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A portable UPnP-based high performance content sharing system for supporting multimedia devices

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Abstract Since the development of traditional home multimedia is yet to be improved, the various multimedia devices are used for playing media content. Under the advancement of modern science and technology, there are various formats of compact discs to store and play multimedia content, such as VCD, DVD, portable disks, etc., and the latest, Blu-ray disc. However, it is difficult for these devices to share the content without any configuration. In order to solve the problem of playing effectively, we propose a portable UPnP-based high performance content sharing system for supporting multimedia devices, which includes a content sharing server, and media players. The content sharing server can realize the share services and file control of the portable disk, iPod, DVD, digital TV, and other devices, so that users no longer need to carry out complex processes to install software and settings, as the media players can allow users to play the multimedia file on any media device.

Keywords UPnP · Multimedia · Content sharing

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1 Introduction

Home multimedia entertainment has become an indispensable part of life, with more digital products, and the question of effectively managing the equipment has become a very important topic. For example, when buying a new DVD player, it is necessary to consider whether it uses the same input signal source as the existing device, and the intended location of this new player. Whenever there is an addition of new multimedia equipment, these problems often perplex the user. Additionally, as digital cameras become popular, and the cost of memory cards becomes inexpensive, there are usually hundreds of photo files to be organized after each use, including photos and videos. Without an effective management system, the same files which are distributed on different computers waste hard disk space.

Through developed home networking technology, these digital devices can be connected by a local area network, and then established into a home multimedia center, which is convenient for sharing and managing. At present, this can be achieved by the UPnP protocol, and this architecture in a home network can achieve high performance sharing of resources and communications among different devices [1–9]. However, the communications protocol of this architecture achieves multimedia file sharing and access through computer installation and configuration, which is difficult for general users without proper knowledge of installation or operation, as it is neither an intuition-based installation and use, nor a simple sharing mechanism [10–12]. Moreover, the current home multimedia applications of the UPnP protocol remain based on personal computers, most of which are limited to media servers and media renderers that can only share and play computer files [13–17]. Some common hardware equipment, such as DVD players, digital TV, and other devices, still lack support and application. In addition, there are many multimedia devices and equipments in digital homes, which are not compatible with all multimedia players or playing sources. Therefore, this study proposes an architecture that integrates the majority of multimedia devices used into a complete and simple system, thus, improving the shortcomings of old systems.

With the content sharing server of the proposed architecture, only one home computer is required to share all multimedia files with newly added devices, whether a DVD, TV tuner, or portable storage, such as MP3 player or iPod, to achieve high performance management and sharing of multimedia entertainment. In conjunction with the plug-and-play mechanism, new multimedia equipment can be easily added or removed, without the need of settings and installation knowledge. The media players are used to communicate with the content sharing server, enabling the multimedia files of all devices to be played by the media players. These players also combine the feature of intelligent remote control, allowing users with no knowledge of computer operation to easy access.

2 Related work

2.1 Universal plug and play

UPnP (Universal Plug and Play) is a communications protocol developed by the UPnP™ Forum. The technology defines the architecture of the P2P network connec-

tions of various devices, wireless devices, and personal computers. UPnP is based on Internet communications protocols, such as IP, TCP, UDP, HTTP, XML, and SOAP, and its basis is IP addressing. Each device must have a DHCP client end, which is automatically searched when first connecting to the network. A domain name is obtained in the connection process of the DNS server or transfer, and then the device should use the domain name in the next operation; otherwise, the device should use its IP address. If there is no DHCP server available, the device will automatically set an IP address.

The first step in UPnP networking is Discovery. When a device is added into the network, UPnP Discovery Protocol allows the device to use SSDP (Simple Service Discovery Protocol) to broadcast its services to the Control points. Similarly, when a Control point is added to the network, it can search for information related to UPnP devices in the network.

The second step is Description. When a Control point detects a device, in order to receive more information about the device, the Control point must obtain more information from the URL in the Discovery Message sent by the device.

The third step is Control. When the Control point accesses device description information, it can send commands to the device. The Control point sends a Control message to the Control URL of the service (included in the device description), which is described with XML through SOAP. Its operation is similar to the function call, as the server returns a value related to the response control message.

The fourth step is Eventing. Control directs subscribed device's service actions to obtain updated information, which is updated by sending Event Messages that include one or more variables regarding state information, including their current values.

The fifth step is Presentation. Devices have a web interface, through which the Control point can obtain Presentation information on a device. The URL is loaded in the browser, and users are allowed to perform related control and view operations.

2.2 System booting

A system will perform a series of initialization actions at the start-up stage, which involves the stability of hardware signals and software systems and allows the system to enter into a stable state.

