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Real-time H.263+ Rate Control Algorithm for Interactive Video Applications under RCBR Network

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ABSTRACT

This paper presents a novel real-time H.263+ rate control algorithm for realtime interactive video applications under RCBR network, which supports bandwidth renegotiations during data transmission. It is especially suitable for the transmission of non-stationary video traffics. The proposed rate control algorithm communicates with the network to renegotiate the required bandwidth for the underlying video and chooses its control strategies according to the renegotiation results. The proposed algorithm controls both the spatial and temporal qualities at the same time to enhance human visual perceptual quality. Experimental results are provided to demonstrate that the proposed rate control algorithms can achieve superior performance with a low computational.

Ⅰ. Introduction

In recent years, the demands and interests on video communication have beengrowing rapidly, and the video data is expected to be the most significant component among the multimedia traffics over the network. However, it is not a simple problem to transmit video traffics reliably through the network because the video data requires a large amount of bandwidth compared to other multimedia data such as speech, audio and text. Furthermore, the generic characteristics of video traffics are very burst, which makes the problem more difficult and challenging.

As mentioned earlier, since the amount of video data is enormous compared to other multimedia data, it is indispensable to employ effective video compression algorithms for the video/multimedia systems. Recently, digital video coding techniques have advanced rapidly. International standards such as MPEG-1, 2 and 4, H.261, H.263/+/++ and H.26L have been established or under development to accommodate different needs by ISO/IEC and ITU-T, respectively. Among various video-coding standards, H.263+ [4] is the emerging state-of-the-art low bit video compression technique for Internet video transmission, of which core ingredients include the block-based motion compensation and the block-based DCT coding. And also, the rate control algorithm plays a crucial role in video transmission. It regulates the output bit-stream to meet certain given conditions, as well as enhances the quality of coded video. However, the rate control algorithms are not standardized since they are independent on the decoder structure.

In general, suitable communications between the network and video encoders can increase the network utilization and enhance video quality at the same time [1]. In recent years, thus some bandwidth-renegotiation approaches have been proposed to handle the non-stationary video traffics efficiently over the network. Under the networks supporting bandwidth renegotiation, the video encoder can renegotiate the allowable bandwidth during the transmission. RCBR (renegotiated CBR) [2] is proposed as a simple but quite effective approach to support the renegotiations, while it still needs to be improved to work reliably in real network environments.It can be implemented in both ATM network and the Integrated Service Internet by using the

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resource management (RM) cell mechanism, and the refreshment of the network reservation state using the RSVP (resource reservation protocol) signaling protocol, respectively [2,3]. Note that the bandwidth renegotiations can be interpreted as a compromise of ABR (available bit rate) and VBR. Before requesting renegotiation, the video encoder has to estimate the amount of the required channel bandwidth for the underlying video, and also has to decide when to renegotiate. Then, a signaling message requesting increase or decrease of the channel bandwidth is sent from thevideo encoder to the network. Finally, the network resource management system decides whether the request can be accepted or not according to the current network situations. Note that, in general, more renegotiations can increase the network utilization, however they may cause larger signaling overhead.

In this work, we present a novel adaptive H.263+ ratecontrol algorithms for video communication under the networks supporting bandwidth renegotiation. The proposed algorithms include the required bandwidth estimation scheme, channel bandwidth renegotiating process, encoding frame rate adjustment algorithm and frame-layer rate control algorithm. One unique feature of the proposed rate control algorithms is that they can renegotiate the bandwidth with the network if needed, and also control the spatial and temporal qualities simultaneously according to the renegotiation results.

Ⅱ. Proposed Rate Control Algorithm

Note that in contrast to the streaming case, the information about the future scenes is not available at the encoder side, and the latency becomes very critical in the interactive video applications. Thus, the proposed rate control algorithm mainly focuses on the low latency, and all the processes are carried on instant (current) frame-based, resulting the renegotiation requests occur aperiodically. That is, when the spatial quality of the current frame becomes out of the predetermined range, first, the required bandwidth to keep it within the range under the reference encoding frame rate is estimated. Then, the estimated bandwidth is renegotiated with the network. It employs different control strategiesselectively according to the results of the renegotiation with the network. If the renegotiation request is accepted, the current frame is encoded with the new channel bandwidth. Otherwise, we adjust the encoding frame interval to prevent the degradation of the spatial quality. The proposed adaptive rate control algorithm can be summarized in the following:

Step 1: Calculate the distortion of the last encoded frame.

