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A remote control and media-sharing system using smart devices

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ABSTRACT

The remote control and media sharing of electronic devices are key services in smart homes. The incorporation of mobile smart devices in these services has become a popular trend. Existing services require that these devices are located in the same local network. This paper presents the design and implementation of an integrated service architecture that supports the remote control of home appliances and the sharing of digital media between indoor and outdoor devices. The proposed design follows standards related to digital homes, and this study presents the details of its hardware and software components.

1. Introduction

With the popularity of various types of digital consumer products, digital content is becoming increasingly common. The sharing of various digital media, such as videos, photos, and music, between consumer products has become a popular trend. Some commercial solutions provide platforms to integrate home audio-visual devices. For example, a personal computer can control the playing and recording of TV programs or videos on a DVD player. A smart TV can integrate multimedia and Internet services together.

The Digital Living Network Alliance (DLNA) [1], which is responsible for defining interoperability guidelines between multimedia devices, was initiated in 2003. The underlying technology of DLNA is Universal Plug and Play (UPnP) [2] for media management, discovery, and control. The UPnP standard, which includes a set of standard network protocols such as TCP/IP, HTTP, and Simple Object Access Protocol (SOAP), enables digital devices with networking capability to connect to each other. Over two hundred member companies follow the DLNA guidelines in their products.

DLNA-compliant devices can seamlessly discover each other in the same home network, sharing services and media. The DLNA standard defines four types of devices: Digital Media Server (DMS), Digital Media Controller (DMC), Digital Media Player (DMP), and Digital Media Renderer (DMR). A DMS stores and provides media content to other devices. A DMC can discover media content and command a DMR to play the content. A DMP, which consists of a DMC and a DMR, can discover and play media content directly.

Digital media can be shared between DLNA devices for the users' convenience. However, users cannot benefit from such service when staying outdoors, since a remote device cannot directly join home DLNA networks. Thus, some solutions are required to extend the basic service model of DLNA. For example, a mobile user can retrieve and play media streams from an indoor DMS by connecting an external device to a home network using the Session Initiation Protocol (SIP) [3]. However, this solution is only capable of one-way media sharing. Home-to-home media sharing can be achieved by setting up a DLNA proxy server in each home [4].

Making living environments smarter will require modern technologies other than DLNA/UPnP. For example, integrating sensor technology and automatic control in home appliances enables remote function control, power control, and remote surveillance [5–8]. A typical way to integrate different services and devices in heterogeneous home networks, including X10, wireless LAN, Bluetooth, and Ethernet, is to set up a residential gateway in the home based on the standards such as Open Service Gateway Initiative (OSGi) and Multimedia Home Platform (MHP) [9].

This paper presents a straightforward method of constructing a residential gateway using a popular smartphone to establish a service architecture that provides remote access and control to any home appliances. The powerful functions of smartphones enable several mobile personal services [10–12]. The home appliances in this system include any DLNA or UPnP devices and non-UPnP

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devices. The prototype system provides the functions of remotely monitoring and switching the power of a home device, and sharing media content between an indoor device and a remote device.

The proposed system is based on an open-source platform for easy deployment. Those traditional home devices without built-in UPnP functions are externally equipped with control boards, and hence these devices can be remotely controlled using an indirect method. The control board contains an open-source microcontroller that can be easily programmed to control robots, lighting, and other devices. Also, this control board provides a linkage to external modules, including sensor modules and wireless communication modules.

A previous conference paper [13] presented the initial concept of this prototype system. This study presents the system by introducing more implementation details and providing a performance evaluation. The remainder of this paper is organized as follows. Section 2 presents a brief introduction of the UPnP and DLNA standards. Section 3 presents the system design. Section 4 presents system operations. Section 5 presents the developed system. Finally, Section 6 provides concluding remarks.

2. Background knowledge

The UPnP standard is an open and point-to-point protocol that enables the plug-and-play of a device in IP networks. The UPnP protocol specifies the communication between control points (or controllers) and devices. A device is any instrument that provides services. A service provides a list of executable actions and a list of state variables. For example, a time service contains a state variable that records the current time and two actions that set and get the current time, respectively. A control point can discover the presence of other devices to run the services of these devices.

