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Cross-class Priority based Video Streaming in DiffServ Domain

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Abstract

With the development of image processing and network technologies, more and more video applications emerged. To ensure quality of service for simultaneously transmitted multimedia and data streams, DiffServ (Differentiated services) is proposed. However, the current standard of DiffServ is not suitable for video streaming. In this paper we propose a cross-class priority (CCP) based video streaming scheme, in which packets of different frame types are assigned to different traffic classes to occupy more scheduling opportunities. Simulation results show that more video packets could be received when CCP policy is adopted. Thus CCP policy can tolerate a relatively high data rate of data stream. Scheduling mode and video sequence employed, and settings of RED parameters of different traffic classes are factors that influence the performance of CCP based scheme too.

Keywords: *Video streaming; cross-class priority; inner-priority; DiffServ; RED*

1. Introduction

More and more video applications in the Internet facilitate people's daily life. Since a video stream often have a high data rate, the issue of Quality of Service (QoS) balancing for video and data streams emerges. Although ***DiffServ*** (Differentiated services) [1,2] is a good architecture for synchronously transmission of video and data streams, how to deploy it becomes a new issue. There are several existed studies about this issue. Some studies tried to ensure video streaming within DiffServ framework [3,4,5], some others focused on improvement of DiffServ framework for video streaming [6,7,8], and the others paid attention to specific aspect such as fairness scheduling [9] and further differentiation of video applications [10]. A comprehensive evaluation of video streaming over DiffServ domain in our previous work showed that scheduling mode influences video transmission performance significantly while the influence of RED parameters is slight. Also we proposed an inner-priority (IP) based video streaming scheme in DiffServ domain, in which all frame types of the video stream belong to the same traffic class (implemented as a Policy). To recognize the priorities of different frame types, each frame type is assigned a distinct dropping probability. Simulation results showed that the inner-priority based scheme outperforms the scheme without priorities.

The limitation of inner-priority based scheme is that the received video quality will degrade significantly when the data rate of either the video stream or the data stream is extremely high because the video stream only occupies the scheduling opportunity of one traffic class. To solve this problem, a cross-class priority (CCP) based video streaming scheme in DiffServ domain is proposed in this paper. Each frame type belongs to its own traffic class so that more scheduling opportunities could be obtained by the video stream.

The rest of the paper is organized as follows. Section 2 introduces the simulation environments. Evaluation results of proposed scheme and comparative schemes and

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corresponding discussion are presented in Section 3. Finally, Section 4 concludes the paper and points out the future work.

2. Simulation Environments

Simulations are based on the integrated platform of ns-2 [11] and Evalvid [12], implemented by C. H. Ke [13].

2.1. DiffServ in ns-2

There are four traffic classes supported in NS-2 DiffServ module (refer to four physical queues), each of which has three dropping precedences (refer to three virtual queues, and each virtual queue is assigned a code point and regarded as a RED queue). Consequently, there are twelve treatments of traffic. Each packet is enqueued into a physical queue and assigned a dropping precedence.

The most important component in NS-2 DiffServ module is Policy, which defines the service level that a traffic class should receive. There are six policy models defined in NS-2 DiffServ module, among which we only use Null policy (has only one virtual queue and does not downgrade any packets) in this paper.

As for scheduling mode among different physical queues, NS-2 DiffServ module supports Round Robin (RR, the default one), Weighted RR (WRR), Weighted Interleaved RR (WIRR), and Priority (PRI).

To implement IP based scheme, a video stream is assigned with one physical queue and each frame type matches a virtual queue. To implement CCP based scheme, each frame type has its own physical queue.

2.2. Simulation Topology

Simulation topology is presented as Figure 1. S1 generates a video stream and S2 produces a CBR data stream. Edge router (E1 and E2) and core router(C) forward packets for the sources. Packet size of both steams is 1500 bytes. Bandwidth of each link is set as the figure shows.

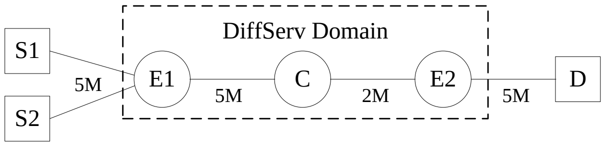


Figure 1. Simulation Topology

2.3. Video Sequences

Sequence news, foreman and akiyo with CIF resolution are adopted in the experiments. Data rates at each second of the three sequences are shown in Table 1. The frame rate of each sequence is 30/s.

