Power-Rate-Distortion Analysis for Wireless Multimedia Networks

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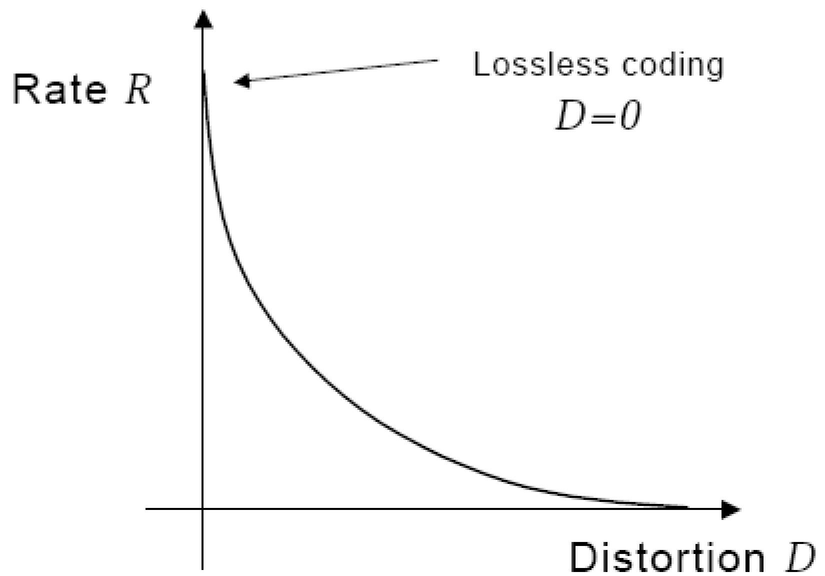
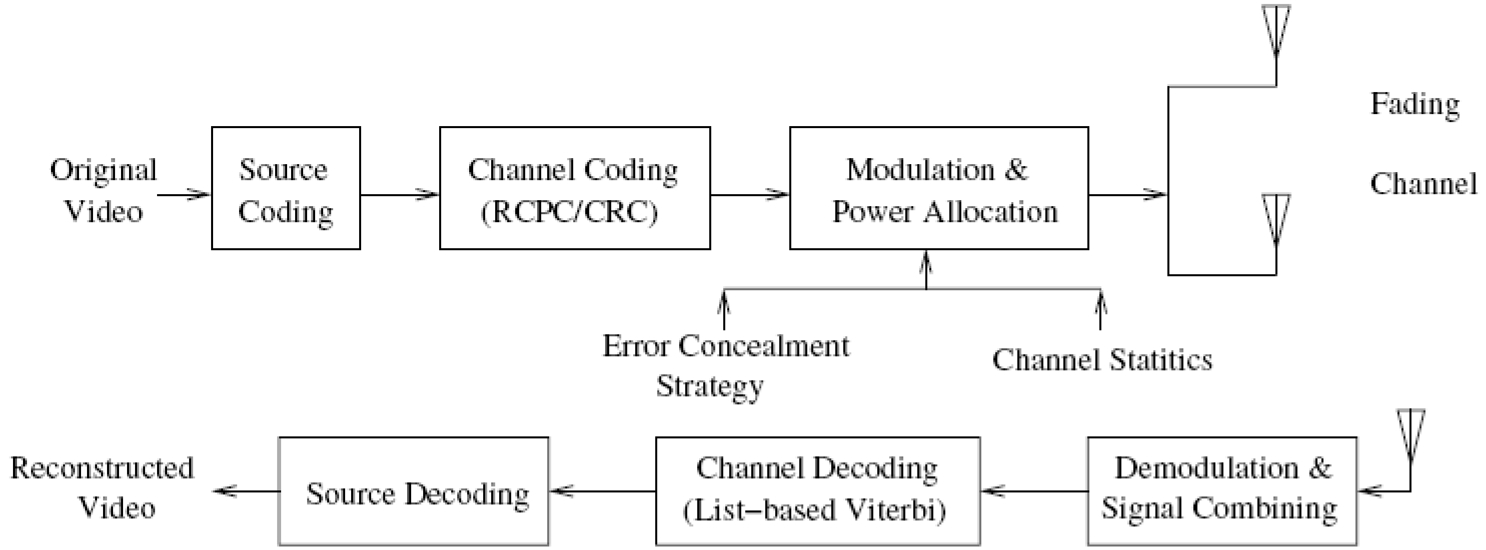
Rate-Distortion (Source Coding)

- Lower the bit-rate *R by allowing some acceptable distortion D of the signal.*



Wireless Multimedia Networks

- *Rate* and *Distortion* is also affected by ***Communication***



“Power-Rate-Distortion” Problem

- Sensors are power-limited
  - Consider power-efficiency in dominant operations
- Dominant operations:
  - Sensing, Computation, Communication
- Computation: *Source coding*

How does *P* relates to *R-D* ?

