International Journal of Computer Networks and Communications Security

VOL. 2, NO. 8, AUGUST 2014, 268–278
Available online at: www.ijcncs.org
ISSN 2308-9830

On the Signaling Analysis of SIP-Based Terminal Mobility Management within IEEE 802.11 and 802.16 Heterogeneous Networks

Wen-Shiung Chen[1], Ruei-Bang Chen[2], Jeng-Yueng Chen[3], and Lili Hsieh[4]

[1, 2] VIP-CCLab., Dept. of Electrical Engineering, National Chi Nan University, Puli, Nantou, Taiwan

[3] Dept. of Information Networking Technology, Hsiuping University of Science and Technology, Dali, Taichung, Taiwan

[4] Dept. of Information Management, Hsiuping University of Science and Technology, Dali, Taichung, Taiwan

E-mail: [1]wschen@ncnu.edu.tw

ABSTRACT

This paper analyzes the SIP-based mobility management behavior within a heterogeneous network interconnecting IEEE 802.11-based wireless local area network (WLAN) and IEEE 802.16-based wireless metropolitan area network (WMAN). Our work focuses on signaling processes, during handoff between 802.11 and 802.16 networks. Particularly, the MAC layer technologies of 802.11 and 802.16 are examined in great detail. The SIP-based handoff procedure consists of the following sub-procedures: (i) Mobile Host (MH) initialization at MAC layer, (ii) Acquisition of a new IP address using Dynamic Host Configuration Protocol (DHCP) in a newly connected network, (iii) SIP terminal mobility management process for both pre-call mobility and mid-call mobility. Our analytical results and experimental results show the signaling delay and overhead of handoff between 802.11 and 802.16 heterogeneous networks.

Keywords: *Terminal Mobility Management, IEEE 802.11, IEEE 802.16, SIP, Heterogeneous Network.*

1 INTRODUCTION

Nowadays, with advent of emerging wireless network technologies, mobile devices are equipped with multiple wireless access interfaces. The interface for IEEE 802.11 wireless local area network (WLAN) is very prevalent among mobile devices. The new emerging IEEE 802.16 wireless metropolitan area network (WMAN) will also gain its position in next-generation network. Thus, we believe that future mobile devices must be equipped with mechanisms for mobility management in order to provide a seamless handoff service while users are moving around between 802.11 and 802.16 heterogeneous networks.

Although there are some well-known protocols for mobility management, for instance, Mobile IP [1] and TCP-Migrate [2], they require mobile devices to have certain modifications at network and transport layers, respectively. On the other hand, Session Initiation Protocol (SIP) [3], which works at application layer, is transparent to the underlying networks. Hence, no modification is required at underlying layers. In this paper, we use the application-layer mobility management to explore the handoff signaling overhead and delay.

SIP is primarily designed for establishing point-to-point multimedia sessions. SIP is also suitable for mobility management [4][5], such as terminal mobility, service mobility, session mobility, and personal mobility. Besides, 3G Partnership Project (3GPP) has defined the IP multimedia subsystem (IMS) [6], based on SIP, to support 3G users. In addition, W. Wu et al. [7] also proposed research about handoff signaling between WWANs and WLANs using SIP mobility management protocols. As 802.16 networks emerged, it raises our interest to analyze the handoff performance of an on-going session while its user device is on the move between 802.11-based and 802.16-based networks.

Over the past years, there have been many dedications to the research of mobility. People study the vertical mobility among UMTS, 802.11, 802.16, and other cellular IP networks. For instance, [7][8] studied problems and methods of mobility between WWAN and WLAN, the handoff is described very clearly. Taaghol et al. discussed seamlessly mobility of 802.16 in 3G networks [9]. It is ready to present a specific solution that enables seamless mobility. Besides, [10]-[12] are concerned with mobility between 802.11 and 802.16 networks. [10] introduced the solution of IPv6 mobility into the integration of 802.11 and 802.16 networks. The researches of [11][12], based on advanced 802.21 network [13], support mobility between 802.11 and 802.16 networks.

In this paper, we analyze the handoff between 802.11 and 802.16 using SIP terminal mobility management. The analytical results show the signaling overhead and signaling delay of handoff between 802.11 and 802.16 networks in the manner that is similar to [14]. The rest of this paper is organized as follows. In Section 2, we present a brief overview of the protocols of 802.11g and 802.16e, and SIP terminal mobility management mechanism. The handoff procedures between 802.11 and 802.16 networks are described in detail in Section 3. The algorithms of handoff signaling are processed in Section 4. In Section 5, we present our analytical results about handoff signaling delay and overhead. Finally, we give a conclusion in the last section.

2 PROTOCOL OVERVIEW

Firstly, we briefly describe the 802.11 and 802.16 technologies. Then, the SIP terminal mobility management is also investigated.

2.1 Brief Review of IEEE 802.11

At the MAC layer of 802.11g protocol [15], there are two fundamental mechanisms, one is called distributed coordination function (DCF), which is a contention-oriented and random access scheme, using the carrier sense multiple access with collision avoidance (CSMA/CA) mechanism. The other is called point coordination function (PCF), which is contention-free, i.e., the medium is controlled by a polling mechanism. In this work, we focus only on the DCF.

The CSMA/CA mechanism is shown in Fig. 1. Whenever a host wants to transmit a packet, it has to sense the medium first. If the channel is idle, the host waits for a time period called distributed inter-frame space (DIFS). If the channel remains idle for a period of time greater than or equal to a DIFS, the host sends a control frame called the request to send (RTS), as shown in Fig. 2. Otherwise, the host backs off and keeps monitoring the channel till the channel is measured idle for a DIFS. The back-off time is shown in equation (1). The back-off time adopts an exponential scheme:

$$\text{Backoff Time} = \text{Random}() \quad \text{slotTime} \qquad (1)$$

After, the host transmits an RTS frame. The destination acknowledges the reception of an RTS frame by sending back a control frame called the clear to send (CTS) after waiting a short inter-frame space (SIFS). Upon receiving the CTS, the host waits for a SIFS, and then, sends the data packet. Upon receiving the data packet, the destination waits for a SIFS, and then sends back an acknowledgement control frame to show that the data have been received. Both RTS and CTS frames can be read by nearby listening nodes, which create or update their own timers, called network allocation vector (NAV), containing the information of the period of time in which the channel remains busy.

