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

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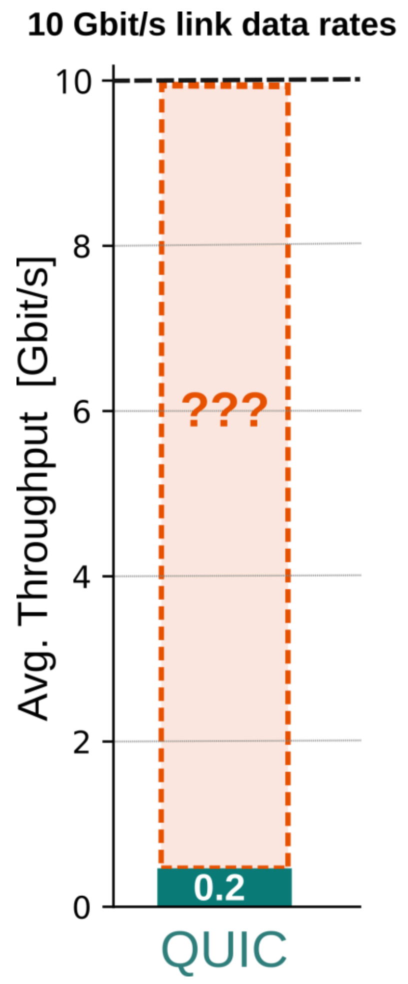
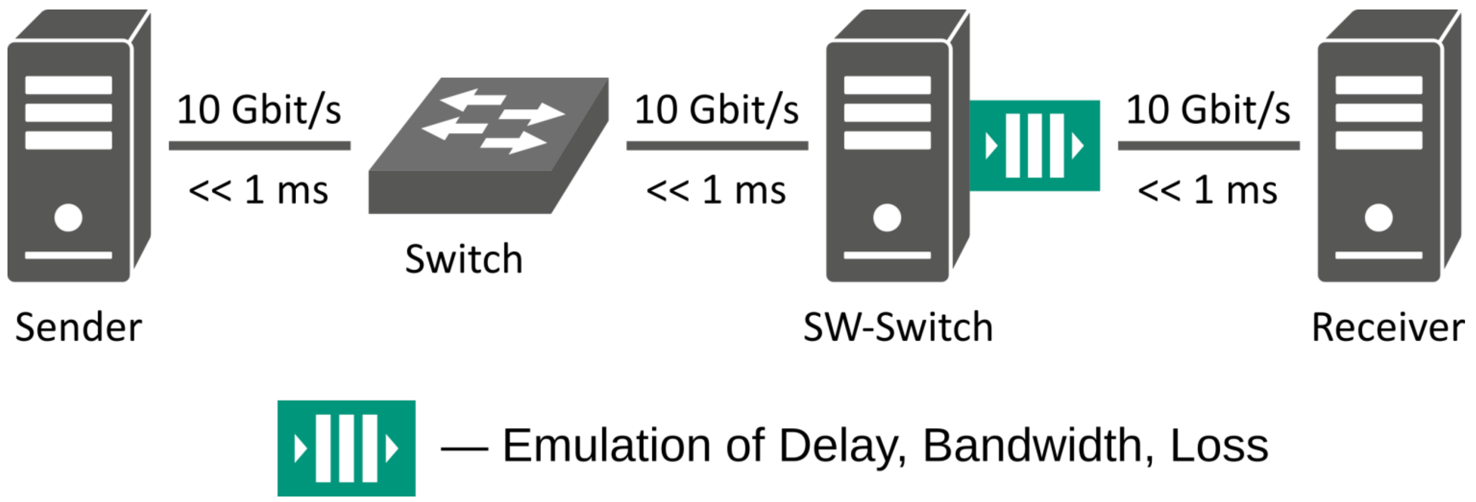
Motivation

- "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

Evaluated Implementations

Karlsruhe Institute of Technology

Six popular QUIC implementations
with traffic generators (perf clients) available

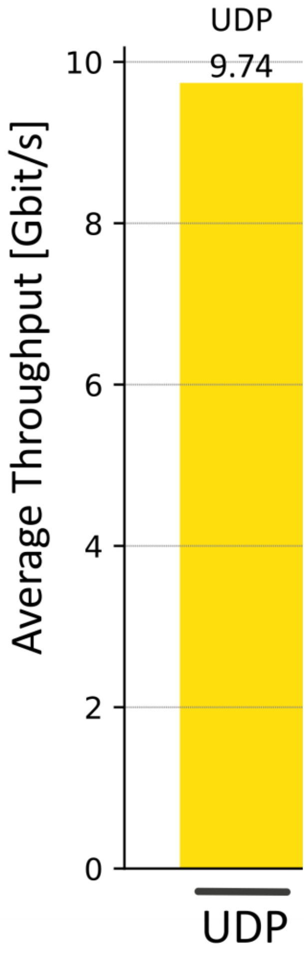
- lsquic (Litespeed)
- msquic (Microsoft)
- mvfst (Facebook)
- s2n-quic (Amazon)
- picoquic
- quinn

