State of the bloat

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My background

Name: Toke Høiland-Jørgensen

- Master's student of computer science and mathematics at Roskilde University (RUC).
- Currently writing my master's thesis.
- Involved with bufferbloat research since October 2012.
- Author of the `netperf-wrapper` testing tool.

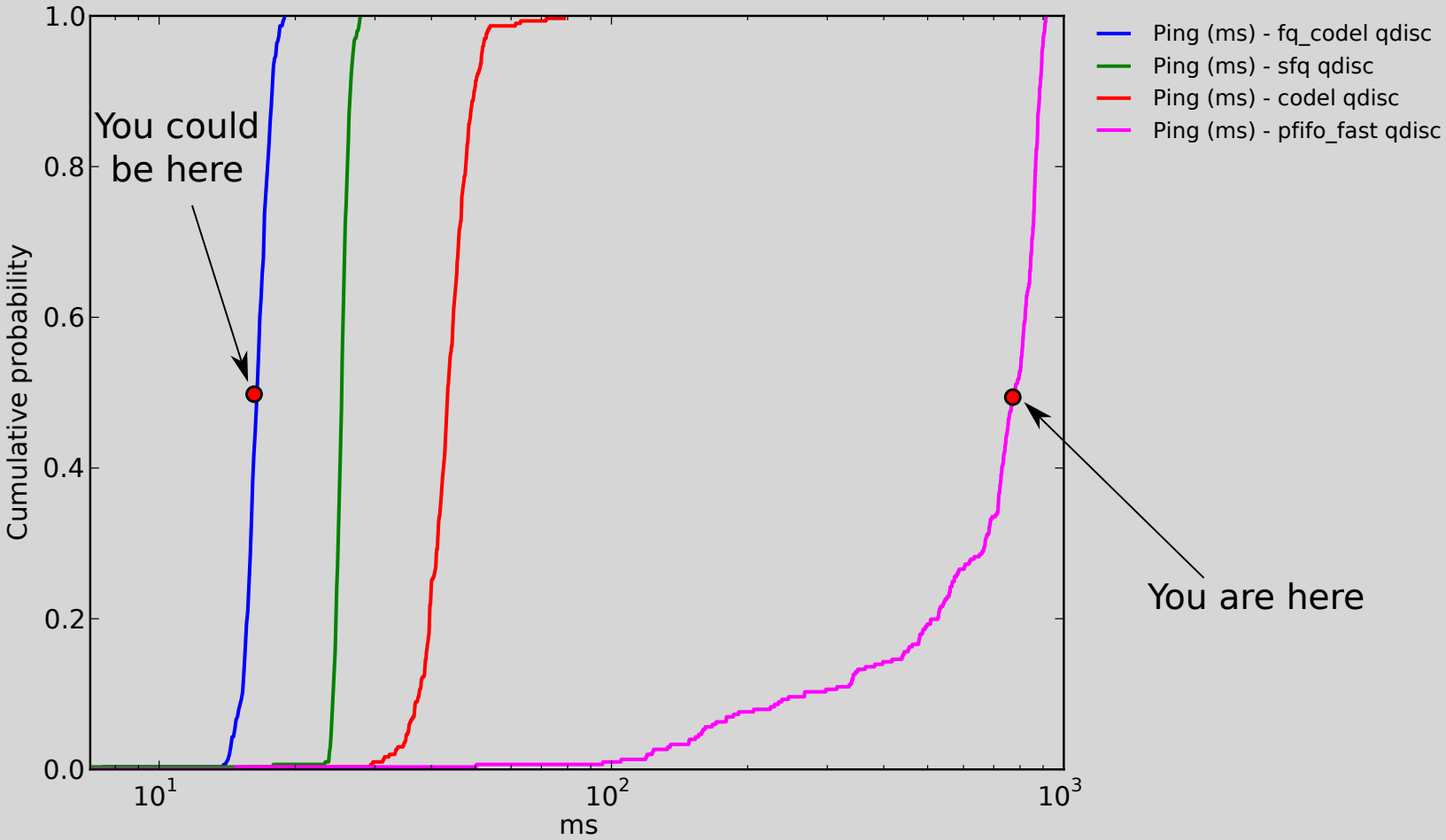
Outline

- Introduction
- The problem: networks and bloated buffers
- Mitigation mechanisms in the Linux kernel
- Test results
- Testing methodology and best practices

Spoiler

Effects of bufferbloat mitigation - RRUL test

Latency during four TCP streams in each direction.



Note the log scale.

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Excess, poorly managed, buffering in network equipment, which causes latency spikes as the network link reaches capacity.

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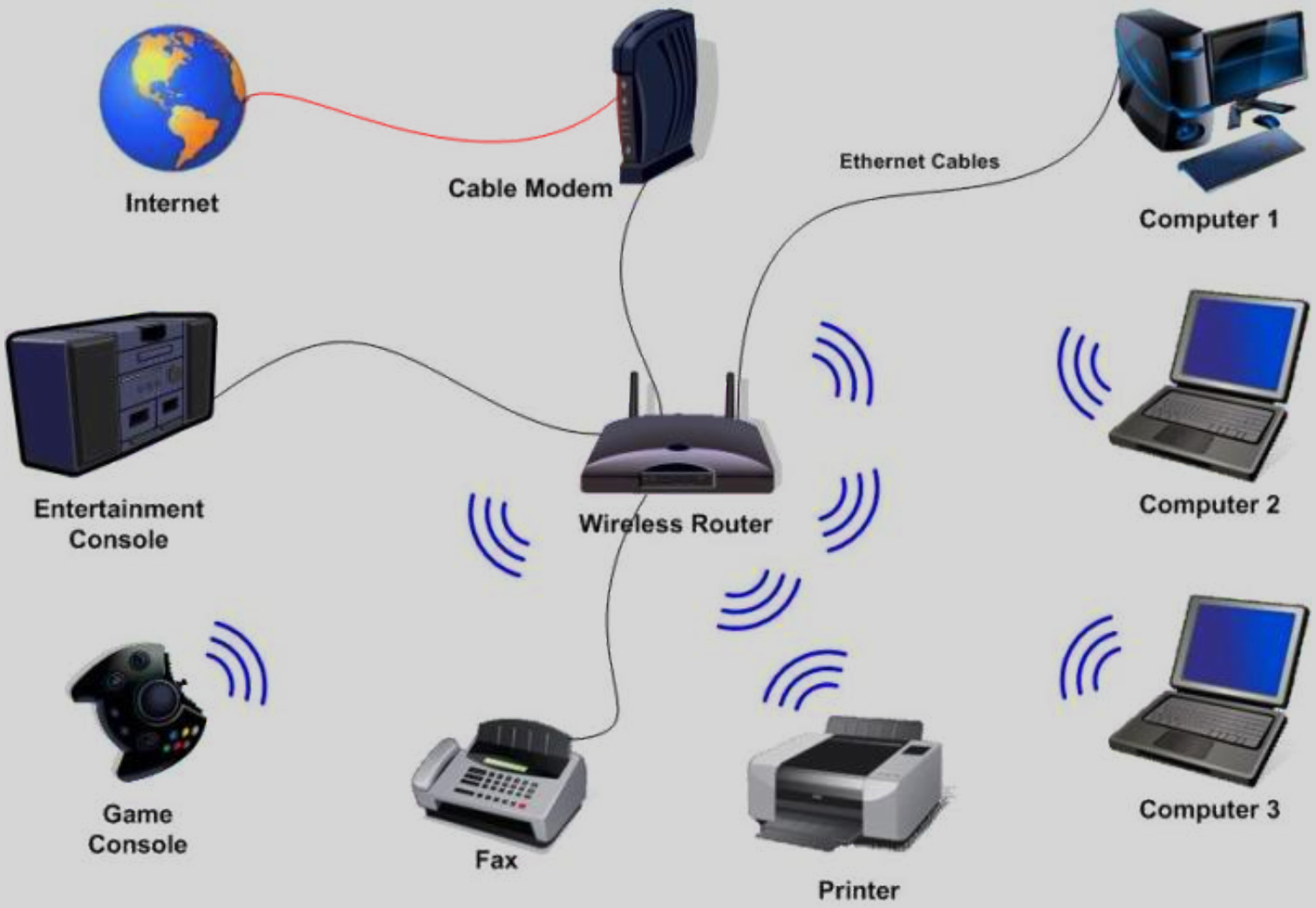
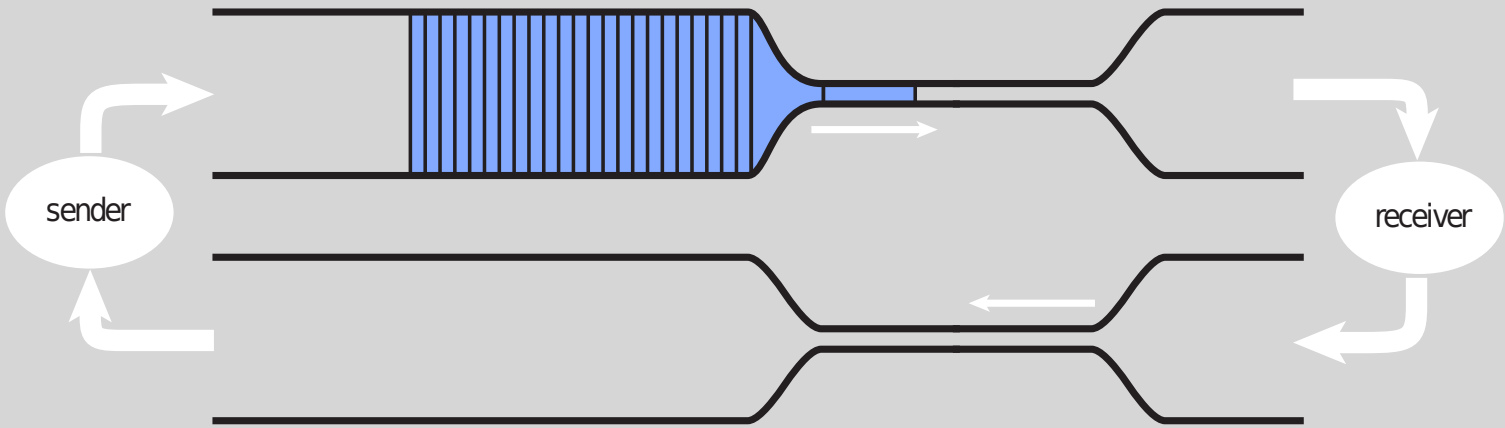
- Severely degrades the experience for users of *interactive* traffic.
  - This includes VoIP, remote shells and web browsing.

