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# Enhanced H.264/AVC stream switching over varying bandwidth networks

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**Abstract:** This paper proposes an efficient video stream switching scheme among compressed video streams coded at different quality levels and bit rates. The conventional stream switching scheme in H2.64/AVC is effective in switching, but degrades the compression efficiency of the transmitted stream even if the switching operation does not take place. In the proposed scheme, no modification is made to the original compressed streams so the compression efficiency is maintained at switching points. Consequently switching points can be assigned flexibly in our efficient scheme without noticeable bit rate overhead. It is shown by experimental results that the proposed scheme outperforms the conventional switching scheme.

**Keywords:** H.264/AVC, marionette frames, steam switching

**Classification:** Science and engineering for electronics

## References

[1] Advanced Video Coding for Generic Audiovisual Services, ITU-T Rec. H.264 and ISO/IEC 14496-10 (MPEG-4 AVC), ITU-T and ISO/IEC JTC 1, Version 8 (SVC extension), July 2007.

[2] K. Psannis and Y. Ishibashi, "Efficient Flexible Macroblock Ordering Technique," *IEICE Trans. Commun.*, vol. E91-B, no. 08, pp. 2692–2701, Aug. 2008.

[3] M. Karczewicz and R. Kurceren, "The SP- and SI-frames design for H.264/AVC, The SP- and SI-frames design for H.264/AVC," *IEEE Trans. Circuits Syst. Video Technol.*, vol. 13, no. 7, pp. 637–644, 2003.

[4] H.264/AVC Software Coordination, software version: JM 14.0, [online] http://iphome.hhi.de/suehring/tml/

[5] K. Psannis, M. G. Hadjinicolaou, and A. Krikelis, "MPEG-2 streaming of full interactive content," *IEEE Trans. Circuits Syst. Video Technol.*, vol. 16, no. 2, pp. 280–285, 2006.



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## 1 Introduction

For a video streaming system, guaranteed end to end QoS (Quality of Service) over the entire streaming period may be difficult to achieve. For example, the bandwidth available for video streaming may change during the streaming period. To utilize the bandwidth efficiently and avoid congestion caused by the overflow, the outgoing bit rate of the streaming application needs to be adjusted to fit the available bandwidth in real time. The simplest way of achieving bandwidth scalability in the case of pre-encoded sequences is by representing each sequence using multiple and independent streams of different bandwidth and quality. The server then dynamically switches between the streams to accommodate the variations of the bandwidth available to the client.

In the existing video coding standards most video frames in the stream are compressed using motion compensated coding. Directly switching between streams at these inter-coded frames (P or B frames) tends to cause the mismatch of reference frames and results in incorrect reconstruction. The quality of reconstructed video may be degraded significantly [1]. In the prior video encoding standards, perfect (mismatch-free) switching between bitstreams is possible only at frames, which do not use any information prior to their location, i.e., at I-frames. The drawback of using I-frames in these applications is that, since I-frames do not exploit any temporal redundancy, they require much larger number of bits than P-frames at the same quality.

The H.264/AVC standard introduces enhanced error robustness capabilities enabling resilient and reliable transmission of compressed video signals [2]. Moreover H.264/AVC standard introduces new frame types which called primary and secondary SP/SI frames to facilitate steam switching. The main feature of SP-frames is that identical SP-frames can be reconstructed even when different reference frames are used for their prediction. This property allows them to replace I-frames in applications such as switching, random access, and error recovery/resilience. The coding efficiency of the SP-frames is much higher than that of intra-coded frames, but they are still less efficient than normal P-frames. Therefore, the overall coding efficiency is still degraded if many switching points are assigned [3].

On the other hand another method to enable real time bit rate adjustments during the streaming period is the use of scalable video coding. That is, a video source is encoded into different quality levels or layers. During the transmission, the sender can choose not to transmit data in some of the layers to adjust the outgoing bit rate. The method is suitable for streaming over heterogeneous channels, but it degrades the overall compression efficiency and increases the computational complexity of both the encoder and the decoder [1]. Thus, a new stream switching scheme is proposed in H.264 as described in the next section.


