Performance Analysis of a Mobile WiMAX Network under the Impact of Node Mobility and Handover

Baljinder Kaur
Dept. Computer Science
Punjabi University, Patiala.
India.

Jyotsna Sengupta
Dept. Computer Science
Punjabi University,
Patiala. India.

ABSTRACT
In a cellular network, as the mobile devices move from cell to cell during an ongoing continuous communication, handover is performed for switching from one cell frequency to a different cell frequency, without interruption to the ongoing session. Mobile WiMAX handover mechanisms suffer from certain drawbacks, particularly related to wastage of channel resources, handover latencies and loss of data. However, the long interruption of handover is horrible for delay and packet loss sensitive real-time applications such as VoIP and Video conferencing. Success of a good mobility framework largely depends on the potential of performing quick and seamless handovers. So, different handover related WiMAX research issues need to be addressed, both to allow WiMAX to fulfill its potential and to ensure that it sees more widespread adoption. This research work aims to analyze the impact of node mobility and handover on the performance of a mobile WiMAX network.

General Terms
Mobile WiMAX, Handover, Delay, Mobility.

1. INTRODUCTION
The rapid growth in the area of communication has generated

the need of mobility during communication. The mobility of a terminal is a requirement of great importance, supported by a procedure known as handover. Handover is a technique for maintaining air link to base station even when mobile node is moving with high velocity and changes its geographical position [8]. The handover can be due to the movement of mobile subscriber or due to change in radio channel condition or due to cell capacity constraints.

In a cellular system, the geographical area is divided into adjacent, non-overlapping, hexagonal shaped cells. Handover is a well designed mobility management technique in which a connected cellular call or a data session is transferred from one cell site (base station) to another without disconnecting the session. Cellular services are based on mobility and handover, allowing the user to be moved from one cell site range to another or to be switched to the nearest cell site for better performance. Mobile WiMAX IEEE 802.16e standard gives full mobility support to the nodes of cellular networks, at higher broadband speeds than other broadband networks like Wi-Fi.

From wide perspective handovers may be split into two groups: horizontal HO and vertical HO. When the HO is within the same technology, for example, between WiMAX cells, it is called a horizontal HO or traditional handover as depicted in Fig 1. If it is executed between different technologies, for example, WiMAX to Wi-Fi, then it is called vertical HO.

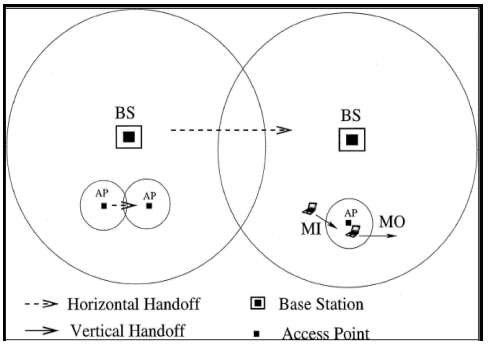

Figure1: Horizontal and Vertical Handover [5].

Horizontal HOs are easy to implement because the operation is typically made under the same operation domain. Vertical HOs, on the other hand, are typically executed between different operators and require a much more complex signaling. The main distinction between VHO and HHO is symmetry. While HHO is a symmetric process, VHO is an asymmetric process in which the MS moves between two different networks ith different characteristics [5]. Difference between Vertical and Horizontal Handovers is presented in Table 1.

Table 1. Difference between Vertical and Horizontal Handovers [11].

