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Evaluation on Inner-priority and Cross-class Priority based Multiple Video Streaming under DiffServ Architecture

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Abstract

Since both video compressing rate and network bandwidth keep increasing continuously, more and more video applications emerged. Although DiffServ (Differentiated services) is a simple and effective architecture to ensure quality of service for simultaneously transmitted video and data streams, it is not suitable for multiple video streaming. In this paper we evaluate the performance of multiple video streaming using standard DiffServ architecture and two priority based enhanced schemes (named IP based scheme and CCP based scheme). Simulation results show that (1) IP based scheme outperforms CCP based scheme and standard DiffServ. (2) WRR and WIRR scheduling modes are suggested to be adopted. The higher the data rate of a video is, the larger the weight of that video should be set to. (3) RED parameters for different queues should be carefully set according to the available bandwidth for video streams, and the data rates and coding structures of different videos.

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

1. Introduction

Since video always includes abundant information and is more impressive than other forms of information, people prefer to accept it. With the development of network and video compression technologies, it becomes possible for networks to streaming videos. Thus many video applications such as video surveillance and video on demand emerged. Consequently, network nodes must deal with the synchronously transmission of video and data streams. Video streams always need more bandwidth while data streams can not tolerate starvation. A suitable scheme to differentiate these two stream categories is required.

To solve the problem, specialists of Internet Engineering Task Force (IETF) proposed ***Differentiated services*** (DiffServ) [1,2] in 1998. DiffServ is a scalable and coarse-grained architecture to classify streams and then ensure their transmission according to their categories. Therefore, DiffServ could provide differentiated quality of service (QoS) guarantee for video, audio and data streams.

DiffServ has several parameters to provide multiple scheduling priorities. How to set these parameters becomes a key issue which determines various QoS guarantee levels for different streams. Existing studies on video streaming over DiffServ can be classified into three categories: (1) studies in the first category discussed the issue of how to set parameters to ensure video streaming [3,4,5]; (2) studies in the second category tried to improvement the DiffServ architecture to increase the protecting level of video streams [6,7,8]; (3) studies in the third category paid attention to some specific aspects such as further differentiation of video applications [9] and fairness scheduling [10].

In our previous work, we evaluated the performance of video streaming under standard DiffServ architecture and also proposed two priority based video streaming schemes, i.e. an inner-priority (IP) based scheme and a cross-class priority (CCP) based scheme in

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DiffServ domain. In the former scheme all frame types of a video stream belong to the same traffic class (implemented as a Policy). Each frame type is assigned a distinct dropping probability to recognize the priorities of different frame types. In the latter scheme each frame type has its own traffic class. However, previous studies only focused on the transmission of a single video stream. In this paper, a comprehensive evaluation for multiple video streaming is performed to verify the performance of different schemes and to find the parameter setting principles of these schemes.

The rest of the paper is organized as follows. Section 2 explains two priority based video streaming schemes in details. Section 3 introduces the simulation environments. Evaluation results and corresponding discussion are presented in Section 4. Finally, Section 5 concludes the paper.

2. Two Priority based Schemes

In DiffServ domain, a flow is marked by the source-destination node pair. Several flows could be aggregated and be assigned a policy. Investigating the current DiffServ standard, a policy may include one, two or three code points and each of them identifies a dropping probability. A PHB, which indicates the forwarding behavior in core routers of DiffServ domain, is assigned to each code point. Multiple dropping probabilities could be adopted to implement priority based scheduling.

In IP based video streaming scheme, a video stream belongs to a single traffic class and each frame type is assigned a code point. Thus each frame type is correlated to a PHB, which is identified mainly by a set of RED parameters, i.e. the lower and the higher queue length thresholds and the dropping probability. The more important the frame type is, the looser parameters setting is employed.

On the other hand, CCP means each frame type of a video stream belongs to a distinct traffic class. Thus each frame type has its own policy and may have multiple dropping probabilities. However, according to our previous evaluation, employing multiple dropping probabilities is not necessary for a single frame type.

3. Simulation Environments

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

3.1. NS-2

Network simulator (abbreviated as NS) is a discrete event simulator targeted at networking research. Although NS has its official support, it also included contributions from other researchers. Thus it is an open platform and each researcher may contribute his module for specific research field. NS-2 is the second version of NS, and it uses Object Tcl (OTcl) and C++ simultaneously. NS also has the third version with many novel characteristics. NS-2 can run on many operating systems such as GNU/Linux, FreeBSD, Solaris, Mac OS X and Windows.

