Evaluation of JSCC for Multi-hop Wireless Channels

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Outlines

- Introduction and overview
- Related work
- System model
- Simulation results
- Conclusion
- Bibliography

Introduction and overview

- Wireless Channel
  - More demand on transmitting video and image
  - Error inherit channel
- JSCC — Balance between source and channel coding
  - Source Coding—remove redundancy
  - Channel Coding—add redundancy
  - Joint source-channel coding (JSCC)—put two parts together

Related Work

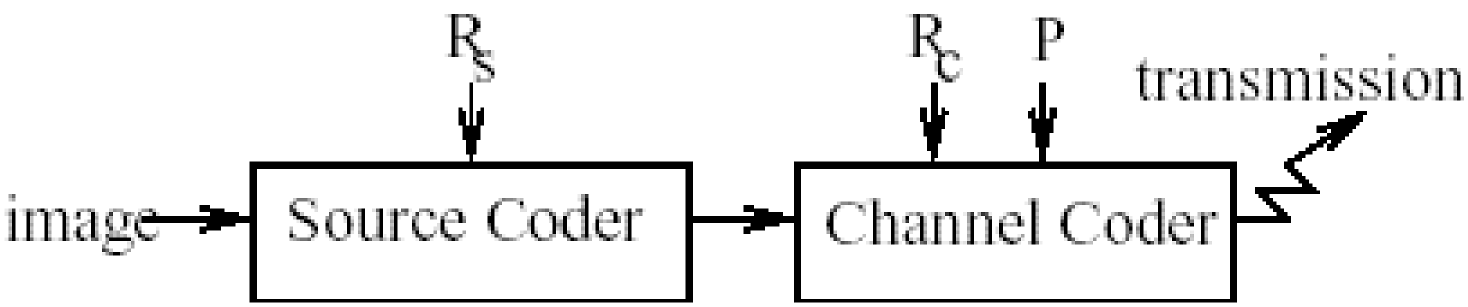
- Source Coding
  - Decomposition algorithms
    - Wavelet transformation (JPEG2000)
    - Cosine transformation
  - Quantization
    - Lloyd-Max Quantizer
    - lattice vector quantizer
    - Trellis Coded Quantizer (TCQ)
    - Vector Quantizer
  - Coding
    - Entropy constrained coding: Arithmetic, LVC, Hoffman,etc.
    - TCQ

Related Work (cont'd)

- Channel Coding
  - Block code (Oldest error combating codes)
  - Convolutional code (Viterbi Decoding)
  - Turbo code (Concatenated convolutional codes)

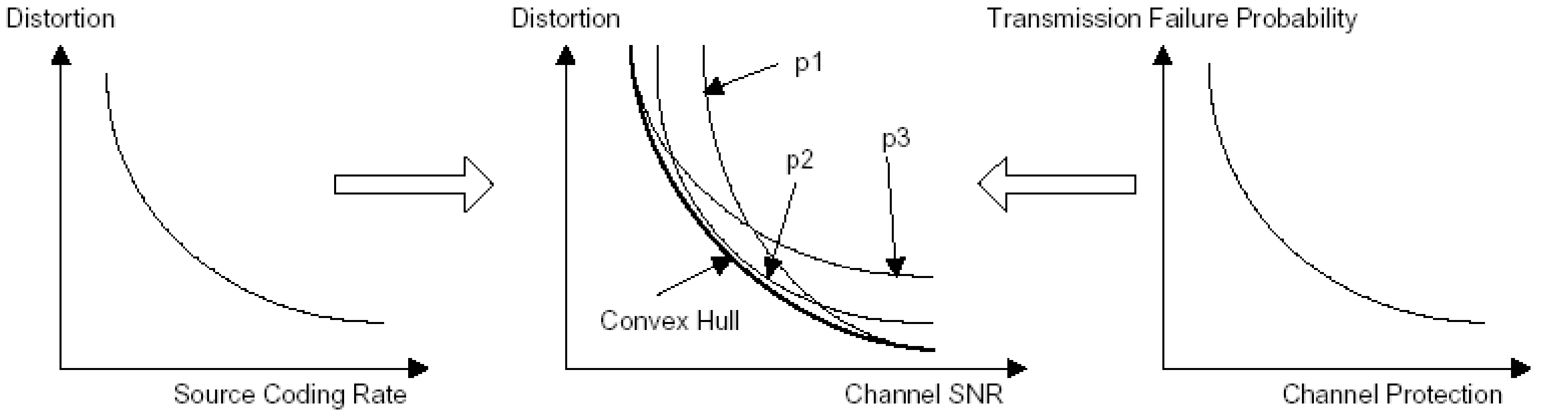
Related Work

- Joint Source-Channel Coding
  - Priority based
  - Rate allocation based



Related Work (cont'd)