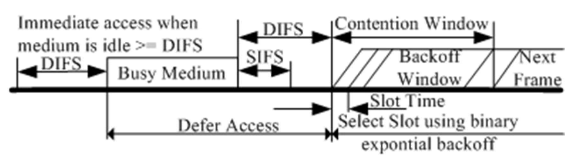

Fig. 1. CSMA/CA access mechanism.

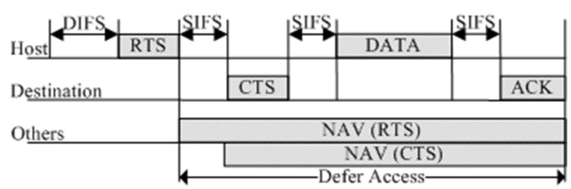

Fig. 2. RTS/CTS access mechanism.

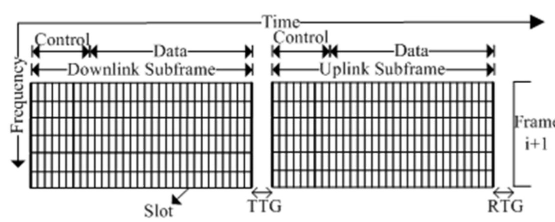

Fig. 3. An example of 802.16 TDD frame structure.

2.2 Brief Review of IEEE 802.16

At the PHY layer of 802.16 protocol [16], there are two medium access methods: 1) time-division duplexing (TDD), and 2) frequency-division duplexing (FDD). TDD is a duplex scheme where uplink and downlink transmissions occur at different times but may share the same frequency, as shown in Fig. 3. A frame may contain an uplink sub-frame, a downlink sub-frame, TTG (transmission transition gap) and RTG (receive transition gap). The downlink frame contains a control sub-frame, i.e. the broadcast message, and a data sub-frame (used for user data slot). The uplink sub-frame contains a control sub-frame that contains contention slots of ranging and bandwidth requests and a data sub-frame (used for user data slots).

The MAC layer of the 802.16e protocol supports five quality-of-service (QoS) scheduling types: unsolicited grant service (UGS) for the fixed-size real-time data streams service, extended real-time polling service (ertPS) for the variable-size real-time data streams service with silence suppression, real-time polling service (rtPS) for the variable-size real-time data streams service, non-real-time polling service (nrtPS) for the variable-size non-real-time data streams service, and best effort service (BE) for service with no rate or delay requirements.

2.3 Brief Review of SIP-based Terminal Mobility

Basically, SIP is an application-layer signaling control protocol for creating, modifying, and terminating sessions with one or more participants.

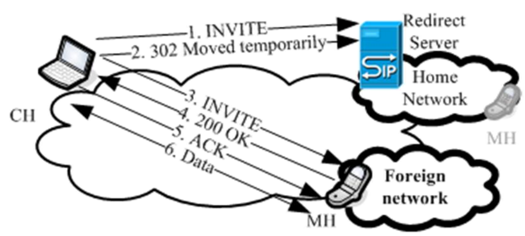

Fig. 4. SIP pre-call mobility.

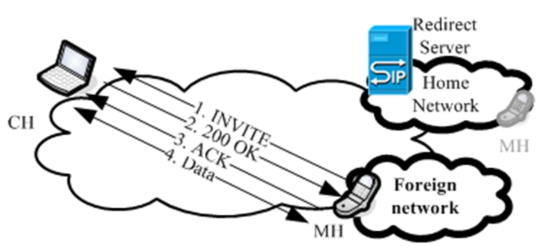

Fig. 5. SIP mid-call mobility.

SIP supports two types of terminal mobility: pre-call mobility and mid-call mobility. The pre-call mobility is that the MH acquires a new IP address before establishing a session. The MH transmits a new REGISTER to its home registrar whenever it obtains a new IP address. The mid-call mobility enables the MH to maintain its ongoing session even when the point of attachment to the network is changed. When the MH moves during a session, it must transmit a new INVITE to inform the CH (Correspondent Host) of its new IP address in order to resume the ongoing session. In this paper, we focus on both the pre-call mobility, shown in Fig 4, and the mid-call mobility, shown in Fig. 5.

3 HANDOFF BETWEEN 802.16 AND 802.11 NETWORKS

In this section, we will show SIP terminal mobility management for handoff signaling between 802.16 and 802.11 networks in detail. The proposed framework is illustrated in Fig. 6.

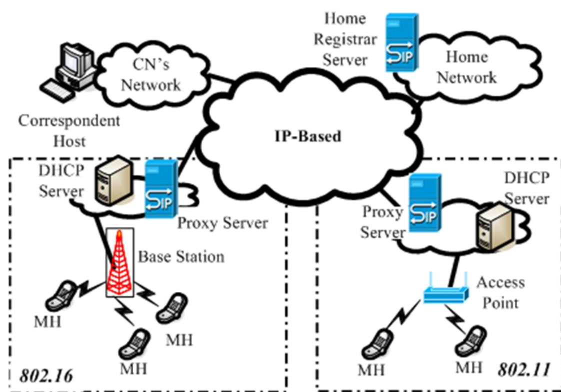

Fig. 6. Interworking framework of 802.16 and 802.11 networks.

3.1 Pre-call Mobility from 802.16 to 802.11 Networks

The pre-call signaling flow of handoff procedure from 802.16 to 802.11 networks is shown in Fig. 7. The handoff procedure is divided into three phases and described as follows:

(1) MH initialization at 802.11 MAC layer. The MH joins the network entry initialization with the access point (AP).

(2) DHCP [17] registration. The MH acquires an IP address form the DHCP server.

(3) Application layer mobility management mechanism via SIP registration. It uses SIP terminal mobility management to complete the handoff.

The procedure performs six steps in the first phase: (1) probe request, (2) probe response, (3) authentication request, (4) authentication response, (5) association request, and (6) association response. The MH broadcasts probe request frames to search the AP in range of the device in operation. The appropriate AP generates and responds a probe response frame, which includes the AP information. There are two types of authentication model in 802.11: the open system, and the shared key protection. In this paper, the security issue is not considered for clarity. Hence, it works in the open system mode, i.e., no authentication in the authentication request and authentication response. Then, the MH transmits an associate request frame to the AP. The AP responds this request by transmitting an association response frame to the MH. Once the MH receives the association response frame, the initialization is completed from the MAC-layer perspective.

