

Reduction of Handover Interruptions in Mobile WiMAX Based on Signal Strength and Distance

Mary Alatise, Mjumo Mzyece and Anish Kurien

Department of Electrical Engineering/French South African Institute of Technology (F'SATI)

Tshwane University of Technology, Private Bag X680, Pretoria 0001, South Africa

Tel: +27 12 382 4191, Fax: +27 12 382 5294

Email: alatisemary@gmail.com, {MzyeceM, KurienAM}@tut.ac.za

Abstract—Supporting mobility is one the major challenges in wireless networks. To support mobility in any wireless network, the application of an efficient handover control scheme is crucial. In hard handover scenarios in mobile WiMAX networks, a Mobile Station (MS) may experience handover disruptions and handover delays during transmission which could result in connection drops and waste of resources. In order to address some of these potential problems associated with hard handovers, a Relative Signal Strength with Threshold and adaptive Hysteresis and Distance (RSTH-D) scheme is proposed in this paper. This scheme seeks to initiate quick handover so as to reduce handover delays, avoid interruption of transmission and effectively utilise available radio resources. It is shown, through the simulation results obtained, that the proposed scheme has significant performance benefits compared to relative signal strength with hysteresis and threshold schemes. The performance of the various schemes is compared in terms of handover delay, handover probability and the average number of handovers.

Index Terms—Mobile WiMAX, handover, hysteresis

I. INTRODUCTION

WiMAX (Worldwide Interoperability for Microwave Access) is a promising emerging broadband wireless network standard. The IEEE 802.16e mobile WiMAX standard was developed from the previous IEEE 802.16-2004 fixed WiMAX standard [1, 2]. Mobile WiMAX supports mobility allowing users to move anywhere at any time and be served as long there is network coverage within the area.

Consequently an important amendment in IEEE 802.16e is the support for Handover (HO). The HO process maintains the required signal strength to support continuous data transmission for all types of applications by enabling the Mobile Station (MS) to switch from one Base Station (BS) to another. To perform handover efficiently, the MS scans all the Neighbour Base Stations (NBSs) and selects the most appropriate BS to be handed over to in order to avoid disconnection and maintain adequate quality of service (QoS). When a MS releases its connection from the Serving Base Station (SBS) and re-establishes its connection with the Target Base Station (TBS), a break in transmission is experienced during the process. This discontinuation of connection is referred to as handover interruption, and is

closely linked to the handover delay or handover latency [3]. It is necessary to minimise these effects as they lead to the degradation of signal strength and services. In mobile WiMAX, three major types of HO are defined: Hard handover (HHO), Macro Diversity Handover (MDHO) and Fast Base Station Switching (FBSS). The HHO is mandatory in mobile WiMAX, while MDHO and FBSS are optional [1, 4]. HHO is characterised by “break-before-make”. This implies that current radio resources are released before new resources are used. The MS releases its connection from the SBS before establishing a new connection to the TBS. The MS can only be connected to one BS at a time from which HO must take place. HHO is comparatively simple to implement, but suffers from handover delay and service interruptions issues that need to be addressed. For MDHO and FBSS, the MS is connected to multiple BSs, collectively termed as the Diversity Set (DS). For FBSS, the MS communicates with only one BS in the DS which is called the Anchor BS while for MDHO, the MS communicate with two or more BSs in the DS.

The remainder of this paper is organised as follows: Section II provides a brief overview of related work. Section III describes the conventional HO process in IEEE 802.16e. Section IV explains the proposed scheme in detail. The simulation scenario and performance analysis is presented in Section V and the conclusion is provided in Section VI.

II. RELATED WORK

The mobile WiMAX standard recommends, the Relative Signal Strength Indicator (RSSI) as basis for handover decision. However, handover schemes based on RSSI alone are not sufficient to reduce the number of handovers, handovers interruptions and handover delay [5]. In this paper, Relative Signal Strength (RSS) is a scheme that measures only the signal strength to initiate handover. The Relative Signal Strength with absolute Threshold and fixed Hysteresis (RSTH) scheme initiates handover only when the signal of the SBS drops below the absolute threshold value and when the signal strength of the TBS becomes stronger than the SBS by a hysteresis value. Redundant handovers caused by the ping-pong effect occur when the MS switches to the TBS and later returns to the previous BS continuously. To minimise the effect of ping-pong, the authors in [6] propose an adaptive handover decision algorithm based on the users' movement estimated from the

signal strength information. The proposed scheme is able to minimise redundant handovers.

