QoS Support Downlink for WiMAX Network

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Abstract. We develop new scheduling algorithms for the IEEE 802.16d based broadband wireless access system, in which radio resources of both time and frequency slots are dynamically shared by all users. Our objective is to provide a fair and efficient allocation to all the users to satisfy their quality of service. IEEE 802.16 based wireless access scheme(commonly known as WiMAX) is considered as one of the most promising wireless broadband access for communication networks in metropolitan areas today. Since this broadband wireless access system defines the concrete quality of service(QoS) requirement, a fair scheduling(FS) scheme is necessary to meet the QoS requirements. Many Scheduling schemes have been proposed earlier with the purpose of throughput optimazation and fairness enhancement. Here we present FS to derive its performance bounds. Our analysis demonstrates that FS support the delay requirement.This scheduler proposes a new scheduling scheme reflecting the delay requirement of rtps connections with respect to the various nrtps connections to achieve the optimal QoS requirement, without the excessive resource consumption since it 1) achieves low average as well as maximum delay for low-throughput applications 2) provides fairness regardless of variation in server capacity3) is computationally efficient.

Keywords: QoS, IEEE 802.16, WiMax, rtps, nrtps.

1 Introduction

IEEE 802.16[1] architecture includes one Base station (BS) and Multiple Subscriber Station(SS) Communication occurs in two directions: from BS to SS is called Downlink and from SS to BS is called Uplink. During downlink, BS broadcasts data to all subscribers and subscribers selects packets destined for it. IEEE 802.16[2] standard also known as worldwide interoperability for microwave access (WiMAX) defines two modes to share wireless medium: point-to-multipoint (PMP) mode and mesh mode. In the PMP mode, a base station (BS) serves several subscriber stations (SSs) registered to the BS. In IEEE 802.16, data transmission is on the fixed frame based. The frame is partitioned into the downlink subframe and the uplink subframe. The frame duration and the ratio between the downlink subframe and the uplink subframe are determined by the BS. In the PMP mode, the BS allocates bandwidth for uplink and downlink. The BS selects connections to be served on each frame duration. IEEE 802.16 defines four classes of service type such as unsolicited grant service (UGS), real-time polling service (rtPS), non-real-time polling service (nrtPS) and best

K. Singh, A.K. Awasthi, and R. Mishra (Eds.): QSHINE 2013, LNICST 115, pp. 989–997, 2013.

effort (BE) service. Each service class has requirements to be met to serve the applications that belong to the category. The UGS is designed to serve the applications having stringent delay requirement, like voice over IP (VoIP). The rtPS is designed for the applications having the less or stringent delay requirement, like video or audio streaming service. The nrtPS does not have the delay requirement; however, it has the minimum reserved rate requirement. To satisfy these QoS requirements, we need a well-designed scheduling scheme. However, IEEE 802.16 specification does not describe the scheduling scheme, and it leaves the implementation of a scheduling scheme to device manufacturers' decision. The scheduling scheme plays an important role in the quality of service (QoS) provision. Many scheduling schemes have been proposed. An overview of scheduling schemes in wireless networks is presented in[3][4][5]. There are many papers suggesting scheduling schemes[6][7] to reflect the QoS requirement. The proportional fair scheduling has been introduced in [7][8].The concept of the proportional fair scheduling is widely accepted in scheduling design. In the current work we have proposed an alternate scheduling scheme based on proportional fairness. The scheduling parameters have been selected based on the number of connections in the network.

2 System Model

PMP mode and mesh mode are the two types of operating modes define for IEEE802.16. In the PMP mode SSs are geographically scattered around the BS. The performance of IEEE 802.16 in the PMP mode is verified in[8][9]. Our system model is based on a time-division-duplex (TDD) mode. The IEEE 802.16 frame structure is illustrated in Fig.1[2]. The downlink subframe starts with preamble followed by frame control header (FCH), downlink map (DL-MAP), uplink map (UL-MAP) messages and downlink burst data. The DLMAP message defines the start time, location, size and encoding type of the downlink burst data which will be transmitted to the SSs. Since the BS broadcasts the DLMAP message, every SS located within the service area decodes the DL-MAP message and searches the DL-MAP information elements (IEs) indicating the data bursts directed to that SS in the downlink subframe. After the transmit/receive transition gap (TTG), the uplink subframe follows the downlink subframe. IEEE 802.16 provides many advanced features like adaptive modulation coding (AMC), frame fragmentation and frame packing. In the current work, the focus is on the downlink scheduling scheme.

