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VOSHM - A Velocity Optimized Seamless Handover Mechanism for WiMAX Networks

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Abstract

For seamless handover in heterogeneous wireless networks, service continuity and minimal handover disruption time are the primary requirements. The emerging Media Independent Handover (MIH) standard proposes to address these requirements through the introduction of link performance prediction features. In particular the MIH Event Service introduces a *Link_Going_Down* event which utilizes L2 performance characteristics to trigger predictive events. While the MIH standard proposes a framework by which L2 events can be communicated to the upper layer, it does provide detail on the performance characteristics which trigger these events. In this paper, we design a MIH based Velocity Optimized Seamless Handover Mechanism (VOSHM) for WiMAX networks. We analyse how the handover probability value, which is a critical parameter used to trigger link going down event, is effected by the velocity of the mobile node. A number of simulation scenarios illustrating handover between WiMAX and 3G networks are evaluated. Our results indicate that VOSHM can reduce more than 95% handover delay in comparison to without utilizing the Link_Going_Down trigger.

Keywords: MIH, IEEE802.21, IEEE 802.16, WiMAX, Handover

1 Introduction

Wireless Networks have been developed rapidly during the last decade and have become widely adopted as many device manufacturers integrate more network interfaces into their devices. Many cell phone models support both Wi-Fi [1] and third generation (3G) wireless networks. Notebook computers are available with built-in support for Wi-Fi, WiMAX [2], and 3G. As this trend towards multi-interface devices continues, the need for sophisticated resource and mobility management mechanisms arise. Media Independent Handover (MIH) is a draft standard under development by the IEEE 802.21 working group [3]. MIH proposes to support the seamless session continuity during network migration. It defines a framework which significantly improves handover performance between heterogeneous network technologies. It also defines a set of tools to exchange information, events, and commands to facilitate handover initiation and handover preparation. IEEE 802.21 does not attempt to standardize the actual handover execution mechanism. Therefore, the MIH framework is equally applicable to systems that employ mobile IP at the IP layer as to systems that employ Session Initiation Protocol (SIP) at the application layer [14].

In this paper, we design a Velocity Optimized Seamless Handover Mechanism (VOSHM) for WiMAX networks. In particular we focus on the predictive Link_Going_Down event which relies on a fast handover mechanism using L2 triggering. Implementations specified by the National Institute of Standards in Technology (NIST) propose a handover probability value which is calculated using received signal strength and the threshold of received signal strength to determine when Link_Going_Down should be triggered. This paper focuses on the optimization of the calculation of the handover probability value considering the Mobile Node's (MN) velocity. Several simulated scenarios are undertaken which utilize NS2 [4] and the WiMAX mobility package from NIST [5]. Our results indicate that handover time reductions of up to 95% are achievable using the VOSHM approach.

2 Related Work

In recent years, research had focused on MIH seamless horizontal and vertical handovers in heterogeneous networks. In [14], authors describe and discuss the design considerations for a proof-of-concept IEEE 802.21 implementation and share practical insights into how this standard can optimize handover performance. [12] focuses on the MIH interfaces specifications in relation to the two emerging future mobile communication network technologies, WiMAX and 3G-LTE/SAE. In [9], authors design an enhanced Media Independent Handover Framework (eMIHF), which extends IEEE 802.21 by allowing for efficient provisioning and activation of QoS resources in the target radio access technology during the handover preparation phase. [7] focuses on how IEEE 802.21 supports seamless mobility between IEEE 802.11 and IEEE 802.16. [6] discusses how MIH can enhance mobility management; the authors evaluate mobile WiMAX via simulating its capacity to support real time applications in high-speed vehicular scenarios and assesses the potential of using cross-layer information made available by MIH. [13] presents a simulation study of handover performance between 3G and WLAN access networks showing the impact of mobile users' speeds, the mobile devices are based on the IEEE 802.21 cross layer architecture and use WLAN signal level threshold as handover criteria.

