Rate-Constrained Scalable Video Transmission over the Internet

Bo Hong and Aria Nosratinia
Department of Electrical Engineering, University of Texas at Dallas

Abstract

Forward error correction (FEC) is used widely to address the packet loss problem for Internet video. In this work, we show that packet size plays a very important role in rate allocation of FEC-based methods. We develop a probabilistic framework for the solution of rate allocation problem in the presence of overhead. We apply this analysis to an unequal error protection scheme combined with Fine Granularity Scalability (FGS) in the MPEG-4 video standard. Given a total available bandwidth, optimal assignment of FEC and packet size is achieved simultaneously by minimizing end-to-end distortion.

Packetization and Channel Model

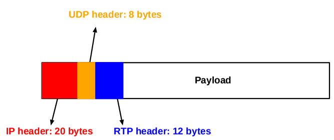

Fig. 1: Structure of a video packet

- Minimum packet header: 40 bytes (IP/UDP/RTP)
- Max. packet length: 1500 bytes (Ethernet MTU)
- Long packets reduce overhead
- Shorter packets: more efficient FEC codes
- Packet loss over Internet is not iid
- Packet loss prob. is independent of packet size

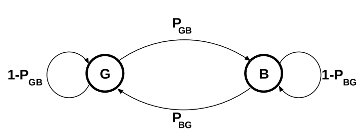

Fig. 2: Channel model

- A two-state Markov model
- Described by average packet loss probability Pb and average burst loss length Lb

Proposed Algorithm

- Based on MPEG-4 FGS
- Video interleaved into block of packets (BOP)
- Reed-Solomon codes, rate (n,m1) and (n, m2)

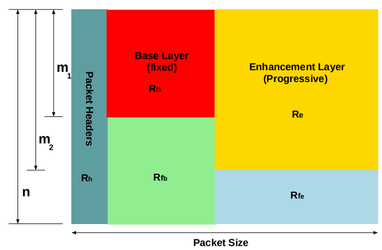

Fig. 3: Structure of a block of packet (BOP)

$$\min_{R_{fb}, R_e, R_{fe}, R_h} D,$$
subject to $R_{fb} + R_e + R_{fe} + R_h \le R - R_b$

$$D = (1 - P_1 - P_2)D_0 + P_1 D_1 + P_2 D_2$$
$$= \sum_{i=0}^{n-m_2} P(i, n)D_0 + \sum_{i=n-m_2+1}^{n-m_1} P(i, n)D_1 + \sum_{i=n-m_1+1}^{n} P(i, n)D_2$$

- P(i,n) = Prob (i losses| n packets)
- D_1: distortion when the base layer is received correctly and part of the enhancement layer is lost

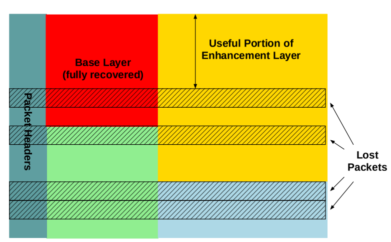

Fig. 4: Packet loss and video recovery

$$D_1 = \sum_{j=0}^{n-i} p_j d_j$$

P_j = Prob (first error in packet j+1 | i losses)

$$p_j = p(A|B) = p(A, B)/P(i, n)$$
$$= p(A)R(i, n-j)/P(i, n)$$

- A: the first error in packet j+1
- B: i losses out of n packets
- R(i,n) = P(B, packet -1 lost)

$$p(A) = \begin{cases} (1-P_b)P_{GB} + P_b(1-P_{BG}), & j = 0 \\ (1-P_b)(1-P_{GB})^j P_{GB} + P_b P_{BG}(1-P_{GB})^{j-1} P_{GB}, & 1 \le j \le n-i \end{cases}$$

Results

- 1 BOP = 10 frames = 1 sec

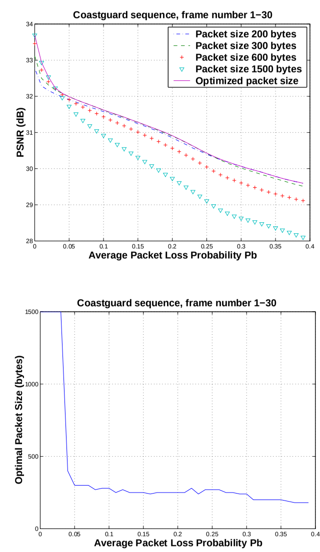

Fig. 5: Performance (up) and optimal packet size (bottom) of the Coastguard sequence

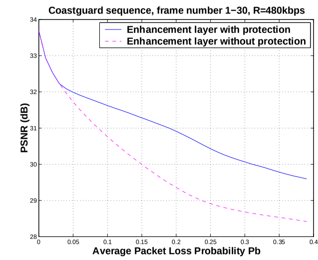

Fig. 6: Performance of protecting the enhancement layer

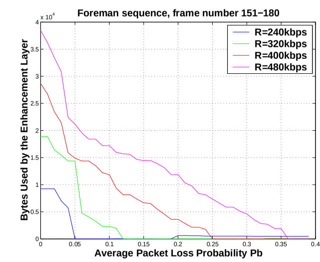

Fig. 7: Enhancement layer bit rate

Conclusion

- Packet header has a significant effect on the reconstructed video quality.
- This work presents probabilistic modeling of packet header effects.
- The enhancement layer should be protected in the majority of cases and the corresponding FEC rate should be taken into account in the bit allocation problem.