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## 2 Proposed Technique

Assume that we have multiple bitstreams generated independently with different encoding parameters, corresponding to the same video sequence. We denote the sequence of bitstream A with the quantization parameter QA and the sequence of bitstream B with the quantization parameter QB as follows.

$$\begin{array}{ccccccccc} I_{A0}^{QA} & \rightarrow & P_{A1}^{QA} & \rightarrow & P_{A2}^{QA} & \rightarrow & \ldots\ldots & \rightarrow & P_{A(N-1)}^{QA} \\ & & \downarrow & & \downarrow & & & & \downarrow \\ & & P_{A1}^{QB}(M) & & P_{A2}^{QB}(M) & & \ldots\ldots & & P_{A(N-1)}^{QB}(M) \\ \\ & & P_{B1}^{QA}(M) & & P_{B2}^{QA}(M) & & \ldots\ldots & & P_{B(N-1)}^{QA}(M) \\ & & \uparrow & & \uparrow & & & & \uparrow \\ I_{B0}^{QB} & \rightarrow & P_{B1}^{QB} & \rightarrow & P_{B2}^{QB} & \rightarrow & \ldots\ldots & \rightarrow & P_{B(N-1)}^{QB} \end{array}$$

$N$ is the distance between I-frames, defining a Group of Pictures (GOP). Note that arrows indicate motion compensation predictions relationships. We propose the use of P(Marionette)- {P(M)-} frames in order to efficiently switch from bitstream A to bitstream B and vice versa. P(M)- frame is not a real frame, instead is a predicted frame which repeats the previous frame, exploiting the motion compensation predictive coding technique between similar frames. It should be emphasized that no modification is made to the original compressed frames at the switching points in the proposed technique. Therefore the switching points can be assigned freely according to the need of applications and networking conditions without any degradation in the coding efficiency. The P(M)-frame encodes the difference between the same video frame and such a difference is almost zero. Actually the P(M)-frame contains codes for not coded Macroblocks and are representing by fixed bit pattern [5]. Hence, it does not require a large number of bits to encode it. Effectively this results in repeating the previous frame in the decoder. As the P(M)-frame is only transmitted when switching occurs, the bit rate overhead introduced by the above very efficient method is very small. Assume that the server initially sends bitstream A up to the third frame $P_{A2}$ after which it starts sending bitstream B. The transmitting sequence for switching from bitstream A to bitstream B will then be

$$I_{A0}^{QA} \rightarrow P_{A1}^{QA} \rightarrow P_{A2}^{QA} \rightarrow P_{A2}^{QB}(M) \rightarrow P_{B3}^{QB} \rightarrow P_{B4}^{QB}$$

It should be noted that, in order to achieve identical reconstruction, the quantization parameter used for the $P_{A2}^{QB}(M)$-frame should be equal to the quantization parameter used for the predicted frame in the bitstream B. Note that the P(M)-frame can only be used for successfully decoding the next frame at the switching point.

In Fig. 1, we present examples illustrating switching between bitstreams using P(M)-frames. Fig. 1 depicts the PSNR profile of bitstream A encoded with QA=19 and bitstream B with QB=13 and two additional bitstreams created by switching between them. In each case, we switch from bitstream A encoded with QA=19 to bitstream B encoded with QB=13 but at different frames, namely at frames number 10 and 20. As can be seen from Fig. 1


