Optimization Handover Procedure in IEEE 802.16E Netwok

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Abstract— Mobile WiMAX is a broadband wireless access technology having the ability to carry voice, data and video services. When a mobile station shifts from one serving station to another, a handover operation takes place which has a critical effect on real-time applications. This study discusses some of the general aspects of handover in mobile WiMAX networks, the IEEE 802.16/WiMAX network architecture and the MAC layer features that enable handover mechanism. There is also an analysis of the effect of the packet size of generated packets per second and the effect of mobility with focus on the impact of packet size and mobile speed. Currently, the WiMAX standard asserted that hard handover is compulsory; therefore the focus of this study is hard handover while Macro diversity handover and fast base station switching are not the primary focus in this report.

Index Terms— Wimax, broadband wireless, mobile station, handover operation, mobility, effect of packet size, acro diversity handover, fast base station switching

1 Introduction

Worldwide Interoperability for Microwave Access (WiMAX) is one of the latest concepts in wireless technology for broadband mobile access. This latest and innovative technology of WiMAX is capable to transmit wireless data through multiple transmission techniques including portable or mobile internet access through point to multi-points connections. The future generation networks would be requiring for variable and high data rates, quality of services and seamless mobility along with standardization allowing different vendors to operate independently between networks utilizing different technologies. [1]. WiMAX is the technology which is capable of fulfilling these qualities especially for mobil devices. This technology is often referred to as IEEE 802.16e-2005 [2] specifying fixed data transmission scheme providing broadband connection to wider areas in cities and towns.

The theoretically achievable data rate was rated as 70 Mbps ranging up to 50 km and IEEE approved frequency band ranging from 2 GHz and 11 GHz for the non-line-of-sight setup using base stations mounted on roofs or buildings facilitating the use of 134.4 Mbps in a 28MHz channel for long distances exceeding 50km through vehicular speeds [3]. Cellular mobile technologies like 3G are used in handing over voice calls because this was not possible with broadband mobile devices. Applications such as voice over IP (VoIP) services require the use of seamless connection [4]. This requirement rises the need to establish seem less handover connections across cell boundaries [1] especially when a mobile device in a car or train is connected to a network, the use of voice or la;6rge download is appropriate for handing over latency when mobile WiMAX is used. 3G network operators in mobile communications technologies were using technologies including High-Speed Packet Access (HSPA) and Wideband Code Division Multiple Access (WCDMA) and are now globally looking and evaluating the potential profitability of fourth generation (4G) mobile communications technologies. 4G technological devices like mobile Worldwide Interoperability are compatible with Microwave Access (WiMAX) and Long Term Evolution (LTE) [5].

2 Handover requirement in WiMax

WiMAX utilizes Orthogonal Frequency Division Multiplexing (OFDM) and Scalable Orthogonal Frequency Division Multiple Access (SOFDMA) [7]. For Non-Line-Of-Sight the specific frequency range is 2-11 GHz and for Line Of Sight it is 10-66 GHz. On physical layer of WiMAX communication is possible for a distance of around 8 km with theoretical bitrates up to 70 Mbps for NLOS transmission [8]. With Line Of Sight this coverage may range up to 50 km [9]. With all these technological advantages, however, the handover in Mobile WiMAX Networks could cause packet losses resulting in service interruption. This is the reason that handover has become an important issue in determining the performance of WiMAX network [1]. Usually, the handover technique being used in Mobile WiMAX Networks is the hard handoff (HHO) which is often refer to as break-before-make and the two optional soft handoffs known also as make-before-break refer to as Fast Base Station Switching (FBSS) and Macro Diversity Handoff (MDHO). [10] In this report, there is a detailed description of these systems. This study focuses on the Received Signal Strength (RSS) which provides supportive enablement for Mobile Station (MS) to switch from the old Base Station (BS) to the new type. It also takes into consideration the evaluation of the effect of user mobility on handoff performance in practical environment [10].

WiMAX provides better performance than its predecessor 3G mobile technologies. In this study, we shall be focusing on the mobility and cell cross-over handling issues in WiMAX. Handover or Handoff latency is the time taken by a mobile

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station (MS) to move across one base station (BS) coverage to another that is the switching time between accessed networks in a mobile environment [12]. This switching time is a very significant factor in the performance of mobile WiMAX. Any delay in handover may negatively influence the performance of mobile WiMAX and becomes more critical when service quality of real-time applications of mobile users is the ultimate requirement.

