A Novel Downlink Handover Priority Scheduling Algorithm for Providing Seamless Mobility and QoS in IEEE802.16e BWA System

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Abstract

In IEEE 802.16e wireless metropolitan area networks, users could take their broadband connections with them as they move from one location to another with different speeds. Providing QoS is more challenging for mobile subscribers at vehicular speeds than for others. On the other hand, time variability and unpredictability of the wireless channel may cause QoS degradation for these users. Therefore, providing seamless handovers especially at vehicular speeds is necessary for maintaining QoS. This paper proposes a new downlink handover priority scheduling algorithm for different scheduling services which is providing lossless handovers and QoS. Taking the power degradation rates into consideration, this algorithm assigns higher priority to the users who have higher speeds. A priority based AMC (Adaptive Modulation and Coding) is also performed for better performance. The analysis results show the efficiency of proposed scheme.

I. Introduction

IEEE802.16e broadband wireless access (BWA) systems are providing multiple services for both fixed and mobile users [1]. In December 2005, the IEEE group completed and approved IEEE 802.16e-2005, an amendment to the IEEE 802.16-2004 standard that added mobility support [2]. The IEEE 802.16e-2005 standard defines a framework for supporting mobility management. In particular, the standard defines signaling mechanisms for tracking subscriber stations as they move from the coverage range of one BS (Base Station) to another when active or as they move from one paging group to another when idle.

In IEEE 802.16e, the HO (Handover) process is defined as the set of procedures and decisions that enable an MS (Mobile Subscriber) to migrate from the air interface of one BS to the air interface of another. The standard also has protocols to enable a seamless handover of ongoing connections even for users at vehicular speeds up to 120kmph.

IEEE 802.16e suggested a process in which BS allow each MS to monitor and measure the radio condition of the neighboring BSs called *scanning*. Three levels of associations can be performed for handover during scanning process, association level 0, 1 and 2. Association is an optional initial ranging procedure occurring during scanning interval with respect to one of the neighbor BSs. Also, the two optional handover mechanisms are FBSS (Fast BS Switching) and MDHO (Macro Diversity Handover). In both mechanisms the MS and the BS shall maintain a list of BSs that are involved in handover with the MS called the diversity set. During MDHO MS communicates on the downlink and the uplink with all the BSs in the diversity set while in FBSS an MS communicates with one of the BSs in the diversity set called Anchor BS.

Up to now, different handover schemes had been proposed. In [3] and [4] fast handover schemes are presented. [3] proposed that a mobile subscriber station can receive downlink data before synchronization with uplink during handover which reduces data transmission delay and packet loss for real-time downlink service. In [4], proposed algorithm can reduce handover operation delay by reducing unnecessary neighboring BS scanning. But [3] and [4] has not presented an efficient algorithm for other scheduling services. In [5], it proposed to perform different handover mechanisms for different scheduling services in order to guarantee delay performance during handover. However, it does not work on other QoS requirements such as handover failure and handover packet dropping rate. Finally, [6] proposed a handover priority scheduling algorithm which takes into account buffer occupancy and channel conditions. Thus, the system is able to provide low handover packet dropping rate. But [6] does not take speeds of MSs or power degradation level into

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consideration [7]. In this paper, a downlink handover priority scheduling algorithm is proposed to reduce packet dropping and handover failure during handover process. In the scheduler, the flows of a scheduling service which have the highest power degradation rate, obtain the highest priority. A priority based AMC is also proposed to prevent packet loss during handover process.

The remainder of this paper is organized as follows. Section II describes the handover procedure in IEEE 802.16e. The proposed scheme is introduced in section III. In section IV performance results obtained by computer simulation are presented and discussed. Finally, we present our conclusion in section V.

II. Handover procedure in IEEE 802.16e system

The handover procedure in IEEE 802.16e has several steps as shown in Fig. 1. During cell reselection the MS performs scanning and association with neighbor BSs for the purpose of evaluating MS interest in HO to a potential target BS. After cell reselection, the MS remains the normal operation with the serving BS. A handover begins with a decision for an MS to HO from a serving BS to a target BS. The decision may originate either at the MS or the serving BS by either MOB_MSHO-REQ or MOB_BSHO-REQ messages.

An MS shall transmit a MOB_HO-IND message for final indication that it is about to perform a handover. This message is also used for handover cancellation or handover rejection. Thus, after a handover process has been initiated, the MS can cancel it at any time. After selection of the target BS synchronization between MS and its new downlink transmission will be performed. The MS uses the ranging channel to perform the initial ranging process to synchronize its uplink transmission with the BS and get information about initial timing advance and power level. The MS can skip or shorten this stage if it performed association with the target BS during the cell reselection/scanning stage.