Step 2: If the distortion is larger than the upper limit of a predetermined distortion range (fast motion change interval) or less than the lower limit of it (slow motion change interval), go to Step 3. Otherwise go to Step 6.

Step 3: Estimate the bandwidth to keep the spatial qualities to be in the predetermined range with the same encoding frame interval.

Step 4: Renegotiate the estimated bandwidth with the network.

Step 5: If the renegotiation requests are accepted, keep the encoding frame interval same. Otherwise adjust the encoding frame interval.

Step 6: Encode the current frame with the updated channel bandwidth or the new encoding frame interval. And update the model coefficients. Go to step 1 to continue.

By the way, the renegotiating time interval is related to the network utilization and signaling overhead. Actually, video encoders prefer to renegotiate their channel bandwidth more often. However, each renegotiation needs signaling overhead. Therefore, we need a trade-off between

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the number of renegotiations and the network utilization. In this work, we use the following rule to control the renegotiating time interval.

If $t_{cur} - t_{prev} > T_{\min}^{renego}$, try the renegotiation. Otherwise, do not try the renegotiation,

where $T_{\min}^{renego}$ is the minimum time interval for the renegotiation, t_{cur} is the current time when the renegotiation is required, and t_{prev} is the time of the previous renegotiation.

1. R-D modelin

The R-D modeling techniques are essential for developing fast rate control algorithms. These can be categorized into two approaches: statistical modeling techniques and empirical databased modeling techniques. In this work, we employ an empirical databased frame-layer R-D model using quadratic rate model [6] and affine distortion model with respect to the average QP (quantization parameter) in a frame, which is given by

$$\hat{R}(\overline{q}_i) = (a\overline{q}_i^{-1} + b\overline{q}_i^{-2}) \cdot MAD(\hat{f}_{ref}, f_{cur}),$$
$$\hat{D}(\overline{q}_i) = a'\overline{q}_i + b', \tag{1}$$

where a, b, a' and b' are the model coefficients, $\hat{f}_{ref}$ is the reconstructed reference frame at the previous time instant, f_{cur} is the uncompressed image at the current time instant, $MAD(\cdot,\cdot)$ is the mean of absolute difference between two frames and $\overline{q}_i$ is the average QP of all macroblocks in the i_{th} frame respectivley. The model coefficients are determined by using the rate-distortion table obtained by the previous encoding results. In order to increase the accuracy of the R-D model, an outlier-removing algorithm is also adopted: If the difference between the estimated value by the models and a datum of the rate-distortion table is greater than a threshold, the datum is discarded, and then based on the refined data, the coefficients are re-calculated by the same method.

2. Required Bandwidth Estimation

The required bandwidth can be determined by the motion change in the underlying video and the predetermined spatial quality range. In this work, the amount of required bandwidth is determined by Eqs. (3) and (4).

$$BW_{req} = \mu \cdot BW_{\min} + (1-\mu) \cdot BW_{\max}, \tag{3}$$

where μ is a constant $(0 \le \mu \le 1)$, and

$$BW_{\max} = \frac{a'}{D_{\min} - b}\left(a + \frac{b \cdot a'}{D_{\min} - b}\right) \cdot MAD(\hat{f}_{ref}, f_{cur}) \cdot \frac{F_{samp}}{F_{init}},$$
$$BW_{\min} = \frac{a'}{D_{\max} - b}\left(a + \frac{b \cdot a'}{D_{\max} - b}\right) \cdot MAD(\hat{f}_{ref}, f_{cur}) \cdot \frac{F_{samp}}{F_{init}}, \tag{4}$$

where $D_{\max}$ and $D_{\min}$ are the upper limit and lower limit of the tolerable distortion range, and F_{samp} and F_{init} are the sampling frame rate (30 fps) and the initial encoding frame rate, respectively. Now, the new bandwidth is assigned according to the renegotiatingresults as follows.

$$BW_{new} = \begin{cases} BW_{req} & \text{if } D < D_{\min}, \\ BW_{req} & \text{if } D > D_{\max} \text{ and the request is accepted}, \\ BW_{cur} & \text{otherwise}. \end{cases} \tag{5}$$

3. Encoding Frame Interval Adjustment Scheme

If the renegotiation requests are rejected by the resource management system of the network, the spatial quality of each frame can be deteriorated below the predetermined range and the degradation will be propagated to the following frames. Thus, we need to adjust encoding frame interval to maintain spatial quality as good as possible. The proposed encoding frame interval adjustment scheme is summarized in Eq. (6).

