Designs of Access Mechanisms in IEEE 802.16e Mobile Systems

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***Abstract*—In this paper, we first propose a call admission control algorithm for IEEE 802.16e mobile WiMAX system. We then design the handover mechanism according to the general handover procedure specified by the IEEE 802.16e-2005 standard. Performance evaluations via simulations are conducted to compare the system performance for the network with or without handover procedures employed. It is also found that the transmission quality is subject to the modulation rate change significantly in the mobile environments. The proposed mechanisms are shown to reduce connection blocking rate and packet dropping rate effectively to enhance the efficiency of the mobile WiMAX system.**

***Index Terms*—WiMAX, IEEE 802.16e, call admission control, mobile system, handover.**

I. Introduction

WiMAX is a technology that provides last mile internet access service in WMAN (Wireless Metropolitan Area Network). It also provides QoS, mobility and power saving mechanism which are defined in relevant IEEE 802.16 Standards [1],[2]. WiMAX system comprises two parts: SS (Subscriber Station) or MS (Mobile Subscriber Station) and BS (Base Station). The maximum transmission range is about 50km with 75Mbps available bandwidth. The link rate for each BS-MS pair is about 300k~2M bps. WiMAX network uses BS to connect core network. All packet transmission between WiMAX core network and MS must be forwarded by the BS. In IEEE 802.16e, the maximum MS speed can be supported up to 120km/hr (equal to the vehicular speed). The IEEE 802.16 standards have defined the specifications for both MAC (Media Access Control) layer and PHY (Physical) layer.

To support QoS in the WiMAX network, the BS may implement CAC (Call Admission Control) mechanism to decide whether to admit or reject the connection request. CAC is also used for reserving bandwidth for admitted connection and thus reducing the contention occurrence. For the admitted connection, the BS will then implement the bandwidth allocation mechanism to grant the bandwidth based on current bandwidth utilization and QoS parameters. The scheduling scheme is then executed to determine the actual packet transmission time of each connection.

Five service types are defined in IEEE 802.16e-2005 standard, which includes UGS (Unsolicited Grant Service), ertPS (Extended Real-time Polling Service), rtPS (Real-time Polling Service), nrtPS (Non Real-time Polling Service), and BE (Best Effort). The UGS is designed to support real-time service flow that generates fixed-size data periodically, such as T1/E1, VoIP without silence suppression. The ertPS is designed to represent real-time service flow that generates ON-OFF type data on the periodical interval, such as VoIP with silence suppression. The rtPS is designed to support real-time service flow that generates variable size data, such as video streaming services. The nrtPS is designed to support non real-time service flow that generates variable size data, such as FTP. The BE is designed to support best effort service, such as email.

In the mobile WiMAX environment, the handover procedure occurs when the MS moves into the service range of another BS. Two HO (handover) processes are defined in IEEE 802.16e-2005 standard: the hard handover process and the soft handover process. The hard handover is also called break-before-make handover. The MS starts connections with target BS only after disconnecting service with the serving BS. On the other hand, the soft handover is also called make-before-break handover. The MS starts connections with target BS before disconnecting service with the serving BS.

In this paper, the QoS mechanisms for the employment in the mobile WiMAX environment are proposed. We compare the performance of various traffic type data with or without handover procedures in the mobile WiMAX environment via simulations. The connection blocking probability and packet dropping rate under various scenarios are investigated.

The rest of this paper is organized as follows. Related works are described briefly in Section II, followed by the proposed call admission control mechanism in Section III. The handover procedures are proposed in Section IV. In Section V, performance evaluations are conducted. Finally, we draw our conclusions in Section VI.

II. Related Works

Reference [3] provides a cross layer handover procedure to reduce delay duration during handover procedure. Using Fast Mobile IPv6 mechanism for handover procedure, it activates both predictive and reactive mechanisms. The predictive mechanism is used when MS has enough reserved time to handle the handover procedure. The MS obtains new CoA before the handover procedure starts. On the other hand, the reactive mechanism is used when MS does not have enough handover time. In such case, MS gets new CoA after the handover procedure finishes.