- Different channel coding rate and source coding rate combination gives different performance
- To hit the best rate allocation point according to determined channel condition to minimize distortion

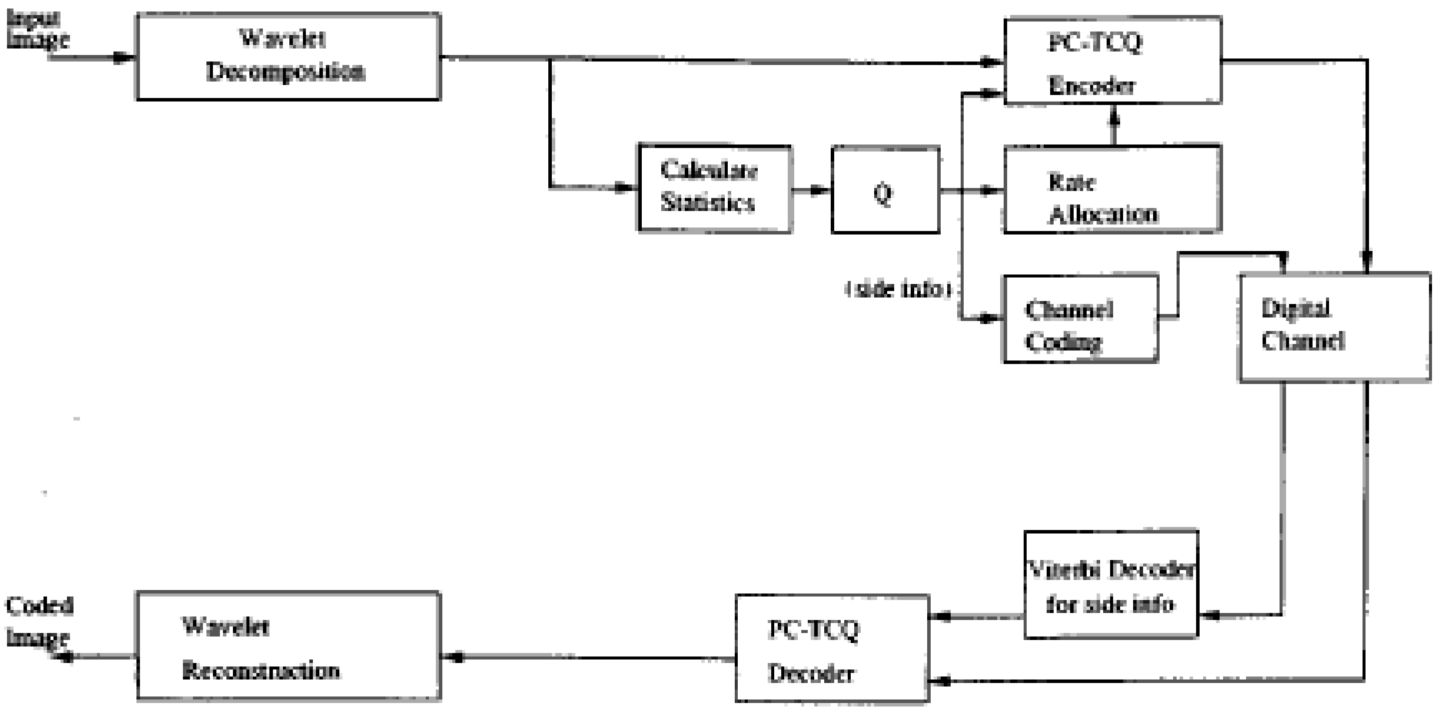


Related Work (cont'd)

- Different Channel Properties
  - Rayleigh flat fading
  - White Gaussian noise
  - Binary channel
  - Rate calculation and allocation
- Image decomposition
  - Wavelet decomposition
    - Both space and frequency domain

Related Work (cont'd)

- An example of complete JSCC system structure (rate allocation based)



System Model

- Source information and coding model
  - Information source generates analog numbers uniformly distributed between 0 and 1 at discrete time.
  - The source symbols are sampled by a Lloyd-Max quantizer with different rates of 2 bits per symbol, 3 bps and 4 bps

System Model (cont'd)