A typical home network

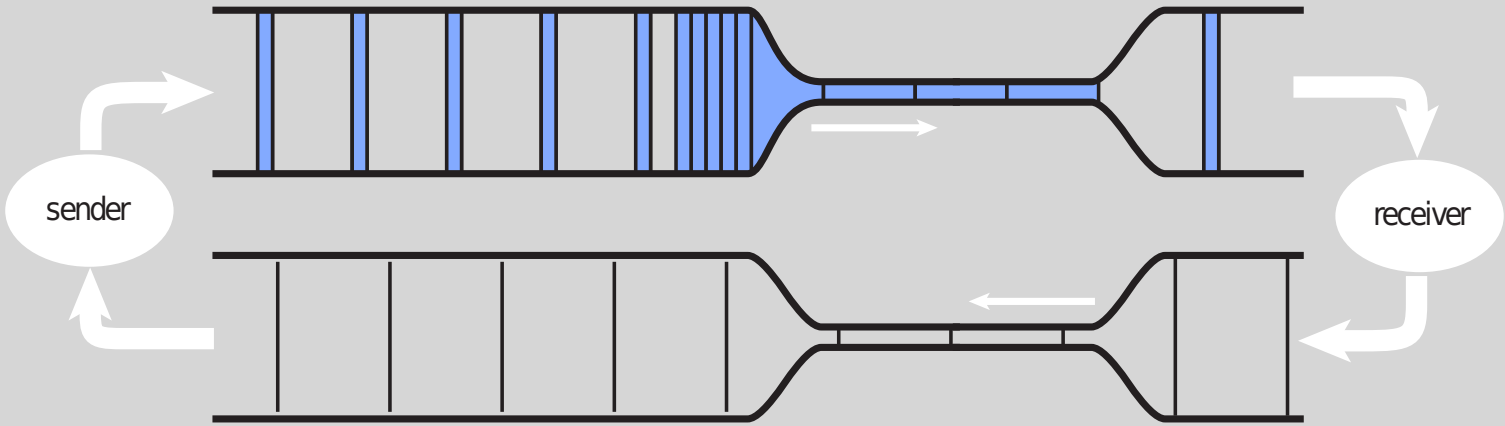


Network traffic going through a bottleneck

TCP Connection Startup

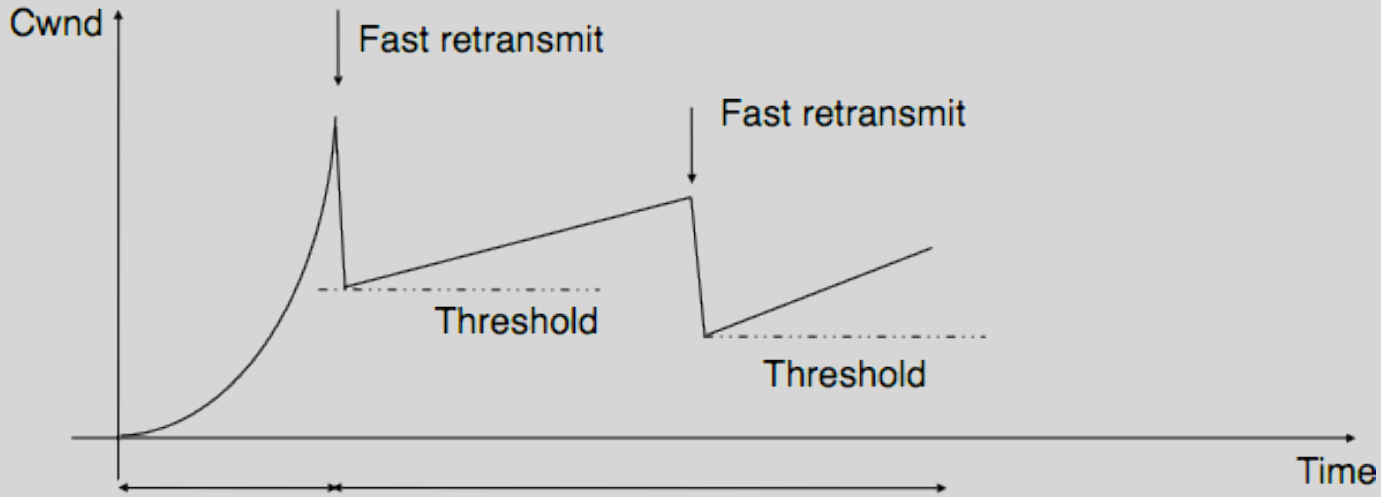


TCP Connection After One RTT



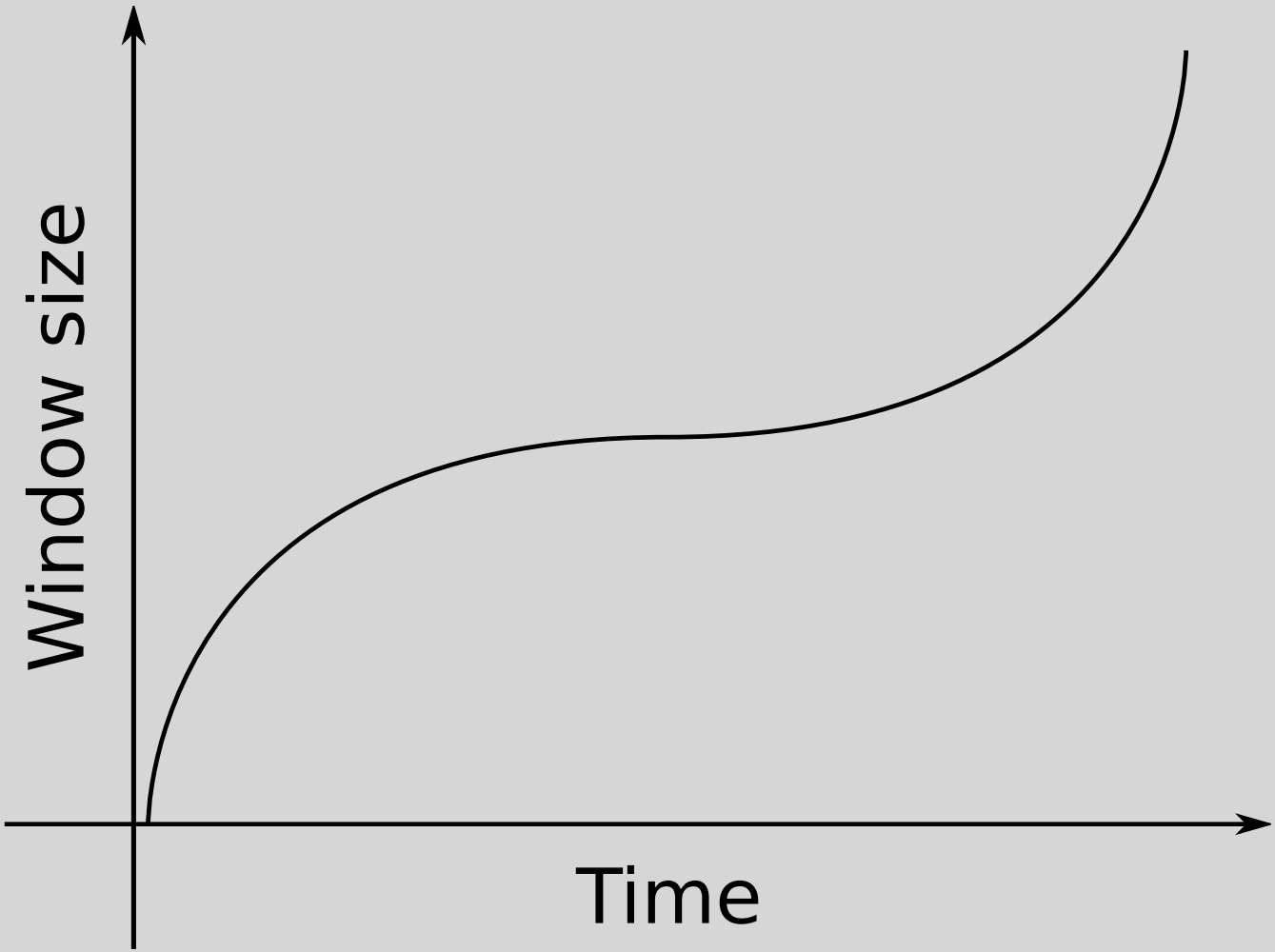
The workings of TCP

TCP congestion control



The workings of TCP (cont.)

Linux default: TCP CUBIC



Taming TCP: CoDel and fairness queueing

- CoDel (Controlled Delay) is a new AQM algorithm by Van Jacobson and Kathleen Nichols.
- Directly measures queueing delay and reacts to it.
- Drops packets before queues fill up, and drops at increasing rate if they stay full.

