Outline

- Challenges for wireless video streaming
- Subjective viewing test
  - Test setup
  - Results and analysis
- Media-aware distributed rate allocation
  - Optimization framework
  - Protocol design
  - Performance evaluation
- Conclusions

Network Heterogeneity

Media Heterogeneity

- Different video has different utility of rate, depending on resolution, codec choice, and video content
- How to best trade off their quality?
Subjective Evaluation

- Evaluation of quality combinations of HD/SD image pairs
- Mean-opinion-scores (MOS) from 28 viewers, 4 data sets

MOS of Individual HD/SD Images

MOS of Image Pairs

MOS as Function of Allocated Rates
MOS of Allocation Results

- Minimizing weighted MSE best approximates subjectively preferred allocation
- How to achieve this in practice?

Wireless Network Model

- Link utilization: \( u_l = \frac{F_l}{C_l} \)
- Utilization over interference set: \( \bar{u}_l = \sum_{l' \in L_l} u_{l'} \)

Video Distortion Model

- Dependent on video content and encoder settings
- Parameters updated for every GOP (~0.5 s)
Optimization Objective

\[ \min_{\{R^s\}} \sum_s w^s D^s (R^s) \]
\[ \text{s. t. } \tilde{u}_l < \gamma, \forall l \in L \]

- Motivated by results from subjective viewing test
- Convex objective function with linear constraints

Distributed Solution

- Congestion price update:
  \[ \lambda_l := \lambda_l - \kappa (\gamma - \tilde{u}_l) C_l \]
  residual utilization

- Video rate update:
  \[ R^s = \arg \min_R \left[ w^s D^s (R) + \Lambda^s R \right] \]

\[ \Lambda^s = \sum_{l \in P^s} \sum_{i \in L_i} \frac{\lambda_l C_{li}}{C_l} \]

Protocol Design

Update congestion price: \( \lambda_l, \Lambda^s \)
Report accumulated congestion price \( \Lambda^s \)
Advertise video rate \( R^s \)
Exchange link state with neighbors: \( n_i, \lambda_i \)

Protocol in Action

Convergence time: 1 ~ 2 seconds
Comparison with TFRC: Single-Hop Network

- Improvement of average video quality: 0.6 ~ 1.7 dB

Comparison with TFRC: Multi-Hop Network

- Improvement of average video quality: 2.4 ~ 4.1 dB

Conclusions

- Subjective viewing test results motivate media-aware rate allocation for wireless video streaming
- A distributed rate allocation protocol:
  - media-aware: adaptation to video contents
  - network-aware: accommodation of traffic contention over heterogeneous wireless link speeds
  - cross-layer: fast convergence via rate advertising
- Outperforms media-unaware TFRC:
  - More balanced quality among streams
  - Higher average video quality
Related Work

- Rate allocation for wired network
  - TCP congestion control \[V. Jacobson 1988\]
  - TCP-Friendly Rate Control (TFRC) \[Floyd, Fall 1999\]
  - Pricing-based mathematical framework \[Kelly 1997-98\] \[Chiang 2007\]

- Video streaming over wireless networks
  - Flow control via multiple TFRC connections \[Chen, Zakhor, 2004-06\]
  - Media-aware centralized channel time allocation \[Kalman, van Beek, Girod 2005\]