Requirements for Simulation and Modeling Tools

Sally Floyd

NSF Workshop

August 2005

Outline for talk:

- Requested topic:
  - the requirements for simulation and modeling tools that allow one to study, design, and evaluate the next generation transport protocols (and routing protocols).
- What I will talk about:
  - Requirements for simulation tools.
  - One plan for getting these tools: ns3.
  - Requirements for modeling tools.
  - One plan for getting these tools: tmrg (the transport modeling research group).

Tools Needed for Simulations:

- A faster simulator:
  - For simulations of HighSpeed TCP.
- A simulator with smaller memory requirements:
  - For simulations with rich mixes of web traffic.
- A simulator with IP tunnels, firewalls, etc.:
  - For simulations of Quick-Start problems.
- Realistic router buffer architectures:
  - For simulations of the VoIP variant of TFRC.
- Realistic injections of random timing noise:
  - So that I don't have to review so many papers showing the regular patterns of scenarios with one-way traffic of long-lived flows all with the same packet size and round-trip time.
- …

One Plan for Getting Needed Tools: ns3

- A faster simulator, smaller memory footprint.
- Improved emulation capability.
- More wireless models.
- TCP stack emulation, DCCP.
- IPv4 and IPv6 support, NATs.
- XORP/Click routing.
- Integrate other open-source networking code.
- Maintenance (validation, documentation, etc.).
- …

Tools Needed for Modeling:

(1) For our own research, and to make the evaluation of the work of others more productive.

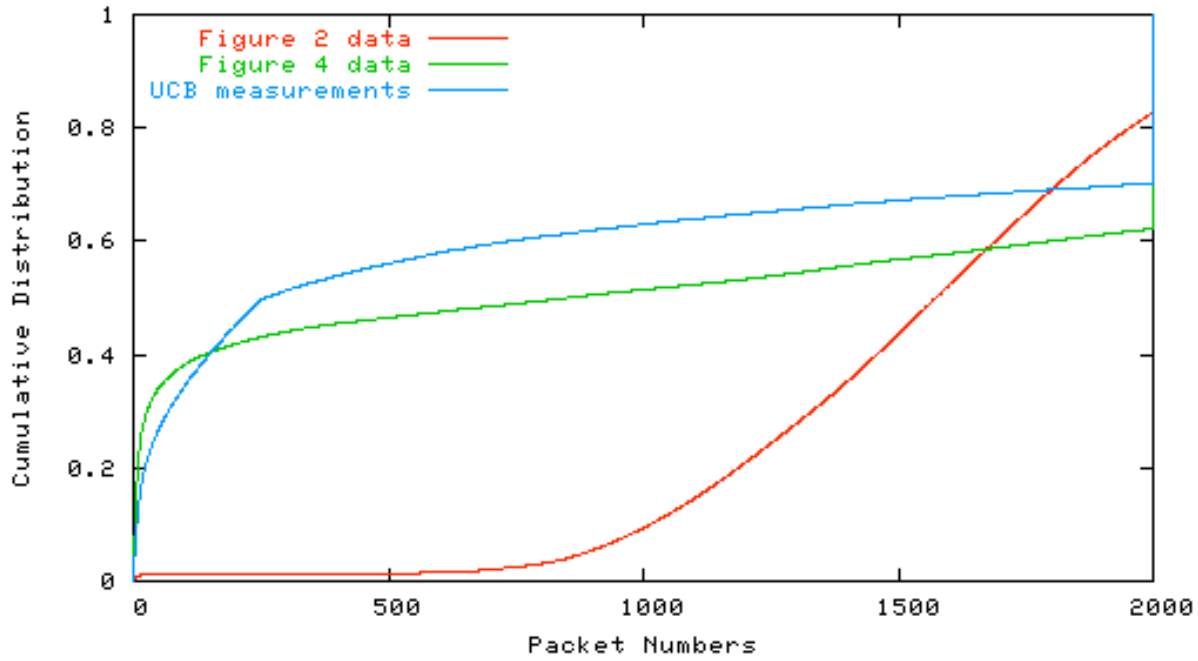
(2) This talk is focused on research on congestion control.