Reference [4] considers the quality of service issue when HO occurs in mobile WiMAX environment. It defines five

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more scheduling priorities in additional to the original five priorities defined in the standard of IEEE 802.16-e 2005: HO_UGS, HO_ertPS, HO_rtPS, HO_nrtPS, and HO_BE (with priority order: HO_UGS > HO_rtPS and HO_ertPS > UGS > rtPS and ertPS > HO_nrtPS > nrtPS > HO_BE >BE). The CAC mechanism provides higher priority for handover call.

III. Proposed Call Admission Control Algorithm

Due to the varying capacities provided to mobile stations with different modulation schemes, the design of the CAC mechanism becomes much more complicated than that in the fixed configuration.

A. *Call Admission Control Mechanism*

The CAC mechanism with mobility taken into account is described as follows:

The main function of the CAC is to evaluate whether an incoming call connection should be accepted according to the requested bandwidth of the call and the available bandwidth of the system. The system accepts the connection if it is able to provide sufficient bandwidth, and vice versa. The upper bound limit of the available bandwidth is adjusted to the modulation scheme in use. Admission control is consequently achieved based on this limit.

Since the system is mobile, modulation changes with respect to the state of movement. Therefore, the admission control should consider multiple bandwidth limits, each adapting to its corresponding modulation scheme. When receiving a new connection requesting *NEW_UL_CALL_BW* (or *NEW_DL_CALL_BW*), the CAC determines if a ratio is greater than *MAX_UL_BW_RATE* (or *MAX_DL_BW_RATE*), as shown in (1) and (2). If the ratio is below this limit, the new connection is accepted. Otherwise, it is rejected.

B. *Bandwidth Ratio Calculation*

The method of estimating this ratio is called the bandwidth ratio calculation (BRC), denoted as the function *check_bw_rate*(*BW*), with BW being the bandwidth of interest, in this case, *check_bw_rate*(*NEW_UL_CALL_BW*) or *check_bw_rate*(*NEW_DL_CALL_BW*). BRC is computed as the sum of the proportion of used bandwidth in each modulation scheme (factoring in the modulation used during the connection request and the requested bandwidth) to its respective bandwidth upper limit. The resulting ratio is used as the basis in determining call admission.

$$check\_bw\_rate(NEW\_UL\_CALL\_BW) \leq MAX\_UL\_BW\_RATE \quad (1)$$

$$check\_bw\_rate(NEW\_DL\_CALL\_BW) \leq MAX\_DL\_BW\_RATE \quad (2)$$

where

NEW_UL_CALL_*BW*: uplink bandwidth request of new connection,

NEW_DL_CALL_*BW*: uplink bandwidth request of new connection,

MAX_UL_BW_RATE: maximum available uplink bandwidth ratio,

MAX_DL_BW_RATE: maximum available downlink bandwidth ratio.

IV. Proposed Handover Procedures

The General Handover procedure is implemented in this paper. We assume that every MS has the ability to acquire the SNR for all BS signals, and determine the condition for handovers based on this information.

When a MS decides to handover, it sends a MOB_MSHO_REQ message to the serving BS notifying the start of the procedure. This message contains the received signal strength information acquired by the MS of its nearby neighbor base stations. Upon receiving the MOB_MSHO_REQ message from the MS, the serving BS first terminates all communication activity with the MS, then stores all data packets destined to the MS. The BS, using a HO_pre-notification message, subsequently queries all neighboring BS retrieved from the MOB_MSHO_REQ message for the availability of the requested bandwidth and QoS level for the disconnected MS. The nearby base stations respond with HO_pre-notification_response, acknowledging the bandwidth and QoS level that could be provided. From this information the serving BS, selects the recommended target base stations by sending a MOB_BSHO_RSP message.