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- Fairness Queueing is a mechanism to divide *flows* into separate queues.
- The goal is to interleave packets from different flows.
- Prevents a single flow from using up all the bandwidth.

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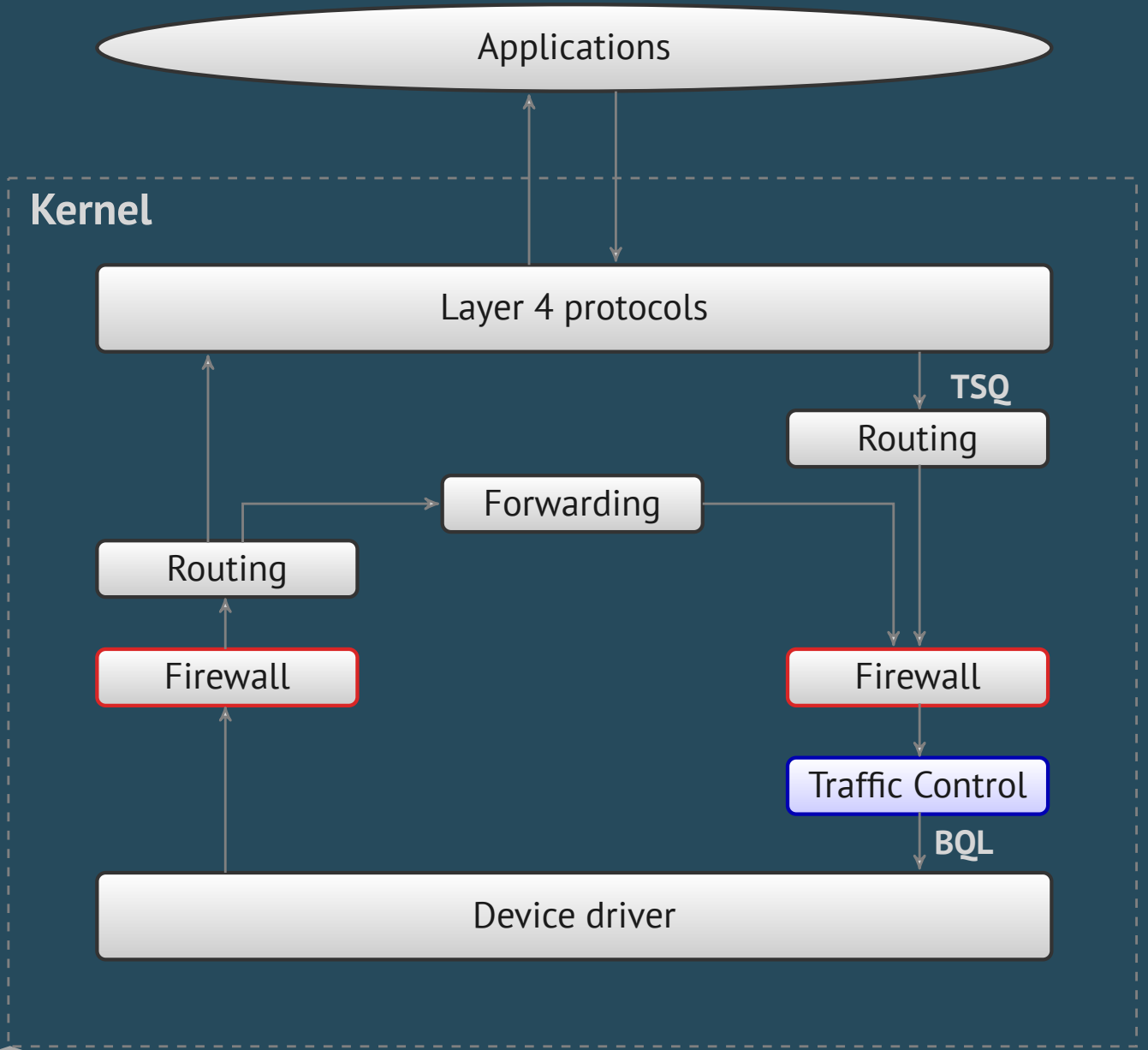
The linux kernel network subsystem



TCP Small Queues (TSQ)

- Introduced in Linux 3.6 by Eric Dumazet.
- Enhancement to the TCP stack (i.e. *above* the traffic control layer).
- Makes the TCP stack aware of when packets leave the system.
  - Sets a configurable limit (default 128KiB) of bytes in transit in lower layers.
  - After this limit, keeps the packets at the TCP layer.
- This allows for more timely feedback to the TCP stack.

Byte Queue Limits (BQL)

- Introduced in Linux 3.3, by Tom Herbert of Google.
- Sits between traffic control subsystem and device drivers.
  - Requires driver support (ongoing effort).
- Keeps track of number of *bytes* queued in the driver.
- Addresses variability of packet sizes (64 bytes up to 4KiB w/TSO).
- Unneeded in the presence of software rate limiting.

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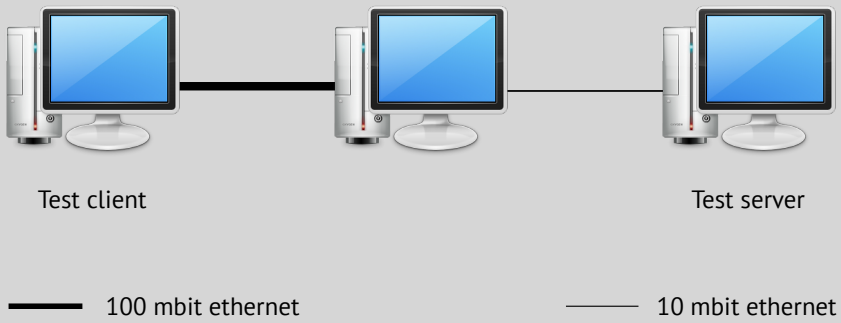
- Enhancements to the Stochastic Fairness Queueing (`sfq`) qdisc.
  - Optional head drop, more hash buckets, no permutation.
- Combination of CoDel and DRR fairness queueing in the `fq_codel` qdisc.
  - Prioritises thin flows.
  - This is currently the best bufferbloat mitigation qdisc in mainline Linux.

Outline

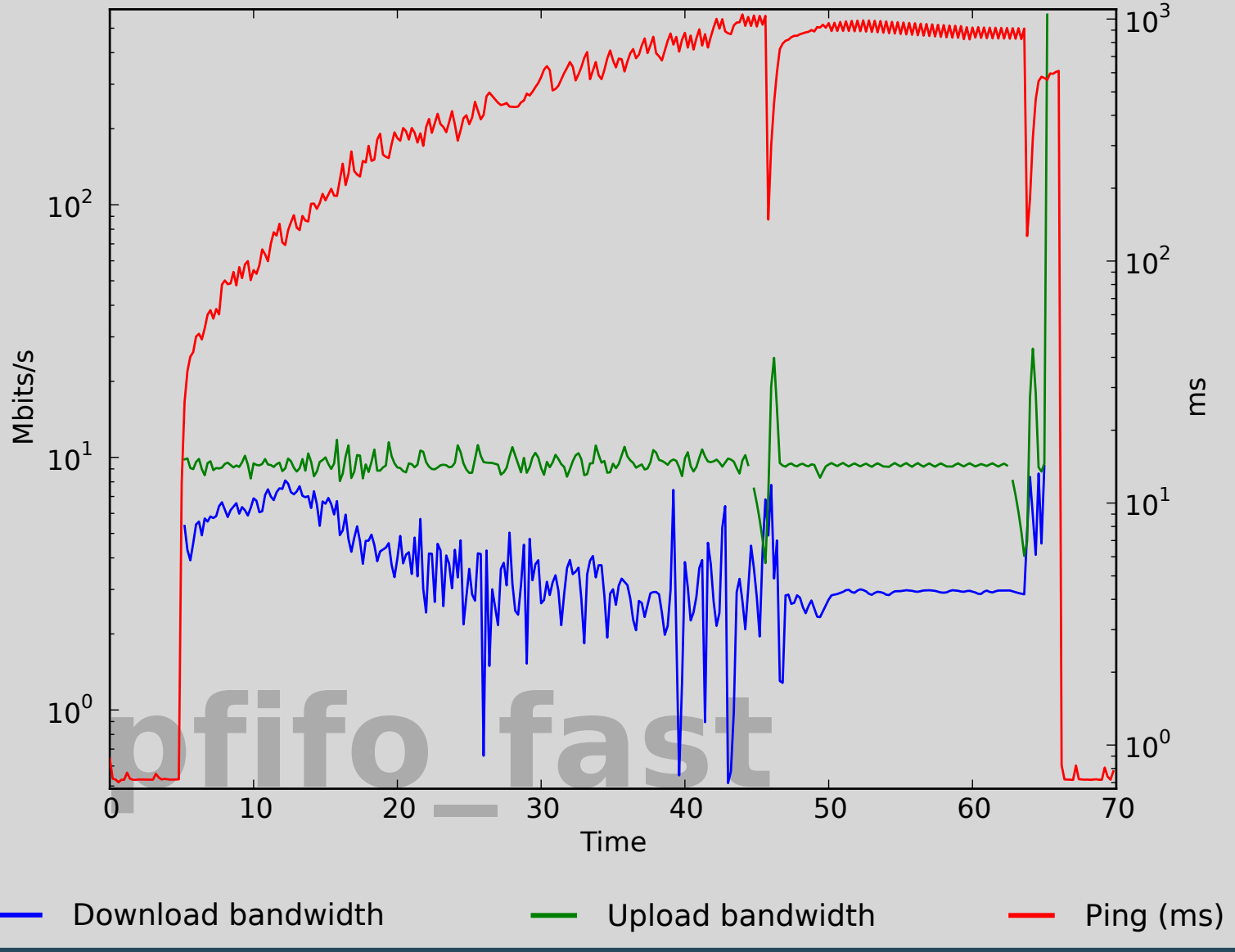
The research behind this

- Experiments done as part of university project.
- Three computers networked in lab setup.
- Switch the active `qdisc` and compare results.
- Goal: Real-world measurements on shipped Linux kernel.

