Minimax Disappointment Video Broadcasting

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Seminar Outline

1. Motivation and Introduction

2. Background Knowledge

3. Simulation Systems Configuration

4. Results and Conclusions

Motivation

1. Multiple users receiving the same transmission under different channel situations.

2. Different class of users can be mapped to different received SNR values.

3. Need to effectively and meaningfully evaluate the performance of a broadcasting system.

4. Traditional weighted averaging schemes either penalize certain user class or are too ad-hoc.

Minimax Disappointment Criterion

1. Denote the ith user's optimal performance as P_i, obtained by applying JSCC to this user alone.

2. Denote each user's actual received performance as p_i, p_i is usually smaller than P_i.

3. $J_i = P_i - p_i$ is the ith user's *disappointment* value, $J = \max(J_i)$ is the broadcasting performance.

4. We set out to minimize J, the maximum of all users' disappointment value.

Minimax Disappointment Criterion (MD)

1. Fairness: no class of users is penalized more than the others.

2. Individuality: users under different channels do *expect* different performance.

3. Tractability: system optimization falls in the Minimax optimization framework.

4. MD is not limited to JSCC, it can be a universal broadcasting performance criterion.

Background Knowledge

1. Joint source-channel coding (JSCC)

2. Video source coding

   a. Video source coders

   b. Rate Control

3. Channel coders

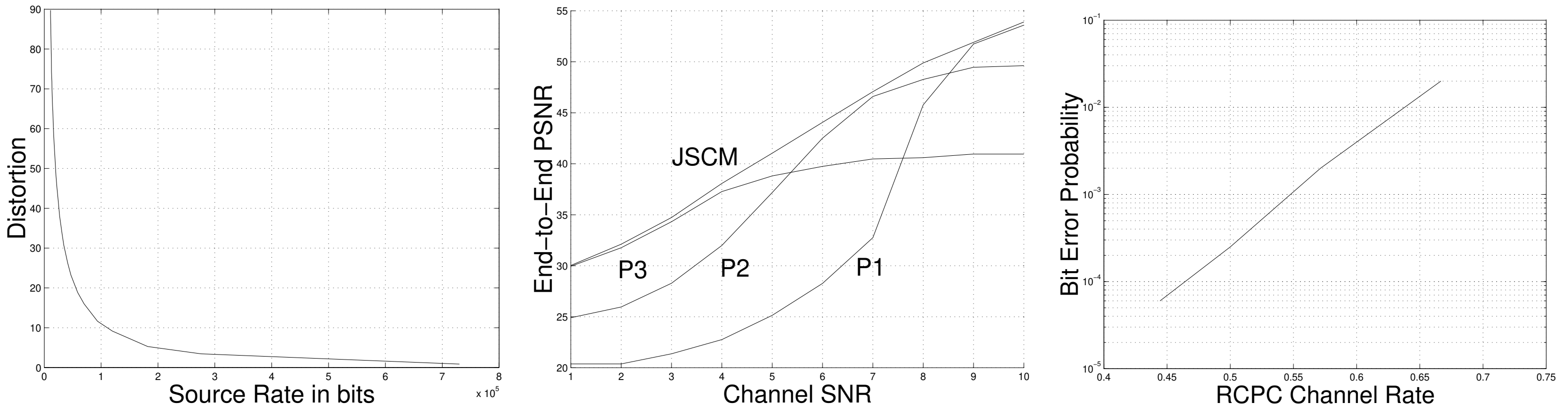
Joint Source-Channel Coding

1. Information separation theorem is valid under the impractical assumption of point-to-point transmission and allowing infinite delay (long keywords).

2. True JSCC involves the co-design of source and channel codes, we focus on the more general joint source-channel matching. (JSCM)

2. Joint source-channel matching improves performance by optimizing limited system resources (bandwidth, power, etc) between source and channel.

Joint Source-Channel Matching



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

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

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

Video Source Coders

1. Intra-frame coding (Motion-JPEG, Motion-SPIHT): low efficiency, random-frame accessibility.

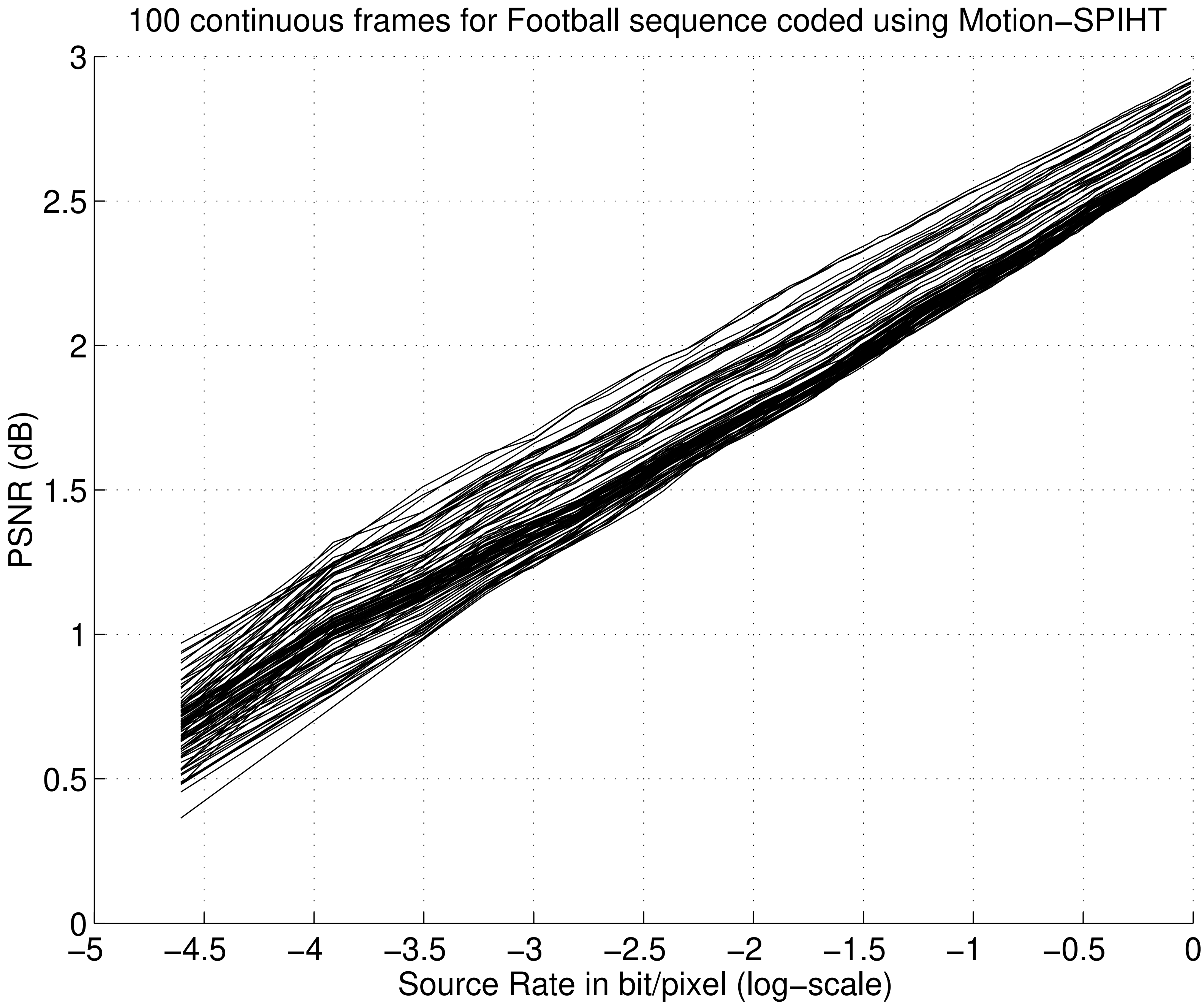
2. Inter-frame coding: exploiting frame dependency

