Mobile Home to Home
-Technology for Controlling Access to Content between Different Home Networks-

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ABSTRACT

We have developed an access control technique called Mobile Home to Home (MH2H) for remotely accessing original content stored on a DLNA server device such as a PC or hard disk recorder in a home from a DLNA player and renderer devices in a visited home, such as a television or game console. MH2H allows content to be accessed without installation of special devices in the visited home or software in the PC, and allows content to be accessed remotely with existing DLNA devices simply by bringing along a mobile device which is used for access management. The concept of using subscribers' cellular phones to access contents stored on their own servers is similar to Pocket U. Moreover, MH2H enables to watch video content with friends or family using DLNA-compatible televisions. This paper discusses usage scenarios for MH2H systems, and presents an outline of the system design and the results of evaluating a prototype system.

Keywords: DLNA, Home Network, Internet, Cellular phone, Remote Access.

1 Introduction

The Digital Living Network Alliance (DLNA) [1] has issued guidelines for the seamless sharing of digital content such as photos, music and video among PCs, consumer electronics and mobile handheld devices (MHD). A growing number of PCs and other types of consumer electronics support version 1.0 of the DLNA guidelines [2], and MHD and renderer devices that support version 1.5 [3] (established in October 2006) are also starting to appear on the market. By using a cellular phone (hereafter we refer to "MD") as one device to perform content sharing, users can access digital content anywhere in their homes, and can use a DLNA-compatible TV to display photos and video recorded at home or outside.

There are also many users who want to be able to access content stored in a server device (SD) connected to their home network (HN) while they are away from home. To meet this demand, NTT DOCOMO began offering the Pocket U service in June 2008. This service allows users to remotely access their content at any time by using a 3G cellular network to access the PC on the HN, instead of having all their content in the MD. This not only eliminates storage capacity limitations but also makes it unnecessary to copy content to the cellular phone before it can be played back elsewhere. Users who want to access content in their HN only need to taking their cellular phone with them as usual. However, when visiting friends and family, it would be better if digital content could be displayed on a larger screen by accessing the content in the SD from the visited home network (VHN). A new framework is needed for this use case because the Pocket U service is provided within a different scope of usage. Meanwhile in the DLNA framework, the sharing of content in an HN and on the road are the current scope of application, which means it is not possible to remotely view content from the VHN in the HN even when using a DLNA-compatible TV.

There are two major methods to remotely access content between different home networks. One method is to establish a connection between the HN and VHN via virtual private network using home gateways [4]–[10]. In the other method, the MD downloads contents from the SD in the HN, and behaves as a SD to play them over the WLAN in the VHN [3], [11]. The former requires the addition of a new device in each home while needs to prepare or replacement an additioal devices or in each homes, while the latter has limitations of content quality and size and spends too much power to transmit data. Thus, neither method copes with both usability and performance.

In this paper, we explain Mobile Home to Home (MH2H) as an access control technique for remotely accessing original content stored on an SD such as a PC or hard disk recorder (HDR) in the HN from DLNA devices in the VHN, such as a digital media player and digital media renderer (hereafter we refer to "PD" and "RD" respectively). MH2H allows content to be accessed without installation of special devices in the VHN or software in the SD, and allows content to be accessed remotely with existing DLNA devices simply by taking the MD which is used for access management. The MD establishes a link to the HN to provide SD content information to the PD and RD in the VHN and to manage connections in content transmission, thereby allowing access control to be performed in more detail. Since the MD does not transmit the content by itself, it can avoid the overheads associated with packet processing. These results in a service similar to Pocket U whereby users can use their MDs to access original content stored on their own SDs in its original quality, while they are out visiting friends or family with a DLNA-compatible TV.

This paper describes usage scenarios for MH2H systems, and presents an overview of the system design and the results of evaluating a prototype system.

