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A *wireless* network detection and control system for intelligent agricultural greenhouses based on NB-IOT technology

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Abstract. In order to reduce unnecessary labor input in agriculture and maximize production efficiency, a NB-IoT technology based wireless network detection system for intelligent agricultural greenhouse plants was designed. Through the emerging Internet of Things technology NB-IoT[1], the system can conduct remote real-time monitoring and intelligent control of the growing environment of crops in agricultural greenhouses[2]. In agricultural greenhouses layout based on stm32 microcontroller to shed internal environment parameters in a wireless sensor network for data acquisition, and then collected data through the I^2C[3]protocol to micro controller, the controller will receive the data transmission to the NB - IoT module, uploaded to the cloud, finally received by remote terminal and displayed to the user. Similarly, users can also remotely issue control commands to the microcontroller in the greenhouse through the terminal interactive interface, so as to realize the unmanned intelligent control of the environment in the greenhouse.

1. INTRODUCTION

Traditional mode of agricultural management is based on agricultural workers to cyclical growth environment of crops and crop growth conditions for artificial observation. In order to prevent the crop growth environment parameters appear unpredictable changing environment caused by production to reduce, farmers must invest a lot of time and energy to focus on the growth of crops. It makes the production efficiency low. The production potential of agricultural greenhouse has great room to improve.

With the rapid development of modern science and technology, the former farming mode with labor as the main productivity has been gradually replaced by modern science and technology, resulting in the unprecedented improvement of production efficiency. The manpower needed in agriculture is gradually reduced, and the productivity has been greatly released. But technology never stops. With the development of intelligent era, in order to be able to more optimize the mode of agricultural management, further improve the production efficiency, this paper proposed a wisdom agricultural greenhouses plant based on the technology of NB-IoT wireless network test system. It could achieve a remote on crops planting base of environmental parameters real-time monitoring, effectively to avoid the unnecessary loss of production and improve the efficiency of agricultural production.

2. SYSTEM SCHEME DESIGN

This paper designed an intelligent agricultural[4] greenhouse environment Internet of things real-time detection system based on STM32. The system is mainly divided into three hierarchical structures: system perception layer, wireless communication layer and application layer. The network topology model of the system is shown in Figure 1. The system perception layer is the fundamental part of the whole system, which is particularly important. The system perception layer is mainly composed of wireless sensor acquisition node network[5], including air temperature sensor, air humidity sensor, light sensor, soil moisture sensor. Each sensor node to the growth of agricultural greenhouse environment data for testing, and the transmission of data collected through a serial port to the microcontroller, micro controller to transmit data processing through a serial port to NB - IoT module, by NB - IoT upload data to the cloud server, end users can through the application software for farm in greenhouse environment parameters real-time monitoring. The main function of the wireless communication layer is to transmit the data collected by the wireless sensor network node to the cloud server and receive the data by PC terminal or mobile terminal. This system adopts the latest NB-IoT technology, which can realize the corresponding modules of telecom, Mobile and Unicom platform operators. Compared with the previous ZigBee Internet of Things technology, it has more access Numbers, and can realize simultaneous networking of a great number of different devices. At the same time, the price is low, the power consumption is very low, and the battery power can be used for many years, fully meeting the design requirements of agricultural greenhouse monitoring environmental system. The system framework structure is shown in Figure 1.
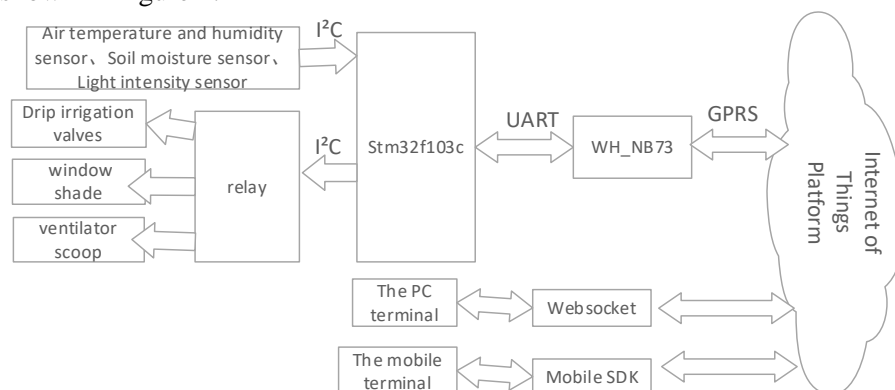

