Joint Source-Channel Matching for Wireless Video Transmission

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Outline of Presentation

- Motivation
- General Approach
- Specific System Realization
- Results and Conclusions
- Most Recent Research

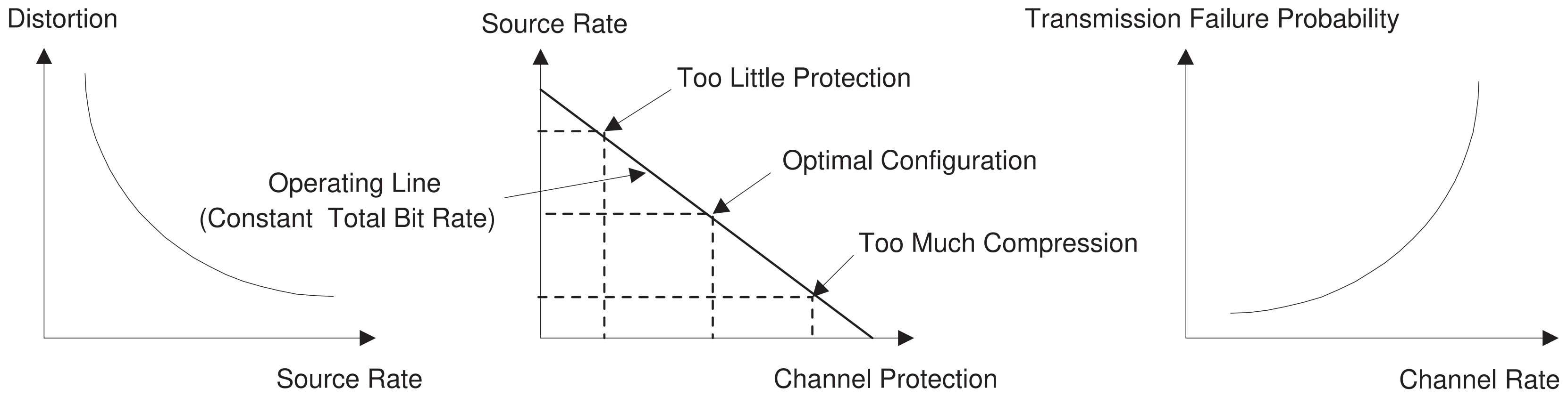
Introduction

- Advantages of applying JSCM for wireless image transmission have been widely demonstrated.

- Certain difficulties arise in implementing JSCM for wireless *video* transmission:
  - Video coders are generally more complex than image coders.
  - Real-time delay constraints and rate control introduce significant new challenges.

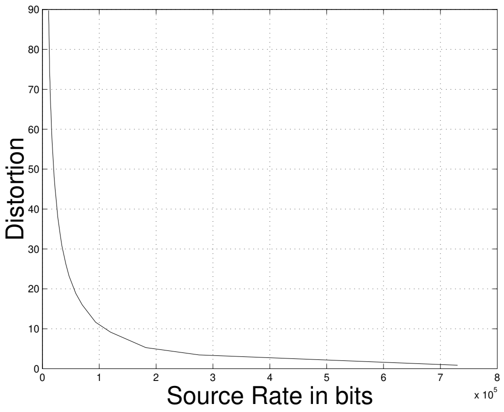
- A general matching scheme is desirable because of real-world system implementation constraints.

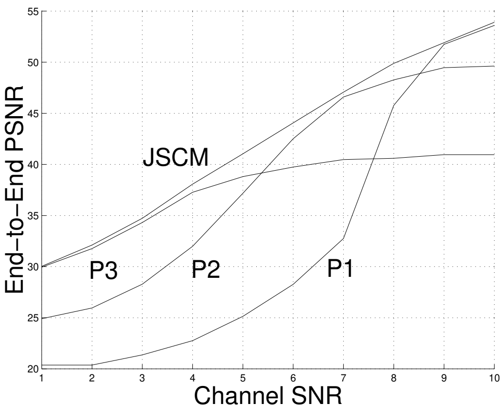
Joint Source-Channel Matching (I)

