QoS ASSURED DOWNLINK PROPORTIONAL FAIR SCHEDULER FOR MITIGATION OF STARVATION FOR nrtPS AND BE IN WI-MAX NETWORKS

Neha Kak*

Brijesh Kumar*

Pooja Gupta*

Triveni Raina**

Abstract: *The performance of any network essentially depends on quality of service required and also on the scheduling scheme. In our paper we focus on analyzing essential QoS parameters like delay, jitters, throughput associated to four proportional fair scheduling as proposed by Lim & Kim [2] and Gupta et al [3]. We extend the idea of parameters such that the number of downlink connections of rtPS for starvation is drastically reduced for lower priority of service flows of nrtPS and BE to achieve the optimal QoS requirement without the excessive resource consumption.*

Key words: *QoS, IEEE 802.16, WiMax, rtPS, nrtPS, BE*

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*Lingayas University, Faridabad

**Tech Mahindra, Noida

1. INTRODUCTION

1.1 Wimax Technology and QoS Analysis

Wimax acronym for Worldwide Interoperability for Microwave Access supports both fixed and wireless mobile broadband. It is one of most promising technology for Broadband Wireless Access (BWA) aiming to provide services on a scale of Metropolitan Area Network (MAN)[3]. IEEE 802.16 based wireless scheme i.e. Wimax not only concentrates on lowering the cost of wired connections by enhancing features but also focusing highly on QoS(Quality of Service) requirements.

On the other hand QoS (Quality of Service) refers to a broad collection of networking technologies and techniques. The goal of QoS is to provide guarantees on the ability of a network to deliver predictable results. Elements of network performance within the scope of QoS often include availability (uptime), bandwidth (throughput), latency (delay), and error rate.

In Broadband Wireless communications, QoS is still an important criterion. So the basic feature of WiMAX network is the guarantee of QoS for different service flows with diverse QoS requirements. While extensive bandwidth allocation and QoS mechanisms are provided, the details of scheduling and reservation management are left not standardized. In fact, the standard supports scheduling only for fixed-size real-time service flows. The scheduling of both variable-size real-time and non-real-time connections is not considered in the standard. Thus, WiMAX QoS is still an open field of research and development for both constructors and academic researchers. The standard should also maintain connections for users and guarantee a certain level of QoS. Scheduling is the key model in computer multiprocessing operating system. It is the way in which processes are designed priorities in a queue and provide mechanism for bandwidth allocation and multiplexing at the packet level.

1.2. Wimax Architecture

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.

In IEEE 802.16 the BS (Base Station) centrally allocates the channels in different slots to different SSs (Subscriber Stations) for uplink and downlink which in turn allocates these resources to the various connections they are supporting at that time. Since BS is aware of the channel state of sub channels for all SSs and therefore can exploit channel user diversity by allocating different sub channels to different SSs as shown in the Fig1 below.

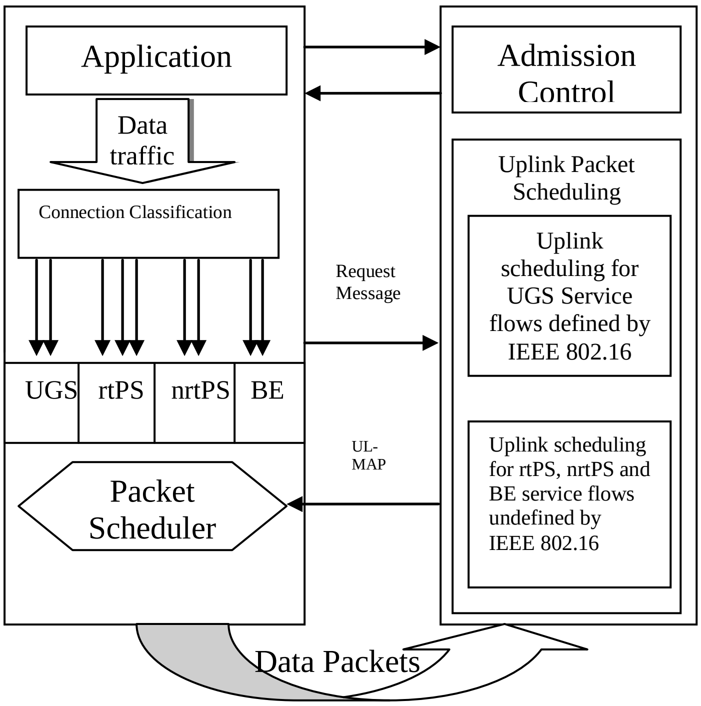


Figure 1: Wimax Architecture

In our case the packets are transferred from source node (rtPS) to destination node (nrtPS or BE) after following various scheduling, modulation and routing technique Kim and Lim [2] and Gupta et al[3].Here rtPS connection acts as base whereas nrtPS and BE serve as SSs. The overall system throughput can be maximized by allocating a sub channel to the SS with the best channel state. [2, 12]

1.3 QoS Service Classes

To support the different types of traffic with their various requirements IEEE 802.16-2005 defines four QoS service classes: Unsolicited Grant Scheme (UGS), Real Time Polling Service (rtPS), Non Real Time Polling Service (nrtPS), BE(Best Effort)..

UGS is designed to support real time data stream consisting of fixed size data packets issued at periodic intervals such as E1/T1 and voice over IP without silence suppression. The main

QoS parameters are maximum sustained rate (MST), maximum latency and tolerated jitter (the maximum delay variation.

rtPS: This service class is for variable bit rate (VBR) real-time traffic such as MPEG compressed video.

nrtPS: This service class is for non-real-time VBR traffic with no delay guarantee. Only minimum rate is guaranteed. In the nrtPS scheduling service, the BS provide unicast uplink request polls on a 'regular' basis, one second or less, which guarantees that the service flow receives request opportunities even during network congestion.

BE: This class is designed to support data streams for which no minimum service guarantees are required, like the case in HTTP traffic. The BS does not have any unicast uplink request polling obligation for BE SSs. Therefore, a long period can run without transmitting any BE packets. [16]

These are summarized in Table 1.