Figure 1 The system framework structure

The function of the application layer of the system is to store and analyze the data transmitted from the cloud server, and then make a reasonable decision and issue corresponding instructions for remote real-time monitoring of the environmental parameters of the agricultural greenhouses[6]. It mainly realizes the human-computer interaction process of the user's remote terminal. Considering the user's effective real-time monitoring of the agricultural greenhouse environment, this system not only provides the upper computer application on the PC end, but also provides the user with a convenient and fast WeChat small program application on the mobile end. Network topology model of the system as shown in Figure 2.
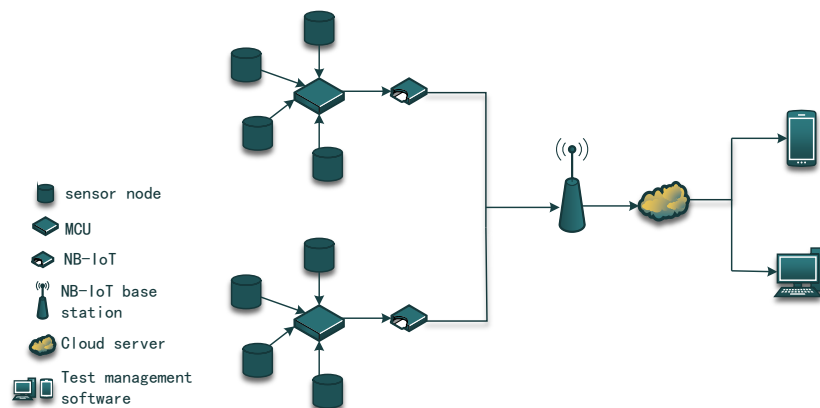
Figure 2 Network topology model of the system

3. HARDWARE DESIGN

3.1 Selection of main control chip

The MCU used in the system is the STM 32 microprocessor[7], and the 32-bit RISC core has a maximum 128-bit ADC, 3 universal 16-bit timers, 1 PWM timer, 2 IIC interfaces and SPI interfaces at the high performance @Cortex-M3 operating frequency of 72MHz. Built-in flash for up to 128K bytes and SRAM. A USART interface can fully meet the system design requirements of a USB interface and an interface.

3.2 Construction of wireless sensor network

The sensor used in the air temperature and humidity data acquisition module is the DHT11 sensor[8]. The DHT11 sensor is internally integrated with the calibrated digital signal output, temperature and humidity composite acquisition chip. It has temperature and humidity data acquisition capabilities and complete A/D conversion technology. Furthermore, it ensures that the temperature and humidity acquisition process can be more reliable and stable. The DHT11 sensor includes NTC temperature measuring element and resistance humidity sensing element. Compared with other temperature and humidity sensors, this sensor has faster response, stronger interference and more favorable price. therefore, DHT11 has a very high cost performance.

The power supply voltage of DHT11 sensor is 3.5V. The temperature measurement range is 0-50℃. The measurement accuracy is ±2. The humidity measurement range is 20-90% RH. The measurement accuracy is ±5% RH. DHT11 USES 4 rows of needles. The DHT 11 data pin adopts single bus mode, which is mainly used for the synchronization and communication between sensor and MCU. The communication data includes integer and decimal parts. DHT11 was initially driven for about 1s unstable time and was ordered not to be issued at this time. When the microprocessor sends a start signal to the sensor, the sensor stops the low power mode and starts the high speed mode. A response is sent when the start signal stops. When 40 bits of data are sent, the command to get the signal would be triggered. At this point, you can read that part of the data.

