IEEE 802.16e 에서 멀티캐스트 MAP 의 효율적 전송 기법

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Efficient transmission of multicast MAP in the IEEE 802.16e

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Abstract

The IEEE 802.16e suggests the use of multicast sub-MAPs whose messages are differently encoded according to the operating condition. In this case, it is desired for the base station to properly choose a modulation and coding set (MCS) associated with operating condition. In this paper, we consider the use of an adaptive modulation coding (AMC) scheme for the multicast sub-MAP that achieves the same MAP coverage as the broadcast MAP while minimizing the signaling overhead. We consider the adjustment of the threshold for the AMC according to the channel condition without explicit information on the channel condition, significantly reducing the amount of the signaling overhead. Simulation results show that when it is applied to voice-over-IP (VoIP) services, the proposed scheme can enhance the VoIP capacity.

I. Introduction

The IEEE 802.16e standard specifies a new wireless access system, which provides a state-of-art solution for the last-mile technology [1]. Mobile worldwide interoperability for microwave access (m-WiMAX) is a commercial IEEE 802.16e based orthogonal frequency division multiple access (OFDMA) system supporting time-division duplex (TDD). The m-WiMAX can support a wide range of data services and applications with various QoS requirements. The m-WiMAX can support bursty data traffic at high peak rates while simultaneously supporting streaming video and latency-sensitive voice traffic over the same channel [2]. Adaptive modulation and coding (AMC) and hybrid automatic repeat request (HARQ) have also been introduced to the m-WiMAX to enhance the coverage and capacity in mobile environments [2].

In the IEEE 802.16e (or m-WiMAX), the resource allocation information is conveyed in the MAP message at the beginning of each frame, allowing the scheduler to effectively change the resource allocation on a frame-by-frame basis in response to the bursty nature of traffic [1, 2]. The MAP message contains the allocation information on both the downlink (i.e., DL-MAP) and the uplink (i.e., UL-MAP). The MAP information needs to reliably be delivered to users even near the cell boundary. It is usually encoded by QPSK modulation at a code rate of 1/2 with six repetitions (i.e., an effective code rate of 1/12), corresponding to the lowest spectral efficiency of the IEEE 802.16e [1, 2]. As a consequence, the signaling overhead for the MAP message is not small [3]. In particular, in services of many data packets with small sizes such as voice-over-IP (VoIP) traffic, the amount of MAP signaling overhead can be unacceptably large [2].

To reduce the MAP overhead, the IEEE 802.16e can utilize multicast sub-MAP messages each of which can be encoded differently according to the operating condition (e.g., the carrier-to-interference plus noise ratio (CINR)) [1, 2]. It is desirable to optimally choose the MCS level to minimize the signaling overhead for the sub-MAP. However, most of previous results have been reported on the use of broadcast MAP messages, not on the use of sub-MAP messages [3, 4, 5].

When using the sub-MAP messages, the BS needs accurate downlink CINR of users in order to determine the MCS level for the sub-MAPs. The BS can get the downlink CINR from the channel quality indicator (CQI) reported by users. However, it is not easy for the BS to get accurate downlink CINR for sub-MAPs via CQIs since the CQIs are used for the purpose of AMC for the downlink data burst. For instance, users scheduled only in the uplink don't need to report the CQI, but users scheduled in the downlink need to send the CQI according to the period of CQI report, which is related to the AMC for their data bursts. Moreover, the BS cannot obtain accurate downlink CINR of users in high mobility even when receiving the CQI [6]. The MCS level for the sub-MAP can be determined based on the average CINR (e.g., slow AMC using average CINR (geometry)) [6]. However, the BS should provide a margin for the CINR threshold considering the discrepancy between the average and accurate downlink CINR. In fact, this margin can be dependent on the power delay profile [7, 8].

In this paper, we consider an AMC scheme for the sub-MAPs to reduce the MAP signaling overhead without explicit information on the channel condition. The proposed scheme adjusts the threshold for the MCS in response to the sub-MAPs. The BS lowers the threshold level by a small step when a user responds to its own sub-MAP. Otherwise, it raises the threshold level by a large step to meet the desired message error rate (MER). Then the proposed scheme determines the MCS level considering both the spectral efficiency and the amount of these messages. The proposed scheme can considerably reduce the MAP overhead and thus increase the system capacity when applied to services such as VoIP services which require a large MAP overhead.

Section II describes the downlink frame structure and the MAP overhead in the IEEE 802.16e system. Section III presents the proposed scheme to determine the optimum MCS level and the CINR threshold level. Section IV verifies the performance of the proposed scheme by computer simulation. Finally, Section V concludes the paper.

