HighSpeed TCP and Quick-Start for Fast Long-Distance Networks:

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TWVWG

March, 2003

Topics:

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- HighSpeed TCP.

S. Floyd, HighSpeed TCP for Large Congestion Windows
draft-floyd-tcp-highspeed-02.txt
URL: http://www.icir.org/floyd/hstcp.html

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S. Floyd, Limited Slow-Start for TCP with Large Congestion Windows
draft-floyd-tcp-slowstart-01.txt

- Quick-Start.

A. Jain and S. Floyd, Quick-Start for TCP and IP.
draft-amit-quick-start-02.txt
URL: http://www.icir.org/floyd/quickstart.html

The Problem: TCP for High-Bandwidth-Delay-Product Networks

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- Sustaining high congestion windows:

A Standard TCP connection with:

– 1500-byte packets;

– a 100 ms round-trip time;

– a steady-state throughput of 10 Gbps;

would require:

– an average congestion window of 83,333 segments;

– and at most one drop (or mark) every 5,000,000,000 packets (or equivalently, at most one drop every 1 2/3 hours).

This is not realistic.

What is HighSpeed TCP:

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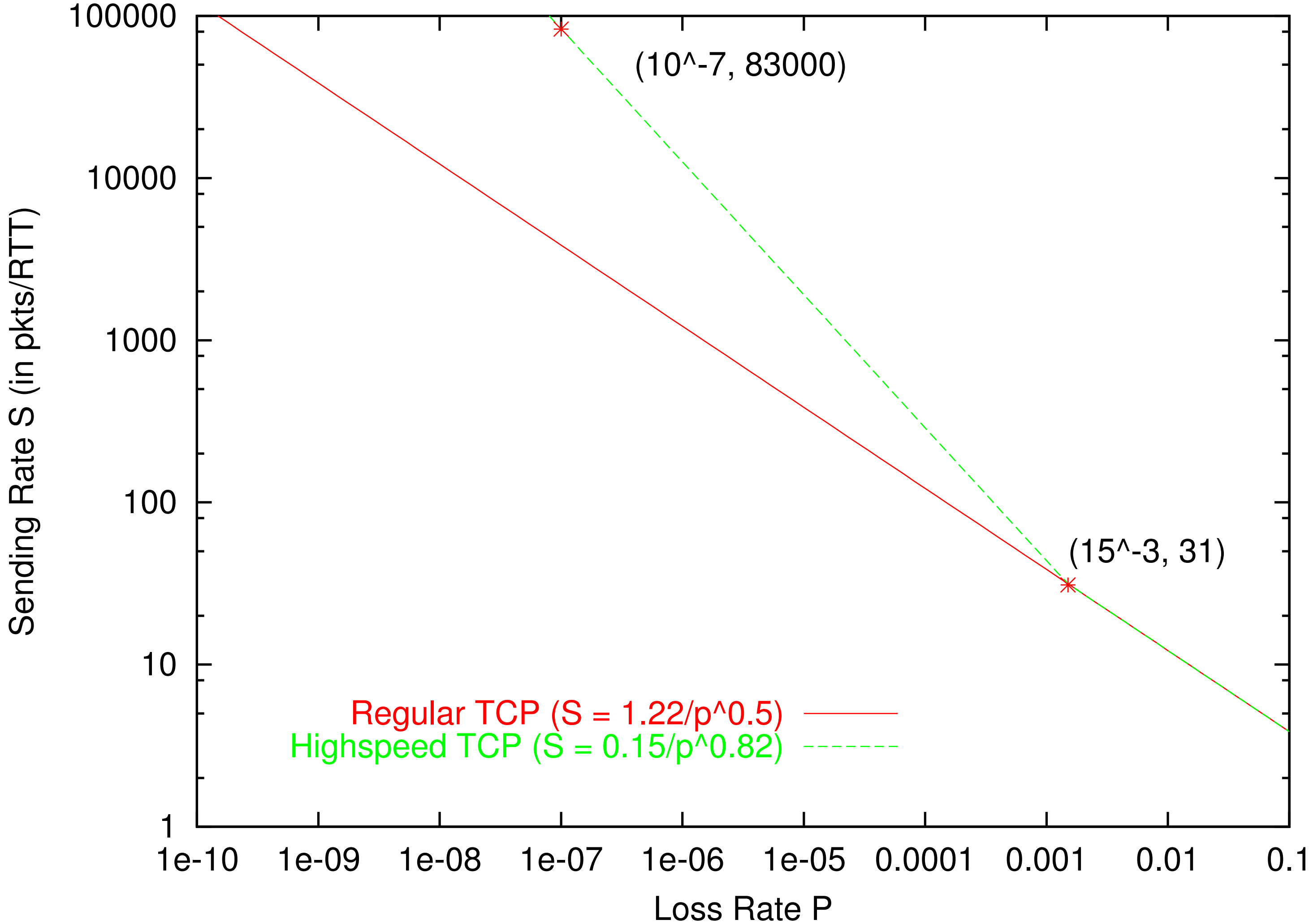
- Just like Standard TCP when cwnd is low.

