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Optimal Bandwidth Reservation for Video Streaming in DiffServ Domain

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Abstract

With the emergency of more and more video applications, the problem of providing differentiated Quality of Service (QoS) for various kinds of streams should be solved. DiffServ was proposed to balance transmission guarantee of video and data streams. Existing studies focused on the promotion of video receiving quality by allocating excess resources. In this paper we propose an optimal bandwidth reservation mechanism, aiming at proper amount of bandwidth reservation and good video transmission performance. This mechanism tries to find a moderate reservation according to the video characteristics and buffer size of forwarding routers. Various video sequences and different buffer sizes are employed in the performance evaluation experiments and simulation results verify that (1) Proposed mechanism show its adaptability to data rate, data rate variation and continuous burst of the streaming video. (2) Proposed mechanism presents good performance under various buffer sizes. (3) The amount of bandwidth reservation, which is determined by the streaming video and buffer size of forwarding routers, is moderate to ensure video receiving quality.

Keywords*: Video Transmission; Bandwidth Reservation; DiffServ; Buffer Size*

1. Introduction

With the development of network and video encoding technologies, more and more video applications emerged. To provide different Quality of Service (QoS) for video streams and data streams, DiffServ (Differentiated services) [1,2] was proposed. Existed studies about video streaming in DiffServ domain focused on maximization of video receiving quality. Some studies tried to ensure video streaming within DiffServ framework [3-5], some others focused on improvement of DiffServ framework for video streaming [6-8], and the others paid attention to specific aspect such as fairness scheduling [9] and further differentiation of video applications [10].

As we known, video streams often have huge amounts of data. More important, the data rate of a video stream varies dramatically. Thus, the difficulty for video streaming in DiffServ is to reserve the proper bandwidth for a specific video stream. In the previous study, we made a comprehensive evaluation to solve the problem and obtained the following conclusions.

(1) Bandwidth requirements of different video streams depend on content features and network parameter.

(2) Content features include data rate and its variation, and continuous burst. Bandwidth of a video sequence should be reserved on the basis of its data rate. If variation of data rate is significant, more bandwidth is required. If continuous burst occurs, additional bandwidth should be reserved.

(3) Network parameter is buffer size in routers. Large buffer size always decreases bandwidth requirement and improves video receiving quality.

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In this paper we design an optimal bandwidth reservation mechanism for different video streams, considering data rate, variation of data rate and continuous burst of a video stream, and buffer size of the forwarding router.

The rest of the paper is organized as follows. Algorithm of optimal bandwidth reservation is presented in Section 2. Simulation environments are described in Section 3. Section 4 gives simulation results and corresponding discussions. Finally, Section 5 concludes the paper.

2. Optimal Bandwidth Reservation

2.1. Basic Version

Assume that R is the set of video data rates at different periods and bw is the amount of reserved bandwidth. Without considering buffer size, the number of bits waiting to be forwarded in router buffer at each period can be computed as:

$$b_1=pos(r_1-bw) \tag{1}$$

$$b_{i+1}= pos(b_i+r_{i+1}-bw) \tag{2}$$

If x is a positive, $pos(x)$ returns x. Otherwise, $pos(x)$ returns 0.

Ordinarily, buffer size is measured by the maximum allowed number of queuing packets, denoted by N_p. The maximum bits that the buffer may hold (b_M) can be calculated as:

$$b_M = N_p\times 1024\times 8 \tag{3}$$

Where 1024 is the maximum length of a video packet. When encapsulating video packets, a video frame is divided into several packets and all the packets have a length of 1024 bytes except the last packet.

To avoid packet loss, sufficient bandwidth should be reserved to satisfy the condition: for each r_i in R, $b_{i+1} < 2b_M$. The basic version of optimal bandwidth reservation (bwo_b) is the minimum bw that meets the requirement.

2.2. Standard Deviation Compensation Version

The above version of optimal bandwidth reservation considers data rate and continuous burst of a video stream, together with buffer size of the router. However, data rate variation of the video stream is not considered. To solve the problem, standard deviation of data rate is adopted to measure the variation. The standard deviation compensation version of optimal bandwidth reservation (bwo_{sd}) is:

$$bwo_{sd} = bwo_b+stdev(R) \tag{4}$$

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 DiffServ Configurations

NS-2 DiffServ module provides four traffic classes (refer to four physical queues), each of which may own three dropping precedences (refer to three virtual queues). Policy defines the service level that a traffic class should be treated. There are six policy models and we use Null policy (has only one virtual queue and does not downgrade any packets) in this paper because it is simple and suitable for bandwidth reservation.