The MS decides whether to hand off to one of these BS according to signal strengths, and sends MOB_HO_IND to the serving BS notifying of its decision (if it chooses to handover, the HO_IND_type field within the MOB_HO_IND message is set to 'serving BS release', if not, then it is set to 'HO reject'). After receiving MOB_HO_IND, the serving BS, knowing the MS handover decision, sends necessary information for the handover in the HO_Confirm message to the target BS. In addition, it forwards the previously stored data packets from the MS to the target BS via the core network, and deletes all information associated with the MS from the serving BS.

Connections from the MS are re-established with the target BS by information gained from the HO_Confirm message and assigned new connection IDs. These IDs are updated with the MS through RNG_REQ/RSP messages, thus completing the handover procedure and continuing data flow.

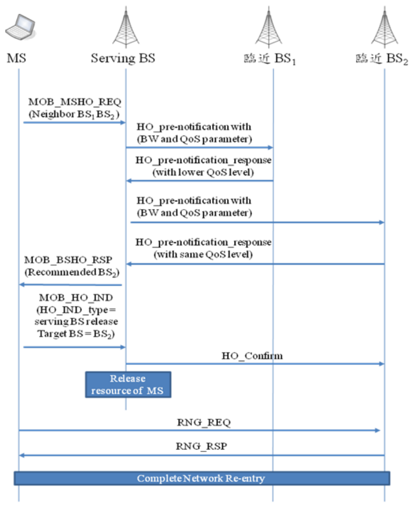

Fig. 1. General handover message flow.

In the IEEE 802.16e-2005 standard, the criterion of handovers is not specified. Hence, we use SNR threshold value between the MS and BS when evaluating handovers.

To prevent the ping-pong effect in the handover process, we use the method of Relative Signal Strength with Hysteresis [5].

Fig. 2 shows the MS moving between two adjacent regions and the changing SNR of the serving BS and target BS in relation to time, where the X axis is the SNR value and Y axis being time.

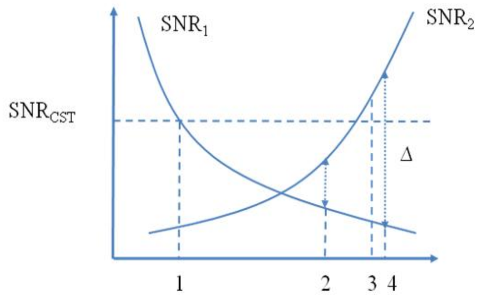

Fig. 2. SNR change between old/new BSs 1.

The most suitable time window for handover is when the SNR_1 of serving BS becomes lower than the handover signal strength threshold SNR_{CST}, and when the SNR_2 of the target BS is greater than the SNR_1 of the serving BS by Δ, as shown by (3) and (4).

The Relative Signal Strength with Hysteresis and Threshold method is implemented as follows. Equation (3) and (4) represent the handover conditions of the system. In this study, Δ is regarded as OFFSET. Utilizing this method presents two advantages: 1) While the communication channel quality with the current serving BS remain adequate, unnecessary handovers do not occur even in the event of a nearly BS with a stronger signal strength; 2) When a MS switches to a new BS, it will not handover immediately back to its previous BS if the distance between is shortened again as it changes its direction of movement. The SNR_1 of the previous BS must exceed the SNR_2 of the new BS by Δ in order for the MS to handover back to the previous BS, thus preventing ping-pong effect.

$$SNR_1 < SNR_{CST} \quad (3)$$

$$SNR_2 > SNR_1 + \Delta \quad (4)$$

V. Performance Results

The simulation environments and parameters are shown in the following tables, and performance results are exhibited from Fig. 3 to Fig. 10.