A modification of the handover process for mobile WiMAX exploiting distance as another parameter to initiate fast handover has been considered by various authors. In [7], the authors use the Global Positioning System (GPS) to determine the MS position and calculate the distance between the BSs. The use of GPS provides accurate locations, but it is quite complex and costly to implement. It requires additional hardware on the MS which increases the cost of the MS device. A technique proposed in [8] requires adding new Downlink (DL) management messages in order to minimise service interruptions. This paper proposes to combine signal strength and distance to improve handover performance and overall QoS. The scheme seeks to minimise the previously discussed handover-related challenges in mobile networks.

III. CONVENTIONAL HANDOVER PROCESS

Handover (HO) in mobile WiMAX can be divided into two major phases: the Network Topology Acquisition phase and the Actual HO process [4]. The Network Topology Acquisition phase precedes the actual HO process which includes handover decision and initiation, synchronisation and ranging, cell re-selection and termination context.

The HO procedures are explained further as follows. The Base Station (BS) broadcasts information about the network using the Mobile Neighbour Advertisement (MOB_NBR_ADV) message. The message provides channel information for NBSs which is provided by each BS's own Uplink Channel Descriptor (UCD) message transmission. With the gathering of information by the BSs with the assistance of the backhaul network, the MS starts scanning to choose the most suitable BSs for the HO.

In the process of cell re-selection, the MS scans or associates with one or more BSs to determine a final selection of the TBS. The decision of HO may arise either from the MS or the SBS. When the MS decides HO, a Mobile MS HO Request (MOB_MSHO-REQ) message is sent [4]. Once a final decision is made on the TBS, the MS informs the SBS about the HO activity by sending a Mobile HO Indication (MOB_HO-IND) message. At this point, the MS breaks its association with the SBS and begins a new association with the TBS. To minimise handover delay, an efficient handover scheme must be employed at this stage. The next phase after selecting the TBS is the network re-entry. It includes the MS authorisation and registration with the TBS. At this phase the MS is fully connected to the TBS. Thereafter, the MS starts its normal operation with the TBS.

IV. PROPOSED SCHEME

The MS scans and selects the appropriate BS that guarantees the possibility of maintaining the connection among the adjacent BSs as shown in Figure 1. In this paper, the proposed handover initiation scheme is based on the Relative Signal Strength with Threshold and adaptive

Hysteresis and Distance (RSTH-D) technique. To initiate handover, the following conditions have to be met.

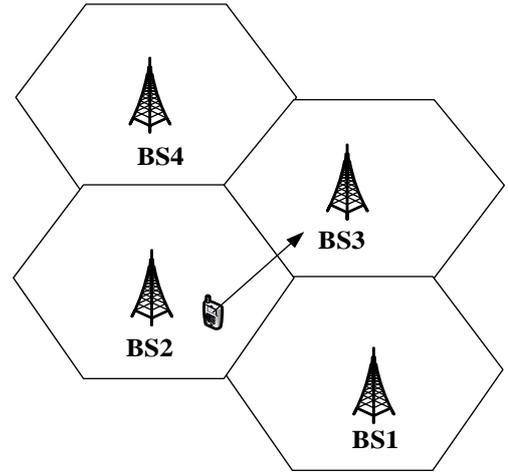


Figure1: Network Scenario

- The average RSS of the SBS drops below an absolute threshold value TH dB and the average RSS of the TBS becomes stronger than that of the SBS by a hysteresis HYS dB.
- The measured distance of the MS from the SBS must exceed that of the TBS by a threshold distance thd .

