UPnP Based Intelligent Multimedia Service Architecture for Digital Home Network

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Abstract

Demand of multimedia contents in home network is growing rapidly and UPnP is expected to bring better multimedia experience with various A/V devices. However, UPnP A/V architecture, which allows the multimedia contents to be shared between A/V devices, is limited to the environments where interoperable contents format and identical network protocols are used. In this paper, we propose an intelligent multimedia service framework which enables A/V contents to be adopted and shared according to user multimedia environments. We design and implement our multimedia service architecture based on UPnP A/V service and MPEG-21 multimedia framework.

1. Introduction

Home network technology provides a multimedia home service in which multimedia contents in home network device can be shared with other A/V devices which have playback capabilities. DLNA(Digital Living Room Alliance)[1] published its guideline for interoperable home multimedia service and UPnP(Universal Plug and Play) forum defines UPnP A/V architecture[2] to enable UPnP based home multimedia service.

The UPnP A/V architecture provides the communication protocols for an A/V source device and an A/V rendering device to share multimedia contents. The DCP (device control protocol) for UPnP A/V architecture has a negotiation mechanism to decide a pair of multimedia file format and network protocol to use before actual transfer of the content is made. However, UPnP A/V architecture can not ensure the best multimedia experiences if both A/V devices do not support common multimedia contents formats and network transfer protocols. In this case it is required to adopt A/V contents according to multimedia environments where A/V contents will be rendered.

Researches to give better multimedia experience have been studied broadly for the user mobility [3], UMA(Universal Multimedia Access)[4] and composite multimedia environment[5]. However, home network is essentially different with other research environments. The home network has multiple heterogeneous devices with different capabilities, and they communicate with other home network devices using home network middleware such as UPnP. In addition, because home is private place home network is the best place to adopt multimedia contents for better multimedia experience without breaking of Internet's end-to-end transparency [6].

In this paper, we propose an intelligent multimedia service architecture, which enables A/V contents adaptation between home A/V devices. The proposed architecture includes home A/V devices and a home server system which has the central role of multimedia processing. Communication architecture between home server and A/V devices is designed, and multimedia environment information such as user information or device characteristics is reflected during its A/V contents adaptation. UPnP is used to control A/V devices and MPEG-21 DIA tool is used to capture multimedia environment information.

2. Intelligent A/V service framework

2.1 UPnP A/V architecture for home server

UPnP A/V architecture provides control mechanism to support multimedia sharing regardless of diversity of device type, content format and transfer protocol. It defines general interactions between A/V control points and A/V devices based on standard UPnP operation. According to UPnP A/V architecture, a media server is the device which provides multimedia contents and contents browsing and it has content directory, connection management and AVTransport

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service. A media renderer is the home network device which consumes multimedia content. Media renderer provides services like controlling of rendering device, connection management and AVTransport service. UPnP A/V controller coordinates all operations of the multimedia while taking into account transport protocol and file format to transfer. Then, actual A/V contents are transferred from media server to media renferer via out-of-band network transfer protocol such as FTP or HTTP. Overall UPnP A/V architecture is shown in Figure 1.

To provide best multimedia experience, home multimedia service has to combine multimedia sharing with proper intelligent algorithms. Intelligent multimedia service requires more processing power for intelligent algorithms and processing of multimedia contents. However, until now home multimedia service mainly focus on multimedia contents transfer based on peer-to-peer A/V framework.

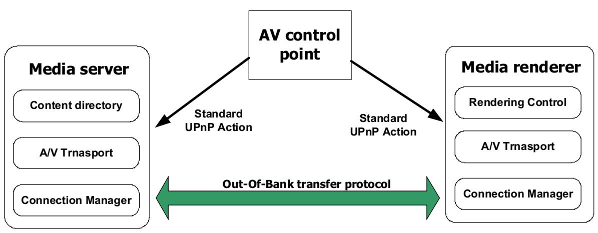

Figure 1. UPnP A/V Architecture

However, it is not feasible for processing power limited home network devices to perform various intelligent services by themselves. Thus, we propose home server centralized framework, in which home server is located in delivery path from media server toward media renderer and provides processing power required for intelligent jobs during A/V multimedia service. For our home server centralized framework, we adopt UPnP A/V architecture to include the interaction between home server and A/V devices. With our framework, various intelligent service algorithms can be applied without modification of existing UPnP architecture and stacks. For this reason, the intelligent service itself is not the main concern of this paper although we use multimedia adaptation to display intelligently adapted multimedia contents on handheld device.