3 Multi User Scheduler of the MAC Layer

In this section, a multiuser scheduler is designed at the medium access control (MAC) layer. Delay requirement is taken into account in the scheduler design. The AMC, packet fragmentation and packet packing have not been considered. In case of the UGS traffic, the required bandwidth is reserved in advance. Hence, only rtPS, nrtPS and BE connections are focused in the design.

3.1 Proportional Fair Scheduling

The proportional fair scheduling [10] has shown an impressive guideline in scheduler design because it maximizes the total sum of each SS's utility. In the proportional fair scheduling, the metric for each connection is defined as follows

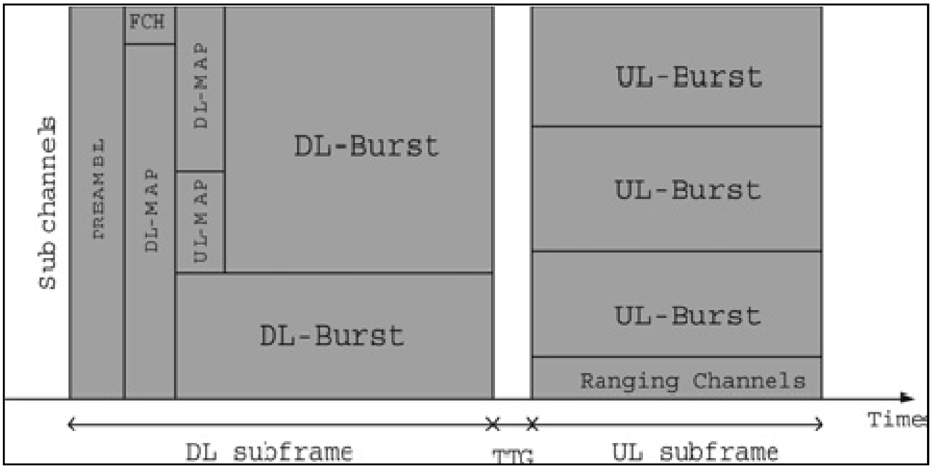

Fig. 1. IEEE 802.16[2] frame structure

$$\phi_i(t)=DRC_i(t)/R_i(t). \quad (1)$$

where DRC_i [12] is the rate requested by the SS_i and R_i is the average rate received by the SS_i over a window of the appropriate size T_c [2][12]. The average rate R_i is updated as

$$R_i(t+1)=(1-1/T_c)R_i(t)+1/T_c * \text{current transmission rate}. \quad (2)$$

where T_c is the window size to be used in the moving average. The proportional fair scheduler selects the connection that has the highest metric value.

3.2 Proposed Fair Scheduling (FS)

In the proportional fair scheduling, the strict fairness is guaranteed, however the QoS requirement is not reflected. To the knowledge of authors normally various rtps connections for QoS have been discussed in the literature with regard to one specified nrtps connection. The present authors have generalized this concept by associating various parameters of x_i defined as (various) rtps connections to the parameter k_i associated to the (various) nrtps connections Thus, the general Fair Scheduling(FS) scheme is being introduced that satisfies the delay requirement.

The metric value of the rtPS connections with the delay requirement should be increased as the queuing delay increases because the scheduler selects the connection with the highest metric value with BE connections, because BE connections are in the lowest priority. For the above mentioned condition the equations for rtps,nrtps and BE are proposed by the authors in paper [2].Here we are generalizing the equation by proposing a new scheduling scheme based on the following metrics for rtPS, nrtPS and BE connections given as :

$$\Phi_{rt,i}(t) = 1/R_{rt,i}(t) + C(1+2/\pi * \arctan(|d|)). \quad \text{if } q_i > 0 \text{ and } d \geq d_{min.} \qquad (3)$$
$$= 1/R_{rt,i}(t) + C. \quad \text{if } q_i > 0 \text{ and } d < d_{min.}$$
$$0 \quad \text{if } q_i = 0$$

$$\Phi_{nrt,i}(t) = 1/R_{nrt,i}(t) + C. \quad \text{if } q_i > 0 \qquad (4)$$
$$= 0 \quad \text{if } q_i = 0$$

$$\Phi_{BE,i}(t) = 1/R_{BE,i}(t). \quad \text{if } q_i > 0 \qquad (5)$$
$$= 0 \quad \text{if } q_i = 0$$

