ADAPTIVE BITRATE REGULATION FOR SCALABLE VIDEO APPLICATIONS

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H.264/SVC and Rate Control

- H.264 Scalable Video Coding (H.264/SVC)
  - An extension of H.264/AVC standard
  - Provide scalability in temporal, spatial and SNR dimensions
  - Create a video bit stream that is structured in layers
- Rate control (RC)
  - Regulate encoding bitrates to meet network bandwidth while obtaining optimum encoding quality
  - Very crucial in video compression and communication

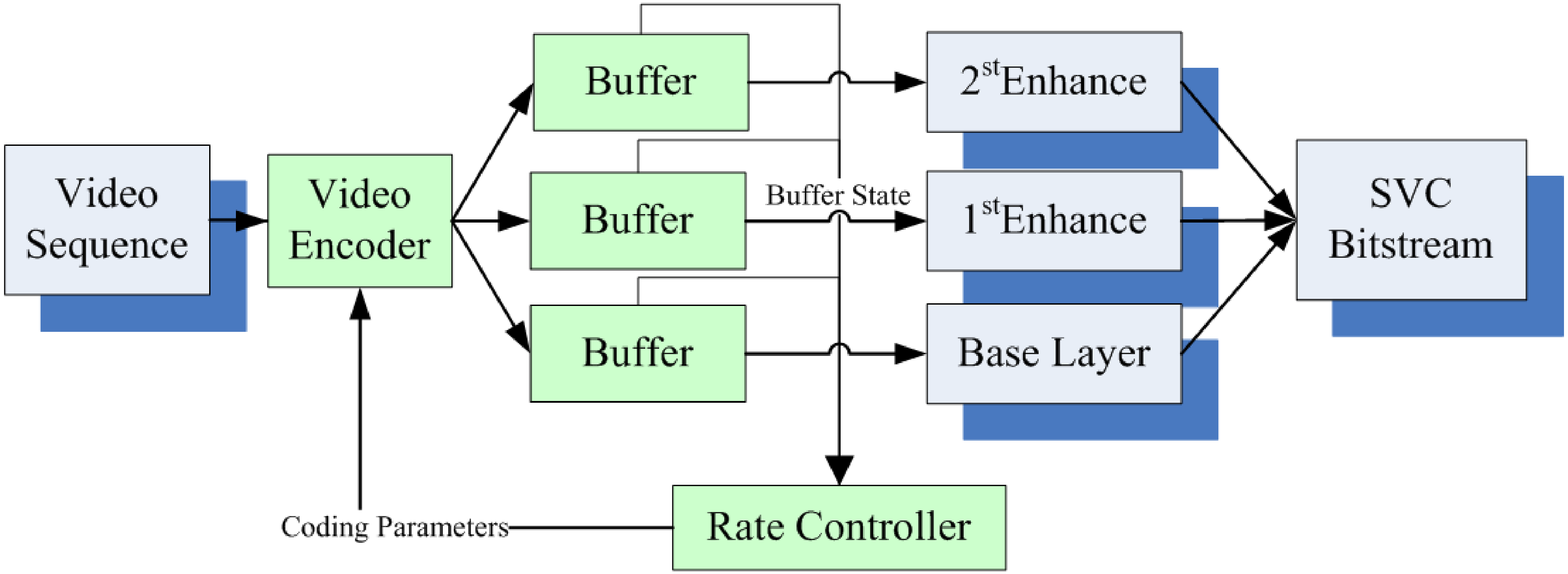
H.264/SVC Rate control (RC)

- Regulate the encoding bitrate of each SVC layer to meet the network bandwidth while obtaining optimum encoding quality
- Related Work
  - Very few RC developed for H.264/SVC
  - Most of them typically apply H.264/AVC RC approaches to each scalable coding layer individually
  - Perform target bit prediction within the same encoding layer
  - Inter-layer prediction has not been considered
- Limitation:
    - When an abrupt change happens, target bit estimation for the current frame only based on its previous frame might not be accurate and effective
    - Might degrade RC performance