TCP and (pure) UDP as comparison

- iperf3
- netperf

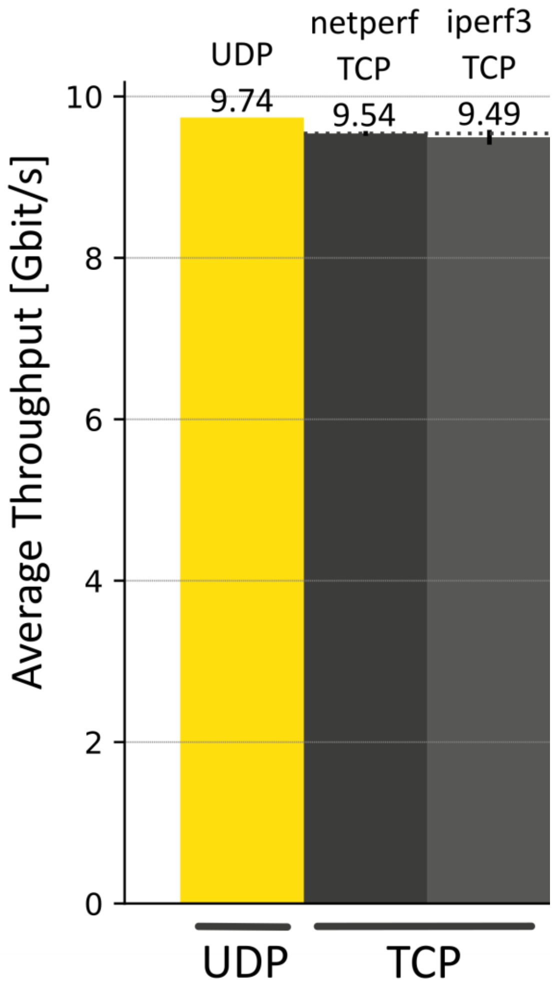
(For all TCP and QUIC traffic: Cubic as congestion control algorithm)

Results: Sustained Throughput



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

Results: Sustained Throughput



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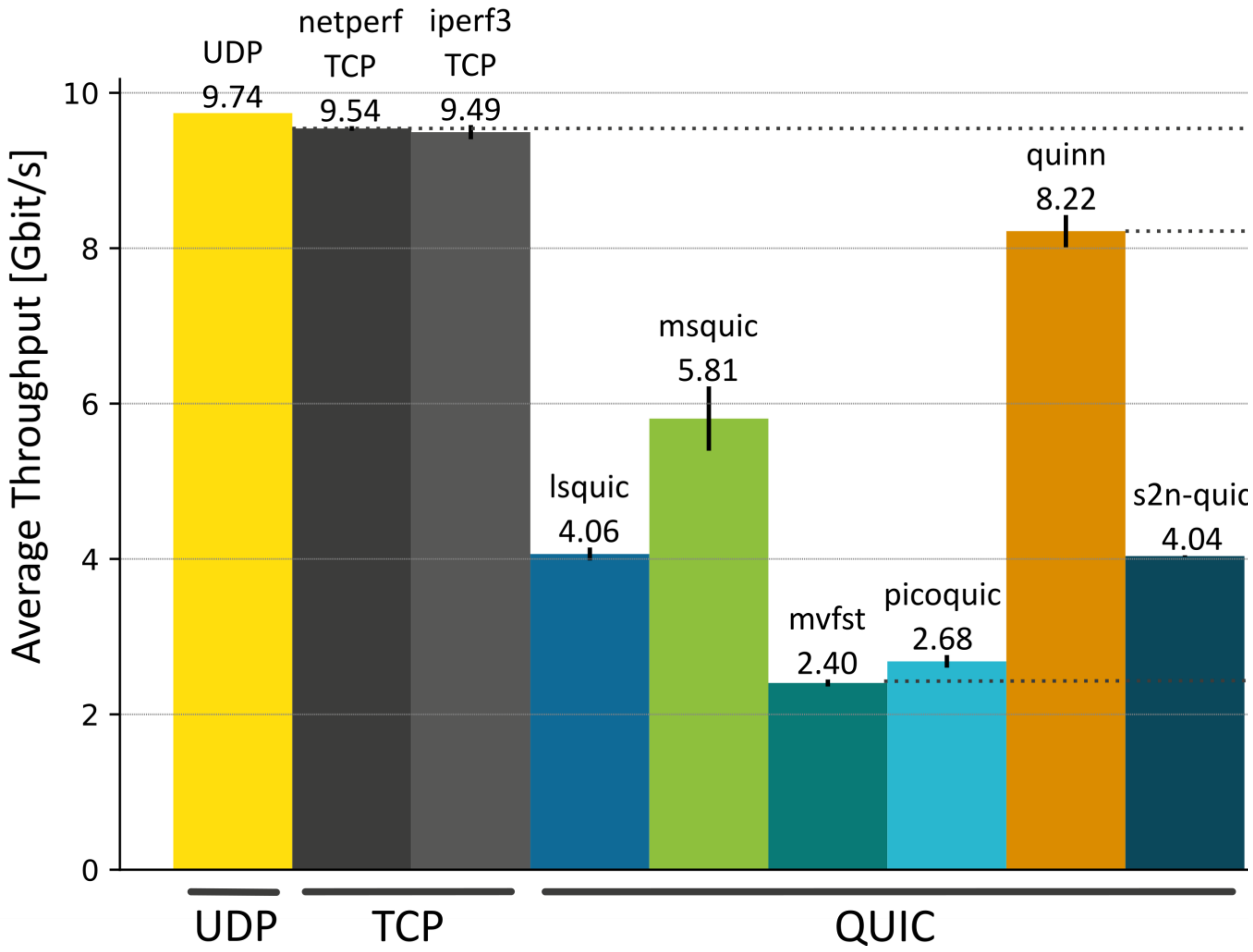