Finally, after the HO request/response handshake has completed, the MS may begin the actual HO. At some stage during the HO process, the MS terminates service with the serving BS. This is accomplished by sending a MOB_HO-IND message with the HO_IND_type value indicating serving BS release. If the HO_IND_type field specifies serving BS release, the BS shall start the Resource retain timer. The serving BS shall retain the connections, MAC state machine, and PDUs (Protocol Data Units) associated with the MS for service continuation until the expiration of Resource retain timer. As said above, expiration of Resource retain timer leads to handover failure. Handover failure may cause by other reasons too. For example, an MS at vehicular speed may leave the cell before receiving the response of its handover messages. Handover process may have packet dropping too. Handover drop is defined as the situation where an MS has stopped communication with its serving BS either in the downlink or in the uplink before the normal handover sequence outlined in Cell Selection and Termination with the serving BS has been completed. Therefore, these two handover loss reasons should reduce for QoS requirements.

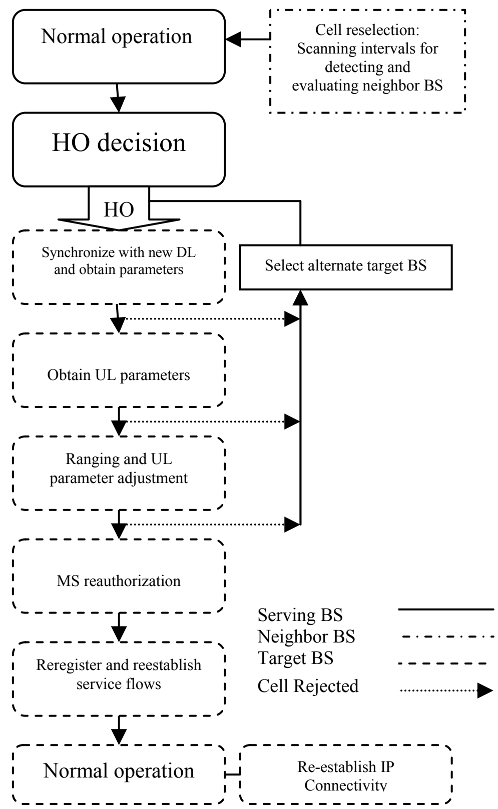

Fig. 1 Handover procedure in IEEE 802.16e system

III. Proposed scheme for lossless handover

A. System model

An IEEE 802.16e BWA system is implemented. The model supports five handover mechanisms as mentioned before. Five scheduling services are defined too, namely UGS (Unsolicited grant service), rtPS (Real-time polling service), ertPS (Extended rtPS), nrtPS (Non-real-time polling service) and BE (Best-effort). A scheduling service is determined by a set of QoS parameters that quantify aspects of its behavior.

The UGS is designed to support real-time service flows that transport fixed-size data packets on a periodic basis, such as T1/E1 and Voice over IP without silence suppression. The rtPS support real-time service flows that transport variable-size data packets on a periodic basis, such as moving pictures experts group (MPEG) video. The ertPS is a scheduling mechanism which builds on the efficiency of both UGS and rtPS. This service supports real-time applications, such as VoIP with silence suppression, with variable data rates but require guaranteed data rate and delay. The nrtPS is designed to support delay-tolerant data streams, such as FTP, that require variable-size data grants at a minimum guaranteed rate. And BE is designed to support data streams, such as Web browsing and P2P, that do not require a minimum service-level guarantee. These services are classified in four service classes with respect to their priority, as shown in Table 1. In this paper, we call these traffic classes as class A, B, C or D.

Table 1 Scheduling Service Classes with Their Priorities

Scheduling Service Classes	UGS	rtPS, ertPS	nrtPS	BE
	(From Highest Priority to Lowest)			
Maximum Sustained Rate	Yes	Yes	Yes	Yes
Minimum Reserved Rate	No	Yes	Yes	No
Maximum Latency Tolerance	Yes	Yes	No	No
Class-of-Service	A	B	C	D

B. Proposed downlink handover priority scheduling algorithm

IEEE802.16e BWA systems should support the Simple Mobility and Full Mobility features. The subscriber may move at speeds up to 60 kmph with brief interruptions during handover in simple mobility while the system provides a seamless handover for an MS at speeds up to 120 kmph in full mobility. To meet these challenges the system should prevent handover failures and reduce handover packet dropping, especially for subscribers at vehicular speeds using high priority scheduling services, such as VoIP.

