Network-Initiated Terminal Mobility in Voice over 3GPP-WLAN

Wei-Kuo Chiang
Department of Computer Science & Information Engineering, National Chung Cheng University, Chiayi 621, Taiwan, R.O.C.
Email: wkchiang@cs.ccu.edu.tw

Hsin-Fu Huang
Networks and Multimedia Institute, Institute for Information Industry, Taipei 106, Taiwan, R.O.C.
Email: voodoo0406@gmail.com

Abstract—This paper proposes a network-initiated terminal mobility mechanism (NITM) to facilitate handover with the session initiation protocol (SIP) in 3GPP Voice over WLAN (3GPP VoWLAN). We design the E2E tunnel state model running on the packet data gateway (PDG) using the CAMEL concept, and introduce the mobility server (MS) as a SIP application server to re-establish sessions with third party call control (3PCC). The MS is triggered to provide the terminal mobility service from the PDG by detecting the state transition of the E2E tunnel state model that represents the occurrence of a handover. This mechanism can advance the time to re-establish sessions. That is, our approach can provide smaller handover delay than mobile-initiated terminal mobility; moreover, it can handle mobility without additional support from the mobile host (MH). In addition, the handover missing problem (messages lost) might happen when the MH moves under communication. With the help of the MS, the lost messages are re-sent, and the handover missing problem, including simultaneous movement, is therefore solved.

Index Terms—IP multimedia subsystem, WLAN telephony, SIP mobility, handover, IN/CAMEL, mobility server

I. INTRODUCTION

WLAN has the advantages of high bandwidth and low license fee, compared with UMTS/GPRS, so it can provide users rich multimedia services with lower price. Voice over IP (VoIP) has developed rapidly in recent years. VoIP allows us to make telephone calls in data networks like the Internet. VoIP avoids the tolls charged by the ordinary telephone service and provides more new services. With rapid deployment of WLAN, it becomes the current trend to apply VoIP to WLAN. However, mobile users accessing WLAN are free to move, an efficient terminal mobility mechanism is crucial in VoWLAN.

SIP mobility is an application layer solution to terminal mobility [1][2]. However, the major drawback of SIP mobility is the considerable handover delay which makes it unsuitable for real-time services such as VoIP. Hence we propose a network-initiated terminal mobility mechanism (NITM) to shorten the handover delay. By applying the concept of IN/CAMEL (intelligent network/customized applications for mobile network enhanced logic)[3], we design the E2E tunnel state model running on the packet data gateway (PDG). We introduce a SIP-based application server, mobility server (MS), to IMS in 3GPP VoWLAN. The MS can re-establish session with third party call control (3PCC). The MS is triggered to provide terminal mobility service from the network component PDG by tracking the detection points in the state transition of the E2E tunnel state model. Because the NITM is an active-triggering mechanism, it avoids the passive-triggering drawback in SIP mobility that the mobile host (MH) has to poll the operation system to detect the change of IP address [4]. Therefore, our approach can provide small handover delay and handle mobility without additional support from the MH.

Moreover, the handover missing problem might happen when the MH moves under communication. The handover missing problem means that there are messages sent to the MH which happens to change its location. These messages get lost since they are sent to the MH's previous location. Simultaneous movement is a special case of the handover missing problem. It happens while both communicating sides are changing their IP addresses, and it might lead to the termination of a session. With the help of the MS, the lost messages are re-sent, and the handover missing problem is therefore solved.

The aim of this paper is to investigate the terminal mobility in 3GPP VoWLAN. The remainder of the paper is organized as follows. In section II, 3GPP VoWLAN architecture are introduced. In section III, a mobile-initiated terminal mobility is presented. In section IV, the NITM is proposed to handle the terminal mobility. In section V, we take the simultaneous mobility problem for example to describe how the NITM solves the handover problem.

