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Friedrich-Alexander-Universität
Technische Fakultät



Protocols, QUIC, and SATCOM

2nd QUIC and Satellite Open Stakeholder Meeting

Thursday 2nd December 2021 (online)

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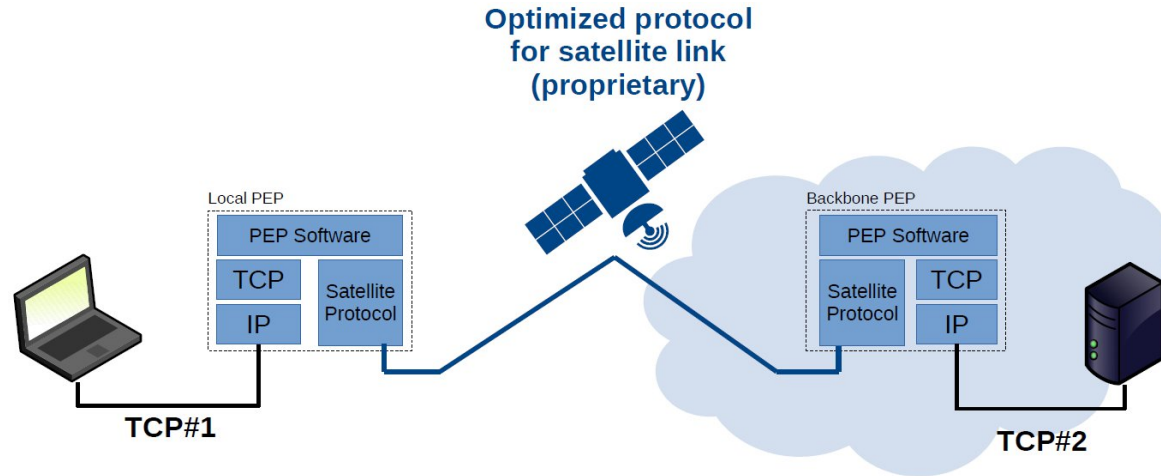
Reinhard German



Motivation

- Performance Enhancing Proxies not applicable in case of encrypted transport layer headers (e.g., VPNs or QUIC)

<https://www.cs7.tf.fau.eu/research/quality-of-service/qos-research-projects/sat-internet-performance>