In addition, there are four scheduling modes which tell how to choose a packet to forward from different physical queues. Priority mode (PRI), in which priority is arranged in sequential order, is chosen in this paper. This mode has an important parameter (BW_{max}) which defines the limit on the maximum bandwidth a particular physical queue can obtain. That is to say, BW_{max} is the reserved bandwidth of a physical queue.

In all the experiments of this paper, the video stream and the data stream are assigned to queue 0 and queue 1 respectively. Therefore, the data stream could obtain scheduling opportunities after the video stream uses up its bandwidth reservation (BW_{max} of queue 0).

3.2 Simulation Topology

Simulation topology is presented as Figure 1. S1 generates a video stream and S2 produces a CBR data stream with a data rate of 1.2Mbps (R_d). Packet size of data steam is 1500 bytes. Bandwidth of the link between C and E2 depends on the video sequence.

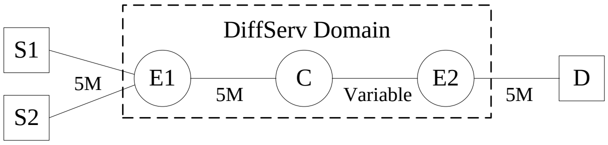


Figure 1. Simulation Topology

3.3. Video Sequences

To perform a comprehensive evaluation, six video sequences are chosen: news, foreman and akiyo with CIF resolution and coastguard, container and hall with QCIF resolution. These sequences have distinct characteristics in data rate and its variation, and continuous burst. Half-second is defined as the period length in this paper. And data rates at each half-second of the six sequences are shown in Table 1. The frame rate of coastguard is 20/s and the frame rates of other sequences are 30/s.

3.4. Comparative Schemes

To verify the performance of the two versions of optimal bandwidth reservation, we introduce four comparative schemes as follows:

(1) Average (abbreviated as Avg): set BW_{max} to the average data rate of a video stream.

(2) Adaptive (abbreviated as Adapt): change BW_{max} to the data rate of the incoming period at the beginning of that period.

(3) History-1 (abbreviated as His-1): use historic calculated average data rate to predict the data rate of next period at the end of each period. Let ra_{old} and r_{cur} be data rates of the old average and the current period respectively. Then the new average data rate (ra_{new}) can be calculated as: $ra_{new}=\alpha\times ra_{old}+\beta\times r_{cur}$. α and β are adjustable parameters in the equation. In History-1 scheme, α and β are both set to 0.5. The initial value is equal to the average data rate of the video stream.

(4) History-2 (abbreviated as His-2): similar to History-1 except that α is set to 0.8 and β is set to 0.2.

Table 1. Data Rate at Each Second of Six Sequences (bps)

No.	news	foreman	akiyo	coastguard	coastguard	container	hall
1	1136720	1947504	646912	814432	199664	395696	367808
2	1425152	2262688	795936	801968	858864	404064	458192
3	951760	1669312	631360	611760	243792	291152	423232
4	1220768	2134224	706592	164656	306160	399536	508400
5	1287248	2071664	789392	798608	120672	409664	464688
6	1170640	1932688	610864	621120	307408	294368	303040
7	1470800	2266352	763328	587984	119328	408624	498736
8	1358240	1755728	759200	1111472	611008	261872	517216
9	1047664	1767152	488208	215408	271440	176976	337536
10	1363040	2473040	791680	191504	836352	221808	447408
11	1341072	2494064	774880	361808	274512	217424	451632
12	1027456	1851184	474992	189696		186256	353856
13	1397728	2685648	699008	800240		219744	453968
14	1254368	2254640	685712	1300448		722752	310464
15	986720	2480128	628640	1298048		876176	192160
16	1355904	2948336	762800	954736		394416	67648
17	1372352	3352688	783232	328368		412560	997216
18	1092208	2953632	543120	311808		322688	553888
19	1334096	2943776	749664	261328		413104	468272
20	1410240	3721792	796832	883728		415072	533888

In the next section, the basic version of optimal bandwidth reservation is denoted as Optimal-B (abbreviated as Opt-B) and the standard deviation compensation version is denoted as Optimal-SD (Opt-SD).

