The QUIC Transport Protocol: Design and Internet-Scale Deployment

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Google

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A QUIC history

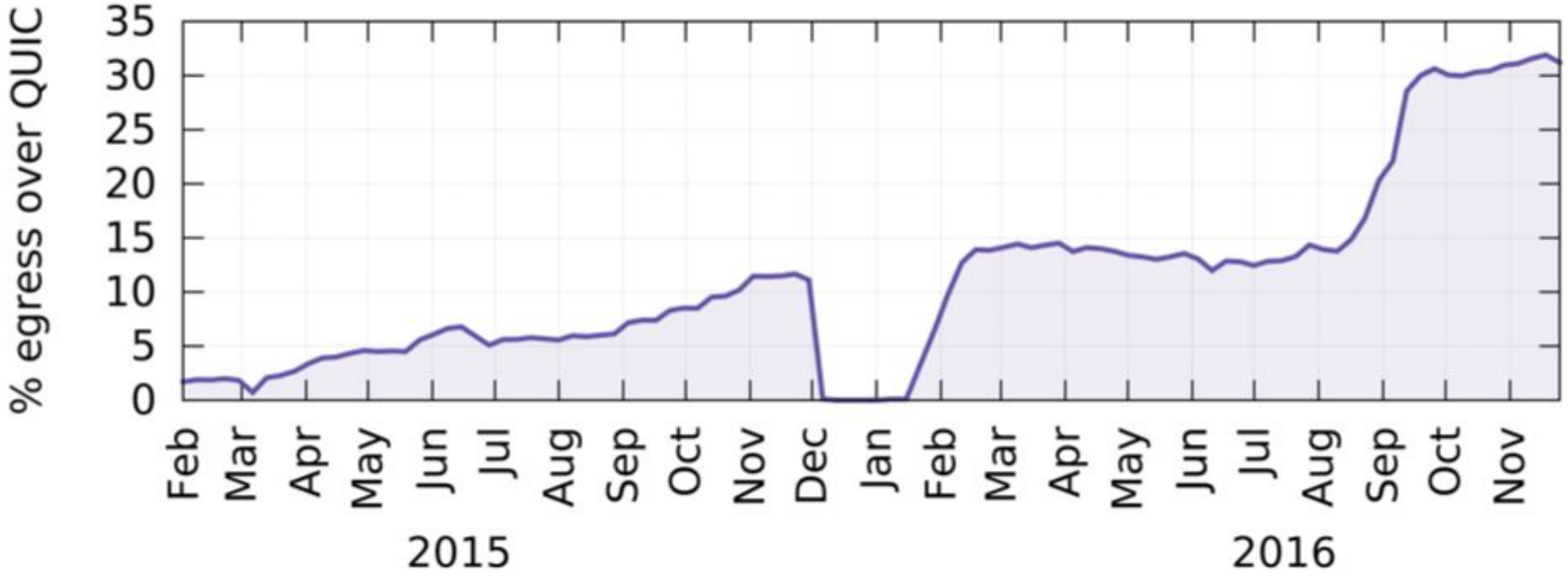
Protocol for HTTP transport, deployed at Google starting 2014

- Between Google services and Chrome / mobile apps
- Reduced page-load latency and video rebuffers
  - YouTube Video Rebuffers: 15 - 18%
  - Google Search Latency: 3.6 - 8%
- 35% of Google's traffic (7% of Internet)