In this system, the GY-30 digital light intensity sensor is used to collect the light intensity data in the agricultural greenhouse. The BH1750FVI chip module is mainly used for internal components, mainly relying on 3-5V power supply voltage, and the light intensity range is 0-65535Lx. The 16-bit AD converter can be directly output, omitting complex calculations, and embedded in it. The GY-30 digital light intensity sensor does not distinguish environmental light sources and is close to the spectral characteristics of visual sensitivity[9]. Wide range of brightness can be measured with 1LX precision. NXP and IIC protocols are mainly used for data transmission. Internal modules include communication level conversion and can be connected to the MCU.

The soil moisture sensor module is used to collect soil moisture data. The corresponding threshold value can be adjusted and controlled by potentiometer to accurately control soil moisture. When

humidity is lower than the set value, D0 output is high level. When it is higher than the set value, D0 output is low level. LM393 comparator chip with stable operation state and 3.3V ~ 5V operation voltage is used, which is suitable for most MCU power supply. The rangefinder in the module can be used to adjust the soil moisture threshold. Clockwise adjustment will increase the humidity threshold. Counterclockwise adjustment will correspondingly reduce the humidity threshold. The digital output D0 is directly connected with the single-chip microcomputer to detect high and low levels of soil moisture through the single-chip microcomputer. The analog output A0 of the small module can be converted through the AD module to obtain more accurate soil moisture value.

3.3 Wireless communication module

In the choice of wireless communication module, mobile cellular network has more advantages than Bluetooth and ZigBee and other short example transmission. NB-IoT technology[10] has the advantage of strong coverage and wide mobility. Its application in smart agriculture system can greatly improve the portability of the system and improve the setting of distributed node data collection. The main reasons for considering NB-IoT are the following advantages. NB-IoT covers a wide area, with 20dB more gain than existing networks at the same frequency band, equivalent to 100 times the area covered. NB-IoT consumes very little power, and its terminal modules can last up to ten years. NB-IoT has the ability to provide extremely strong supporting connections, with up to 100,000 connections per sector. The NB-IOT module of this system is selected as WH-NB730 chip. The chip supports mobile, Unicom and Telecom NB-IOT network access, 2-channel TCP/UDP and 1-channel CoAP passthrough. With simple configuration, bidirectional data transfer from serial port to network can be realized.

Initialization of NB IoT module is also its networking process, including module power-on, IMEI writing, base station search, base station connection, etc. And then, Data is sent to NB‑IoT module in the form of AT command. Data will be encapsulated as CoAP protocol packet by NB IoT and sent to IoT platform. IoT platform receives the data, then parsed the CoAP protocol package and stored the data. It finds the matching codec plug-in according to the device profile file, parsed the data to match the service described in the device profile, and stored on the platform or pushed to the northbound application. Applications obtain IOT management platform data through the visually displayed North data query interface.

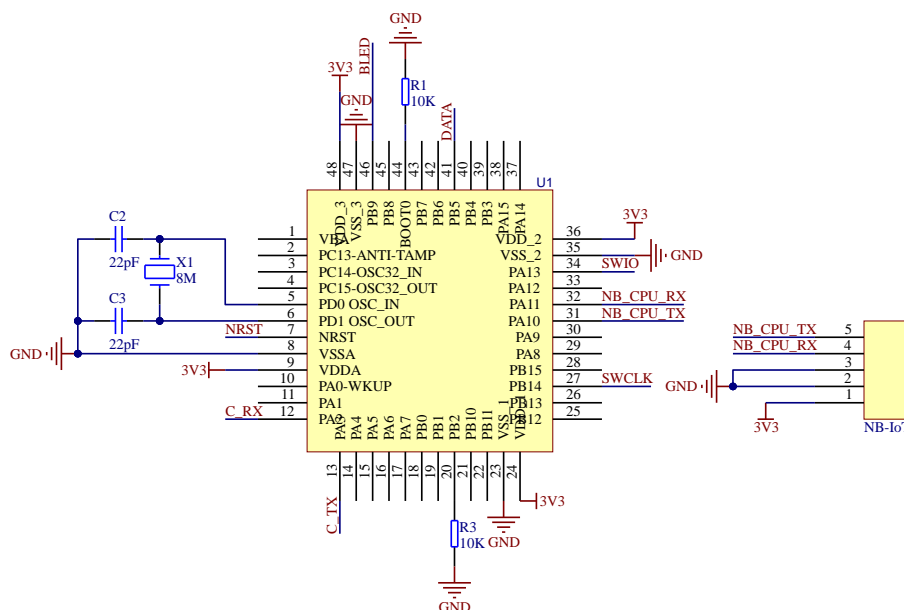Figure 3 is the connection diagram of WH-NB73 and STM32：

