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Research on Security System of Smart Home Based on ZigBee

Yuhan Du

Electronic Engineering, Maynooth International Engineering College, Fuzhou, Fujian, 350108, China
466534361@qq.com

ABSTRACT

In view of the drawbacks of traditional smart home using wired layout, and the problem that it can not accurately transmit and integrate home information, this paper proposes a new type of smart home using ZigBee protocol in wireless sensor network compared with the advantages of traditional smart home. This paper introduces a smart home system based on CC2530 wireless MCU ZigBee network nodes. The remote monitoring system is applied to the smart home environment under the ZigBee protocol, which is used to better deal with the security problems of smart home.

KEYWORDS

Smart home; Wireless sensor network; ZigBee; CC2530; Remote monitoring system

1. INTRODUCTION

1.1. Background and Significance of the Topic

With the development of science and technology and the progress of wireless sensor networks (WSN), high-tech and intelligent technology from the smart building into the home office users, smart home is more and more widely used in people's lives. Smart home is a comfortable, safe, convenient, environmentally friendly and energy-saving family living space based on residential plaorm, combined with architectural theory, fuzzy control technology, network communication technology, automation technology [1], through intelligent control and management. Compared with the traditional home, the smart home is based on the original living function. It has also changed from the original passive static structure to a tool with active intelligence. The smart home security system is an important subsystem of the smart home system.

In recent years, with the continuous improvement of people's economic level, living standards have been greatly improved. But at the same time, due to the increasing mobility of social personnel, the increasing income gap and other factors, the social structure and social security problems have become increasingly serious. In addition, the introduction of various household appliances and accommodation floors are generally high, the community environment is uneven, and the safety of people's life and property can not be effectively guaranteed. For this reason, more reliable and practical security facilities have become a top priority to ensure the comfort, tranquility and happiness of family life.

1.2. Research Status and Development Trend At Home and Abroad

Compared with foreign smart home, China's technology development and research are relatively later than foreign countries. Since 2007, China's smart home has entered a stage of rapid development. On

the basis of basic smart home security, many companies have begun to focus on research and development, the development of intelligence has gradually become mature, and the form of products has become diversified. It has laid a good foundation for our country in the field of smart home and produced excellent smart home products. Like Haier's U-home [2]. The product includes household appliances, lighting and curtain control, multimedia entertainment, and has made outstanding achievements in security support such as visual intercom, security alarm, environmental detection, remote monitoring and fault feedback. At the same time, many technology companies like Huawei and Xiaomi, which develop mobile phones, have also invested in the research and development of smart home [3].

In recent years, China has focused on the application of advanced wireless communication and sensing technology to the field of smart home [4]. Wireless sensor network technology is introduced into the smart home system, which overcomes the problems of complex wiring and high energy consumption in the traditional home system. Similarly, smart home security system and smart home remote monitoring system derived from wireless network technology are the hot research frontiers at present, and the rational use of these two systems is an important prerequisite to ensure home security.

2. INTRODUCTION TO ZIGBEE

2.1. Origins of ZigBee Technology

The ZigBee protocol is a wireless communication standard developed by the ZigBee Alliance. The ZigBee Alliance was founded in August 2001. So far, in addition to Invensys, Mitsubishi Electronics, Motorola, Samsung and Philips and other internationally renowned large companies, the alliance has about 100 member enterprises, and is growing rapidly. It covers semiconductor manufacturers, IP service providers, consumer electronics manufacturers and OEMs. The name of ZigBee comes from the ZigZag-shaped dance that honey communicates with each other. When pollen is found, bees tell their companions the location, distance and direction of pollen through ZigZag-shaped dance [5]. This method makes the honey group form a communication network to obtain and exchange information. ZigBee technology has been listed as one of the ten technologies with the fastest development and the broadest market prospects in the world in 2004.

