Advance Access publication on November 20, 2008 doi:10.1093/comjnl/bxn062

Design and Implementation of the DLNA Family Intercom System for Smart Homes

CHIN-FENG LAI[1], HSIEN-CHAO HUANG[1], YUEH-MIN HUANG[1,*] AND HAN-CHIEH CHAO[2,3]

[1]*Department of Engineering Science, National Cheng Kung University, Tainan City, Taiwan, Republic of China*
[2]*Institute of Computer Science & Information Engineering and Department of Electronic Engineering, National Ilan University, I-Lan, Taiwan, Republic of China*
[3]*Department of Electrical Engineering, National Dong Hwa University, Hualien, Taiwan, Republic of China*
**Corresponding author: huang@mail.ncku.edu.tw*

In a traditional intercom system that only allows place-to-place communication in a house, it is necessary to dial the extension number of a specific family member, or dial each extension number individually via the intercom broadcasting, in order to reach the desired person. Additional master stations controlled the intercom system are required, and it is load to maintain the stations for general users. In order to solve these problems, we propose the digital living network alliance (DLNA) compatible family intercom system (DFIS): the architecture to support user mobility. This architecture makes it possible to quickly reach a family member without the knowledge of the extension number that caters to a fixed location. In other words, it will be not necessary to dial the extension number of the location of the desired person. We introduce call control and phone handling under the subject of DFIS architecture and demonstrate that the proposed DLNA family intercom device and DLNA family intercom adaptor can work well.

Keywords: Intercom; DLNA; SIP; UPnP

Received 13 January 2008; revised 25 September 2008

1. INTRODUCTION

The rapid development of home networking technologies has empowered home devices with network interactivity. As a result, home networks are getting increasingly popular with home communication solutions by enabling users to communicate using consumer electronics (CE) or PCs within the family. However, a vast majority of intercom systems currently deployed are still of the analog variety. Such traditional intercom systems suffer over time from a reduction in voice quality due to the aging of wires [1]. Therefore, it becomes necessary to replace wires and facilities within a certain time period, which implies a waste of money and manpower. Also, since the communication is conducted device-to-device, it is difficult to always reach the desired person, and the latter has no foolproof way to determine the identity of the caller. Though much technology exists to support person-to-person communication, these require other communicational applications or managerial servers. It is difficult to install applications on CE devices and maintain servers for general users. In order to facilitate person-to-person communication in the digital home networking environment without additional devices or applications, a standard protocol is required.

Therefore, we propose the digital living network alliance (DLNA) family intercom system (DFIS) architecture as a replacement for the traditional intercom system. The DFIS consists of two main parts: the DLNA family intercom device (DFID) and the DLNA family intercom adaptor (DFIA). The DFID is used to replace the extension devices in the traditional intercom system, whereas the DFIA provides the signal conversion functions (such as the conversions of the universal plug and play (UPnP)–session initiation protocol (SIP) converter and the UPnP–public switched telephone network (PSTN) converter) to facilitate external communication using DFIDs.

We will go over the details in subsequent sections. Section 2 discusses DLNA-related technologies. Section 3 describes the overall architecture of the DFIS and illustrates the system

architectures of the DFID and the DFIA. Section 4 describes phone handling and call control under the DFIS. Section 5 shows the demonstration process and its results. Finally, Section 6 outlines the conclusions.

2. RELATED WORK

The DLNA is an international collaboration of CEs, computer industry and mobile device companies that makes products which are compatible with each other. The main objective of the DLNA is to establish a seamless and interoperable network. In such an environment, multimedia services across different devices, involving PCs, CEs and mobile devices, are developed easily and conveniently [2, 3]. Figure 1 illustrates the DLNA transmission architecture as stated in the DLNA guidelines [4].

According to the guidelines, the DLNA standards are to be implemented in the form of firmware. Manufacturers, therefore, can effortlessly develop compatible applications based on the middleware for IP-network platforms. The DLNA Guidelines Version 1.0 supports both Ethernet (IEEE803.3u) and Wi-Fi (802.11 a/b/g).