   a. 3D waveform coding (3D-DCT, 3D-SPIHT).

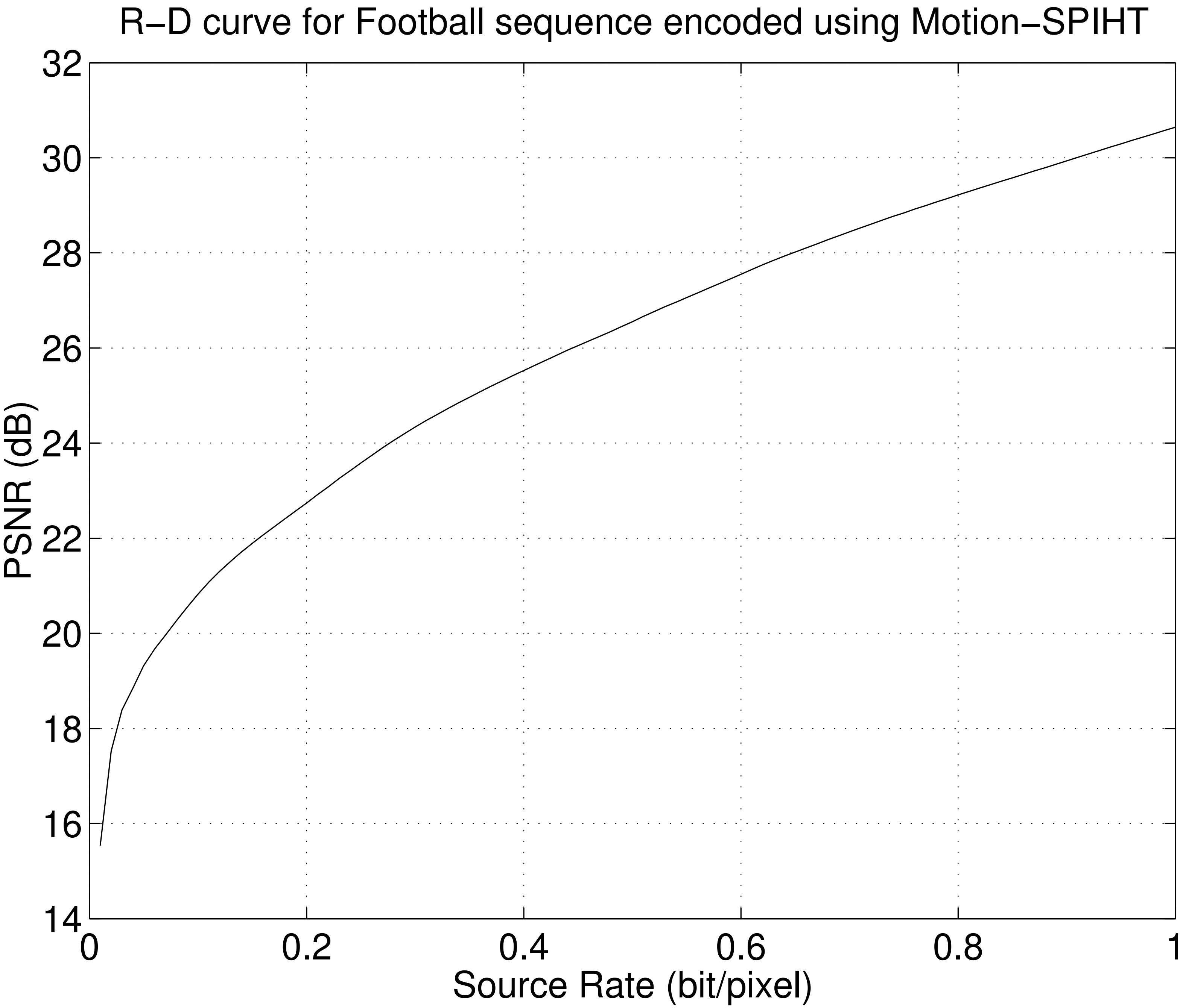
   b. Motion-Compensated coding (MPEG, H.26x).

   c. Object-Knowledge based model coding.

