

Research on Smart Living Technology based on WSN

ZHOU Xiao-yan, HUANG Ting-lei, LIU Pin, LIAO Zhao-lai

School of Computer Science and Engineering

Guilin University of Electronic Technology

Guilin, China

e-mail:xyz545002@163.com

Abstract—As the development of sensor technology and communication technology, the realization of smart home is not longer out of reach. This paper provides a design of smart home system based on wireless sensor network (WSN) within the ZigBee criterion. For the different network condition of different houses, we employ different networks (Internet or UMTS) to achieve remote control of the house's electric equipments. As the most important part of smart home system, a gateway is not only the bridge of two heterogeneous networks but also the controller. We provide two gateway structures—the WSN integrate Internet (WII) gateway and the WSN integrate UMTS (WIU) gateway—to achieve information exchange between heterogeneous networks. We also give appropriate hardware and software schemes to fulfill these gateway structures.

Keywords—WSN; Internet; UMTS; WLAN AP; gateway

I. INTRODUCTION

With the rapid development and increasing maturity of wireless communication, integrate circuit, sensor technology and the MEMS (Micro-electro Mechanical Systems), the production of sensors which is low power consuming, inexpensive, multifunctional and tiny sized become possible. These sensors which integrate information collection, data processing and wireless communications and other functions in small volume form an Ad hoc network system which can be used in military, environmental, medical, industrial, family and other applications. Benefited from the third generation telephony (3G), mobile phone users (via UMTS) and remote PC users (via Internet) can monitor and control their house' electrical equipments conveniently at any time and any where. We can say that smart home is not longer out of reach.

This paper designed a smart home system based on wireless sensor network conformed ZigBee as the sensors' communication criterion and integrated the WSN with other heterogeneous networks to reach the purpose of remote monitor and control. Aim at different network circumstance of different houses, we used different schemes to achieve the remote monitor and control, that is, using wireless local area network access point (WLAN AP) to integrate WSN and Internet if the house had already overcast by WLAN or using the UMTS which is a most wildly applied form of 3G to integrate WSN and Internet where WLAN have not overcasted the house.

The rest of this paper is organized as follows. In section

II, we first show the whole structure of the smart home system, introduce the ZigBee to the sensor network and then design two gateway structures named WII gateway and WIU gateway. In section III and IV we provide some hardware and software to this design respectively. In section V, the conclusion follows.

II. SYSTEM DESIGN

The smart home system can be divided into two parts: the wireless sensor network (WSN) and the gateway. The WSN is a network that a large number of sensor nodes communicate with each other via wireless and work similarly as the Ad hoc network. The gateway is the key to integrate WSN with other heterogeneous networks. In our design, we used the gateway as a monitor and a controller in electric equipments—monitor, lighting-control, recording the data of water meter, ammeter and gas meter and also anti-theft. Figure 1 show the structure of the smart home system. The microprocessor ARM9 is implemented in the gateway as the control center which manages the whole system and roles as the gateway. Users can monitor and control the intelligent equipments in the house through the internet or the UMTS networks.

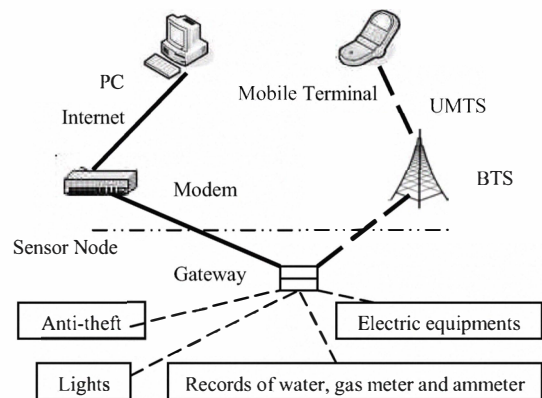


Figure 1. Structure of the smart home system

A. Design of the Sensor Network

The sensor nodes which are deployed inside or outside the house are used to sense the conditions of electric equipments running, lights, meter-records and the security in the house. They communicate with each other through wireless signals and work just like an Ad hoc network which has not the central node, nodes can enter or exit the networks

freely and at the same time, the whole network will not destroyed for some nodes' disability. This kind of network consisted of a huge number of nodes are usually called WSN. There are several reasons for us to choose WSN as the form sensors work together. First, without the wired communicate medium, it will save lot of money in the cost of material. Secondly, benefited from the wireless communication, it will be less difficult in construction and also save money. Thirdly, wireless communication can adapt the changes of sensor nodes' locality caused by transiting the furniture or appending new electric equipments.