2.2. Advantages of ZigBee Technology

The main advantages of ZigBee technology are as follows:

2.2.1. Low power consumption

There are three devices in ZigBee network: coordinator, router and terminal node. Low power consumption is only for terminal nodes, because routers and coordinators need to be powered on all the time, and only terminal nodes can sleep regularly. Two No.5 batteries can last from 6 to 24 months on low-power standby, eliminating the hassle of recharging or frequent battery changes.

2.2.2. Low rate

ZigBee has different data transmission rates in different frequency bands. In general, Zigbee operates at a lower rate of 20 to 250 kbit/s to meet the requirements of low-rate data transmission.

2.2.3. The delay is short

Zigbee is extremely responsive, switching from sleep mode to active mode in just 15 milliseconds, and nodes are connected to the network in just 30 milliseconds, which significantly reduces energy consumption.

2.2.4. Close range

Typically, the communication distance between two similar ZigBee nodes can effectively cover a range of 10 to 100 meters, which basically meets the needs of the average home or workplace.

2.2.5. Large capacity

Zigbee supports star, slice, and mesh network architectures and is capable of forming large-scale networks of up to 65,000 nodes.

2.2.6. License-free wireless communication frequency band

Zigbee's 2.4GHz band is available worldwide for license-free use when operating in the Industrial, Scientific and Medical (ISM) band using Direct Sequence Spread Spectrum (DSBS) technology. License-free access is also available in the 868MHz band in Europe and the 915MHz band in North America.

2.2.7. High security

Zigbee uses the AES-128 encryption algorithm to provide data integrity checking and authentication. This security mode can be used flexibly to ensure its security attributes.

2.2.8. Low cost

The initial cost of ZigBee module is about $3, which can be reduced to $2 after wide application, equivalent to RMB 10 ~ 20.

2.3. ZigBee Topology

In WPANs with low data rates, there are two types of wireless devices: full-featured devices (FFDs) and simplified-featured devices (RFDs). An FFD can communicate with both other FFDs in the network and RFDs in the network, but RFDs can only communicate with FFDs [6], so they cannot communicate with each other.

In ZigBee networks, topology formation is considered as a central issue. For different environments and project requirements, ZigBee networks provide three types of network topologies: star, tree, and point-to-point. Compared to the other two types of topologies, the cluster-tree topology exhibits higher connectivity and lower routing cost, which makes it more suitable for periodic monitoring application scenarios [7]. In this paper, we describe how smart home security systems can adopt a cluster-tree type of network topology design

The tree topology is a unique point-to-point configuration. Most of the devices use ffd technology and rfd can be added as leaf nodes to the tail of the tree network. The responsibility of the ZigBee PAN coordinator is to start the network and pick some core network parameters to be used as the basis of the tree network. By utilizing the ZigBee coordinator, the network has the potential to be expanded as well. In a tree-like network topology, the coordinator employs a hierarchical routing strategy to move data and control information within the network [9]. Tree networks are composed of parent-child relationships, where new nodes are connected to existing coordinators as children. Figure 1 illustrates a typical tree structure.

