Equation-based Congestion Control for Unicast Traffic

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Why work on non-TCP forms of end-to-end congestiol control?

- Traffic without end-to-end bandwidth guarantees (e.g., best-effort traffic, better-than-best-effort forms of diff-serv) requires end-to-end congestion control to avoid congestion collapse.

- TCP-based congestion control is not suitable for some unicast applications (e.g., streaming multimedia).

- Understanding equation-based congestion control for unicast is a first step towards designing viable congestion control for multicast applications.

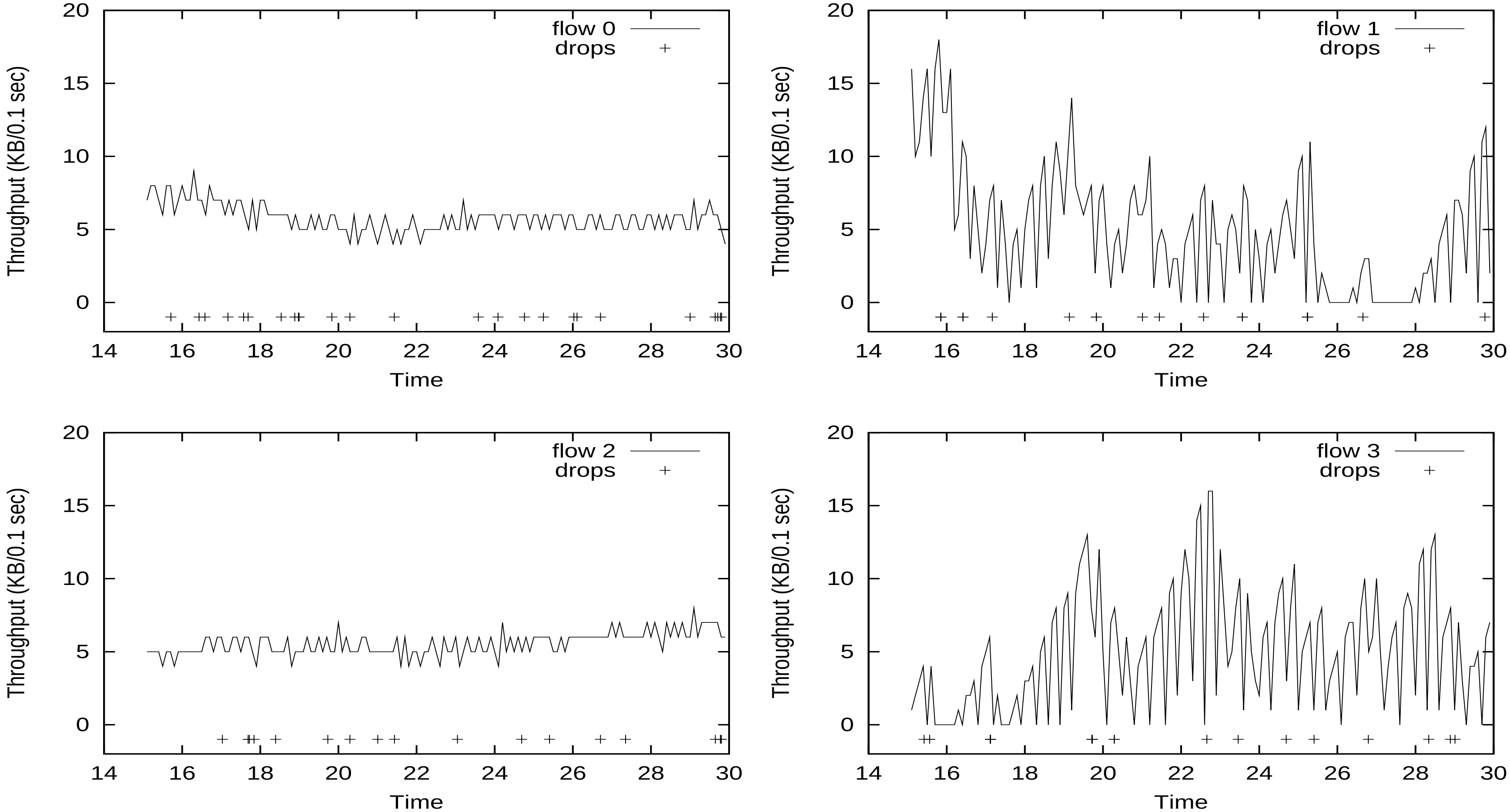
Why do some unicast applications not use TCP?

- Reliable delivery is not needed.