QoS Category	Applications	QoS Specifications
UGS Unsolicited Grant Service	VoIP	-Maximum Sustained Rate -Maximum Latency Tolerance -Jitter Tolerance
rtPS Real-Time Polling Service	Streaming Audio or Video	-Minimum Reserved Rate -Maximum Sustained Rate -Maximum Latency Tolerance -Traffic Priority
ErtPS Extended Real-Time Polling Service	Voice with Activity Detection (VoIP)	-Minimum Reserved Rate -Maximum Sustained Rate -Maximum Latency Tolerance -Jitter Tolerance -Traffic Priority
nrtPS Non-Real-Time Polling Service	File Transfer Protocol (FTP)	-Minimum Reserved Rate -Maximum Sustained Rate -Traffic Priority
BE Best-Effort Service	Data Transfer, Browsing, Web etc.	-Maximum Sustained Rate -Traffic Priority

Table 1: QoS Service Classes [16]

2. SYSTEM DESIGN

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.2 [2] given below.

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. [2, 12]

2.1 Multi- User scheduler of the MAC Layer

In this section a multi user scheduler is designed at the medium access control (MAC) layer. Here we take the delay requirement into account in the scheduler design. AMC, packet fragmentation and packet packing have not been considered. In case of the UGS traffic the required bandwidth is reserved in advance. Thus we only take rtPS, nrtPS and BE connections which are focused in the design. [2][12]

2.2 Novel design of proportional fair scheduling

The proportional fair scheduling [2] has shown an impressive guideline in the scheduler design because it maximizes the total sum of each SS's utility. 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, Gupta et al [3] 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. In case of Kim and Lim [2] and Gupta et al [3] there is no starvation for nrtps whereas starvation for BE in both the cases is 100%.But for fairness of scheduling, in this paper, we extend this idea of scheduling parameters being selected such that the number of connections of rtPS be connected to nrtPS and BE with the least starvation to both the traffics. In this case according to Lim and Kim they have taken the ratio x:k as to 1:1 whereas Gupta takes ratio as x:k as to 1:2, 1:3, 1:4 for the above four schedules corresponding to the values of k and in each case they have given 100% starvation to BE.

Now for fairness of the scheduling, since the starvation of BE is also to be reduced as such we take the connections of rtps to nrtps and BE in the ratio such that x:k:k' :: 1:1:1 which is not possible in their case. They have taken the values xi such that xi is equal to 1 to 10.We have therefore designed novel set of connections from rtps to nrtps ranging from xi equal to 1 to 12 and computed the delay corresponding of four connections each of rtps , nrtps and BE. This results into almost hundred percent mitigation of starvation in both cases of nrtPS and BE though at the cost of increase in delay.

2.3 The following notations are used throughout this paper:

$\Phi_i(t)$:the metric for fair scheduling

$DRC_i(t)$:rate requested by ith SS (Subscriber System)

$R_i(t)$:Average Rate received by ith SS

T_c: size of window

R: Transmission rate.

C and C': intensities associated to the corresponding delays d and D

Traffic connections…rtps, nrtps and BE

3. PFS AS SCHEDULER DESIGN

This novel proportional fair scheduling (PFS), [2] has shown an impressive guideline in scheduler design because it maximizes the total sum of each SS_i utility. The metric as defined in [2] for each connection is given as follows:

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

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, 3, 4, 12].

The average rate Ri is updated as

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

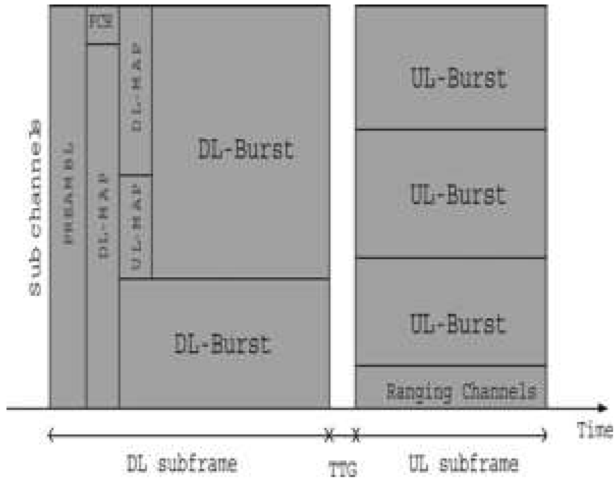


Figure. 2. IEEE 802.16[2] frame structure

3.1 Proposed Novel Proportional Fair Scheduling (PNPFS)

In the proportional fair scheduling, the strict fairness is guaranteed, however the QoS requirement is not reflected. To the knowledge of authors rtps connections for QoS have been discussed in the literature with regard to one specified nrtps connection, Kim et. al.[2] and Gupta et al. [3,4]have generalized this concept by associating various parameters such as scheduling ratio xi of rtps class parameter associated to k number of nrtps class. Thus, the general scheduling scheme is being introduced that satisfies the delay requirement. In this paper we have generated a number of fair scheduling schemes corresponding to the parameter k so that the delay requirements are minimized with regard to corresponding nrtps schemes as mentioned below. 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 nrtps connections, because nrtps connections are in the lowest priority. For the above mentioned conditions the equations for rtps and, nrtps are proposed by the authors in papers [2], [3]. Here we are generalizing the above equation by proposing a new scheduling scheme based on the following metrics for rtPS, nrtPS and BE connections are given as:

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

$$= 1/R_{rt,i}(t)+ C. \quad \text{if } q_i>0 \text{ and } 0<d< dmin.$$

$$= 0 \quad \text{if } q_i=0$$

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

$$= 0 \quad \text{if } q_i=0$$

$$\Phi_{BE,i}(t)= 1/_{RBE,i}(t). +C' \quad \text{if } qi>0 \qquad (5)$$

$$= 0 \quad \text{if } qi=0$$

The parameter d is the queuing delay and C means the intensity of the delay requirement in the rtPS connections to nrtPS connections. Here we define the parameter D as the queuing delay and C' means the intensity of delay requirement in rtPS to BE 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

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

$= (1-1/Tc)\ R_{rt,i}(t)$, 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 [2, 3, 12].

