

## Design of Smart Home System Based on the Technology of Internet of Things

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**Abstract:** With the development of the “Internet of Things” industry, there is a vast potential for future application on the smart home system. The study introduces a smart home system, which consists of sensory level based on the sensor, wireless network level based on the technology of ZigBee and the application level used on the human-computer interaction. The experiments show that the ZigBee wireless network has a good performance and the whole system comes up to expectation.

**Key words :** IOT, smart home system, WSN, zigbee

### INTRODUCTION

Internet of Things (IOT)-a global network that links physical and virtual objects through data capture and communication (European Union definition)-is becoming a major new industry in the world (Zhen *et al.*, 2011; Qing *et al.*, 2008; David *et al.*, 2005). In China, the IOT went by the name of WSN (Wireless Sensor Network) in the past (Qi, 2010). In fact, the WSN is an important part of the IOT, which can connect the things to the Internet (NIE *et al.*, 2011). Man (2010) studies the smart home system based on ARM. NIE *et al.* (2011) analyses the strategic thinking of the internet of things and m2m services. NIE *et al.* (2011) studies the security architecture on the trusting internet of things. Currently the technology standard, application service and the industry development of the IOT are at the starting stage (Bing *et al.*, 2011). The global applications mainly concentrate on the fields such as transport, logistics, industrial control, environmental monitoring, intelligent security protection and so on Hua-Dong, (2011). Smart home system is also one of the applications of the IOT (Jin-shui, 2007). The ZigBee technology is used in this level (Qing *et al.*, 2008). The ZigBee network follows the standard of IEEE802.15.4 and it has high efficiency but low power dissipation and complexity (WU *et al.*, 2011). Liu (2011) analyse the design and implementation of intelligent home control system based on ZigBee technology. It's suitable for transmit control information through the equipments.

This study discusses a smart home system which based on the WSN. The system can not only monitor the data in the home such as temperature data, humidity data and so on, but also remote control the household appliances, such as switching power supply and drawing the curtains. First the overall framework of system and its levels are introduced. Then the hardware and the software are explained. Finally the system is completed and tested.

### FRAME OF THE SYSTEM

**Overall framework of the system:** The study process of system can be described as below: when a person wants to control the household appliances, he can run the software on the computer and through the IP address the software can connect to the controller. From the human-computer interface the environment indoors is monitored. If he wants to turn on the light switch, he click the button on the interface, then the light will be put on and it can be seen from the real-time monitor. In other words, people can control the household appliances far away as long as there is a networking computer.

According to the demand, the system should contain three levels: sensory level, wireless network level and the application level. The other peripheral hardware equipment such as sensors, processor and the gateway server are also included. The overall framework is showed in Fig. 1.

#### System levels:

- **Sensory level:** This level is responsible for one study, which is original information collection. The information includes the status data such as temperature, humidity and the on-off state of the household appliances. These status will be shown to the person through the interface. In order to achieve this function, some sensors must be used in this level.
- **Wireless network level:** This level is to pass data collected by the sensors to the controller and transmit the control command to the household appliances.
- **Application level:** Three parts are involved in this level: the controller, web server and the human-computer interface. Controller is the center of the system, which is responsible for communication each network (the ZigBee wireless network and the Internet network). There are three functions of the web server: first is video information collection

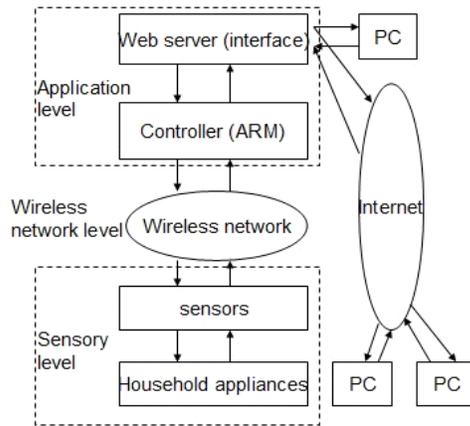


Fig. 1: Framework of smart home system

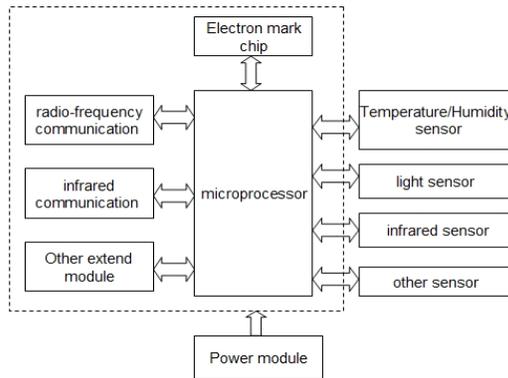


Fig. 2: Sensor node structure

through the USB camera, second is to transmit the data to the Internet by the TCP/IP protocol, third is to listen and receive the requests send from the clients by the socket.

