilities according to user habits, and plan a more comfortable and environmentally friendly life for users. However, this kind of smart home equipment is not popular in China. The design of this report is a smart lighting system included in the smart home. The entire system is designed to try and implement technologies that are not common in ordinary households in China. And to achieve energy saving and intelligent control of lighting and its intensity. In this project, a prototype was developed for simulation using model home.

II. RELATED WORKS

Wide variety of literature on IoT, cloud platform and wireless control suggests huge interest in these areas of research. In [1], safety of IoT smart home is discussed, and the components of a similar smart home system are introduced. Details about the network management of the Internet of Things platform and flexibility and security of the smart home system based on (full form of CPS) CPS are also given. Users are encouraged to use firewalls, use well-tested modules to access smart home networks, and allow developers to develop hardware such as routers to build bridges between home networks. In [2] and [3], the role of the LoRaWAN remote network control series has been discussed. Author proposed a solution that does not require Internet access and allows local IoT end nodes to be connected to the LoRaWAN gateway at low cost and low power consumption. The three building blocks (gateway, network server and application server) of the LoRaWAN architecture are implemented in a box based on Raspberry Pi and LoRaWAN modules. The Wi-Fi access point provides local access to application data, and even if there is no Internet access, community members can also access their community data. This article was also a source of inspiration towards the intelligent lighting system designed and presented in this article, followed the design of WIFI module, and used its technology to more conveniently and effectively connect to the corresponding Internet of Things platform [2]. For [3], the author discusses the AMI technology, IOT, and LoRa protocol together. According to the actual geographic information in Germany, the number of gateways to be arranged, and the packet loss rate, the LoRaWAN has the advantages of low consumption, high efficiency, and long-distance transmission. It cannot effectively support every IoT system. Therefore, in the production of smart homes, considering the actual work scope and practicality, the Loran protocol and LoRaWAN gateway are not the most preferred.

So far, we have abandoned LoRa technology and started to switch

to Wi-Fi modules and Alibaba Cloud platforms. In [4], Arduino-based controlled irrigation system design using a Wi-Fi module was introduced. The humidity sensor sends signals to the Arduino development board and sends notifications through the IoT platform. This usage is like the intelligent lighting system in this article. The system designed in this article is based on STM32, so it will be slightly different. The article briefly describes how to connect the sensor to the development board through the ESP8266 Wi-Fi module and how to connect it to the IoT system and read the data.

To study suitable protocols for connecting the system to the IoT cloud platform further investigation was done. In [5], the author presented a particularly important protocol in the Internet of Things access: MQTT. Explain the advantages of MQTT: open source, reliable, light and simple. It can be deployed with very few resources, can guarantee reliable and safe transmission of messages, supports real-time notification of messages, and can be easily integrated with enterprise applications. Low bandwidth, low energy consumption, low cost, small mobile application bandwidth, high bandwidth utilization, and low power consumption. The system can connect to the server on the Alibaba Cloud official website by filling in the server IP, port number, password and other information on the MQTT.fx-1.3.1 software [6]. On sensor connection learning, in [7], this article designs an intelligent road lighting system in the park. It uses the PIR function to allow Arduino to communicate wirelessly through the ZigBee protocol using the XBee module. When the PIR sensor detects the human body, it will turn on the corresponding lights and the previous and next lights connected to it. The lights at both ends of the road are always on to ensure that the user will not be left in the dark and indicate that the lights are present when the user approaches the road.

III. DESCRIPTION OF INTERNET OF THINGS

The Internet of Things (Internet of Things, IoT) is simply a network of things and things. Through sensors such as infrared sensors, biosensors, flow sensors and other information sensing equipment, according to the protocol selected by the manufacturer, any item is connected to the internet for information exchange and communication to achieve intelligent identification, positioning, tracking, monitoring and management. It is not difficult to see that the Internet of Things still operates on the Internet as the core, but on this basis, users can interact and exchange information between items. This highly interactive network connects people, servers, and items, allowing users to enjoy the services of the Internet of Things system at any time and place.

IV. DESCRIPTION OF MQTT PROTOCOL

MQTT is called Message Queuing Telemetry Transport. Is a "lightweight" messaging protocol based on the publish / subscribe paradigm issued by IBM. MQTT has the characteristics of low occupancy, low overhead, light weight and openness. Therefore, when the designed system hardware performance is poor or the network environment is bad, the MQTT protocol can fully play its role. MQTT is often used in the Internet of Things. To operate an IoT device, it must be connected to the Internet so that the devices can collaborate with each other and with back-end services. The basic network protocol of the Internet is TCP / IP, and the MQTT protocol is built based on the TCP / IP protocol stack. The MQTT protocol serves as the application layer and manages TCP as the transport layer. Therefore, the MQTT protocol has gradually formed a standard for IoT communication. When connecting, the MQTT server is usually a total of software or devices.

