國立交通大學

資訊科學與工程研究所

碩 士 論 文

在 WiMAX/WiFi 異質網路上跨層媒介獨立換手機制

A Cross-Layering Media-Independent Handover Mechanism in Heterogeneous WiMAX/WiFi Networks

研 究 生：黃月慧

指導教授：陳耀宗 教授

中 華 民 國 九 十 八 年 七 月

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摘要

無線技術普及在最近幾年，共存多種無線技術是一個研究議題。在發展未來無線通訊系統過程有一重要的挑戰是在跨不同的無線存取技術時，提供使用者一個無縫隙的服務，並且透過單一行動裝置去維持服務品質。然而，當行動節點跨不同網路移動時，多樣化的設計會導致服務品質下降。對於下一世代網路來說，整合異質性網路將是一個重要議題。在一個無線存取網路換到另一個無線存取網路時，由於降低整個換手時間以及服務中斷時間，來支持無縫隙移動並且確保進行中的連結不會被中斷。

在這篇論文中，我們為了實行整合 IEEE 802.11 無線區域網路和 IEEE 802.16 無線都會區域網路，使用一個由 IEEE 所發展的新標準。IEEE 802.21 也叫做媒介獨立換手(MIH)，提供一個架構來幫助同質性換手以及異質性換手。首先，我們描述在 IEEE 802.21 換手程序，並且與其他文獻上提出之方法比較。再來是，我們說明我們所提出的方法運用 FMIPv6，換手在異質性網路上，並且對於不同的方法進行數學分析。最後，我們在 NS2 模擬器上，模擬以及比較我們的方法和其它已提出的方案。

關鍵詞: WiMAX, WiFi, MIH, 異質性換手

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Abstract

Wireless technologies have been popularized these recent years and it is a research issue to the coexistence and seamless service across multiple wireless technologies. The main challenge in the development of future wireless communication systems is to provide users with a wide range of services across different radio access technologies through a single mobile node, while maintaining the quality of service requirements. However, design varieties can lead to service degradation as the mobile node move across different systems. The integration of heterogeneous networks will be a trend for next generation networks. For supporting seamless mobility and ensuring the ongoing session not to be disrupted from one access network to another, it is necessary to reduce total handover time and service disruption time.

In this thesis, we try to integrate IEEE 802.11 WLANs and IEEE 802.16 WMANs, using the new standard developed by IEEE standard group. IEEE 802.21 is also called Media Independent Handover (MIH) which provides a framework for facilitating homogeneous handover and heterogeneous handover. First, we describe handover procedure of IEEE 802.21 and compare it with the completed method from the literature. Second, we discuss our proposed scheme using FMIPv6 to handover across networks and use mathematical analysis for different schemes. Last, we perform experiment on the NS2 simulator and compare it with the other existed methods from the literatures.

Keywords: WiMAX, WiFi, MIH, Heterogeneous handover

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Chapter 1 Introduction

During recent years, mobile device has become more popular because the availability of portable devices grows and wireless technology improves. A variety of wireless technologies (e.g., Wi-Fi, WiMAX, CDMA, GSM, GPRS, UMTS and Bluetooth) are mainly deployed for providing new Internet applications and services. But there is still no killing wireless technology supporting all current and future applications, the integration of heterogeneous networks will be an idea for next generation (4G) networks. One of the main purpose of fourth generation networks is to allow mobile users to use always best connected (ABC) session through heterogeneous networks [1].

The real-time applications are very popular for the mobile users, for example, VoIP, video streaming, IPTV etc., then selecting the most appropriate networks should be based on various factors such as quality of service (QoS), transmission rate, coverage, security, economic cost and user preferences. Especially, the QoS definitions are different in individual networks hence the QoS mapping is also an important issue in the integrated network's aspect. Moreover, the handover latency related to seamless mobility is a major issue, therefore we concentrate on reducing handover latency time.

In general, there are two types of handovers for modern network environment: horizontal handover and vertical handover. For horizontal handover, it is happened to homogeneous network. We focus on vertical handover that occurs in heterogeneous networks and it can be differentiated basically between make-before-break and break-before-make. Make-before-break is soft handover that user traffic flows are continuously available during handover procedure. On the other hand, break-before-make is hard handover and it may disrupt the services in a short time. For a vertical handover, a mobile terminal must establish both a new link layer connection and a new IP configuration to maintain connectivity.

Our goal is to support seamless mobility and to guarantee the ongoing session is not to be disrupted in handover duration by reducing handover latency time and service disruption time (SDT). The former represents the time elapsed between when the mobile node (MN) receives MIH_Link_Going_Down.IND event until handover is done. During the SDT, the MS is not able to receive packets in serving network until it has re-established a connection with the target BS or AP. Therefore, reducing the SDT is important in supporting seamless handover for real-time applications.

The reasons of handover are divided into two major categories: First, mobile users may move anywhere and across different networks, for example, high moving speed makes received signal strength decreased quickly. Second, mobile users want more bandwidth to support their QoS, but the bandwidth of current network is insufficient for satisfying all bandwidth allocation requests, so we should make handover procedure to select better network service.

IEEE 802.11 is also called WiFi that is used for local area network (LAN) generally. For a metropolitan area network (MAN), the Institute of Electrical and Electronics Engineers (IEEE) formed a group called 802.16 to develop Worldwide Interoperability for Microwave Access (WiMAX). WiMAX is an air interface of Fixed Broadband Wireless Access system (BWA) and it not only supports fixed location users but also has been extended to provide mobility functionality. Table 1.1 provides a summary comparison of WiMAX with WiFi. The integrated network that includes WiFi and WiMAX will bring a combined improvement to the services provide to mobile users.

Table 1.1 Comparison WiMAX with WiFi

Parameter	Fixed WiMAX [2]	Mobile WiMAX [3]	WiFi
Standard	IEEE 802.16-2004	IEEE 802.16e-2005[3]	IEEE 802.11 a/b/g
Multiplex	TDM	TDM/OFDMA	CSMA
Frequency	3.5GHz and 5.8GHz initially	2.3GHz, 2.5GHz, and 3.5GHz initially	2.4GHz,5GHz
Date rate	75Mbps	15Mbps	802.11a/g 54Mbps 802.11 b 11Mbps
Coverage	6.4-10 kilometer	1.6-5 kilometer	100 meters

In fourth-generation wireless network environment, a new scenario in Third Generation Partnership Project (3GPP) assists the integration and develops a new system architecture standardized with tightly coupled approaches in the context of 3GPP Release 8 Specifications. But, 3GPP's scenario isn't yet well defined. On the other hand, the 802 family defines a protocol called media-independent handover (MIH) framework under the IEEE 802.21 that efficiently assists the integration of heterogeneous networks between IEEE 802 and non-IEEE 802 (e.g., 3GPP and 3GPP2) access technologies, and enables seamless mobility in 4G environment.

Using MIH framework to combine two important technologies (802.11 and 802.16), and to reduce the handover latency time and the SDT is our purpose. A typical integrated scenario was depicted in Fig. 1.1, in which WiMAX BS1 serves mobile node1 (MN1) through a point-to-multipoint (PMP) connection and there are also WiFi client directly connected to the APs (e.g., MN2 connected to AP 1). The dual PDA (MN3) under overlapped area of WiMAX BS1 and AP1 can select a better connection from alternative systems or connect to both systems. The dual PDA (MN4 or MN5) may move into subway or building and cause weak signal, if the device is in dual mode that equipped with two interfaces (WiMAX and WiFi), it may detect and associate another interface before the current connection is lost. Network mobility (NEMO) is a novel research on moving networks in which the whole network is mobile. For example, the mobile user travels by public transportation (trains, buses, ship, etc.)

and associates with network through the vehicle gateway in the transportation. The vehicle gateway may provide WiFi connectivity on the inside, and use WiMAX connectivity through dual interfaces (WiFi/WiMAX) for outside, because WiMAX BS coverage area is larger than WiFi one.

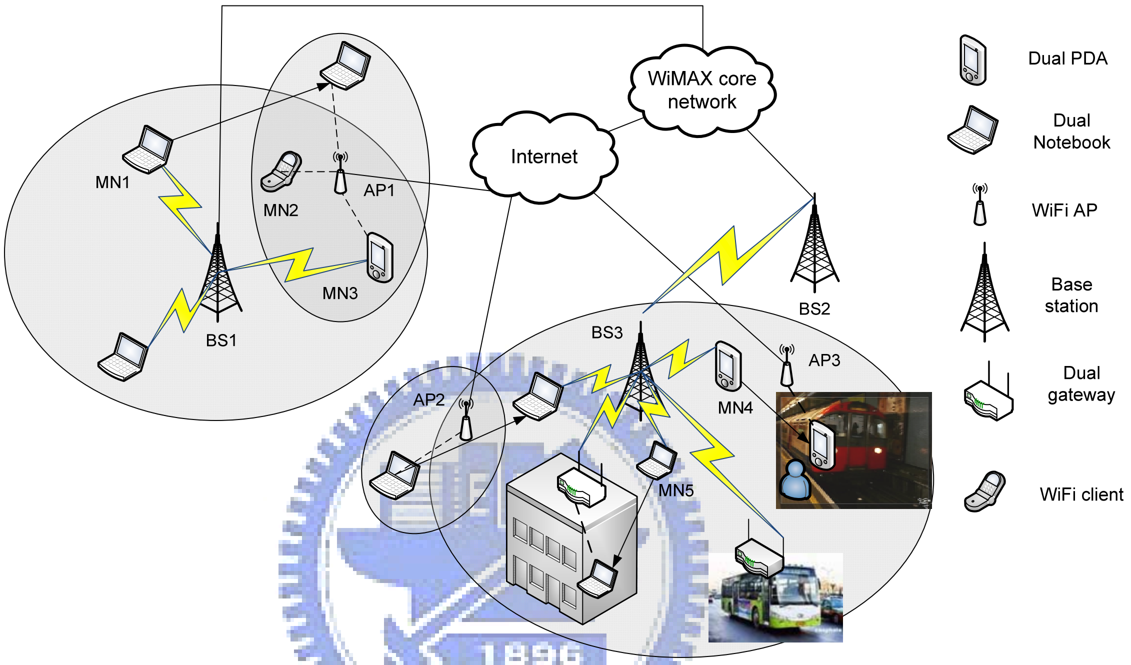

Figure 1.1 Scenarios for integrated WiFi and WiMAX networks

IEEE 802.21 provides the "glue" at layer 2 (or "layer 2.5") to make two interfaces work together as one. It mainly facilitate handover decision by supplying the upper layers (layer three [L3] and higher) uniform information about layer 2 (L2) triggers. In a L3 handover, it uses mobile IP version six (MIPv6) [4] to support mobility scenario. Nevertheless, MIP is insufficient to support time sensitive due to the time delay of movement detection, confirming uniqueness of new IP address, and binding update. Therefore, other propositions like fast MIPv6 (FMIPv6) [5] or hierarchical MIP are recommended to overcome the weakness of MIPv6. In this article, we propose a novel handover procedure using IEEE 802.21 and FMIPv6 to support seamless mobility for 4G environment.

The remainder of this article is organized as follows. In Chapter 2, we present the IEEE

802.11 and 802.16 handover procedure based on the IEEE 802.21 MIH standard [6] and compare with IEEE literatures method. In Chapter 3, we discuss our proposed scheme in detail and compare it with others. Sequentially, numerical analysis is mathematically illustrated for performance comparison. The simulator is NS-2.29 and the simulation results are presented in Chapter 4. Finally, we present some conclusions and future directions in Chapter 5.

Chapter 2 Background

In this chapter, we briefly describe the IEEE 802.21 standard, including the information services, event services, command services and illustrate relevance of them on the IEEE 802.21 framework. We show the architecture for using IEEE 802.21 to communicate among MNs.

In the following, we first address the handover procedure between WiMAX/WiFi networks and describe the flowchart of standard approach. Further, in the IEEE literature it proposed to decrease the SDT using FMIPv6 in L3. Next, we aim at the difference of standard approach and the literature approach.