4. Evaluation

4.1. Results Under default Buffer Size

The default buffer size for red queues in NS-2 DiffServ module is 50 packets. Thus b_M is equal to 409600 bits. Table 2 summarizes the average data rate (r_a), standard deviation of data rate ($stdev(R)$) and bwo_b/bwo_{sd} under default buffer size of each sequence.

Table 2. r_a, stdev(R), bwo_{sd} and bwo_b of Six Sequences (Mbps)

	news	foreman	akiyo	coastguard	container	hall
r_a	1.250	2.400	0.694	0.541	0.372	0.435
$stdev(R)$	0.160	0.561	0.103	0.354	0.171	0.179
bwo_b	1.216	3.039	0.660	0.900	0.400	0.434
bwo_{sd}	1.248	3.151	0.680	0.970	0.435	0.469

Combining Table 1 and Table 2, we can draw the following conclusions on characteristics of different sequences:

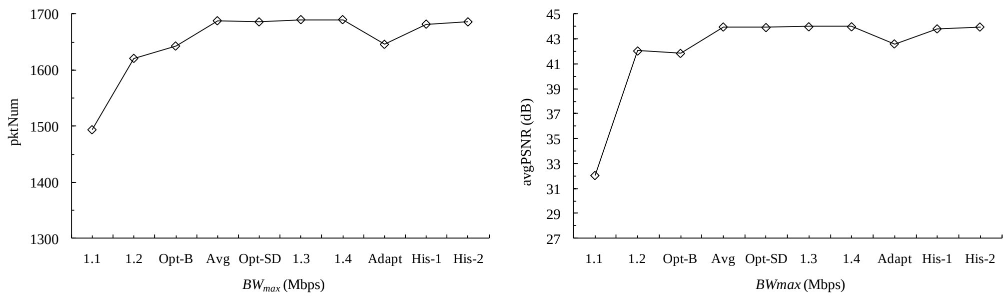
(1) Sequences with CIF resolution have higher data rate than those sequences with QCIF resolution. Among CIF sequences, akiyo has a relatively low data rate. And coastguard has a relatively high data rate among QCIF sequences.

(2) High data rate does not always mean drastic variation of data rate. We notice that both news and akiyo have a remarkable steady variation, while coastguard and container have drastic variations.

(3) Relationship between bwo_b and r_a is determined by continuous burst. If continuous burst is remarkable, bwo_b will be higher than r_a. Two typical example of continuous burst are period 16 to 20 of foreman and period 13 to 16 of coastguard. Otherwise, bwo_b is lower than r_a, such as news and akiyo.

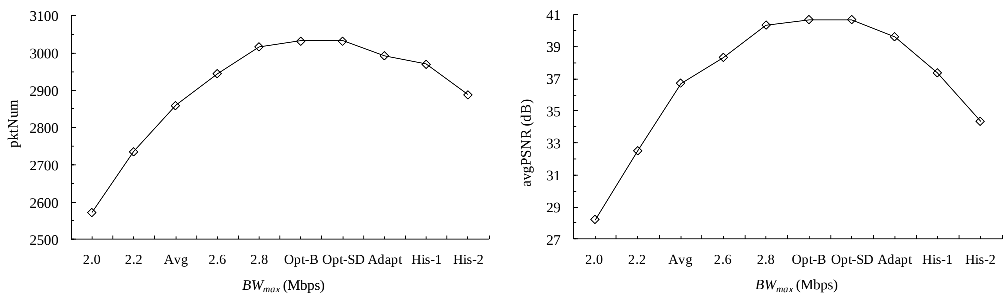
(4) Gap between bwo_b and bwo_{sd} is determined by $stdev(R)$, just as equation (4) describes.

In the experiments we set $BW_{C,E2}$ based on the streaming sequence to generate congestion. Figure 2 to Figure 7 show the evaluation results.