- Lloyd-Max Quantizer
  - minimize quantization noise variance

$$\min \sigma_q^2 = \min \sum_{k=1}^{L} \int_{x_k}^{x_{k+1}} (x - y_k)^2 p(x)\, \mathrm{d}x$$

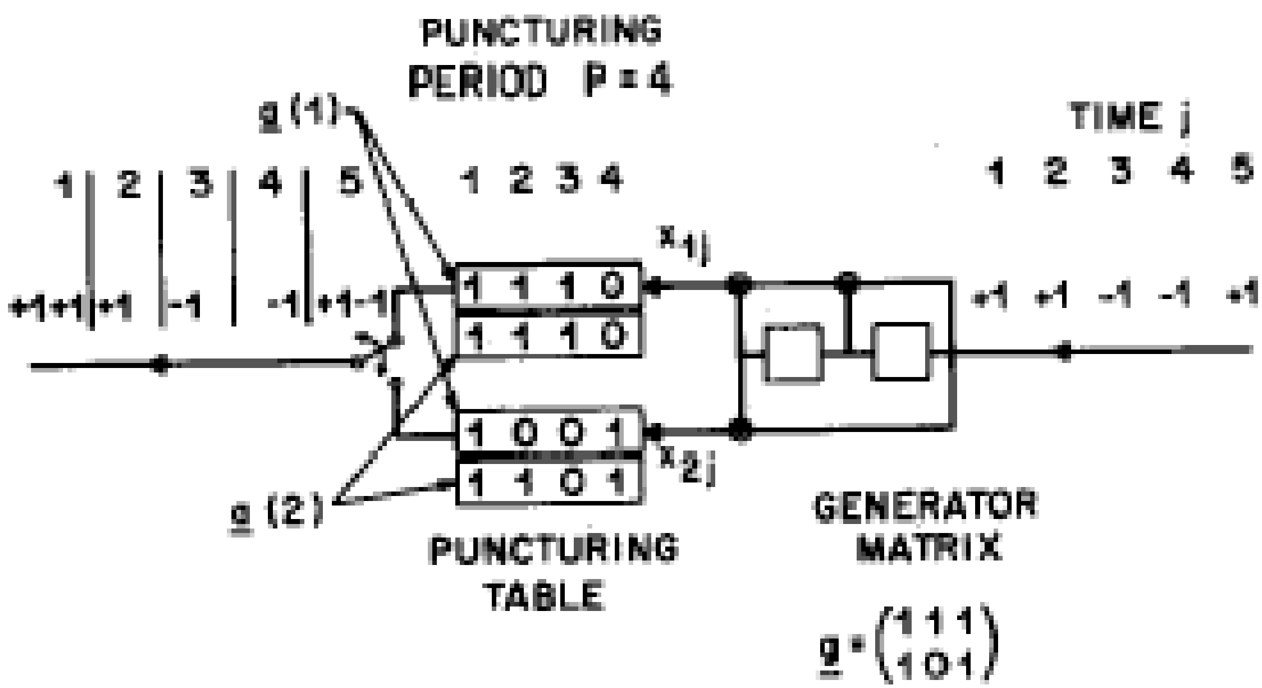
for:

$x_k \qquad k = 2,3,\ldots,L$

$y_k \qquad k = 1,2,\ldots,L$

- If the source is uniformly distributed, this quantizer collapses to a uniform quantizer.

System model (a similar RCPC coder)



System Model (cont'd)

- Channel coding model (RCPC example)
  - convolutional encoder
    - With the mother code rate 1/2
    - Viterbi decoder
  - rate compatible puncture code
    - Puncture period is 4
    - Without puncturing the coder provides 1/2 convolutional code. With matrix a(1), the rate becomes 4/5. With matrix a(2), the rate is 4/6.