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$$I_{enc} = \begin{cases} I_{ref} & \text{if the request is accepted,} \\ I_{ref} + \Delta I & \text{if the request is rejected,} \end{cases} \tag{6}$$

where I_{enc} is the new encoding frame interval, I_{ref} is the reference encoding frame interval and

$$\Delta I = \left\lceil \left(\frac{BW_{req}}{BW_{ref}} - 1 \right) \cdot \beta \cdot I_{ref} \right\rceil .$$

Until the next renegotiation, the encoding frame interval can be fixed or adjusted finely to minimize the motion unsmoothness caused by the sudden change of the encoding frame interval when the renegotiation requests are rejected [8]. Now, the target bit budget for the current frame can be determined with the updated channel bandwidth/encoding frame interval by Eq. (7).

$$B_{tar} = BW_{new} \cdot I_{enc} . \tag{7}$$

And it is allocated to macroblocks by TMN8rate control algorithm. Note that the low latency is guaranteed by using TMN8, and by sacrificing the temporal quality unnoticeably (sometimes a little), the spatial quality can be improved.

Finally, we would like to give some comments on spatial and temporal artifacts for encoded video mentioned earlier. Blocking, ringing and texture deviation artifacts are thetypical spatial quality degradations, which can be often observed in low bit rate video. While, the flickering and motion jerkiness are known to be the typical temporal artifacts. The flickering artifact is caused by the fluctuation of spatial quality between adjacent frames, while motion jerkiness is observed when abrupt changes in theencoding frame rate (or interval) occur or when the encoding frame rate goes below a certain threshold. Generally, it is more difficult to measure the temporal artifacts than the spatial artifact. However, it is empirically observed that the flickering effect can be reduced significantly by keeping the spatial image quality of each frame to be almost constant [18]. Therefore, the conventional PSNR (peak signal-to-noise ratio) is employed for the spatial quality measure, and the difference of PSNR values ofadjacent frames is used to measure the flickering artifact in this work.

Ⅲ. EXPERIMENTAL RESULT

In this experiment, the UBC H.263+ [4] source codes and the macroblock layer rate control of TMN8 [7] are used for the implementation of the proposed algorithms. The performance evaluation has been made based on thesubjective as well as the objective tests. Note that the proposed rate control algorithms do not treat I-frames. However, since the H.26L Evaluation Delay Model User Guide recommends that the bit rate for the I-frame must not be greater than one second worth of bit transmission at the assumed channel bit rate, in this experiment, we have encoded the I-frames with QP=15 to meet this condition. We assume the following RCBR management rule.

Simple Resource Management Rules of RCBR network:

1. If networks can accommodate the requested channel bandwidth under the current network situation, the renegotiation request is accepted. Otherwise, the renegotiation request is rejected and the bandwidth is not changed.
2. The renegotiation request is always accepted if the requested bandwidth is less than the current bandwidth.
3. The minimum renegotiating time interval is set to control the signaling overhead.

"Foreman (QCIF)", and "Silent Voice (QCIF)" videos are usedfor this test. The predetermined PSNR range is set to 29 dB to 32 dB for Foreman, and 30 dB to 31 dB for Silent Voice. In this experiment, three minimum renegotiating time intervals of 0, 0.5 and 1 second are examined, and β and μ are set to 0.5 and 0.7, respectively. The experimental results when all

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renegotiation requests are accepted are given in Fig. 1 and 2, and summarized in Table 1 and 2. We can observe that as the renegotiating time interval becomes larger, the occurrence rate that the spatial quality of frames become out of the predetermined PSNR range gets higher although more bits is used and the PSNR fluctuation becomes higher. (See Fig. 1 and 2 and Table 1 and 2.) It means that the encoder cannot use the channel bandwidth efficiently as therenegotiating time interval becomes larger.