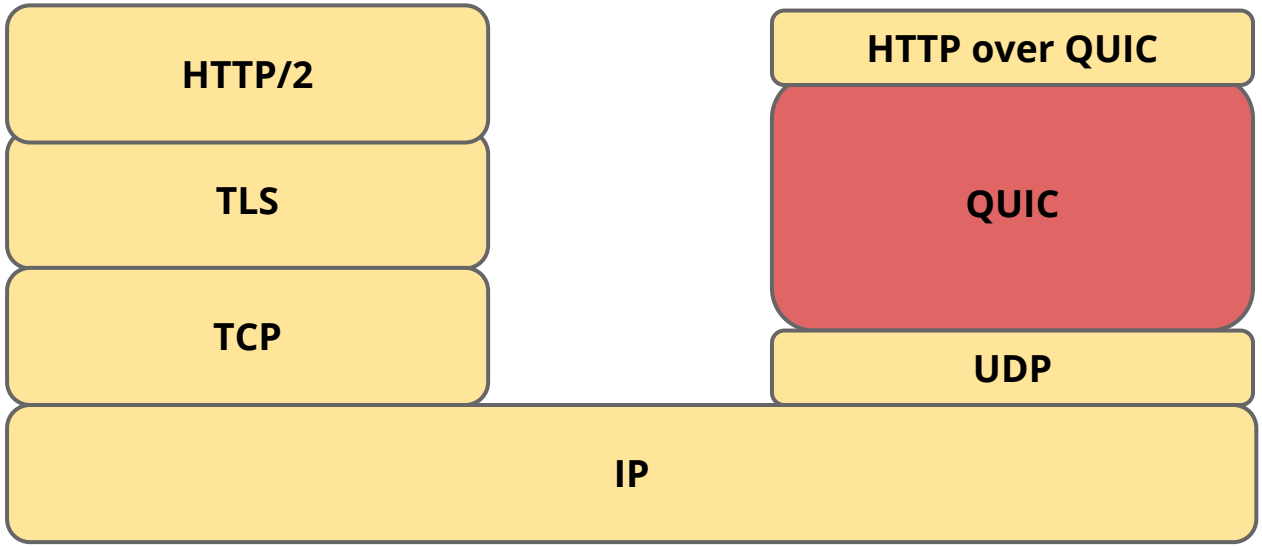
IETF QUIC working group formed in Oct 2016

- Modularize and standardize QUIC

Google's QUIC deployment



What are we talking about?



QUIC Design Aspirations

- Deployability and evolvability
- Low latency connection establishment
  - mostly 0-RTT, sometimes 1-RTT
- Multistreaming and per-stream flow control
- Better loss recovery and flexible congestion control
  - Richer signaling (unique packet number)
  - Better RTT estimates
- Resilience to NAT-rebinding

Metrics

- Latency
  - Search
  - Video Playback
- Video Rebuffer Rate
- Application-defined metrics
  - Matter to apps, drive adoption
  - Include non-network components

Search and Video Latency

		% latency reduction by percentile						
		Lower latency				Higher latency		
	Mean	1%	5%	10%	50%	90%	95%	99%
Search								
Desktop	8.0	0.4	1.3	1.4	1.5	5.8	10.3	16.7
Mobile	3.6	-0.6	-0.3	0.3	0.5	4.5	8.8	14.3
Video								
Desktop	8.0	1.2	3.1	3.3	4.6	8.4	9.0	10.6
Mobile	5.3	0.0	0.6	0.5	1.2	4.4	5.8	7.5