A number of studies have investigated handover algorithms to optimize network migration. [8] develops a vertical handoff decision algorithm that enables a wireless access network to not only balance the overall load among all attachment points but also to maximize the collective battery lifetime of MNs. Handover performance and its impact on real time applications are investigated in [10], authors investigate the use of signal strength as part of the Link_Going_Down trigger to improve the handover performance and propose methods to set appropriate thresholds for the trigger. [11] proposes a link trigger mechanism which can be applied to IEEE 802.21 for seamless horizontal and vertical handovers in heterogeneous wireless networks which is adaptively and timely fired in accordance with the network conditions. [15] and [16] propose a new predictive handover framework that uses the neighbor network information to generate timely the link triggers so that the required handover procedures can appropriately finish before the current link goes down. [17] proposes a novel architecture which is called Seamless Wireless internet for Fast Trains (SWiFT), it relies on a fast handoff mechanism by L2 triggering using a handover probability value evaluated by high speed movement and received signal strength to decide handoff.

3 Media Independent Handover Background

The Media Independent Handover (MIH) is a standard being developed by IEEE 802.21 which aims at enabling handovers between heterogeneous networks by defining a networks model which includes different entities with specific roles and supports several services [6]. The importance of MIH derives from the fact that a diverse range of broadband wireless access technologies are available and in the course of development, including GSM, UMTS, CDMA2000, WiFi WiMAX, Mobile-Fi and WPANs. Multimode wireless devices that incorporate more than one of these wireless interfaces require the ability to switch among them during the course of an IP session, and devices such as laptops with Ethernet and wireless interfaces need to switch similarly between wired and wireless access. MIH provides mechanisms to prepare the target network before handover execution occurs, reducing latency [7]. MIH defines the Media Independent Event Service for the propagation of events, the Media Independent Command Service which allows the MIH user to issue specific actions on lower layers, and the Media Independent Information Service to provide network details as shown in Figure 3-1 and Figure 3-2. [3]

MIH Event Service include many kind of events which will be sent to the multiple higher layer entities, higher layers entities can register to receive event notification from a particular event source. The MIH Function can help in dispatching these events to multiple destinations. These events are treated as discrete events. As such there is no general event state machine. However in certain cases a particular event may have state information associated with it, such as the Link_Going_Down event. A Link_Going_Down event is usually used to indicate a link going down in advance and notify the upper layers for making a preparation to handover. For example, when the battery level of the terminal is low and the currently used link will disconnect soon, a Link_Going_Down event may be generated in order to prepare for a handover to the module that has lower power consumption (As an example, a GSM module usually has lower battery consumption than a WiFi module) to lengthen the usable time of terminal.

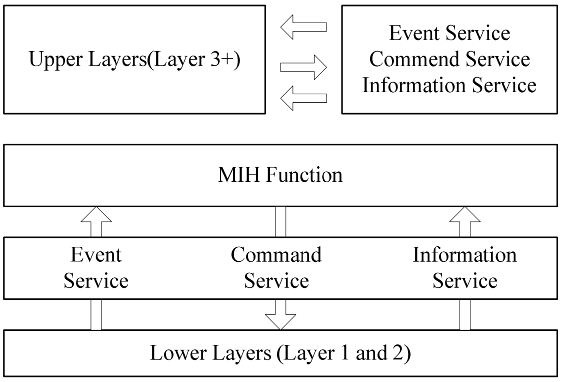

Figure 3-1 MIH Function

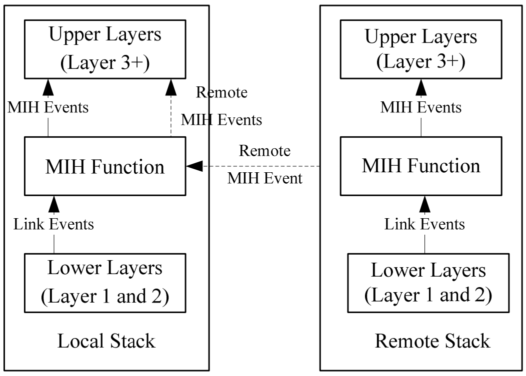

Figure 3-2 Remote and Local MIH Event Service

4 Velocity Optimized Seamless Handover Mechanism (VOSHM)

For seamless handover in heterogeneous wireless networks, service continuity and minimal handover disruption time are the primary goals. A Link_Going_Down event implies that a Link_Down event is imminent within a certain time interval. Therefore, the effectiveness of the Link_Going_Down trigger is critical in achieving this goal. If a Link_Down event isn't received within specified time interval then actions due to a previous Link_Going_Down may be rejected [3], as in Figure 4-1, those events will minimize connectivity disruption during link switching and influence the handover performance. The timing of a the triggering of a Link_Going_Down event is a tradeoff between (a) a delayed trigger, which will lead to a long service disruption, resulting in packet lost and delay (b) an early trigger, which may force the handover to a new interface even when the link quality of the old interface is still sufficient to decode data [15].

