Congestion-optimized multi-path streaming of video over ad hoc wireless networks

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Outline

- Ad hoc wireless network model
- Congestion-optimized stream routing
- Video distortion model
- Experimental results
Wireless ad hoc networks

- Collection of wireless nodes with no infrastructure
- Every node can be a source, a destination or a relay
- Many applications: search and rescue, home network…
Motivation

- Video streaming requirements
  - High data rates
  - Hard delay constraints

- Path diversity
  - May increase error resiliency
  - Can provide higher aggregate data rates
  - Needs multi-path routing and flow partitioning
Ad Hoc Wireless Network Model

- 15-node network
- Fixed power, simultaneous transmissions

\[
SINR_{ij} = \frac{d_{ij}^{-\alpha}}{BN + \sum_{k \neq j k \neq i} d_{kj}^{-\alpha}}
\]

\[
C_{ij} = \frac{B}{2} \log(1 + \gamma SINR_{ij})
\]

[Rappaport, 1996]

- Assumptions
  - Static nodes
  - Every node has global information
Existing Routing Algorithms

- Optimization and flow assignment
  - Classic problems: [Kleinrock, 1976], [Bertsekas and Gallager, 1987]
  - Resource allocation: [Xiao, Johansson and Boyd, 2002]

- Routing for wireless ad hoc networks
  - DSDV: [Perkins and Bhagwat, 1994]
  - AODV: [Perkins and Royer, 1999]
  - DSR: [Johnson and Maltz, 1996]
  - TORA: [Park and Corson, 1997]
Congestion-Optimized Stream Routing

- Congestion defined as the average queuing delay over the network

\[ \Delta = \frac{1}{C - f} \]

Example: M/M/1 model

- So minimizing the congestion results in:

\[ \text{Min. } \sum_{(i,j)} \frac{f_{ij}}{C_{ij} - f_{ij}} \]

Subject to:

- rate constraints at the source and destination
- flow conservation, flow positivity
- capacity constraints

- Paths extracted from the solution
Solution Example
Setton et al. : Congestion-optimized multi-path streaming of video over ad hoc wireless networks

Video Distortion with Self Congestion

Good Picture quality

Bad picture quality

Self congestion causes late loss

$D = D_{enc} + D_{loss}$

$D_{enc} = D_0 + \frac{\theta}{R-R_0}$

$D_{loss} = \kappa \, P_{loss}$

[Stuhlmüller, Förber, Link and Girod 2000]
Modeling the Influence of the GOP Length

Simulation results using NS
Sequence: Foreman QCIF
Sequence length: 8 s
Codec: H.264
Frame rate: 30 fps
Playout deadline: 350 ms
Packetization: 1 f./packet
Number of realizations: 400
Random packet loss rate: 1%
Simulation results using NS
Sequence: Foreman QCIF
Sequence length: 8 s
Codec: H.264
Frame rate: 30 fps
Playout deadline: 500 ms
Packetization: 1 f./packet
Number of realizations: 400
No random loss
Video Streaming Results: Sequence (1)

Foreman QCIF Sequence

1 path
80 kbps, PSNR 32.5 dB

3 paths
187 kbps, PSNR 36.2 dB
6 paths heuristic
187 kbps, PSNR 36.2 dB

6 paths optimal
278 kbps, PSNR 38 dB
Conclusions

- Benefits of path diversity for video over ad hoc networks
  - May increase the available data rate between hosts
  - Better resource utilization through optimization
- Video distortion model
  - Combines the influence of encoder distortion and transmission delay
  - Predicts and compares behaviors of different streaming scenarios and different coding structures
- Future work
  - Consider mobile nodes  [Zhu et al. to appear MMSP 2004]
  - Combine with capacity allocation and cross-layer design  [Yoo et al. to appear MMSP 2004]