Simultaneous Mobility Support with IEEE 802.21 Media Independent Handover

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Abstract*-The simultaneous mobility is a special case when two communication nodes start handover at about the same time. The IEEE 802.21 Media Independent Handover (MIH) and the Media-independent Pre-Authentication (MPA) techniques have been integrated to improve heterogeneous handover performance; however, they cannot resolve the simultaneous mobility problem. Hence, this article proposes an enhanced IEEE 802.21 MIH in order to resolve the simultaneous mobility problem. We first introduce new messages and service primitives for handover information exchange between the Point of Server (PoS) and the mobile node (MN) in the enhanced IEEE 802.21 MIH services. In addition, we extend the handover execution function of the mobility manager (MM) on the MN, and also enhance the intelligence of the PoS. When the MN and the corresponding node (CN) establish a connection, their MMs will advise the IP address of their corresponding PoSs to each other. If the MN starts handover, its MM will send a message with its new IP address to the PoS of the CN. After completing the handover procedure and attaching the new network, the MN performs the information query procedure to inquire its PoS about the latest IP address of the CN to check whether the CN also moves simultaneously. Furthermore, the Master-Slave Determination procedures derived from H.245 are proposed on the PoS in order to handle the racing conditions fairly when two nodes in a simultaneous mobility issue the re-establishment process at about the same time. We demonstrate the message flows of the simultaneous mobility based on the enhanced IEEE 802.21 MIH separately with two mobility protocols, SIP and MIPv6. Mathematical analysis presents that the handover latency can be shortened with our proposal.*

Keywords: *Heterogeneous Handover, Media Independent Handover, Simultaneous Mobility*.

1. Introduction

In Next-Generation Network (NGN), mobile devices or terminals equipped with multiple network interfaces will roam seamlessly across heterogeneous networks through different technologies such as IEEE802.11, IEEE802.16, CDMA, GSM, and so on. Supporting seamless roaming between heterogeneous networks is a challenging task since each access network may have different mobility, QoS and security requirements.

The IEEE 802.21 framework [1] and the Media-independent Pre-Authentication (MPA) technique [2] have been integrated to improve heterogeneous handover performance. The IEEE 802.21 framework is intended to facilitate handover between heterogeneous access networks by exchanging information and defining commands and event triggers to assist in the handover decision making process. The objective of the IEEE 802.21 is to optimize the mobility management by reducing the handover latency, selecting the most suitable candidate target network (CTN), and avoiding the Ping-Pong movement. Many current researches of IEEE 802.21 focus on these features [3-6].

Media-independent Pre-Authentication (MPA) is a mobile-assisted, secure handover optimization scheme that works over any link-layer and with any mobility management protocol. With MPA, a mobile node is not only able to securely obtain an IP address and other configuration parameters from a CTN, but is also able to send and receive IP packets using the obtained CTN IP address before it physically attaches to the CTN. This ability to communicate at layer-3 before establishing layer-2 connectivity is a great benefit in terms of reducing handover delays.

Non-simultaneous mobility means that only one mobile node occurs handover while the other one remains stationary when communicating. Simultaneous mobility is the special case when two communication end nodes are mobile and both move at about the same time. Moreover, the disruption caused by the simultaneous mobility may far exceed the typical disruption caused by the non-simultaneous mobility; therefore, we must solve it properly. In [7], the authors had identified the problem of simultaneous handover and analyzed solution mechanisms.

We will propose an enhanced IEEE 802.21 MIH to resolve the simultaneous mobility problem. The rest of this paper is organized as follows. In the next section, we introduce the related works of the IEEE 802.21 and the simultaneous mobility. Then we present the enhanced IEEE 802.21 for simultaneous mobility in Section 3. In Section 4, we show the message flow of our mechanism with SIP and MIPv6 and compare it with the IEEE 802.21 using Wong's receiver-side mechanism for simultaneous mobility. Finally, we conclude this paper in Section 5.

2. Related Works

2.1. IEEE 802.21 MIH

The IEEE 802.21 introduces a Media Independent Handover (MIH) function between layer 2 and upper layers. Figure 1 shows the placement of the MIH function and its relationship with upper and lower layer elements. The MIH function is located both in the MN and the network node protocol stack, and provides three types of services: the media independent event service (MIES), the media independent command service (MICS), and the media independent information service (MIIS).

