Fast Uplink Radio Resource Allocation in Mobile WiMAX

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Abstract

Nowadays, wireless packet data services are provided over Wireless MAN (WMAN) with high data rate and mobility. The wireless access systems of WMAN are based on OFDMA (Orthogonal Frequency Division Multiple Access). Since in the WMAN-OFDMA network uplink (UL) resource allocation happens on shared channel, long resource allocation time can occur. The long delay influences the wireless packet data services seriously. In this letter, we propose a new scheme to allocate UL radio resources to a MSS (Mobile Subscriber Station) on a CQICH (Channel Quality Indication Physical Channel) which is a dedicated channel. Through extensive simulations, it has been validated that the proposed scheme improves performance of file upload and download in application services by reducing the resource allocation time.

Key words : Resource allocation, Uplink radio resource, Broadband wireless access system, OFDMA

1. Introduction

Recent advances in wireless networks have begun to commercialize WMAN-OFDMA based on IEEE 802.16 broadband wireless access [1,2]. Mobile WiMAX has been defined as new WMAN service for higher bandwidth with broader coverage. For the new WMAN service IEEE 802.16 WMAN-OFDMA technology employs TDD (Time Division Duplex) to maximize downlink (DL) throughput.

The IEEE 802.16e OFDMA-TDD system employs a dynamic resource allocation scheme to allocate radio resources to a MSS (Mobile Subscriber Station) when the MSS want to send packet data. In the scheme, the MSS should always send BR (Bandwidth Request) to a BS (Base Station) whenever it has packet data to transmit on uplink (UL). If multiple MSSs have packet data to transmit at the same time, they will contend each other to obtain radio resources from a BS on Ranging channel, which is shared channel, placed on the first UL symbol in a frame. The contention among the MSSs occurs collision of BR and the BR collision involves delay for UL resource allocation. The UL resource allocation delay can directly influence the performance of UL Burst services. Especially in TCP applications (i.e., FTP, Web service) the existing resource allocation scheme results in low throughput due to the long delay.

In this paper, we propose a new resource allocation scheme from a BS where MSSs transmit the request of UL resource on a CQICH (Channel Quality Indication Physical Channel). From the proposed scheme we can reduce service delay and at the same time minimize the implementation complexity than the existing scheme.

the paper is organized as follows. In Section 2, we introduce the current resource allocation in IEEE 802.16e. we propose our scheme in Section 3. Section 4 presents the theoretical analysis and Section 5 presents evaluations for an experimental analysis. In Section 6, we conclude the paper.

2. Resource allocation in IEEE 802.16e OFDMA-TDD system

In the current WMAN-OFDMA system, MSSs request UL resources to a BS when they have packet data for transmission. A BS admits the resource requests of MSSs and assigns OFDMA UL symbols to MSSs. Fig. 1 shows current procedure for UL resource allocation between a MSS and a BS [1,2]:

1. A MSS sends BR (Bandwidth Request) CDMA code on the Ranging Channel to be allocated UL resource for BR Header transmission. If the MSS cannot receive any admission in CDMA

Allocation IE (Information Element) for the UL resource request, it re-sends BR CDMA code after exponential back-off.

2. A BS scheduler allocates UL resource for the MSS to send BR Header.
3. The BS broadcasts CDMA Allocation IE to indicate UL-MAP, which represents UL symbol region, for BR Header transmission of the MSS.
4. The MSS sends BR Header to the BS in order to notice the size of data burst for transmission.
5. The MSS sends BR Header to the BS in order to notice the size of data burst for transmission.
6. The BS broadcasts UL-MAP information to let the MSS know where UL symbol region for UL Burst transmission is allocated.
7. The MSS transmits UL Burst on the allocated UL symbol region.

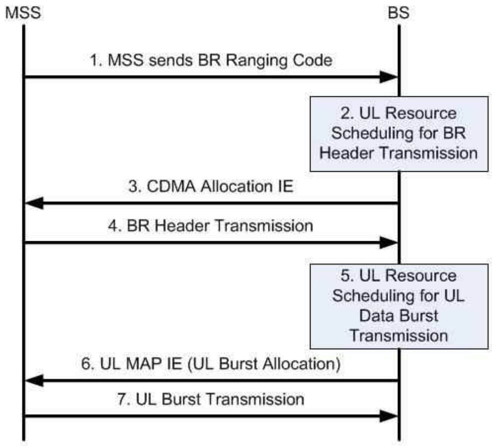


Fig. 1. UL Resource Allocation Procedure.