2.1 Review of IEEE 802.21

The 802.21 framework is also called media-independent handover (MIH), which includes a signaling framework and triggers that obtain available information from lower layer (MAC and PHY) and sends it to the high layers (network to application layers). Furthermore, MIH is uniform for the diverse L2-specific technology information in order to support the handover decision so that the upper layers can abstract the heterogeneity aspects that belong to different technologies. MIH functionality can facilitate both mobile-initiated and network-initiated handovers for improving the user experience. The standard [6] consists of following elements: MIH user, service access point, MIH function (MIHF). The MIH user is functional entities that use the services provided by the MIHF. The details of service access point and MIH function are described on section 2.1.1 and 2.1.2 respectively.

2.1.1Service Access Points (SAPs)

The MIHF interfaces with other layers and functional planes using Service Access Points (SAPs). Each SAP consists of a set of service primitives that specify the interactions between the service user and service provider, and it defines both media-independent and media-dependent interfaces. The SAPs are depicted in Fig. 2.1 and include the following:

-**MIH_SAP**, a media independent SAP between the MIHF and upper layers of the MIH user, and responsible for uniform interface for higher layers to control and monitor different links regardless of access technology.

-**MIH_LINK_SAP,** an abstract media dependent SAP between the MIHF and lower layers media-specific protocol stacks of technologies such as IEEE 802.3, IEEE 802.11, IEEE 802.16, 3GPP etc., control and monitor media specific link for the MIHF.

-**MIH_NET_SAP**, a media dependent SAP that provides transport services over the data plane on local node, and supports the exchange of MIH information and messages with remote MIHFs.

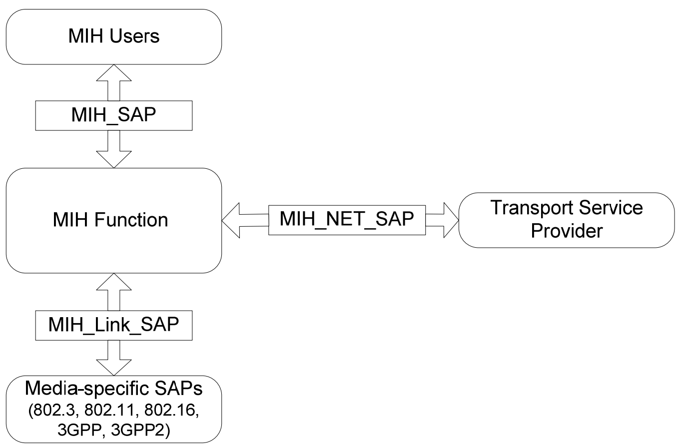

Figure 2.1 Relationship between different MIHF SAPs

2.1.2 Media Independent Handover Function Services

The MIHF is a logical entity that supplies the unified interface to the upper layers and independent of the underlying access technology. MIH services can use either local operation occurring within a protocol stack or remote operation occurring between two MIHF entities. For example, remote communication can happen between an MIHF entity in a MN and another MIHF entity located in the network (Fig. 2.2). MIHF encompasses three main services that assist handovers across heterogeneous networks: media independent event services, media independent command services, media independent information services.

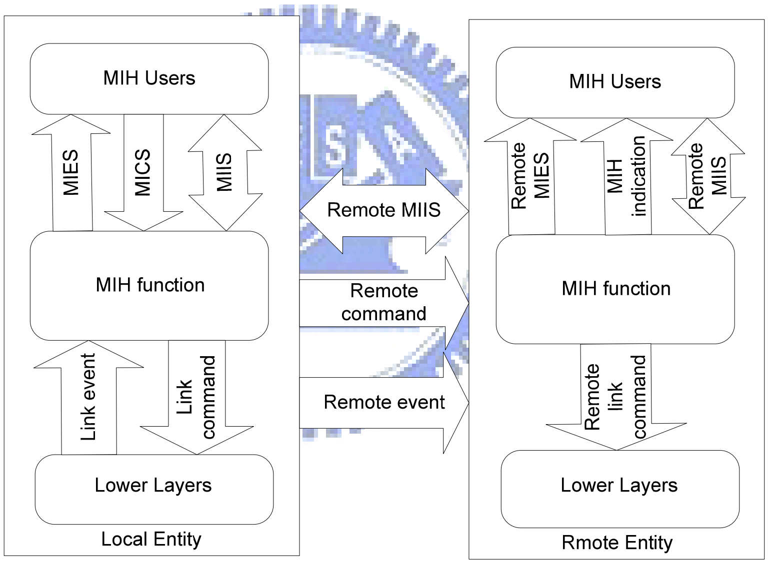

Figure 2.2 Communication between local and remote MIHF entities

Media Independent Event Services (MIES)

The MIES provides event classification, event filtering and event reporting which are corresponding to dynamic link characteristics such as link status and link quality. Events may express change in the states and transmission behaviors of the physical, data link, and logical link layers (e.g., Link_Up, Link_Down, Link_Detected) or predict state changes of these layers (e.g., Link_Going_Down). When events occur, MIH users subscribe to receive notifications. There are two main categories of events: link events and MIH events. First event originates from the lower layers and propagates upward, then later event that originates from the MIHF. All events also can be classified further into local events or remote ones. Local events can propagate across different layers within the local protocol stack of an MIH entity. Remote events are sent from a remote MIHF to local MIHF through the network. For example, a Link_Down created from the link layer of local entity is delivered to the MIH user of the same entity. If a remote MIH user subscribed to this event, the local Link_Down event is forwarded over the network to this remote MIH user as depicted in Fig. 2.2.

Media Independent Command Services (MICS)

The MICS provides commands that can control the link state and is sent to the lower layers. Commands can be issued by both local and remote MIH users. For example, an MIH user gathers information on the reconfiguration or selection of an appropriate link (e.g., Link_Get_Parameters, Link_Actions). Either a local protocol stack or a remote entity can receive a command from MIH users. Local commands propagate from the MIH users to the MIHF and then from the MIHF to the lower layers. Remote commands are delivered from MIH users via a MIHF in one protocol stack to another MIHF in a peer protocol stack. Furthermore, remote commands also can be forwarded down to lower layers as link commands or up to MIH users as MIH indications. In Fig. 2.2, a Link_Actions command is either a local command that is produced by an MIH user and delivered from the MIHF to L2 of the same node or a remote command that is delivered from the local node MIHF to L2 of the remote node via peer MIHF.

Media Independent Information Services (MIIS)

In order to optimize handover the MIIS provides a framework and corresponding mechanism for an MIHF to discover specific network information about networks within a geographical area and to enable more effective handover decision making and execution. The MIIS provides a set of information elements (IEs), the information structure and its representation, and a query/response type for information transfer. This information service provides mostly static information, such as channel information, the MAC address and security information of a point of attachment (PoA) defined in detail latter. Other dynamic information about different access networks, such as current available resource levels, state parameters, and dynamic statistics should be obtained directly from the respective access networks. The common representation of the repository information across different technologies uses completely a unified representation such as resource description framework (RDF) and type-length-value (TLV) [6]. Specifically, the information required for handover decisions is not available locally, but the MIH protocol can be implemented to access remote information sources. Network and other information can be stored in a network element referred to as an information server.

In IEEE 802.21 terminology, the L2 connectivity to the network (BS/AP) is referred to as PoA. The MIHF functionality is used in the element called point of service (PoS) that is a network-side MIHF instance that exchanges MIH messages with an MN-based MIHF. Both PoA and PoS can be combined together.

2.2 Handover procedure between WiMAX/WiFi networks

The scope of IEEE 802.21 in handover clearly handles handover initiation and handover preparation, but handover execution is dealt in other protocols, such as higher-layer mobility management protocols (e.g., MIPv6, SCTP, and SIP). In Fig. 2.3, the handover initiation employs radio measurement reporting procedure in order to make old devices configured to report measurements when specific thresholds are crossed. The type of this measurement report may display an emergent handover request or just a periodic information message. When MN detects a new link, it sends trigger (Link_Detected) from the available link layers to the upper layer. In the following, the MN needs a query for a remote MIIS server that maintains information for available networks in the area of a particular MN.

In the handover preparation, the MN starts the scan for the neighbor networks. The QoS context must be transferred to the new network in a resource availability check process. The consequence of a radio resource availability check and other information from the network are the input to the handover decision algorithm that is out of the scope of the standard. Furthermore, radio resource must be reserved for the selected network.

Finally, handover execution includes L2 signaling and higher layer signaling, they are out of the scope of the standard. Because L2 signaling is dealing with network specific procedure, and higher layer signaling generally is responsible for other protocol, like the MIPv6.

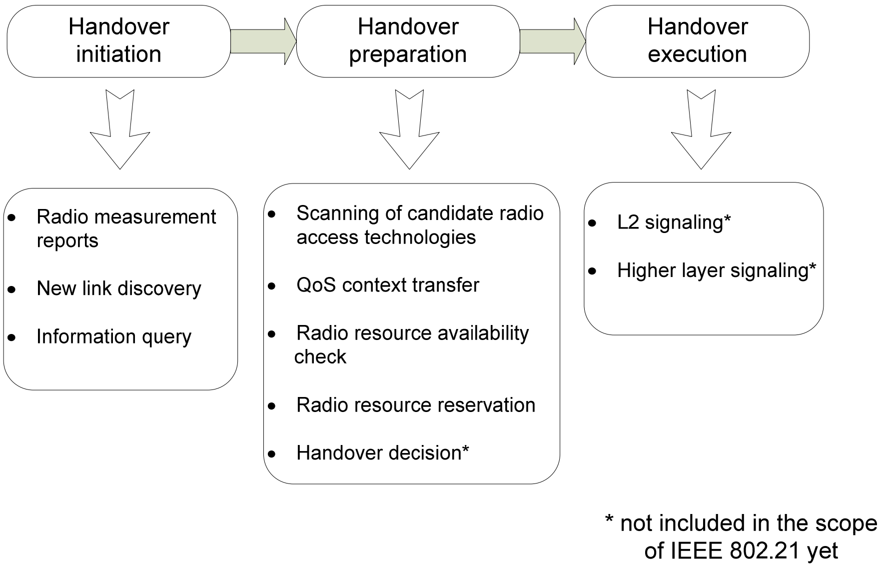

Figure 2.3 Scope of IEEE 802.21 in handover

This section presents two kinds of handover procedure for an integrated WiMAX and WiFi networks. The first approach is provided by IEEE 802.21 standard and is described in section 2.2.1. The second approach is recommended by the IEEE literature and is illustrated in section 2.2.2.

2.2.1 The original approach in IEEE 802.21 standard

The handover procedure can be initiated by a mobile device or a wireless network. In the mobile-initiated handover procedure of dual radio node, both radios involved in handover can transmit/receive at the same time as shown in Fig. 2.4. Each message is formed as MIH_XXX.YYY, where XXX denotes its functionality and YYY denotes its purpose (i.e., REQUEST = REQ, INDICATION = IND, RESPONSE = RSP, CONFIRM = CNF, ACKNOWLEDGE = ACK). The mobile node is connected to the WiFi network and the handover procedure operates the following steps:

(1) The MN receives the 802.11 link measurement report from the MIH_Link_Parameters_Report.IND event. When the MN receives a mobile

_neighbor_advertisment message from the WiMAX BSs followed by a MIH_Link_Detected.IND event from the MAC layer toward the MIH user through MIHF, the MN becomes aware of a new connectivity opportunity.

(2) The MN periodically queries the MIIS by the MIH_Get_Information.REQ/RSP message for gathering information about neighbor PoAs and their characteristics.

(3) When the MIH_Link_Going_Down.IND event happens on the current WiFi network, the MN enters the handover preparation process and performs the MIH_Link_Actions.REQ to scan the link status of the candidate networks. The MN discovers the WiMAX network and can acquire the candidate WiMAX network's DL_MAP, UL_MAP, DCD and UCD parameters.