The parameter d is the queuing delay and C means the intensity of the delay requirement in the rtPS connection. The parameter d_{min} is the minimum delay that triggers the service differentiation between the rtPS connection and nrtPS connection, and q_i means the queue length of the connection i. Note that R_{rt}, R_{nrt} and R_{BE} are updated in the same manner as in the proportional fair scheduling, that is

$$R_{rt,i}(t+1) = (1-1/T_c)R_{rt,i}(t) + r/T_c \text{ if connection } i \text{ is scheduled.} \qquad (6)$$
$$= (1-1/T_c)\, R_{rt,i}(t) \quad \text{otherwise}$$

where T_c is the window size to be used in the moving average and r is the current transmission rate requested by the SS. The long-term rate is the average sum of the previously scheduled transmission rates during the time window T_c, where the high T_c value means that the long-term rate changes slowly because the average is taken over many previous transmission rates. The long-term rate of a connection decreases exponentially before the connection is scheduled, and it increases when the connection is scheduled. We do not consider the AMC, so r is a constant. On every frame, the scheduler selects the connection that has the highest metric value. Owing to the delay requirement term in the rtPS metric, rtPS connections are served more frequently than other connections when the queuing delay increases.

3.3 Determination of Novel Parameters with Analysis

The scheduling ratio x as the average number of scheduling times for rtPS connection per k nrtPS scheduling has been defined. If rtPS and nrtPS connections are scheduled equally, the scheduling ratio x equals k, and if rtPS connection is scheduled more frequently than nrtPS connection, the scheduling ratio x becomes larger than k. The average scheduling interval in the rtPS connection is ((k+x)/k) frames because, on the average, k nrtPS is scheduled corresponding to the scheduling of x rtPS connections.

As a result of this, the average scheduling interval in nrtPS connection is (k+x) frames. At the steady state, the average long-term rates of rtPS and nrtPS connections at the scheduling instance are as follows:

$\overline{R_{rt}} = \overline{R_{rt}}(1-(1/T_c))^{(k+x)/x} + (r/Tc)$, at the steady state, we obtain

$$\overline{R_{rt}}=(r/T_c)/\ (1-(1-(1/T_c))^{(k+x)/x} \qquad (7)$$

Analogously, Since $\overline{R_{nrt}} = \overline{R_{nrt}}(1-(1/T_c))^{(k+x)} + (r/Tc)$ at the steady state, we obtain

$$\overline{R_{nrt}}=(r/T_c)/\ (1-(1-(1/T_c))^{(k+x)} \qquad (8)$$

We consider the same assumption as in[11] that the average metric value for each connection at the scheduling instance becomes similar to each other. Hence,

$$1/\overline{R_{rt}}(1-(1/T_c))^{(k+x)/x} + C(1+(2/\pi)\arctan(|d|)).$$
$$\approx 1/\overline{R_{nrt}}(1-(1/T_c))^{(k+x)} + C. \qquad (9)$$

From (7) and (8) , (9) can be written as

$$(1-(1-(1/T_c))^{(k+x)/x})*T_c/\ (r*(1-(1/T_c))^{(k+x)/x}) + C(1+(2/\pi)\arctan(d)).$$
$$\approx (1-(1-(1/T_c))^{(k+x)})*T_c/(\ r*(1-(1/T_c))^{(k+x)}) + C. \qquad (10)$$

Put $(1-1/T_c)=X$, $L=1+(2/\pi)\arctan(d)$, therefore from above equation we have

$$(1-(X)^{(k+x)/x}\ )*T_c/(r*(X^{(k+x)/x}) + C*L$$

$$(1-(X)^{(k+x)})*Tc\ /(\ r*(X^{(k+x)}) + C$$

$$\text{i.e. } C*(L-1)=(Tc/r)*((1-(X)^{(k+x)}/X^{(k+x)} - (1-(X)^{(k+x)/x})/X^{(k+x)/x}))$$

$$C*(2/\pi)*\tan^{-1} d=(Tc/r)*((X^{(k+x)/x} - X^{(k+x)})/X^{((x*x+k*x+k+x)/x)}) \qquad (11)$$