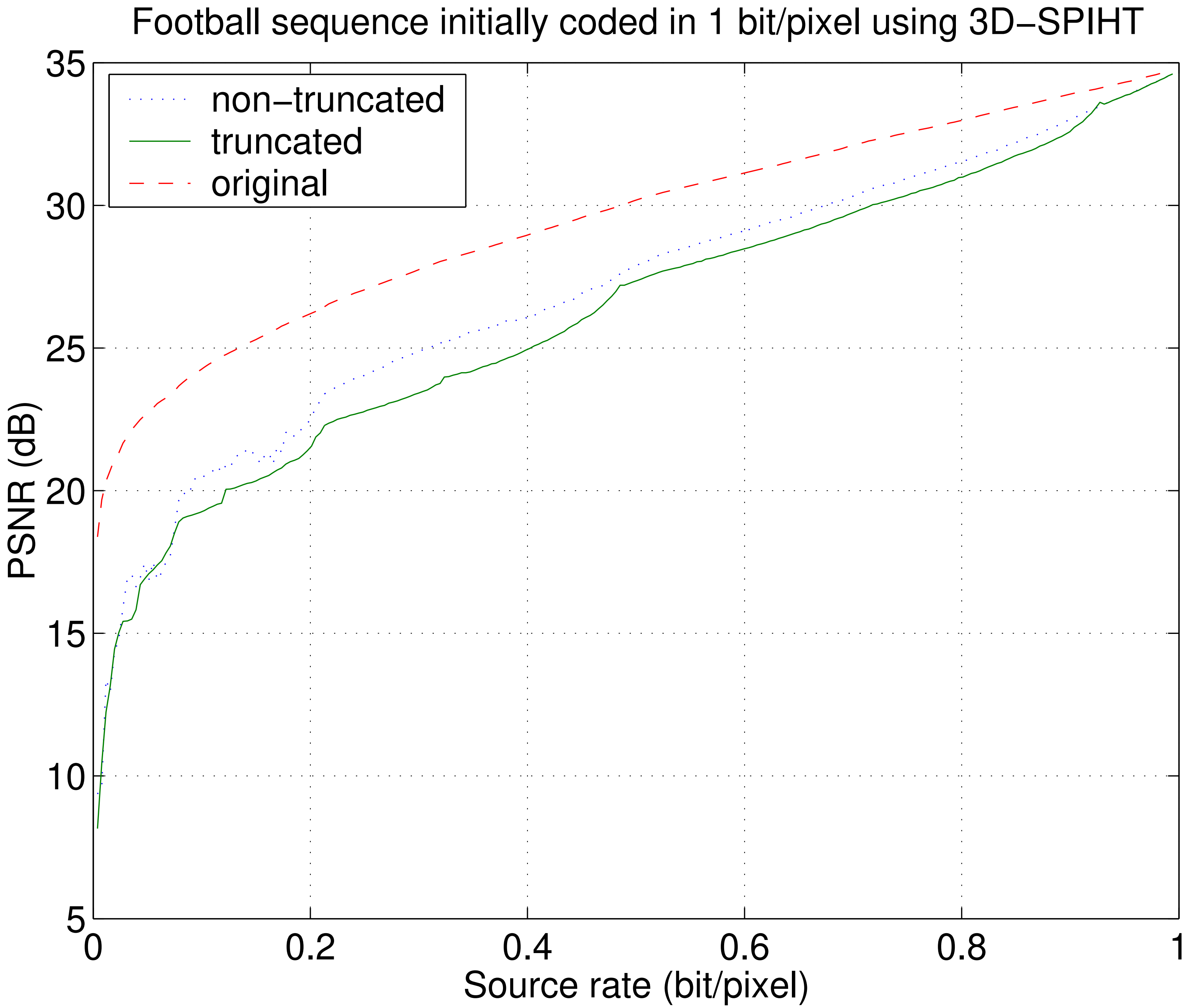
RD-Curve: SPIHT



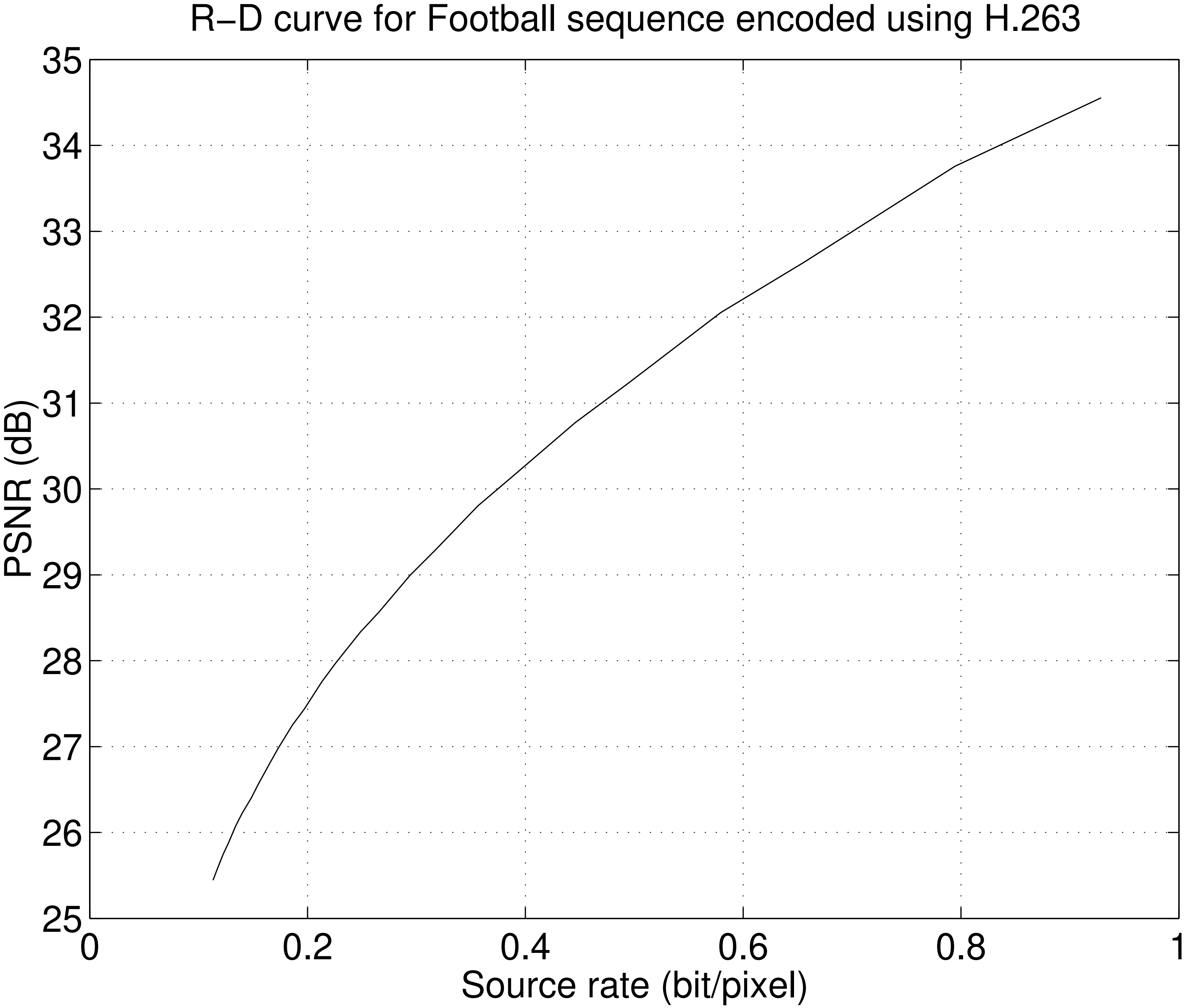
RD-Curve: Motion-SPIHT



RD-Curve: 3D-SPIHT

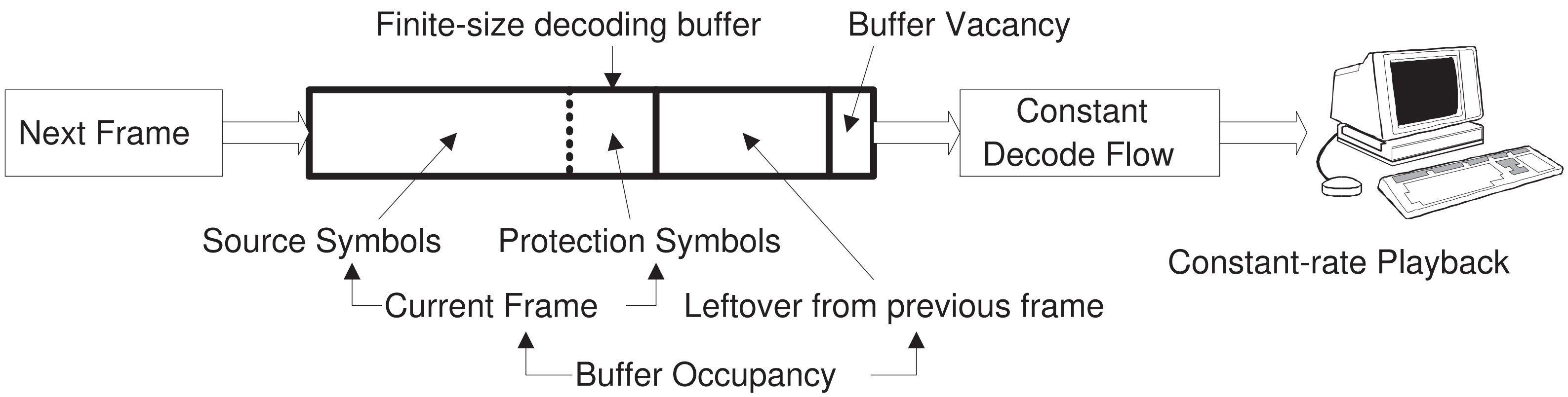


RD-Curve: H.263



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.



Channel Coders

1. Reed-Solomon (RS): block codes with good ability to correct channel burst errors, defined by (n, k, t), can correct t errors.

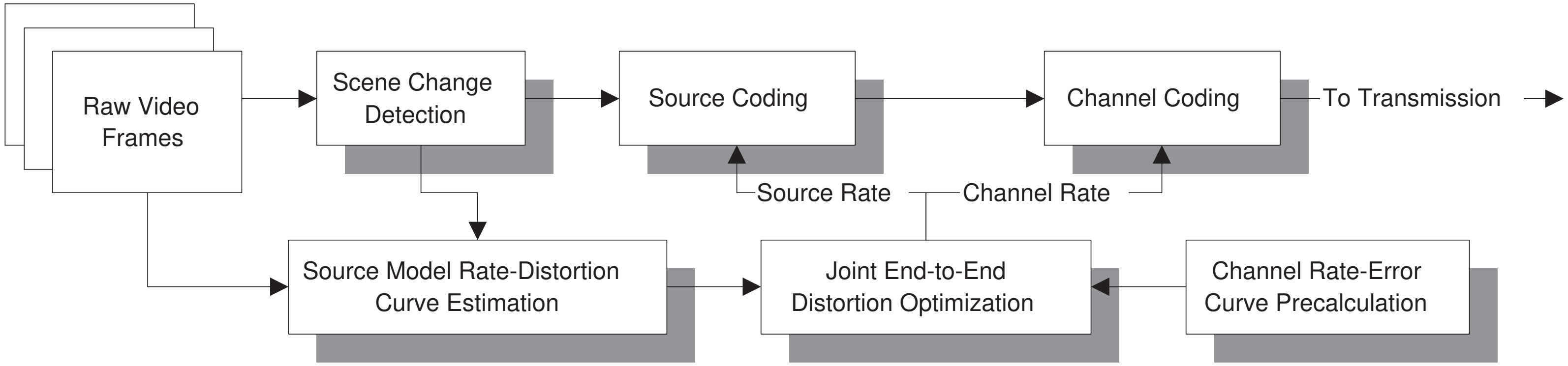