4. NOVEL PARAMETERS WITH ANALYSIS

In this paper we define the scheduling ratio x as the average number of rtPS connection per k1 number of nrtPS and k2 number of BE connections where k2≤k1. In order to avoid BE starvation, we extend this idea to BE connections given by the following two cases:

4.1 Case I:

If rtPS and nrtPS connections are scheduled equally, the scheduling ratio x equals k1 corresponding to no connections to BE for k2=0. Following Kim and Lim [2] and Gupa et al [3], if rtPS connection is scheduled more frequently than nrtPS connection, the scheduling ratio x becomes greater than k1. Now the average scheduling interval in the rtPS connection is ((x+k1)/x) frames because, on an average, k1 nrtPS schedule correspond to x rtPS connections. As a result of this, the average scheduling interval in nrtPS connection is (k1+x) frames. At the steady state, the average long-term rates of rtPS and nrtPS connections at the scheduling instance are as follows:

R_{rt} = Rrt (1-(1/T_c))(k1+x)/x + (r/ T_c), at the steady state, we obtain

Rrt =(r/ T_c)/ (1-(1-(1/ T_c))(k1+x)/x (7)

Analogously, Since $Rnrt = Rnrt$ (1-(1/ T_c))(k1+x) + (r/ T_c) at the steady state, we obtain

$Rnrt$ =(r/ T_c)/ (1-(1-(1/ T_c))(k1+x) (8)

We consider the same assumption as in [14] 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/ Rrt (1-(1/ T_c))(k1+x)/x + C(1+(2/π)arctan(d))

≈1/ $Rnrt$ (1-(1/ T_c))(k1+x) + C (9)

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

((1-(1-(1/ T_c))(k1+x)/x)/ ((r/ T_c)/ (1-(1/ T_c))(k1+x)/x) + C(1+(2/π)arctan(d))

≈ ((1-(1-(1/ T_c))(k1+x))/(r/ T_c)/(1-(1/ T_c))(k1+x)) + C. (10)

5.2 Case II:

Now if rtPS connection is scheduled after k1 nrtPS connections with k2 BE connections (with less frequently), the scheduling ratio x becomes greater than k2, where k2≤k1. Now the average scheduling interval in the rtPS connection is ((x+k2)/x) frames because, on the average, the number of k2 BE schedule correspond to x rtPS connections subject to k2≤k1. As a result of this, the average scheduling interval in BE connection is (k2+x) frames. At the steady state, the average long-term rates of rtPS and BE connections at the scheduling instance are as follow:

$Rrt = Rrt$ (1-(1/ T_c))(k2+x)/x + (r/ T_c), at the steady state, we obtain

Rrt =(r/ T_c)/ (1-(1-(1/ T_c))(k2+x)/x (11)

Analogously, Since R_{BE} = $Rnrt$ (1-(1/ T_c))(k2+x) + (r/ T_c) at the steady state, we obtain

R_{BE} =(r/ T_c)/ (1-(1-(1/ T_c))(k2+x) (12)

As in [14], the average metric value for each rtPS and BE connection at the scheduling instance with delay D becomes similar to each other.

Hence,

1/Rrt (1-(1/ T_c))(k2+x)/x + C'(1+(2/π)arctan(D)).

≈1/RBE (1-(1/Tc))(k2+x) + C'. (13)

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

$((1-(1-(1/ T_c))(k2+x)/x)/ ((r/ T_c)/ (1-(1/ T_c))(k2+x)/x) + C'(1+(2/\pi)\arctan(D))$.

$\approx ((1-(1-(1/ T_c))(k2+x))/(r/ T_c)/(1-(1/ T_c))(k2+x)) + C'$ (14)

We note here

$0\leq k2\leq k1$, such that x:k1:k2=1:1:1 where x,k1 and k2 are positive integers. …… (14)'

Now generalizing each of the above equations (10) and (14) for *i* iterations corresponding to the above parameters such as x, k1, k2, C,C', d and D and on simplifying these equations we have as follow:

$$di=\tan(((\pi* T_c)/(2*r*C)** ((1-1/ T_c)(k1+x)/x -(1-1/ T_c)(k1+x))]/(1-1/ T_c)((x*x+k1*x+k1+x)/x)] \quad (15)$$

and

$$Di=\tan(((\pi* T_c)/(2*r*C')** ((1-1/ T_c)(k2+x)/x - (1-1/ T_c)(k2+x))]/(1-1/ T_c)((x*x+k1*x+k2+x)/x)] \quad (16)$$

5. ANALYSIS OF NRTPS AND B.E TRAFFICS WITH REGARD TO RTPS TRAFFIC AS A BASE STATION

5.1 In their paper, Gupta et al [3] ,using eqs (7),(8)have obtained the parameters of delay d from eq.(10) as against scheduling ratio x corresponding to k1=1,2,3 and 4. In particular, their findings are such that for k1=1, almost all types of parameters including various forms of delays turn out approximately 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 k1 in {1, 2, 3, 4} and obtained that the delays corresponding to first five rtPS connections are smaller than subsequent nrtPS connections but in start these increase more than nrtPS for x >4 and it is true for all values of k1. 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 downlink 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 .Recently Raina et al [12] have discussed and presented a scheduling scheme reflecting the delay requirements by introducing the same delay intensities corresponding to different ratios which does not give the maximum mitigation of starvation to lower priority classes such as BE traffic .Now in this paper, we generalize the idea of [2,3,12] and to study delay D as associating to rtPS so that it associates k1 connections to nrtPS traffic and k2 connections to BE traffic in the fair proportional ratio subject to x:k1:k2=1:1;1 to allow maximum mitigation of starvation to BE traffic. Analogously using eqns. (11) and (12) we obtain the parameters of delay D from eq. (14) subject to (14)'. We then study the relative behavior of d and D.

5.2 Now we determine the solution set (d_i, D_i) corresponding to the various parameters C, C', x_i (i=1..12)and k1 and k2 take the values {1, 2, 3, 4}. As each of parameters C and C' increase, each of the delays d_i and D_i decrease because each of queuing delays D_i and d_i are inversely proportional to C' and C respectively. We notice here that our results turn out on parallel lines with the results given in papers [2, 3] for the values k1=1 such that x: k1=1:1 with no connections of BE. We observe that with increase in x, the delays corresponding to BE for all values of k2≤k1 are smaller than respective delays of nrtPS and rtPS as can be seen from the below given diagrams.

6. SIMULATION RESULTS OF FOUR FAIR SCHEDULING SCHEMES

Using Matlab, the values of D (delays) corresponding to different prescribed values of xi, k1, k2 for 1≤x_i ≤12, 1<k1,k2≤4, Ci,Ci' taking each of the three values of(C, C')={(0.1,0.2),(0.05,0.06),(0.01,0.02)} as 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: k1:k2 .Thus in this paper we design the three parameters having the ratio x: k1:k2:: 1:1:1 which is only possible if we set the nodes x of rtPS as multiples of 3 and this case we take varying from 1 to 12.Then in this case we get the maximum starvation mitigated for the lower priority traffic BE.