- More aggressive than Standard TCP when cwnd is high.
  – Uses a modified TCP response function.

- HighSpeed TCP can be thought of as behaving as an aggregate of N TCP connections at higher congestion windows.

- Joint work with Sylvia Ratnasamy and Scott Shenker, additional contributions from Evandro de Souza, Deb Agarwal, Tom Dunigan.

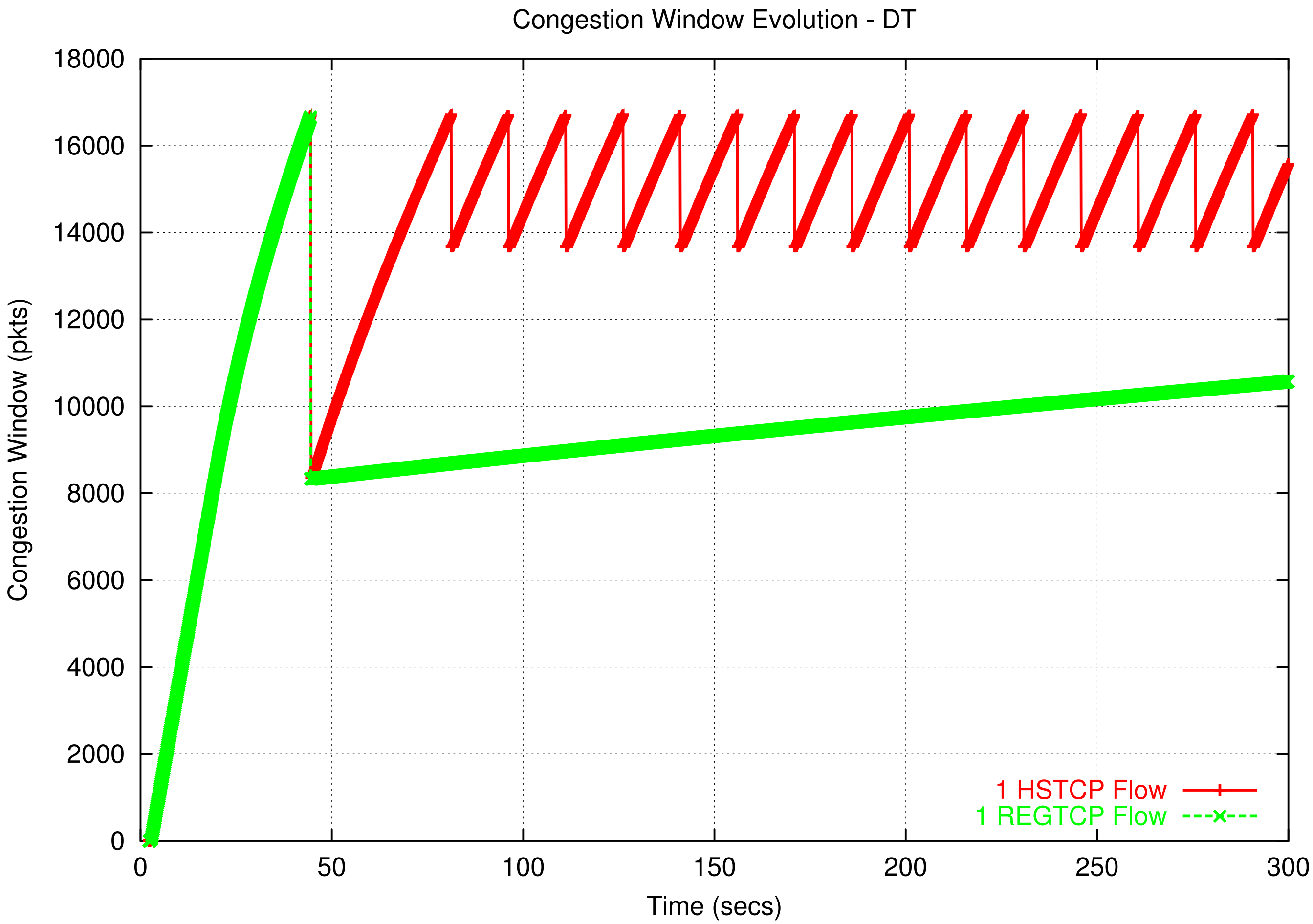
HighSpeed TCP: the modified response function.