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Handshake Latency

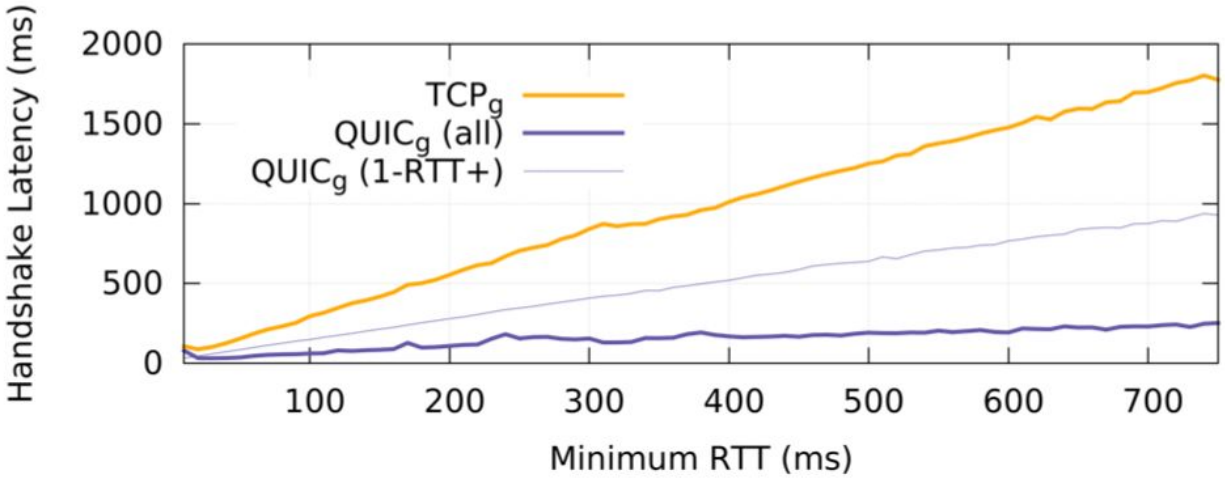
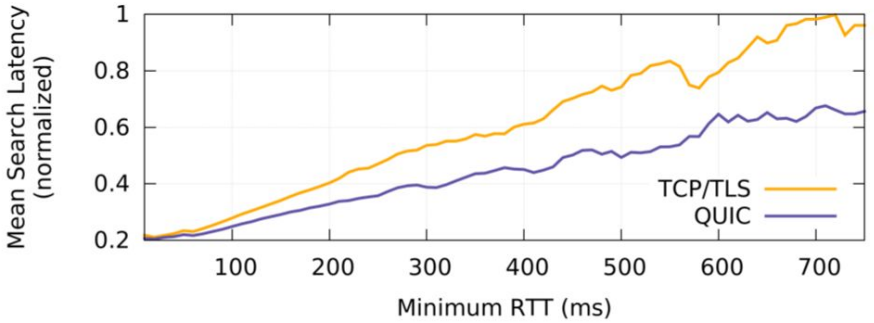


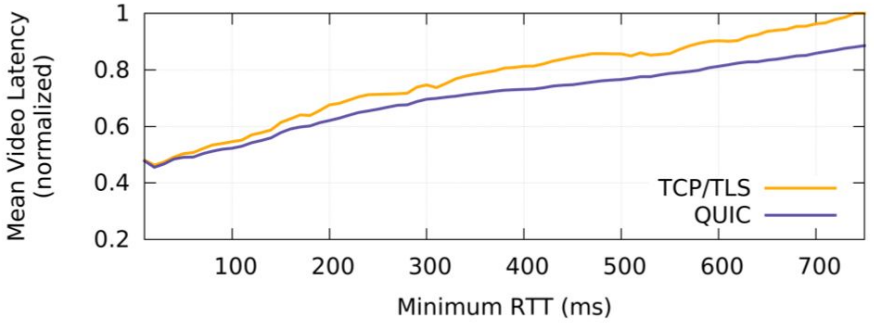
Figure 7: Comparison of handshake latency for $QUIC_g$ and TCP_g versus the minimum RTT of the connection. Solid lines indicate the mean handshake latency for all connections, including 0-RTT connections. The dashed line shows the handshake latency for only those $QUIC_g$ connections that did not achieve a 0-RTT handshake. Data shown is for Desktop connections, mobile connections look similar.

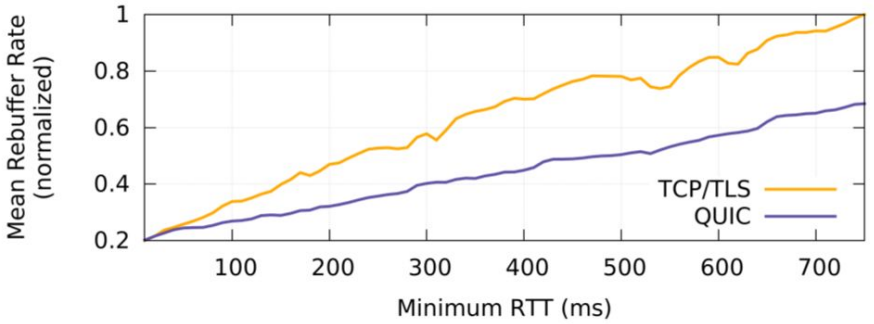
Video Rebuffer Rate

		% rebuffer rate reduction by percentile				
		Fewer rebuffers			More rebuffers	
	Mean	< 93%	93%	94 %	95%	99%
Desktop	18.0	*	100.0	70.4	60.0	18.5
Mobile	15.3	*	*	100.0	52.7	8.7