3.2. Evalvid and myEvalvid

Evalvid is a well-designed framework and tool-set for quality evaluation of video transmission over simulated or real networks. This framework can not only measure QoS parameters of the underlying network such as loss rate, delay and jitter, but also provide video quality evaluation for received video based on the calculated frame-by-frame PSNR. Evalvid is designed for those researchers who want to evaluate their network design/setup in terms of user perceived video quality.

To evaluate video transmission performance in NS-2, C. H. Ke extended Evalvid into ***myEvalvid***.

3.3. DiffServ in NS-2

There are three steps to carry out packet forwarding in NS-2 DiffServ domain. Firstly, traffic classification is performed at the edge router. As the results, traffic is classified into several categories. Then, each packet is marked with a code point according to its category. Thirdly, packet is scheduled based on its code point in every core router. NS-2 DiffServ module uses four physical queues to indicate four traffic categories. In addition, each traffic category has three dropping precedences. That is to say, there are three virtual queues in each physical queue. Therefore, there are totally twelve treatments of traffic. Each packet belongs to a physical queue and is assigned a dropping precedence.

In NS-2 DiffServ module, each virtual queue matches a code point and is regarded as a RED queue. As we all know, a RED queue has three important parameters: the lower queue length threshold, the higher queue length threshold and the dropping probability. Ordinarily, larger queue length thresholds mean less dropping operations. However, we must recognize that different virtual queues share the scheduling opportunity of one physical queue. Therefore, distinct parameters for the three virtual queues should be set to provide differentiated QoS guarantee. As a result, the packet in the virtual queue with higher priority will receive better treatment when congestion occurs.

NS-2 DiffServ module consists of three components. The first one is called Policy which defines the service level that a traffic class could receive. In NS-2 DiffServ module, there are several policy models, each of which could be bound with different parameters. The second component is Edge router and the last one is Core router. Functions of these two components are introduced above. In addition, a PHB table is held in NS-2 DiffServ module. Both edge router and core router use this table to perform mapping between code points and physical/virtual queues.

Policy models defined in NS-2 DiffServ module are described as follows:

- Time Sliding Window with 2 Color Marking (abbreviated as TSW2CMPolicer), having only one parameter: committed information rate (CIR). There are two dropping priorities in this policy model. When CIR is exceeded, the lower dropping priority will be used. Otherwise, the higher priority will be adopted.
- Time Sliding Window with 3 Color Marking (abbreviated as TSW2CMPolicer), having two parameters: CIR and PIR (peak information rate). Thus there are three dropping priorities. If both CIR and PIR are not exceeded, the highest priority will be used. If only CIR is exceeded, the medium dropping priority will be used. Otherwise, the lowest dropping priority will be adopted.
- Token Bucket (tokenBucketPolicer), using CIR and CBS (committed burst size) as parameters. Also this policy model has two dropping priorities. If the size of arriving packet is larger than CBS, the lower priority will be adopted. Otherwise, the higher priority will be used.
- Single Rate Three Color Marker (srTCMPolicer), having three parameters CIR, CBS, and EBS (Excess Burst Size). If both CBS and EBS are not exceeded, the highest priority will be used. If only the CBS is exceeded, the medium dropping priority will be adopted. Otherwise, the lowest dropping priority will be used.
- Two Rate Three Color Marker (trTCMPolicer), using CIR, CBS, PIR, and PBS (peak burst size) as parameters. There are three dropping priorities in this policy model.
- NullPolicer: does not perform packet downgrade.

NS-2 DiffServ module provides four scheduling modes among different physical queues: Round Robin (RR), Weighted Round Robin (WRR), Weighted Interleaved Round Robin (WIRR), and Priority (PRI). The default scheduling mode is RR

In addition, NS-2 DiffServ module has four dropping modes: (1) RIO-C (RIO Coupled), the default dropping mode. The dropping probability of an out-of-profile packet is calculated according to the weighted average lengths of all virtual queues. On the other hand, if an arriving packet is within the profile, the dropping probability will be determined by the size of its virtual queue only. (2) RIO-D (RIO De-coupled), both dropping probabilities are calculated according to the size of one virtual queue. (3) WRED (Weighted RED), all probabilities are calculated according to a single queue length. (4) DROP, similar to the drop tail queue.