Changes since draft-floyd-tcp-highspeed-00.txt:

- Added a discussion of HighSpeed TCP as roughly emulating the congestion control response of N parallel TCP connections.
- Added mention of an alternate, linear response function; Scalable TCP from Tom Kelly.
- Added a section on ”Tradeoffs for Choosing Congestion Control Parameters”.
- Added discussions on: related work about changing the PMTU;
  the TCP window scale option;
  time to converge to fairness.

Simulations from Evandro de Souza:



HighSpeed TCP (red) compared to Standard TCP (green).

HighSpeed TCP in a Drop-Tail Environment?

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- Drop-Tail queues: a packet is dropped when the (fixed) buffer overflows.

- Active Queue Management: a packet is dropped before buffer overflow.

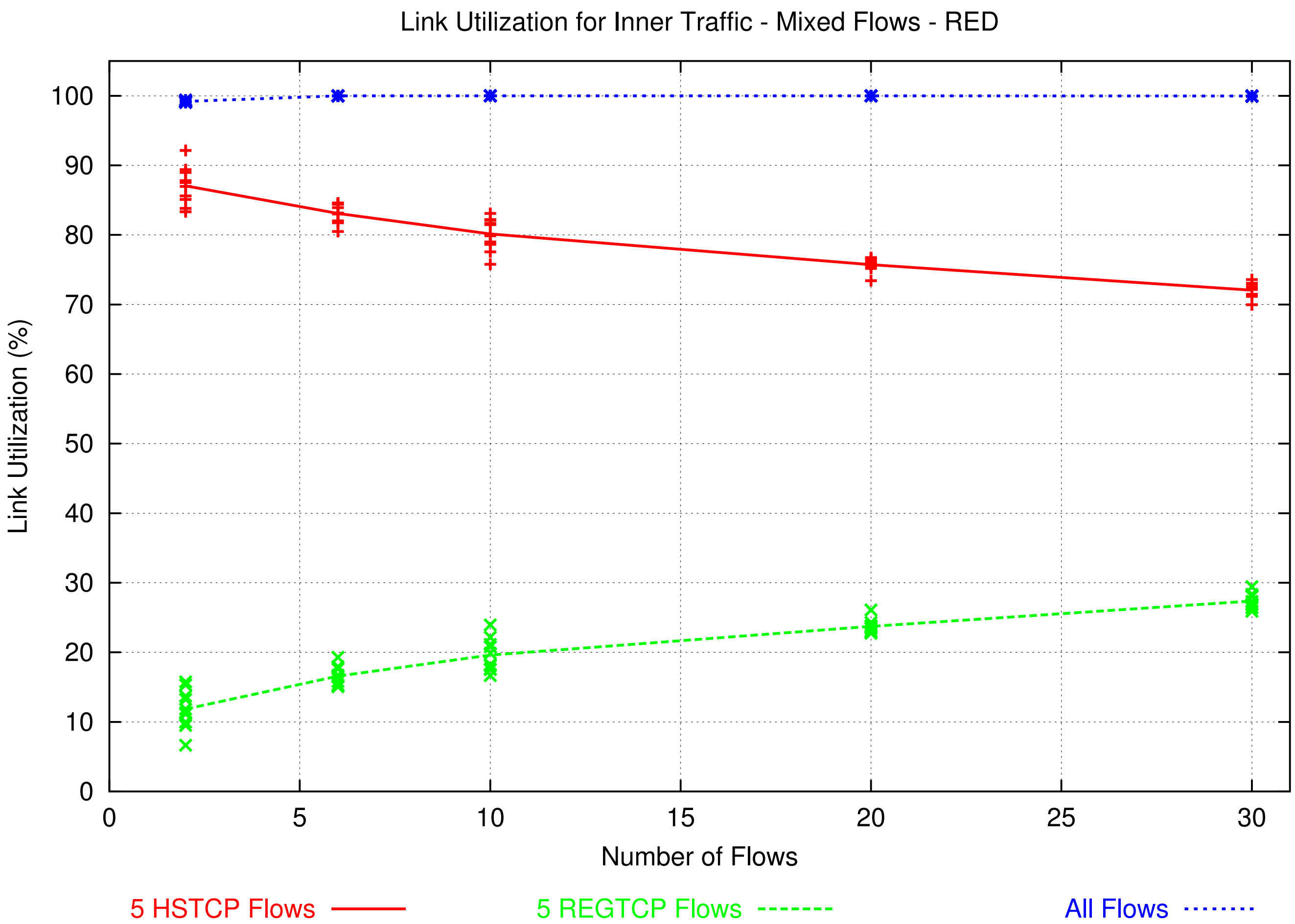
E.g. RED, where the average queue size is monitored.