- Source coding
  - R_s ↑, Compression distortion ↓, Compression power ↓
  - R_s ↓, Compression distortion ↑, Compression power ↑

- Channel coding
  - R_c ↑, Transmission error ↓, Transmission power ↑
  - R_c ↓, Transmission error ↑, Transmission power ↓

- Modulation

  E_b or E_s is related to bit error rate (BER)
  - E_b ↑, Transmission error ↓, Transmission power ↑
  - E_b ↓, Transmission error ↑, Transmission power ↓

Literature Survey

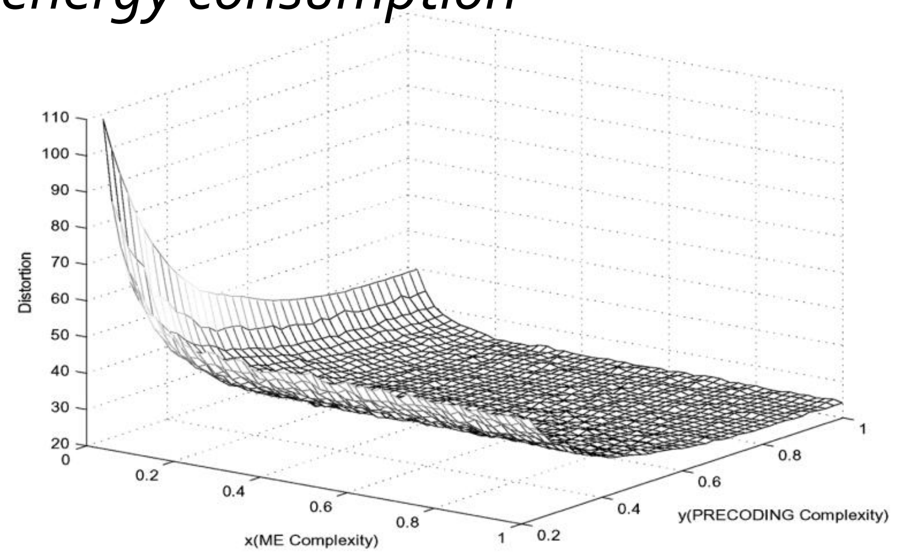
- Possible Categorization:
  - R-D analysis (Video Coding)
  - R-D analysis (Communication)

  - P-R-D analysis (Video Coding)
  - **P-R-D analysis (Video Coding and Communication)**

  - P-D analysis (Communication)

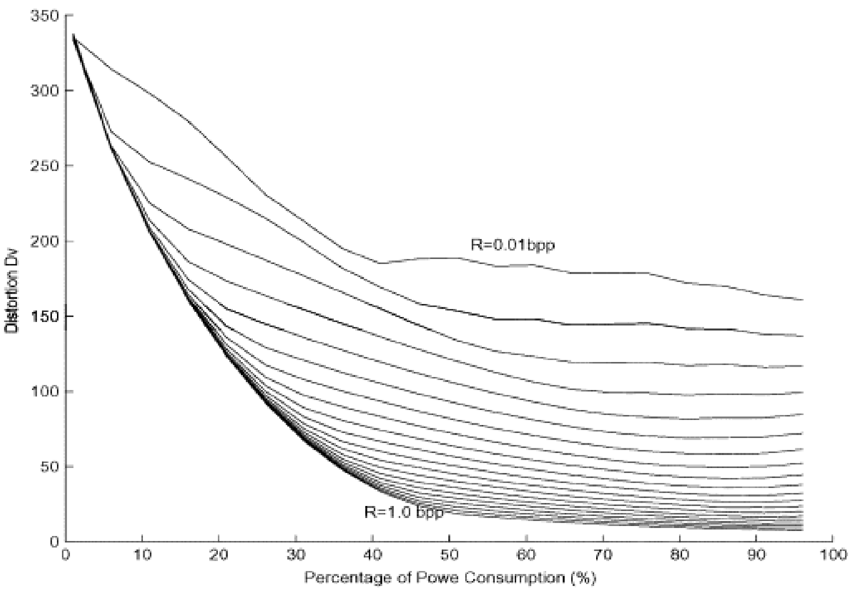
He et al., "Power-Rate-Distortion Analysis for Wireless Video Communication Under Energy Constraints", IEEE Transactions on Circuits and Systems for Video Technology, 2005.

