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Handover Techniques in Mobile WiMAX Networks: Analysis and Comparison

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Abstract: Mobile WiMAX, in the past few years has become one of the most important technologies because it has the ability to provide users with a high speed wireless connection in a Metropolitan Area Network. Mobility brings with it the need of handovers which occur when a user moves from one cell to the other. Handover is considered as a highly important issue in mobile WiMAX. This paper discusses the conventional handover procedure along with some of the techniques that deal with handover and latency reduction. These include cross layer handover technique, latency reduction in handover using mobility pattern and other MAC layer handover algorithms.

Key words: Mobile WiMAX · Handover · Latency · Performance analysis · MAC layer handover

INTRODUCTION

WiMAX stands for *Worldwide Interoperability for Microwave Access*. Based on the 802.16 IEEE standard published in 2004,it provides a wireless data transmission scheme inmetropolitan areas for a broadband connection [1]. However the user lacked the ability to move from one cell to another during the transmission. It only provides fixed and nomadic access. In a fixed access mode the user is not allowed to move and the user device is fixed to a single location during the network subscription. Whereas the nomadic access mode allows the user to move around in the same cell but does not allow a cell to cell movement which means the user should establish the connection again every time when they move to a new cell [2]. Later in 2005, 802.16e [3] standard known as mobile WiMAX was introduced which allowed full user mobility. Mobile WiMAX successfully fulfills the requirements for high data rate, large area coverage and low cost.The mobile WiMAX standard supports peakdata rates of around 30 Mbps and average data rates between 1 Mbps and 4 Mbps. 802.16e based Base Station (BS) can support both fixed and mobile broadband wireless access (BWA).

When a user moves from one cell to another,a handover (HO) process is initiated in order to switch the wireless connection from the serving BS to the new BS, without interrupting any communication that was in progress. As described in [3], the handovers are divided into two main types, Hard Handover (HHO) and soft handover mechanisms. Macro Diversity Handover (MDHO) and Fast Base Station Switching (FBSS) are considered as soft handover mechanisms and are optional whereas the HHO is mandatory [9]. The existing HO mechanism is facing difficulties in the form of wastage of available resources, loss of data and handover latency. Mobile WiMAX also faces competition from other wireless technologies such as Long Term Evolution (LTE) [3]. Mobile WiMAX holds a clear advantage overthese technologies as it offers much higher data rates and a

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wider transmission range, but the handover related issues must be resolved to allow WiMAX to compete in the market and fulfill its potential.

This paper gives an overview of mobile WiMAX and discusses the performance of different handover algorithms and schemes.These mechanisms proposed by Choi [8], Z.Zhang [9], Lee [10] and H. Fattah [11] reduce HO latency when compared to the default HO mechanism currently followed by the mobile WiMAX.

Rest of the paper is organized as follows: Section II gives an overview of OFDMA in mobile WiMAX.Basic handover procedure followed by mobile WiMAX is described in Section III. Section IV analyzes different HO mechanisms which are discussed in Section V.Section VI finally concludes the paper.

OFDMA in Mobile WIMAX: The physical layer of mobile WiMAXuses Orthogonal Frequency Division Multiple Access (OFDMA)for uplink and downlink due to its bandwidth efficiency, robustness signal distortion and multipath fading resulting from mobility and wireless networks. In OFDMA, the multiplexed frequencies are orthogonal to each other and their spectra overlap with the neighboring carrier [4]. Orthogonality is a property that allows signals to be transmitted over the common channel and detected without interference [5].Sub channelization defines sub channels that can be allocated to subscriber stations depending on the channel conditions and data requirements. The available subcarriers may be divided into several groups of subcarriers called sub channels. Mobile WiMAXallows sub channelization in both the uplink and the downlink. Sub-channelization in the uplink can save a user device transmit power because it can concentrate power only on certain sub-channel(s) allocated to it [6].

For modulation [5], the serial data bit stream is converted from series to parallel into an OFDM symbol. These symbols are modulated using 16-QAM, converted into time domain using Inverse Fourier Transform (IFFT) and transmitted across the radio channel. For successful reception, the reverse procedure is implemented on the receiver side.

Handover in Mobile WIMAX

Handover and Latency: Handover is a mechanism to maintain uninterrupted user communication session during a user's movement from one location to another [7].

When the Mobile Station (MS) moves to another cell and performs handover, the service packets for the MS will be delayed and the service might be disrupted for some time [8]. This delay is known as Latency time.