2 MH2H

2.1 Service Requirement

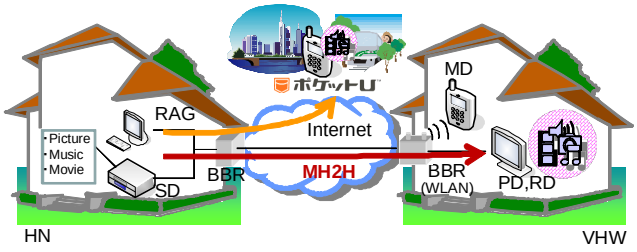

Figure 1: An illustration of content viewing using the MH2H

Figure 1 shows an example of how MH2H could be used in practice. Pocket U is used for the playback of all content outside the home, while MH2H covers the use of content within VHN. In the MH2H service, a functionally enhanced MD and a Remote Access Gateway (RAG) in the HN are linked to the RD and PD in the VHN, whereby the photos, music and video files stored in the SD can be accessed over the Internet by the PD and RD. Here, the PD and RD in the VHN and SD in the HN are products conforming to DLNA guidelines. In MH2H, the MD can implement four functions according to the following usage scenarios together with performing access control as a key device for controlling the HN:

1) Mobile Server Function The MD in the VHN behaves as a temporary virtual server that only provides device information and status change notification of the SD in the HN, enabling content stored in the SD to be displayed and played back on the PD (Fig. 2(a)). The PD is a DLNA guideline v1.0 compatible device, and that retrieves content from the SD directory.

2) Renderer Control Function The MD behaves as a controller which controls the RD in the VHN to display and play back the contents stored on the SD in the HN (Fig. 2(b)). The RD gets contents from the SD directory.

3) Seamless Playback Function The MD in the VHN behaves as a controller that operates the RD and a mobile digital media player (M-DMP) by itself, whereby the display and playback of contents stored on the SD in the HN can be migrated seamlessly between the MD and the RD in the VHN. In other words, users can watch some of the content on the MD, and then watch the rest on the RD. In this function, content converted for display on the MD is played back on the MD in the same way as in the Pocket U service, while the original content is played back on the RD (Fig. 2(c)).

4) Service Extension Function When the MD is away from the VHN, the content stored on the SD in the HN can continue to be displayed and played back for a fixed period governed by the mobile server function and seamless playback function. As a result, the PD can show a video for a limited period of time after the MD left.

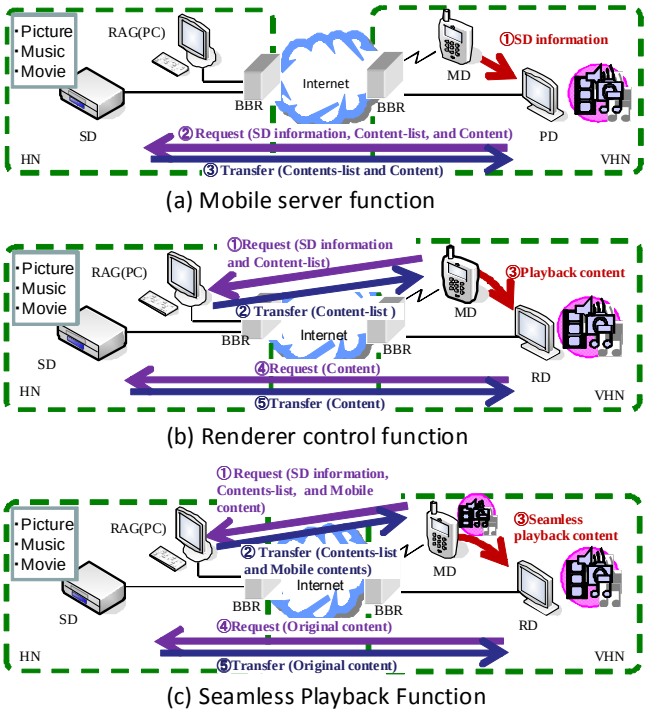

Figure 2: Usage scenarios

2.2 System Design Policy

The design principles behind the implementation of these usage scenarios are: (i) using the MD to control permission to access content from the VHN to the HN and prevent malicious access, and (ii) implementing efficient assignment of functions and operating sequences to avoid additional processing loads (and power consumption) associated with the transfer of packets in the MD.

The specifications derived from these two design principles are as follows.

- To prevent malicious access from unspecified users, the RAG allows temporary access to the registered MD and DLNA devices in the VHN that have permission to connect by the MD. When the MD is left, access is immediately terminated. Access from unauthorized VHNs (external IP addresses) is always denied.
- The RAG manages the number of registered MDs and the number of simultaneous connections to the RAG.
- The RAG acts as a virtual server, providing unified management of content lists stored on all the SDs in the HN, and converting and saving content for the MD (preliminary transcoding/translation). Moreover it transfers content in response to content playback requests from the MD, and transfers original content in the SD in response to content playback requests from the PD and RD.
- The MD implements the following functions: management of RAG connections in the HN (authorization re-

quests, keep-alive responses), transfer of SD information (device description, event notification), playback of content on the MD, and RD control. The PD and RD transfer original content stored on the SD directly through the RAG (bypassing the MD), thereby avoiding increased processing load (power consumption) in the MD.