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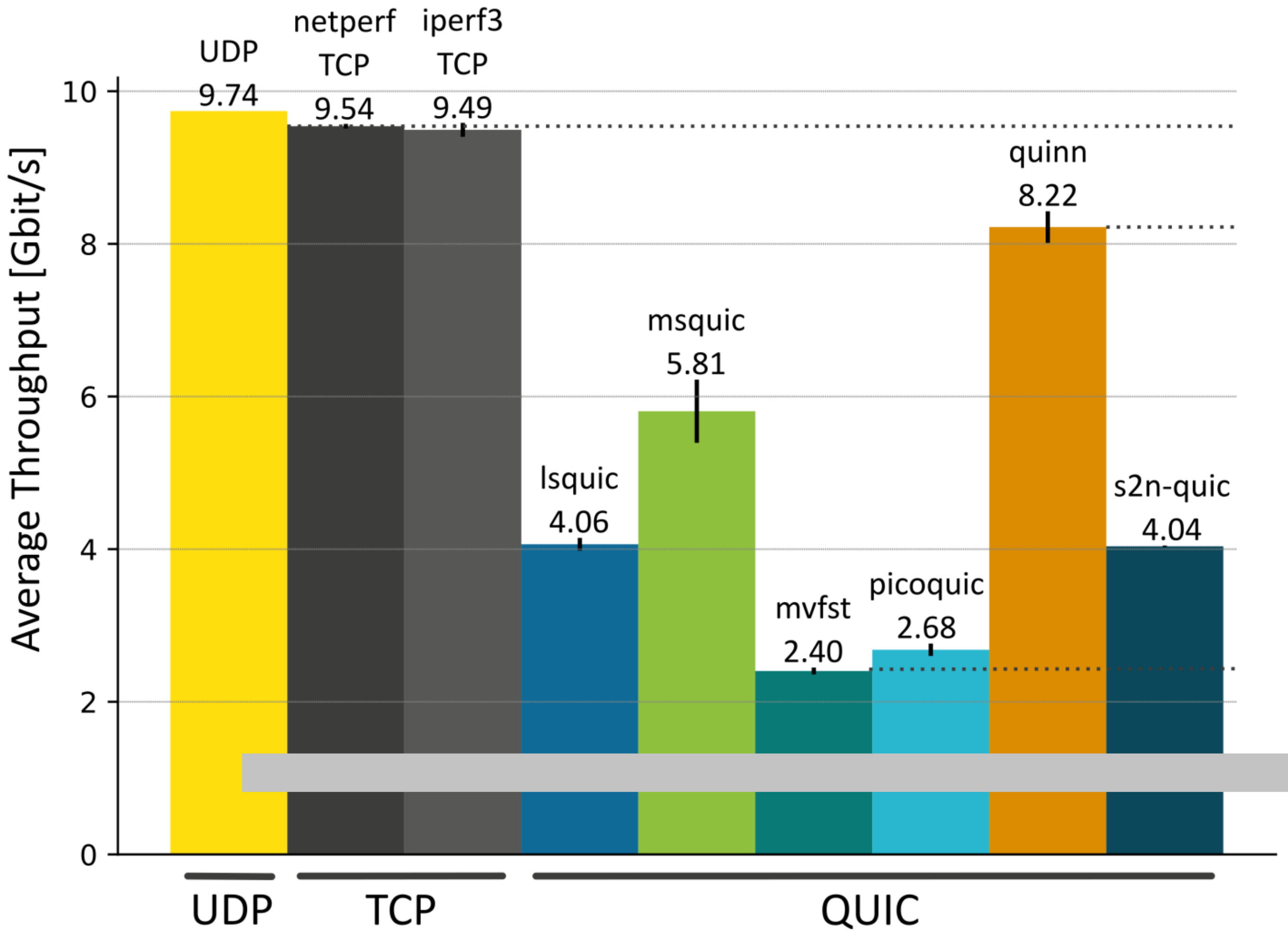
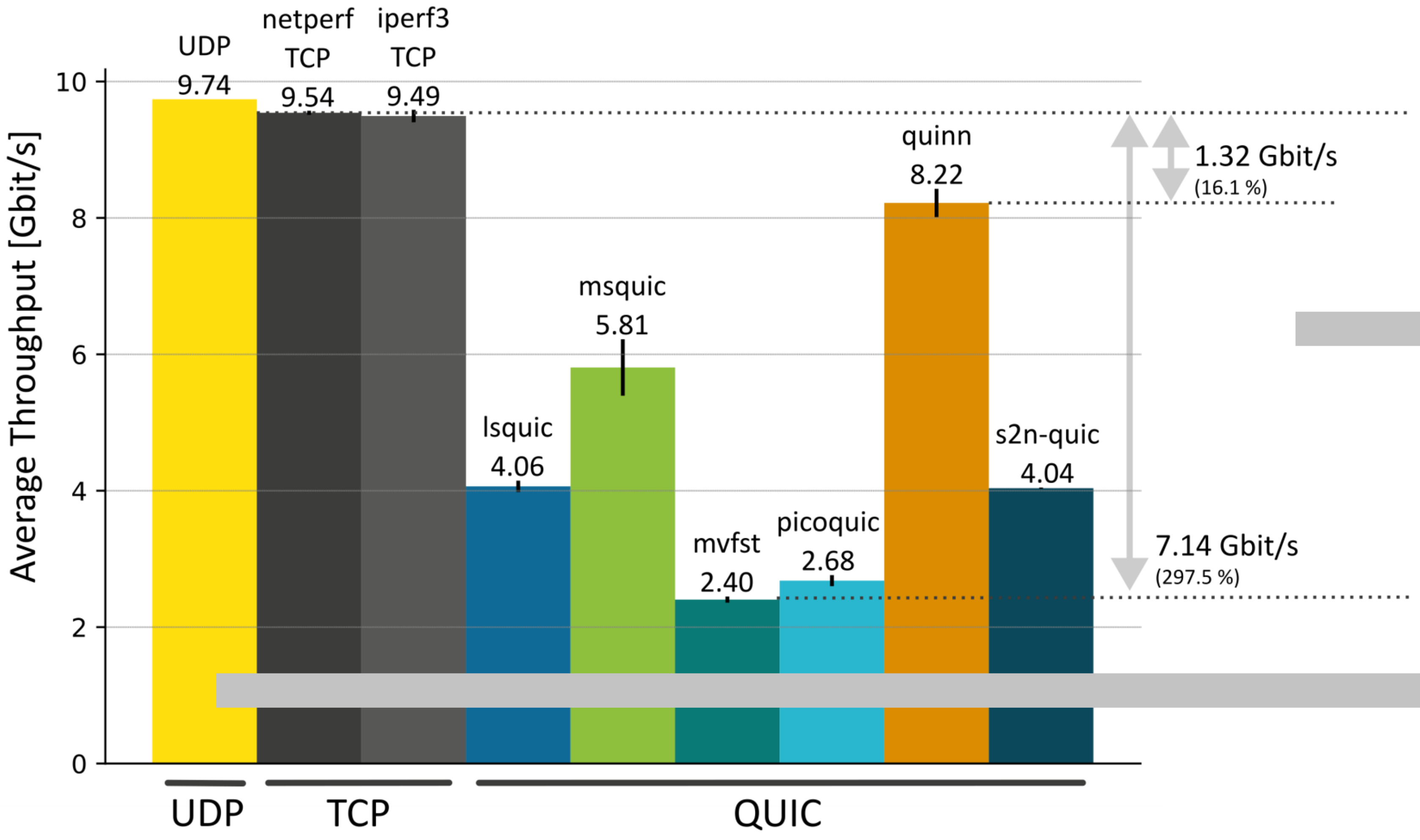
Results: Sustained Throughput