3.4. Implementation of Two Priority based Schemes

As section III.C describes, a traffic class is implemented by a physical queue, which includes multiple virtual queues. And each virtual queue, which is an implementation of a code point (PHB), has it own RED parameters. Therefore, in IP based scheme, only one physical queue is assigned to a video stream and each virtual queue of the physical queue serves for a frame type. In CCP based scheme, each frame type has its own physical queue. These physical queues of the video stream are recommended to employ only one virtual queue. We implemented CCP and IP policies in DiffServ of NS-2.

3.5. Simulation Topology

Figure 1 describes the simulation topology, in which S1, S2 and S3 produce video sequences and S4 generates a CBR data stream. Routers including edge routers (*E*1 and *E*2) and core router (*C*) are responsible for forwarding packets to the destination (D). In all experiments, packet size of both steams is set to 1500 bytes.

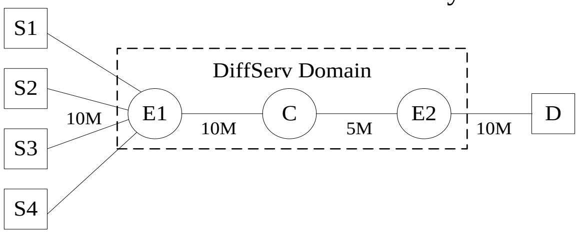


Figure 1. Simulation Topology

3.6. Video Sequences

As described above, three sources (S1, S2 and S3) generate one video sequence (news, foreman and akiyo) respectively. These video sequences are CIF resolution. Duration of each sequence is 10 seconds (30 frames per second). To recognize the difference of data rate among the three sequences, we show data rates at each second of the three sequences in Table 1.

Table 1. Data Rates 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

In addition, the coding structure influences video streaming significantly. Therefore, the frame numbers (N_f) and packet numbers (N_p) of different frame types (packet size is 1500 bytes) of each sequence are presented in Table 2. From the table we notice that the percent of I frames in foreman sequence is relatively lower than those in akiyo and news sequences. Furthermore, foreman sequence has more P frames. From this table we can also know that I frames always hold lots of packets, P frames often have several packets and B frames often have few packets.

Table 2. N_f and N_p of Three Sequences

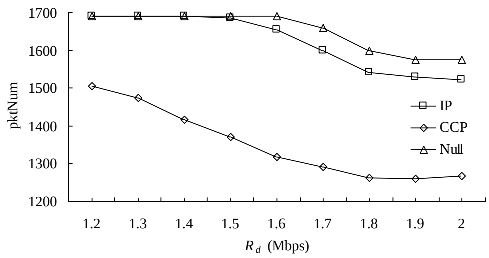
	news	foreman	akiyo
$N_{f,I}$	34	34	34
$N_{f,P}$	67	79	67
$N_{f,B}$	199	187	199
$N_{p,I}$	834	1084	544
$N_{p,P}$	499	1328	262
$N_{p,B}$	357	665	199

4. Evaluation

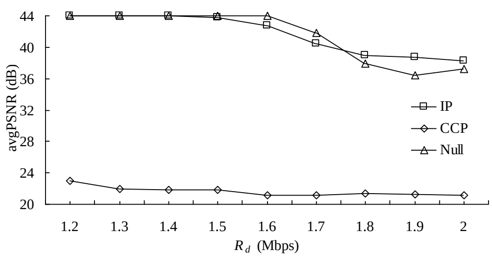
4.1. Basic Experiments

In this kind of experiments, we focus on the performance comparison among CCP, IP and Null policies when the generating rate of data stream (R_d) varies. The data stream is assigned a TSW2CM policy, using default RED parameters with CIR=1.2Mbps. In IP policy, RED parameters settings for three virtual queues of each video stream are all “50-50-0”, “20-40-0.25” and “10-20-0.5”. For a RED parameters setting such as “50-50-0”, the first and the second “50” mean the lower and the higher queue length threshold values respectively, and “0” means the dropping probability value. Since “50-50-0”, “20-40-0.25” and “10-20-0.5” are for I, P and B frames respectively, I frame packets are protected well. In CCP policy, RED parameters settings for I, P and B frames are also “50-50-0”, “20-40-0.25” and “10-20-0.5” respectively. The difference is that in CCP policy each frame type matches a traffic class which in IP policy each video stream matches a traffic class.