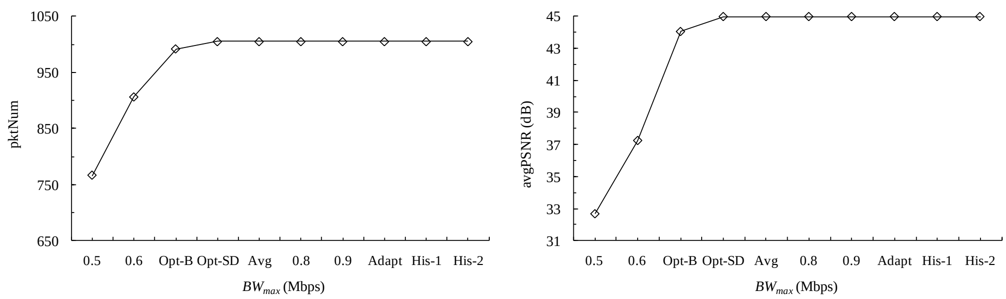
(a) pktNum Result (b) avgPSNR Result

Figure 2. Results of News Sequence, *$BW_{C,E2}$*=2Mbps



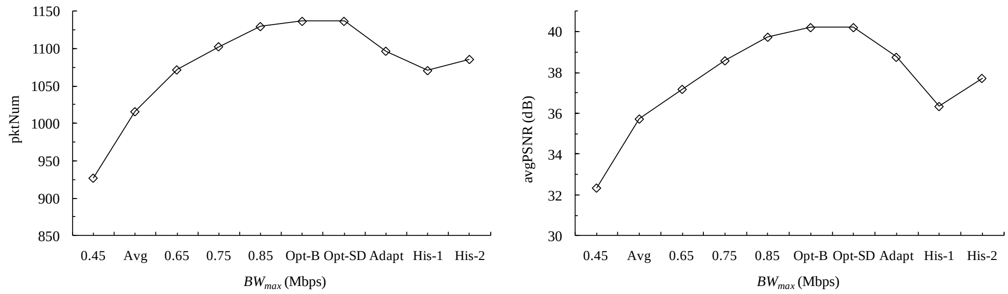
(a) pktNum Result (b) avgPSNR Result

Figure 3. Results of Foreman Sequence, *$BW_{C,E2}$*=3Mbps



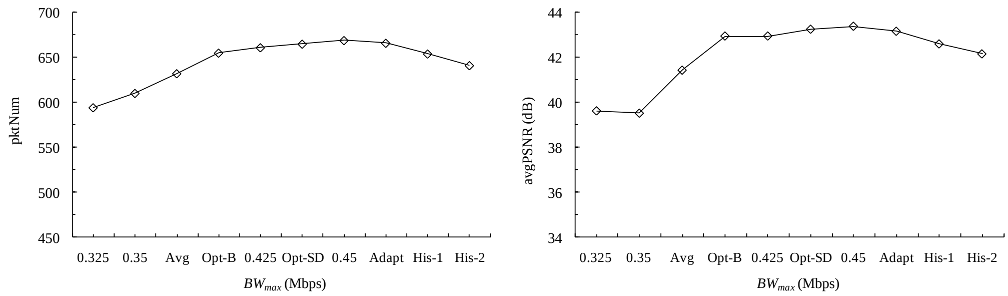
(a) pktNum Result (b) avgPSNR Result

Figure 4. Results of Akiyo Sequence, *$BW_{C,E2}$*=1.5Mbps



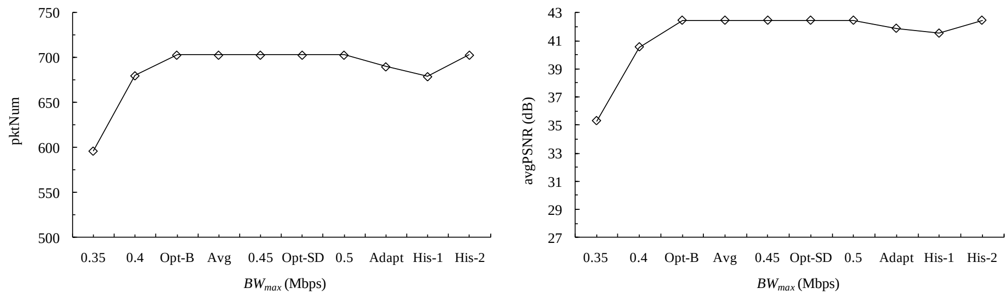
(a) pktNum Result (b) avgPSNR Result

Figure 5. Results of Coastguard Sequence, $BW_{C,E2}$=1.3Mbps



(a) pktNum Result (b) avgPSNR Result

Figure 6. Results of Container Sequence, $BW_{C,E2}$=1.2Mbps



(a) pktNum Result (b) avgPSNR Result

Figure 7. Results of Hall Sequence, $BW_{C,E2}$=1.2Mbps

From these figures we can draw the following conclusions.