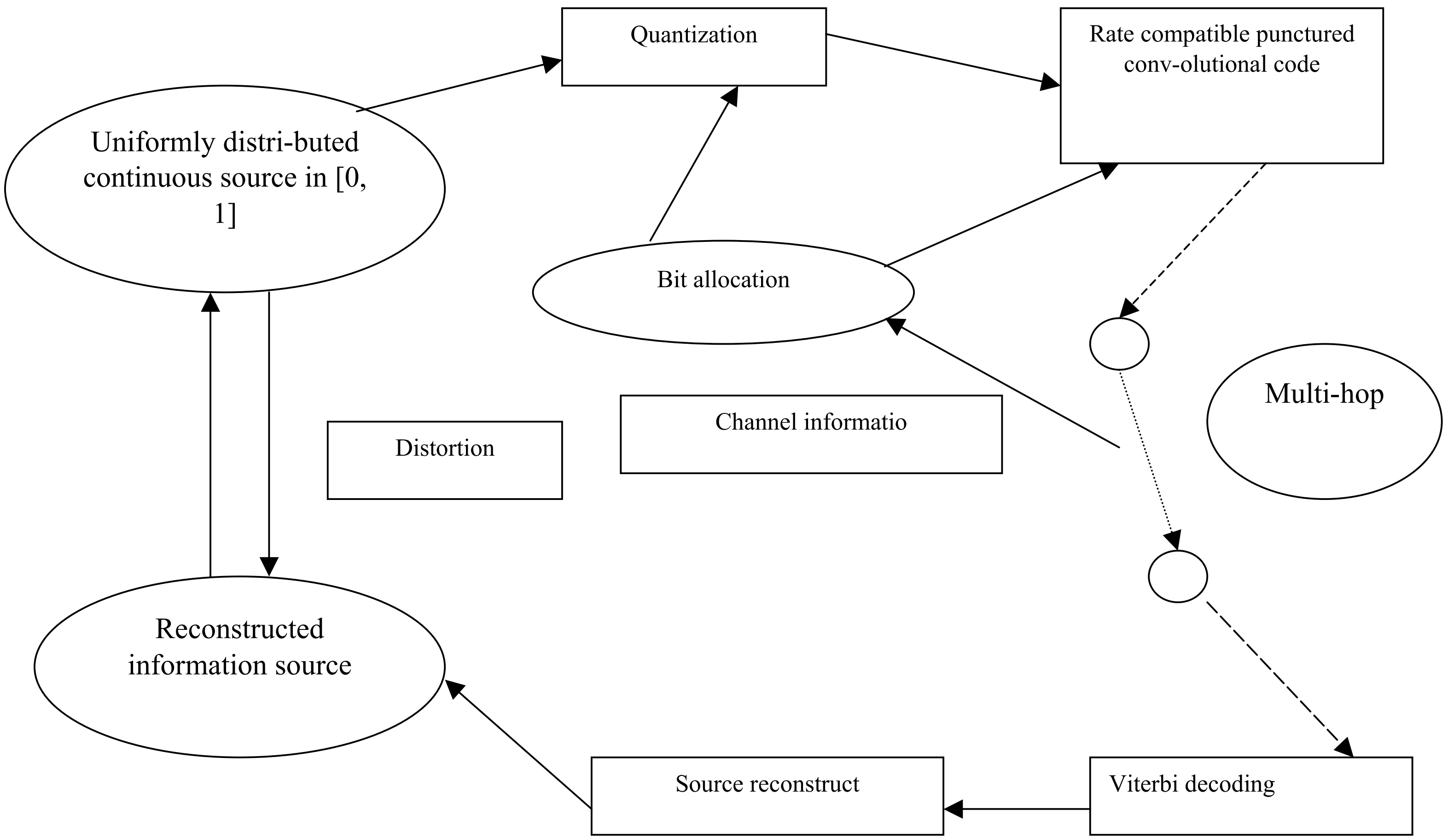
System Model (cont'd)

- The RCPC coder we are using here
- Rate 1/4 mother convolutional coder
- Memory 4
- Puncture period 8
- Provides flexible rate 8/(8+L), L=0,1, …, 24