In the second phase, the procedure performs four steps: (7) DHCP DISCOVER, (8) DHCP OFFER, (9) DHCP REQUEST, and (10) DHCP ACK. The MH broadcasts DHCP DISCOVER packets to search DHCP servers. The appropriate DHCP server responds a DHCP OFFER packet to offer its service with such information as the new IP address to be assigned to the MH. The MH transmits a DHCP REQUEST packet to the DHCP server to confirm the offer made. Finally, the DHCP server confirms using transmits a DHCP ACK packet.

Finally, in the third phase, the procedure is completed by the following four steps. (11) After the MH acquired a new IP address, the MH must re-register the SIP HR (Home Registrar) to confirm its new IP address by transmitting a SIP REGISTER packet. The REGISTER packet uses the same identifier as in the new IP address contained. (12) When the SIP HR receives and accepts it, the SIP HR generates a 200 OK response packet to the MH. The pre-call mobility overall handoff procedure is completed.

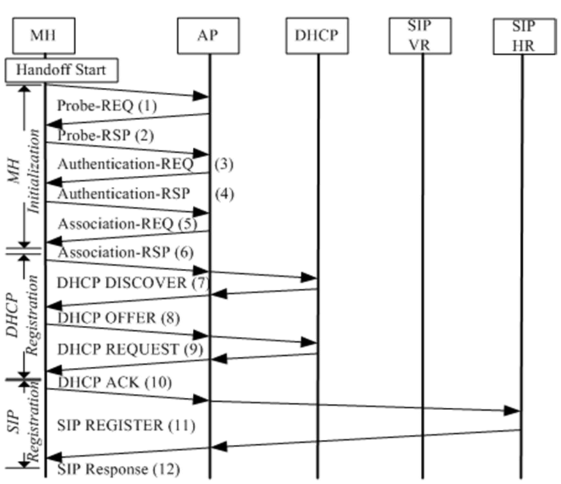

Fig. 7. Signaling flow from 802.16 to 802.11.

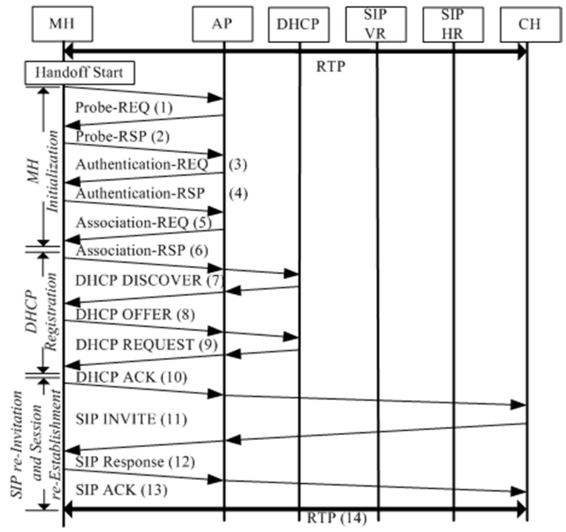

Fig. 8. Signaling flow from 802.11 to 802.16.

3.2 *Pre-call Mobility from 802.11 to 802.16 Networks*

The signaling flow of the handoff from 802.11 to 802.16 networks is shown in Fig. 8. The handoff procedure is divided into four phases and described as follows:

(1) MH initialization at 802.16 MAC layer. The MH joins the network entry initialization with the base station (BS).

(2) DHCP registration. The MH acquires an IP address form the DHCP server.

(3) MAC layer connection setup. Since 802.16 is the connection-oriented network, the MH needs to request the BS for creating a transport connection with the BS.

(4) Application layer mobility management mechanism via SIP registration. It uses SIP terminal mobility management to complete the handoff.

The procedure performs ten steps in the first phase: (1) DL-MAP, (2) DCD, (3) UCD, and (4) UL-MAP. Above the messages are periodically broadcast by the BS. Firstly, MH learns the downlink physical synchronization information from the DL-MAP message, and gets the downlink and uplink parameters from the DCD and the UCD messages. The DCD message defines the characteristics of the downlink physical channels; the UCD message defines the characteristics of the uplink physical channels and contention slot range for ranging and bandwidth requests. Then, MH gets the UL-MAP message that contains uplink map information elements (IEs). (5) RNG-REQ, and (6) RNG-RSP allow the MH to acquire the correct transmission parameters from the network, such as timing offset and transmit power level. For contention-based ranging mode, the MH generates and transmits an RNG-REQ message to the BS by choosing randomly the ranging slot. After the BS received an RNG-REQ, the BS generates and responds an RNG-RSP message to the MH to provide basic CID and primary management CID that the MH will continue the following procedure. If BS asks the MH for ranging again by an RNG-RSP message, the MH will have to transmit another RNG-REQ message again. (7) SBC-REQ and (8) SBC-RSP are for the MH to negotiate basic capabilities with the BS. The MH generates and transmits a SBC-REQ message to the BS for request of such as bandwidth allocation support, authorization policy support, and etc. In this paper, the security issue is not considered for clarity. Thus, PKM-REQ/RSP processes are not presented. Afterward, a SBC-RSP message is transmitted by the BS in response to a received SBC-REQ message. This message contains result of the request. (9) REG-REQ and (10) REG-RSP are the registration processes which may allow the MH to enter the network and become manageable. The MH transmits a REG-REQ message to the BS, including the information such as handover supported, ARQ support and etc. Afterward, a REG-RSP message is transmitted by the BS in response to the received REG-REQ packet. This message contains result of the request.

In the second phase, the procedure needs the same DHCP signal as the one that was described in previous section about handoff from 802.16 to 802.11 networks. In the third phase, there are four steps during connection setup, such as (15) DSA-REQ, (16) DSX-RVD, (17) DSA-RSP and (18) DSA-ACK. The MH transmits a DSA-REQ message to create a transport connection. The request message contains QoS related information. After this message is authenticated by the BS, it transmits a DSX-RVD message to the MH. Then, a DSA-RSP message is transmitted by the BS in response to a received DSA-REQ message. Finally, the MH transmits a DSA-ACK message to the BS after receiving the DSA-RSP message. During the processes mentioned above, for example, the scheduling type is assumed to be best effort. The steps in the fourth phase are the same as those in the third phase described in previous section about handoff from 802.16 to 802.11 networks.