Taking the personal computer as an example, after the power is turned on, the system will begin the initialization of the motherboard, including the initialization of the South/North Bridge chips and the CPU. Then the CPU executes 0xFFFF0, which is the entry point of BIOS ROM, and jumps to the actual position of BIOS application. In BIOS, the first action executes the basic Power On Self Test (POST) to ensure that the system can operate normally during the start-up stage. Then, CMOS reads the hardware configuration, and then peripheral hardware will begin initialization.

The BIOS searches for bootable devices and reads the 512 bytes sectors at the beginning of the hard-disk that it reads to the Master Boot Record (MBR), which loads the bootstrap loader into the memory. It then transfers master control power to the bootstrap loader, and allows the bootstrap loader to initialize the environment settings required for system operation, which is loads into the system core (Kernel). After it unzips the Kernel into the main memory, it uses the function of the Kernel to

test peripheral hardware devices, such as drive storage devices, CPU, network cards, and sound cards.

After the initialization of the Kernel is complete, it mounts the root file system to enter the User Mode, after which, there should be corresponding script files that set environment variables, and then begins related services or loading extra core modules, in order for the system to execute application programs.

2.3 Hot plug

The device is recorded in the /dev menu by the core, which then assigns a set of major and minor numbers. When the same type of device is installed again, the core assigns the next major and minor numbers. Thus, if the system detects the first USB printer after start-up, the USB printer will have a major number of 180 and a minor number of 0, and be pointed toward /dev/usb/lp0; while the second USB printer will have a major number of 180 and a minor number of 1, and be pointed toward /dev/usb/lp1. If detection order is switched for the next start-up, its direction of entry also will be switched.

However, there is a problem of only one solution, udev, which is a program executed in the user space. By the inserting or removing the event message provided by hotplug, as well as device information, it can produce a dynamic /dev, providing a permanent device name.

3 Proposed system architecture

3.1 Overall system structure

At present, the UPnP has specified 7 device types as shown as Table 1.

Each type has its corresponding service, while media servers and media renderers are most common in home multimedia systems. The role of the media server, for sharing multimedia, is often limited to a personal computer. After installing the main programs and setting shared folders, the computer mainframe has the functions of a server. The devices in the home network can share resources from a media server, and play streaming video and sound files. However, it is difficult for most commonly used multimedia equipment, such as a DVD player or digital TV, to share resources in the network under the UPnP architecture as the equipment have no proper specifications. In order to improve this shortcoming, this study aims to include DVD players, digital TV, flash disks, and iPods in the sharing mechanism of the media server.

As shown in Fig. 1, the existing home network (Ethernet network) is used to develop the portable UPnP-based content sharing system, which includes multimedia components, such as iPod, flash disk, DVD player, multimedia files, sharing system, and player. The content sharing server is based on a packaged flash disk. After connecting a local area network, it can construct a sharing system without any settings, and the flash disk can be removed after start-up for other uses. The multimedia player can execute the player programs automatically after the flash disk is inserted, so that plug-and-play can be achieved without complicated settings. In order to realize the

Table 1 UPnP specified devices

Category	Service
Audio/Video	MediaServer:3 MediaServer:2 MediaRenderer:2 MediaServer:1 MediaRenderer:1
Basic	Basic Device:1
Home	Digital Security Camera:1
Automation	HVAC:1 Lighting Controls:1
Networking	Internet Gateway:1 WLAN Access Point:1
Printer	Printer Enhanced:1 Printer Basic:1
Remoting	Remote UI Client:1 Remote UI Server:1
Scanner	Scanner:1

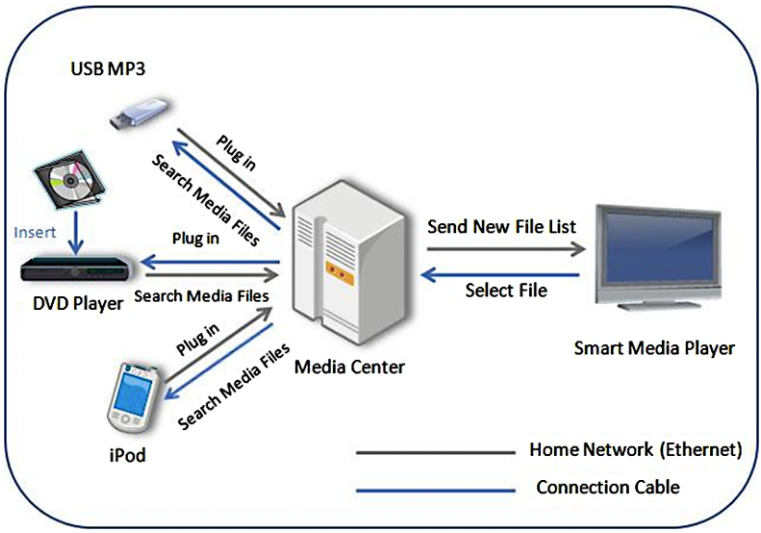

Fig. 1 System architecture

above functions, it is necessary to plan the automation procedures after the flash disk start-up. First, a mounting problem of the device should be considered. In addition to

