An Ad-Hoc VoIP System Implementation using UPnP

Lin-huang Chang[1,2], Ping-da Chuang[1], Yu-Jen Chen[2],
Graduate Inst. of Networking and Communication Eng., ChaoYang Univ. of Tech., Taichung, Taiwan[1]
Department of Information Management, ChaoYang Univ. of Tech., Taichung, Taiwan[2]

Abstract-It has been prevalent nowadays for VoIP application. However, the user may need lots of configuration for the network connectivity and the application. In this paper, we will present an Ad-Hoc VoIP system design and implementation using UPnP with free configuration. We also propose the SIP assistant to solve the problem for the Ad-Hoc network with no particular SIP server.

Keywords: VoIP, SIP, IPv6, Ad-Hoc Network, UPnP

1. Introduction

The traditional phone system is based on circuit switched network architecture. It however has been deployed on the packet switch based network such as Internet Protocol (IP) network. This is known as Voice over IP (VoIP). The earliest service using VoIP system was designed by ITU with H.323 protocol [4] in 1996. Due to the complication of VoIP system using H.323, IETF defined the SIP [6] protocol in 1999 to deploy VoIP system with simplicity and flexibility.

On the other hand, most internet applications or services such as instant messaging or VoIP use client/server architecture. This design requires obtaining the address of the counterpart prior to making a connection. On some cases, we expect to have a simplified architecture at which the users do not acquire any information of the counterpart before communication.

In this paper, we design an Ad-hoc architecture implementing with UPnP protocol. When a user enters such network, it will obtain all devices information of this network via UPnP, such as IP address and user corresponding name. To realize the VoIP, SIP is used for signaling after acquiring the related information.

The advantage of our design is configuration free for mobile node to use VoIP service with UPnP. Relying on the Plug and Play concept, every device's information will be transmitted to those with UPnP support by multicasting and vice versa. We also propose and design the SIP assistant in corporate with our system architecture to fully accomplish the Ad-Hoc network with VoIP application.

2. Background

2.1 Universal Plug and Play (UPnP)

UPnP technology provides a distributed and open network structure over TCP/IP and HTTP architecture. Through the support of the communication among control points, devices and services defined and expressed by Extensible Makeup Language (XML), UPnP technology realizes the intelligent connection to control and transfer data for point-to-point networks. While using UPnP, one can join a network dynamically, obtain an IP address automatically, announce ones facility ability or search the existence devices and services. Completed by the automatic processes, all devices can communication directly.

At present, UPnP has already been applied to home network [3] [5], it can link and control all kinds of Intelligent Appliances (IA). Since UPnP does not need device drivers, the established network by UPnP is interface independent. Also, UPnP uses standard TCP/IP to enable seamless proximity networking with the existing network [2]. Furthermore, UPnP application program can be implemented by any programming language and executed on any operating system. UPnP uses the description of HTML form to describe the controlling interface of the device. It not only allows the device suppliers to offer user's interface that based on browser, but also allows developers to make their own device interfaces.

UPnP architecture is composed of the control points and devices. All devices are connected with distributed and peer-to-peer network structure. It means the communication between control point and device does not go through the third party. UPnP device uses Simple Service Discovery Protocol (SSDP) to discover the target and then uses Simple Object Access Protocol (SOAP) to achieve the remote controlling. The data transmission is completed by using General Event Notification Architecture (GENA). This architecture provides a configuration free network environment for UPnP devices to interact with each other and further connect to the Internet to use the network resources. This will be location, devices and even network topology irrelative.