In this study, an effort will be made to explore the effects of mobility on the applications currently in use when a mobile device moves from one Base Station to another Base Station for different speeds during handover. Another focus is on whether there is any effect of packet size on the handover techniques as well how it will have the impact on the latency and throughput with increase in the packet size and will there be any influence associated with this increment on the quality of network.

When a mobile device moves across one Base Station to another, a connection handover or handoff occurs which affects the Quality of Service and Mobile Broadband Network accessibility. In WiMAX, the seamless mobility without any interruption for applications that require real time services is still needed to be explored. It is essential, however, to understand and explore the parameters like speed and handover performance that may have impact on handoff. The deployment of Wireless Local Area Networks (WLAN) is limited with small coverage area, low-speed movement support for users and interference compatibility issues [6]. The Mobile WiMAX standard as defined by IEEE802.16e standard covers the limitations like extended cell coverage area, enhanced data rate and mobility enhancement support [14]. Mobile Handover depends on the mobility of user, changes in the condition of radio channel and cell capacity.

2.1 Mobile WiMAX features

In cellular communication system, the mobility of service through handover from one access area to another access area or cell is of critical importance. In IEEE standard for 802.16-2004, there was no support defined for mobile movement while in 802.16e-2005 the enhancement of mobile devices moving at vehicular speeds was included. It is challenging to investigate broadband wireless access technologies like WiMAX for a smooth and seamless support to the device mobility [4]. It is critical to for the provision of steady services of multimedia streaming data during and when mobile stations are to handover and to tackle the problem of eliminating the disruption time (DT) during handover especially to reduce the delay time of real-time services such as VoIP and video bit streaming [1]. WiMAX operation is advantageous over other wireless technologies like Wi-Fi and 3G, therefore efficient handover is promising. This will also improve the operational efficiency of wireless devices and eliminated handover delay time will also enhance mobile usage.

Mobile WiMAX provides scalability and great flexibility in network deployment and services. The features supported in Mobile WiMAX include:

1. Mobile WiMAX provides internet access anytime and anywhere with multiple handover mechanisms. It supports hard handover which is can be defined as break-before-make links as well as soft handover which is make-before-break links. There is a comprehensive support for advanced Quality of Service and low latency real-time applications as well as advanced triple A's functionality of Authorization, Authentication, and Accounting.
2. The superior performance of Mobile WiMAX is further advanced with the usage of Orthogonal Frequency Division Multiple Access. This is a multiplexing technique that suits well to multipath environments giving network operators higher throughput and capacity along with great flexibility in managing spectrum resources. The indoor coverage of Mobile Wimax is also improved.
3. WiMAX uses performance enhancement technologies like Time Division Duplex (TDD) that uses a single frequency channel, with uplink and downlink traffic which is separated by a guard time.
4. WiMAX also supports Frequency Division Duplex (FDD) that keeps the uplink and the downlink channels separate in frequency which dominates in 3G networks.
5. For IP-based services, using single channel for the uplink and downlink makes WiMAX simple and cost-effective while implementing Multiple Input Multiple Output (MIMO) and beam forming than in CDMA-based networks. [21].
6. The flexibility feature of WiMAX deployment provides the ability to expand networks capacity and throughput. WiMAX is useful to deploy for the edge infrastructure.
7. The downlink data rate in WiMax can be up to 63 Mbps per sector and Up-Link data rates can be up to 28 Mbps per sector in a 10 MHz channel by using Multiple-Input-Multiple-Outpu (MIMO) antenna.
8. The scalability of Mobile WiMAX is the feature through which it can be able to work in different channelization from 1.25 to 20 MHz to comply with varied worldwide requirements. In the longer term WiMAX can be used with specific geographic needs such as providing affordable internet access in rural settings and enhancing the capacity of mobile broadband access in metro and suburban areas.

2.2 Mobility Management in WiMAX:

There is an increased requirement of managing the mobility in wireless networks. The network standards of IEEE 802.16 gained interest because of network over IP infrastructure and the capability to carry both data and real-time traffic such as VoIP. Some of the important factors to be considered for the provision of seamless services in wireless mobile communication environment are like how the delay or disruption in mobile devices can be minimized for seamless communication. Services like Voice over IP and other applications that require real time services are challenging because of long handover latency both in layer 2 as defined in standard IEEE 802.16e Air Interface and layer 3 that is Mobile IP 802.16e. The basic purpose behind this amendment was to maintain mobile clients to remain connected while supporting mobility and portability. The standard IEEE 802.16e can also be used for fixed network services.