TABLE I: Simulation Parameters 1

Parameters	Value
Number of BS	3
Number of MS	4、6、8、10
Modulation Supported	QPSK、16QAM 3/4、64QAM
Traffic Supported	UGS/ertPS/nrtPS/rtPS/BE
Mobility	Yes
Scope	3500 x 3500 m
Number of Symbol each DLsubframe	26 symbols
Number of Symbol each ULsubframe	21symbols
MAX_UL_RATE	1
MAX_DL_RATE	0.8
Packet Size	160 byte
BWALLOC_FRAME_NUM	5 frames
Frame Duration	5m Sec
Simulation Time	7200 sec
SNR_{CST}	12.5 db
OFFSET	3 db
HANDOVER_WAITING_TIME	3sec

TABLE II: Simulation Parameters 2.

Parameters	*UGS value*	*ertPS value*	*rtPS value*	*nrtPS value*	*BE value*
Call Idle time/Arrival	1 Sec	1 Sec	1 Sec	1 Sec	1Sec
	Exponential	Exponential	Exponential	Exponential	Exponential
Call Duration	10 Sec	10 Sec	10 Sec	10 Sec	10 Sec
	Exponential	Exponential	Exponential	Exponential	Exponential
Packet Interval	20m Sec	20m Sec	20m Sec	20m Sec	20m Sec
	CBR	Silence Suppression	Exponential	Exponential	Exponential
Latency	100m Sec	100m Sec	500m Sec	1000m Sec	1000m Sec
Average Rate	64 kbps	64 kbps	256 kbps	48 kbps	x
Maximum Sustained Traffic Rate	64 kbps s	64 kbps	384 kbps	64 kbps	x
Minimum Traffic Rate	64 kbps	64 kbps	128 kbps	32 kbps	x
Grant	64 kbps	64 kbps	256 kbps	40 kbps	x

A. *Case 1:*

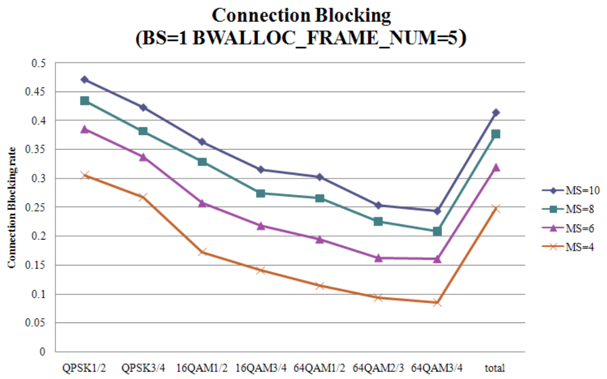

Fig. 3. Connection blocking rate (single BS).

Fig. 3 shows the rate of connection blocking rate experienced by the BS with different numbers of connecting MS. It can be obtained that when switching from QPSK 1/2 to 64QAM 3/4, the total bandwidth of the system is increased, and the connection blocking rate is gradually decreased. Hence for the CAC, using a modulation scheme with a higher total bandwidth allows more connections to be established, resulting in a lower connection blocking rate. On the other hand, system load is increased with increasing MS numbers, resulting in higher connection blocking rates for whichever modulation scheme used.

B. *Case 2:*

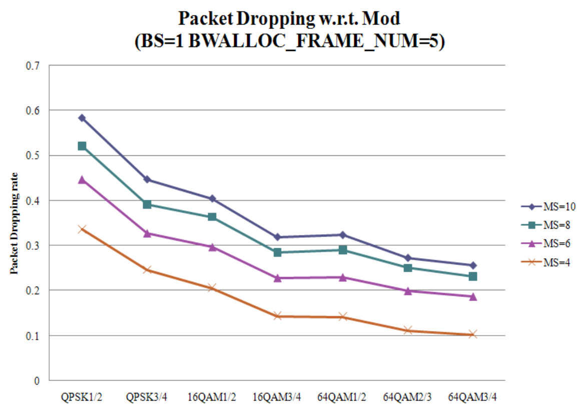

Fig. 4. Packet dropping rate vs. modulation rate (single BS).