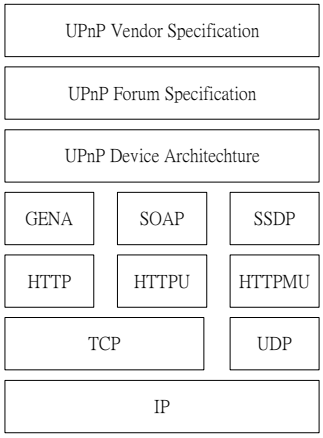

Figure 1 UPnP protocol stack

As shown in figure 1, from the top view, the highest layer is vendor-specific information about the device. The second layer describes the essential and non-essential functions for different classes of devices defined in UPnP Forum specification. The next layer defines the basic device architecture which supports UPnP protocol. In the fourth layer, the communication protocols used between devices are defined. All these layers are stacked on top of HTTP application layers. The two bottom layers show the independence of the underlying entity circuit as long as the TCP/IP is applied then UPnP will be supported.

The complete UPnP processes are composed of addressing, discovery, description, control, event and description interface based on HTML. The detailed processes related to our system are described in the next sub-sections.

I. Addressing

Every networking device needs to have a unique address that could communicate with other devices on the network. Since our system uses IPv6 architecture, the device must use link-local addressing in IPv6 protocol to achieve auto configuration according to the regulation supported by UPnP Forum to IPv6. A link-local address is composed of link-local prefix "fe80::" as well as the device's identification (interface identifier), such as the MAC address 00:02:6f:09:b1:da of network interface card (NIC). For such case, the link-local address will be fe80::202:6fff:fe09:b1da.

II. Discovery

When a device is added to the network, it sends out the discovery message to the control point showing the participation on the network. This message will also announce the device's services. On the other hand, when a control point is added to the network, it will multicast (use ff02::c address with port number 1900 in IPv6 environment) a search for suitable devices or services on the network. The communication protocol SSDP is used in this step.

III. Description

The control point does not know much about one device when it just discovers it. It therefore uses HTTP protocol to retrieve the device's description from the URL provided by the device via the discovery message. Description is usually expressed in XML format, including device's type, model number, manufacture's name and manufacture's URL. It also includes a list of all embedded devices and services. For each service, it includes a list of the commands or actions and parameters or state variables.

IV. Control

After retrieving a description of one device, it sends a control message to the control URL to manage the device and use its service. Control message is also expressed in XML format. The communication protocol SOAP is used in this process.

V. Event

Each service offered by the device has one or more state variables. When these variables change, the device publishes update message. Other control points correlating with this service will receive this changed information and update its state variables too.

VI. Presentation

If a device provides the function with web control, the control point can use the device's URL to browse and even manipulate the device.

2.2 Ad-Hoc Network

In recent years, the vigorous development of wireless network encourages people to use all kinds of mobile devices. People can connect to the network at any time and location to obtain resources on the network. For the infrastructure wireless network, when two devices want to communicate with each other, they need to rely on the wireless base station such as access point (AP) to transmit data. Due to the limitation of places, interference and cost with AP, the ad-hoc network [1] with no infrastructure and allowing mobile devices to communicate peer-to-peer is becoming prevalent.

The Mobile Ad-Hoc Network is called MANET at will. It is a network that uses wireless communication technology composed of lots of wireless devices. It allows single device or workstation directly carries on the point-to-point communication without the relay via AP as long as the device or workstation has installed 802.11 wireless network card [9]. Because the node in the wireless network can be moved freely at any time without the restriction on direction or ranges, the network topology will change at any time and completely differ from traditional network. In general, routing

protocols can not make adjustment [7] of route due to the addition or removal of nodes during the communication between two mobile nodes. Therefore, a new protocol is required for these mobile nodes to communicate with each other while the network topology changes from time to time. So the wireless mobile device on the Ad-Hoc network will possess the routing functionality similar to routers, however routing protocol nay be different from routers for infrastructure network.

2.3 VoIP and SIP

Along with the Internet technology progress, the Internet used to transmit data has evolved to carry real time voice and video as well as multimedia. It has been a kind of new try and trend for the Internetworking technology to provide the service of the traditional telecommunications. The traditional telecommunication allows one person to converse with people at any corner in the world through the Public Switched Telephone Network (PSTN) with a telephone. Because the popularity and low-cost of the Internet, researchers have proposed the integration of traditional telephone into the internet network [10] to accomplish Voice over Internet Protocol (VoIP). Potentially lower bandwidth requirement, the widespread availability of IP as well as integration of voice and data applications are also the reasons for IP to be an attractive choice for voice transport.