Macro mobility and micro mobility are two categories of mobility management solutions. Macro mobility refers to the movement of mobile stations in between two network domains. In micro mobility management the mobile stations move between two subnets within the same network domain. When mobile stations move within the base station sector then the most critical factor for mobile applications is handover or handoff latency from one base station to another.

3 Handover process of the IEEE 802.16e mobile WiMAX standard

The handover is the procedure or process of the movement of a mobile station between the air-interfaces related to different base stations. Mobile stations are sometimes forced to move from one base station to another because the target base station may have better QoS, or the cell covered by the base station may be overloaded or there are any restrictions of the coverage area of the serving base station.

In a mobile communications setup, handover process is one of the most critical processes to be addressed. At MAC layer the basic aim is to provide seamless roaming to a mobile station amongst existing base stations and the aim is to make the seamless process with minimum set of requirements [7]. In mobile WiMAX, the handover procedure can be of two types – the horizontal handover and the vertical handover. The horizontal handover occurs when the mobile station changes to a different wireless cell within the same wireless access network technology and the vertical handover process takes place when the handover is performed across heterogeneous wireless access network technologies. [4]. In the time to come, where the mobile technology will be the future of internet, the mobile stations may need to move across different technologies of base stations. If a mobile station interrupts the connectivity with serving base station before starting or establishing connectivity with another base station then this will be a Hard Handover while if a mobile station keeps a secondary connection with the serving base station then this is known as soft handover. The IEEE 802.16e standard only supports hard handover in Mobile WiMAX profile in which the mobile station actually breaks up its connectivity with the existing base station before transferring to the target base station. The delay resulting in this transition affects on the performance of running applications. This makes the hard handover as only available option as a roaming technique amongst various technologies. The other alterative is soft handover which is maintaining another connection simultaneously but that increases the use of network resources [22]. The standard IEEE 802.16e provides two mechanisms for such soft handover are Fast Base Station Switching (FBSS) and the Macro Diversity Handover (MDHO).

3.1 Handover Stages

There are two main phases of MAC layer handover; the pre-registration and real phase of handover. It is essential for the mobile station to explore and search out the characteristics of potential base station in order to select as a connectivity partner. The figure shown below gives an overview of various stages involved and the situation of the handover decision:

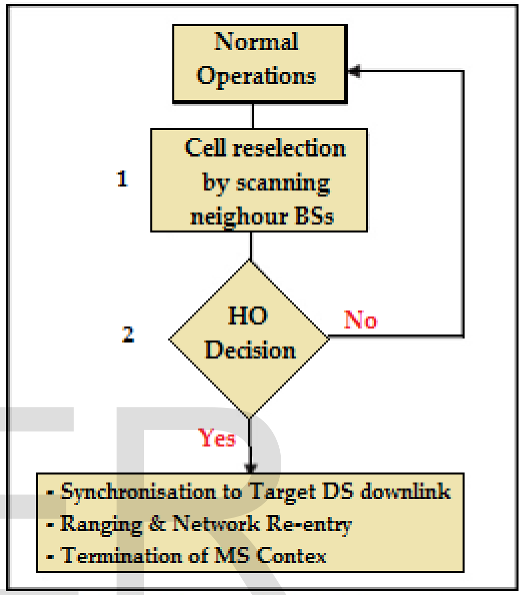

Figure showing Handover process stages

A mobile station releases a message to start acquiring information about network topology during pre-registration. The mobile station uses this information to select the target base station. At the completion of this phase, the base station is selected and the mobile station is pre-registered with the establishment of connection and packets exchanged between the mobile station and base station. After pre-registration, actual handover takes place. The mobile station transmits a message for the commencement of the session. The mobile station is released from current base station and associated with target base station. After making the decision and before associating with target base station, the mobile station completes the stages like synchronization and ranging before finishing its communications with the previously serving base station.

3.2 The acquisition of Network topology

When the mobile station changes its position in a mobile network then there are quite frequent changes in network topology. Before the initialization of a handover, the mobile station needs to acquire some essential information about the network. The mechanism adopted can be of various kinds including scanning and network topology advertisement. The information gathered through this mechanism is then used to

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determine the process of handover, performance of the network connectivity and security. [22].