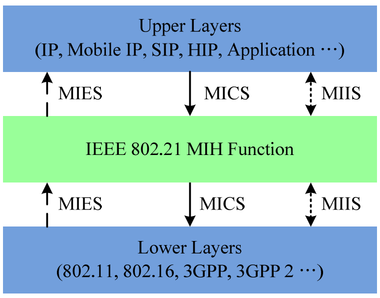

Figure 1. IEEE 802.21 MIH services [1]

The MIES is responsible for detecting events and reporting them from both local and remote interfaces. This type of service is provided from lower layers to upper layers. The MICS offers commands to higher layers to control the lower layers regarding handover. Commands follow a top-down direction as opposed to events. The MIIS is the key service of IEEE 802.21, which provides the mechanism for retrieving static information about neighboring networks to assist the handover decision. An MN gets the heterogeneous neighborhood information by requesting information elements (IEs) from an information server (IS). The access point (AP) is referred to as point of attachment (PoA) and describes the network side endpoint connected to the MN with a layer-2 connection. In addition to the PoA, the MN communicates with a peer MIH function located in a network node called point-of-service (PoS).

2.2. Simultaneous Mobility

In [7], Wong et al. indentified the simultaneous mobility problem and they proposed the mechanisms for resolving related problems in Mobile IPv6 (MIPv6) and SIP. Their simultaneous mobility solutions are: forwarding proxy in the previous network; combination of sender-side and receiver-side mechanisms; receiver-side mechanisms only. The authors recommended the receiver-side mechanisms for solving the simultaneous mobility problem.

3. The Enhanced IEEE 802.21

In order to enhance the IEEE 802.21 MIH functions, we first modify the behaviors between the PoS and the MN; then we create two new messages: one is for the MN to update its latest IP address and the other is to notify the PoS of the CN its new IP address. We also define a new type of information element for the information query, and enhance the functions of the PoS and the MN; finally, we design the Master-Slave Determination procedure to overcome the racing condition between the MN and the CN.

3.1. The Behaviors of the PoS and the MN

According to the IEEE 802.21 Draft [1], the PoS hosts MIH services. When the PoS receives the information query sent by the MN, it helps the MN to find its IS and forwards the information query message to the IS. When the IS responds with the information, the PoS also forwards the response to the MN. The information contains the static parameters of the MN's neighboring networks. In order to solve the simultaneous mobility problem, we need to extend the behaviors of the PoS and the MN.

In our mechanism, while the MN establishes a connection with the CN, the MN sends a new message MIH_Update_PoS to inform the IP address of its PoS to the CN. During the handover process, the MN sends a new message called MIH_Update_IP to the PoS of the CN as well as the CN. In addition, the CN's PoS buffers the

MIH_Update_IP message which is sent by the MN. We also add the Communicating Node's IP (CNIP) in MIH_Get_Information as a new type of information elements (IE). The MN may send the request, MIH_Get_Information.CNIP_Request, to its PoS for the latest IP address of the CN. When the PoS receives the CNIP request, it responds the CNIP response with the CN's latest IP address to the MN if there exists a buffered MIH_Update_IP with respect to the CNIP request. Furthermore, in order to eliminate the racing condition, the MIH_Update_IP needs to carry a value for our Master-Slave Determination procedure. The Master-Slave Determination procedure will be discussed in the following section.

3.2. The Extended Service Primitives

The information elements of the MIIS contain the network operator, SSID, rate, and so on. If we hope to provide some information via MIIS to solve the simultaneous mobility problem, the information service message needs to include the latest IP address of the CN and statusDeterminationNumbers generated by the MN and the CN for the Master-Salve Determination procedure. This information can be used to re-establish the session between the MN and the CN, and overcome the racing condition to resolve the simultaneous mobility problem.

Table 1(a) shows the format of the MIH_Update_PoS and Table 1(b) shows the format of MIH_Update_IP. The PoS buffers the MIH_Update_IP till the Buffer Timer expired. The Buffer Timer will be discussed in the following section.

