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Fast Vertical Handover utilizing Sleep mode in WLAN and WiMAX Heterogeneous Networks

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***Abstract*-Vertical handover (VHO) latency needs to be minimized for successful handover especially in heterogeneous network environments. In this paper, we propose a VHO scheme to reduce handover latency in heterogeneous wireless networks composed of WLAN and WiMAX networks. The proposed scheme utilizes sleep mode operation of the WiMAX when a mobile station (MS) switches its serving network from WLAN to WiMAX. In this scheme, a MS is connected to its target network and enter to the sleep mode before performing VHO procedure. When the vertical handover occurs, a MS merely returns to the awake(normal) mode and resumes data transmissions with WiMAX. By these prior operations, VHO latency can be dramatically reduced. To evaluate the performance of proposed scheme, simulation has been designed and performed. Results show that VHO latency can be reduced from 57.15 ms of the conventional scheme to 4.28 ms by the proposed one.**

Keywords: Sleep mode, Vertical handover, WiMAX, WLAN

I. INTRODUCTION

Next generation wireless networks need to provide higher data rate and support mobility in a seamless manner. To provide a solution to these demanding needs, various methods have been proposed. One is to integrate conventional networks such as WLAN, WiMAX and other 3G services [1][2], then we can take advantage of the networks all at once.

In heterogeneous networks, a mobile station (MS) needs to switch its serving network to maintain connectivity or to improve service quality. Therefore, vertical handover (VHO) is one of the major issues to be prepared for the success of heterogeneous networks [3]. When a MS performs VHO, it needs to exchange more information and takes more time to switch their connection than the case of the horizontal handover (HHO) [4]. However, long handover latency can make a MS to be disconnected from its serving network and failed in handover. Therefore we need to minimize VHO latency as much as possible.

Currently, there have been studies to reduce the VHO latency to the level of the HHO. For example, dual-mode handover scheme was proposed to reduce the service disruption time [5]. This work suggested that a MS activates both interfaces only during the handover period, and decides when to perform handover on the basis of two pre-defined threshold values and hysteresis margin. In this case, network entry procedure is performed again and again whenever VHO is necessary. In [6], a cross-layer vertical handover (CVH) decision model was proposed to reduce VHO latency. In this work, a match-maker service, that is shim-layer in architecture of the CVH model, gathers information related to handover from multi-layer, and then makes an optimal decision when to perform VHO. However, it may need major modification of existing system standards to apply this scheme.

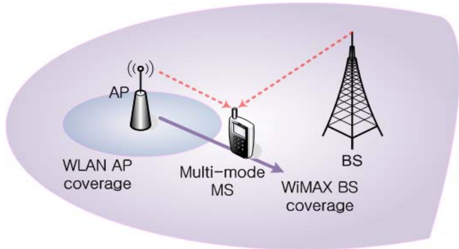


Figure 1. VHO from WLAN to WiMAX

In this paper, we propose a scheme to reduce VHO latency, when a MS switches its serving network from WLAN to WiMAX as shown in Fig. 1. The proposed scheme utilizes the operation of the sleep mode defined already in the standard [7]. Similar idea has been outlined in [8], however, in this paper we propose detailed VHO procedure utilizing the sleep mode, and we also analyze the performance of the VHO latency in detail based on protocol procedures specified by existing system standards. In this scheme, a MS being connected to WLAN also connects to WiMAX and then enters the sleep mode. When VHO becomes necessary, the MS merely returns to the awake mode from the sleep mode. In this way the VHO latency can be dramatically reduced by omitting some of network entry procedures to WiMAX. In addition, we propose simplified network entry procedures through sharing the information between networks, and utilizing the information exchange process defined in the IEEE 802.21 Media Independent Handover (MIH) standards [9].

The rest of this paper is organized as follows. In section II, we present two methods applied to the proposed VHO scheme. The sleep mode operation defined in WiMAX, and the way of applying it to VHO are described in Section III. Then the proposed VHO scheme is described in Section IV. Numerical results and discussions to show the gain of the proposed scheme are presented in Section V. Finally, Section VI concludes the paper.

