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Evaluation on Content Aware Video Transmission in DiffServ Domain

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Abstract

With the development of network and video compression technologies, more and more video applications emerged and enriched people's daily life. Since high data rate of videos could exhaust bandwidth and starve data streams, DiffServ (Differentiated services) is proposed to balance synchronous transmission of two stream types. However, most existed researches aimed at receiving quality promotion of video streams, leading to poor performance of data streams. In this paper we try to find how to reserve proper amount of resources for video streams by evaluating transmission of various video sequences. Results show that (1) video transmission performance is content aware and is determined by data rate, data rate variation and continuous burst of the video. Reserved bandwidth of a video should be proportional to its data rate. If data rate variation is significant, more bandwidth should be reserved. If continuous burst occurs, additional bandwidth is required. (2) If accurate data rate and its variation can be obtained and data rate variation and/or continuous burst are remarkable, adaptive bandwidth reservation is recommended. Otherwise, fixed reservation is better. (3) Large buffer size in routers will improve the video receiving quality.

***Keywords**: Video Transmission; Content Aware; DiffServ; Evaluation*

1. Introduction

With the increase of Internet bandwidth and the progress of video compression technology, more and more video applications emerged in the past decade. Since a video stream often has a high data rate, massive video applications exhausted the capacity of Internet. It is necessary to balance the transmission performance between video and data streams. It was thought that ***DiffServ*** (Differentiated services) [1-2], which provides a coarse-grained and scalable architecture for synchronous transmission of video and data streams, could fulfill this task. The difficulty is how to define the requirements of different video streams so that the transmission of video streams can be guaranteed. Existed studies 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].

Existed schemes guaranteed video transmission by providing priority or assigning sufficient resources, resulting in poor performance of data streams. In this paper we aim to assign a moderate amount of resources for a video stream. As we known, resource requirement of a certain video depends on the features of the video, including data rate, coding structure and so on. Therefore, content aware resource assignment is investigated. As for network environments, we focus on the influence of buffer size.

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The rest of the paper is organized as follows. Simulation tools, network topology and features of different video sequences are described in Section 2. Section 3 gives evaluation results and corresponding discussions. Finally, Section 4 concludes the paper.

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). In the last mode, priority is arranged in sequential order. That is to say, queue 0 always has the highest priority, and then turns to queue 1, queue 2 and queue 3. Since a video stream always has higher priority than a data stream, PRI mode is suitable for our evaluation. There is a key parameter in PRI mode, setting a limit on the maximum bandwidth a particular queue can obtain. We use BW_{max} to indicate this parameter.

2.2. 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). Edge router (E1 and E2) and core router(C) forward packets for the sources. Packet size of both steams is 1500 bytes. Bandwidth of the link between C and E2 depends on the video sequence. Bandwidths of other links are set as the Figure shows.

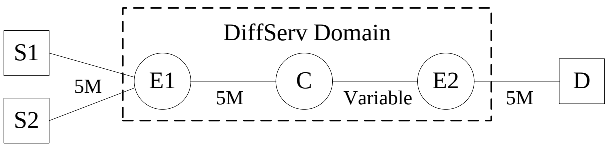


Figure 1. Simulation Topology

2.3. Video Sequences

To perform a comprehensive evaluation, we choose six video sequences: news, foreman and akiyo with CIF resolution and coastguard, container and hall with QCIF resolution. 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. Thus, coastguard has more than 20 half-seconds.

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

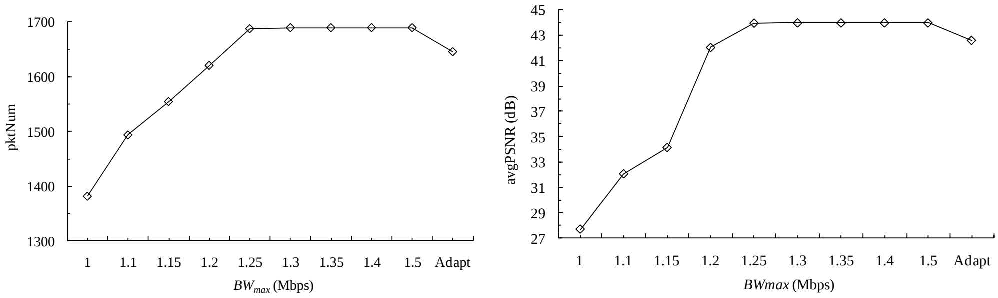
No.	news	foreman	akiyo	coastguard	coastguard	container	hall
1	1136720	1947504	646912	814432	199664	395696	367808
2	1425152	2262688	795936	801968	858864	404064	458192
3	951760	1669312	631360	611760	243792	291152	423232
4	1220768	2134224	706592	164656	306160	399536	508400
5	1287248	2071664	789392	798608	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
avg	1250208.8	2398312	694117.6		540590.97	372197.6	435462.4