This paper is based on “Network-Initiated Triggering for Mobility in Voice over 3GPP-WLAN,” by Wei-Kuo Chiang and Hsin-Fu Huang, which appeared in the Proceedings of the 4th European Conference on Universal Multiservice Networks (ECUMN’07), Toulouse, France, February, 2007. © 2007 IEEE.
missing problem. In section VI, we evaluate the handover delay and the improvement ratio of the NITM compared with the mobile-initiated terminal mobility. In section VII, we conclude this paper.

II. PRELIMINARY

In this section, we first make a description of the 3GPP-WLAN interworking architecture, including the introduction of key components in the architecture and the E2E tunnel establishment procedure between the MH and the PDG. Then we briefly describe the IP multimedia subsystem defined by the 3GPP.

A. 3GPP-WLAN Interworking Architecture

3GPP develops a 3GPP-WLAN interworking architecture to enable cellular system operators to provide WLAN access as an integral component of their total services [5]-[7], and the architecture is chosen as our target network discussed in this paper.

A.1. Key Components in 3GPP-WLAN Interworking

Four main components in the 3GPP-WLAN interworking architecture are 3GPP authentication authorization accounting (AAA) server/proxy, WLAN access gateway (WAG), packet data gateway (PDG) and home subscriber server (HSS). The 3GPP-WLAN interworking architecture is illustrated in the left side of Figure 1. The functionalities of these components are described below.

3GPP AAA Server/Proxy — The 3GPP AAA server retrieves authentication information and subscriber profile from the HSS to authenticate the 3GPP subscriber. The 3GPP AAA server can route AAA signaling to/from another 3G networks as well, in which case it serves as a proxy and is referred to as the 3GPP AAA proxy. Besides, the 3GPP AAA server also allocates a pseudonym and/or a re-authentication identity to the MH which could exploit them to re-authenticate and re-establish tunnel as fast as possible.

WAG — The WAG is a gateway that routes packets received from/sent to the MH to/from the PDG to provide the MH with 3GPP packet switched services. In addition, routing rules, QoS policies and filters, retrieved from the 3GPP AAA server, are applied to the WAG after the tunnel is established.

PDG — The PDG is the gateway toward external IP networks. The PDG allocates a remote IP address (RoA) to the MH and builds the E2E tunnel between the MH and it. IP multimedia subsystem (IMS) or the 3GPP packet switched services may be accessed via a PDG in home or visited network. The PDG routes packets received from/sent to the packet data network to/from the MH and performs decapsulation and encapsulation.

HSS — The HSS is the entity storing authentication and subscription data required for the 3GPP subscriber to access services.

A.2. E2E Tunnel Establishment

The WLAN MH needs to establish an end-to-end (E2E) tunnel between the MH and the PDG before using the 3GPP packet switched (PS) services. At the beginning of the tunnel establishment, a number of extensible authentication protocol (EAP) request and response message exchanges are executed between the 3GPP AAA Server and the MH to perform WLAN access authentication and authorization. If the EAP authentication and authorization are successful, the WLAN allocates a local IP address to the MH, and the MH uses this local IP address to identity itself in the WLAN.

By performing DNS query, the MH retrieves a list of PDG addresses, and then the MH selects a PDG from the list and sends an initial tunnel establishment request to the PDG to establish an E2E tunnel. The PDG contacts the 3GPP AAA Server to retrieve the information for the mutual authentication part of the tunnel establishment. If the MH is authorized to use the PDG, the PDG allocates a remote IP address and a P-CSCF to the MH. The MH uses this remote IP address to identity itself in the network that the MH is accessing for the 3GPP PS services.

B. 3GPP IP Multimedia Subsystem

The IP multimedia subsystem (IMS) is introduced in 3GPP release 5. The IMS specifies the functional entities such as user equipment (UE), call and session control function (CSCF), application server (AS) and multimedia resource function (MRF). Figure 2 shows the IMS architecture for 3GPP VoWLAN.

The CSCFs in the IMS are distinguished into the following three roles: proxy CSCF (P-CSCF), interrogating CSCF (I-CSCF) and serving CSCF (S-CSCF). Each of them has different functionalities.