2. Rate-Compatible Punctured Convolutional Codes (RCPC): convolutional codes obtained by puncturing a low-rate code, allowing transmission in incremental redundancy.

Optimization Toward Single User Class

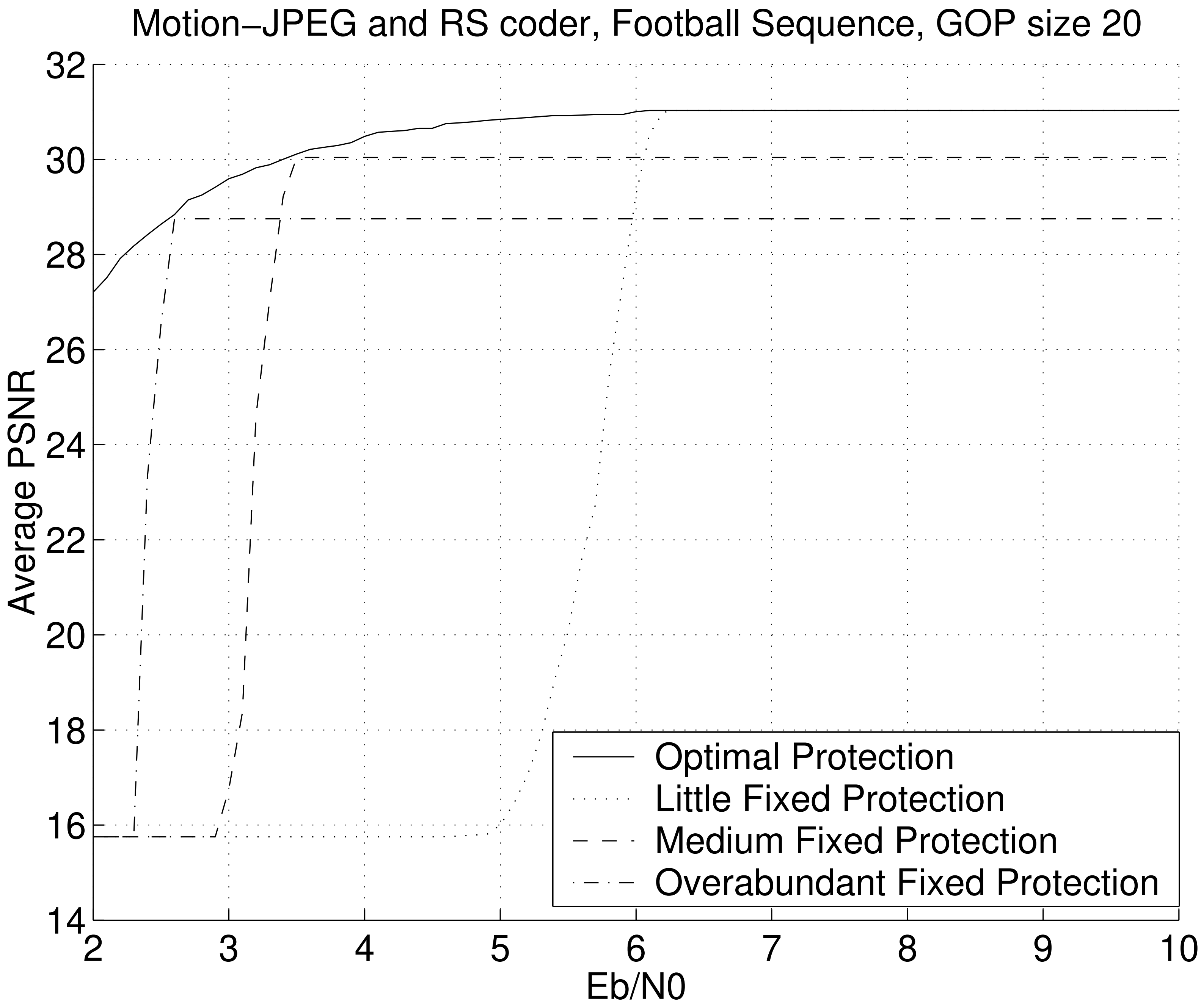
1. Obtain best end-to-end performance within the constraints of limited channel capacity, delay and rate-control requirement, with regard to current user's channel situation.

