DOWNLINK SCHEDULING DELAY ANALYSIS OF RTPS TO NRTPS AND BE SERVICES IN WIMAX

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Abstract: *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 IEEE 802.16 standard defines the concrete quality of service (QoS) requirement, a scheduling scheme is necessary to meet the QoS requirements. Many scheduling schemes have been proposed earlier with the purpose of throughput optimization and fairness enhancement. However, few scheduling algorithm support the delay requirement. In this study, authors propose a new downlink scheduling scheme reflecting the delay requirement of rtPS connections with respect to the various nrtPS and BE connections to achieve the optimal QoS requirement, without the excessive resource consumption.*

Keywords: *QoS, IEEE 802.16, WiMax, downlink fair scheduling scheme, rtPS, nrtPS, BE*

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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.

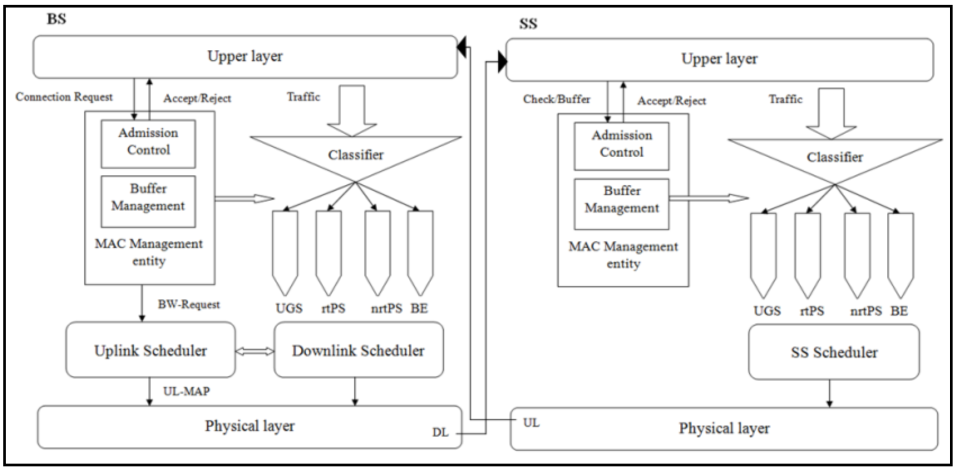
IEEE 802.16 defines four classes of service type such as unsolicited grant service (UGS), real-time polling service (rtPS), non-real-time polling service (nrtPS) and best effort (BE) service. Each service class has requirements to be met to serve the applications that belong to the category. The UGS 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 and BE connections do not have the delay requirement; however, these have 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. Recently, Kim and Lim[2] proposed QoS requirement by adding the delay requirement term in the proportional fair scheduling scheme to support the scheduling scheme that one of the rtPS and nrtPS connections is scheduled on every scheduling instance. They define the scheduling ratio x as the average number of scheduling times for rtPS connections per one nrtPS connection. If rtPS and nrtPS connections are scheduled equally, the ratio x becomes unity otherwise if rtPS connection is scheduled more frequently than nrtPS connections, the scheduling ratio x is taken greater than unity. Recently, Pooja Gupta et al [13] have proposed an alternate scheduling scheme based on proportional fairness. The scheduling parameters have been selected based on the number of connections of rtPS connections to specified number of nrtPS connections in the network. The scheduling algorithm must provide fairness to all the requests with different QoS classes. The channel starving lower priority BE requests and nrtPS requests must also be satisfied leading to fairness especially for downlink transmission. In this paper, we extend this idea of scheduling parameters being selected such that the number of connections of rtPS be connected to nrtPS as also to the BE since we do not like to see BE starving rather than doing the action that does not allow outside interference to causing hurdle in smooth functioning of the network.

2. SYSTEM ANALYSIS

PMP mode and mesh mode are the two types of operating modes defined for IEEE 802.16. 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. 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 as depicted in the figure below:



Architecture of WiMax

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

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

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

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

where Tc 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 GENERAL SCHEDULING SCHEME

In the proportional fair scheduling, the strict fairness is guaranteed, however the QoS requirement is not reflected. According to Kim and Lim [2] various rtPS connections for QoS have been discussed with regard to one specified nrtPS connection. Recently, Pooja Gupta et al [13] have generalized this concept by associating various parameters of x_i defined as n number of rtPS connections to a parameter associated to various nrtPS k (parameter) connections for k=1,2,3 and 4. Thus, the general scheduling scheme corresponding to parameter k is being introduced that satisfy various delay requirements.