V. MATERIALS AND METHODS

These materials are needed throughout this design:

- An STM32 development board
- An OLED screen
- Four small LED used to indicate
- A PIR sensor
- A temperature Sensor
- A Light sensor
- A PWM driver
- A LED light board
- An ESP8266 Wi-Fi module
- Two switch buttons

The operation flowchart of the entire system is as follows:

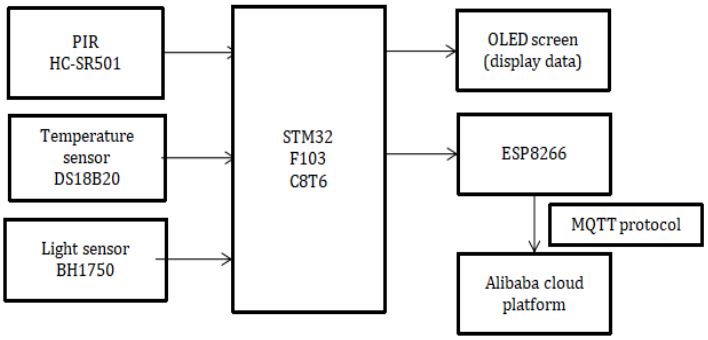

Fig. 1: System Architecture

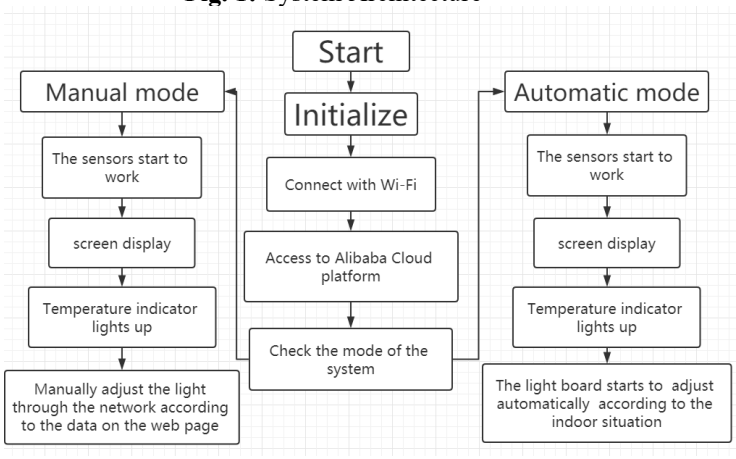

Fig. 2: System flowchart

VI. SYSTEM ANALYSIS

This is an IoT based intelligent lighting system implemented on the STM32 development board. Divided into manual and automatic mode. In manual mode, the system is connected to the Alibaba Cloud system through the Wi-Fi module, and can remotely detect data through the web page to perform active light brightness adjustment. In automatic mode, the system will adjust the temperature indication and the brightness of the lamp board according to the three sensors. Figure3 shows the schematic diagram of the system

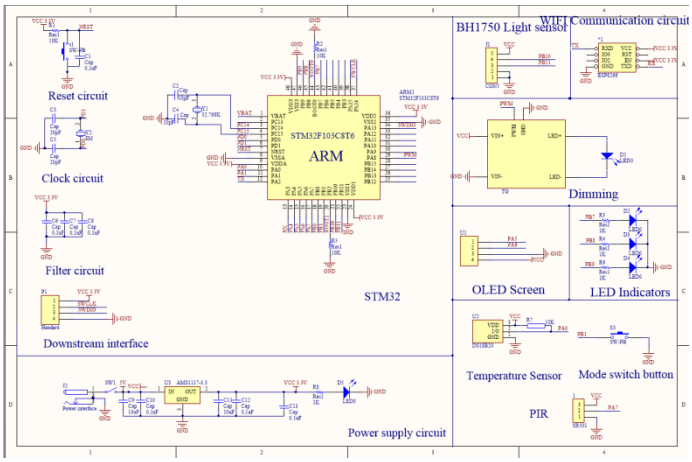

Fig. 3: Schematic diagram

STM32 part contains reset circuit, clock circuit, filter circuit and downstream interface. Power supply part contains power interface and U3 AMS1117-3.3 power supply clip. Sensor part contains sensors, Wi-Fi module, LED, buttons and OLED screen.