As for the information query procedure, we add a new type of information element called Communicating Node's IP address (CNIP) into MIH_Get_Information. When the MN attaches to the new network, it will perform the information query procedure of CNIP request. As shown in Table 1(c), the CNIP request includes the MN's IP address, the CN's IP address, and its own statusDeterminationNumber. After receiving the CNIP request, the PoS performs the Master-Slave Determination procedure if there exists a buffered MIH_Update_IP with respect to the CNIP request, and then replies the CNIP response. The CNIP response message is illustrated in Table 1(d). The CN's latest IP address and the result of the Master-Slave Determination procedure were included in the CNIP response message. Therefore, the MN can use this information in the CNIP response to resolve the simultaneous mobility and the racing conditions.

Table 1. The extended IEEE 802.21 service primitives for simultaneous mobility

Command	(L)ocal, (R)emote	Remote Direction	Comments
MIH_POS_IP	L, R	Client -> Client	Advise the IP of its POS to CN

(a) MIH_Update_PoS Command

Command	(L)ocal, (R)emote	Remote Direction	Comments
MIH_Update_IP	L, R	Client -> Client	Update the IP to CN's PoS.

(b) MIH_Update_IP Command

Type	Length	Parameters	
CNIP_Request	Variable	source IP	destination IP
		statusDeterminationNumber	

(c) CNIP Request

Type	Length	Parameters	
CNIP_Response	Variable	source IP	destination IP
		Master-Slave (Boolean)	

(d) CNIP Response

3.3. The Design of PoS

The basic function of the PoS is helping the MN to find its IS during the information query procedure. Figure 2 shows the intelligence of the enhanced PoS for simultaneous mobility. The enhanced PoS may receive two new MIH messages: MIH_Get_Information.CNIP_Request, and MIH_Update_IP.

- MIH_Get_Information.CNIP_Request received: The PoS seeks for the CN's latest IP address. If the PoS has buffered the MIH_Update_IP which is sent by CN, the PoS will perform the Master-Slave Determination procedure. After the procedure completed, if the MN is the master, the PoS will respond the MIH_Get_Information.CNIP_Response to the MN; else if the MN is the slave, the PoS will reply nothing to the MN.
- MIH_Update_IP received: The PoS buffers the message and triggers the Buffer Timer. The PoS stores the latest CN's IP address and the CN's statusDeterminationNumber. The Buffer Timer was designed to be in the PoS to save the memory space. In order to ensure the MN can get the CNIP report, the time of Buffer Timer must be defined. We will illustrate the Buffer Timer in Section 4.

3.4. The Design of MN

The design of IEEE 802.21 based MN can be referred to the concept of the Mobility Manager (MM) [3]. In addition to the functions such as power management module, user policies module, and handover decision module, we create the new module called handover execution as shown in Figure 3.

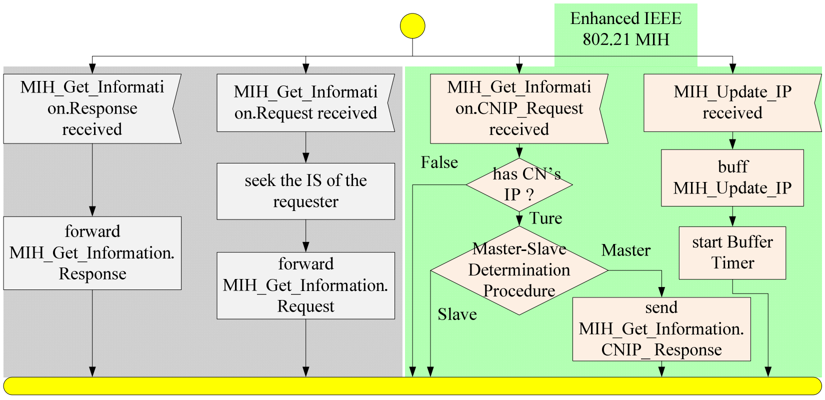

Figure 2. Intelligence of the Point of Service

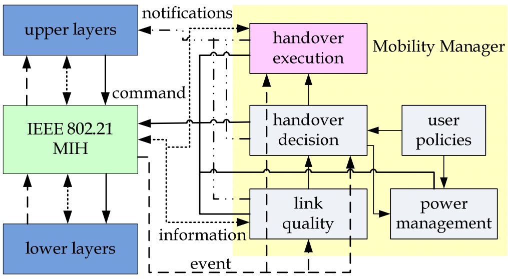

Figure 3. Modules of the Mobility Manager

The main function of the handover execution module is to resolve the simultaneous mobility problem. It uses MICS and MIES to communicate with other layers and uses MIIS to request the CNIP report. Figure 4 shows the intelligence of the Mobility Manager.