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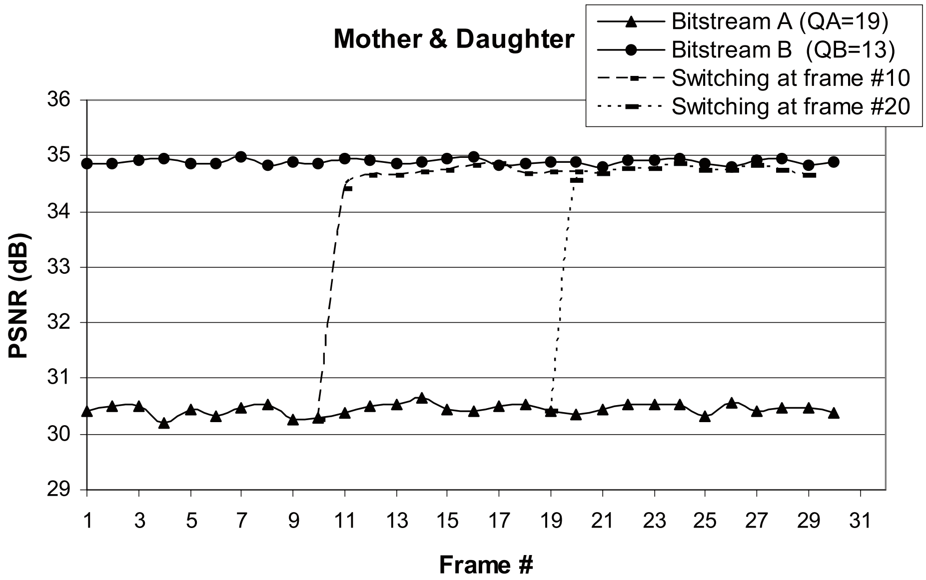


**Fig. 1.** PSNR profile of switching between bitstream 1 and bitstream 2 with P(M)-frames.

the PSNR values of the reconstructed frames are almost identical after the switch diverge at frame number 10 and frame number 20, respectively. Hence the P(M)-frames compensate the mismatch of reference frames between bitstream A and bitstream B.

## 3 Results

We provide simulations results to illustrate the coding efficiency of P(M)-frames. First we compare the coding efficiency of P(M)-frames with SP-frames, I- and P-frames. Simulations were done using the H.264 Test Model [4]. The test video sequence is Mother & Daughter in QCIF format ($176 \times 144$ pixels/frame) and encoded at target frame rate of 15 frames per second (fps). The number of frames to be encoded/decoded is 150 frames.

Fig. 2 gives a comparison of coding efficiency of I-, P-, SP- and P(M)-frames, in terms of their PSNR as a function of bit rate. These results are generated by encoding each frame of a sequence as either an I-, P-, SP-, or P(M)-frames, with the exception of the first frame, which is always an I-frame. It should be noted that the quantization parameter for the primary SP-frame is adjusted so that the overall PSNR of bitstream is close to the original bitstream (set as QA-6). It can be observed in Fig. 2 that P(M)-frames have higher coding efficiency than P- and I-frames respectively. On the other hand, SP-frames have lower coding efficiency than P-frames and higher coding efficiency than I-frames. Note, however, that P(M)-frames provide functionalities that are usually achieved only with I-frames with minimum bit rate overhead.

In the following, we present simulation results when P(M)-, SP- and I-frames are introduced at fixed intervals, as it will be the case when enabling bitstream-switching or random-access functionality. Fig. 3 illustrates the results obtained under the following conditions: the first frame is encoded


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as an I-frame and at fixed intervals, in this case 1 second, the frames are encoded as P(M)-, I- or SP-frames while the remaining frames are encoded as P-frames. Also included in Fig. 3 is the performance achieved when all the frames are encoded as P-frames. Note that in this case, none of the switching functionalities can be obtained while it provides a benchmark for comparison with both P(M)- and SP- cases. As can be seen in Fig. 3, P(M)-frames while providing the same functionalities as I-frames have higher coding efficiency than SP-, and I-frames and almost the same coding efficiency as P-frames.