- Acknowledgements are not returned for every packet, and the application would prefer a rate-based to a window-based approach anyway.

- Cutting the sending rate in half in response to a single packet drop is undesirable.

Why do some unicast applications not use TCP?



Equation-based congestion control (left column) and TCP (right column).

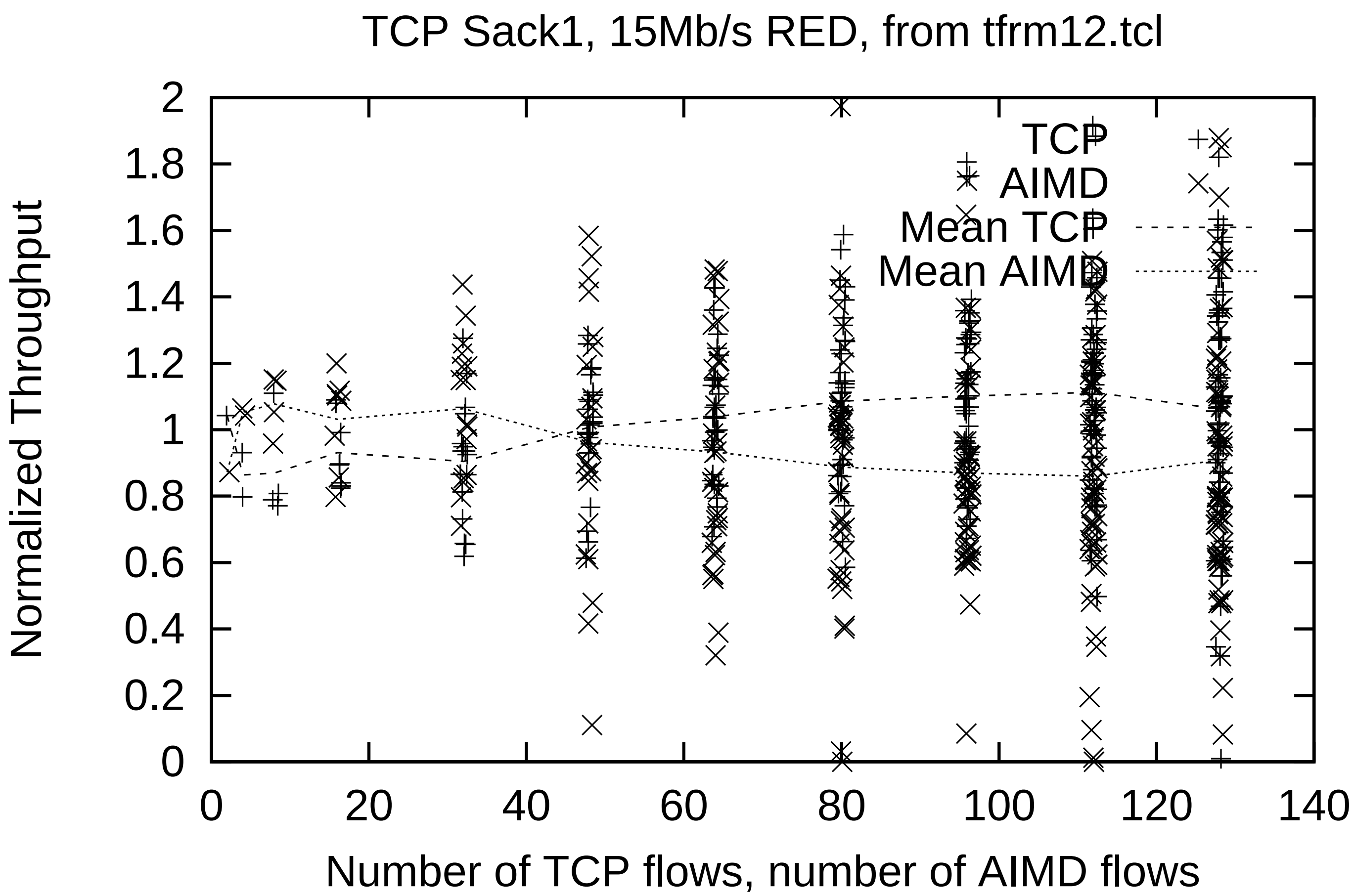
Other possibilities for end-to-end congestion control for unicast streaming media?

- Use a rate-based version of TCP's congestion control mechanisms, without TCP's ACK-clocking.
  - The Rate Adaption Protocol (RAP) [RH99].