II. System Description of IEEE 802.16e

II-1. Downlink subframe structure

The IEEE 802.16e scheme has a TDD frame structure, i.e., each frame comprises downlink and uplink subframes. The downlink subframe consists of a preamble, a frame control header (FCH), MAP messages and multiple downlink data bursts [1, 2]. The IEEE 802.16e uses a slot comprising 48 data subcarriers as the minimum unit for resource allocation. Letting S_{FCH}, S_{MAP} and S_{data} be the number of slots for the FCH, MAP message and total data bursts, respectively, it can be seen that

$$S_{FCH} + S_{MAP} + S_{data} \le R_{slot} \qquad (1)$$

where R_{slot} is the number of maximally allowable downlink slots.

II-2. MAP overhead

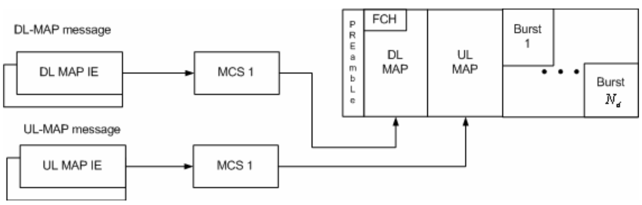
We consider the MAP overhead associated with the broadcast MAPs and multicast sub-MAPs. The MAP overhead is defined by the number of slots for the MAP message. Since the FCH uses a fixed number of slots (equal to four slots), the MAP overhead directly influences the system capacity of the downlink. We represent the MCS level from 1 to M in an ascending order of the spectral efficiency, where ρ_m denotes an MCS level of $1 \le m \le M$. We assume that each user transmits a single data burst in each frame. We consider a compressed format which uses one-dimensional allocation of the UL-MAP message excluding the MAC header because the overhead for this type of message is less than that for a normal message [1, 3].

Fig. 1 (a) shows that the broadcast MAP comprises the DL- and UL-MAP messages. Each MAP message contains multiple information elements (IEs) in proportion to the number of data bursts. It is modulated with an MCS level of 1 (i.e., at the lowest spectral efficiency). When the broadcast MAP is used with $J(=48)$ number of subcarriers per slot, the MAP overhead S_{MAP} can be represented as [1]

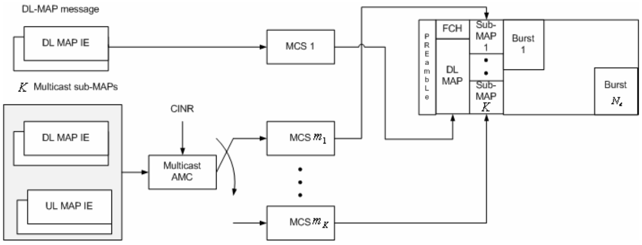
$$S_{MAP} = \left\lceil \frac{h_{BC}\left(N_d, N_u\right)}{J \cdot \rho_1} \right\rceil \qquad (2)$$

where $\lceil x \rceil$ denotes the smallest integer not less than x, N_d and N_u are the number of users scheduled in the downlink and uplink, respectively, the denominator $J \cdot \rho_1$ represents the number of bits in each slot with a MCS level of m, and h_{BC} denotes the number of information bits for both the DL- and UL-MAP messages containing the allocation information of N_d and N_u users, respectively.

Fig. 1 (b) illustrates the downlink subframe structure for the multicast MAP messages, where each of K sub-MAPs is differently encoded. The DL-MAP message contains K Sub-MAP-pointer-IEs, while the sub-MAPs contain the information on the resource allocation; the DL-MAP-IEs and UL-MAP-IEs [1]. When the sub-MAPs are used, the MAP overhead can be represented as



(a) Broadcast MAP messages.



(b) Multicast MAP messages.

Fig. 1. Downlink subframe structure.

$$S_{MAP} = \left\lceil \frac{h'_{BC}(K)}{J \cdot \rho_1} \right\rceil + \sum_{k=1}^{K} \left\lceil \frac{h_{MC}\left(b_{d,m_k}, b_{u,m_k}\right)}{J \cdot \rho_{m_k}} \right\rceil \qquad (3)$$

where h'_{BC} denotes the number of bits in the DL-MAP message when the sub-MAPs are used, h_{MC} denotes the number of bits in each sub-MAP, m_k denotes the MCS level for the k-th sub-MAP, and b_{d,m_k} and b_{u,m_k} denote the number of users in the downlink and the uplink, respectively, belonging to the k-th sub-MAP message with MCS level m_k [1]. It can be seen that the more the sub-MAPs are used, the larger the size of the MAP messages is required. To reduce the MAP overhead, it is desirable to determine the number of the sub-MAPs and associated MCS levels to increase the spectral efficiency.