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

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

Results: Sustained Throughput



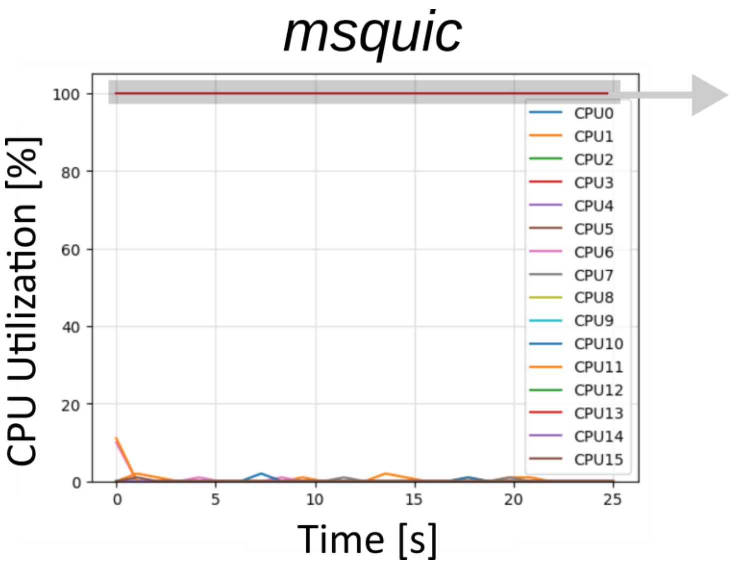
Average throughput of one single flow (10 runs, each 30s)

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

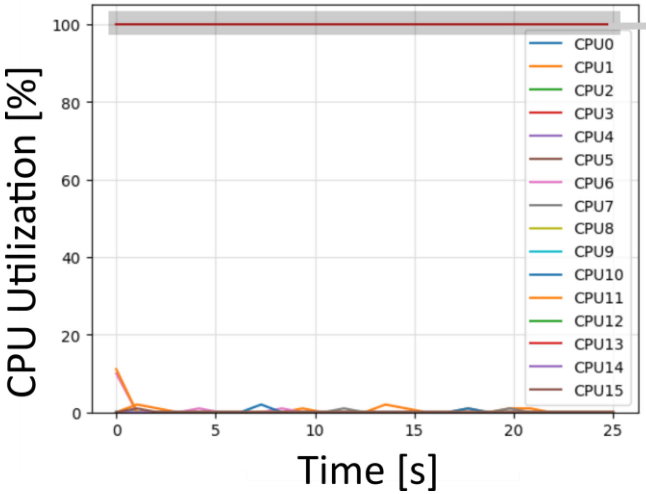
Potential Reasons for Limitations



Limited by single core performance (no multi-threading)

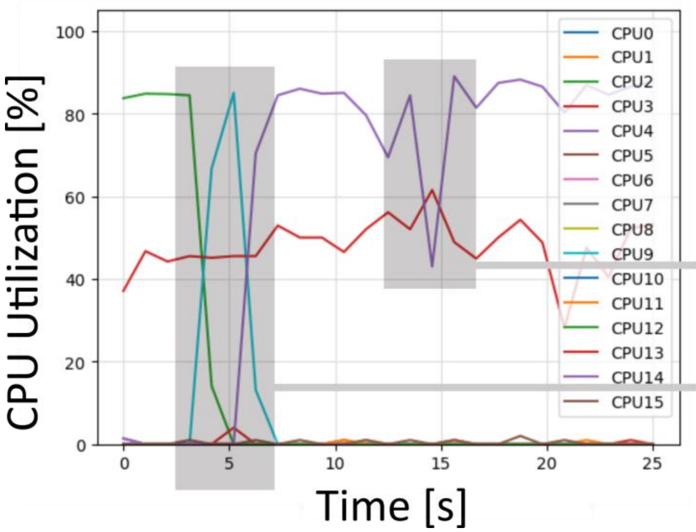
Potential Reasons for Limitations

msquic



Limited by single core performance (no multi-threading)