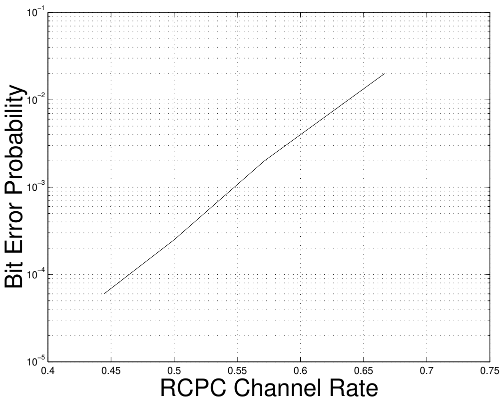


- Increasing source rate leads to less compression and reduces distortion.
- Increasing channel rate reduces the amount of protection and increases expected distortion.
- Limited channel capacity introduces a trade-off between the source and channel rates.

Joint Source-Channel Matching (II)







- Fixed-parameter systems ($p1$, $p2$, $p3$) perform poorly under unfavorable channel situations.

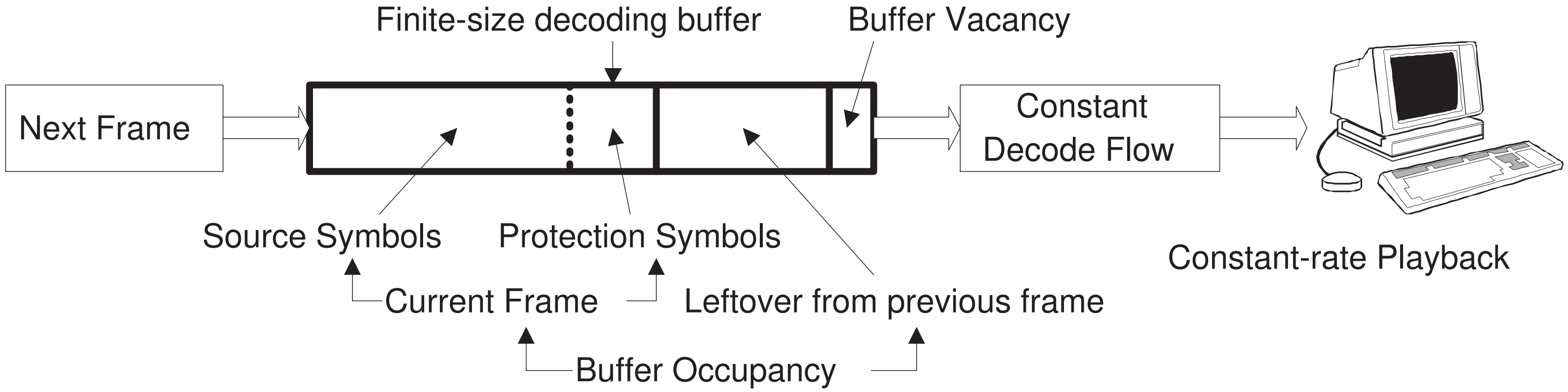
- Adapting to the varying channel situation, JSCM jointly allocates source and channel rates.

- JSCM always yields the optimal coding parameters, which are located on the convex hull.

Video Transmission Issues

- Delay Constraint: in video transmission, only a small, finite delay is allowed.

- Rate Control: finite decoding buffer size and a constant playback rate requirement.



