

Effective Contention-based Bandwidth Request Scheme for QoS Enhancement in IEEE 802.16e

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Abstract— In this paper, we propose an effective contention-based bandwidth request scheme to differentiate the contention scheme of each quality of service(QoS) type in IEEE 802.16e systems. Especially, the scheme is focused on the improvement for extended real-time polling service(ert-PS). The proposed scheme allows the ert-PS to use multicast polling in the normal condition, but to adopt both multicast and broadcast polling under collision. Through the simulation, we show that the proposed bandwidth request mechanism reduces the bandwidth grant delay of ert-PS due to a high probability of successful bandwidth request. Therefore, the ert-PS with the proposed scheme can resolve the contention faster than the conventional mechanism.

Keywords— WiMAX, Bandwidth Request, ert-PS, Contention Resolution, QoS

I. INTRODUCTION

The IEEE 802.16/WiMAX is widely considered as a strong candidate solution for broadband wireless access systems. Moreover, IEEE 802.16e amendment added IEEE 802.16 standard to the mobility function and voice over IP(VoIP) in wide area. In the IEEE 802.16e, five service classes are classified according to the degree of the QoS requirements of each service; Unsolicited Grant Service(UGS), real-time Polling Service(rtPS), extended real-time Polling Service(ertPS), non real-time Polling Service(nrtPS), and Best Effort (BE). The UGS service is designed for constant bit rate real-time flows such as E1/T1 or VoIP without silence suppression and the rtPS service is for real-time Variable Bit Rate(VBR)-like flows such as MPEG video. The ertPS is designed to compensate the drawbacks of the UGS and rtPS when servicing VoIP with silence suppression. The nrtPS service supports non real-time flows requiring delay-tolerant data stream such as FTP and the BE service is for best effort traffic such as HTTP [1].

The IEEE 802.16 standard defines a request and grant mechanism to reserve bandwidth. Requests refer to the mechanism that subscriber stations(SSs) use to indicate to the base station(BS) that they need uplink bandwidth allocations. A request may come as a stand-alone bandwidth request message or it may come as a piggyback request defined as an option. Since the burst profile associated with a connection ID (CID) can change dynamically, all requests for bandwidth shall be made in terms of the number of bytes needed to carry

the MAC header and payload, but not the PHY-layer resources, such as number of subchannels and number of orthogonal frequency division multiplexing (OFDM) symbols. Grants refer to the mechanism that the BS allocates bandwidth to SSs based on the request information [1].

Especially, the IEEE 802.16 suite defines two main polling modes, which are the unicast polling and contention-based polling, to support different bandwidth allocation requirement. The unicast polling is used to poll a SS having a connection individually. On the other hand, the contention-based polling is to poll a group of users(multicast polling) or all the users(broadcast polling) at a time, when it is not enough the bandwidth to poll each SS. In the contention-based polling, if the bandwidth request message is collided with the others due to sending multiple request messages at the same time, truncated binary exponential backoff algorithm will be used to resolve the contention. But, even though it may resolve the contention, it results from the increase of the bandwidth grant delay, which is the measurement time between sending the bandwidth request messages and sending the data payload after allocating the bandwidth.

In order to increase the bandwidth efficiency, the ertPS servicing VoIP with silence suppression utilizes unsolicited bandwidth grants in talk-spurt and the unicast polling or the contention-based polling in silent period[2]. However, because the nrtPS and BE also use the contention-based polling, the ertPS contends with two classes in one contention period equally. It could additionally suffer bandwidth grant delay increment. Therefore, it is necessary to study how to reduce the bandwidth grant delay of the ertPS when the contention-based polling is adopted for ertPS.

Recently, many scientific researchers have proposed many polling mechanisms in IEEE 802.16 to improve the performance. Previous studies just have been focused on optimization of the contention period size [3], an adaptive bandwidth request mechanism for nrtPS [4], analysis of the multicast and broadcast pollings [5], and an adaptive contention resolution scheme for VoIP [6].