- In a Drop-Tail environment:

Assume that TCP increases its sending rate by P packets per RTT.

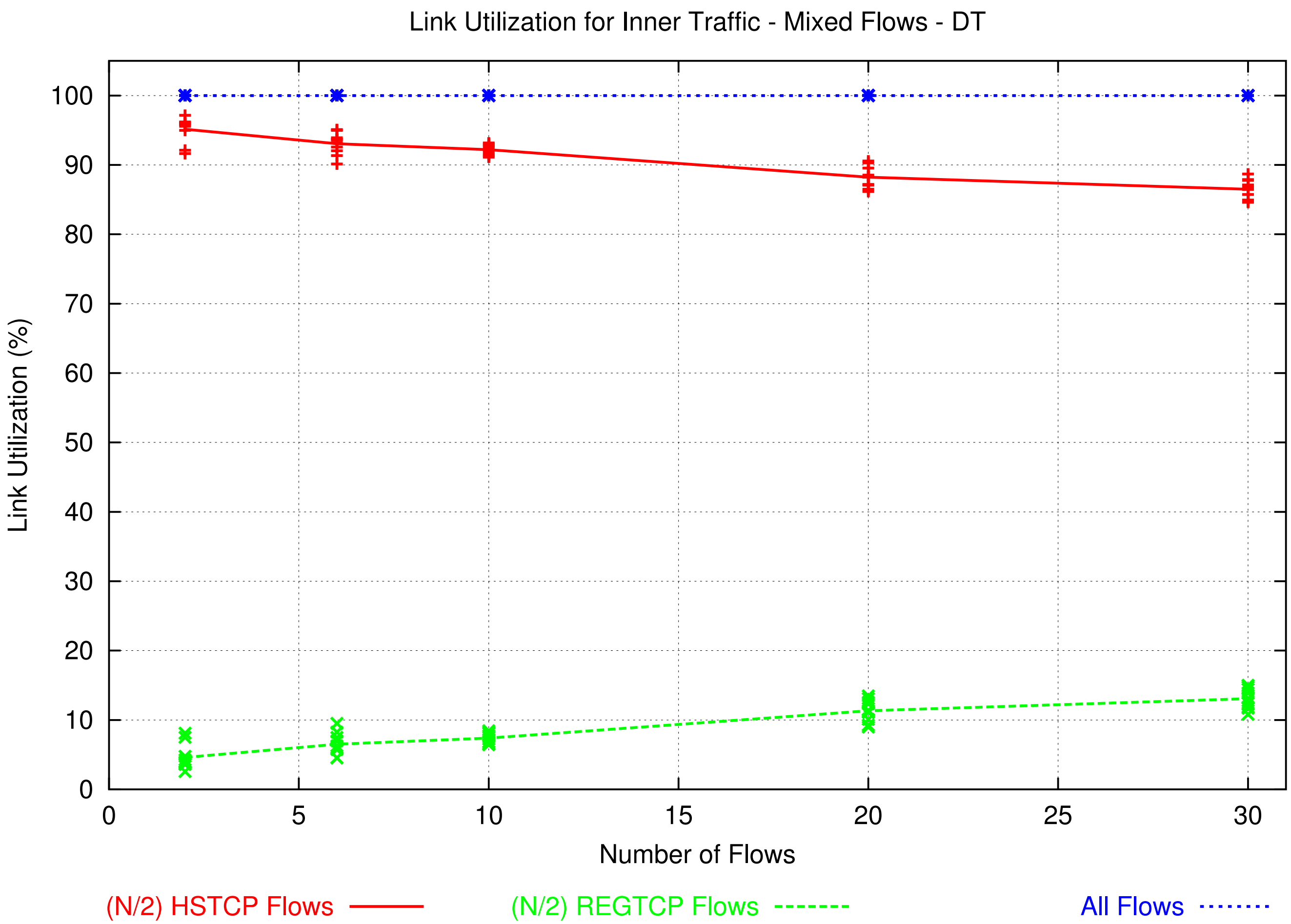
Then P packets are likely to be dropped for each congestion event for that connection.