- 5G NTN SA WG2 Meeting S2-2105611

Key Issue: Discussion on connected protocols in case of GEO SAT long delays

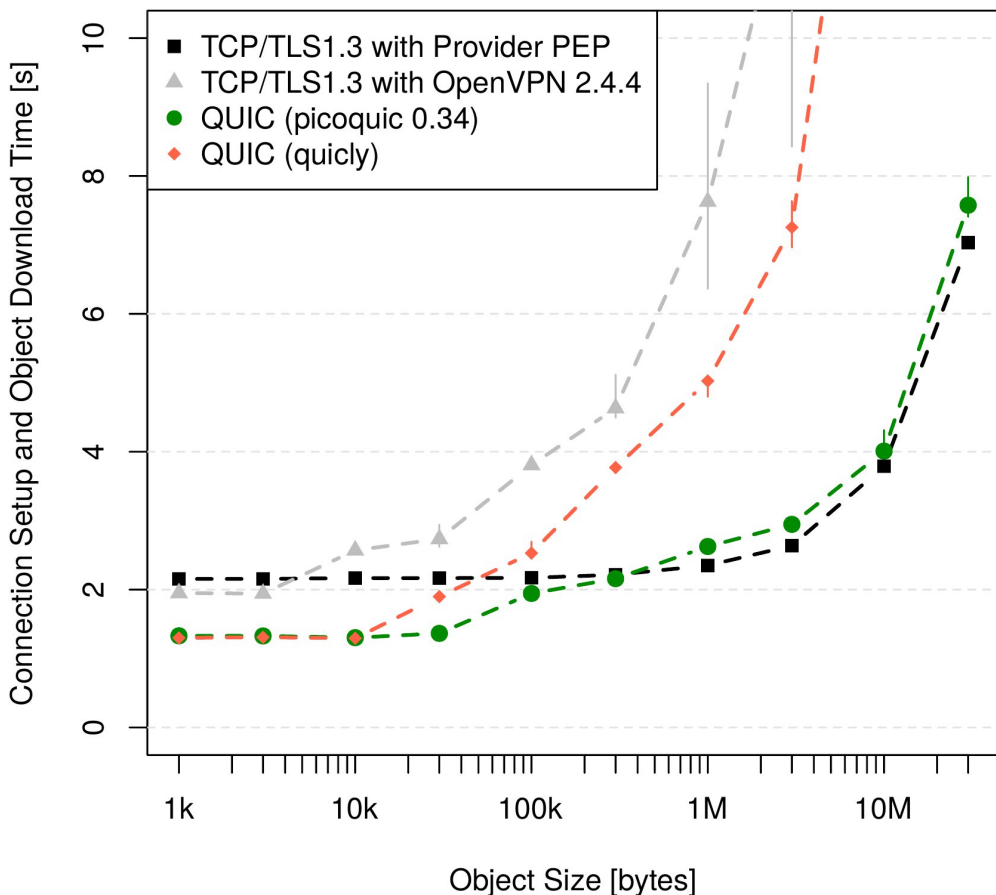
https://www.3gpp.org/ftp/tsg_sa/WG2_Arch/TSGS2_146E_Electronic_2021-08/Docs/S2-2105611.zip

Outline

- Part 1
 - Simple black-box measurements
 - Varying object sizes
 - Real satellite operator, TCP with and without OpenVPN, quicly and picoquic
- Part 2
 - Simple black-box measurements
 - Different HTTP versions
 - Different real satellite operators, with and without Wireguard VPN
- Part 3
 - QUIC interop runner with geostationary satellite links
 - With and without loss, real satellite operators
 - Time-offset plots for detailed analysis

Part 1

Object size vs. connection setup and object download time



- Eutelsat Konnect Zen
 - 50 Mbit/s forward link
 - 5 Mbit/s return link
- TCP/TLS1.3
 - TCP handshake 1 RTT
 - TLS1.3 handshake 1 RTT
- QUIC
 - client/server with default settings
 - Handshake 1 RTT
 - picoquic a91130d Jan. 2021
 - quicly 8a1346e Jan. 2021
- OpenVPN client/server running on hosts

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Part 2

Page load time of artificial website using different HTTP versions

- *off-the-shelf* software
 - Google Chrome 94.0.4606.54
 - OpenLiteSpeed 1.7.4 web server HTTP/1.1, HTTP/2, HTTP/3 (QUICv1)
- Artificial website based on httparchive.org statistics
 - 70 objects * 30 kbyte/object = 2.1 Mbyte
- Wireguard VPN client/server running on hosts
- Real satellite operators
 - Eutelsat Konnect Zen (50/5 Mbps)
 - skyDSL2+ L Premium (50/6 Mbps)
 - Novostream/Astra Connect L+ (20/2 Mbps)
 - Bigblu Konnect Bronze (16/3 Mbps)
 - Starlink Beta