Previous Link_Going_Down algorithms are based on pre-defined thresholds associated with the received signal strength. If the current received signal strength's value crosses the received signal strength threshold ($P_{rxthred}$), then the Link_Going_Down trigger is generated and the handover process starts [11], as shown in Figure (4-2). Based on the Fritz path loss model [18] in (4.1), the received signal strength depends on the path loss exponent and the distance from the transmitter which are both time-varying parameters.

$$\left[\frac{P_{rx}(d)}{P_{rx}(d_0)}\right]_{dB} = -10\beta\log(\frac{d}{d_0}) \tag{4.1}$$

In (4.1), d is the distance between the receiver and the transmitter expended in meters, $P_{rx}(d)$ is the received signal strength in watts at distance d, β is the path loss exponent, and $P_{rx}(d_0)$ is the received signal strength at the close-in reference distance d_0. The generation of Link_Going_Down trigger is based on a weighted average based measurement algorithm of Received Signal Strength Indicator (RSSI). In VOSHM, we use link confidence to measure the probability of the handoff once the received signal strength goes below the weighted signal strength threshold [17], as shown in Figure 4-2.

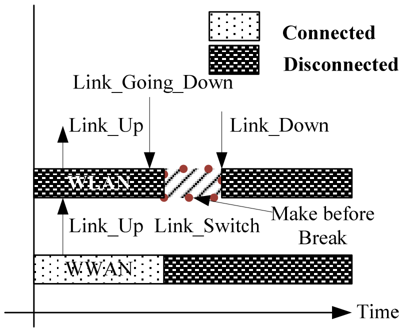

Figure 4-1 MIH Event Servers Triggers

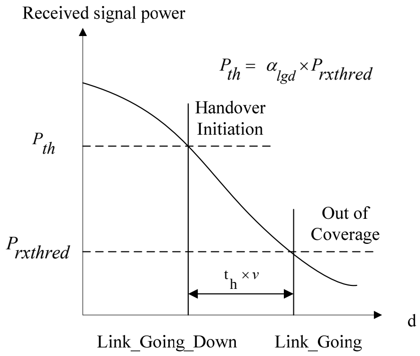

Figure 4-2 Link_Going_Down Event

R_x is the received signal strength, it is measured and the average value of the received signal strength (R_{xavg}) is calculated by averaging the signal strength of the past few received symbols. R_x is recorded in each successfully received packet to represent the network station of the current MN. R_{xavg} will be updated in (4.2), the $R_{xavg}.new$ is the current average value of the received signal strength, and the $R_{xavg}.old$ is the average value of the received signal strength which was calculated last time. The value of α is a factor, the higher value α is, the more influence of current received signal strength is, and also the less influence of last time's average received single strength is. The factor of α will help to avoid the random influence of *new_val*. Here we set the α with the default value of 1, which means only consider the influence of the current received signal strength, and ignore the influence of the last time's average received single strength.

$$R_{xavg}.new = \alpha \times new\_val + (1 - \alpha) \times R_{xavg}.old \quad (4.2)$$

The weighed strength threshold P_{th} is calculated in (4.3), here the $P_{rxthred}$ is the threshold level of the received signal strength. α_{lgd} is the anticipation factor, which is defined as a configurable constant larger than 1.

$$P_{th} = \alpha_{lgd} \times P_{rxthred} \quad (4.3)$$

When the value of R_{xavg} is larger than P_{th}, usually the packet can be successfully received. When the R_{xavg} is less than P_{th}, (4.4) will be used to calculate the handover probability. A 100% handover probability would indicate certainty that the link is definitely going down within the specified time interval. When the handover probability is less than $confidence_{th}$ (here we use the value which is 80%), it will trigger the Link_Down event, and the handover will happen.