The current scheme can manage UL resources without waste because a BS recognizes how much UL resources for MSSs are required by request of the MSSs. However, the current scheme takes long time to allocate UL resources when contention occurs by collision of CDMA ranging code from multiple MSSs. To increase the number of ranging code in order to reduce the CDMA ranging collision probability invokes implementation complexity in a BS. In addition, since the UL-MAP is broadcasted for all MSSs, there exists UL-MAP overhead to send CDMA Allocation IE.

3. The proposed UL resource allocation

The proposed scheme utilizes CQICH as piggybacking the request of UL resource. The CQICH, which is a dedicated channel for a MSS assigned by a BS, is used to report the DL CINR (Carrier-to-Interference-plus-Noise Ratio) for either diversity sub-channels or band AMC sub-channels. By exploiting CQICH, the proposed scheme can reduce the resource allocation time and minimize implementation complexity. Fig. 2 shows the procedure for the proposed UL resource allocation between a MSS and a BS:

1. The proposed scheme uses the reserved CQICH codeword. The codeword indicates how much the MSS requests bandwidth on UL when it begins to send UL-Burst.
2. A BS scheduler allocates UL resource for the MSS to send initial UL-Burst.
3. A BS broadcasts UL-MAP information to let the MSS know where UL symbol region for initial UL-Burst transmission is allocated.
4. The MSS transmits UL Burst on the allocated UL symbol region.

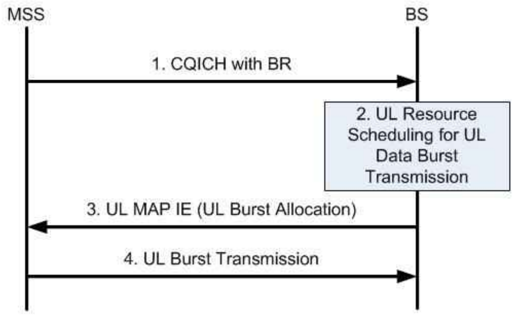


Fig. 2. The proposed UL Resource Allocation Procedure.

The proposed scheme does not require the increment of ranging code capacity or the expansion of the Ranging Channel in order to reduce the ranging collision because CQICH is dedicated channel to a MSS assigned by a BS. To report CINR on the CQICH, a MSS uses the feedback encoding from 0b0000 to 0b1011 and other codes are reserved. In the proposed scheme, we can utilize the reserved codes to request UL resource allocation.

4. Analysis

4.1 Collision probability

There happen collision in a contention slot with probability p_c by simultaneous access of multiple MSSs. The ranging collision probability p_c can be calculated by LEE [3]. Let available ranging code-region pairs are R_c. They are composed of combination of ranging regions and a number of ranging codes. In general, a ranging code is transmitted on 144 subcarriers in BPSK modulation. Since one OFDM symbol has 864 subcarriers as user tones, 6 ranging regions are available. If 3 OFDM symbols are used, the ranging regions are 18 and the ranging code-region pairs R_c is 180 when a number of ranging codes is 10. Given n users, the collision probability presented by permutation is

$$p_c = 1 - \frac{{}_{R_c}P_n}{R_c^n},$$

where R_c should be greater than n.

4.2 Duration for UL resource allocation

In the current IEEE 802.16e system, total duration for successful UL burst transmission T is $T = T_1 + T_2 + T_3 + T_4 + T_5 + T_6$, where T_i, $i = 1,\cdots,6$, are defined as follows:

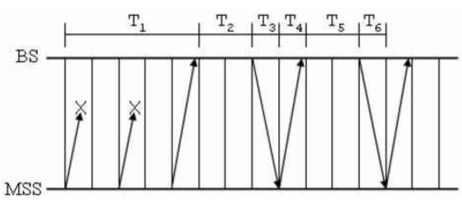


Fig. 3. Required time for the current UL resource allocation.