The base station gets the network topology information enabling it to broadcast the information. This advertisement of network topology makes the synchronization of mobile station with base station lot simpler and easy. This procedure is less time consuming also than the initial network entry procedure.
The scanning process in mobile handover is a two step process in which the mobile station looks for base station in the first stage and keeps on monitoring the available target base stations. This scanning also involves scanning the frequencies to obtain downlink channel from Base station. When a mobile station transmits the scanning request then this means that the mobile station starts the request for the allocation of scanning intervals.

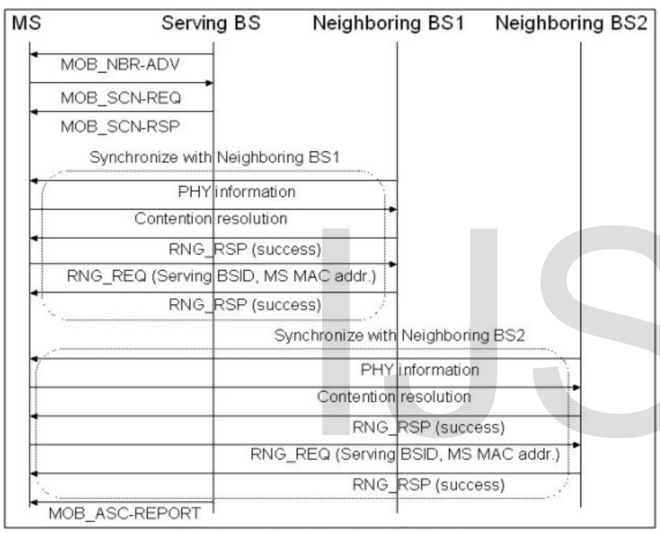

Figure: Network topology acquisition.

3.3 Ranging in handover:

As specified by the IEEE 802.16e standard, it is essential that the mobile station with real-time services requirement may establish an association with neighboring base station previously to conduct the handover procedure [12]. This is called ranging and it occurs during scanning interval while there is the availability of the handover association. This helps to accelerate the process of election of the most appropriate base station and it is also critical for the mobile station to establish an association with neighboring base station previously to conduct the handover procedure. However, for services for non-demanding real-time traffic association may be considered as optional [20]. And the throughput will decrease if the scan/association process occupies too many resources [11]. The following figure illustrates the ranging process:

Ranging is to establish physical connection. It is a similar procedure as the mobile devices enter into a network except association of a mobile station. With the usage of an efficient and proper resolution scheme, the latency in ranging of a mobile station can be reduced. The security issues, authentication procedures and key management protocol issues related to the mobile station and base station are also negotiated during ranging process. Ranging process can be further utilized to reduce the delay in handover as if the fast ranging and pre-registration are used then this may also increase the probability of

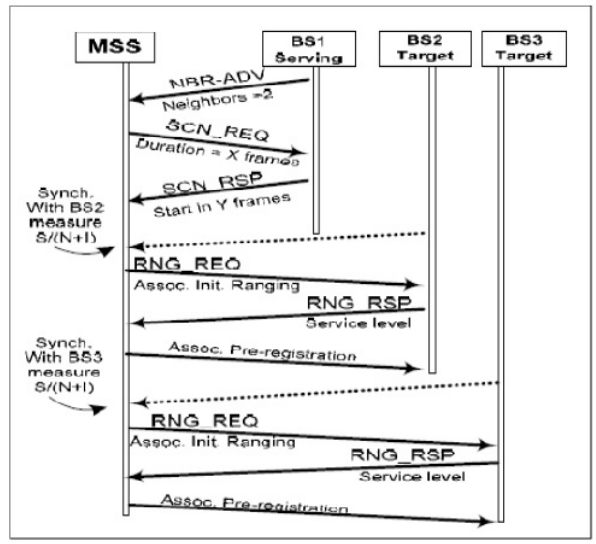

Figure: Ranging in IEEE 802.16e.

successful handover process.

3.4 Cell reselection:

When the scanning and association procedures are completed successfully then cell reselection stage occurs. In Cell Reselection, the mobile station utilizes the information collected in previous stages [19][22]. The cell reflection procedure actually does not disconnect and re-establish the connectivity between the mobile station and base station.