The experimental results for the case when the renegotiation requests are rejected are presented in Fig. 3 and 4, and the data is summarized in Table 3 and 4. The performance of the proposed algorithm is compared with that of TMN8 under CBR whose bandwidth is the average value of RCBR. The minimum renegotiating time interval is set to 0.5 sec, and the predetermined PSNR range is kept same as the above, so that the renegotiation requests are rejected when the required bandwidth is greater than 96kbps and 32kbps for Foreman and Silent Voice, respectively. The results show that the proposed algorithm improves the average PSNR as well as reduces the PSNR fluctuation by sacrificing the number of encoded frames.

Ⅳ. CONCLUSION

In this work, we have presented a novel adaptive H.263+ rate control algorithm for the realtime interactive video communication under the network supporting bandwidth renegotiation. The proposed algorithm estimates the required bandwidth based on the instant motion change to reduce the latency. By the experimental results, it is observed that the human visual perceptual quality is kept almost constant when the bandwidth request is accepted, and the degradation can be reduced by adjusting the encoding frame number (or interval) when the request is rejected. The experimental results with real scenes show that the proposed bandwidth renegotiation and adaptive H.263+ rate control algorithms can serve as promising techniques to transmit the non-stationary video traffics over the network. Compared with the conventional TMN8, the proposed algorithms improve the quality of the compressed video significantly in both objective and subjective tests. Furthermore,the relation between the renegotiation minimum interval and the quality of compressed video are examined. The performance analysis including RCBR network efficiency and the amount of control-signaling overhead will be our further research topics.

REFERENCE

[1] T. V. Lakshman, A. Ortega, and A. R. Reibman, "VBR video: Tradeoffs and potentials," Proceeding of the IEEE, Vol. 86, pp. 952-973, May 1998.

[2] M. Grossglauser, S. Srinivasan and D. C. Tse, "RCBR: A simple and efficient service for multiple time-scale traffic," IEEE/ACM Trans. on Networking, Vol. 5, No. 6, pp. 741 755, Dec. 1997.

[3] A. Mohammad, "Using adaptive linear prediction to support real-time VBR video under RCBR Network service model," IEEE/ACM Trans. on Networking, Vol. 6, No. 5, pp. 635 644, Oct. 1998.

[4] ITU-T, Video codec Test model, near-term, version 8 (TMN8), H.263 AdHoc Group, Portland, June 1997.

[5] T. Kim, B. Rho and J. Kim, "Bandwidth renegotiation with traffic smoothing and joint rate control for VBR video over ATM," IEEE Trans. on Circuits and Systems for Video Technology, Vol.10, No.5, Aug 2000.

[6] T. Chiang and Y. Q. Zhang, "A new rate control scheme using quadratic rate distortion model," IEEE Trans. on Circuits and Systems for Video Technology, Vol. 7, pp. 246-250, Sept 1997.

[7] J. Ribas-Corbera and S. Lei, "Rate control in DCT video coding for low-delay video communication," IEEE Trans. on Circuits and Systems for Video Technology, Vol. 9, pp. 172-185, Feb

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1999.

[8] H. Song, J. Kim and C. C. Jay Kuo, "Real-time encoding frame rate adjustment for H.263+ video over the Internet,"Signal Processing: Image Communication, Vol. 15, No. 1-2, pp. 127 148, Sep. 1999.

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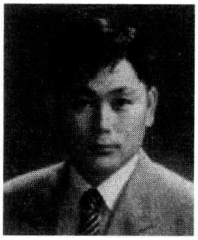

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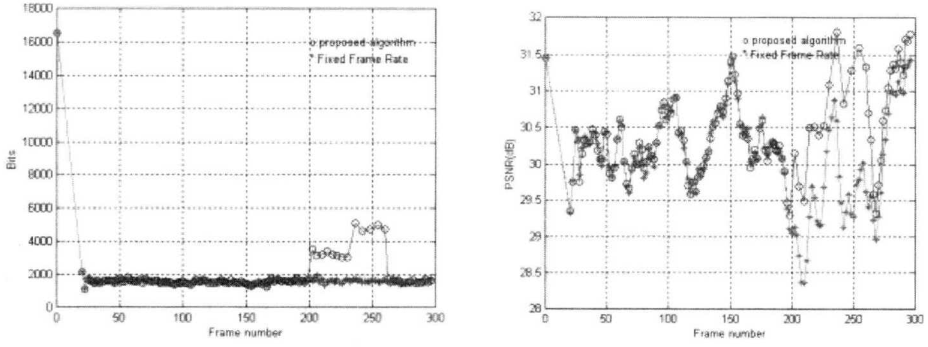
<주관심 분야> Multimedia communication/signal processing, Packet video, Network protocols necessary to implement a functional real-time image/video application.