To accomplish VoIP, we need the support from the Internet communication protocols such as H.323, Media Gateway Control Protocol (MGCP) and Session Initiation Protocol (SIP). SIP is an application-layer control protocol designed to be a part of the overall IETF multimedia data and control architecture. SIP can be used in conjunction with several other IETF protocols such as the Session Description Protocol (SDP) for describing multimedia sessions, the Real-time Transport Protocol (RTP) for transporting real-time data and providing Quality of Service (QoS), the Real-Time Streaming Protocol (RTSP) for controlling delivery of streaming media, and the Session Announcement Protocol (SAP). It is expected to become a powerful alternative to H.323. It is a signaling protocol which handles the setup, modification, and tear-down of multimedia sessions. SIP can invite a unicast or multicast conference. The invited persons can be some persons or machines such as storage devices. SIP can support internet multi communication, telephone call and real-time data transmission [8]. It can be used in signaling for transmitting various kinds of forms such as the voice, video or context message. It realizes an intact multimedia communication.

Since the circuit-switched and IP-based networks will exist side by side for a long time, VoIP is expected to be a gradual evolution from circuit-switched network and they will need to interwork as seamlessly as possible. In other words, users of existing circuit-switched systems should be able to place calls to VoIP users, and vice versa. This comes to the MACP which describes the functions to be supported by a distributed gateway system. By using MACP for media gateway control and SIP as the call-signaling protocol, it is realized as softswitch architecture. In this paper, however, we will just focus on the SIP architecture of VoIP.

3. System Architecture

The system architecture is shown in Figure 2 as an Ad-Hoc network. All devices that support UPnP protocol within the same network segment of this architecture are connected and communicated via Ad-Hoc mode with no particular server for signal redirecting or routing.

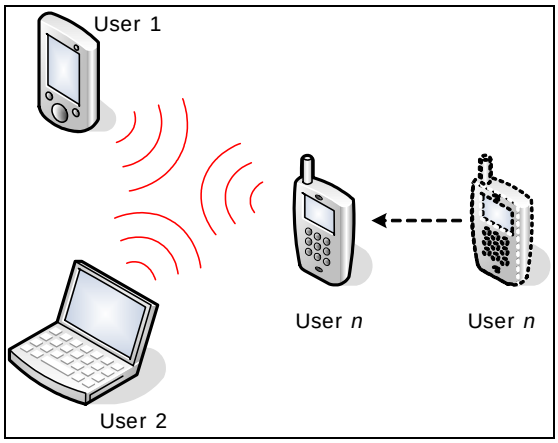

Figure 2 Network architecture

We do not need a physical SIP server since there was a full Ad-Hoc design. In our research, we design and present a SIP assistant concept in our system, as shown in Figure 3.

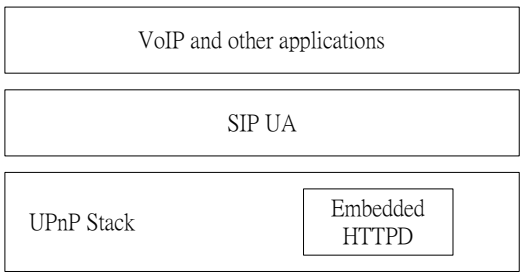

Figure 3 System architecture

SIP assistant collected the information that from UPnP mechanism. It translates the raw data came from UPnP stack into well-known format for SIP UA and data are stored separately. This mechanism simplified the SIP UA design and provided operational that without particular SIP server.