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The P-CSCF behaves like a proxy server and forwards SIP messages to the IMS network. The P-CSCF also behaves like a user agent in abnormal conditions. The I-CSCF is responsible for SIP message forwarding, HSS interrogation and S-CSCF selection. The S-CSCF performs registration and call setup services for the UE and is responsible to communicate with application servers to support value-added services.

The S-CSCF applied the filter criteria to determine whether to forward SIP requests to the AS. These initial filter criteria (IFC) are stored in the HSS as part of the user profile and downloaded to the S-CSCF upon user registration, or upon a terminating initial request for an unregistered user if unavailable. After downloading the user profile from the HSS, the S-CSCF accesses the filter criteria and invokes the appropriate application in the unregistered user if unavailable. After downloading the user profile from the HSS, the S-CSCF accesses the filter criteria and invokes the appropriate application in the unregistered user if unavailable.

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III. MOBILE-INITIATED TERMINAL MOBILITY

In this section, we present the mobile-initiated terminal mobility, abbreviated by MITM, based on SIP mobility. SIP mobility supports terminal mobility in the application layer and can be applied to 3GPP-WLAN interworking architecture. However, it doesn’t work accurately in the situation of simultaneous mobility. To straighten out this, a stationary server, referred to as signaling buffer (SB), is proposed. In order to impose no changes to the existing IMS, the SB should be considered as an application server but not coupling with the S-CSCF. The SB, no matter resided in the sender’s home network or the receiver’s home network, is invoked and inserted in the signaling path upon the respective S-CSCF received a SIP initial request matching the corresponding initial filter criteria. As the preferred solution, only the receiver’s SB would buffer the request messages [9].

Additionally, the messages buffered in the SB would be released spontaneously in two cases. One case is that the acknowledgment has been received, and the other case is no acknowledgment and no re-registration request have been received until a timeout timer expires which represents the user is disconnected from call abnormally. Whenever receiving a registration request from a user, the S-CSCF performs a third party registration to the SB of the user, which is interested to be informed about the user registration event, and then the SB immediately retransmits the buffered request messages of which destinations meet the address of the user.

Incidentally, the original idea of SIP mobility is to re-establish session before SIP registration. However, in IMS, the new P-CSCF establishes security associations with the MH and the S-CSCF solely after SIP registration procedure completed successfully; before that, SIP messages can not be delivered to the MH and the S-CSCF accurately via the P-CSCF. Besides, the MH may not be allowed to register in the new P-CSCF network, so the MH has to perform SIP registration to check the permission before sending a SIP re-INVITE request.

Figure 3 illustrates the signaling messages exchanged between two mobile hosts adopting the mobile-initiated terminal mobility, as described in the following steps for details.

Step 1. MH1 moves from WLAN1 to WLAN2.

Steps 2-7. MH1 detects the change of IP address and then performs SIP registration.

Steps 8-23. MH1 sends a re-INVITE request to MH2 to re-establish session. Once receiving the request, the S-CSCF of MH1 forwards it to the SB in the home network of MH1 along the signaling path established during session setup, and so does the S-CSCF of MH2, but only the SB in the home network of MH2 (here, as a receiver) would buffer the request. Lastly the session is re-established.

IV. NETWORK-INITIATED TERMINAL MOBILITY

The handover process stopping the communication for a period of time is a serious problem for real-time services such as VoIP. In SIP mobility, the MH re-establishes the session when it moves to different networks. Because the MH usually detects the change of IP address by polling the operation system, the polling time becomes a significant part of the handover delay. Hence, we propose a network-initiated terminal mobility mechanism (NITM) to reduce the handover delay in this section.

In the NITM, we design the E2E Tunnel State Model running on the packet data gateway (PDG), and add a new SIP-based application server, mobility server (MS), to IMS in VoWLAN. The MS can re-establish session with third party call control (3PCC). The 3PCC refers to the ability of one entity to create a call in which communication is actually between other parties [10]. The MS is triggered to provide terminal mobility service from the PDG. Because the MS is notified actively, the interval the MH polls the operation system can be removed. Moreover, there is no need for the MH to support any terminal mobility, since the session is re-established by the MS.
A. VoWLAN E2E Tunnel State Model

We refer to CAMEL phase 4 [11] to design the VoWLAN E2E tunnel state model. The state model runs on the PDG and tracks the state of the tunnel between the MH and the PDG, as shown in Figure 4. The dynamic area (DA) is similar to the routing area in UMTS/GPRS and is composed of one or several WLANs.

