PET
Priority Encoding Transmission

Coping with lossy Packet-based networks

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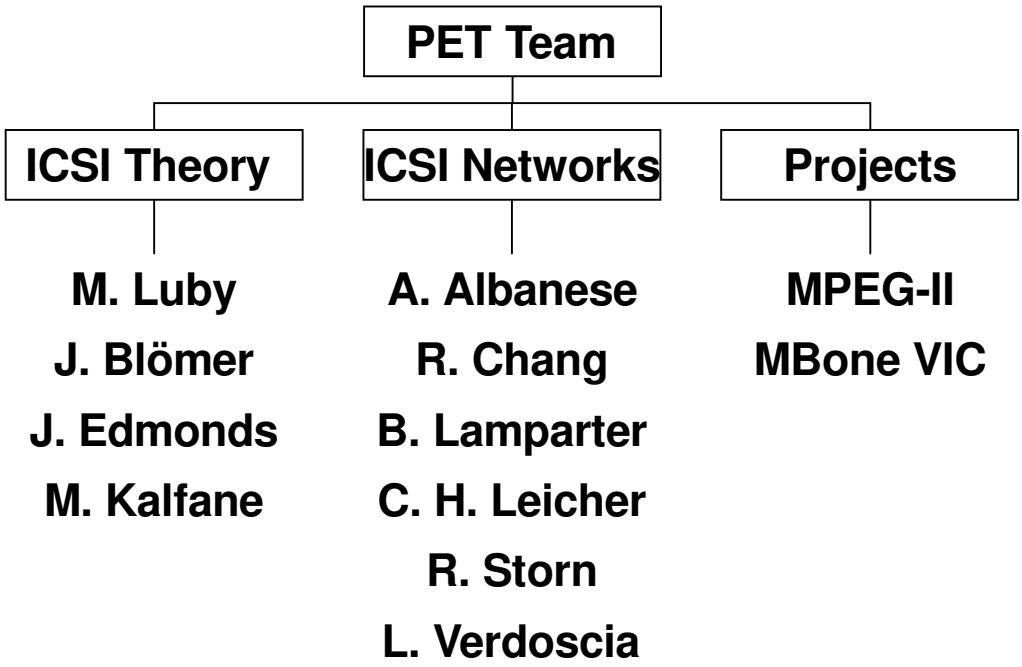
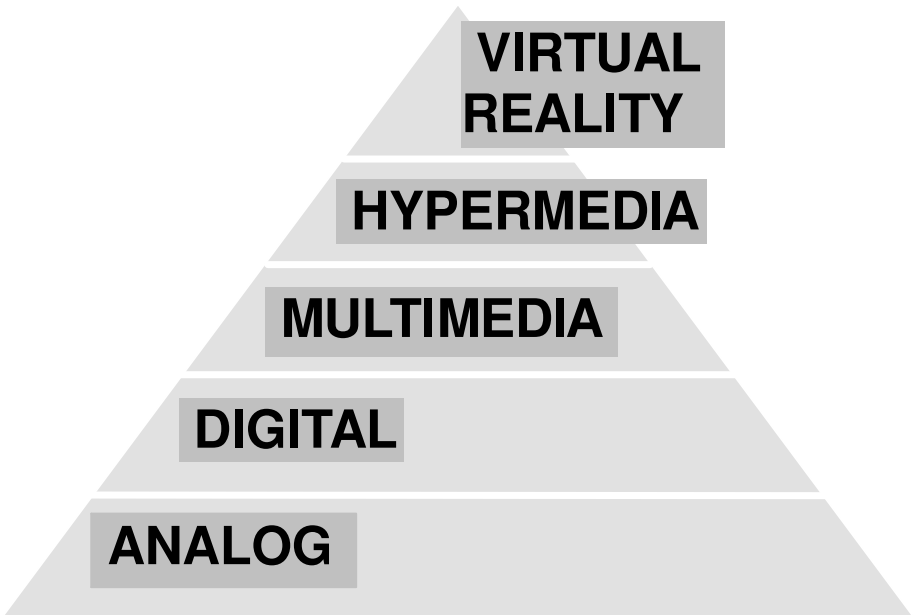
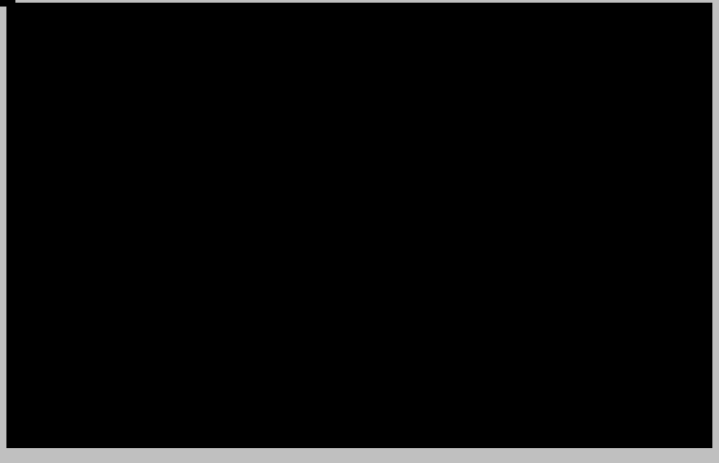
Coping with Variable Loss in Bursty Packet Networks



Information Media Evolution



Video Conferencing



Video on Demand

Computer Mediated Communication Applications

- Virtual Communities
- Browsing
- Navigation
- Collaboration
- Distance learning
- Telemedicine
- Telecommuting
- Commerce
- Entertainment

Application Requirements

- **Wide Area Network Interfaces (Global Interoperability)**
- **Scaleability (Heterogeneity)**
- **Multicast (Groups)**
- **Realtime (Interactive)**