For non real-time service such as e-mail or file transfer, Latency time is not an issues. However, the delay sensitive applications, such as video streaming service, should be delivered within the delay of 20 to 25ms. If the transmission delay of real-time packets is longer than the play out delay, those packets will be discarded and packet lossprobability is increased [8].

Handover Procedure: For a handover process, the Serving BS broadcasts information message, typically using MOB NBR-ADV [7], that contains information of neighbor BSs. The MS scans the neighbor BSs periodically and selects the target BS candidates, on the basis of quality of signals or other parameters and sends a handover request message to the serving BS. The Serving BS then exchanges the handover messages with the target BSs candidates and finally selects a target BS. It sends the handover response message to the MS. The MS, on the reception of message, breaks the connection with the serving BS and makes the connection with target BS and performs network re-entry process. The Target BS gets the security information of the MS from the serving BS. MS can receive or send traffic after network re-entry process. The network re-entry process consists of synchronization with new downlink, ranging and synchronization with uplink, reauthorization and re-registration procedures.

After breaking the connection with Serving BS, the MS synchronizes with new downlink of Target BS to obtain DL and UL transmission parameters. The MS conducts ranging process to acquire correct timing offset and power adjustments. For this ranging process, Target BS uses Fast-Ranging IE to provide a non-contention based ranging opportunity to the MS [8]. If the MS does not receive the Fast-Ranging IE message, it conducts contention based ranging process by transmitting the CDMA codes.

The MS can skip re-authorization and re-registration processes, only if the target BS has received all security and the MAC states information by the backbone network from the serving BS, during the handover process. However, the target BS, for transmitting the CID update information, has to send unsolicited REG-RSP message [8].

Handover Mechanisms: The HO latency remains as an issue that affects real-time applications. Many researchers have introduced proposals to improve the HO mechanism for real-time applications.This section reviews some of the proposals for improving the HO mechanism.

Mobility Patterns: In [9], an efficient MAC layer handoff scheme using mobility patterns is presented by Zhenxia Zhang, to minimize the handoff latency. Mobility patterns are implemented to help the MS predict the target BS and minimize the scanning time. The mobility pattern table consist of previous BS's ID, target BS's ID and handoff times and is maintained by the serving BS. The information recorded in the table is updated during every successful handoff process. Furthermore, the serving BS can forward data packets to the target BS to decrease the packet loss ratio.

To evaluate the performance of proposed scheme, Zhang tested four types of scan processes and compared WiMAX standard HO scheme with the proposed scheme.

- Type 0 is scan without association. SS needs only downlink synchronization to achieve the physical channel information of the target BS.
- Type 1 is scan/association without coordination. SS has to complete the contention-based ranging, after the downlink synchronization, to exchange physical parameters with the BS.
- Type 2 is association with coordination. SS completes a fast ranging, after the downlink synchronization, to exchange physical parameters with the BS.
- Type 3 is network assisted association reporting. All ranging response messages are sent by the serving BS to the SS, using a MOB ASC-REPORT message.

The proposed scheme reduces the handover latency by almost 40% and 50% for type0 scan and type1 scan respectively. Similarly, handover time is lesser for the proposed scheme then handoff latency time using type2 and type3 scan.

Fast Handover Algorithm for Ieee 802.16e Broadband Wireless Access System: In [10], Lee presented fast HO algorithm for IEEE 802.16e BWA toreduce the waste of the wireless channel resources and theHO latency. His proposed algorithm includesTarget BS Selection (TBS), Fast Synchronization and Association (FSA) and Optimized HO Initiation Timing (OHIT). Here HO operation time is analyzed with four different HO scenarios. It will result to increase system throughput and certify the efficiency of the proposed algorithm. Some parameters of the scheme are depends on backbone network traffic condition, cell-loading rate, user mobility and CINR.

- Type 1 is contention based ranging with pre-association.
- Type 2 is contention based ranging without pre-association.
- Type 3 is non-contention based ranging with pre-association.
- Type 4 is non-contention based ranging without pre-association.

The amount of saved HO operation time when each proposed algorithm is used is shown in *Table 1*. TBS saves HO operation time as it reduces the number of neighboring BS to one which is most likely to be the target BS. FSA reduces more HO operation time with low cell loading rate, but less time with high cell loading rate. FSA allows synchronization and association done without interfering current data transmission using unused slots. Nevertheless it has to wait if unused slot is not found, thus it reduces less HO operation time with high cell loading rate. OHIT reduces the same amount with all HO types as it depends on MS mobility and not on the HO type.