3.3 Mid-call Mobility from 802.16 to 802.11 Networks

The mid-call signaling flow of handoff procedure from 802.16 to 802.11 networks is shown in Fig. 9. The handoff procedure is divided into three phases and described as follows:

(1). MH initialization at 802.11 MAC layer. The MH joins the network entry initialization with the access point (AP).

(2). DHCP registration. The MH acquires an IP address form the DHCP server.

(3). Application layer mobility management mechanism via SIP re-invite. It uses SIP terminal mobility management to complete the handoff, and then, re-establishes the media session, that is the RTP packets are resumed to exchange between MH and CH as usual.

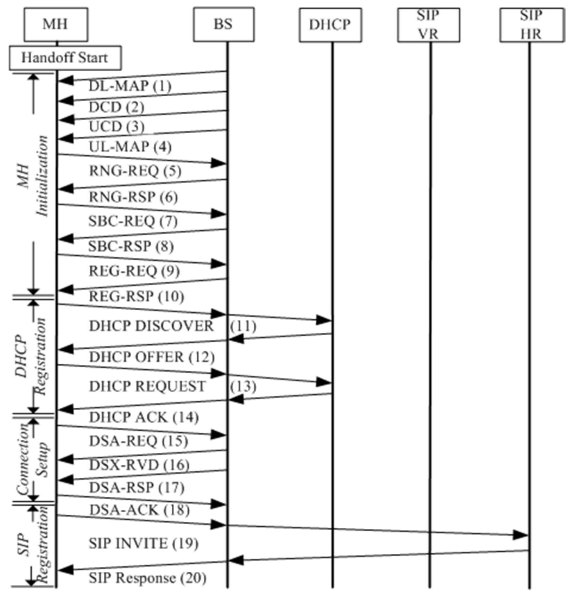

Fig. 9. Signaling flow from 802.16 to 802.11.

The steps in the first phase and second phase are individually the same as those in the first phase and the second phase described in previous section about pre-call mobility between 802.16 and 802.16 networks.

In the third phase, the procedure performs four steps as follows. (11) After the MH acquired a new IP address, the MH must re-invite the CH to confirm its new IP address by transmitting a SIP INVITE packet. The INVITE packet uses the same call identifier as in the original call ID and the new IP address contained at the SDP [18]. (12) When the CH receives and accepts it, the CH generates a 200 OK response packet to the MH. (13) After the MH received the 200 OK packet, the MH transmits the SIP ACK packet to the CH. Now, the MH can resume the original media session with the CH. (14) Once the first resumed RTP packet arrives the CH, the mid-call mobility overall handoff procedure is completed.

3.4 Mid-call Mobility from 802.11 to 802.16 Networks

The signaling flow of the handoff from 802.11 to 802.16 networks is shown in Fig. 10. The handoff procedure is divided into four phases and described as follows:

(1). MH initialization at 802.16 MAC layer. The MH joins the network entry initialization with the base station (BS).

(2). DHCP registration. The MH acquires an IP address form the DHCP server.

(3). MAC layer connection setup. Since 802.16 is the connection-oriented network, the MH needs to request the BS for creating a transport connection with the BS.

(4). Application layer mobility management mechanism via SIP re-invite. It uses SIP terminal mobility management to complete the handoff, and then re-establishes the media session, that is, the RTP packets are resumed to exchange between MH and CH as usual.

The steps before application layer mobility management are individually the same as those performed in pre-call mobility between 802.16 and 802.16 networks described in previous sections. The steps in the fourth phase are the same as those in the third phase described in previous section about mid-call mobility handoff from 802.16 to 802.11 networks.

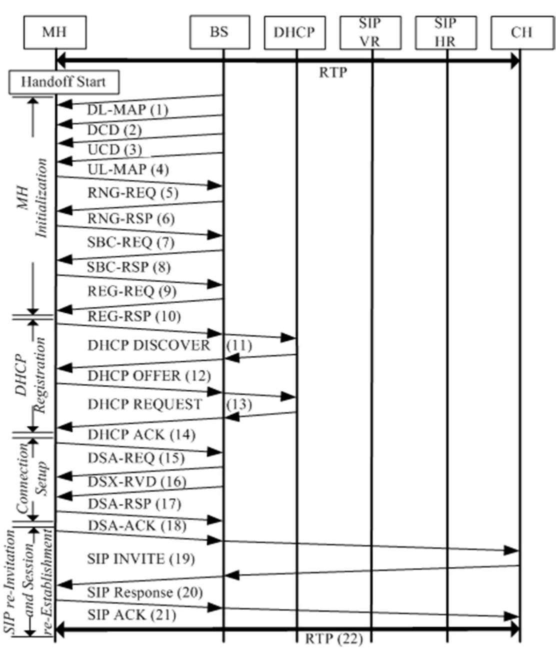

Fig. 10. Signaling flow from 802.11 to 802.16.

4 ALGORITHMS OF HANDOFF SIGNALING

In this section, our algorithm proposes the equations about signaling transmission delay and overhead, derived from the work by Banerjee et al. [14] which is somewhat simplistic with respect to the circumstances of the 802.11 and 802.16 hybrid networks. We consider not only the signaling transmission time at network and above layers, but also the process time at MAC layer. Hence, we propose the following performance evaluation equations,

$$D_{handoff} = \frac{L \times H}{BW_{wired}} + MAC_{time} \tag{2}$$

$$O_{handoff} = \frac{L_{wireless} + (L_{wired} \times H)}{T_s} \tag{3}$$

Referring to [3]-[5],[14]-[18], we calculate the sizes of signals in layer 3 and above using wireshark [19]. We itemize the relevant parameters as shown in Tables 1 and 2.