The DLNA standards define the main product types, including the digital media server (DMS), the digital media player (DMP), the digital media renderer (DMR), the digital media controller (DMC) and the digital media printer (DMPr). The DMS provides the functions of access, retrieval, recording and storage of digital media content. The DMR receives digital media content exposed by the DMS and plays them. The DMC can search digital media content exposed by the DMS and establish the connection between the DMR and the DMS. The DMP involves the capability of DMC and DMR simultaneously. The DMPr provides printing services for the DLNA devices. In order to discard the annoying setup procedures of IP networks, the DLNA utilizes the network detection features of the UPnP audio and video (AV) [5] and the UPnP device architecture [6] to discover digital media content exposed by the DMS without any manual intervention. Transmission is currently limited to the support of the HTTP protocol. Later versions will incorporate the real-time transport protocol (RTP).

The multimedia formats that can be transmitted are categorized as: required and optional support. Required support applies to the JPG, LPCM and MPEG-2 formats. The optional support category includes the PNG, GIF, TIFF, AAC, AC-3, ATRAC3Plus, MP3, WMA9, MPEG-1, MPEG-4, AVC and WMV9 formats. Since the speed of network transmissions still has room for improvement, most vendors tend to support the compression formats with high-compression ratios [7, 8].

Although the DLNA currently provides many communication solutions for home multimedia devices, the DLNA standardizations are not yet comprehensive [9, 10]. There are no definitions for intercom devices. In order to resolve the interoperability issue among intercom devices in home networking environments, we propose the DFIS for phone handling and call control. Further, we demonstrate the workings of the DFID and the DFIA, within the DFIS.

3. PROPOSED SYSTEM ARCHITECTURE

The proposed DFIS consists of two parts, the DFID and the DFIA. The DFID inherently involves the capabilities of a DMS and a DMP, and it can be used to communicate with other DFIDs in the DLNA network and SIP phones or PSTN phones outside the DLNA network. In the following sections, the architectural components and the phone handling and call control features of the DFID and the DFIA will be described in detail.

3.1. DLNA family intercom device

The DFID, as shown in Fig. 2, includes features such as user profile management, DFIS device discovery and phone transmission manager. The details are described as follows:

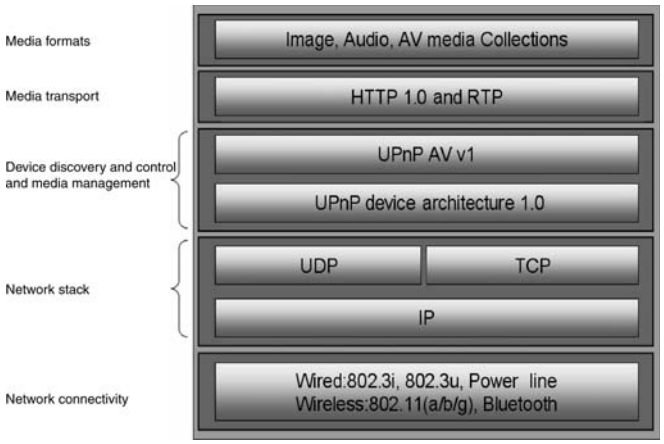

FIGURE 1. The DLNA transmission architecture.

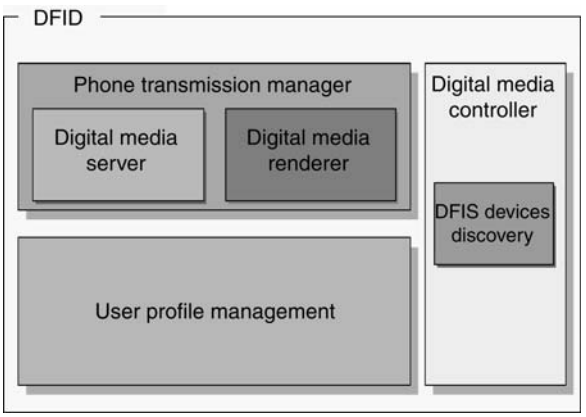

FIGURE 2. DLNA family intercom device.

```
<UserProfileList>
  <UserProfile>
    <deviceType>urn:schemas-upnp-org:device: DLNA Intercom :1</deviceType>
    <friendlyName>Billy</friendlyName>
    <modelName> DLNA Intercom </modelName>
  </UserProfile >

  <UserProfile>
    <deviceType>urn:schemas-upnp-org:device: DLNA Intercom :1</deviceType>
    <friendlyName>Mary</friendlyName>
    <modelName>DLNA Intercom</modelName>
  </UserProfile >

  <UserProfile>
    <deviceType>urn:schemas-upnp-org:device: DLNA Intercom :1</deviceType>
    <friendlyName>Tom</friendlyName>
    <modelName> DLNA Intercom </modelName>
  </UserProfile >
<UserProfileList>
```

FIGURE 3. Example of user profile.