Relative Fairness with RED queue management:



Simulations from Evandro de Souza.

Relative Fairness with Drop-Tail queue management:



Simulations from Evandro de Souza.

Conclusions:

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- This proposal needs feedback from more experiments.
- My own view is that this approach is the fundamentally correct path:
  – given backwards compatibility and incremental deployment.
- More results are on the HighSpeed TCP web page.
  – http://www.icir.org/floyd/hstcp.html
  – Simulations from Evandro de Souza and Deb Agarwal (LBNL).
  – Experimental results from Tom Dunigan (ORNL).
  – Experimental results from Brian Tierney (LBNL).
  – Experimental results from Les Cottrel (SLAC).
  – Experimental results from Tom Kelly on Scalable TCP.

HighSpeed TCP requires Limited Slow-Start:

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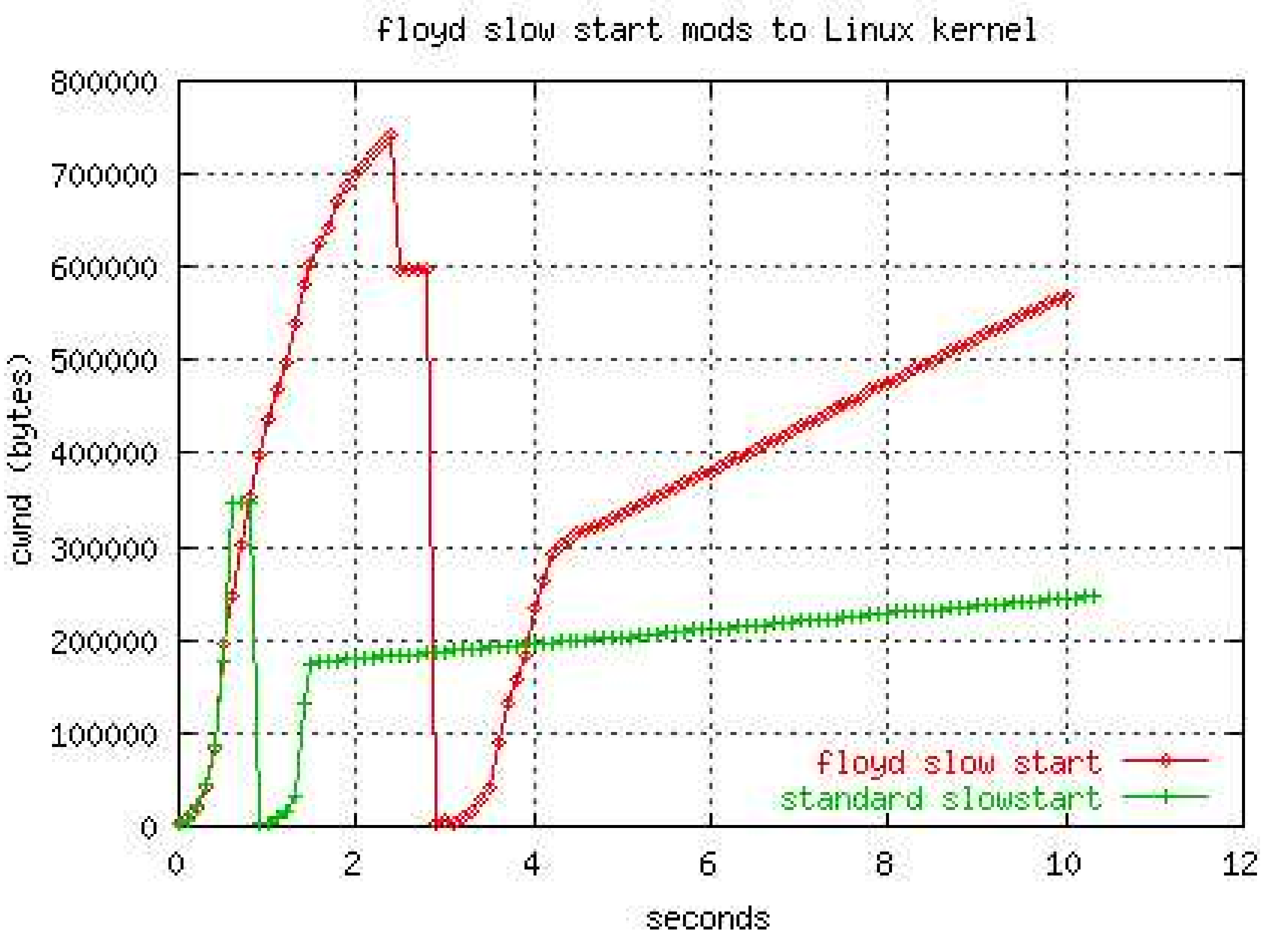
- Slow-starting up to a window of 83,000 packets doesn't work well.
  - Tens of thousands of packets dropped from one window of data.
  - Slow recovery for the TCP connection.
- The answer: Limited Slow-Start
  - Agent/TCP set max_ssthresh_ N
  - During the initial slow-start, increase the congestion window by at most N packets in one RTT.