(4) The MN checks the resource availability status of the candidate network by sending the MIH_MN_HO_Candidate_Query.REQ message to the serving PoA (WiFi AP). After serving PoA received the message from the MN, it sends MIH_N2N_HO_Query.REQ message toward the candidate PoAs in order to retrieve resource information from candidate networks. As a consequence, the candidate PoAs may perform their call admission control (CAC) to confirm whether they support the MN session requirements as without degenerating the existing sessions in the candidate networks. The CAC result (session totally, partially, or not at all supported) is sent in MIH_N2N_HO_Query_ Resources.RSP message that is followed by a MIH_MN_HO_Candidate_ Query.RSP message.

(5) In the following, MIH user can perform the handover decision considering both the resource available at the candidate PoAs and the user's preferred selection of the target network.

(6) The MN sends MIH_MN_HO_Commit.REQ message to the serving PoA to indicate the decided target network information.

(7) The serving PoA reserves the resource at the target network through MIH_N2N_HO_Commit.REQ/RSP messages. Specially, WiMAX L2 re-establishment can happen in parallel with resource reservation process, because the MN equips with two interfaces. Moreover, the handover procedure already proceeds to handover execution.

(8) After completing WiMAX L2 re-establishment, the mobile IP procedures use MIPv6 to perform the L3 handover. Due to the lack of space we reduce MIPv6 [4] procedure in Fig. 2.4, and describe some details in the next paragraph.

When the MN receives router advertisement (RA) message that is periodically sent by the target access router (T-AR), it detects that it has moved to a new network. The MN can also send a router solicitation (RS) message for requesting the T-AR to send a RA message back. The RA message included new network prefix information, hence the MN will create a new care-of-address (NCoA). The MN may use either stateless [7] or stateful [8] address auto-configuration to produce its NCoA. The NCoA must be verified after duplicate address detection (DAD) for uniqueness on the new network. However, DAD takes a quite long time with respect to the handover latency. To execute DAD, the MN has to send several neighbor solicitations (NS) message(s) to its NCoA and wait for a response for at least one second. This hints serious additional time is inevitable in handover. For this reason, the MN should handle DAD in parallel with its communications ideally. After the confirmable NCoA is available, the MN must send a binding update to update the binding cache in its home agent and its correspondent(s).

(9) The MN sends the MIH_MN_HO_Complete.REQ message to the target PoA on the WiMAX network and the target PoA exchanges the MIH_N2N_HO_Complete messages with the serving PoA on the WiFi network to release the resource that

was reserved for the MN on the original network.

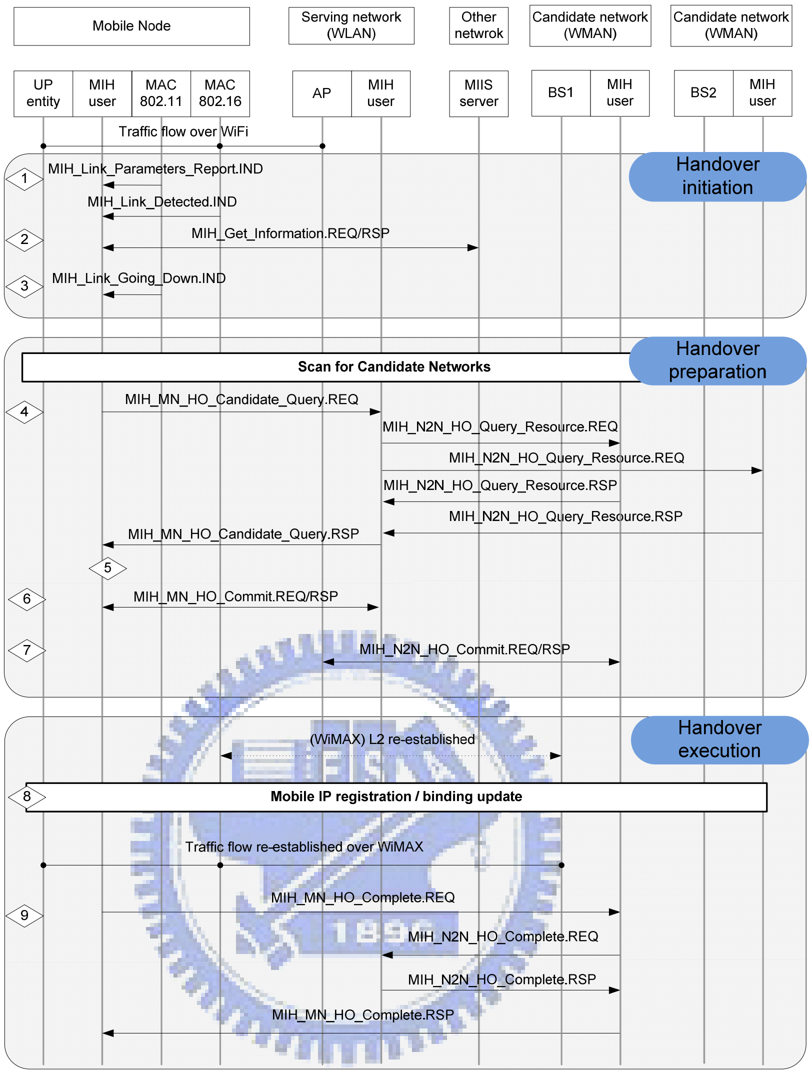

Figure 2.4 Message flow from WiFi to WiMAX in IEEE 802.21 standard

2.2.2 Another approach in IEEE literature

According to our survey, integrating MIH mechanism into WiMAX/WiFi network handover may be an effective solution. However, the related research for this integration is little. We have interest in the literature [9], because it recommends approach that uses FMIPv6 to reduce handover latency. Next, we describe handover approach of the literature in the following and it is also a mobile-initiated handover procedure. In Fig. 2.5, the steps of handover procedure are almost same as that in standard approach, so we omit step (1) to step

(5) from Fig. 2.5 and integrate it with FMIPv6 signaling to deal with L3 mobility management. The MIH messages depicted by filled lines, while MIPv6 and technology-specific messages are expressed by dashed and dotted lines, respectively. The handover procedure operates as follows:

(1) ~ (5) The steps are almost same as the standard approach. Exceptionally, the MN initially is connected to the WiMAX network and receives a beacon from the WiFi APs followed by a MIH_Link_Detected.IND event from the MAC layer toward the MIH user.

(6) After making the handover decision, the MN exchanges the router solicitation for proxy (RtSolPr) and proxy router advertisement (PrRtAdv) messages with the serving AR (S-AR) in order to get the new network prefix of the T-AR. After receiving a PrRtAdv message, the MN configures NCoA.

(7) Then the MN sends a fast binding update (FBU) message to the S-AR. Upon receiving this message, the S-AR sends handover initiate (HI) message to the T-AR. The T-AR executes DAD procedure to verify the uniqueness of NCoA and responds with handover acknowledge (HAck) message to the S-AR. At this time, the tunnel between the MN's old CoA and its NCoA at the T-AR is established. The T-AR stores the tunnel packets in a buffer until it receives a fast neighborhood advertisement (FNA) message from the MN.

(8) Because a DAD procedure needs a long execution time, the L3 handover execution is interlaced simultaneously with MIH_Handover_Commit message (MN Request, N2N Request/Response, MN Response).

(9) When the S-AR receives a HAck message, it responses FBAck messages to the MN and the T-AR. If the MN receives the FBAck message in the serving network before the L2 handover take place, the predictive FMIPv6 procedure will enable the MN to

move to the target network, and MN can begin to quickly receive packets from the T-AR. This is possible because the packets were already tunneled from the S-AR to T-AR via NCoA. If the MN does not receive any FBAck message from the S-AR before the MN's disconnection from the serving network, the predictive mode FMIPv6 can not be executed, whereas FMIPv6 must continue in reactive mode that the MN must wait for the L2 handover to complete and restart partially the L3 handover procedure.

(10) After the MN receives an FBAck message, the MIH user activates the WiFi interface by using MIH_Link_Action.REQ message to initiate the L2 handover. When the L2 handover completed, the MN sends a fast neighborhood advertisement (FNA) message to the T-AR in order to begin the traffic forwarded to the MN.

(11) The step is like step (9) in the 802.21 standard.

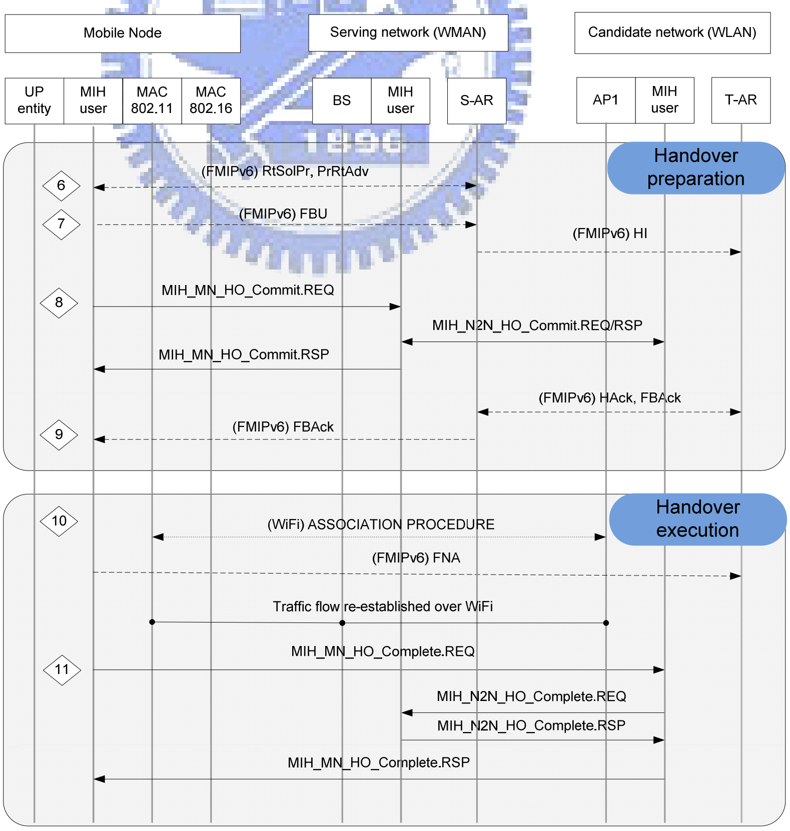

Figure 2.5 Message flow from WiMAX to WiFi in the literature

The literature only provides a make-before-break approach that the MN session can benefit from seamless handover, but does not take account of the FMIPv6 in reactive mode, it may cause session disrupted and packet lost.

2.2.3 Compare the standard with the approach in literature

The approach of standard is principally different from that in the literature which uses the FMIPv6 to execute the IP layer handover. There are two mechanisms in the FMIPv6, anticipated and tunnel-based handover [10] . In anticipated handover, the MN receives these L2 triggers indicating that the MN is about to perform an L2 handover. In tunnel-based handover, the S-AR can tunnel packets to the T-AR and store them in the T-AR's buffer during the L2 handover procedure in order to reduce packet loss rate.

We focus on handover latency and the SDT in both standard's method and literature's method. The handover latency is defined when the MN receives MIH_Link_Going _Down.IND event until handover completion is done. During the SDT, the MN is not able to receive packets in serving network until it has re-established a connection with the target PoA. The handover latency time presented in the standard equals approximately the one discussed in the literature, because both of them need the total time of L2 and L3 handover processes.

For the SDT, there is a special condition in the standard, when the L3 handover of the MN is finished, the MN connectivity with serving PoA is still active, for example, the make-before-break approach, in which the SDT is almost 0 second. Of course, the MN has dual radio technologies and can perform handover in heterogeneous networks. In another condition, the MN may move fast so it causes break-before-make handover, and the SDT is increased with the L2 and L3 handover finished time. As mentioned above, the maximum SDT in total is to add up L2 and L3 handover time.

In the literature, the SDT is evaluated because when the MN received an FBAck message from the S-AR until the MN received forward packet from T-AR (Fig. 2.6). The SDT of the literature equals to the total time including the L2 handover time, FNA message transmitting time and packet forwarding time from the S-AR. In the literature, the author only illustrates the handover as make-before-break handover only without addressing break-before-make handover. In break-before-make approach, the FMIPv6 is in reactive mode and it usually causes packet loss.

