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Design and implementation of security system for smart home based on IOT technology

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Abstract

In the world today, home security is becoming necessary nowadays as the possibilities of intrusion are increasing day by day. This design adopts the idea of "Internet of Things close to life and easy to use" as a design concept, and builds a smart home system based on the internet of things. The modules included in this design include a getaway board module, a node module, and an APP module. The main functions realized are: the PC can display the temperature and humidity data collected by the node board through the browser and control the switch state of the LED Light of the control node board through the browser, and can also display the temperature and humidity data collected by the node board through an APP and control the switch state of the LED Light of the gusset plate. The communication between the PC and the node board and communication between an APP and the node board need to transfer through the gateway board, so the gateway board is the communication bridge of the whole system. In order to realize the role of the gateway board communication bridge, the design of the gateway board uses NPC's LPC1769 as the master MCU. The system builds an Ethernet service controller by the LPC1769 embedded Ethernet module and DP83848 chip. Built a gateway system with the wifi module, NB-IOT module and W25Q128 memory chip. The software is based on the uC/OS-II real-time operating system, equipped with uIP protocol tasks and other task modules, and built into a webserver function.

Keywords: smart home, internet of things, NB-IOT, wifi;

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1. Introduction

The Internet of Things refers [2] to ubiquitous end devices and facilities, including sensors with "intrinsic intelligence", mobile terminals, industrial systems, building control systems, home intelligence devices, video surveillance systems, etc., and externally enabled, such as RFID-attached assets, individuals and vehicles carrying wireless terminals, etc. "smart parts or animals" or "smart dust" through a variety of wireless and / or wired long distance and / or short-range communication networks to achieve interoperability (M2M), application integration (Grand Integration / MAI), and cloud-based SaaS operations and other modes, intranet (Intranet), private network (Extranet), and / or the Internet (Internet) environment, using appropriate information security mechanisms[2] to provide secure, controllable and even personalized real-time online monitoring, location and traceability, alarm linkage, dispatching command, plan management, remote control, security, remote maintenance, online upgrade, management and service functions such as statistical reports, decision support, and leadership of the desktop (Cockpit Dashboard), to achieve "all things, high efficiency, energy saving, safety, environmental protection, control, camp" integration TaaS service.

Smart home [4],[5] is a versatile system includes visual intercom, home security, remote monitoring of home appliances, remote video surveillance, telemedicine diagnostics and care systems, online education systems, and home movie star systems. The advent of the concept of the internet of things has broken the traditional thinking of the past. The idea in the past has been to separate the physical infrastructure from the IT infrastructure, on the one hand, airports, roads, buildings, and on the other hand, data centers, personal computers, broadband, and so on. In the era of the internet of things, reinforced concrete and cables will be integrated into chips and broadband as a unified infrastructure.

With the wide application of electronic technology in real life, people and more and more aware of the convenience brought by electronic products to life, especially in the 1980s, the emergence of smart home provides and more enjoyable life for people broad platform. Although smart home development has been around for 30 years, smart products are still the mainstream of today's development, especially the emergence of the internet of things, and further promote its development. Therefore, this design research on smart home products is in line with the trend of the world, and makes itself into the industry of smart home product development, so this product research and development has great research significance. With the NB-IOT standard freeze in June this year, the foundation of the large-scale commercialization of the recently-recognized NB-IOT has finally been implemented. It is widely believed that 2017 will be the first year of commercial use of the NB-IOT network. As a low-power WAN technology promoted by Huawei and many operators, NB-IOT received extensive attention in the industry since its launch. The topic of LoRa and NB-IOT has not been interrupted. One of the NB-IOT Alliance members of Vodafon, one of its executives even publicly stated that "NB-IOT will lead to LoRa's demise".

2. Related work and methodologies used

2.1. System design

According to the design requirements and functions, the system includes gateway board, a node board, a PC, and Android phone. The main control MCU of the nuclear gateway board adopts the LPC1769 chip, the BN-iot module adopts the xbee module, the wifi module adopts the wifibee module, the main control chip of the NB-iot node adopts the LPC1114 chip, and the temperature and humidity sensor adopts the DHT11 sensor. The working framework of the system's overall module is shown in Figure 1.

