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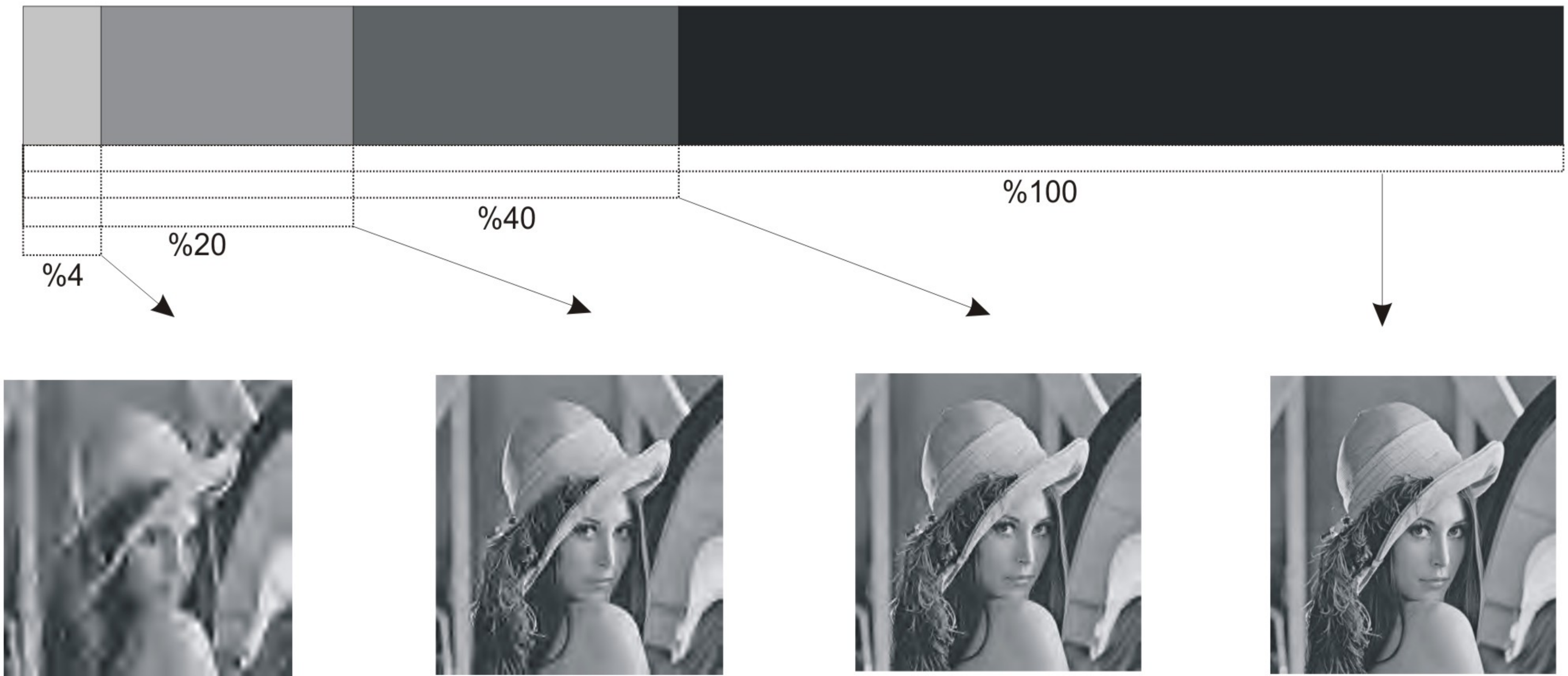
Concatenated Block Codes for Unequal Error Protection of Embedded Bit Streams

Suayb S. Arslan, Pamela C. Cosman and Laurence B. Milstein,
ECE, UC San Diego, La Jolla, CA

Embedded bit streams and progressive reconstruction
- Introduction

Embedded bit stream



0.01bpp, PSNR=22.55dB | 0.05bpp, PSNR=27.17dB | 0.1bpp, PSNR=29.81dB | 0.25bpp, PSNR=33.7dB

- Unequal Error Protection (UEP) is achieved by channel coding.