- Commercial equipment conforming to version 1.0 and 1.5 of the DLNA guidelines is used for the SD in the HN and the PD and RD in the VHN which are related with a digital media server (DMS), digital media player (DMP), and digital media renderer (DMR).

3 Implementation

An MH2H system is implemented by adding the following functions to the RAG and MD.

3.1 RAG

3.1.1 Port Forwarding

A broadband router (BBR) conforming to Universal Plug and Play (UPnP) [12] is set up to forward packets arriving from external IP addresses and designated port numbers to the RAG, and the BBR settings are cleared when the application is canceled.

3.1.2 Keep-alive

The communication between the RAG and MD is periodically checked to ensure that the MD belongs to the VHN. If the MD transmits a disconnection request packet or does not respond to a periodical check packet, it is denied access to the RAG even if accessed from a DLNA device in the VHN. Moreover, access is always denied from outside the VHN to which the MD belongs.

3.1.3 DLNA Aggregate

The RAG performs a virtual server, and it obtains content list information from all the SDs in the HN for unified management, and transmits the stored list in response to content list requests from the MD, PD and RD.

3.1.4 Media Format Management

The RAG converts the media format and bit rate of the content (video or music) stored on the SD in the HN according to a content conversion list (Table 3.1.4). When content is requested from the MD, it transmits the converted content, and when content is requested from the PD or RD, it transfers the original content stored on the SD.

For JPEG image files of up to 4,096 $\times$ 4,096 dots, a function for transferring them as 640 $\times$ 480 dot images is required as a DMS's mandatory item by the DLNA guidelines, so this is not implemented in the RAG.

Table 1: Content conversion list

	Before transcode /translate	After transcode /translate
Video	MPEG2 10 Mbps or less	WMV 128 kbps or less
Music	AAC 320 kbps or less	AAC 128 kbps or less

3.2 MD

3.2.1 External IP Address Acquisition/Notification

First of all, the MD accesses to the VHN over a wireless LAN (WLAN) by permission of friends or family. After that, UPnP is used to acquire an external IP address [13] from the BBR of the VHN to which the MD belongs, and this IP address is notified to the RAG with a connection request packet.

3.2.2 DLNA Device Capability Notification

In order to mitigate traffic loads between the RAG and MD, the RAG transmits a minimized device capability packet which contains only media formats and resolutions/bit rates supported by the MD and RD. The MD notifies the RAG about these capabilities beforehand. Figure 3 shows an example of the device capability of the RAG and SD related with JPEG files for the MD. Due to a limitation of MD screen size, it only describes `JPEG_SM` as supported resolution (VGA) and a thumbnail `JPEG_TN`.

```
POST HTTP/1.1
SERVER: Windows 5.1, UPnP/1.0 DOCOMO MH2H UPnP/1.0
DATE: Tue, 4 March 2008 08:00:00 GMT
EXT:
CONTENT-TYPE: text/xml;charset="utf-8"
CONTENT-LENGTH: 1320

<?xml version="1.0" encoding="utf-8"?>
<s:Envelope s:encodingStyle="
http://schemas.xmlsoap.org/soap/encoding/" xmlns:
s="http://schemas.xmlsoap.org/soap/envelope/">
  <s:Body>
    <u:SetProtocolInfo xmlns:u="
    urn:schemas-upnp-org:
    service:ConnectionManager:1">
      <Sink> http-get:* image/jpeg_tn:*,
      http-get:* image/jpeg_sm:*</Sink>
    </u:SetProtocolInfo>
  </s:Body>
</s:Envelope>
```

Figure 3: Device capability of the RAG and SD for the MD

3.2.3 Player Function

The MD supports the M-DMP function to listen to music and view pictures and video, exactly as in the case of the Pocket U service. It accesses the RAG over the WLAN and plays the converted content remotely from the VHN.