(1) More bandwidth reservation always leads to more receiving packets and better decoding quality. However, excess bandwidth reservation is not necessary because it will degrade the transmission quality of other streams. For example, bwo_{sd} (0.68Mbps) is enough for akiyo sequence. Thus Avg (0.694Mbps) or more bandwidth is not necessary.

(2) Opt-SD always achieves the best or near the best performance. When foreman, akiyo and coastguard sequences are transmitted, Opt-SD outperforms all other schemes. Performance of Opt-SD is near the best when news and container sequences are transmitted. As for hall sequence, Opt-B, Avg and Opt-SD all obtain the best performance. Notice that bwo_b and bwo_{sd} do not work because $BW_{C,E2}$ is limited to 3Mbps.

(3) Opt-B is not as good as Opt-D.

(4) All the other schemes, including Avg, Adapt, His-1 and His-2, are not adaptable to various sequences.

(4.1) Performance of Avg is excellent when streaming news, akiyo or hall, because data rate variations of these sequences are not significant. Nevertheless, it shows poor performance when streaming those sequences that have drastic variation of data rate, such as foreman, coastguard and container.

(4.2) On the contrary, Adapt shows better performance than Avg when foreman, coastguard and container are streamed, although it seldom provides the best performance.

(4.3) Performance of His-1 and His-2 is between that of Avg and that of Adapt. Also performance comparison between these two schemes depends on the streaming sequence.

4.2. Results under Various Buffer Sizes

In the above experiments, the default buffer size (50 packets) is adopted. This subsection discusses the adaptability to buffer size.

Table 3 and Table 4 present bwo_b and bwo_{sd} under various buffer sizes for each sequence.

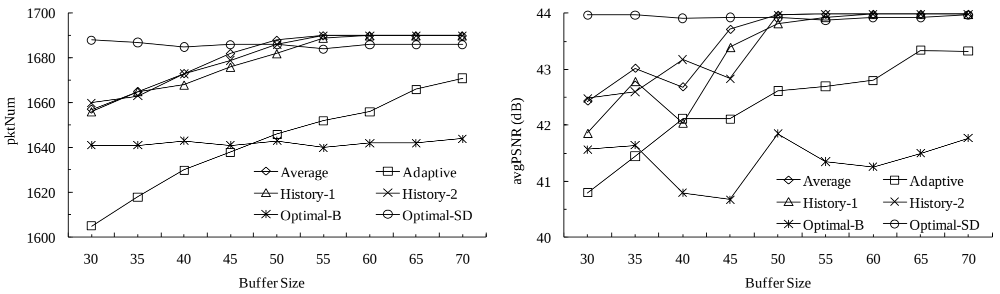
Table 3. bwo_b under Various Buffer Sizes (Mbps)

buffer size	news	foreman	akiyo	coastguard	container	hall
30	1.238	3.231	0.67	1.05	0.55	0.53
35	1.232	3.149	0.667	1.015	0.513	0.495
40	1.226	3.08	0.665	0.97	0.475	0.475
45	1.221	3.059	0.658	0.94	0.431	0.454
50	1.216	3.039	0.654	0.9	0.4	0.434
55	1.211	3.018	0.649	0.884	0.38	0.414
60	1.207	3.0	0.645	0.86	0.37	0.4
65	1.202	2.98	0.641	0.83	0.356	0.384
70	1.197	2.96	0.6375	0.805	0.345	0.38

Table 4. bwo_{st} under Various Buffer Sizes (Mbps)