The two conditions can be expressed mathematically as follows:

$$(RSS_{SBS} < TH) \cap (RSS_{TBS} > RSS_{SBS} + HYS) \quad (1)$$

$$D_{SBS} > D_{TBS} + thd \quad (2)$$

V. SIMULATION SCENARIO AND PERFORMANCE ANALYSIS

A. Simulation Scenario

The three major factors that affect the propagation in a mobile WiMAX network are shadow fading, path loss and multipath fading. Multipath fading typically follows a Rayleigh distribution. The received signal strength measurement is averaged by using an exponential averaging window to alleviate the impact of multipath fading. The signal received by the MS is considered to contain only two components: shadow fading and path loss. Path loss is dependent on the distance between two locations and shadow fading is caused by large scale variations in the terrain profile along the path from the MS to the BS [9]. In this paper, the path loss propagation is modelled using the COST 231 model [10] for a medium-sized city and is given by:

$$Pl = 46.3 + 33.9 \log(fc) - 13.82 \log(h_{bs}) - a(h_m) + (44.9 - 6.55 \log(h_{bs})) \log d + CM \quad (3)$$

where Pl is the 50th percentile (median) value of

propagation path loss, fc is the carrier frequency (GHz), h_{bts} is the height of the BS, $a(h_m)$ is the mobile antenna gain function, h_m is the height of the MS, d is the radio path distance and CM is the correction factor (0 dB for the medium-sized city and suburban areas and 3 dB for metropolitan centres). The signal strength received by the MS from the SBS (RSS_c) and the adjacent BSs (RSS_i) can be expressed as follows, respectively:

$$RSS_c(k) = Pt_c - Pl - L_c \quad (4)$$

$$RSS_i(k) = Pt_i - Pl - L_i \quad i = 2, \dots, N \quad (5)$$

where Pt represents the transmitting power of the BS in dBm, Pl represents the path loss in dB, i is the number of NBSs, L_c and L_i represent the shadowing variables. N denotes the total number of NBSs. The signal is characterised by a log-normal distribution with zero mean and σ for the BSs given by:

$$\sigma = (1 - \exp(-2Vt_s / d0)) / 2\sigma_s \quad (6)$$

where σ_s represents the standard deviation of slow fading, V is the average velocity of the MS, t_s is the sampling rate and $d0$ is the correlation distance.

The relative average RSS is the difference between the average signal strengths from the SBS and the adjacent BSs. This is given as:

$$R(k) = RSS_c(k) - RSS_i(k) \quad (7)$$

where $k=1, \dots, D/ds$. D is the distance between adjacent BSs, ds is the sampling interval, RSS_c and RSS_i are the signal strengths received by the MS from the SBS and the NBSs, respectively. The received signal strength of Equations (4) and (5) are smoothed using an exponential window function in order to reduce the fading effects [11].

A handover algorithm with adaptive hysteresis value H , is proposed. This is given as [13]:

$$H = \max \left\{ \gamma \left(1 - \frac{d_{MS,SBS}}{R} \right)^\beta, 0 \right\} \quad (8)$$

where $d_{MS,SBS}$ is the distance between the MS and SBS and R is the BS radius. The term $d_{MS,SBS}$ is a function of velocity and time as expressed by:

$$d_{MS,SBS} = \frac{v_{MS}}{t} \quad (9)$$

where v_{MS} is the velocity of the MS and t is the amount of time required for the MS to move to the location where handover should be executed (the cell edge). The distance is calculated at a sample distance interval of 1 m. The expected distances of the MS from the SBS and TBS are

computed as follows:

$$D_{SBS}(k) = d + \xi_{SBS} \quad (10)$$

$$D_{TBS}(k) = (D - d) + \xi_{TBS} \quad (11)$$

where ξ_{SBS} and ξ_{TBS} are modelled as zero mean independent wide sense stationary Gaussian random processes representing distance measurement errors with standard deviation σ_ξ . The average distance measurement error increases with σ_ξ [13]. It reflects the magnitude of the measurement error at any sampling point. The relative distance of the MS from the SBS and TBS is given by:

$$D_R = D_{SBS}(k) - D_{TBS}(k) \quad (12)$$

With the proposed scheme, HO is initiated only if the TBS's signal strength is stronger than that of the SBS by the hysteresis value H . From (8) the coefficient γ determines the range of H and the exponent β , determines its shape. In this paper, the following assumptions were made during simulation. The positions of all the MSs were randomly generated. The Probability Random Direction Mobility Model (PRDMM) is considered for the MS's movement because it permits the MS to travel to the edge of the simulation area at a constant speed and direction [14]. It was also assumed that the MS travels at a constant velocity of 20 m/s (72 km/h). The simulation parameters used are given in Table 1. The simulations are performed in a simulator developed in MATLAB (2010a) and the results are evaluated with the following performance metrics: handover delay, handover probability and the average number of handovers. To achieve consistency and reliability in the output data, each simulation scenario was carried out 10 times.