Table 1. Performance comparison according to the minimum renegotiating time intervals. (Foreman)

Min. Renegotiating Time Interva	No. of Out-of- Range Frames	PSNR (dB)		Average Bits per Frame (kbits)
		Average	STD	
0 sec.	19	30.76	0.958	4.005
0.5 sec.	30	30.90	1.223	4.328
1 sec	28	30.70	1.147	4.154

Table 2. Performance comparison according to the minimum renegotiating time intervals. (Silent Voice)

Min. Renegotiating Time Interva	No. of Out-of- Range Frames	PSNR (dB)		Average Bits per Frame (kbits)
		Average	STD	
0 sec.	22	30.65	0.414	1.771
0.5 sec.	30	30.61	0.486	1.381
1 sec	30	30.67	0.549	1.807



(a) (b)

Fig. 1 Bit-rate and PSNR plots when renegotiations are rejected (Silent Voice). (a) Bit-rate plot and (b) PSNR plot.

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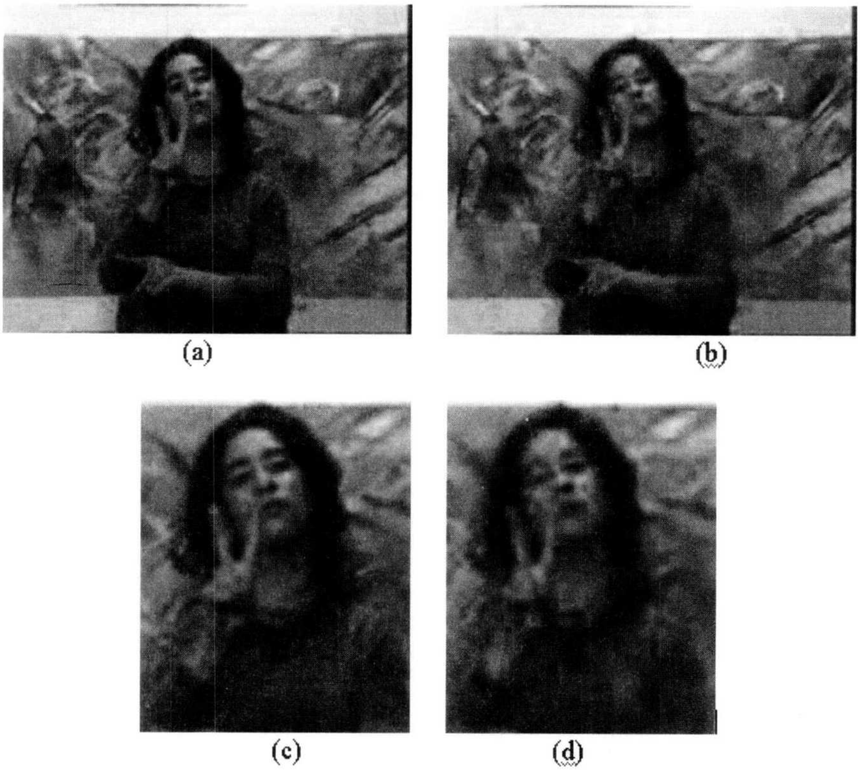

Fig. 2 Visual quality comparison between proposed variable frame rate and fixed frame rate algorithms: (a) Proposed algorithm, (b) fixed frame rate (255thframe), and (c) and (d) are the enlarged face and hand parts of (a) and (b), respectively

Table 3. Performance comparison between the fixed encoding frame interval and the proposed encoding interval adjustment algorithm (Foreman)

Rate Control Method	Average PSNR	STDEV of PSNR	No. of Encoded frms
TMN8 (CBR, 43kbps)	29.24	1.203	141
Proposed Algorithm (Average BW, 43kbps)	30.53	0.951	132

Table 4. Performance comparison between the fixed encoding frame interval and the proposed encoding interval adjustment algorithm (Silent Voice)

Rate Control Method	Average PSNR	STDEV of PSNR	No. of Encoded frms
TMN8 (CBR, 43kbps)	30.19	0.644	89
Proposed Algorithm (Average BW, 43kbps)	30.47	0.488	74