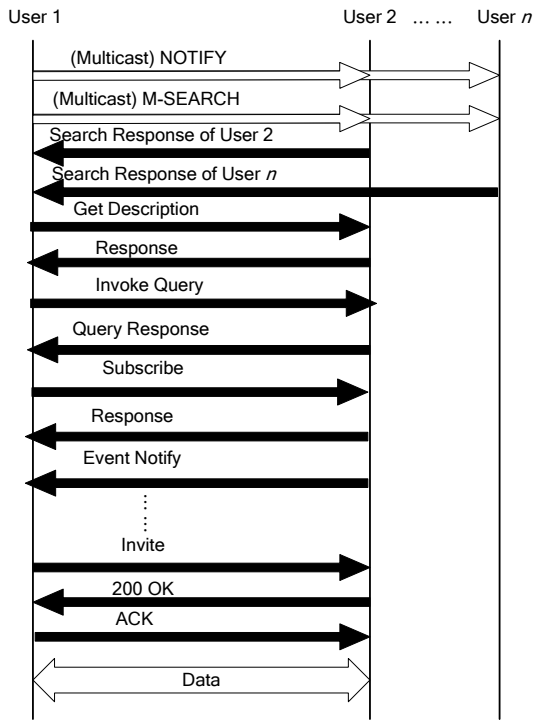

Figure 4 Flow chart of the system

Figure 4 shows the time chart of our system. It represents the process flow from user 1 who advertises itself when entering the network, and then gets the detail description from each available device. The following section will provide the system analysis and implementation of the detail process.

4. System Implementation and Analysis

According to the definition in UPnP Device Architecture Version 1.0 constituted by UPnP Forum, there are two basic elements in the protocol, control points (or called controller) as well as devices. As we mentioned before, when a device enters a network, it will advertise itself to notify all other devices over the network that support UPnP protocol for its existence and being alive. On the other hand, when a control point enters the network, it may need to know the information about all other devices. So it multicasts a search request according to UPnP protocol and all other devices will reply the basic information to the control point after they get the request.

As an example in our design, User 1 will employ the "NOTIFY" command in UPnP protocol to notify all devices over the network, as shown in Figure 5. It relies on multicast mechanism to deliver this message to all devices. However, User 1 still has no information about other devices. So it employs another request "M-SEARCH" asking for the search target (ST). From the functional point of view, the user in our system plays the roles of both the device and the control point.

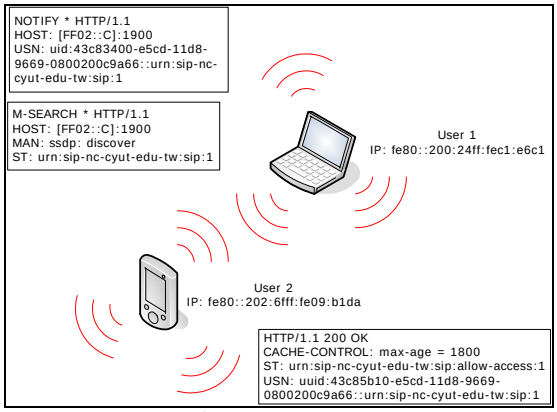

Figure 5 Performing the advertisement

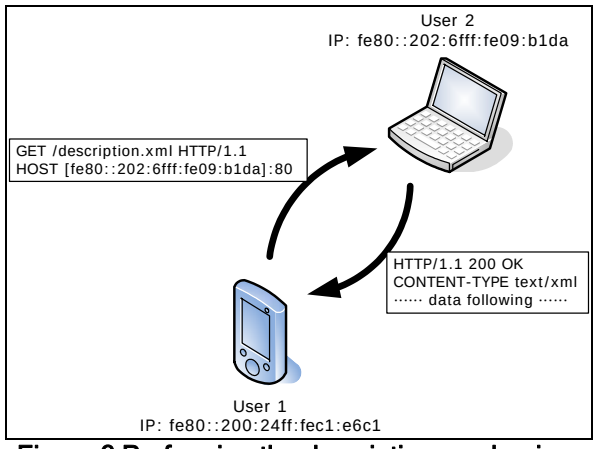

Figure 6 Performing the description mechanism

After acquiring the basic information, it needs to know the detail services provided by the device such as the accessible variables and actions. This detail description can be obtained by using Control and Event mechanism in UPnP protocol separately. As shown in Figure 6, User 1 may send device description and service requests to other users through its description URL by GET method.