If the MH subscribes a MS to support terminal mobility, the SIP subscriber information (SSI) related to the MS must be retrieved from the 3GPP AAA Server or HSS to the PDG to maintain the VoWLAN E2E tunnel state model when the MH attaches to the PDG. The SSI contains the address of a SIP AS (here, the MS), identification of the service to be invoked (service key), list of detection points to be armed, and an indication of default handling in case of exceptions.

When the MH moves to another dynamic area, two cases might turn up. In case one, the MH attaches to another PDG, the subscribed service might be triggered due to the state transition of the E2E tunnel state model from Idle state to Change_of_Position_E2E_Tunnel state which is running in the new attached PDG. That is, the new PDG sends a PUBLISH request (a SIP message) to the MS to inform of the MH’s latest location; and then, the MS executes the terminal mobility service for the MH, and the session is able to continue. Case two is the MH doesn’t attach to a new PDG; that is, the MH’s remote IP address remains. Only a fast re-authentication and a tunnel re-establishment over IPSec are issued in this condition.

B. Mobility Server

The MS is a SIP application server in IMS, which can also be seen as the mobile agent of the MH. When the MH moves to different network, the PDG notifies the MS of the MH’s latest location, and then the MS re-establishes the session with 3PCC.

With the help of the MS, one approach is proposed to handle the signaling part of handover missing problem. The approach uses the MS to buffer the SIP messages sent to the MH, and the MS re-sends the buffered messages to the MH in case of handover missing problem. Therefore, the MH can receive the lost messages.

All the messages buffered in the MS are released after a period of time. This period of time is equal to a PDG timeout time; that is, the buffered messages is absolutely adequate. If the MS didn’t receive a PUBLISH request from the PDG after this period of time, it means that the MH doesn’t handover to another network, and then the buffered messages are released. On the contrary, if the MS received a PUBLISH request, it implies the occurrence of the MH handover, and the buffered messages need to be re-sent. SIP stack will ignore the redundant SIP messages automatically by checking the CSeq field in SIP header, so we don’t care whether the SIP messages re-sent is needless.

C. Session Establishment Flows of the NITM

During session setup, the S-CSCF forwards the initial INVITE request to the MS to activate the terminal mobility service in the NITM. The NITM doesn’t need to modify the existent S-CSCF. Figure 5 shows the session setup flows of the NITM. The flows are almost the same with the normal session setup flows except the MS is triggered to support services. The MS acts as a SIP proxy, and all the SIP messages sent to MH are proxied by the MS. In steps 2, 8, 12, 15, 19 and 22, INVITE, OK and ACK messages are proxied to the MS; moreover, the MS records the Call-ID, To tag, From tag and SIP URI for later session re-establishment. Besides, the MS also buffers these messages. Whenever the handover missing problem happens, the MS can re-send the lost messages.

D. Terminal Mobility Flows of the NITM

Figure 6 is the message flows for the terminal mobility with the NITM in VoWLAN. The flows are split into two parts: SIP re-registration and 3PCC. For dealing with the handover missing problem, the MS would buffer SIP
messages and re-send these messages after SIP registration. For simplicity, we assume that there is no SIP message buffered in the MS, so the re-sending step is omitted.

In Figure 6, the overlap steps are marked in dotted lines. It means that these steps can be executed simultaneously with other steps. For example, step 8 is not delayed by step 7 since the MS can send the INVITE (a SIP message) request and the 200 OK response at the same time, so step 7 is omitted when analyzing performance. Taking step 22 as another example, the MS sends ACK requests to both the MH and the CH simultaneously, step 22 can be omitted since this step is shorter than steps 18-21.

Step 1. The MH moves from WLAN1 to WLAN2, and the MH establishes tunnel with the new PDG.