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 lower priority. Pooja Gupta et al[13] proposed a scheduler that combines both EDD and priority for assuring nrtPS better performance without any impact on other classes. In order to avoid BE starvation, we extend this idea to BE connections. Here opportunity is used such that BE traffic is served whenever opportunity is available but for most of the time BE starves for throughput, bandwidth etc. Even though there are lots of conventional scheduling algorithms they are not meeting all the required QoS parameters. The performance effecting parameters like fairness, bandwidth allocation, throughput and delay jitters have been studied and found out that none of algorithms perform effectively for both fairness and bandwidth utilization simultaneously [4]. This paper concentrates on keeping the tradeoff of the parameters so that the delay remains minimum. Here we generalize the equation by proposing a new scheduling scheme based on the following metrics for rtPS, nrtPS and BE (classes) connections are given as:

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

$= 1/R_{rt},i(t)+ C.$ if q_i >0 and $0<d< d_{min.}$

$= 0$ if $q_i = 0$

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

$= 0$ if $q_i = 0$

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

$= 0$ if $q_i = 0$

The parameter d is the queuing delay and C means the intensity of the delay requirement in the rtPS connections to nrtPS connections. 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. We note here that R_{rt}, R_{nrt} and R_{BE} are updated in the same manner as in the proportional fair scheduling, that is

$R_{rt},i(t+1) = (1-1/T_c)R_{rt},i(t) + r/T_c$, if connection *i* is scheduled. (6)

$= (1-1/T_c) R_{rt},i(t)$, otherwise

where Tc 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 Tc, where the high Tc 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

In this paper we define the scheduling ratio x as the average number of rtPS connection per k number of nrtPS and k' number of BE connections where k'≤k. In order to avoid BE starvation, we extend this idea to BE connections given by the following two cases:

Case I:

If rtPS and nrtPS connections are scheduled equally, the scheduling ratio x equals k corresponding to no connections to BE for k'=0. Following Kim and Lim[2] and Pooja Gupa et al[13], if rtPS connection is scheduled more frequently than nrtPS connection, the scheduling ratio x becomes greater than k. Now the average scheduling interval in the rtPS connection is ((x+k)/x) frames because, on an average, k nrtPS schedule correspond to 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

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

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

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

We consider the same assumption as in [11] that the average metric value for each of rtPS and nrtPS connection at the scheduling instance becomes similar to each other with delay d. Hence,

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

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

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

Case II:

Now if rtPS connection is scheduled after k nrtPS connections with k' BE connections (with less frequently), the scheduling ratio x becomes greater than k', where k'<<k. Now the average scheduling interval in the rtPS connection is ((x+k')/x) frames because, on the average, the number of k' BE schedule correspond to x rtPS connections subject to k'<<k. As a result of this, the average scheduling interval in BE connection is (k'+x) frames. At the steady state, the average long-term rates of rtPS and BE connections at the scheduling instance are as follow:

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

$$\overline{R_{rt}}=(r/T_c)/ (1-(1-(1/T_c))^{(k'+x)/x} \quad (11)$$

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

$$\overline{R_{BE}}=(r/T_c)/ (1-(1-(1/T_c))^{(k'+x)} \quad (12)$$

As in [11], the average metric value for each rtPS and BE connection at the scheduling instance with delay D becomes similar to each other. Hence,

$$1/\overline{R_{rt}}(1-(1/T_c))^{(k'+x)/x} + C(1+(2/\pi)\arctan(D)).$$
$$\approx 1/\overline{R_{BE}}(1-(1/T_c))^{(k'+x)} + C. \quad (13)$$

From (11) and (12), (13) can be written as

$$((1-(1-(1/T_c))^{(k'+x)/x})/ ((r/T_c)/ (1-(1/T_c))^{(k'+x)/x}) + C(1+(2/\pi)\arctan(D)).$$
$$\approx ((1-(1-(1/T_c))^{(k'+x)})/(r/T_c)/(1-(1/T_c))^{(k'+x)}) + C \quad (14)$$

We note here $0\leq k'<k\leq x-k$, for k and x being positive integers.

Now generalizing each of the above equations (10) and (14) for *i* iterations corresponding to the above parameters such as x, k, k', C, d and D and on simplifying these equations we have as follow:

d_i=tan(((π*Tc)/(2*r*C)*[((1-1/Tc)$^{(k+x)/x}$ – (1-1/Tc)$^{(k+x)}$)]/(1-1/Tc)$^{((x*x+k*x+k+x)/x)}$], (15)

and

D_i = tan(((π*Tc)/(2*r*C)*[((1-1/Tc)$^{(k'+x)/x}$ – (1-1/Tc)$^{(k'+x)}$)]/(1-1/Tc)$^{((x*x+k'*x+k'+x)/x)}$], (16)

We note here k≠k' in view of 0<k'<k and x=$x_{i,}$ 0≤i≤10.