III. Proposed AMC for Multicast Sub-MAPs

In this Section, we consider an AMC scheme for the sub-MAPs, where the BS adjusts the CINR threshold for the selection of MCS level to minimize the MAP overhead. We assume that the BS is aware of whether the sub-MAPs are successfully delivered to users or not, in response to the sub-MAPs.

In the IEEE 802.16e, users who receive the HARQ-DL-MAP-IE in the sub-MAP send an ACK signal after a certain amount of delay, called ACK delay. However, when users do not successfully receive the sub-MAP through the downlink, they do not send an ACK signal through the uplink. Thus, the BS can acknowledge successful delivery of multicast messages by detecting the ACK signal. Since the ACK signals are transmitted with high reliability, they can be detected by the BS at a very low error rate [9]. Users who did not receive the HARQ-UL-MAP-IE in the sub-MAP cannot transmit their data bursts to the BS. In this case, the BS can acknowledge successful delivery of the sub-MAPs by detecting the data bursts in the uplink. Thus, the BS can adjust the CINR threshold of each user by monitoring the user response to the sub-MAPs as

$$\delta_u = \begin{cases} \delta_u - \Delta_{Down} & \text{detection of CQI or uplink data bursts} \\ \delta_u + \Delta_{Up} & \text{otherwise} \end{cases} \qquad (4)$$

and

$$th_{u,m} = th\_init_m + \delta_u \qquad (5)$$

where δ_u denotes the threshold margin of user u, th_init_m and $th_{u,m}$ denote the initial and current CINR threshold for MCS level m of user u, respectively, and Δ_{Down} and Δ_{Up} denote the step size for down and up, respectively, to satisfy the desired MER [10]. It should be noted that the threshold margin is upper-limited by $\delta_u \le \delta_{\max}$ since it can unnecessarily be large due to detection errors. The upper limit $\delta_{\max}$ corresponds to the largest fade margin required for the desired MER among possible channel conditions [8]. Since the number of the sub-MAPs is less than M, each sub-MAP message may contain information on multiple users who experience different CINRs. In this case, the message needs to be modulated at an MCS level corresponding to the minimum of these CINRs [11]. Thus, it is desirable to consider users who are in the range of CINR corresponding to the MCS level of their sub-MAPs in the previous transmission.

The BS can adjust the CINR threshold to satisfy the desired MER by monitoring the response to the sub-MAPs even though it has no full channel information. We define the AMC function $f_u(\gamma_u)$ which selects the MCS level for user u according to the CINR γ_u as

$$f_u(\gamma_u) = \arg\max_{m=1,\dots,M} \{\gamma_u \geq th_{u,m}\}. \quad (6)$$

The MCS level for the sub-MAPs has an effect on both the spectral efficiency and the amount of MAP messages. Moreover, the MAP overhead is associated with the output from the combination of the two factors from (3). Thus, the optimum MCS level can be determined by simultaneously considering the following two factors. First, a candidate set for the MCS level of the sub-MAPs can be determined using the threshold obtained in the above. The MCS level can be determined by finding the minimum MCS level of x and the maximum MCS level of y for all users, given by

$$x = \min_u f_u(\gamma_u) \text{ and } y = \max_u f_u(\gamma_u). \quad (7)$$

The MAP messages need to include the minimum MCS level to maximize the delivery possibility. Therefore, (K - 1) MCS levels are chosen between ($x+1$) and y, where K should be less than or equal to (y - x +1). We can consider L candidate sets for the MCS level, each of which comprises K MCS levels, given by

$$\{q_{K,1,1},\dots,q_{K,1,K}\},\dots,\{q_{K,i,1},\dots,q_{K,i,k},\dots,q_{K,i,K}\},\dots,\{q_{K,L,1},\dots,q_{K,L,K}\} \quad (8)$$

where L denotes the number of combinations of (K - 1) taken from MCS levels between ($x+1$) and y (i.e., ${}_{y-x}C_{K-1}$), $q_{K,i,k}$ denotes the k-th MCS level of the i-th candidate set.