3. Evaluation

3.1. Results and Analysis of News Sequence

Firstly, let's evaluate the news sequence receiving quality as the maximum bandwidth (BW_{max}) reserved for it varies, shown in Figure 2. "Adapt" in x-axis means BW_{max} is dynamically set according to the actual data rate presented in Table 1, varies at each half-second. Two performance metrics are evaluated: the number of total received packets (pktNum) and average PSNR (avgPSNR). Ordinary, these two metrics are consistent because more received packets always lead to high decoding quality. If the importance of video packets is considered, the results become different. For example, MPEG4 codec has three kinds of frames: I frame, P frame and B frame. Since I frame is the most important, loss of I frame packet often causes serious situation. However, importance of video packets is not considered in this paper.

Therefore, we find that the variation trends of two metrics are similar. As BW_{max} increases, both pktNum and avgPSNR keep on increasing. When BW_{max} reaches 1.25Mbps (the average data rate of news sequence), degradation can be ignored. And no packet is lost after 1.3Mbps. However, we notice that there are some cycles in Table 1 that have higher data rates than 1.25Mbps. Then what is the reason for such a good performance? There are two reasons which can explain the results: (1) buffer in router C can hold some packets queuing to be forwarded in previous cycles; (2) although data rate of news sequence varies at each half-second, variation extent is not significant. These two reasons are closely linked.



(a) PktNum Result (b) AvgPSNR Result

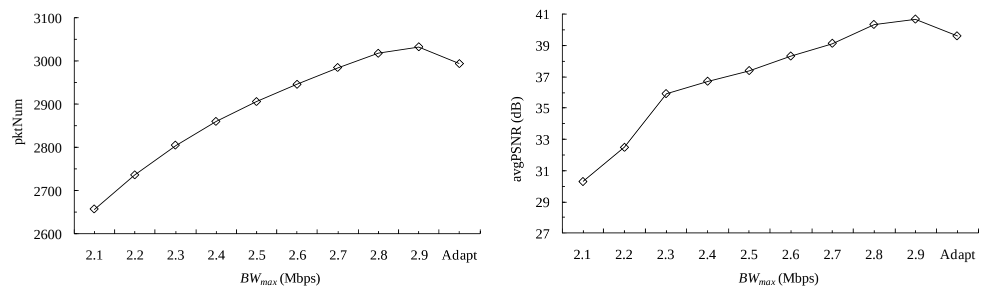
Figure 2. Results of News Sequence, $BW_{C,E2}$=2Mbps

On the contrary, we notice that "Adapt" mechanism does not show an expectable performance. The main reason is that variation of video data rate and BW_{max} setting are not synchronous. Let's take cycle 15 and cycle 16 as examples. When it comes to cycle 16, data rate variation occurred in advance, resulting in packet loss before BW_{max} setting varies. Notice that data rate of news sequence is relatively high when default buffer size (50 packets) is employed.

3.2. Results and Analysis of Other Sequences

Figure 3 show the results of foreman sequence, which show similar trend. That is, both pktNum and avgPSNR keep on increasing as BW_{max} increases. Notice that the average data rate of foreman sequence is 2.5Mbps. We find that the performance of "Adapt" mechanism is much better than that of "Average" mechanism in which BW_{max} is set to 2.5Mbps fixedly. And "Average" mechanism achieves a comparative performance when BW_{max} is set to 2.8Mbps. This is an opponent conclusion against that using news sequence. So what are the reasons?

Recall Table 1 we find that there are huge amounts of video packets from cycle 16 to cycle 20. When "Average" mechanism is employed, buffer in router C cannot hold continuous burst so that a lot of packets are dropped. On the other hand, although "Adapt" mechanism causes packet loss when data rate variation occurs, a suitable BW_{max} keeps more packets from being dropped. According to the results of news and foreman sequences, we know that not only data rate and its variation but also continuous burst must be considered when reserving bandwidth for a video stream. Notice that even if BW_{max} is set to 2.9Mbps, the receiving quality is still far from perfect because buffer size is not large enough.



(a) PktNum Result (b) AvgPSNR Result

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

Figure 4 to Figure 7 show the results of the other sequences: akiyo, coastguard, container and hall in turn.