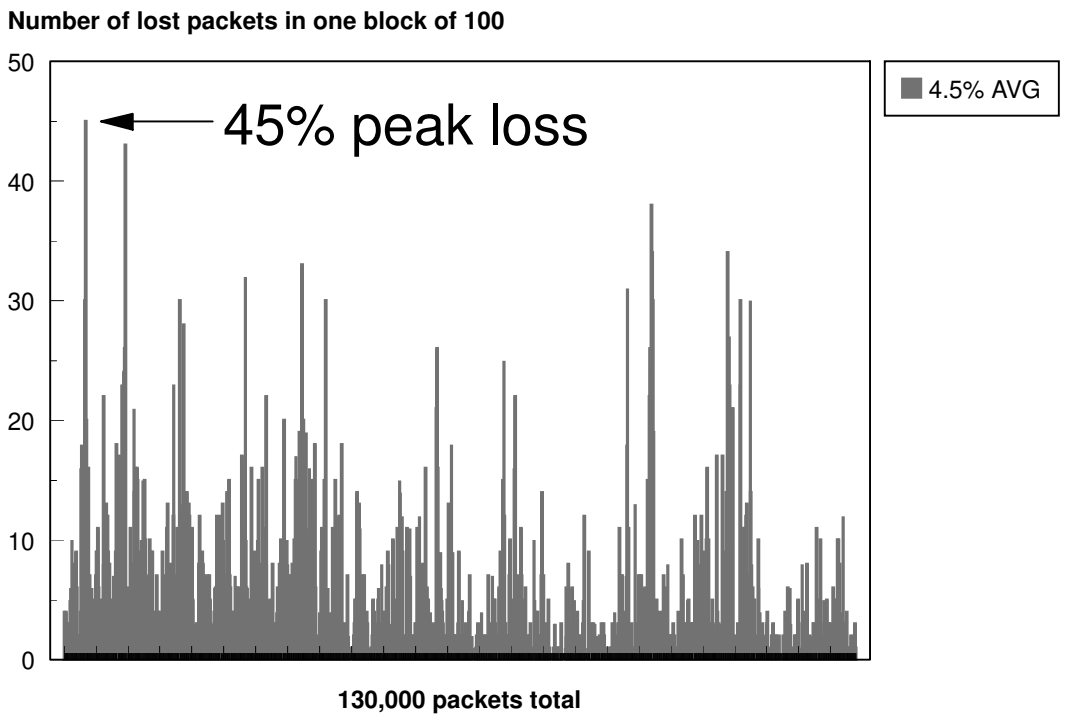
Lossy Packet-Based Network

- Multiple Receivers
- Multiple Routings
- Burstiness
  - Time
  - Space

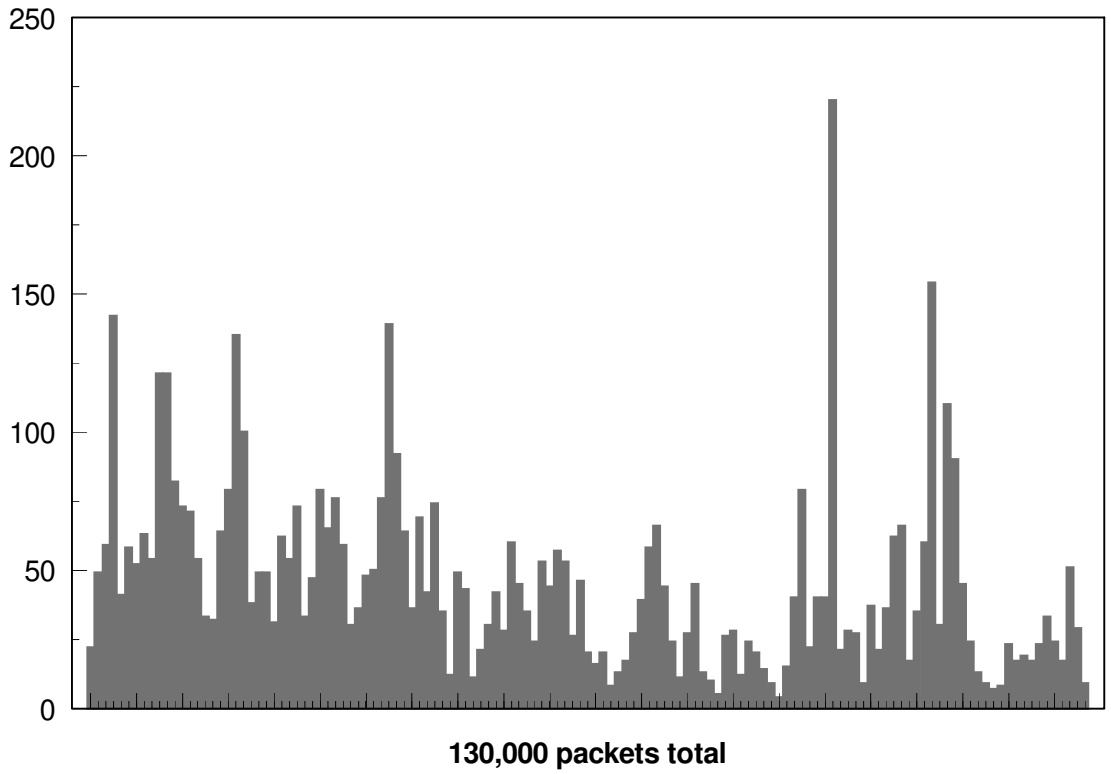
Xerox PARC Forum (captured)

Graceful Acquisition of Message with number of Packets received

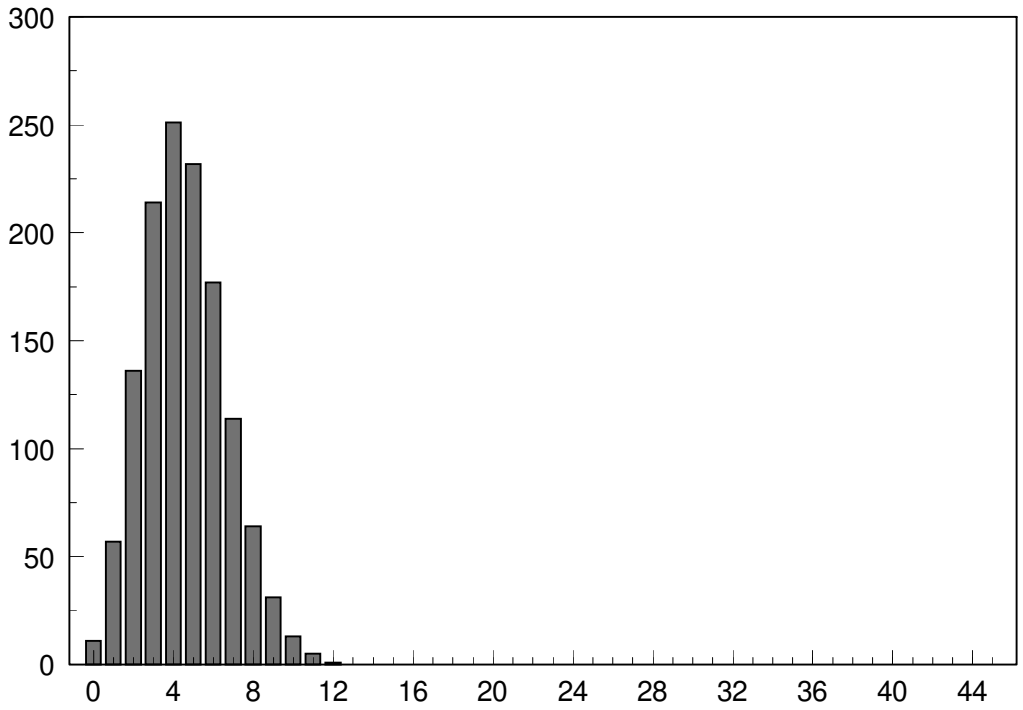
Packet Loss per 100 from Palo Alto to Berkeley