Letting $b_{d,q_{K,i,k}}$ be the number of users using MCS level $q_{K,i,k}$ among N_d users scheduled in the downlink, it is given by

$$\begin{cases} \#\left(u \mid q_{K,i,k} \leq f_u(\gamma_u) < q_{K,i,k+1}\right); & 1 \leq k \leq K-1 \\ \#\left(u \mid f_u(\gamma_u) \geq q_{K,i,k}\right); & k = K \end{cases} \quad (9)$$

where #(•) denotes the number of users in each set. Letting $b_{u,q_{K,i,k}}$ be the number of users belonging to an MCS level of $q_{K,i,k}$ among N_u users scheduled in the uplink, it is also given by (9).

The optimum MCS level can be determined by finding both the number of MCS level, $\hat{K}$, and the MCS candidate index $\hat{i}$ to minimize the MAP overhead as

$$\left(\hat{K},\hat{i}\right) = \arg\min_{K,i}\left(\left\lceil \frac{h'_{BC}(K)}{J\cdot\rho_1}\right\rceil + \sum_{k=1}^{K}\left\lceil \frac{h_{MC}\left(b_{d,q_{K,i,k}}, b_{u,q_{K,i,k}}\right)}{J\cdot\rho_{q_{K,i,k}}}\right\rceil\right). \quad (10)$$

Finally, the MCS level of the sub-MAP can be determined as

$$\hat{k} = \arg\max_{k=1,\dots,\hat{K}} f_u(\gamma_u) \geq q_{\hat{K},\hat{i},k}. \quad (11)$$

IV. Performance Evaluation

The performance of the proposed scheme is verified by computer simulation in a regularly placed 19-cell environment (with 3 sectors per cell). It is assumed that users are uniformly distributed in the cell, and that the user gets the strongest received power from the serving sector and gets interference from other sectors. It is also assumed that the minimum geometry for a call admission is set to -5 dB (i.e., all users in services are assumed in channel condition with geometry higher than -5 dB). The shadowing correlation between the sectors in neighbor cells is set to 0.5, while that between the sectors in the same cell is 1.0. The frame error rate is related to the CINR of all subcarriers comprising the data bursts of each user via an exponential effective SINR mapping (EESM) method [12]. It is also assumed that the G.729 codec generates a voice frame of 20 bytes at every 20 msec at a constant bit rate of 8 kbps and a conventional RTP (12 bytes)/UDP (8 bytes)/IP (20 bytes) header size (40 bytes) is compressed to a 2-byte data by using CRTP or ROCCO [13]. The simulation is performed in ITU multi-path power delay profile environments comprising 40 % Pedestrian-A, 30 % Pedestrian-B and 30 % Vehicular-A at a user speed of 30 km/h. The BS performs the AMC based on the average CINR for both the multicast sub-MAPs and data bursts. We consider the use of the largest-weighted-delay-first (LWDF) scheduling scheme to satisfy low delay QoS requirements for the VoIP service [14]. Table 1 summarizes the simulation parameters, where Δ_{Down} =0.01, Δ_{Up} =0.99, and δ_u = 8.9 dB* . Thiese values correspond to the fade margin required for an MER of 1 % in Pedestrian-A environments.

For performance comparison, three mapping methods are considered; broadcast MAPs (denoted by *BC*), multicast MAPs with four MCS levels and one margin for the threshold (denoted by *MC-fixed*), and the proposed (denoted by *Proposed*) scheme. It is assumed that the *MC-fixed* uses a margin corresponding to the upper limit since the BS should satisfy the desired MER without the information on the channel condition. It is also assumed that the *MC-fixed* uses the sub-MAPs which contain at least one user, among four sub-MAPs each of which uses QPSK-1/12, QPSK-1/8, QPSK-1/4 and QPSK-1/2, respectively.

Fig. 2 depicts the percentage of users according to the desired MER. The MAP coverage is defined as the percentage of users satisfying an MER of 1% [2]. If the MER is less than 1%, it implies that a lower MCS level is applied compared to the channel condition. Since the *BC* sends the MAP to all users using QPSK-1/12, it can be assumed that most of users except users near the cell boundary can have an MER less than 1%. The *MC-fixed* sends the sub-MAPs at different MCS levels, while using a conservative margin for the MCS. As a consequence, the MC-*fixed* has a high probability of having an MER less than 1%. This implies that the *BC* and *MC-fixed* have increased MAP overhead due to the use of low MCS levels. It can be seen that the proposed scheme has a MAP coverage similar to the *MC-fixed* at the MER larger than 1%, but it has lower MAP coverage than the others at the MER less than 1%. This is mainly because the proposed scheme adjusts the MCS level to meet the desired MER in response to the receiving status, which reflects the channel conditions. Thus, it can be inferred that the proposed scheme can provide the same MAP coverage as the *BC* while reducing the MAP overhead by adjusting the MCS level according to the channel condition.