In make-before-break handover, the approach of standard is better than the literature's approach in the SDT, but in a presupposition the MN must move slowly. Further, the predictive mode of FMIPv6 supporting tunnel based mechanism can store packets in buffer to avoid packet loss.

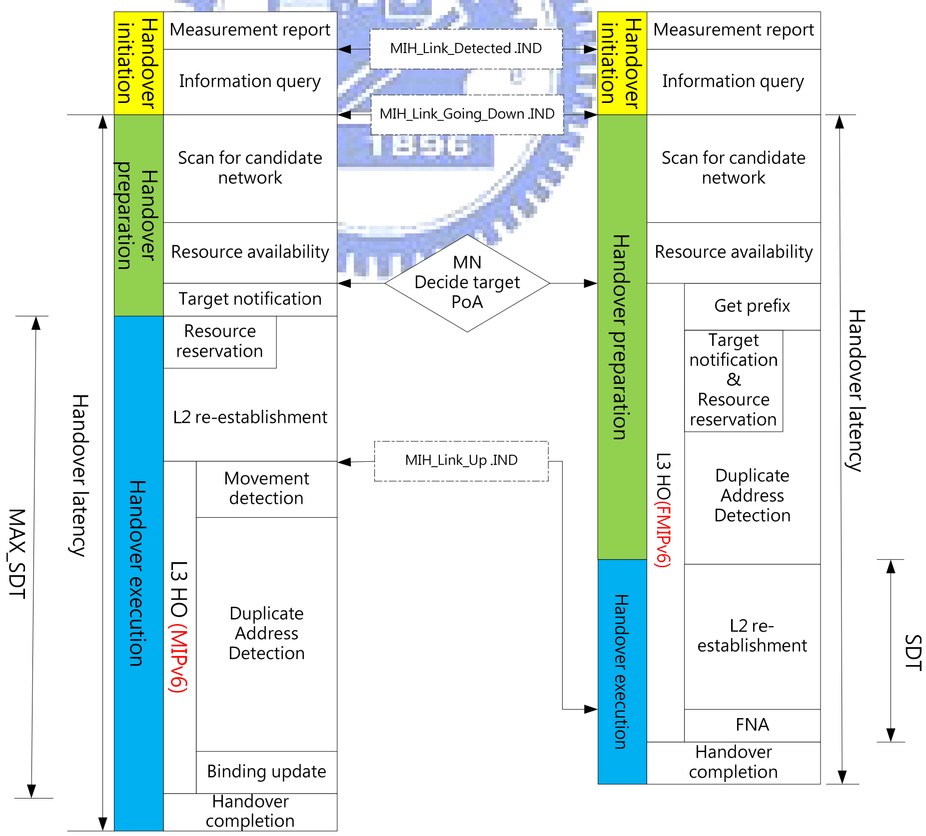

Figure 2.6 Comparison of the standard with the literature

Chapter 3 The Proposed Scheme

In this chapter, we explain what problems make the SDT increasing and address our motivation. The SDT and packet loss rate are both significant factors in supporting seamless handover for real-time applications. Moreover, we take MN's speed into account because it influences packet loss rate and the SDT. However, it is one of the most important parameters to support the required capability of wireless networks for high mobility users. The overlap distance between serving PoA to target PoA is also another important parameter. Several research works [11-14] propose MIH services to improve the SDT in order to offer always best connected in the 4G. Our intention provides seamless handover in either low or high speed of the MN.

Based on the above observation, we proposed a scheme for handover in WiMAX/WiFi heterogeneous networks. In Section 3.1.1, we introduce three main mechanisms in our proposed scheme. Next, we describe message flow of our proposed approach in detail. The scheme can reduce more SDT in heterogeneous WiMAX/WiFi networks. In the following, we use mathematic analysis to evaluate handover latency in three methods.

3.1 Proposed Scheme

3.1.1 Three Main mechanisms

The handover procedure of our proposed scheme is represented in Fig. 3.1 and the differences in comparison with the literature approach are noted in red color. Three mechanisms to assist reducing the SDT are addressed in our proposed scheme, including pre-DAD procedure, parallel handover, and buffer mechanism. We illustrate them one by one in detail as follows.

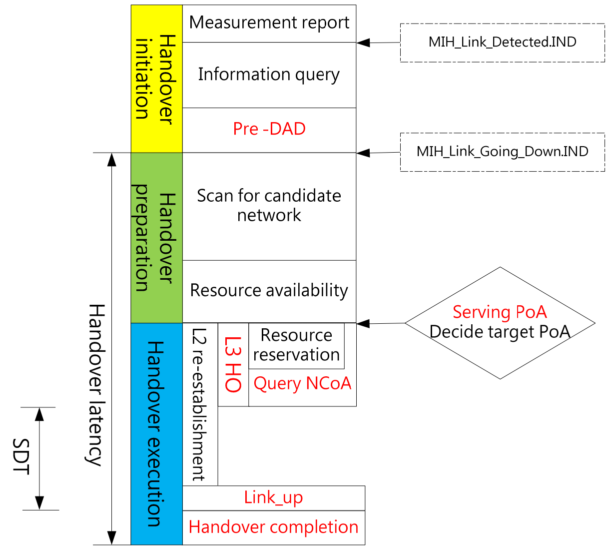

Figure 3.1 Our proposed scheme in handover procedure

Pre-DAD procedure

The time of DAD execution takes at least one second, it causes the L3 handover latency much longer than the L2 handover latency. However, we discover the elapsed time when the MN receives MIH_Link_Detected.IND event until triggered by MIH_Link_Going_Down.IND and is dependent on the MN's speed and overlap distance between the serving PoA and the target PoA. In general, this time is longer than the time since the MN receives MIH_Link_Going_Down.IND event to the service is disrupted. For this reason, we want to move DAD process before it receives MIH_Link_Going_Down.IND event and provide a mechanism called Pre-DAD procedure to overcome the long disruption problem.

When the MN detects a new link, it can query the MIIS about the new PoA information and forward the interface hardware address to the S-AR by Pre-DAD.IND messages. Upon receiving the message from the MN, the S-AR replies a Pre-DAD.ACK message to the MN and configure some new IPv6 address for the MN with all S-AR neighbor network prefix. As mentioned above, address configuration can be done stateless or stateful in IPv6 networks. In this mechanism, the S-AR can assist the MN in generating some new IPv6 address and address configuration is stateful. The 128 bits IPv6 address is configured by a 64-bit suffix combined with new network prefix. Note that the 64 bits suffix can be generated randomly or be based on the interface hardware address. The S-AR configures the number of NCoAs depending on the number of ARs neighbor with the S-AR. The number of ARs neighbor with the S-AR is in accordance with network topology. For example, NCTU76_CC has five neighbor ARs in network topology of NCTU campus (Fig. 3.2). If NCTU76_CC is the S-AR for the MN, it can generate five NCoAs for the MN with the individual network prefix and stored in the S-AR or the individual AR.

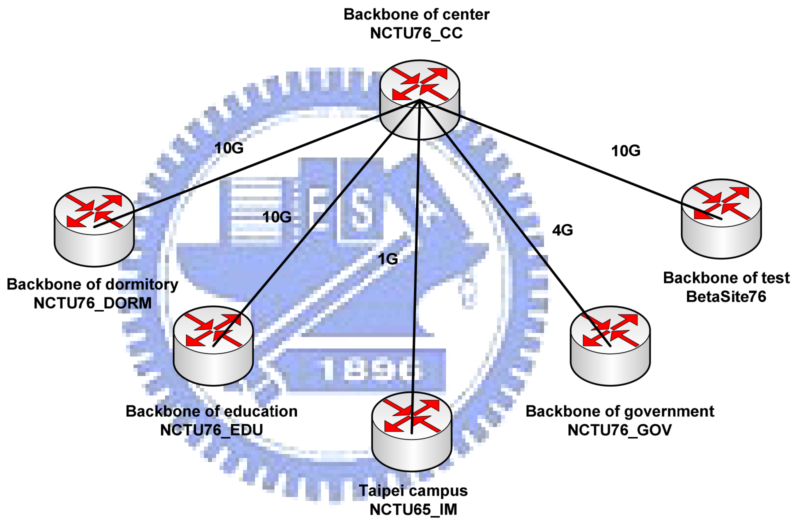

Figure 3.2 Network topology of NCTU campus

However, there are two conditions in our mechanism. In the first condition, the S-AR must configure these NCoAs with the new network prefix and the interface hardware address from the MN and all of the ARs must do those as mentioned above. Actually, the interface hardware address from the MN doesn't conflict with each other, because it is unique within the network. These NCoAs created by the S-AR are already unique and could not be verified by DAD procedure. In addition, these NCoAs are only stored in the S-AR. In the second condition, the S-AR configures these NCoAs with the new network prefix which is based on either the interface hardware address from the MN or generated randomly. Moreover, these

NCoAs must be confirmed with DAD procedure and stored both in the S-AR and the corresponding T-AR.

Parallel handover

Because the MN may have two or more interface to support service connection in heterogeneous networks, the L2 handover procedure can happen in parallel with the L3 handover process. When MIH user knows target PoA, it can instruct target interface of the MN to execute the L2 handover procedure and send a Query_NCoA.REQ message to the S-AR by using another interface of the MN in order to do the partial L3 handover process. The Query_NCoA.REQ message includes target PoA information which informs the S-AR that the MN wants to handover under which PoA and applies for NCoA of the MN. The L2 handover procedure can simultaneously be executed with the partial L3 handover process. For this reason, we only select longer handover process to calculate handover latency. In our proposed scheme, the L2 handover process is longer than the partial L3 handover, and we count the time of the L2 handover into handover latency.

Buffer mechanism

We used FMIPv6 to implement the L3 handover process and employed tunnel-based handover mechanism. When the S-AR receives a Query_NCoA.REQ message from the MN, the S-AR assigns an NCoA to the MN based on target PoA of the MN and establishes the tunnel between the current CoA of the MN and its NCoA at the T-AR. The T-AR intercepts the tunneled packets and stores them in a buffer until it receives a Link_Up.IND message. The Link_Up.IND is the first message delivered from the target PoA when the MN and the target PoA complete the re-association. Upon reception of the message, the T-AR replies a Link_Up.Ack message to the target PoA and forwards the buffered packets to the MN.

Instead of sending a FNA message to T-AR by MN, the target PoA informs the T-AR to reduce the SDT as soon as the MN attaches to the new link. Hence, buffer mechanism is to save the packet during the L2 handover procedure and attain to the purpose of seamless handover.

3.1.2 Message flowchart

In this section, we illustrate our proposed scheme in Fig. 3.3 and use FMIPv6 in the L3 handover procedure. In the following, we describe the message flowchart of Fig. 3.3 step by step and the MIH message depicted by filled lines, while FMIPv6 and technology-specific messages are expressed by dashed and dotted lines, comparatively. The handover procedure operates as follows:

(1) The MN receives the MIH_Link_Parameters_Report.IND event from serving interface that called S-MAC and it includes link measurement report. The message can be sent periodically for informational reasons. When the T-MAC of the MN detects a new link from new PoA, it triggers a MIH_Link_Detected.IND event to inform the upper layer.

(2) The MN periodically queries the MIIS via the MIH_Get_Information.REQ/RSP message to gather information about neighbor PoAs and their characteristics.

(3) When the MN detected a new link, it can query the MIIS about the new PoA information and forward the interface hardware address to the S-AR via Pre-DAD.IND messages. Upon receiving the message from the MN, the S-AR responds a Pre-DAD.ACK message to the MN and configures some NCoA for the MN with all S-AR neighbor network prefix. As above mentioned, we use the second condition, the S-AR is configures these NCoAs with the new network prefix and based on either the interface hardware address from the MN or generated

randomly. Moreover, these NCoAs must be confirmed with DAD procedure and be stored both in the S-AR and the corresponding T-AR.

(4) Upon reception of the MIH_Link_Going_Down.IND event from the S-MAC, the MN initiates handover preparation process and deliveries the MIH_Link_Actions.REQ to scan the link status of the candidate networks.

