Photo-to-Grandma Problem: Compression Meets the Network

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Photo-to-Grandma Problem

- Send digital photograph to Italy
- Can use FedEx or regular postal channel
  - FedEx 99% reliable
  - Postal 80% reliable
- Only allowed one item (CD, zip, floppy) per envelope
- Trade-off cost/quality/reliability

Grandma Has Internet

- cost cheap (except for ISP charges)
- quality perfect
- reliability perfect

$cheap
(ISP)

No Internet

- Grandma has zip drive and/or CD-ROM, no Internet
- I have a zip drive and/or a CD/DVD burner
- FedEx channel
  - cost $39.99 expensive
  - quality perfect
  - reliability 99% almost perfect

$39.99

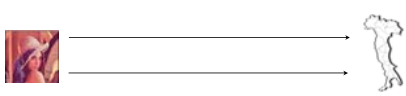
No Internet

- Grandma has zip drive and/or CD/DVD-ROM, no Internet
- I have a zip drive and/or a CD/DVD burner
- Postal channel
  - cost $3.40 cheap
  - quality perfect
  - reliability 80% not extremely reliable

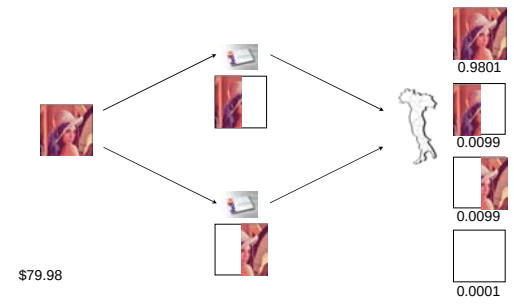
$3.40

Photo-to-Grandma Problem

- Grandma has no zip drive nor CD-ROM, no Internet
- Floppy: have to use two

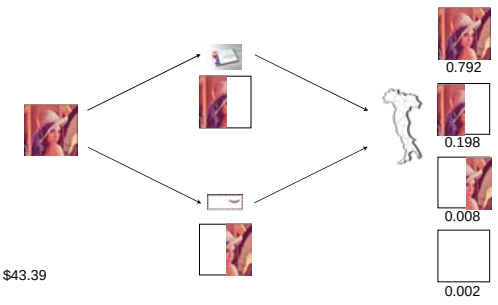


Parallel FedEx Channel



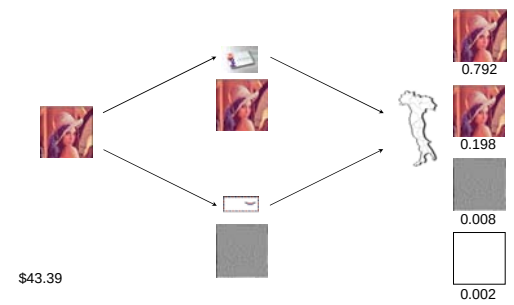
$79.98

Heterogeneous Channel (dumb way)



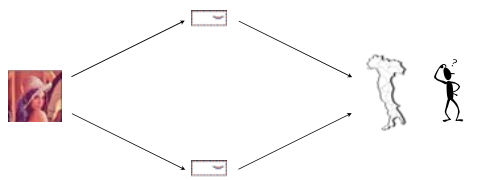
$43.39

Heterogeneous Channel (smart way) MR



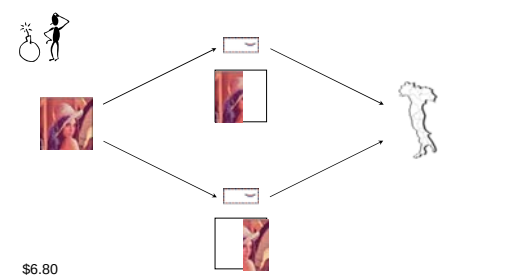
$43.39

US/Italian Postal Channel



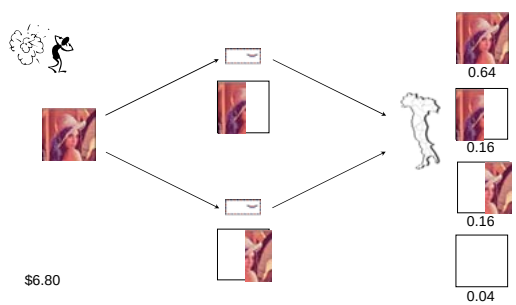
$6.80

US/Italian Postal Channel



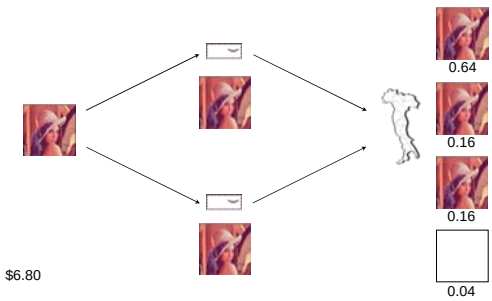
$6.80

US/Italian Postal Channel



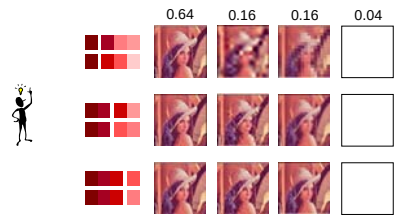
$6.80

US/Italian Postal Channel



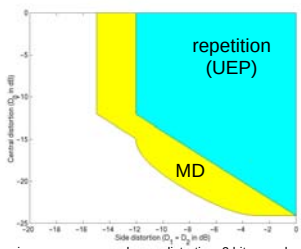
Variable Repetition (UEP)

- Progressive source code MR
- Some amount of coarse (high-priority) data is repeated



Are Sophisticated Methods Useful?