lsquic



Scheduling between CPU cores degrades throughput

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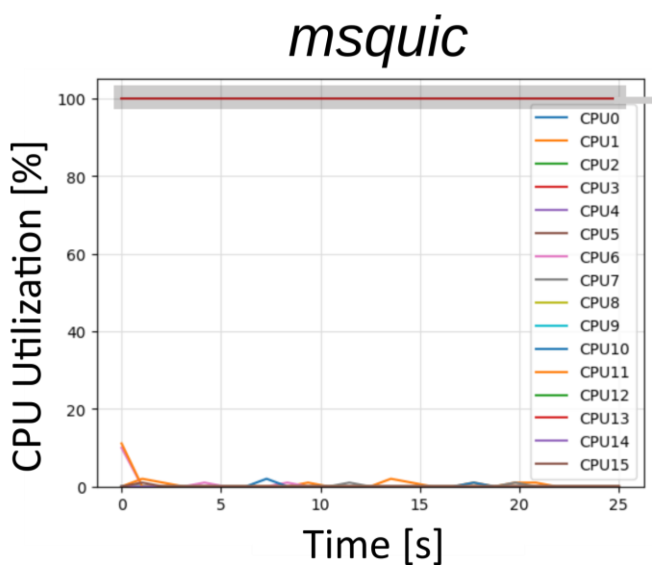

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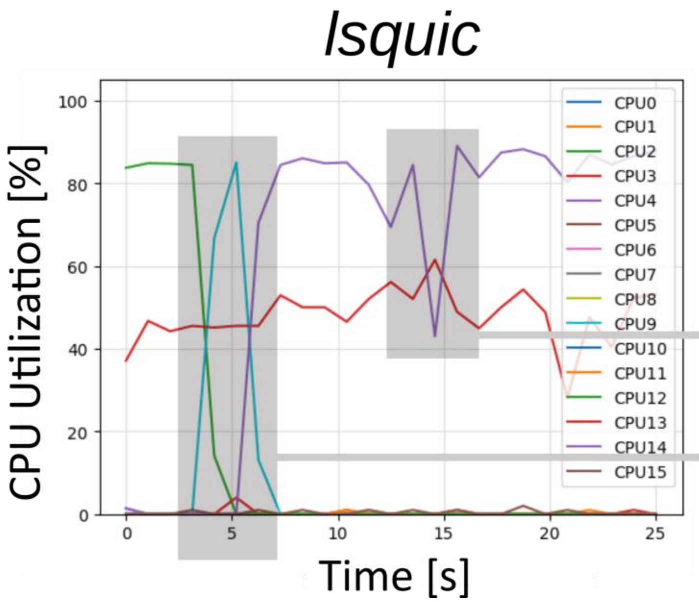
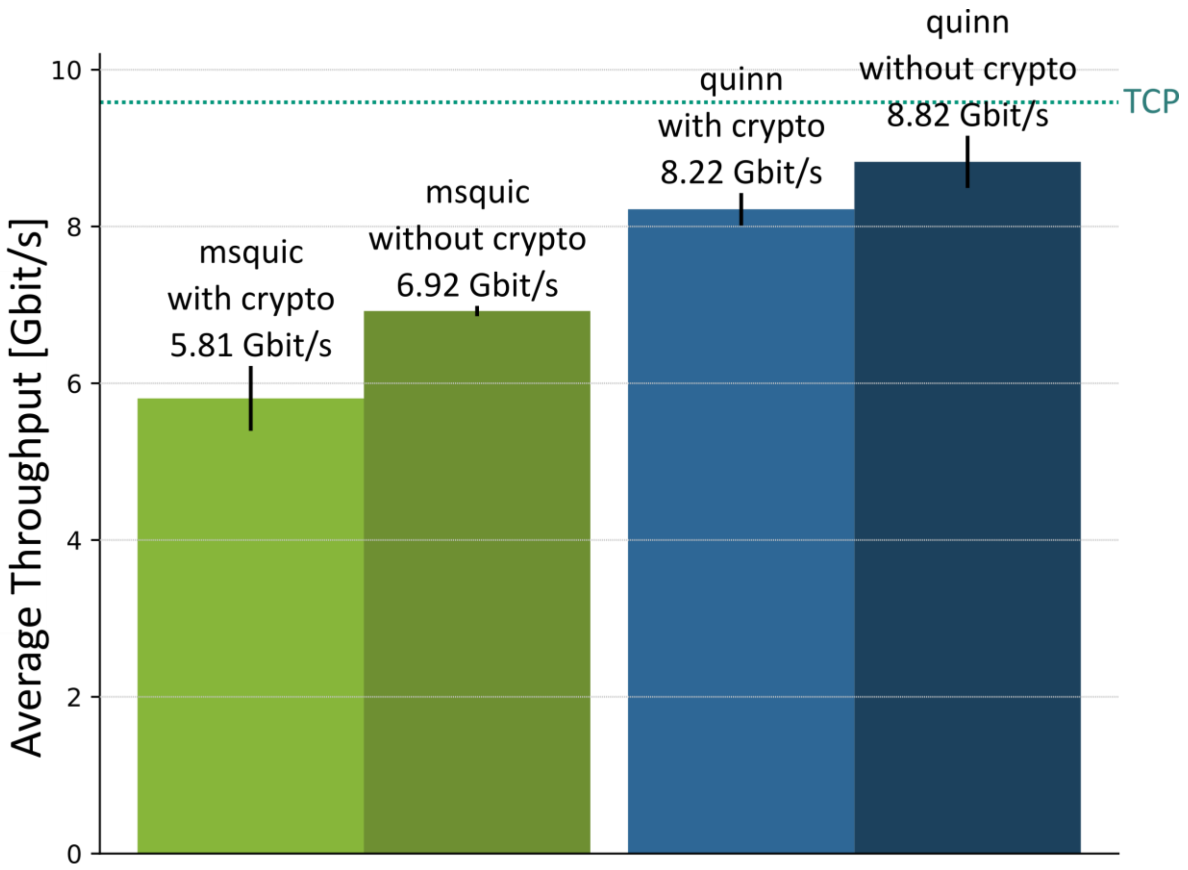