(5) The MN sends a MIH_MN_HO_Candidate_Query.REQ message to the serving PoA and two parameters of this message are CandidateLinkList and QosResourceRequirements. The first parameter instructs the serving PoA to check resource availability status for the list of candidate PoAs. The second parameter is minimal QoS resources required at the candidate network. After serving PoA received the message from the MN, it retrieves resource information from candidate networks by sending MIH_N2N_HO_Query.REQ message toward the candidate PoAs. As a consequence, the candidate PoAs may perform their CAC to confirm whether they support the MN session requirements without degenerating the existing sessions in the candidate networks. The CAC result is sent through the MIH_N2N_HO_Query_Resources.RSP message to reply the serving PoA.

(6) Upon receiving the MIH_N2N_HO_Query_Resources.RSP message, the serving PoA selects the target PoA based on CAC result. Specially, the target PoA is selected from serving PoA in our proposed scheme in order to omit the MIH_MN_HO_Commit.REQ/RSP messages as well as to enter resource reservation process quickly. The serving PoA sends MIH_MN_HO_Candidate_ Query.RSP to notify the MN regarding the selected target PoA.

(7) When the serving PoA selects target PoA, it can reserve the resource in the target network via MIH_N2N_HO_Commit.REQ/RSP messages.

(8) When the MN receives the MIH_MN_Candidate_Query.RSP message, the MN

sends a Query_NCoA.REQ message to the S-AR in order to ask an NCoA for the MN and L2 re-establishment can be executed in parallel, because the MN equipped with two interfaces. The S-AR assigns an NCoA to the MN via a Query_NCoA.RSP message and establishes the tunnel between the MN's old CoA and its NCoA at the T-AR. The T-AR stores the tunnel packets in a buffer until it receives a Link_Up.IND from the target PoA. By the way, the S-AR deletes other unused NCoA for the MN by sending the Cancel_Unused_NCoA.IND/ACK messages to other neighbor ARs.

(9) When the L2 handover is completed, the T-MAC of the MN triggers a MIH_Link_Up.IND event to MIH user and informs that the MN attaches to the new link. In our scheme, the target PoA informs the T-AR to reduce the SDT, instead of exchanging FNA message twice between T-AR and MN.

(10) When the MN attaches the target PoA, the target PoA releases resource to serving PoA by exchanging the MIH_N2N_HO_Complete.REQ/RSP messages with the serving PoA.

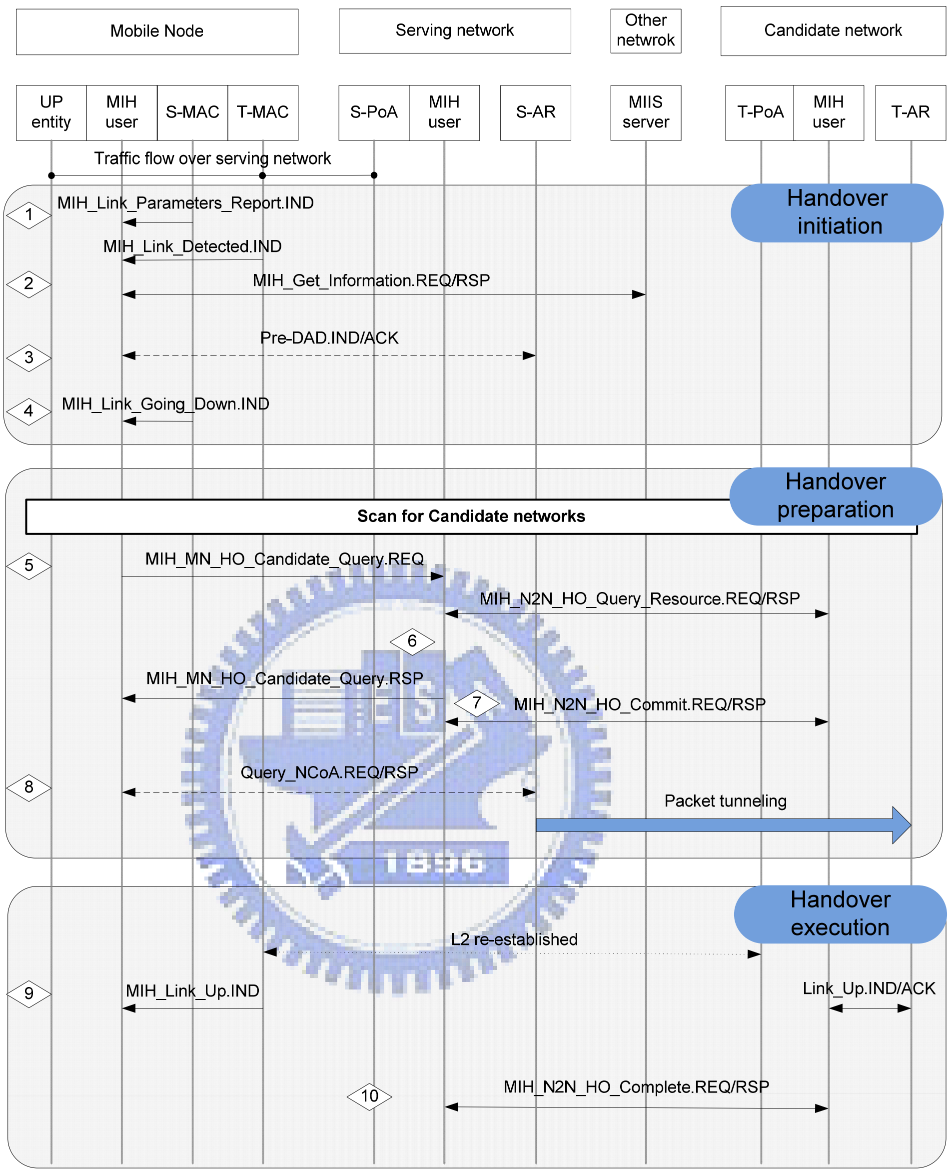

Figure 3.3 Our proposed message flow in WiMAX/WiFi networks

3.2Mathematical analysis

We introduce a mathematical analysis to compare the performances of the original scheme among the standard, the literature approach and our proposed scheme. In this section, we show the performances of the handover latency. We define that the handover latency is started when the MN receives the MIH_Link_Going_Down.IND event until handover completion is done. The SDT will be analyzed in Chapter 4.

3.2.1 Numerical of three approaches

In Fig. 3.4, we use the network topology for mathematical analysis and the default propagation delay in backbone network sets 1 millisecond (ms). We take account of simplicity to make some reasonable assumptions, which are listed below.

- In IEEE 802.16e, the interaction of the message is based on the duration of a frame. We evaluate that the message processing time (<< 1ms) is far shorter than the frame duration, meaning that the message transmission delay in the network nodes is at least a frame long.
- The time of delivering MIH events, commands or information on the inside of the MN is much shorter (<< 1ms), so they can be ignored.

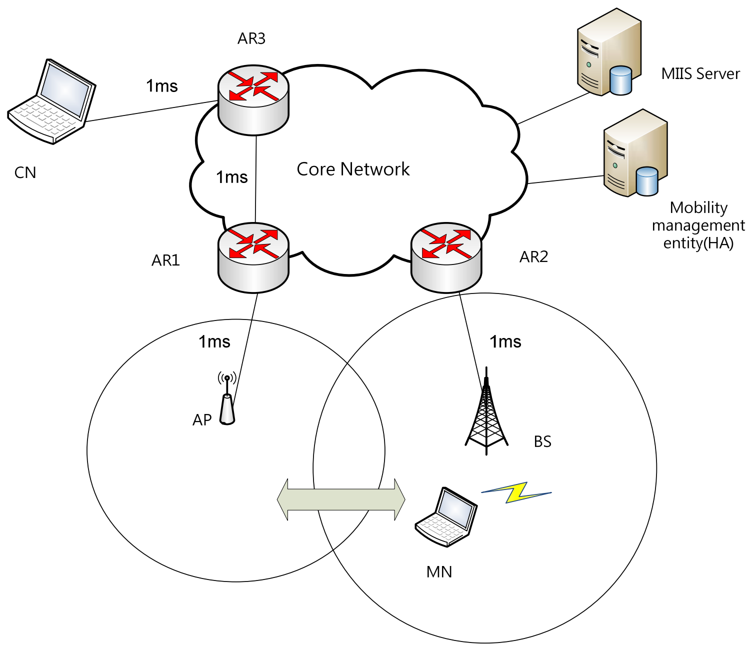

Figure 3.4 The network topology of mathematical analysis

In order to analyze three approaches for handover performance, the following parameters are used:

Table 3.1 The parameters in mathematical analysis

Parameter	Value (ms)	Description
T_{frame}	5	Frame duration of IEEE 802.16e PHY
$T_{scan\ WiMAX}$	85	Scan for 802.16 candidate network
$T_{scan\ WiFi}$	140	Scan for 802.11 candidate network
$T_{WiMAX\ L2}$	287	Latency of IEEE 802.16 network re-entry procedure
$T_{WiFi\ L2}$	195	Latency of IEEE 802.11 network re-entry procedure
T_{DAD}	1000	Time needed to perform a DAD process
$RTT_{MN\text{-}TAR}$	--	The round-trip time between the MN and target AR
$RTT_{MN\text{-}SAR}$	--	The round-trip time between the MN and serving AR
$RTT_{TAR\text{-}HA}$	2	The round-trip time between target AR and home agent
$RTT_{SAR\text{-}TAR}$	2	The round-trip time between serving AR and target AR

In Table 3.1, the $RTT_{MN\text{-}TAR}$ and $RTT_{MN\text{-}SAR}$ values are depending on the MN in WiMAX or WiFi network environment, so we illustrate them later and other parameters are referred to NIST publisher [15]. We assume that the MN spent 2 ms for sending message in WiFi network and the value from the average of simulation result. Note that the handover latency is the total time of handover preparation process and handover execution process, because it starts while the MN received MIH_Link_Going_Down.IND event. They are assumed to be expressed in Equation (1).

$$T_{HO\_Latency} = T_{HO\_pre} + T_{HO\_exe} \quad (1)$$

We calculate the time of the MIPv6 and FMIPv6 for the standard and the literature approach separately. The MIPv6 consists of three operations: movement detection, DAD process and binding update. In movement detection, the MN uses MIH mechanism to detect movement via L2 trigger events and it gets the network prefix by exchanging RS/RA messages with T-AR. During DAD process, the MN sends NS message to its NCoA and wait for a response for at least one second. Then, the MN must perform the binding update operation by informing its home agent (HA) and correspondent node (CN) of its new location. The MIPv6 can be expressed as in Equation (2).

$$T_{MIPv6} = T_{RS/RA} + T_{NS} + T_{DAD} + T_{BU} = T_{DAD} + 3RTT_{MN\text{-}TAR} + RTT_{TAR\text{-}HA} \quad (2)$$

For the FMIPv6, the MN exchanges the RtSolPr/PrRtAdv messages with serving AR in order to get the new network prefix of the T-AR. Before DAD process, the MN exchanges FBU/FBAck with the S-AR and it exchanges HI/HAck with the T-AR to perform DAD process. After completing the L2 handover, MN sends an FNA message to inform the T-AR forwarding packets to it. Then, FMIPv6 can be expressed in Equation (3).

$$T_{FMIPv6} = T_{RtSolPr/PrRtAsv} + T_{FBU} + T_{HI/HAck} + T_{DAD} + T_{FBAck} + T_{FNA}$$
$$= T_{DAD} + 2RTT_{MN\text{-}SAR} + RTT_{SAR\text{-}TAR} + RTT_{MN\text{-}TAR} \quad (3)$$

Next, we have two kinds of handover conditions including WiMAX → WiFi and WiFi → WiMAX. We analyze the handover latency for three approaches individually.

■ **WiMAX → WiFi**

We can calculate Equation (2) and (3) based on value of Table 3.1 as follows.