Problem Formulation

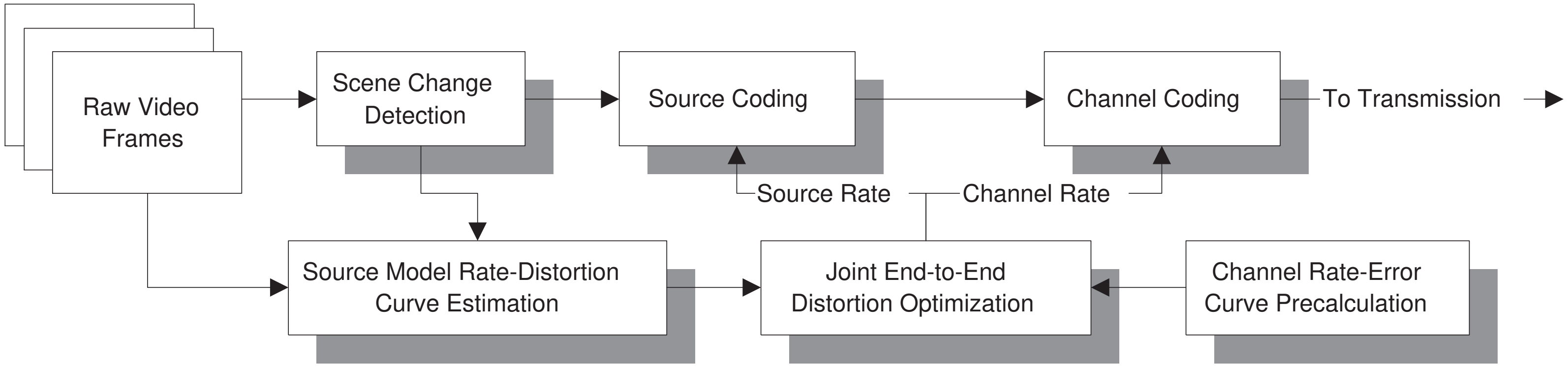
- Situation: groups of N video frames need to be coded and transmitted.

- Goal: minimize pre-defined cost function with respect to source and channel parameters.

- Constraint: avoid decoding buffer overflow and maintain a constant decoding rate.

- Strategy: constrained nonlinear optimization problem, solved using gradient descent algorithm with penalty function.

General System Diagram



- The above general structure applies regardless of the source and channel coders being used.

- To demonstrate, we use Motion-JPEG source coder and Reed-Solomon (RS) channel coder.

Motion-JPEG and RS Coder

- Motion-JPEG coder: all frames in JPEG format, rate adjusted by the *quality factor*, q.
- Reed-Solomon coder: Fixed-length code (n, k, t) capable of correcting t channel burst errors.
- Optimization: minimize expected end-to-end distortion with respect to q and t.
- Simplification: we use fixed q and t for each frame group assuming no scene change.

Implementation Details

- Source model parameters are obtained by evaluating anchor points followed by interpolation.
- Gradient descent algorithm uses the smallest allowable fixed step size (1 for q and 2 for t).
- Smart system initialization procedure ensures a convergence rate of no more than 5 iterations.
- System complexity level is the same as DCT.

