QUIC(k) Enough in the Long Run?
Sustained Throughput Performance of QUIC Implementations

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Motivation

- "QUIC is a secure general-purpose transport protocol." [RFC9000]

- Our research indicated slow throughput performance: A QUIC-based prototype achieved ~200 Mbit/s on a 10 Gbit/s capable testbed...

- Related work
  - Primarily focused on latencies and flow completion times
  - Only few prior evaluations on sustained throughput in high bandwidth environments
Evaluation Setup

Setup Sender, SW-Switch, Receiver:
- CPU: Intel Xeon W-2145, 3.7–4.5 GHz, 8 Cores
- RAM: 128 GB (4x 32 GB DDR4 with 2666 MT/s)
- NIC: Intel X550-T2 (10 Gbit/s)
- OS: Linux Ubuntu 22.04.1 LTS, Kernel 5.15.0-56

— Emulation of Delay, Bandwidth, Loss
Evaluated Implementations

Six popular QUIC implementations with traffic generators (perf clients) available
- lsquic (Litespeed)
- msquic (Microsoft)
- mvfst (Facebook)
- s2n-quic (Amazon)
- picoquic
- quinn

TCP and (pure) UDP as comparison
- iperf3
- netperf

(For all TCP and QUIC traffic: Cubic as congestion control algorithm)
Results: Sustained Throughput

Average throughput of one single flow (10 runs, each 30s)

UDP 9.74
Results: Sustained Throughput

Average throughput [Gbit/s]

UDP
9.74

netperf
9.54

iperf3
9.49

TCP

Average throughput of one single flow (10 runs, each 30s)
Results: Sustained Throughput

Average Throughput [Gbit/s]

- UDP: 9.74
- netperf TCP: 9.54
- iperf3 TCP: 9.49
- msquic quinn: 5.81
- lsquic quinn: 4.06
- mvfst: 2.40
- picoquic: 2.68
- s2n-quic: 4.04

Average throughput of one single flow (10 runs, each 30s)
Results: Sustained Throughput

UDP data path through the Linux Kernel is no bottleneck for QUIC.
TCP* significantly outperforms QUIC implementations (from 16.1 % up to 297.5 %)

*TCP limited by testbed – Single TCP flow can achieve even 40+ Gbit/s [2]

UDP data path through the Linux Kernel is no bottleneck for QUIC

Results: Sustained Throughput

Average throughput of one single flow (10 runs, each 30s)
Potential Reasons for Limitations

*msquic*

Limited by single core performance (no multi-threading)
Potential Reasons for Limitations

**msquic**

Limited by single core performance (no multi-threading)

**lsquic**

Scheduling between CPU cores degrades throughput
Potential Reasons for Limitations

Inefficient Usage of CPU Resources

- `msquic`: Limited by single core performance (no multi-threading)
- `lsquic`: Scheduling between CPU cores degrades throughput
Impact of Cryptography

➔ QUIC's performance gap: More than overhead by cryptography
Evolution of QUIC Throughput Performance

- QUIC Implementations already getting quicker

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<tr>
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<tbody>
<tr>
<td>Picoquic</td>
<td>489 Mbit/s</td>
<td>2.68 Gbit/s</td>
<td>5.48x</td>
</tr>
<tr>
<td>Mvfst</td>
<td>325 Mbit/s</td>
<td>2.40 Gbit/s</td>
<td>7.38x</td>
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Throughput Comparison with [3] from 2020
Further Issues

Packet Loss

→ QUIC implementations stronger affected by packet losses than TCP

Packet Reordering

→ mvfst, quinn, lsquic, and s2n-quic misinterpret reordered packets as losses
Conclusion

- Current QUIC implementations: Not a up to par with TCP regarding sustained throughput rates
  - QUIC's performance gap: More than overhead by cryptography
  - Inefficient usage of CPU resources

- Possible solutions
  - Better usage of multiple CPU cores
  - Avoid scheduling between CPU cores
  - Offloading to (optimized) Kernel functions
References


ACK Ratios

![Diagram showing ACK Ratios for different protocols]

- Isquic: 23.46
- Msquic: 72.18
- Mvfst: 20.02
- Picoquic: 104.34
- Quinn: 49.71
- S2n-quic: 23.27
ACK Ratios

→ ACK Ratio seemingly not correlated with throughput performance
Impact of Offloading

→ Offloading can improve performance