II. THE PROPOSED VHO SCHEME

We first consider the case in that a MS performs entire network entry procedure when VHO occurs. A MS performs entire network entry procedure as described in Fig. 2(a) and start data transmission with a specific

(a) (b)

Figure 2. Simplified network entry procedure

WiMAX base station (BS), after disconnection with its serving WLAN access point (AP). We consider this case as a "*Conventional*" VHO scheme.

To reduce the VHO latency time, we have considered two methods. As the first one, we suggest that a MS performs VHO with simplified network entry procedure, on the assumption that WLAN and WiMAX networks are tightly coupled and some information related to VHO can easily be shared between two networks [10]. Then, a specific BS can acquire information related to network entry process (e.g., BSID , existence of neighbor BSs, and association parameters) to WiMAX through WLAN AP. Fig. 2(b) shows that the network entry procedure can be simplified using these parameters obtained beforehand. In this way, a MS can perform the network entry procedure which is composed only of synchronization, ranging and registration. In addition, the serving BS provides a MS with unique ranging code and dedicated transmission opportunity. Therefore, the raging process time can also be reduced by applying non-contention based ranging in this case, since a MS perform shorter ranging process than conventional contention-based one.

As the second one, we propose a scheme in that a MS performs VHO utilizing the sleep mode. When a MS can be connected to both WLAN and WiMAX, we assume that it can send and/or receive data with WLAN AP, while enters to the sleep mode with maintaining a connection with a specific WiMAX BS. When a MS need to execute VHO, it just performs wake-up process without performing network entry procedures to WiMAX.

In consideration of applying those methods, two main ideas applied to our VHO scheme are as follows: (1) By sharing the information related to VHO between networks, we can simplify the network entry procedure, and also can reduce the VHO latency; and (2) By applying the sleep mode to VHO, a MS just performs wake-up process when VHO occurs, and the VHO latency can dramatically reduced as compared with the conventional scheme.

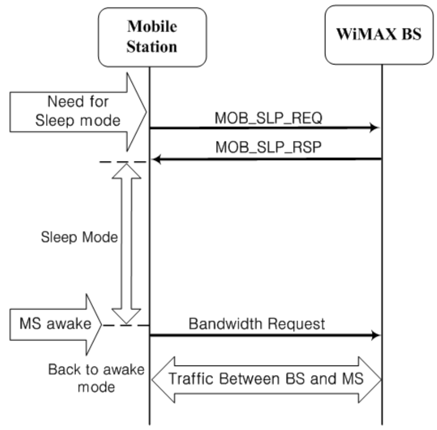


Figure 3. Sleep mode operation in WiMAX

III. APPLYING THE SLEEP MODE TO VHO

In this section, we first make some assumptions on both MSs and networks, which are required for applying sleep mode to perform VHO. We assume that MSs are multi-mode with WLAN and WiMAX interfaces. However, a MS cannot send and/or receive data to both networks at one time. We also introduce the sleep mode operation defined in WiMAX. After that, we suggest the method how to utilize it for VHO from WLAN to WiMAX.

A. Sleep mode operation defined in WiMAX

The main objective of the sleep mode is reducing energy consumption to extend operational lifetime of MS, when there is nothing to send and/or receive between a MS and its serving BS. Furthermore, it can reduce bandwidth utilization by releasing its radio resources in pre-defined intervals.

A MS registered with a specific WiMAX BS can be in a operational mode, for example, awake (normal) mode, sleep mode, or idle mode. A MS in the awake mode can send and/or receive data packets according to the scheduling of BS. On the other hand, a MS in the sleep mode can be absent from its serving BS during pre-negotiated intervals. Moreover, a MS can perform some operations such as scanning neighbor BSs, signaling with other BSs.

Fig. 3 illustrates the sleep mode operation defined in WiMAX. Before entering to the sleep mode, a MS informs the necessity of the sleep mode to its serving BS using sleep request message (MOB-SLP-REQ). After that, it receives response message (MOB-SLP-RSP) from the serving BS and enters to the sleep mode. When exchanging these messages, a MS and its serving BS can negotiate two pre-negotiated time intervals, namely, sleep window and listening window. During the sleep window, a MS basically can turn off most of its circuits in order to minimize energy consumptions. If any packet(s) destined to a MS arrive at a BS, these packets are buffered. During a listening window, a MS waits for a traffic indication message (MOB-TRF-IND), which indicates whether there had been any buffered packet(s) during the previous sleep window interval. Using this message, a MS can decide whether or not to stay in the sleep mode.

