Interactive Multimedia on the Internet

- Interactive multimedia over the Internet
  - video teleconferencing, distributed VR
- Media requirements and characteristics
  - low latency
  - periodic transmission times
  - tolerant of some loss
  - elastic but lower bounded bandwidth requirement
- Application specific congestion management
  - Ranges from none to responsive

Outline

- Problem - Supporting multimedia over the Internet
- Context - Active Queue Management
  - Drop-tail on Full (FIFO)
  - Random Early Drop (RED)
  - Flow Random Early Drop (FRED)
- Towards better support for multimedia flows
  - Class Based Thresholds (CBT)
- Empirical evaluation

Congestion Avoidance

- Drops are the only widely used indicator of congestion
- Drops and retransmissions
  - Congestion collapse
  - TCP’s congestion avoidance (Jacobson)
Traditional Queueing in the Router (FIFO)

- Full queues
  - no room for bursts of packets
  - Synchronized back-off (TCP/IP)
- Lock-out phenomena
- High drop-rate
- High latency

Active Queue Management
Random Early Detection (RED)

- Weighted average accommodates bursty traffic
- Multiple modes based on threshold values
- Probabilistic and forced drops
  - avoid consecutive drops
  - drops proportional to bandwidth utilization
  - (drop rate equal for all flows)

FIFO and RED Vulnerable to Misbehaving Flows

Queue Management and Congestion Avoidance

  - Deploy Active Queue Management (e.g. RED)
    - Avoid full queues, reduce latency, reduce packet dropping, avoid lock-out phenomena
  - Continue research into mechanisms to deal with unresponsive or aggressive flows. (Floyd & Fall)
    - Unresponsive traffic's impact on RED, FIFO
- Multimedia is “unresponsive” for a reason.
  - can tolerate some loss
  - price for unnecessary reliability is too-high
Flow Random Early Detect (FRED) Goals

- **Fairness**
  - Protect all TCP flows from effects of aggressive flows
  - Protect fragile TCP flows
  - Establish drop rate proportional to load

TCP Performance with FRED

Class Based Thresholds (CBT) Goals

- **Isolation**
  - Responsive from unresponsive
  - Unresponsive: Multimedia from aggressive

- **Flexible Fairness**
  - Something more than equal shares

- **Light weight**
  - Minimal state

- **Maintain benefits of RED for responsive traffic**
  - Feedback
  - Distribution of drops
Class Based Thresholds (CBT) Design

- **Isolation:**
  - Packets are classified into one of several classes
  - Separate statistics kept for each class
  - Marked (multimedia) and unmarked non-TCP traffic are monitored with aggregate statistics

- **Flexible Fairness:**
  - Configurable thresholds determine ratios between classes during periods of congestion

- **Light weight:**
  - State per class instead of per flow, one queue

- **Maintain benefits of RED for responsive traffic:**
  - Continue to apply RED policies to TCP

Class Based Thresholds (CBT)

- **Tagged traffic is allocated a share of the queue using a threshold on average queue occupancy**

- **Other traffic is limited to a share of the queue using a (small) threshold on average queue occupancy**

![Diagram](image-url)
Class Based Thresholds (CBT)

- Maintain a single FIFO queue but track the average number of packets in the queue from each class.
- Drop packets from a class based on policy for that class:
  - During times of congestion, each class is limited to a fixed share of network bandwidth in proportion to the threshold.

Empirical Evaluation

Experimental Setup

- Senders transmit a mix of TCP, real-time, and non-real-time UDP traffic.

Experimental Results

TCP Throughput

<table>
<thead>
<tr>
<th>Time (seconds)</th>
<th>TCP Throughput (Kbytes/Sec)</th>
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<tbody>
<tr>
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Experimental Results - TCP

CBT vs. Packet Scheduling

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<th>Time (seconds)</th>
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Multimedia Latency

Drop Rate for Continuous Media

<table>
<thead>
<tr>
<th>Queue Management Scheme</th>
<th>Drop Rate for Continuous Media</th>
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</thead>
<tbody>
<tr>
<td>FIFO</td>
<td>32.4%</td>
</tr>
<tr>
<td>RED</td>
<td>30.0%</td>
</tr>
<tr>
<td>FRED</td>
<td>35.7%</td>
</tr>
<tr>
<td>CBT</td>
<td>1.3%</td>
</tr>
<tr>
<td>Packet Scheduling</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

- Proper resource allocation
- Only Packet Scheduling has a lower drop rate for continuous media

Results

- Active Queue Management comparison
  - Better TCP performance
  - Less state than FRED (no per flow state)
  - Lower latency to multimedia applications
  - Lower drop rate for multimedia

- Packet scheduling comparison
  - Comparable performance

Summary

- Current queue management schemes are vulnerable to aggressive flows.
- Calls for mechanisms to identify and penalize unresponsive flows
- Class-Based Thresholds provides isolation for TCP and multimedia while providing a useful level of service for multimedia.
- Allocation of the buffer offers comparable performance and is simpler than packet scheduling.