In this paper, we propose an effective bandwidth request scheme to improve the ertPS performance providing more bandwidth request opportunity to the ertPS than the nrtPS and BE in a frame. We focus on the efficient adoption and QoS enhancement of the two polling modes. The key idea of our scheme is that the operation of the proposed scheme is

performed by treating the ertPS more importantly than the nrtPS and BE by allowing one or combination of multicast and broadcast pollings. It is shown through simulation that the successful transmission probability in the proposed scheme is higher than the standard mechanisms such as multicast and broadcast polling. In addition, the bandwidth grant delay is less than the standard mechanism. We begin from the IEEE 802.16 MAC layer and basic bandwidth request scheme in Section II. In Section III, we present the proposed bandwidth request scheme and the detailed analysis. The performance of the proposed scheme is evaluated in Section IV. Finally, a conclusion is drawn in the Section V.

II. BANDWIDTH REQUEST SCHEME IN IEEE 802.16E

A. Overview of MAC Layer

Figure 1 describes a Time Division Duplexing(TDD) frame in IEEE 802.16 standard. The frame is divided into two subframes: downlink subframe and uplink subframe. The downlink subframe is generally broadcast and starts with a preamble and a frame control header. The preamble is used by the PHY for synchronization and equalization. The frame control header specifies the presence of control information within the downlink subframe. DL-MAP(Downlink MAP) and UL-MAP(Uplink MAP) follow the frame control header and specify the usage of the downlink and uplink subframes, respectively. The following downlink bursts carry the data to transmit to SSs. The uplink subframe consists of the new SSs joining the channel (Initial Ranging Period), the SSs competitively requesting uplink bandwidth (Contention Request Period), and the SSs transmitting data or uniquely requesting uplink bandwidth (Data Transmission Period) allocated by the BS. There are multicast and broadcast contention period for bandwidth request in uplink subframe. The DCD(Downlink Channel Descriptor) and UCD(Uplink Channel Descriptor) messages provide the burst profiles, which mean parameter sets of the physical channel, of the downlink and uplink, respectively. Especially, the bandwidth request and ranging related parameters are defined in the UCD message.

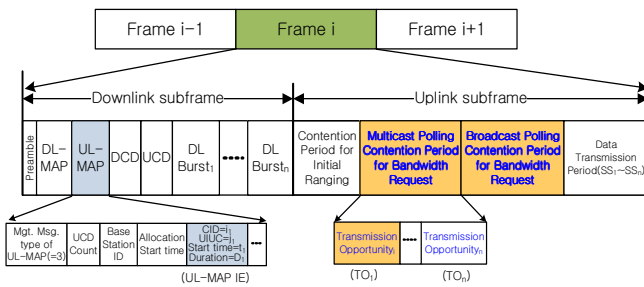


Figure 1. Frame structure of IEEE 802.16/WiMAX

The IEEE 802.16 classifies five QoS classes according to the several QoS parameters in order to support various services efficiently. The ertPS is defined to compensate the disadvantages of the UGS and rtPS when servicing VoIP with

silence suppression. Thus, it maintains granting the fixed amount of the bandwidth while the required bandwidth is constant but changes the bandwidth grant only when changes of the bandwidth request occur.

B. Basic Bandwidth Request Scheme

The SSs utilize one of the four bandwidth request schemes which are unsolicited bandwidth grant, piggyback bandwidth request, unicast polling, and contention-based polling in the uplink. The unsolicited bandwidth grant means fixed allocation of the bandwidth during the connection without the polling and bandwidth requested by piggybacking can be only incremental. In the IEEE 802.16, the polling refers to the process whereby dedicated or share uplink resources are provided to the SS to make bandwidth request[3]. It is divided into unicast polling and contention-based polling. The unicast polling is performed by periodic polling of the SSs individually. Therefore, the bandwidth request message never collides in the unicast polling. On the other side, the collision is occurred by the contention-based polling because some SSs contend to send the bandwidth request messages in the predetermined contention period of the uplink subframe. The contention-based polling can be utilized when the available bandwidth for all SSs is not enough or there exist many SSs with inactive state which means no need of the bandwidth to improve the bandwidth efficiency. However, if multiple bandwidth request messages select the same transmission opportunity, resulting in the collision, truncated binary exponential backoff scheme with the backoff start value and the backoff end value defined in the IEEE 802.16 standard is used to resolve the contention.