Tests from Tom Dunigan:



This shows Limited Slow-Start, but not HighSpeed TCP.

Changes since draft-floyd-tcp-slowstart-00.txt:

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- Small changes in presentation.
- The addition of a section of Experiments.
- More citations to related work.

Other small changes for high congestion windows:

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- More robust performance in paths with reordering:

Wait for more than three duplicate acknowledgments before retransmitting a packet.

- Recover more smoothly when a retransmitted packet is dropped.

Additional Problems:

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- Starting up with high congestion windows?
- Making prompt use of newly-available bandwidth?

What is QuickStart?

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- In an IP option in the SYN packet, the sender's desired sending rate:
  - Routers on the path decrement a TTL counter,
  - and decrease the allowed initial sending rate, if necessary.
- The receiver sends feedback to the sender in the SYN/ACK packet:
  - The sender knows if all routers on the path participated.
  - The sender has an RTT measurement.
  - The sender can set the initial congestion window.
  - The TCP sender continues with AIMD using normal methods.
- From an initial proposal by Amit Jain

Changes from draft-amit-quick-start-00.txt:

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- Deleted the QS Nonce, in favor of a random initial value for the QS TTL (for preventing cheating receivers).
- The addition of a Related Work section (including a discussion of tradeoffs of XCP vs. Quick-Start).
- Added a section on ”The Quick-Start Request: Packets or Bytes?”