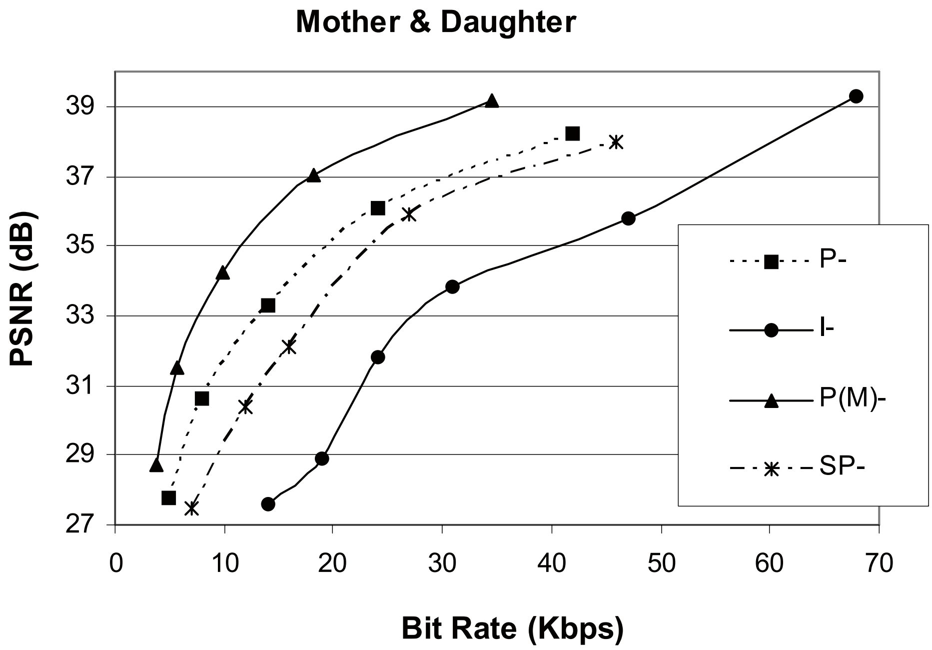


**Fig. 2.** PSNR as a function of Bit Rate.

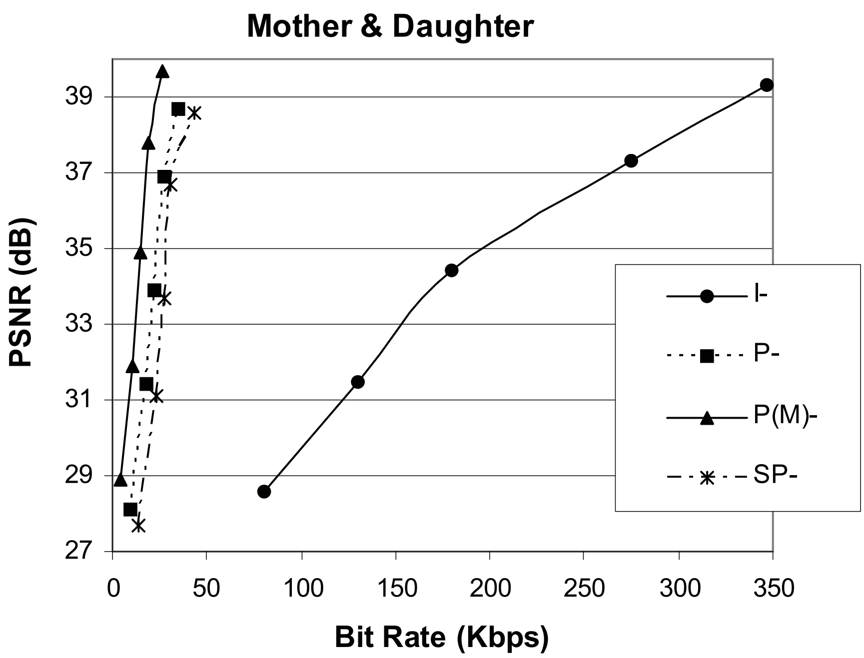


**Fig. 3.** PSNR as a function of Bit Rate.

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## 4 Conclusion

A very efficient stream switching scheme is proposed among compressed video streams coded at different quality levels and bit rates. The proposed very efficient technique does not degrade the coding efficiency of received video when not switching occurs. Therefore switching points can be assigned freely based on application requirements and network conditions. It was shown by the experimental results that a minimum number of overhead bit rate is introduced when switching occurs. A comparative study demonstrated that the proposed technique outperforms the conventional stream switching scheme using primary and secondary SP/SI frames in H2.64/AVC standard. The proposed very efficient technique can be used and integrated into H264/AVC without violating the standard. Hence it can serve as useful extension for H.264/AVC and to any other frame- based encoding standard. Future work involves optimization of the proposed technique for H.264/AVC switching over combined networks from wireline to wireless links. It should be noted that if VCR-like interactive functions [5] were carried out the performance of the proposed technique could be better improved. This is also a potential research direction.


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