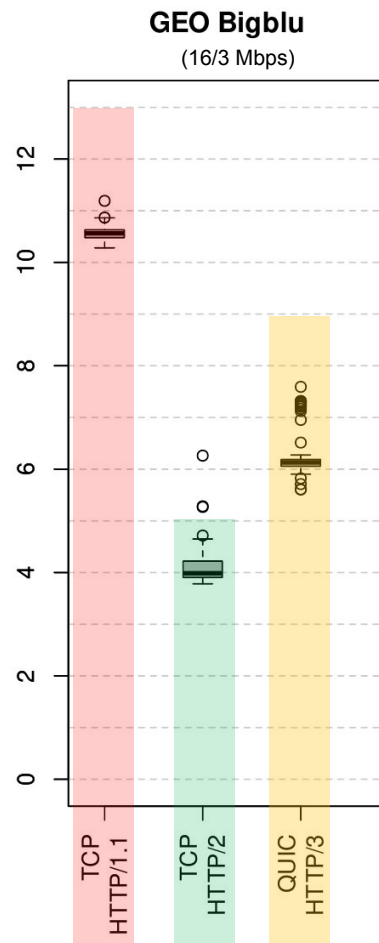
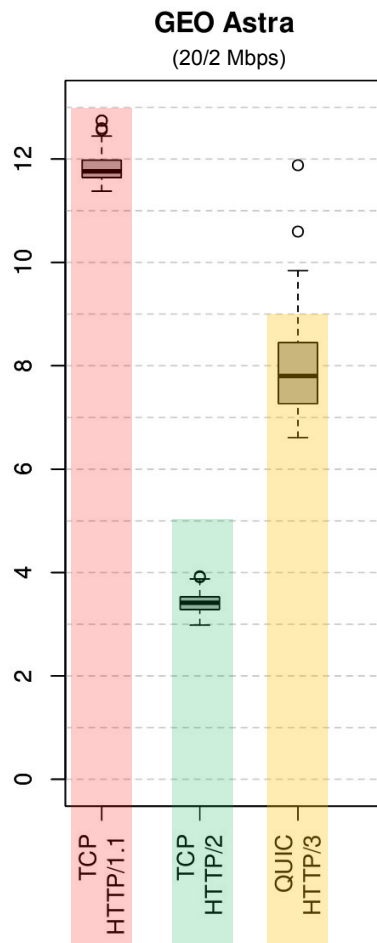
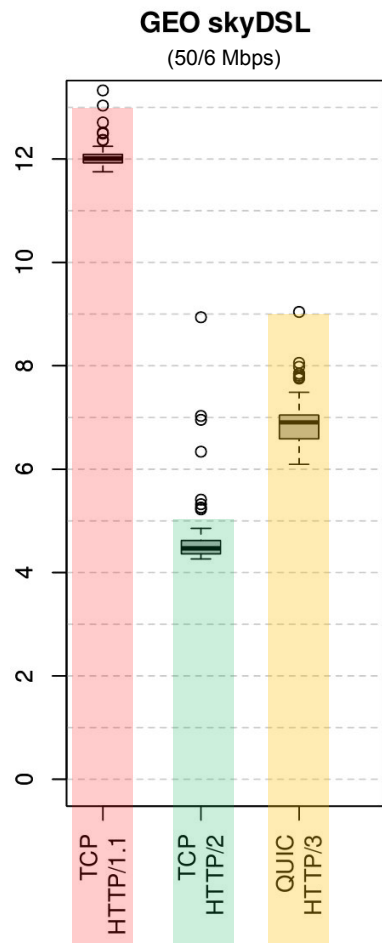
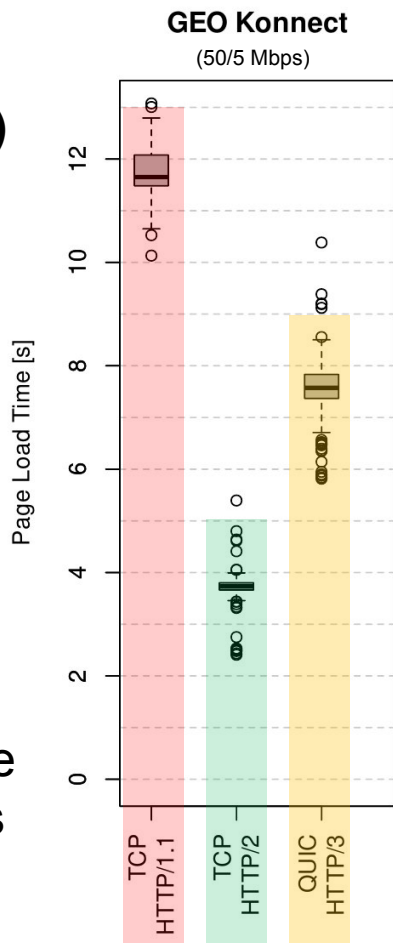
**without
VPN
(with PEP)**