$$probability = \frac{P_{th} - R_{xavg}}{P_{th} - R_{rxthred}} = \frac{\alpha_{lgd} \times R_{rxthred} - R_{xavg}}{(\alpha_{lgd} - 1) \times R_{rxthred}} \quad (4.4)$$

Now we find out how to set the value of α_{lgd} to get the best handover performance in the VOSHM. We know that the most important factor which will influence the Link_Going_Down trigger is the required handover time (t_h), as shown in Figure (4-2). In the t_h period, the Link_Going_Down trigger should be invoked prior to an actual Link_Down event by at least the time required to prepare and execute a handover [11]. And P_{th} is the received signal strength at the handover initiation time. So from the path loss model of (4.1), if the MN moves away from the base station with the speed of v, the t_h is derived as follows,

$$t_h = \frac{d_0}{v}\left(\frac{P_{rx}(d_0)}{P_{rxthred}}\right)^{\frac{1}{\beta}}\left[1 - 1/\left(\frac{P_{th}}{P_{rxthred}}\right)^{\frac{1}{\beta}}\right] = \frac{d_0}{v}\left(\frac{P_{rx}(d_0)}{P_{rxthred}}\right)^{\frac{1}{\beta}}\left[1 - \frac{1}{\alpha_{lgd}^{1/\beta}}\right] \quad (4.5)$$

From (4.5), we can see that the t_h will be influenced by the value of v. To get the relationship between them, suppose the MN moved with two different speed v_1 and v_2, so that we can get v_1's handover time t_{hv1} and v_2's handover time t_{hv2} as follows,

$$\begin{cases} t_{hv1} = \frac{d_0}{v_1}\left(\frac{P_{rx}(d_0)}{P_{rxthred}}\right)^{\frac{1}{\beta}}\left[1-\frac{1}{\alpha_{lgdv1}^{1/\beta}}\right] \\ t_{hv2} = \frac{d_0}{v_2}\left(\frac{P_{rx}(d_0)}{P_{rxthred}}\right)^{\frac{1}{\beta}}\left[1-\frac{1}{\alpha_{lgdv2}^{1/\beta}}\right] \\ t_{hv1} = t_{hv2} \end{cases} \tag{4.6}$$

From (4.6), we can get the α_{lgdv1}'s value as follows. With (4.7), we set the appropriate factor of α_{lgdv2} with the moving speed of v_2 if given the values of v_1, and α_{lgdv1}.

$$\alpha_{lgdv2} = \frac{1}{\left[1-\frac{v_2}{v_1}\left(1-\frac{1}{\alpha_{lgdv1}^{\frac{1}{\beta}}}\right)\right]} \tag{4.7}$$

5 Simulation Design and Evaluation

5.1 Scenario Description

In order to test the performance of our VOSHM handover algorithm for WiMAX networks we use NS2 together with the NIST mobile package. Figure 5-1 shows the topological structure of the simulated network. There are 8 nodes, the Router (Node3) is the sender and the Mutiface node (Node5) is the receiver. There are two base stations in the networks, one is a WiMAX base station (Node6) (coverage is 500m) and the other one is a UMTS base station (Node1). The mutiface node has two interfaces, one is a WiMAX interface (Node 7) and the other one is a UMTS interface (Node2). In this test scenario, the Node3 starts sending a Constant Bit Rate (CBR) traffic stream with a packet size of 500 bytes at 0.02 second intervals at the beginning and the mutiface node will move out of the WiMAX coverage with different speeds of 1m/s (m/s: meters/second), 2m/s, 5m/s, 10m/s, 20m/s and 50m/s. (Here we have only considered speeds under 50m/s, more experiments for high speeds will be done in the future)