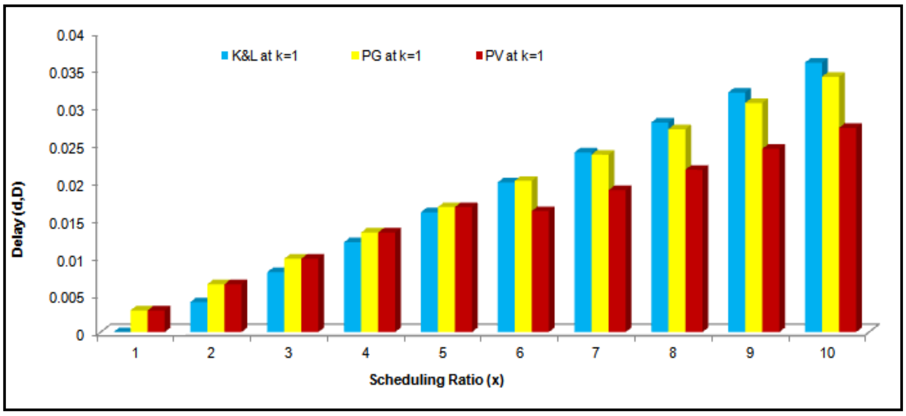
In their paper, Pooja et al [13] ,using eqs (7),(8)have obtained the parameters of delay d from eq.(10) as against scheduling ratio x corresponding to k=1,2,3 and 4. In particular their findings are that as x=k=1, almost all types of parameters including various forms of delays turn out on the parallel lines as derived by Kim and Lim [2]. Using simulation based on statistical analysis they have obtained various parameters including different kinds of delays corresponding to the values of k in {1, 2, 3, 4} and obtained that the delays corresponding to first five rtPS connections are smaller than subsequent nrtPS connections but start increasing more than nrtPS for x >5 and it is true for all values of k. Recently, a number of papers have discussed that BS scheduler can guarantee minimum bandwidth for each service flow and ensure fairness and QoS in distributing excess bandwidth among all connections. At the same time,for the down link scheduler in SS (rtPS) can provide differentiated and flexible QoS support for all of the four scheduling service types. It can both reduce the delay of real time applications and guarantee the throughput of non real applications also enhancing bandwidth utilization of the system and fairness of resources even at lower traffic intensity. In view of the downlink service we propose rtPS as an efficient scheduling scheme which eliminates the starvation problem of lower priority class services nrtPS and BE. Thus in this paper, we generalize the idea of [13] to study delay D associated as rtPS connections to number of k' BE connections. Analogously using eqns. (11) and (12) we obtain the parameters of delay D from eq. (14). We then study the relative behavior of d and D.

Now we determine the solution set ($d_{i,}$ D_i) corresponding to the various parameters C, x_i and k_i and k'_i . As the parameter C increases, each of the delays d_i and Di decrease because each of queuing delays Di and d_i are inversely proportional to C. We notice here that our results turn out to coincide with the results given in papers [2] and [13] for the values k=1 such that x: k=1:1 with no connections of BE. We observe that with increase in x, the delays corresponding to BE for all values of k'<k are smaller than respective delays of nrtPS and rtPS as can be seen by the following diagrams corresponding to respective tables.

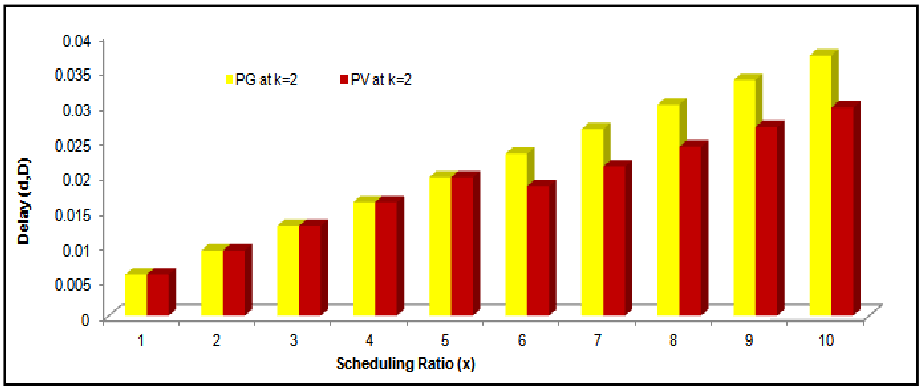
4. SIMULATION RESULT

Using Matlab, the values of D (delays) corresponding to different prescribed values of x_i, k, k' and C for 1≤x i ≤10,1<k<=4 and 1,=k', C<=3 are given in the following tables. Since rtPS connections are whole numbers therefore, their connections with nrtPS and BE have to be in ratio of x:k:k' involving three parameters instead of two parameters as in x:k=1:1,[2,13]. Thus in this case we have:

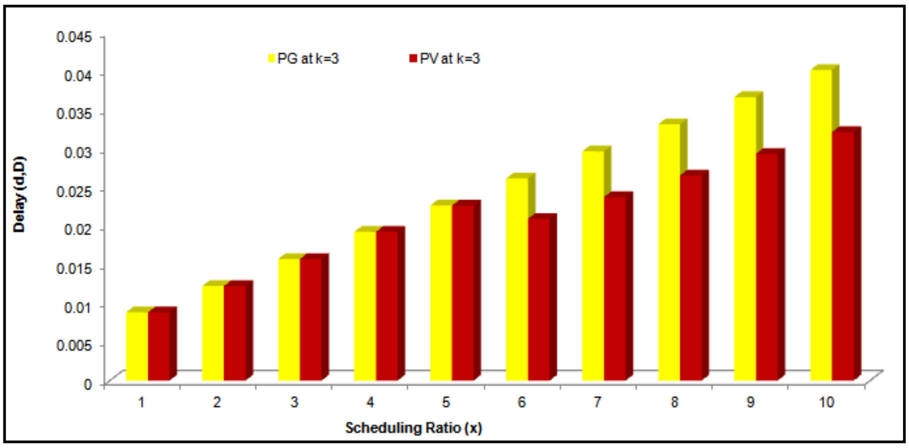
Table 1 for C = 0.1(intensity of delay for rtPS, nrtPS and BE connection)										
k'/x	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
K&L at k=1	0	0.004	0.008	0.012	0.016	0.02	0.024	0.028	0.032	0.036
PG at k=1	0.0029	0.0064	0.0098	0.0133	0.0167	0.0202	0.0237	0.0271	0.0306	0.0341
PV at k=1	0.0029	0.0064	0.0098	0.0133	0.0167	0.01616	0.01896	0.02168	0.02448	0.02728
PG at k=2	0.0059	0.0093	0.0128	0.0162	0.0197	0.0231	0.0266	0.0301	0.0336	0.0371
PV at k=2	0.0059	0.0093	0.0128	0.0162	0.0197	0.01848	0.02128	0.02408	0.02688	0.02968
PG at k=3	0.0088	0.0122	0.0157	0.0192	0.0226	0.0261	0.0296	0.0331	0.0366	0.0401
PV at k=3	0.0088	0.0122	0.0157	0.0192	0.0226	0.02088	0.02368	0.02648	0.02928	0.00802
PG at k=4	0.0117	0.0152	0.0187	0.0221	0.0256	0.0291	0.0326	0.0361	0.0396	0.0431



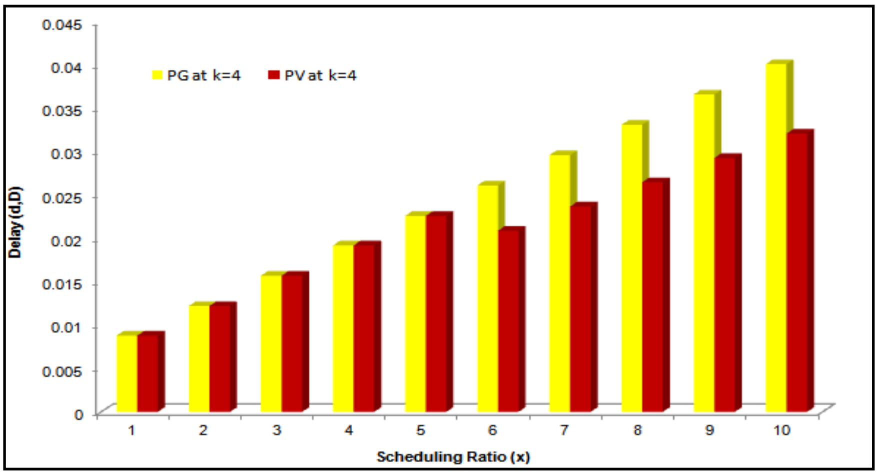
In the above graph for k=1, we notice that as x increases, the delays corresponding to each of five rtPS, four nrtPS and one BE connections for K&L,PG and PV methods increase. However, we notice that for first five values of x, respective delays of BE>nrtPS.>rtPS and then there follows transition and for the next five values the delays reverse such that BE<nrtPS<rtPS justifying doing away with the starvation of BE.



In the above graph for k=2, we notice that with the increase of x, each of the delays of PG and PV increase. However first five rtPS delays of PV are larger than the respective delays of PG i.e. for first five rtPS values delays of PV>PG and for four delays of nrtPS we find PV<PG and for one BE delay PV<<PG, again justifying the involvement of BE in the network