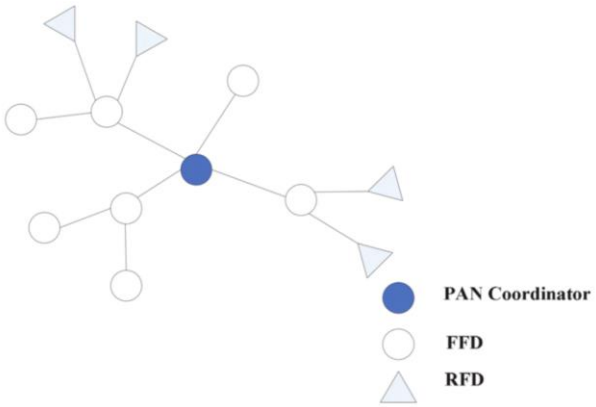

Figure 1. A typical tree topology

3. SMART HOME SECURITY SYSTEM DESIGN

3.1. Smart Home Security System Structure

Figure 2 presents us the detailed architecture of the remote smart home monitoring system. Through rational planning of home network nodes, it is divided into several parts, and the corresponding function modules are designed according to different needs. It can be mainly categorized into two main types: wireless ZigBee terminal and ZigBee Internet gateway. The former is the control center of the whole control system, while the latter is responsible for controlling each home node. The key terminal devices of the system include a variety of wireless devices such as wireless switches, wireless curtains and wireless metering sockets. These devices are connected to a unified gateway through a wireless network and then controlled by the corresponding software. Each end device integrates a CC2530 and matching functional components. These modules are connected to each other through serial ports or networks to form a complete wireless network system. the CC2530's main responsibility is to communicate with the gateway and other ZigBee devices.

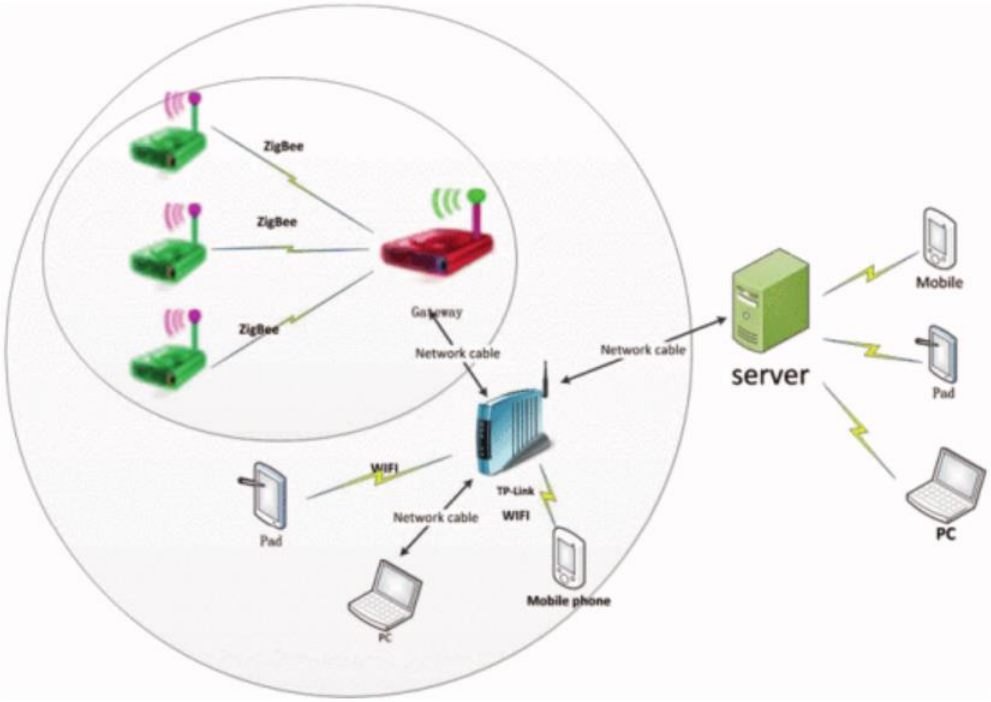

Figure 2. The structure of remote smart home system

Among them, a large number of modules are scattered in the computer monitoring center coordinated and controlled by CC2530. The computer detection center is connected with the video module and the GPRS module [10], which can send the alarm information to the mobile phone client through the GPRS network. The user can also view the video information through the PC terminal to determine whether there is a false alarm in the non-security situation.