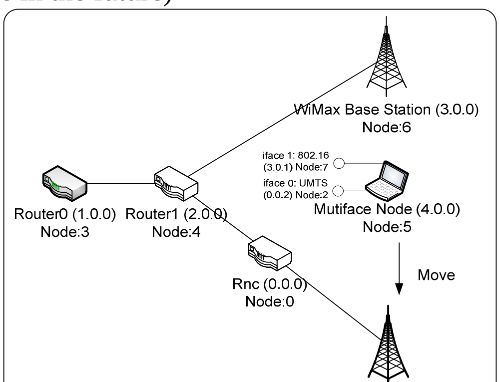

Figure 5-1 Topologic Diagram of the Network

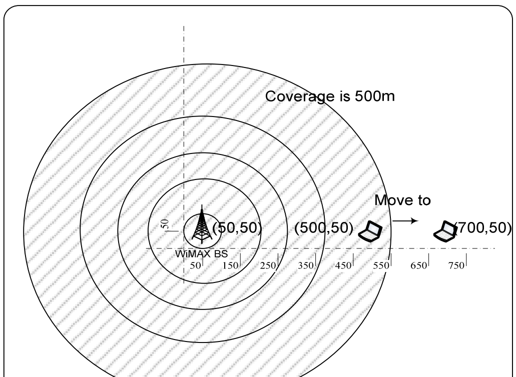

Figure 5-2 Location Diagram of the Network

In Figure 5-2, we can see the MN and WiMAX base station's location. The WiMAX base station is located at (50m, 50m), and the MN is located at (500m, 50m). In the test scenario, the MN will move from (500m, 50m) to (700m, 50m) with different speeds.

5.2 Test Results and Evaluation

In the above test scenarios, the MN moves far away from the WiMAX base station. In this way, handover occurs when the MN moves out of WiMAX network coverage. Using (4.7) we calculate the appropriate value of the α_{lgd}. We first calculate the optimal value of α_{lgd} when moving at fixed speed (e.g. 1m/s).

We define the handover start time (t_{start}) as the time of the last packet which is received through the WiMAX network. The handover end time (t_{end}) is also defined as the time of the first packet which is received through the UMTS network. Handover time ($t_{handover}$) is calculated as follows:

$$t_{handover} = t_{start} - t_{end} \quad (5.1)$$

To determine the optimal value of α_{lgd} when the speed of mobility is 1m/s, we first check the handover performance when α_{lgd}'s value is set between 1.000 ~ 1.050. From Table 5-1 and Figure 5-3 we can get the best performance when α_{lgd} is set with the value of 1.010. The reason for this value is because (1) the handover duration time is the shortest (2), the handover start time is very near to the normal handover (α_{lgd} =1.000) start time resulting in full utilization of the WiMAX network. We also note that handover duration time will not decrease obviously when the α_{lgd} is larger than this value.

α_{lgd}	Start Time (s)	End Time (s)	Handover Time (ms)
1.000	59.990355666	60.740015	749.659334
1.005	59.988127295	60.040015	51.887705
1.010	59.890879092	59.920015	29.135908
1.015	59.768472284	59.800015	31.542716
1.020	59.649604186	59.680015	30.410814
1.025	59.530185779	59.560015	29.829221
1.030	59.408425740	59.440015	31.58926
1.035	59.288470041	59.320015	31.544959
1.040	59.168813825	59.200015	31.201175
1.045	59.070462874	59.100015	29.552126
1.050	58.948617319	58.980015	31.397681

Table 5-1 Handover Start End Time (1m/s)

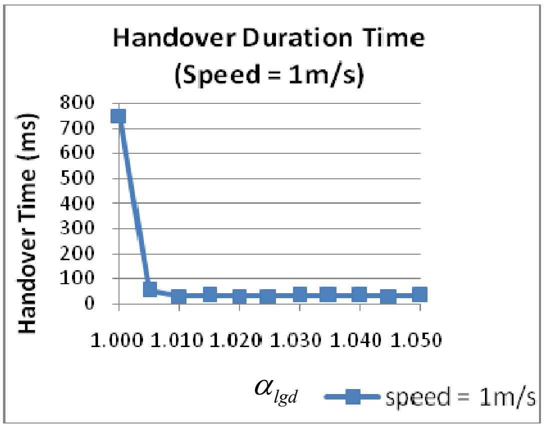

Figure 5-3 Handover Time (1m/s)

Using (4.7) with $\alpha_{lgdv1=}$1.010, and v_1=1m/s, we calculate the value of α_{lgd} with the speeds 2m/s, 5m/s, 10m/s, 20m/s and 50m/ (here we set the β with the value of 1).