Step 2. During tunnel establishment, this causes a state transition from Change_of_Position_E2E_Tunnel to E2E_Tunnel_Established in VoWLAN E2E tunnel state model running in the new PDG. After allocating a remote IP address to the MH and finishing the P-CSCF discovery, the new PDG sends a PUBLISH request to the MS to trigger the terminal mobility service. The PUBLISH request contains public user ID, private user ID, home network domain name, the MH’s remote IP address, and the IP address of the P-CSCF corresponding to the MH. Figure 7 is an example of a PUBLISH request [12].

Steps 3-6. The MS performs SIP registration on behalf of the MH. In steps 3-4, the HSS checks whether the MH is registered already, and the HSS indicates whether the MH is allowed to register in the P-CSCF network. In steps 5-6, the MS performs SIP registration.

Step 7. The SIP third-party registration completes. The MS replies a 200 OK response to the PDG.

Steps 8-22. The MS re-establishes session with 3PCC. All the SIP messages should be buffered in the MS at both sides to be prepared for the handover missing problem.

Figure 8. Message flows for the simultaneous mobility in the MITM.
Step 1. MH2 moves from WLAN4 to WLAN3.

Steps 2-7. MH2 detects the change of IP address and then performs SIP registration.

Steps 8-13. MH2 sends a re-INVITE request to MH1 to re-establish session. Once receiving the request, the S-CSCF of MH2 forwards it to the SB in the home network of MH2 along the signaling path established during session setup, and so does the S-CSCF of MH1, but only the SB in the home network of MH1 (here, as a receiver) would buffer the request.

Step 14. MH1 moves from WLAN1 to WLAN2.

Step 15. The re-INVITE request from MH2 is sent to WLAN1, and MH1 therefore loses this message.

Steps 16-21. MH1 detects the change of IP address and performs SIP re-registration.

Step 22. MH1’s S-CSCF re-sends the re-INVITE request to MH1 in WLAN2.

Steps 23-35. Session re-establishment completes. The MH1 and the MH2 resume their communication.

B. The NITM for Simultaneous Movement

In the NITM, all of the SIP messages are forwarded to the MS, and the MS would buffer all of these messages. After the PDG informs the MH’s latest location to the MS, the MS re-send these buffered messages to the MH’s latest location immediately to solve the simultaneous mobility problem.

Figure 9 shows the message flows of the network-initiated triggering mechanism to handle mobility under simultaneous movement.

Step 1. MH2 moves from WLAN4 to WLAN3.

Steps 2-7. The new PDG of MH2 detects MH2’s moving and sends a PUBLISH request to inform the MS of MH2. The MS performs SIP registration on behalf of MH2.

Steps 8-13. MH2’s MS sends a re-INVITE request to MH1 to re-establish session. But in step 12, MH1 also moves from WLAN1 to WLAN2, and MH1 does not perform SIP registration yet. The re-INVITE request therefore gets lost since it is sent to WLAN1.

Steps 14-20. The new PDG of MH1 detects MH1’s moving and sends a PUBLISH request to inform the MS of MH1. The MS performs SIP registration on behalf of MH1.

Step 21. MH1’s MS re-sends the re-INVITE request to MH1 in WLAN2.

Steps 22-29. Session re-establishment completes. The MH1 and the MH2 resume their communication.

VI. PERFORMANCE ANALYSIS

In this section the NITM is compared with the mobile-initiated terminal mobility. The comparative analysis done here is on the basis of handover delay only. The following notations are used in the analysis:

- The time switching wireless access network is $T_{s2}$.
- The time for Layer 3 detecting is $T_{32}$, i.e., the time between reception of an L2 trigger and DHCP replay.
- The time to establish the IPSec tunnel between the MH and the new PDG is $T_{Tunnel}$.
- The time to initiate a tunnel establishment to the new PDG and obtain a remote IP address is $T_{Tunnel-}$.

Compared with $T_{Tunnel}$, $T_{Tunnel-}$ saves a period of time, which is the response delay time from the new PDG to the MH.