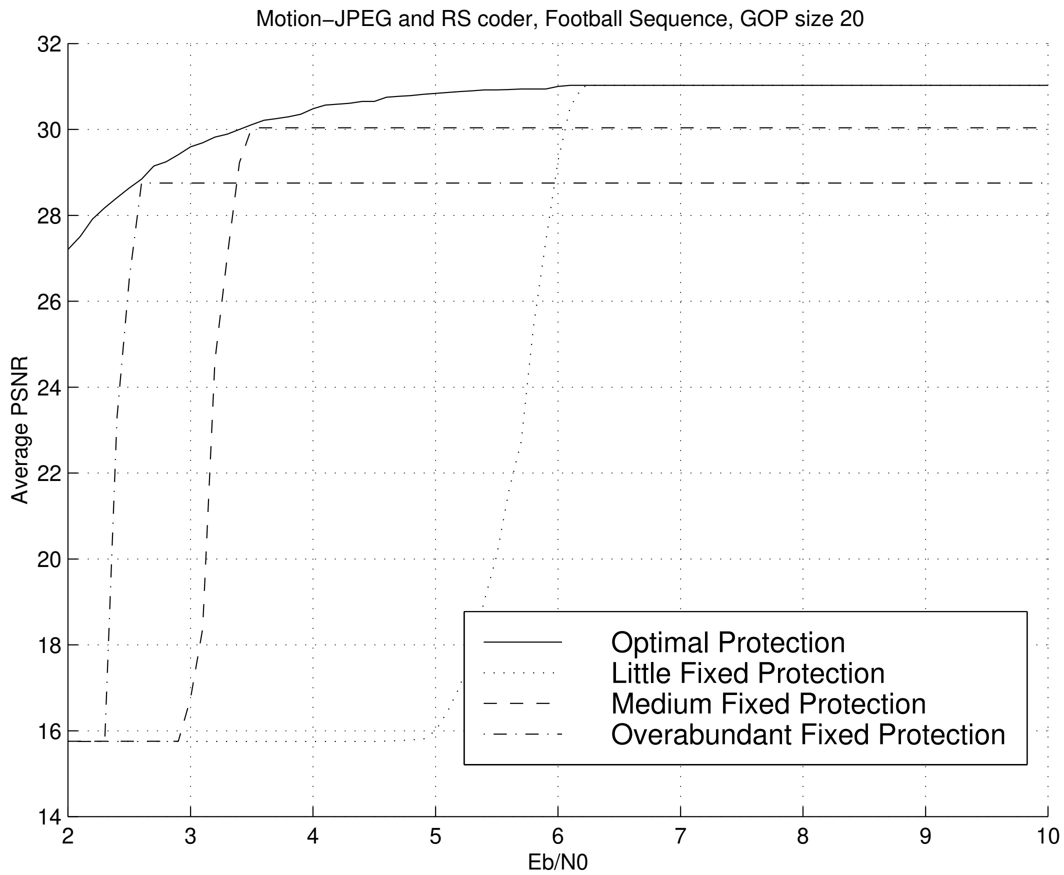
CBR and RS Coder

- Conditional Block Replenishment (CBR) coder only transmits significantly changed blocks.
- Blocks are DCT transformed, quantized and symbol coded before transmission.
- Source rate adjusted by N_b: the number of blocks to transmit for the current frame.
- Optimization: find N_b and t which yields the *minimax* frame distortion.

Implementation Details

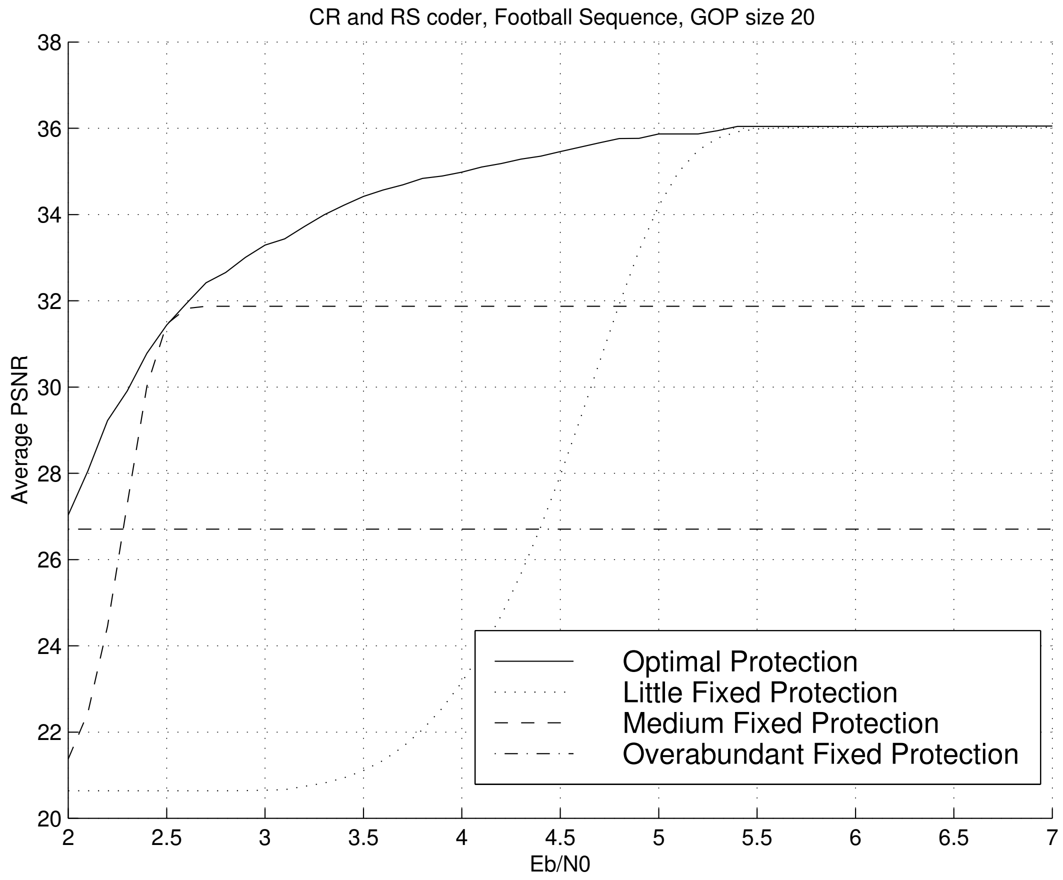
- Source model parameter estimation adds no extra computation to the overall complexity.
- Minimax distortion criterion strikes a balance between frame quality and quality variation.
- System initialization procedure again ensures convergence after no more than 5 iterations.
- System complexity level is the same as DCT.

