The Implementation of Smart Home System Based on 3G and ZigBee in Wireless Network Systems

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Abstract

Currently the smart home system is mainly used in a number of upscale communities and has not been widely used for ordinary people. As we all know, the smart home controller integrally stores a large number of audio, video, image information. It requires a high-speed and real-time network which can make it possible to let mobile phones become a control terminal. The purpose of this paper is to improve the performance of the control network in current smart home system, and to design the controller module which is used ARM server as our home controller processor. The autonomous control and reconstruction can be realized both by home controller gateway and wireless network nodes, the most basic and important unit, which is the ZigBee wireless network module in those home appliances. Wireless module communicates with the wireless gateway normally, at the same time, connects with the mobile terminals to remotely monitor the 3G mobile phones.

Keywords: *Smart Home System, ZigBee, ARM Server, 3G Mobile Phone, Wireless Network Module*

1. Introduction

Currently the smart home system is mainly used in a number of upscale communities and has not been widely used for ordinary people. It cannot be meet the ordinary people requirements and the rapid development of the appliances technologies. Mobile phone is so extensively used by people on anytime and anywhere. A lot of mobile phones can connect to 3G network. As we all know, the smart home controller integrally store a large number of audio, video, image information. It requires a high-speed and real-time network which can make it possible to let mobile phones become a control terminal [1, 2].

We employ ZigBee as the basic indoor networking technique of wireless smart-home sensor network. ZigBee which is characterized by its short distance application, simple structure, low power consumption and low rate, becomes the standard that IEEE groups designed for family short-distance wireless connectivity. By using IEEE 802.15.4 specification as MAC and PHY standards, ZigBee technology is quite suitable for indoor home network [3]. We choose ARM server as our home controller processor. The self-organization and reconstruction can be realized both by home controller gateway and wireless network nodes, the most basic and important unit, which is the ZigBee wireless network module in those home appliances. Wireless module communicates smoothly with the wireless gateway; at the same time, connects with the mobile terminals to remotely monitor the 3G mobile phones [4].

The purpose of this thesis is to improve the deficiencies of the control network in current smart home system, and to design the controller module, 3G module and wireless module of the smart home control system, in order to use mobile phones as the "remote control" for smart home system.

2. Design of Smart Home Hardware and Software

Our system has the Lord controller, cable unit module, wireless module (Figure 1). This is the basic component of smart home system. Of course for these parts can be fully extended, everyone has his own choice, so the smart home is the most basic human nature and life harmony. But now based on practical terms, need most is to realize its basic functions, according to this idea, we make the following design:

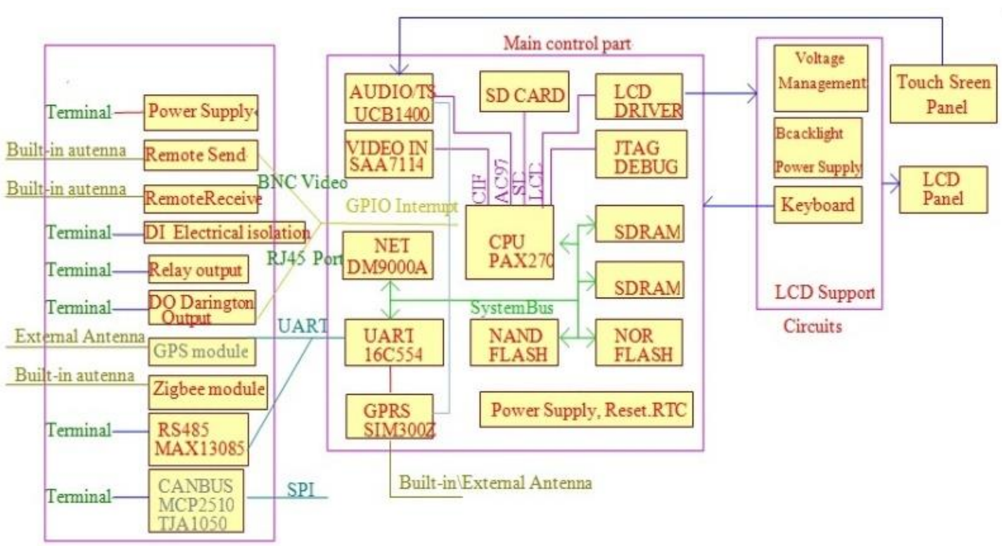

Figure 1. Controller structure design chart

System hardware structure as shown in Figure 2: The ARM controller's main functions are operating date input and output I/O port and other parts, at the same time, achieving the acceptance and transmission of ZigBee date transmission and 3G Network communication and other functions. Therefore, the system need to choose more general-purpose I/O port and rich external resources for being easy to build chips of peripheral circuits.