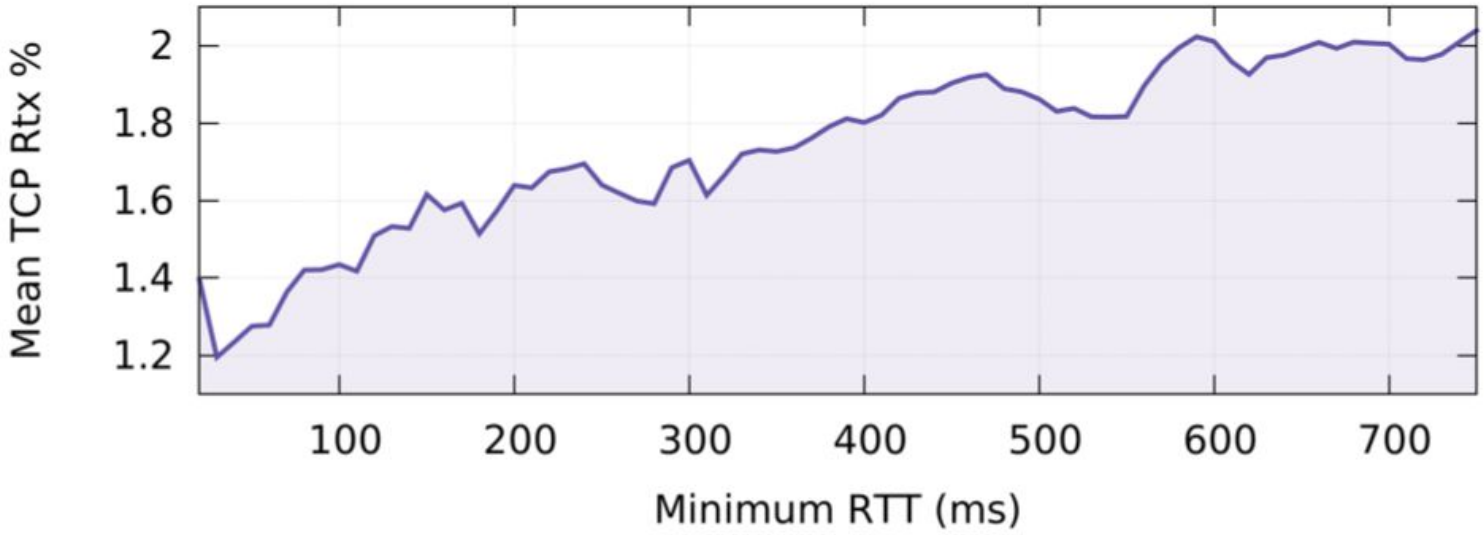
All metrics improve more as RTT increases ...





