Graceful Degradation over Packet Erasure Channels through Forward Error Correction

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Motivation

We want to transmit images over packet erasure networks with no feedback channel.

- UDP-based transport on the Internet.
- Cell loss in ATM networks.

Our Approach

Use a state-of-the-art image coder.

- Don't modify the image coder.

Use a powerful channel code to protect the image from packet loss.

- Add controlled redundancy.

Adapt the strength of the channel code to the data.

- Account for the "value" of the data.
- Use an estimate of channel conditions.

Overview

Background and Framework.

- Progressive Image Compression.
- Reed-Solomon Channel Codes.
- Packet Loss.
- Unequal Loss Protection.

Design of Assignment Algorithm.

Results of Redundancy Assignment.

Conclusion and Future Work.

Progressive Image Transmission

A progressive image coder outputs a coarse approximation and then repeatedly refines it.

- Automatically sorts the output according to its "value."
- Important information appears early in the compressed sequence.
- A higher image fidelity results from decoding longer sequences of coder output.

Reed-Solomon Channel Codes

Systematic (N, k) Reed-Solomon codes:

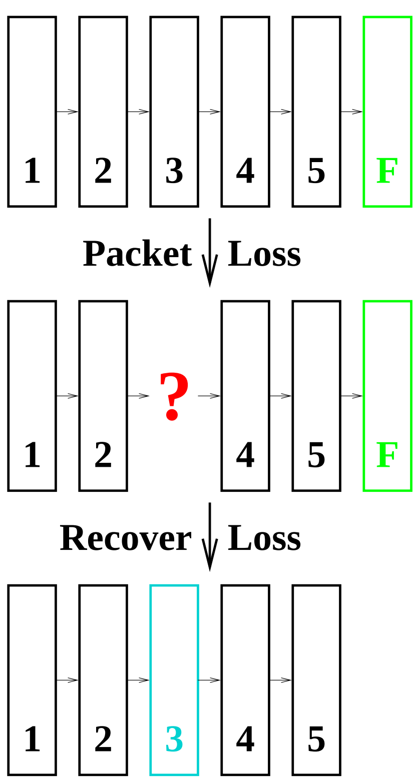
- Input k source symbols.
- Output $N-k$ FEC symbols.
- N symbols total.

The receiver can decode the k source symbols from *any* size-k subset of the N symbols.

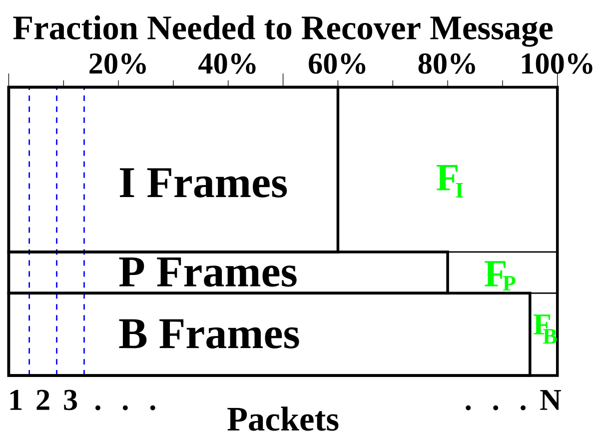
Example: a (10,7) Reed-Solomon code.

- Generate 3 FEC symbols to add to the 7 source symbols.
- Transmit the 10 symbols.
- If any 7 of those 10 symbols arrive, the 7 original source symbols can be recovered.

Recovery from Packet Loss

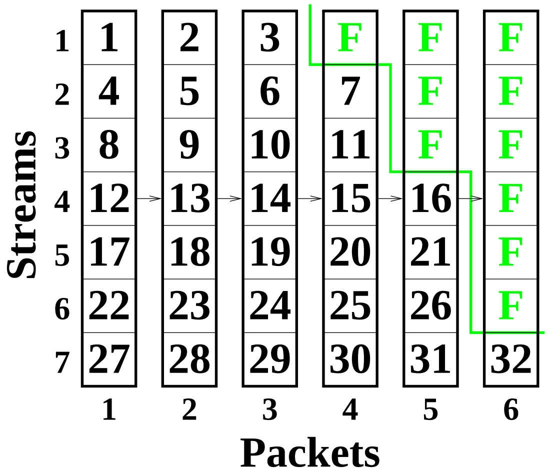


Priority Encoding Transmission (Albanese, Bloemer, Edmonds, Luby, Sudan) (1994)