Adopting all the proposed algorithms, HO operation time is reduced with the cell loading rate 0% and 50%, about 300-400 ms and 300-600 ms respectively.

Fast Handover Sceme for Real-Time Downlink Services: In [8], Choi, proposed an enhanced link-layer handover scheme in which mobile station can receive real-time downlink service from BS during a handover process, before the synchronization with the uplink. This scheme reduces handover latency and packet loss probability for real-time downlink applications. Choi introduces a new MAC management message, Fast DL_MAP_IE, which supports the downlink data during handover. This scheme is suitable for downstream data such as video streaming. It assumes that service disruption only occurs during the network re-entry process and MS could receive the real-time packet during handover decision and cell-selection procedure. Hence, it only considers the

Table 1: Saved HO operation times using Lee's algorithms

CELL LOAD	SCHEME	TYPE 1	TYPE 2	TYPE 3	TYPE 4
0%	TBS	300	230	300	230
0%	FSA	450	345	450	345
0%	OHIT	50	50	50	50
50%	TBS	450	380	350	280
50%	FSA	338	285	288	200
50%	OHIT	50	50	50	50

Table 2: Handover Methods

Conventional Scheme 1 obtain MS use Fast	Contention based ranging. Target BS does not information from backbone network and does not DL MAP_IE
Conventional Scheme 2 use Fast	Fast ranging. Target BS does not obtains MSS information from backbone network and does not DL MAP_IE
Conventional Scheme 3 information from MAP_IE	Fast ranging. Target BS obtains MSS backbone network and does not use Fast DL
Proposed Scheme information from	Fast ranging. Target BS obtains MSS Backbone network and uses Fast DL MAP_IE

network reentry process for evaluation of handover.Choi,including his proposed scheme, consider four handover method, as show Table 2.

Fig. 1 shows the service disruption times, during handover process, of these schemes. The service disruption times of conventional scheme 1 and 2 are greater than conventional 3 or proposed scheme, because of the long re-authorization process. In proposed scheme, packet transmission time is reduced by network re-entry time, which includes ranging, re-authorization and re-registration process. Hence, the service disruption time of proposed scheme is quite less than any other handover scheme.

D. A New Handover Mechanism for Ieee 802.16e Wireless Network: H. Fattah [17] proposes a handover algorithm that reduces the handover latency using information about the service flow running on the MS and acquiring the best possible target BS.

According to this scheme, MS chooses base stations as candidate that supportall of its active service flows.In order toaccommodate this requirement, the advertising message (MOB NBR-ADV) contains a "*Scheduling Service Supported*" thatindicates the scheduling services supported in BS. After selecting the candidate list, MS starts sending scan request message to the serving base station. The MS measures the RSSI of the candidate BSs and selects Bss with their RSSI values greater than the lower threshold and the hysteresis value. Association procedure starts that further shorten the BSs list by adding some metrics such as mobility support.

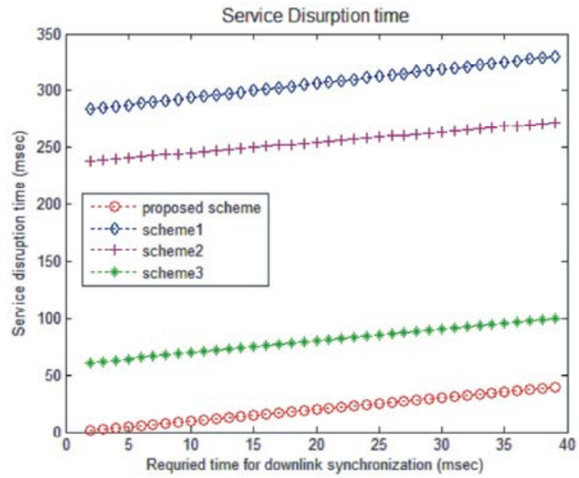

Fig. 1: Downlink Service disruption time vs. synchronization time for Choi's proposed scheme as compared to others.