1. Microcontroller:

The STM32F103C8T6 selected here is used as the main control of the entire system and is programmed in C language under the environment of Keil. As the core of the entire system, STM32 is responsible for controlling each sensor and connecting it to the WIFI module. When Alibaba Cloud platform sends information back, it can also be responsible for receiving the corresponding instruction and controlling the driver to adjust the light. Figure 4 shows all the program header files in the entire project.

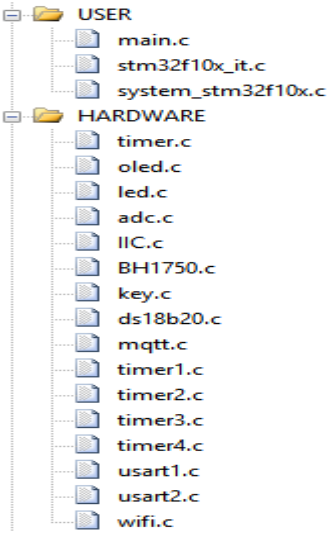

Fig. 4: Files in STM32

Main. C plays the core role as the main file (the detailed code will be shown in the appendix) and is responsible for calling all the following sub-files to make it work. Due to the use of MQTT protocol, in order to prevent disconnection, we need to use 4 timers to constantly send signals to the server. The OLED, LED, BH1750, KEY, DS18B20 files are all display, sensors and lighting hardware used throughout the system. The ADC file is used to convert the continuous signal in analog form to the discrete signal in digital form. The IIC file is an integrated circuit bus. Without it, various parts of the circuit will not work properly. The USART file is used for serial communication with the Wi-Fi module and sending data to Alibaba Cloud platform. The first file is used for connection debugging and the second is used to send data to the platform. The MQTT file is used to connect the hardware system to Alibaba Cloud platform. The code can be found on internet. We need to log in the correct product name and key in the file.

The logic of the entire system program is reflected in the MAIN file. Perform the detection mode first.

A. If it is in the automatic mode, PIR detects whether there are people in the room, and then judges whether to turn on the LED light board. The temperature sensor detects the room temperature. The indicator light is less than 15 ℃ for level 1, 15-25 ℃ for level 2, and more than 25 ℃ for level 3. The light sensor detects the indoor brightness to adjust the brightness of the lamp board.

B. If it is in manual mode, after connecting to the WIFI node, initialize the parameters of the sensor, module, serial communication, timer and MQTT server. USART 2communicates with the WIFI module to upload data to Alibaba Cloud platform. Four timers ensure the stability of sending and receiving file packets. In terms of remote control, the sending mail address controls the light board switch and brightness through the IIC protocol.

2. OLED Screen:

This screen is used to display the mode, temperature, indoor light intensity, and whether there are people present. By setting the display characters, the sensor data can be input to the corresponding position of the display to achieve the user-friendly viewing effect. The display is enabled in both modes.

3. All sensors and light:

These sensors play their role, respectively. PIR is used to detect the situation of the personnel; the temperature sensor is responsible for uploading temperature data and controlling the temperature indicator; the light sensor is used to upload the light intensity, and it plays the role of allowing the STM32 to read the data and send PWM waves to the driver to control the light.

4. ESP8266 Wi-Fi Module

The Wi-Fi module belongs to the Internet of Things transmission layer. Its function is to convert the serial port or TTL level to an embedded module that conforms to the Wi-Fi wireless network communication standard. The built-in wireless network protocol IEEE802.11b.gn protocol stack and TCP / IP protocol stack. The traditional hardware equipment embedded in the Wi-Fi module can directly use Wi-Fi to connect to the Internet, which is an important part of implementing wireless smart home, M2M and other Internet of Things applications.

5. Alibaba Cloud Platform

Alibaba Cloud platform is an open source open source Internet of Things platform. Connect the hardware to the platform through a protocol and log in to the product to manage and use it. Figure 5 shows the Alibaba Cloud main interface.

