

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

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### FEC

### Systematic Lossy Error Protection (SLEP)

- ❑ Error resilience by supplementary parity bit stream
- ❑ Error resilience by supplementary Wyner-Ziv bit stream
- ❑ Lossless protection of video bit stream
- ❑ Lossy protection of video waveform
- ❑ Trade-off between:
  - source bit rate
  - parity bit rate
- ❑ Trade-off between:
  - source bit rate
  - Wyner-Ziv bit rate
  - Loss in Wyner-Ziv decoding
- ❑ Severe error cliff
- ❑ Graceful degradation

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### 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]

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### Outline

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

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### SLEP Using Redundant Slices

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### RS Encoding Across Redundant Slices

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### RS Decoding Across Redundant Slices

Decode and display in place of lost primary slice

$n$

$k$

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[Stuhlmüller et al., 2000]

$p = \Pr\{\text{primary slice arrives in error}\}$

Input Video

H.264/AVC ENCODER

Encode Primary Pic

Motion Vectors + Coding Model

Entropy Decoding

$Q^{-1}$

$T^{-1}$

Output

H.264/AVC DECODER

Entropy Decoding

$Q^{-1}$

$T^{-1}$

MC

Encode Redundant Pic (Requantize)

Motion Vectors + Coding Model

Side info

Entropy Decoding

Decode Redundant Slice

Recovered motion vectors for erroneously received

RS Encoder

Parity Slices

Erasure Decoder

Side info

Entropy Decoding

Decode Redundant Slice

Recovered motion vectors for erroneously received

$R_p + R_{WZ} \leq C$

$D_r$

$D_p$

$D_{op}$

$R_{WZ} = \frac{n-k}{k} R_r$

$P_{WZ} = \sum_{m=k}^{n-1} \binom{n-1}{m} (1-p)^m p^{n-1-m}$

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### 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

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

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### Model Vs. Experimental Simulation

Foreman.CIF  
100 frames  
 $R_p = 1$  Mbps  
 $R_{WZ} = 100$  kbps, 200 kbps

I-P-P-P...

PSNR [dB]

Symbol Error Probability

$R_r = R_p$

$R_r = R_p/2$

$R_r = R_p/4$

$R_r = R_p/10$

PSNR avg. over 30 traces

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

Error-free  
35.7 dB  
QP=28

SLEP with redundant description  
30.9 dB  
QP=28

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### 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:

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

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## 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  $R_{FEC}^\dagger, D_{FEC}^\dagger$  be the source coding bit rate and distortion for the optimal FEC scheme.

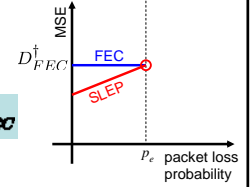
**Maximize**  $R_p$

**subject to**

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

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

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



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

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