The Quick-Start Request Option for IPv4

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```
     0           1           2           3
+-----------+-----------+-----------+-----------+
| Option    | Length=4  |  QS TTL   | Initial   |
|           |           |           | Rate      |
+-----------+-----------+-----------+-----------+
```

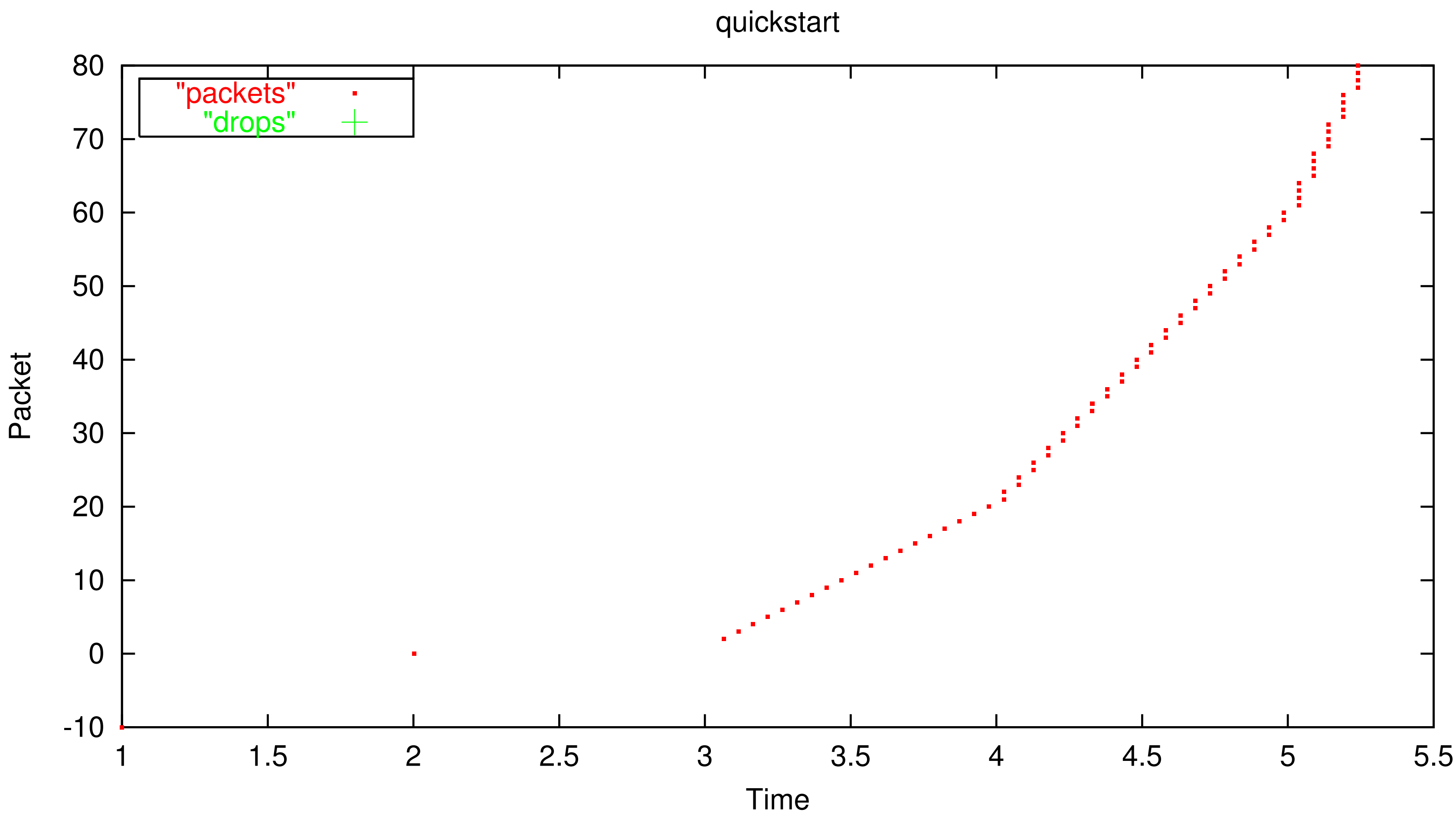
- Explicit feedback from all of the routers along the path would be required.

- This option will only be approved by routers that are significantly underutilized.

- No per-flow state is kept at the router.

Quick-Start in the NS Simulator:

- Added to NS by Srikanth Sundarrajan.



Questions:

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- Would the benefits of Quick-Start be worth the added complexity?
  – SYN and SYN/ACK packets would not take the fast path in routers.
- Is there a compelling need to add some form of congestion-related feedback from routers such as this (in addition to ECN)?
- Is there a compelling need for more fine-grained or more frequent feedback than Quick-Start?
- Are there other mechanisms that would be preferable to Quick-Start?

Architectural sub-themes favoring incremental deployment:

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- A goal of incremental deployment in the current Internet.
- Steps must go in the fundamantally correct, long-term direction, not be short-term hacks.
- Robustness in heterogeneous environments valued over efficiency of performance in well-defined environments.
- A preference for simple mechanisms, but a skepticism towards simple traffic and topology models.
