The Research and Implement of Smart Home System Based on Internet of Things

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***Abstract*—With the rapid development of Internet of Things, smart home which regarded as one of the main application domains, obtained more and more people's attention. In this paper, the characteristics and disadvantages of smart home system are analyzed. Then a smart home system based on B/S(Browse/Server) module is introduced. Through publishing the household wireless sensor network data to the web page of a remote server, users can control the household devices conveniently and remotely. Its system architecture, hardware design and implementation approach are given. This system provides a more flexible and more convenient control for smart home system and is beneficial for the popularity and promotion of smart home system.**

Keywords-smart home; control system; Internet of Things

I. INTRODUCTION

The emergence and integration of new technologies characterized by perception and intelligence have changed the future development of information technology from the Internet to the Internet of Things. And the development of the Internet of Things also introduced new concepts and vaster development space for the smart home.

The smart home system based on Internet of Things has the following characteristics:

1) Compatibility of different communication technologies. It can converge many heterogeneous communication technologies by fixing various communication interfaces on the home gateway.

2) Ubiquitous service. With the use of ubiquitous access network, no matter where the users are, the real-time smart home information can be obtained conveniently.

3) Comprehensive perception. The comprehensive and real-time monitoring of home devices can be achieved by using a variety of physical and logical sensors.

4) Conveniently control. The smart home system can be controlled by the mobile terminal, PC, and many other communication equipments, and the control results can be real-time displayed through all sorts of visual interfaces [1].

As one of the core application domains in the Internet of Things, smart home attracts the most attention from the market. According to some reports, in the next several decades, the smart home industry will become one of China's main industry and the market prospects are very bright. Smart home system can improve the collection of traditional decoration with modern family living environment to meet the increasing demands of life [2]. This paper introduced a smart home control system based on B/S module which has good fexibility, easily expanded, high relibility and so on.

II. SYSTEM ARCHITECTURE

Referring to the multilayer thinking of IoT, a layer architecture model of smart home system based on Internet of Things is put forward as shown in figure 1. This architecture includes the following sections:

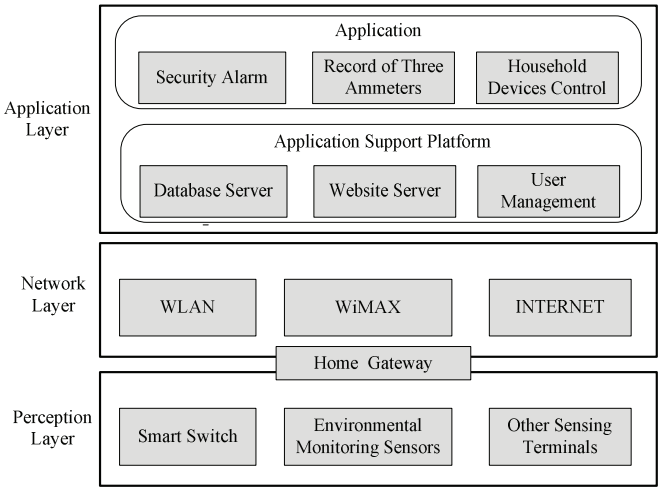

Figure 1. Layer architecture model of smart home control system.

1) Perception Layer. Perception layer is the lowest level of the whole structure. By using a variety of physical and logical sensors, household devices can achieve the comprehensive and real-time monitoring of the house. The sensors include

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environmental monitoring sensors, household devices control sensors, camera, GPS and other sensing terminals.

ZigBee as a low-complexity, low-power, low-cost and short-range wireless communication technology has broad application prospect in the field of smart home [3]. So we choose ZigBee wireless sensing technology as the perception layer information collecting and processing technology and use a mesh architecture to compose the WSN(Wireless Sensor Network).

2) Home Gateway. Home gateway connects the perception layer and the network layer. It gathers information from the perception layer and transmits it to the network layer. Home gateway plays a role as a protocol conversion unit and can compatible with a variety of communication technologies. We believe that the design of the gateway should be considered more scalability than compatibility, so this paper presents a low-cost, convenient, scalable gateway design method.

3) Network Layer. The network layer is consist of various kinds of wired and wireless communication networks such as WLAN(Wireless Local Area Network), mobile cellular network, Internet, etc. This layer is responsible for the transmission and processing of the getting information from perception layer. And through the heterogeneous network integration technology, resources can be shared by each network.

4) Application Layer. Application layer provides the interface between smart home system and users, which combined with industry needs to realize smart home applications based on Internet of Things. This layer is consists of application support platform and concrete applications. To support complex and intelligent applications, the interconnection environment needs devices of diverse functions to work in cooperation.

5) Application Support Platform. Smart home application support platform provides some common supports and abilities for the smart home applications, and it also provides open interfaces to enable applications access and use network resources and capabilities. By this means, it can shield upper layer application from the lower layer adverse factors and can simplify and reduce the upper layer application development and deployment complexity. In order to shielding the differences of application development, we select B/S(Browse/Server) model as the development framework. It contains a database server for data interaction with lower networks, a Web site server for accessing data from the database server and publishing services to the Internet and so on.