- Best Current Practice sets of simulation scenarios:
  - For typical congested links;
  - For traffic in high-bandwidth networks;
  - For traffic over wireless networks;
  - For VoIP traffic;
  - Etc.

Needed: Tools for Evaluating Scenarios in Simulations, Experiments, and Analysis:

- Characterizing aggregate traffic on a link:
  - Distribution of per-packet round-trip times:
    - Relevant to: fairness, delay/throughput tradeoffs.
    - Measurements: Jiang and Dovrolis.
  - Distribution of per-packet sequence numbers:
    - Relevant to: burstiness of aggregate traffic.
    - Measurements:distribution of connection sizes.
  - Alpha/beta traffic (traffic bottlenecked here or elsewhere):
    - Relevant to: burstiness of aggregate traffic.
    - Measurements:Sarvotham et al.

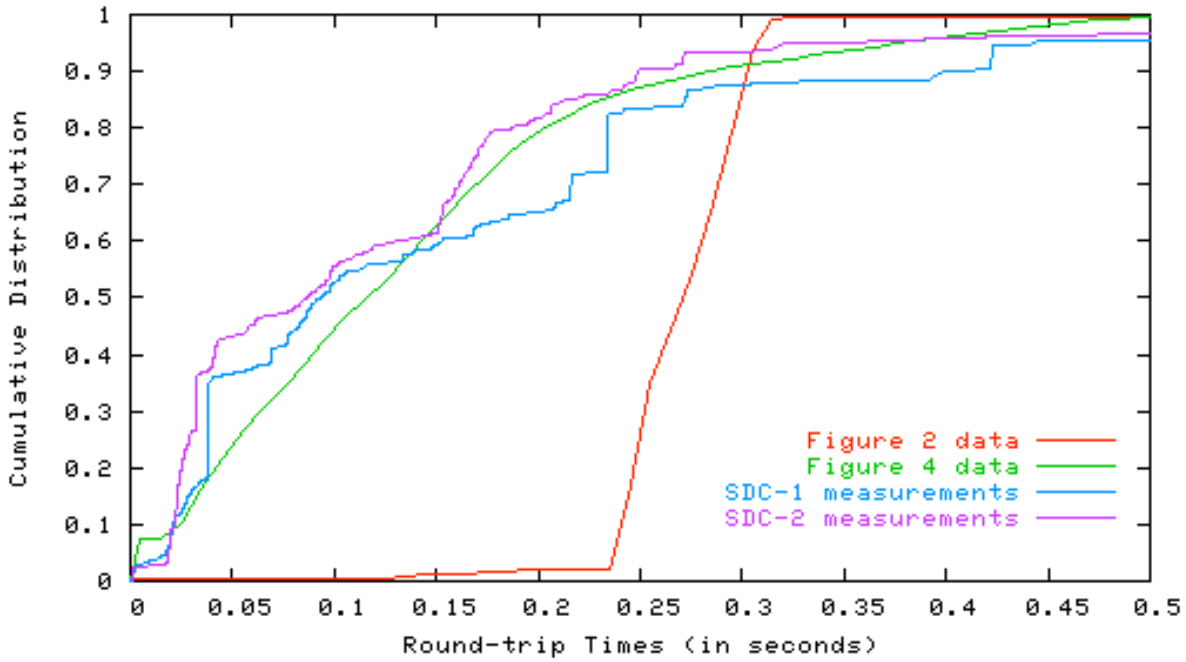
Distribution of Flow Sizes



- Distributions of packet numbers on the congested link over the second half of two simulations, with data measured on the Internet for comparison.

  [Floyd and Kohler, 2002]

Distribution of RTTs



- Distributions of packet round-trip times on the congested link of two simulations, with data measured on the Internet for comparison.