B. Performance Analysis

Figure 2 shows the signal strength results obtained between the MS and the multiple BSs. The signal parameters are measured in each scanning reporting period of 1 second. Among the BSs shown in Figure 1, the BS with the strongest signal quality is selected by the MS. The signal strength for BS1 and BS4 decreases as the MS approaches the cell boundary, therefore the potential BS is BS3 because of the MS direction. Switching to BS1 or BS2 could cause unnecessary handover. Figure 3 shows the comparison between hysteresis and the average number of handovers for only two BSs (SBS and TBS). The effects of other NBSs were ignored. It was demonstrated that as the hysteresis value increases, the number of handovers decreases. The result of the proposed scheme with exponent 4 and coefficient 20 is shown as the red point (single point). The red point indicates that despite the increase in the hysteresis value the number of handovers remained constant. The same figure shows that the average number of handovers for the proposed scheme remained constant and

never exceeded one. This shows that handover interruption can be minimised. Figure 4 demonstrates the trade-off between the mean number of handovers and handover delay. The figure reveals that an increase in the hysteresis value decreases the number of handovers and increases handover delay. Therefore the number of handovers can be reduced at the cost of increasing handover delay. The simulation results in Figure 5 compares the two existing methods with the proposed scheme. The proposed scheme shows improved performance compared to the two conventional methods. Figure 5 also shows that the RSS and RSTH schemes initiates fast handover before approaching the cell boundary of the BS which leads to unnecessary handover and waste of resources. With the RSTH-D scheme, however, handover is initiated just a few metres away from the cell boundary to reduce the number of handovers provided that the signal strength is still strong enough to maintain communication before execution.

Table 1: Simulation parameters

Simulation parameters	Value
Handover type	HHO
BS to BS distance	2000 m
Cell Radius, R	$D/\sqrt{3}$
Frequency	2.5 GHz
MS height	1.5 m
BS height	32 m
BS transmitting power	43 dBm
Propagation model	COST 231-Hata
Threshold value	-90 dB
Mobile Velocity	20 m/s
Standard deviation	8 dB
Scanning reporting period	1 s
Frame duration	10 ms
Mobility model	PRDMM
Mobility pattern	Earth bound vehicle
Correlation distance, $d0$	30 m
Coefficient, γ	20 [16]
Exponent, β	4 [16]
Hysteresis margin	0, 2, 4, 6, 8, 10, 12, 14, 16, 18 & 20 dB
Threshold distance, thd	30 m