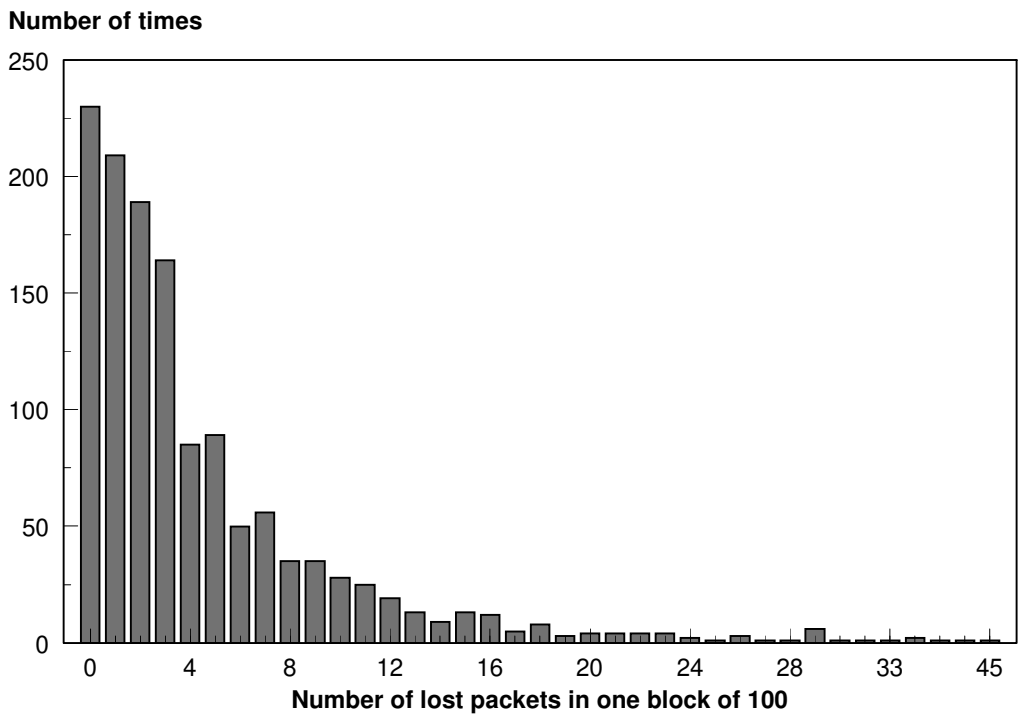
Loss Packets / 1000



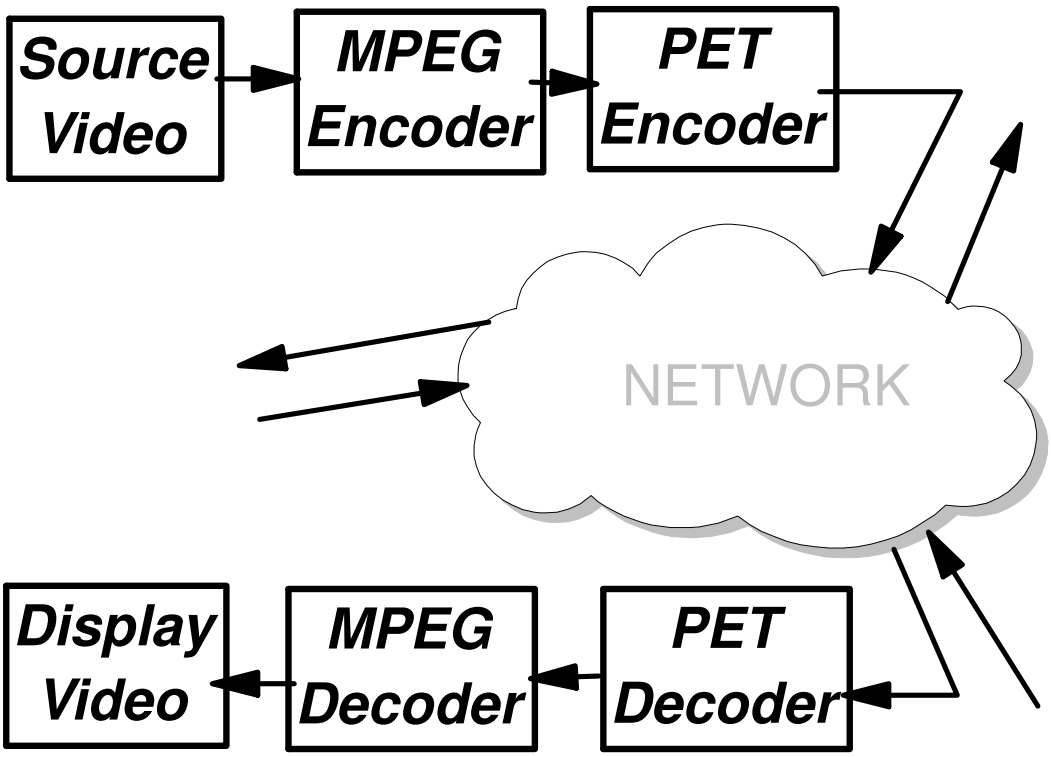
Packet Loss Distribution
Poisson Model 4.6%