Fig. 4 shows the different number of MS and their packet dropping rates. Similar to Fig. 3, total system bandwidth increases when switching modulation from QPSK 1/2 to 64QAM 3/4, resulting in lower connection blocking rates. For all modulations schemes, the packet dropping rate is increased with more connecting MS. Since employing 16QAM 3/4 and 64QAM 1/2 provide the same total bandwidth capacity, the packet dropping rates are identical.

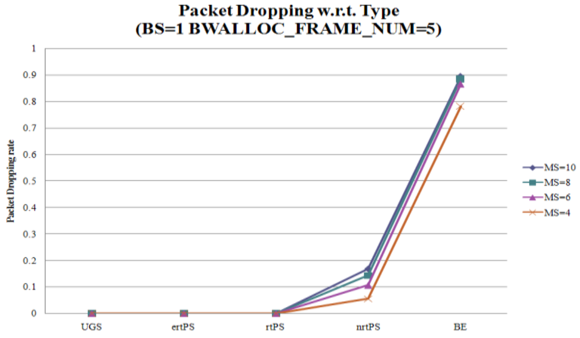

Fig. 5. Packet dropping rate vs. QoS type (Single BS).

Fig. 5 shows the packet dropping rates for different QoS types. Due to different priorities assigned to each type, the bandwidth is more likely to be allocated to packets with higher priorities. The priority level decreases from UGS to BE, resulting in increasing packet dropping rates. From these four plots it can also be seen that for all QoS traffic types, an increasing number of MS induces more loading on the system, leading to higher packet dropping rates.

C. *Case 3:*

Fig. 6 and Fig. 7 show the effect of handovers and corresponding parameters on system performance. It can be observed that a higher number of handovers does not necessarily lead to lower connection blocking and packet dropping rate, which is also the case with lower number of handovers. Optimal performance can only be achieved when the appropriate parameters are chosen.

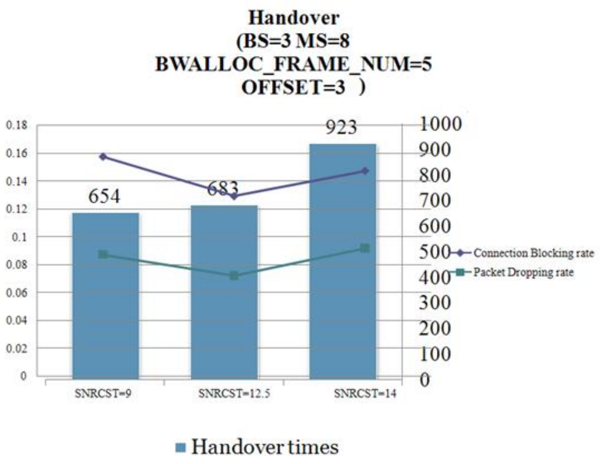

Fig. 6. Handover times vs. SNR_{CST}.

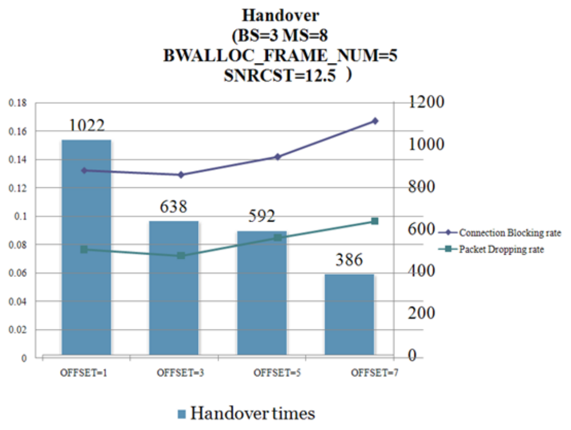

Fig. 7. Handover times vs. OFFSET.