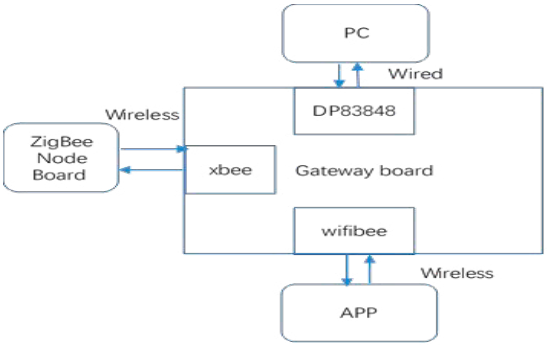

Fig. 1. The framework of the overall system module

- Xbee module: The xbeeS2 modue from Digi is a short-range, low-power data transmissions module with a 2.4GHz band, built-in NB-iot protocol stack, and all peripheral circuits through the configuration software X-CTU on the PC. Configure the module to transmit power channel and other network topology parameter. The NB-iot coordinator is an xbee module integrated on the embedded gateway board that connects to the MCU through a serial port. After the networking of the xbee module is successful, the received data is output through its port, and the transmitted data is input through its serial port.
- Wifibee moule: The wifibee module induces an 802.11 b/g wireless transmitter, a 32-bit processor, a TCP/IP stack, a real-time clock, a power management unit, and an analog sensor interface. This module is per-installed with Roving firmware. To increase its integration to reduce the development time of applications that is critical to the user. In the simplest and most practical setup, the hardware only needs four connections (power, tx, rx ground) to create a Wireless data connection. The wifibee module is widely used in the United States, Canada, Australia, Israel and Europe. Establishing RF communication does not require any additional configuration and the module's default configuration supports a wide variety of Device application. You can also use the command to configure the module to perform some special function that you have customized. When the wifibee module receives data, it outputs through its serial port, and when it sends data through its serial port.
- NB-iot Node Board: the BN-iot gusset plate of this experiment was a laboratory board. The NB-iot node board is composed of LPC1114 chip, FT232RL chip, DHT11 senser and xbee model. The LPC1114 is the core of the entire node board. FT232RL is interface conversion chip that convert USB to serial UART interface. DHT11 is a temperature and humidity sensor the collects temperature and humidity data. The xbee module is responsible for connecting to the NB-iot network.

2.2. Overview of the design of the gateway board

The gateway board is mainly composed of LPC1769 main control chip, W25Q18FV chip, xbee module wifibee module. LPC1769 is the heart of the whole system. The responsibility of W25Q18FV chip is to store webpage data, xbee module establishes NB-iot network, wifibee module is responsible for communication with APP. The peripheral structure of the gateway board is shown in Figure 2.

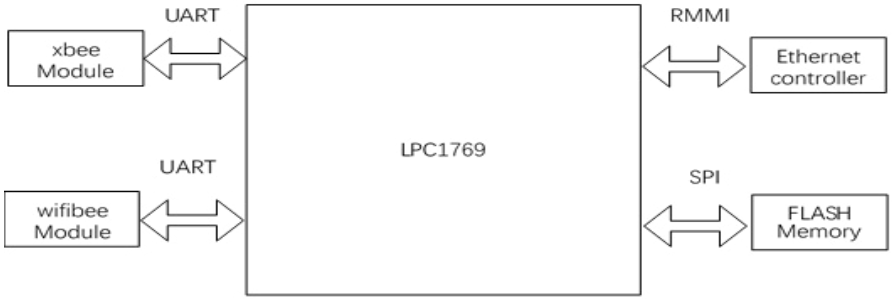

Fig. 2. Gateway board peripheral structure

The LPC1700 series AMR is a second-generation ARM cortex-M3 core-based micro-controller from NXP. It is a high-performance, low-power 32bit microprocessor designed for embedded system applications with an operating frequency of up to 120MHz. A 3-stage pipeline and Harvard architecture with independent local instructions and data structures and a low-performance third bus for peripherals, enabling code execution speeds of up to 1.25 MIPS/MHz and including an internal that supports random jumps Prefects unit. The LPC1700 series ARM adds a dedicated flash memory acceleration module, which enables the running code in Flash to achieve better performance. It is suitable for instrumentation, industrial communication, motor control, lighting control, alarm system and other fields [25].

The peripheral components of the LPC1700 series Cortex-M3 micro-controller include up to 512KB of flash memory, 64KB of data memory, Ethernet MAC, USB master/slave/OTG interface, 8-channel general purpose DMA controller, 4 UARTs, 2 CAN channel, 2 SSP controllers, SPI interface, 3 I2C interfaces, 2-input and 2-output I2S interfaces, 8-channel 12-bit ADC, 10-bit DAC, motor control PWM, quadrature encoder interface, Four general-purpose timers, a 6-output general-purpose PWM, an ultra-low-power RTC with independent battery power, and up to 70 general-purpose I/O pins [9].