Table 1: Input parameters for handoff

Parameters	Values
BW_{wired}	100 Mb/s (Ethernet)
$BW_{wireless}$	54 Mb/s (802.11g), 15 Mb/s (802.16e)
802.11g PHY	
DIFS/SIFS/slotTime	50 μs/10 μs/20 μs
802.16e PHY	
System bandwidth	5 MHz
Sampling frequency (F_S)	5.714 MHz
Frame size	10 ms
No. of slots per frame (Downlink:Uplink = 1:1)	896(control), 6130(data) 148(RTG), 84(TTG)

Table 2: Input parameters for handoff

L	Values (Bytes)
Ethernet/802.11/802.16/LLC IP/UDP/RTP/BW request 802.16 fragmentation/grant header	26/28/6/4 20/8/12/6 2/2
Probe-REQ/RSP Authentication-REQ/RSP Association-REQ/RSP	11/26 6/6 43/40
DL-MAP(DL-MAP IE), UL-MAP(UL-MAP IE) RNG-REQ/RSP, SBC-REQ/RSP REG-REQ/RSP, DSA-REQ DSX-RVD, DSA-RSP/ACK	7,4 21/53,70/63 74/94/209 08/216/80
SIP INVITE, Response with SDP, ACK SIP REGISTER, Response	682,856,435 438,330
DHCP DISCOVER/OFFER DHCP REQUEST/ACK	300/304 326/346
RTS/CTS/ACK	20/14/14

The parameter L is the overall size of a signal. Regarding a SIP INVITE signaling message, the overall signaling size must consist of its UDP, IP, LLC and MAC headers. However, in the 802.16 network, broadcast messages are not considered while calculating signaling transmission delay and signaling overhead. Since those broadcast messages happen regardless of the handoff process. The parameter H is the hop count between the correspondent host and BS (or AP). The parameter T_s is the average time that the mobile host stays in a subnet. The parameters BW_{wired} and BW_{wireless} denote the bandwidth of wired links and wireless links, respectively.

The parameter MAC_{time} in the equation (2) is the signaling transmission time over a wireless link. According to Fig. 6, MAC_{time} is equal to time of $L/BW_{wireless}$ plus the processing time of CSMA/CA and RTS/CTS (shown in Fig. 11). According to Fig. 7, along the downlink, there is the transmission time of a signal itself (based on the bandwidth allocated by BS) plus the period of time that BS receives and forwards the signal. Along the uplink, there is the transmission time of a signal itself (based on the bandwidth allocated by BS) plus the period of time that MH generates the signal, requests the bandwidth and acquires time to transmit (shown in Fig. 12 and Fig. 13).

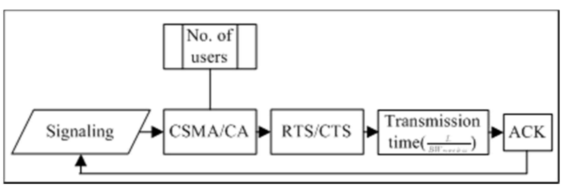

Fig. 11. Signaling flowchart for 802.11 bandwidth access.

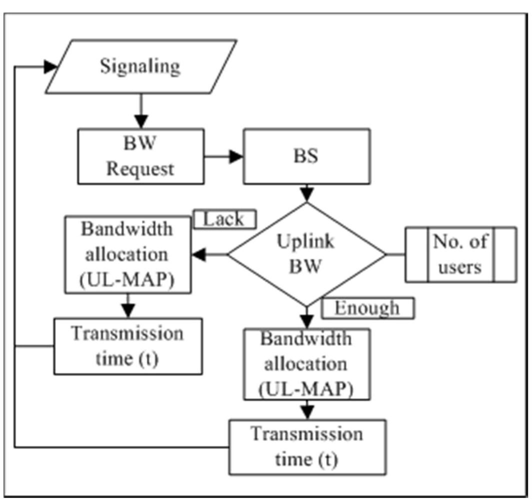

Fig. 12. Signaling flowchart for 802.16 bandwidth access (Uplink).

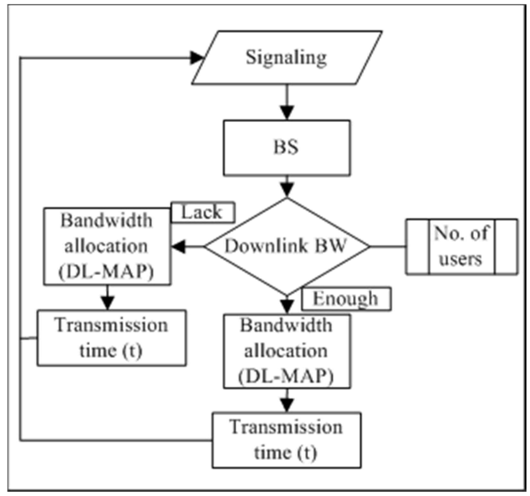

Fig. 13. Signaling flowchart for 802.16 bandwidth access (Downlink).

The parameter Lwireless in the equation (3) is the overall signaling size, taking place in-between the MH and the AP (or DHCP, BS, HR). Similarly, the parameter Lwired in the equation (3) is the overall signaling size, happening in-between the CH and the AP (or DHCP, BS, HR).

5 ANALYTICAL RESULTS OF HANDOFF SIGNALING

In this section, our analysis is based on the VoIP scenario. Using SIP-based mobility management between 802.11 and 802.16 networks, we explore their signaling delay and overhead. The codec G.711 is used during the experiments. The number of users stands for the total stationary VoIP users in the network that the MH stays prior to handoff. The analytical results of signaling transmission delay are shown in from Fig. 14 to Fig. 19 and overhead are shown in from Fig. 20 to Fig. 25.

Fig. 14 and Fig. 15 indicate that the delay of handoff from 802.11 to 802.16 is greater than the one from 802.16 to 802.11. It results from the different MAC layer access mechanisms. The procedures of handoff from 802.11 to 802.16 are more than the ones of vice versa. Due to CSMA/CA mechanism, the transmission delay is susceptible to the number of users, i.e., more users introduce more delays. Although there is a 160-byte VoIP packet transmitted every 20 ms, the network bandwidth is not consumed so much. Figs. 16 and 17 may provide more deep results about the handoff delay. In Fig. 16 and Fig. 17, the bigger the hop count is, the more signaling delay is (curve A). And the delay generated by CSMA/CA is related to the number of users (curves B, C and D) but unrelated to the hop count. Besides, while the number of users is less than 10, the increase of signaling delay is little. Otherwise, CSMA/CA would play a major role in signaling delay. In addition to CSMA/CA mechanism, the RTS/CTS process time (<50 μs; 10 μs + 10 μs +) causes delay, too.