Test setup



Two TCP streams + ping - `pfifo_fast`



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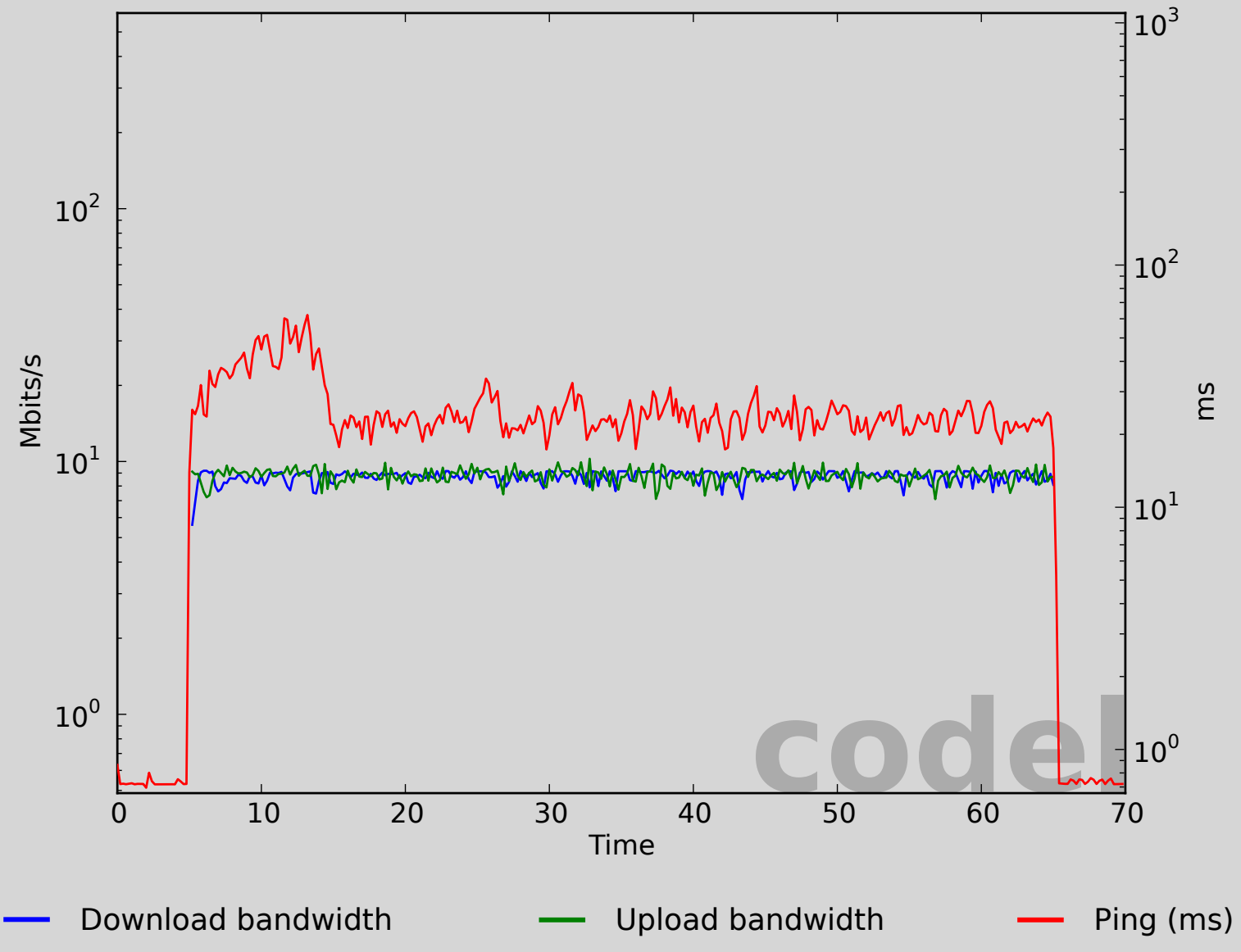
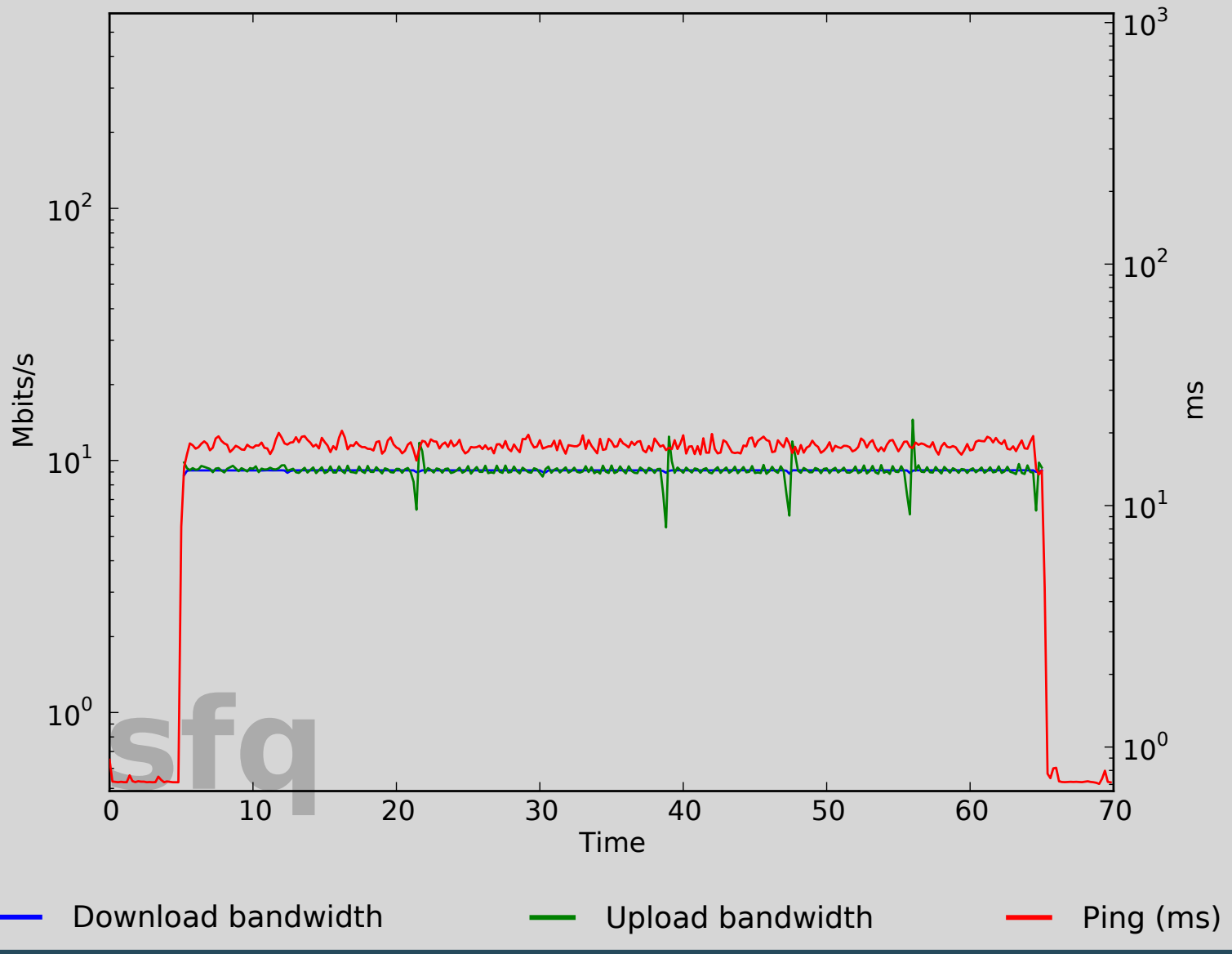
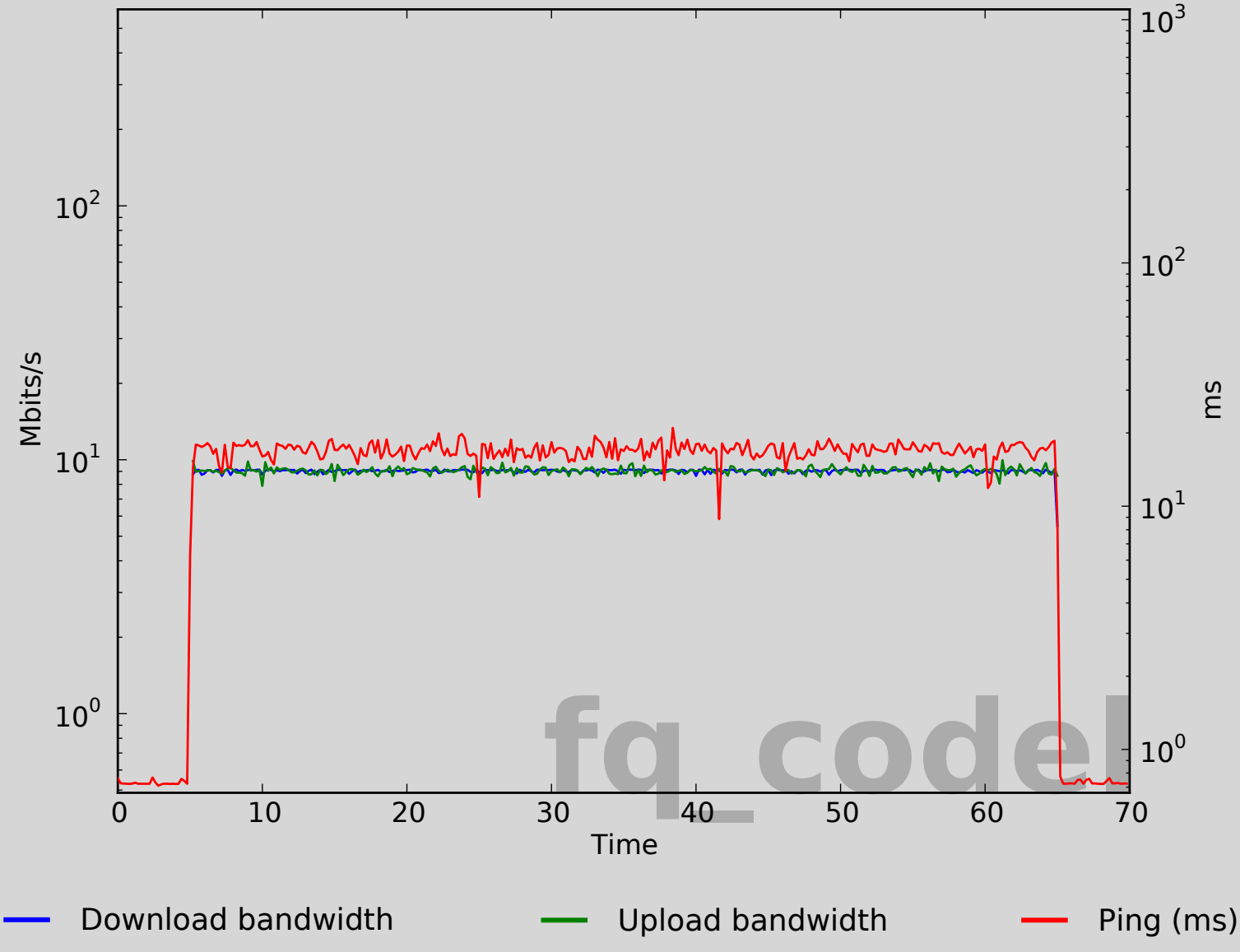