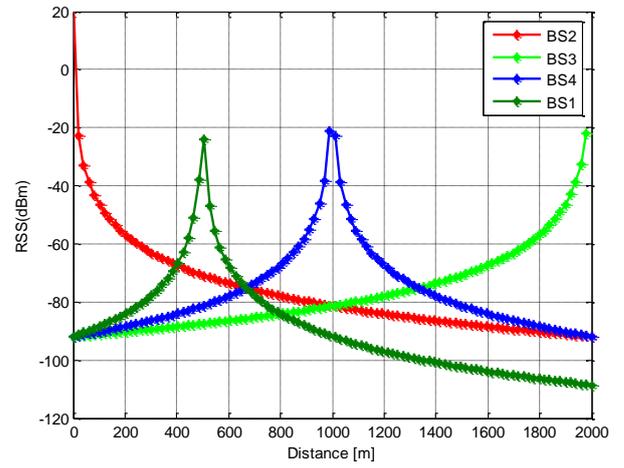


Figure 2: Signal Strength results for BSs

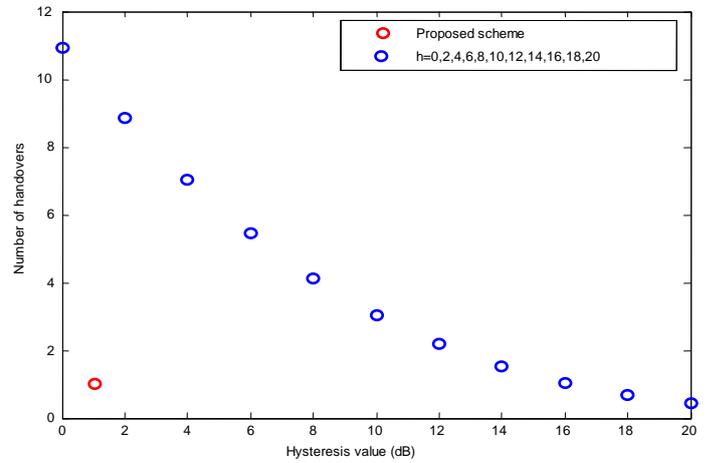


Figure 3: Number of handovers versus hysteresis

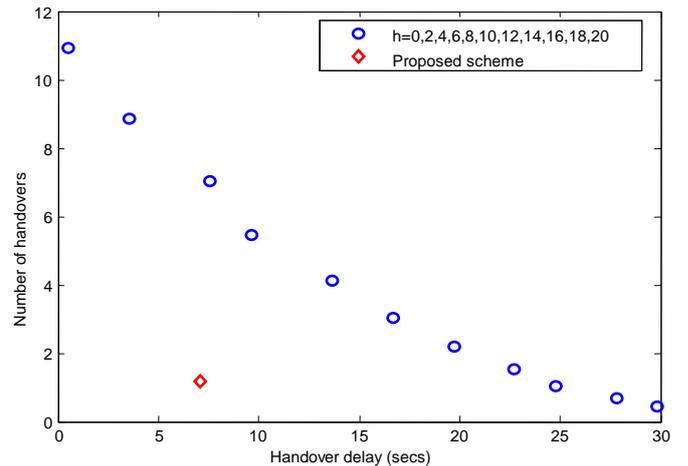


Figure 4: Number of handovers versus handover delay

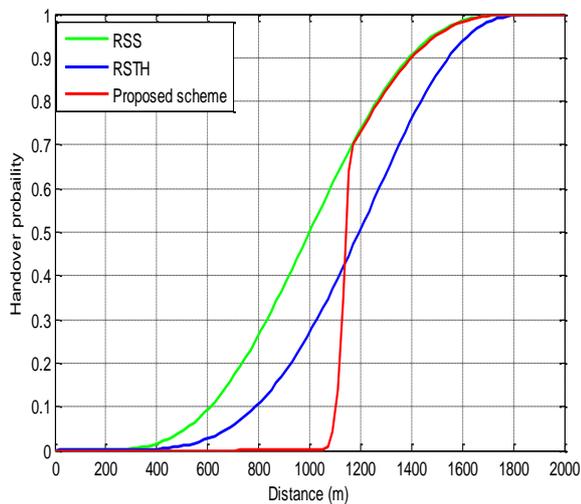


Figure 5: Simulation results comparing the RSS, RSTH and RSTH-D schemes.

VI. CONCLUSION

This paper proposed a method for handover based on a combination of the signal strength and MS position to initiate fast handover. The results show that handover probability can be affected by hysteresis, averaging and thresholds (threshold value and threshold distance) parameters. The ping-pong effect is reduced if the above parameters are used collectively. This scheme does not require any additional hardware at the BS or the MS. Since handover initiation is also based on distance, the proposed scheme can reduce handover delay and maintain adequate quality of service (QoS). Simulation results show that the proposed scheme reduces the number of handovers and provide efficient radio resources utilisation as well. Future work will consider other performance measures such as successful handovers and blocking probability.

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Mary Alatise received her undergraduate degree in 2008 from the Federal University of Technology, Akure and is presently studying towards her Master of Technology degree at Tshwane University of Technology, South Africa. Her research interests include performance analysis, mobility, and handover and resource management in broadband wireless networks.