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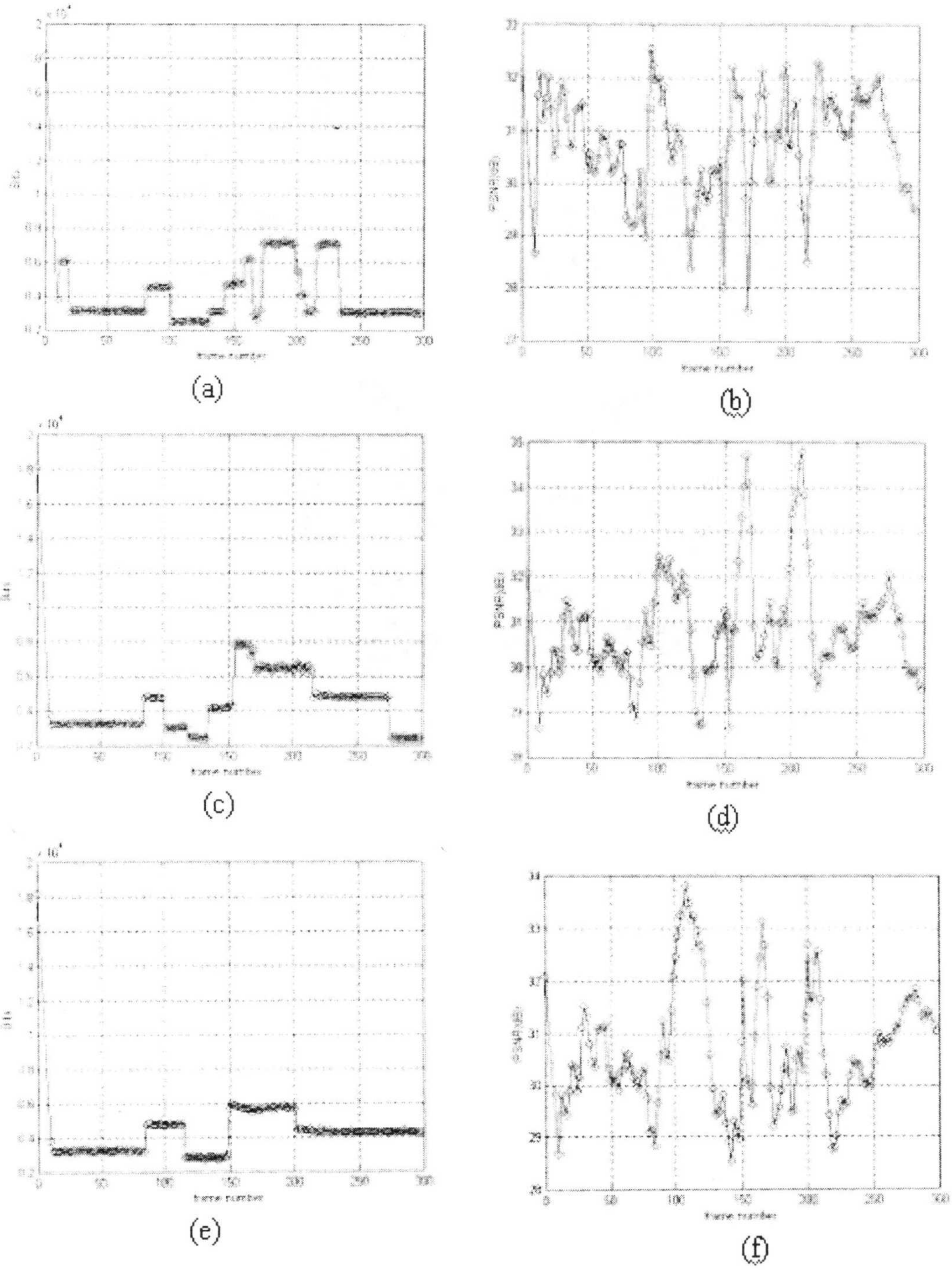

Fig. 3 Bit rate and PSNR plots of Foreman w.r.t. different minimum renegotiating time intervals.
(a) Bit rate plot and (b) PSNR plot when the minimum time interval is 0sec,
(c) Bit rate plot and (d) PSNR plot when the minimum time interval is 0.5sec, and
(e) Bit rate plot and (f) PSNR plot when the minimum time interval is 1sec.