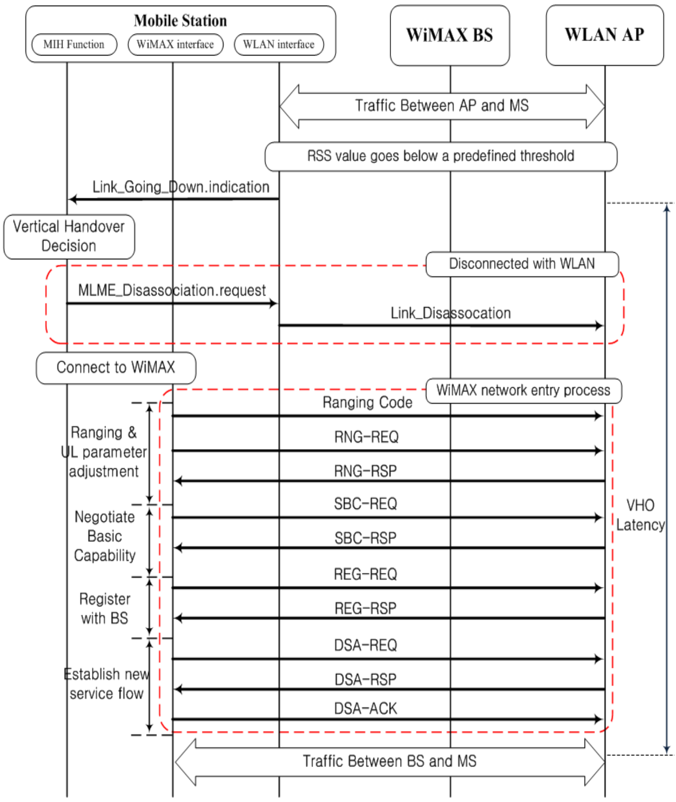


Figure 4. Conventional VHO Procedure

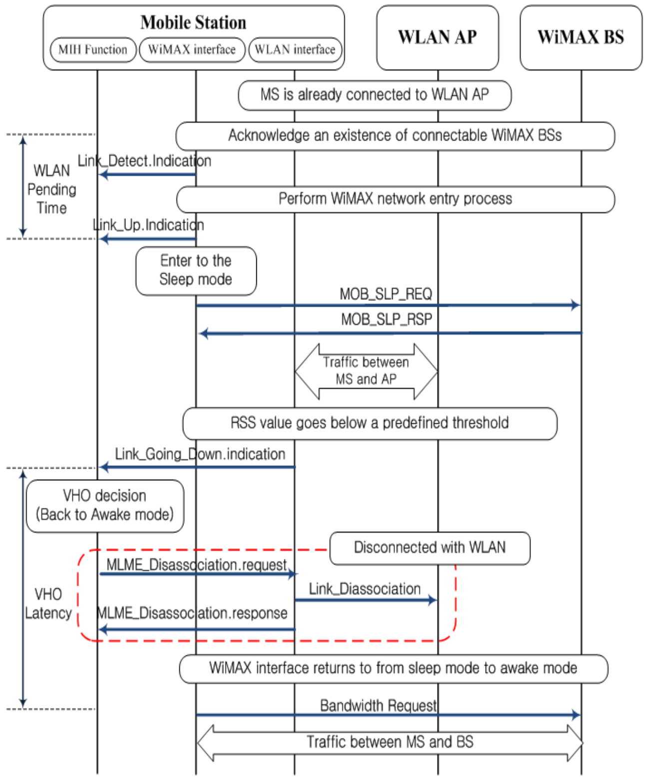


Figure 5. VHO Procedure utilizing the sleep mode

On the other hand, a MS can wake up prematurely during the sleep window to start uplink data transmissions by necessity. In this case, a MS should return to the awake mode immediately and send a bandwidth request message to its serving BS. After that, a MS can send data to its serving BS. In this paper, we apply this procedure to VHO procedure.

