Problem Statement

- Broadcast given encoded image to multiple users to minimize aggregate distortion
- For each packet: Should we transmit (blocking other transmissions) or Drop (incurring distortion)
- Users prioritize packets differently—what does this mean for the transmission scheme?

Contributions

- General offline algorithm for optimal transmission
- Optimal online algorithm for Bernoulli i.i.d. channel losses
- Multiple Distortion Measures
  - PSNR typically measured against original High Resolution image
  - Problem: Diversity of multimedia users
    - Scalable media allows for many resolutions
    - A Low Res (LR) user only cares about LR
  - MDM account for user’s viewing capability
    - Up to 4dB gains can be achieved by incorporating MDM [1]

Examples

- Recvd image → Original image
- Dropping → Transmitting
- LR Recvd → LR Original

Optimal Transmission Policy

Stochastic Shortest Path Problem

- State: \((v, m, s)\)
  - \(v_i = 1\) if user \(i\) has not received packet \(m\)
  - \(m\) is index of Head of Line packet
  - \(s\) = channel state
- Costs:
  - Backlog: \(B(m)\)
  - Distortion (if not Rx): \(d^m\)
- Actions:
  - Transmit or Drop HOL

Dynamic Programming Algorithm

\[
J(v, m, s) = \min_{\text{backlog}} \{ \alpha B(m) + \min \{E(v', s') J(v', m, s') \} \} + \sum_{i} v_i d_i + E(v', s', s) J(v', m + 1, s')
\]

Special Case

- i.i.d. Bernoulli packet losses
- If transmitted packet is not successfully received by all users, return to the same state.

Optimal Threshold Policy

- Let \(d_i\) be the reduction in distortion to user \(i\), if the HOL packet is received
  - \(d_i = 0\) if it has already been received (\(v_i = 0\))
  - \(d_i = d_i^f\) if it has already been received (\(v_i = 0\))

Transmit if:

\[
\alpha B(m) \leq s_1 d_1 + s_2 d_2
\]

Otherwise, drop

Sketch of Proof

- Consider the case of 2 users
- Look at HOL packet \(m\)
- Assume user 2 has already received HOL packet, so \(d_2 = 0\)
- Once user 1 receives packet \(m\), move to next packet
- Cost of Transmitting:
  \[
  f + K = \alpha R(m) + s_1 s_2 K + s_1 s_2 (f + K) + s_1 s_2 K + s_1 s_2 (f + K)
  \]
- Cost of Dropping: \(d_1 + K\)
- Therefore, transmit when:
  \[
  \alpha B(m) \leq s_1 d_1
  \]

Experimental Results

- Benchmarks:
  - Persistent: Error free transmission. Transmit until all users Receive packet
  - Single Distortion Measure: \(d^1 = d^2\)
  - Upperbound: assume separate transmitter to each user

PSNR vs. # time slots

Special Case

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Summary

- Proposed offline DP algorithm to generate optimal transmission policy for general scenarios
- Prove simple threshold policy is optimal for i.i.d. Bernoulli packet losses
- Up to 2dB gains can be achieved by considering Multiple Distortion Measures

References