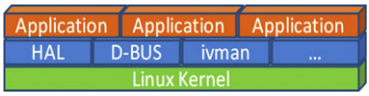

Fig. 2 Linux framework

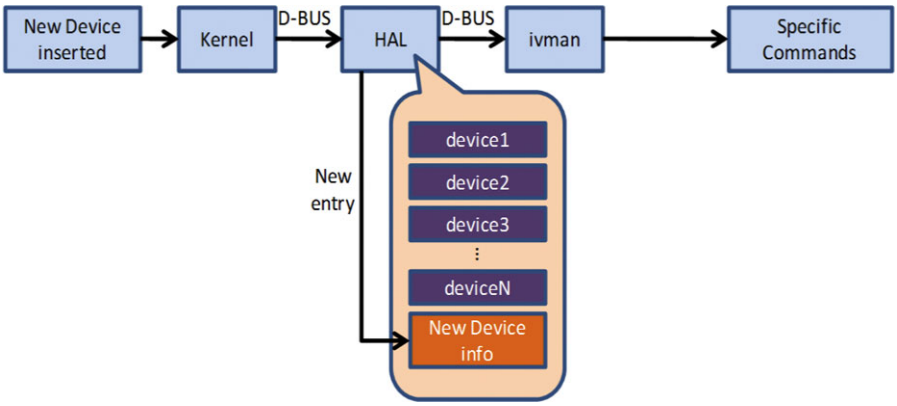

Fig. 3 Automatic mount process

the hot-plug and udev supported by the Linux core, the D-BUS, HAL, and ivman are used to realize the automatic mounting system. Its framework is shown in Fig. 2.

D-BUS is a set of inter-processes of the communication (IPC) system of Linux, which provides a simple, yet powerful, mechanism that allows different applications to communicate. D-BUS has three unique features; first, the basic units of information transmission messages are of a fixed size, rather than byte streams with different lengths. IPC is divided into multiple-stage messages, which includes header and payload, and can support various data types. Second, D-BUS is based on BUS. While the simplest method to realize IPC is direct communication between programs, D-BUS uses a message bus daemon to route information to each program, so that one program can communicate multiple goals. Third, D-BUS can support both a system bus and a session bus simultaneously, and has a wide range of applications.

HAL (Hardware Abstraction Layer) is an abstraction layer of software execution, which provides a unified interface for hardware and application programs. The attributes management of equipment is one of the most important tasks of HAL. Under the Linux system, HAL regards each hardware device as a device object, and each device object can be identified by a unique id that contains hardware information and configuration settings, according to standard attribute specifications. HAL can obtain device lists, attribute values, and ability descriptions of devices of specific types, enabling the application program to learn about the available equipment, their types, characteristics, capabilities, and usage.

Ivman (Ikke's Volume Manager) is the device manager program that executes in the user space. Ivman can execute special commands when devices are added or removed. When a device is added, ivman calls for a pmount or mount command mounting device, and then the XML format configuration setting determines which action should be executed. The process of automatic mounting of a device is shown in Fig. 3. When a new device is added, the core system acquires the device information

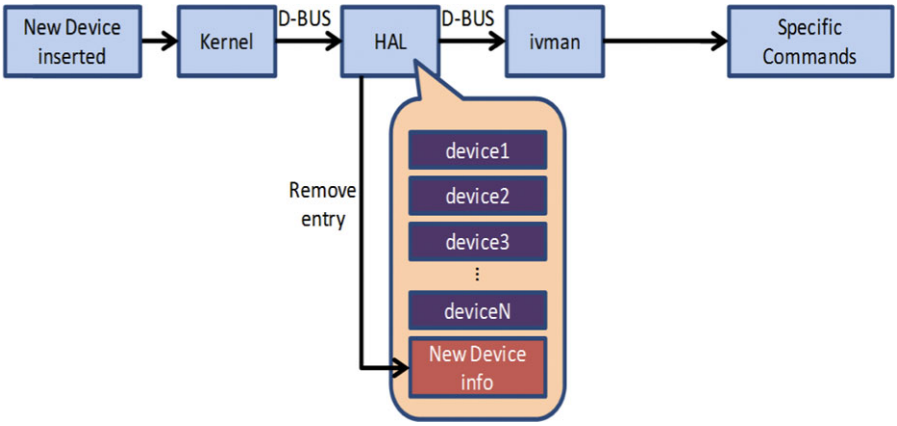

Fig. 4 Remove device process

through the hot plug and udev, and transmits this information to the D-BUS. The HAL detects the new device through the D-BUS message and obtains its information for entry. Ivman is the handler of HAL, and it detects a new device through D-BUS, then sets mounting and executes corresponding commands through the configuration files. When HAL detects, through the D-BUS, that a device is removed, it removes the entry of the device, and then ivman executes corresponding commands, as shown in Fig. 4.