$T_{MIPv6} = T_{DAD} + 3RTT_{MN\text{-}TAR} + RTT_{TAR\text{-}HA} = 1000 + 3*2*3 + 2*2 = 1022_{(ms)}$

$T_{FMIPv6} = T_{DAD} + 2RTT_{MN\text{-}SAR} + RTT_{SAR\text{-}TAR} + RTT_{MN\text{-}TAR}$

$= 1000+2*2*(5+1) +2+2*(2+1) = 1034_{(ms)}$

Specially, T_{FMIPv6} is larger in milliseconds than T_{MIPv6}, because the MIPv6 is executed in WiFi network and the FMIPv6 is accomplished in WiMAX network. The handover latency consists of several operations, such as scan, resource availability, target notification, etc. Then we can accord with Fig. 2.6 and Fig. 3.1 to calculate the handover latency for three schemes. In our proposed scheme, we calculate time of the L2 re-establishment but do not calculate the time of fractional L3 handover process in handover execution. In Link_Up process, it spends time sending Link_Up.IND/ACK messages and forwarding packet from the T-AR to the MN. The handover latency based on equality (1) can be calculated as follows:

$T_{Standard} = T_{HO\_pre} + T_{HO\_exe}$

$= (T_{scan\_WiFi} + \text{Resource availability} + \text{Target notification})$

$+ (T_{WiFi\_L2} + T_{MIPv6} + \text{Handover completion})$

$= 120 + (5+3)*2 + 5*2 +195+ 1022+ (2+3)*2= 1373_{(ms)}$

$T_{Literature} = T_{HO\_pre} + T_{HO\_exe}$

$= (T_{scan\_WiFi} + \text{Resource availability})$

$+ (T_{FMIPv6} + T_{WiFi\_L2} + \text{Handover completion})$

$= 120 + (5+3)*2+1034 + 195 + (2+3)*2=1375_{(ms)}$

$T_{Proposed} = T_{HO\_pre} + T_{HO\_exe}$

$= (T_{scan\_WiFi} + \text{Resource availability})$

$+ (T_{WiFi\_L2} + \text{Link\_Up} + \text{Handover completion})$

$=120+ (5+3)*2+195+1+3+2*3= 341_{(ms)}$

■ **WiFi → WiMAX**

Similarly, we calculate Equations (2) and (3) in the following.

$T_{MIPv6} = T_{DAD} + 3RTT_{MN\text{-}TAR} + RTT_{TAR\text{-}HA} = 1000 + 3*2*(5+1) + 2*2 = 1040_{(ms)}$

$T_{FMIPv6} = T_{DAD} + 2RTT_{MN\text{-}SAR} + RTT_{SAR\text{-}TAR} + RTT_{MN\text{-}TAR.}$

$= 1000+2*2*(2+1) +2+2*(5+1) = 1026_{(ms)}$

The handover latency that based on Equation (1) can be calculated as follows:

$T_{Standard} = T_{HO\_pre} + T_{HO\_exe}$

$= (T_{scan\_WiMAX} + \text{Resource availability} + \text{Target notification})$

$+ (T_{WiMAX\_L2} + T_{MIPv6} + \text{Handover completion})$

$= 85 + (2+3)*2 + 2*2 + 287 + 1040 + (5+3)*2 = 1442_{(ms)}$

$T_{Literature} = T_{HO\_pre} + T_{HO\_exe}$

$= (T_{scan\_WiMAX} + \text{Resource availability})$

$+ (T_{FMIPv6} + T_{WiMAX\_L2} + \text{Handover completion})$

$= 85 + (2+3)*2 + 1026 + 287 + (5+3)*2 = 1424_{(ms)}$

$T_{Proposed} = T_{HO\_pre} + T_{HO\_exe}$

$= (T_{scan\_WiMAX} + \text{Resource availability})$

$+ (T_{WiMAX\_L2} + \text{Link\_Up} + \text{Handover completion})$

$= 85 + (2+3)*2 + 287 + 1 + (5+1) + 2*3 = 395_{(ms)}$

3.2.2 Performance comparison

Based on the above analyses, we arrange the results of mathematical analyses in Fig. 3.5 and we clearly discover that our proposed scheme outperforms other methods. Because of pre-DAD process, the handover latency of our proposed scheme is much reduced than the handover latency of the standard. In our proposed scheme, the L2 re-establishment mainly influences the handover latency and the secondary affection is scan process. For MN, the handover time from WiFi to WiMAX is longer than the time from WiMAX to WiFi due to L2 re-establishment and scan process.

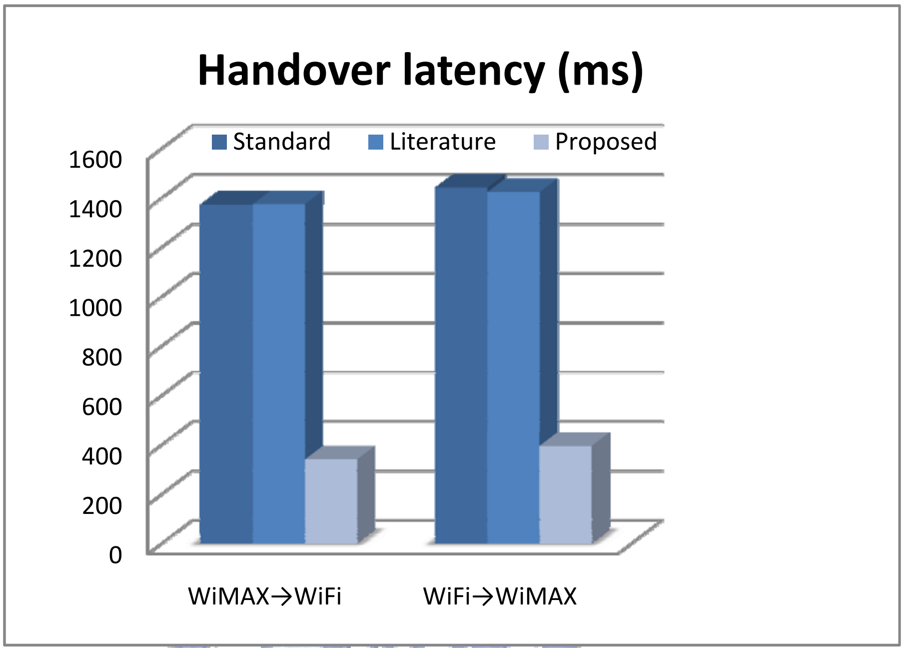

Figure 3.5 Comparison of the handover latency among three approaches

As illustrated in Table 3.2, we could compare improvement between different performances of handover latency, utilizing Equation (4)

$$\textbf{Improvement} = \frac{\text{Latency}_{\text{standard}} - \text{Latency}_{\text{compared}}}{\text{Latency}_{\text{standard}}} \quad (4)$$

Table 3.2 Theoretical performance comparison

Handover latency	WiMAX→WiFi	Improvement	WiFi→WiMAX	Improvement
Standard	1373	--	1442	--
Literature	1375	-0.146%	1424	1.25%
Proposed	341	75.16%	395	72.61%

In the WiMAX→WiFi environment, our proposed method improves over the standard 75.16% in mathematical analysis. Another WiFi→WiMAX environment, it is better than the standard 72.61%. Therefore, using our proposed scheme can decrease the handover latency significantly.

Chapter 4 Simulation Results

In order to simulate the latency time and packet loss during handover, we use NS-2 (version 2.29) tool [16] with mobility module [17]. This module is implemented by National Institute Standards and Technology (NIST) to provide a platform for manipulation of heterogeneous handover by using MIH proposal. Many real-time applications, such as video and audio service, have been available for experimental and practical uses. Traditionally, UDP had been used as a transport layer protocol for real-time applications instead of TCP. UDP is a much simpler protocol without connection setup delays, flow control and retransmission. We use UDP as the test traffic for avoiding the complex TCP mechanism such as retransmission. Two scenarios are designed to measure our proposed scheme. In scenario I, the MN moves from WiMAX to WiFi network. In scenario II, it redirects from WiFi to WiMAX network.

4.1 Scenario I

4.1.1 Network topology

We would like to evaluate the performance during handover of a mobile node (MN) and we create a network topology which has one MN, one corresponding node (CN), one access point (AP), one base station (BS), a MIIS, a home agent (HA) and three routers as shown in Fig 4.1.

In Fig 4.1 each wired link bandwidth equals 100Mb, propagation delay time equals 1ms and we use drop tail queue policy. The WiMAX (IEEE 802.16e) cell is overlapped with the coverage area of a WiFi AP (IEEE 802.11b). It is assumed that one MN equipped with two interfaces and is connected to WMAN before it goes through the WLAN coverage area.

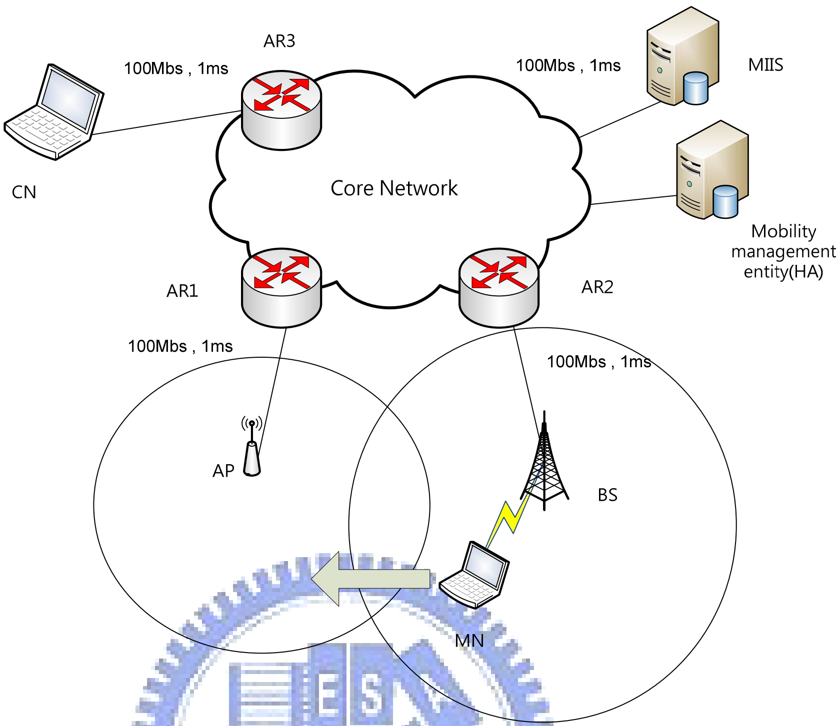

Figure 4.1 Network topology of simulation I

The simulation time is 110 seconds, and we use constant bit rate (CBR) traffic in 9^{th} seconds from the CN to the MN. The MN starts to move in 10^{th} seconds and its speed is 10 meter per second. For CBR traffic, we use Voice over Internet Protocol (VoIP) and video streaming to experiment and check the arrival of sequence number the MN received, we can observe which packet is delivered successfully and which one gets lost. Parameters of simulation are shown as follows:

Table 4.1 Parameters of simulation

<table>
<tr><th colspan="2">Parameter</th><th>Value</th></tr>
<tr><td colspan="3">Network Topology</td></tr>
<tr><td colspan="2">WiMAX cell coverage</td><td>1000meter(m)</td></tr>
<tr><td colspan="2">WiFi cell coverage</td><td>100m</td></tr>
<tr><td colspan="2">Coverage area</td><td>40m</td></tr>
<tr><td colspan="3">WiFi Configuration</td></tr>
<tr><td colspan="2">Data rate</td><td>11Mbps</td></tr>
<tr><td colspan="2">Beacon interval</td><td>100 milliseconds(ms)</td></tr>
<tr><td colspan="2">MinChannelTime</td><td>0.02s</td></tr>
<tr><td colspan="2">MaxChannelTime</td><td>0.06s</td></tr>
<tr><td colspan="3">WiMAX Configuration</td></tr>
<tr><td colspan="2">Dcd_interval</td><td>5s</td></tr>
<tr><td colspan="2">Ucd_interval</td><td>5s</td></tr>
<tr><td colspan="2">Default modulation</td><td>OFDM_16QAM_3_4</td></tr>
<tr><td colspan="2">Frame duration</td><td>5ms</td></tr>
<tr><td colspan="3">Mobility Model</td></tr>
<tr><td colspan="2">Velocity</td><td>10 meter per second(m/s)</td></tr>
<tr><td colspan="2">Path</td><td>Straight line</td></tr>
<tr><td colspan="3">CBR traffic</td></tr>
<tr><td rowspan="2">VoIP</td><td>Packet size</td><td>200bytes</td></tr>
<tr><td>Data rate</td><td>64Kbps</td></tr>
<tr><td rowspan="2">VideoStreaming</td><td>Packet size</td><td>1500bytes</td></tr>
<tr><td>Data rate</td><td>1Mbps</td></tr>
</table>

4.1.2 Simulation results

The results of simulation in Fig. 4.2, Fig. 4.3 and Fig. 4.4 focus on VoIP traffic. CN sends constantly VoIP packets to the moving MN and the fixed speed of the MN is 10 m/s. We monitor the arrival of every packet labeled the sequence number. Fig. 4.2 illustrates the result of the standard; Fig. 4.3 illustrates the result of the literature; Fig. 4.4 illustrates the result of our proposed scheme. To take notice of the gap in Fig. 4.2, the horizontal width of the gap points at the SDT which means that the MN can not receive any packet in the duration. In addition, the vertical height point of the gap points at the number of lost packet which means that those packets are lost during the handover procedure.