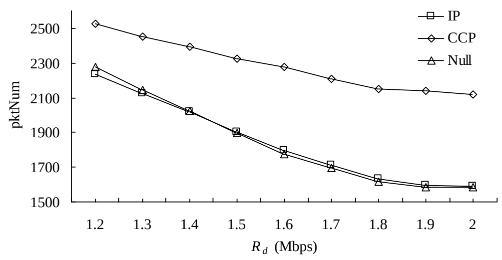
Notice that the default RR scheduling mode is employed and different video sequences have various data rates and coding structures. Figure 2 gives the number of total received packets (pktNum) and average PSNR (avgPSNR) results, and table 3 to 5 give the number of lost frames (L_f) of various frame types for each sequence.



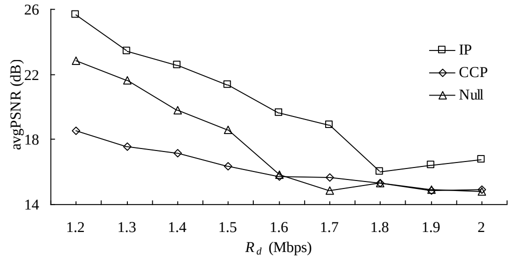
(a) pktNum of news



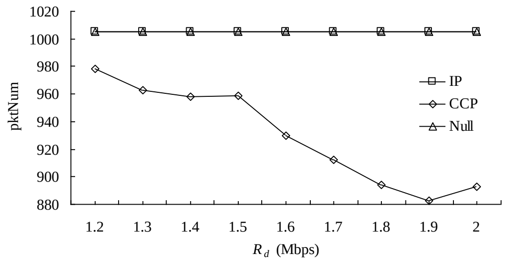
(b) avgPSNR of news



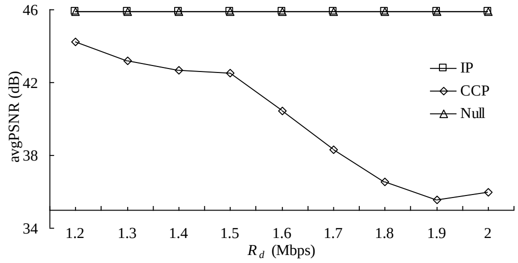
(c) pktNum of foreman



(d) avgPSNR of foreman



(e) pktNum of akiyo



(f) avgPSNR of akiyo

Figure 2. Results of Different Video Sequences when R_d Varies

Table 3. L_f of News in Figure 2

R_d (Mbps)	*IP*			*CCP*			*Null*		
	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$
1.2	0	0	0	30	27	0	0	0	0
1.3	0	0	0	32	30	0	0	0	0
1.4	0	0	0	32	31	0	0	0	0
1.5	0	0	5	32	33	0	0	0	0
1.6	0	0	29	33	43	0	0	0	0
1.7	0	0	78	33	43	0	0	6	14
1.8	1	1	104	33	46	0	3	12	50
1.9	0	0	113	33	42	0	5	14	61
2.0	1	2	111	33	47	0	4	13	61

Table 4. L_f of Foreman in Figure 2

R_d (Mbps)	*IP*			*CCP*			*Null*		
	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$
1.2	8	42	172	27	40	10	16	42	108
1.3	14	35	173	28	41	10	18	45	125
1.4	11	61	174	28	45	10	21	49	137
1.5	15	65	175	31	47	10	24	54	153
1.6	18	69	177	33	50	10	30	58	164
1.7	21	69	177	33	58	10	31	61	170
1.8	30	61	181	33	63	10	32	64	175
1.9	26	71	181	33	65	10	32	65	176
2.0	25	71	181	33	66	10	32	65	176