Simulation Results (MJPEG-PSNR)



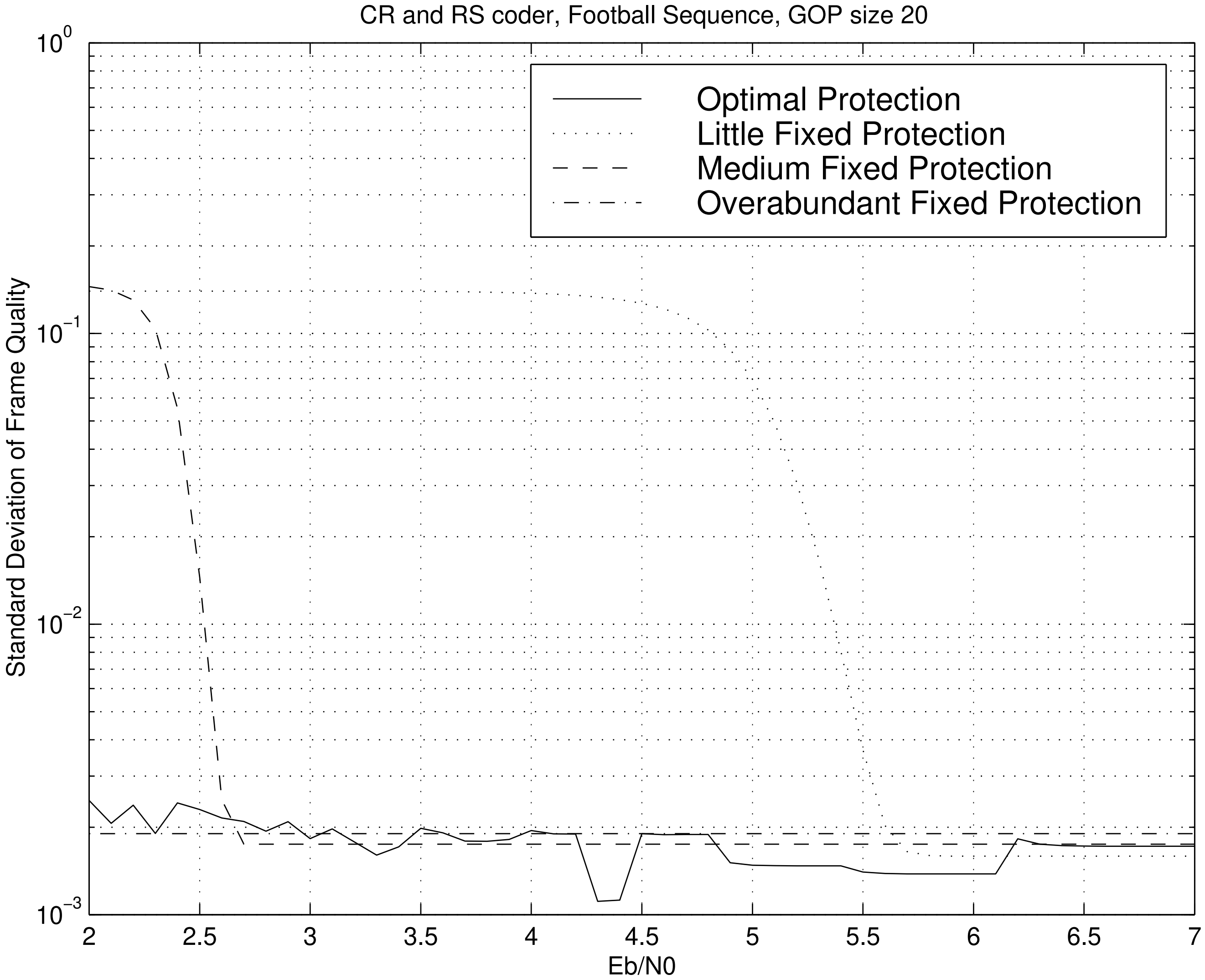
Our system always equals or beats any fixed-parameter system. The gain in performance is significant in some regions.