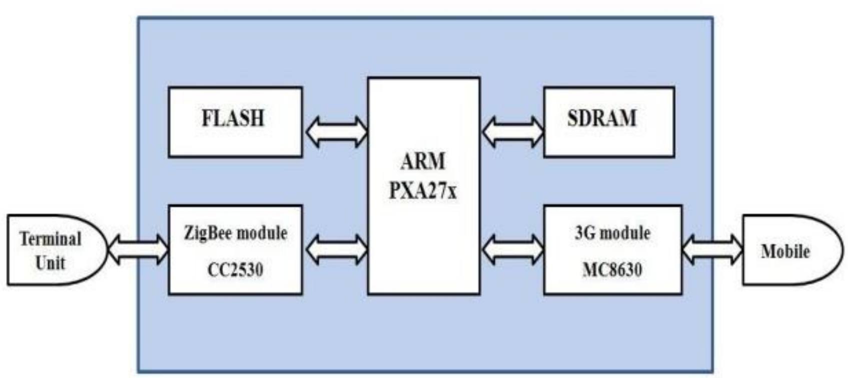

Figure 2. Hardware System Structure

As shown in Figure 2, we adopt H57V2562GTR-75C as some piece of SDRAM, ensure that have enough memory and make its normal operation. Nand flash is K92G08UOC chip is used by the controller's storage. Of course, our SDRAM and Nand flash part can be extended. If some images and video information need more storage, we can use USB storage equipment, for example, including USB flash disk and hard disk storage.

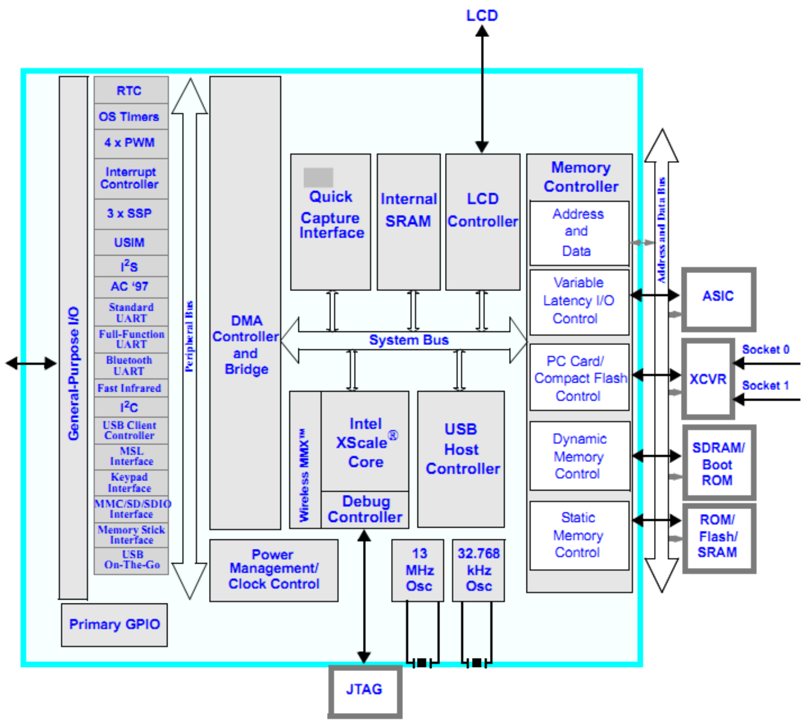

Figure 3. PXA27x series Processor Block Diagram

ARM master module is composed of the ARM controller, FLASH, SDRAM and related peripheral circuits. Intel Corporation in the end of 2003 the most robust performance out of PXA27x series embedded processor, PXA27x series based on the embedded processors ARMv5E Xscale core, the highest frequency of up to 624 MHz [5]. Because Intel announced the communication and application processor business to sell to Marvell, and Intel's communication and application processor, XScale is the core of technology. We select Intel Corporation PXA27x series as the system's processor (Figure 3), PXA27x series based on the embedded processors ARMv5E Xscale core, low-power, high performance(the highest frequency is up to 624 MHz), very suitable for embedded product development. With LCD controller, 3-channel UART, 4-channel DMA, IIC and SPI bus interface, General-purpose I/O port, one USB host interface and two USB device interface and other resources. These resources based on PXA270X can meet overall system requirements for the processor.