Table 2 presents the frame numbers (N_f) and packet numbers (N_p) of different frame types (packet size is 1500 bytes), which indicate the differences of data rates and coding structures among these sequences. From the table we find that I frames always have many packets. And news and akiyo sequences have more I frames relatively.

Table 1. Data Rate at Each Second of Three Sequences (kbps)

Second No.	news	foreman	akiyo
1	1280.94	2105.10	721.42
2	1086.26	1901.77	668.98
3	1228.94	2002.18	700.13
4	1414.52	2011.04	761.26
5	1205.35	2120.10	639.94
6	1184.26	2172.62	624.94
7	1326.05	2470.14	692.36
8	1171.31	2714.23	695.72
9	1232.28	3153.16	663.18
10	1372.17	3332.78	773.25

Table 2. N_f and N_p of Three Sequences

	news	foreman	akiyo
$N_{f,I}$	34	34	34
$N_{f,P}$	67	79	67
$N_{f,B}$	199	187	199
$N_{p,I}$	834	1084	544
$N_{p,P}$	499	1328	262
$N_{p,B}$	357	665	199

3. Evaluation

3.1. Basic Experiments

In this kind of experiments, we focus on the performance comparison among CCP, IP and Null policies and the influence of RED parameters setting.

As mentioned before, each frame type has it own RED parameters in both CCP and IP policies. Since I frame has the highest priority, a “50-50-0” setting should be employed. The first and the second “50” mean the lower and the higher queue length threshold values respectively, and “0” means the dropping probability value. Thus “50-50-0” means do not drop I frame packets actively. That is to say, packet loss only occurs when the queue is full. The first experiment evaluates the influence of RED parameters setting of P frames. In this experiment, news sequence is adopted. RED parameters of B frames are set to “0-0-1” which means drop all the B frame packets. The generating rate of data stream (R_d) is 1.2Mbps. And the data stream is assigned a TSW2CM policy, with CIR=1.0Mbps. Figure 2 gives the number of total received packets (pktNum) and average PSNR (avgPSNR) results, and table 3 gives the number of lost frames (L_f) of various frame types.

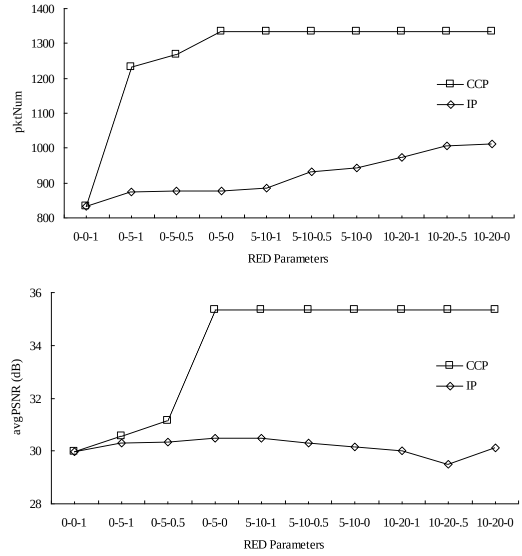


Figure 2. Results of Different RED Parameters Setting of P Frames, CCP and IP Policies

Table 3. L_f in Figure 2

RED of **P** frames	*CCP*			*IP*		
	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$
0-0-1	0	67	199	0	67	199
0-5-1	0	60	199	0	63	199
0-5-0.5	0	50	199	0	62	199
0-5-0	0	0	199	0	61	199
5-10-1	0	0	199	0	61	199
5-10-0.5	0	0	199	1	61	199
5-10-0	0	0	199	2	60	199
10-20-1	0	0	199	4	57	199
10-20-0.5	0	0	199	6	56	199
10-20-0	0	0	199	8	38	199

From the results we can find that pktNum and avgPSNR of CCP policy are much higher than those of IP policy. The reason is that CCP policy occupies three traffic classes so that the video stream obtains more scheduling opportunities. In CCP policy, the received video quality is determined by the limitation of RED parameters setting of P frames. With the limitation getting looser, all P frames are received. Transmission of P frames will not occupy the scheduling opportunity of I frames. On the contrary, I, P and B frames share the scheduling opportunity of the same traffic class. The increase of the number of received P frames finally leads to loss of I frames. Another fact is that the importance of I frames is higher than that of P frames. Take "5-10-0" and "10-20-1" of IP policy as the comparison example. Since the avgPSNR of "5-10-0" is larger than that of "10-20-1", we can draw the conclusion that the distortion caused by 2 (4-2) I frames is larger than that caused by 3 (60-57) P frames.