In most of proposed scheduling algorithms, there is no difference between a user who is moving at vehicular speed in cells overlap areas and a pedestrian user. Taking power degradation rate as an important parameter during handover process, this paper proposes a downlink handover priority scheduling algorithm, operating as follows:

A Handover Zone is defined, where the RSS (Received Signal Strength) received by an MS is between Handover Threshold and the MSL (Minimum Signal Level) value, as shown in Fig. 2. When an MS moving away from its serving BS e.g. BS1 to the target BS e.g. BS2, handover procedure is initiated when the signal drops below the handover threshold. The system calculates handover threshold in order to collect all the users who are transmitting or receiving MOB_MSHO-REQ, MOB_HO-IND and MOB_BSHO-REQ messages in handover zone. The handover procedure can be successful until the RSS is greater than MSL value; otherwise link quality will not acceptable and may cause handover failure, due to excessive packet loss. By default, the MSL value is greater in higher priority services and has direct relation with the expiration time of Resource Retain Timer. Handover procedure is done with association level 2 which uses non-Contention-based ranging. To provide the required QoS necessities of scheduling services, the Round Robin scheduling is applied.

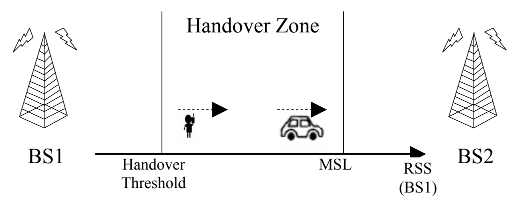

Fig. 2 Handover Zone

To provide lossless handovers, the proposed scheduling algorithm serves the service flow *i* with the highest priority P_i which is calculated with the following formula:

$$P_i = p_{SC_i} + p_{rss_i} + p_{rss'_i} + p_{rss''_i} \tag{1}$$

Where, p_{SC_i} is the service class priority of the flow *i*, which can take four values for service classes A, B, C or D. By default, p_{SC_i} has greater value in higher priority services. The next three terms are the RSS and its derivatives priorities:

$$p_{rss_i} = K_p . RSS_i \tag{2}$$

$$p_{rss'_i} = K'_p . \frac{d}{dt} RSS_i \tag{3}$$

$$p_{rss''_i} = K''_p . \frac{d^2}{dt^2} RSS_i \tag{4}$$

Where, RSS_i is the RSS rate received by an MS using service flow *i*. K_p, K'_p and K''_p are prioritization constants. The priority terms p_{rss_i}, $p_{rss'_i}$ and $p_{rss''_i}$ are very small for mobile users who are out of handover zone, called normal users. Thus, commonly the scheduler serves normal users with lower priority than users in handover zone. Note that RSS_i can locate MS position and $\frac{d}{dt} RSS_i$ can monitor its speed in handover zone. The term

$\frac{d^2}{dt^2} RSS_i$ helps with the priority expression to be more accurate by monitoring MS acceleration.

As we know, power-level fluctuations can occur due to mobility, fast fading and shadow fading or any combination thereof. Generally, the user with these power fluctuations needs to perform handover procedure in order to maintain its connection quality. But, in some cases power fluctuations are momentarily and there is no need to perform handover procedures for such users. In order to remove these users from high priority users, we replace P_i with $P_{i_{avg}}$ which is calculated with the following formula:

$$P_{i_{avg}} = \delta P_{i_{new}} + (1-\delta)\, P_{i_{old}} \qquad (5)$$

Where, δ is a constant between 0 and 1, which depends on the amount of signal variation (e.g., kind of shadowing). It is currently chosen experimentally. The priority $P_{i_{avg}}$ can eliminate normal users with transitional power-level fluctuations from high priority users. Therefore, the proposed scheduling algorithm assigns higher priority to deserving mobile users by monitoring the RSS of each user and its degradation behavior. Simulation results validate the performance of proposed algorithm as depicted in section IV.

C. Adaptive modulation and coding scheme

An AMC scheme is applied in order to compensate downlink channel fluctuations during transmission. The scheme enables the system to transmit with higher data rates in good channel conditions and avoid excessive packet dropping in poor channel conditions by reducing data rate. Therefore, efficient bandwidth utilization and high throughput can be achieved. Proposed AMC enables the scheduler to select the appropriate coding and modulation for each allocation. Thus, users in handover zone achieve higher data rates and better throughput, since the scheduler gives higher priorities to them. Several AMC schemes are proposed, namely, 16-state and 64-state Quadrature Amplitude Modulation (QAM), Quadrature Phase Shift Keying (QPSK) and Binary Phase Shift Keying (BPSK) with coding rates of 1/2, 2/3 and 3/4, as shown in Table 2.