Based on 802.16 MAC-layer mechanisms, the MH requests desired uplink bandwidth from BS. As the number of users is less than 70, the MH handoff signaling transmission delay is almost the same. Since, below this number of users, the network bandwidth can offer enough bandwidth for the MH to handoff. When the number of users is between 71 and 73, the bandwidth that BS can allocate will gradually reduce. Once the bandwidth is insufficient, the MH may need two or more sub-frames to transmit a single signal.

As the number of users is greater than 73, the bandwidth is drained. Hence, the MH cannot get the bandwidth to complete handoff signaling transmission. In addition to the available bandwidth, the waiting time for delivery after the signal is generated is also a factor. Hence, in heterogeneous networks, differences in MAC layer mechanisms and handoff procedures result in different MH handoff delay between 802.11 and 802.16 networks. Figs. 18 and 19 may provide more deep results about the handoff delay. In addition, in Fig. 18 and Fig. 19, the result indicates that the increase of hop count increases the delay little. Regarding the delay caused by bandwidth and access mechanism, it causes delay of a few milliseconds. The results shown in Fig. 15 and Fig. 19 are similar to those in Fig. 16 and Fig. 17. The delay of handoff is affected mainly by the bandwidth and access mechanism. (In Fig. 18, curve A is less than the curves B, C, D, E and F. In Fig. 19, curve A is less than the curves B, C, D, E, F, G and H) In addition, the curves plotted in Fig. 18 and Fig. 19 are almost the same as the number of users is between zero and 73 since the signaling almost equals.

In Fig. 20 and Fig. 21, the hop count is 30. Whenever the average stay time is, the signaling overheads of handoff of both directions are almost the same. Although the procedures of handoff from 802.11 to 802.16 are more than the ones of vice versa, the handoff overheads of both directions are almost the same, due to bigger 802.11 MAC header and additional RTS/CTS/ACK. MH gets less and less bandwidth as the number of stationary 802.16 users increases. It may cause a signal to be fragmented for transmission during handoff from 802.11 to 802.16. Nevertheless, such a fragmentation causes only up to additional 10-byte (two fragmentations + one MAC header) overhead. Thus, the increase of signaling overhead is subtle.

Besides, the results in Figs. 22 to 25 reveal the effect of handoff signaling overhead between 802.11 and 802.16 networks. Fig. 22 and Fig. 23 indicate that the signaling overhead of handoff procedure is greater than the signaling of bandwidth access mechanism. Fig. 24 and Fig. 25 indicate a similar result, too. Hence, the handoff signaling overhead is not clearly revealed by the signaling of bandwidth access mechanism between 802.11 and 802.16 networks. Moreover, signaling of handoff procedure (curve B) is almost the same as the number of users between zero and 73 since each fragmentation is only up to additional 10-byte.

6 CONCLUSION

In this paper, we present the signaling analysis of handoff between 802.11 and 802.16 networks. In these results, we discover the difference concerning handoff between 802.11 and 802.16 networks. For the case of handoff from 802.11 to 802.16 networks, it generates more delays. For the case of handoff from 802.16 to 802.11 networks, the main delay is caused by the 802.11 CSMA/CA and RTS/CTS mechanisms. However, the handoff delay and overhead in SIP are inevitable. If trying to reduce the handoff delay and overhead, it is required to include other handoff techniques for the SIP-based terminal mobility management in heterogeneous networks.

7 REFERENCES

[1] C. Perkins, IP mobility support for IPv4, IETF RFC-3344, 2002.

[2] A. C. Snoeren and H. Balakrishnan, An end-to-end approach to host mobility, 6th ACM/IEEE International Conference on Mobile Computing and Networking, 2000, pp. 155-166.

[3] J. Rosenberg et al., SIP: session initiation protocol, IETF RFC-3261, 2002.

[4] E. Wedlund and H. Schulzrinne, Mobility support using SIP, 2nd ACM/IEEE International Conference on Wireless and Mobile Multimedia, 1999, pp. 76-82.

[5] H. Schulzrinnea and E. Wedlundb, Application-layer mobility using SIP, ACM SIGMOBILE Mobile Computing and Communications Review, Vol. 4, No. 3, 2000, pp. 47-57.

[6] 3GPP Release 5, Stage 2. 5.9.0, IP multimedia subsystem, TS 23.228.

[7] W. Wu, N. Banerjee, K. Basu and S. K. Das, SIP-based vertical handoff between WWANs and WLANs, IEEE Wireless Communications, Vol. 12, No. 3, 2005, pp. 66-72.
[8] Q. Zhang, C. Guo, Z. Guo and Z. Zhu, Efficient mobility management for vertical handover between WWAN and WLAN, IEEE Communications Magazine, Vol. 41, No. 11, 2003, pp.102-108.
[9] P. Taaghol, A. K. Salkintzis and J. Iyer, Seamless integration of mobile WiMAX in 3GPP networks, IEEE Communications Magazine, Vol. 46, No. 10, 2008, pp. 74-85.
[10] S.-F. Yang and J.-S. Wu, Mobile IPv6 mobility management in integrated Wi-Fi and WiMAX networks, IEEE 65th Vehicular Technology Conference, 2007, pp. 1152-1156.
[11] G. Lampropulos, A. K. Salkintzis and N Passas, Media-independent handover for seamless service provision in heterogeneous networks, IEEE Communications Magazine, Vol. 46, No. 1, 2008, pp. 64-71.
[12] L. Eastwood, S. Migaldi, Q. Xie and V. Gupta, Mobility using IEEE 802.21 in a heterogeneous IEEE 802.16/ 802.11-based, IMT-advanced (4g) network, IEEE Wireless Communications, Vol. 15, No. 2, 2008, pp. 26-34.
[13] IEEE Standard 802.21/D9.0 Draft, IEEE standard for local and metropolitan area networks: media independent handover services, 2008.
[14] N. Banerjee, W. Wu and S. K. Das, Mobility support in wireless Internet, IEEE Wireless Communications, Vol. 10, No. 5, 2003, pp. 54-61.
[15] IEEE Standard 802.11g-2003, Part 11, Wireless LAN medium access control (MAC) and physical layer (PHY) specifications, amendment 4: Further higher data rate extension in the 2.4 GHz band, 2003.
[16] IEEE Standard 802.16e-2005 and IEEE Standard 802.16-2004/Cor1-2005, IEEE Standard for Local and Metropolitan Area Networks, Part 16, Air interface for fixed and mobile broadband wireless access systems amendment 2: Physical and medium access control layers for combined fixed and mobile operation in licensed bands and corrigendum 1, 2006.
[17] R. Droms, Dynamic host configuration protocol, IETF RFC-2131, 1997.
[18] M. Handley and V. Jacobson, SDP: session description protocol, IETF RFC-2327, 1998.
[19] Http://www.wireshark.org/.