As for akiyo sequence, both “Adapt” and “Average” (BW_{max}=0.7Mbps) mechanisms achieve perfect performance because data rate of akiyo sequence is relatively low and its variation is not significant.

With regard to coastguard sequence, results are quite different. Performance of “Adapt” mechanism is much better than that of “Average” mechanism (BW_{max}=0.54Mbps). From Table 1 we can find that coastguard sequence has the following features: (1) variation of data rate is remarkable; (2) data rates of many cycles are much higher than the average data rate; (3) continuous burst occurs, for example from cycle 13 to cycle 16. These features of video sequence lead to the results.

For container sequence, “Adapt” mechanism shows better performance too because there is also a continuous burst from cycle 14 to cycle 15. And for hall sequence, “Average” mechanism shows better performance because variation of data rate is not significant and there is not continuous burst. Notice that the average data rates for container and hall sequences are 0.375Mbps and 0.435Mbps respectively.

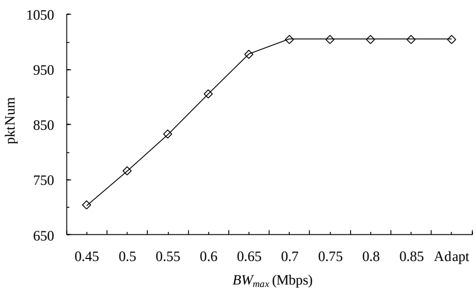
From the above results we can draw the following conclusions:

(1) When more bandwidth is reserved for video stream, both pktNum and avgPSNR show better performance.

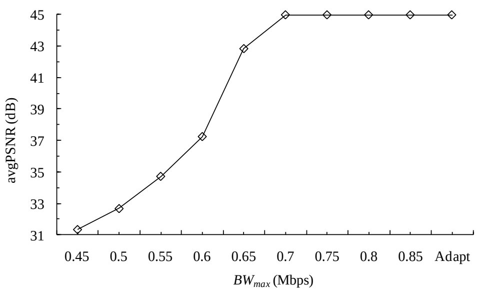
(2) Three features of a video sequence influence the receiving quality: data rate, variation of data rate and continuous burst. Reserved bandwidth of a video sequence should be proportional to its data rate. If variation of data rate is significant, more bandwidth should be reserved. If continuous burst occurs, additional bandwidth is required.

(3) “Adapt” mechanism outperformance “Average” mechanism when variation of data rate is significant and/or continuous burst occurs. However, there are two problems related to “Adapt” mechanism. One is the cost of data rate estimation because the actual data rate distribution cannot be obtained in most cases. The other is the accuracy of estimation. It is very difficult to estimate the incoming data rate.

(4) “Average” mechanism show good performance when variation of data rate is not significant. Average data rate of a video is relatively easier to be obtained. For example, estimation based on historical data is very close to the average data rate. A balancing part can be added on the basis of average data rate when reserving bandwidth for a video, according to the extent of data rate variation and continuous burst.