In Fig. 4.2, the handover begins around 94.53s when the MN received MIH_Link_Going_Down.IND event. Around 95s, the MN service is disrupted before WiFi connection is established due to the MN moving too fast. The SDT is about 903.03ms. During the SDT, the MN is unable to receive any packet from CN and those packets are lost because not any mechanism is available to buffer and forward those packets for the MN. Hence, the packet loss rate is very high and the performance is degraded seriously.

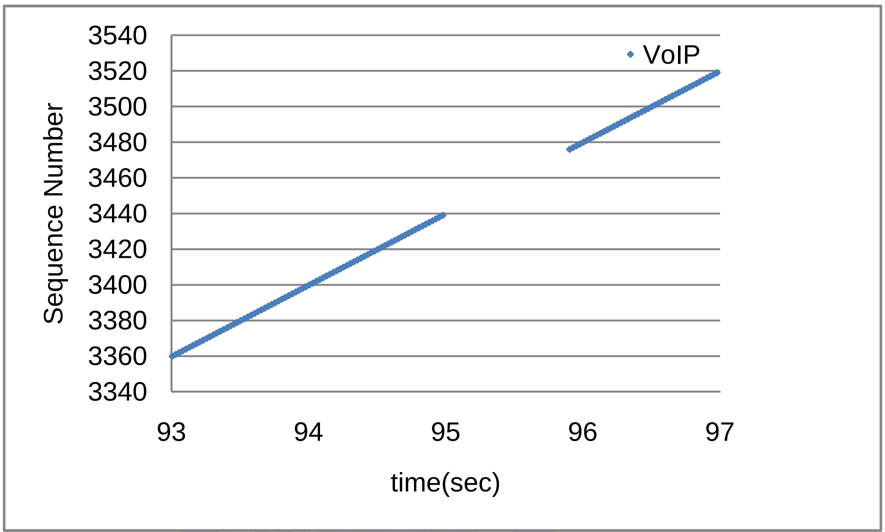

Figure 4.2 The simulation result in standard

In Fig. 4.3, the method proposed in the literature is used. The MN's moving speed is 10 m/s same as above. At this moving speed, the MN can't receive FBAck message in time so that the handover procedure performs FMIPv6 reactive mode. Therefore, when the MN finished L2 re-establishment of WiFi interface, the MN must send an FNA message to T-AR, with an encapsulated FBU message and complete DAD process. The SDT starts at 95s and ends at 96.2s, so the SDT is 1206.79ms in total.

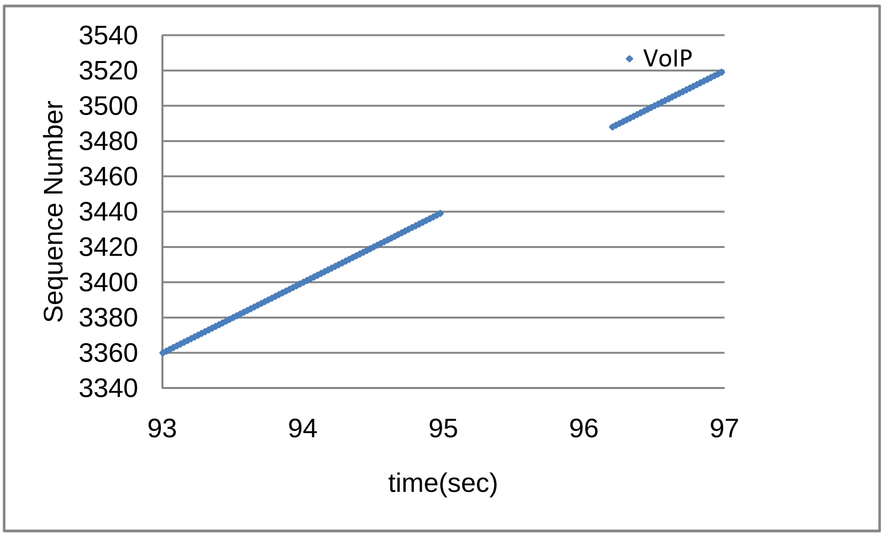

Figure 4.3 The simulation result in the literature

The simulated result of our proposed scheme is shown in Fig. 4.4. The T-AR forwards the buffer packets to the MN when the T-AR receives Link_Up.IND message from the serving PoA. The MN receives Query_NCoA.RSP message around 94.66s and the MN receives the forwarded packets around 94.86s, so the total SDT is 195.38ms.

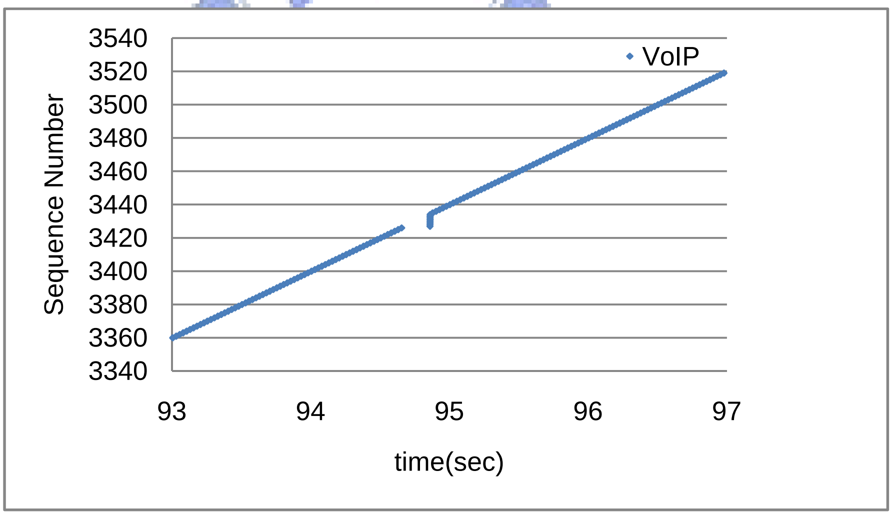

Figure 4.4 The simulation result of our proposed scheme

Observing Table 4.2, we compare that the SDT of three approaches. We can find clearly that the SDT of our proposed approach is much lower than that of the standard. Our improvement is 78.364%, because our proposed three mechanisms can omit some messages. The handover approach in the literature performs in reactive mode and it doesn't gain any improvement.

Table 4.2 The SDT of three approaches

SDT	WiMAX→WiFi	Improve over standard
Standard	903.031	--
Literature	1206.785	-33.64%
Proposed	195.376	78.364%

We change the MN moving speed between 1 m/s and 30 m/s. In the simulation, the moving speed changes when MN moves every 5 meters. We compare our proposed scheme with the method in standard and the literature. To understand clearly the influence of moving speed, the curves of the standard method presented in Fig. 4.5 describes the relation between the SDT and moving speed of MN. Specially, our proposed scheme features a stable value, so it can support high speed of the MN and performs the buffer mechanism before the service disruption. Although the performance of our proposed scheme in low speed is worse than that of the standard, the former one has good performance when moving speed surpasses 5 m/s. Because of the buffer mechanism, we can store packets during the SDT and the SDT of our proposed scheme is around 195ms. The literature approach, MN moving speed is 1 m/s and is suitable for predictive mode, and the buffer mechanism is like our proposed method. On the other hand, MN moving speed is 5 m/s such that the reactive mode is executed. Therefore, MN has to re-establish WiFi connection and execute DAD process after original connection disrupting.

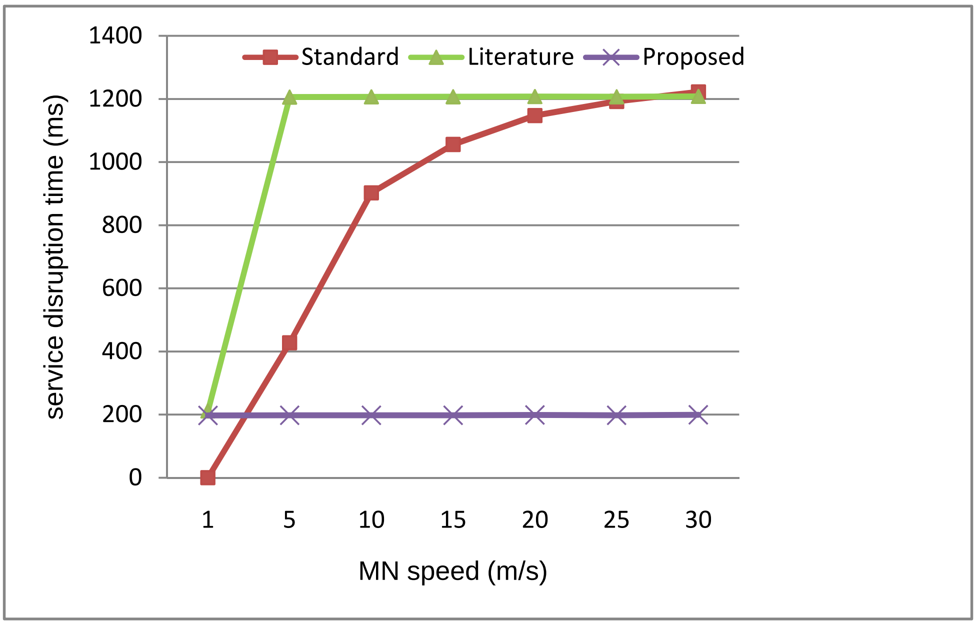

Figure 4.5 The simulation result in our proposed scheme

4.2 Scenario II

4.2.1 Network topology

In Fig. 4.6, the parameters of scenario II is same as those in scenario I, but the MN is under WiFi AP and handover is performed from WiFi to WiMAX network.