More detail user information, such as the corresponding name, sip contact URL, availability, capability and so on, is required for remote user. It can be achieved by using description step in UPnP protocol which is followed by the control step.

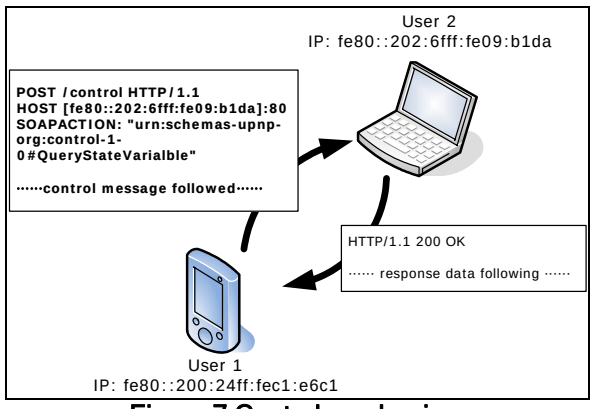

Figure 7 Control mechanism

During the control step, User 1 sends out the query request as shown in Figure 7. The query defined by Simple Object Access Protocol (SOAP) is a request for variable values of remote user. The remote user may response the value or error code after receiving the request.

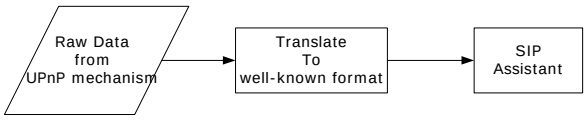

Figure 8 Data flow of SIP Assistant

For now, User 1 has gained all necessary information for SIP signaling. This gathered information by UPnP will be translated into SIP format and registered in our proposed SIP assistant, as shown in Figure 8. Then, the SIP UA acquires the remote user lists from the SIP assistant databases that stored on each user's local storage devices rather then request from particular SIP server.

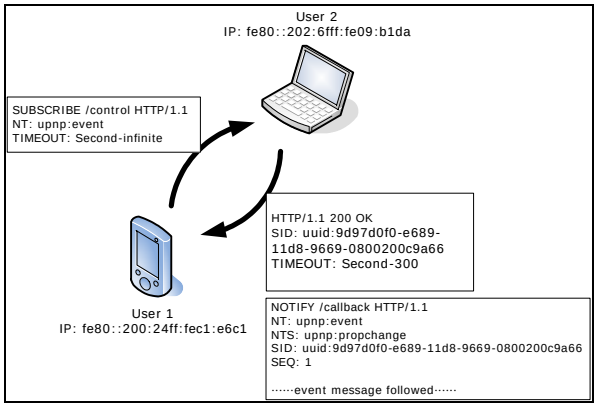

Figure 9 Performing the subscription

Occasionally, in some circumstances, the remote user might change its own information or variable, such as contact name. In this case, the remote user may re-advertise itself to notify all devices about the change and all devices may start over all the processes discussed above. It makes some overhead and could be quite time consumed. Especially, it is an important issue on power computing and energy consumption for mobile devices even hand held devices like PDA.

In our system design, we employ the event mechanism in UPnP protocol to resolve the start over problem and make the process more efficient. This is accomplished by performing the subscription as shown in Figure 9. User 1 sends a subscribed request to the remote user with an assigned period. While the remote user changes its own information within this period, it just sends a unicast to notify the subscriber for the change directly in stead of starting over from the discovery mechanism. This unicast notification differentiates the advantage of our system design from the general multicast one.