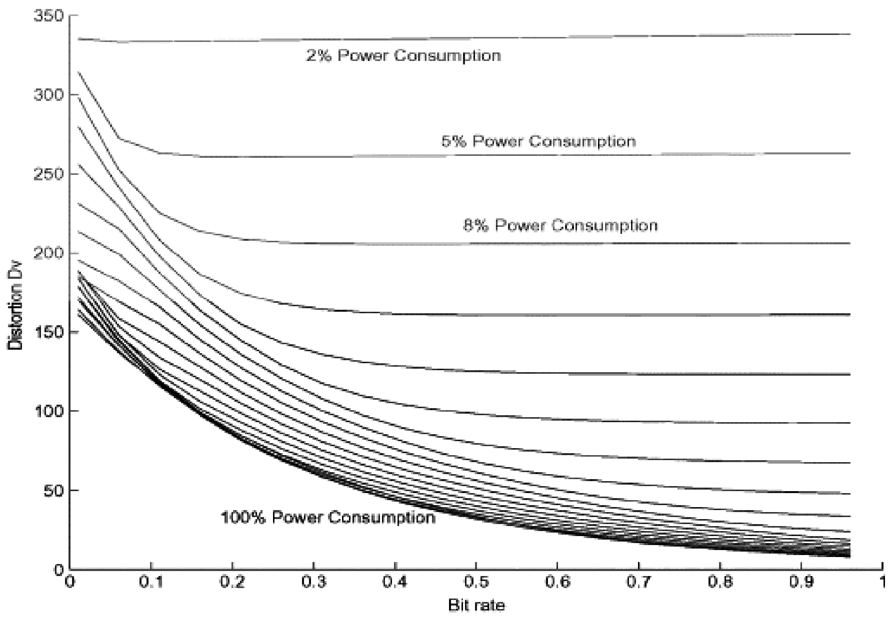
- P-R-D model for a system that
  - automatically adjust its complexity control parameters
    - the available energy supply
    - while maximizing the picture quality.
- Using dynamic voltage scaling (DVS), *the complexity scalability* can be translated into *energy consumption scalability*
- $P \propto f_{CLK}^3$
  - $f \propto$ C (number of processor cycles/sec)



He et al., "Power-Rate-Distortion Analysis for Wireless Video Communication Under Energy Constraints", IEEE Transactions on Circuits and Systems for Video Technology, 2005.

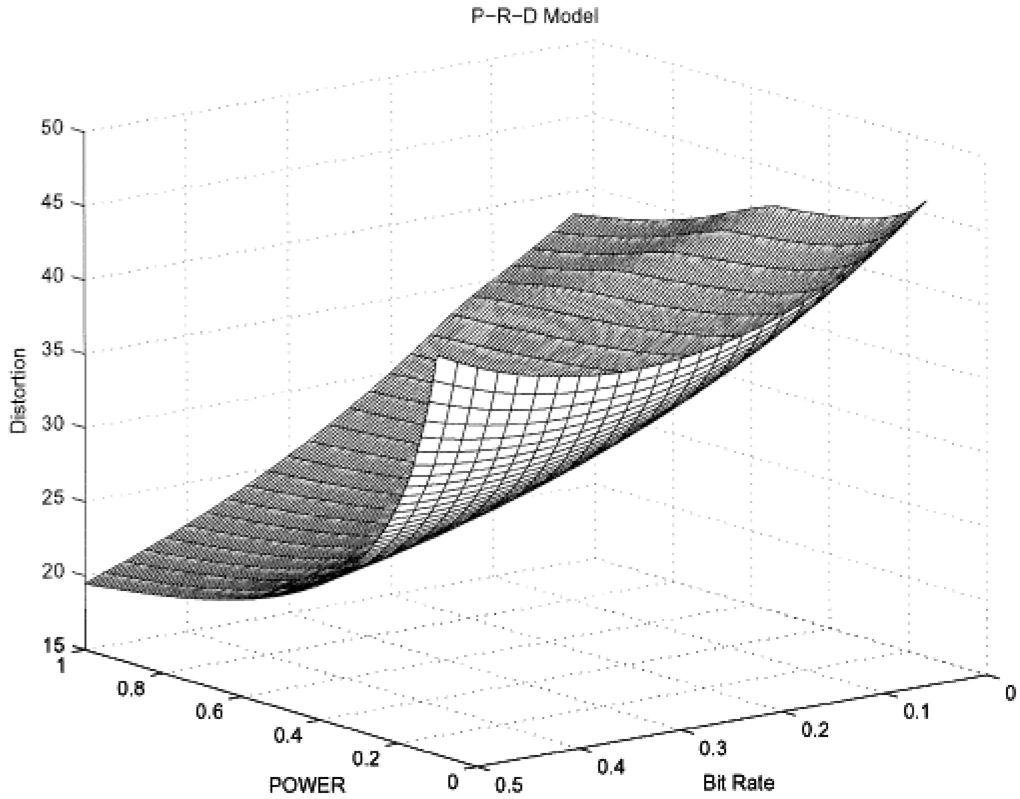
- P-D and R-D results:





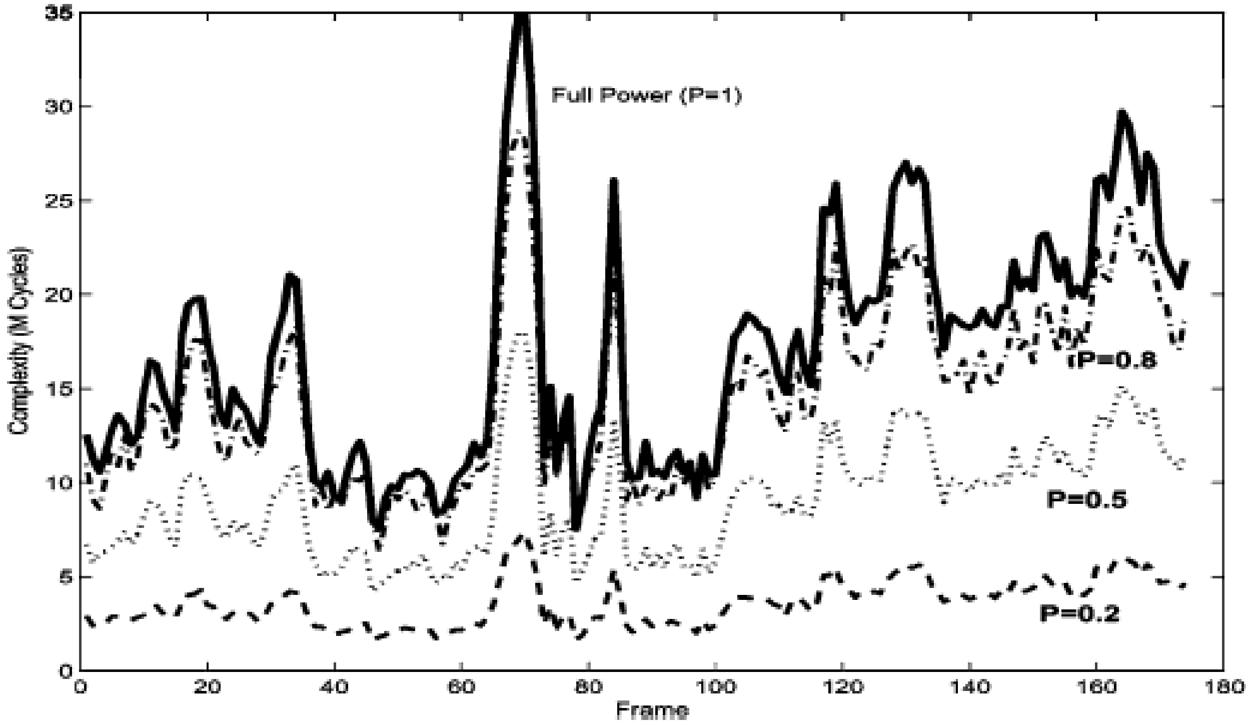
He et al., "Power-Rate-Distortion Analysis for Wireless Video Communication Under Energy Constraints", IEEE Transactions on Circuits and Systems for Video Technology, 2005.

- P-R-D Results:



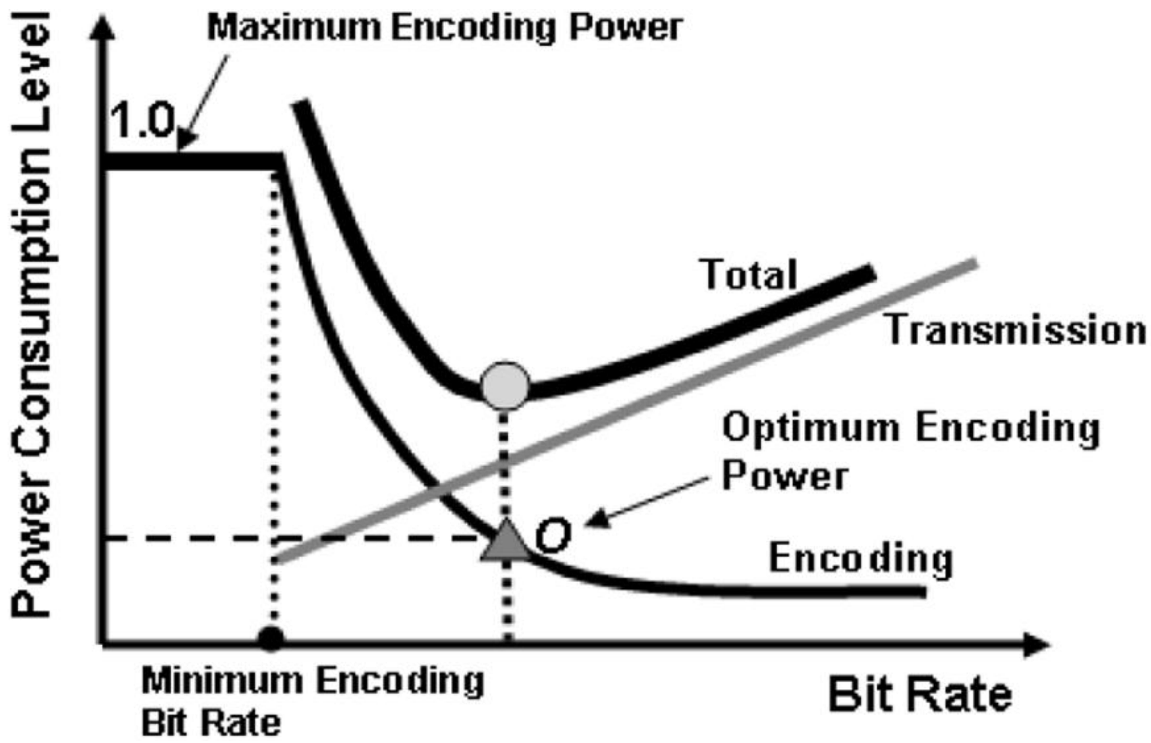
He et al., "Energy Minimization of Portable Video Communication Devices Based on Power-Rate-Distortion Optimization", IEEE Transactions on Circuits and Systems for Video Technology, 2008.