The other function of the handover execution on the MM in the MN is to inform the IP address of its PoS to the CN. The MIH event: MIH_Link_PDU_Transmit_Status can be used to notify the MM when there is a connection established with the MN. After receiving the MIH_Link_PDU_Transmit_Status.indication, the handover execution sends the MIH_Update_PoS message to the CN. When the CN starts handover, it sends the MIH_Update_IP message with the IP address of the MN's PoS as the destination.

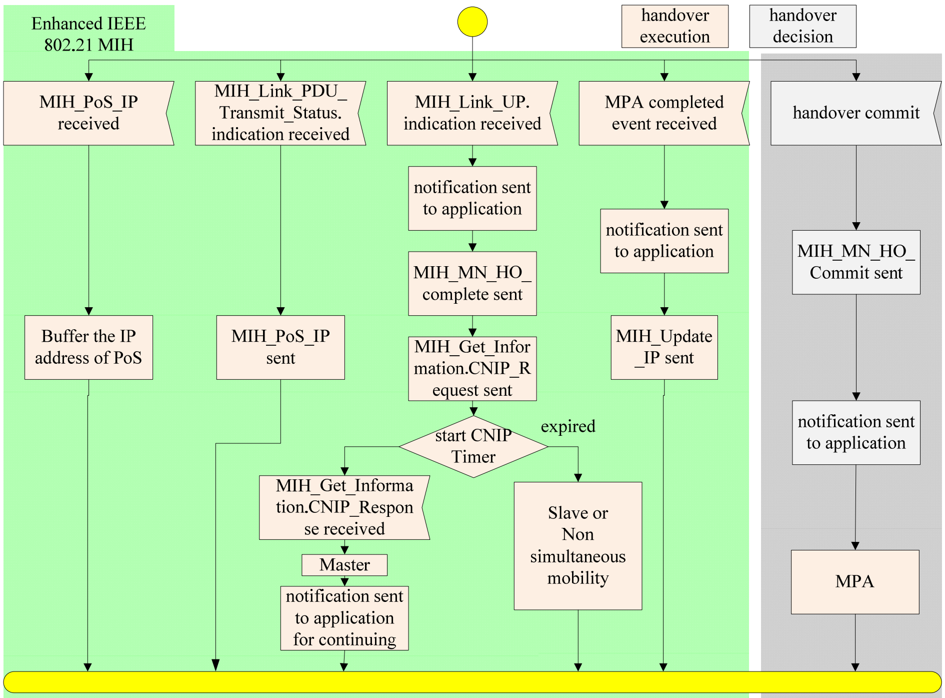

Figure 4. Intelligence of the Mobility Manager

The MPA mechanism helps the MN to save the time of configuring new IP and authentication procedure. While the MM receives the MPA completed event, the handover execution notifies the application and sends the MIH_Update_IP message to the PoS of the CN. If the MM receives the MIH_Link_Up.indication, the handover execution notifies the application again and sends the MIH_MN_HO_complete to the network interface for releasing the old link. Then it delivers the MIH_Get_Information.CNIP_Request to the last PoS and starts the CNIP Timer (illustrated in Section 4). If the CNIP Timer is expired, it means that the CN is not moving simultaneously, or the MN is determined to be the slave in the Master-Salve Determination. Only when the MN receives MIH_Get_Information.CNIP_Response, its MM notifies upper layers to re-establish the session. The connection can be established by the SIP re-INVITE or the binding update.

3.5. Master-Slave Determination Procedure

In the simultaneous mobility scenario, both the MN and the CN may send the SIP re-INVITE or binding update to re-establish the session. We refer to ITU-T H.245 and adapt the Master-Slave Determination procedures to eliminate the racing condition [10]. As seen in Figure 5, when the MN and the CN send the MIH_Update_IP messages to their respective PoSs, the messages include their latest IP addresses and their statusDeterminationNumber. While the CNIP query is sent by the MN/CN, it must also contain the statusDeterminationNumber which the MN/CN had generated. The statusDeterminationNumber is a random value from 0 to 2^{24}-1. Then these PoSs will determine whether the MN or the CN is to be the master, and the PoS for the master replies the CNIP response.