This design mainly uses the Ethernet peripheral functions of the LPC1769.The Ethernet module contains a full-featured 10Mbps or 100Mbps Ethernet MAC (Media Access Controller) that optimizes its performance by using DMA hardware acceleration. The Ethernet module has a large set of control registers that provide: half-duplex/full-duplex operation, flow control, control frames, retransmission hardware acceleration, receive packet filtering, and wake-up on the LAN. The automatic frame transmission and reception operations using the Scatter-Gather DMA alleviate the CPU workload. The Ethernet module is an AHB host that drives the AHB bus matrix. Through the matrix, it can access all the ram memory on the chip. It is recommended that Ethernet use ram exclusively by using one of the ram modules to handle Ethernet communications. Then the module can only be accessed by Ethernet and CPU, perhaps GPDMA, to get the maximum bandwidth of the Ethernet function. The Ethernet module uses the SMII (Simplified Media Independent Interface) protocol and the on-chip MIIM (Media Independent Interface Management) serial bus, as well as MDIO (Manage Data Input/Output) to interface with the off-chip Ethernet PHY.

2.3. Overview of uC/OS Operating system and uIP Protocol

The uC/OS-II is μC/OS, it is a portable, implantable ROM, droppable, pre-emptive, real-time multitasking operating system kernel. It is widely used in microprocessors, microcontrollers and digital signal processors. The μC/OS and uC/OS-II are designed for embedded applications in computers, and most of the code is written in C. The CPU-related parts of the CPU are written in assembly language, and the assembly language part of a total of about 200 lines is compressed to a minimum in order to facilitate porting to any other CPU. Users can embed uC/OS-II into the developed product as long as they have a standard ANSI C cross compiler and software tools such as assembler and connector. The uC/OS-II features high execution efficiency, small footprint and excellent real-time performance and scalability. The smallest kernel can be compiled to 2KB.uC/OS-II has been ported to almost all well-known CPUs.

Strictly speaking, uC/OS-II is just a real-time operating system kernel it only such as task scheduling, task

management, time management, memory management, communication and synchronization between tasks. No additional services such as input and output management, file system, network, etc. are provided. However, due to the good scalability and open source of uC/OS-II, these non-essential functions can be completely implemented by users themselves according to their needs. The uC/OS-II goal is to implement a pre-emptive real-time kernel based on priority scheduling and provide the most basic system services such as semaphores, mailboxes, message queues, memory management, and interrupt management. The uC/OS-II is designed with only one CPU in the system. In such a system, only one task at a specific moment will occupy the CPU, while other tasks can only be in other states. The tasks in uC/OS-II have five states: sleep state, ready state, running state, waiting state, and interrupt service status [6].Under system management, a task can be transformed between five different states. The conversion relationship is shown in Figure 3.

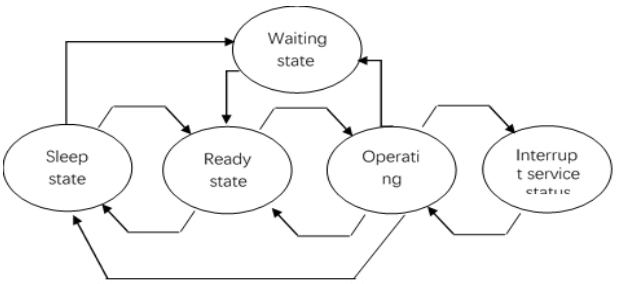

Fig. 3. Task statues switching of uC/OS-II

The uC/OS-II is released as source code, but it does not mean it is open source software. You can use it for teaching and peaceful research; but if you use it for commercial purposes, you must obtain a commercial license through Miriam.

uIP is a very small TCP/IP protocol stack designed specifically for 8-bit and 16-bit microcontrollers. uIP is written entirely in C and can be easily ported to a variety of different architectures and operating systems. A compiled stack can run in a few kilobytes of ROM or hundreds of bytes of RAM. And the hardware processing layer, the protocol stack layer and the application layer share a global buffer area, and there is no copy of the data, which greatly saves space and time. Due to its simple structure and reliable function, many 8-bit microcontrollers are ported to the uIP protocol stack [1]. The uIP protocol stack removes the functions that are not commonly used in TCP/IP, simplifies the communication process, but retains the protocols that must be used for network communication. The design focuses on the network layer and transmission of IP/TCP/ICMP/UDP/ARP. Layer protocol ensures the versatility and structural stability of the code.