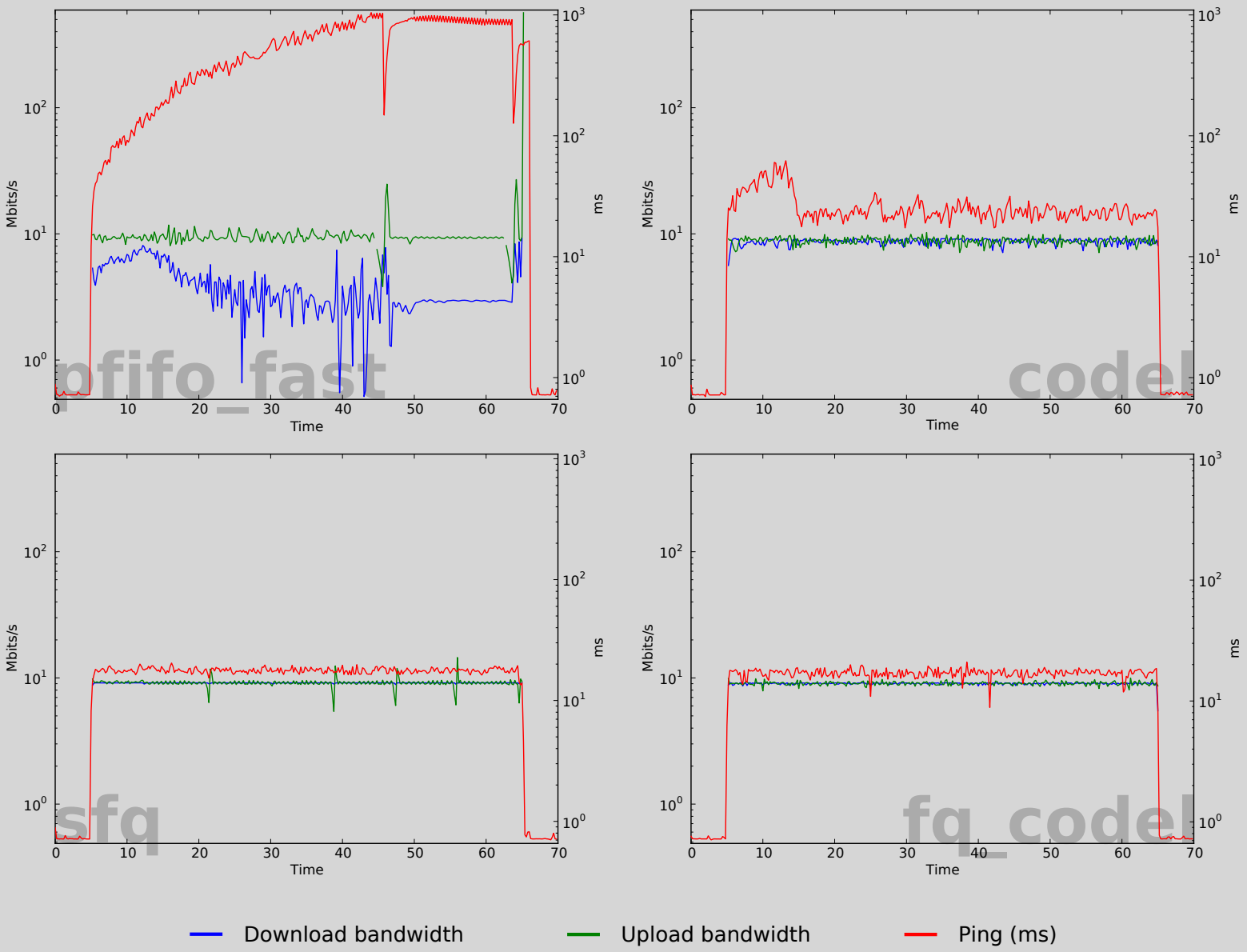
Two TCP streams + ping - `sfq`



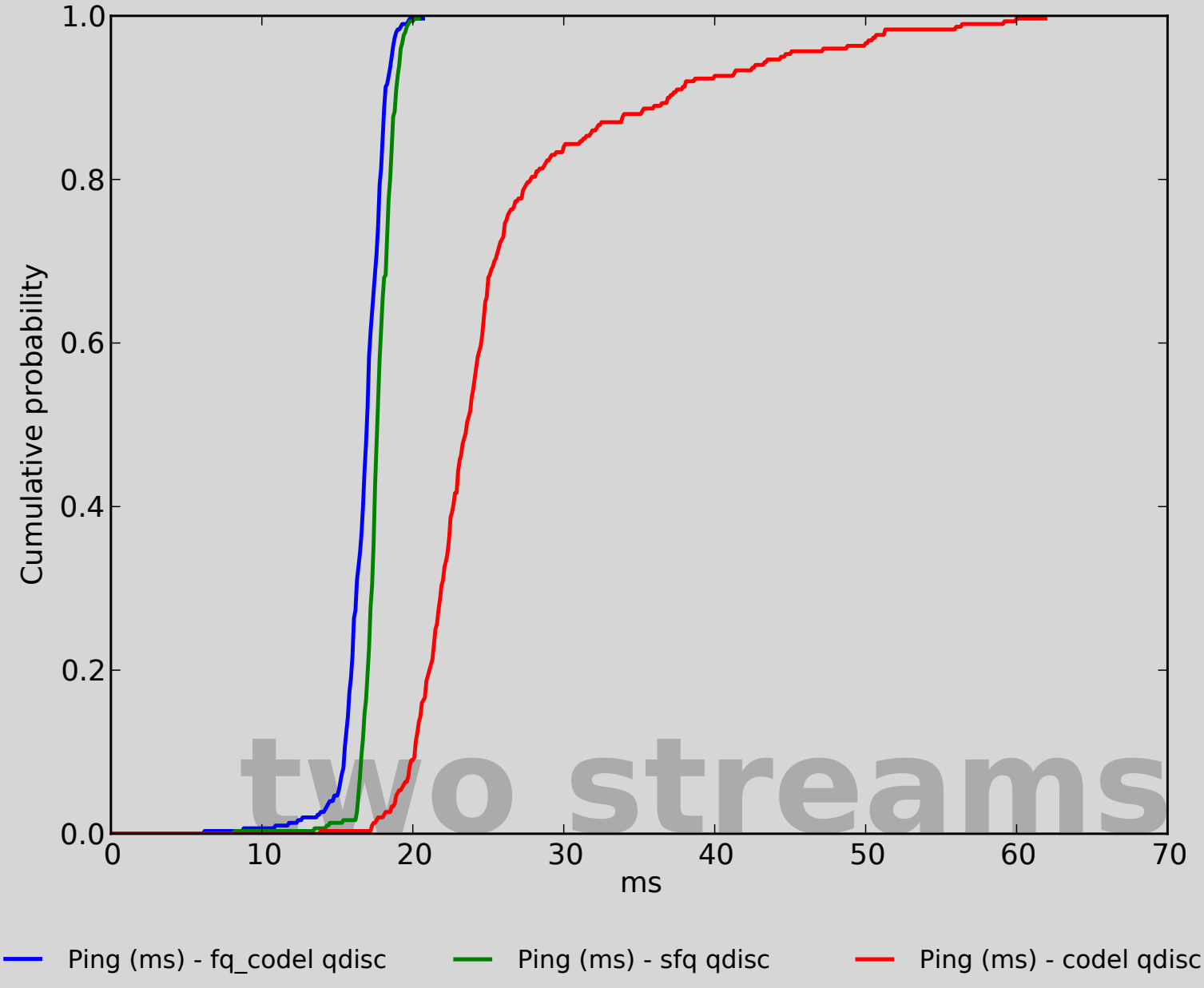
Two TCP streams + ping - `fq_codel`



Two TCP streams + ping - comparison



Two TCP streams + ping - CDF



The RRUL test

- Runs four concurrent TCP streams in each direction.
  - Each stream (optionally) has different diffserv marking.
- Simultaneously measures UDP and ICMP ping times.
- Supports IPv4 and IPv6.