Since we added home server into standard UPnP A/V architecture, the contents transfer path should be changed to go through home server so that home server can participate in requested A/V service. Home server is located logically between media server and media renderer and acts as an intermediate which receives the contents from media server and passes adapted contents to media renderer.

Because only A/V controller is the device that initiates and coordinates the interaction of AV transport, it is necessary to modify the control point algorithm to lead the connection to go through home server system as shown in Figure 2.

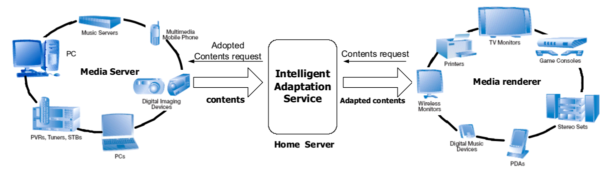

Figure 2. Intelligent home multimedia service

The steps to coordinate A/V service in UPnP A/V architecture are modified like below.

1. Device Discovery using UPnP's SSDP(Simple Service Discovery Protocol). A/V control point can discover media server and media renderer using standard UPnP Discovery mechanism.

2. Locate Desired Contents. Using media server's browsing()/search() actions, A/V control point locates desired contents. This function returns network transfer protocols and file formats that media server supports.

3. Protocol and format consideration. A/V controller identifies and selects transfer protocol and file format to use to transfer. Media renderer's Connection Manager::GetProtocol Info() returns protocol information which media renderer supports and media server returns the transfer protocol and file format in step2. Here, file format and network protocol selection algorithms are out of the UPnP standard and it can be extended to consider adaptation capability in order to reflect A/V adaptation service.

4. Configure server/Renderer. Either media server and media renderer implements ConnectionManager:: PrepareForConnection() action. This function will return an AVTransport InstanceID which will be used with AVTransport service to control the flow of transfer such as play, rewind, seek, etc. In addition to standard preparation of connecting media server and media renderer, A/V controller controls the adaptation engine to prepare the adaptation for intelligent service. This action includes intelligent adaptation decision considering user multimedia environment information which will be addressed later. Along with this, A/V controller prepares to receive and send A/V stream properly.

5. Select desired Content. According to the service scenario, A/V controller invokes AVTranspor tService::SetAV TransportURI() to set the multimedia item to be transferred. A/V controller sets the contents by calling the function with URI(Universal Resource

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Identifier). The interaction for A/V service can be categorized into two service mechanisms; push and pull mode. URI setting will be set up according to service mechanism scenario. In push model such as streaming, A/V controller makes the media server to store URI to indicate the home server while A/V controller setups URI on the media renderer in the pull mode such as HTTP GET.

6. A/V transport using AVTransport service starts A/V transport. It calls either media server or media renderer AVtransport service and it also starts adaptation process.

7. Adjusts A/V renderer using renderer's rendering control service. A/V controller can adjust the way that contents are played in the renderer.

Together with modification of multimedia contents path, intelligent service has to provide connection management and transfer control interactively or automatically. Related to the connection management and coordination of transfer control, UPnP provides two services: ConnectionManager and AVTransportService. Either media server or media renderer implements AVTransportService according to the transfer service types. When the media is transferred with pull mode such as http-get mechanism, the real control of network and transfer should be managed at the home server rather than media renderer as previously described in Figure 3.

On the other hand, if the push mechanism is used, media server's AVTransport can be used to control the A/V transfer. In this case, A/V controller can use media server's AVTranportService without additional implementation of AVTransport manager on home server. In the case of connection manager, if A/V service is provided in push mode, home server can use it without any other service. But if the pull mode is used, home server can implement ConnectionManager' service so that it can monitor the current connection and manage it rather than using media renderer's ConnectionManager. Figure 3 shows the interaction diagram of asynchronous push mechanism based on HTTP GET protocol.

According to the UPnP A/V architecture, A/V controller can run on the same machine of A/V device or it can run on separate device. However, when the A/V controller is located in media devices or separate device, it has to discover the location of home server before A/V interaction between media server and media renderer is changed to reflect home server. It consequently requires modification of UPnP device stack to support additional discovery of home server and A/V controller modification.