ZigBee is an emerging wireless network standard which is mainly used in wireless personal area network (WPAN) and developed on the IEEE 802.15.4 wireless standard. The IEEE 802.15.4 defines two underlying agreement, that is the physical layer and media access control layer. Then ZigBee Alliance defines the network layer and application layer based on the IEEE 802.15.4. Compared with other wireless communication protocols, ZigBee protocol is compacter and simpler, and easy to implement. The characteristics of ZigBee are showed in follow:

1) *Low power consumption.* This is benefited for the short working- periods, the sleeping mechanism and low power consuming in transfer and receive signal.

2) *Low cost.* The Protocol of ZigBee is simple and requires small storage space, which significantly reduces the cost of ZigBee, so that the price of per ZigBee chip is only 2 U.S. dollars with free royalties. The band to ZigBee is 2.4GHz, 868MHz (Europe) and 915MHz (USA) which are the license-free band.

3) *Large capacity of network.* Each ZigBee network can support 255 nodes. If used the network coordinator, the whole network can accommodate more than 65,000 nodes.

4) *High reliability of data transmission.* For the collision avoidance mechanism and the data fully confirm mechanism in MAC layer, ZigBee provide a high reliability of data transmission.

Above all, since the foundation of ZigBee Alliance in August 2001, now ZigBee Alliance has already attracted a hundred of chip companies and wireless equipment companies to join in. So we can purchase a wide rang of ZigBee modules produced by different companies for various applications. For the advantages listed above, it is quite appropriate for us to introduce the ZigBee into the sensor network.

B. WSN Gateway

When two heterogeneous networks want to exchange information and share data, we must convert the protocols of these two networks. And a gateway is the right equipment to achieve this point. Owing to the different way of remote monitor—a personal computer visit the WSN via Internet or a mobile terminal visit the WSN via the 3G network, for example, UMTS—this paper design two kinds of gateway to fulfill these two conditions, they are WII gateway (WSN integrate Internet gateway)and WIU(WSN integrate UMTS gateway).

No matter what kind of gateway the smart home system used, gateway is essentially a sink node in WSN. A sink node is the exit of the whole WSN with its characters of large data-throughput and high request of computation ability and storage ability. In addition, the transmission bound of sink node is larger than the ordinary sensor nodes, so than all data can transfer to the monitor center. Usually the sink node must be high efficiency and has durative power supply. In the application of smart home system, we design that the sink node is supplied by external electrical source.

The WSN gateway obtains the information collected by sensor nodes through the ZigBee radio frequency and then Gateway system software and support software operate these information (for example, data analysis, fusion and extraction) based on its access network and data needs of user. After that the information are transformed into proper format of Internet or UMTS, according to the protocols of different layers from the bottom to up. Figure 2 displays the WSN gateway structure we designed for the smart home application.

For the house overcast by WLAN, a WII gateway used WLAN AP to integrate the WSN with Internet. The AP (access point) is the bridge between wired network and the wireless network and it is used to connect with each wireless client and then integrate the wireless network as a whole into Ethernet. In the WLAN AP structure, we introduce a Proxy-based framework to WII gateway in order to avoid exhausting the whole of energy and computational resource in either sensor nodes or the gateway. Relate research such as Z. Z. Marco and K. Bhaskar [2] proposed the proxy-based framework, we proposed a novel structure that revises the mechanism to reduce the system load. Sensor nodes turn into sleep-mode except the gateway requires the latest information in WSN.