The second experiment investigates the influence of RED parameters setting of B frames. In this experiment, RED parameters of P frames are set to "5-10-1", whose avgPSNR is the best in the former experiment. R_d and CIR of data stream remain unchanged. Figure 3 and table 4 give the results, which show that although pktNum of IP policy is much smaller, avgPSNR of IP policy outperforms that of CCP policy in almost all cases except for "0-0-1". Although I, P and B frames share the scheduling opportunity of one traffic class in IP policy, I frames have the absolute high priority. Thus most lost packets are P and B frame packets. In CCP policy, I frames only have 1/4 scheduling opportunity even if they have their own traffic class (there are four physical queues in the implementation of DiffServ of ns-2). Since most packets are I frame packets in news sequence (see table 2), many I frame packets are lost, leading to significant degradation of received video quality. To avoid this situation, unequal weights of different traffic classes should be employed in CCP policy (see the next sub-section).

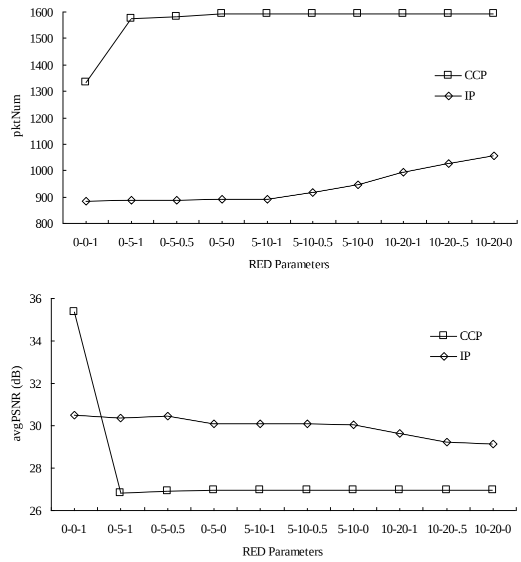


Figure 3. Results of Different RED Parameters Setting of B Frames, CCP and IP Policies

Table 4. L_f in Figure 3

RED of **P** frames	CCP $L_{f,I}$	CCP $L_{f,P}$	CCP $L_{f,B}$	IP $L_{f,I}$	IP $L_{f,P}$	IP $L_{f,B}$
0-0-1	0	0	199	0	61	199
0-5-1	26	0	30	1	61	197
0-5-0.5	26	0	18	1	61	195
0-5-0	26	0	0	3	62	189
5-10-1	26	0	0	3	62	188
5-10-0.5	26	0	0	3	62	186
5-10-0	26	0	0	3	62	156
10-20-1	26	0	0	5	60	150
10-20-0.5	26	0	0	6	60	139
10-20-0	26	0	0	6	60	92

As the opponent of CCP and IP policies, Null policy is employed. Figure 4 and table 5 present the results. Compared to figure 2 and figure 3, figure 4 has different x-axis because there is only one dropping priority in Null policy and we want to show the comprehensive results. Notice that "50-50-0" means do not drop any packet actively. Making a comparison between the results of this experiment and those of the former two experiments, we find that: (1) pktNum of Null policy is higher than that of IP policy and is lower than that of CCP policy. (2) avgPSNR of Null policy is much lower than those of IP and CCP policies because: (a) compared to IP policy, more I frame packets are dropped; (b) compared to CCP policy, the lost packet number of every frame type is relatively high. (3) Packet loss distribution influences the decoded video quality significantly. Decoded avgPSNR when dropping probability equals to 1 is much lower than that when dropping probability equals to 0, even if pktNums of both instances are comparative. The reason is that the number of perfect received frames (frames having no lost packets) is much lower when dropping probability equals to 1. Particularly, the setting “0-5-1” shows zero avgPSNR because all frames are not decodable.