This study allows a content sharing server to incorporate commonly used multimedia devices of a digital home (e.g. iPod, flash disk, and DVD player), and most popular TV programs to realize the UPnP sharing mechanism of: (1) digital TV, (2) DVD player, (3) flash disk/iPod, through the simplest method. This study also develops an intelligent remote control for the Media Player, and provides a simple operational interface to play multimedia content.

3.2 Content sharing server

In order to enhance the support of a content sharing server for digital TV and DVD players, this study converts multimedia resources into virtual files, and uses a VLC Core to realize streaming video functions.

3.2.1 Digital TV

Since the UPnP multimedia server does not provide digital TV channels, this study uses a USB digital tuner to provide digital TV functions. After the tuner is inserted into the device, the system core loads the corresponding digital TV turner firmware, and then HAL adds the entry, followed by ivman notifying the media server to update its database and create a virtual file to open a series flow server. This flow is shown in Fig. 5.

Figure 6 shows some practical applications. Presently, the tuner is first used to scan digital TV channels available, and then each channel is established into a virtual

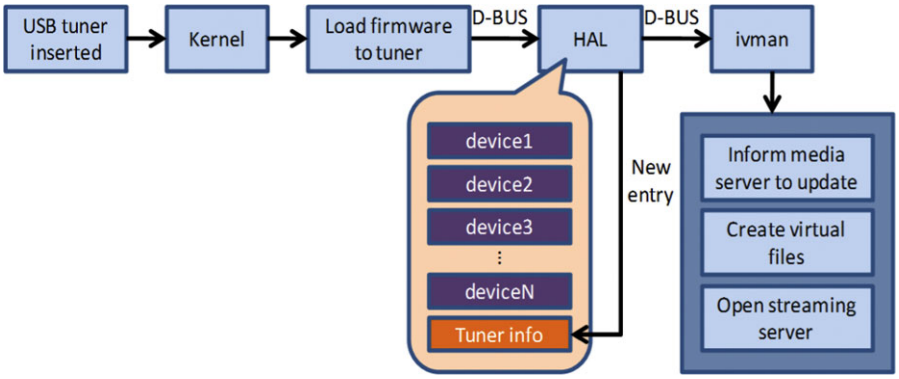

Fig. 5 Mount tuner device flow

Fig. 6 Tuner establish into multimedia center

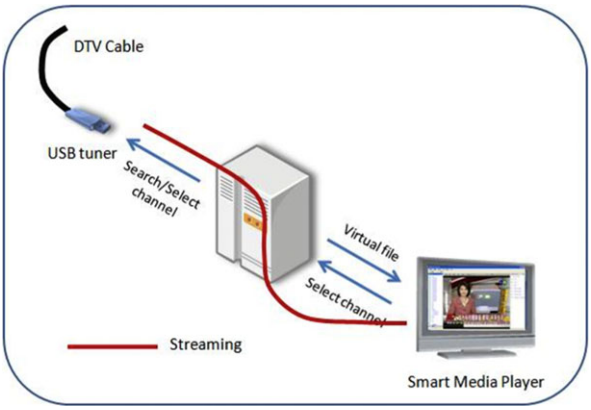

Fig. 7 TV Tuner UPnP format

```
<item id="0000000000000004"
parentID="0000000056" restricted="0">
 <dc:title>04-0-DiMoTV</dc:title>

<upnp:class>object.item.videoItem.videoBroad
cast</upnp:class>
 <res protocolInfo="http-
get:*:video/mpeg:*">http://140.116.226.225:2
2222/MediaServer/VideoItems/0000000058.tv
</res>
</item>
```

file that is placed in the sharing list of the multimedia center. When a user plays the digital TV, the server automatically controls the parameters of the channels to play the selected channels. Under hardware limitations a digital TV tuner can only be applied to one channel at a time, so that when a user is watching a certain channel, other users can only share the same channel when choosing the same tuner signal. Figure 7 shows the example of the TV tuner description encoded in XML using the SOAP format and transported over an HTTP connection.