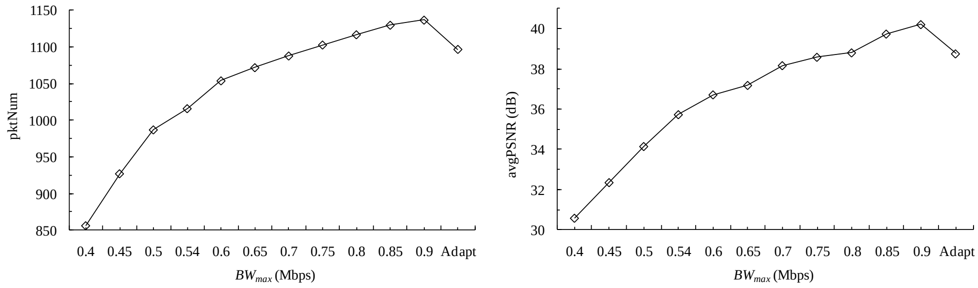


(a) PktNum Result



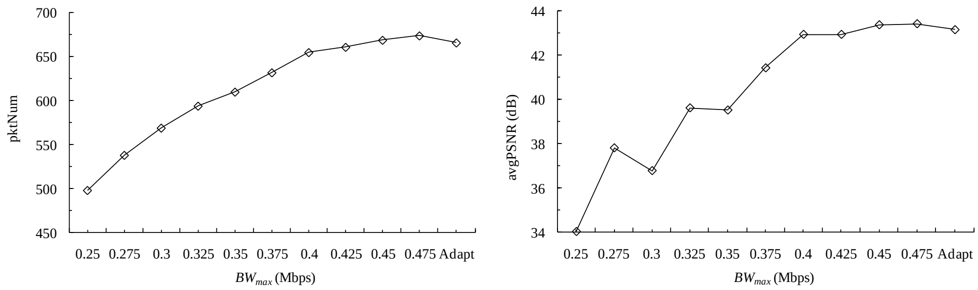
(b) AvgPSNR Result

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



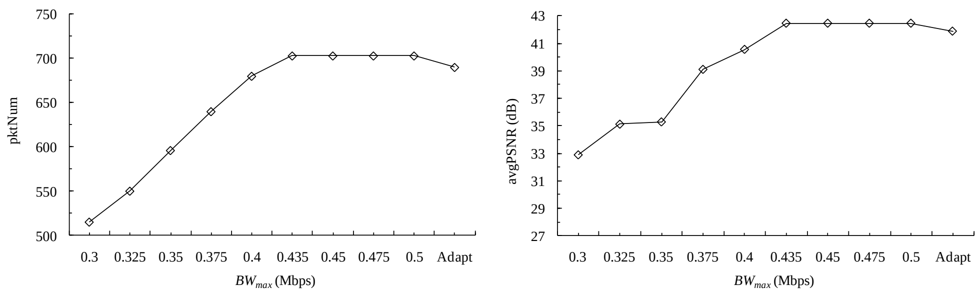
(a) PktNum Result (b) AvgPSNR Result

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

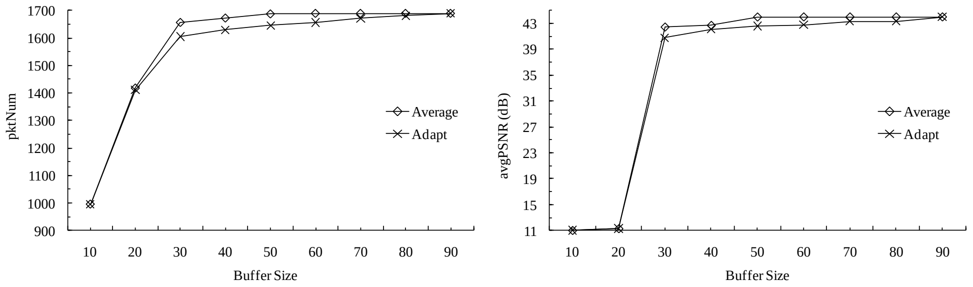


(a) PktNum Result (b) AvgPSNR Result

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

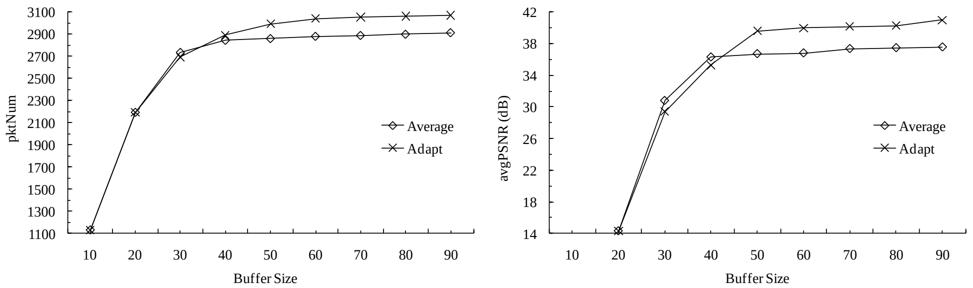
3.3. Influence of Buffer Size

In the above experiments, the default buffer size (50 packets) is adopted. From the results we find that most sequences except foreman can obtain perfect receiving quality (without packet loss) when BW_{max} is set to a proper value. In this subsection, we evaluate the influence of buffer size in routers. "Adapt" and "Average" mechanisms are evaluated, and the results of other BW_{max} settings can be deduced. Figure 8 to Figure 13 present the results.