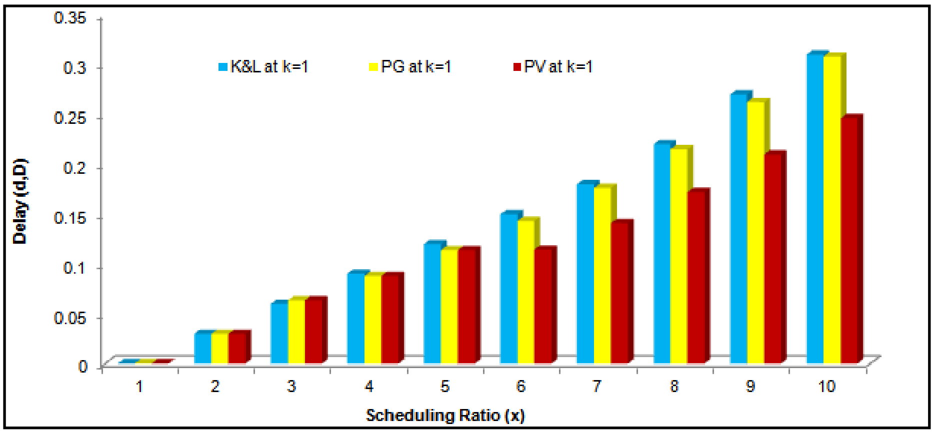


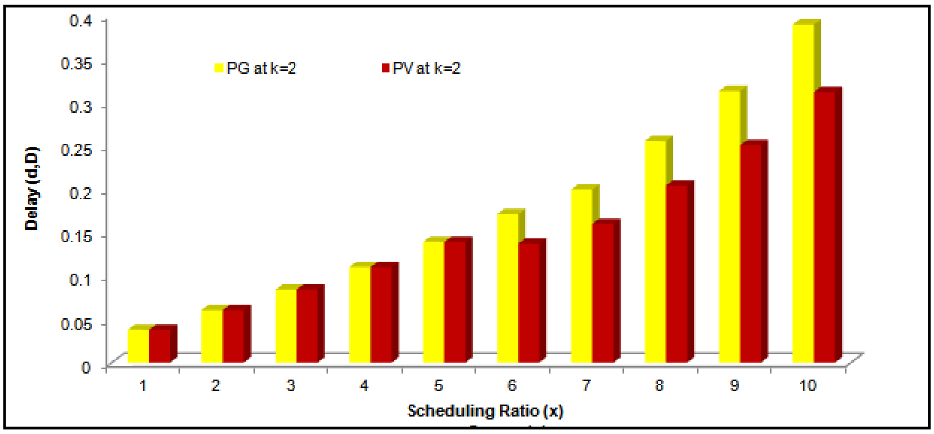
In the above graph for k=3,we notice here that in each of the scheduling schemes corresponding to all given values of C we find as the nodal values increase ,the respective delays of rtPS, nrtPS and BE also increase. However, for first five rtPS values PV delays >delays of PG, for next four nodal values of x gives nrtPS values such that PV delays<delays of PG and for one BE connection PV delay is substantially decreased as compared to PG delay.

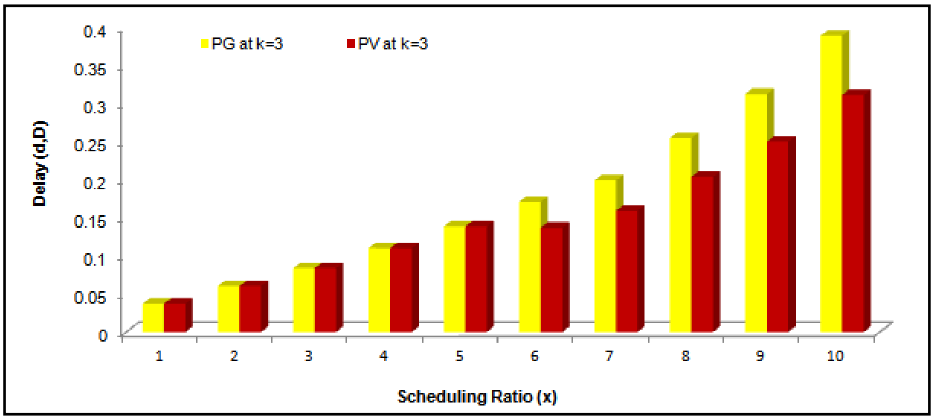


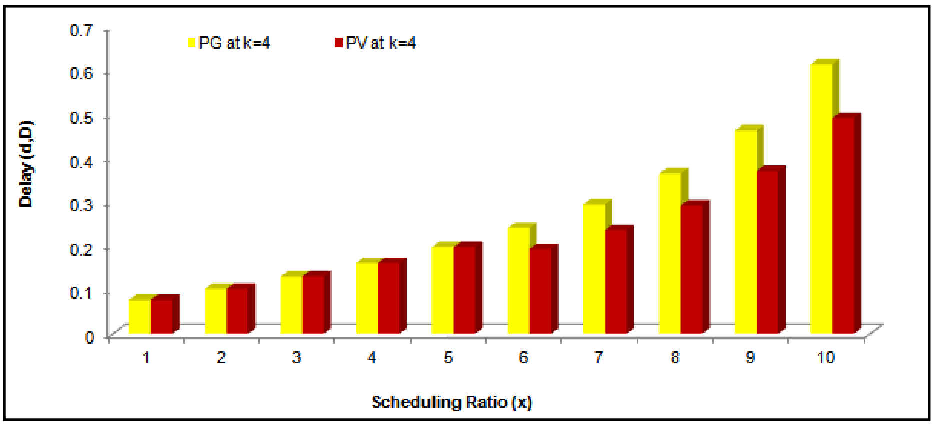
In the above graph for k=4, we notice that as x increases, the delays corresponding to each of five rtPS, four nrtPS and one BE connections for K&L,PG and PV methods increase. However, we notice that for first five values of x, respective delays of BE>nrtPS.>rtPS and then there follows transition and for the next five values the delays reverse such that BE<nrtPS<rtPS justifying doing away with the starvation of BE.