### HARDWARE OF THE SYSTEM

- Design of the sensor:** The structure of the sensor node is showed in Fig. 2. The sensor SHI71 is used on the collection module of temperature and humidity. The SCK is used to synchronous communicate between the microprocessor and SHI71. DATA tri state gate is used to read data. When the interrupt response request is coming, the processor and the sensor will be awake and turn to the activity pattern (Ming *et al.*, 2009). The data is 16 bit binaries and it will be converted to the decimal numeral. Then the temperature and the humidity will be calculated by the formula. The radio-frequency communication module uses the SPI of the USART of MSP430. CC1100 is configured by the MSP430 through the SPI and then

SPI is used as data interaction between MSP430 and CC1100.

The infrared communication module uses the TA pattern of the MSP430. The transmitting circuit is made up of the infrared emitter and some decoupling resistor and capacitor. The command signal of digital household appliance is often data stream which only includes 0 and 1. When the 0 data is sending, the infrared signal is output under the TA pattern. When the data 1 is sending, the high level signal is output under the I/O pattern. These data streams collected from the household appliances are stored in the MSP430 and the sending function is encapsulated as a module in the physical layer (David *et al.*, 2005). The commands are supplied to the higher level who can call them to control the household appliance.

- ZigBee wireless network:** The equipments of ZigBee wireless network contains Full Function Device (FFD) and Reduced Function Device (RFD) (LIU and Guang-ming, 2011). The network nodes are consisted of three parts: Coordinator (ZC), Router (ZR) and terminal Device (ZD). The power switches of household appliances connects to the ZigBee node module by the relay. The ZigBee module initializes to the receiving status in order to receive the control command sent from ZC, then it can control the switch power to turn on/off according to the command.
- The design of hardware of ZigBee nodes are basically the same. The differences are the master nodes (ZC) interacting with the controller, the slave nodes (ZD) interacting with household appliances, the router node interacting with master nodes and slave nodes. The structure of hardware are mainly RF and control interface. The CC2340 are used as the node hardware, which has two working volt: 3.3V used at external I/O and 1.8V used at internal I/O. There are two crystal oscillators in the system: essential crystal oscillator (32M) which offer the reference clock to CC2430 for the 250 kb/s data receiving and optional crystal oscillator (32.68 kHz), which offer reference clock to the sleep pattern.
- The module of controller:** The Real6410 is used as the develop board and the S3C6410 made by Samsung is used as processor, which contains the ARM11 as the kernel. The DDR (123M) and NandFlash (1GB) are integrated in the board. There are some peripherals offered by the backplane, such as two RS-232 serial ports, a USB HOST interface, a self-adapting Ethernet interface and so on.

### SOFTWARE OF THE SYSTEM

**Design of the ZigBee node:** The FFD web node is responsible for buiding network, allocating ID for child nodes, recieving data sent from child nodes and sending the data to the ARM controller. The RFD node is to

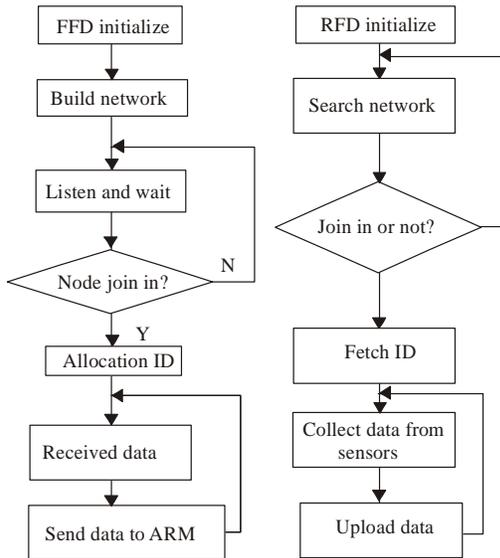


Fig. 3: Work flow of ZigBee

searching network, sending the data collected from sensor to the FFD node real-time. The nodes' flow of study is shown in Fig. 3.