**HTTP/1.1
poor**

**HTTP/2
good**

**HTTP/3
mediocre**

**neglectable
differences
between
operators**



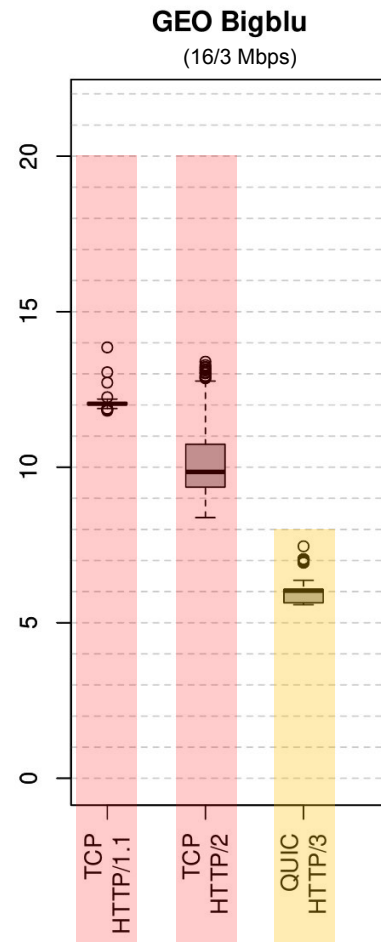
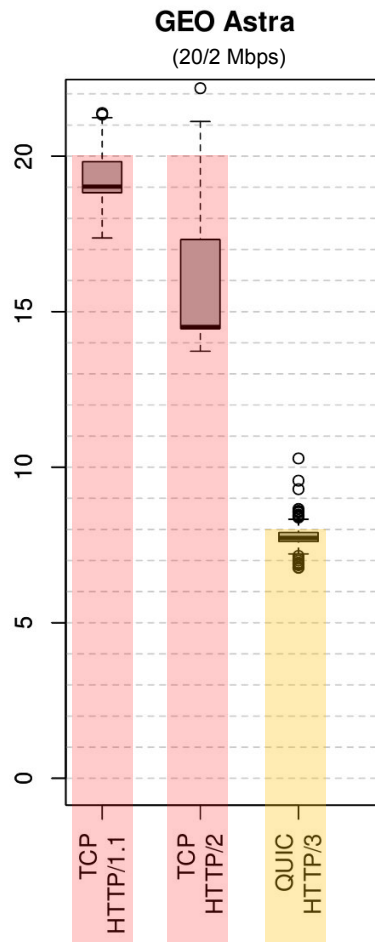
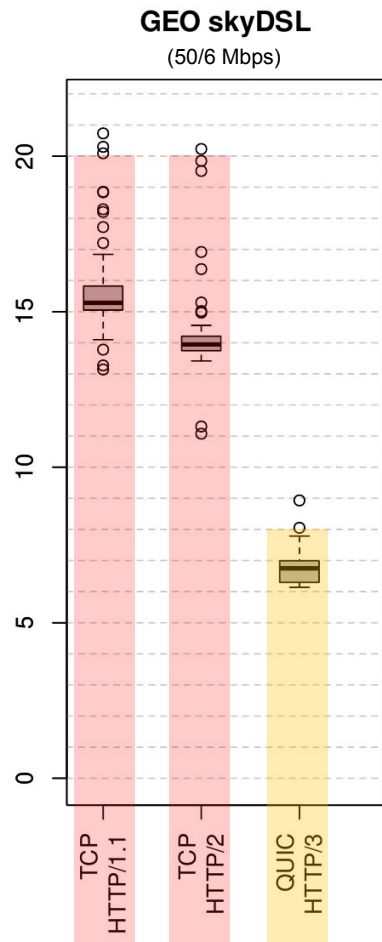
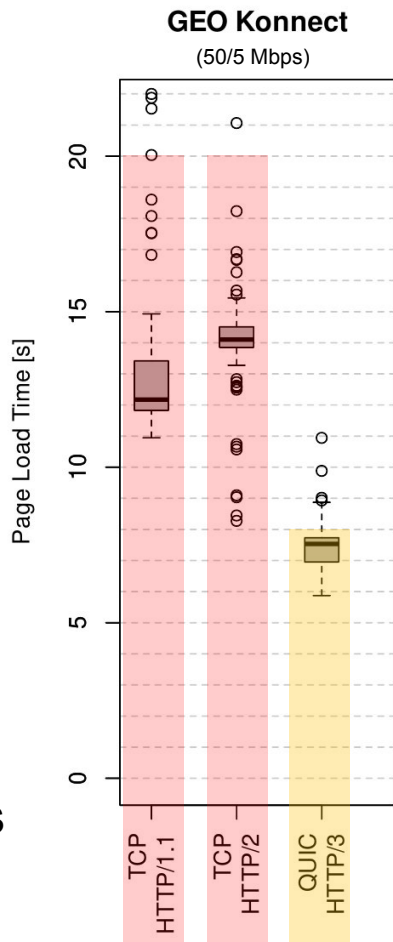
with VPN
(without
PEP)