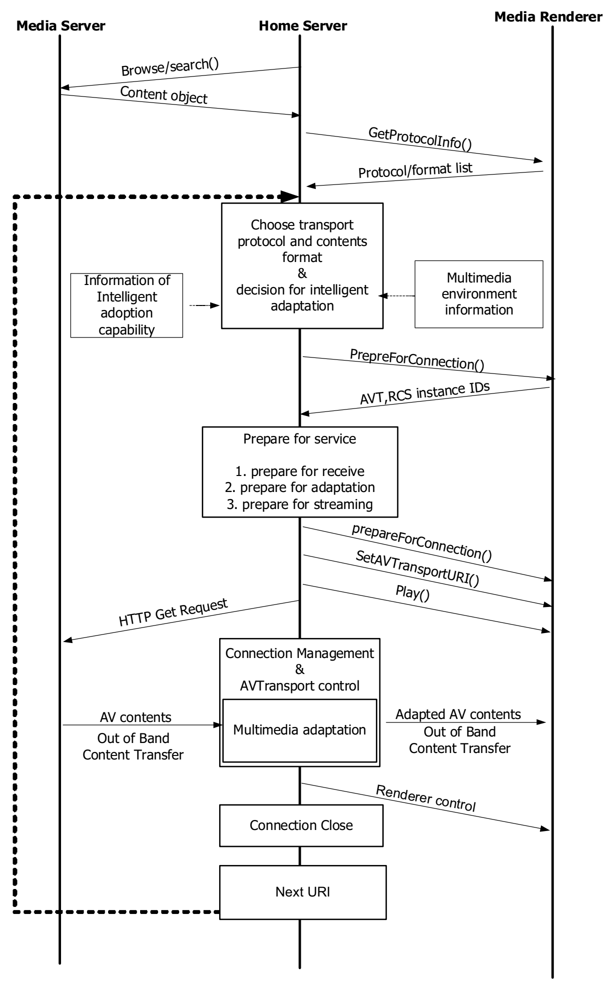

Figure 3. Interaction for Asynchronous push

To overcome this problem, we assume that the A/V control point is located in home server system together. By doing so, A/V controller does not need to worry about the location of home server and other complex interaction problem between A/V controller and home server's intelligent service when A/V controller is separated from home server. We physically integrate UPnP A/V control point, A/V transport and intelligent service module into single home server as shown in Figure 4.

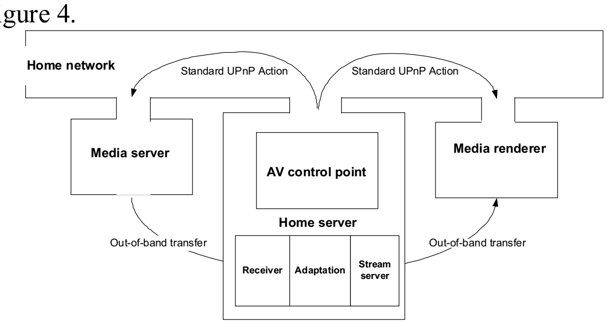

Figure 4. Home server using UPnP A/V

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A/V controller interacts with home server's intelligent service module such as adaptation module. UPnP defines DCP(Device Control Protocol) for control of UPnP-connected devices but adaptation service or other intelligent multimedia processing service are not defined as a standard. Consequently, at this time, the interaction between intelligent multimedia adaptation service module and A/V controller module in home server are made by integrating them together, but we have a plan to define the interfaces between intelligent service module and A/V controller so that our framework can integrate with various intelligent multimedia algorithms such as A/V adaptation or location based multimedia mobility.

2.2 Remote I/O support

As described before, multimedia service is initiated and controlled by A/V controller which runs in home server. Consequently, user is supposed to request the A/V service using home server. But it is a way far from the goal of this intelligent A/V service which is supposed to give more freedom to user. User always wants to operate the A/V service with his/her near personal device like a PDA or cellular phone.

Remote control usage of user can be achieved by using UPnP presentation or UPnP Remote I/O service. UPnP supports HTML presentation and its capability is wholly implementation dependent of device venders. Using some techniques like CGIs or PHPs, it is possible to provide dynamically changed web pages and user input mechanism. Then, user can access the services with near interaction devices. However, although it is simple and interoperable way for user interaction, it is insufficient for easier and general interoperability. On the other hand, UPnP Remote I/O is a standard UPnP DCP(Device Control Protocol) which moves the point of user interaction away from the application running on specific device. Remote I/O makes it possible for input and output services such as mouse, keyboard and display, which consequently comprise user interface to be connected remotely. For the actual transfer of UI data, out-of-band data transfer protocol and eventing such as XHT or RDP[7] are used.

We adopt remote I/O service into our home server framework to provide interaction with remote user. This framework frees the user interaction from the home server system and user always connects home server first to use intelligent multimedia service. Thus, a client who desires to support A/V function, needs to only support remote I/O function to connect home server rather than implementing their own intelligence with A/V functions. By doing so, we can achieve the framework which consists of home server centered architecture. The overall architecture of our framework is shown in Figure 5.