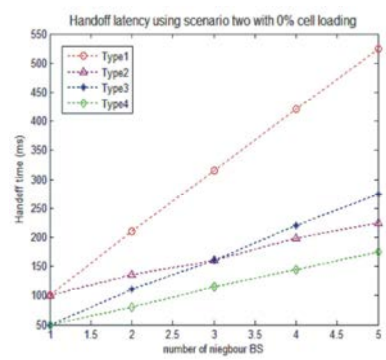

Fig. 2 (a): Handover time with 0% cell loading in scenario2

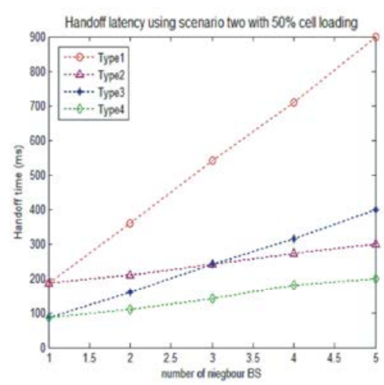

Fig. 2 (b): Handover time with 50% cell loading in scenario2

The handover initiates when the RSSI value of the serving base station is below a lower threshold. MS sends the handover request message to the serving base station that indicate that the MS wants to handover and includes the short list of the base station obtained in association

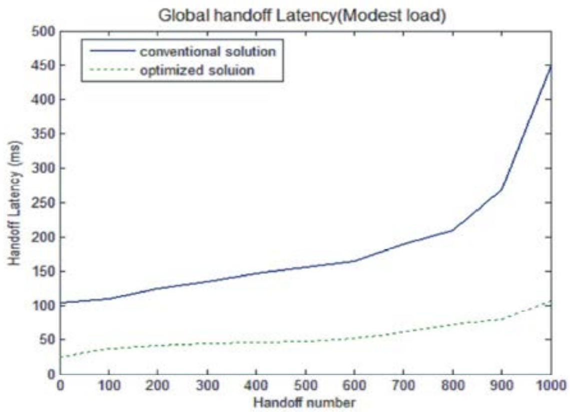

Fig. 3: Global Handover Latency (modest load)

procedure. Once the message is transmitted, the MS waits for the response. After receiving the response message from the serving base station, MS send handover initiation message that indicate the target base station. MS then starts normal re-entry procedure with the target base station.

The evaluation is based on two different association procedures. In the first scenario, the MS information is not available to the neighbor BSsand, therefore, authentication andregistration phases must be conducted by the MS. In the second scenario, the MS information is available to the neighbor BSs over the backbone network and hence MS can eliminate the association procedure and perform ranging operation to the target BS only. Fig 2 (a), Fig (b).

According to the results, the handover latency in second scenario is less than the first due to the elimination of basic capability negotiation, authentication and registration phases.

Cross-layer Fast Handover Scheme: In [12], Chen proposes a cross-layer solution which improves layer 2 handover process by cross-layer tunneling. The benefit of the scheme is that it minimizes direct message transportation between MS and neighboring Bss. In this scheme two tunnels are created. A Layer 2 tunnel is established between the MS and the serving BS and a Layer 3 tunnel is established between the serving and the target BSs. Chen uses Layer 3 to redirect and relay MAC-layer messages used during the HO, between the MS and the BS. This speeds up layer 2 handover process, as it reduces the ranging or scanning latency and eliminates the network re-entry latency. This improves the handover latency for both downlink and uplink transmission.

Chen, considered the conventional and his proposed optimized solution and presented a comparison of global handover latency in modest and heavy load mode.The global handover latency is greatly improved (more than 60% in the modest load) in the optimized solution as shown in Fig.3

DISCUSSION

As previously described, Zhang [9], Lee [10], H. Fattah [11], Ling Chen [12] and Sik Choi [8] aimed to improve HO latency to support real-time applications.

Choi [8] consider packet transmission delay during HO process and reduces latency only for downlink traffic. This scheme is efficient for downstream data such s video streaming and inefficient for applications such as VOIP and video conferencing. Unlike Choi [8], Chen [12] proposed a cross layer solution which reduces the HO latency of Layer2 by minimizing scanning latency and eliminates the network re-entry procedure for both uplink and downlink.

In [10], Lee presented fast HO algorithm to reduce theHO latency by combining the proposed algorithms (TBS, FSA and OHIT). The number of scanned BS is reduced to one, synchronization, association process and data transmission takes place simultaneously and the channel resource wastage is reduced by timely allocation of ranging slot of target BS. Like Lee [10], Zhang [9]alsoimproved HO latency by reducing the number of scanned BS. The target BSis selected using mobility pattern table. In H.Fattah [11], proposed and analyzed the performance of new algorithm that maintains the QoS parameters when performing HO to target BS by RSSI measurement. Unlike Lee [10], H.Fattah reduces HO latency by selecting that BS which is supported by the active running services on MS. Whereas Lee reduced HO latency by TBS, FSA and OHIT.