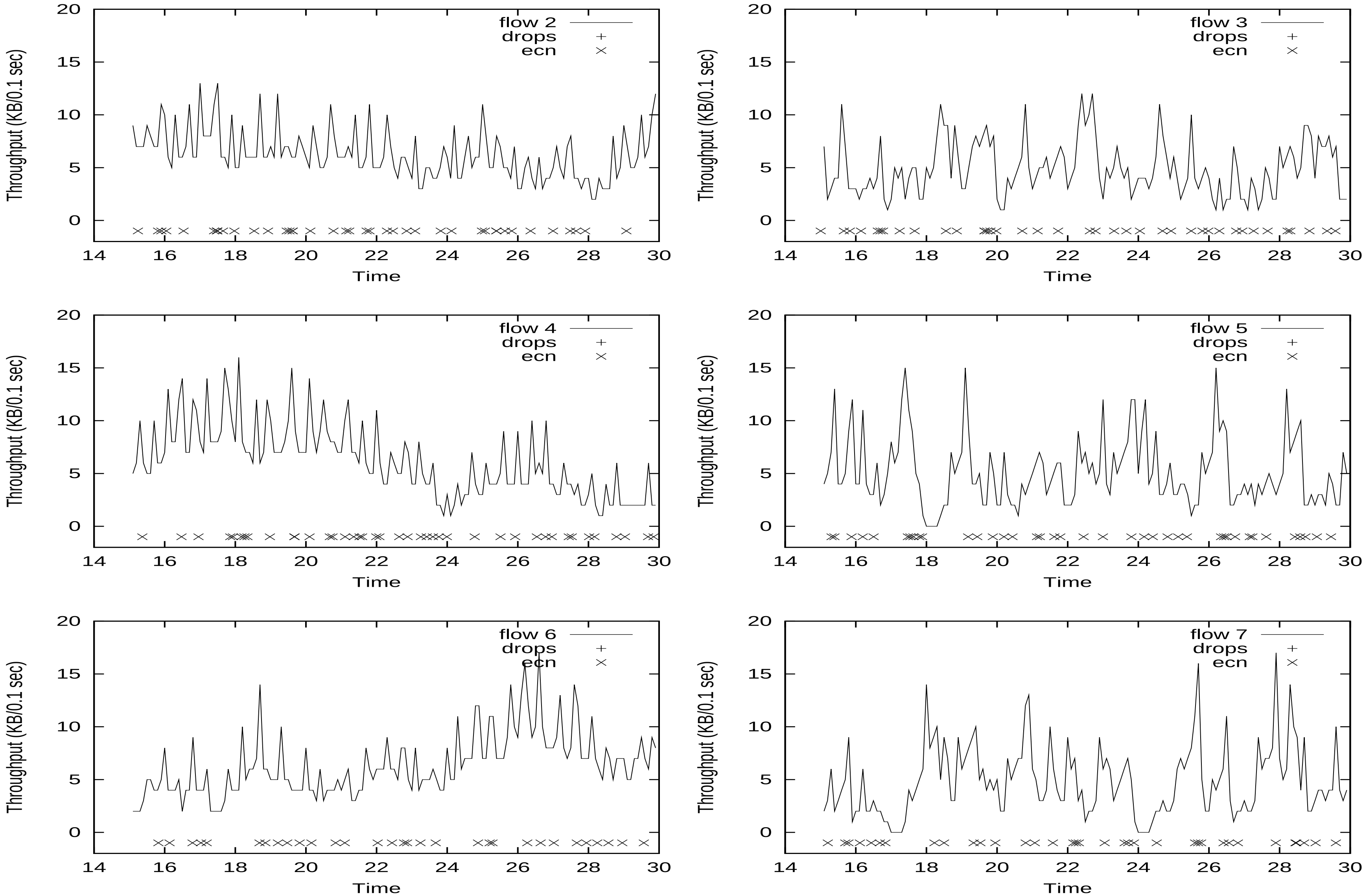
- AIMD with different increase/decrease constants.
  - E.g., decrease multiplicatively by 3/4, increase additively by 3/7 packets per RTT.

- Equation-based congestion control:
  - adjust the sending rate as a function of the longer-term packet drop rate.