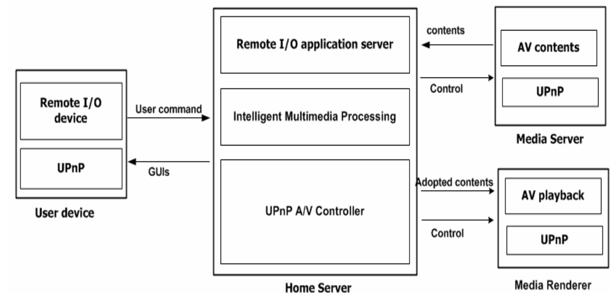

Figure 5. Multimedia service using Remote I/O

2.3 Multimedia environment consideration

In the proposed system, home server adapts multimedia content to user's multimedia environment. This multimedia environment consists of user profile, device and environment which surrounds the user. This context information affects the decision of home server during intelligent A/V service. Multimedia information is collected by intelligent agents or user's manual input from media renderer. Then, the information is expressed in a universally accessible and uniquely consumable syntax and semantics so that home server can receive and understand it in standardized way.

We adopt MPEG-21 DIA (Digital Item Adaptation)[8] tools because it specifies syntax and semantics for the broad multimedia environments. The current MPEG-21 DIA tools provide usage environment, resource adaptability and digital item adaptation. The other reason for choosing MPEG-21 is that UPnP media server uses MPEG-21 DIDL-Light to describe multimedia content, so our system can be integrated into UPnP framework without loss of generality. The next design issue is exchanging of MPEG-21 DIA tools between UPnP A/V devices and home server. MPEG-21 aims to provide general integration framework which includes creation, transaction, delivery and consumption of digital content, however the framework itself doesn't care underline network issues such as network protocol and message types. Especially in home network environment, the communication should be established in a common way in order for different home network devices to participate. In this sense, our framework communicates MPEG-21 DIA on the top of most promising UPnP home network middleware.

Many user based multimedia adaptation research and works such as HTTP negotiation, HTTP

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headers[4] and OPES[6], adaptation process is tightly combined with communication request/response between A/V devices. However, because we separate transfer of MPEG-21 DIA Tools from multimedia contents transfer itself, A/V service can be achieved more smoothly without any consideration on multimedia environment. Thus, to request adapted multimedia service, user requests multimedia content as same as how they did before, then adaptation is made taking into account of DIA tools which is transferred by UPnP. And this multimedia environment exchange service should be broad enough to cover all the possible context information. So we propose to use create new service which can be used separated to communicate multimedia environment, while freeing each device from context environment acquisition.

With UPnP, there are three ways to send DIA tools to home server. The first is using XML based device description. However description can not address dynamically changing multimedia environment, so it is not efficient way. Second, UPnP has some pre-defined services which can be used to know device specific information such as AVTransport::Get DeviceCapabilities or renderingControl Service. But it is not enough to reflect needs of representing various multimedia environments. The third choice is to define new general service (DCP, device control protocol) to run on media renderer side and send description over UPnP. We adopt third mechanism and user context description is designed as a separate service in addition to device's own service as shown Figure 6.

This multimedia environment service can be used in more advanced way and it is implementation dependent. For example, home server can collect all the multimedia environment of devices when service announce or service discovery time and maintain caches of those collected environments to shorten service time, or it may request whenever it needs multimedia environment.

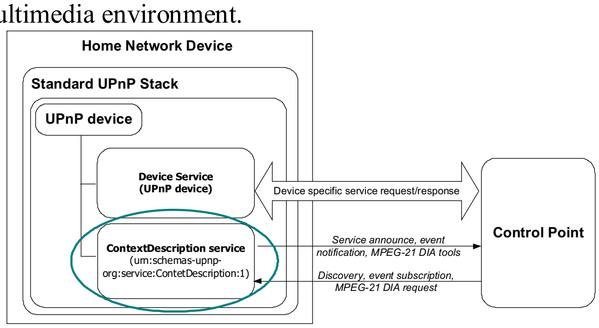

Figure 6. Multimedia environment service

Also, dynamic management of multimedia environments can be achieved using UPnP event model in our architecture. Home server can subscribe and be notified an event, which reflects a change in multimedia environment. This event mechanism can be used to dynamically adapt multimedia content to the multimedia environment changes. For example, multimedia mobility[3] service which provides contents seamlessly when the user moves to other area can be realized with our multimedia framework when combining with proper localization mechanism.