3.2.4 Controller Function

According to the procedure specified in version 1.5 of the DLNA guidelines, the MD acts as a digital media controller (DMC) and discovers RDs in the VHN. After that it controls the RD to play back and stop content which is stored on the SD in the HN remotely. Figure 4 shows an example of the remote content playback request packet which is called "SetAVTransportURI" in the DLNA. The MD requests the RD to play a content on the SD in the HN.

```
POST /_urn:schemas-upnp-org:service:
AVTransport_control HTTP/1.1
Host: 192.168.2.20:58336
User-Agent: DOCOMO MH2H-DMC, UPnP/1.1
DATE: Tue, 4 March 2008 9:00:00 GMT
SOAPACTION: "urn:schemas-upnp-org:service:
AVTransport:1#SetAVTransportURI"
Content-Type: text/xml; charset="utf-8"
Content-Length: 418

<?xml version="1.0" encoding="utf-8"?>
<s:Envelope s:encodingStyle="
http://schemas.xmlsoap.org/soap/encoding/" xmlns:
s="http://schemas.xmlsoap.org/soap/envelope/">
   <s:Body>
      <u:SetAVTransportURI xmlns:u="urn:
         schemas-upnp-org:service:AVTransport:1">
         <InstanceID>0</InstanceID>
         <CurrentURI> http://210.254.227.113:30000/
         1681-1682.mpg </CurrentURI>
         <CurrentURIMetaData>...
         </CurrentURIMetaData>
      </u:SetAVTransportURI>
   </s:Body>
</s:Envelope>
```

Figure 4: A remote content playback request packet (SetAVTransportURI)

3.2.5 Mobile Server Function

The MD provides the device description and device capability and event notification functions of the DMS, in conformity with the version 1.0 of the DLNA guidelines for PDs. However, the content list and content are transferred directly from the RAG and SD by describing the external IP address and designated port number of the HN. Figure 5 and 6 show an example of the device capability and device description of the RAG and SD in the HN. An icon file (`<icon>`), a service description file (`<SCPDURL>`), and a SD control URL (`<controlURL>`) are related with the RAG, and a server event (`<eventSubURL>`) is related with the MD.

```
NOTIFY * HTTP/1.1
HOST: 239.255.255.250:1900
CACHE-CONTROL: max-age=180
LOCATION: http://192.168.2.20:30000/
NT: urn:schemas-upnp-org:device:MediaServer:1
NTS: ssdp:alive
SERVER: Windows/5.1 UpnP/1.0 DOCOMO MH2H UPnP/1.0
USN: uuid: da16920d-9660-9e82-6cba-b2674fd29677::
urn:schemas-upnp-org:device:MediaServer:1
```

Figure 5: Device capability for the PD in the VHN

```
HTTP/1.1 200 OK
SERVER: Windows/5.1 UPnP/1.0 DOCOMO MH2H UPnP/1.0
DATE: Tue, 4 March 2008 10:00:00 GMT
LAST-MODIFIED: Tue, 4 March 2008 09:30:00 GMT
CONTENT-TYPE: text/xml;charset="utf-8"
CONTENT-LENGTH: 2578

<?xml version="1.0" encoding="utf-8"?>
<root xmlns="urn:schemas-upnp-org:device-1-0"
xmlns:dlna="urn:schemas-dlna-org:device-1-0">
<specVersion>
  <major>1</major>
  <minor>0</minor>
</specVersion>
<device>
  <dlna:X_DLNADOC>DMS-1.00</dlna:X_DLNADOC>
  <deviceType>urn:schemas-upnp-org:device:
  MediaServer:1</deviceType>
  <friendlyName>Virtual_SERVER</friendlyName>
  <manufacturer>NTT DOCOMO, Inc.</manufacturer>
  <manufacturerURL>http://www.nttdocomo.com/
  </manufacturerURL>
  <modelName>MH2H Media Server</modelName>
  <modelURL>http://www.nttdocomo.com/</modelURL>
  <UDN>uuid: da16920d-9660-9e82-6cba-b2674fd29677
  </UDN>
  <iconList>
    <icon>
      <mimetype>http://210.254.227.113:30000
      /image/jpeg</mimetype>
        <width>48</width>
        <height>48</height>
        <depth>24</depth>
        <url> http://210.254.227.113:30000/
        description/dms_sm.jpg</url>
      </icon>
      <icon>
        <mimetype> http://210.254.227.113:30000
        /image/jpeg</mimetype>
        <width>120</width>
        <height>120</height>
        <depth>24</depth>
        <url> http://210.254.227.113:30000
        /description/dms_lrg.jpg</url>
      </icon>
  </iconList>
  <serviceList>
    <service>
        <serviceType>urn:schemas-upnp-org:service:
        ContentDirectory:1</serviceType>
        <serviceId>urn:upnp-org:serviceId:
        ContentDirectory</serviceId>
        <SCPDURL> http://210.254.227.113:30000
        /description/av_cds.xml</SCPDURL>
        <controlURL> http://210.254.227.113:30000
        /control/ContentDirectory</controlURL>
        <eventSubURL>event/ContentDirectory
        </eventSubURL>
    </service>
    <service>
        <serviceType>urn:schemas-upnp-org:service:
        ConnectionManager:1</serviceType>
        <serviceId>urn:upnp-org:serviceId:
        ConnectionManager</serviceId>
        <SCPDURL> http://210.254.227.113:30000
        /description/av_cms.xml</SCPDURL>
        <controlURL> http://210.254.227.113:30000
        /control/ConnectionManager</controlURL>
        <eventSubURL>event/ConnectionManager
        </eventSubURL>
    </service>
  </serviceList>
</device>
</root>
```