In the multicast polling, two management messages (MCA-REQ and MCA-RSP) are used to assign and unassign SSs to and from the polling group. The BS always decides about membership dynamics by sending MCA-REQs and SSs reply to changes with the latter messages, while the broadcast polling uses broadcast CID, which all SSs receive during the connection and used when broadcasting the data or the message in downlink.

The bandwidth request options according to scheduling services are shown in Table 1. Each class is allowed to adopt one or more schemes. The UGS only uses the unsolicited bandwidth grants and unicast polling using PM(Poll_me) bit optionally. The rtPS is allowed to use the unicast polling and the piggyback request and the nrtPS and BE is allowed all of the mechanism except for the unsolicited bandwidth grants. The ertPS is allowed all of the mechanism. Normally, the bandwidth of VoIP service classified into the ertPS is granted by using the unsolicited bandwidth grants in the talk-spurt and the unicast polling or the contention-based polling in the silent period. If the unicast polling is used in that period, it is possible to change from the silent period to the talk-spurt with small bandwidth grant delay, which is time from sending the bandwidth request message to directly before sending the data in the allocated bandwidth, due to no collision, but it wastes the bandwidth for polling.

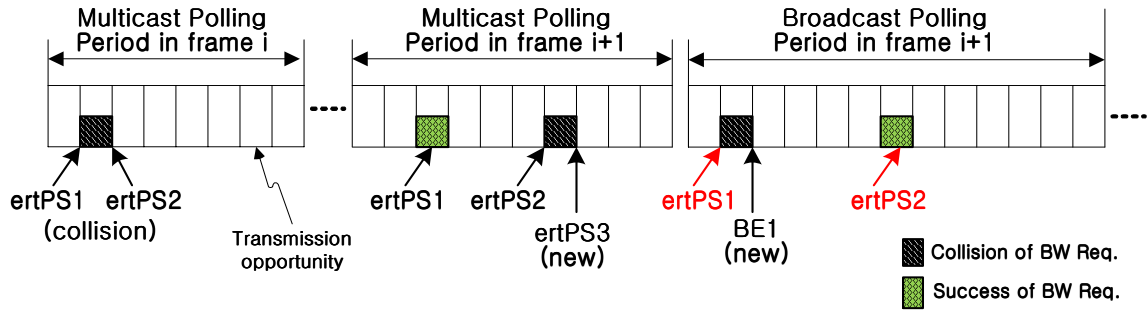


Figure 2. Proposed bandwidth request scheme under ertPS collision

TABLE 1. BANDWIDTH REQUEST SCHEMES AS TO SCHEDULLING TYPE

Scheduling Type	Piggyback	Unicast polling	Contention-based polling
UGS	Not allowed	PM bit	Not allowed
ertPS	Extended piggyback	Allowed	Allowed
rtPS	Allowed	Allowed	Not allowed
nrtPS	Allowed	Allowed	Allowed
BE	Allowed	Allowed	Allowed

In order to save the polling bandwidth, setting the long polling interval is also not efficient way because it increases waiting time to send the bandwidth request message caused by unpredictable start time of the talk spurt. On the other hand, in the case of the contention-based polling, it saves the bandwidth, but it increases more bandwidth grant delay in collision. Particularly, the bandwidth grant delay of the ertPS increases rapidly when the ertPS, nrtPS, and BE participate in the same contention period. Even through, the ertPS uses the multicast polling; it cannot satisfy the bandwidth grant delay compared with the use of unicast polling.