- Learning from actual deployment is an invaluable step.
- The Internet will continue to be decentralized and fast-changing.

Extra slides:

Is this a pressing problem in practice?

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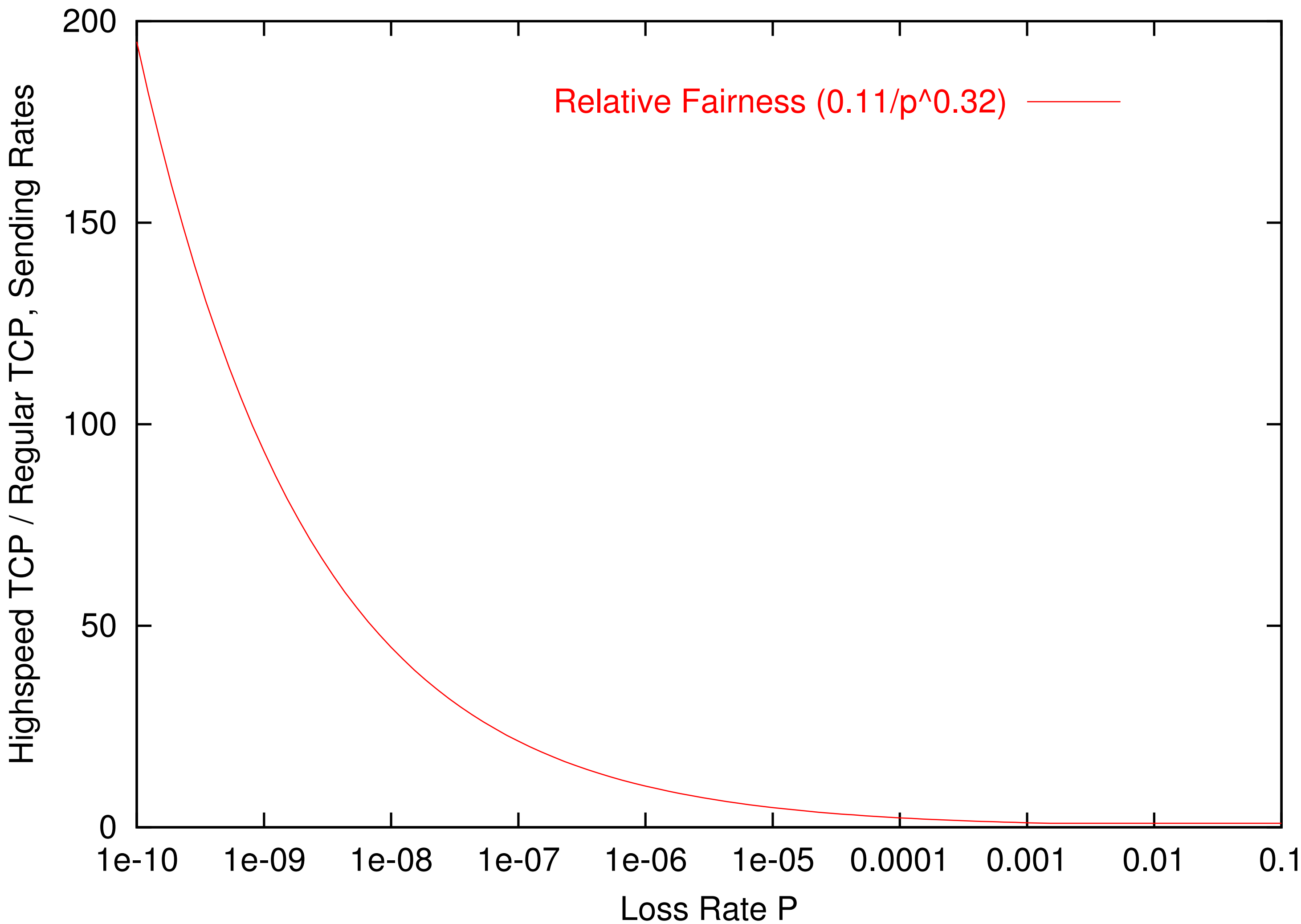
- Nope. In practice, users do one of the following:
  – Open up N parallel TCP connections; or
  – Use MulTCP (roughly like an aggregate of N virtual TCP connections).

- However, we can do better:
  – Better flexibility (no N to configure);
  – Better scaling (with a range of bandwidths, numbers of flows);
  – Better slow-start behavior;
  – Competing more fairly with current TCP (for environments where TCP is able to use the available bandwidth).

HighSpeed TCP: Relative fairness.



HighSpeed TCP: Simulations in NS.

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- ./test-all-tcpHighspeed in tcl/test.

- The parameters specifying the response function:
  - Agent/TCP set low_window_ 38
  - Agent/TCP set high_window_ 83000
  - Agent/TCP set high_p_ 0.0000001

- The parameter specifying the decrease function at high_p_:
  - Agent/TCP set high_decrease_ 0.1

HighSpeed TCP: The Gory Details:

w	a(w)	b(w)
38	1	0.50
118	2	0.44
221	3	0.41
347	4	0.38
495	5	0.37
663	6	0.35
851	7	0.34
1058	8	0.33
1284	9	0.32
1529	10	0.31
1793	11	0.30
2076	12	0.29
2378	13	0.28
...		
84035	71	0.10

The Limited Slow-Start pseudocode:

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For each arriving ACK in slow-start:
  If (cwnd <= max_ssthresh)
     cwnd += MSS;
  else
     K = 2 * cwnd/max_ssthresh ;
     cwnd += MSS/K ;
```