Fig. 3 depicts the VoIP capacity associated with the outage, where the VoIP capacity is defined as the number of users in a sector experiencing the outage less than 5%. A user is said in an outage, if 98% tail latency is greater than 100msec. The proposed scheme can save the resource, enabling to reduce the MAP overhead. This implies that the proposed scheme can accommodate more users transmitting VoIP packets. In this figure, the *proposed-50%* denotes the performance when the detection error rate for the ACK signal or uplink data bursts reaches to 50%.

* This value was obtained by simulation.

In this case, since the threshold margin for the MCS is close to the upper limit, the proposed scheme cannot obtain gain by adjusting the threshold for the MCS. In fact, the *proposed-50%* can be interpreted as the lower limit of the performance of the proposed scheme since the uplink CQI is modulated with high reliability [9], and the error detection probability is usually less than 10^{-2} [15]. Thus, it can be inferred that the proposed scheme can provide the best performance in free detection error condition, and it can outperform the *BC* and *MC-fixed* even when the detection error rate is high.

V. Conclusions

We have proposed an AMC scheme for the multicast sub-MAPs in the IEEE 802.16e system. The proposed scheme adjusted the threshold of users for the MCS level to satisfy the desired MER without requiring the information on the CINR and channel condition, while reducing the MAP overhead, which implies the improvement of the spectral efficiency for the multicast messages. The simulation results show that the proposed scheme is quite effective for the application to VoIP related services, compared to the use of broadcast messages and fixed multicast messages.

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Table 1. Simulation parameters.

Parameters	Values
Carrier frequency	2.3 GHz
Duplex	TDD
Frame duration	5 ms
Number of downlink OFDM symbols	27
FFT Size	1024
Channel bandwidth	8.75 MHz
Subcarrier allocatoin	PUSC
Cell radius	0.5 km
HARQ	Chase combining, 3 retransmissions
MCS	QPSK-1/12,QPSK-1/8, QPSK-1/4,QPSK-1/2, QPSK-3/4,16QAM-1/2, 64QAM-1/2
Path loss model (d: km)	28.6+35*log10(d) dB
Shadowing model	Log Normal Std. dev. 8dB
BS antenna pattern	70°(-3dB) with 20dB front-to-back ratio
Receiver algorithm	Maximal ratio combining

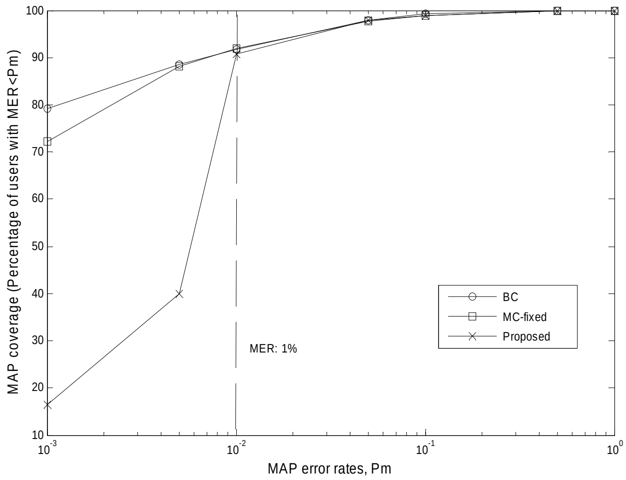

Fig. 2. Percentage of active VoIP users satisfying MERs

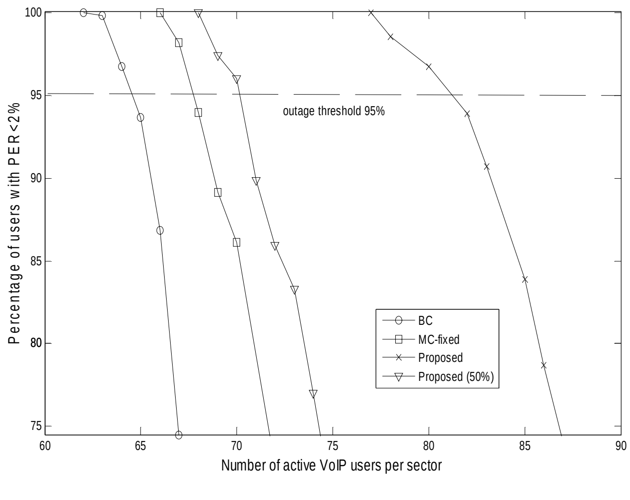

Fig. 3. Percentage of users with PER<2% according to the number of active VoIP users per sector