  [Floyd and Kohler, 2002]

Characterizing the end-to-end path: the synchronization ratio.

- Relevant to:
  - convergence times for high-bandwidth TCPs.
- Measurements:
  - the degree of synchronization of loss events between two TCP flows on the same path.
- Affected by:
  - AQM mechanism, traffic mix, TCP variant, etc.
- Under investigation by:
  - Grenville Armitage and Qiang Fu.

Characterizing the end-to-end path: drop rates as a function of packet size

- Relevant for:
  - evaluating congestion control for VoIP and other small-packet flows.
  - E.g., TFRC for Voice: the VoIP Variant, draft-ietf-dccp-tfrc-voip-02.txt,
- Measurements:
  - compare drop rates for large-packet TCP, small-packet TCP, and small-packet UDP on the same path.
- There is a wide diversity in the real world:
  - Drop-Tail queues in packets, bytes, and in between.
  - RED in byte mode (Linux) and in packet mode (Cisco).
  - Routers with per-flow scheduling:
    - with units in Bps or in packets per second?

Example: congestion control for VoIP

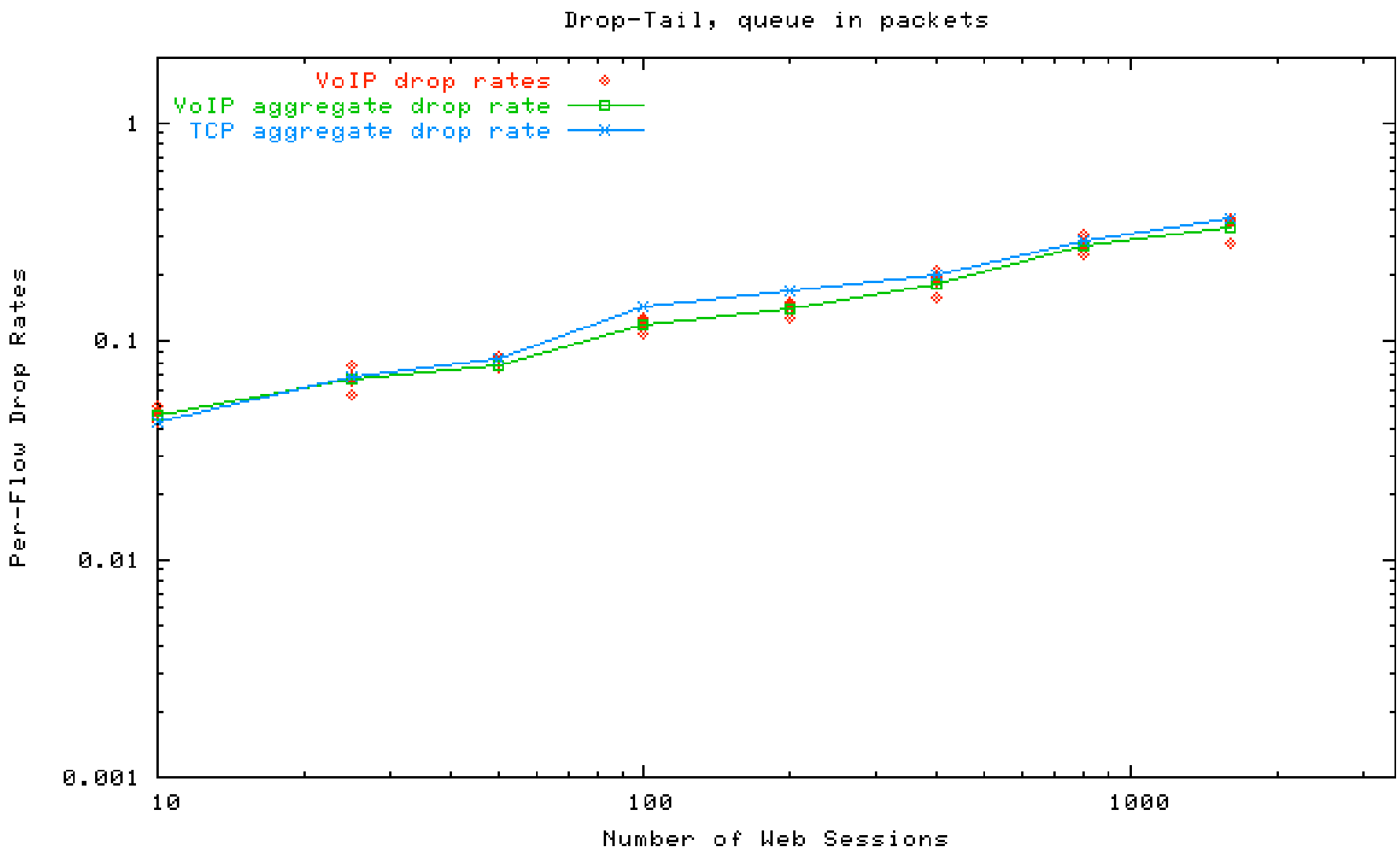
- TFRC (TCP-Friendly Rate Control):
  - The same average sending rate, in packets per RTT, as a TCP flow with the same loss event rate.
  - More slowly-responding than TCP -
    - Doesn't halve the sending rate in response to a single loss.
  - The mechanism:
    - The receiver calculates the loss event rate.
    - The sender calculates the allowed sending rate for that loss event rate.