Table 2 AMC Schemes and Receiver SNR Assumptions

Modulation	Coding Rate	Receiver SNR
BPSK	1/2	3
QPSK	1/2	6
	3/4	8.5
16-QAM	1/2	11.5
	3/4	15
64-QAM	2/3	19
	3/4	21

IV. Performance results

A. Simulation model

A discrete event simulation program written in NS2 [8] and C++ has been designed for simulating IEEE 802.16e BWA networks. The system is a Time Division Duplexing (TDD) with frame length 5ms. The model has 20 cells and supports scanning and handovers. Mobile users have different speeds of the range from 0 km/h to 120 km/h while using four scheduling services. Speed changing method is following a uniform distribution. Multipath fading and shadowing effect are also included. Total bandwidth is divided equally between four scheduling services. Simulation parameters are shown in Table 3.

Table 3 Simulation Parameters

Parameter	Value
Frequency Bandwidth	5 MHz
Duplexing Mode	TDD
Frame Duration	5 ms
Scan Iteration	2
Cell Radius	500 m
Number of Cells	20
Number of MSs	0-90
User Mobility Speed	0-120 kmph
Modulation Scheme	BPSK,QPSK,16QAM, 64QAM
Shadowing	Log-normal zero mean, 8dB stdev

B. Simulation results

In order to validate the performance of proposed handover scheduling scheme, this paper studies two handover metrics, namely handover packet dropping and handover failure probability. For every 5s interval, performance results are updated and the mean value is calculated after the simulation progress.

Two simulation scenarios are performed. The first one is a system uses the proposed handover scheduling algorithm. In second scenario the system uses conventional scheduling algorithm while priority terms p_{rss_i}, $p_{rss'_i}$ and $p_{rss''_i}$ are zero for all mobile users. Fig.3 shows the performance of the handover packet dropping rate, which is defined as follows:

$$p_{HO-dropping} = \frac{number-of-dropping-packets}{total-number-of-generated-packets} \qquad (6)$$

Since, the proposed algorithm assigns higher priority to users who are in handover zone, decreasing the number of dropping packets in first scenario is acceptable. When the instantaneous number of mobile users increases, we have more users in handover zone and more handover procedures occur. However, when the system load is high and there are many users using scheduling services, the proposed algorithm provides higher dropping rate. This is because the proposed algorithm assigns higher priority to users in handover zone, while there are many other flows with full buffers in system.

Fig. 4 shows handover failure probabilities in mentioned scenarios. The proposed algorithm has better performance, since it gives higher priority to the users who are in handover zone. As the number of mobile users increases, more users get involved in handover procedures. Therefore, when the system load is very high, two scenarios have almost the same handover failure probabilities because the system has to perform too many handovers at the same time, regardless of user's priorities. Note that high system loads do not occur regularly and the system may use other scheduling algorithms in such situations.

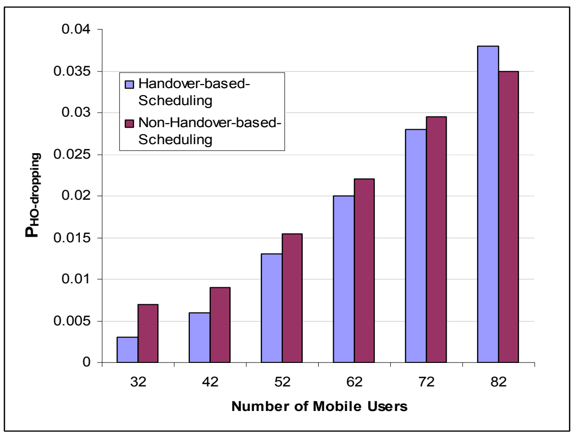

Fig. 3 Handover packet Dropping Probabilities

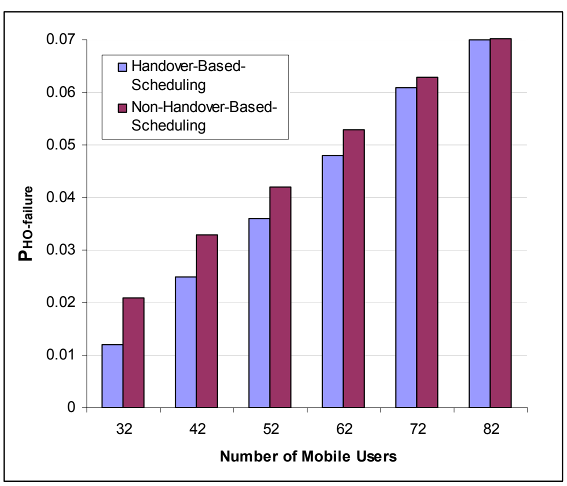

Fig. 4 Handover Failure probabilities

V. Conclusions

In this paper, we proposed a downlink handover scheduling algorithm, which provides lossless handovers and QoS in IEEE 802.16e BWA system. Considering the power degradation rates, this algorithm assigns higher priority to the users who have higher speeds. A priority base AMC is also included for better performance during handover procedures. Analysis results show that, the proposed algorithm has a great impact on handover failure and handover packet dropping probabilities.

Acknowledgments

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