Progressive source compression
- Error propagation

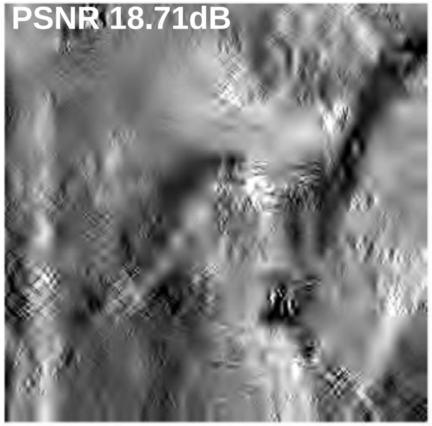
Lena Image

0.25bpp=65536bits.

Single bit is in error

a)

Decode all 65536bits



1500th bit position

Truncated

Just use 1499 bits

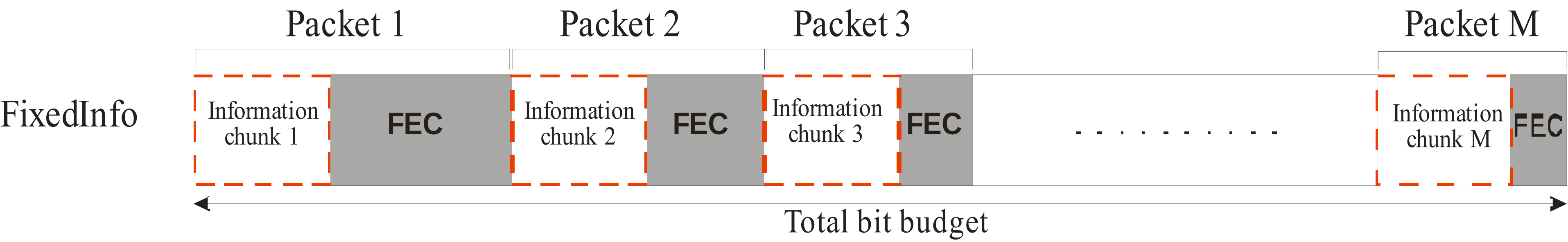
b)

20000th bit position

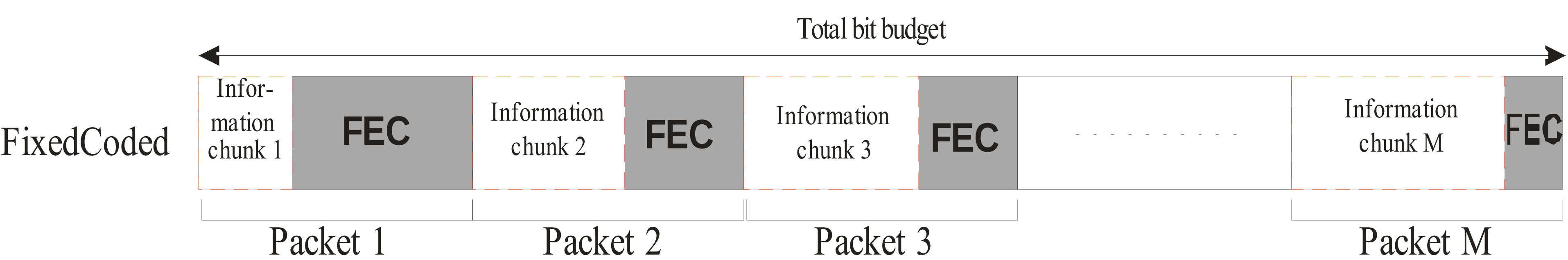
Just use 19999 bits

Previous work on FEC based Progressive source coding

- Forward Error Correction (FEC) is deployed in two major ways:

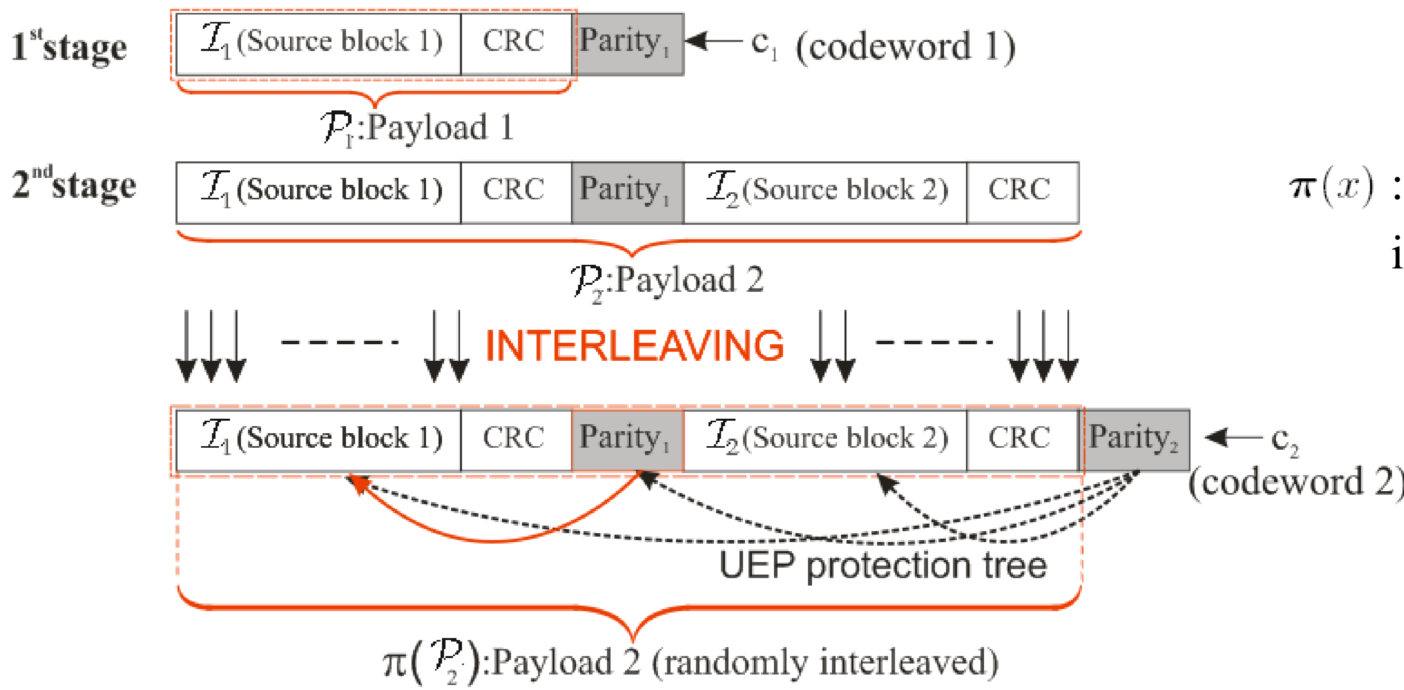


- Size of information chunks are equal.



- Size of packets are equal.

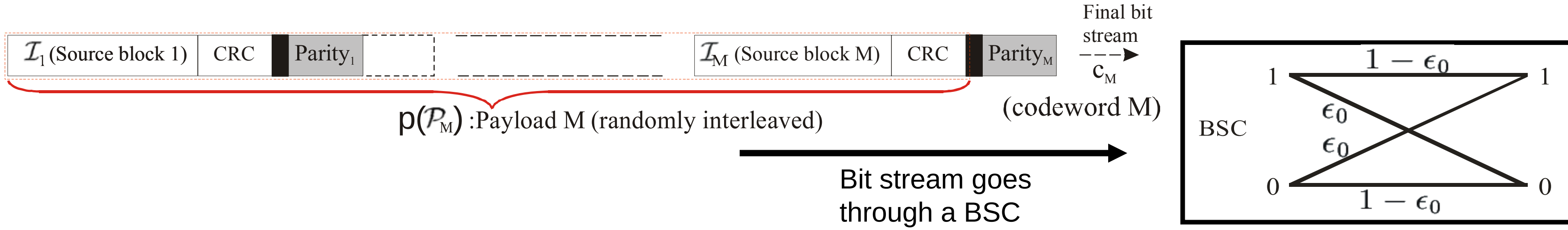
Concatenated Coding for Embedded Bit Streams
- *Proposed Coding Structure and UEP*



$\pi(x)$: random block interleaver.