Scheduling between CPU cores degrades throughput

➔ Inefficient Usage of CPU Resources

Impact of Cryptography



➔ QUIC's performance gap: More than overhead by cryptography

Evolution of QUIC Throughput Performance

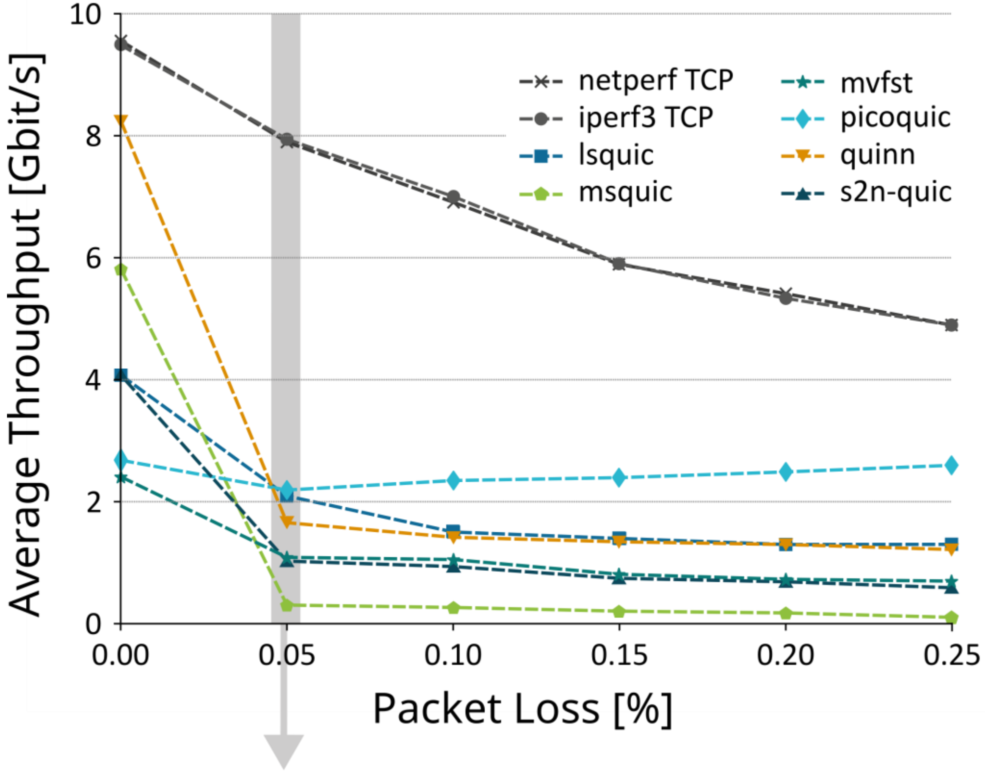
- QUIC Implementations already getting quicker

Implementation	Throughput in 2020 [3]	Throughput in 2023 [1]	Performance Increase
Picoquic	489 Mbit/s	2.68 Gbit/s	5.48x
Mvfst	325 Mbit/s	2.40 Gbit/s	7.38x