The UPnP operations include six steps: addressing, discovery, description, control, event notification, and presentation. A device gets an IP address from a Dynamic Host Configuration Protocol (DHCP) server in the addressing step. A control point discovers other devices in the same network by sending a search request in the discovery step. This search request is a multicast message made using the M-Search method in HTTP. This search request also contains an ssdp:discover method in the Simple Service Discovery Protocol (SSDP). A device responds to the search request by sending a unicast message with the ssdp:alive method to the control point. The search response contains information such as the device type, a device identifier (or Unique Service Name, USN), and a Uniform Resource Locator (URL) to the device profile or description. The device profile is a description file in eXtensible Markup Language (XML) format that primarily consists of a list of URLs for accessing the services of the device.

A device that has just joined the network can send a multicast message with the ssdp:alive method to show its presence to all control points. When a device wants to leave the network, it sends a multicast message with the ssdp:byebye method to inform all control points of its departure. In the description step, a control point obtains a device profile by sending an HTTP request with the GET method to the profile's URL. In the control step, a control point can remotely invoke a service function by sending an HTTP request with the POST method to the service URL. The service invocation in this request message is specified using SOAP headers and elements. In the event notification step, a control point can subscribe to a certain event to learn the state change of a device. If a device contains a web page showing the device status, a control point can access this page in the presentation step.

The DLNA standard [14] is built over the UPnP device architecture and the UPnP AV standard (an audio and video extension of UPnP) (Fig. 1). The media format layer defines the supported media types, which primarily include music, videos, and pictures. The media management layer provides functions to DLNA devices in managing and publishing media content, and enables communication between a DMC and a DMR (or DMP). The device discovery and control layer provides the same six-step operations of UPnP, and a DMC acts as a control point. The media transport layer specifies HTTP as the basic transport protocol for media content. The network stack and network connectivity layers define the supported network types and protocols.

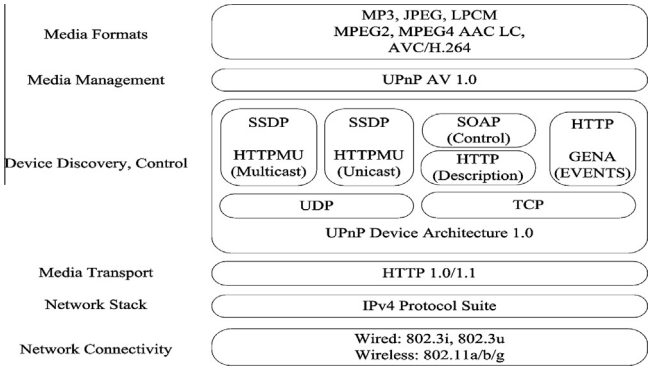

Fig. 1. DLNA layered architecture.

The DLNA service model is restricted to home networks for security reason. To extend this service to public networks, a secure residential gateway is needed to interwork with outdoor devices. The SIP server can be integrated into the gateway [3] such that an outdoor device acting as a SIP client can retrieve media registered by home DMSs. Another solution [4] is to let an outdoor device connect back to the home network using the Virtual Private Network (VPN) technology. Our solution is also based on the VPN, but our system has two distinguishing features against the above two solutions. First, both outdoor DMPs and outdoor DMSs are available. Second, remote control functions to traditional non-UPnP appliances are supported.

One important issue not widely addressed in this paper is about security. Certain prevention technologies from security threats are necessary. For example, digital content needs to be protected by using Digital Rights Management (DRM) technology. Unauthorized users can not access some home appliances or some media files. Secure networking solutions can be applied such as the link-layer solution: WPA (Wi-Fi Protected Access), the network-layer solution: IPsec (IP Security), the transport-layer solution: SSL (Secure Socket Layer), and the application-layer solution: PGP (Pretty Good Privacy). The interested reader is referred to [15–17] for details.

3. System design

This section presents the details of the system design, and Fig. 2 shows the service architecture. This system can extend smart living services from an indoor environment to an outdoor one. This architecture provides the following services:

- A user in the home or out of the home can monitor and control home appliances and share digital content with home DLNA-compliant devices through a mobile phone. For example, remote device A turns off the desk lamp and downloads a music file from an indoor DLNA device in Fig. 2.
- Two outdoor users can share digital content as if they were on the same home network. For example, remote device B can access image files from remote device A in Fig. 2.
- An outdoor user can redirect the play of digital content to a local DMR. For example, remote device C can command a local DMR to retrieve and play a video from an indoor DLNA device in Fig. 2.