Design and Realization of Domestic Smart Gateway Based on Wireless Sensor Network

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Abstract. This paper proposes a smart domestic gateway used to manage power consumption, which realizes the interoperability across wireless sensor network (WSN), Wi-Fi and Internet. This system achieves smart home power consumption management. The implementation of hardware and software of the gateway has been explained in detail.

Introduction

In this day and age, power management is an important consideration in any home security application as, often, sensors and bell boxes are in less than convenient physical locations [1]. As a result, developing the information technology and intelligent technology is the new trend of domestic smart power consumption management and a new type of smart power management system is needed. The smart power management system enables grid management and visualization to be very effective as it incorporates real time monitoring data and historic engineering data into an integrated system, analyzing scenarios based on various modules and making it possible to collect, monitor and control real time data with accuracy [2]. In this way, people can control and manage the power consumption of household appliances in the family, and power supply centers have the means to acquire the demands for power from each family, which provides necessary basic information for the implementation of smart grid.

WSNs are emerging as a new paradigm, consisting in the collection of information in a collaborative manner, where independent sensor nodes collect and share information. With low complexity, low cost, low power, WSNs are widely used to build the wireless communication family network and playing an increasingly significant role in the smart home system [3]. However, the development of WSNs in the field of smart home system is encountering a huge challenge in the connection among WSNs and other heterogeneous networks. As an innovation solution for that, the domestic smart power management system and a new type of a domestic smart gateway will be presented and described by the paper. Working as the medium of family WSNs, family Wi-Fi and external Internet, this gateway enables people to access to smart power management easily at home via Wi-Fi, and provides Web Services for the remote visiting client like power station through Internet.

Domestic Smart Power management System

The basic structure of the domestic power management system is shown in Fig. 1. The power monitoring nodes in sockets are connected to the relevant household appliances, which are used to acquire current, voltage and other power data. The data are transmitted to the gateway via the ZigBee network. Power consumption information can be gotten by means of the software in the terminals such as smart phones, notebook computers or other Wi-Fi-enabled devices. Furthermore, the gateway exchanges the data with the power supply center via Internet, which data are the basis to establish robust and smart the power grid.
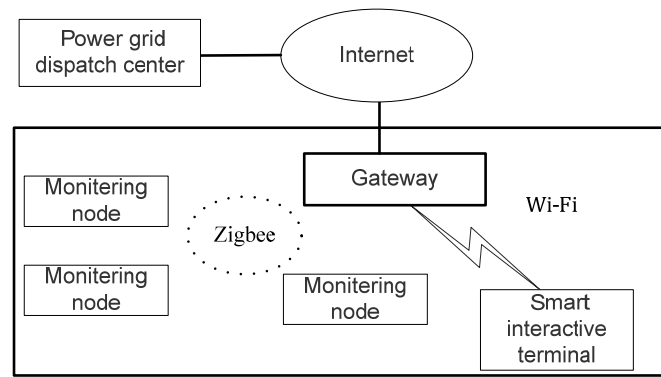
Fig.1 Structure of domestic smart power management system

As the key device in this system , the gateway should work with Ethernet, Wi-Fi, and ZigBee network communications[4]; provide Web Services function for remotely visiting client; support Wi-Fi network organization and IP address assignment; contain ZigBee protocol stack; be equipped with database for the storage and management of a vast amount of power data.
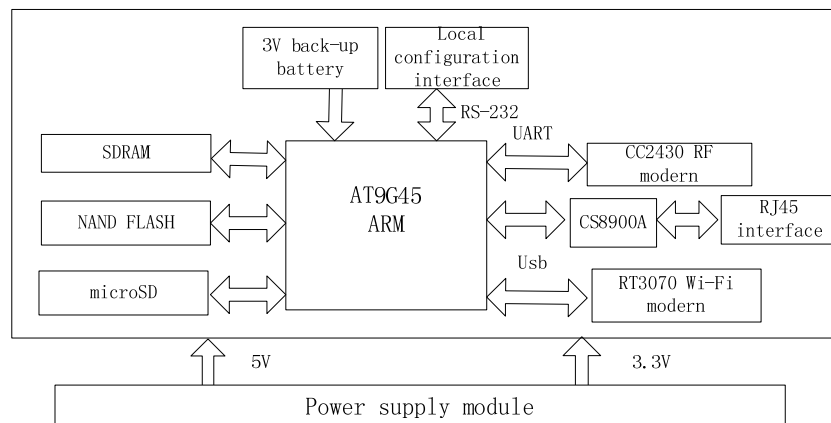
Hardware Design of Smart Gateway

Fig.2 Structure of gateway hardware design

Gateway hardware architecture is shown in Fig. 2. It consists of power supply module, ARM controller module, Wi-Fi module, CC2430 radio frequency (RF) module, and so on.