THE PROPOSED RESEARCH

- Basic Idea
  - When an abrupt change happens, predict the current frame's target bits from the previous layer might be more accurate as the abrupt change has already been reflected when encoding in the previous layer
- Proposed an Adaptive Inter-layer RC for H.264/SVC
  - Unique features
    - Propose Inter-layer bit estimation
    - Develop a switch model

Adaptive Inter-layer RC – Overall System Structure



ADAPTIVE INTER-LAYER RC – A & B

- A. Rate-Complexity-Quantization (R-C-Q) Model
  - R-C-Q relationship in k^{th} SVC layer [1, 2]

$$R_k = \alpha_k \times e^{-\beta_k \times QP_k}$$

[1] Zhou, Y. Sun, Z. Feng and S. X. Sun, " New rate-distortion modeling and efficient rate control for H.264/AVC video coding," *Signal Processing - Image Communication*, Volume 24, Issue 5, May 2009, pp: 345 -356

[2] J. Yang, **Y. Sun**, Y. Zhou and S. Sun, "Incremental Rate Control for H.264 AVC Scalable Extension," *International Journal of Multimedia Tools and Applications (Springer)*, Vol. 64, Issue 3, pp. 581-598, June 2013

- B. QP Calculation for Intra-frames

$$QP_{intra,k} = \frac{Sum_{PQP}}{N_P} - 1 - \frac{N_{IntraPeriod}}{15}$$

ADAPTIVE INTER-LAYER RC – C

- C. Adopt our proposed Proportional-Integral-Differential (PID) buffer control technique[3]
  - To tune the initial frame bit target for each layer to avoid buffer overflow and/or underflow

$$PID_{t,k} = K_p \times E_{t,k} + K_i \times \sum_{\tau=1}^{t} E_{\tau,k} + K_d \times (E_{t,k} - E_{t-1,k})$$

with $$E_{t,k} = B_{T,t}^{k} - B_{f,t}^{k}$$

[3] **Y. Sun** and I. Ahmad, "A Robust and Adaptive Rate Control Algorithm for Object-Based Video Coding," *IEEE Transactions on Circuits and Systems for Video Technology*, VOL.14, No. 10, Oct. 2004, pp.1167 – 1182

  - Obtain the bit increment for the current frame relative to its previous frame by:

$$\Delta R_{k,1} = PID_{t,k} - PID_{t-1,k}$$

Adaptive Inter-layer RC – D

- D. Switched Inter-Layer Bit Estimation
  - PID buffer controller:
    - Effectively predicts current frame's target bits according to its previous frame's info, on the same layer
    - Limitation: when abrupt change happens, it might not work good
  - Solution: Inter-layer Bit Prediction
    - Predict current frame's target bits from the previous layer
  - Inter-layer bit estimation: calculate the current frame's bit increment based on its previous layer by:

$$\Delta R_{k,2} = \frac{R_{t,k-1} - R_{t-1,k-1}}{R_{t-1,k-1}} \times R_{t-1,k}$$

Adaptive Inter-layer RC – D (cont'd)

- D. Switched Inter-Layer Bit Estimation (Cont'd)
  - Inter-layer bit estimation:
    - Useful for abrupt changes of video sequence
    - Might not work efficiently when no obvious changes
  - Switching Model: to predict the frame target bits either from the current layer or from the previous layer

$$\textit{if } sign(\Delta R_{k,2}) = sign(\Delta R_{k,1}) \textit{ and } |\Delta R_{k,2}| > |\Delta R_{k,1}| \textit{ then}$$

$$\Delta R_{\text{inter,k}} = \Delta R_{k,2}$$

$$\textit{else}$$

$$\Delta R_{\text{inter,k}} = \Delta R_{k,1}$$

$$\textit{endif}$$

Adaptive Inter-layer RC – E & F

- E. Incremental QP Calculation for Inter-frames
  - After the bit increment is obtained, calculate QP by using our previous proposed method:

$$QP_{Inter,t}^{k} = QP_{Inter,t-1}^{k} - \frac{1}{R^{k}_{Inter,t-1} \times \beta_{Inter,k}} \times \Delta R_{Inter,k}$$