Packet Loss Histogram



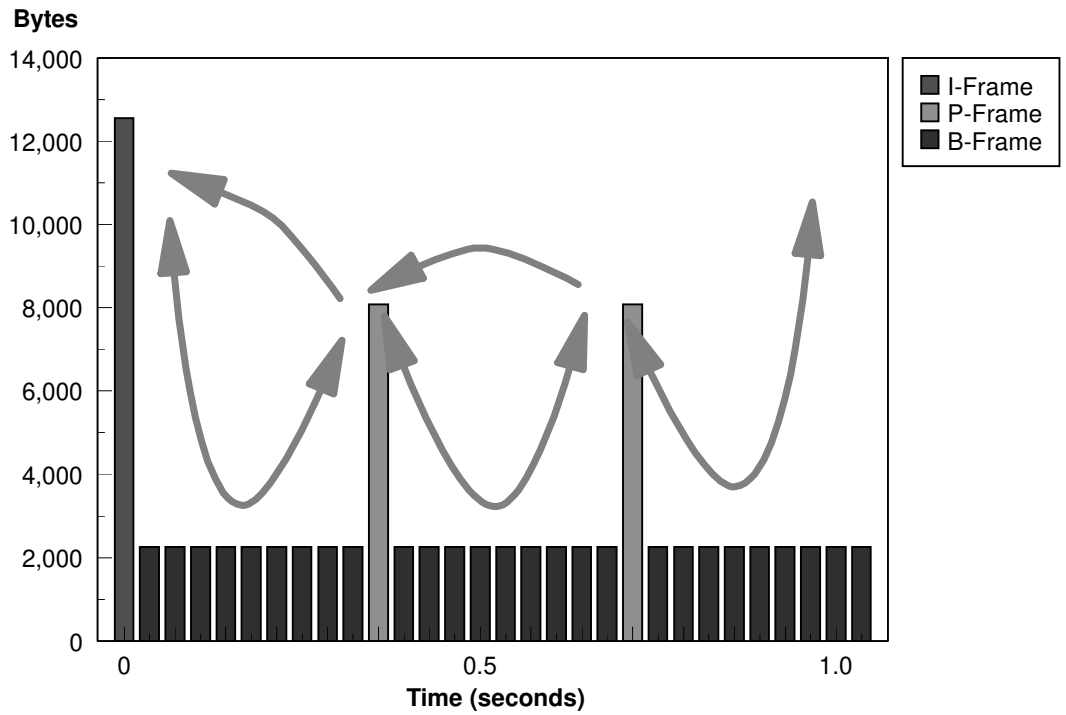
Multicast Network



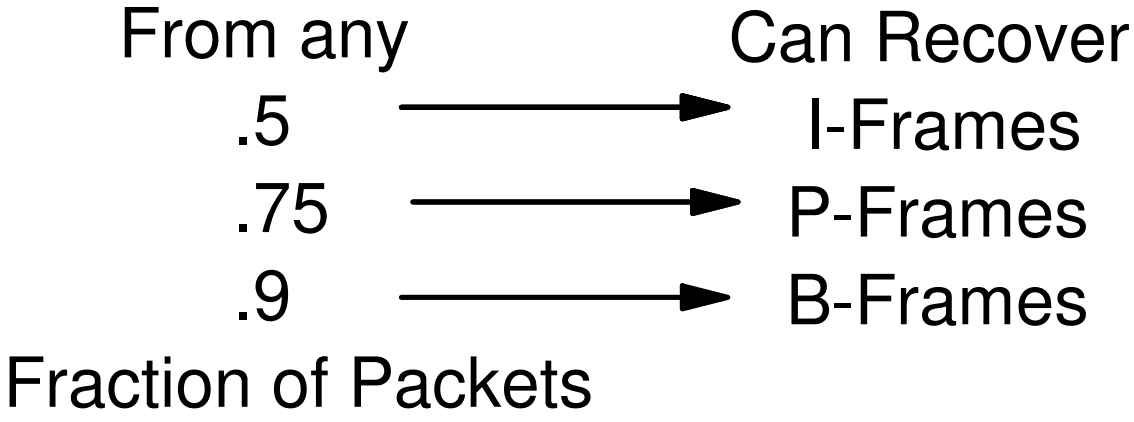
Video Transmission Comparisons

	Bandwidth requirements	Quality degradation with losses
Full bit map	HIGH	LOW
MPEG	LOW	HIGH
MPEG + PET	LOW	LOW