III. HARDWARE DESIGN

Based on the functional requirement of the system, the hardware design is divided into two parts: the detecting terminal and the home gateway.

A. Design of Detecting Terminal

The hardware of detecting terminal mainly consists of the ZigBee module, smart sensors, household devices and other periherals. The architecture of detecting terminal shows in Figure 2.

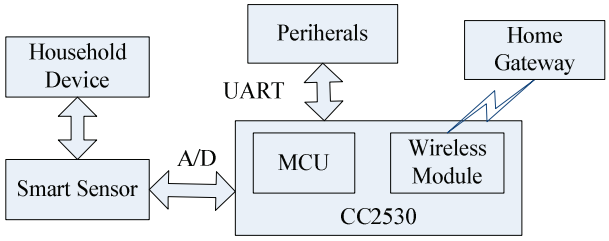

Figure 2. The architecture model of detecting terminal.

The CC2530 chip is the ZigBee module basis part of the system. CC2530 system-on-chip consists of a high-performance and low-power 8051 MCU, 2.4-GHz IEEE 802.15.4 compliant RF transceiver, two powerful UARTs with support for several serial protocols, 12-bit ADC with eight channels and configurable resolution and built-in ZigBee protocol stack(Z-Stack) [4].

According to the different needs of perceptive information, household devices carry difference sensors, some are for environmental monitoring, some are for devices control. The smart sensors connect to MCU through the A/D module which converts analog signals to digital signals.

B. Design of Home Gateway

In order to reduce the development cost and design difficulty, the home gateway only provides the most basic interfaces, and the rest of them are designed to be an extensible interface module.

The architecture of home gateway shows in Figure 3. It mainly consists of ZigBee module, USB communication module and extensible interface module.

The ZigBee module plays a role as a coordinator which is responsible for establishing, maintaining and managing the network.

The wireless RF module is used for receiving the wireless signal, which is sent from detecting terminal. Then the CPU deals with the signal and transmits it to USB module through serial port (UART).

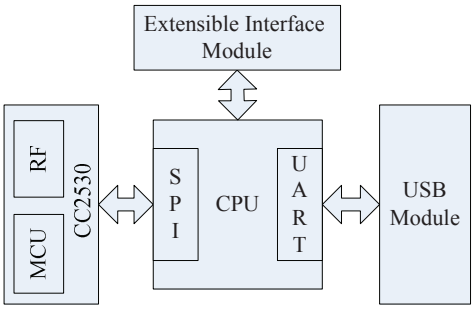

Figure 3. The architecture model of home gateway.

The extensible interface module is used for extending the capabilities of home gateway. For example users can add a PCI card and Rj45 interface on this module and connect to the Internet directly. By adding a wireless ir repeater module, the system can control household devices with infrared communication module. Using the reserved UART interface, LCD, keyboard and other peripherals can be added to the gateway.

IV. SOFTWARE DESIGN

Design of software in the system mainly includes the design of perception layer software and that of application support platform. The software of perception layer is responsible for the data collection, procession and wireless transmission of the WSN; the application support platform facilitates the development of smart home application based on WEB pages and GUI(Graphical User Interface).

A. Software Design of Perception Layer

Software design of perception layer mainly consists of these parts: initialization of each device, network composition, data procession and event handing. The software design is based on TI's Z-Stack, and using IAR Embedded Workbench as a development tool to write software in the application layer of Z-Stack [5]. The software provides standard interfaces and device definitions for different devices. The workflow shows in Figure 4.

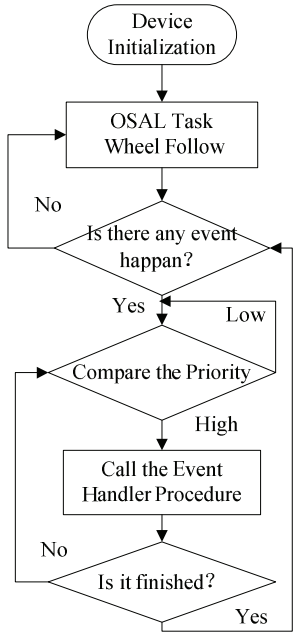

Figure 4. Perception layer software workflow.

1) Initialization of household devices: When a device joins a network, it needs to register in the gatway and be assigned a 16-bit address. The address is used for identifying devices and sending data within the network. The ZigBee implementation uses a routing protocol that is based on the AODV (Ad hoc On demand Distance Vector) routing protocol for ad hoc networks. This protocol facilitates an environment capable of supporting mobile nodes, link failures and packet losses [6].

2) Task management in OSAL system: When the above initialization is completed, the function osal_start_system () is called to run a OSAL system. This function is the main loop function of the task system. It will look through all task events and call the task event processor function for the task with the event. Function osalTaskAdd() is used to add a task to the OSAL system. A task consists of 2 functions – init and messages processing. Messages processing function takes in events, then processes one of them and returns the rest back to the main loop.