III. PROPOSED BANDWIDTH REQUEST SCHEME

In the ertPS servicing the VoIP with silence suppression, the contention-based polling is required for the bandwidth utilization or in the condition of insufficient bandwidth to support all ertPSs of the unicast polling, thus, it need to improve the performance even with the contention-based polling. Therefore, we propose the effective bandwidth request scheme to reduce the bandwidth grant delay of the ertPS through differentiation of each class using the multicast and broadcast pollings and providing more bandwidth request opportunity the collided ertPS than the others. The proposed scheme is represented by Figure 2. Basically, we assign the ertPS to the multicast polling, the nrtPS to another multicast polling to remove influence of the performance of the ertPS and differentiate with the BE, and the BE to the broadcast polling. In addition, if once the ertPS is collided, it is allowed to participate in the broadcast polling. Thus, the collided messages are requested during both the multicast and the broadcast polling periods in a frame to succeed in the

bandwidth request fast. To avoid duplicated bandwidth request, the BS compares the CID of the ertPS succeeded during the multicast polling period and the CID of the ertPS succeeded during the broadcast polling period, discarding the bandwidth request message requested during the broadcast polling period and not allocating the bandwidth. Since it is possible to receive the bandwidth if at least one of two bandwidth request message succeeds during the contention, the successful bandwidth request probability is increased largely. However, it is inevitable to degrade the performance of the BE. If it still causes collision, the contention resolution scheme is repeated.

The probability of successful transmission of the bandwidth request message in a frame is given by [3] as

$$P_s = \left(\frac{L-1}{L} \right)^{N-1} \quad (1)$$

where L is the size of the frame and N is the number of users. From this equation, we can form the equation that is the successful bandwidth request probability of the ertPS in the proposed scheme compared with the standard mechanisms, which means all QoS classes allowed to the contention-based polling contend equally in the broadcast polling and separately in the multicast polling. The several variables are used in the equation such that the number of the ertPS, the nrtPS, and the BE user is N_{ertPS} , N_{nrtPS} , and N_{BE} , respectively. And the size of two contention periods (multicast and broadcast) is set to $L_M (=L_{ertPS} + L_{nrtPS})$ and $L_B (=L_{BE})$, respectively. Also, N and L indicate $N_{ertPS} + N_{nrtPS} + N_{BE}$ and $L_{ertPS} + L_{nrtPS} + L_{BE}$.

First, in the event that three classes contend in the broadcast polling, which is equal to the probability of successful transmission of the bandwidth request messages in a frame (P_s) due to the same value of L and L_B ($L=L_B$). Therefore, the probability in the broadcast polling is

$$P_B = \left(\frac{L_B-1}{L_B} \right)^{N-1} = P_s \quad (2)$$

Then, in case that the ertPS only contends in their multicast polling period, which is the standard mechanism based on the multicast polling, the equation is represented as

$$P_M = \left(\frac{L_{ertPS}-1}{L_{ertPS}} \right)^{N_{ertPS}-1} \quad (3)$$

Lastly, in the proposed scheme, the equation divides into two conditions: no collision and collision. Under no collision, the probability is the same as the probability in the multicast polling. However, the probability under collision is derived from the blocking probability. The blocking probability of the multicast and broadcast polling (P_{M_block} , P_{B_block}) is obtained as $1-P_M$, $1-P_B$. Therefore, the equations are represented as (4).

$$\begin{aligned}
P_{QoS, NoCol} &= P_M = \left(\frac{L_{ertPS} - 1}{L_{ertPS}} \right)^{N_{ertPS} - 1} \\
P_{QoS, Col} &= 1 - P_{M_block} \cdot P_{B_block} \\
&= 1 - (1 - P_M) \cdot (1 - P_B) \\
&= 1 - (1 - P_M - P_B + P_M \cdot P_B) \\
&= P_M + P_B - P_M \cdot P_B
\end{aligned} \quad (4)$$

IV. PERFORMANCE EVALUATION

In this section we compared the proposed scheme with standard mechanisms which the ertPS contends in the broadcast polling with the other classes and in the multicast polling. During the simulation, we assumed the size of the contention period is kept optimally according to the number of contending user and the broadcast polling period maintains two times longer than the multicast polling period. Its simulation parameters are listed in TABLE 2. To be simplicity, we only apply our scheme in ertPS, nrtPS and BE services.