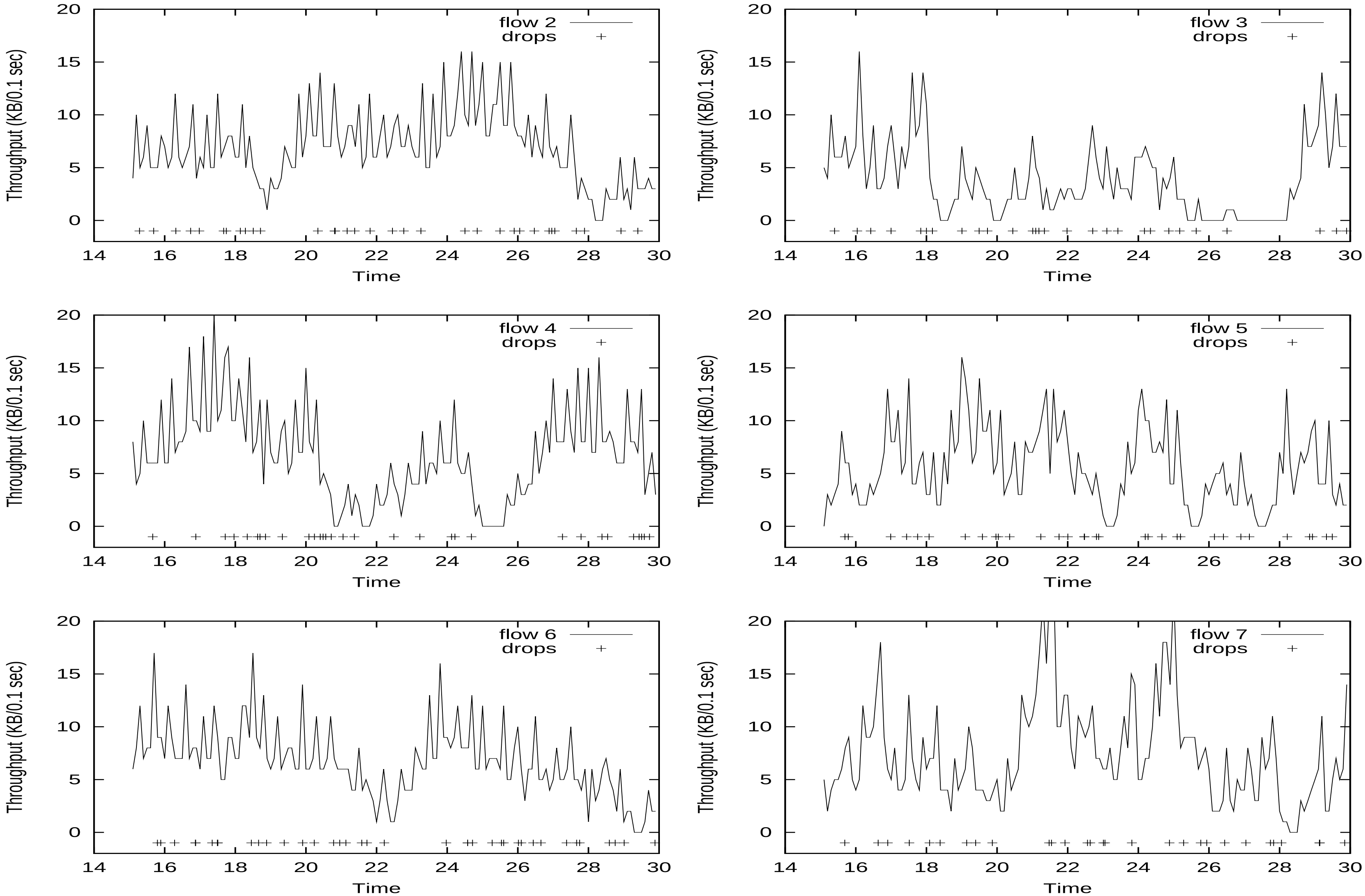
AIMD with different increase/decrease constants:



AIMD: decrease multiplicatively by 7/8, increase additively by 2/5 packets per RTT.



AIMD[2/5, 7/8] (left column) and TCP (right column) flows, with ECN.



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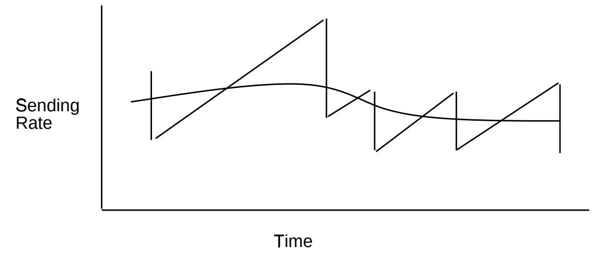


Equation-based congestion control:

• Use the TCP equation characterizing TCP's steady-state sending rate as a function of the RTT and the packet drop rate.

• Over longer time periods, maintain a sending rate that is a function of the measured roundtrip time and packet loss rate.