- P- R (~ Encoding Complexity):



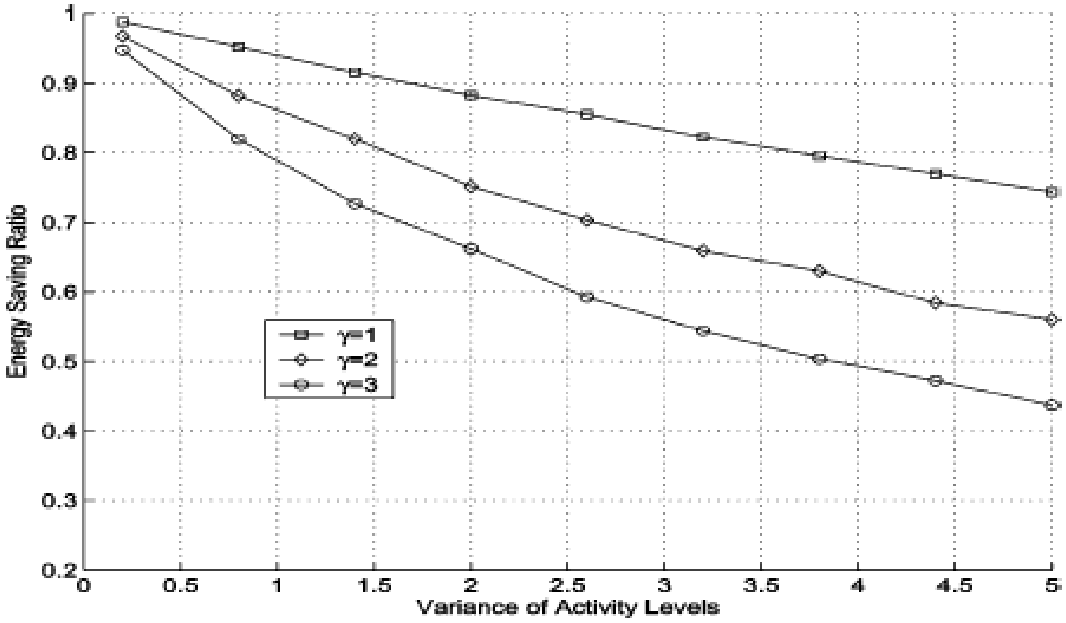
He et al., "Energy Minimization of Portable Video Communication Devices Based on Power-Rate-Distortion Optimization", IEEE Transactions on Circuits and Systems for Video Technology, 2008.

- P-R-D for Encoding+Transmission:

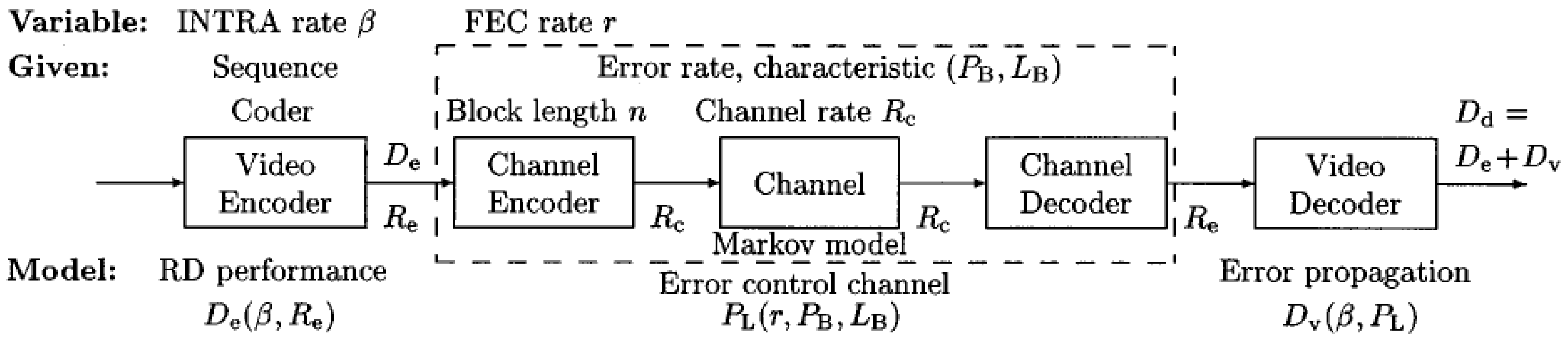


He et al., "Energy Minimization of Portable Video Communication Devices Based on Power-Rate-Distortion Optimization", IEEE Transactions on Circuits and Systems for Video Technology, 2008.

