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Title	**QoS Management Subheader for Facilitation of Uplink Scheduling**	
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Re:	IEEE P802.16e/D3 Letter Ballot	
Abstract	This contribution introduces a new type of MAC subheader, which provides dynamic QoS parameters for uplink scheduling.	
Purpose	The document is contributed to support certain comment on IEEE P802.16e/D3 Letter Ballot.	
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QoS Management Subheader for Facilitation of Uplink Scheduling

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1. Introduction

As a demand on multimedia messages and interactive video applications is expected to emerge in the near future, some means of providing QoS-aware uplink resource management will become essential. In general, the base station scheduler does not have direct access to the individual user's dynamic QoS parameters. In order to support the QoS scheduling for the uplink, therefore, the relevant parameters must be readily available via signaling over the uplink. This document proposes to introduce another MAC subheader, including the dynamic QoS parameter, which can be piggybacked with the uplink payload as some other subheaders. As additional subheader is just a stand-alone message, it does not change any part of the existing specification, while providing various dynamic QoS parameters in a flexible manner to facilitate any type of scheduling algorithm that may be implemented in the future.

2. Problem Statements

When the different users see channels of different capacities for a time-varying wireless channel as in IEEE 802.16e standard, a packet scheduling algorithm is an essential means of providing QoS differentiation among users while achieving efficient resource utilization. In fact, it is a common practice to employ some type of the packet scheduling algorithm to determine which user to be served in order, on the basis of the PHY mode and some QoS-related parameters. Proportional fairness (PF) algorithm is one of the most popular wireless packet scheduling algorithm, commonly employed for a broadband wireless packet data system, e.g., cdma2000 1x EV-DO. We note that most of the scheduling algorithm is based on some sort of dynamic parameters, which reflect the urgency of the current packet and/or the instantaneous data rate to be supported at the moment. For example, the PF algorithm relies on the dynamic rate control (DRC) or equivalently, channel quality indicator (CQI), which is periodically reported by individual terminal, and the average data rate served so far. Given these two parameters, throughput can be optimally traded off with fairness, giving each user roughly equal air time. Denoting the dynamic rate control at time t for user i by $DRC_i(t)$ and the average data rate provided for user i by $R_i(t)$, the PF algorithm is summarized as follows:

❶ Initialization: at time slot $t = 0$, set $R_i(0) = 0$ for all i

❷ Scheduling: at time t, select for transmission the user i^* with the smallest value of $\delta_i(t)=DRC_i(t)/R_i(t)$ ➔ $i^* = \arg\max_i \{\delta_i(t)\}$

❸ Updating: For i from 1 to K, $R_i(t+1) = (1-1/t_c)\cdot R_i(t)+1/t_c\cdot DRC_i(t)$

In the above, $\delta_i(t)$ denotes the priority metric for user i, governing which user to be served ahead of the others. Other than PF algorithm, some algorithm deals with the latency of individual user, especially for those who are sensitive to the packet delay. One particular example is the modified LWDF (Largest Weighted Delay First) algorithm [3], which takes the average delay of each user into account, now with the following priority metric:

$$\delta_i(t) = \frac{a_i DRC_i(t) W_i(t)}{R_i(t)}$$

where $W_i(t)$ denote the average delay of user i and a_i is a constant. Note that it provides a good tradeoff between fairness and efficiency subject to delay constraint $W_i(t) > T_i$ in the sense that $\Pr(W_i(t) > T_i) \leq \varepsilon_i$. As far as the downlink is concerned, all those parameters, e.g., $W_i(t)$ and $R_i(t)$, to determine the priority metric for the given scheduling algorithm are immediately available in the base station.

Most of the previous studies on the packet scheduling algorithm are concerned with the downlink only, simply because downlink efficiency is critical to support broadband internet traffic concentrated toward downlink. As a demand on multimedia messaging and interactive video applications increases, however, uplink scheduling will be an essential means of providing QoS-aware resource management for uplink. As all users are spatially distributed without knowing the bandwidth requirement of individual user, the relevant information must be frequently reported toward the base station so as to schedule the uplink utilization. In the current standard, only means of reporting the individual user's bandwidth requirement is the bandwidth request (BR) message, delivered either through a BR header, which is a special type of MAC header, or a grant management (GM) subheader, which is piggybacked with the uplink payload. All these headers quantify the bandwidth request in the number of bytes that are required by the corresponding user. We note the BR is a quantity merely to represent the queue length or changes in the queue length. As the queue length is just an indirect measure of indicating the current traffic demand or load, it cannot be explicitly used to deal with QoS requirement, especially for the delay-sensitive or loss-sensitive applications. In the modified LWDF algorithm, for example, the average delay experienced by individual user must be periodically reported to the base station scheduler. Some algorithm requires two or more dynamic parameters, e.g., queue length and residual lifetime [4].