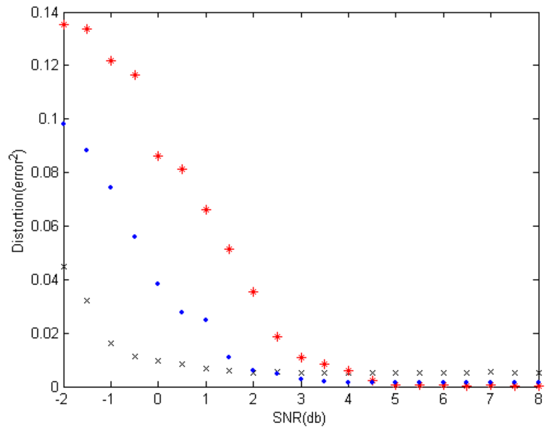
System Model

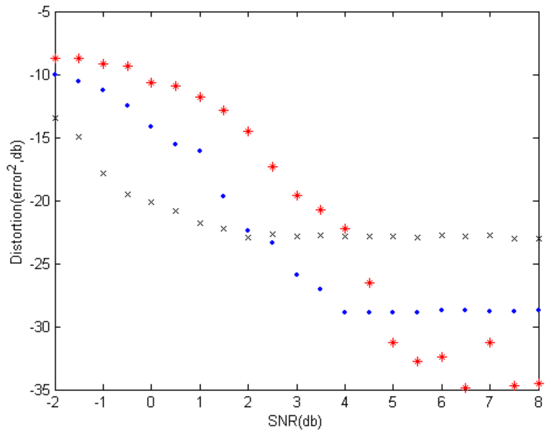
- Three different rate allocations
  - Rs=2 bps, Rc=1/4, Rt=8 bps;
  - Rs=4 bps, Rc=1/2, Rt=8 bps;
  - Rs=3 bps, Rc=4/11, Rt=8.25bps;
- Channel Model
  - single link white Gaussian noise channel
  - simulate multi hop channel, which possesses different SNR characteristics over different links
  - Rayleigh flat fading channel with white Gaussian noise

System Model (cont'd)



Simulation Results





- Cross: Rt=8bps; Rs1=2bps; Rc1=1/4;
- Star: Rt=8bps; Rs2=4bps; Rc2=1/2;
- Dot: Rt=8.25bps; Rs3=3bps; Rc=4/11;

Simple uniform quantization plus RCPC over single WGN link

Simulation Results (cont'd)

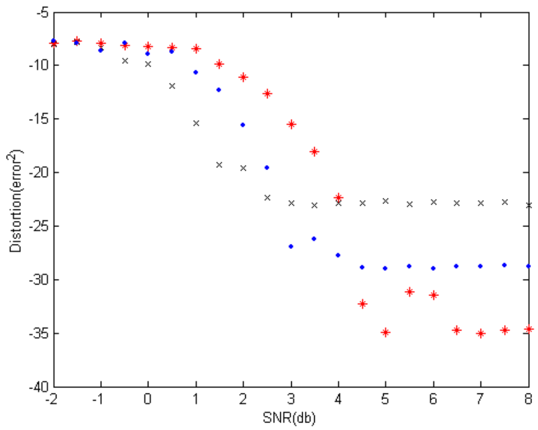


Fig1

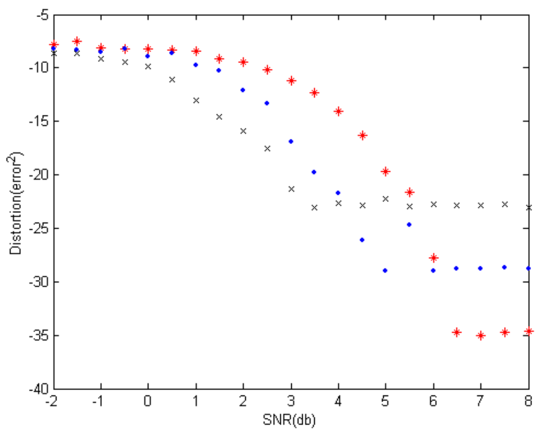


Fig2

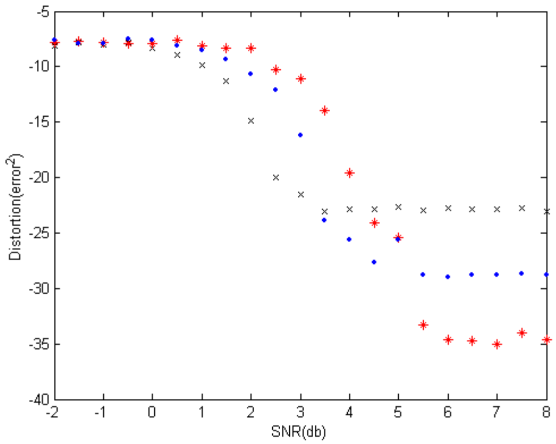
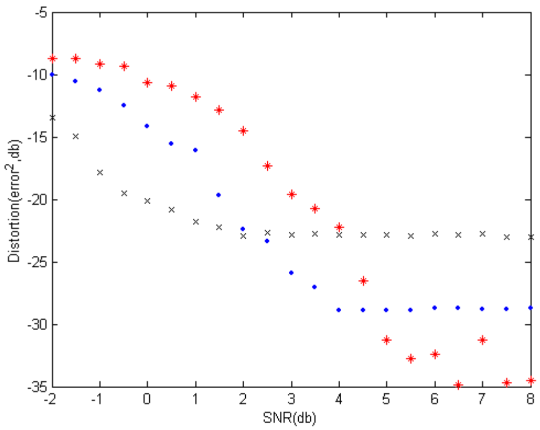