- Results (compared to fixed power):
  - γ: microprocessor power consumption parameter



Stuhlmüller et al.,"Analysis of Video Transmission over Lossy Channels", IEEE Journal on Selected Areas in Communications, 2000.

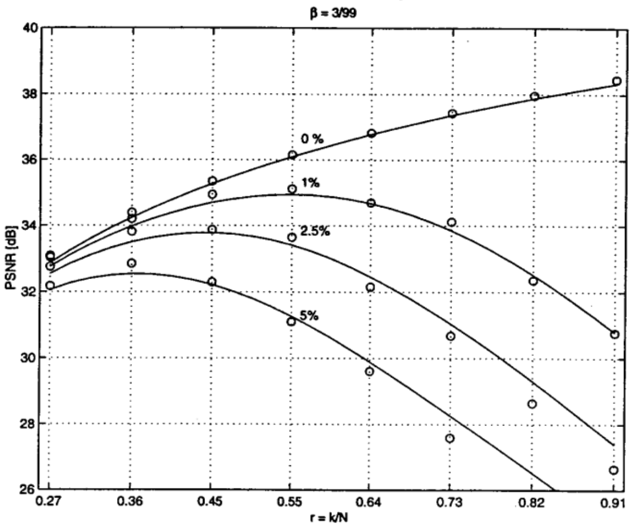


- Channel: 2-state Markov model describing burst errors on the symbol level.
- Reed–Solomon codes for forward error correction.
- Simulation using an H.263 video codec

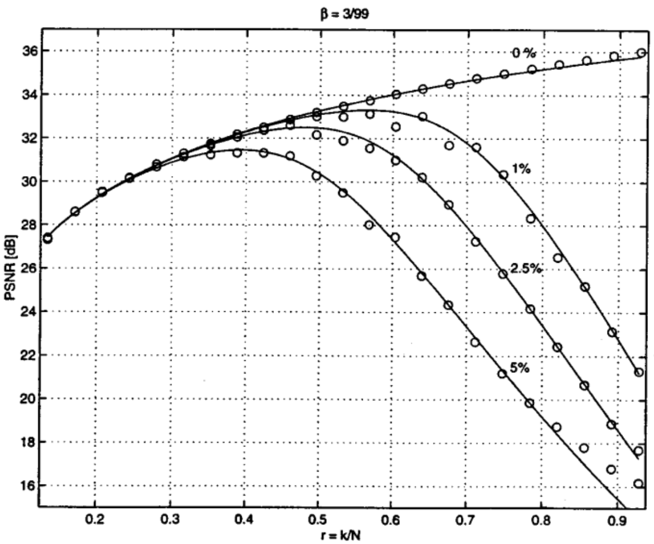
Stuhlmüller et al.,"Analysis of Video Transmission over Lossy Channels", IEEE Journal on Selected Areas in Communications, 2000.

- FEC rate: r = k/n
- To maintain a constant channel data rate:
  - $R_e = r.R_c$