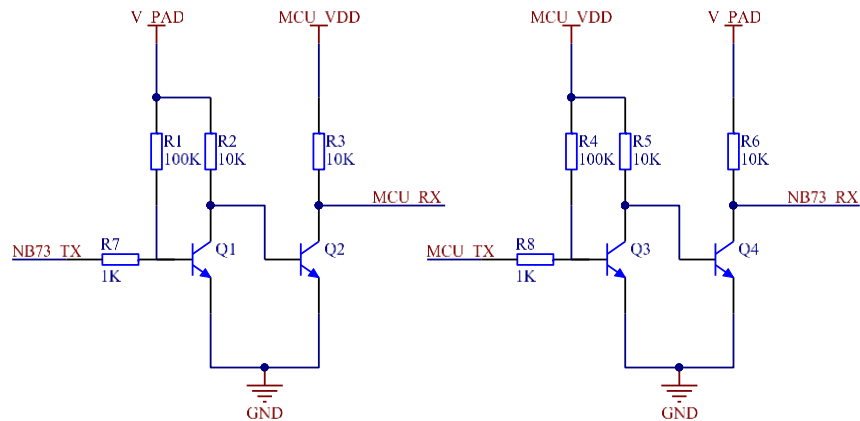Figure 3 the connection diagram of WH-NB73 and STM32

Figure 4 UART level conversion circuit

As STM32 microcontroller is adopted in this system, when the I/O power voltage of UART is 3.3V, level matching is required. If the level is not matched directly, low power consumption cannot be used and leakage current will occur. The UART level conversion circuit is shown in Figure 4.

4. DESIGN OF MONITORING MANAGEMENT SOFTWARE

4.1 MCU software design

The SCM control part of the system is written with Keil. The running process is shown in Figure 5. The main control chip is STM32F03, whose main role is to control the peripheral circuit and various functional modules, including the sending, receiving and processing of the data collected by the sensor. The whole flow chart mainly includes the main function program, WH-NB73 communication protocol and sensor control program. With the main control chip as the core, the driver is run and the parallel work of system hardware is completed.
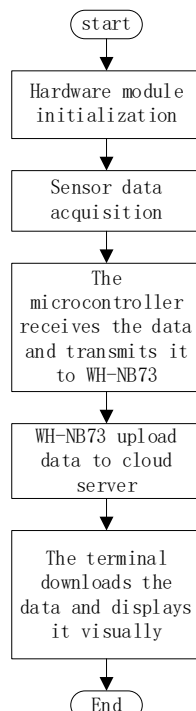

Figure 5 Software flow chart of lower computer

4.2 CoAP protocol

Since some resource-limited devices can not directly use HTTP protocol, the CoAP protocol[11] appears to connect such devices to the Internet, and the NB-IOT module here is in such devices. The WEB protocol of the CoAP protocol meets the M2M requirements of the constrained environment. CoAP protocol is based on UDP by default, supports single broadcast and multicast requests, can exchange messages asynchronously, provides simple proxy caching mechanism, and supports observer mode and block transfer mode. Figure 6 shows an overview of the CoAP protocol structure.

offests	octet	0								1								2								3							
octet	bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
4	32	VER		Type		Token Length				Request/Respose Code								Message ID															
8	64																																
12	96	Token(0-8bytes)																															
16	128	options(if Available)																															
20	160	1	1	1	1	1	1	1	1	Payload(if Available)																							