TABLE 2. THE SIMULATION PARAMETERS

Parameter	Value
Frame duration	5ms
Duplexing mode	TDD
Unlink : Downlink	1:2
OFDM symbol	10μs
Transmission opportunity size	20μs
Contention-based reservation timeout	5ms

Figure 3 shows the successful transmission probability of the ertPS. The proposed scheme shows the highest probability about 0.9 compared with the standard mechanism because of providing more bandwidth request opportunity of the collided ertPS.

Figure 4 compares the performance of bandwidth grant delay of ertPS ($N_{ertPS}=25$) under the simulation settings shown in TABLE 2. The bandwidth grant delay of the proposed scheme may be measured about 10ms. The proposed scheme takes the shortest delay compared to two standard polling schemes. The proposed scheme with the highest successful transmission probability and the shortest bandwidth grant delay indicates that the contention is resolved faster than the standard mechanisms.

V. CONCLUSIONS

We have proposed and investigated an effective contention-based bandwidth request scheme to differentiate the ertPS in IEEE 802.16e. The proposed scheme allows the ertPS to send the collided bandwidth request messages during the multicast

polling period and the broadcast polling period, respectively. From the analytical and simulation results, we have learned that the ertPS with the proposed scheme outperforms the standard mechanisms under the collision condition. We conclude that the proposed scheme is a better option for the IEEE 802.16e system.

REFERENCES

- [1] IEEE 802.16-2004 "Part 16: Air Interface for Fixed Broadband Wireless Access Systems", Oct. 2004.
- [2] Loutfi Nuaymi, "WiMAX: Technology for Broadband Wireless Access", John Wiley & Sons, Ltd.
- [3] Sung-Min Oh and Jae-Hyun Kim, "The Analysis of the Optimal Contention Period for Broadband Wireless Access Network", PerCom2005 Workshops, vol. 8-12, pp. 215 - 219, Mar. 2005.
- [4] Sang-Jin Kim, Woo-Jae Kim, and Young-Joo Suh, "An Efficient Bandwidth Request Mechanism for Non-Real-Time Services in IEEE 802.16 Systems", COMSWARE 2007, Jan. 2007.
- [5] Lidong Lin, Weijia Jia, and Wenyan Lu, "Performance Analysis of IEEE 802.16 Multicast and Broadcast Polling based Bandwidth Request", WCNC 2007, Mar. 2007.
- [6] Dong-Hoon Cho, Jung-Hoon Song, Min-Su Kim, and Ki-Jun Han, "Performance Analysis of the IEEE 802.16 Wireless Metropolitan Area Network", DFMA 2005, Feb. 2005.

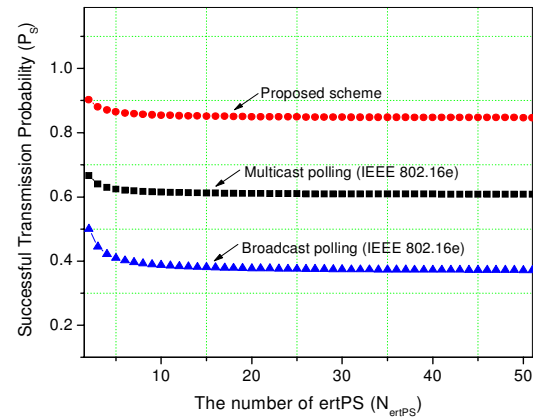


Figure 3. Successful transmission probability versus the number of ertPS

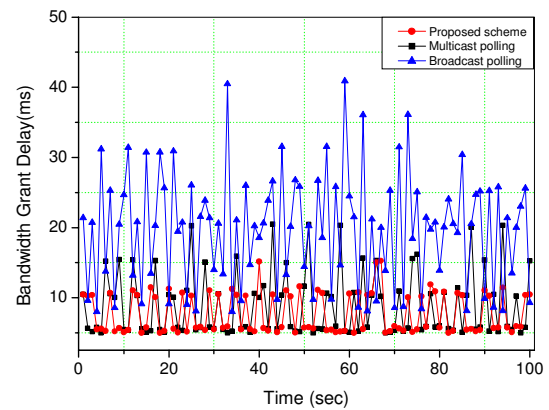


Figure 4. Bandwidth grant delay of ertPS ($N_{ertPS}=25$)