Example:
MPEG Group of Pictures



User Priority Specifications

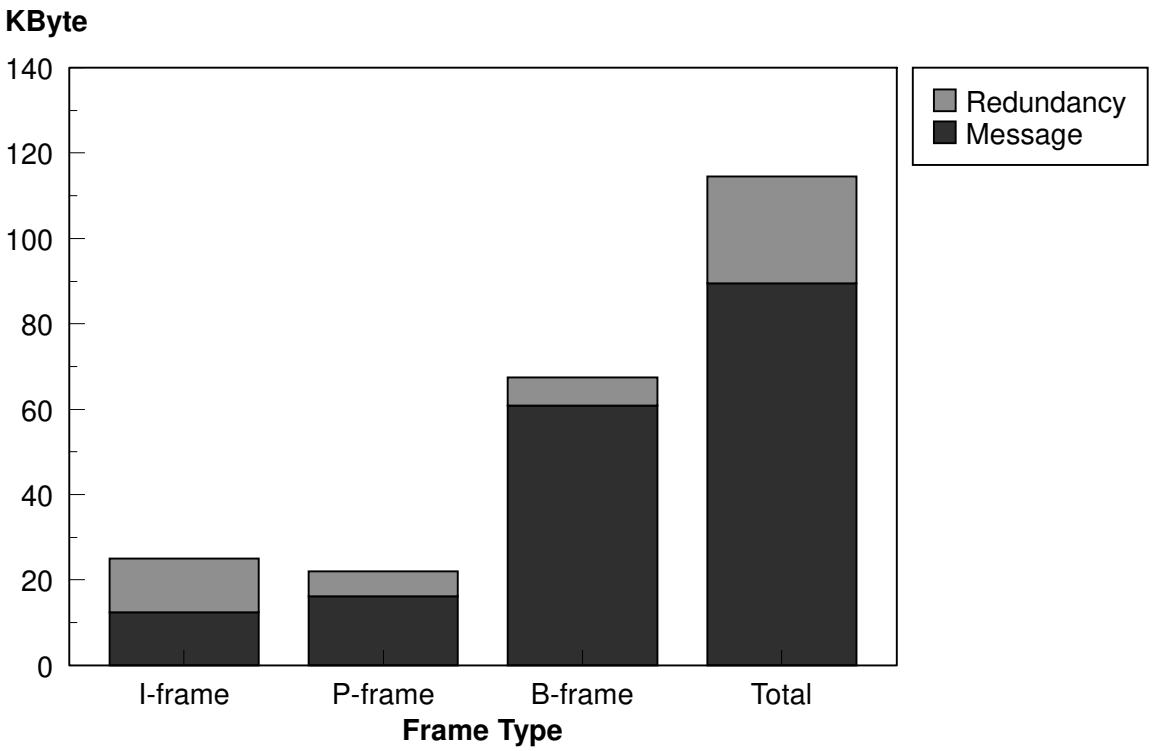


Calculating Size of Encoding

$$|\text{Encoding}| = \frac{|\text{I-Frame}|}{0.5} + \frac{|\text{P-Frame}|}{0.75} + \frac{|\text{B-Frame}|}{0.9}$$