Figure 6: Device description for the PD in the VHN

3.3 Content Playback Sequence

Figure 7 shows the sequence of operations to play back a video content according to the usage scenario of the mobile server in Fig. 2(a). The TV (PD) in the VHN accesses the PC (SD) in the HN in accordance with the device description of the MD. The PC is already switched on, and the RAG acquires the device description and content list of the PC. Moreover, the MD is connected by the WLAN to the VHN.

When the application starts up in the VHN, the MD transmits a connection request for the establishment of a connection to the RAG (Fig. 7①), and receives the response to this request and the SD information in the HN (Fig. 7②). The TV transmits a Simple Service Discovery Protocol (SSDP) M-SEARCH signal when it is switched on (Fig. 7③), and receives the response from the MD (Fig. 7④). After that, the TV receives the device description which includes the external IP address and port number of the HN that is acquired by the MD in step ② (Fig. 7⑤, ⑥). Also, a Generic Event Notification Architecture (GENA) SUBSCRIBE signal is used to transmit to the MD a report request describing changes of state such as switching the SD on or off, or adding/deleting content (Fig. 7⑦, ⑧), and receiving state notifications from NOTIFY signals (Fig. 7⑨, ⑩). After that, when adding/deleting content stored on the SD or starting up/shutting down the SD, the change in state is transmitted as an event report from the RAG to the MD and PD.

When the user searches for content or moves a folder, the search results and content list are displayed on the TV using Simple Object Access Protocol (SOAP) and Content Directory Service (CDS) protocols (Fig. 7⑪, ⑫). After a video has been selected, the content is played back by streaming data between the PC and TV (Fig. 7⑬, ⑭).

4 Implementation of MH2H System

4.1 Preliminary Tests

To confirm the feasibility and usefulness of the MH2H system, we implemented the above mentioned usage scenarios where the prototype RAG is connected to the MD and commercial DLNA devices. Moreover, we included capabilities for event notifications to the PD in the VHN by adding and deleting content on the SD in the HN, and terminating services to the PD and RD by disconnecting the MD from the VHN.

For this implementation we used a commercial desktop PC as the RAG and a FOMA F1100 cellular phone as the MD equipped with the Microsoft Windows Mobile 6 operating system. The HN and VHN were connected over the Internet, and the F1100 cellular phone was connected to the VHN over a WLAN (IEEE 802.11g). A HDR: SONY BDZ-A70 as the SD and a TV: SONY BRAVIA KDL-40X1000 as the PD were used as commercial DLNA devices. A prototype DigiOn DIXIM DMA-2200 was used for the RD because there was no commercially available DMR DLNA device. Even though the version 1.5 of the DLNA guidelines had been published, the DLNA did not start a certification logo program for DMSs at that time. The menu screen of the prototype application in the MD is shown in Photo 1. By enter the external IP address and port number of the HN, it is possible to connect to the RAG and select each function. In the following, we will describe the evaluation results obtained when implementing the mobile server, renderer control and seamless playback functions.