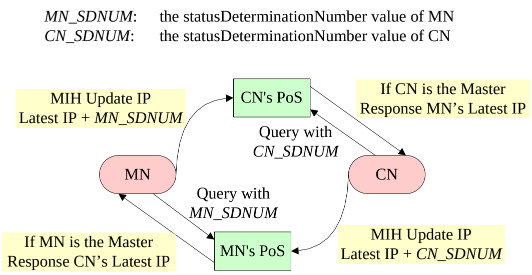

Figure 5. Master-Slave Determination procedure

The statusDeterminationNumbers of the MN and the CN are compared with each other using module arithmetic to determine which the master is. The status determination procedure is shown in Figure 6. If the difference between statusDeterminationNumbers modulo 2^{24} is equal or less than 2^{23}, the MN is the master, or else, the MN is the slave. If the MN is determined to be the master, the MN continues the normal session re-establishment procedure; if it is determined to be the slave, the MN cancels the re-INVITE request and waits for the CN to re-establish the session.

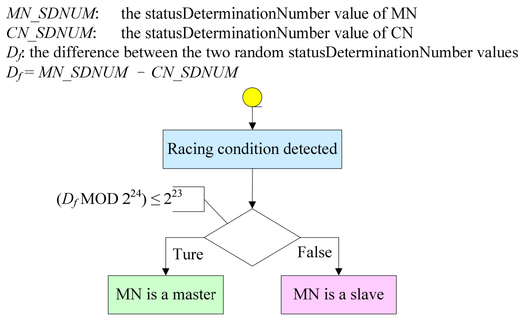

Figure 6. Status Determination Procedure

4. Scenario and Comparison

In order to demonstrate the ability of our proposal to shorten handover delays, we show the message flows of simultaneous mobility based on the enhanced IEEE 802.21 MIH with two mobility protocols, SIP-based mobility [11] and MIPv6 [12], and compare the performance with the IEEE 802.21 plus Wong's receiver-side mechanism for simultaneous mobility [7].

4.1. Scenario Description

Figure 7 describes the message flow of simultaneous mobility in the enhanced IEEE 802.21 MIH with SIP. Network i has the PoA i and the PoS *i*, *i* = 1, 2, 3, 4. There are two Information Servers (IS) which are separately located in the home networks of the MN and the CN. In this scenario, both the MN and the CN are the IEEE 802.21 enabled nodes. There is an existing data stream between them. The media stream is a SIP call using Real-time Transport Protocol (RTP). The figure shows the link quality module (LQ), the handover decision module (HD) and the handover execution (HE) in the Mobility Manager (MM) with two network interface (NI 1 and NI 2) of the MN. Because the behavior of the CN is similar to that of the MN, the figure only illustrates the modules in the MN.

The Buffer Timer on PoS 3 guarantees that the CN can receive the MN's latest IP address. Here, we use *X* to denote the transmission time for the existing data stream between the MN and the CN;

hence, the transmission time between the MN and PoA 3/PoS 3 is also X since PoA 3 and PoS 3 is closed to CN. And, we use Y denote the transmission time between the MN and PoA 1/PoS 1. So it is anticipated that $X > Y$. The handover time H is considered as the time between the handover initial and the handover completed (Steps 3a-12a). The Buffer Timer on the PoS must consider the handover time (H) and the transmission time of the CNIP request (Y). Therefore, the best Buffer Timer is $H+Y$.

In a case when the MN sends the MIH_Get_Information.CNIP_Request to PoS 1, the MN starts the CNIP Timer to wait the CNIP response from PoS 1. The time of the CNIP Timer can be assumed to be $H + X$, where H is the time for the CN to complete handover from network 3 to network 4 and X is the transmission time of MIH_Update_IP. If the MN waits for the time $H + X$ and still does not receive any CNIP response from PoS 1, the MN will know the CN is not moving simultaneously and stops waiting the CNIP response.

Figure 7 is easily adapted to illustrate the simultaneous mobility problem in the enhanced IEEE 802.21 MIH with MIPv6, just replacing SIP with MIPv6, and re-INVITE with binding updates.

