Achieving Bounded Fairness for Multicast and TCP Traffic in the Internet

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Outline

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- Design Objectives
  - Essential Fairness
- Random Listening Algorithm (RLA)
  - Essentially Fair to TCP
  - Multicast Fairness
  - Performance
Problem Statement

- Based on current Internet infrastructure.
  - Drop-tail gateways prevail.
  - RED gateways preferred.
- Based on end-to-end packet loss information.
- TCP background traffic.

Different receivers lose packets at different times.
Design Objective – TCP-like

- Responsive to congestion.
- Probe available bandwidth.
- Multicast fairness.
- Fair to TCP.
Restricted Topology

Multicast connection

TCP connection

\[ S \]

\[ R_1 \]

\[ R_2 \]

\[ R_{N-1} \]

\[ R_N \]

\[ m_1 \]

\[ m_2 \]

\[ \mu_1 \]

\[ \mu_2 \]

\[ \mu_N \]

\[ m_1+1 \]
Concepts

- **Soft bottleneck:**
  \[ k = \arg \min_i \{ \mu_i / (m_i + 1) \}, \quad i = 1, \ldots, N. \]

- **One share of bandwidth:**
  \[ \lambda_{min} = \mu_k / (m_k + 1). \]

- **Absolute fairness** (equal share): \( \lambda_{RLA} = \lambda_{min}. \)

- **Essential fairness** (bounded share):
  \[ 0 < \lambda_{RLA} < \mu_k, \quad a \lambda_{min} \leq \lambda_{RLA} \leq b \lambda_{min}, \quad a \leq b \leq N. \]
Random Listening Algorithm

Based on TCP SACK.

- **Loss detection**: selective ACK
- **Congestion detection**: losses within 2 RTT are grouped.
- **Window adjustment** policy: random listening.
  - Upon a congestion signal: \( W \leftarrow \frac{W}{2} \) w.p. \( \frac{1}{n} \).
  - \( n = \# \) of rcvrs reporting congestion frequently.
  - Once a pkt is ACKed by all rcvrs, \( W \leftarrow \frac{W+1}{W} \).
Properties of RLA

- Share with TCP through drop-tail:
  - congestion frequency.

- Share with TCP through RED:
  - same loss probability.

- Essentially fair to TCP:
  - RED: $\frac{1}{3} \lambda_{TCP} \leq \lambda_{RLA} \leq \sqrt{3n} \lambda_{TCP}$.
  - drop-tail: $\frac{1}{4} \lambda_{TCP} \leq \lambda_{RLA} \leq 2n \lambda_{TCP}$.
Properties of RLA (cont)

- Multicast fairness.
- Simple, similar to TCP.
- No need to locate soft-bottleneck.
Multicast Fairness

DOP

fairness line

pipe1 pipe2 pipe3

cwnd1 cwnd2
Multicast Fairness

Two dimensional Markovian process:

- desired operating point (DOP) is recurrent.
- avg $cwnd$’s of the two senders are the same.
- average drifts point towards DOP.
- probability mass focuses on area around DOP.
Performance of RLA
Result: Drop-tail Gateways

Throughput

- L1
- L3 level
- L4 level
- Partial L4
- L21

RLA
Best TCP
Worst TCP

congestion
Results: RED Gateways

Throughput

- RLA
- Best TCP
- Worst TCP

Congestion
Results: Drop-tail Gateways

![Bar chart showing the number of window cuts for different levels and congestion scenarios. The x-axis represents different levels (L1, L3 level, L4 level, Partial L4, L21) and the y-axis represents the number of window cuts. The chart has bars for RLA, Best TCP, and Worst TCP, indicating varying performance levels under congestion.](image-url)
Results: Different RTTs

- Generalized RLA:
  - random listening threshold set to \( \frac{rtt_i}{rtt_{max}}^2 / n \).

- Preliminary Performance:
Summary

- Desirable Performance:
  - homogenous receivers: $\lambda_{RLA} < 4 \lambda_{TCP}$ for any n.
  - unbalanced congestion: $\lambda_{RLA} \leq O(n) \lambda_{TCP}$; (DT)
  - reasonably fair to TCP as shown by simulation.

- “Random listening” idea applies to other forms of control as well.