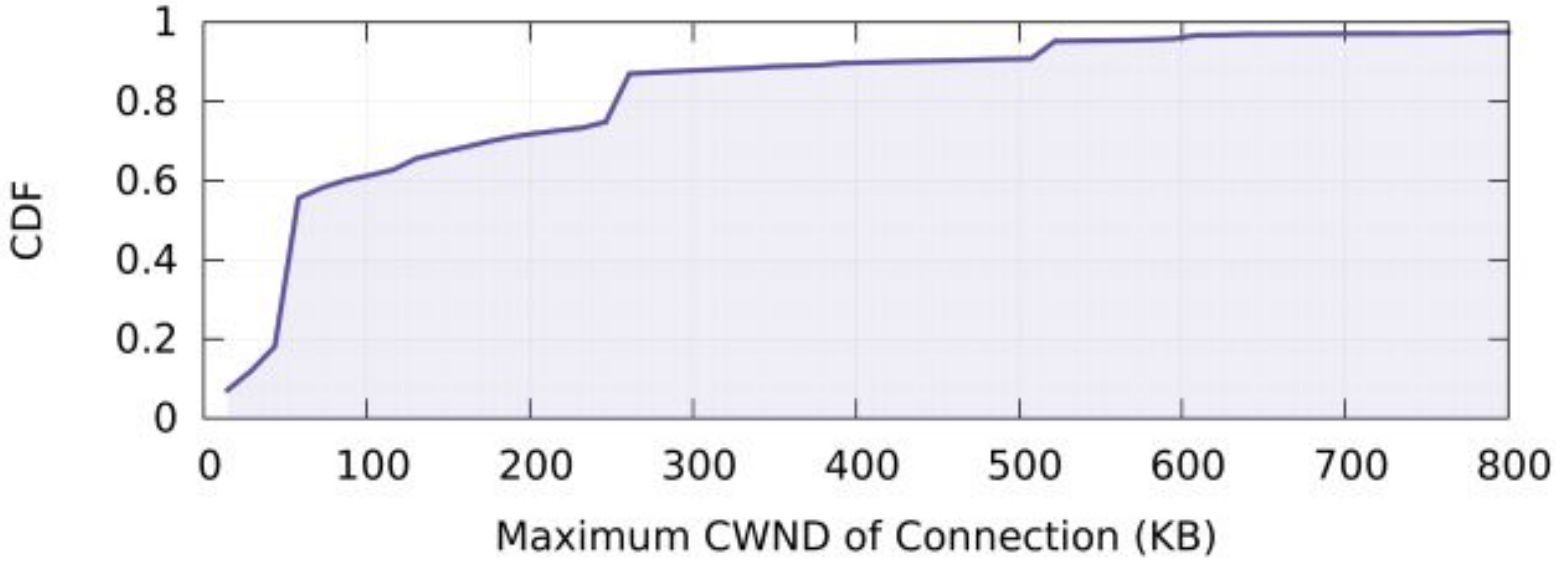


Network loss rate increases with RTT



TCP receive window limit

4.6% of connections have
server's max cwnd == client's max rwnd



QUIC improvement by country

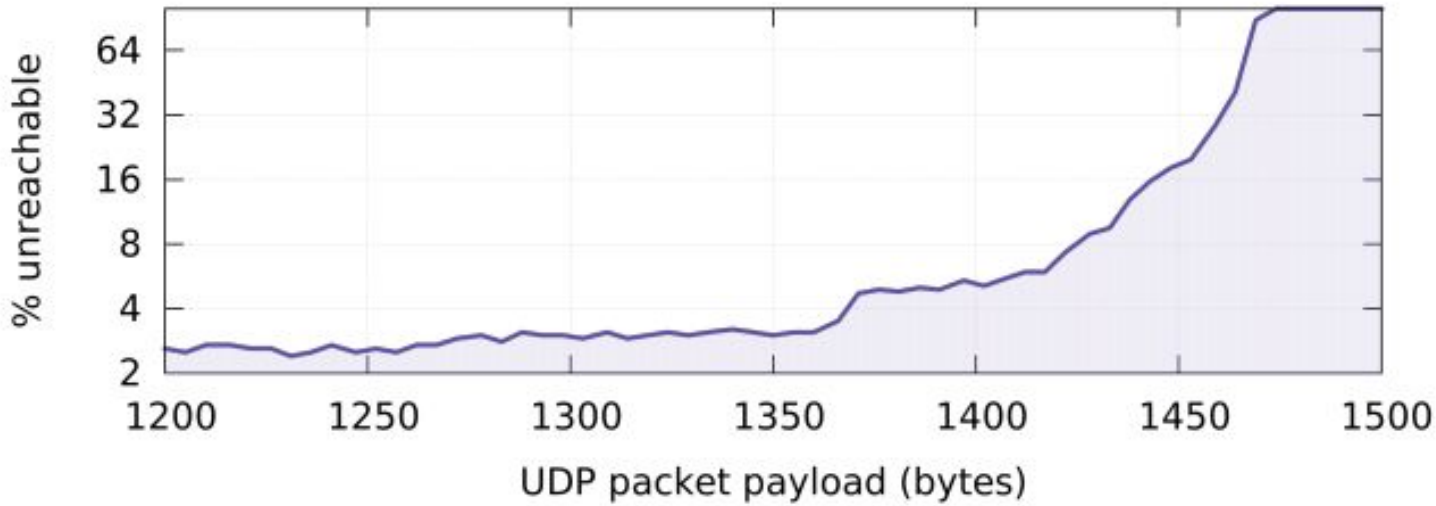
			% Reduction in Search Latency		% Reduction in Rebuffer Rate	
Country	Mean Min RTT (ms)	Mean TCP Rtx %	Desktop	Mobile	Desktop	Mobile
South Korea	38	1	1.3	1.1	0.0	10.1
USA	50	2	3.4	2.0	4.1	12.9
India	188	8	13.2	5.5	22.1	20.2