Table 2 for C = 0.01(intensity of delay for rtPS, nrtPS and BE connection)										
k/x	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
K&L at k=1	0	0.03	0.06	0.09	0.12	0.15	0.18	0.22	0.27	0.31
PG at k=1	0.0002	0.03	0.0635	0.0877	0.1139	0.143	0.1761	0.215	0.2622	0.308
PV at k=1	0.0002	0.03	0.0635	0.0877	0.1139	0.1144	0.14088	0.172	0.20976	0.2464
PG at k=2	0.0374	0.0601	0.0841	0.11	0.1386	0.1711	0.1991	0.2548	0.3125	0.3892
PV at k=2	0.0374	0.0601	0.0841	0.11	0.1386	0.13688	0.15928	0.20384	0.25	0.31136
PG at k=3	0.0568	0.0806	0.1062	0.1343	0.1662	0.2032	0.2476	0.3034	0.3767	0.4803
PV at k=3	0.0568	0.0806	0.1062	0.1343	0.1662	0.16256	0.19808	0.24272	0.30136	0.38424
PG at k=4	0.0771	0.1024	0.1301	0.1614	0.1975	0.2408	0.2946	0.3649	0.463	0.6131



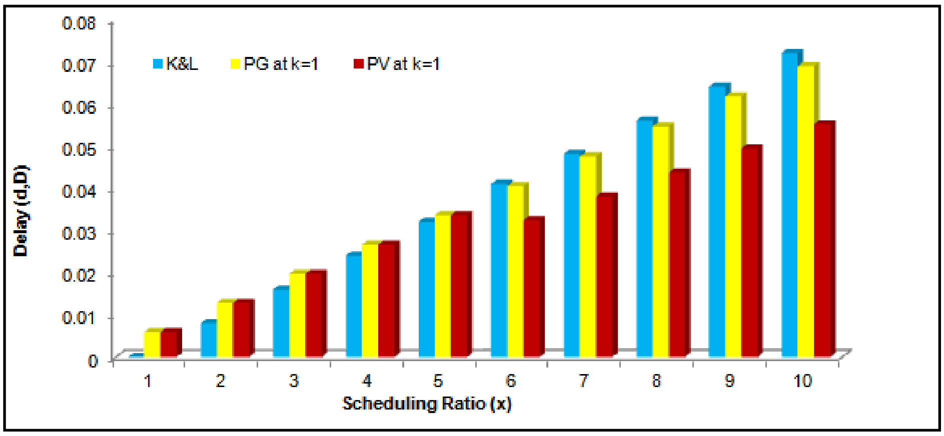


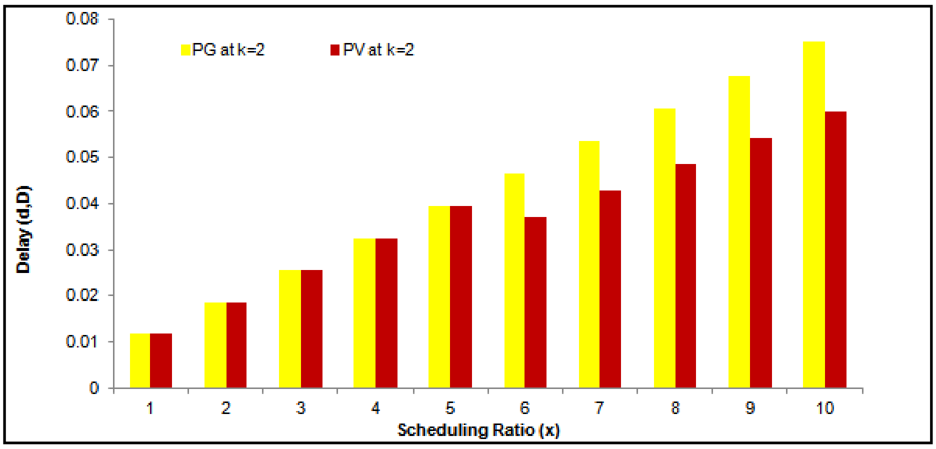


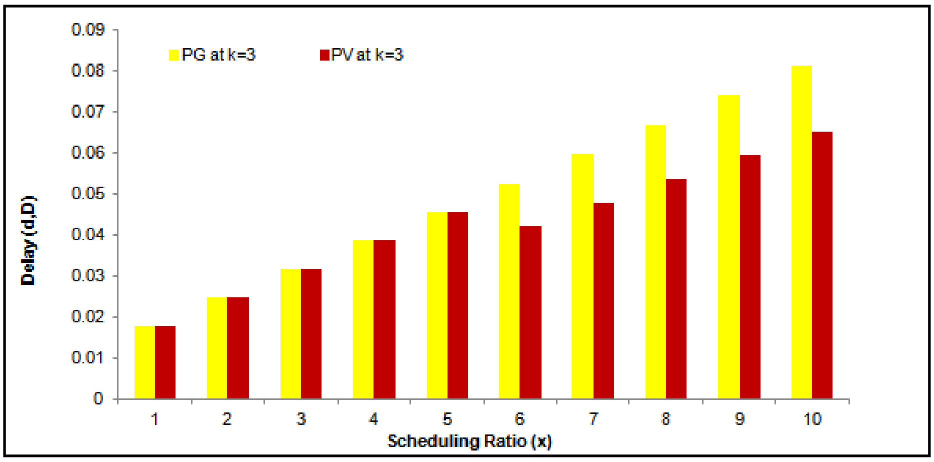


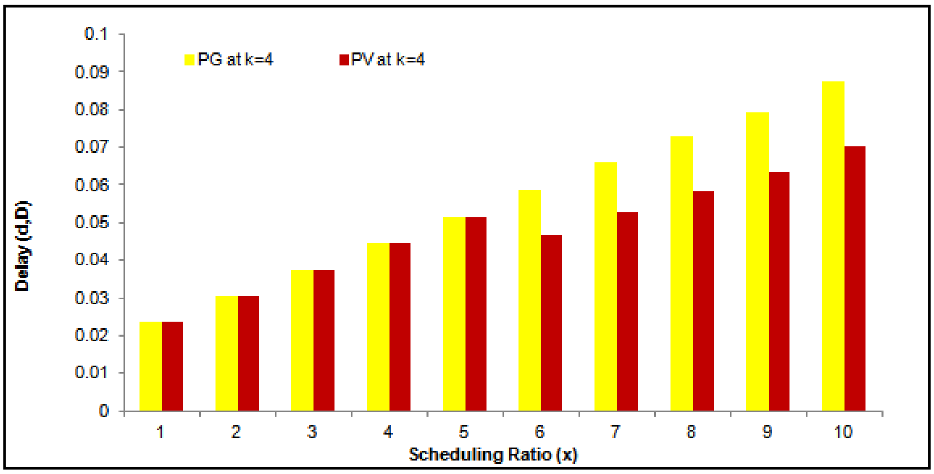