HTTP/1.1
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some
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Part 3

QUIC interop runner with geostationary satellite links

- QUIC interop runner <https://interop.seemann.io>
 - Interoperability testing of 14 QUIC implementations
 - Implementations available in Docker containers, link emulation with ns-3
 - Two performance-related measurements: goodput, crosstraffic
 - Client requests a 10 Mbyte file from the server
 - Goodput test: good performance for all implementations
- Added satellite related scenarios
 - Master thesis of Sebastian Endres (thanks!)
 - Link emulation with ns-3
 - SAT with 600ms RTT, 20 Mbps forward link, 2 Mbps return link
 - SATLOSS with additional 1% uniform loss rate
 - Running tests over real satellite links
 - Added time-offset and other diagrams generated from pcap traces



About

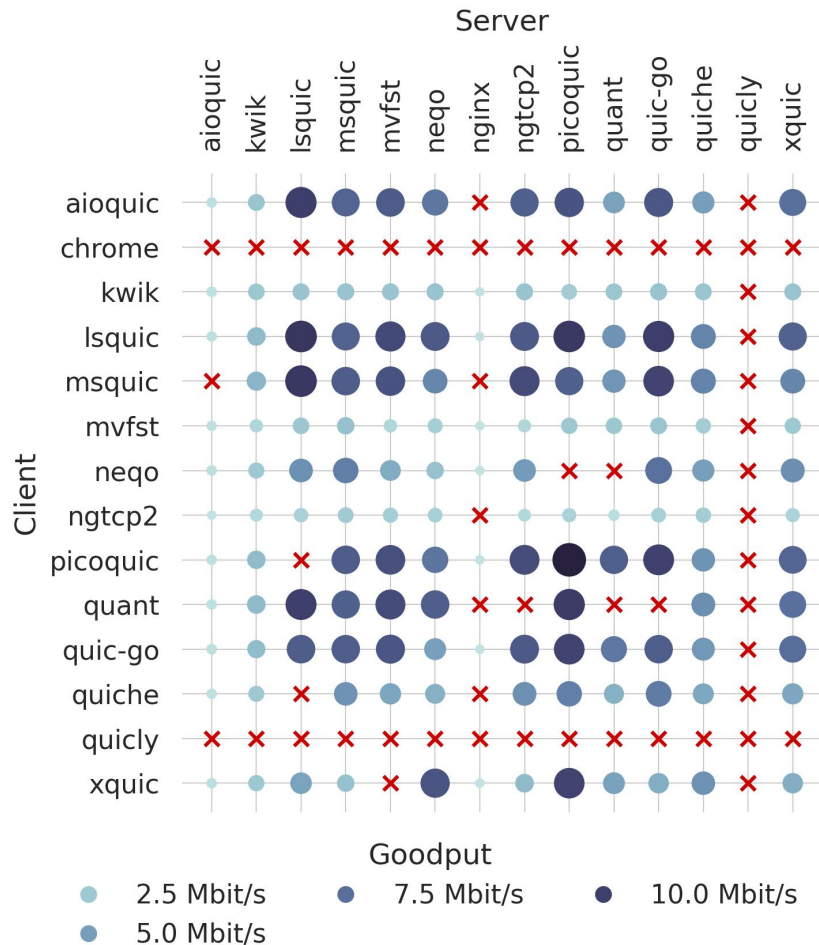
This is a specialized variant of the [QUIC Interop Runner](#). Usually it is used to test the interoperability of [QUIC](#) implementations. Here we exploit the great work of [Marten Seemann](#) to run satellite measurements on all of these client and server [implementations](#).