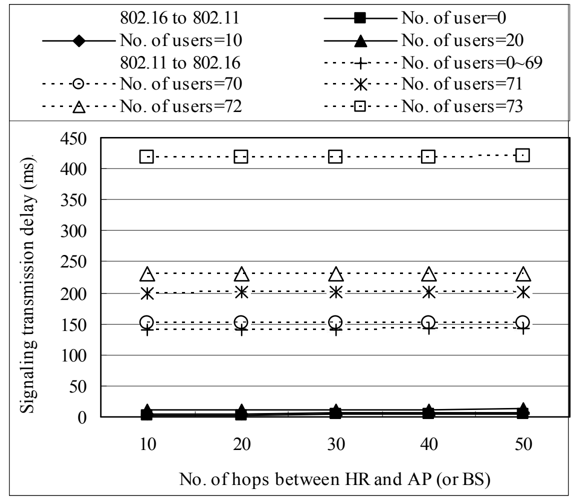

Fig. 14. Results of signaling transmission delay (pre-call).

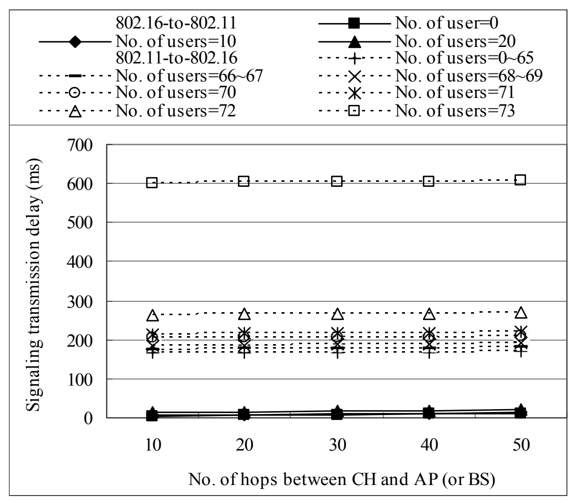

Fig. 15. Results of signaling transmission delay (mid-call).

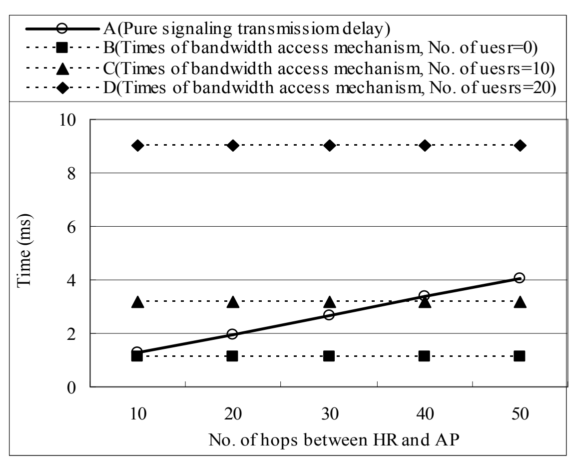

Fig. 16. Results of signaling transmission delay from 802.16 to 802.11 (pre-call).

Wen-Shiung Chen et. al / International Journal of Computer Networks and Communications Security, 2 (8), August 2014

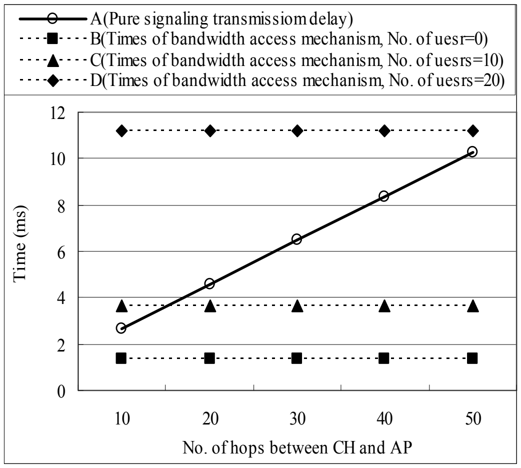

Fig. 17. Results of signaling transmission delay from 802.16 to 802.11 (mid-call).

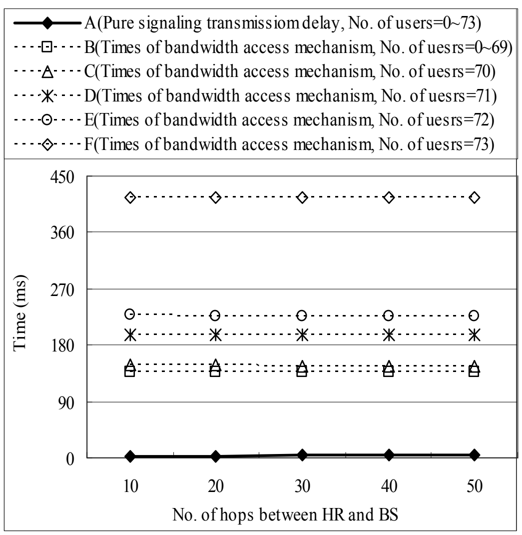

Fig. 18. Results of signaling transmission delay from 802.11 to 802.16 (pre-call).