Parameter	Vertical Handover	Horizontal Handover
Access Technology	Changed	Not changed
QoS Parameters	May be changed	Not changed
IP Address	Changed	Changed
Network Interface	May be changed	Not Changed
Network Connection	More than one connections	Single connection

2. HANDOVER PROCESS
Handover is essential for supporting MS mobility in mobile Cellular environments and it enables an MS to change its air interface from one BS to another. A basic handover procedure divided into the following procedures: cell reselection, handover decision and initiation, synchronization to target BS downlink, termination with the serving BS, and network re-

entry. Six different stages involved in handover process are:

- **Cell Reselection:** Mobile Station (MS) acquires info about the Base Station (BS) in the Network and evaluate the Possibility to perform handover.
- **Handover Decision and Initiation:** The initiation of a handover is the decision to migrate the MS from the serving BS to Target BS. Handover request will trigger a sequence of Handover specific message to be sent in-between MS and BS.
- **Synchronization:** To Establish Communication with the target BS, the MS need to synchronize to its D/L Channel.
- **Termination of Services:** Termination of services at the serving BS is the last step in the handover process. The serving BS will terminate all the associated MS.
- **Handover cancellation:** During the handover the MS has the right to cancel the handover and resume normal communication with the serving BS.

2.1 Mobility Support

Similar to the different cellular and broadband technologies, global mobility related research in WiMAX is mostly focused on two main areas of concern: location management and handover management. In the former, the underlying network technology tracks and maintains the exact whereabouts of wireless terminals in cases when they are powered-on, powered-off or even on the move. On the other hand, the latter deals with the active transfer of wireless terminals from the control of a BS in one cell to the control of another BS in a different cell .

Mobility aspects in WiMAX are specified as an individual Mobility Agent (MA) layer, above the MAC (link) layer, with some network layer signaling to develop a complete solution. The existing WiMAX mobility structure defines three types of link layer handover procedures in a homogeneous environment. Of these, Hard Handover (HHO) is the default handover mechanism and two soft handover mechanisms, Macro-Diversity Handover (MDHO) and Fast Base Station Switching (FBSS), are the optional procedures [12].

2.2 Quality of Service (QoS)

Support for QoS is a fundamental part of the WiMAX MAC layer design. WiMAX defines a concept of a service flow. To support a wide variety of applications, mobile WiMAX defines five scheduling services: UGS, rtPS, ertPS, nrtPS and BE [9].

- **The UGS (Unsolicited Grant Service)** is similar to the CBR (Constant Bit Rate) service in ATM, which generates a fixed size burst periodically. This service can be used to replace T1/E1 wired line or a constant rate service. It also can be used to support real time applications such as VoIP or streaming applications. Even though the UGS is simple, it may not be the best choice for the VoIP in that it can waste bandwidth during the off period of voice calls.

- **The rtPS (real-time polling service)** is for a variable bit rate real-time service such as VoIP. Every polling interval, BS polls a mobile and the polled mobile transmits bw- request (bandwidth request) if it has data to transmit. The BS grants the data burst using UL-MAP-IE upon its reception.

- **The nrtPS (non-real-time polling service)** is very similar to the rtPS except that it allows contention based polling.

- **The BE (Best Effort)** service can be used for applications such as e-mail or FTP, in which there is no strict latency requirement. The allocation mechanism is contention based using the ranging channel.

- **The ertPS (Extended rtPS)** was introduced to support variable rate real-time services such as VoIP and video streaming. It has an advantage over UGS and rtPS for VoIP applications because it carries lower overhead than UGS and rtPS.

3. RELEATED WORK

3.1 Handover

In cellular telecommunications, the term handover or handoff refers to the process of transferring an ongoing call or data session from one channel connected to the core network to another. Handover process will happen when the MS moves and needs to change the BS to which it is connected in order to provide a higher signal quality (due to signal fading, interference levels, etc.) or the MS can be serviced with higher QoS at another BS.

The most promising Broadband Wireless Access (BWA) candidate, WiMAX and its latest amendment IEEE 802.16e which expands the standard to allow mobile subscriber station was discussed by Hoymann et al [7]. This paper shows that the enhanced IEEE 802.16e standard supports the handover procedure and has the capability to fulfill the requirements regarding the mobility management of future telecommunication systems. Goals that have been tackled during the specification of the HO procedures of IEEE 802.16e are small signal overhead over the air interface, low latency and minimum packet losses.