VoIP TFRC:

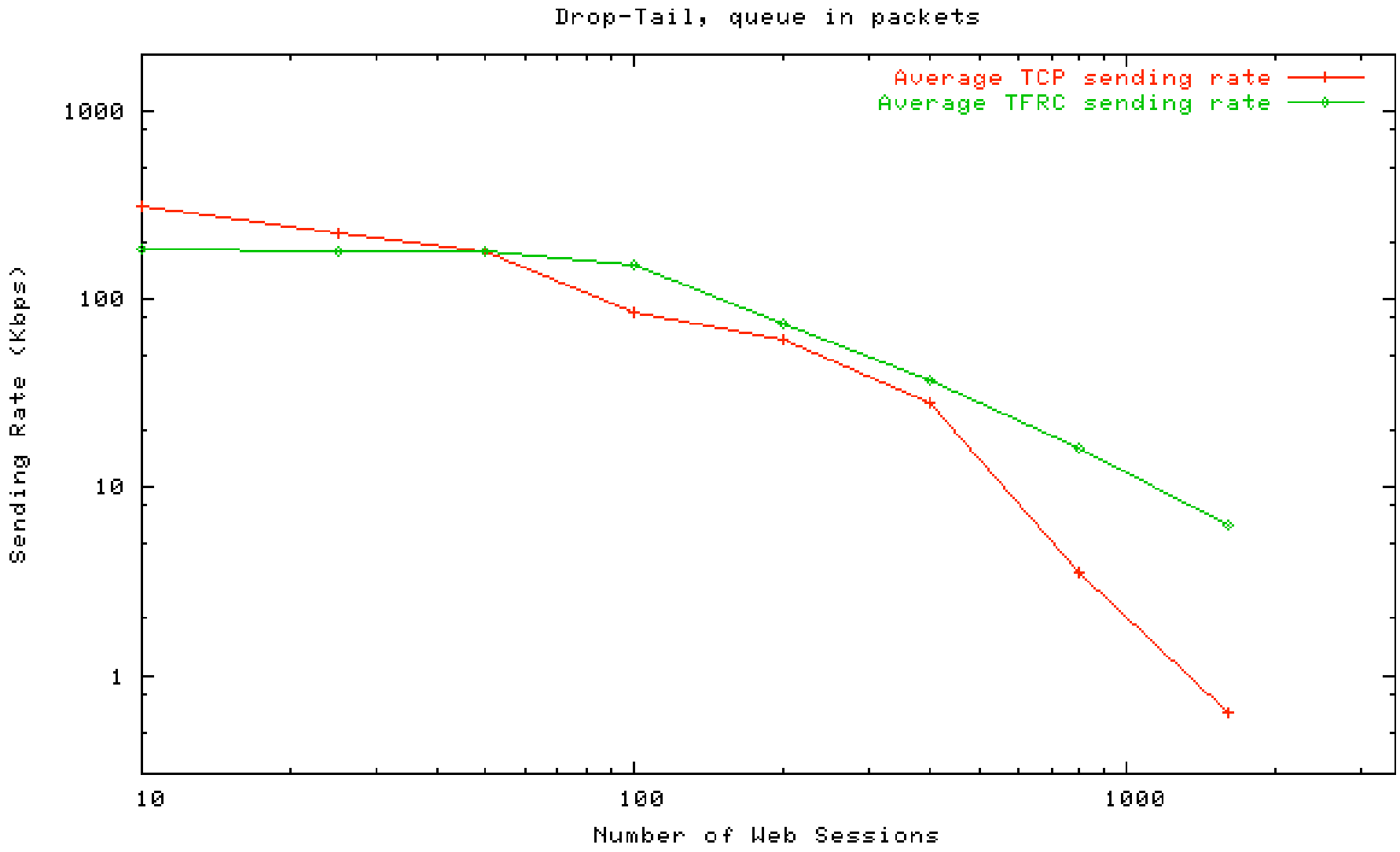
- A variant of TFRC for flows with small packets:
  - Sending at most 100 packets per second.
- The goal:
  - The same sending rate in bytes per second as TCP flows with large packets and the same packet drop rate.
- The problem:
  - Works fine when flows with small packets receive a similar packet drop rate as flows with large packets…