3.2.2 DVD player

Most UPnP multimedia servers cannot play or control a DVD player. When a CD enters a multimedia server, the system proposed by this study could automatically enter into read-mode, scan the DVD sections, sound tracks, and subtitles, and then input virtual files comprised of the sound and subtitles into the sharing files list, allowing direct play of the DVD content, in the form of home network streaming, through remote players. The flow is shown in Fig. 8. The DVD control function of fast forward or reverse is transmitted to the DVD player through the network in the form of an UPnP Event, as shown in Fig. 9. In addition, this study allows more than two players to share the content of the same DVD player. If a user is watching a DVD, and other users want to use this DVD player, they can only watch the same content and cannot fast forward or reverse. Figure 10 shows the example of the DVD player

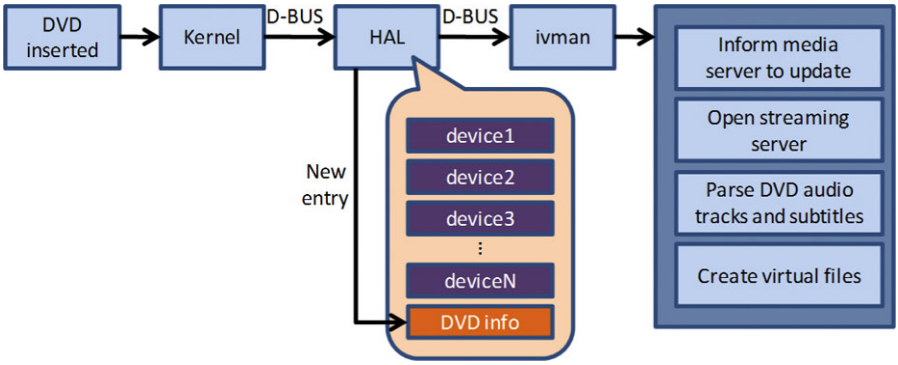

Fig. 8 Mount DVD player flow

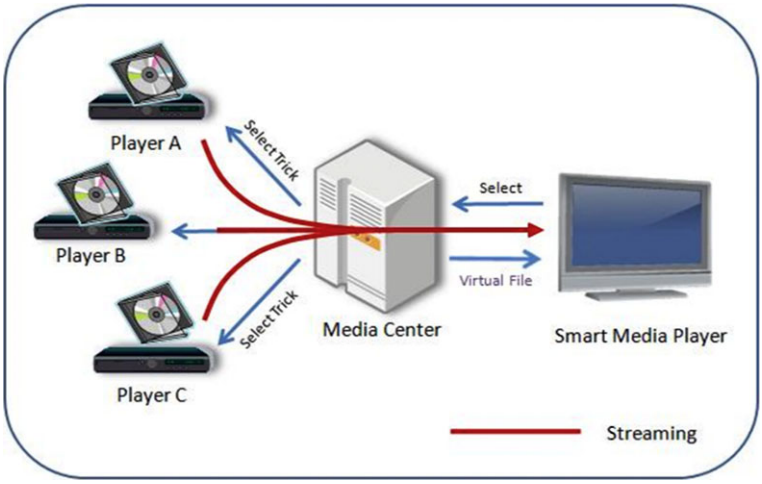

Fig. 9 DVD player establish into multimedia center

Fig. 10 DVD player UPnP format

```
<item id="0000000000000001"
parentID="0000000037" restricted="0">
 <dc:title>Hanada</dc:title>

<upnp:class>object.item.videoItem.videoBroad
cast</upnp:class>
 <res protocolInfo="http-get:*:video/mpeg:*"
bitrate="0"
size="4328268444">http://140.116.226.225:2
2222/MediaServer/VideoItems/000000003A.d
vd</res>
</item>
```

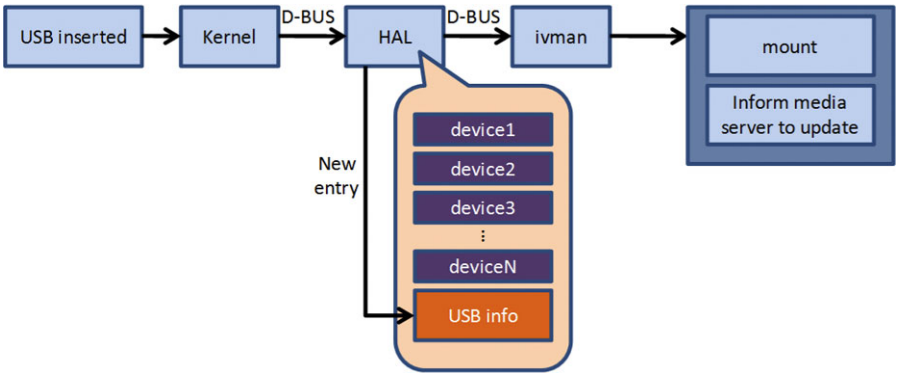

Fig. 11 Mount USB disk flow

description encoded in XML using the SOAP format and transported over an HTTP connection.