2. Achieve a certain level of system generality so JSCM can be applied to various standard source-channel coder combinations.

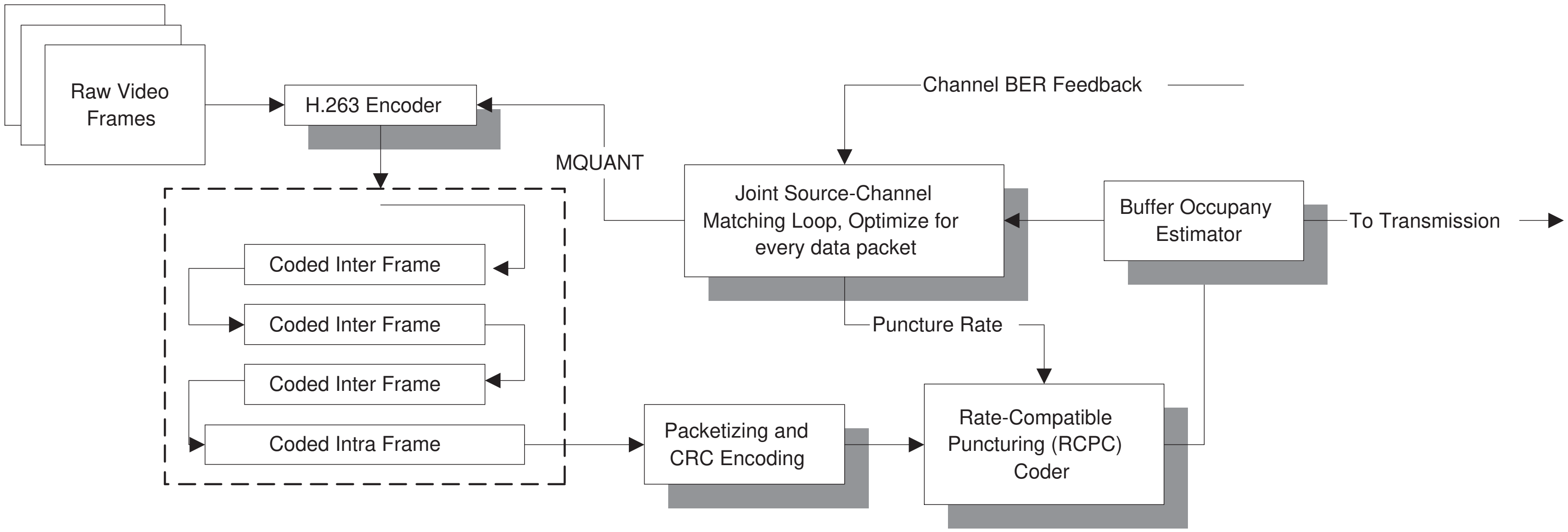
General System Diagram



Simulation Results (MJPEG-RS)