Speed	2m/s	5m/s	10m/s	20m/s	50m/s
α_{lgd}	1.020	1.052	1.120	1.247	1.980

Table 5-2 α_{lgd}'s Value when Move with Different Speeds

Speed	α_{lgd}	Start(s)	End(s)	Handover Delay Time(ms)
2m/s	1.000	34.991138903	35.740015	748.8761
5m/s	1.000	19.989452051	20.760015	770.5629
10m/s	1.000	14.99012625	15.760015	769.8887
20m/s	1.000	12.48741909	13.240015	752.5959
50m/s	1.000	10.98886948	11.740015	751.1455

Table 5-3 Handover Start End and Delay Time without Link_Going_Down Trigger

Table 5-3 indicates the handover start, end and delay time without utilizing the Link_Going_Down trigger (α_{lgd} =1.000). Results show that the handover delay time is so long that it is higher than 700ms. High handover delay disrupts service continuity and degrades perceived quality of communication of active connections.

The total handover delay is comprised of two parts, $L2_{handover}$ and $L3_{handover}$.

$$t_{handover} = L2_{handover} + L3_{handover} \tag{5.2}$$

The L2 handover delay comprises of delay due to switching of the channel and network entry, it consists of the synchronization delay and ranging and registration latency, usually it is a constant value which link technology specified at all speeds and all α_{lgd}. However the L3 handover delay is not a constant value which can be reduced. The most important factor in L3 handover is the delay contributed due to the neighbor discovery mechanism [17]. Once a L2 connection is established, a Link UP is detected by the MIHF, which triggers a Router Solicitation (RS) message to discover the prefix of the new link. To reduce the L3 handover delay, the MN needs to finish the L3 handover before the current link breaks. L2 triggers can provide information about events which can help L3 and above entities better streamline their handover.

VOSHM uses the predictive Link_Going_Down event which relies on a fast handover mechanism using L2 triggering. Link_Going_Down trigger can be used to indicate “broken link is imminent” and notify the upper layers for making a preparation to start handover produce, it is used as a signal to initiate handover procedures, so the L3 handover can be done before the current link break. Also in VOSHM, the value of α_{lgd} is very important when the MN’s velocity is different; an appropriate value of α_{lgd} can help MN start handover neither too early nor too late.

Speed	α_{lgd}	**Start (s)**	**End (s)**	**Handover Delay Time (ms)**	**Improve (%)**
2m/s	1.020	34.888759115	34.920015	31.255885	95.33
5m/s	1.052	19.87101936	19.900015	28.99564	97.42
10m/s	1.120	14.85111704	14.880015	28.89797	98.07
20m/s	1.247	12.32923626	12.360015	30.77874	98.36
50m/s	1.980	10.71067168	10.740015	29.34332	98.57

Table 5-4 Handover Start End and Delay Time with Appropriate Value of α_{lgd}

Table 5-4 displays the handover results when using VOSHM which not only uses formula (4.7) to set the appropriate value of α_{lgd}, and also use (4.4) to calculate the handover probability and trigger the Link_Down when the handover probability is larger than 80%. Results indicate that the handover start time is close to the handover over start time when do not utilize the Link_Going_Down trigger (which means it use current network sufficiently) and also VOSHM reduces more than 95.33% handover delay time than without utilizing the Link_Going_Down trigger.

6 Conclusion and Future Work

In this paper, we design a MIH based Velocity Optimized Seamless Handover Mechanism (VOSHM) for WiMAX networks. In particular we focus on the predictive Link_Going_Down event which relies on a fast handover mechanism using L2 triggering. Implementations specified by the National Institute of Standards in Technology (NIST) propose a handover probability value which is calculated using received signal strength and the threshold of received signal strength to determine when Link_Going_Down should be triggered. This paper focuses on the optimization of the calculation of the handover probability value considering the Mobile Node’s (MN) velocity. We present results which illustrate that VOSHM can reduce more than 95% handover delay in comparison to the experiments results which do not utilize the Link_Going_Down trigger.

In the future, the mechanism could be improved in the following aspects: finding out other parameters which may predict the Mobile Node's location variation and trying to avoid the influence of the received signal strength random change on handover performance. Moreover, how to select the best candidate network needs to be researched in the next stage.

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