3.2. ZigBee Device Type

In a ZigBee network, there are three main device classes: namely, coordinators, routers, and end devices [11]. The coordinator acts as the core of the entire network and is responsible for building, maintaining, and managing the network. In addition, it has the control function of monitoring the area. The main responsibilities of the router are to allow other devices to access the network, perform multi-hop routing, and packet forwarding. End devices have the ability to access and exit the network, send and receive data, and have the option to enter a dormant state

4. HARDWARE DESIGN OF SMART HOME SECURITY SYSTEM

4.1. Introduction to CC2530

CC2530 is a system-on-chip [12] developed by Chipcon for embedded ZigBee applications. It supports the 2.4-GHz IEEE 802.15.4/ZigBee protocol. The CC2530 has 3 different memory access buses: Special Function Register (SFR), Data (DATA) and Code/External Data (CORE/XDATA) [13]. While the CC2530 is in idle mode, any interrupt can restore the CC2530 to active mode. Some interrupts can also wake the CC2530 from sleep mode. A memory crossbar at that core of the system use the SFR bus to connect the CPU, DMA controller, and physical memory to all external device.

4.2. Function Introduction of CC2530

The functional pin diagram for the CC2530 is shown in Figure 3.

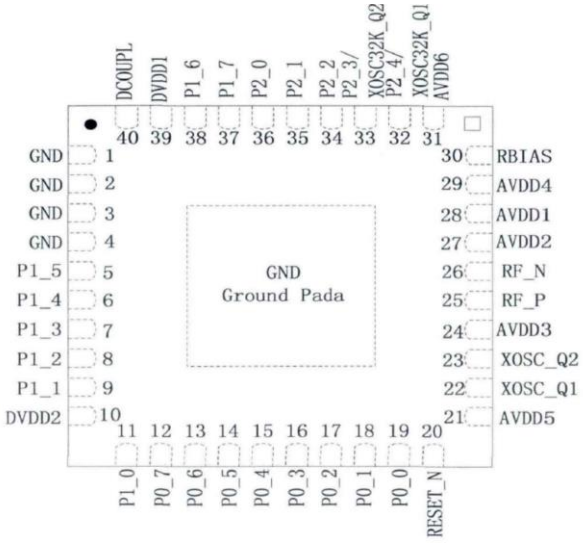

Figure 3. Function pin figure of CC2530

4.3. ZigBee Networking Process

The ZigBee network is initially built by the coordinator, while other nodes join the network by submitting a join request, the exact steps of network formation can be found in Fig. 4 [14]. When the first FFD device is activated, the device first performs an energy scan of the default active channels in the physical layer in order to identify possible interfering factors and to sort these channels

according to their energy values. The next step is to aggressively perform the scanning operation and filter the channels that are most suitable for current use. The coordinator becomes the first node to achieve success in the network.