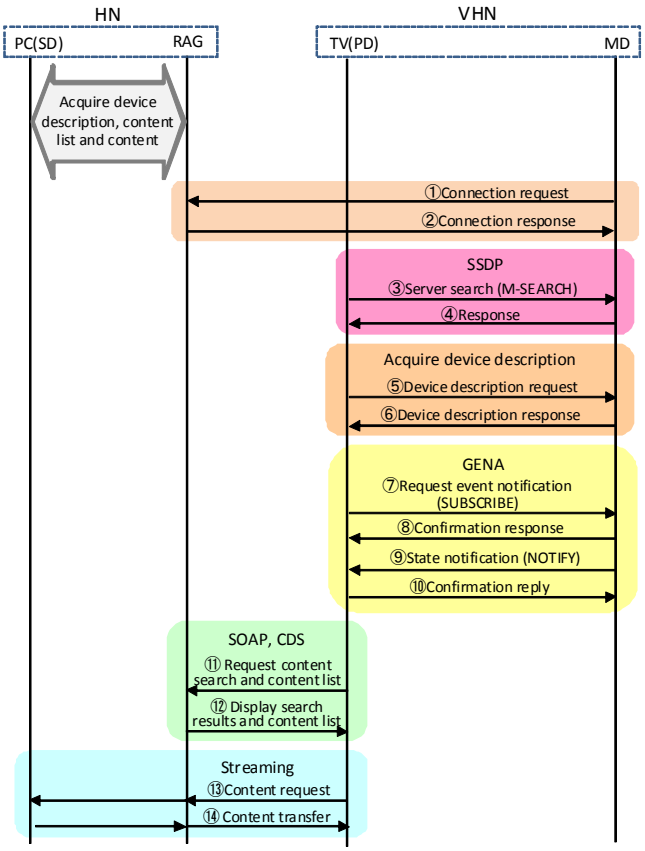

Figure 7: Content viewing sequence by the MH2H

Photo 1: Menu screens of the prototype application

1) Mobile Server Function When the mobile server function is started up in the MD, the SD in the HN is temporarily added to and displayed in the PD's list of SDs. When a folder

is selected, its contents are listed in just the same way as the contents of an SD in the local network without delay (Photo 2, 3). The SD has the following contents: photo files ranging in resolution from 640 × 480 to 4,096 × 4,096 dots (JPEG), video files with bit rates ranging from 6 to 15 Mbit/s (MPEG-2), and music files with bit rates ranging from 64 to 320 kbit/s (AAC). The results showed that in spite of retrieving content from the remote HN, the PD was able to achieve smooth display/playback with no deterioration or breaks in video or music. Moreover, we confirmed that the PD stopped the playback quickly upon demand, and it eliminated the listing of the content and SD in the HM when the mobile server function was ended in the MD. Furthermore, we also tested another two PDs, SONY PlayStation3 and Canvas Online CP1, and they could work well too.

Photo 2: A control screen of the mobile server

Photo 3: A content list displayed on the PD

2) Renderer Control Function We used the RD to display and play images, music and video stored on the SD in the HN according to commands entered from the MD. We confirmed that the system was able to respond without delay to commands such as pause, play, fast forward and rewind, which were acted upon within one second even when performed repeatedly. Figure 8 shows the time-sequence graph for the renderer control function when the RD is playing a video. The MD controls the RD using SOAP protocols to get and play the video using "SetAVTransportURI" and "Play" messages. After that, the RD declares the state as "PLAYING" by sending the GENA NOTIFY message.