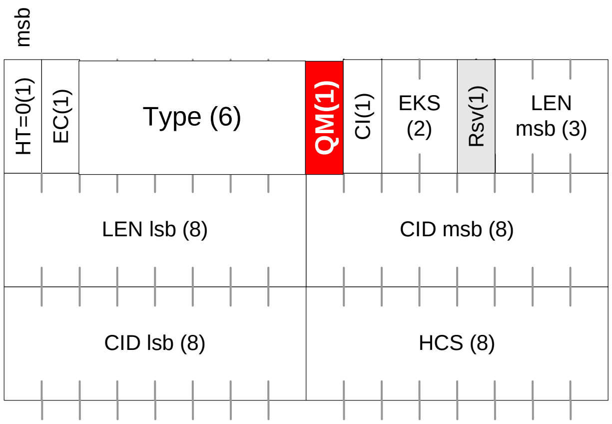
In summary, the current standard does not specify any effective means of providing dynamic QoS parameters that may be required for uplink QoS scheduling, depending on the type of uplink packet scheduling algorithm. As the packet scheduling algorithm is just a choice of implementation, the standard must be flexible enough to accommodate any type of scheduling algorithm.

3. Proposed Changes

To support the uplink QoS parameters, a QoS management (QM) subheader is defined as an additional subheader. One reserved bit that is now a QoS management bit can be used to indicate the presence of the QM subheader. As the reserved bit is used, the existing format of MAC header is not subject to any change. If the QoS management bit is set, dynamic QoS Parameters shall be transported by a QoS management subheader. The format of the QoS Management subheader is specified in Table 14.

Remedy 1:

[Change the figure 19 in "the baseline document Section 6.3.2.1.1 Generic MAC header in page 37."]



P 37. Figure 19—Generic MAC header format

Remedy 2:
[Add the following tables to "the baseline document Section 6.3.2.2 MAC subheaders and special payloads in page 43."]

6.3.2.2.7 QoS Management subheader

If the QoS management bit in the MAC Type field (see Table 6) is set, dynamic QoS Parameters shall be transported byQoS management subheader. The format of the QoS Management subheader is specified in Table 14.

Table 14. QoS Management subheader format

Syntax	**Size**	**Notes**
QoS Management Subheader( ) {		
No. Parameters	**2 bits**	**The number of parameters**
for (i = 0 ; i < No. Parameter ; i++) {		
Dynamic QoS Parameters	**4 bits**	
}		
If !(byte boundary) {		
Padding nibbles	**Variable**	
}		
}		

4. Effect of Uplink QoS Scheduling: Illustration

To illustrate how the dynamic QoS parameters play an essential role of improving the system performance over the uplink, some results in [4] are quoted here. The contention-free distributed dynamic reservation MAC protocol with deterministic scheduling (C-FD^{3}R MAC) algorithm is a typical example of contention-free mechanism of the reservation request and a mobile-assisted (distributed) uplink scheduling under a framework of dynamic reservation TDMA as in IEEE 802.16 standard. We note that it is implemented with two different dynamic parameters, the estimated residual lifetime and queue length. The proposed approach is compared with dynamic slot assignment (DSA++) algorithm, proposed in the context of wireless ATM. To show how much performance gain can be affected by the scheduling algorithm and by the choice of different dynamic parameters, simulation results and analysis are quoted from [4] as follows:

The design objective of C-FD^{3}R scheme is to guarantee the real-time constraint of rt-VBR traffic class while maximizing the multiplexing gain among all ATM traffic classes. In other words, all rt-VBR traffic class is subject to delay constraint, i.e., the cell transfer delay not to exceed the delay bound max_CTD. Figures 1 and 2 show the cell transfer delay and cell loss ratio of rt-VBR traffic versus the number of WT's offered for rt-VBR respectively. In Figures 1 and 2, a value inside a circle denotes the number of WT's offered for nrt-VBR. As can be seen from Figure 1, the C-FD^{3}R system maintains the cell transfer delay of rt-VBR session constant within the delay bound (max_CTD = 30 ms), regardless of the number of WT's offered in the system. For the DSA++ system, meanwhile, the corresponding cell transfer delay increases steadily as the number of WT's offered for rt-VBR increases and ultimately, it exceeds the delay bound. The corresponding performance gain of the C-FD^{3}R system is further manifested by the cell loss ratio, as presented in Figure 2. The cell loss ratio for rt-VBR in the C-FD^{3}R system is significantly low as compared with that for the DSA++ system. Furthermore, it is not affected by the number of WT's offered for nrt-VBR. From Figures 1 and 2, it obvious that the C-FD^{3}R system outperforms the DSA++ system in both delay and cell loss for rt-VBR traffic.