Simulation Results (CBR-PSNR)



Our system always equals or beats any fixed-parameter system. The gain in performance is significant in some regions.

Simulation Results (CBR-VAR)



Our system yields small frame quality variation over the entire range of channel situations

Generality Of Our System

- Inexpensive parametric-model approach for characterizing source-coder performance.

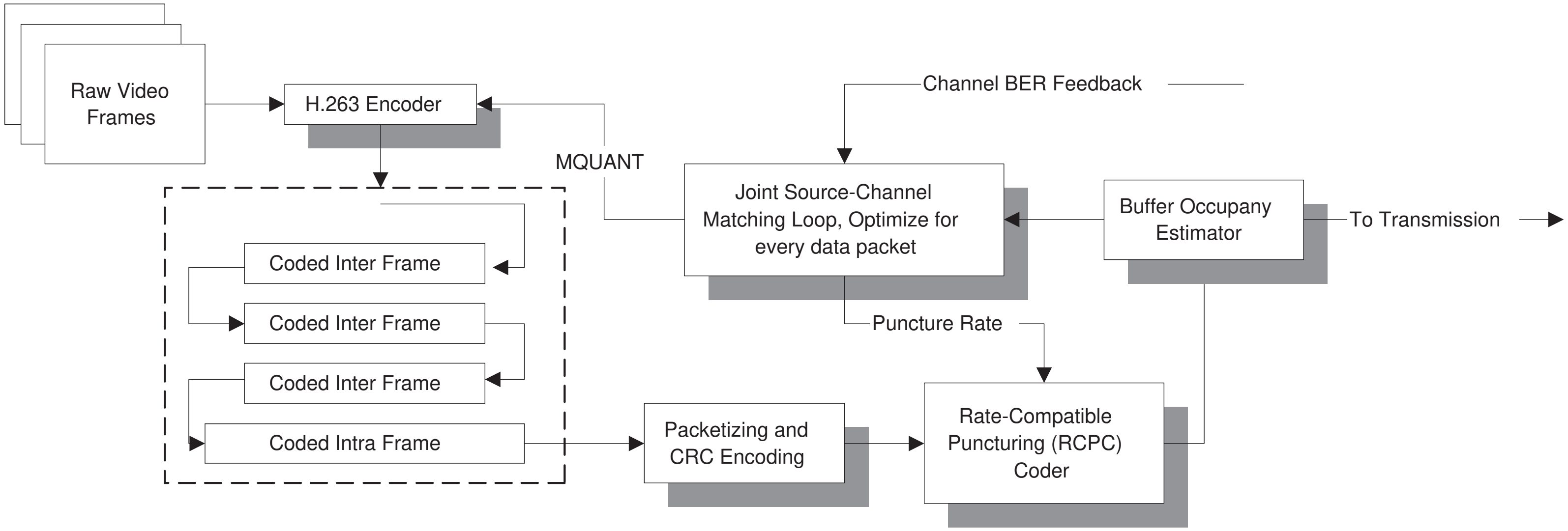
- Model parameters can be estimated online; no explicit knowledge about source coders required.

- Applicable to many coders, including standard ones.