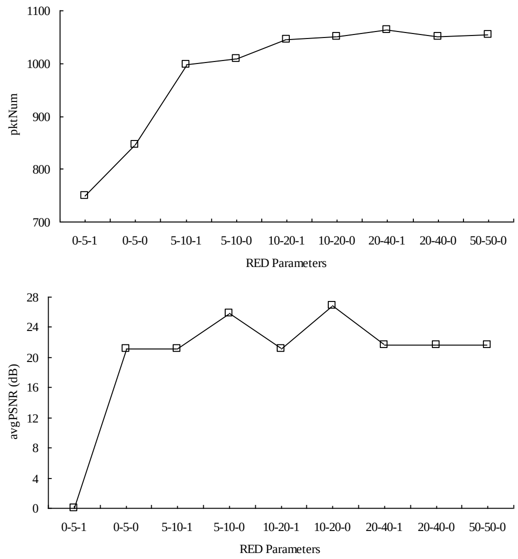


Figure 4. Results of Different RED Parameters Setting under Null Policy

Table 5. L_f in Figure 4

RED parameters	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$
0-5-1	34	67	199
0-5-0	32	60	153
5-10-1	32	61	136
5-10-0	20	51	123
10-20-1	32	60	125
10-20-0	23	37	113
20-40-1	32	51	126
20-40-0	32	27	155
50-50-0	32	27	155

3.2. Influence of Scheduling Mode

Figure 5 shows the results when adopting WRR scheduling modes. When CCP and IP policies are used, the RED parameters settings of I, P and B frames are “50-50-0”, “20-40-0.25” and “10-20-0.5” respectively. And when Null policy is employed, default setting is used. In the figure, the x-axis gives two weights of video stream and data stream queues. For example, “2-1” means the weight(s) of video stream queue(s) is 2 (notice that there are three queues for video streaming in CCP policy) and the weight of data stream queue is 1. From the figure we can find that:

(1) Both pktNum and avgPSNR of CCP policy are the best among three policies because more scheduling opportunities are obtained.
(2) pktNum of Null policy is slightly higher than that of IP policy while avgPSNR of IP policy is relatively high.
(3) The received video quality of CCP policy is much better when the weights of video stream queues are higher.

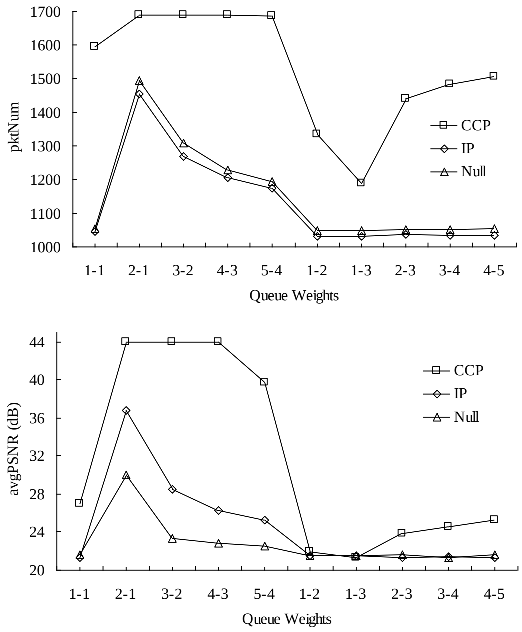


Figure 5. Results of WRR Scheduling Modes

Table 6. Lf in Figure 5

	CCP			***IP***			***Null***		
	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$
1-1	26	0	0	32	46	181	32	27	155
2-1	0	0	0	2	3	137	22	3	89
3-2	0	0	0	12	41	168	30	14	117
4-3	0	0	0	18	49	178	31	20	130
5-4	7	0	0	21	44	171	31	18	126
1-2	32	37	0	32	25	181	32	28	155
1-3	33	46	0	32	25	181	32	28	155
2-3	31	0	0	32	44	178	32	28	157
3-4	30	0	0	32	45	180	32	26	154
4-5	29	0	0	32	48	182	32	26	149

Figure 6 and table 7 present the results of deploying unequal weights for different frame types in CCP policy. “3-2-1-2” in x-axis means the weights of I, P, B frames and data stream are 3, 2, 1, 2 respectively. From the results we can find that the weight of data stream should be relatively low to achieve good received video quality. The weights setting among I, P and B frames is more complicated. When the weight of data stream is not high, the weight of each frame type should be set to a relatively high value to occupy more scheduling opportunities. On the contrary, if the weight of data stream is high (for example 4 or 5), we should improve the weight of I frames and leave the weights of P and B frames relatively low (see the results comparison between 4-2-1-4 and 4-3-2-4).