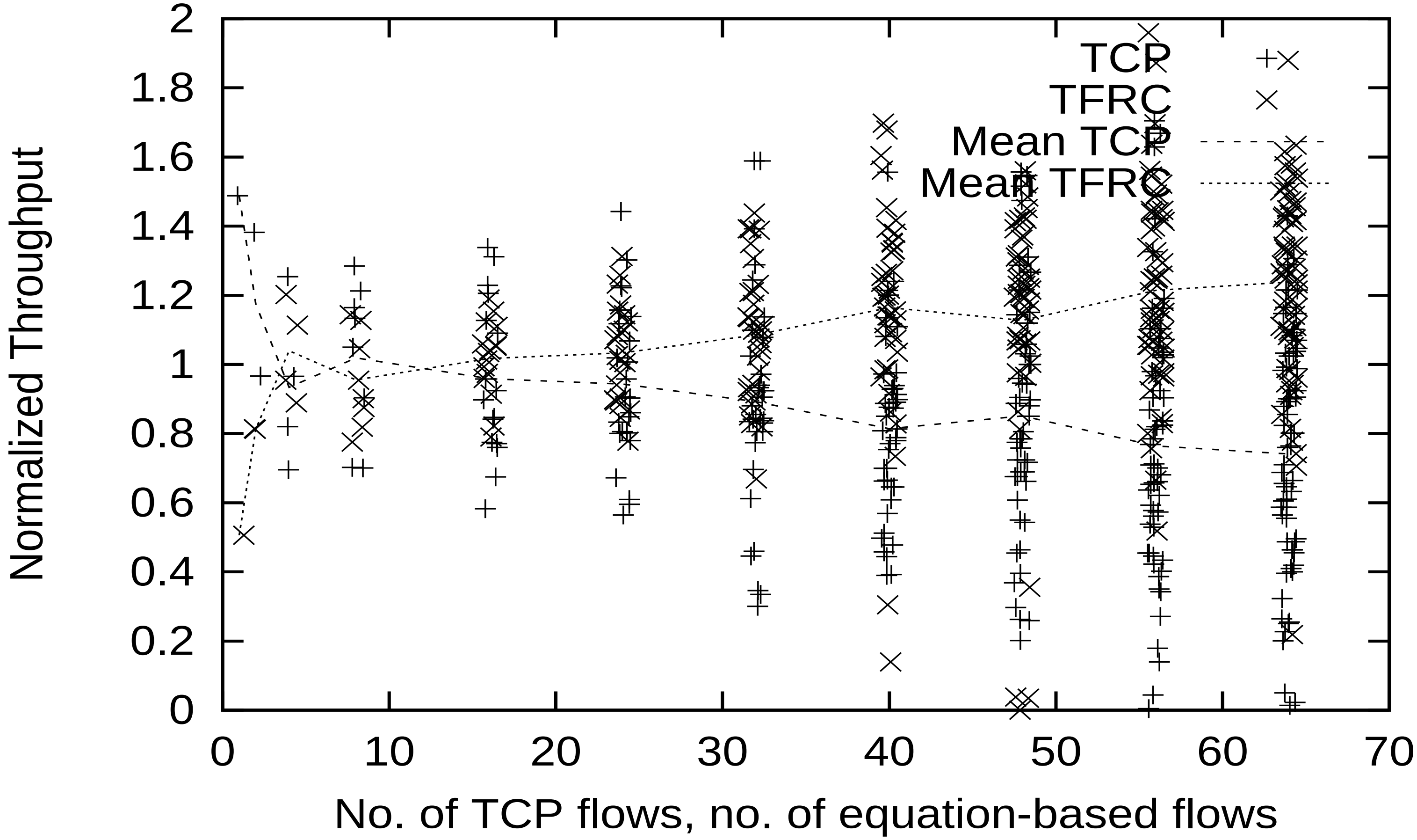
• The benefit: Smoother changes in the sending rate in response to changes in congestion levels.

• The justification: It is acceptable not to reduce the sending rate in half in response to a single packet drop.