- T_1 : Duration from instant that a MSS sends the first CDMA ranging code for bandwidth request to instant that a BS successfully receives the CDMA ranging code for bandwidth request.
- T_2 : Processing time at the BS to allocate UL-Burst for BR Header transmission from the MSS.
- T_3 : Time for CDMA Allocation IE transmission.
- T_4 : Time for BR Header transmission.
- T_5 : Processing time at the BS to allocate UL-Burst for the MSS.
- T_6 : Time for UL-MAP transmission.

T_2 and T_5 are the processing times in a BS required for UL resource scheduling and these values depend on the implemented scheduling of the BS. T_3, T_4 and T_6 are the air transmission time and we assume that these values use a single frame, where a time slot for the single frame is 5ms. T_1 is a variable because of collision of MSSs on shared channel.

In analysis of $E[T_1]$, we consider back off time which is uniformly distributed in the region (0 to 2^{a+n-1}) when $n=1,2,\cdots,b-a+1$ or in the region (0 to 2^b) when $n \geq b-a+2$, where the range of a and b is $1 \leq a \leq b \leq 15$, after the MSS experiences n-th collision. Here the a and b are system parameters which are transmitted by UCD (Up-link Channel Descriptor) to all MSSs [1,2]. Then the $E[T_1]$ is

$$\begin{aligned} E[T_1] &= \sum_{n=0}^{\infty} E[T_1|N=n] \cdot P\{N=n\} \\ &= (1-p) + \sum_{n=1}^{b-a+1} (1-p) \cdot p^n \cdot \{n + \sum_{k=1}^{n} 2^{a+k-1}\} \\ &\quad + \sum_{n=b-a+2}^{\infty} (1-p) \cdot p^n \cdot n(1+2^b), \end{aligned}$$

where p is a probability of collision on CDMA ranging channel of MSSs. The probability of MSSs for Bandwidth Request ranging can be approximated by p_c of the collision probability in Section 4.1. The $E[T_1]$ describes that UL resource will not be allocated permanently if the collision infinitely happens. Thus a number of retrial to send CDMA ranging code should be limited in order to prevent the infinite UL resource allocation time caused by the infinite CDMA ranging code retransmission from MSSs [1,2].

In case of the proposed scheme, as shown in Fig. 4, total duration for successful initial UL burst transmission T is $T = T_a + T_b + T_c$, where T_i, $i = a, b, c$, are defined as follows:

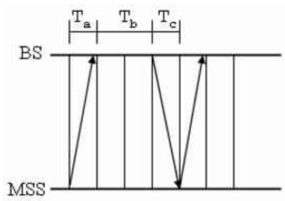


Fig. 4. Required time for the proposed UL resource allocation.

- Ta : Duration from instant that a MSS sends CQICH codeword for BR on CQICH.
- Tb : Processing time at a BS to allocate UL-Burst for a BS.
- Tc : Time for UL-MAP transmission.

Since the CQICH codeword is dedicated to the corresponding MSS, there is no collision over the air and no retrial from the MSS. Accordingly T_a is assumed to be a single frame. T_b and T_c are equal to T_5 and T_6 in the current scheme. Thus the proposed scheme can efficiently reduce the total duration.

5. Evaluation

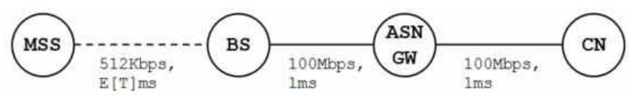
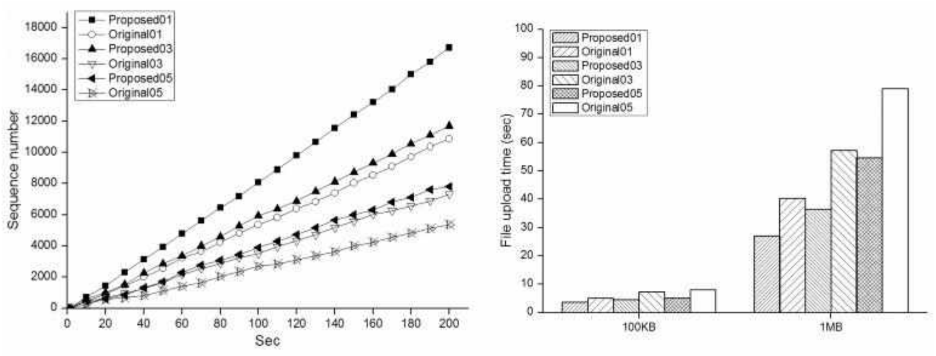


Fig. 5 The network scenario.