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- The four streams pretty reliably loads any link to capacity.
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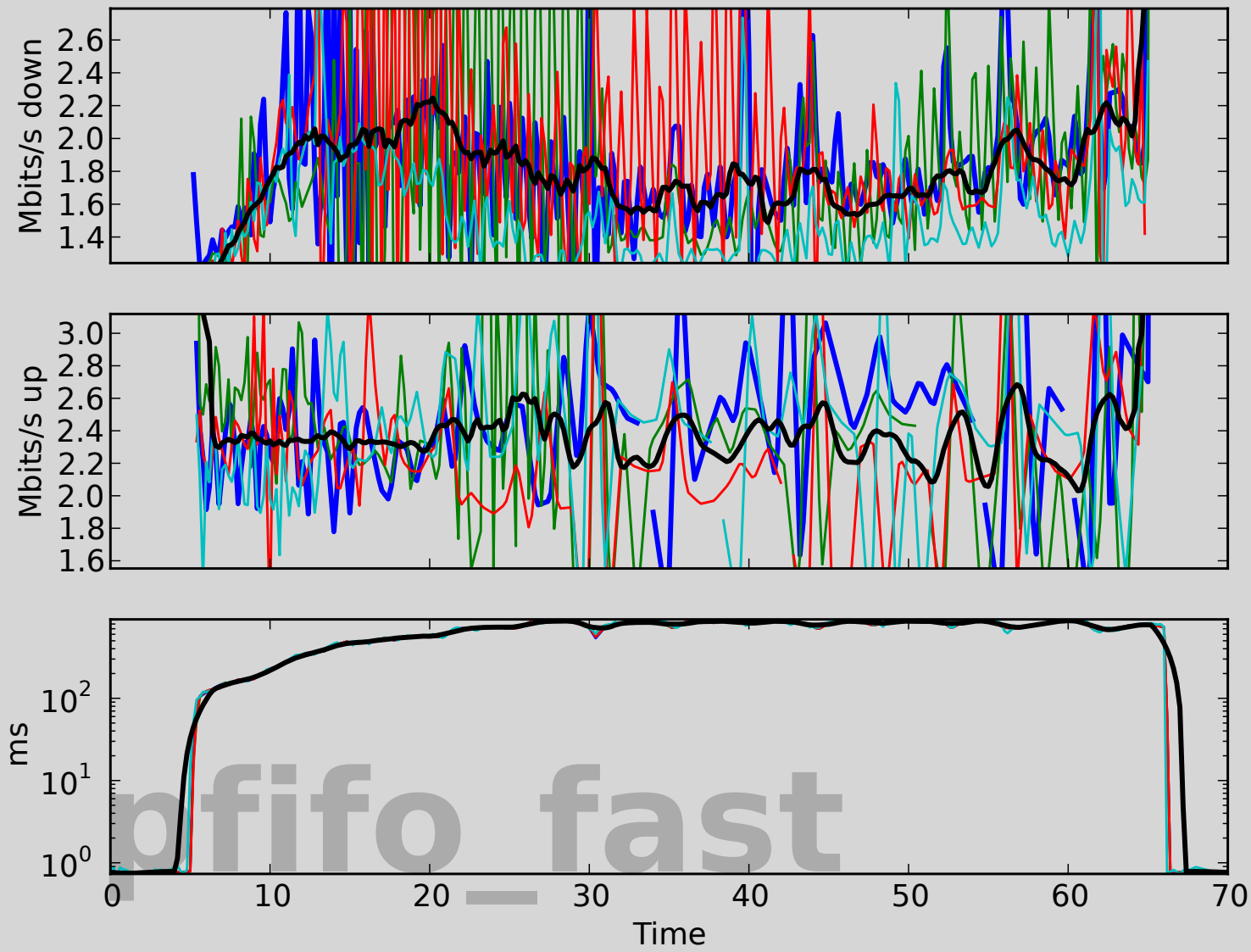
- Works well as a backdrop for testing other stuff.
  - The Chrome benchmark works well for websites.

RRUL test - pfifo_fast



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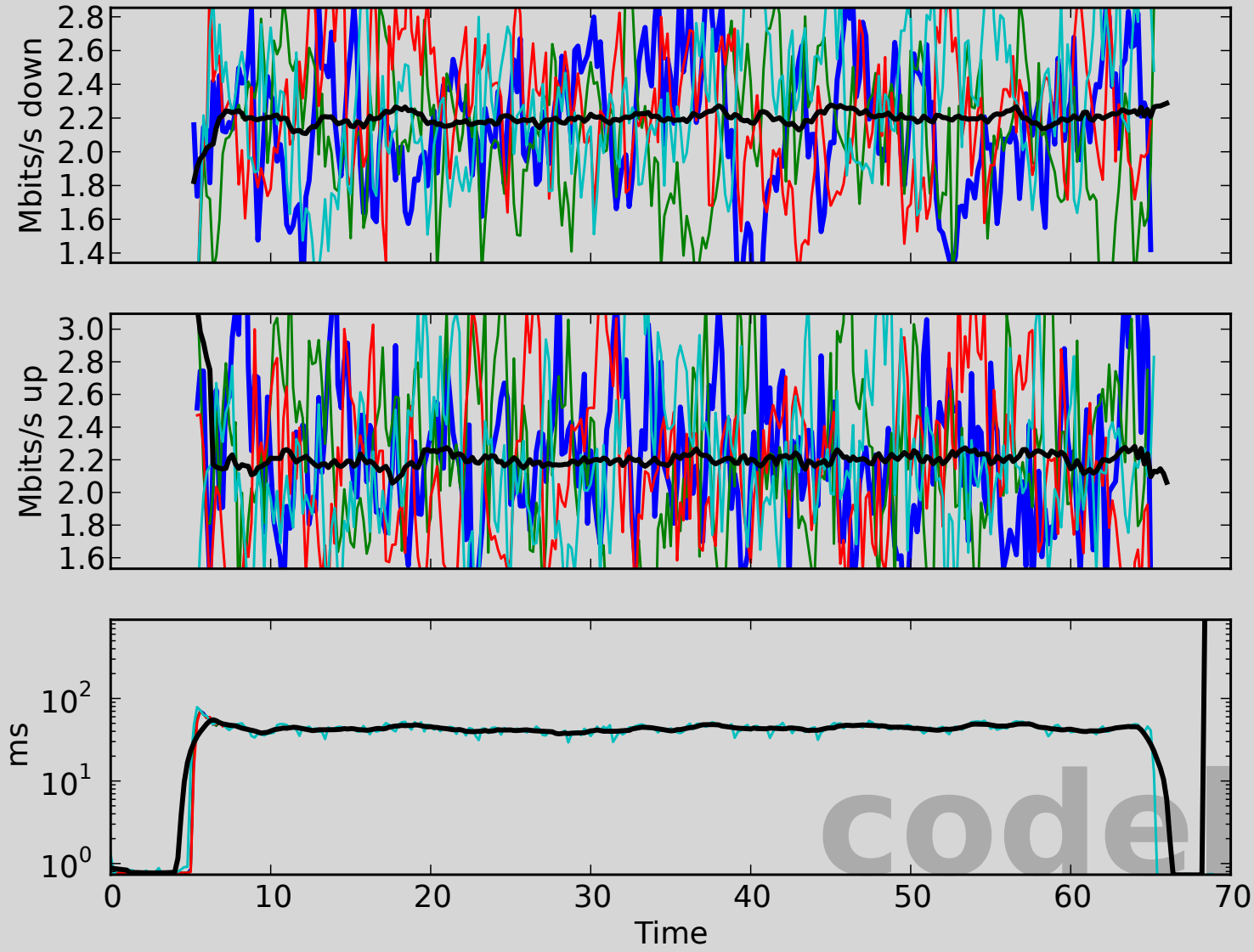