- Proposed scheme consists of *M* stages.
- CRC: Cyclic Redundancy Check code for error detection.
- Decoding is done in the reverse order.
- Based on the CRC checks, each information chunk is determined to be useful or not. Only the information chunks up to the first chunk with a CRC failure are used to reconstruct the source.

Concatenated Coding for Embedded Bit Streams
- Proposed Coding Structure and UEP



- Code rates are chosen from a finite code set $\mathcal{C}$. This set has limited number of code rates in it.
- Using concatenated coding, we can virtually enlarge the size of the set.
- Example: Consider *M*=2, use RCPC code set:

$$\mathcal{C} = \{ 8/12, 8/16, 8/22, 8/26 \}.$$

Code rates / Error probability	**8/12**	**8/16**	**8/22**	**(8/12, 8/16)**	**8/26**
$\varepsilon_0 = 0.06$	1.2×10^{-1}	8×10^{-3}	1×10^{-4}	4.3×10^{-5}	1.3×10^{-5}
$\varepsilon_0 = 0.07$	1.7×10^{-1}	1.8×10^{-2}	3.2×10^{-4}	9×10^{-4}	4.1×10^{-5}

Decoded bit error rate.

Concatenated Coding for Embedded Bit Streams
- Optimization

- Define $\mathcal{R} = \{r_1, \ldots, r_M\}, \mathcal{B} = \{b_1, \ldots, b_M\}$ where $r_i \in \mathcal{C}$
  - r_1 protects the first information chunk, r_2 protects the first and the second information chunk, etc…
  - b_1 is the number of information bits in the *source block 1*, b_2 is the number of information bits in the *source block 2*, etc…
- Optimization criterion: **Minimization of expected distortion**.
- Optimize M and the set $\{\mathcal{B}, \mathcal{R}\} = \{b_1, b_2, \ldots, b_M, r_1, r_2, \ldots, r_M\}$ subject to a total bit budget *B*.
- Iterative descent search to find optimal source block sizes.
- A <u>constrained</u> exhaustive search to find optimal code rates and *M** (optimal *M)*.

Numerical results
- Simulation parameters

- RCPC and RC-LDPC code sets:

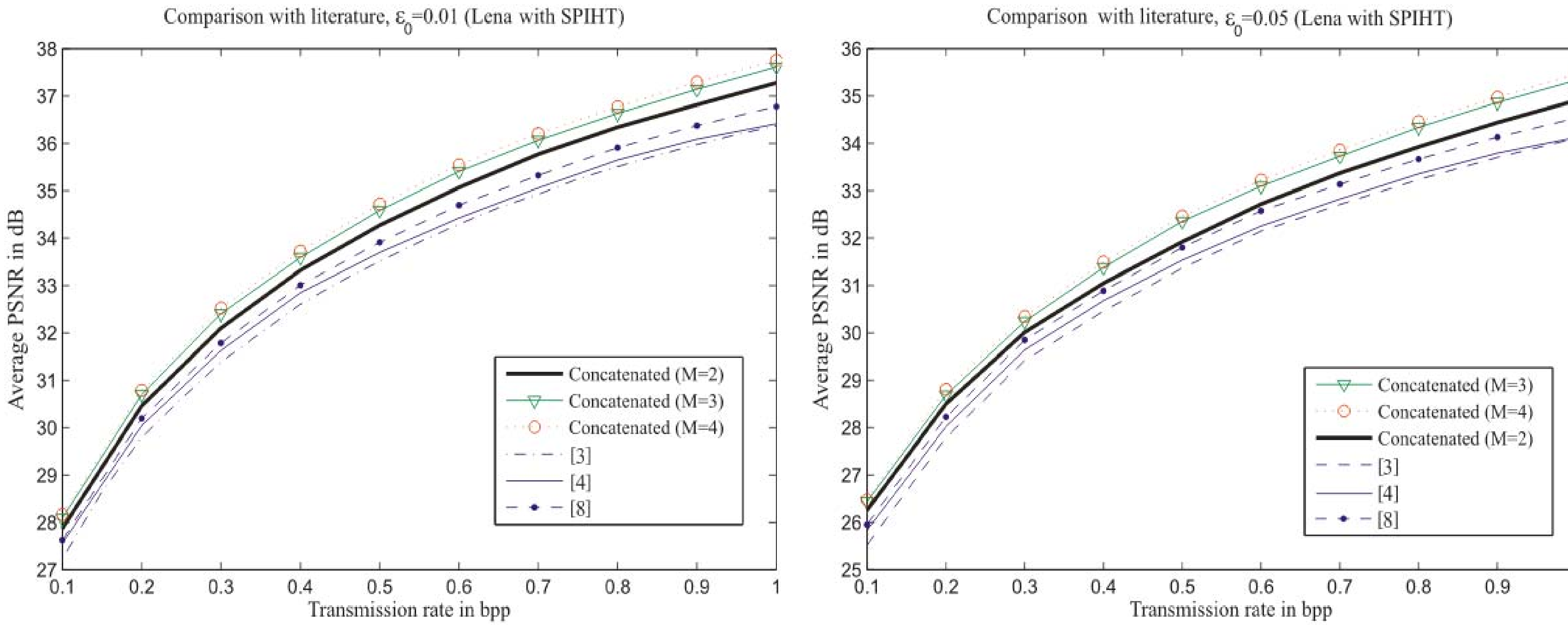
$$C_{RCPC} = \{8/9, 8/10, 8/12, 8/14, 8/16, 8/18, 8/20, 8/22, 8/24, 8/26, 8/28, 8/30, 8/32\}$$

