Modeling and Optimization of a Systematic Lossy Error Protection System Based on H.264/AVC Redundant Slices

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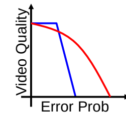
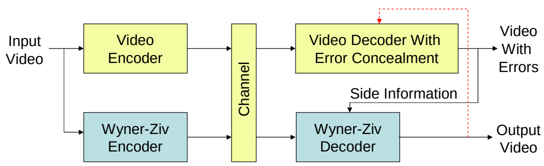
FEC vs. **Systematic Lossy Error Protection (SLEP)**



FEC:
- Error resilience by supplementary parity bit stream
- Lossless protection of video bit stream
- Trade-off between:
  - source bit rate
  - parity bit rate
- Severe error cliff

SLEP:
- Error resilience by supplementary Wyner-Ziv bit stream
- Lossy protection of video waveform
- Trade-off between:
  - source bit rate
  - Wyner-Ziv bit rate
  - Loss in Wyner-Ziv decoding
- Graceful degradation

Systematic Lossy Error Protection (SLEP)

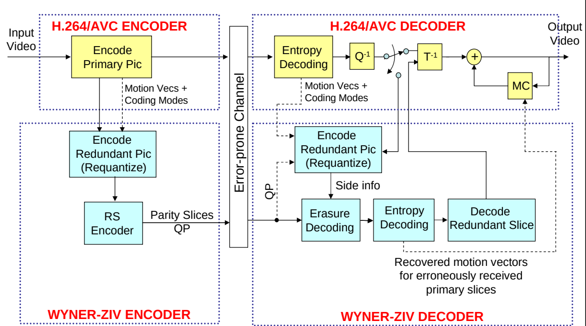


- Analogous to systematic lossy source/channel coding *[Shamai, Verdú, Zamir, 1998]*
- Wyner-Ziv coding by applying Reed-Solomon codes across H.264/AVC redundant slices *[Rane, Baccichet, Girod, 19th JVT mtg, Geneva 2006]*

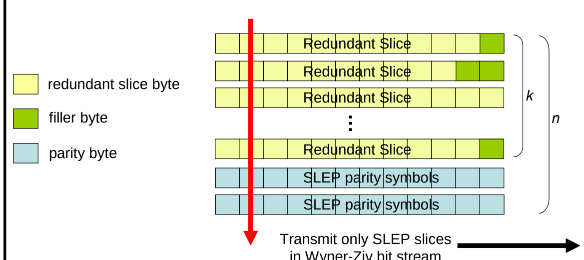
Outline

- SLEP implementation using H.264/AVC redundant slices
- Model for end-to-end rate-distortion performance
- Resilience vs. quality trade-off in SLEP

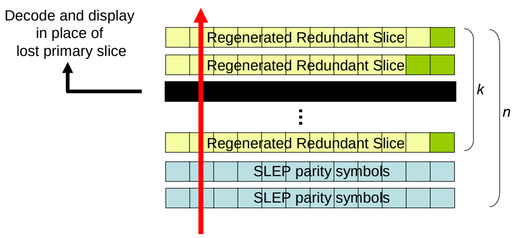
SLEP Using Redundant Slices

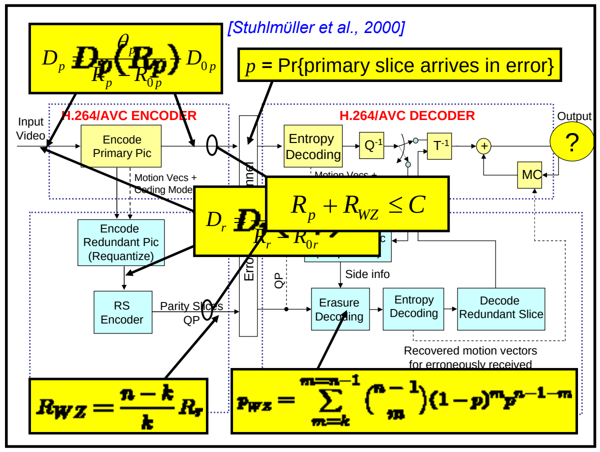


RS Encoding Across Redundant Slices



RS Decoding Across Redundant Slices





Distortion in Received Video Packet

After taking expectations of pixel-wise squared errors,

Error propagation from previous frame

$$D[i] = (1-p)D[i-1]$$

Quantization mismatch from Wyner-Ziv decoding

$$+ p \cdot p_{WZ}(D[i-1] + D_r - D_p)$$

Error concealment distortion

$$+ p \cdot p_{EC}(D[i-1] + \text{MSE}[i, i-1])$$

Model Vs. Experimental Simulation

Foreman.CIF
100 frames

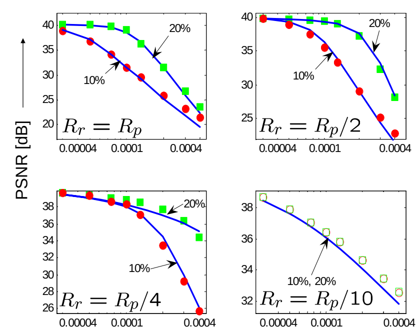
R_p = 1 Mbps
R_{WZ}=100 kbps, 200 kbps

I-P-P-P…

Previous frame error concealment

Random symbol errors

PSNR avg. over 30 traces



Systematic bit rate 408 kbps, WZ bit rate ~ 40 kbps
Symbol error probability = 5 x 10^{-4}

Error-free
35.7 dB
QP=28

SLEP with redundant QP = 48
28.9 dB

Resilience vs. Quality Trade-Off in SLEP

For a packet loss probability p_e

- Bit rate of the "best" redundant description:

$$R_r = \min\left((C - R_p)\frac{1-p_e}{p_e}, R_p\right)$$

- Quality loss due to best redundant description:

$$\Delta = p_e \frac{N+1}{2}(D_r - D_p)$$

Conclusions

- SLEP achieves graceful trade-off between error resilience and video quality, and mitigates FEC cliff
- Quality loss from WZ decoding modeled as function of quantization mismatch and extent of error propagation

Backup (1): Optimization of a SLEP System

For maximum packet loss probability p_e, find bit rates for encoding the primary and redundant slices, i.e., R_p, and R_r, that maximize output picture quality.

Let $R^{\dagger}_{FEC}, D^{\dagger}_{FEC}$ be the source coding bit rate and distortion for the optimal FEC scheme.

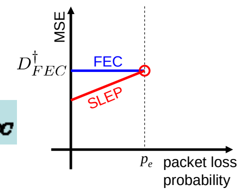
Maximize R_p

subject to

$$R_p + \frac{p_e}{1-p_e} R_r \leq C$$

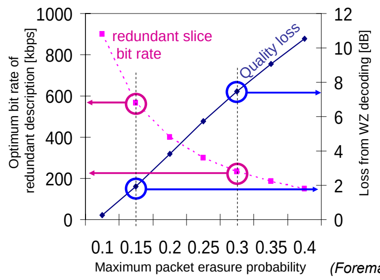
$$D_p + \frac{N+1}{2} p_e (D_r - D_p) = D^{\dagger}_{FEC}$$

$$0 \leq R_r \leq R^{\dagger}_{FEC} \leq R_p \leq C$$



Backup (2): Resilience vs. Quality Trade-Off

$$\mathcal{D} = \frac{1}{N} \sum_{i=1}^{N} D[i] = D_p + \frac{N+1}{2} p(D_r - D_p)$$



(*Foreman.CIF* @ 1 Mbps)