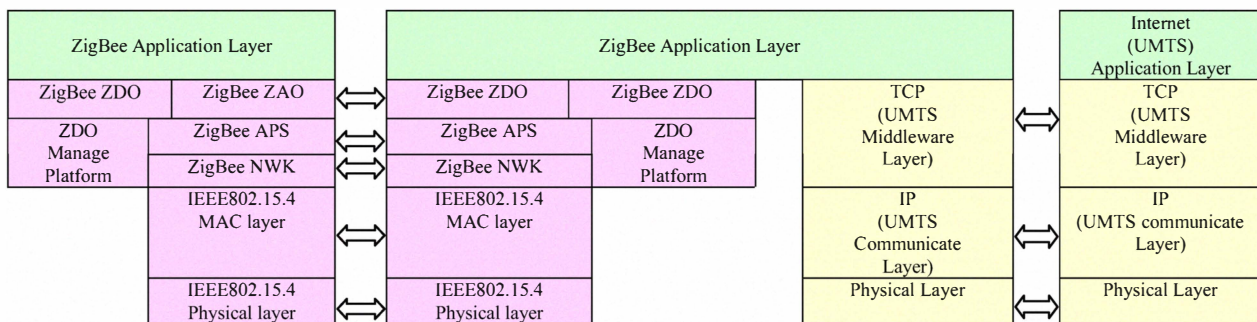


Figure2. The WSN Gateway Structure

The proxy-based framework of WII Gateway could be divided into four parts: RA (Router Agent), UA (User Agent Core), SC (Service Core), and SA (Sensor Agent). RA (Router Agent) provides the infrastructure of the whole structure and it is divided into two different parts: Hardware-level and OS. The Hardware-level provides the I/O hardware components such as USB2.0, RJ-45 and so on. The OS control various devices in hardware-level and also provides a platform for other components like UA, SC, and SA. SA (Sensor Agent) is a part while data transmitting between the gateway and WSN. SA is divided into RF (Radio Frequency), MCU (Micro-Controller Unit) and SPA (Serial Port Agent). MCU processes the data in Network and MAC layer of ZigBee protocol stack and SPA is Application layer in ZigBee protocol stack and regarded as the bridge between WSN and SC (Service Code). UA (User Agent) provides web service control, such as HTTP and Telnet for users to control WII gateway remotely. UA is divided into APCI (Access Point Control Interface) and SNCI (Sensor Networks Control Interface). SC (Service Core) sends the instruction to WSN and stores the data from WSN. SC is composed by RPA (Replication Agent) and DB (Database).

The architecture of WIU gateway consists of four layers which are Physical Layer, Communication Layer, Middleware Layer and Application Layer respectively. Physical layer provides the physical connection to UMTS network via a UMTS module, and access to the node of the sensor network through a ZigBee module. Network Interfaces is the communication layer. Two different communication technologies are supported by the WIU gateway: the wide range UMTS communication interface and the short-range sensor network communication interface. Middleware Layer divides communication between the sensors and the users, encapsulates the internal organization of the sensor network and provides API function to the users. The user application layer employs the API functions that are provided by the sensor network middleware.

III. HARDWARE DESIGN

The smart home system mainly consists of node module, ZigBee module, UMTS module and main controller which is also called gateway. The main controller is the kernel of the system which makes the information exchange between WSN and other form of network become possible. Figure3 and Figure4 show the system block diagram based WII gateway and WIU gateway respectively.

The work process of the smart home system as follow: when the WLAN AP module or the UMTS module receives instructions form remote user, first it has to verify the legitimacy of the instructions and then send the legit instructions to the main controller. The main controller will decode the instructions, extract the control object command and control information command. Finally the main controller will sent commands to the specified node through the ZigBee module to monitor or control the terminal equipment.

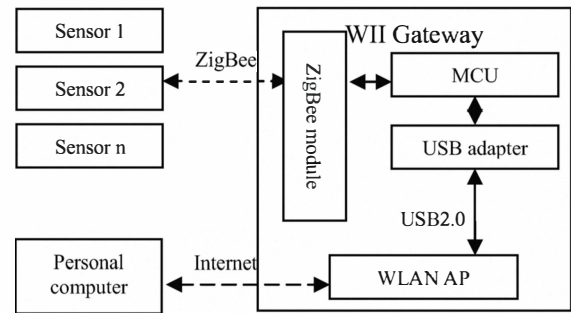


Figure3. System Block Diagram Based WII Gateway

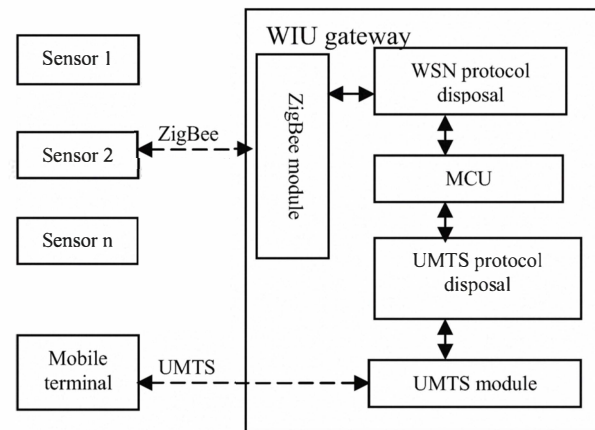


Figure4. System Block Diagram Based WIU Gateway

This design uses Samsung 16/32-bit ARM920T RISC microprocessor as the main controller. The ARM microprocessor is low power consumption and high reliability, which is suitable for controller for the smart home system. ARM920T achieved in MMU, AMBA bus, and Harvard cache architecture. The architecture has an independent 16 KB instruction and 16 KB data Cache, and also has on-chip DMA, UART, PWM timer, 10-bit ADC and other system peripherals. Such advantages of ARM920T can simplify the design of the main controller.

The CC2430 design by Chipcon Company is used as the ZigBee module. The CC2430 chip integrates the front ZigBee RF, the memory and 8051 microcontroller cores on one chip, and is produced in the 0.18 μ m CMOS technology, Its working current is 27mA, in the receive mode, the current loss is less than 27mA and in the transmit mode, the current loss is less than 25mA. The feature of sleeping mode and the short-time required in switching between active mode and sleeping mode, particularly suitable for those application requiring a very long battery life. In the design of node module, we used the soft-core microprocessor of CC2430 directly as the node's microcontroller and than to form the different nodes control unit with sensors and actuators.