In the first version of WiMAX standards mobility was not supported at all. Becvar and Zelenka [4] focused on the description of full mobile WiMAX that supports mobile nodes and presented an overview of the handover types. Then with time, several types of handovers in WiMAX technology were introduced because of the need of user mobility. Hard handover allows only low speed mobility (portability or simple mobility). FBSS and MDHO belong to the group of the soft handovers and were implemented for higher speed mobility (portability, simple mobility or full mobility). In both handover types the diversity set is maintained. The main difference between MDHO and FBSS is, that in MDHO is applied the selection diversity and diversity combining in uplink and downlink, respectively. In FBSS all data traffic is processed only in the anchor BS. This paper also discussed the updating procedures which are used during movement of the mobile stations and various WiMAX access types as: Fixed access, Nomadic access, Portability and Simple mobility and Full mobility.

An optimization of the Handover procedure in WiMAX Network was discussed by Hamid and Mahmud [6]. Handover is very significant factor in the performance of mobile WiMAX, but because of the presence of unnecessary ranging/scanning in Layer two along with the network re- entry procedure enormous handover latency occurs. Due to the HO delay and wireless resource waste, there occurs significant level of service level degradation. For the elimination of such degradation in service level; adequate intelligence utilizing neighbor advertisement message for efficient scanning algorithm, modified dedicated ranging and network re-entering method are proposed in this paper. Performance analysis also reflects the significant upgrade in performance level through this optimized handover scheme. In a nutshell,

acceleration of HO process through the proposed scheme brings out an organized change in IEEE 802.16e standard for HO and thus ensures the improved performance in mobile WiMAX network.

In order to increase the efficiency of handover schemes, Ashoka et al [2] presented an experimental study on network-based handover and host-based handover in mobile WiMAX. Analysis of the performance of the two standardized handover schemes, namely the Mobile IP and the ASN-based Network Mobility (ABNM), in mobile WiMAX were made using simulation. The results were promising for the applicability of network-based handover technology, and encouraging for network-based handover research. Most other protocols for mobility management tend to require modifications to the MS software stack. With the MS being independent of mobility management, mobile devices can be designed for mobile WiMAX without any need to cater for frequent software updates and irrelevant of the handover protocol used in the network. Overall this paper demonstrated that the ABNM handover scheme can strengthen the capability of mobile WiMAX network operators to manage and control their networks more efficiently in terms of handover delay and throughput.

3.2 Horizontal Handover

Horizontal handover is used where handover takes place between BSs within the same type of network technology. This arrangement is often called a homogenous network. The horizontal handoff can also be either soft or hand. In

horizontal handoff, soft handoff is more commonly used, because collaboration between components in the same type of network can be more easily achieved.

The impact of mobility on QoS of WiMAX (IEEE 802.16e) with CBR application was analyzed in [3]. This paper analyzed the impact of mobility on the QoS parameters (Throughput, Average Jitter and Average end to end Delay) of a mobile WiMAX network (IEEE 802.16e) with CBR (Constant Bit Rate) application. The results concluded that as the handover takes place, then due to connection timeouts, connection time lags, data traffic congestion and interference, jitter occurs and because of this average end to end delay increases, but when mobile node again come to its registered base station both jitter and average end to end delay will decrease although.

A mobility improvement handover algorithm in Mobile WiMAX should take less scan time during handover. According to the existing draft version of IEEE 802.16e standard, the HO will be initiated when the RSSI (Received Signal Strength Indication) of the serving BS is lower than the threshold value. It does not consider the effect of velocity and scan threshold value, the HO threshold is set as a constant. But [1] showed that the velocity of the MS affects the HO delay and to cope with this problem a mobility improvement HO scheme was used in which HO threshold was varied with velocity of the MS. The results showed that the HO delay below 50ms limit when speed changes from 20m/s to 29m/s and the HO delay greatly reduced when the speed exceeds 29m/s which is approximately equal to 105km/h. Thus, this HO scheme can provide seamless communication for Mobile WiMAX in high velocity and real time applications.