B. Method of applying the sleep mode to VHO

We proposed that a MS can perform the network entry procedure to WiMAX before performing VHO in order to reduce the VHO latency. To perform these prior operations, we assume that a WLAN interface can defer data transmissions with a serving AP for a while. We consider this time as a "*WLAN Pending Time*". Applying the sleep mode to VHO, a MS should connect to their target network and enter the sleep mode before performing VHO. When VHO become necessary, a MS just need to return to the awake mode and resume data transmissions by sending a bandwidth request message to WiMAX BS. Due to these prior operations, VHO latency from WLAN to WiMAX can be dramatically reduced.

IV. THE PROCEDURES OF VHO

In this section, we first describe the conventional VHO procedure, then the procedures of the proposed scheme. The proposed scheme has two cases. The first one is that we use both of simplified network entry method and the sleep mode operation to the VHO procedure. The other one is for the case that the only sleep mode operation needs to be applied. In this case, the VHO can be performed simply by returning to the awake mode from the sleep mode.

A. Conventional VHO Procedure

Fig. 4 shows the VHO procedure utilizing conventional scheme, when a MS change its serving network from WLAN network to WiMAX network. At first, WLAN interface informs the necessity of performing VHO using the Link_Going_Down.indication message defined in IEEE 802.21 MIH standards. After the MIH function (MIHF) decides when to perform VHO, WLAN interface disconnects with its serving AP and WiMAX interface performs the network entry procedure (e.g., scanning, synchronization, ranging and registration) defined in WiMAX. After that, a MS can send and/or receive data with a specific BS. In this case, we assume that a MS already gets the information about the existence of neighbor BSs and available radio resources.

B. Proposed VHO Procedure

Fig. 5 shows VHO procedure for the first VHO case. We assume that a MS is within the coverage of a WLAN AP, and exchanges data packets with its serving AP. Preparing fast VHO to WiMAX network, a MS obtains information related to network entry procedure to WiMAX periodically. If a MS can connect to WiMAX BS, WiMAX interface performs simplified network entry procedure to a specific BS while deferring data transmissions with its serving AP. After this WLAN pending time, WiMAX interface enters to the sleep mode and WLAN interface resumes data transmissions with its serving AP.

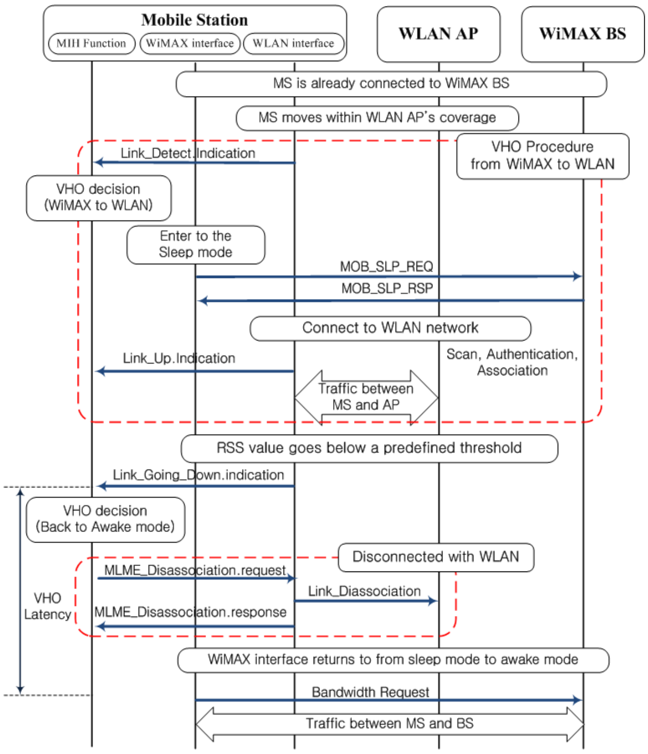


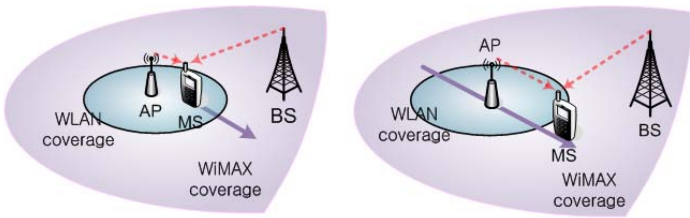
Figure 6. VHO Procedure utilizing the sleep mode (With no WLAN Pending)