When the device is introduced into home network, control point can discover it using UPnP SSDP protocol and it can request multimedia contents information and save it on its database. Or depending on the implementation, home server can request multimedia environment information when it is necessary by user's A/V request. The simple multimedia environment service description for illustration purpose is shown in Figure 7.

```
<?xml version="1.0"?>
<scpd xmlns=" urn:schemas-upnp-org:service:Contet
Description:1">
<actionList>
<name> get_data </name>
<argumentList>
<argument>
<name>Element</name>
<direction>out</direction>
<name>description</name>
<direction>out</direction>
<relatedStateVariable>A_ARG_TYPE_Desc</relatedStateVaria
ble>
</argument>
</action>
<serviceStateTable>
<stateVariable sendEvents="yes">
<name>A_ARG_TYPE_Desc</name>
<dataType>string</dataType>
</stateVariable>
```

Figure 7. Multimedia environment service based on XML

2.4 Home server architecture

Figure 8 shows the logical components of home server system and interaction of modules. For adaptation, home server uses a rule parser, which decides the intelligent service mechanism through interacting with multimedia environment managing module. The interconnection has four different planes; remote control communication based on UPnP remote I/O, A/V transport using out-of-band protocol, control mechanism of A/V controller and MPEG-21 delivery plane.

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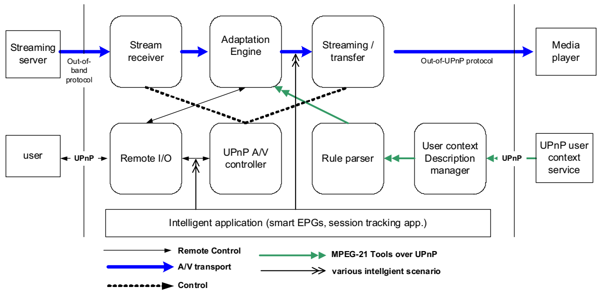

Figure 8. Home server architecture

In intelligent multimedia service framework, home server provides contents browsing for user to locate A/V content via remote I/O. Along with this, home server has several modules which include intelligent service module, multimedia environment management module, multimedia content transfer and remote I/O support.

3. Implementation

For the purpose of verification of proposed framework, we implemented a test-bed which adapts multimedia contents on its way of UPnP A/V service. For media server and media renderer, Intel UPnP tools' binary codes were used without modification because media server and media render do not need to be modified as mentioned before. In the Linux based home server, open source tool VLC(VideoLan Client) which provides AV content adaptation was adopted as a intelligent service module and integrated with UPnP AV control module. Multimedia environment service was implemented on media renderer with Siemens UPnP stack. In our scenario, home server received low bandwidth MPEG-2 AV from the media server via http-get protocol, then provides MPEG-4 adapted multimedia contents to media renderer in real-time. The controls were provided to remote user with PDA via RDP[7] protocol.

4. Conclusion and future work

In this paper, we proposed intelligent multimedia service framework in digital home network using UPnP and MPEG21 DIA tools. In the future, we are planning to expand our intelligent home network framework into OSGi platform[9] and define general interfaces between the framework and various intelligent services so that more various multimedia services scenario can be built on our framework.

5. References

[1] Home networked device design guidelines ver 1.0. Digital Living Home Alliance, 2004

[2] M. Jeronimo, and J. Weast, UPnP Design by Example, Intel Press, 2003

[3] YI CUI, KLARA NAHRSTEDT, DONGYAN XU, “Seamless User-Level Handoff in Ubiquitous Multimedia Service Delivery,” Multimedia Tools and Applications, 22, 137–170, 2004

[4] Interoperable Adaptive Multimedia Communication C.Timmerer, H. Hellwagner, Multimedia, IEEE , Volume: 12 , Issue: 1 , Jan.-March 2005 Pages:74 - 79

[5] Adhoc personal ubiquitous multimedia services via UPNP G. Schneider, C. Hoymann, S. Goose, Multimedia and Expo, 2001. ICME 2001. IEEE International Conference on , 22-25 Aug. 2001 Pages:901 - 904

[6] Open Pluggable Edge Services(OPES) Working Group, http://www.ietf-opes.org/.

[7] Walker, M. R., Edwards, J., Jeronimo, M., Ritchie, J. G., and Saint-Hilaire, Y., “Remote I/O: Freeing the Experience from the Platform with UPnP Architecture.” Intel Technology Journal. November 2002).

[8] MPEG-21: The 21st century multimedia framework J.Bormans,J.Gelissen,A.Perkis,Signal Processing Magazine, IEEE , Volume: 20 , Issue: 2, March2003 Pages:53 – 62

OSGi Alliance, http://www.osgi.org

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