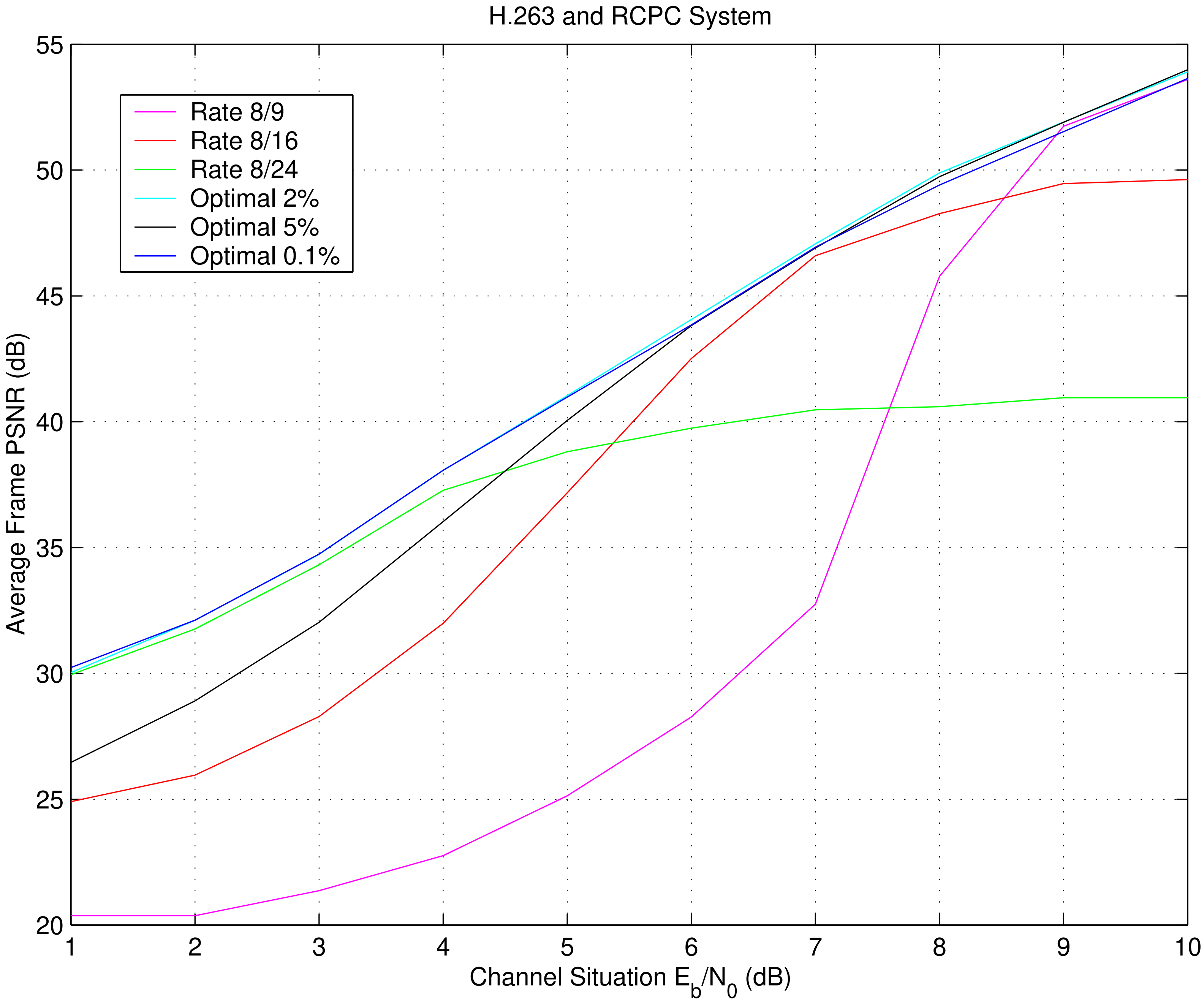


Self-adaptive Suboptimal System



H.263 and RCPC Coder

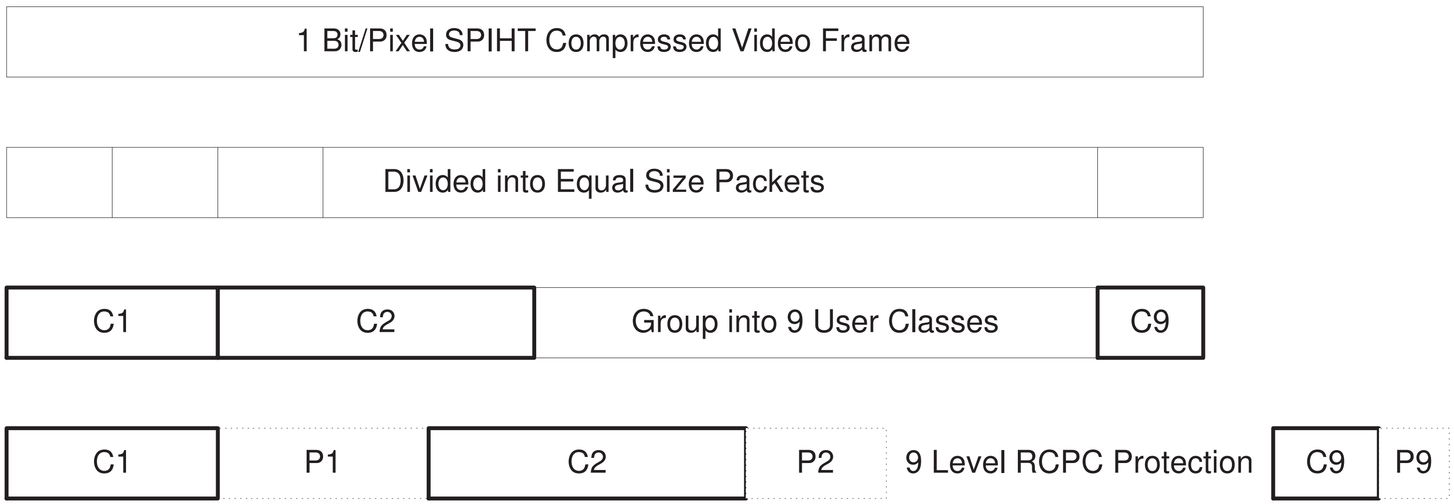
Simulation Results (H.263-RCPC)



MD Broadcast Simulation Parameters

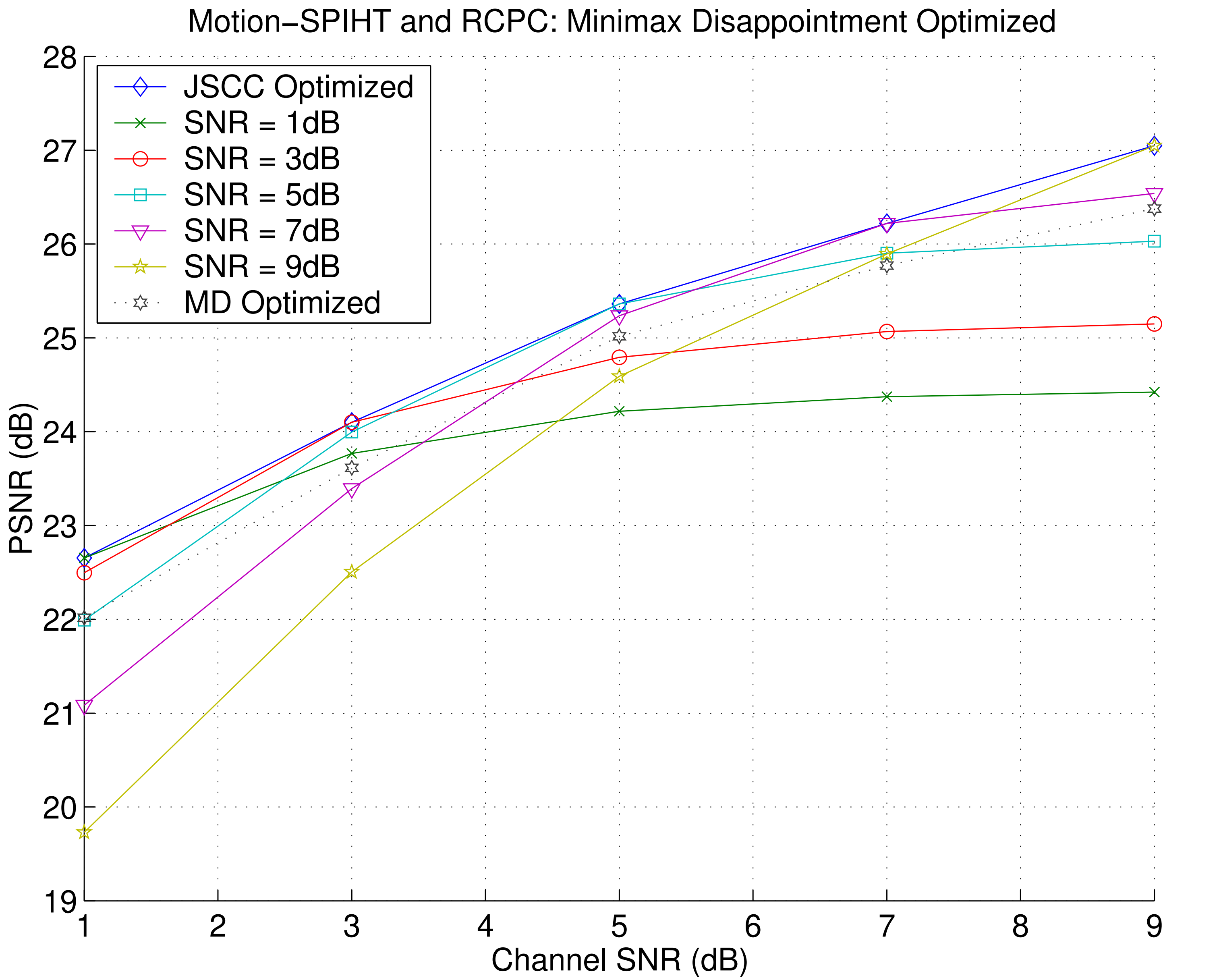
1. Fast-motion football sequence in QCIF format.
2. Five user classes with channel SNRs spread out evenly in the range of 1dB to 9dB.
3. RCPC encoder with 9 available puncture rates.
4. Limited channel capacity of approximately 1 bit/pixel.
5. We tested both the case of limited channel capacity and the case of limited transmission power.