For performance analysis, we have compared Lee's [10] combinedTBS, FSA and OHIT and Zhang's[9] algorithms in different scanning types. We have considered WiMAX standard and type scan as supposed by Zhang [9]. The results are shown in Fig. 4, Fig. 5 and Fig. 6.

Both Lee's and Zhang's algorithm greatly reduce the HO latency. However, the performance of Zhang's algorithm outperforms Lee's algorithm in all type scans (except in type 1 scan for 0.5 cell load ratio, the performance of both algorithms is approximately equal).

Table 3. Shows a comparison between all five HO techniques discussed above.

Table 3: Comparison ofdiscussed HO techniques.Table1: Saved HO operation times using Lee's algorithms

	Choi [8]	Zhang [9]	Lee [10]	H.Fattah [11]	Chen [12]
Technique	Link-layer HO algorithm	MAC layer HO scheme	Fast HO algorithm	Service flow HO algorithm	Cross-layer HO scheme
Layer	MAC	MAC	MAC	MAC	MAC and Network
Objective	Reduce the HO latency and packet loss ratio for downlink real-time services	Reduce the HO latency by using Mobility pattern table	Reduce the HO latency by minimizing unnecessary scanning and association process	Reduce the HO latency by active flow services	Reduce the ranging latency and eliminates network re-entry
latency	Less than 50ms (downlink)	Less than 175 ms (scan without association.)	Less than 300ms (50% cell loading)	Less than 200ms (Contention-free ranging in scenario 2)	Less than 100ms (downlink and uplink)

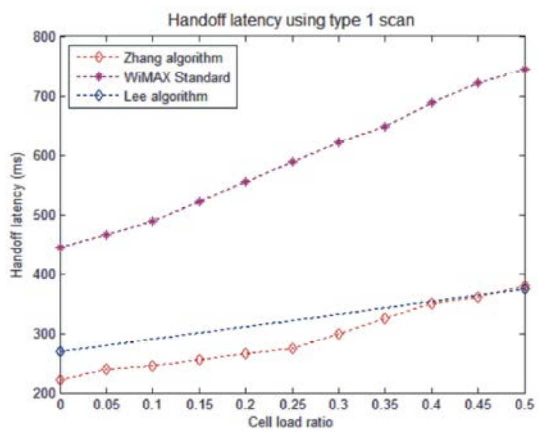

Fig.4: Handoff latency using type 1 scan

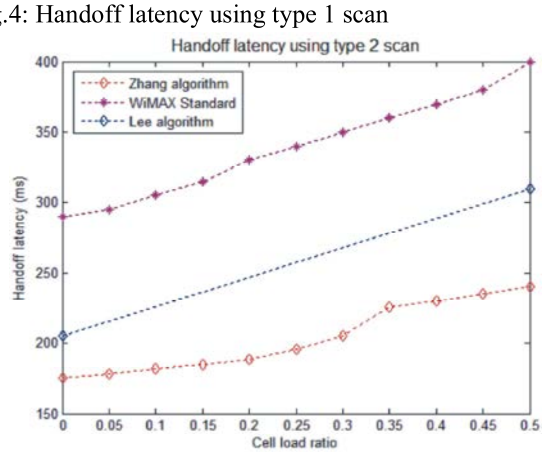

Fig. 5: Handoff latency using type 2 scan

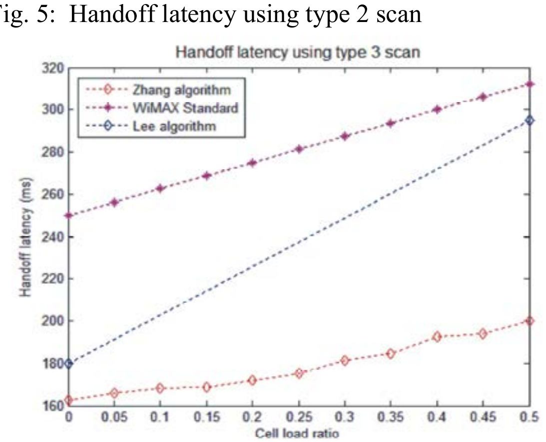

Fig. 6: Handoff latency using type 3 scan

CONCLUSION

Providing mobility inWiMAX networks through seamless HO mechanisms has become a significant area of research in Mobile Wireless Networks. Several handoff techniques for mobile WiMAX networks have been studied and compared on the basis of handover requirement, initiation and latency. The most efficient among these is Zhang's mobility pattern scheme [9]. As shown by thorough analysis, it reduces the HO latency by almost 50% when compared to the conventional HO mechanism followed by WiMAX standard.

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