We further observe here that with increase in delays corresponding to rtPS, nrtPS and BE for all values of k1 and k2 corresponding to C'are smaller than the respective corresponding to rtPS and nrtPS for values of C as can be seen by the following diagrams

6.1 Table-Analysis

A. For, C=0.1 and k1=1…4 d, delays of 6 flows of rtPS traffic and6 flows of nrtPS traffic

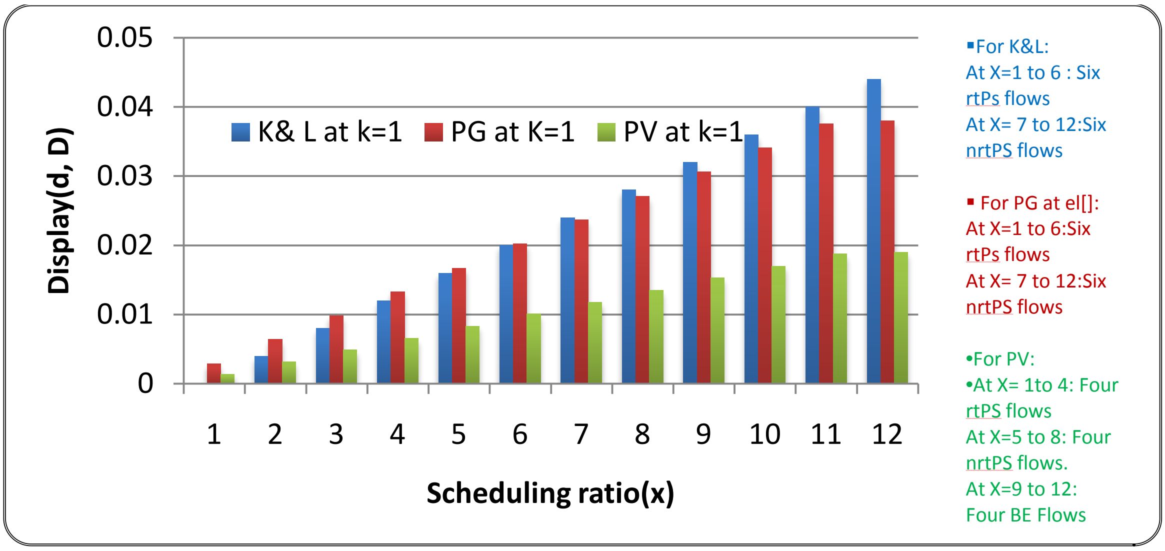
And

For, C'=0.2 and k2=1 …..4. D delays of 4 flows of rtPS traffic, 4 flows of nrtPS traffic and 4 flows of BE traffic.

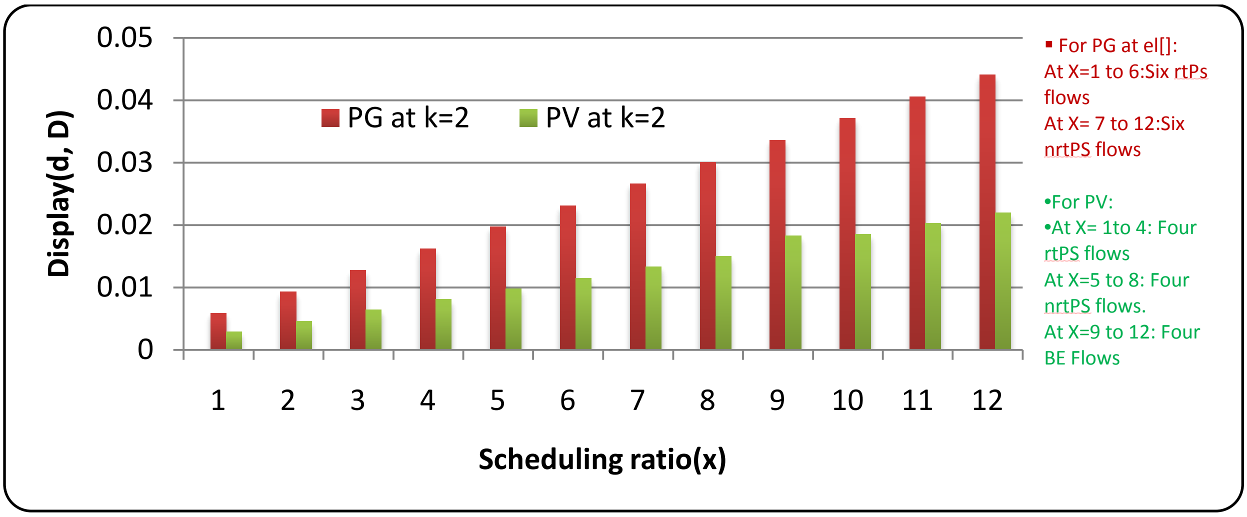
We note here that for K&L, k=k1=1, for P.G, k1=k=1 and P.V, K2=k=1, etc.

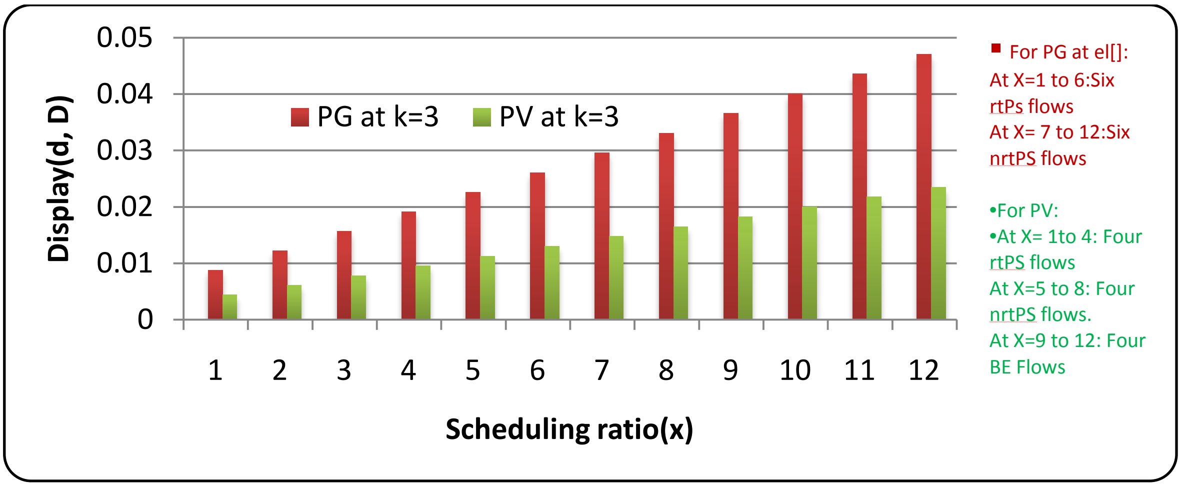
Table 1 for C = 0.1 and C'=0.2(intensity of delay for rtPS, nrtPS and BE connection)