[2] J. Yang, **Y. Sun**, Y. Zhou and S. Sun, "Incremental Rate Control for H.264 AVC Scalable Extension," *International Journal of Multimedia Tools and Applications (Springer)*, Vol. 64, Issue 3, pp. 581-598, June 2013

- F: Encoding and Post-Encoding Process
  - Use QP to encode the current frame
  - Do related process after encoding

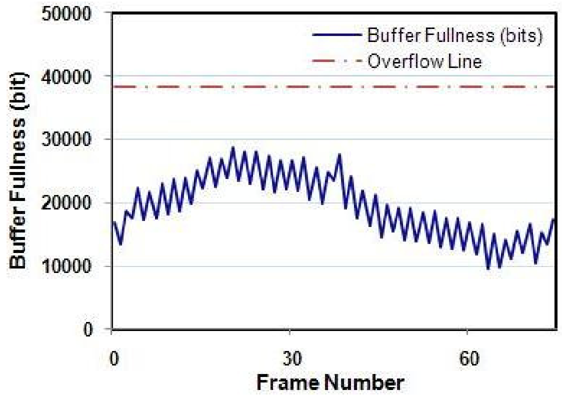
OVERALL PERFORMANCE COMPARISONS FOR BASIC LAYER RC

Seq. (CIF)	Alg.	Bit Rate (Kbps)		Skip Fr.	PSNR (dB)	ΔPSNR (dB)
		Target	Actual			
Akiyo	W043	256	259.90	0	44.03	0
	Proposed	256	258.13	0	44.62	0.59
	Fixed QP	256	253.83	-	44.95	0.92
Bus	W043	512	552.84	7	30.65	0
	Proposed	512	511.51	0	31.90	1.25
	Fixed QP	512	537.144	-	32.18	1.52
Foreman	W043	1024	1090.67	5	40.56	0
	Proposed	1024	1028.31	0	41.68	1.12
	Fixed QP	1024	1026.20	-	41.62	1.06
Flower	W043	2048	2238.10	11	36.32	0
	Proposed	2048	2044.40	0	39.18	2.86
	Fixed QP	2048	2041.86	-	39.25	2.93

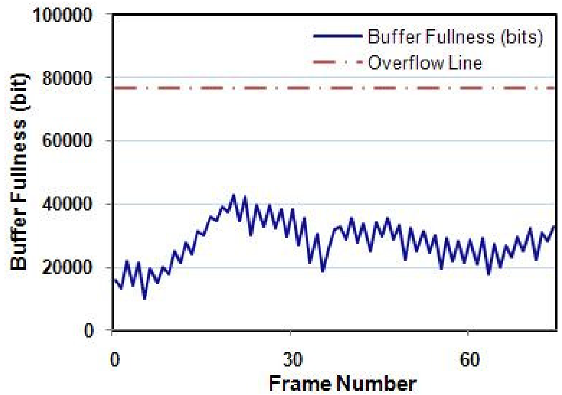
Overall Performance Comparison – Multilayer RC

Seq.	Layer	Targt Bitrate (Kbps)	Fixed QP			Proposed			ΔPSNR (dB)
			Actual Bitrate (Kbps)	PSNR (dB)	Iter.	Actual Bitrate (Kbps)	PSNR (dB)	Skip Frame	
CoastGuard	0	96	93.46	33.35	14	97.52	33.24	0	-0.11
	1	192	184.99	37.54	17	195.28	37.51	0	-0.04
	2	512	493.12	32.75	20	515.10	32.82	0	0.07
Bus	0	128	128.41	32.40	3	129.79	32.22	0	-0.18
	1	256	242.97	38.58	20	258.91	38.62	0	0.04
	2	1024	1022.73	35.78	6	1029.77	35.82	0	0.04
Husky	0	64	65.49	23.57	20	65.48	23.60	0	0.03
	1	128	123.33	27.34	20	131.12	27.44	0	0.10
	2	256	252.41	20.35	16	260.45	20.37	0	0.02