The satellite link emulation uses [this](#) ns-3 scenario. Parameters are:

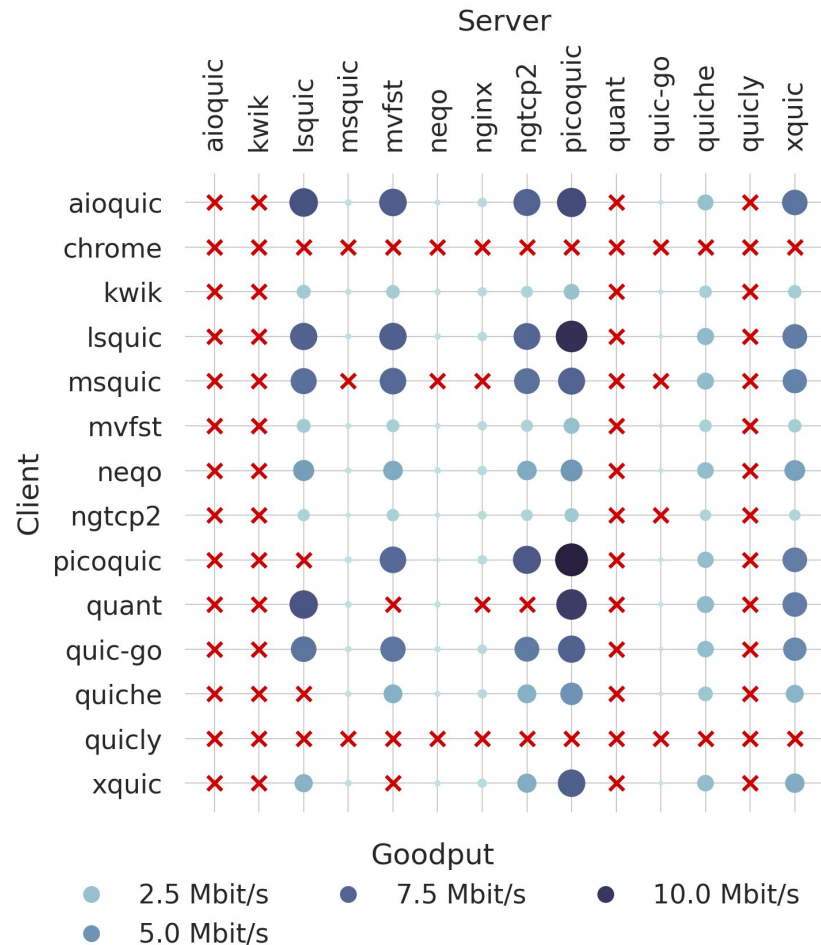
Measurement Results

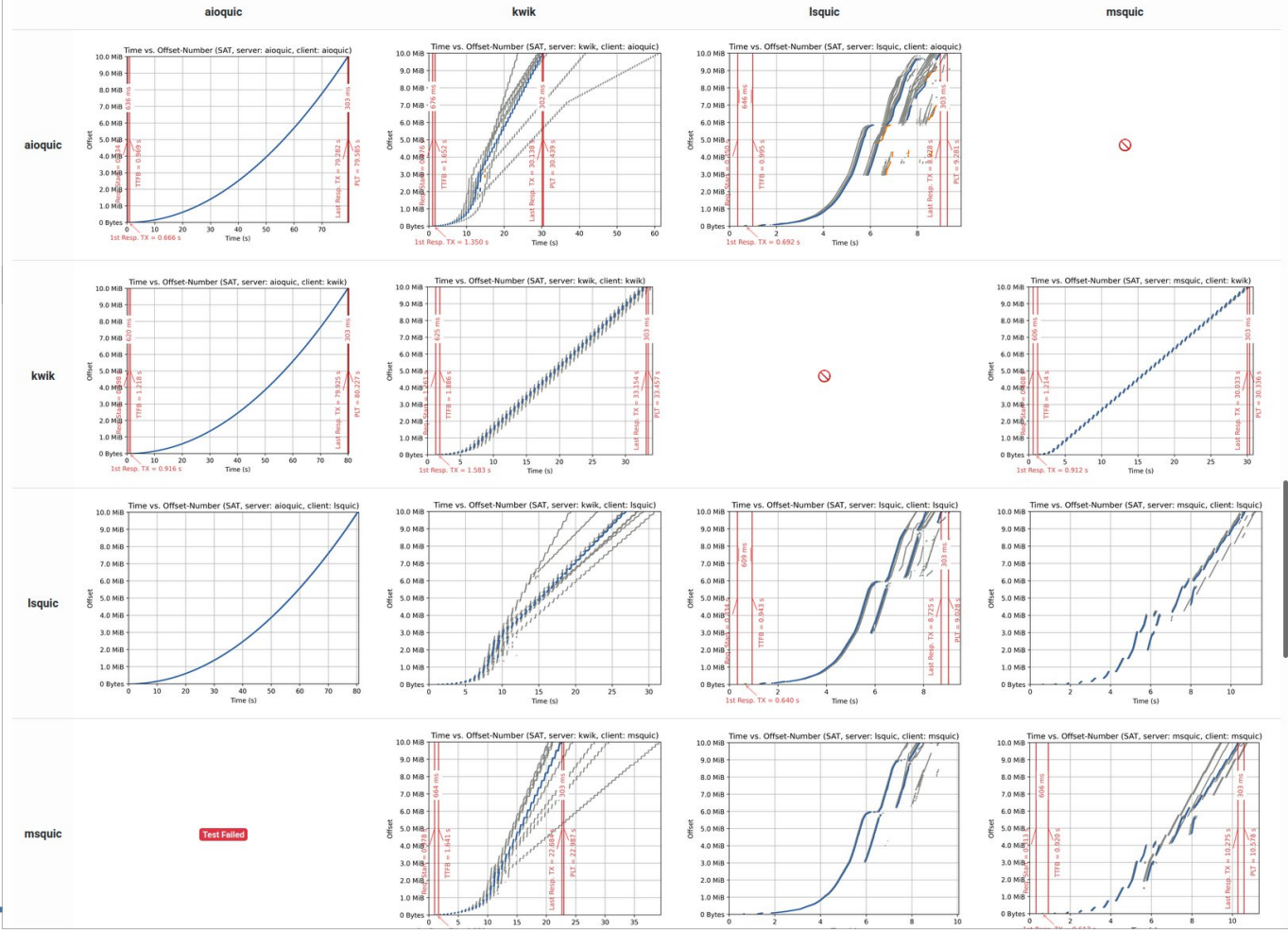
	aiouqic	kwik	lsquic	msquic	mvfst	neqo	nglrx	ngtcp2	picoquic	quant	quic-go	quiche	quicly	xquic	Efficiency
aiouqic	G: 9171 (± 27) kbps SAT: 1058 (± 0) kbps SATL	G: 8637 (± 113) kbps SAT: 2760 (± 611) kbps SATL	G: 9546 (± 19) kbps SAT: 10093 (± 430) kbps SATL: 8463 (± 279) kbps	G: 9417 (± 25) kbps SAT: 8082 (± 466) kbps SATL: 504 (± 60) kbps	G: 9289 (± 34) kbps SAT: 8481 (± 680) kbps SATL: 7858 (± 364) kbps	G: 8610 (± 78) kbps SAT: 7079 (± 2266) kbps SATL: 403 (± 27) kbps	G: 9423 (± 36) kbps SAT	G: 9427 (± 22) kbps SAT: 8249 (± 375) kbps SATL: 7519 (± 285) kbps	G: 9384 (± 29) kbps SAT: 8944 (± 422) kbps SATL: 8883 (± 402) kbps	G: 9099 (± 