4.2. Comparison

We compare the Enhanced IEEE 802.21 MIH with the IEEE 802.21 plus Wong's receiver-side solution for simultaneous mobility. In the receiver-side mechanism, the binding update or re-INVITE which is sent by the CN must go through the home server of the MN. Therefore, the MN's home server buffers the CN's latest IP address. If the MN moves and reregisters to its home server, the home server will forward the buffered message to the MN. However, the time for the re-registration procedure is unpredictable; hence, the time for the MN to get the CN's latest IP address is unpredictable too. Thus, the MN in the Enhanced IEEE 802.21 MIH can get the CN's latest IP address faster than the receiver-side mechanism does.

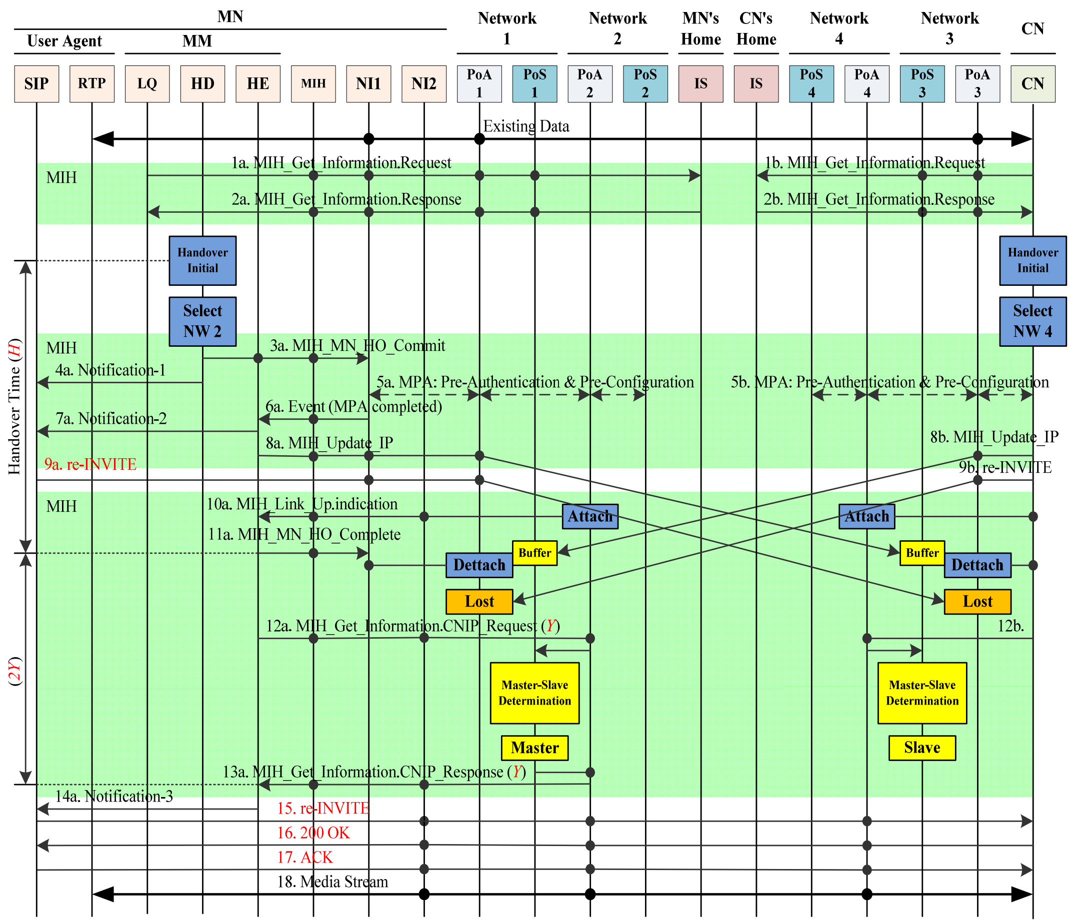

Figure 7. Message flow for simultaneous mobility in the Enhanced IEEE 802.21

As shown in Figure 8, we assumed the time for the MN to attach to new network and perform the re-registration process is an unpredictable time *U*. The total time between binding update initiation and the CN's latest IP address received from the home server by the MN in the receiver-side mechanism is *H+U+2X* because the transmission time between the MN and its home server (HS) is *X*. The time for the MN to get the CN's latest IP address from the PoS in the Enhanced IEEE 802.21 MIH is *H+2Y*, as shown in Figure 7, since the steps 10a, 11a, and 12a execute almost at the same time after the MN attaching to the new network. Compare the total handover time in the receiver-side mechanism with that in our proposal, *H+U+2X* > *H+2Y*. If the MN re-registers immediately while attaching to the new network, we can ignore the unpredictable time *U*. The total handover time in the receiver-side mechanism becomes *H+2X* and it is still greater than that in our proposal because of *X* > *Y*.