When the received signal strength from serving AP goes below pre-defined threshold, WLAN interface informs the MIHF of a necessity of the VHO. At this moment, it uses Link_Going_Down message similar to conventional one. After that, WLAN interface disconnect with AP and WiMAX interface just change its mode from the sleep mode to the awake mode. And after sending bandwidth request message, a MS can communicate with target BS using allocated bandwidth.

When a MS has ever been connected with WiMAX before being connected to WLAN, it may not need to perform the network entry procedure anymore. In this scheme of the second VHO case, the procedure becomes even simpler. The VHO can be performed simply by returning to the awake mode from the sleep mode. Fig. 6 shows VHO procedure for the case.

TABLE I
SYSTEM PARAMETERS AND MODELS

Parameters and Models	Description
Propagation Model	Two-ray Ground
Antenna Model	Omni-directional Antenna
Interference Queue	Drop-tail Queue
Queue Length	50 Packets length
Packet Type	CBR
Frame duration	5 ms
Modulation Scheme	OFDM, 16-QAM, R=3/4
Velocity of MS	2 m/s
WLAN AP Coverage	50 m
WiMAX BS Coverage	1 km



(a) Scenario I (b) Scenario II

Figure 7. Simulation Scenarios

V. PERFORMANCE EVALUATION

A. Simulation Environments

To evaluate the performance of the proposed VHO scheme, we designed and performed a simulation using NS-2. In the simulation, the heterogeneous network is consists of a WLAN AP and a WiMAX BS, and the coverage of the AP is fully covered by that of the BS. The system parameters and models applied in this simulation are listed in TABLE I. Fig. 7 shows two simulation scenarios. The first VHO case needs to be applied in the scenario I. Scenario II shows an example where the second VHO case can be applied.

We estimated the VHO latency in link-layer to evaluate the performance of the proposed scheme. As a performance measure, the VHO latency is defined as a time interval between the time to receive the Link_Going_Down message and the time to resume data transmissions with a target network. In case of the conventional VHO scheme, a MS can resume data transmissions after establishment of new service flow with WiMAX networks. In case of the proposed one, it resumes data transmissions after sending a bandwidth request message to its serving BS. To compare the result of the proposed scheme, we also evaluated the performance of the conventional one.

B. Simulation Results

In case of the conventional scheme, the VHO latency is an estimated 57.15 ms. This is the case that no collision takes place during ranging process in network entry procedure to WiMAX. If collisions occur, the VHO latency may increase significantly.

The WLAN pending time for connection with WiMAX is measured as 30.01 ms. The time which is spent for wake up procedure from sleep mode to awake mode is achieved about 4.28 ms. In scenario I, the WLAN pending time may be considered as part of VHO latency. Consequently, the total VHO latency can be regarded as 34.29 ms. Even in this case, VHO latency is still much shorter than that of conventional VHO scheme.

In scenario II, results show that the VHO latency can be dramatically reduced to 4.28 ms by applying the second VHO procedure. This means the VHO latency can become much shorter to 7.5% of conventional scheme by utilizing the proposed one in this paper.

VI. Conclusion

In this paper, we propose a novel VHO scheme utilizing the sleep mode operation in WiMAX. The main objective of the proposed scheme is to reduce the VHO latency as much as possible. The methods which induce shorter VHO latency in the proposed scheme are simplified network entry procedure through sharing the information between networks, and applying the sleep mode operation.

With the proposed scheme, the VHO latency can be dramatically reduced to 4.28 ms from 57.15 ms of the conventional scheme. Even for the case that the WLAN pending needs to be performed and the time of 30.01 ms is considered as part of the VHO latency, it is shown that the overall latency can be 34.29 ms, much shorter than that of the conventional scheme.

The proposed scheme is shown to be very efficient to make the VHO more successful. It may also be applied to the heterogeneous networks not only composed of WLAN and WiMAX, but also composed of WiMAX and other networks.

Acknowledgment

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