$$C_{RC-LDPC} = \{8/10, 8/11, 8/12, 8/13, 8/15, 8/16, 8/18, 8/20, 8/22\}$$

- Embedded bit stream: Three 512×512 images encoded with *SPIHT* and *JPEG2000* progressive image coders.
- Decoders: Viterbi Algorithm (VA) / List Viterbi Algorithm (LVA) / Max-Product Algorithm.
- Channel: BSCs with crossover probabilities 0.01, 0.03, 0.05, 0.08 and 0.1.
- Packet size: Variable. Transmission rate: Variable.
- Random block interleaver.

Numerical results using RCPC
- *Performance comparisons with VA* **[Lena with SPIHT]**

- **[3]**: *FixedInfo* with informations blocks of size 200bits. Single optimal code for each packet (EEP).
- **[4]**: *FixedCoded* with information blocks of size 202bits. Optimal code per packet.
- **[8]**: Serial coding is achieved by **[3].** The packets are also coded vertically with RS codes. [two dimensional code].
- **Concatenated**: Proposed scheme using RCPC code set.



- *In summary:* **Concatenated** gives more than 1dB PSNR improvement over **[3]** and 0.5dB PSNR improvement over **[8]** in all the simulations carried out with VA. Similar gains are obtained using LVA.

Numerical results using LDPC

- *Performance comparisons with Max-Product Algorithm* [Lena with JPEG2000]

- *ConRCPC*: Proposed scheme using the RCPC code set.
- *ConLDPC*: Proposed scheme using the RC-LDPC code set.
  - [5] uses Rate Compatible Turbo Codes (RCTC).
  - [7] uses Irregular Repeat and Accumulate (IRA) codes.
  - [9] uses Rate Compatible LDPC codes.

Lena @ r_{tr} = 0.5 bpp	ε_0	
Systems	***0.03***	***0.1***
ConRCPC	33.1	30.4
ConLDPC	35.7	34.1
RC-LDPC **[9]**	35.4	33.3
IRA **[7]**	35.4	33.1
RCTC **[5]**	35.1	32.7

Lena @ r_{tr} = 1 bpp	ε_0	
Systems	***0.03***	***0.1***
ConRCPC	36.2	33.4
ConLDPC	38.8	37.1
RC-LDPC **[9]**	38.3	36.2
IRA **[7]**	38.2	36.0
RCTC **[5]**	37.7	35.8

Conclusions

- A robust concatenated block coding mechanism is proposed for embedded bit streams.
- Enlarges the given finite code set by providing more protection levels than is possible using the code rate set directly.
- Flexible information block size adjustment, concatenated block coding and random block interleavers.
- The proposed coding scheme outperfoms published results for BSCs.

References

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