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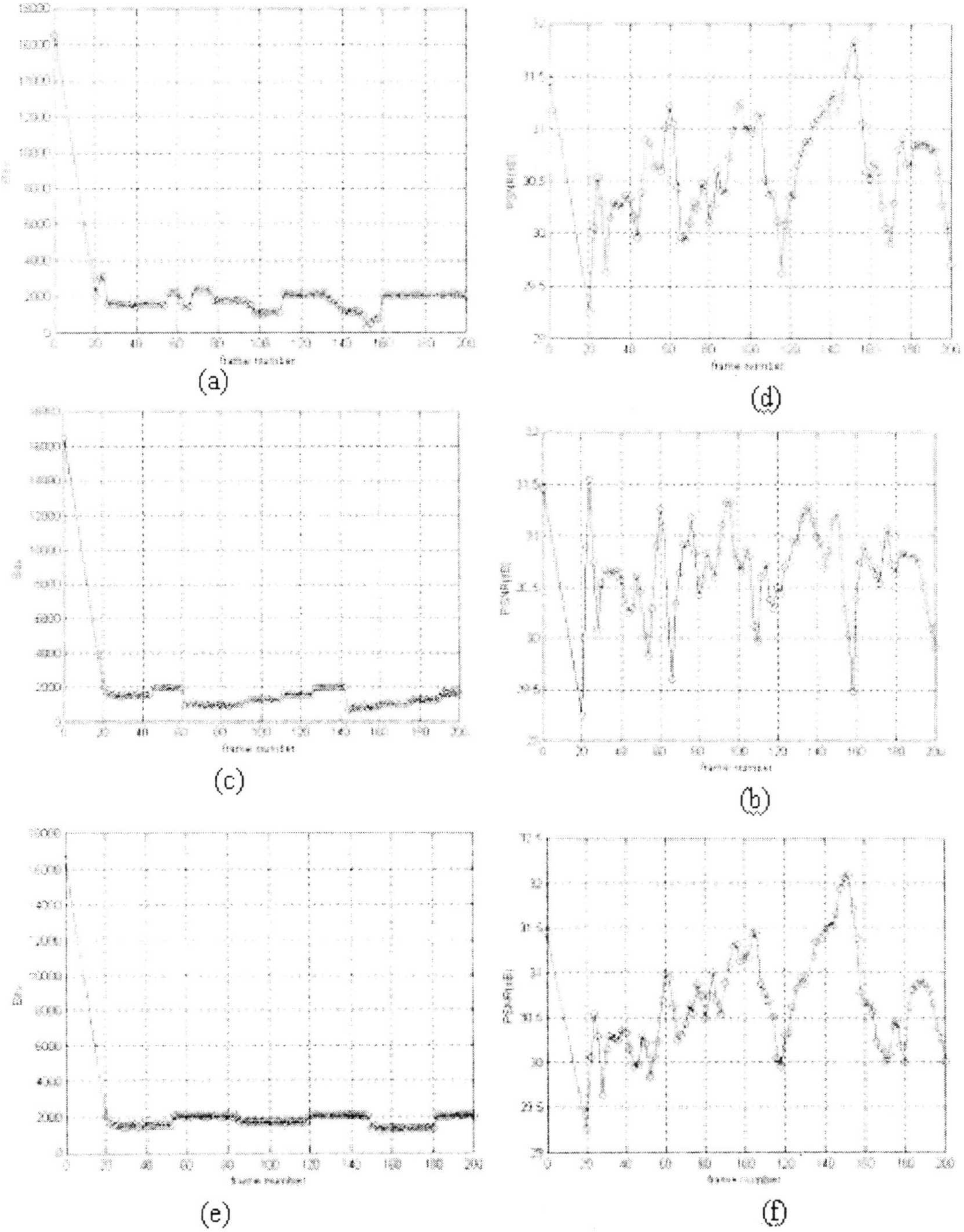

Fig. 4 Bit rate and PSNR plots of Silent Voice w.r.t. different minimum renegotiating time intervals.
(a) Bit rate plot and (b) PSNR plot when the minimum time interval is 0sec,
(c) Bit rate plot and (d) PSNR plot when the minimum time interval is 0.5sec, and
(e) Bit rate plot and (f) PSNR plot when the minimum time interval is 1sec.

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