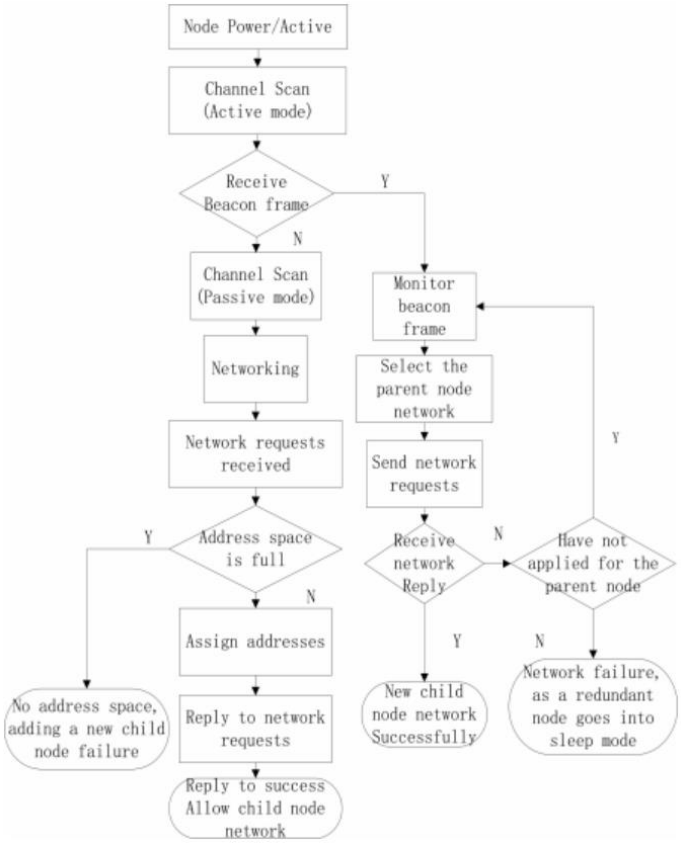

Figure 4. ZigBee networking flowchart

After the network construction is completed, all non-coordinator nodes are defined as child nodes [15] and submit connection requests to the communication network they belong to. During the network probing phase, these nodes actively search for potential parent nodes. Once connectable nodes are identified, they send a request to join the network to the selected parent node and wait for its reply. Upon receiving a join request, the parent node does not approve it immediately, but first performs an exhaustive evaluation of the request. This evaluation process involves checking the network capacity, security protocols followed and other network health indicators. The parent node approves the request only when all the necessary conditions are met. Upon approval, the parent node sends a response to the child node marking its successful joining of the network. In this response process, the parent node assigns a unique short address to the newly joined child node for node identification and localization within the network. Each node, both parent and child, follows this method to continuously maintain the network structure and order. As the first full-featured device (FFD) in the network, the coordinator plays a key role in the early stages of network establishment. The coordinator is not only responsible for initializing the network build, but also periodically broadcasts beacon frames to maintain network synchronization and process network requests from new nodes. These beacon frames provide the nodes in the network with synchronized time frames and necessary network information, thus improving the efficiency and orderliness of the whole network.

However, when the number of child nodes mounted by the parent node reaches the upper limit, i.e., the network address has been fully allocated, the parent node will no longer accept new join requests. In this case, the new node must search again for other potential parent nodes to try to join the network. This mechanism ensures that the network does not suffer from overcrowding which affects its performance and efficiency. Overall, this dynamic node management and address allocation strategy allows Zigbee networks to scale effectively and adapt to changing environmental requirements.

4.4. Hardware Design of Gateway Module

The gateway not only has outstanding functionality, but also its computational performance standards are extremely high. Therefore, in this study, we have chosen a 32-bit LM3S9B96 microcontroller and a low-power RF chip, CC2520.The LM3S9B96 is an ARM Cortex M3 processor developed by TI, which has been widely acclaimed for its high quality, fast response time, and excellent interface immunity. This system combines 16-bit and 32-bit instruction sets, aiming for an optimal balance between code density and performance. The CC2520 is mainly responsible for the overall organization of the ZigBee network and handles the reception and transmission of data to and from the end devices. The gateway also integrates an Ethernet interface, enabling remote access and monitoring. In addition, the core task of the gateway is to collect, store and process all the data from ZigBee, which places high demands on its storage capacity. For this reason, we designed a microSD card interface solution. In order to better meet the needs of local users, we specially designed a TFT touch screen as the interaction interface between the user and the device. Through this device, users are able to easily adjust personal parameters, view historical data, and perform real-time monitoring and management of ZigBee sensor nodes and other home automation devices. Figure 5 shows the hardware configuration of the gateway.