WiMAX system needs a fast handover scheme that efficiently reduces the handover delay and maintains stable data transmission. Xujie Li [14] Proposed that the MS used GPS function for the selection of target BS which saves the scan time efficiently. Meanwhile, a handover code and a ranging opportunity from the target BS are received before the MS executes the handover process so that the MS can implement handover ranging in non-contention based handover ranging opportunity that the target BS allocated. The results demonstrated that the proposed handover scheme omitted the RNG_REQ (code) and RNG_RSP (code) compared with the conventional handover scheme.

An empirical study of the impact of traffic type, node mobility and handoff on the performance of a mobile WiMAX IEEE 802.16 network was made by Kangwook [10]. Four traffic types: FTP, HTTP, VoIP and Video Conferencing were considered for the investigation. It was observed that both FTP and HTTP are satisfactorily transmitted regardless of the volume of traffic on the network. The experimental results showed that FTP and HTTP are not significantly affected when node speed is increased (node mobility) although the average response time increases to an acceptable level. Moreover, the packet loss ratios remains at a low level meaning the packet can be recovered by retransmission and throughput increases as well. However, the delay-sensitive traffic m-VoIP and Video conferencing are certainly influenced when node speed increases. High average packet loss ratio indicates that the audio and video packets may not be delivered to their destination in time without data loss. Lastly, the impact of handoff on the performance of mobile WiMAX was also investigated in this study. In FTP transmission, there was no noticeable difference in performance with or without handoff for a node speed up to

70km/h, but some difference gradually appears. In HTTP transmission, there was no noticeable difference in performance between enabled handoff and disabled handoff at any node speed. However, under heavy-traffic, the influence of handoff was easily observed at any node speed and its influence intensified with increasing node speed. As expected, for any amount of transmitted video conferencing and m-VoIP traffic, delay increases linearly after handoff was adopted. Unexpectedly, the throughput for all four traffic types increases significantly and packet loss ratio decreases either slightly or moderately after handoff is adopted. This phenomenon seems to be due to the fact that handoff allows the traffic to be divided between two BSs.

A model of mobility for WiMAX network users, introducing horizontal handover mechanism with channel reservation was proposed by Salhani et al, [13]. The goal of this paper was to adapt channel reservation (CR) mechanism in WiMAX network and use it to improve horizontal handover. To perform the channel reservation they considered three different approaches: by neighbor nodes (NNs) (cooperative approach), by the BSs (individual approach) or by both (mixed approach). It is shown that the channel reservation mechanism reduces clearly the handover blocking rate and it does not degrade the performance of the system. Therefore, the worst channel reservation mechanism degrades all the performance criteria. The three approaches were compared and it was shown that when there is a light density of users the best performance results are obtained when the reservation is achieved by a BS rather than when MNs send their requests through a NN. Moreover, the efficiency of channel reservation mechanism is considerable when there are a low number of channels. Besides, the cooperative approach indicates good results when the density of users increases. This density is related to the system dimensions. So, this paper evaluated that channel reservation mechanism improves horizontal handover without reducing the performance of the system.

4. CONCLUSION

Mobile WiMAX facilitates effective FTP and HTTP packet transmission between nodes and server for a large-size network. Consequently; one can conclude that increasing the speed of nodes has either a slight or a significant influence on the performance of all four traffic types (FTP, HTTP, VoIP and Video Conferencing). Node mobility does not seriously

affect delay-tolerant traffic types (FTP and HTTP) for any node speed. However, node mobility significantly affects delay-sensitive traffic types (VoIP and Video conferencing). Fortunately, the impact of node mobility on real-time traffic types can be reduced by the use of priority QoS and MCS settings. However, this cannot reduce the packet loss ratio to a level which would allow mobile communication to maintain land-line call quality. After handoff is adopted, the throughput for all four traffic types increases significantly and packet loss ratio decreases either slightly or moderately as the handoff allows the traffic to be distributed between two BSs. In addition, although handoff increases delay slightly, it also allows wider coverage and higher throughput and reduces packet loss ratio. Consequently, use of soft handoff is recommended to minimize the impact of handoff on real-time traffic transmission.

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