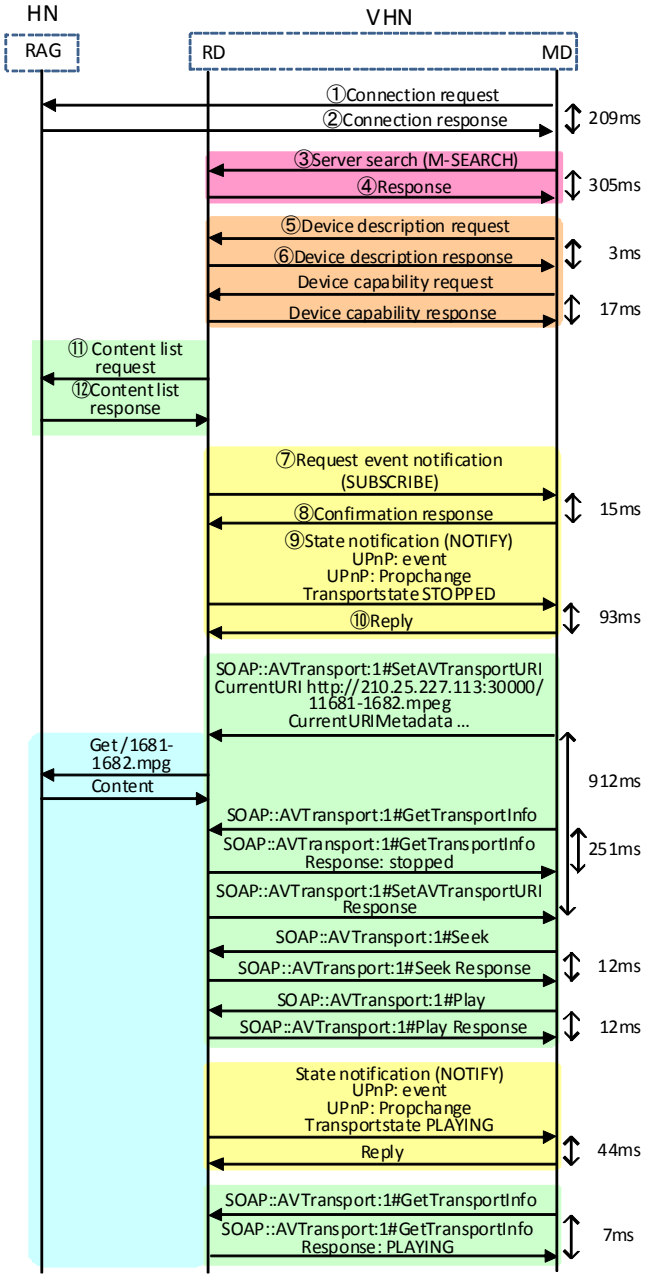

Figure 8: Time-sequence graph for renderer control function

3) Seamless Playback Functions To confirm that the display device switching and media format switching are performed saemlessly, we used the RD to perform seamless playback of photos, music and video that were being displayed and played back on a MD. First of all, the MD played back the contents of image files (JPEG) with a resolution of 640 × 480 dots, video files (WMV) with a bit rate of approximately 400 kbit/s and music files (AAC) with a bit rate of 128 kbit/s.

After that the MD was able to find and select the RD for seamless playback while play back content. Then, the selected RD was able to continue playback smoothly with no large breaks or disruption, and it played back the contents of image files (JPEG) with a resolution of 4,096 × 4,096 dots, video files (MPEG- 2) with a bit rate of 15 Mbit/s and music files (AAC) with a bit rate of 320 kbit/s (Photo 4, 5). We also confirmed the seamless playback among the MD and RDs. All of the content switching capabilities were verified.

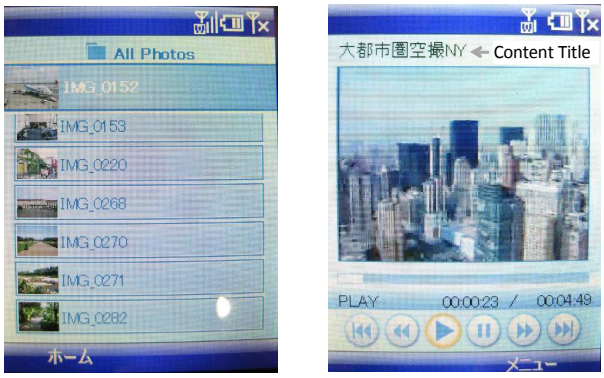

Photo 4: Content list and playback screens on the MD

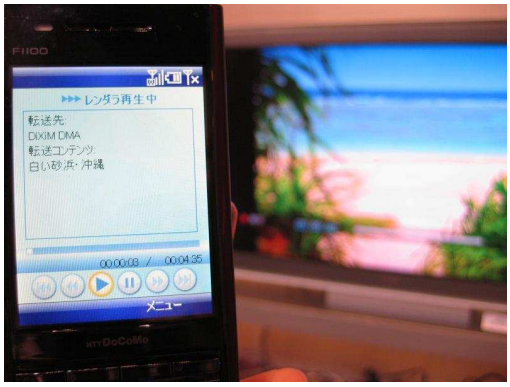

Photo 5: Seamless playback screens on the MD and RD

4.2 Demonstration

We delivered a keynote speech and demonstration of this MH2H system at CEATEC JAPAN 2008 [14]. There was a large audience who heard the presentation "DLNA Expands from the Home into the Mobile Space," which included the latest DLNA activity, DOCOMO's approach to DLNA, and Nokia's vision of leveraging DLNA in the convergence of mobile/home entertainment. The MH2H demonstration at the NTT DOCOMO exhibition booth was also well attended (6, 7).

We faced a bit of difficulty with the installation of the system, because there were a lot of WLAN access points around there, causing severe interference. In spite of that, the MD was able to connect to the VHN without modification over the WLAN, and we confirmed that the system operation was completely successful, as in the case of the preliminary tests.