For ZigBee framework, we chose the new design of the Texas instruments CC2530 chip (Figure 4). The memory capacity is 256K. For our design and ZigBee protocol stack, we need the chip to hold strong Flash storage, 256K CC2530 can satisfy the more complex design and application. The chip is widely used in automatic control, monitoring and many other fields.

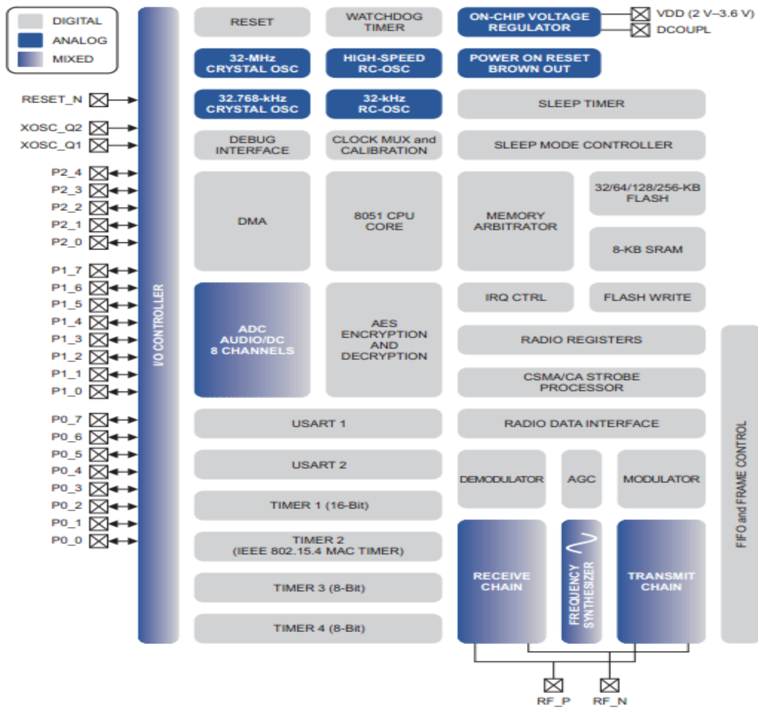

Figure 4. CC2530 of ZigBee module chip

In fact we use mobile phone as the controller to control ARM architecture. This controller also runs a transplant independent research and development of the Linux operating system. The operating system is the whole intelligence lives in the central part of the control system.

Application layer	Embedded ARM server
Operating system layer	TCP/IP protocol stack
Diver layer	3G, ZigBee mudule
Hardware layer	

Figure 5. Control terminals software structure

Software of the whole system uses the ARM architecture. Control terminal is the server because it provides service, and the phone or computer of the user is the client. The software structure of control terminal was shown in Figure 5. It consists of hardware driver layer founded on hardware, operating system layer and application layer. Hardware driver layer including 3G module driver, ZigBee module driver, and so on. The operating system layer adopted embedded Linux operating system, as Linux is open source operating system, and convenient to transplantation and development, and has the TCP/IP protocol stack. The Application layer transplant embedded ARM server Linux operating system.

3. Implementation of Smart Home Network System

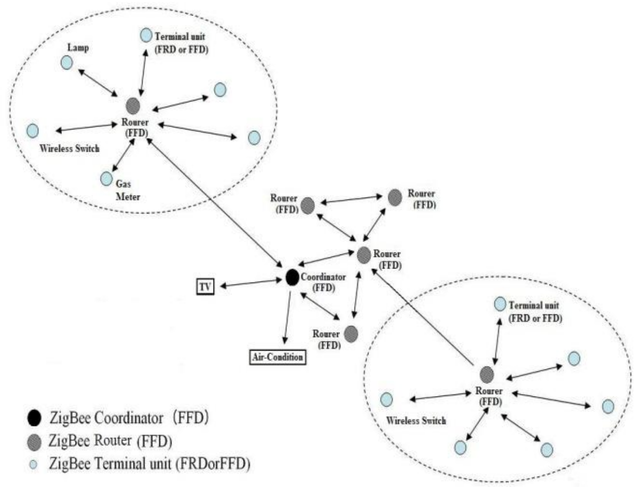

Figure 6. Smart Home Network based on ZigBee

We design our ZigBee networking structure and smart home network based on ZigBee (Figure 6). The procedures of ZigBee network deployment.

Design: to construct a complete ZigBee network consists of two procedures: network initialization and connecting nodes to the network. Adding nodes to the network requires two procedures: connecting with the network through coordinator, and connecting through existing parent node.