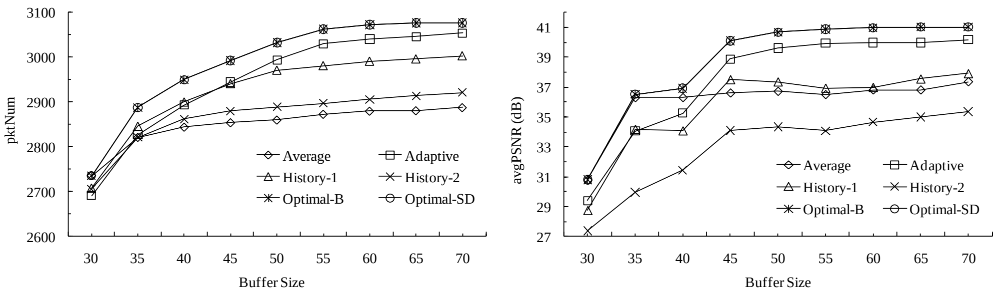
buffer size	news	foreman	akiyo	coastguard	container	hall
30	1.27	3.343	0.69	1.12	0.585	0.565
35	1.264	3.261	0.6876	1.086	0.547	0.53
40	1.258	3.192	0.685	1.04	0.510	0.51
45	1.253	3.171	0.679	1.01	0.464	0.489
50	1.248	3.151	0.675	0.97	0.435	0.469
55	1.243	3.13	0.67	0.955	0.413	0.449
60	1.239	3.112	0.665	0.931	0.403	0.435
65	1.234	3.09	0.662	0.901	0.389	0.419
70	1.229	3.07	0.658	0.876	0.38	0.415

Figure 8 to Figure 13 show the evaluation results.