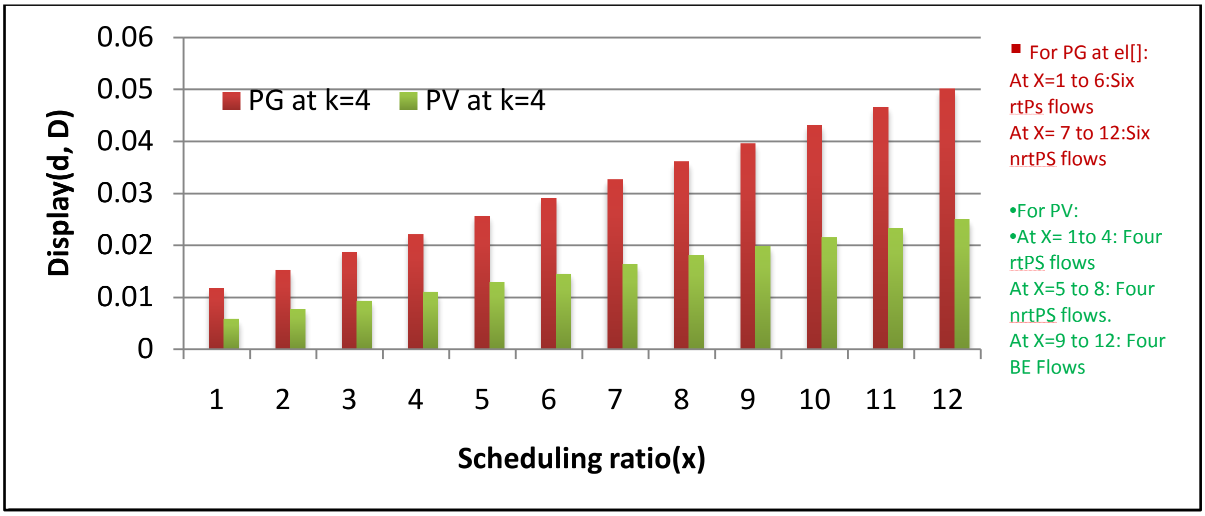
k1& k2/x_i	⟶	1	2	3	4	5	6	7	8	9	10	11	12
C=0.1	K&L at K=k1=1	0	0.004	0.008	0.012	0.016	0.02	0.024	0.028	0.032	0.036	0.04	0.044
C'=0.1	PG at K=k1=1	0.0029	0.0064	0.0098	0.0133	0.0167	0.0202	0.0237	0.0271	0.0306	0.0341	0.0376	0.038
C'=0.2	PV at K=k2=1	0.0014	0.0032	0.0049	0.0066	0.0083	0.0101	0.0118	0.0135	0.0153	0.017	0.0188	0.019
C=0.1	PG at K=k1=2	0.0059	0.0093	0.0128	0.0162	0.0197	0.0231	0.0266	0.0301	0.0336	0.0371	0.0406	0.0441
C'=0.2	PV at K=k2=2	0.0029	0.0046	0.0064	0.0081	0.0098	0.0115	0.0133	0.015	0.0183	0.0185	0.0203	0.022
C=0.1	PG at K=k1=3	0.0088	0.0122	0.0157	0.0192	0.0226	0.0261	0.0296	0.0331	0.0366	0.0401	0.0436	0.0471
C'=0.2	PV at K=k2=3	0.0044	0.0061	0.0078	0.0096	0.0113	0.013	0.0148	0.0165	0.0183	0.02	0.0218	0.0235
C=0.1	PG at K=k1=4	0.0117	0.0152	0.0187	0.0221	0.0256	0.0291	0.0326	0.0361	0.0396	0.0431	0.0466	0.0501
C'=0.2	PV at K=k2=4	0.0058	0.0076	0.0093	0.011	0.0128	0.0145	0.0163	0.018	0.0198	0.0215	0.0233	0.025



Here d delays representing P.G et al.[3] increase for first six rtPS connections over the same type and no. of flows of Kim and Lim[2] and decrease accordingly for the next six nrtPS connections .However, D delays representing the P.V's of four rtPS connections increase with the increase in x for first four connections and also increase for next four connections for nrtPs and again increase for last four connections of BE .However, from the above table we confirm that in view of greater BE delays we observe the mitigation of maximum starvation for the lower priority traffic. For k2=k=1,we further analyze here that maximum delays of the rtPS of present first four connections to each of the the connections corresponding to Kim and Lim [2] and P.G et al[3] have the variation of 50% and 48% respectively. Delays for next P.V of nrtPS flows with each of the two rtPS and nrtPS flows of Kim and Lim[2] andP.G et al [3] have variation of 54% and 33.3%.Maximum delays of the last four P.V of BE connections with each of the four nrtPS connections of Kim and Lim [2] and P.G et al [3] have variation of 56% and 50%.In conclusion this confirms that if we have to have a fair scheduling for support to better QoS then for mitigation of starvation for the least priority connection we have to meet the requirement of maximum delay to enhance varying between 33.3% and 56% as compared to maximum starvation of BE in K&L[2] and P.G[3].