3. Experiment and results

3.1. Customization of communication protocols

Since xbee and wifibee are configured to communicate in transparent mode, in order to facilitate data processing and secondary development, the design customizes a transport protocol between xbee communication and wifibee communication with APP. The format of its transport protocol is shown in Table 1.

Table 1. Protocol Packet Format

HeadFlag	PacketLength	Commond Id	Commond Para			CRC	RearFlag
1Byte	1Byte	1Byte	nByte			1Byte	1Byte
0X7E	LEN	CmdID	0X00 ~ 0XFF	…	0X00 ~ 0XFF	0X00 ~ 0XFF	0X7E

Table 2 is a description of the protocol in Table 1.The protocol description is shown in Table 2.

Table 2. Protocol Description

Head Flag	Packet header, fixed to 0x7E
Packet Length	The entire packet length, 1 byte in length, contains all bytes from HeadFlag~RearFlag
Commond Id	instruction.
Commond Para	Instruction parameters.
CRC	The CRC check, the value of the CRC is the sum of the PacketLength value plus the Commond Id value.If CRC=PacketLength+Commond Id, then OK, otherwise, the verification fails.
Rear Flag	End of packet, fixed at 0x7E

Since the system needs to transmit data content temperature and humidity data and control the semaphore of the LED switch, Commond Id defines two instructions, as described in Table 3.

Table 3. Instruction Description

Command	Command Id	Commond Para				
		ParaLength	ParaData0	ParaData1	ParaData2	…
Temperature and humidity	0x01	0x07	temperature	humidity	invalid	invalid
light	0x02	0x06	0x01 or 0x00	invalid	invalid	invalid
To be determined	To be determined					

As shown in Table 3, when Command Id is 0x01, only the first two data are valid for the Commond Para parameter, which are temperature data and humidity data. When Command Id is 0x02, only the first data is valid for the Commond Para parameter. ParaData0 is 0x01 for the light-on action, and ParaData0 is 0x00 for the light-off action.

3.2. Implementation of xbee communication

The xbee module can be configured through the X-CTU host software. The X-CTU host computer interface is shown in Figure 4.

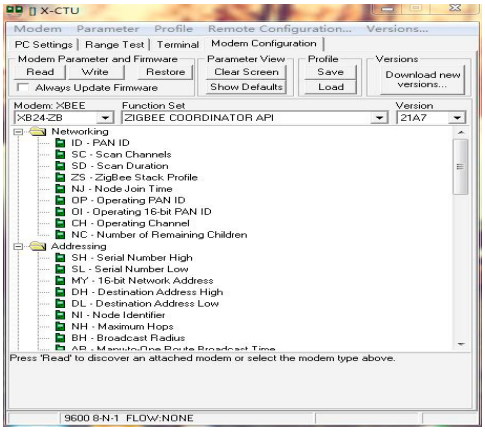

Fig. 4. X-CTU interface

The xbee networking condition must have a module configured as a coordinator, so the xbee module on the gateway board is configured as a coordinator through X-CTU, and the xbee module of the node board is configured as a terminal through X-CTU.Once configured, the xbee modules can communicate with each other.

3.3. Implementation of wifibee communication

This design needs to configure the wifibee module as a wifi service hotspot for the APP to connect and communicate with the APP. Wifibee's configuration tool can be implemented only with a serial port assistant. In the serial port assistant, enter the command code in turn:

1. set wlan join 7
2. set ip dhcp 4
3. set ip address 192.168.190.1
4. set ip gateway 192.168.190.1
5. set ip netmask 255.255.255.0
6. set ip remote 2000
7. save
8. Reboot

Through the above command configuration, wifibee is configured as a wifi hotspot with an IP address of 192.168.190.1 and a port number of 2000.

3.4. App implementation process

The main function of the app is to display the temperature and humidity data information collected by the gateway board and to control the state of the LED Light switch. This design app only contains one interface. The interface mainly contains five function controls, namely three Buttons and two TextViews. The three Buttons are respectively defined as connecting wifibee action, lighting the node board LED light action, and turning off the node board LED light action, and their ids are defined as StartConnect, SendLON, and SendLOFF, respectively. The function of the two TextViews is to display the temperature value and the humidity value, and their ids are defined as txt_temp and txt_humidity, respectively.