111) kbps SAT: 4740 (± 666) kbps SATL	G: 9416 (± 36) kbps SAT: 8748 (± 497) kbps SATL: 348 (± 38) kbps	G: 9373 (± 40) kbps SAT: 4963 (± 231) kbps SATL: 2486 (± 285) kbps	G SAT SATL	G: 9315 (± 22) kbps SAT: 7486 (± 618) kbps SATL: 6668 (± 369) kbps	G: 92 % SATL: 22 %
kwik	G: 8792 (± 173) kbps SAT: 1050 (± 1) kbps SATL	G: 8563 (± 65) kbps SAT: 2656 (± 41) kbps SATL	G: 9391 (± 254) kbps SAT: 2802 (± 50) kbps SATL: 1866 (± 88) kbps	G: 9322 (± 113) kbps SAT: 2873 (± 6) kbps SATL: 444 (± 38) kbps	G: 9285 (± 37) kbps SAT: 2827 (± 43) kbps SATL: 1774 (± 104) kbps	G: 8461 (± 105) kbps SAT: 2836 (± 25) kbps SATL: 459 (± 48) kbps	G: 9488 (± 12) kbps SAT: 867 (± 3) kbps SATL: 858 (± 2) kbps	G: 9326 (± 34) kbps SAT: 2838 (± 50) kbps SATL: 1342 (± 205) kbps	G: 8852 (± 84) kbps SAT: 2355 (± 185) kbps SATL: 2406 (± 182) kbps	G