The power supply module converts 220V alternating power into DC 5.0V and 3.3V, and 3V backup battery is used to keep the RTC clock running in case of power failure.

ARM master control module is AT9G45 chip produced by ATMEL Corporation and the prerequisite SDRAM, NAND FLASH. AT9G45 has internal MMU (Memory Management Unit) and is of high integration, expansibility and processing speed. It is well suited for developing a gateway.

RT3070 chip module is used as Wi-Fi module supporting for IEEE 802.11g, IEEE 802.11b wireless protocol. RF module consists of TI Corporation's CC2430 chip and its peripheral circuits. With internal ZigBee protocol stack, CC2430 contains 2.4GHz RF radio transceiver circuit, which adds many conveniences to the networks functions development. CS8900A chip is used as crystal LAN ISA Ethernet controller. CS8900A connects ARM chip and the RJ45 interface with a voltage transformer.

A microSD card module is used for power data storage and a RS-232 interface for local system configuration.

Software Design of Smart Gateway

The first step of developing the software is to transplant operation system. In the gateway, Linux system is transplanted into microcomputer AT9G45.Wi-Fi drivers, serial drivers and microSD card driver are installed or replanted for the corresponding hardware module.

The second step of developing the software is to develop applications. The applications are divided into 6 modules: system configuration module, database module, Web Services module, routing and address assignment module, monitoring node management module and smart interactive terminal management module. Each module runs as an individual process in system. The relationships of each module are shown in Fig. 3.
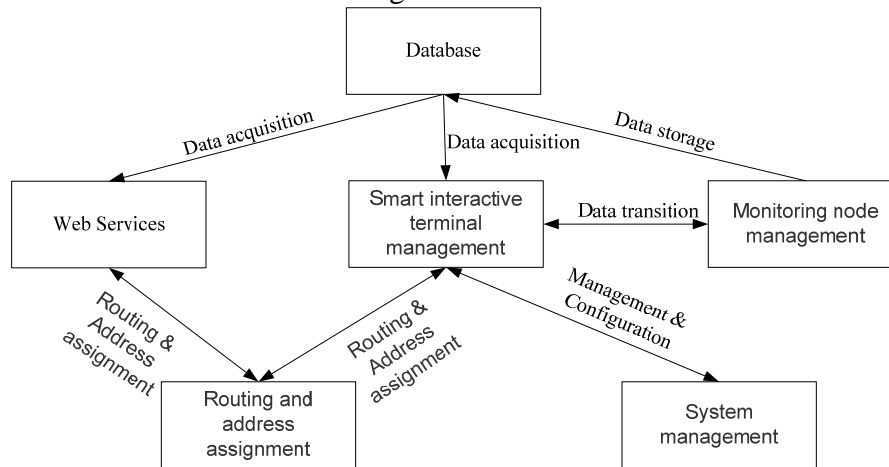

Fig.3 Relationships of the module

The following is the functional description of each module.

(1) *Database module* is responsible for database creation and data revision, maintenance and queries. SQLite is selected as the system database because SQLite is open source code, small size, with fast responding speed and various of API support. The design of the tables is as follow:

1) *User information table*: store user ID and passwords, which are used for certification of users logging from smart interactive terminals.

2) *Household appliances information table*: used to keep the record of device types of appliances and assign different ID numbers for each involved appliance.

3) *Historical data table*: storage of the voltage, current, active power, reactive power, power factor and accumulative electricity consumption data from the smart monitoring nodes. The data is saved with timestamp.

4) *Operation record table*: record the operation commands from smart interactive terminal, such as electric relay control, historical data inquiry and etc.

(2) *Web Services module* provides remote visiting service for the power supply centers. The working process is as follow: firstly, the power supply center sends a SOAP request message to the gateway. Once receives the request, the gateway passes the message to the request Web Services request processor. Secondly, the request processor resolves the SOAP request message and generates a corresponding SOAP response. Finally, gateway sends the SOAP response to the power supply center through HTTP protocol.

(3) *Routing and address assignment module* enables the gateway to support static routing and dynamic routing with RIP (Routing Information Protocol). NAT (network address translation) and DHCP (Dynamic Host Configuration Protocol) are supported as well, which provide unlimited automatic or static IP address assignment.

(4) *System configuration module* provides logs, IP address, clock synchronization and other configuration management. These configurations can be set by user locally (via the RS232 configuration interface) and remotely (via the smart interactive terminal).