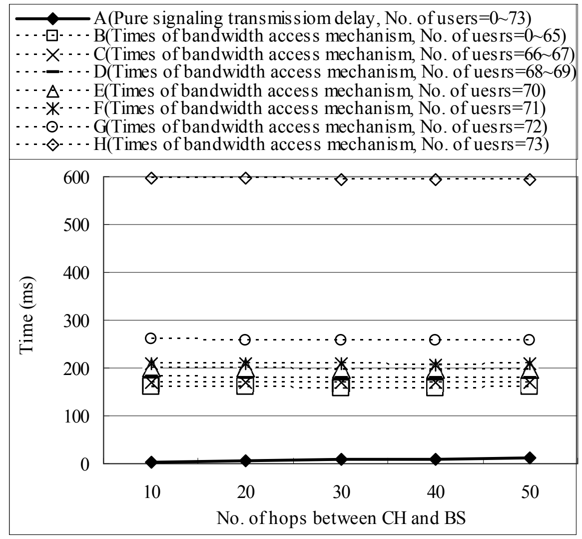

Fig. 19. Results of signaling transmission delay from 802.11 to 802.16 (mid-call).

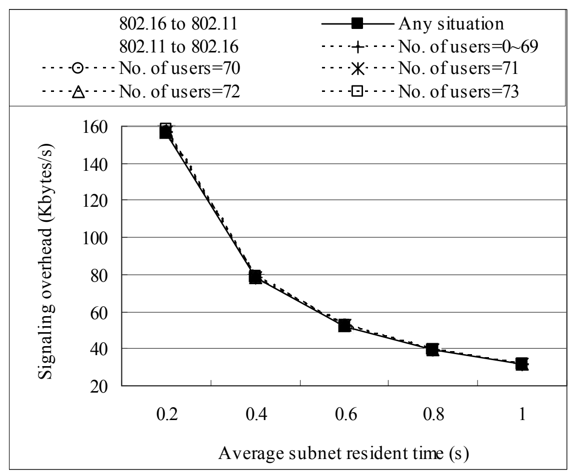

Fig. 20. Results of signaling overhead (pre-call).

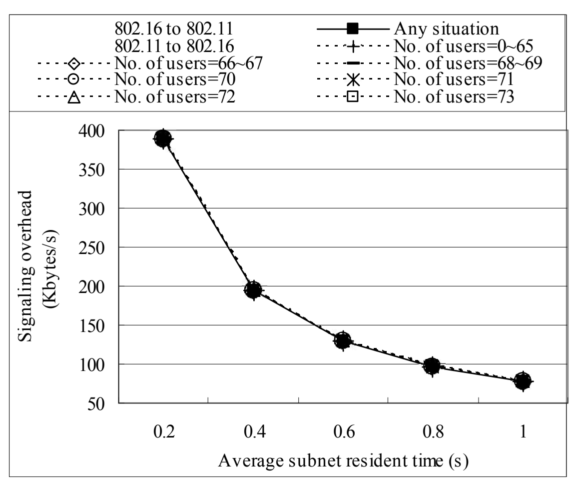

Fig. 21. Results of signaling overhead (mid-call).

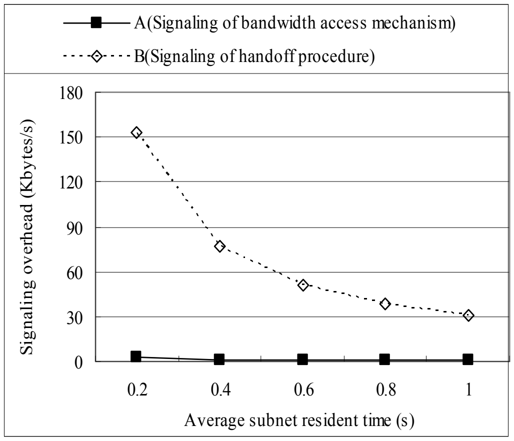

Fig. 22. Results of signaling overhead from 802.16 to 802.11 (pre-call).

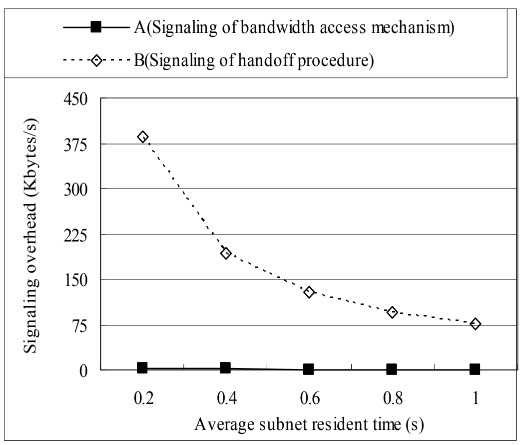

Fig. 23. Results of signaling overhead from 802.16 to 802.11 (mid-call).

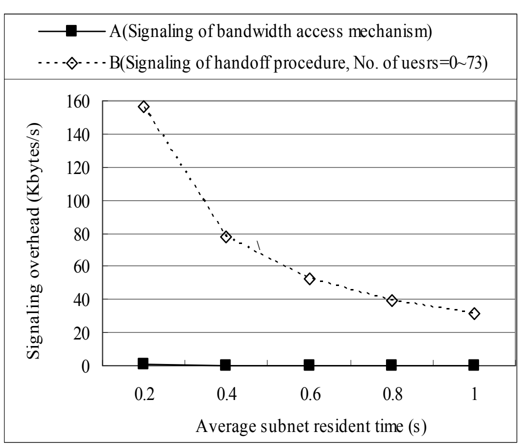

Fig. 24. Results of signaling overhead from 802.11 to 802.16 (pre-call).

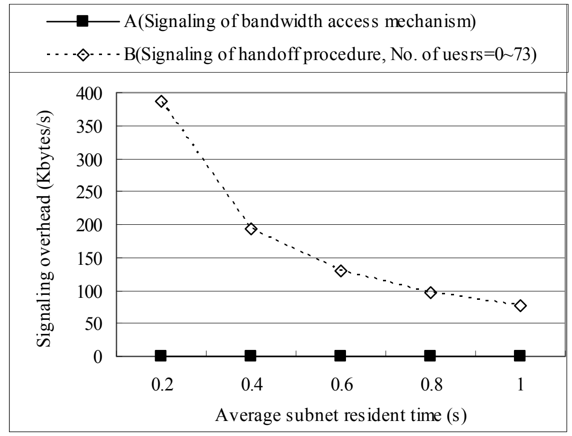

Fig. 25. Results of signaling overhead from 802.11 to 802.16 (mid-call).