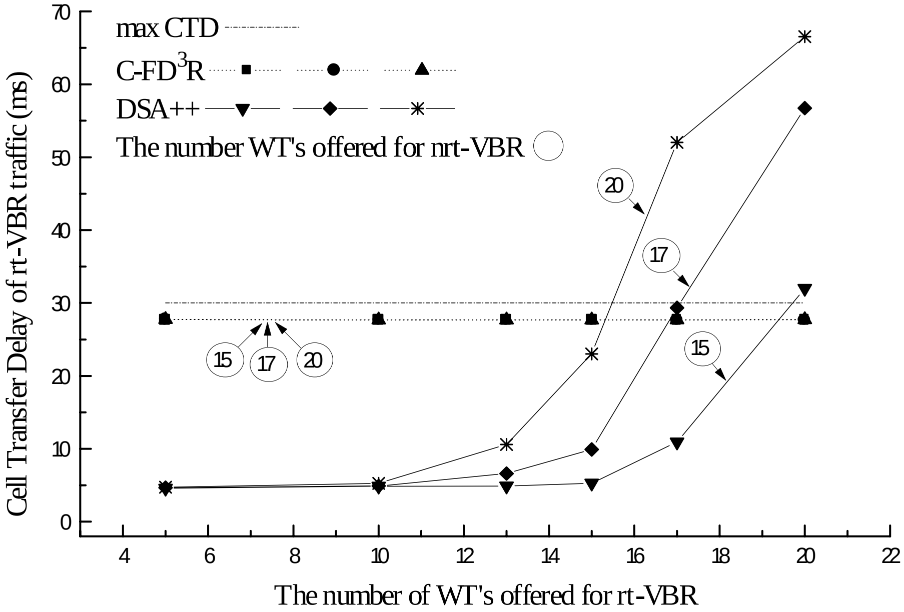


Figure 1. Cell Transfer Delay of rt-VBR traffic vs. the Number of WT's Offered for rt-VBR

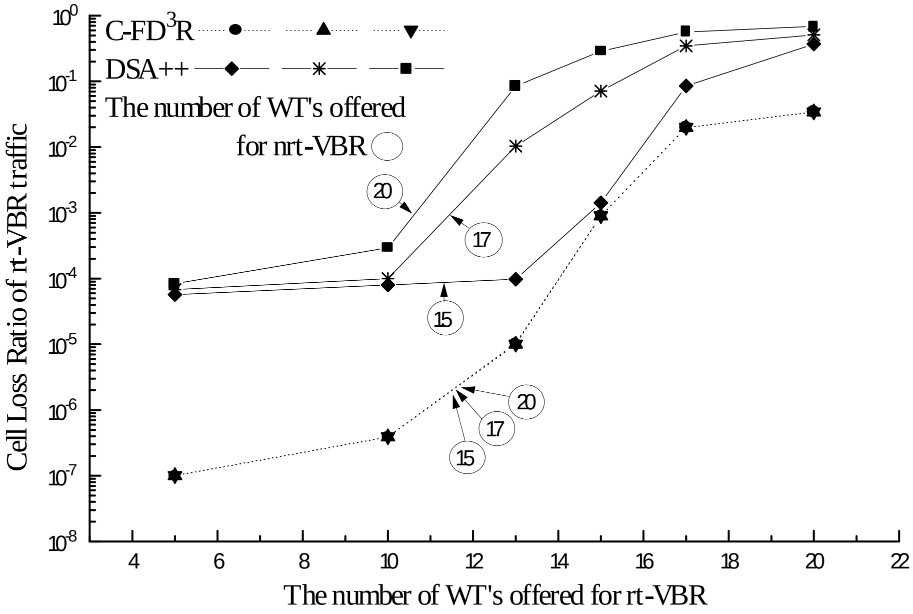


Figure 2. Cell Loss Ratio of rt-VBR Traffic vs. the Number of WT's Offered for rt-VBR

5. References

[1] IEEE P802.16e/D3-2004 Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Band.

[2] IEEE P802.16-REVd/D5-2004 Air Interface for Fixed Broadband Wireless Access Systems

[3] Matthew Andrews, Krishnan Kumaran, Kavita Ramanan, Alexander Stolyar, and Phil Whiting, Raijiv Vijayakumar, "Providing Quality of Service over a Shared Wireless Link," *IEEE Communications Magazine*, pp150-154, February 2001.

[4] Chung Gu Kang, Chang Wook Ahn, Kyung Hun Jang, and Woo Sik Kang, "Contention-Free Distributed Dynamic Reservation MAC Protocol with Deterministic Scheduling (C-FD3R MAC) for Wireless ATM Networks," *IEEE Journal of Selected Areas in Communications*, Vol. 18, No. 9, p.1623~1635, September 2000.