3.1.1. User profile management

Before a phone call, the users' data are stored in XML files along with the UPnP device description, in order to identify the users of the DFID device. All users have their own specific XML files. The DMC manages the users' information files. Once the DFID is started, the user interface of the DFID will request the user to select his XML file, in order to represent his information to the other DFIDs. As shown in Fig. 3, XML tags of UPnP device descriptions are used in the user profiles in order to track users, using the intercoms at any given time, on the UPnP user interfaces. Therefore, the description files of the DFID are dynamically created.

3.1.2. DFIS device discovery

The DMC offers the 'Discovery' functionality, which seeks out all the DLNA devices in home networks. All DLNA devices, however, cannot serve as telephones. Having to search through devices, one by one, to find one that can serve as a telephone is a very cumbersome experience for any user. In order to enable the calling DFID to know if a receiving DFID can serve as a telephone, virtual files of the DFIDs need to be created and classified, stating whether a device can be used as a telephone. Then, it allows a caller to search for devices that are classified as 'telephone'. Such a search will yield detailed information on the receiving DFIDs-device names, authors, the type of transmission protocol, content formats and the audio/video data support and relay this information to the calling DFID.

3.1.3. Phone transmission manager

At this point, the receiving end will know which users are on the DFID. Connections can be made to the uniform resource identifier (URI) of the DFID. The default source of URI on the DFID is the audio input device. Therefore, once the receiving end is connected to the URI of the calling DFID, communication between users can begin immediately. After connecting to the URI, the first action of the UPnP ConnectionManager is to PrepareForConnection( ), which means that the calling DFID instructs the receiving DFID to prepare for another transmission that is about to send out audio and video data. If the receiving DFID provides transmission services for audio and video, this action will generate feedback asking the calling DFID for the InstanceID. The InstanceIDs are used to differentiate between instances of various audio/video transmission services. Each instance of an audio/video transmission service introduces a unique number to the connection between the calling DFID and the receiving DFID. At this point, the DMR of the calling DFID is able to connect to the source of the URI on the DMS of receiving DFID, and the DMR of the receiving DFID is able to connect the source of the URI on the DMS of the calling DFID. Subsequently, the actions of the DFIDs are controlled to imitate ordinary telephones between callers and receivers. Finally, when the DMC would like to terminate a connection, it can trigger the ConnectionComplete( ) action on the UPnP ConnectionManager to drop the connection.

3.2. DLNA family intercom adaptor

Within the system, the DFIA devices convert UPnP, SIP and PSTN signals for communication. In the DLNA network environment, these SIP and PSTN devices, in order to communicate with UPnP devices, can be treated as a collection of virtual DFIDs. These virtual DFIDs hold the account information of registered SIPs retrieved from the SIP proxy or PSTN devices, such as accounts of SIP phones or PSTN phone numbers or information related to the home network. At the same time, the DFIA is also a collection of virtual SIP phones in the SIP network that are converted from the DFIDs in the DLNA network and registered with the SIP proxy. Therefore, it is similar to a PSTN line. In order to perform the conversions for these protocols, it is necessary for the DFIA to own the components required by the UPnP, SIP and PSTN. Meanwhile, we also define the two bridges of components to complete the conversion of protocols. Figure 4 shows the DFIA architecture that completes the message conversions for the UPnP, SIP and PSTN.

3.2.1. PSTN device manager

The PSTN device manager dials the PSTN through the Foreign Exchange Subscriber (FXS) using UPnP device phone numbers and handles the subsequent data transmission. Consequently, when the UPnP call is played from the PSTN, the PSTN device manager can forward the PSTN signal to the UPnP device manager.

3.2.2. UPnP device manager

The UPnP device manager serves two functions. First, it converts DFIDs into virtual SIP/PSTN devices. At this point, the UPnP device manager plays the role of the DMC, using its