The construction of ZigBee network is initialed by the coordinator. Each ZigBee node which wants to connect with the network should meet the following two requirements:

● This node is FFD node, and can work as ZigBee coordinator.

● This node is not connected with other network. Otherwise, this node can only serve as a child node. There is only one coordinator in one ZigBee network.

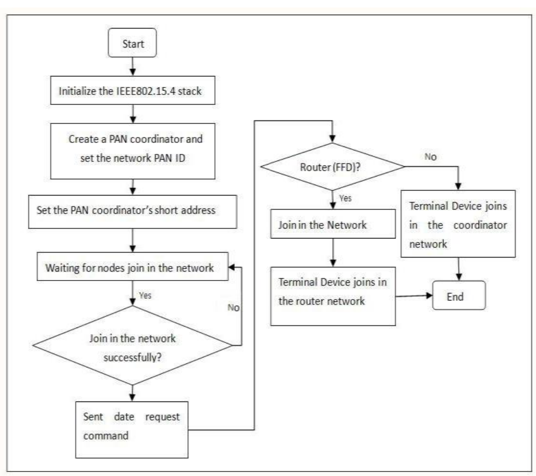

Figure 7. The main program of ZigBee flow chart

Network initialization process is as follows (Figure 7):

● Identified network coordinator. First, we should make sure whether the node is a FFD node or not. Then we should make sure this FFD node is not serving as a coordinator in other network and current network doesn't have a coordinator. By active scanning, it sends a beacon request command, and makes T_scan_duration. If there is no beacon scanned during the period, then there is no coordinator within the POS of this FFD node. The FFD node now can serve as a coordinator to build a ZigBee network, and produce and broadcast beacon.

● Scan the signal channel. This includes energy scanning and active scanning. First, energy scanning should be carried out for appointed or default signal channel to avoid possible interference. Sort the measured energy values ascending first, abort the channels whose energy values exceed the permit value, and label the others as available ones. Then conduct active scanning, to search the network information within the range of the node. The information transmits in the network as beacon frame, while acquired by the active signal channel by scanning. Finally we find a best and comparative calm signal channel according to the records. This channel should be in the range of fewest ZigBee networks. It would be best if there are not any ZigBee devices. During the active scanning, Mac layer would abort all the frames received by phy layer data service, except the beacon.

● Set of network ID. After finding the suitable signal channel, the coordinator would select a network identifier (PAN ID, value<=0x3FFF) for the network. This ID should be unique for the channel, and not conflict with other ZigBee networks. It cannot be the radio address oxFFFF either, as this address is reserved. We can monitor the other network IDs or scan the appointed signal channel, to choose a PAN ID which would not conflict with the others. There are two address models for ZigBee network: extensive address (64 bit) and short address (16 bit). The extensive address is allocated by the IEEE as the unique mark for the device. The short address serves as mark for the device in the local network. Within a network, the short address for each device should be unique. When the child node connects with the network, the short address is allocated by the patent node and serves for communication. For the coordinator, the usual short address is 0x0000.

After the above procedures, ZigBee reticulated network is successfully initialized. Then we can add other nodes to it. The node would select the parent node with the strongest signal, including the coordinator, within its range. When it is connected, it would be allocated with a short address, by which it would send and receive the data. The network topotaxy and address would be saved in respective flash.

The node connects with the network through the coordinator. When the coordinator is fixed, the node should connect with the network through the coordinator. Considering the capacity of the network and the characteristics of FFD/RFD, this article would only base on the situation of FFD node and the flow chart of FFD node connect with the network through the coordinator.

To establish the connection, FFD node should submit request to the coordinator. The coordinator receives the request and permits the connection, and then responses to the node. After the connection is established, the data can be send and receive. Followings are the procedures (Figure 6, 7):

● Searching for network coordinator. The node would actively scan the coordinator. If there is beacon acquired within the duration, the node acquires the information of the coordinator and submits the request for connection. After selecting the suitable network, the higher layer would set up the physical layer and PIB attribute such as PHY current channel and Mac PAN

ID of the Mac layer. If there is no beacon detected, the node would start the scanning after the interval.

● Submitting associate request command. The node would submit associate request command to the coordinator. After receiving the command, the coordinator would reply an ACK, and submit connect direct primitive to its higher layer to admit the reception of the request. This doesn't mean the connection is established, just means the reception of the request. When the higher layer of the coordinator's Mac layer receives the primitive, it would decide to allow the connection request or not according to its resource situation (the memory storage and energy), and responses to the node's Mac layer.