B. For C=0.05 and k1=1…4. d ,delays of 6 flows of rtPS traffic and6 flows of nrtPS traffic

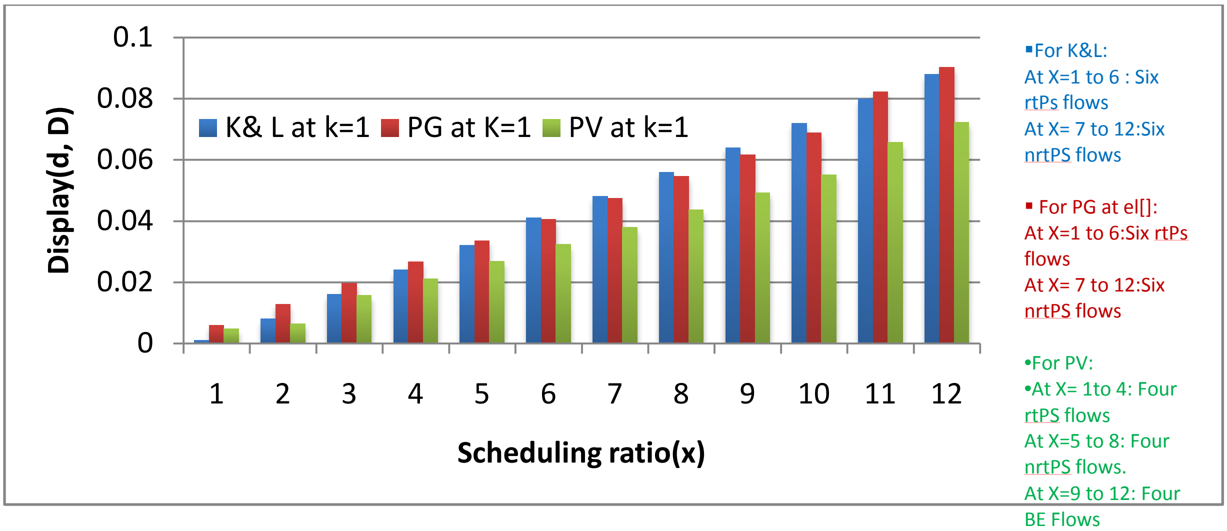
And

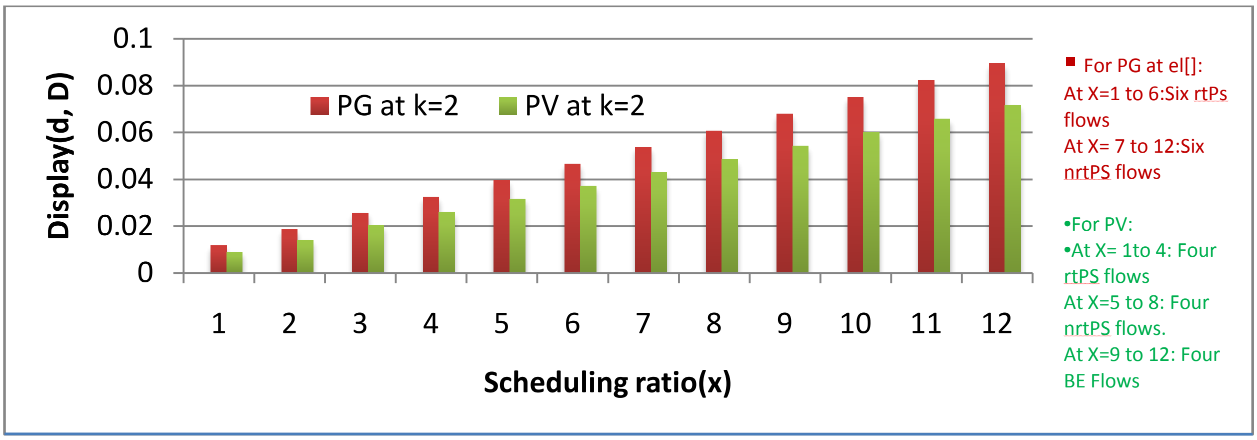
For C'=0.06 for k2=1…… 4. D delays of 4 flows of rtPS traffic, 4 flows of nrtPS traffic and 4 flows of BE traffic

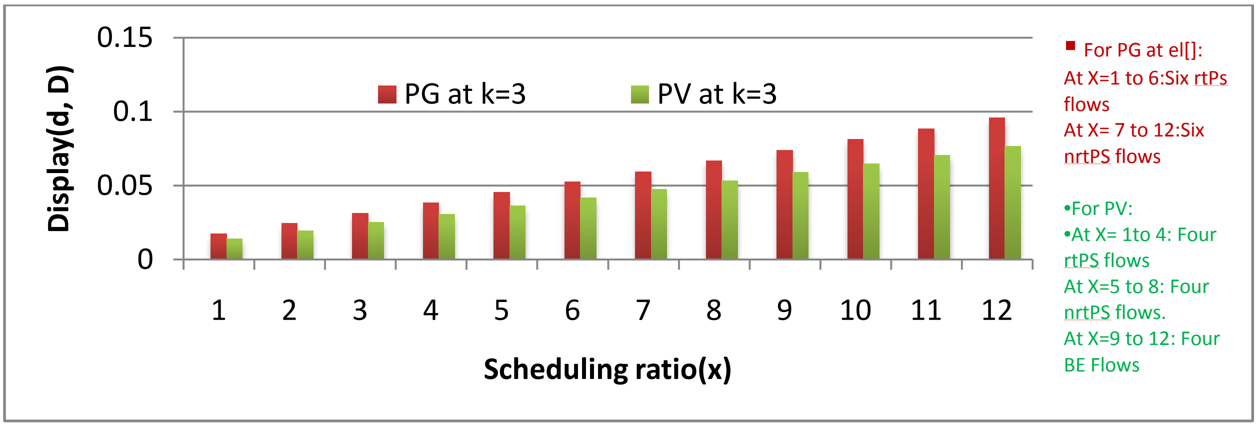
We note here that for P.G, k=k1=1 and P.V, k=k2=1, etc.

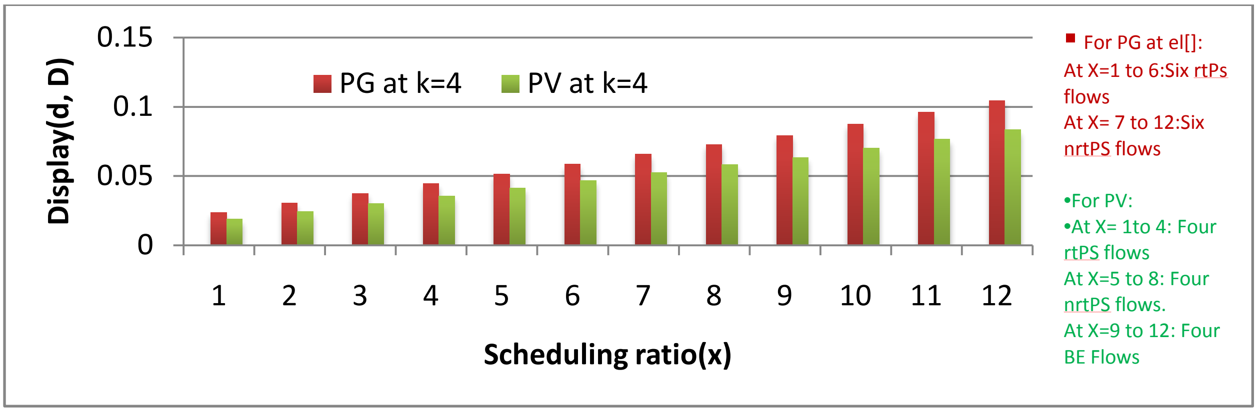
In case of k=2,3 and4 we here discuss the behavior of d delays of P.G et al [3] and D delays of P.V corresponding to the same set of values of C and C' as given by 6.In all the above three case we find that in case PG et al [3] with the increase of nodes x varying from 1 to 6 ,the corresponding rtPS flows in delay d gradually increase and then for the next values varying from 7 to 12,nrtPS flows in delay d also gradually increase. Similarly, incase of P.V we find the delay D steadily increase in first four rtPS flows, also delay D increase steadily for next four nrtPS flows and finally again delay D increase steadily for the last four values BE from x equals 9 to 12.From the above graph it is seen that there is maximum mitigation of starvation happening for nrtPS connections and mostly to the lower priority connection BE.