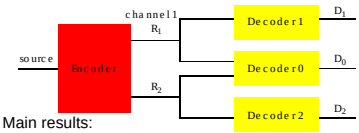
- Variable repetition significantly suboptimal



- Gaussian source, squared error distortion, 2 bits per channel, idealized

Information Theoretic Formulation

- Source described in two streams at rates R_1 and R_2
- Three decoders with distortions D_0, D_1, D_2



- Main results:
  [Berger, Cover, El Gamal, Ozarow, Witsenhausen, Wolf, Wyner, Ziv, '79-'82]
- Generalization to more channels: Venkataramani (2000)
- channels ↔ descriptions ↔ envelopes ↔ packets

Applicability of MD

Signal must be useful in degraded form

When reliable transport is "expensive"
- Retransmission not possible
- Retransmission takes too much time
- Power constraint forces high uncoded loss rate
- Effective channel coding takes too much time

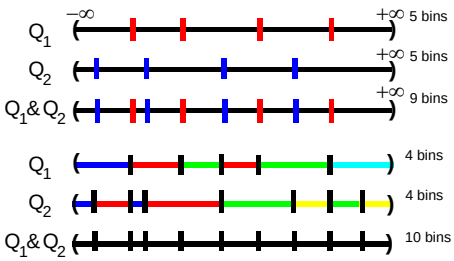
Examples
- Internet -- interactive applications
- Multi-hop multi-route wireless
- Bluetooth
- IBOC (digital radio)

Practical Techniques

- MD scalar quantization (MDSQ)
  [Vaishampayan, 1993]
- **MD correlating transforms (MDCT)**
  [Orchard, Wang, Vaishampayan & Reibman, 1997]
  [Goyal & Kovacevic, 1998]
- **Quantized frame expansions for MD (QFE)**
  [Goyal, Kovacevic & Vetterli, 1998]
  [Goyal, Kovacevic & Kelner, 2000]
- **MD vector quantization (MDVQ)**
  [Fleming & Effros, 1999]
- **MD lattice vector quantization (MDLVQ)**
  [Servetto, Vaishampayan & Sloane, 1999]
  [Kelner, Goyal & Kovacevic, 2000]

MDSQ

- Pioneered by [Vaishampayan, 1993]



MDLVQ Example

Description 1: 'c'

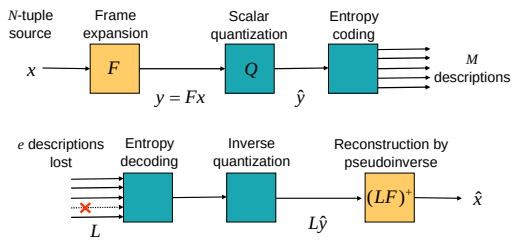
Description 2: 'a'

MDLVQ

- We look for a lattice, geometrically similar sublattice and an injective map
  [Servetto, Vaishampayan & Sloane, 1999]
- We define a new distance depending on the probability of loss
- Further improvement: we fix the sublattice and move the points of the fine lattice

Loss probability 0 | Loss probability 0.4 | Loss probability 0.4

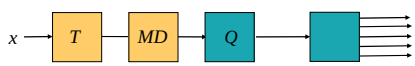
Quantized Frame Expansions



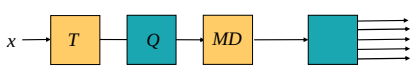
L : operator representation of losses (I_M with e rows deleted)

MDCT

- Correlate back the decorrelated data



- Usually, T and MD are orthogonal
- If we want biorthogonal MD
  - integer-to-integer MD



Demonstrations

Audio coding with correlating transforms

- With R. Arean
- Modified Bell Labs' PAC (perceptual audio coder)
  - Original coder: approx. uncorrelated transform coeff.
  - Modification:
    - generate correlated transform coefficient pairs
    - send elements of a pair in different descriptions

Loss %	SD PAC (20kbps)	MD PAC (26kbps)
0		
50		

Demonstrations

Speech coding with MDSQ

- With F. Masson
- Frequency-hopping cordless phone
  - Original coder: adaptive linear prediction (like G.726)
  - Modification: use MDSQ of prediction errors
  - Current product: usable up to 3/25 lost packets
  - Modified: similar quality for 6/25 lost packets
    - bandwidth increase not prohibitive

Losses	Original (32 kbps)	MD (40 kbps)	MD (48 kbps)
1/25			
3/25			
6/25			

Demonstrations

Audio coding with MDLVQ

- With F. Masson
- Built coder using psychoacoustic prefilter
  (Schuller & Edler, 1999)
  - MSE in filtered domain ↔ perceptual quality
  - quantizing at threshold removes "irrelevance"
  - lossless compression then removes "redundancy"
- Simulation:
  - with no losses, perceptually lossless
  - with losses, better quality than UEP-based coder

Comments

- Degradable data over lossy links
  - don't code for a lossless link
  - choose component appropriately
- MD does not require independent channels
  - description can go over correlated channels
  - they can use the same physical channel twice
- MD is not channel coding
  - not dedicated to low probability of error of discrete data
- MD is not regular source coding
  - does not produce a single stream
- Is MD joint source-channel coding?
  - can be a component of a JSCC

Directions For Research

- Complex problem of efficient communication of data
  - quality (distortion)
  - cost (bits, …)
  - reliability
- Develop a toolbox containing techniques for different combinations of parameters
  - MR (for reliable links)
  - MD (for unreliable links)
- More details on MD (some links restricted):
  http://andrew.cmu.edu/user/jelenak/index.html > Interests > MD