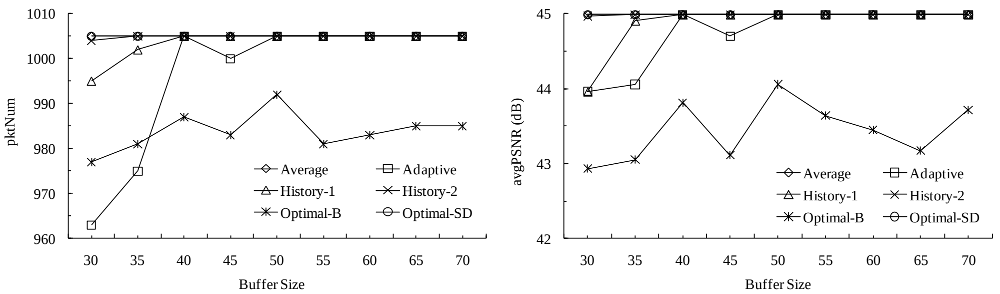
(a) pktNum Result (b) avgPSNR Result

Figure 8. Results of News Sequence, $BW_{C,E2}$=2Mbps



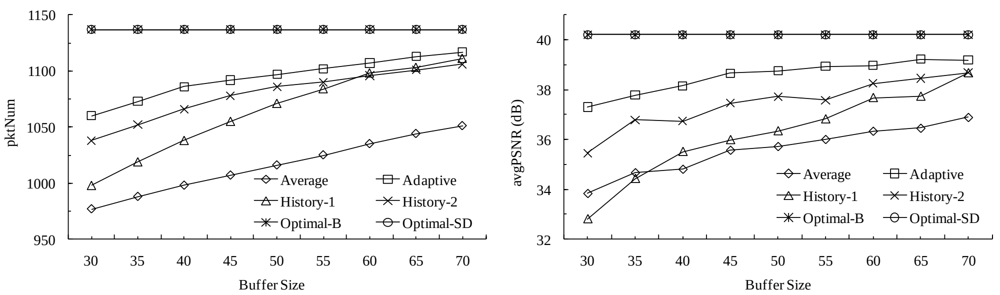
(a) pktNum Result (b) avgPSNR Result

Figure 9. Results of Foreman Sequence, $BW_{C,E2}$=3Mbps



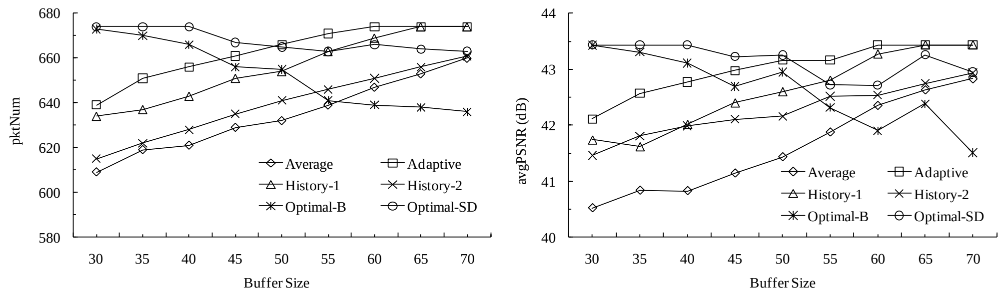
(a) pktNum Result (b) avgPSNR Result

Figure 10. Results of Akiyo Sequence, $BW_{C,E2}$=1.5Mbps



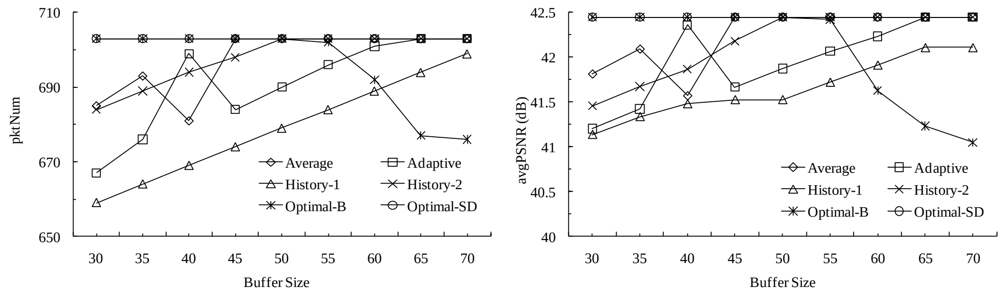
(a) pktNum Result (b) avgPSNR Result

Figure 11. Results of Coastguard Sequence, $BW_{C,E2}$=1.3Mbps



(a) pktNum Result (b) avgPSNR Result

Figure 12. Results of Container Sequence, $BW_{C,E2}$=1.2Mbps



(a) pktNum Result (b) avgPSNR Result

Figure 13. Results of Hall Sequence, $BW_{C,E2}$=1.2Mbps

From these figures we can draw the conclusions:

(1) From the perception of adaptability to buffer size, Optimal-SD shows the best performance. When news, akiyo, coastguard and hall sequences are streamed, the number of receiving packets and the video decoding quality remain steady. As for contain sequence, there is a slight degradation as the buffer size enlarges. But compared to other schemes, the variation is not significant. With regard to foreman sequence, we find that performance variation is sharp. However, recall that: 1) foreman has a tremendous data rate; 2) foreman has continuous bursts at the last five periods; and 3) $BW_{C,E2}$ is limited to 3Mbps. Therefore, limited $BW_{C,E2}$ and buffer size cause severe packet loss. The only way to avoid packet loss is to increase the buffer size.

(2) Optimal-B shows poor performance under all buffer sizes when news and akiyo are streamed and under large buffer sizes when container and hall are streamed. But it does present good performance when foreman and coastguard are streamed. The results verify that standard deviation compensation is necessary.

(3) Let's concentrate on the amount of bandwidth reservation. Recall Table 2 and Table 4 we can conclude as follows.

(3.1) When streaming foreman, coastguard and hall sequences, Optimal-SD reserved more bandwidth than Average, resulting much better performance.

(3.2) With regard to akiyo sequence, Optimal-SD consumes less bandwidth but obtains as good performance as Average.

(3.3) As for news sequence, when buffer size is relatively small, Optimal-SD consume more bandwidth and provides better performance. And when buffer size enlarges, less bandwidth is consumed and the approximate perfect performance is achieved.

(3.4) Container sequence is an exception. Results are similar to those of news sequence when buffer size is small. However, with buffer size increasing, Adaptive and History-1 outperform Optimal-SD. Our future studies will focus on this issue.

(4) In most cases, Adaptive, History-1 and History-2 show poor performance. Recall that these three schemes keep BW_{max} changing and History-1 and History-2 must measure data rate all the time and compute the newest average data rate. That is to say, these three schemes cost more but gain less.

5. Conclusions

In this paper we propose a bandwidth reservation optimization mechanism to ensure video streaming in DiffServ domain under different buffer sizes and using various videos. Simulation results show that:

(1) Proposed mechanism (standard deviation compensation version of optimal bandwidth reservation, Optimal-SD) is adaptable to the characteristics of video streams (news, foreman and akiyo with CIF resolution, and coastguard, container and hall with QCIF resolution), including data rate and its variation and continuous burst.

(2) When various buffer sizes are employed, Optimal-SD provides the best performance in most cases and shows near the best performance in other cases.

(3) Concerning to the bandwidth reservation, Optimal-SD reserves more bandwidth when data rate variation is drastic (often results in severe congestion) and gains much better performance. And in other conditions, Optimal-SD consumes less bandwidth and achieves comparative performance.

Acknowledgements

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