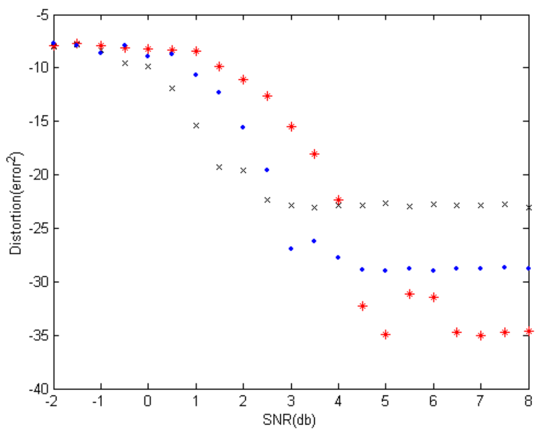
Fig3

- Fig 1: SNR1=2*SNR2; two-hop
- Fig 2: SNR1=SNR2; two-hop
- Fig 3: SNR1=SNR2/2=2*SNR3/3 three-hop

Multiple WGN links, WGN channel
the same rate allocation as in last case

Simulation Results (cont'd)





- Comparison of one hop and two hop link.
- The worse link in two hop channel is the same as the single link.
- They have similar structure around the high SNR end.

- Figure 1 one hop distortion vs. SNR
- Figure 2 two hops SNR1=2*SNR2 distortion vs. SNR2

Simulation Results (cont'd)

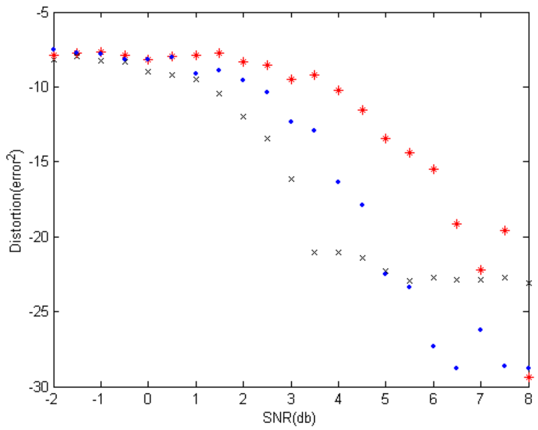


Fig 1

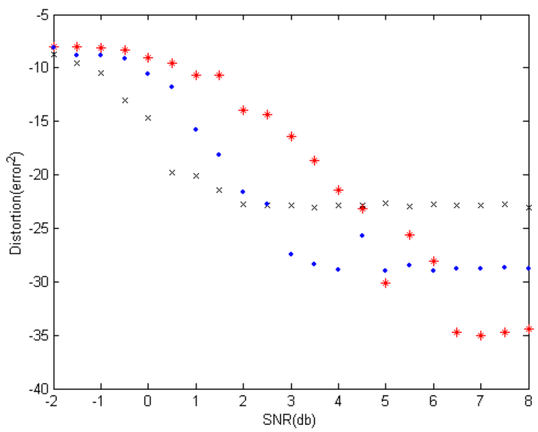


Fig 2

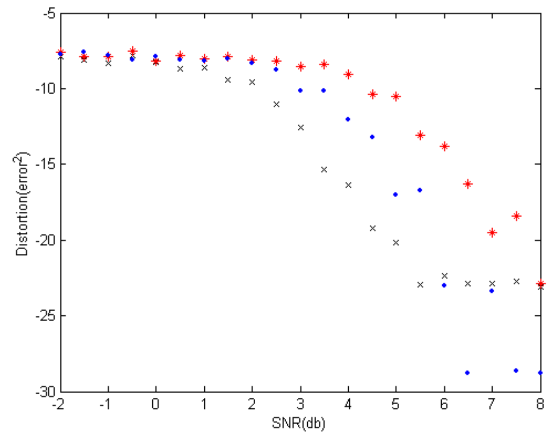


Fig 3

- Fig 1: mean power =2.0
- Fig 2:With mean power of 5.0
- Fig 3:
  - Hop 1: with mean power =2.0;
  - Hop 2: E(r^2) =1.5;
  - Hop 3: E(r^2) =1.0;

Multihop Rayleigh flat fading channel
The same WGN as previous

Conclusion

- Adaptively allocating rates between source coding and channel coding can achieve optimal performance with varying channel states.
- In multi-hop scenario, the accumulated noise counts, hence the worst link, which contributes most to the error, should be considered as the dominant factor in rate allocation.

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