Figure 6 The overview of the CoAP protocol structure

4.3 PSM sleep algorithm

The main application scene of intelligent agricultural system is open farmland area. As the same time, the power supply is inconvenient. So the system adopts battery power supply. In order to prolong the battery life, PSM sleep algorithm is introduced to reduce the power consumption of data acquisition terminal. The data acquisition terminal will shut down the receiving and sending signal and disconnect from the interaction with the cloud. The microcontroller is in a sleep state and its peripheral circuit is in power-saving mode, so the power consumption of the terminal can be reduced to the maximum extent. At this time, the cloud server cannot transmit any data command that the user of the application layer terminal applies to the data acquisition terminal with software. Only when the data acquisition terminal and the cloud server platform re-establish the connection, data commands can be transmitted to the data acquisition terminal. When data upload the cloud server platform is completed, base station will open timer, generally the default 20 s, between the 20 s if data acquisition terminal has been no upload data. Base station will release with connection wireless terminals. And then, data collection terminal would be the Idle state and start the timer, timer timeout after into PSM dormancy mode again. The specific working mode is shown in Figure 7：

Figure 7 PSW algorithm model

4.4 PC software design

The upper computer software on the PC terminal is written with Visual Studio, which is mainly composed of four parts: node selection, greenhouse environment control, real-time display of environmental parameters in the greenhouse and system feedback information. After selecting the node selection module and clicking "Ok", the environmental parameters in the agricultural greenhouse will display air temperature, air humidity, soil humidity and light intensity in the column of real-time parameter display. In the column of system feedback information, the reminder message of successful sending of node data will also appear. By selecting the selection box on the right of drip irrigation valve, ventilation window, shade cloth and light feeder in the environmental control column of the greenhouse, the opening and closing of these four braking links can be selected to control the parameters inside the agricultural greenhouse. The specific upper computer software operation interface is shown in Figure 8.

Figure 8 PC monitoring software interface

4.5 Mobile terminal software design

The mobile terminal software of this system mainly uses the development of WeChat Applet[12]. Because WeChat applets development is a new way of software development. WeChat applets development cycle is short, development after the completion of no need to download and install, through WeChat scan code to complete the installation.

Figure 9 shows the visual management interface of WeChat small program for environmental monitoring of intelligent agricultural greenhouses, which is mainly divided into four parts: node selection, display of environmental parameters, environmental control and system feedback information. And the realization function of each part is basically consistent with that of PC upper computer management software.

Figure 9 The management interface of WeChat applet

5. SYSTEM TEST AND RESULT ANALYSIS

A complete description of the overall software and hardware design of the system have been given in the preceding part. The following is the experimental data after the overall test run of the system, which

can prove that the whole system can achieve its design objectives. The following table takes node 3 as an example. By providing dry battery power to the wireless sensor data transcending node of node 3 inside the greenhouse, select this node in PC or WeChat small program and click "ok" button to send node instruction to node 3 and collect data from the received node.

Table 1 System test data

air humidity	air temperature	soil humidity	Light intensity
62.3%	27.8℃	36.5%	69.6klx
67.6%	29.6℃	36.2%	70.7klx
66.5%	33.5℃	32.8%	77.8klx
70.1%	32,7℃	32.0%	78.7klx
69.3%	32.6℃	31.9%	77.6klx

By analyzing the data in Table 1 and comparing the data with the manual measurement of the environment inside the agricultural greenhouse at that time, it can be found that there is no obvious error in the process of data transmission, thus it can be proved that the remote real-time monitoring of the system is no problem.

The following table is used to test the data obtained from the stability of the NB-IoT chip, the wireless communication module of the system. In this test, a total of 8 node data are set to test the reliability of data communication.

6. CONCLUSION

The real-time environmental monitoring of intelligent agricultural greenhouses designed in this paper can monitor the growth environmental parameters of crops inside the greenhouses in real time and display them on the intelligent equipment in a remote visual way. Moreover, the parameters in the greenhouses can be controlled and adjusted remotely through WeChat small program and PC upper computer. CoAP protocol is adopted for data transmission, which fully guarantees the reliability of data transmission. The PSM energy saving algorithm is designed to minimize the power consumption of the terminal. It can be predicted that in the full arrival of 5G, the smart agricultural greenhouse based on NB-IOT will inject new vitality into China's agricultural development.

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