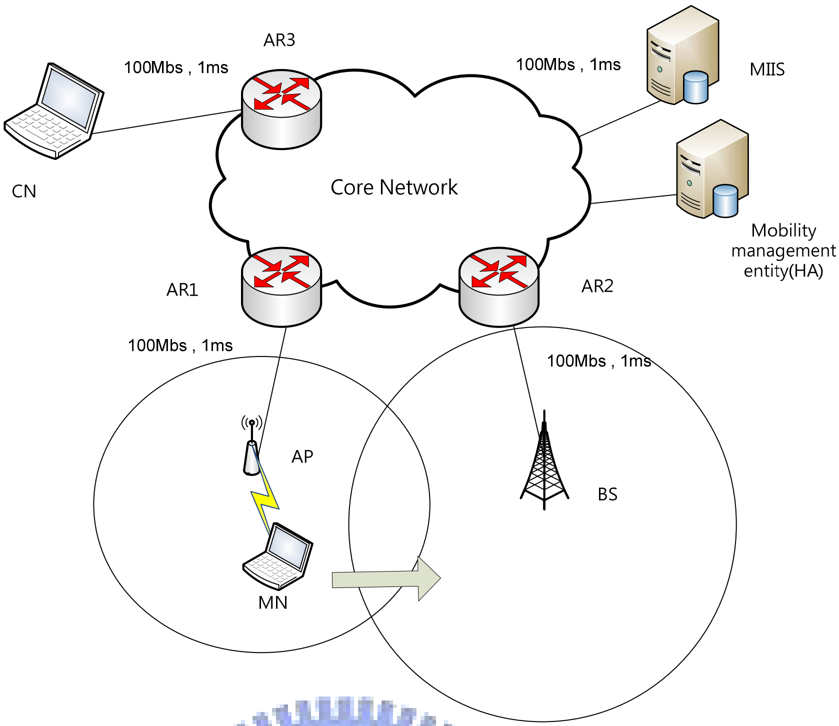

Figure 4.6 Network topology of simulation II

4.2.2 Simulation results

The rules of Fig. 4.7, Fig. 4.8 and Fig 4.9 are the same with those above figures in scenario I. The profiles of simulated results are similar to the profiles of scenario I, but the time of WiMAX connection re-established is longer than the time of WiFi connection re-established. The handover begins around 15.6s and we monitor the arrival of every VoIP packet labeled with the sequence number. The SDT of the method proposed in standard is about 1004.634ms as shown in Fig. 4.7. The SDT is about 1298.37ms as Fig. 4.8 shows and the SDT of our proposed scheme is about 289.87ms as shown in Fig. 4.9.

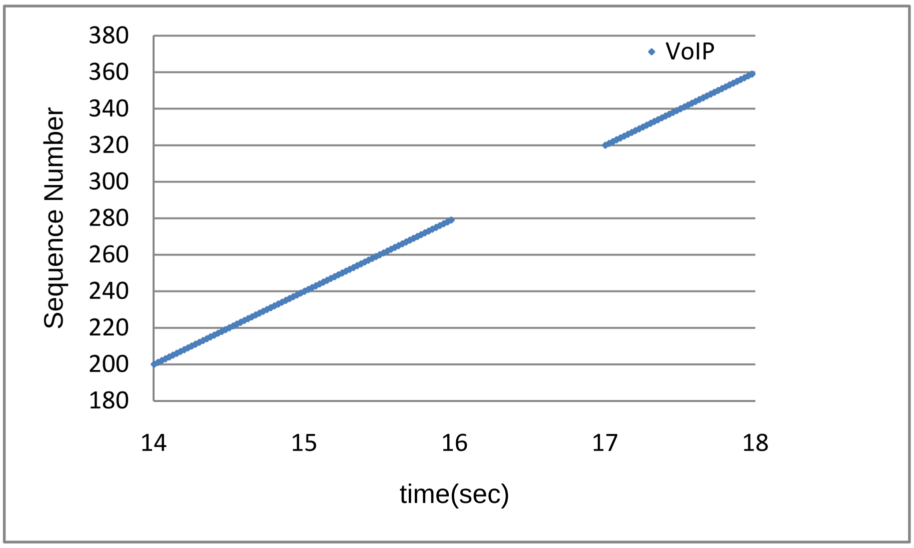

Figure 4.7 The simulation result in standard

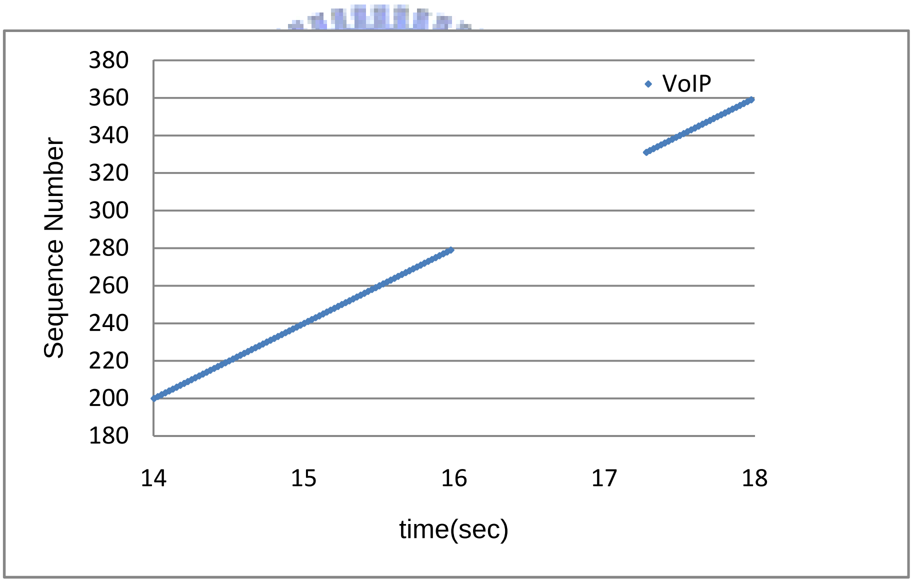

Figure 4.8 The simulation result of the method in literature

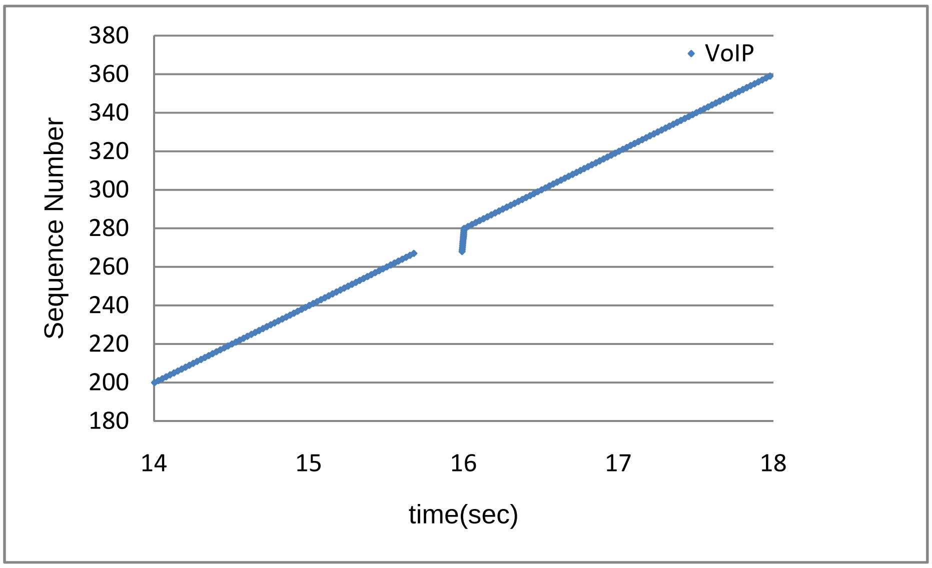

Figure 4.9 The simulation result in our proposed scheme

Table 4.2 illustrates the comparison results of SDT with the different proposed methods, our proposed scheme outperforms the standard 71.175%.

Table 4.3 The SDT of three approaches

SDT	WiFi→WiMAX	Improve over standard
Standard	1004.634	--
Literature	1298.366	-29.24%
Proposed	289.87	71.175%

In the following, we discuss the count of buffered packets by using our proposed method. Table 4.4 shows the simulation result.

Table 4.4 Buffered packet count of our proposed method

Buffered packet count	WiMAX→WiFi		WiFi→WiMAX	
	VoIP	Video streaming	VoIP	Video streaming
Proposed	8	17	12	24

Table 4.5 Simulation performance comparison

Handover latency	WiMAX→WiFi	Improvement	WiFi→WiMAX	Improvement
Standard	1364.244	--	1426.213	--
Literature	1370.762	-0.48%	1419.506	0.47%
Proposed	338.604	75.18%	393.344	72.42%

Finally, we compare handover latency in Table 4.5 when the MN's speed is 1m/s. The method in literature is recommended for predictive mode. We can compare with above mathematical analysis with the simulation result in Fig. 4.10 and Fig. 4.11. The simulation result corresponding to mathematical analysis and our simulation outperforms the standard about 70%.

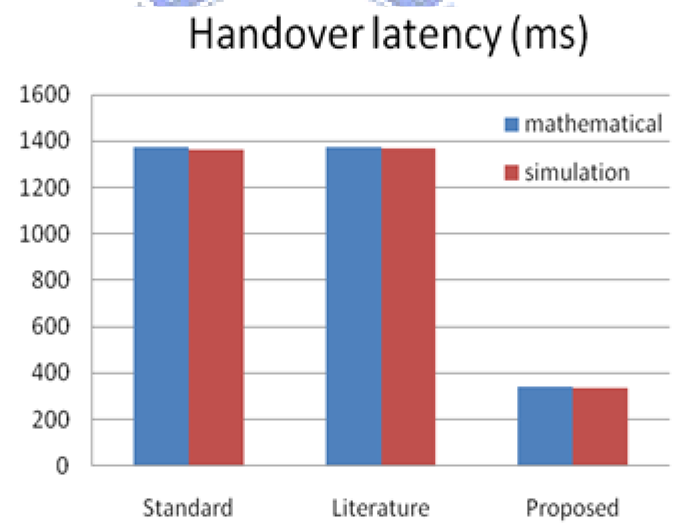

Figure 4.10 The handover latency from WiMAX to WiFi

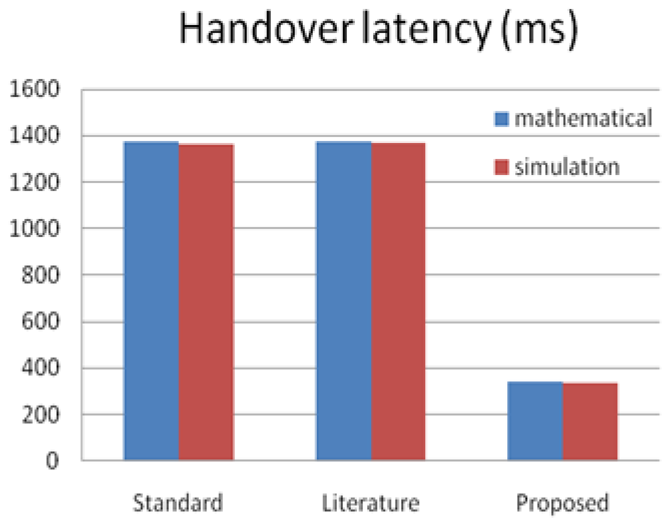

Figure 4.11 The handover latency from WiFi to WiMAX

Chapter 5 Conclusion and Future Works

Seamless mobility is a critical factor if service requirements are supported efficiently in next generation heterogeneous access network. In this article, we present a cross-layer design, which employs MIH and FMIPv6, in order to achieve seamless handover. We use three main mechanisms to assist handover procedure. Firstly, Pre-DAD procedure can anticipate accomplishing DAD process. Second, parallel handover can execute the L2 handover and the L3 handover simultaneously. Last, buffer mechanism can avoid packet loss during handover and allow the MN to receive packet before completing handover.

According to simulation results, the handover latency and the SDT is decreased significantly 70% and the result is well correlated with mathematical analysis. Specially, the method proposed in literature using FMIPv6 doesn't improve the SDT, because it operates in reactive mode when the MN moving speed exceeds 3 m/s. When it is in reactive mode, it has to re-establish L2 connection and perform DAD process after the MN loses original service. So, it spends more time than the standard to complete handover procedure. We use Pre-DAD and parallel handover mechanism to improve the method of the literature and obtain a good performance in both the handover latency and the SDT.

Voice connections ideally have a maximum of delay tolerance which is between 150ms and 200ms. When the MN handovers from WiFi to WiMAX, the current voice delay can't be accepted, but when the MN handovers from WiMAX to WiFi, it is just acceptable. This is necessarily improved in the future studies. For video-on-demand service, we may set a video buffer in the MN to solve the out-of-order packets problem. There are still some problems that should be studied in future research such QoS mapping and security solutions for preventing denial of service (DoS) attacks toward MIIS.

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