End-to-End Differentiation of Congestion and Wireless Losses

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2. Motivation

- Realtime video transmission over network with wireless link
  - No or limited retransmission at the link level => wireless loss can be significant

- Two types of losses:
  - Congestion: buffer overflow -- reduce sending rate
  - Wireless: bit errors -- keep rate, add FEC

- Two advantages of loss differentiation:
  - Transport protocol performance optimization
  - Useful feedback: balance between source and channel coding
    - i.e. accuracy of DCT coefficients vs. amount of FEC
3. Contributions

- End-to-end loss differentiation
  - Non-E2E: Snoop (Balakrishnan’95), I-TCP (Bakre’95)

- Realtime trans. protocol TFRC vs. TCP
  - TCP Friendly Rate Control (TFRC, Floyd’00)
    - Rate-based congestion control protocol designed for unicast streaming applications.

- More general topologies, competing traffic

- Comparative evaluation of multiple LDAs
  - Two previous schemes [Biaz99, Tobe00]
  - A new scheme and two hybrids
4. Overview

- End-to-end loss differentiation
- Interaction with transport protocol
- 3 parameters for differentiation
- Algorithms: Biaz, Spike, ZigZag, Hybrids

Methodology

- Topology: Last-hop, backbone
- Performance evaluation
- Performance metrics
- Error model
- Base algorithms
- Hybrid algorithms
- Summary
5. Loss Diff. Algorithm (LDA)

- TFRC (Floyd’00) with E2E LDA over UDP

- Throughput in TFRC: MTU, RTT, packet loss ratio in forward channel
  - Differentiate at the receiver

- At loss, updates packet loss ratio:
  - Due to congestion => lost
  - Due to wireless error => received
  - No retransmission for video application

- ACK contains packet loss ratio; sent at congestion loss or every RTT
6. Parameters for loss differentiation

- **ROTT**: Relative One-way Trip Time based on timestamp in packet header
  - Spike (Tobe'00), ZigZag
- **PIAT**: Packet Inter Arrival Time
  - Biaz (Biaz'99)
- **# of lost packets in the latest consecutive packet loss**, from the sequence #
  - ZigZag
7. Scheme(1): Biaz (Biaz’99)

- Designed for topology where the wireless link is the last hop, the bottleneck link, and is not shared.

- Based on Packet Inter Arrival Time (PIAT):

  - Wireless: PIAT = 2 pkts trans. time
  - Congestion: PIAT = 1 pkt trans. time

- mBiaz: fine tuned classification window thresholds -- better results
Developed from empirical Internet experience, based on Relative One-way Trip Time (ROTT)

Threshold selection is crucial
9. Scheme(3): ZigZag

- Uses normalized ROTT and # of lost pkts:

More severe loss => longer delay likely
- Most common loss events (1 & 2 pkt loss) are classified as congestion loss

- **LAN speed wired link**
- **wireless last links**
- **wired shared link**

- **BW of the wired shared link** is 86% of the aggregated total of all wireless links BW

- **Bottleneck:**
  - For each connection: the wireless last link
  - For the network: the wired shared link
  - Congestion happens at both the wired and the wireless links

- BW of the backbone wireless link is the smallest among all links: bottleneck from both points of view
- Congestion happens only at the backbone wireless link
12. Wireless Error Model

- Reformulated (Dent’93) Jakes fading model (Jake’74), through computer simulation (Zhao’00)
  - A deterministic method for simulating time-correlated Rayleigh fading channel.

- Packet loss rate: 7.8% (high), 3.1% (medium), 1.0% (low)

- In high loss rate case:
  - Average length of good states: 14.8 packets
  - Average # of packets lost consecutively: 1.3
13. Performance Metrics

- **Throughput**
  - Omniscient ("magic genie") can reach 300% throughput that of original TFRC.
  - Goal: get close to omniscient throughput

- **Congestion loss**
  - High throughput by incurring high congestion: NOT desired.
  - Hurts other traffic -- should be minimized

- **Misclassification rates:**
  - High cong. loss mis. --> high congestion loss
  - High wireless loss mis. --> low throughput
4 schemes with TCP, TFRC, Omni TFRC:

- TCP, TFRC: poor -- unaware of wireless loss
- Omni close to 100% usage; others perform well
  - Probed rate, not accurate, on average < bottleneck BW
TCP, TFRC: lowest $\leq$ wireless loss as cong. loss
Omni: 6% $\leq$ rate probing, upper limit for LDA
Biaz: too high $\Rightarrow$ the reason for modified Biaz
ZigZag: especially low, good
16. Wrls. Last-Hop: Misclassification

- **Biaz**: high congestion mis. + lowest wireless mis. => aggressive
  - => high cong. loss: bad
- **mBiaz**: lowest congestion mis.: goal, very good
- **ZigZag**: low cong. mis., high wrls. mis.: OK
- **Spike**: high cong. & wrls. mis.: bad
All schemes achieved good throughput. They differ in their ability to classify losses correctly:

- Modified Biaz reached best balance at classifying these two type of losses.

Overall, we prefer the modified Biaz in this topology. ZigZag also performs well, but Spike and original Biaz should not be used.
In Wireless Backbone topology, the Spike is the best, ZigZag comes next, two Biaz are useless.
- Full results in paper

No single LDA is the best in both topologies
- Each topology has a clear preferable LDA.

Motivate hybrid LDA that
- Determines topology online according to packet behavior
- Employs LDA preferable to that topology
- Outperformed base schemes -- consistent good performance in both topologies.
  > Full results in paper
Evaluated end-to-end loss differentiation algorithms for video transport protocol

- Multiple LDAs: Two previous, one new
- More realistic situations: 2 topologies, competing traffic

Parameter robustness:
- PIAT (Biaz) only effective on last-hop topology without competition
- ROTT (Spike, ZigZag) much more robust across different configurations
No single LDA is ideal for both backbone and last-hop topologies
  ○ modified Biaz best in wireless last-hop
  ○ Spike best in backbone
  ○ ZigZag relatively well in both

Suggests that a hybrid LDA would be useful
  ○ Proposed two hybrid LDAs
  ○ Outperform base algorithms on both topologies

Next step: use wireless loss info as feedback for video coder at source