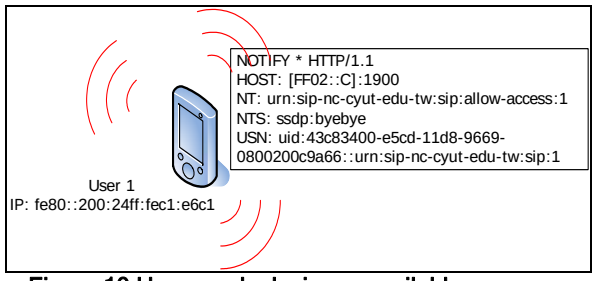

Figure 10 User sends device unavailable message

Finally, a device may announce for leaving if possible while exiting a network. This notification is accomplished by multicasting the "Device Unavailable" message, shown in Figure 10. Any user received such message should remove the leaving user from list. However, due to the unreliable transmission of UDP, some users may not receive the leaving message. It can be solved by identifying CACHE-CONTROL field assigned in advertisement message which represents the advertisement lifetime. The user is considered as leave with no re-advertisement after the lifetime due.

Our system is implemented on Windows platform with the support of Microsoft .NET CE for UPnP developing tool. Also, we design a program between SIP UA and the system, as shown in Figure 3. Besides, we develop a tiny embedded HTTP server in corporate with our system since most UPnP protocol requests are based upon HTTP architecture. The SIP assistant is proposed and well designed to fully accomplish the Ad-Hoc VoIP system with UPnP protocol, as discussed early. Then we implement our system into a PDA that runs the Pocket PC 2003 OS.

5. Conclusion

We have designed and implemented the VoIP application under Ad-Hoc network with UPnP protocol to achieve free configuration. The proposed SIP assistant concept solves the problem for the Ad-Hoc network architecture with no particular SIP server and also makes existing SIP UA compatible with it. However, due to the lack of authentication mechanism in UPnP protocol, the security issue should be considered for future study.

Acknowledgment

The authors would like to thank the support from National Science Council of Republic of China under contract number NSC-93-2622-E-324-011-CC3.

References

[1] X. Bangnan, S. Hischke, B. Walke, "*The role of ad hoc networking in future wireless communications*", Proceedings of International Conference on

Communication Technology, v.2, pp. 1353 -1358, April 9-11 2003.

[2] S. Chemishkian, J. Lund, "*Experimental Bridge LONWORKS / UPnP™ 1.0*", IEEE on Consumer Communications and Networking Conference, pp. 400-405, Jan. 5-8 2004.

[3] K. Dong-Sung, L. Jae-Min, K. W. Hyun, "*Design and implementation of home network systems using UPnP middleware for networked appliances*", IEEE Transactions on Consumer Electronics, v.48, pp. 963-972, Nov. 2002.

[4] ITU, "*Packet-based Multimedia Communications Systems*", Technical Report ITU-T H.323, Version 3, International Telecommunication Union, 1999.

[5] B.A. Miller, T. Nixon, C. Tai, M.D. Wood, "*Home networking with Universal Plug and Play*", IEEE on Communications Magazine, v.39, pp.104-109, Dec. 2001.

[6] J. Rosenberg, et al., "*SIP: Session Initiation Protocol*", IETF RFC 3261, June 2002.

[7] S. Rudiger, G. Ingo, F. Michael, "*Routing in Mobile Ad Hoc and Peer-to-Peer Networks. A Comparison*", Lehrstuhl für Kommunikationsnetze, Technische Universität München, Arcisstr. 21, 80333 München.

[8] B. Ouahidi, M. Bouhdadi, D. Bourget, "*Extending the Internet with the intelligent network capabilities*", European Conference on Universal Multiservice Networks, ECUMN, v.1, pp. 80-86, Oct. 2-4 2000.

[9] E. Royer and C.K. Toh, "*A review of current routing protocols for ad hoc mobile wireless networks*", IEEE Personal Communications Magazine, Apr. 1999.

[10] Z. Yuan, "*SIP-based VoIP network and its interworking with the PSTN*", Electronics & Communication Engineering Journal, v.14, pp. 273-282, Dec. 2002.

[11] UPnP Forum, http://www.upnp.org