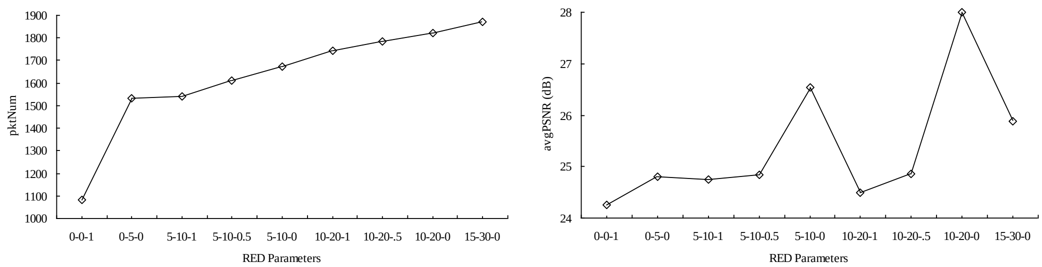
Table 5. L_f of akiyo in Figure 2

R_d (Mbps)	*IP*			*CCP*			*Null*		
	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$	$L_{f,I}$	$L_{f,P}$	$L_{f,B}$
1.2	0	0	0	2	19	0	0	0	0
1.3	0	0	0	6	22	0	0	0	0
1.4	0	0	0	8	26	0	0	0	0
1.5	0	0	0	11	18	0	0	0	0
1.6	0	0	0	15	28	0	0	0	0
1.7	0	0	0	21	34	0	0	0	0
1.8	0	0	0	25	32	0	0	0	0
1.9	0	0	0	27	35	0	0	0	0
2.0	0	0	0	27	32	0	0	0	0

From the results we find that IP policy shows the best performance and the performance of Null policy is better than that of CCP policy. From the perspective of pktNum, IP and Null policies are suitable for news and akiyo because these two sequences have relatively low data rates. For a specific video sequence, the lower the data rate is, the less the number of lost packets is. CCP policy is more suitable for foreman because the other two sequences experience packet loss too. From the perspective of avgPSNR, although pktNum of foreman in CCP policy is higher than those in the other two policies, the avgPSNR is still the lowest. The reason is that CCP policy does not recognize the priority of different frame types in RR mode. Since the scheduling opportunities of different frame types are the same and the number of I frames are much larger than those of P and B frames, many I frames are dropped to hold more P and B frames in CCP policy. Table 4 verifies the results of figure 2(c) and 2(d).

4.2. Influence of RED Parameters

In this sub-section, we discuss the influence of RED parameters setting. In each policy, R_d is set to 1.5Mbps. In IP policy, RED parameters for each virtual queue of news and akiyo are “50-50-0” so that packet loss could be avoided because the scheduling opportunities are enough to transmit all the packets of these two sequences. Therefore, these two videos are perfectly received. For foreman sequence, RED parameters for the virtual queues of I frames and B frames are set to “50-50-0” and “0-0-1” respectively. That is to say, B frame packets are totally dropped and more scheduling opportunities are reserved for I frame packets. Figure 3 shows the results of foreman sequence in IP policy. The x-axis refers to RED parameters setting of the virtual queue of P frames. From the figure we find that although loose limitation of RED parameters could increase the number of received packets, the received quality will not increase continuously because the more important I frame packets will experience loss with the increase of the number of received P frame packets. Notice that “10-20-0” is the best setting and the received video quality is always better when the dropping probability equals to 0.

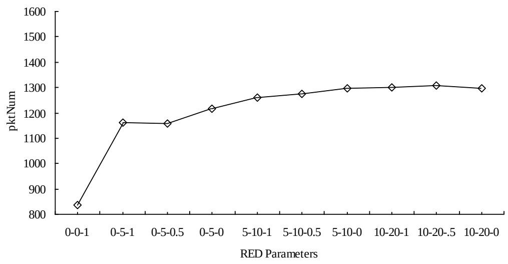


(a) pktNum (b) avgPSNR

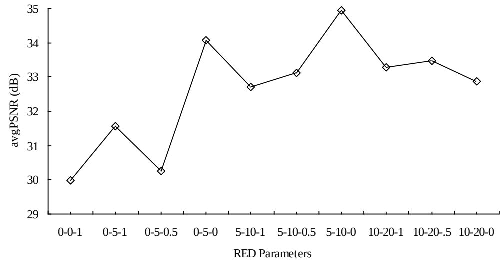
Figure 3. Results of Foreman Sequence, IP Policy

Figure 4 presents the results of different video sequences in CCP policy. In this experiment, RED parameters settings of the virtual queues of I frames and B frames are also “50-50-0” and “0-0-1” respectively. From the figure we can find that the RED parameters influence the performance greatly and the best settings for different video sequences are quite distinct. “5-10-0”, “0-5-0” and “10-20-0” are the best choices for news, foreman and akiyo respectively. And the average avgPSNR of the three sequences reaches the highest point when RED parameters are set to “0-5-0”.