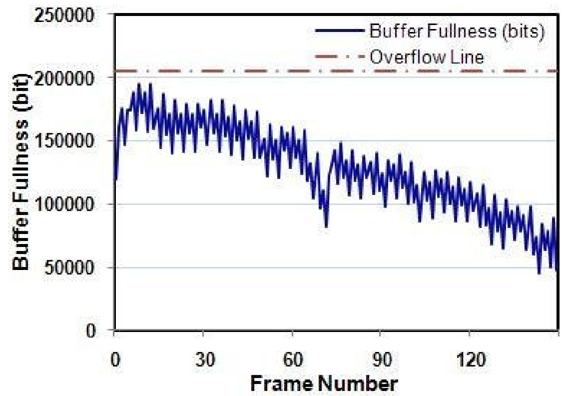
PERFORMANCE COMPARISON – MULTILAYER RC



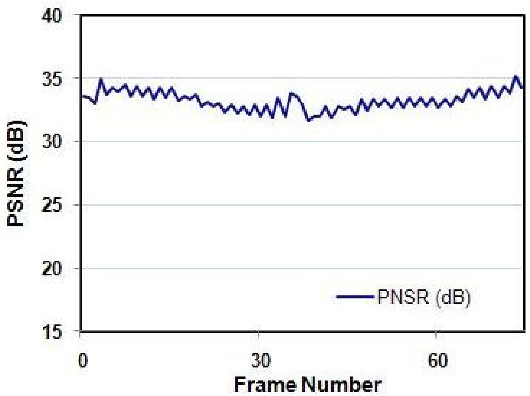
(a) Layer 0 Buffer Fullness (96k)



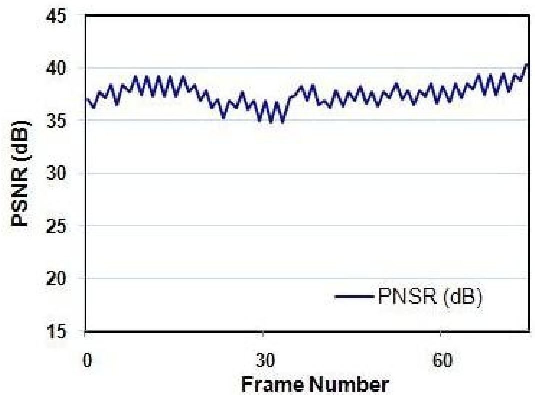
(b) Layer 1 Buffer Fullness (192k)



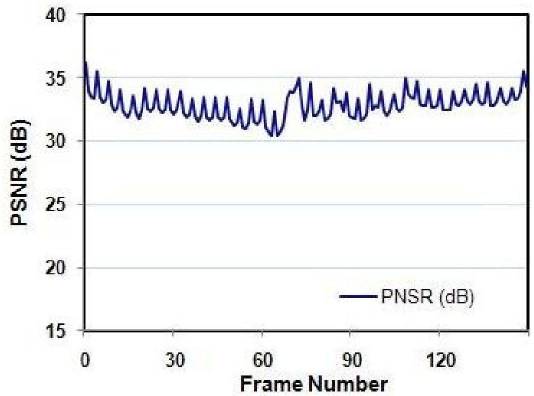
(c) Layer 2 Buffer Fullness (512K)



(d) Layer 0 PSNR (96k)



(e) Layer 1 PSNR (192k)



(f) Layer 2 PSNR (512K)

Coastguard

CONCLUSION

- Proposed an Adaptive Inter-Layer Rate Control Algorithm for H.264/SVC
  - Propose Inter-layer bit estimation
  - Develop a switch model to predict bits either from the current layer or from the previous layer
  - Increase the accuracy of bit estimation and rate control
- Experimental Results
  - Achieve accurate rate regulation
  - Maintains stable buffer fullness
  - Reduces frame skipping and PSNR fluctuation
  - Improve overall coding quality
- Acknowledgment

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