4 THE HANDOVER OPERATION

4.1 Handover decision and initiation

The handover or handoff process takes place only after the mobile station selects the target base station. The handover decision is taken after the perform handover message is sent. During the handover decision making, the mobile station and the target base station exchange messages. The mobile station requests the handover and the base station considering the mobile station message permits the handover. On the other hand, the base station may also force the mobile station to perform handover. The following Figure illustrates the decision, initiation, and ranging procedure in handover of a mobile station to abase station [18].

4.2 Downlink Syncronization:

The next stage in handover comes with the downlink synchronization of the target base station. There are different techniques that can simplify and shorten this process like the neighboring advertisement of base stations can reduce the amount of resources utilized along with reduced latency in network acquisition. Through the advertisement, the mobile station may be able to receive base station ID, its physical frequency and other parameters beforehand [13] [14].

4.3 Network re-entry

For seamless and continuous connectivity, mobile station makes a re-entry process, however, some packets may drop or delayed that may disrupt the service especially those applications which are delay sensitive [20]. Once the security issues and other parameters are negotiated between the mobile station and base station then authentication and registration process starts. The exchanged messages negotiate basic relevance and capabilities. In the next stage, the mobile station acquires IP Address to complete the handover process [15].

4.4 Macro Diversity Handover and Fast Base Station Switching

There are two hard handover modes called Macro Diversity Handover (MDHO) and Fast Base Station Switching (FBSS). In MDHO, the mobile station maintains connectivity with multiple base stations at the same time. In this mechanism, the mobile station remains aware and informed about available base stations in the neighborhood. In MDHO handover, the mobile station starts additional connection with other target base stations in neighborhood. The major disadvantage of this technology is the requirement of multiple antennas resulting in rise of price of the mobile device [22]. Another method is Fast Base Station Switching (FBSS). Like MDHO, in FBSS there remains an anchor base station with which the mobile station pre-register. In MDHO, the information of the mobile station remains in cache so that the communication may remain intact with the target base station [16] [17].

4.5 Reasons for handoff latency

While moving to a new base station within the same subnet, the mobile station performs Layer2 handover through following the process of discovering the available base station, performing authentication, then re-associating itself with the base station and then authenticating again.

If the mobile station moves to a new base station in another subnet then it performs a Layer3 handover in addition to Layer2 through discovery of the a new target base station and then registration and authentication with existing base station and gateway target base station.

While moving to a foreign network, a new address is acquired as the connection point changes. When a new base station or access point is discovered, it takes time. After the discovery, the base station needs to inform the new connection point to its home network. Here comes the handover latency caused due address configuration and home network registration. Secret key exchange and authentication may also be another reason for latency [17].

Users while carrying mobile devices or stations in a mobile environment carry mobile IPs of the device. There are two basic factors affecting the latency while roaming by a mobile station including the disconnection period during Layer 2 handover and signaling latency for updating from mobile station. There is a short period of inactivity when the physical interface of mobile station changes its connection from an old base station or access point to a new target base station or access point. During this time no packets can be sent or received from the mobile device. Latency can significantly affect the handover including:

1. Movement detection time required by the mobile device to detect its movement from one point to another to access new access point
2. IP configuration time required to establish a globally routable address and duplicate address detection.
3. The time required to establish appropriate context time.
4. Time required establishing a binding registration by transmitting a binding update signal and receiving an acknowledgement packet.
5. The time required for route optimization with the current list of accessible hops including return routable procedure detection.

The total IP handover delay will be the sum of these factors [16] [13]. The handover performance of mobility management protocol depends on the type of application used while movement, link layer frame error probability and signaling delay link layer access technology for the mobile station.

5 NS2 Simulation and discussion on Results

To research the handover process in WiMAX and to find out the factors affecting the handover process and creating latency or delay in mobile WiMAX, a network simulator NS2 for WiMAX was setup to mockup the actual process. The scenario designed in NS2 was quite close to the real scenario and simple in testing and effective in analyzing the results. Two base stations were placed in arrow and mobile station was moving through in the coverage area [9]. During this process the handover process was simulated and handover latency was measured. The aim of this simulation was to explore the factors influencing the handover performance in mobile WiMAX network and also its affects on delay sensitive applications like voice or video streaming. The network was tested by setting up different velocities ranging from 10,30,35,50 and 100 m/s along with various packet sizes comprising of 50,256,512,100 and 3000 bytes. The results were then deducted showing measurements in majority of scenarios [10].

