Design and Implementation of UPnP Protocol-based Integrated Home Media and Power Control System

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Abstract—This paper designs and implements an automatic network system utilizing UPnP, wireless network and power line carrier technology. We connect home media device and home gateway device via wireless network to build media service subsystem, and connect home applications and home gateway via power line carrier network to make power control subsystem. Then we convert both subsystems into UPnP virtual devices, which can be searched and discovered with GENA protocol. Besides, we implement an UI component with player and UPnP control point component, which can interact with media server and power management server in home gateway. The software development realizes modular design based on an UPnP application framework.

Keywords—Media Service; Power Control; Home Network; PLC; UPnP

I. INTRODUCTION

The rapid development of digital home industry and the growth of various types of home appliances bring more abundant entertainment experience and convenient living for home users. Entertainment systems and power systems are the two most important subsystems in home. When seek pleasure and comfort of living, people are eager to have a good environment that is energy saving and safety.

The position of home entertainment system is well-known, and the need for the power control system should equally not be ignored. Increasing of home appliances brings more power consumption inevitably. Besides, because home users are not conscious of the standby power consumption, many appliances are in long-term standby or working status, which not only brought the power loss but electrical hazards. Therefore, it is meaningful to construct an intelligent control of power systems.

This paper discusses the integration of UPnP protocol-based home media service system and power control system. The integrated system works within a home network, which consists of wireless local area network and narrowband power line carrier network. Middleware layer of the system is based on UPnP framework and application layer adopts module structure of design. This system includes two parts that are the side of user interaction device and home gateway device. At the same time, we design a separate UI module, which can be deployed in any device, such as mobile device.

II. SCENARIO

The system integrates home media network and power control network through the home gateway device. Home gateway is the core of the system, which includes wireless network module and PLC network modules. It can access a build-in storage medium or other storage medium (such as Mobile disk). Home users can access the home gateway to get media content and implement appliance management through UI and player, which are set to terminal equipment (such as PC, player, PDA, etc). The network itself is the self-organization via UPnP protocol and automatic configuration without too much intervention from home users. The scenario is shown in Fig. 1.

III. SYSTEM ARCHITECTURE

The architecture of UPnP protocol-based home media service and power control system is shown in Fig. 2, which consists of two subsystems that are Media Service subsystem and Power Control subsystem.

Figure 1. Scenario.

Figure 2. System Architecture.
IV. ANALYSIS

A. Requirement analysis

- The design of system needs to support cross-platform features, and the software can be transplanted into a variety of operating system platforms;
- Software requires modular design, based on a unified interface standard;
- The part of UI is separated from the core functions of UPnP Control Point and UPnP Device;
- UPnP UI components can be deployed separately to any application or device which supports UPnP framework, or can be used in combination with other modules without UPnP.

B. Technology Selection

According to the above requirement analysis, the following techniques are selected to support the design and development of software system.

- The software may be used in scenarios of embedded systems and have cross-platform features, so it is feasible to use Python language as base coding language. Python [1] as a cross-platform, efficient programming language is very suitable for prototype system development and functional verification. Besides, because of the well-object-oriented design features, it can reflect design patterns and ideas of software architecture;
- The system uses an UPnP [2][4] framework as the middleware application framework implemented by Python.
- The system uses wxPython [3] as development library of basic UI;
- The prototype system is developed under Linux, which release is Ubuntu 9.10, with Python interpreter of version 2.6.4.

V. DESIGN

A. Design of Media Service Subsystem

Media Service subsystem is realized to share media content between storage of home gateway device and the terminal display device. Discovery between devices and content search use UPnP protocol; the content stream transmission depends on transport protocol which is supported by Player side and Server side together. This subsystem mainly consists of Media Player module and Media Server module.

1) Interactive Mode

Interactive mode between modules of Media Service subsystem is shown in Fig. 3.

2) Module Description

a) Media Player module (MP):
This module includes MP control point component and player component. MP control point can find MS device of Media Server module via UPnP protocol and interact with it, so that this module can control streaming media server and get the list of media content provided by streaming media server. Player is controlled by UI of the top layer. Player in MP module interacts with streaming media server of MS module using non-UPnP protocol, which can be supported by the two components together. The flow analysis of Media Player module is shown in Fig. 4.

b) Media Server module (MS):
This module consists of MS device component and streaming media server component. MS device publishes device description file and service description using UPnP protocol. Currently, the service, which is provided, is Media Directory Service. MP control point in Media Player module can search and interact with the MS device to get media content list. Streaming media server, which is managed by MS device, generates media content list and provides streaming content to player. The flow chart of Media Server module is shown in Fig. 5.
B. Design of Power Control Subsystem

Power Control subsystem is used to realize the electrical equipments control and power data acquisition in home. The physical layer adopts narrowband power line carrier (PLC) communication technology. Centralized management device side (FMU) uses the chip of PLCI38-II-E, and the client acquisition controller (RCU) uses the chip of PLCI36G-III-E, which are all produced by Qingdao Eastsoft, shown in Fig. 6 and Fig. 7.

The centralized management device is connected to the home gateway as a hardware module, and the acquisition controller is joined to power line as the front-side of the controlled equipment. Please refer to the part of PLC that is shown in Fig. 1.

Power Control subsystem consists of Power Manager module and Power Manager Server module, which are deployed in the side of terminal device (like PC) and the side of home gateway.

1) Interactive mode

Interactive mode between modules in Power Control subsystem is shown in Fig. 8.

2) Module Description

- Power Manager module realizes the function of the UPnP control point and provides UI to monitor and control home power system.
- Power Management Server module includes an UPnP device component, which has realized the service of management service to PLC devices.
- PLC interface component is used to connect PLC centralized management device based on private protocol.

C. Design of General UI

Currently, UI and control point are deployed in the same device. In follow-up design, UI as a separate component based on UPnP framework can float any user interaction devices in the home network.

VI. IMPLEMENTATION

A. UPnP App Framework Description

Implementation of the system makes use of BRisa [5] [6] UPnP framework as application development framework. BRisa UPnP framework includes package of base modules, package of UPnP supporting modules that provide library and interface support to realize UPnP device and control point.

Overview of various components in BRisa framework is shown in Fig. 9, which summarizes the main interface functions and class definitions.
B. Media Service Subsystem

1) Media Player

UML class diagram of Media Player module is shown in Fig. 10.

2) Media Server

UML class diagram of Media Server module is shown in Fig. 11. UPnP protocol realizes discovery and interaction between device and control point via GENA protocol and SOAP protocol, which use specific XML files to describe device and service. The XML file of Media Service in above system is shown in Fig. 12.

C. Power Control Subsystem

Core work of Power Control Subsystem is converted the PLC equipment to an UPnP virtual device and then joins in the home network. PLCOperator realizes the functions of PLC hardware access and control protocol transition. Class diagram of the subsystem is shown in Fig. 13.

VII. EXPERIMENTAL VERIFICATION

System demo is shown in Fig. 14 which is the screenshot of Media Service application and Fig. 15 which is the screenshot of Power Control application. The system runs stably on Linux platform of PC and embedded Linux of home gateway device.
VIII. CONCLUSION

In home network, using UPnP protocol to realize effective integration of entertainment system, power control system and other systems is a practical solution to build a digital home integrated management system. The system described in the paper can improve home automation and make our life more convenient. However, the system still requires a lot of intelligent improvements. For example, the Power Control subsystem has gathered the data of nodes within family, but not brought a solution for data analysis and consumption assessment in order that this system can control our home power network intelligently. Therefore, the follow-up work will emphasize the study of domestic intelligence based on family context.

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