$$= 114 \text{ KBytes}$$

MPEG: Byte Distribution



Overall Redundancy = 22%

Calculating Number of Packets

$$|\text{Packet}| = 2\ \text{KBytes}$$

$$\text{Number of Packets} = \frac{|\text{Encoding}|}{|\text{Packet}|}$$

$$= 57$$

Number of Packets to Recover

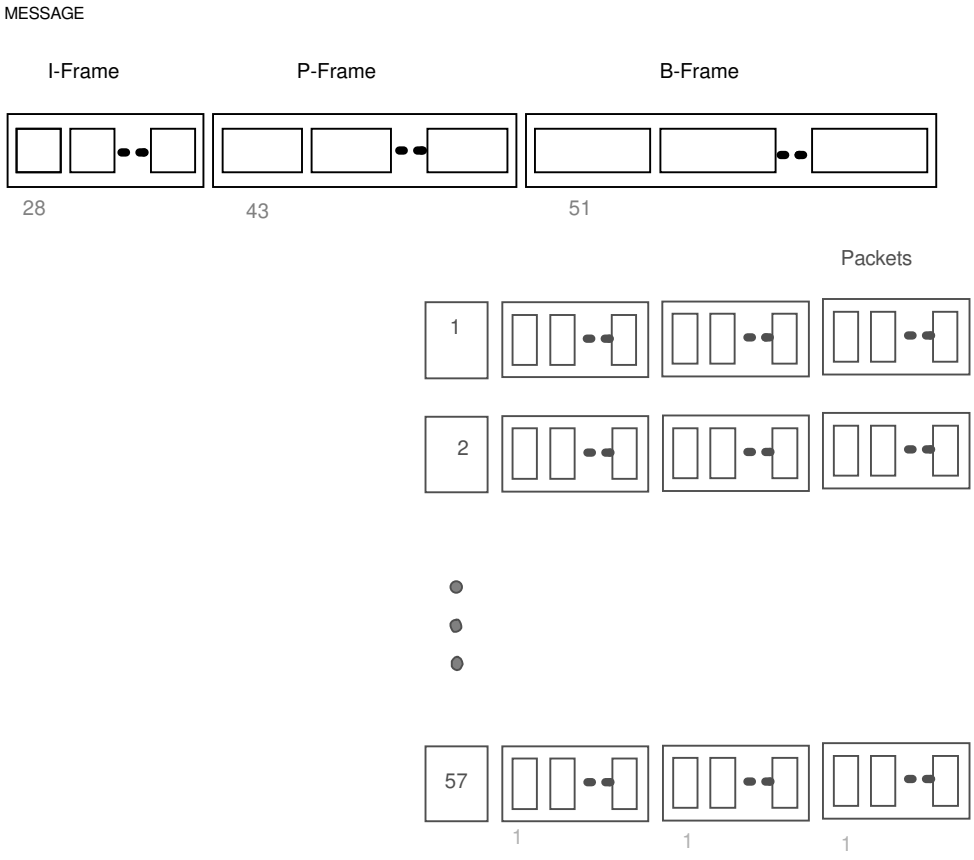
57 Packets total

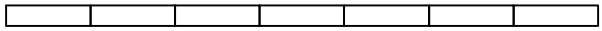
.5 fraction of Packets
= 28 → I-Frames

.75 fraction of Packets
= 43 → P-Frames

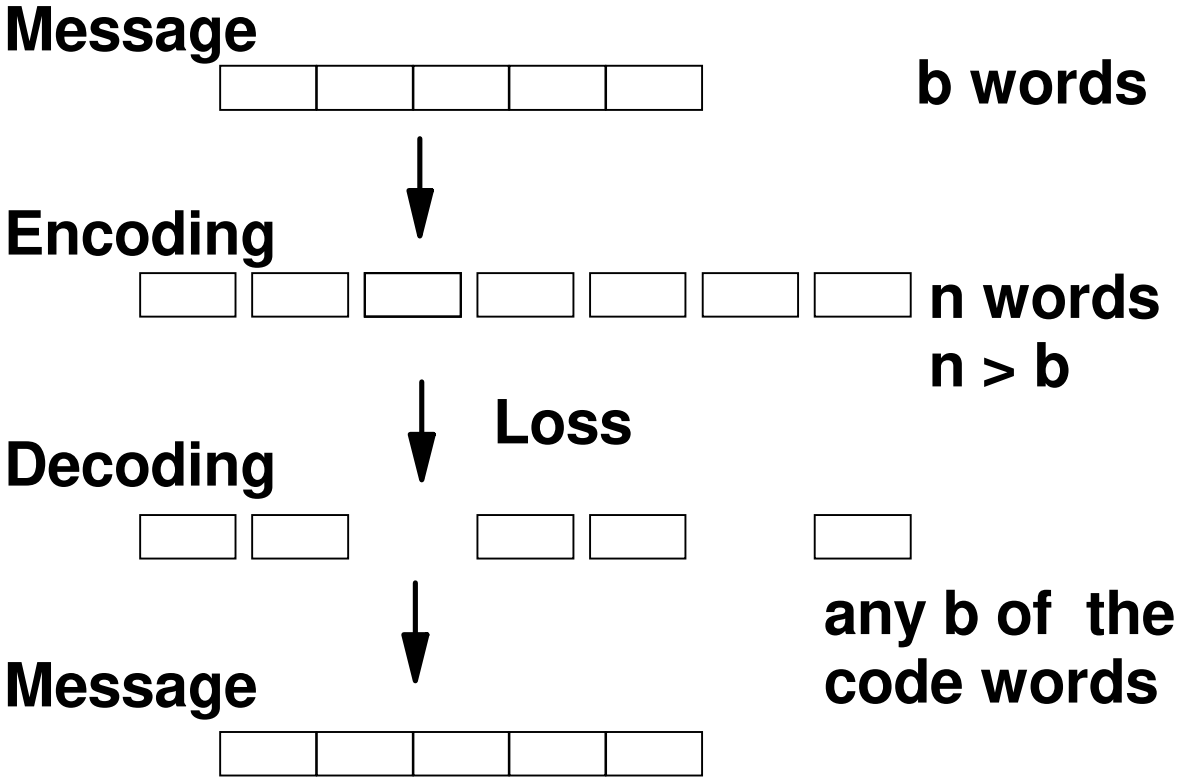
.9 fraction of Packets
= 51 → B-Frames

PET Encoding Process

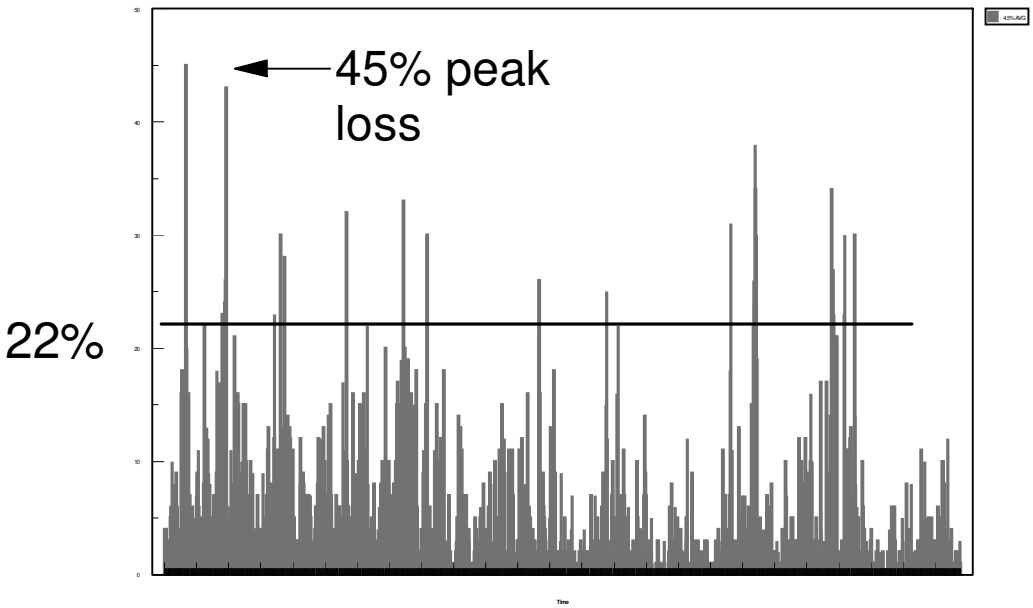




Erasure-Resistant Codes

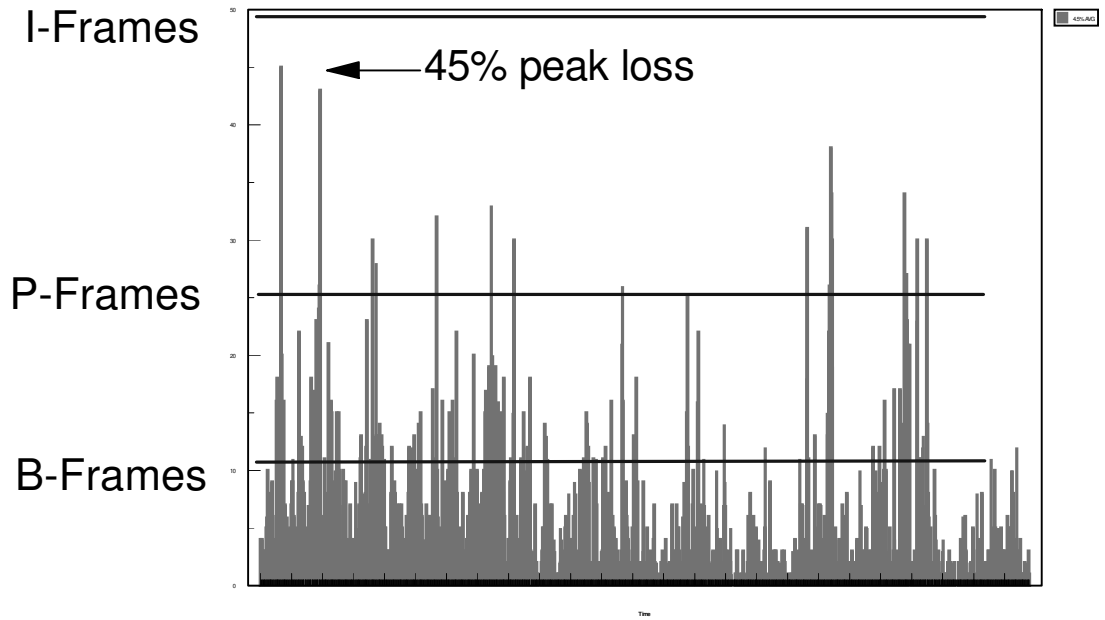


One Level of Redundancy



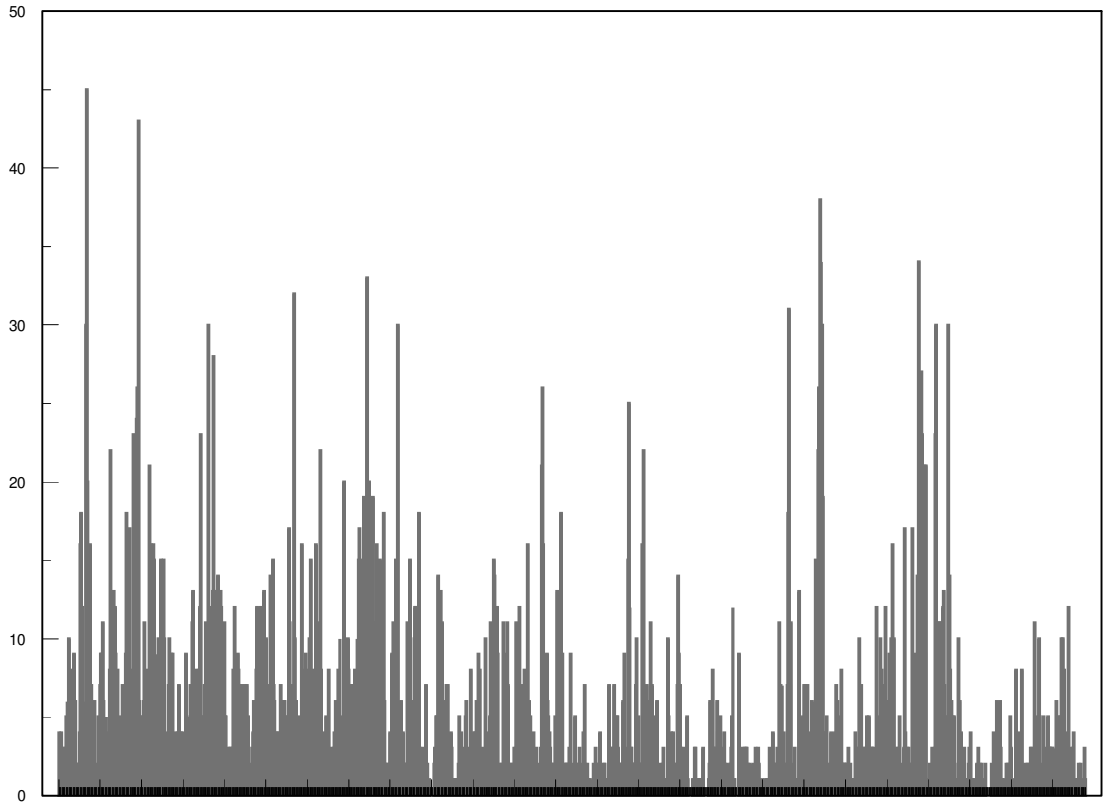
Packet Loss per 100
from Palo Alto to Berkeley

Multiple Levels of Redundancies