The APP must be connected to wifibee to run its function.The control id is StartConnect is bound to listen for the StartClickListener event, and its event mainly performs the action of connecting wifibee. When the StartClickListener event occurs, since is Connecting is initialized to false, the system creates a thread that listens to the server. Since wifibee has been set to IP 192.168.190.1, the port is 2000 wifi hotspot.So define String msgText ="192.168.190.1:2000" as the target of the listening server.When the APP successfully connects to wifibee, it starts to enter the listening state, and its Button will display the “connected” state. The id of the control Button is bound to listen to the SendLightOn event, and its event mainly performs the action of lighting the LED light of the node board.

When the SendLightOn event occurs, first define an array to be sent, ie char sendlighton[]={0x7e, 0x06, 0x02, 0x01, 0x08, 0x7e}, the data in the array conforms to the protocol established by this design. When the SendLightOn event occurs, if the system is properly connected to the server, the APP will light the LED light data to the gateway board.If the system is not properly connected to the server, the APP interface will prompt "No connection."

The control id's id is SendLOFF is bound to listen for the SendLightOFF event, and its event mainly performs the action of turning off the node board LED light. The binding code and event code are the same as the control id of the control button. The only difference is that the SendLightOFF event defines the data sent to the gateway board as the data for the turn-off light, ie char sendlightoff[]={0x7e, 0x06, 0x02, 0x00, 0x08, 0x7e}.

3.5. PC access gateway board test

After configuring the correct setting of the PC network adapter, open the browser and enter 192.168.150.200 to access the gateway board is shown in Figure 5.

Fig. 5. Login interface

In the figure enter the user name and password to enter the corresponding page. The initial user name is: Senwei and the password is: 123456. Enter the user name and password correctly, the PC will first login to the home page interface, the home page interface shown in the PC browser can click the home page, the monitoring canter, control, and send us a request to the server through is navigation bar it shown the monitoring centre interface.

Fig. 6. Home Screen

As shown in Figure 6 due to the limitations of the xbee module and the sensor, the monitoring centre of this design only has the temperature, humidity and light status of the hall as valid data, and other data are analogy data. The temperature value and humidity value shown in Figure 6 are the temperature and humidity data collected by the gusset board. When the light status is ON, it means that the LED Light of the gusset plate is on. If the light status is OFF, it means this time. The LED Light of the gusset is off. The control centre interface is an additional requirement for this graduation project. Therefore, due to limited time, only the opening and closing buttons of the electric light are valid values in the control centre, and other buttons are invalid. When the button of the light is turned on, the Led light of the node board will be lit, and a request of the monitoring centre will occur in the PC browser to display the state of the Led light of the node board when the button of the light is turned off, the LED Light of the node board will be extinguished, and a request of the monitoring centre will occur in the PC browser to display the status of the Led light of

the node board.

3.6. Mobile app access gateway board test

Mobile phone A must connect to the wifibee hotspot in the setup center to implement the APP and wifibee communication function. wifibee has been configured as a wifi hotspot named SANFI, so the mobile APP should be connected with wifibee. For communication, you must connect to the wifi hotspot named SANFI in the phone wifi settings. When the mobile APP is connected to the wifi hotspot, open the APP and click the “Start Connect” button, the APP will enter the listening state, and the “Start Connect button” will switch to the “Connected” state.And display the temperature and humidity data sent by the gateway board in real time.APP interface is in the listening state interface

4. Conclusion and future works

The smart home based on the Internet of Things does not only include the application of embedded technology, but also a complex and comprehensive project. While doing research on embedded systems, we have to consider other issues such as network, environmental protection, and ecology from a system perspective. A lot of the knowledge involved is far from my professional knowledge, such as architecture, home appliances, etc., more involved in a lot of human content. The architecture of the smart home and campus described in this paper is based on the current advanced software and hardware technologies, but it has not completely escaped the shackles of traditional concepts. The design of smart homes must be forward-looking and closely focus on current technology developments to ensure that the structure being designed, the technology used are scalable and have a longer life cycle. The system structure proposed in this paper introduces more advanced software and hardware technologies and determines the direction for further research.

In 2014, Google acquired the smart home company Nest, which caused people in the industry to talk about the development of smart homes. Indeed, with the rapid development of the social and economic level, the pace of life has accelerated, making people more comfortable with the comfort, safety and intelligence of family life. Therefore, the development of smart home must be one of the biggest mainstreams in the 21st century. This graduation design product is in line with the trend of the times. The IOT is used to build a smart home gateway system. Although the functions realized by this design are relatively simple, the system reserves many interfaces for extending functions, such as refrigerators and air conditioners. Control, so there is still a lot of room for development in this graduation design product. And this product has added the app terminal, which makes the whole system more perfect. The operation of the app makes the user more convenient to use. Therefore, the upgrade of the app is also the top priority of this design.

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