- The time to detect the change of IP address in the application layer is $T_{Detect}$.
- The propagation delay between the PDG and the MS is $T_{PDG-MS}$, the propagation delay between the MS and the P-CSCF is $T_{MS-PCSCF}$, and so on.

Assume wireless transmission latency is insignificant compared to wired propagation delays, considering relatively high bandwidth in the wireless link [13].

Suppose that $(T_{L_2} + T_{L_3} + T_{Tunnel-})$ is one unit; the propagation delay across two networks is $\alpha$ unit, and the propagation delay in the same network is $\beta$ unit. It is anticipated that $(0 < \beta < \alpha \leq 1)$ or $(0 < \beta < 1 \leq \alpha)$ for the following reasons:

$(T_{L_2} + T_{L_3} + T_{Tunnel-})$ consists of detach/attach time, two DHCP queries for getting local and remote IP addresses, and fast tunnel re-authentication/re-establishment, so it must be longer than propagation delay in the same network. That is, $\beta < 1$.

The propagation delay across two networks takes longer time than the propagation delay in the same network. So it is anticipated that $\beta < \alpha$.

The propagation delay across two networks increases/decreases depending on the number of routers in path, so it could be longer/shorter than one unit. That is, $\alpha \leq 1$ or $1 \leq \alpha$.
In non-roaming case, the MH always initiates a tunnel establishment to the PDG in HPLMN; in roaming case, we assume the MH simply establishes a tunnel with the PDG in VPLMN. So \( T_{\text{L1} + T_{\text{L3}} + T_{\text{Tunnel}}} \) is supposed to be \( (1 + \beta) \). Also, \( T_{\text{Detect}} \) is assumed to be zero here owing to the possibility of the emergence of mature cross-layer solutions in the future.

Due to the lack of actual IMS deployment, it is delicate to predict the number of calls involving IMS servers in the same domain. We use the following set of data, which comes from the Global System for Mobile Communications (GSM) world [14]:

- Percentage of roaming subscribers: 20%
- Percentage of UE calling a UE in another IMS network: 60%

Table I lists the parameters for analysis and their delay time derived based on the above data.

### A. Handover Delay

According to Figures 3 and 6, the total handover delays of two terminal mobility mechanisms are shown in Table II. \( T_{\text{MITM}} \) is the handover delay of mobile-initiated terminal mobility (MITM). \( T_{\text{NITM}} \) is the handover delay of the network-initiated terminal mobility (NITM).

By applying the set of data in Table I to the equations in Table II, we rewrite them to get:

\[
T_{\text{MITM}} = 1 + 3.4 \alpha + 32.6 \beta ;
\]

\[
T_{\text{NITM}} = 1 + 3 \alpha + 27 \beta .
\]

Comparing the NITM with the MITM, the improvement ratio reaches \( \frac{0.4 \alpha + 5.6 \beta}{1 + 3.4 \alpha + 32.6 \beta} \). Figure 10 plots improvement ratio above as a function of \( \alpha \) and \( \beta \).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Delay (unit)</th>
</tr>
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<tbody>
<tr>
<td>( T_{\text{L1} + T_{\text{L3}} + T_{\text{Tunnel}}} )</td>
<td>1</td>
</tr>
<tr>
<td>( T_{\text{PDG} \leftrightarrow \text{P-CSCF}} )</td>
<td>( \beta )</td>
</tr>
<tr>
<td>( T_{\text{DPG} \leftrightarrow \text{P-CSCF}} )</td>
<td>( 0.2 \alpha + 0.8 \beta )</td>
</tr>
<tr>
<td>( T_{\text{P-CSCF} \leftrightarrow \text{S-CSCF}} )</td>
<td>( \beta )</td>
</tr>
<tr>
<td>( T_{\text{P-CSCF} \leftrightarrow \text{HSS}} )</td>
<td>( 0.6 \alpha + 0.4 \beta )</td>
</tr>
<tr>
<td>( T_{\text{S-CSCF} \leftrightarrow \text{SB}} )</td>
<td>( \beta )</td>
</tr>
<tr>
<td>( T_{\text{P-CSCF} \leftrightarrow \text{MS}} )</td>
<td>( 0.2 \alpha + 0.8 \beta )</td>
</tr>
<tr>
<td>( T_{\text{MS} \leftrightarrow \text{HSS}} )</td>
<td>( \beta )</td>
</tr>
<tr>
<td>( T_{\text{S-CSCF} \leftrightarrow \text{MS}} )</td>
<td>( \beta )</td>
</tr>
</tbody>
</table>