The results of WIRR mode are similar to those of WRR mode.

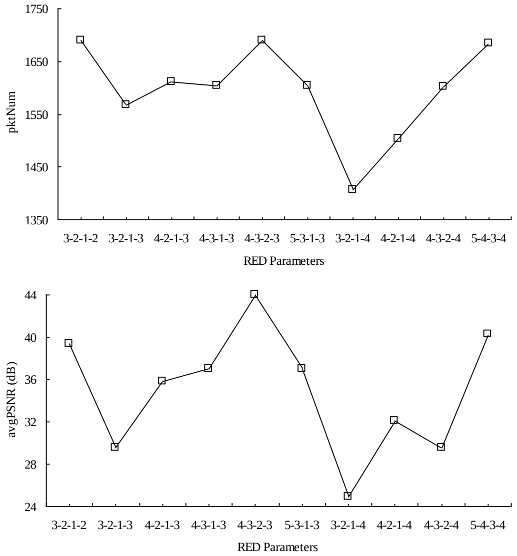


Figure 6. Results of Unequal Weights of Different Frame Types in CCP Policy

Table 7. L_f in Figure 6

	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$
3-2-1-2	0	0	106
3-2-1-3	20	0	147
4-2-1-3	0	17	154
4-3-1-3	0	0	157
4-3-2-3	0	0	0
5-2-1-3	0	17	154
5-3-1-3	0	0	155
3-2-1-4	28	13	157
4-2-1-4	5	42	160
4-3-2-4	23	0	0
5-4-3-4	6	0	0

Figure 7 and table 8 show the results when employing PRI scheduling mode. PRI mode has a parameter which specifies the maximum bandwidth (BW_{max}) that a queue can consume. In this experiment, only BW_{max} of data stream is set and the priority order is like that: data stream > I frames > P frames > B frames. RED parameters settings of this experiment are similar to those of the last experiment.

Since PRI scheduling mode is used, the priority of data stream is higher than that of video stream. From table 1 we know that the average data rate of news sequence is about 1.25Mbps (note that the bandwidth of bottleneck link is 2Mbps). Thus we find that when BW_{max} is lower than 0.75Mbps, the video is perfectly received in every policy. If BW_{max} is equal to or higher than 0.75Mbps, video quality degradation begins. We find that results of figure 7 and figure 3 are quite different. Although BW_{max} of data stream increase continuously, CCP policy shows better performance all the time. The reason is that I frame packets are always transmitted first in PRI mode even if they arrive late.

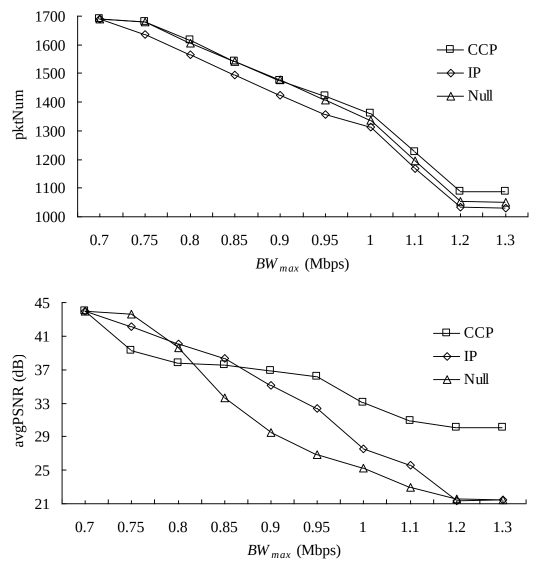


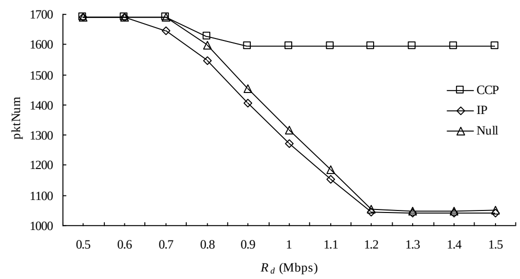
Figure 7. Results of PRI Scheduling Mode