● Waiting for the processing of the coordinator. When the node receives the ACK from the coordinator, the Mac layer would wait for a moment for the connection response from the coordinator. If the response is received during the schedule time, the node would report it to its higher layer. The coordinator would set up a T_response_wait_time while sending the ACK for the coordinator to response to the request. If there is enough resource for the coordinator, it would allocate the node with a 16 bit short address, and generate connection response command, including new address and successful connection condition. Then the node successfully connects with the coordinator, and possesses the ability to send and receive date. If there is no enough resource, the node would send the request again, and connect with the network directly.

● Sending data request command. If the coordinator admits the connection of the node, it would generate associate response command and store it. After the response time, the node would send data request command to the coordinator. After receiving the command, the coordinator would response with ACK and send the associate response command to the node. If the response time is out, and the coordinator has not permitted the connection, the node would try to extract the associate response command from the beacon frame from the coordinator. If it succeeds, the connection is established. Otherwise the node would resend the request until the connection is established.

● Responding. After receiving the associate response command, the node would reply an ACK to confirm the reception of the command. The node would save the short address and extensive address of the coordinator, while the MLME of the node would send connection confirm primitive to the higher layer.

Through the existing node joins a network node:

After the successful association between coordinator and FFD node which is close to it, the other nodes within the range of this network can connect with this network through the FFD node. There are two ways to connect with the network. One is by association. The node connects with the network. The other way is direct. The node connects with the former node as the child node. The first one is the main way to connect with the network. Only the node which is unconnected with other networks would be permitted to connection. During those nodes, some were connected with the network but lose the connection with the parent node, which are called isolated node, while others are new to this network. The isolated node keeps its parent node information in its adjacency list. It can send the request to its parent node directly. If the parent node is capable for the request of connection, it would send the former allocated address to the child node. The connection is done. If the parent node's child nodes have reached the peak, which means the network addresses have all been allocated, the father node could not permit the connection. The child node should search and connect the network as a new node.

For a new node, it would actively or passively scan the available network on one or multiple signal channels set advanced, for the parent node which is capable to permit the connection. It would restore the information of the parent node in its adjacency list. The information includes the version of ZigBee protocol, standard of the STK, PAN ID and the approval information of connection. It would select a parent node with the lowest depth from the adjacency list, and send the request information. If there are two or more qualified parent nodes, it would select one randomly. If there is no one qualified, the connection fails and the process is terminated. If the request is permitted, the parent node would response with a 16 bit network address. Then the child node connects with the network successfully, and is able to communicate. If the request fails, it would search in the adjacency list and send the request again, until the connection is done or there is no qualified parent node in the list.

By this, we can ultimately build up a ZigBee network connecting all the devices. All information would be gathered in the terminal controller. We can check the inner information or control any device within the network by a mobile phone.

For this smart home system, we would adopt different network pattern according to the application environment, mainly based on the tree distribution network pattern (Figure 7).

Implementation of ZigBee control signal: According to CC2530, we adopt the Embedded Workbench IAR Swedish company development environment of the single chip microcomputer programming, realize its network functions. Finally we achieve such a structure: a module as coordinator equipment, for the control of 2 ~ 3 a node equipment. 2 ~ 3 module as node equipment, connected by the control unit of the concrete, Is the control unit such as: electric curtains, electric light, electric appliances, etc. This 2.4 GHz band realized based on the wireless control.

In the design of the single chip microcomputer to key for protocol stack addressing functions. In Zigbee, packets can single point transmission (unicast), multicast (multicast) or radio transmission (broadcast). Here is a addressing examples, for our radio transmission addressing.

For the present worldwide smart home systems, the famous are the United States Honeywell smart home 7000 series (Figure 8). When the network, mobile phone, working model are set, the phone through the 3G network can remote monitoring the home lighting, electric switch, access control, and each kind of sensor state. Also provide message alarm and control function so that monitoring to our home anytime and anywhere. We can use cable, wireless to upgrade software regularly for conduct management, and bring into the united management database.

Figure 8. The Implementation of American Honeywell Smart Home 7000

4. Conclusions

The smart home system discussed in this article mainly improve the traditional smart home system by real-time control of 3G network and the technology of ZigBee wireless network, to consist a smart home system of internet of things. It is traditionally believed the smart home system could enhance the quality of life. The smart home system of internet of things is changing this point of view. The obvious changes are practicality, convenience and easy integration. Every family has its own electricity devices. The intelligent fridge and air condition have different working standards with the traditional lamp and television. They are scattered, disordered and random, not an organic system. The cost for human on time, arrangement and control is very high and unnecessary. With a wireless network like ZigBee, we can combine those disordered electricity devices and form a complete system.

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