Fig. 8 shows the connection blocking rate with respect to the number of connecting MS. Connection blocking rate increases relative to the number of connecting MS. In addition, the connection blocking rate in all cases is lower with the existence of handovers. The reason is due to the fact that, without handovers between BS, it cannot be guaranteed that every MS will transfer data using the suitable modulation scheme, thus resulting in the higher connection blocking rate. This is also the case with Fig. 9, a higher packet dropping rate is observed in the non-Handover configurations.

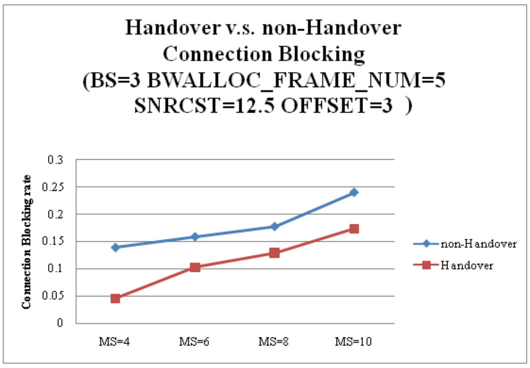

Fig. 8. Connection blocking rate (handover vs. non-handover).

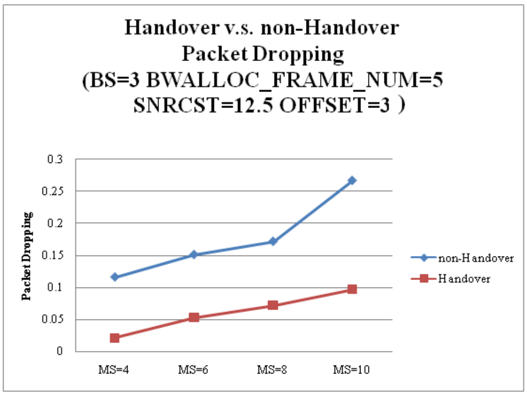

Fig. 9. Packet dropping rate (handover vs. non-handover).

Fig. 10 sets the number of MS at 8 and shows the packet dropping rate with respect to different QoS traffic classes. The graph shows packets with UGS, ertPS, and rtPS types, due to the prioritized bandwidth allocation mechanism, experience better performance than other types in both handover and non-handover settings. Yet, without handovers, the MS may be transferring data using a less suitable modulation scheme for an extended period of time, causing starvation for other lower priority traffic types, resulting in higher packet dropping rates.

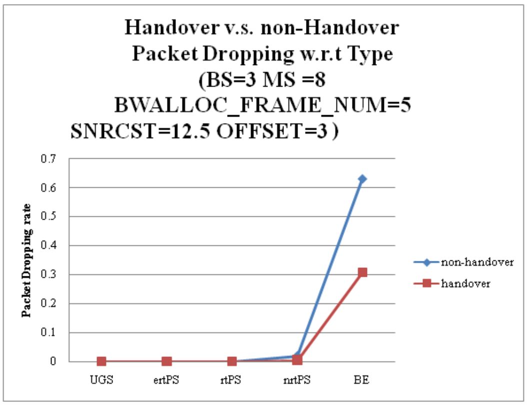

Fig. 10. Packet dropping rate / QoS type (handover vs. non-handover).

Based on these results, it can be concluded that performance in the handover setting far exceeds the non-handover setting.

VI. Conclusion and Future Research

In this study, we referred to the IEEE 802.16e-2005 standard, and proposed a QoS mechanism for mobile environments with network handover procedures. We also proposed a General Handover algorithm. Through the analysis of handover parameters, we reach the conclusion that, a suitable set of parameters must be applied in order to optimize system transfer performance. A relatively higher or lower number of handovers will in general result in poorer performance.

We also studied and analyzed the effects of handovers on system performance against systems without handovers. We observed that a system with handover mechanism shows higher transfer efficiency and lower connection blocking rates and packet dropping rates.

Acknowledgement

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