3.2.3 USB storage

The main feature of flash disk/iPod is plug-and-play. When the entry of a flash disk is added to HAL, ivman mounts this device and notifies the media server to update the database. The flow is shown in Fig. 11.

In practical application, this system only needs to insert a similar storage device into the multimedia sharing center, so that it can be automatically loaded into the share list; and if removed, it is deleted from the share list immediately.

3.3 Media player

As shown in Fig. 12, the proposed Media Player is based on the UPnP AV Architecture, with integrated Control point and Media Renderer.

To achieve the plug-and-play function, the program does not require installation or additional settings, and could be executed by a desktop or laptop computer, after the flash disk is inserted.

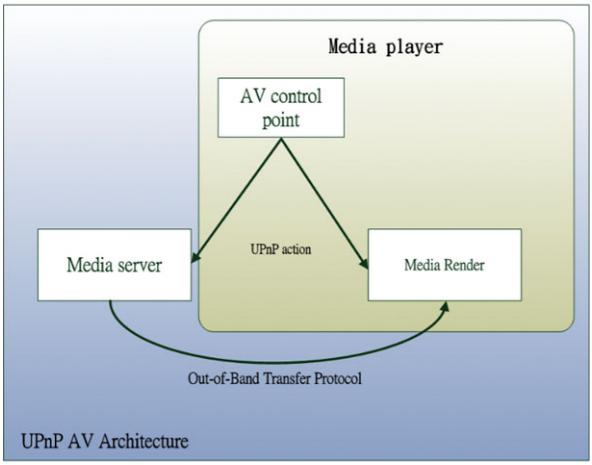

Fig. 12 Media player

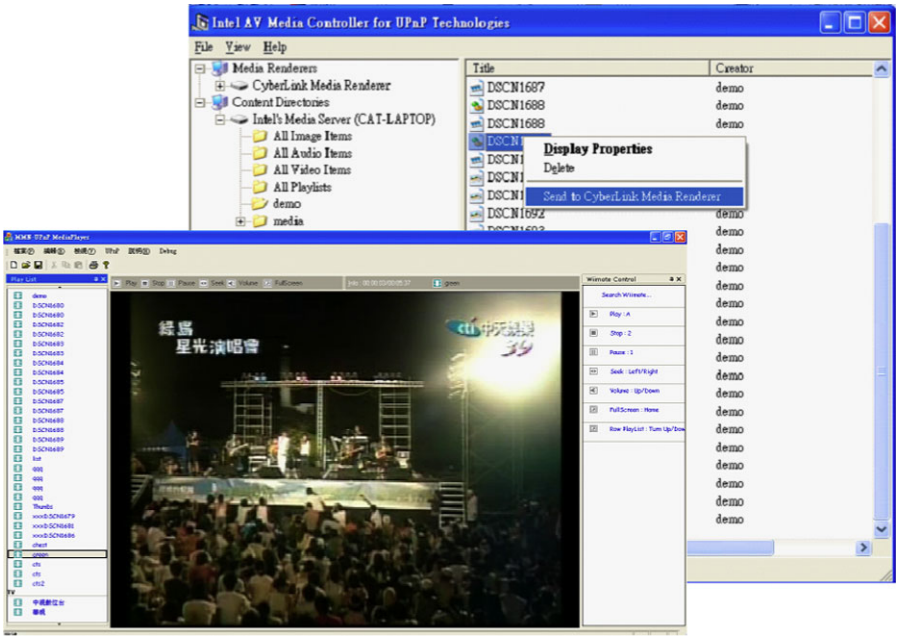

Fig. 13 Media player and Intel UPnP controller

For users who are not familiar with computers, using mouse and keyboard may be difficult, thus, the remote control interface provides simple buttons that allow the user to operate the player interface. This study used the Bluetooth transmission protocol, along with a tri-axial accelerator for judgment, enabling users to operate the system as if controlling a TV or DVD player, without the need of mouse or keyboard.

4 Results and discussion

4.1 Compatibility test

Figure 13 is a Media Player developed by this study. In order to prove that both the content sharing server and the Media Player meet the specifications of standard UPnP communication protocols, this study used a UPnP Controller, provided by Intel, to browse the files in a multimedia sharing center. However, since the Intel UPnP Render does not support video streaming, the player developed by this study was used to browse the sharing files on the Intel Server, and a self-developed server, and play the content.

4.2 Pressure test

In order to test the feasibility of the system in practical application of home multimedia, this study conducted pressure testing. The test environment was based on a local area network, including a media center and eight client ends; the media center provided streaming services to the eight client ends, and the stream quality and server load were observed. The test environment is shown in Fig. 14. The media center was set as a regular personal computer, and the hardware specifications are shown in Table 2. The streaming bit rate of digital TV and DVD was set to 5 Mbps.