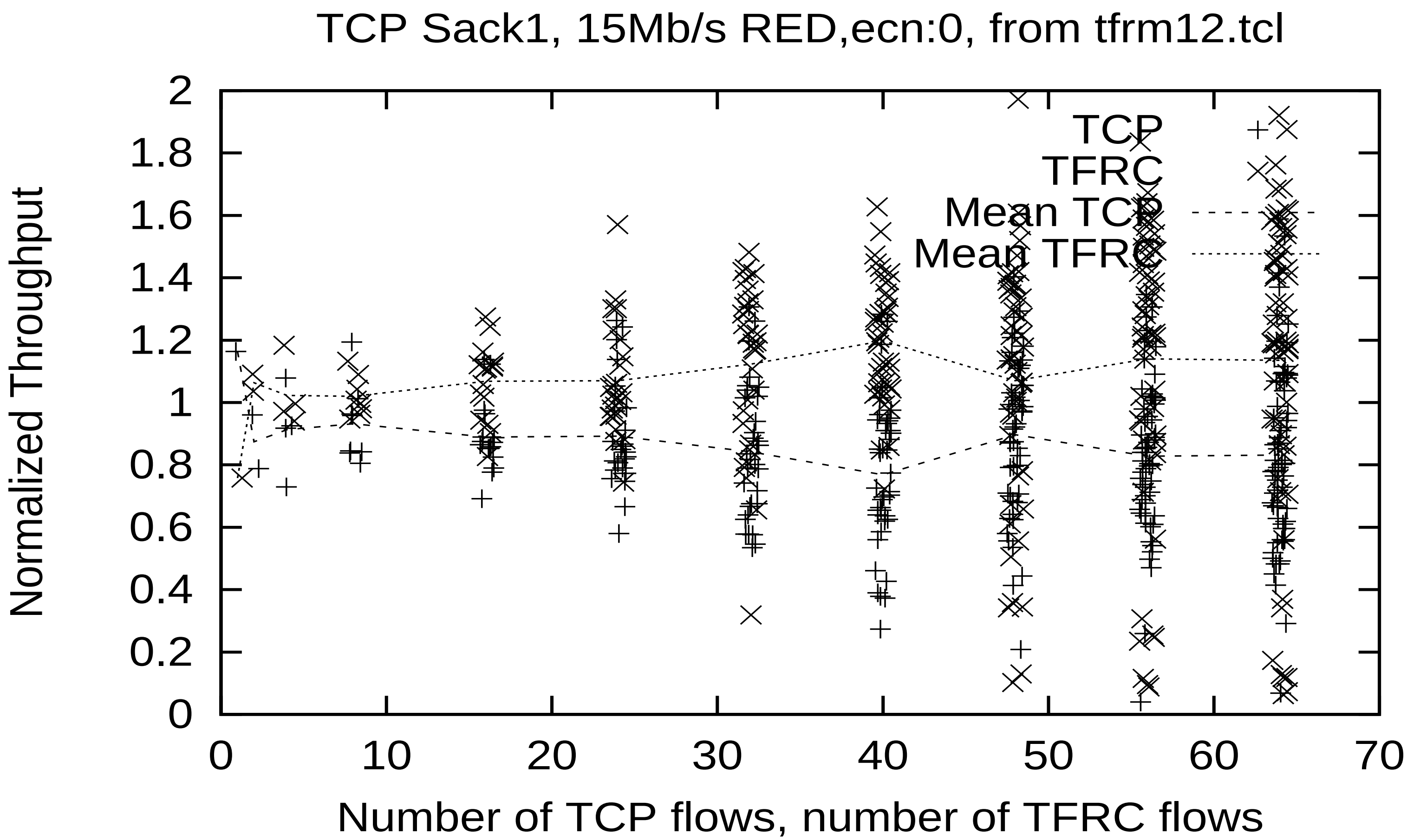
• The cost: Limited ability to make use of a sudden increase in the available bandwidth.

Why use the TCP equation in equation-based congestion control?