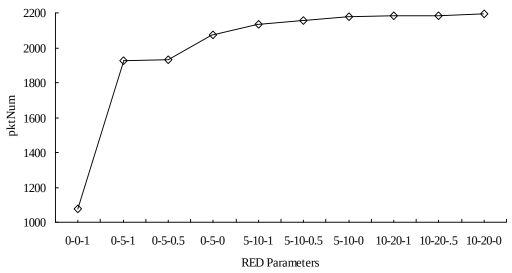
For Null policy, there is no need to change RED parameters setting.



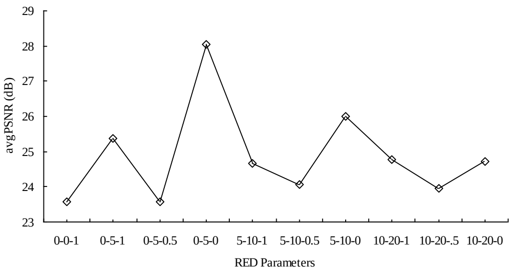
(a) pktNum of news



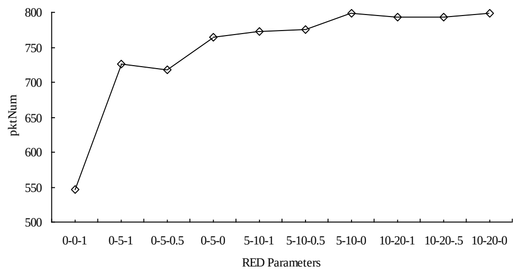
(b) avgPSNR of news



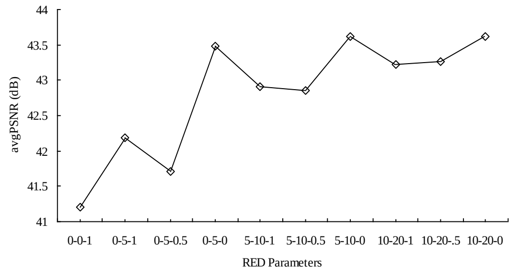
(c) pktNum of foreman



(d) avgPSNR of foreman



(e) pktNum of akiyo



(f) avgPSNR of akiyo

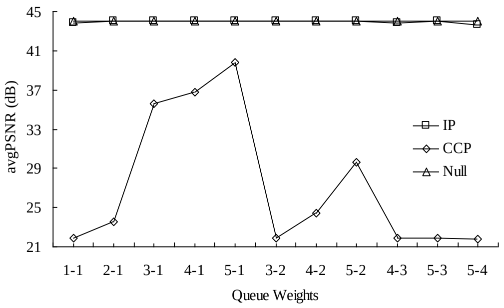
Figure 4. Results of Different Sequences, CCP Policy

4.3. Influence of Scheduling Mode

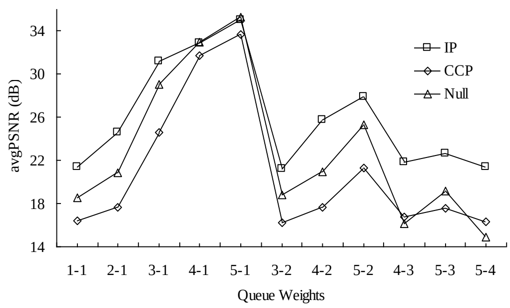
Figure 5 shows the results when adopting WRR scheduling modes. When CCP and IP policies are used, the RED parameters settings of I, P and B frames are “50-50-0”, “20-40-0.25” and “10-20-0.5” respectively. And when Null policy is employed, default setting is used. In the figure, the x-axis gives two weights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

(1) The performance of IP policy is the best under each weight pair. And the performance of Null policy is always better than that of CCP policy.