The first half of Fig. 15 is UPnP package data flow and the second half is the DVD streaming data flow received by Media Player. From the curve of this figure, we find out that the average download speed is 256 kbps and the delay occurs at initialization

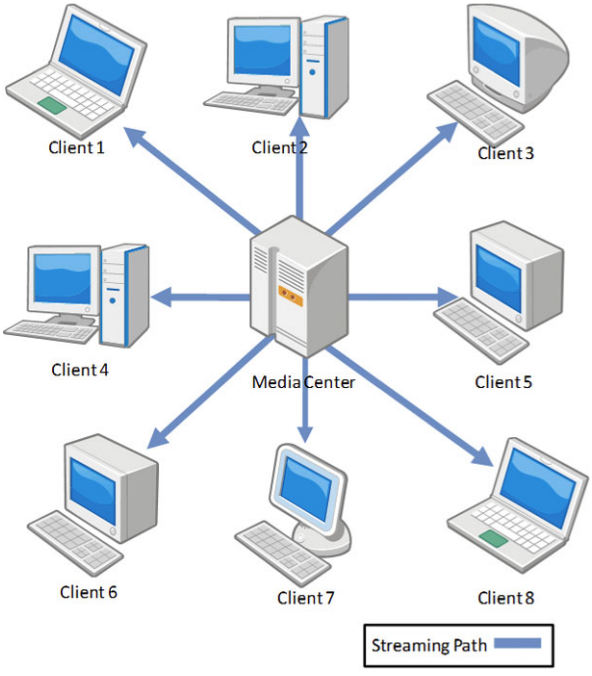

Fig. 14 Testing environment

Table 2 Testing hardware specifications

	System Hardware
Hardware	Details
CPU	Intel(R) Pentium(R) D CPU 3.40 GHz
RAM	1 GB DDR2-667
HDD	Seagate 160 GB 7200 RPM
Network Chip	Intel Gigabit Ethernet Controller
Tuner 1	Twinhan USB 2.0 DVB-T Receiver
Tuner 2	ASUS My Cinema U3000 Mini DVBT Tuner

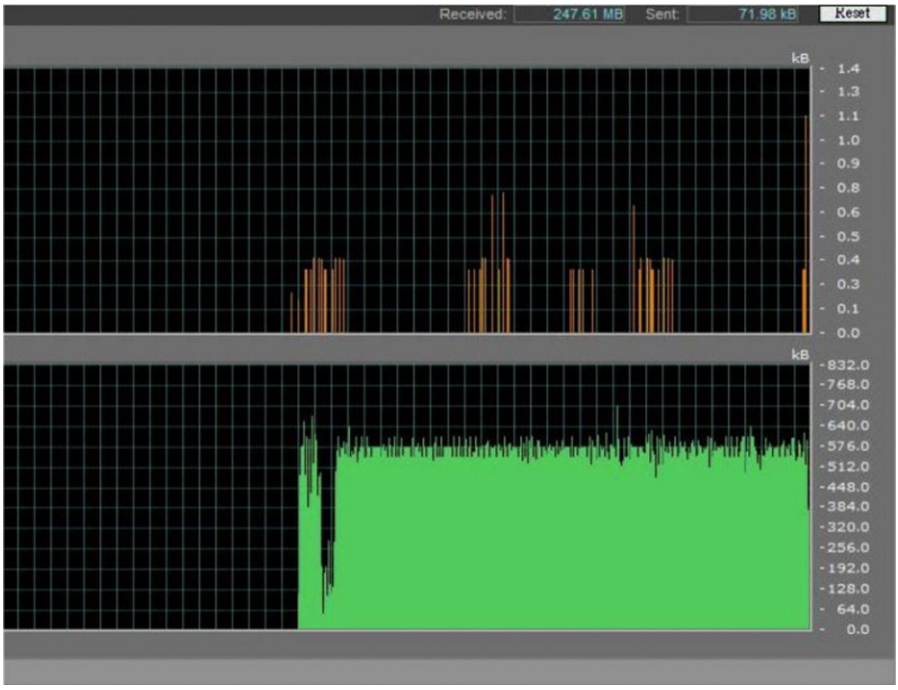

Fig. 15 Network data flow of DVD player

time because of driving the DVD player. Figure 16 shows the results of TV tuner data flow which closely approximates 600 kbps. Because there are many external factors in TV signal, the jitters are more common.

For most home multimedia, the limit of four client ends is acceptable; however, the provision of better streaming quality in media centers has room for improvement. First, it could set suitable bit rates, within the limit of 20 Mbps, to meet the demands of clients ends, so that more clients could share streaming, but visual quality would be affected. Second, the streaming function of P2P (peer to peer) at the client end can be increased in order that the flow burden of the media center could be reduced, as each client end could share the streaming data with other client ends.