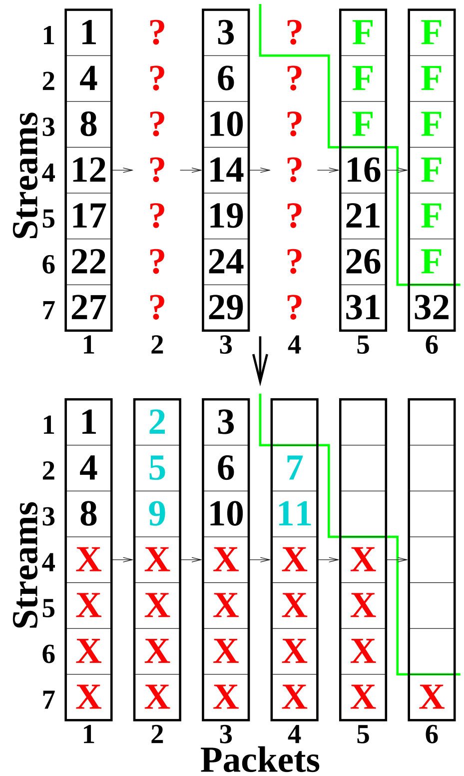
- Each frame group and its FEC occupy a fixed position in each packet.

Unequal Loss Protection



Each row is an independent Reed-Solomon code. Fill in the data cells with the output of the progressive image coder.

Loss of Two Packets



Overview

Background and Framework.

Design of Assignment Algorithm.

- Possibilities and Goals.
- The Algorithm.

Results of Redundancy Assignment.

Conclusion and Future Work.

Algorithm Possibilities

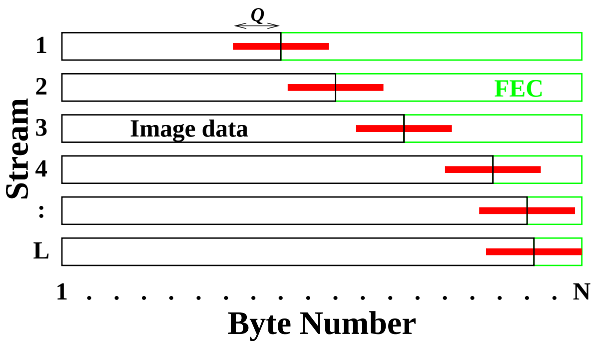
What are the possibilities?

- Computing all permutations is intractable.
- Use a local-search approach with successive refinement.

What is the expected "value" of a byte?

- The product of that byte's "value" and the probability that it can be decoded.

Brief Algorithm Overview

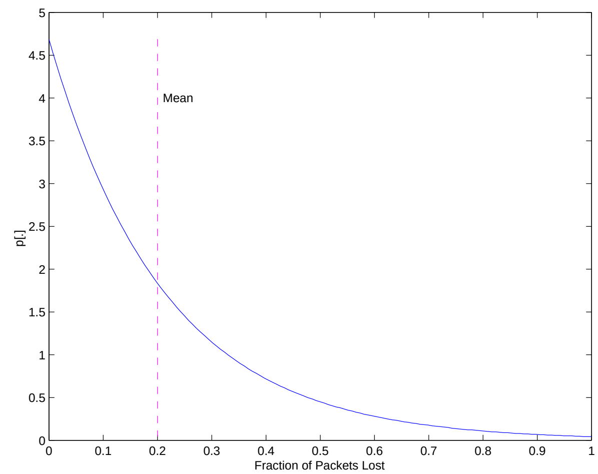


Start with an estimate.

Perform a local-search for a better allocation.