We consider \( \beta \) is any points on the interval \([0.05, 0.5]\). Also, \( \alpha \) is assumed five times longer than \( \beta \) as a moderate distance. The NITM can reduce at least 10.9%~14.7% of handover delay time compared with mobile-initiated terminal mobility. Besides, if the polling time \( T_{\text{Detect}} \) is added back to the mobile-initiated terminal mobility, the NITM will achieve higher improvement ratios.

### B. Effect of Simultaneous Movement

It takes extra delay to re-send the lost messages to the MH when simultaneous movement occurs. According to Figures 8 and 9, the extra delays of the two mechanisms are shown in Table III. \( T_{E_{\text{MITM}}} \) is the extra delay of the MITM. \( T_{E_{\text{NITM}}} \) is the extra delay of the NITM.

By applying the set of data in Table I to the equations in Table III, we rewrite them to get:

\[
T_{E_{\text{MITM}}} = 0.6 \alpha + 8.4 \beta ;
\]

\[
T_{E_{\text{NITM}}} = 0.4 \alpha + 8.6 \beta .
\]
Comparing the extra delays of NITM and MITM, the improvement ratio reaches $0.2\alpha - 0.2\beta$. Also, $\alpha$ is $0.6\alpha + 8.4\beta$ assumed five times longer than $\beta$ as a moderate distance. The NITM can reduce 7.0% extra handover delay time compared with MITM. Moreover, if the polling time $T_{Detect}$ is added back to the mobile-initiated terminal mobility, the NITM will achieve higher improvement ratios.

VII. CONCLUSIONS

In this paper, a network-initiated triggering mechanism for mobility in VoWLAN is proposed. The mechanism is re-establish the broken session by the mobility server with 3PCC, so it can handle mobility without additional support from the MH. Besides, not only the handover missing problem could be resolved and the re-sending procedure is executed as fast as possible. Analytical results show that the handover delay can be reduced significantly using the NITM. Also, the NITM is network-initiated triggering, namely terminal mobility is managed and triggered in core network components but not in the MH, so the NITM could provide a higher power saving efficiency for mobile devices than the mobile-initiated terminal mobility. Furthermore, the network-initiated triggering mechanism can be applied to 3GPP VoWLAN without modifying the existing IMS.

ACKNOWLEDGMENT

This work was sponsored in part by National Science Council under contracts NSC95-2221-E-194-010, and Industrial Technology Research Institute under contract T2-95040-6.

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Wei-Kuo Chiang (wkcchiang@cs.ccu.edu.tw) was born in Taiwan, 1967. He received B.S., M.S., and Ph.D. degrees in computer science and information engineering from National Chiao Tung University (NCTU) in 1989, 1991 and 1996, respectively. In February 2004, he joined the Department of Computer Science and Information Engineering, National Chung-Cheng University, Chiayi, Taiwan, as an Assistant Professor. Before that, he was a Section Manager of the Internet Telecommunications Department at the Computer and Communications Research Laboratories, Industrial Technology Research Institute (CCL/ITRI), Taiwan. Dr. Chiang holds two patents with five pending. His research interests include design and analysis of IP multimedia subsystems, service technologies in next generation networks, mobile computing and wireless networks.

Hsin-Fu Huang received his M.S. degree in computer science and information engineering from National Chung-Cheng University in 2005. He is currently working as an engineer in Institute for Information Industry, Taipei, Taiwan. His research interests include wireless and heterogeneous network, internet telecommunication and next generation network service technology.