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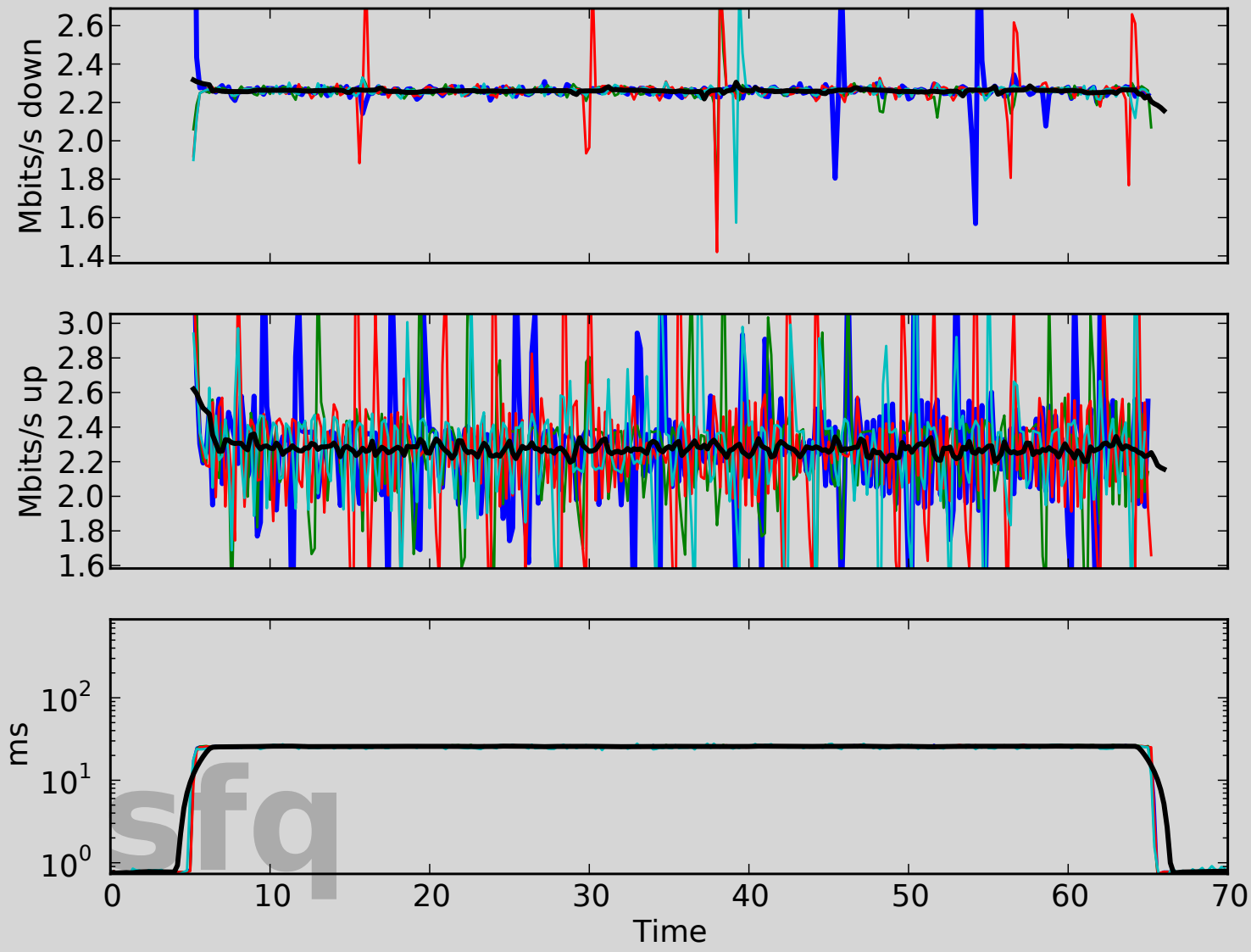

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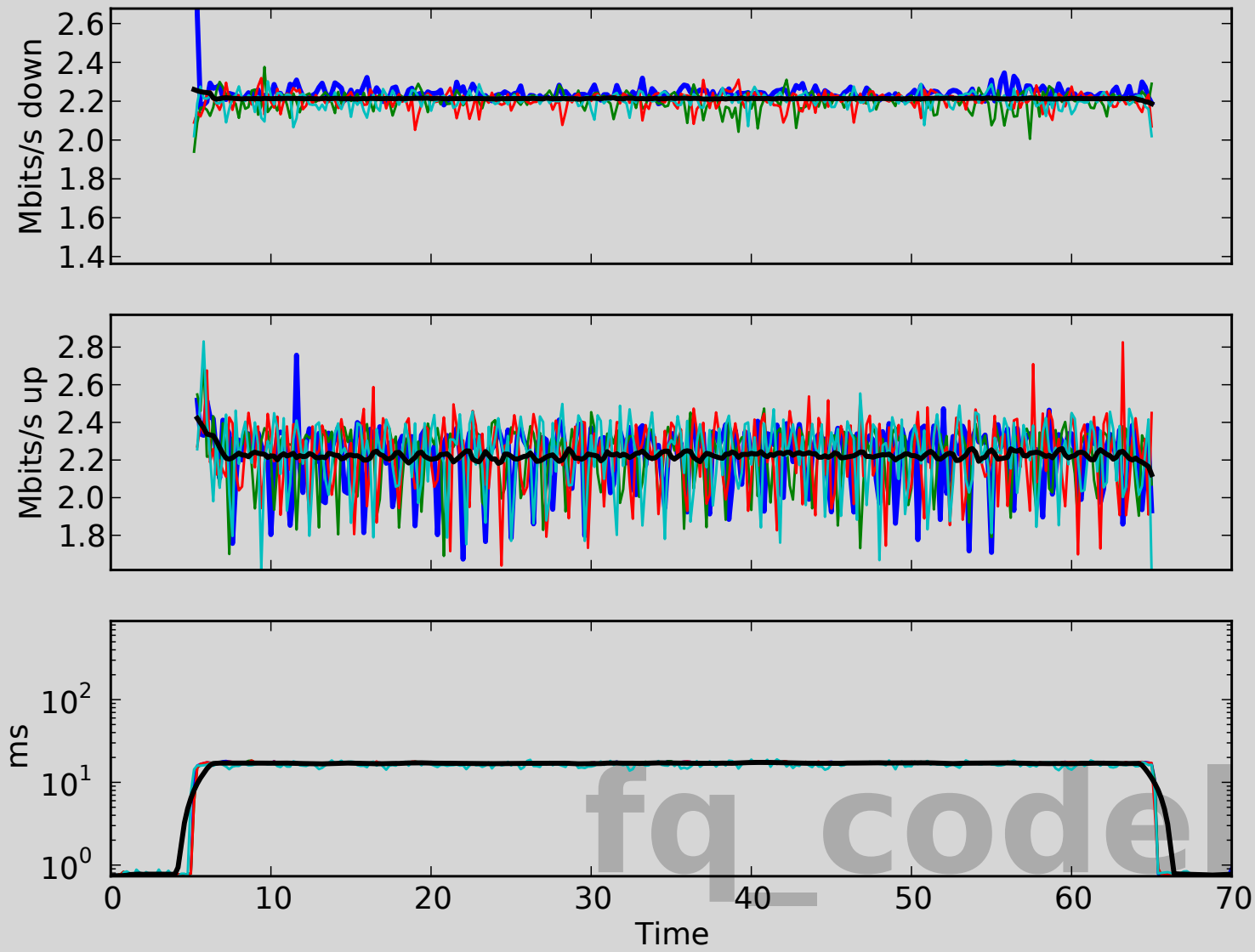

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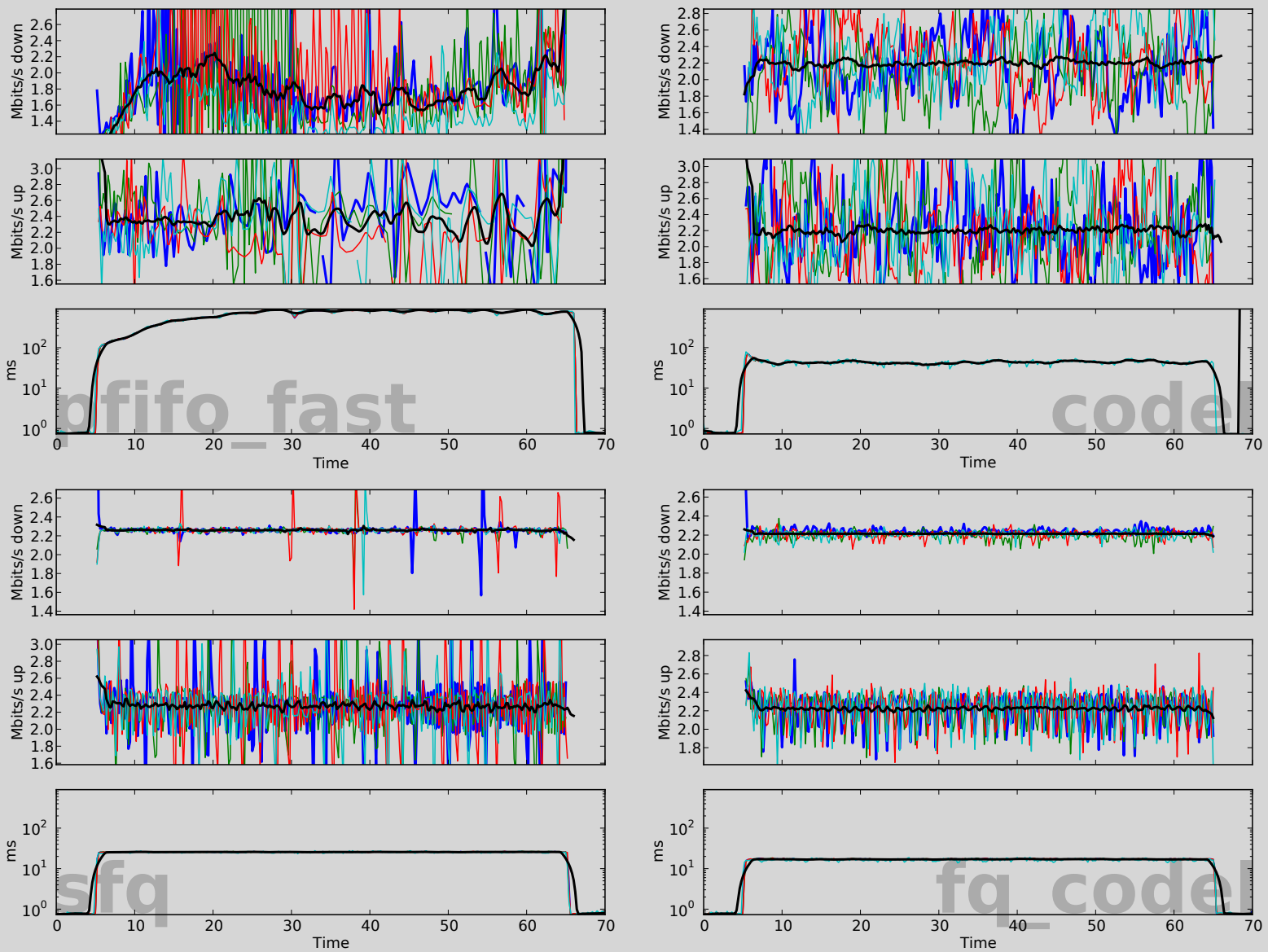