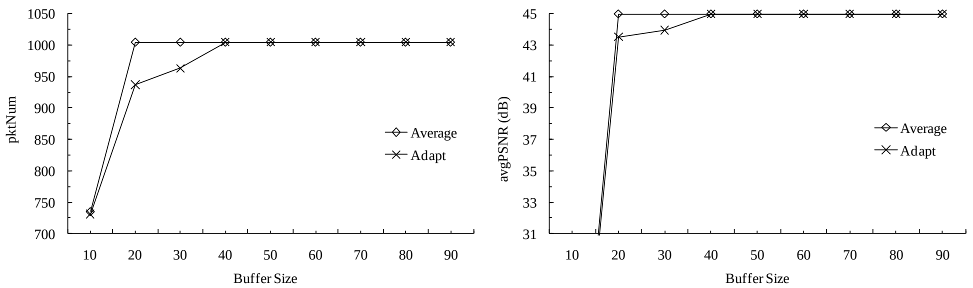
(a) PktNum Result (b) AvgPSNR Result

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



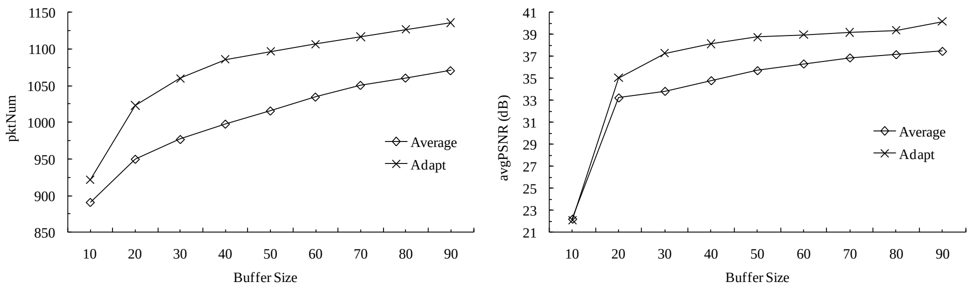
(a) PktNum Result (b) AvgPSNR Result

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



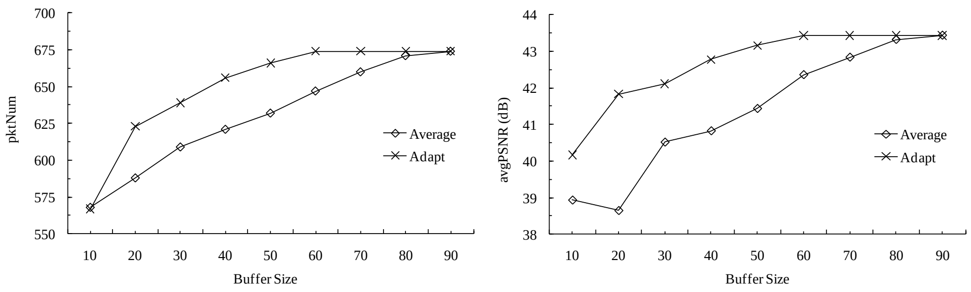
(a) PktNum Result (b) AvgPSNR Result

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



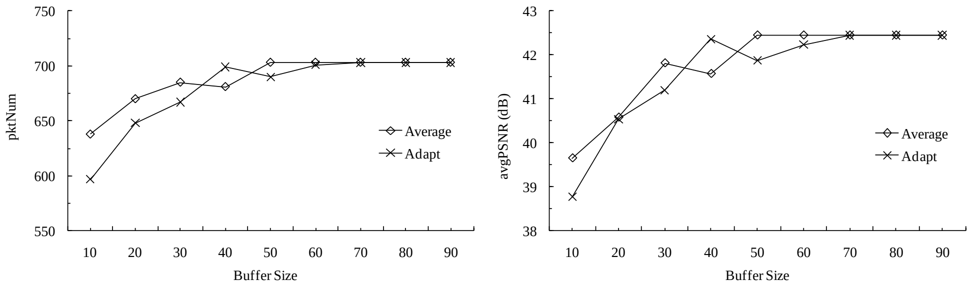
(a) PktNum Result (b) AvgPSNR Result

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) Video receiving quality improves as the buffer size enlarges.

(2) “Average” mechanism outperforms “Adapt” mechanism in most cases when news, akiyo and hall sequences are transmitted. These sequences have relatively stable variation of data rate and have not remarkable continuous burst.

(3) The performance of “Adapt” mechanism is better than that of “Average” mechanism in most cases when foreman, coastguard and container sequences are transmitted. The reason is that data rate variations and continuous bursts of these sequences are remarkable.

(4) Foreman sequence almost reaches the perfect receiving quality when buffer size is set to 90 packets and “Adapt” mechanism is employed.

4. Conclusions

In this paper we attempt to find how to reserve proper amount of resources according to the features of different video streams. Results show that:

(1) Video receiving quality depends on content features and network parameter.

(2) Content features include data rate, variation of data rate 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) “Adapt” mechanism is recommended when variation of data rate is significant and/or continuous burst occurs. And “Average” mechanism is suitable for those videos with relatively stable data rate variation.

(4) Network parameter is buffer size in routers. Large buffer size always improves video receiving quality.

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