Mother&Daughter

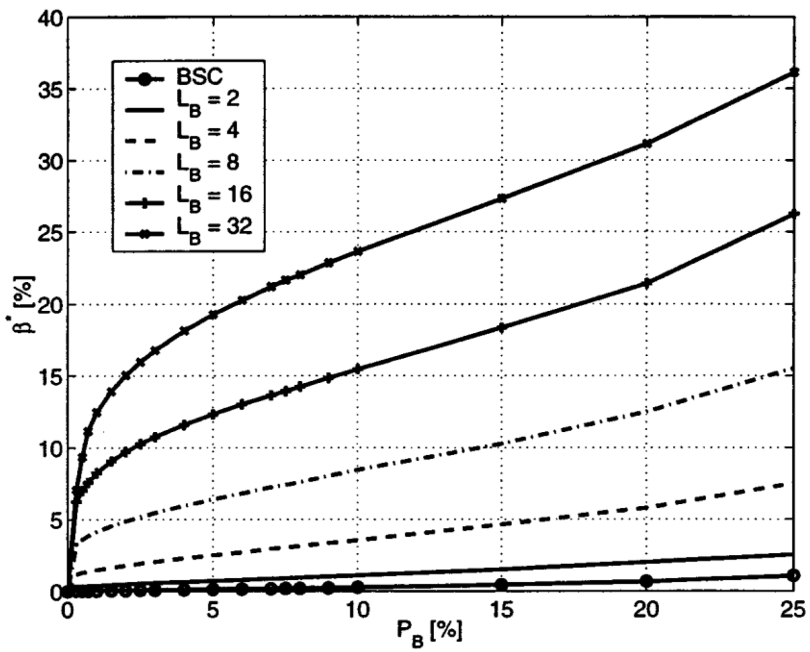


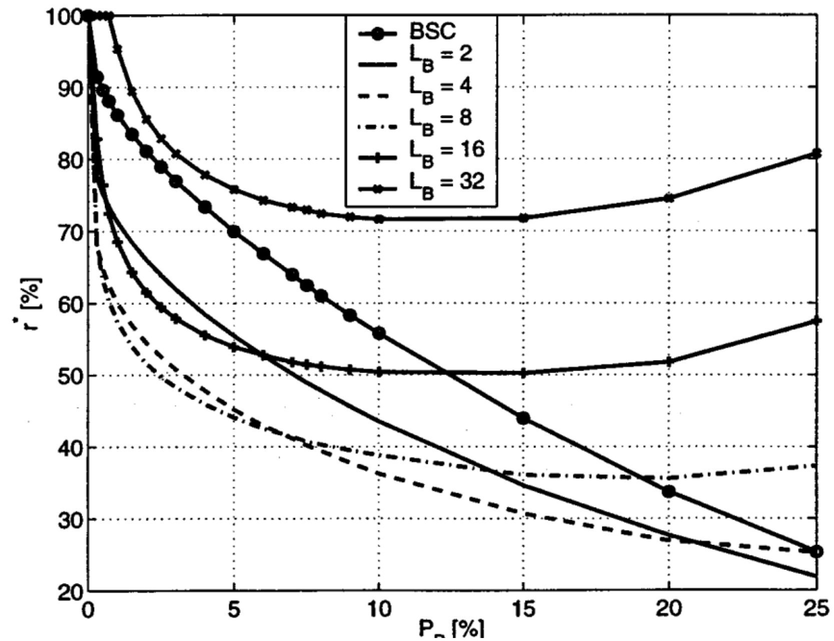
Foreman



Stuhlmüller et al., "Analysis of Video Transmission over Lossy Channels", IEEE Journal on Selected Areas in Communications, 2000.

- Results of numerical minimization of D_d for *Mother&Daughter*





X. Tian, "Efficient transmission power allocation for wireless video communications", IEEE Wireless Communications and Networking Conference, 2004.

- Objective:
  - To minimize distortion, transmission power allocated across packets
- Proposes:
  - Two power allocation algorithms transmission power to packets according to their relative importance
  - Fixed frame power vs variable frame power
    - Morepower to the packets whose lose would result higher distortion
    - More power to frames with high motion

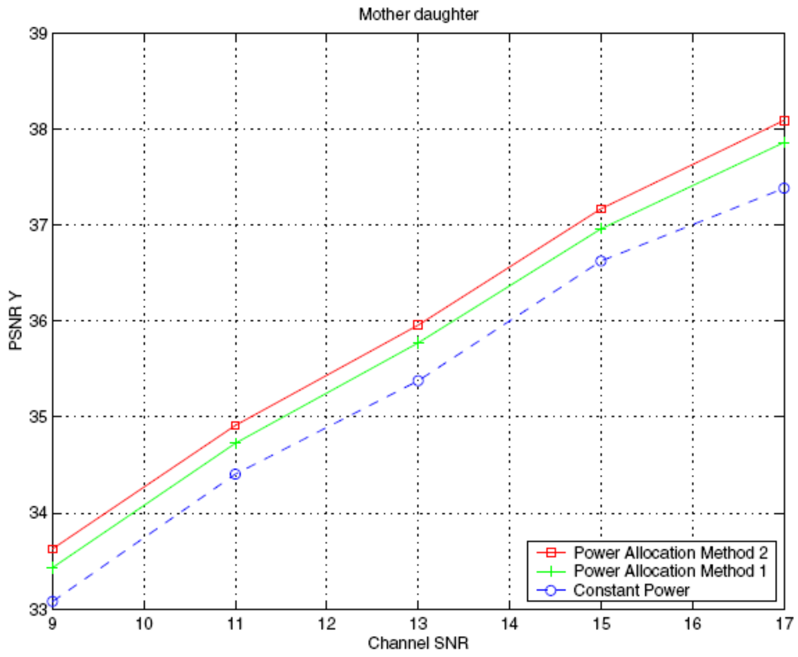
$$\underset{\mathbf{P}_i}{\text{minimize}} \quad \frac{1}{N_{MB}} \sum_{k=1}^{N_i} P_r(i,k) d^c(i,k) \qquad \underset{\mathbf{P}_i}{\text{minimize}} \quad \frac{1}{N_i} \sum_{k=1}^{N_i} P(i,k)$$