- Program develop of ZC:** The ZC receives data from controller and ZD, then transmit the data to each other. First a network will be built and an ID will be given by the system automatically (LIU, 2011). This process can describe as a chosen equipment binding to the ZC by a press action in a period. The ZC collects the binding request from the ZD in this period and creates an item in the binding table. So the function which can handle the press event must be developed. The function collects the information from all ZD and sends them to the ZC. The binding can be started by the ZC or the RFD. When the RFD sends a binding request, the binding will be built if the ZC responses in five minutes, else the request will be deleted because of overtime. When the ZC is bind to the ZD, data can be sent to each other. The process functions can be easily developed according to the type of ZD.
- Program develop of ZD:** The communication part of this program is the same to the ZC program. ZD mainly handles the task real-time such as collecting sensor's signals, turning on/off the power switch according to the command sent from the ZC.
- Application program develop:** Three programs must be developed in this level: controller program, web server program and the human-computer interface program.
- Controller:** The controller is the center of the system. A software platform must be built on this board. For this purpose, the cross-compiling environment for ARM will be built on the host first.

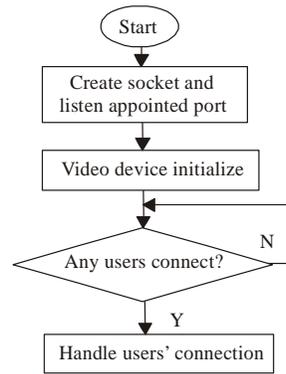


Fig. 4: Work flow of sever

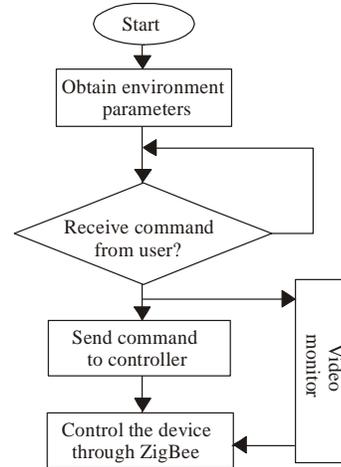


Fig. 5: Work flow of software

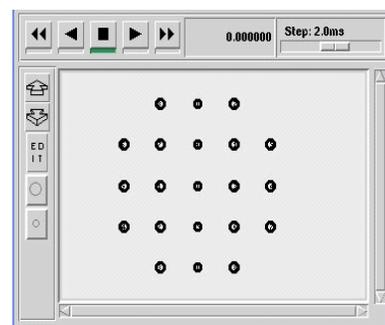


Fig. 6: ZigBee test in NS2

The source program compiled on the host can generate the object code which can run on the board. The main develop tools are listed as below: binary data processing tools binutils, compiling tools gcc and the chained/run library glibc. After compiling binutils-configuring the kernel head file of Linux-first compiling gcc-cross compiling glibc-second compiling gcc, the cross-compiling platform is