    [From Floyd 2005, TFRC for Voice: the VoIP Variant]

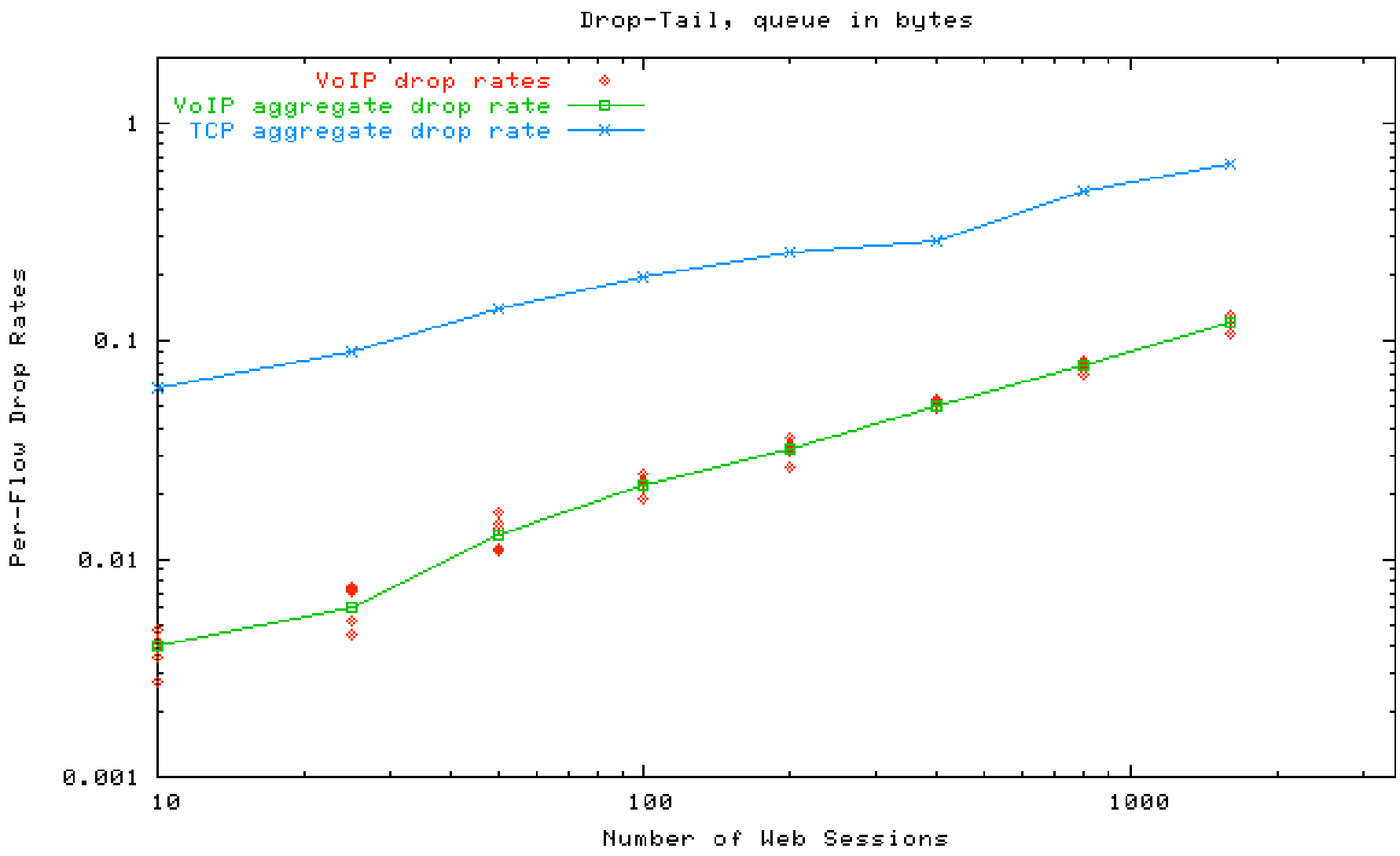
VoIP TFRC, Queue in Packets:



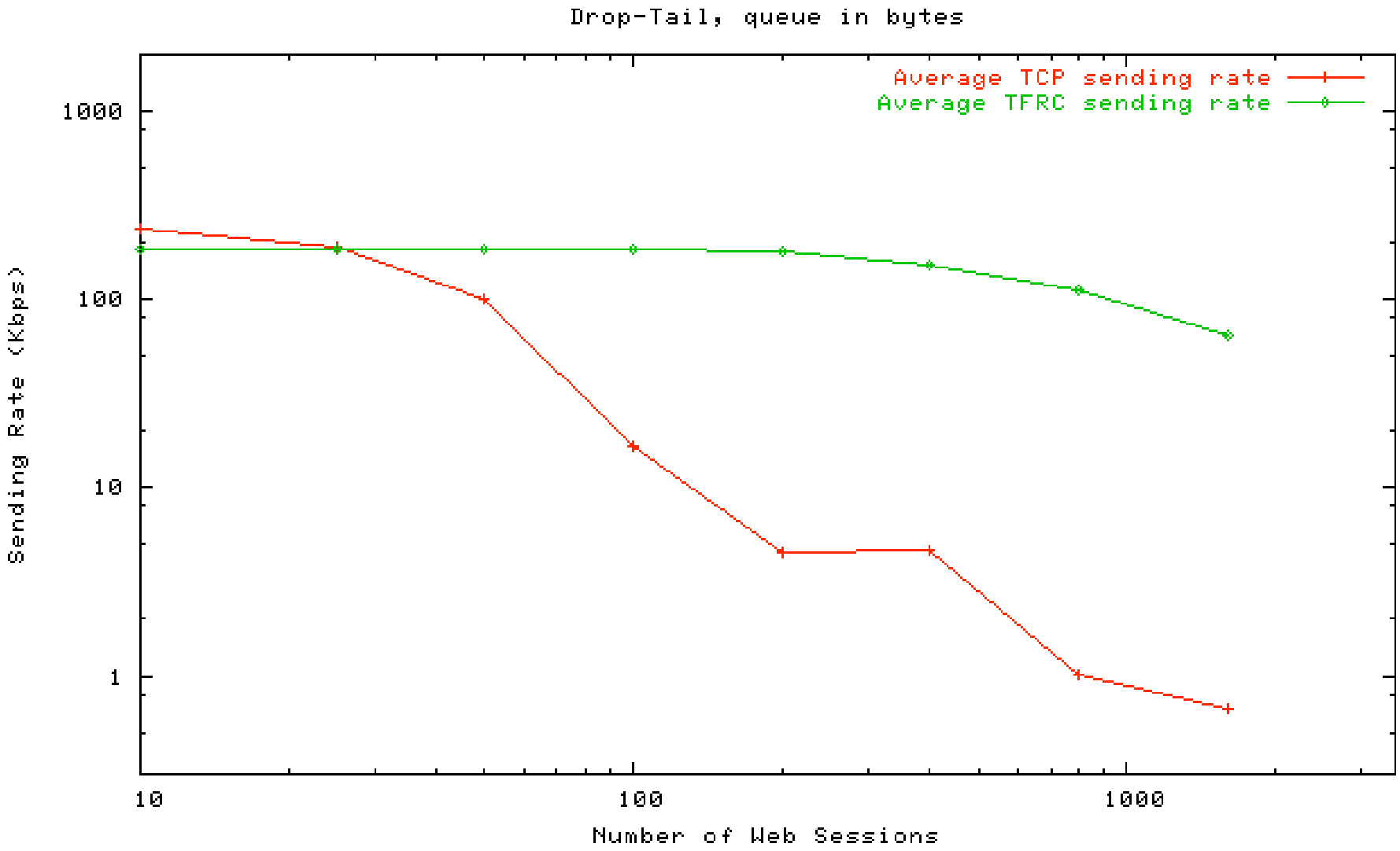
VoIP TFRC, Queue in Packets:



VoIP TFRC, Queue in Bytes:



VoIP TFRC, Queue in Bytes:



Characterizing the end-to-end path: burst-tolerance

- Relevant for:
  - fairness for bursty traffic,
  - throughput/delay tradeoffs, etc.
- Measurements:
  - drop rates as a function of burst size, in ping or TCP traffic.
- Affected by:
  - AQM mechanism, traffic mix.

Characterizing the end-to-end path: Minimization (or not) of packet drops

- Relevant for:
  - throughput/delay/droprate tradeoffs,
  - drop-sensitive traffic.
- Measurements:
  - number of packet drops at the end of slow start;
  - number of drops in a loss event (e.g., round-trip time).
- Affected by:
  - AQM mechanism.

One Plan:
the Transport Modeling Research Group.

- The TMRG (http://www.icir.org/tmrg/) is being created.
- First document:
  - Metrics for the Evaluation of Congestion Control Mechanisms. Internet-draft draft-floyd-transport-metrics-00.txt, May 2005.
- Plan for second document:
  - Tools for Constructing Scenarios for the Evaluation of Congestion Control Mechanisms.
- Plan for further activities:
  - Best current practice sets of simulation and experiment scenarios.

Metrics for the Evaluation of Congestion Control Mechanisms

- Throughput, delay, and packet drop rates.
- Response to sudden changes or to transient events; Minimizing oscillations in throughput or in delay.
- Fairness and convergence times.
- Robustness for challenging environments.
- Robustness to failures and to misbehaving users.
- Deployability.
- Security.
- Metrics for specific types of transport.

References:

- [Floyd 2005], TFRC for Voice: the VoIP Variant, draft-ietf-dccp-tfrc-voip-02.txt
- [Floyd and Kohler 2002], Internet Research Needs Better Models, Hotnets 2002.
- TMRG: http://www.icir.org/tmrg/
- Metrics for the Evaluation of Congestion Control Mechanisms, Floyd, 2005, draft-floyd-transport-metrics-00.txt