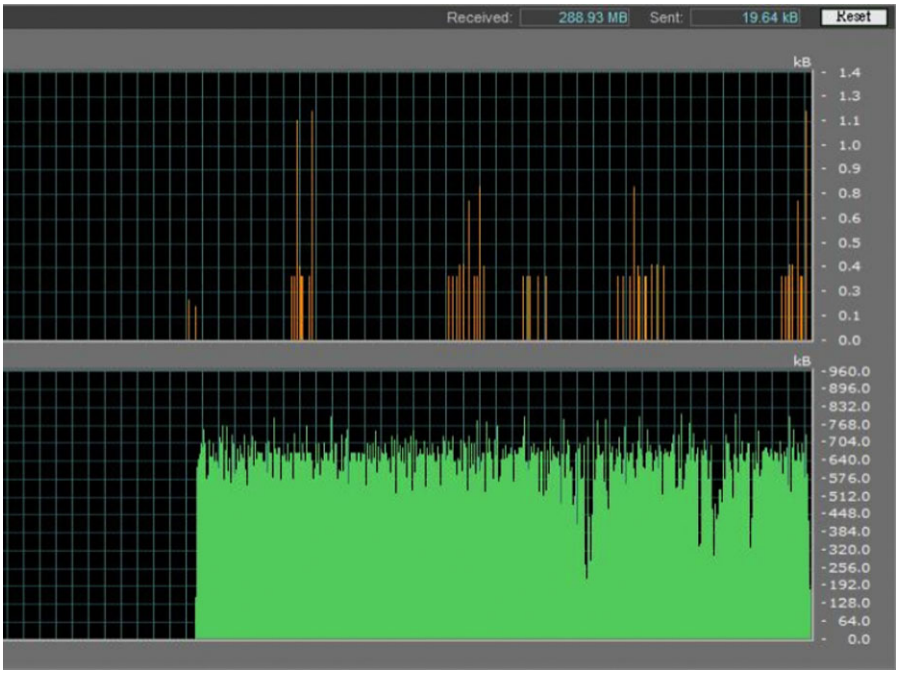

Fig. 16 Network data flow of TV tuner

5 Conclusions

This study completed the prototype of a portable UPnP-based high performance content sharing system for supporting multimedia devices. To make the system more complete, future studies will expand the sensor networks, and use the P2P distributed architecture to expand the sharing functions, providing all players with increased efficiency and power, without wasting bandwidth. In the future, more environmental parameters can be obtained by connecting sensors through ZigBee or RFID development boards to achieve an intelligent seamless play mode.

References

1. UPnP Forum, http://www.upnp.org/
2. Libupnp, http://pupnp.sourceforge.net/
3. CyberLink for Java, http://www.cybergarage.org/net/upnp/java/index.html
4. Domoware, http://domoware.isti.cnr.it/
5. GMediaServer, http://www.gnu.org/software/gmediaserver/
6. GMediaRender, http://gmrender.nongnu.org/
7. UPnP Forum, UPnP Device Architecture v1.0, December 2003 UPnP Forum, UPnP AV Architecture v1.0, December 2003
8. Intel Corporation, Designing a UPnP AV MediaRenderer, May 2003
9. Intel Corporation, Designing a UPnP AV MediaServer, May 2003
10. Wils A, Matthijs F, Berbers Y, Holvoet T, De Vlaminck K (2002) Device discovery via residential gateways. IEEE Trans Consumer Electron 48:478–483

11. Johann B, Antonin C, Mikael D, Clement E, Cristina M (2006) A dynamic-SOA home control gateway. In: IEEE international conference on services computing. IEEE Press, New York, pp 463–470
12. Ing-Yi C, Chao-Chi H (2006) An SOA-based software development management system. In: IEEE/WIC/ACM international conference on Web intelligence. IEEE Press, New York, pp 617–620
13. Kim J, Oh Y, Lee H, Paik E, Park K (2007) Implementation of the DLNA proxy system for sharing home media contents. IEEE Trans Consumer Electron 53:1–2
14. Kim D et al (2002) Design and implementation of home network systems using UPnP middleware for networked appliances. IEEE Trans Consumer Electron 48:963–972
15. Rich C et al (2005) Collaborative help for networked home products. In: Proceedings of IEEE international conference on consumer electronics. IEEE Press, New York, pp 209–210
16. Lee H, Kim S (2006) The u-MUSE system: an integrated UPnP AV home entertainment system supporting rui service and device mobility. In: International conference on hybrid information technology, vol 2. IEEE Press, New York, pp 712–717
17. Jun G (2005) Home media center and media clients for multi-room audio and video applications. In: IEEE consumer communications and networking conference. IEEE Press, New York, pp 257–260