The WLAN AP mainly consisted of ASUS WL-500g which integrate a 4 ports Ethernet hub, one USB2.0 and one parallel port together. Further more, it supports not only the static routing protocol but also RIP v1/v2 dynamic routing

protocol. The common firewall and the particular wireless firewall provide the high security for the network.

The UMTS module uses the Huawei EM770W module. It can provide user with the standard AT command interface. For its rich interface, fast and secure information transmission including data, voice, fax, it is much facilitate for users to employ this module in a smart home system.

IV. SOFEWARE DESIGN

Linux Operating System which is open source, transplantable and supports multiple network protocols is quite suitable for a gateway function and can provide a complete TCP/IP or UMTS protocol support to the system. In addition, benefited from its good stability and real-time, it can also meet the stability and reliability requirements of the whole smart home system. The software of the main controller includes the system initialization, monitoring the alarm signal on anti-theft, and handling and execution remote control instructions. Following Figure5 shows us the flow chart of main controller.

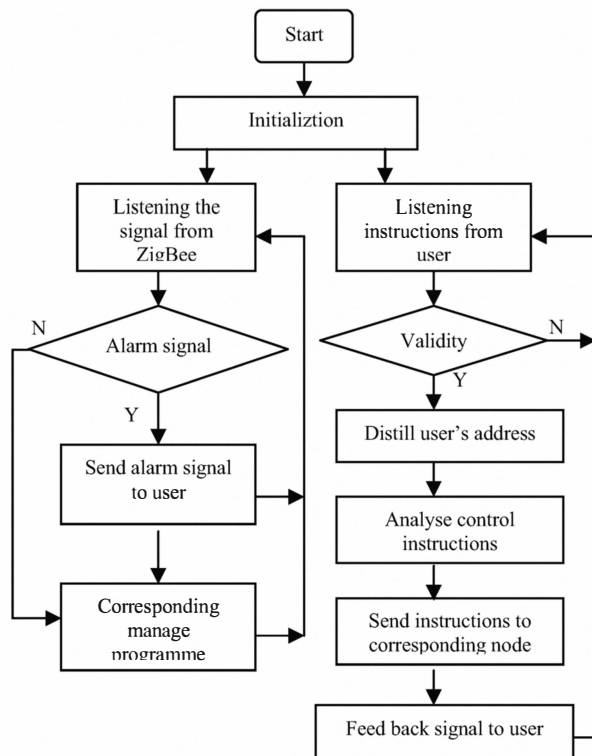


Figure5. Flow Chart of the Main Controller

V. CONCLUSION

The smart home system we design above is used to monitor and control the electric equipments and lights, record the data such as ammeter and water meter, ensure the security in house. We discuss the ZigBee criterion then prove that constructing the wireless sensor network within this criterion is an appropriate scheme. Two novel gateway structures--the WSN integrate Internet (WII) gateway and the WSN integrate UMTS (WIU) gateway—are also designed to achieve information exchange between heterogeneous networks. Appropriate hardware and software schemes to fulfill these gateway structures are given, too. It is believable that the smart home is not far away from us.

REFERENCES

- [1] C. Reinisch, W. Kastner, G. Neugschwandtner, and W. Granzer, "Wireless Technologies in Home and Building Automation", in Proc. 5th IEEE International Conference on Industrial Informatics, Vol. 1, Jun. 2007, pp. 93-98.
- [2] Z. Z. Marco, and K. Bhaskar, "Integrating Future Large-scale Wireless Sensor Networks with the Internet", USC Computer Science Technical Report CS 03-792, Mar. 2003.
- [3] M. Y. Aal Salem, David Everitt and Albert Y. Zomaya, "An Interoperability Framework for Sensor and UMTS Networks", ICWMC'07.
- [4] Ying-Chen Chen, Chi-Cheng Chuang, Ray-I Chang, Jia-Shian Lin, Te-Chih Wang, "Integrated Wireless Access Point Architecture for Wireless Sensor Networks", ICACT 2009, Vol.1 Feb. 2009, pp.713-718.
- [5] Yufei Du, Fung Po Tso, Weijia Jia, "Architecture Design of Video Transmission between UMTS and WSN", First IEEE International Conference on Ubi-Media Computing, 2008 pp.57-62.
- [6] ZHAO Ze, CUILi, "A Remote Health Care System Based on Wireless Sensor Networks", Information and Control, Vo.135, Apr., 2006, pp.265-269.
- [7] OU Jiefeng, LIU Xinghua, "Implementation of Gateway Based on CDMA Model in Wireless Sensor Network", Computer Engineering, vol.33, January 2007, pp.115,116,124.