In the above graphs corresponding to c=0.01 for k=1,2,3 and 4, we notice that as x increases, the delays corresponding to each of five rtPS, four nrtPS and one BE connections for K&L,PG and PV methods increase. However, we notice that for first five values of x, respective delays of BE>nrtPS.>rtPS and then there follows transition and for the next five values the delays reverse such that BE<nrtPS<rtPS justifying doing away with the starvation of BE.

Table 3 for C = 0.05 (intensity of delay for rtPS, nrtPS and BE connection)										
k/x	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
K&L at k=1	0	0.03	0.06	0.09	0.12	0.15	0.18	0.22	0.27	0.31
PG at k=1	0.0002	0.03	0.0635	0.0877	0.1139	0.143	0.1761	0.215	0.2622	0.308
PV at k=1	0.0002	0.03	0.0635	0.0877	0.1139	0.1144	0.14088	0.172	0.20976	0.2464
PG at k=2	0.0374	0.0601	0.0841	0.11	0.1386	0.1711	0.1991	0.2548	0.3125	0.3892
PV at k=2	0.0374	0.0601	0.0841	0.11	0.1386	0.13688	0.15928	0.20384	0.25	0.31136
PG at k=3	0.0568	0.0806	0.1062	0.1343	0.1662	0.2032	0.2476	0.3034	0.3767	0.4803
PV at k=3	0.0568	0.0806	0.1062	0.1343	0.1662	0.16256	0.19808	0.24272	0.30136	0.38424
PG at k=4	0.0771	0.1024	0.1301	0.1614	0.1975	0.2408	0.2946	0.3649	0.463	0.6131