Table 2 for C = 0.05 and C'=0.06 (intensity of delay for rtPS, nrtPS and BE connection)													
k1&k2 /x_i	→	1	2	3	4	5	6	7	8	9	10	11	12
C=0.05	K&L at K=k1=1	0	0.008	0.016	0.024	0.032	0.041	0.0481	0.056	0.064	0.072	0.08	0.088
C=0.05	PG at K=k1=1	0.0059	0.0128	0.0197	0.0266	0.0336	0.0405	0.0475	0.0546	0.0617	0.0689	0.0823	0.0903
C1=0.06	PV at K=k2=1	0.0047	0.001	0.0157	0.0212	0.0268	0.0324	0.038	0.0436	0.0493	0.0551	0.0658	0.0722
C=0.05	PG at K=k1=2	0.0117	0.0186	0.0256	0.0325	0.0395	0.0465	0.0535	0.0606	0.0678	0.075	0.0822	0.0894
C1=0.06	PV at K=k2=2	0.009	0.014	0.0204	0.026	0.0316	0.372	0.0428	0.0484	0.0542	0.06	0.0657	0.0715
C=0.05	PG at K=k1=3	0.0177	0.0246	0.0315	0.0385	0.0455	0.0526	0.0596	0.0668	0.074	0.0813	0.0886	0.0959
C1=0.06	PV at K=k2=3	0.0141	0.0196	0.0252	0.0308	0.0364	0.042	0.0476	0.0534	0.0592	0.065	0.0708	0.0767
C=0.05	PG at K=k1=4	0.0236	0.0305	0.0375	0.0445	0.0515	0.0586	0.0658	0.0728	0.0792	0.0876	0.096	0.1044
C1=0.06	PV at K=k2=4	0.0188	0.0244	0.03	0.0356	0.0412	0.0468	0.0526	0.0582	0.0633	0.07	0.0768	0.0835









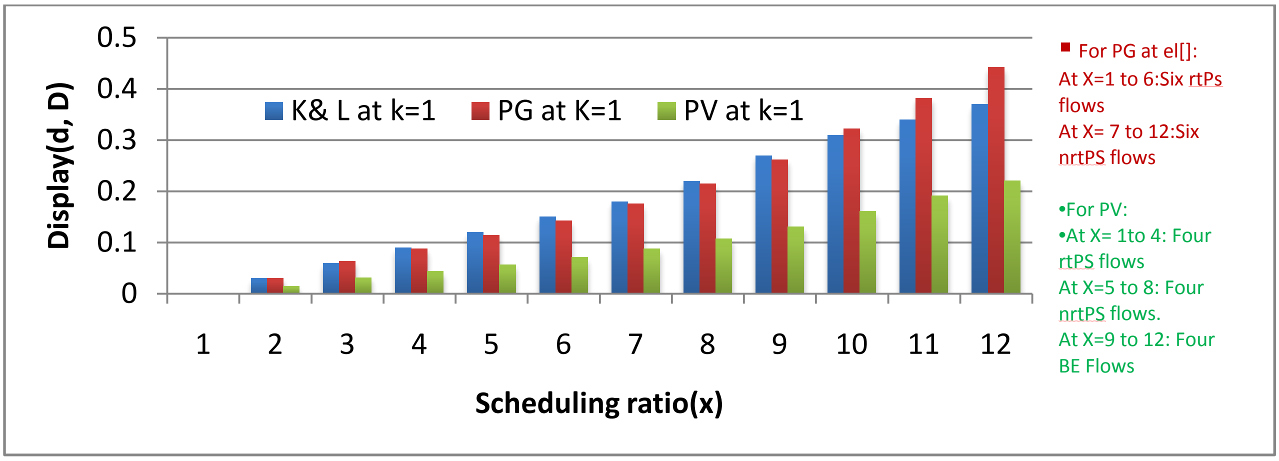
6.3 C=0.01 for k=1,…4 . d ,delays of 6 flows of rtPS traffic and6 flows of nrtPS traffic

And

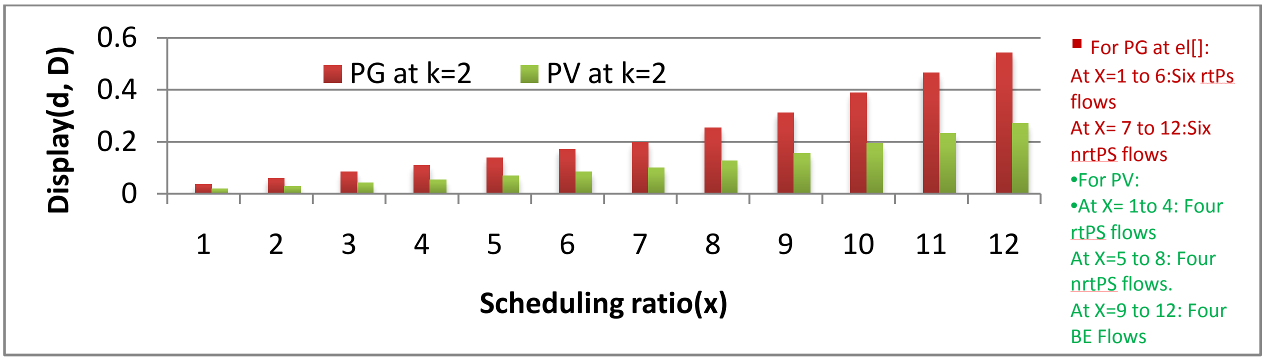
C'=0.02 for k=1, …..,4. D delays of 4 flows of rtPS traffic, 4 flows of nrtPS traffic and 4 flows of BE traffic