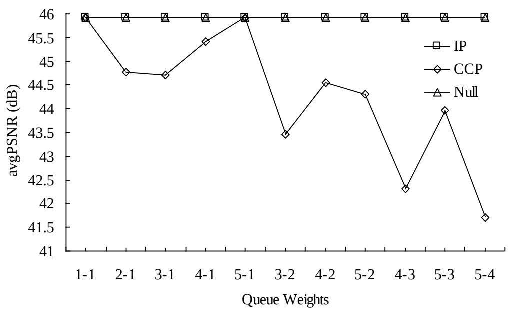
(2) To achieve better received video quality, the weight of video stream queues should be higher than that of data stream queue. The larger the difference is, the better the received video quality is.



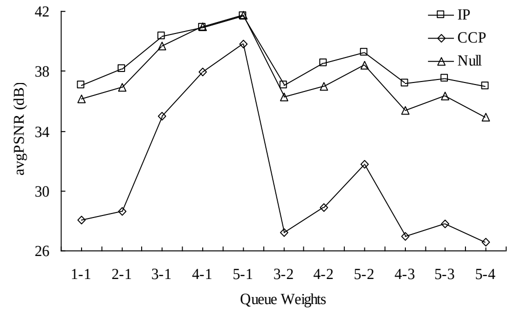
(a) news



(b) foreman



(c) akiyo



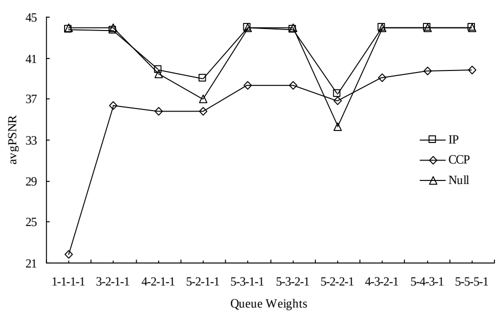
(d) average

Figure 5. Results of Different Sequences, Weights of Video Queues are the Same

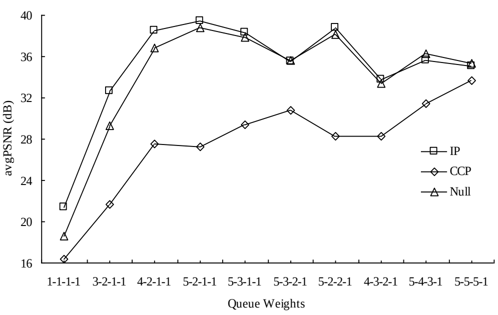
In the second experiment, different weights are employed for different video stream queues. “3-2-1-1” in the x-axis of figure 6 means the weights of physical queues of foreman, news, akiyo sequences and data stream are 3, 2, 1 and 1 respectively in IP and Null policies. “3-2-1-1” also means the weights of physical queues of I, P, B frames and data stream are 3, 2, 1 and 1 respectively in CCP policy. From the figure we find that

(1) For the average avgPSNR of the three sequences, “5-3-2-1” is the best choice for IP and Null policies and “5-5-5-1” is the best choice for CCP policy. The results show that CCP policy suffers from packet loss greatly. Therefore, the video stream queues require extremely high weights.

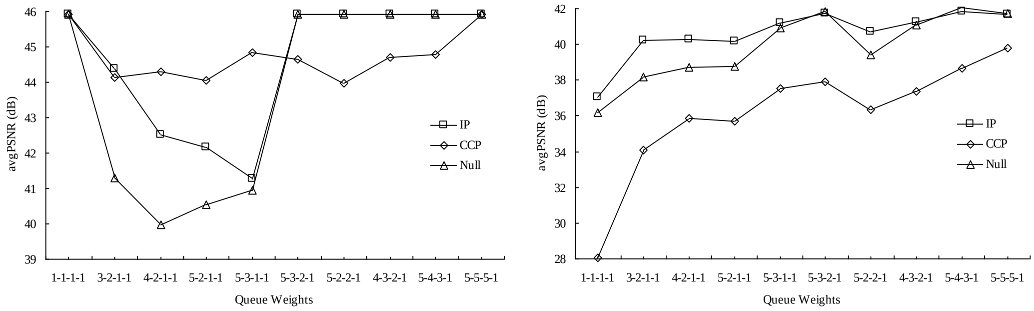
(2) The higher the data rate of a video is, the higher the weight of the video should be set to.