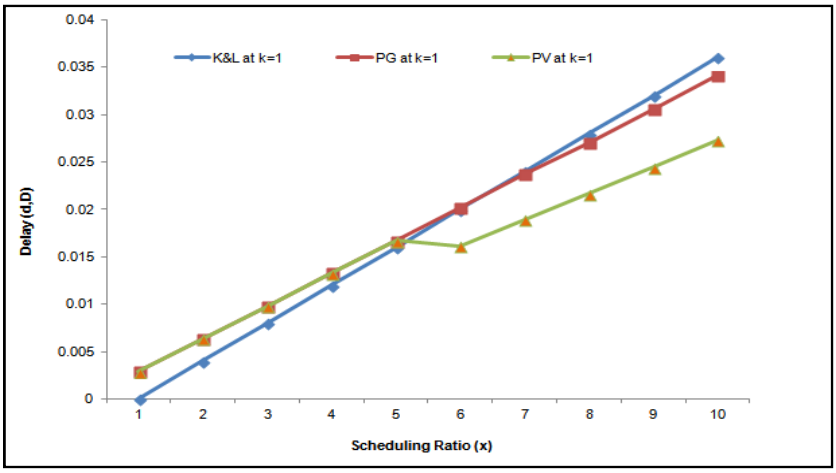


In the above graphs corresponding to c=0.05 for k=1,2,3 and 4, we notice that as x increases, the delays corresponding to each of five rtPS, four nrtPS and one BE connections for K&L,PG and PV methods increase. However, we notice that for first five values of x, respective delays of BE>nrtPS.>rtPS and then there follows transition and for the next five values the delays reverse such that BE<nrtPS<rtPS justifying doing away with the starvation of BE.

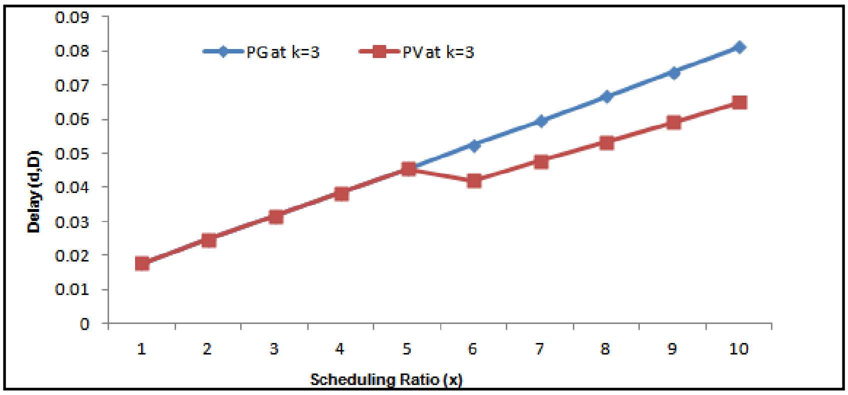
5. ANALYSIS OF DELAYS OF DIFFERENT SERVICE CLASSES

Now in particular, we give the comparison of delay of different classes with regard to the 10 nodes for the cases c= 0.1, k=1; c=0.01, k=2 and c=0.05, k=3 and analyze the comparison of the downlink services within rtPS, nrtPS, BE as given below:

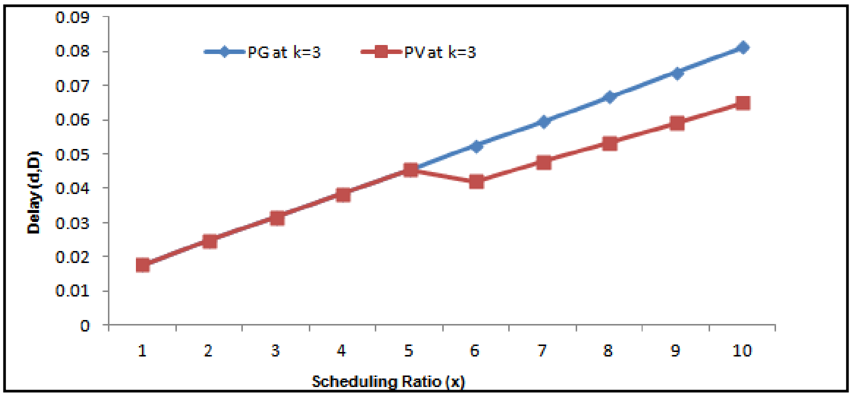
For c=0.1 and k=1:



For c=0.01 and k=2:



For c=0.05 and k=3:



Now comparing the set of values of pair of delays {d,D}corresponding to k=1,2,3and taking the tenth value of(K&L and PG's) nrtPS approximating to BE and compare five rtPS, four nrtPS and one BE connection with the PVs(present values) corresponding to x:k:k' = 5:4:1. We compare these values of 5 rtPS, 4 nrtPS and one BE connection from respective eqn. (10) and eqn.(13) for (k,C)={(1, 0.1),(2,0.01),(3,0.05). We observe in each of the above tables, that for first five values of x, the delays corresponding to rtPS of K&L<PG<PV, for the next four values the delay of nrtPS of K&L>PG>PV and the delay of last connection BE is substantially less than each of rtPS and nrtPS.

5. CONCLUSION

Recently, some papers have discussed the QoS architecture for WiMax but little attention has been given to QoS supporting downlink scheduling scheme from rtPS service to nrtPS and BE services. Here, the authors have discussed and presented a novel scheduling scheme reflecting the delay requirements by introducing the delay requirement term in the proportional fair general scheduling scheme to study the reduction of delay of nrtPS and BE services with respect to different delaying intensities and there by justify overcome of starvation problem of lower priority classes especially BE. Thus, the proposed QoS scheduling architecture can provide tight QoS guarantees for all types of service classes as defined for the proportional fair scheduling scheme.

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