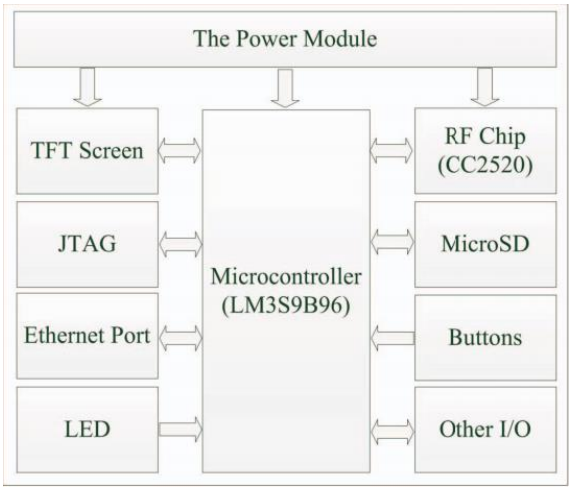

Figure 5. Hardware structure of gateway

4.5. Hardware Design of Terminal Module

In order to improve the overall extensibility of the system, in this paper we have designed 2 separate modules, the communication module and the sensor controller module [16]. By separating the communication module, the study has the ability to use the communication module multiple times, and similarly we can design appropriate circuits and drivers for different sensor controller modules. Based on the practical requirements and experimental environment considerations, we carefully constructed a series of terminal modules, which include wireless switches, curtains, sockets, as well as various types of wireless sensors and alarm modules. Figure 6 presents how the terminal devices are connected to the CC2530.

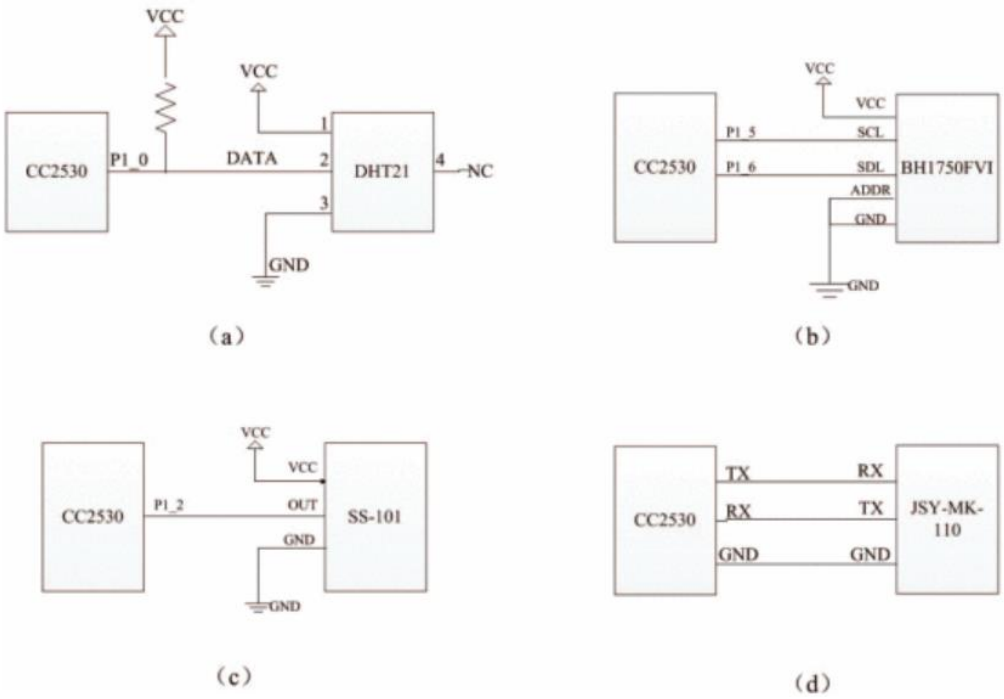

Figure 6. Sensor connection diagram

5. CONCLUDING REMARKS

In the new era, smart home will gradually replace the traditional home to occupy the mainstream of the market. This paper puts forward the application of ZigBee technology in smart home security system in the new era. Taking CC2530 as the hardware security system design, two new hardware modules of wireless ZigBee gateway and ZigBee terminal are proposed to realize the system design. Through the detailed introduction of the origin, advantages and network topology of ZigBee technology, it reflects the advantages of ZigBee technology and wireless sensor network technology in long-distance data transmission in smart homes. The system has the advantages of simple structure, high reliability and strong versatility, which can meet the requirements of users for smart home.

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