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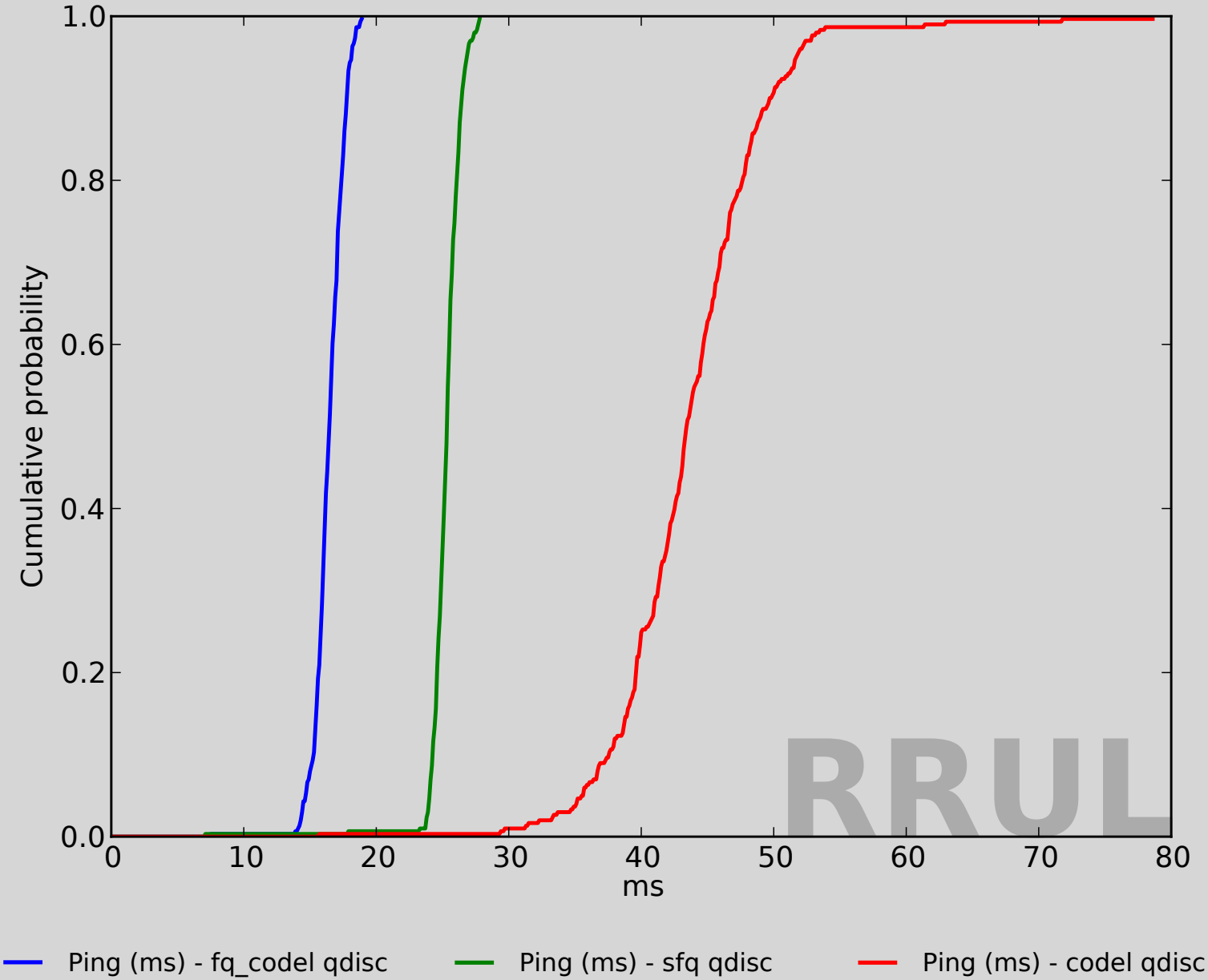
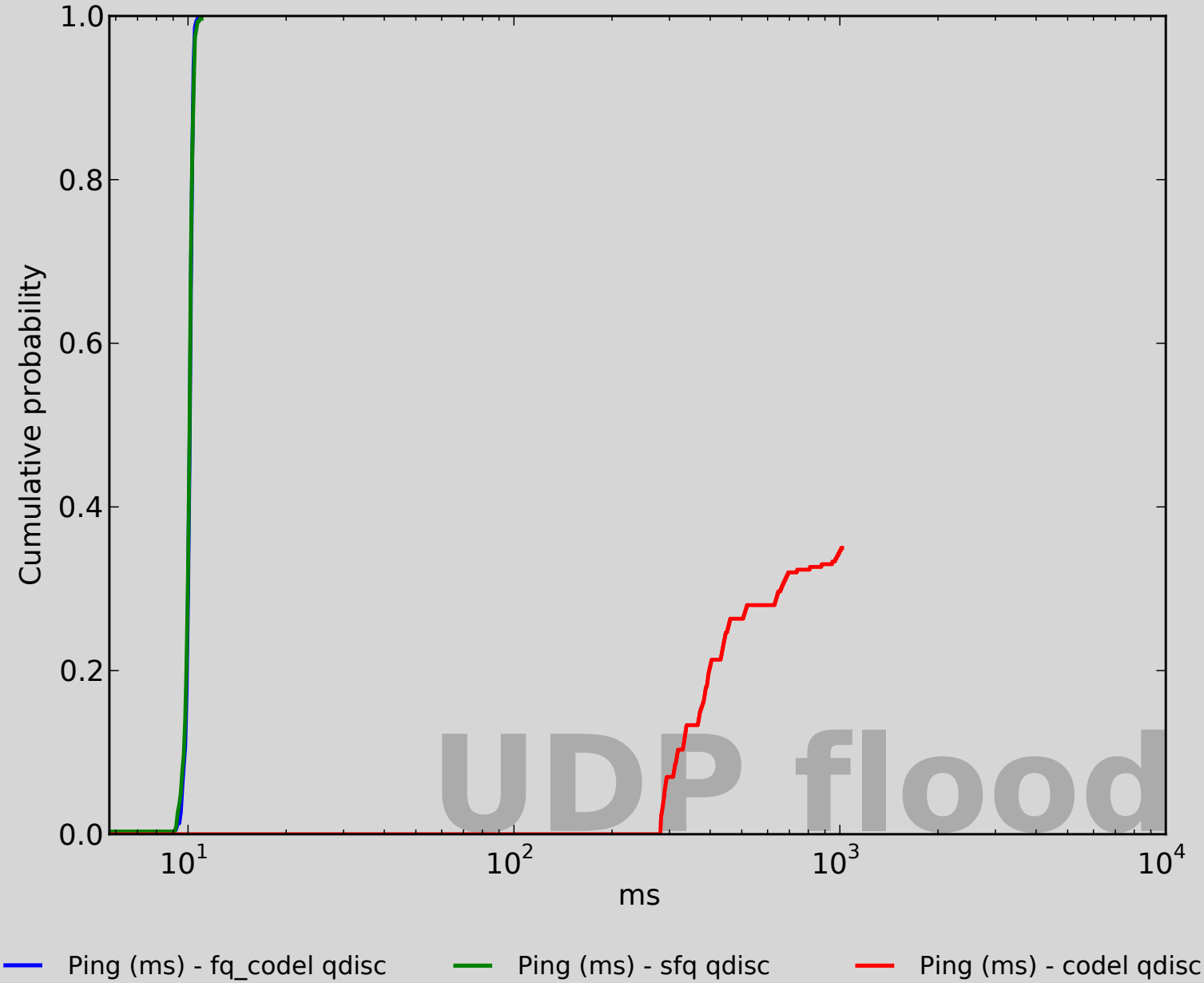


CDF UDP flood



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- Or use `netperf-wrapper` to automate tests!

The `netperf-wrapper` testing tool

- Python wrapper to benchmarking tools (mostly `netperf`).
- Runs concurrent tool instances, aggregates the results.
- Output and intermediate storage is JSON.
  - Exports to CSV.
- Graphing through python `matplotlib`.
- Tests specified through configuration files (in Python).
  - Common tests included (such as RRUL).
- Install: `pip install netperf-wrapper`. Netperf 2.6+.
  - Packages available for Debian/Ubuntu and Arch Linux.

Best configuration practices

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  - BQL defaults developed and tuned at 1Gbit/s+.
  - 1514 (ethernet MTU + header) works well up to $\simeq$10Mbit/s.
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- Make sure driver(s) are BQL-enabled.
  - BQL is Ethernet only, and not all drivers are updated.
  - Esp. many SOCs have drivers without BQL.

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  - Non-Ethernet drivers (DSL etc).
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  - (fq)CoDel doesn't know about buffers at lower levels.
- Beware the cheap switches – and the expensive ones
  - Pause frames and/or excess buffering.

References

- BQL: https://lwn.net/Articles/454390/
- netperf: http://www.netperf.org/netperf/
- netperf-wrapper: https://github.com/tohojo/netperf-wrapper
- Paper on experiments: http://akira.ruc.dk/~tohojo/bufferbloat/bufferbloat-paper.pdf
- RRUL test spec draft: https://github.com/dtaht/deBloat/blob/master/spec/rrule.doc
- Best practices: https://www.bufferbloat.net/projects/codel/wiki/Best_practices_for_benchmarking_Codel_and_FQ_Codel
- My email address: toke@toke.dk

Questions?

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