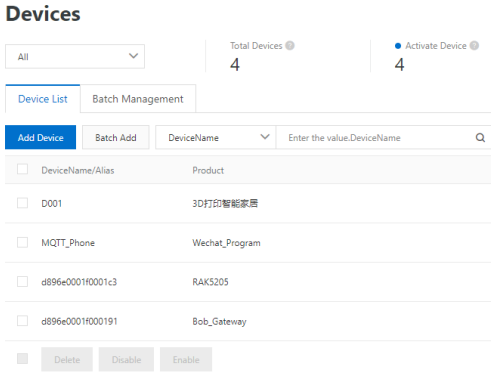

Fig. 5: Main Interface

Here show the components of this intelligent lighting system on the Alibaba Cloud platform

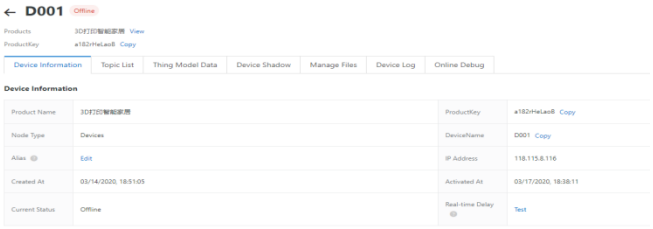

Figure 6 shows the product information of this smart home, including the previously applied product key and IP address.

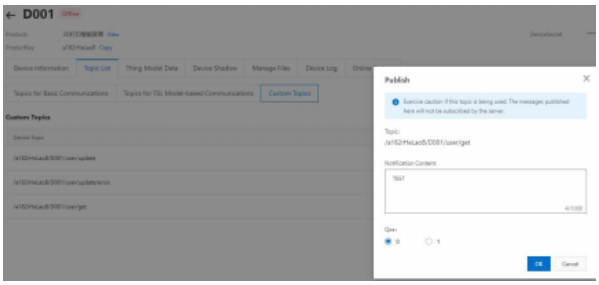

Figure 7 shows the TOPIC list. In the Internet of Things platform, messages are communicated between the server and the device through Topic. Topic is for the concept of equipment, and Topic is for the concept of products. The Topic category of the product will be automatically mapped to all the devices under the product to generate a specific device topic for message communication. The MQTT downlink communication test will use the information release function in the list.

VII. RESULT

Since the goal of the project is to design the physical hardware, it will be tested whether the function is realized when displaying the results. The prototype produced according to the schematic diagram is shown in Figure 8. The prototype contains all the above functions. As shown in the figure, the relevant data is displayed on the screen, the lamp board is lit, and the room temperature is 22.1 ° C, so the temperature indicator is the second level. After connecting to the Alibaba Cloud platform, the remote monitoring interface is shown in Figure 9. The entire interface allows users to remotely monitor the condition of the people in the room, room temperature and indoor brightness data in real time. Click the switch button below to turn the light on and off, then drag the progress bar to adjust the brightness of the light.

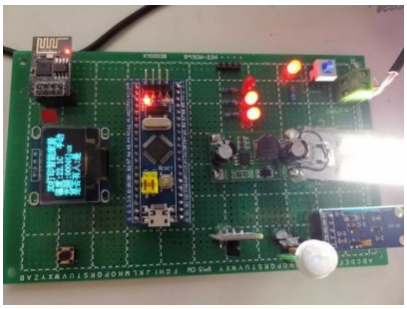

Fig. 8: Prototype machine

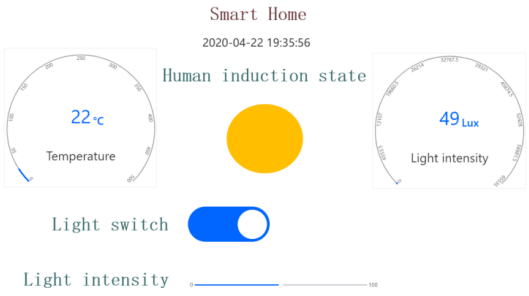

Fig. 9: The Control interface

VIII. CONCLUSION

We have developed an intelligent lighting system for the Internet of Things based on STM32. The system consists of the STM32 development board, ESP8266 Wi-Fi module, OLED screen, some sensors and LED lights. The sensor transmits the data to the Alibaba Cloud platform through ESP8266, which collects, displays, and adjusts the data. The system can be run in automatic or manual mode. The user can choose whether to manually adjust the lighting conditions through the web page wireless / remote, or let the sensor automatically adjust through the data on display. In the entire project, we first considered LoRa technology as the core of the entire smart lighting, and then, by comparison, we believe that the advantages of LoRa cannot be effectively played in the smart home project. Next, we chose to connect the Internet of Things through the Wi-Fi module and the MQTT protocol. In the experiment, we learned how to use STM32 to develop each sensor and how to connect it to the module. Next, we chose Alibaba Cloud platform, the most successful platform in China. Through learning how to use it, we finally achieved the operation of the entire system.

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