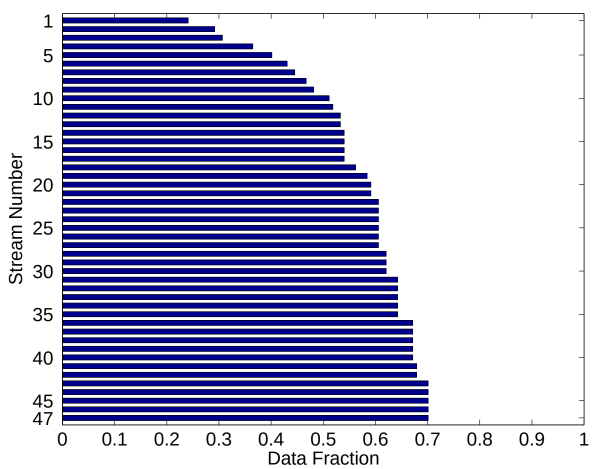
If one is found, update the allocation and iterate.

Model of Channel Properties



Exponential decay with a mean packet loss rate of 20%.

Redundancy Assignment



Bars represent the amount of source data in each stream.

The blank region represents the amount of FEC in each stream.

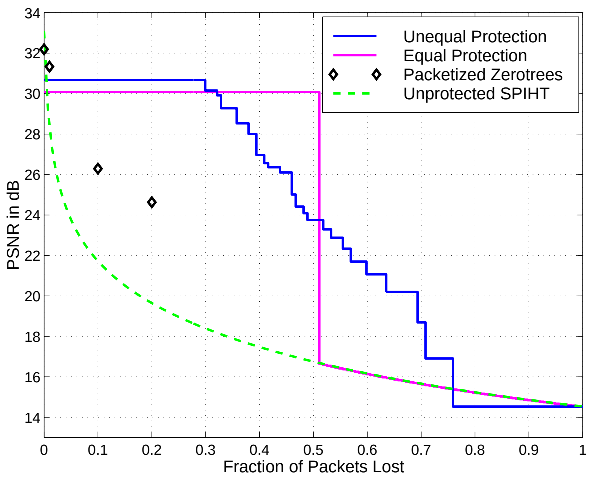
Example Images of Lena

Lena at 0.2 bpp total rate, transmitted in 137 packets, each of size 47 bytes. FEC allocation is for unequal loss protection of 20% mean exponential loss rate.

Loss rates are 30% and 40%.

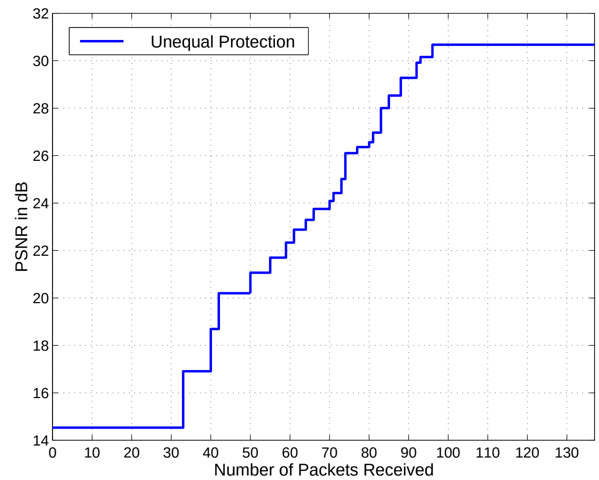
Loss rates are 50% and 60%.

PSNR Plot for Lena



Lena at 0.2 bpp total rate, transmitted in 137 packets, each of size 47 bytes. Packetized Zerotree Wavelet results are from Rogers and Cosman.

"Progressive" with Packets



Alternatively, the algorithm results in a system that is progressive with respect to the number of packets received.

Conclusion

These results lead to three conclusions:

- FEC can be used to provide graceful degradation of image quality.
- This algorithm can optimize for a quality measure by considering the value of each byte of source coder output and an estimate of channel conditions.
- Unequal loss protection provides both a higher PSNR under good channel conditions and a higher expected PSNR overall, compared with equal loss protection.

Future Work

We anticipate some possibilities for future work:

- Examine successive approximation.
- Apply to the generalized Multiple Description problem. (Submitted to ICIP)
- Consider schemes that do not use explicit channel codes.
- isdl.ee.washington.edu/dcl/amohr/dcc99/