(5) *Monitoring node management module* is used to transmit messages between the gateway and the monitoring nodes. There two key tasks for this module: collect the power data from the monitoring nodes and control the monitoring nodes. In order to ensure security of the data transmission in ZigBee network, frame head, specified frame end and CRC checksum are added to message packets. The CC430 module work as a coordinator node to collect massages from the monitoring node. As soon as receives messages, CC430will send the messages to the AT9G45 through UART port. Received by the AT9G45 and pass the legitimacy check, the power data message will be time stamped and written to database. Meanwhile, this module determines whether

it is necessary to transmit control request from smart interactive terminal to monitoring nodes. If necessary, send the control message to the nodes. The process is shown in Fig. 4.
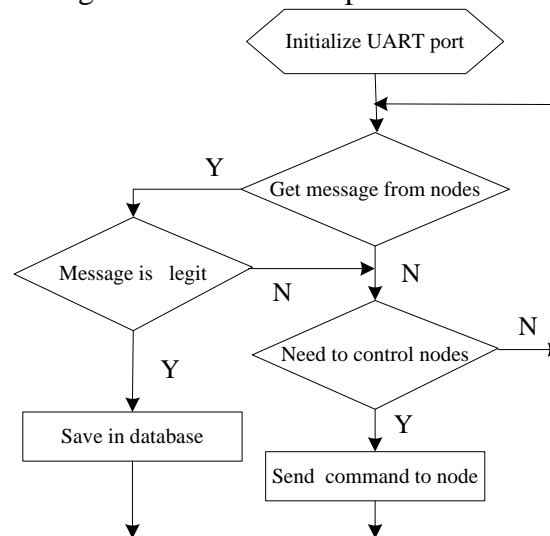
Fig. 4 Monitoring node management module process

(6) *Smart interactive terminal management module* is responsible for the socket communication, including receiving the command message from smart interactive terminal, performing the operation and responding to the smart interactive terminal with a reply message. The working process is as follow: firstly, the gateway listens to the socket port and waits for the connection request from smart interactive terminal. As soon as receives the connection request, the gateway permits the request and builds a connection. And then, the gateway will receives a command message from smart interactive terminal. Furthermore, the received message would be sent to the specific module and invoke the module to perform action. Finally, the invoked module generates and returns the processing result. The result message will sent back to the smart interactive terminal. The process is shown in Fig. 5.
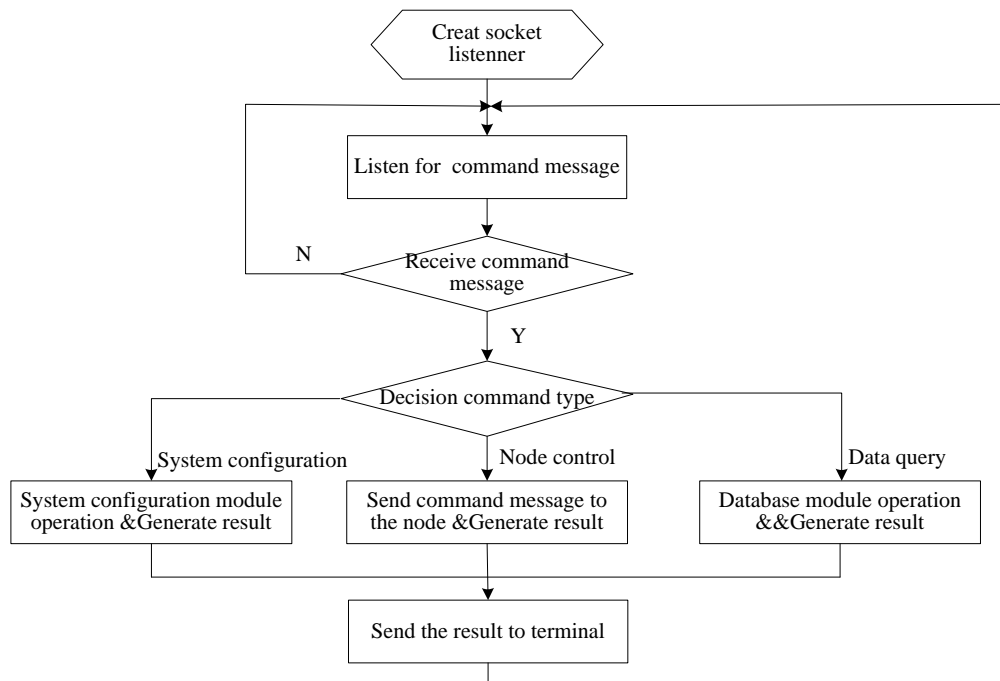
Fig.5 Smart interactive terminal management module process

Conclusion

The growth in embedded computing technology is facilitating development of smart domestic

gateway applications. The technology of domestic smart gateway is developing toward high integration, high modularity and standardization [5]. It is believed that this new type gateway has a promising market prospect.

This paper presents the design of the domestic smart power consumption management gateway. With AT9G45 chips as the master control module, six software modules are developed based on the Linux system. The gateway provides remote visiting services for power stations, and users can access to family power consumption management through smart interactive terminals. The gateway realizes the interconnection of WSN, Wi-Fi and Internet .During the practical test, the performance of the gateway demonstrates great accuracy, timeliness, and reliability, which can been taken advantaged by individual family and power stations for intelligent power management in the future.

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