Table 8. L_f in Figure 7

BW_{max} (Mbps)	CCP			IP			Null		
	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$
0.7	0	0	0	0	0	0	0	0	0
0.75	0	0	108	0	0	48	0	1	7
0.8	0	0	138	0	0	91	7	1	46
0.85	0	0	143	1	0	118	17	1	72
0.9	0	0	159	2	18	138	21	6	83
0.95	0	0	176	6	29	149	25	10	100
1.0	0	35	188	25	8	160	27	12	110
1.1	0	56	196	22	43	174	30	21	134
1.2	0	66	199	32	46	181	32	30	152
1.3	0	66	199	32	25	181	32	28	155

3.3. Influence of R_d

Figure 8 gives the results when employing different R_d. Other parameters are the same as those in section 3.1. If R_d is not higher than 0.7Mbps, the received video qualities of three policies are comparative. If R_d is between 0.8Mbps and 1.0Mbps, CCP policy does not show its advantages because more I frame packets are lost. And when R_d is larger than 1.0Mbps, CCP policy outperforms the other two policies for more scheduling opportunities are obtained.



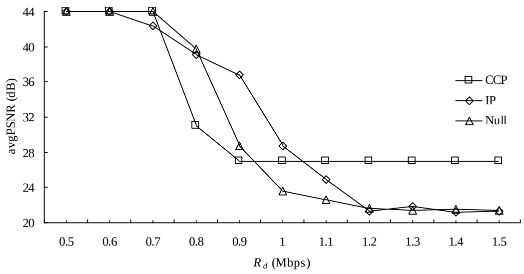


Figure 8. Results of Different R_d

3.4. Influence of Characteristics of Video Sequence

Figure 9 to 12 show the results of various RED parameter settings of foreman and akiyo sequences. To cause properly packet loss, the bandwidths of the link from node C to node E2 are set to 3Mbps and 1.2Mbps for foreman and akiyo respectively. And R_d is set to 0.8Mbps for both sequences. From these figures we find that the best choices of RED parameters setting of different video sequences (to achieve the highest avgPSNR) are distinct. For RED parameters setting of P frames, “5-10-1”, “0-5-0” and “0-5-0” are the best choices for news, foreman and akiyo sequences respectively. For RED parameters setting of B frames, “0-0-1”, “0-5-0” and “0-0-1” are the best choices for news, foreman and akiyo sequences respectively.

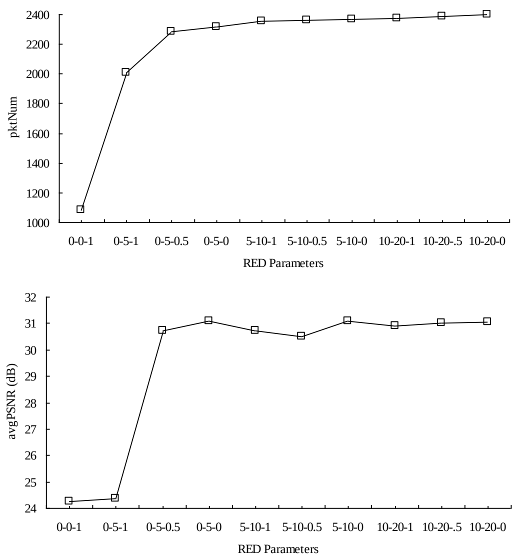
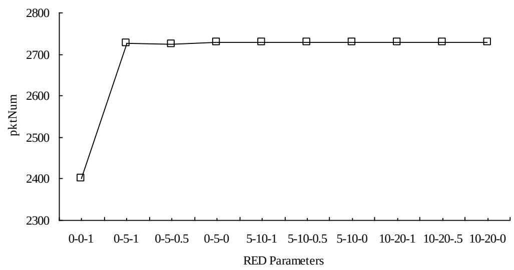


