Systematic Lossy Forward Error Protection for Error-Resilient Digital Video Broadcasting

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Limitations of traditional error-resilience methods

- FEC ("cliff" effect)
- Layered Coding with Priority Encoding Transmission (PET) (Inferior R-D Performance) [Albanese et al., 1996]

Outline

- Systematic source-channel coding framework
- Lossy Forward Error Protection using Wyner-Ziv coding
- Results and Conclusions

Wyner-Ziv coding background

- Side-info at encoder and decoder:
  \[
  X \xrightarrow{\text{encoder}} X' \xrightarrow{\text{decoder}} Y, \quad R_{X,Y}(D) \leq R_X(D)
  \]
- Side-info at decoder only: [Wyner and Ziv, 1975-76]
  \[
  X \xrightarrow{\text{encoder}} \quad Y \xrightarrow{\text{decoder}} X', \quad R_{X,Y}(D) \leq R_{X,X'}^W(D) \leq R_X(D)
  \]
  Can achieve bit-rate savings due to correlation between X and Y.

Systematic Source-Channel Coding

- Enhancing analog transmission systems using digital side information [Pradhan and Ramchandran, 2001]
- Robust predictive coding [Sehgal and Ahuja, 2003]
- Lossy source-channel coding of video waveforms [Aaron, Rane and Girod, 2003]

Systematic lossy forward error protection

- Systematic source-channel coding
- "Lossy" protection
- Fully backward compatible with legacy systems
**Fallback Scheme for error-resilience**

- Fallback when errors occur

**Proposed Wyner-Ziv codec**

- Transmit only parity symbols

**Reed-Solomon codes across slices**

- Transmit along this direction

**Simulation setup**

- **Codecs:**
  - Main Codec → H.26L (JM2.0) codec
  - WZ Codec → H.26L codec and R-S codec.

- **Settings:**
  - 1 Slice = 11 macroblocks = 1/2 GOB for CIF frame
  - Identical slice structure for main and WZ stream

**Results (1) Foreman.CIF**

- Main stream @ 1.092 Mbps
  - FEC (n,k) = (40,36)
  - FEC bitrate = 120 Kbps
  - Total = 1.2 Mbps

- Main stream @ 1.092 Mbps
  - Coarse stream @ 270 Kbps
  - FEP (n,k) = (52,36)
  - WZ bitrate = 120 Kbps
  - Total = 1.2 Mbps

**Results (2) Visual Comparison**

- Foreman 50 CIF frames @ symbol error rate = $4 \times 10^{-4}$
  - With FEC: 1.092 Mbps + 120 kbps (38.32 dB)
  - With FEP: 1.092 Mbps + 120 kbps (38.78 dB)
Results (3) Visual Comparison

Foreman 50 CIF frames @ symbol error rate = 10^{-3}

With FEC
1.092 Mbps + 120 kbps
(33.03 dB)

With FEP
1.092 Mbps + 120 kbps
(38.40 dB)

Results (2) Coastguard.CIF

Main stream @ 3.175 Mbps
FEC (n,k) = (40,36)
FEC bitrate = 352.78 kbps
Total = 3.5 Mbps

Main stream @ 3.175 Mbps
Coarse stream @ 1 Mbps
FEP (n,k) = (44,36)
WZ bitrate = 220 Kbps
Total = 3.4 Mbps

Main stream @ 3.175 Mbps
Coarse stream @ 658 Kbps
FEP (n,k) = (48,36)
WZ bitrate = 220 Kbps
Total = 3.4 Mbps

Ongoing Work : Embedded WZ codec

MPEG Encoder
Wyner-Ziv Encoder A
Wyner-Ziv Encoder B
MPEG Decoder with Error Concealment
Wyner-Ziv Decoder A
Wyner-Ziv Decoder B
S
S'
S''

Conclusions

- Systematic lossy forward error protection scheme for error-resilient digital video broadcasting
- Outperforms conventional FEC schemes, when SER increases
- Fully backward compatible with legacy broadcast systems
- Can construct embedded Wyner-Ziv codec which achieves graceful degradation without layered representation.

Graceful degradation of video quality
Does not require layered representation of original video signal