In this section, we evaluate the performance of the proposed scheme through extensive simulations



(a) Throughput (b) File upload time

Fig. 6 Performance evaluation: FTP (upload).

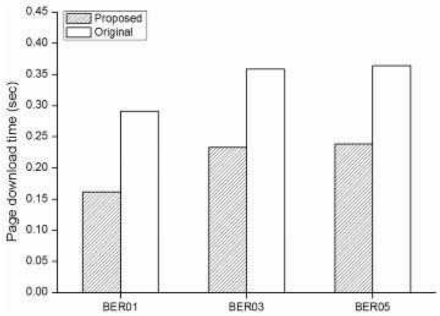


Fig. 7 Performance evaluation: Web (download).

compared with the current resource allocation scheme of IEEE 802.16e OFDMA-TDD. Our simulations run on NS-2, network simulator.

In the evaluation, FTP and Web traffic are used as applications. The network scenario for the simulation is shown in Fig. 5 The link between a MSS and a BS (Base Station) is wireless and errors occur in the wireless link. A MSS requests UL resources to a BS and it transmits data to a CN (Correspondent Node) via ASN GWs (Access Service Network Gateway). The required time for UL resource allocation is calculated by the analysis as we explained in Section 4. For calculation of $E[T_1]$ we assume that the system parameters a and b are 2 and 10 respectively and the collision probability is 5%. In addition, we consider Zorzi [4] model as transmission error on wireless channel and deal with three cases of BER (Bit Error Rate) over the wireless channel: 1%, 3%, and 5%.

The Zorzi et al. [4] investigate a Markov approximation for the block error process which arise in data transmission on fading channels. Let us assume that stream of symbols is subdivided into blocks and a block code maps each block of symbols into an N-symbol codeword. Then, the binary Markov process at sequence i is

$$\beta_i = \begin{cases} 1, & \text{if } \sum_{j=(i-1)N+1}^{iN} \gamma_j > n_\epsilon \\ 0, & \text{otherwise} \end{cases},$$

where γ_j is a binary process about status of symbol j, which depends on modulation schemes and on average SNR on the channel, and n_ε is errors in a block. If we get fewer symbol errors than n_ε, we can correctly receive a data block.

Fig. 6(a) shows the FTP throughput in file upload. Since the proposed scheme reduces the UL resource allocation time, it can enable that a MSS transmits data faster than existing scheme in FTP applications. Thus the proposed scheme represents improved TCP throughput and it shows better performance as BER gets lower. Fig. 6(b) represents file upload time for FTP services. By the same reason that the proposed scheme reduces the UL resource allocation time, it provides us with shorter time for file upload than the existing scheme. When file size to upload is large, the difference of file upload time between the proposed scheme and the existing scheme increases.

Fig. 7 shows that the proposed scheme is superior even in web page download services. In the environment that a MSS requests 2KB web page with Poisson distribution of average 5sec, the proposed scheme represents efficiency in web page download than the existing scheme although BER increases. The proposed scheme enables to quickly respond to web page download because a MSS transmits TCP Ack faster in the proposed scheme than the existing scheme as file upload.

6. Conclusion

Current IEEE 802.16e OFDMA-TDD systems perform contention based UL resource allocation. The existing scheme has delay by collision in contention of MSSs and complex procedures to allocate UL resources. In this letter, we have investigated new UL resource allocation scheme to improve the performance for UL-Burst transmission. The simulation results show that the proposed scheme has many benefits in upload and download of applications.

Acknowledgments

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References

[1] Draft IEEE Standard for Local and metropolitan area networks, ``Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands,'' IEEE P802.16-2005, IEEE, 2005.

[2] WiMAX Forum: http://www.wimaxforum.org/home/

[3] D. Y. Lee and H. S. Cho, ``Mathematical Derivation of Ranging Collision Probability and Period in WiBro System,'' Journal of the Korea Information and Communications Society, Vol. 31, No. 10A, pp. 982-987, October 2006.

[4] M. Zorzi, R. R. Rao and L. B. Milstein, ``Error statistics in data transmission over fading channels,'' IEEE Transactions on Communications, Vol. 46, No. 11, pp. 1468-1477, November 1998.