Throughput Comparison with [3] from 2020

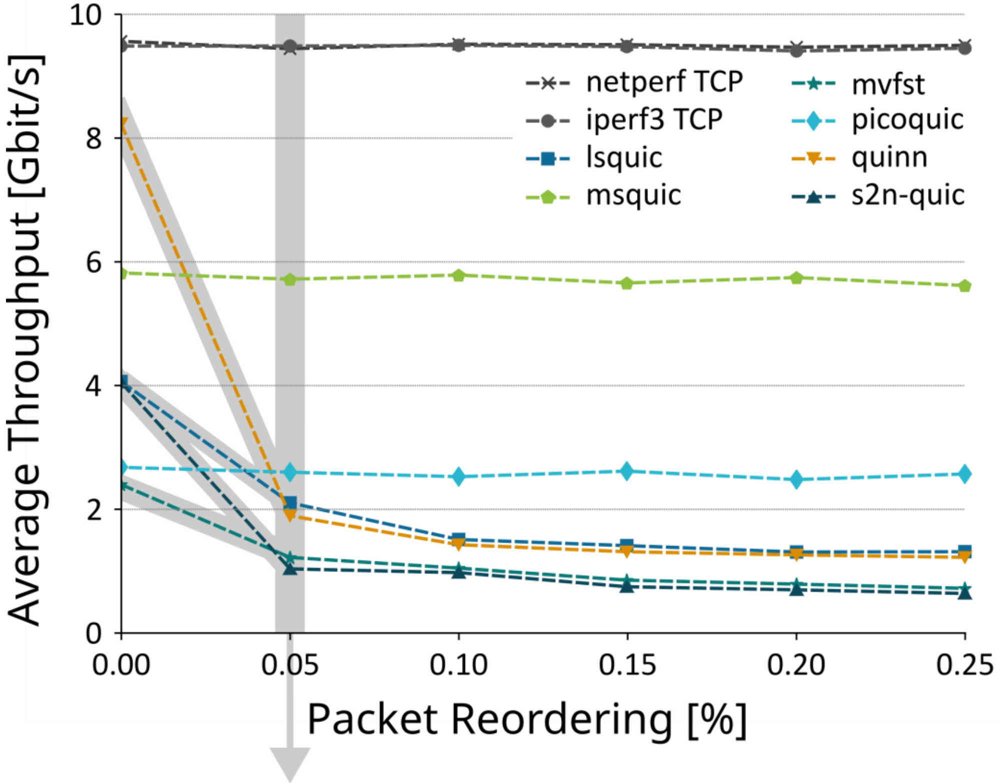
Further Issues

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

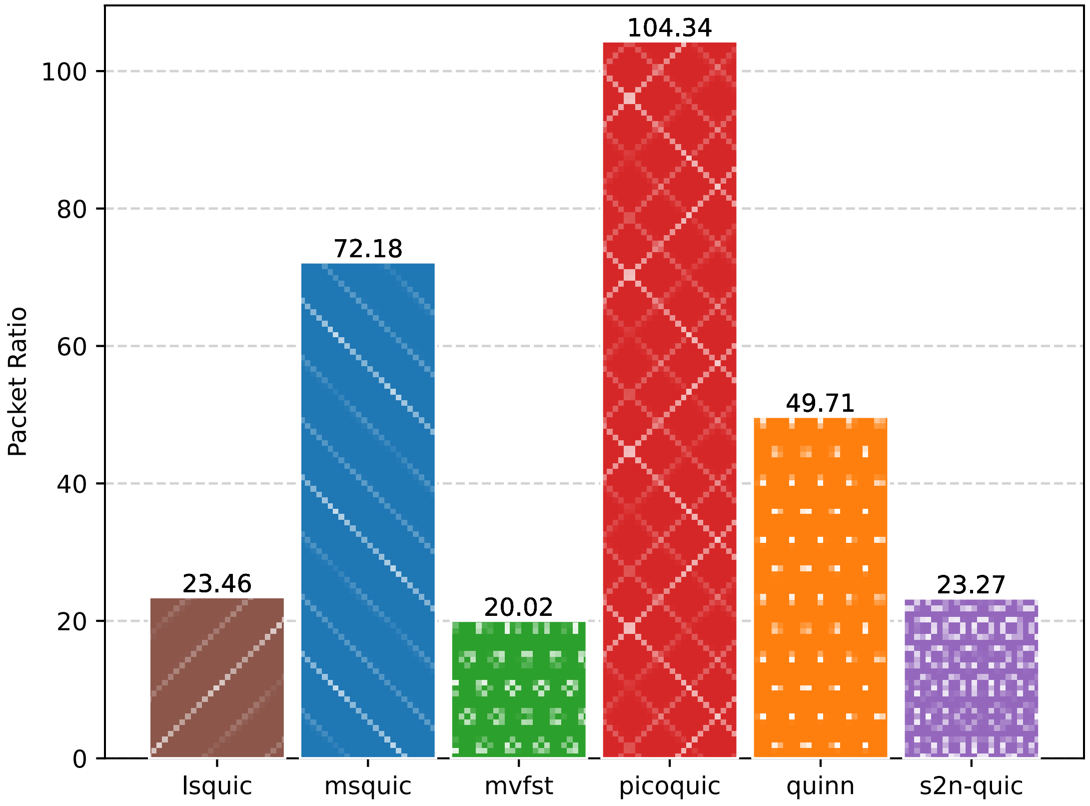
- Current QUIC implementations: Not a up to par with TCP regarding sustained throughput rates
  - QUIC's performance gap: More than overhead by cryptography
  - Inefficient usage of CPU resources

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

References

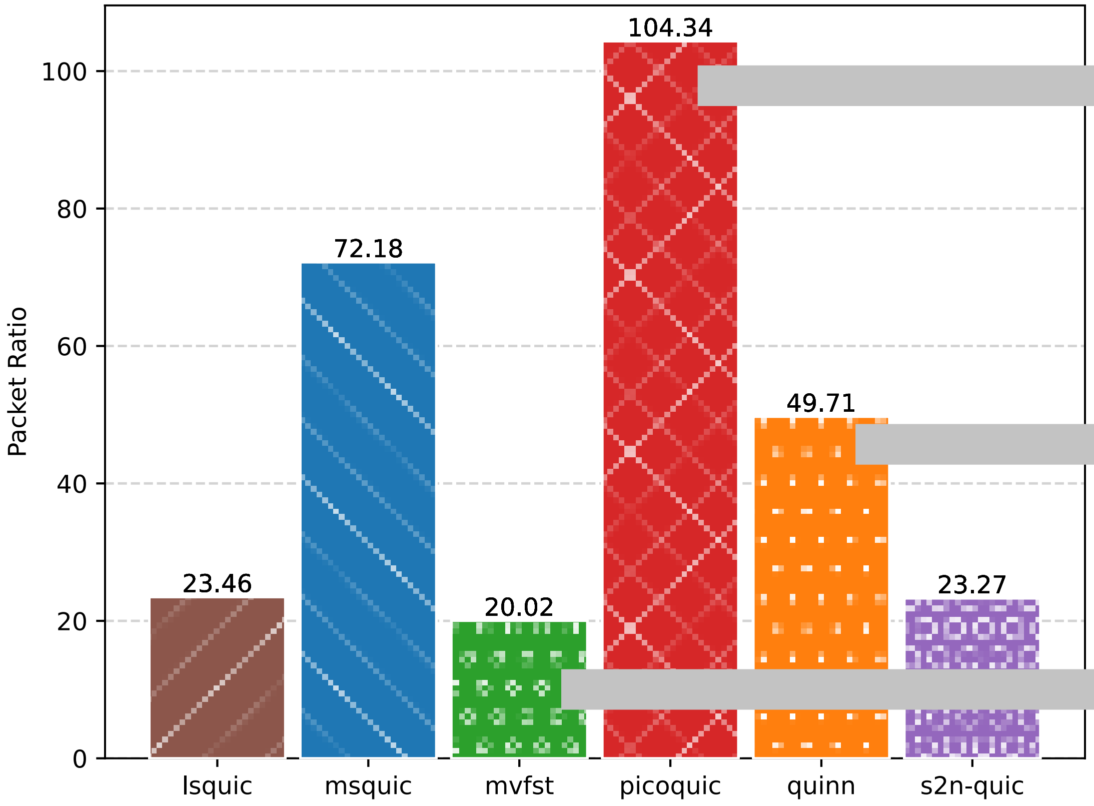
- [1] M. König, O. P. Waldhorst and M. Zitterbart, "QUIC(k) Enough in the Long Run? Sustained Throughput Performance of QUIC Implementations," 2023 IEEE 48th Conference on Local Computer Networks (LCN), Daytona Beach, FL, USA, 2023, pp. 1-4, doi: 10.1109/LCN58197.2023.10223395.
- [2] M. Hock, M. Veit, F. Neumeister, R. Bless and M. Zitterbart, "TCP at 100 Gbit/s – Tuning, Limitations, Congestion Control," 2019 IEEE 44th Conference on Local Computer Networks (LCN), Osnabrueck, Germany, 2019, pp. 1-9, doi: 10.1109/LCN44214.2019.8990842.
- [3] Yang, Xiangrui, et al. "Making quic quicker with nic offload." Proceedings of the Workshop on the Evolution, Performance, and Interoperability of QUIC. 2020.