Conclusions

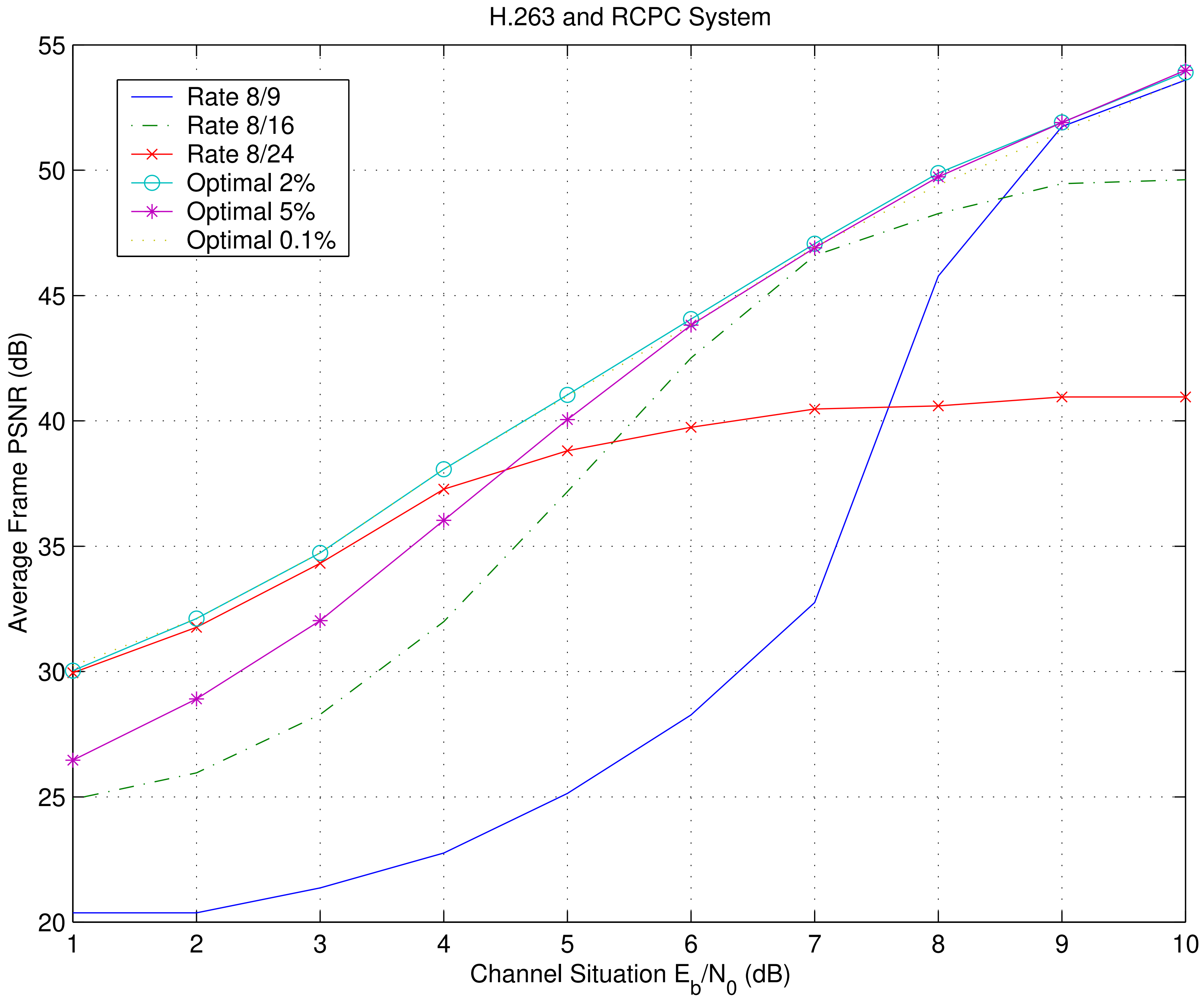
- JSCM provides high-level source/channel coder integration by jointly optimizing end-to-end performance.
- Our method is truly general because of the parametric-model-based approach.
- Our method has low computational complexity and can be implemented online.
- In future work, we will test our scheme on other types of channels such as fading/network channels.

JSCM System: H.263 and RCPC



- The system modifies $MQUANT$ and RCPC puncture rate on a macroblock level.
- Channel situation is estimated using accumulated packet error probability P_{pe}.

Simulation Results (H.263-PSNR)



Minimax Disappointment Video Broadcasting

- Different classes of users can be mapped to different received SNR values.

- Each user class expects a best performance from a JSCM system based on the received SNR.

- All users are somewhat "disappointed" because of the trade-off between the users.

- Minimizing the maximum level of "disappointment" for all the users.

Simulation Results for Video Broadcasting