3) Eevent handing: If there are events for particular task, the function will call the event process routine for that task to handle the events. Events are handled one at a time at the event process routine of the corresponding task. The events in the perception layer are consist of timer events, operation events and response events. Timer events is used for updating the environmental monitoring information periodically by setting a timer. When the coordinator received a the user's control commands, the function will call an operation event process routine to parser the commands and handle the events. A response event handle function is called by a task when it has finished processing a received message.

B. Software Design of Application Support Platform

Software design of application support platform mainly consists of web site creation and maintenance, the build and update of SQL database server and the command processing.

1) Web access: Many web access methods can be selected such as socket programming, C/S(Client/Server) mode and B/S mode. However, as C/S environment is faced with many chanllenges such as faster, easier, and flexible technologies, nowadays people are considering moving client/server environment to browse/server environment for a better service. So the B/S architecture is selected in order to make sure that the user can manage the control system anywhere and anytime.

2) SQL database server: The database server is used for managing the information of household devices, users and control strategies. We use the Microsoft SQL Sever as a database development tool to manage it and use ADO.NET data access technology to exchange data with database management system. *Information classified as follows:*

a) The information of household devices is consist of device type, address, real-time status and history update records. This data sheet is updated periodically.

b) User information includes user identity information, private key, permissions. A user needs to be certified and authenticated before accessing to the system.

c) Control strategies information contains the device control instruction set, the device group information, association information between devices and user-defined control strategies. Such a variety of control methods provide a more flexible and more convenient control for smart home

system and are beneficial for the popularity and promotion of smart home system.

3) Command transmission: The command transmission software mainly consists of four steps. Workflow shows in Figure 5.

a) Step one: The user uses the browser from a mobile terminal or a PC to view the Web page of the smart home system and send commands through a visual interface .

b) Step two: The web server uses ADO.NET technology to visit the database. Then the server retrives the database and queries the matching command list and judges the type of the command. If it`s a control command then go to step three, else go to step four.

c) Step three: Using the control strategies in the database to package the command and sending it to the home gateway. Then the home gateway parses and executes the command. The work flow is finished.

d) Step four: The command is a query command , so the server uses the SQL statement to inquiry the matching equipment information and show the result through a serial of visual interfaces(the data table, the diagram and so on).

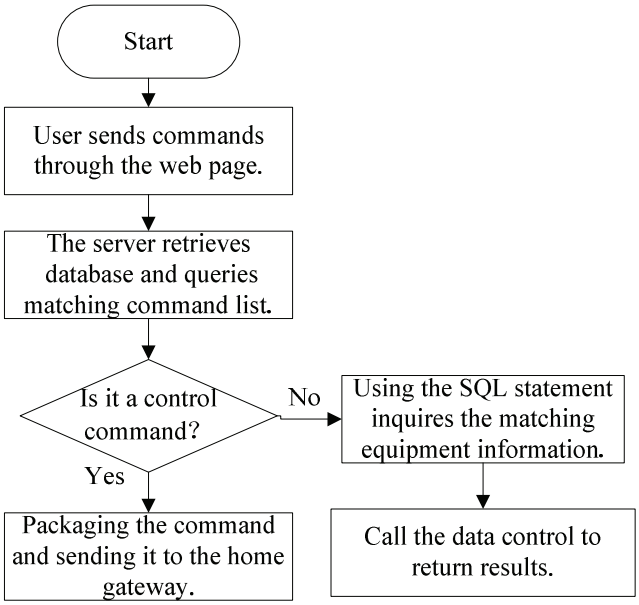

Figure 5. Command transmission workflow.

V. CHALLENGES OF SMART HOME CONTROL SYSTEM

A. Challenges

Although the smart home concept and its market demand have been there for a long time, the development of smart home technology as a breakthrough in the relevant subject, has not been large-scale application of universal [7]. There are two main shortcomings of the smart home system:

1) Although equipped with a variety of communication interfaces can enhance the gateway compatibility, but there universally are the question of the high cost.

2) The real smart home should be the one that by many different devices communicating with each other and without user's operation, realizes the home environmental intelligence, and gives the user a convenient, comfort and safety home environment. However, mostly smart home system is considered to be a monitoring system rather than a providing intelligent services system.

B. Solutions

Aiming at the shortage of the existing solutions, we design this smart home system for the purpose of realizing a real smart home. The solution to reduce the cost of the gateway has been mentioned in preceding sections.

We introduce the concept of coordinated control to the smart home design process and realize the intelligent control by grouping correlative devices and using the user-defined control strategies to manage them. For example, when you open the living room TV, the living room lights will be dimmed and the audio equipment will be opened automatically.

VI. CONCLUSIONS

In this paper, by analyzing the shortcomings of existing technologies, we introduced a convenient and flexible smart home system based on Internet of Things. We have developed a demo version of this system and used a cellphone to query and control it locally and remotedly. The experimental results show that this system can provide a real-time and reliable management for the smart home. It is believed that with the development of Internet of Things, smart home system will become more intelligent and multiplicity.

ACKNOWLEDGMENT

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