The results showed that the handover latency was relatively proportionate to the speed of mobile station. The latency increased as the relative speed increased from 10m/sec to 30m/sec as the time to pass through the area of disconnection reduced. The latency remained the constant at 11 seconds and the increase in relative speed did not have any further effect on handover latency.

Various speed ranges from 10, 30, 35, 50 and 100 m/s and packet size of 50 byte were simulated. Staring from the speed of 10 m/s for the mobile station, one minute observation was taken initially and then the speed was increased till 100 m/s gradually. The results obtained were shown in the following table:

	10 m/s	30 m/s	35 m/s	50 m/s	100/s m
Data(Transfer Packet)	467 packets	456 packets	455 packets	454 Packets	452 Packets
Packet Delivery	83 packets Data 2kb	49 packets Data 5 kb	95 packets Data 5 kb	96 Packets Data : 5 kb	98 Packets Data : 5 kb
Packet Delay [s]	0.00772713	0.00772754	0.00772758	0.00772762	0.00772770
Throughput Transferred	497 b/s	496k b/s	495 b/s	493k b/s	491 b/s
Throughput Generated	500 kb/s	500 kb/s	500 kb/s	500 kb/s	500 kb/s
Connectivity	F.P.T 5.01571 L.P.T 51.60771s	F.P.T 5.01571 s L.P.T 58.20771 s	F.T.P 5.01571 s L.P.T 50.40771s	F.P.T 5.01571s L.P.T 50.30771s	F.P.T 5.0157 s L.P.T 50.10771 s

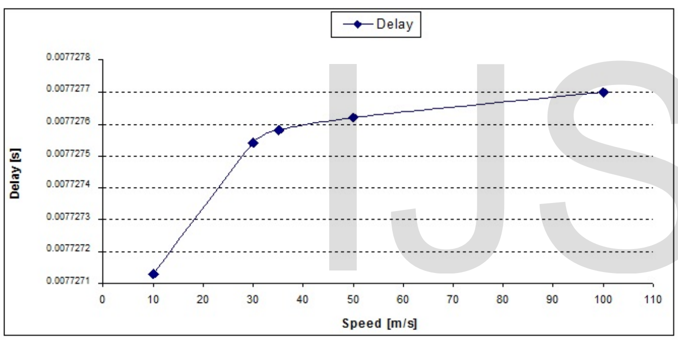

Figure: Delay vs. speed.

Another significant factor noticed was that with increased speed of mobile station, the average jitter increased. Thus the results showed that the speed of mobile station had an influence on jitter.

Table: Result of jitter with different speeds.

Parameter	IEEE 802.16e				
Speed [m/s]	10	30	35	50	100
Jitter [s]	1.71E-05	1.75E-05	1.76E-05	1.77E-05	1.79E-05

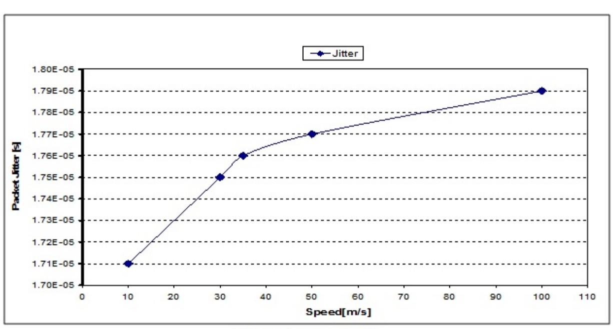

Figure: Jitter vs. speed.

There was an increase in packet loss with increased speed also the delay was higher with large packet size.

6 Conclusion

To sum up, the study focused on the optimization of handover or handoff procedure in Mobile WiMAX IEEE 802.16E standard. The research was carried out and in order to achieve the results close to the real time scenario, network simulation through NS2 was also carried out. The results showed that there are certain parameters or factors that really have an influence on the latency in handover performance of a mobile WiMAX however; there are certain factors which have no influence on the handover performance. The discussion is still a starting effort on this fast evolving field of mobile WiMAX and still has a room of improvement in the field of soft handover as this study was mainly focused on hard handover. The possibilities to work for soft handover techniques like macro diversity and fast base station switching would have a greater insight on the operational capabilities.

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