Broadcasting Simulation System (I)



Motion-SPIHT and RCPC Coder

Simulation Results: MD = 0.6703dB



Broadcasting Simulation System (II)

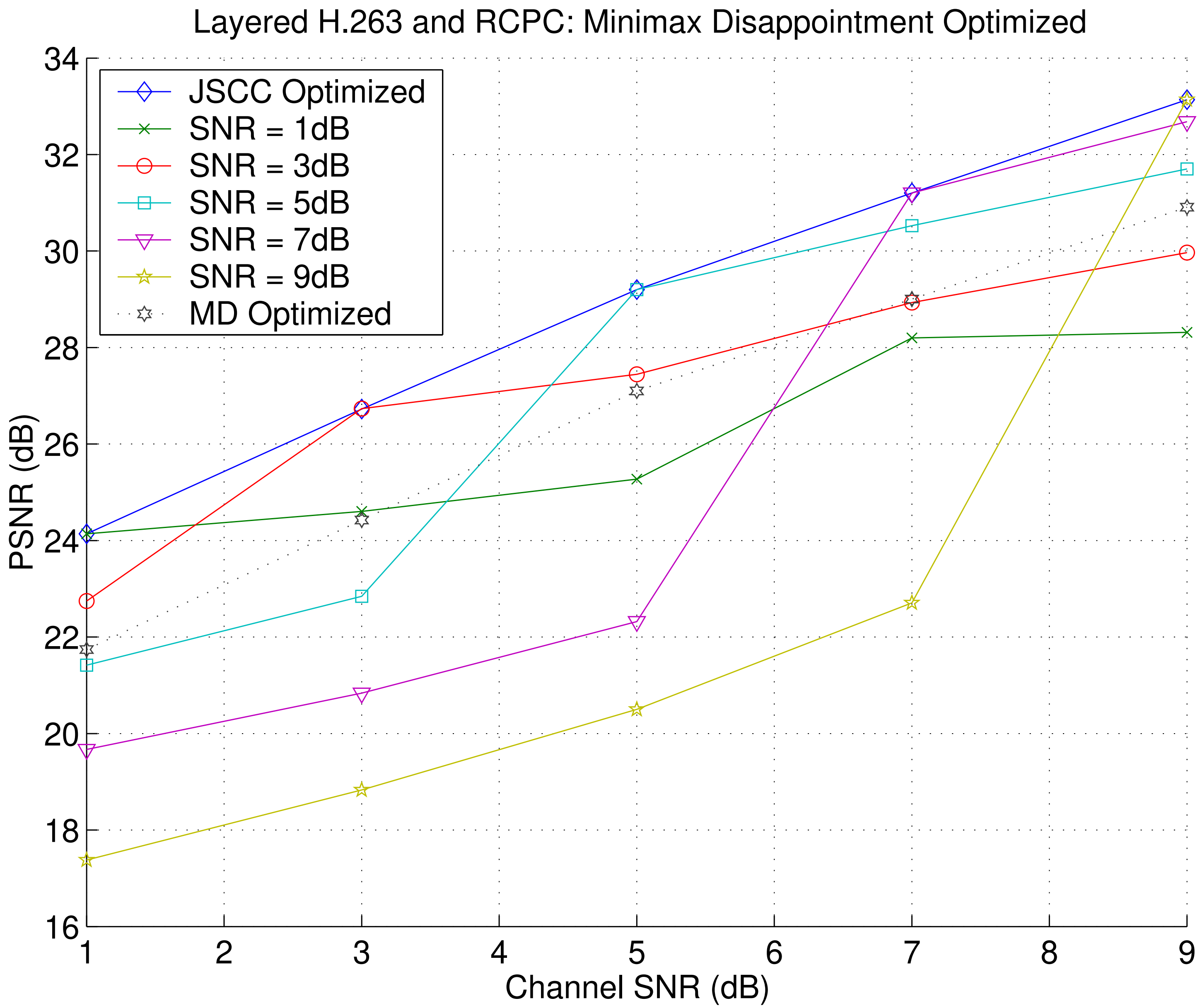
1. Layered-H.263 as source encoder, RCPC as the channel coder.