Figure 9. Results of Different RED Parameters Setting of P Frames, Foreman Sequence



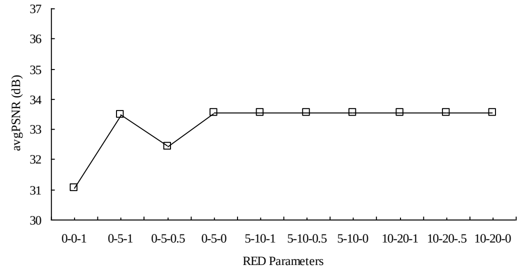


Figure 10. Results of Different RED Parameters Setting of B Frames, Foreman Sequence

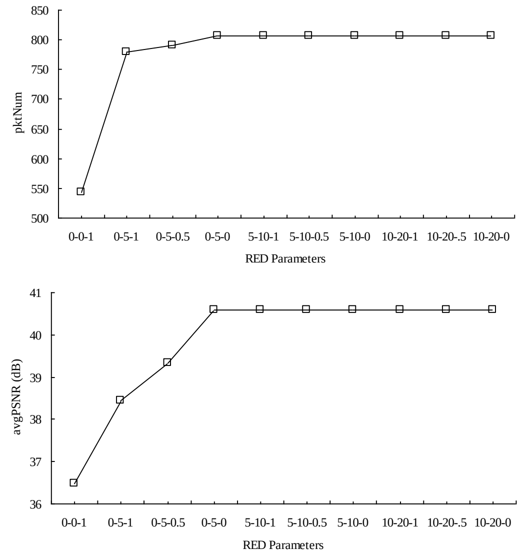


Figure 11. Results of Different RED Parameters Setting of P Frames, Akiyo Sequence

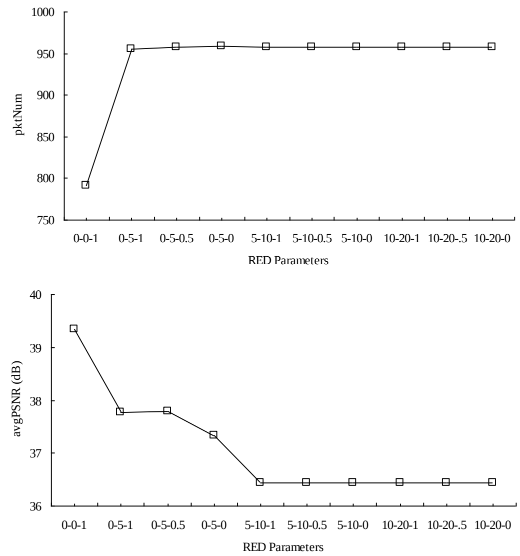


Figure 12. Results of Different RED Parameters Setting of B Frames, Akiyo Sequence

4. Conclusions

In this paper we propose a cross-class priority based video streaming scheme in DiffServ domain, in which packets of different frame types are assigned to different traffic class to occupy more scheduling opportunities. Comprehensive evaluations are performed to make comparison between CCP based scheme and other schemes. Results show that:

(1) With CCP policy, more scheduling opportunities could be obtained by the video stream so that more video packets are received, compared to the situations when IP and Null policies are adopted. Thus the tolerable data rate of data stream (R_d) of CCP policy is higher than those of IP and Null policies.

(2) If RR scheduling mode is employed and I frames are dominate in the video sequence, the received quality of CCP policy may be worse than that of IP policy because the scheduling opportunity of I frames is equivalent to those of P and B frames. Therefore, WRR/WIRR and PRI modes are more suitable for CCP policy because high weight/priority could be assigned to the traffic class to which I frames belong.

(3) Setting of RED parameters is another factor which influences the performance of CCP policy. If R_d is not very high, a loose limitation of RED parameters should be employed for each traffic class. With the increase of R_d, the limitation of RED parameters for the traffic class of B frames should be enhanced first, and then turn to the limitation of RED parameters fro the traffic class of P frames.

(4) Coding structure of video sequence also influence the performance. Actually, settings of scheduling weights of WRR/WIRR mode, priority of PRI mode and RED parameters of each traffic class depend on the coding structure.

In the future we plan to study the issue of streaming of multiple videos in DiffServ domain.

Acknowledgements

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