ACK Ratios



Packet Ratio
0
20
40
60
80
100
23.46
72.18
20.02
104.34
49.71
23.27
lsquic
msquic
mvfst
picoquic
quinn
s2n-quic

ACK Ratios



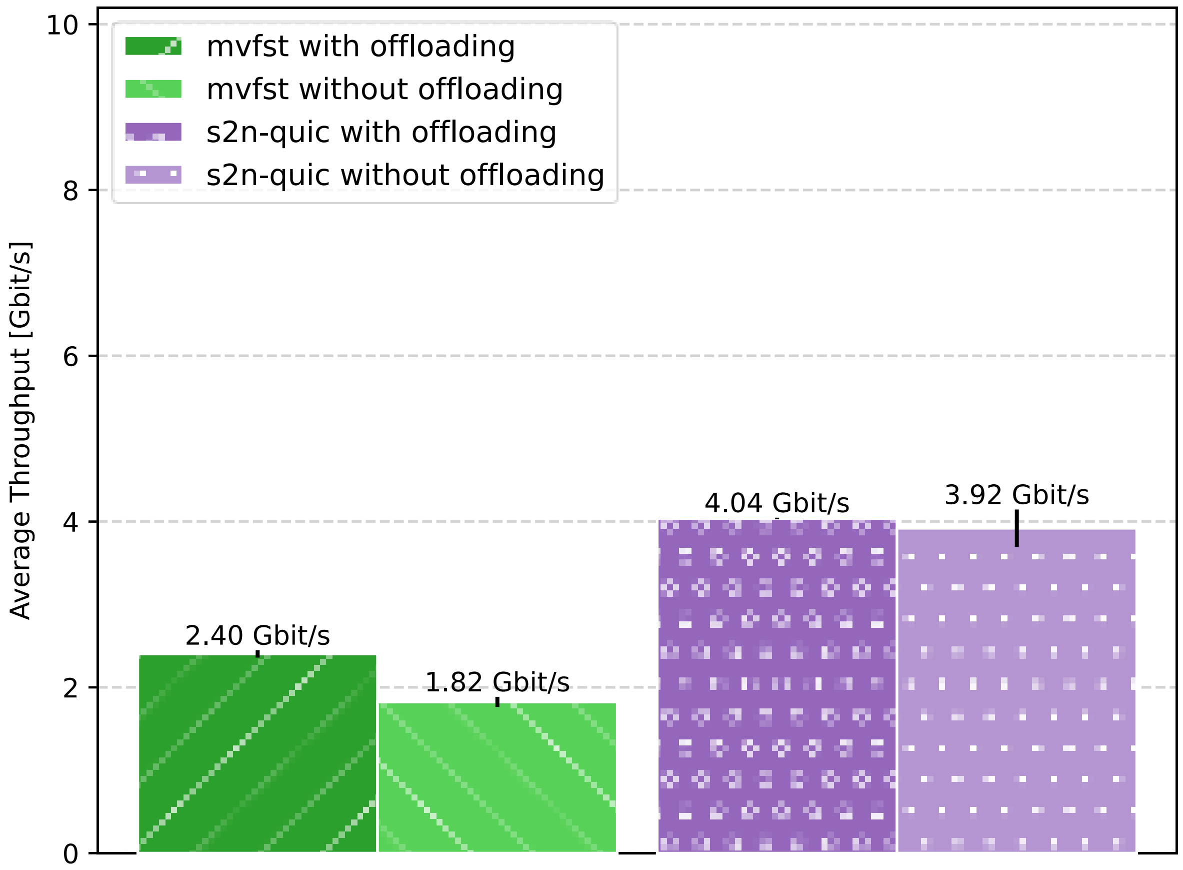
Highest ACK ratio
and low throughput (2.68 Gbit/s)

Best throughput (8.22 Gbit/s)

Lowest ACK ratio
and worst throughput (2.40 Gbit/s)

➔ ACK Ratio seemingly not correlated with throughput performance

Impact of Offloading



➔ Offloading can improve performance