Experiments and Experiences: UDP Blockage

- QUIC successfully used: 95.3% of clients
- Blocked (or packet size too large): 4.4%
- QUIC performs poorly: 0.3%
  - Networks that rate limit UDP
  - Manually turn QUIC off for such ASes

Experiments and Experiences: Packet Size Considerations

- UDP packet train experiment, send and echo packets
- Measure reachability from Chrome users to Google servers



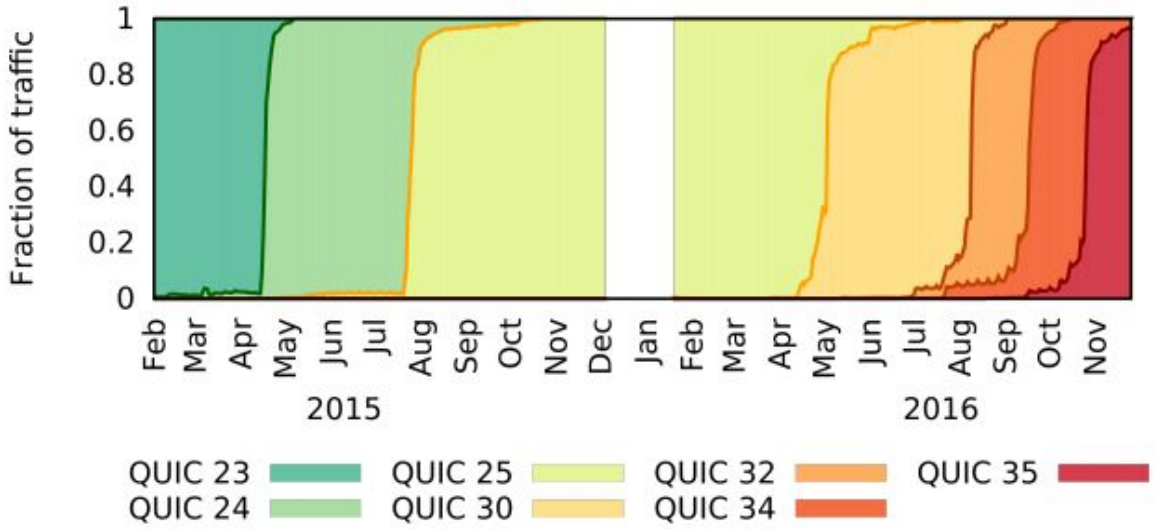
Experiments and Experiences: FEC in QUIC

- Simple XOR-based FEC in QUIC
  - 1 FEC packet per protected group
  - Timing of FEC packet and size of group controllable

- Conclusion: Benefits not worth the pain
  - Multiple packet losses within RTT common
  - FEC implementation extremely invasive
  - Gains really at tail, where aggressive TLP wins

Experiments and Experiences: Userspace development

- Better practices and tools than kernel
- Better integration with tracing and logging infrastructure



Experiments and Experiences: Network Ossification

- Middlebox ossification
  - Vendor ossified *first byte* of QUIC packets (flags byte)
  - … since it seemed to be the same on all QUIC packets
  - Broke QUIC deployment when a flag was flipped

  Encryption is the only protection against network ossification

- Userspace development
  - Has better practices and tools than kernel
  - Better integration with tracing and logging infrastructure