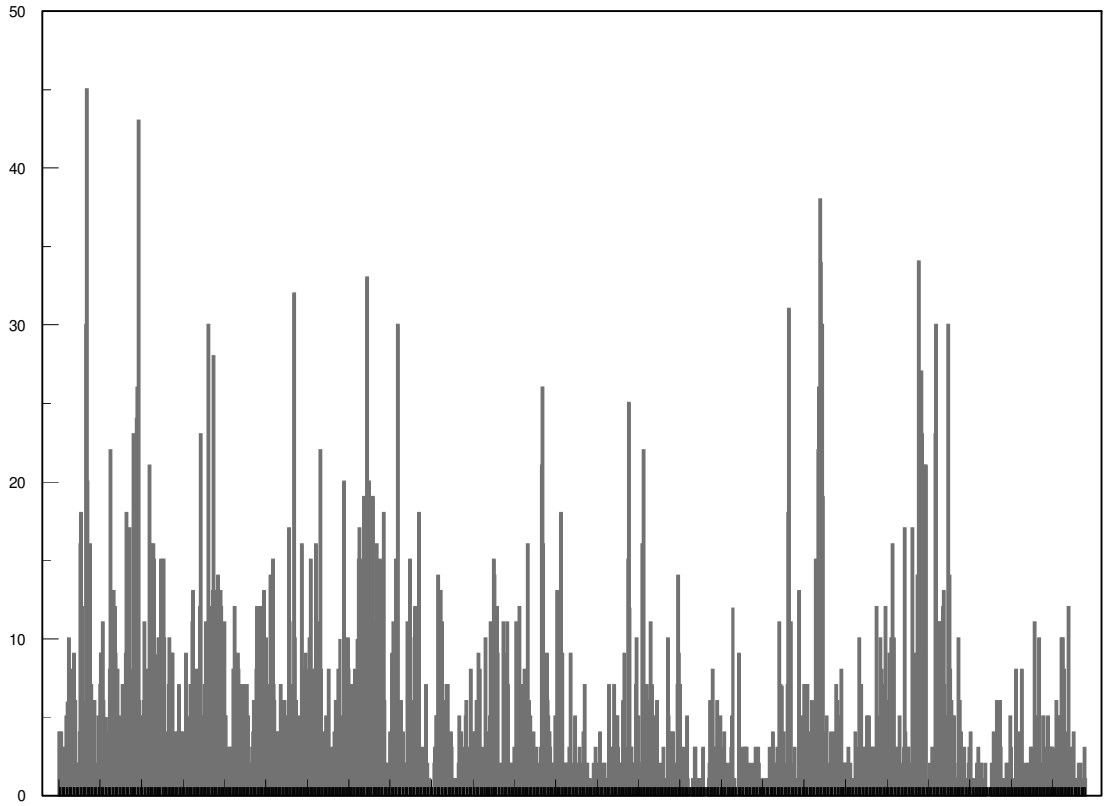


Packet Loss per 100
from Palo Alto to Berkeley

Breaking up with Jarring Abruptness



PET: Shock Absorbers for the Information Highway



Other Ways to Prioritize

- # of frames per sec.
- Sound over Image
- Resolution
- Color

Information Theory Lower Bound

$b_1, b_2, ..., b_m$ = block sizes

$p_1, p_2, ..., p_m$ = fractional priorities

Theorem:

total encoding length $\geq \sum_{i=1}^{m} b_i / p_i$

Other Solutions to Packet Loss

- **Guaranteed Throughput**
- **Prioritized Packets**
- **Resend Lost Information**

Implementations of PET

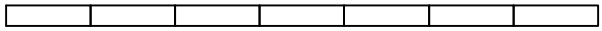
- **Feasible hardware and software solutions**
- **PET can process in real time a proposed MPEG2 standard bit rate on a Sparc-10**
- **Exploring probabilistic PET Systems**