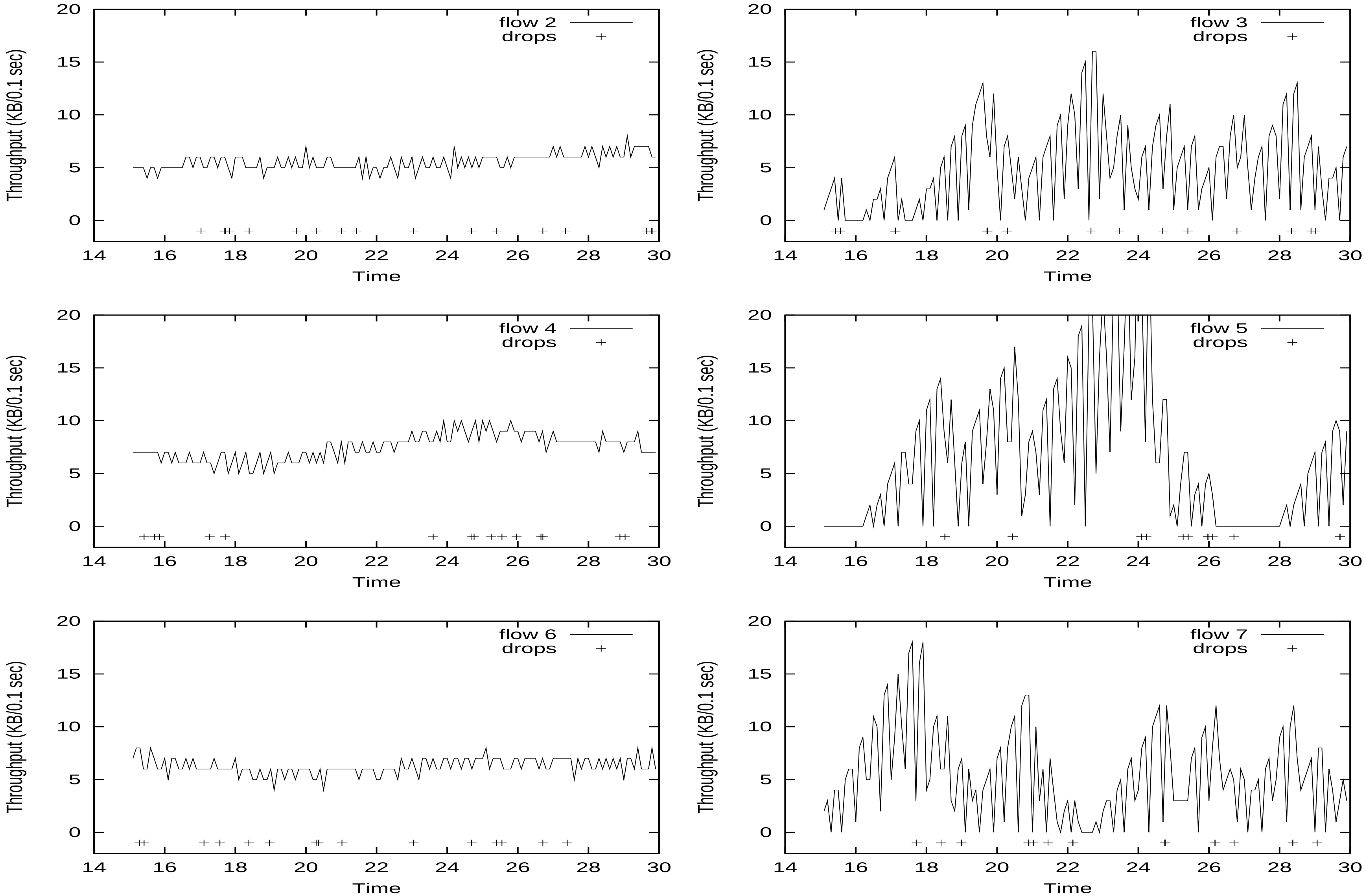
• Because best effort traffic in the current Internet is likely to compete in FIFO queues with TCP traffic.