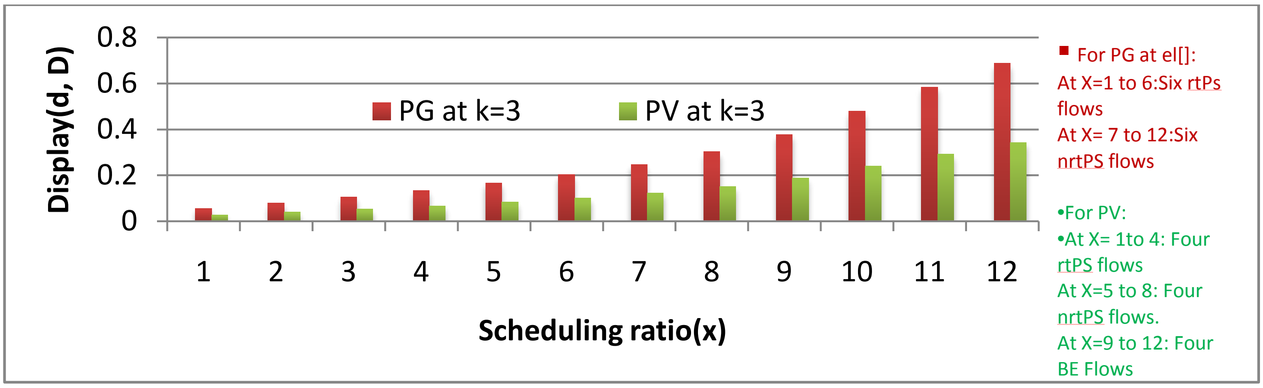
Table 3 for C = 0.01 and C'=0.02(intensity of delay for rtPS, nrtPS and BE connection)

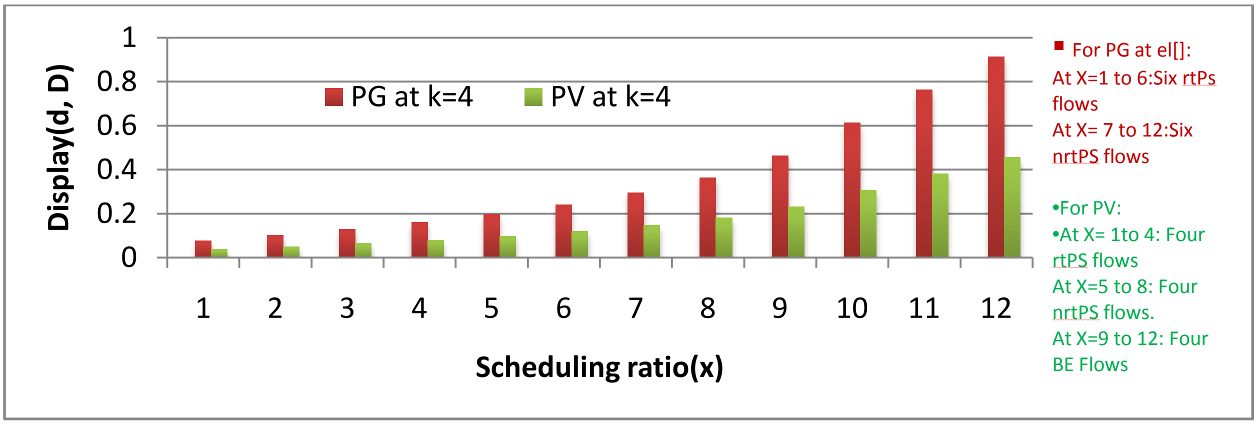
k1&k2 /x_i	→	1	2	3	4	5	6	7	8	9	10	11	12
C=0.01	K&L at K=k1=1	0	0.03	0.06	0.09	0.12	0.15	0.18	0.22	0.27	0.31	0.34	0.37
C=0.01	PG at K=k1=1	0.0002	0.03	0.0635	0.0877	0.1139	0.143	0.1761	0.215	0.2622	0.322	0.382	0.442
C1=0.02	PV at K=k2=1	0.001	0.015	0.0317	0.0438	0.057	0.0715	0.088	0.1075	0.1311	0.161	0.191	0.221
C=0.01	PG at K=k1=2	0.0374	0.0601	0.0841	0.11	0.1386	0.1711	0.1991	0.2548	0.3125	0.3892	0.4659	0.542
C1=0.02	PV at K=k2=2	0.0187	0.03	0.042	0.055	0.0693	0.0855	0.0995	0.1274	0.1562	0.1946	0.2329	0.271
C=0.01	PG at K=k1=3	0.0568	0.0806	0.1062	0.1343	0.1662	0.2032	0.2476	0.3034	0.3767	0.4803	0.5839	0.687
C1=0.02	PV at K=k2=3	0.0284	0.0403	0.0531	0.0671	0.0831	0.1016	0.1238	0.1517	0.1883	0.2401	0.2919	0.343
C=0.01	PG at K=k1=4	0.0771	0.1024	0.1301	0.1614	0.1975	0.2408	0.2946	0.3649	0.463	0.6131	0.7632	0.913
C1=0.02	PV at K=k2=4	0.0385	0.0512	0.065	0.0807	0.0987	0.1204	0.1473	0.1824	0.2315	0.3065	0.3816	0.456



Again, in case of k=2,3 and4 we here discuss the behavior of d delays of P.G et al [3] and D delays of P.V corresponding to the same set of values of C and C' as given by 6.3.In all the above three case we find that in case PG et al [3] with the increase of nodes x varying from 1 to 6 ,the corresponding rtPS flows in delay d gradually increase and then for the next values varying from 7 to 12,nrtPS flows in delay d also gradually increase. Incase of P.V we find the delay D steadily increase in first four rtPS flows, also delay D increase steadily for next four nrtPS flows and finally again delay D increase steadily for the last four values BE from x equals 9 to 12.From the above graph it is seen that there is maximum mitigation of starvation happening for nrtPS connections and mostly to the lower priority connection BE.







7. CONCLUSION

A novel proportional fair based QoS scheduling was designed under traffic conditions. The simulations are carried out and from that traffic includes majority of rtPs connections having excellent performance. When the traffic connections have nrtPS and BE as the majority requests then the performance of these traffics improve. The performance of rtPS and connections sharing fairness metrics has an improved performance with regard to the mitigation of starvation for nrtPS and BE traffics. The BE and nrtPS however hovers around 95% even though the rtPS traffic still has maximum utilization .We further notice here that the mitigation of lower priority schemes depend on respective suitable values of the intensity delays of C and C' as discussed in above fair scheduling.

Thus from the fairness scheduler it is inferred that the proposed rtpS traffic has almost 100% at all traffic nodes satisfying the WiMax QoS requirements. Using downlink scheduling, it does fair management of lower class services such as nrtPS and BE with the help of rtPS as BS.

8. ACKNOWLEDGEMENT

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