QUIC

Congestion Control and Loss Recovery

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QUIC CC is based on TCP CC

- Based on IETF RFCs and academic papers
  - Sections on ack ambiguity do not apply to QUIC
  - Delayed ack issues are corrected for by QUIC's ack
- QUIC embodies the spirit of the papers, but the details are different
- QUIC decouples when to transmit data from what to transmit

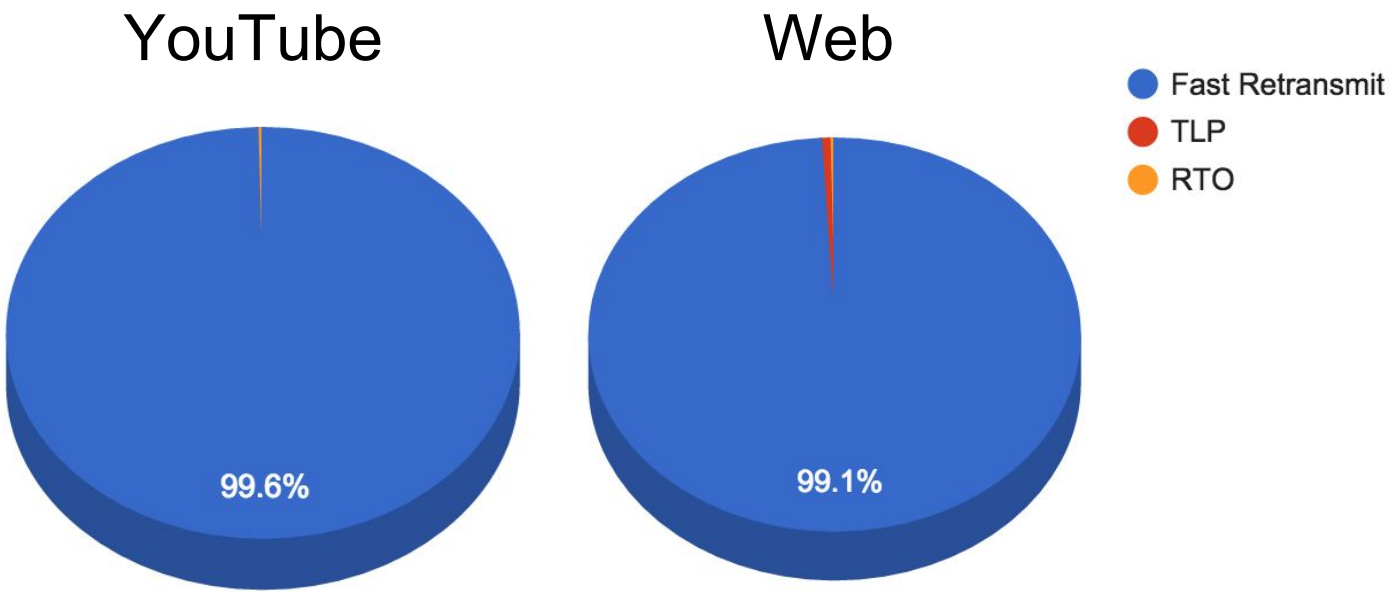
QUIC defaults come from Linux defaults

- TCP Cubic
- Fast Retransmit with a dupack threshold of 3
  - Threshold is FACK style
- RTO with a min of 200ms and a max RTO of 60s
- F-RTO
  - QUIC replaces undo with post-ack CWND reduction

Including all the new improvements

- TLP
  - Always 2 TLPs before RTO
- Early Retransmit with ¼ RTT timer
- PRR
- Pacing
  - Initial burst of 10 packets
  - Send at 2x BDP during slow start
  - Send at 1.25x BDP during congestion avoidance

Loss Recovery: QUIC today



How does QUIC's loss recovery work?

- Each packet has a monotonically increasing packet number
  - No ack ambiguity with retransmits
- Up to 256 NACK ranges (as opposed to SACK ranges)
- FACK with a 3 packet threshold
- Early Retransmit with timer
- Always sends 2 TLPs before the first RTO

QUIC makes constant progress

- Each new ack provides new unambiguous information
- Can exit timeout mode upon the first ack
- No SACK reneging
- Recovers from multiple lost retransmissions trivially

Continuous progress even with 50% retransmit rate

Experiments

Conducted at scale between Chrome and Google servers (including GGC)

Most experiments are enabled with tags in the COPT field of the CHLO.
See crypto_protocol.h in Chromium for a list of tags.

0-RTT's impact

- About 75% connections are 0-RTT connections
- Accounts for between 50 to 80% of the median latency improvements
- 0-RTT helps more when Chrome's pre-connect isn't able to predict the host
- No significant effect on other transport stats

Connection Pooling

- QUIC's connection pooling is equivalent to HTTP/2's
- Improves latency about 10% vs disabling it
- No latency metrics were worse
- Could be improved with better connection pooling via Alt-Svc

Packet Pacing

- Similar to Linux kernel's fq qdisc
- Pacing does
  - improve tail page load latency
  - reduce retransmits ~25%
- Pacing does not
  - change median page load latency
  - change YouTube QoE

IW10 vs IW32

- QUIC defaults to 32, similar to HTTP/2 default
- 30% of QUIC's "time to playback" gains for YouTube due to IW32
- IW10 had equal or slightly worse latency, even at the 95%
- IW10 decreased retransmit rate slightly
  - *IW10 without pacing had higher retransmit rate than IW32 with pacing*
- (Invoked with IW10 connection option. IW03, IW20, and IW50 also available)

Reno vs Cubic

- QUIC defaults to Cubic, similar to Linux
- Latency across all services is extremely similar between Reno and Cubic
- QoE is extremely similar between Reno and Cubic
- Retransmits are ~20% lower with Reno than Cubic
- (Reno available with the RENO connection option)

Why not default to Reno?

We're thinking about it...

1 vs 2 Connection Emulation

- QUIC defaults to 2-connection emulation
- 2-connection shows large improvements in YouTube QoE
- 1- vs 2-connection has a negligible effect on median page load latency
  - 2-connection shows slight improvement in tail latency
- Retransmits are 20% higher with 2-connection

Tail Loss Probe

- QUIC defaults to 2 TLPs before RTO
- Disabling TLP has no effect on median latency
- TLP improves 95% latency almost 1%
- TLP Improves YouTube rebuffer rate almost 1%
- Disabling TLP reduces retransmits 5%

Time based loss detection

- QUIC defaults to FACK with a fixed dupack threshold of 3
- Time-based loss detection waits ¼ RTT after the first NACK for the packet to be lost
- Shows no significant improvements vs FACK on user-facing networks

QUIC

IETF draft: draft-tsvwg-quic-loss-recovery-00

Google