Outline

Two issues

- Concurrent data streams
  - discovering presence of shared bottleneck
  - coordinating distributed senders

- All packets are not equal
  - shielding vulnerable packets
Concurrent Data Streams

- Coordination better than competition
  - shared learning of network conditions
  - reflect user utility rather than network dynamics
    - e.g.: optimal progressive Web page delivery [GB99]

- TCP Session [Pad98]
  - congestion control
  - loss recovery
  - bandwidth sharing
TCP Session Performance

Coordination ⇒ more predictable performance
Concurrent Heterogeneous Streams

- Heterogeneous often implies distributed
  - specialized servers
  - new usage scenarios
    - e.g., listening Internet radio while surfing

- Looking beyond TCP ⇒ looking beyond host-pair coordination
Concurrent Heterogeneous Streams

Web

Audio

Internet

Video

Client

congested links
Challenges & Potential Solutions

- Discovering presence of shared bottleneck
  - indirect: correlation of delay/loss patterns
    - [Bolot93], MINC [CDH+99]
    - do not need synchronized clocks
  - direct: enhanced ECN

- Coordinating distributed senders
  - explicit: receiver-driven flow control
  - implicit: congestion feedback filtering
Congested Intranet Link

Wide-area inverse-muxed T1 links (3 Mbps)
Congested Intranet Link

Significant correlation in queuing delay
Single Congested Link

Connections 1 & 2 share a congested link
Single Congested Link

Shared bottleneck $\Rightarrow$ high delay correlation
Connection 1 traverses two congested links only one of which is shared with connection 2.
Presence of multiple congested links reduces effectiveness of delay correlation technique.
Enhanced ECN

- ECN plus unique router tag
  - tag helps discover shared bottleneck
- Non-unique tags can be used for efficiency
  - periodic re-hashing to avoid persistent collisions
- Works better with multiple congested links
- Could complement delay correlation technique
Coordinating Distributed Senders

- Less frequent ECN
- More frequent ECN

TCP advertised window

RTSP Speed/Pause

Explicit

Implicit
All Packets Are Not Equal

- Certain packets more important than others
  - TCP
    - SYN packet
    - packets sent when window is small
    - retransmission
  - RM repair request
- Vulnerable to loss of important packets
Retransmission Timeouts

Very little data typically sent between timeouts
Shielding Vulnerable Packets

- Diffserv coupled with protocol-specific knowledge
- High drop priority for vulnerable packets
- FIFO scheduling avoids reordering
Summary

- Need to coordinate concurrent data streams
  - E2E/router-assisted detection of shared bottleneck
  - congestion feedback filtering

- All packets are not equal
  - diffserv to shield vulnerable packets

http://www.research.microsoft.com/~padmanab