Now with the help of L and X as defined above and with little algebra, the set of values of delay represented by $d=d_i$ correspond to different sets of values of x,k and C, from equation (11) we have for $d \geq 0$,

$$d= \tan(((\pi*Tc)/(2*r*C)*[\ ((1-1/Tc)^{(k+x)/x} - (1-1/Tc)^{(k+x)})/(1-1/Tc)^{((x*x+k*x+k+x)/x)}] \qquad (12)$$

Now generalizing the above equation if d_i represents the various delays for i iterations corresponding to the above parameters associated to number of rtps,nrtps and intensity such that $d \geq 0$.Thus we have the main result as :

$$d_i=\tan(((\pi*Tc)/(2*r*C)*[\ ((1-1/Tc)^{(k+x)/x} - (1-1/Tc)^{(k+x)})/(\ 1-1/Tc)^{((x*x+k*x+k+x)/x)}],$$

$$\text{However } d_i \geq 0 \qquad (13)$$

here $x_i=i, 0\leq i\leq 10$.However,d_i, C_i, k_i all will take real values under the investigation as given below:

Now we determined the solution set (d_i) corresponding to the various parameters C_i, x_i and k_i . As the parameter C_i increases, the delay d_i decreases because d_i and C_i are inversely proportional to each other. Interestingly we find delays obtain corresponding to the value C_i and x_i and k=1 turn out to be the same in the below given tables[1-3] as given in [2] and for the values other than k=1 we obtain the various forms of delays with regard to rtps via-vice nrtps in subscribed paper. Further we note that if the delay requirement is d_{req}, then we select the smallest parameter C_i, which satisfies $d_i \leq d_{req}$.

4 Simulation Result

The analysis has been done using Matlab for values of d_i(delay) corresponding to different prescribed values of x_i, k_i and C_i, for $1\leq i \leq 4$ as given in the following tables:

Case I:

Table 1. C_i = .05(intensity of the delay requirement in the rtps connection)

k \ x	1	2	3	4
1	0	$0.0845*10^{-3}$	$0.1501*10^{-3}$	$0.2111*10^{-3}$
2	0	0.0085	0.0141	0.0190
3	0	$0.3865*10^{-3}$	$0.6183*10^{-3}$	$0.8113*10^{-3}$
4	0	0.0065	0.0101	0.0129

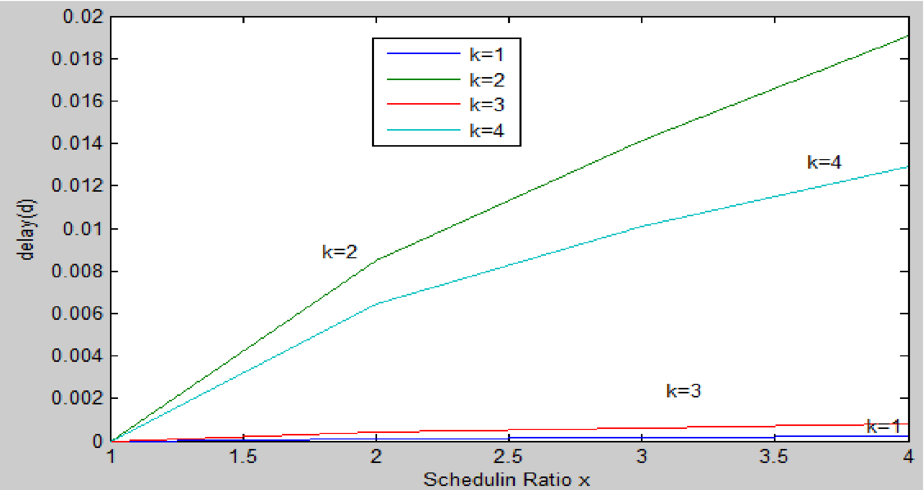

Fig. 2. Delay against Scheduling ratio x when C=.05

Case II:

Table 2. $C_i = 0.08$(intensity of the delay requirement in the rtps connection)

k x	1	2	3	4
1	0	$0.0527*10^{-3}$	$0.0937*10^{-3}$	$0.1317*10^{-3}$
2	0	0.0025	0.0041	0.0056
3	0	0.0028	0.0045	0.0059
4	0	$0.1799*10^{-4}$	$0.2799*10^{-4}$	$0.3598*10^{-4}$