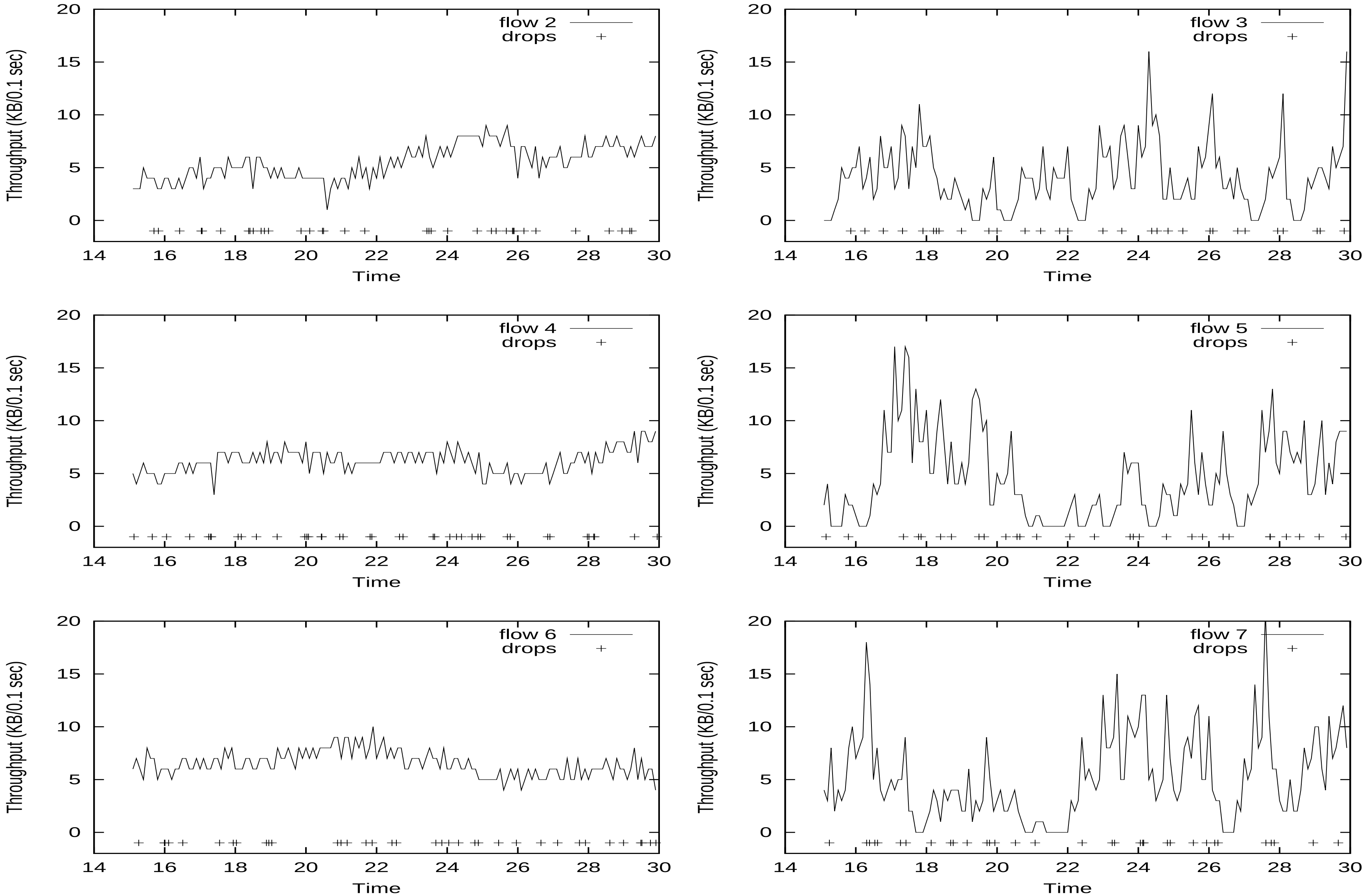
Why use the TCP equation in equation-based congestion control?



These simulation use RED instead of Drop-Tail queue management.



Equation-based congestion control and TCP (with Drop-Tail).



Equation-based congestion control and TCP (with RED, no ECN).

Unicast: Estimating the packet drop rate:

- Goals for the receiver's estimated packet loss rate:
  - Maintains history of most recent loss events;
  - Estimates loss rate smoothly;
  - Responds promptly to successive loss events;
  - Estimated loss rate increases only in response to a new loss event;
  - Estimated loss rate decreases only in response to a new loss event, or to a longer-than-average interval since the last loss.

Unicast: Estimating the packet drop rate, cont.:

• The receiver estimates the average loss interval (e.g., the number of packet arrivals between successive loss events), and inverts to get the packet loss rate.

– In estimating the average loss interval, the first four lost invervals are weighed equally.

– The 5th-8th loss intervals are averaged using reduced weights.

– The receiver reports the loss average to the sender once per RTT.

• The interval since the most recent packet drop counts as a loss interval, if it is longer than the average loss interval.

Unicast: The sender estimating the roundtrip time:

- The sender averages the roundtrip over the most recent several measured roundtrip times, using an exponential weighted moving average.

- The sender uses the average roundtrip time and packet drop rate in the “response function” to determine the allowed sending rate.

- If two report intervals pass without receiving the expected report from the receiver, cut the sending rate in half.

Unicast: The sender's increase/decrease algorithms:

- If allowed sending rate $<$ current sending rate, decrease sending rate:
  – down to allowed sending rate.

- If allowed sending rate $>$ current sending rate, increase sending rate:
  – by at most one packet/RTT;

If the current sending rate is less than one packet/RTT,
 – increase the sending rate more slowly;
 – increase half way up to the sending rate indicated by the equation.

Unicast: Goals for slow-start:

- Perform roughly as aggressively as TCP.

- Exit slow-start if regular feedback is not received from the receiver.

- Never send more than twice as fast as the receiver is receiving.

- On exiting slow-start, smoothly transition to equation-based congestion control:
  - Don't use the experienced packet drop rate directly;
  - Receiver estimates the available bandwidth;
  - Receiver computes the packet drop rate that corresponds to that bandwidth;