Photo 6: An exhibition booth image of NTT DOCOMO in CEATEC JAPAN 2008

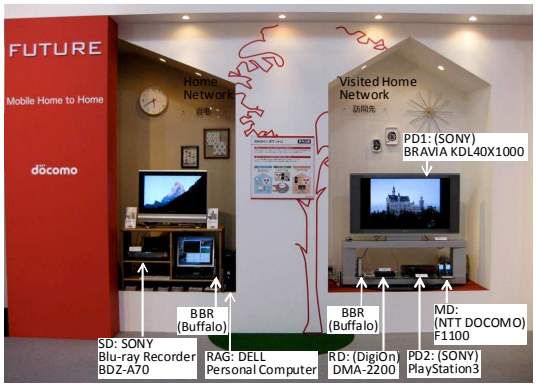

Photo 7: A demonstration system of the MH2H in CEATEC JAPAN 2008

5 Compare with Conventional Methods

In this section, we describe two other conventional methods to remotely access content between different home networks. This paper leaves out an explanation of a remote access using a MHD for want of space [5], [6].

A wide area DLNA communication system [7] and an extended DLNA-based media sharing System (E- DMSS) [8] proposed a connection between the HN and VHN via virtual private network (VPN) using home gateways (hereafter we refer to HomeGW), and the PD can playback content in the SD. To realize these systems, the HomeGW supports Session Initiation Protocol (SIP), DMP, and DMS. MDs acts as gateways to forward the content that are categorized as this type.

The MHDs such as MDs and PDAs which conformed to DLNA guidelines version 1.5 [3] can download content from the SD in the HN and behavior as a M-DMS to play them over the WLAN in the VHN. Portable media players and cellular phones using a composite video signal or high-definition multimedia interface (HDMI) cables have been realized in this manner.

Figure 9 and Table 5 show a comparison among the three types of remote access methods. The HomeGW type can share all content between the HN and VHN, but both the

homes have to setup the gateways. In the case of visiting friends' homes, all the homes have to set up it beforehand or user brings it to connect every time. The MHD type can access the contents stored in it anytime and anywhere and allow them to be viewed from the PD in the VHN. However, there is a limitation of the storage and power consumption of the MD. The MH2H type achieves the optimum trade-off between the HomeGW and MHD types. The MD only provides the SD information to the PD in the VHN and support an authentication to connect the HN. Moreover, the PD can share all of the original content on the SD in the HN without the HomeGW in the VHN. Furthermore, it is released from the restriction of low storage capacity on the MD, and imposes no additional power drain on the MD..

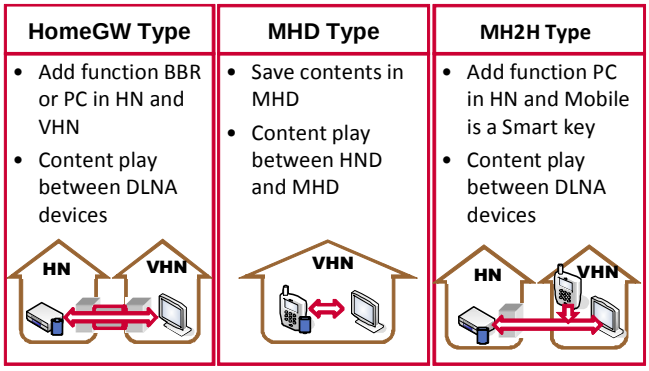

Figure 9: Methods of content sharing between the HN and VHN

Table 2: Compare MH2H and conventional methods

	HomeGW	MHD	MH2H
Usage scenes	△	○	△
Additional device	×	○	○
Support contents	○	△	○
Storage limit	○	△	○
Power Consumption	N/A	△	○

6 Conclusions

We have described an innovative MH2H access control technology which is expected to be developed in the future to allow content to be accessed between the VHN and HN using the MD, RAG, and DLNA devices.

Through the results of the prototype system, it is possible to use the RAG and MD in the HN and VHN to control the remote access of content via the Internet and to manage these activities. This kind of operation has not been possible within existing DLNA guidelines.

In the future, it seems that the importance of linkage between MDs and DLNA devices through local communication means such as the WLAN and a femtocell [15] will continue to increase. We plan to continue in our efforts to develop technologies for expanding the range of new services while making further progress in the study of such fields and the accumulation of know-how.

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