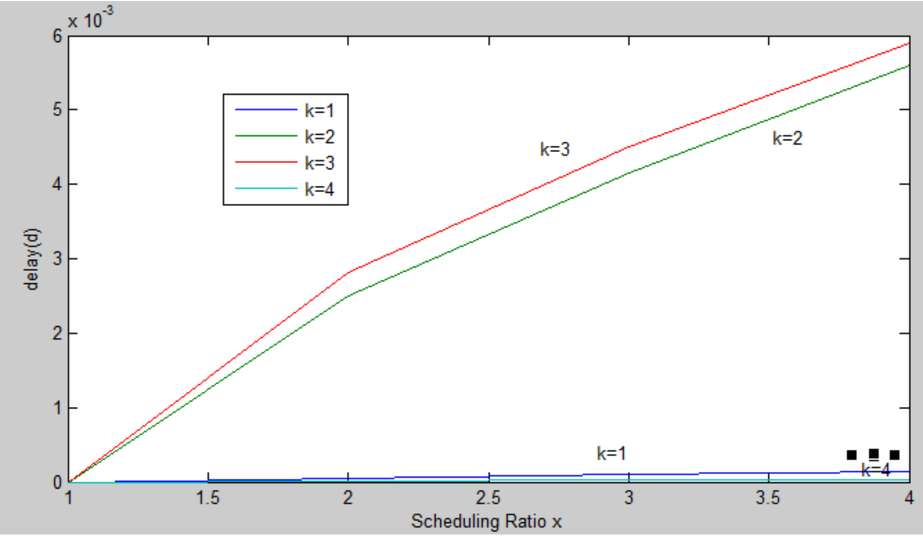

Fig. 3. Delay against Scheduling ratio x when C=.08

Case III:

Table 3. $C_i = 0.1$(intensety of the delay requirement in the rtps connection)

k x	1	2	3	4
1	0	$0.0422*10^{-3}$	$0.0749*10^{-3}$	$0.1053*10^{-3}$
2	0	.0016	.0026	.0035
3	0	.0146	.0233	.0306
4	0	.0015	.0023	.0029

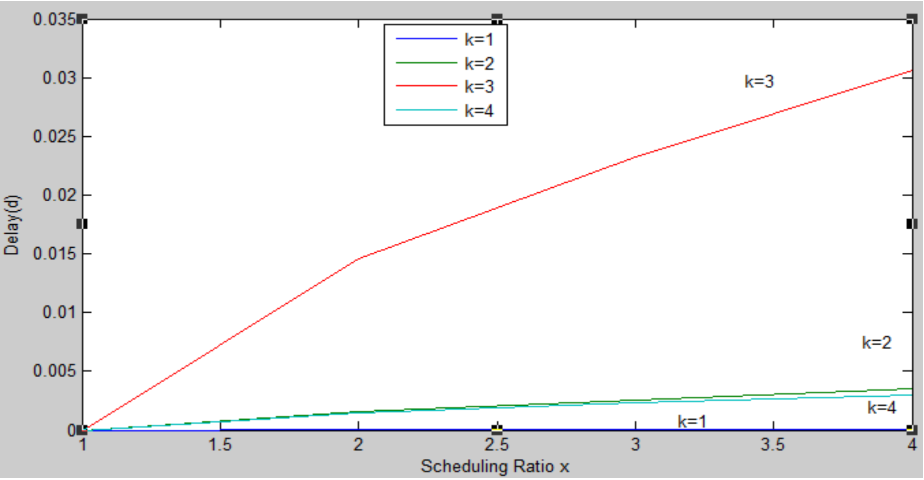

Fig. 4. Delay against Scheduling ratio x when C=.1

Table 4. Simulation Information

Parameter	Value
Packet Size	1500 bytes
Number of nodes	10
Delay requirement	30ms

5 Conclusion

In this paper, scheduling scheme in IEEE802.16 Network has been proposed and simulation results have been discussed. To support the QoS requirement the delay requirement term in the proportional fair scheduling scheme has been added. The main contribution of this paper is that a method has been proposed which will generalize the delay requirement by associating various parameters of x_i defined as (various) rtps connections to the parameter k_i associated to the (various) nrtps connections. The suggested general scheduling scheme satisfies the delay requirement. One can find the appropriate parameter C according to the traffic condition of the networks. After fine tuning of the operating parameter, the delay requirement can be satisfied without excessive sacrifice in the nrtps connection performance.

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