2. Each layer is an independent H.263 stream protected with different RCPC rates.

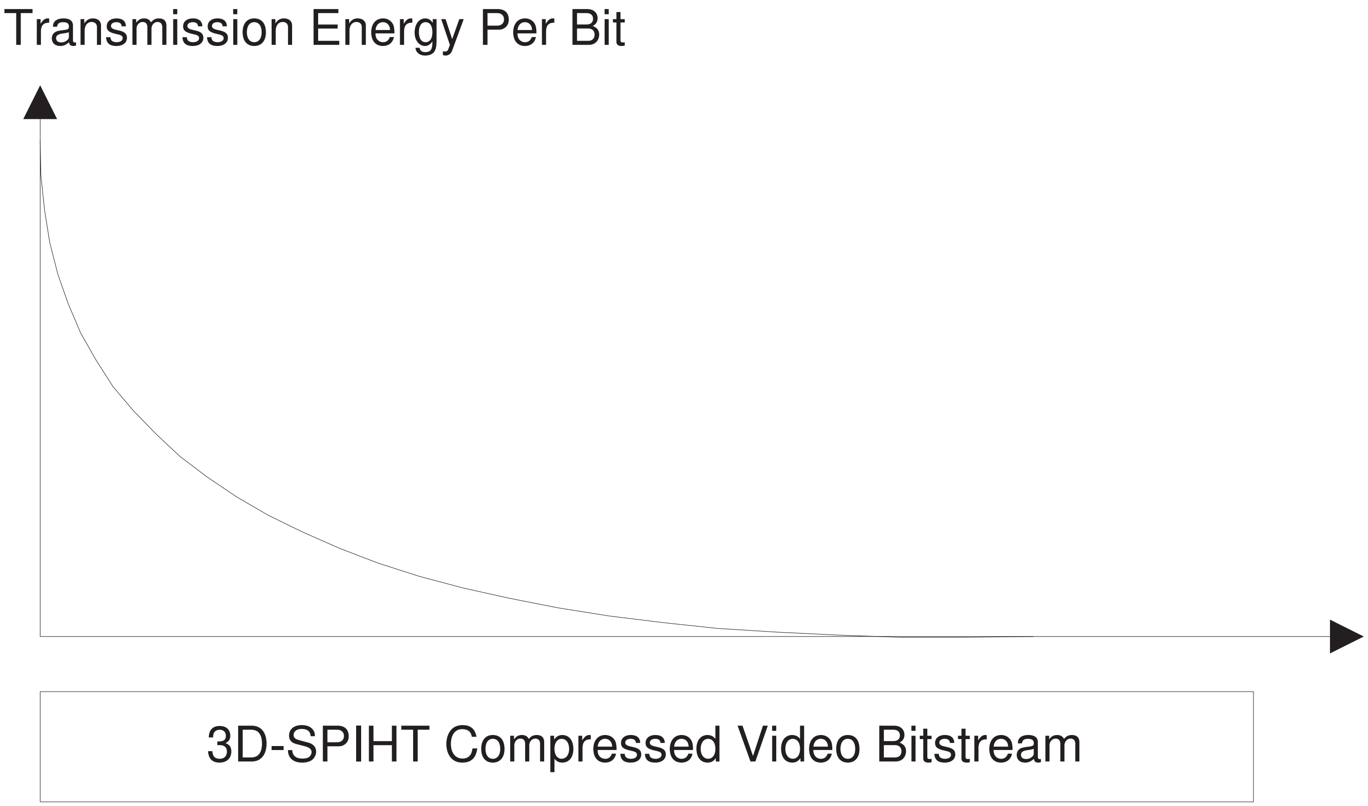
3. Each user class decodes the layer which gives best decoding performance.

4. Inefficient because of retransmission of coarse information, however each layer coder is efficient.

Simulation Results: MD $= 2.4$dB

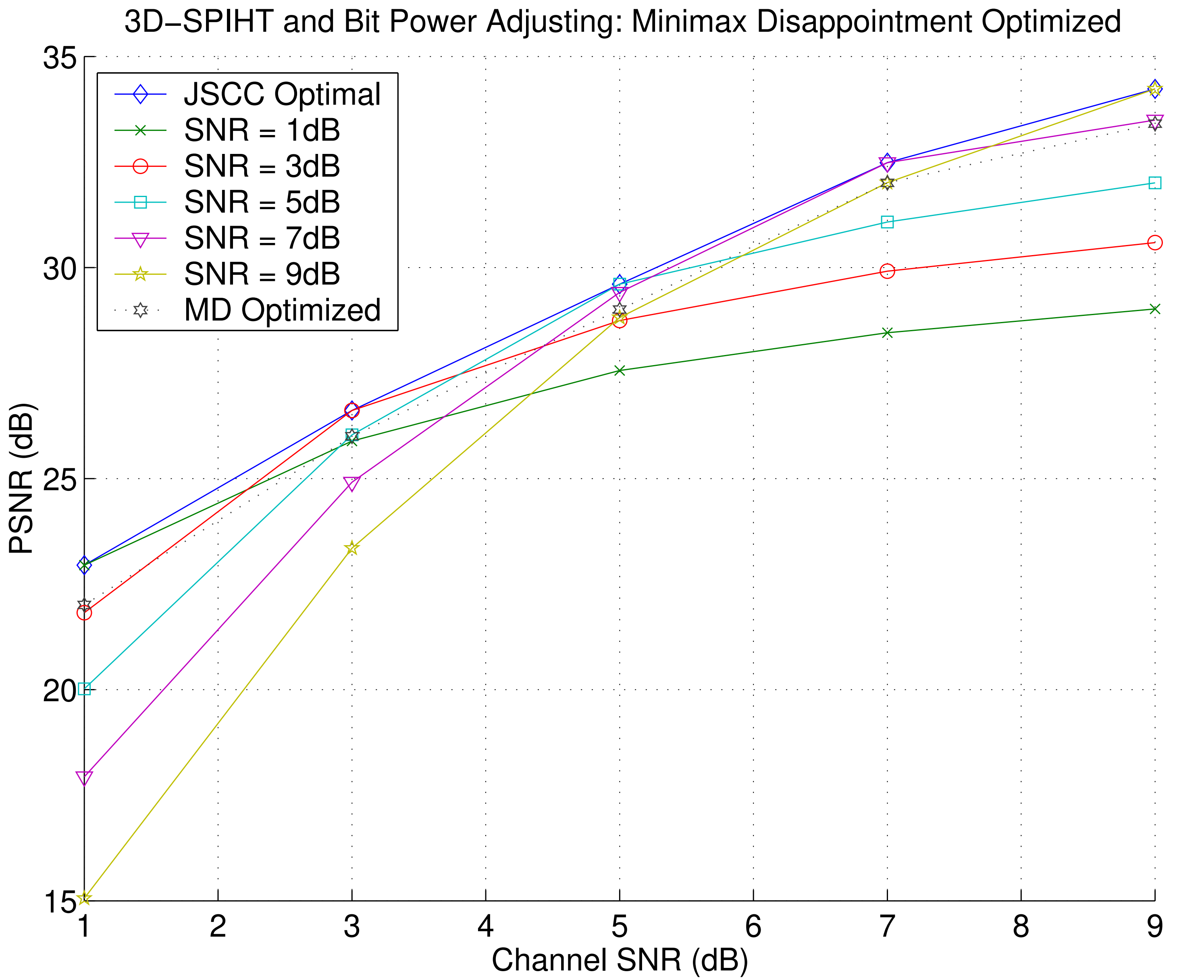


Broadcasting Simulation System (III)



Adjust the transmission power for each bit in a 3D-SPIHT stream under a total power constraint.

Simulation Results: MD = 0.9831dB



Discussion on Optimization

1. Constrained, nonlinear, discrete multi-variable optimization problem, non-trivial to solve.

2. Optimizing for each user class can use gradient-descent algorithms and penalty function approach.

3. We use the *first method of successive approximation* to solve the minimax problem, convergence guaranteed with convex cost function.

Extension: Network Multicasting

1. Multicasting sends the same packets simultaneously to all receivers: bandwidth-efficient.

2. Multicasting is undesirable when users are connected to the network at heterogeneous rates.

3. One popular approach is receiver-driven layered multicast.

4. Similar to broadcasting, JSCC and minimax disappointment can benefit network multicasting.

Conclusion

1. Minimax disappointment can serve as a fair and meaningful broadcasting/multicasting criterion.

2. With layered service, multiple user classes can have the same level of performance degradation.

3. We need a progressive video encoder to achieve good performance with our MD criterion.