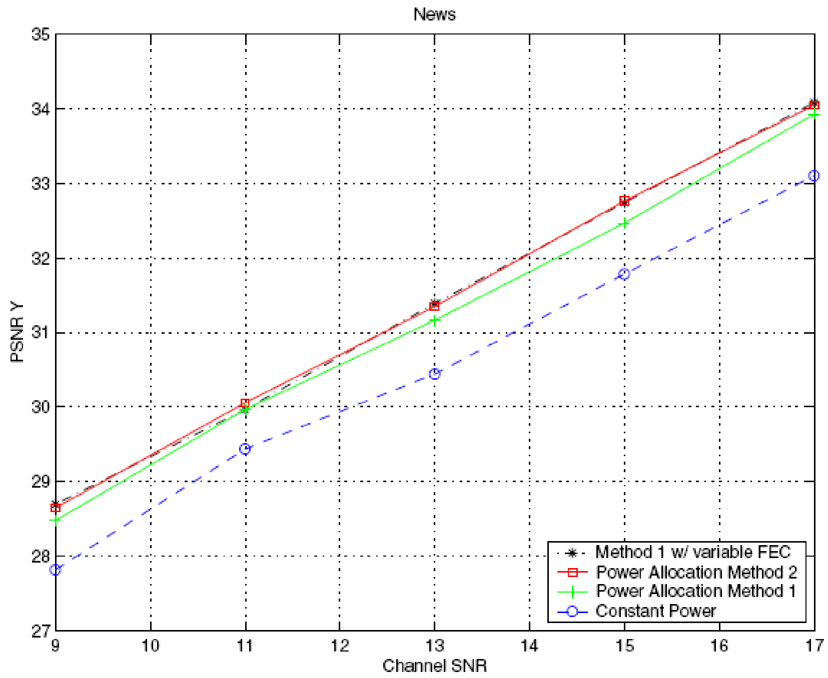
$$\text{subject to} \quad \frac{1}{N_i} \sum_{k=1}^{N_i} P(i,k) \leq P \qquad \text{subject to} \quad \frac{1}{N_{MB}} \sum_{k=1}^{N_i} P_r(i,k) d^c(i,k) \leq D_{TH}$$

X. Tian, "Efficient transmission power allocation for wireless video communications", IEEE Wireless Communications and Networking Conference, 2004.

- Error detection: CRC, Error correction: Convolutional coding
- BPSK modulation

- Results for two QCIF video sequences:



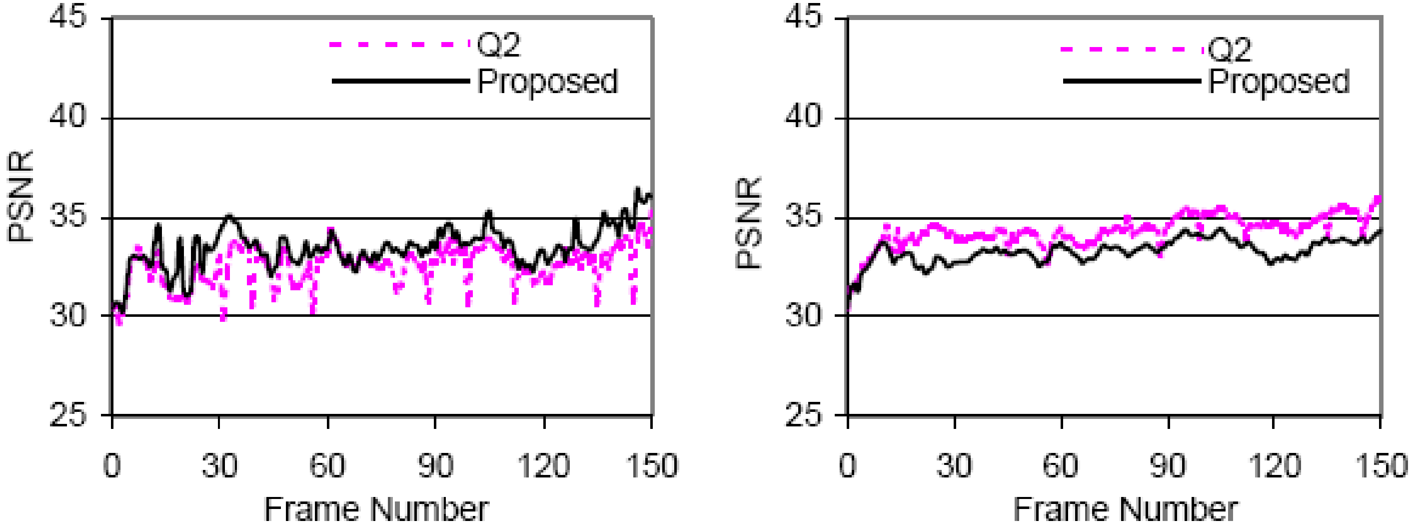


Li *et al.*, "Joint power allocation and rate control for real-time video transmission over wireless systems," *IEEE Global Telecommunications Conference, GLOBECOM '05*, 2005.

- Objective:
  - Improve the visual quality of the regions of interest while saving bits, and also adapting to time-varying wireless channels.
- Method:
  - Segment a frame into ROI and non-ROI.
  - Then allocate more power as well as more bits to ROI to reduce the packet retransmission rate.

Li *et al.*, "Joint power allocation and rate control for real-time video transmission over wireless systems," *IEEE Global Telecommunications Conference, GLOBECOM '05*, 2005.

- "The human visual system (HVS) is more sensitive to the moving regions"
  - Moving regions are classified as the foreground (ROI) while still regions are regarded as the background (non-ROI).
- Results:



(a) Foreground PSNR (b) Background PSNR