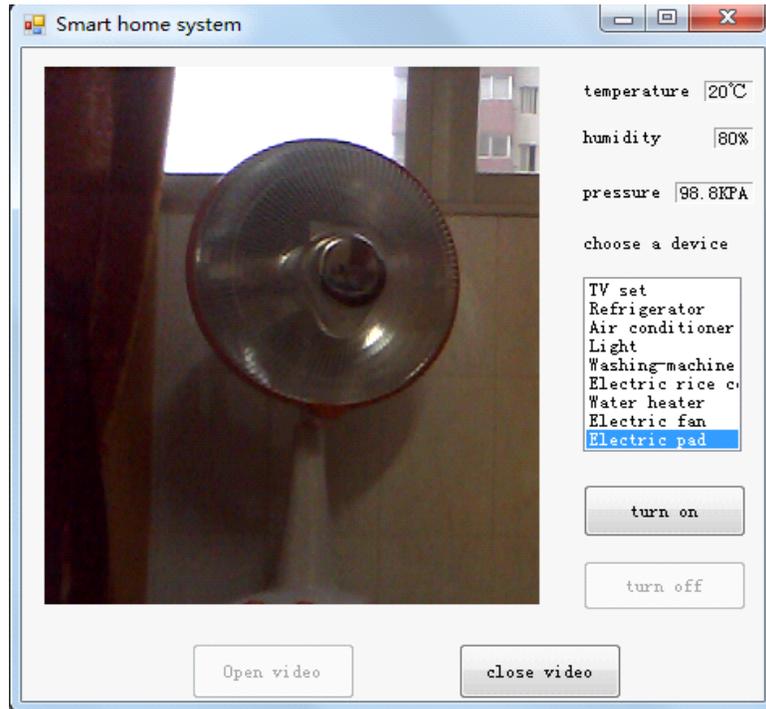


Fig. 7: Interface of the software

already built (MAN, 2010). Then the Linux kernel can be compiled and transplanted to the board. First we enter the main menu of kernel configure and generate the .config file. Second step is to build the dependency relationship. The third step is to build the kernel by building compressed kernel map. The fourth step is to download the kernel to the board. Finally, the file system is loaded to start the system.

- **Web server:** When a suitable kernel of Linux is customized on the ARM11, a server program must be developed whose basic functions are video data collection by the USB camera, data package and sending to the network under the TCP/IP protocol and meanwhile listen by the Socket in order to receive the request sent by client. The server's flow of study is shown in Fig. 4.
- **Human-computer interface:** The system uses Pentium (R) Dual-Core CPU T4400, 2.20 GHz, 2.20 GHz processor, 2.00 GB RAM, Windows7 OS, development tools are Visual Studio C#.NET, the camera is Integrated Camera, the Video collection frame rate is 5f/s.

The system mainly defines five classes: Access Control, Video Control, Temperature Show, Humidity Show and Device Control. Access Control is the master control class which controls the command data sending and status data receiving. Video Control is video control class which includes the methods of start, pause, stop and

image fetching. Through the video people can see whether the system is good running. Temperature Show is the class which shows the temporary and the humidity can be shown by the class of Humidity Show. The Device Control contains some functions such as Refrigerator On, Refrigerator Off, TV On, TV Off, Air-condition On, Air-condition Off and so on. These functions can send the command to the controller to turn on/off the household appliances. The study flow of the software is shown in Fig. 5.

## SYSTEM TESTED

**ZigBee test:** In order to analyze the performance of the ZigBee nodes, the simulation tool NS2 is used to simulate the transmission of ZigBee. The kernel of NS2.30 and the "Makefile" file must be altered for that the NS2 doesn't include the ZigBee module. The ZigBee network built in the laboratory is shown in Fig. 6.

The distance of the adjacent node is 10 m, which transmit the command and information by multiple-hop pattern. In the 900 sec of the experiment, a CBR stream is built from node 9 to node 17 and the block size is 85. Five packages are sent out per second and so four hops are needed to reach the destination node. The delivery rate of packages tested is 97.88%. The end-to-end average delay is 0.026 s. If setting the transmit Poisson flow from node 3 to node 18, then two hops are needed to reach the destination node. The delivery rate of packages is 94.65%,

Table 1: Main test parameters of system

Parameter	Value	Parameter	Status
Temperature	20°C	Refrigerator	on
Humidity	80%	TV set	off
Pressure	98.8KPA	Electronic pad	off

the end-to-end average delay is 0.024 s. The experiment result shows that the ZigBee network made by household devices can transmit the command and data reliably.

**System test:** The smart home controller and the tested PC are accessed the network, then open the control software on PC, enter the IP address of the controller to let the PC access the controller. The interface of system will be opened. People can know the temperature and the humidity in the house through the interface and also can operate the household appliances by click the buttons on the interface. The interface is shown in Fig. 7. The data monitored by the system is listed in Table 1.

### CONCLUSION

This study designs a smart home system based on the technology of IOT, using the ZigBee wireless network and the sensors control circuit to collect information and control status of the whole home system. The intelligent control of the home system is based on the S3C2440 embedded terminal. People can not only obtain the environment information and the status of the household appliances from the PC software interface, but also remote control the device through the Internet. The simulation result of ZigBee on the NS2 and the test experiment of the application software show that the system has certain feasibility and reliability. The further study is to transplant application interface to the mobile phone in order to let people control the system at all times and places.

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