(a) news



(b) foreman



(c) akiyo (d) average

Figure 6. Results of Different Sequences, Weights of Video Queues are Different

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

If PRI mode is employed, the video with the lowest priority will receive poor quality definitely. It is helpless for improving the total performance.

5. Conclusions

In this paper we propose two priority based schemes named IP based scheme and CCP based scheme for multiple video streaming in DiffServ domain. Comprehensive evaluations are performed to make comparison between priority based schemes and non-priority scheme. Results show that:

(1) IP policy always shows the better performance in various conditions, compared to CCP and Null policies. And Null policy outperforms CCP policy in most cases. Therefore, CCP policy should not be employed.

(2) Scheduling mode of DiffServ domain influences the performance significantly. WRR and WIRR modes are suggested to be adopted. As for weight setting of these two modes, we suggest that: (a) higher weights should be set to video streams, compared to that of data stream; (b) the higher the data rate of a video is, the higher the weight of that video should be set to.

(3) Setting of RED parameters is another factor which influences the performance of multiple video streaming. However, the optimal setting of RED parameters is difficult to explore because it depends on several factors such as the available bandwidth for video streams, the data rates and coding structures of different videos.

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References

[1] K. Nichols, S. Blake, F. Baker and D. Black, “Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers”, IETF RFC 2474, **(1998)**.

[2] S. Blake, D. Black, M. Carlson, E. Davies, Z. Wang and W. Weiss, “An Architecture for Differentiated Services”, IETF RFC 2475, **(1998)**.

[3] L. Chen and G. Liu, “A Delivery System for Streaming Video over DiffServ Networks”, IEEE Transactions on Circuits and Systems for Video Technology, vol.20, no.9, **(2010)**, pp.1255-1259.

[4] D. Ong and T. Moors, “Deferred discard for improving the quality of video sent across congested networks”, Proceedings of IEEE International Conference on Local Computer Networks, **(2013)**; Sydney, Australia.

[5] J. Jaffar, H. Hashim, H. Z. Abidin and M. K. Hamzah, "Video quality of service in Diffserv-aware multiprotocol label switching network", Proceedings of IEEE Symposium on Industrial Electronics & Applications, pp.963-967, (**2009**) October 4-6; Kuala Lumpur, Malaysia.
[6] I-Hsuan Peng, Meng-Hsien Lin, Yen-Wen Chen, Fong-Ming Yang, A.Y.S. Su. Improvement of Streaming Video in Differential Service Networks by Using Opportunity RED Mechanism. Proceedings of International Conference on Complex, Intelligent, and Software Intensive Systems, **(2013)**; Taichung, Taiwan.
[7] H. Wang, G. Liu, L. Chen and Q. Wang, "A novel marking mechanism for packet video delivery over DiffServ Networks", Proceedings of International Conference on Multimedia and Expo, **(2011)**; Barcelona, Spain.
[8] F. Li and G. Liu, "A Novel Marker System for Real-Time H.264 Video Delivery Over Diffserv Networks", Proceedings of IEEE International Conference on Multimedia and Expo, **(2007)**; Beijing, China.
[9] S. Zoric and M. Bolic, "Fairness of scheduling algorithms for real-time traffic in DiffServ based networks", Proceedings of IEEE Mediterranean Electrotechnical Conference, (**2010**); Malta.
[10] S. Askar, G. Zervas, D. K. Hunter and D. Simeonidou, "Service differentiation for video applications over OBS networks", Proceedings of European Conference on Networks and Optical Communications, **(2011)**; Newcastle, UK.
[11] The Network Simulator - NS (version 2), http://www.isi.edu/nsnam/ns/.
[12] J. Klaue, B. Rathke and A. Wolisz, "EvalVid-A Framework for Video Transmission and Quality Evaluation", Proceedings of 13th International Conference on Modelling Techniques and Tools for Computer Performance Evaluation, **(2003)**.
[13] C. H. Ke, C. K. Shieh, W. S. Hwang and A. Ziviani, "An Evaluation Framework for More Realistic Simulations of MPEG Video Transmission", Journal of Information Science and Engineering, vol.24, no.2, **(2008)**, pp.425-440.

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