Erasure-Resilient Codes

- **Reed Solomon Codes**
  O(log^2 b)
  (Fast Fourier Transforms)

- **Reed Solomon Codes**
  O(b)
  (Practical)

- **Probabilistic Codes** **O(log b)**
  (Edmonds, Luby)



Erasure-Resistant Codes
Polynomial Scheme

Message

$$p(x) = c_0 x + c_1 x^1 + c_2 x^2 + c_3 x^3$$

b words

Encoding

p(0)	p(1)	p(2)	p(3)	p(4)	p(5)

n words
n > b

Loss

Decoding

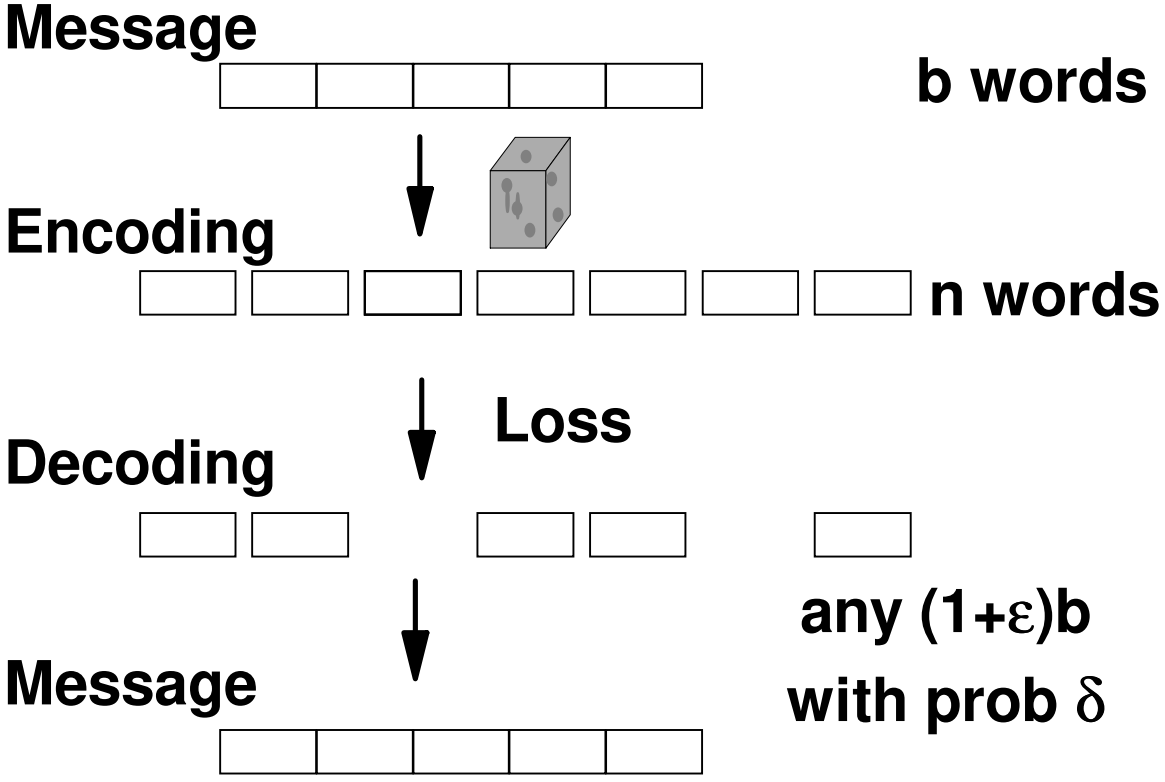
p(0)		p(2)	p(3)		p(5)

any b of the code words

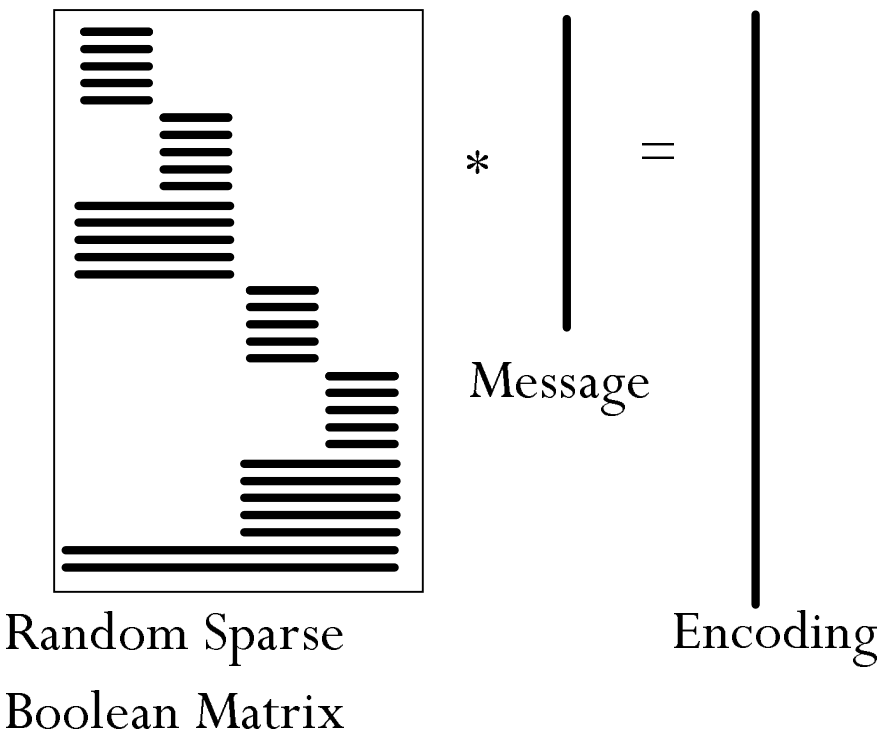
Message

$$p(x) = c_0 x + c_1 x^1 + c_2 x^2 + c_3 x^3$$

Probabilistic Erasure-Resistant Codes



Probabilistic Erasure-Resistant Codes



Conclusions

- Minimal bandwidth for multi-level priority guarantee
- User Oriented
  - no explicit network support required
- No retransmission
  - Amenable to multicast and
  - real-time applications
- Multiple routing strategies possible with
  - packet discard &
  - partial discard policies
- Attractive for teleconferencing applications