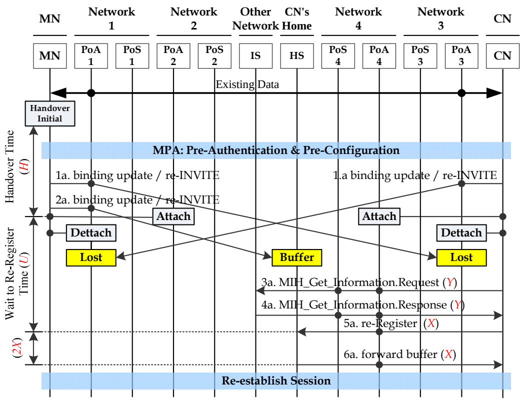

Figure 8. Message flow for simultaneous mobility in the IEEE 802.21 with Wong's receiver-side solution

5. Conclusions

In this paper we have presented the enhanced IEEE 802.21 MIH which can resolve the simultaneous mobility problem in the heterogeneous network. We defined two messages MIH_Update_PoS and MIH_Update_IP in MICS. We also defined the new type of information element called CNIP for MIIS in the information query procedure. In addition, we proposed the handover execution module in the Mobility Manager. The handover execution module handles the new functions of our proposal for simultaneous mobility. Furthermore, we proposed the Master-Slave Determination procedure to eliminate the racing condition of the re-establishment processes issued by the MN and the CN.

References

[1] IEEE P802.21/D10.00, "Draft Standard for Local and Metropolitan Area Networks: Media Independent Handover Services," April 2008.

[2] A. Dutta *et al.*, "Media-Independent Pre-Authentication Supporting Secure Interdomain Handover Optimization," IEEE Wireless Communications, vol. 15, no. 2, April 2008. pp. 55-64.

[3] F. Cacace and L. Vollero, "Managing Mobility and Adaptation in Upcoming 802.21-Enabled Devices," Proc. 4th Int'l. Wksp. Wireless Mobile Apps. And Services on WLAN Hotspots, September 2006, pp.1-10.

[4] Q.B. Mussabbir, W. Yao, Z. Niu, and X. Fu, "Optimized FMIPv6 Using IEEE802.21 MIH Services in Vehicular Networks," IEEE Transactions on Vehicular Technology, vol. 56, no. 6, November 2007. pp. 3397-3407.

[5] G. Lampropoulos, A.K. Salkintzis, and N. Passas, "Media-Independent Handover for Seamless Service Provision in Heterogeneous Networks," IEEE Communications Magazine, vol. 46, no. 1, January 2008, pp. 64-71.

[6] L. Eastwood, S. Migaldi, Q. Xie, and V. Gupta, "Mobility Using IEEE 802.21 in a Heterogeneous IEEE 802.16/802.11-Based, IMT-Advanced (4G) Network," IEEE Wireless Communications, vol. 15, no. 2, April 2008. pp. 26-34.

[7] K. D. Wong, A. Dutta, H. Schulzrinne, and K. Young, "Simultaneous mobility: analytical framework, theorems and solutions," Wireless Communications and Mobile Computing, vol. 7, no. 5, pp. 623-642.

[8] D. Forsberg *et al.*, "Protocol for carrying Authentication for Network Access (PANA)," IETF RFC 5191, May 2008.

[9] A. Rahman, U. Olvera-Hernandez, J.C. Zuniga, M. Watfa, and H.W. Kim, "Transport of Media Independent Handover Messages Over IP," draft-rahman-mipshop-mih-transport-03, IETF Draft, July 2007.

[10] ITU-T Recommendation H.245, "Control protocol for multimedia communication," May 2006.

[11] H. Schulzrinne and E. Wedlund, "Application Layer Mobility Using SIP," ACM MC2R, vol 4, July 2000.

[12] D. B. Johnson, C. E. Perkins, and J. Arkko, "Mobility Support in IPv6," IETF RFC 3775, June 2004.