SAT: 2731 (± 10) kbps SATL	G: 9147 (± 66) kbps SAT: 2856 (± 8) kbps SATL: 342 (± 36) kbps	G: 9315 (± 29) kbps SAT: 2767 (± 30) kbps SATL: 1519 (± 119) kbps	G SAT SATL	G: 9163 (± 50) kbps SAT: 2804 (± 29) kbps SATL: 1729 (± 120) kbps	G: 91 % SATL: 6 %
lsquic	G: 8304 (± 55) kbps SAT: 1043 (± 4) kbps SATL	G: 8637 (± 419) kbps SAT: 3364 (± 531) kbps SATL	G: 9507 (± 131) kbps SAT: 10509 (± 521) kbps SATL: 7663 (± 479) kbps	G: 9272 (± 117) kbps SAT: 8131 (± 240) kbps SATL: 438 (± 74) kbps	G: 9392 (± 33) kbps SAT: 9461 (± 625) kbps SATL: 7733 (± 418) kbps	G: 7348 (± 110) kbps SAT: 8633 (± 49) kbps SATL: 455 (± 4) kbps	G: 9436 (± 19) kbps SAT: 866 (± 2) kbps SATL: 852 (± 2) kbps	G: 9484 (± 72) kbps SAT: 8653 (± 121) kbps SATL: 7420 (± 361) kbps	G: 9422 (± 20) kbps SAT: 10434 (± 398) kbps SATL: 10502 (± 490) kbps	G: 8435 (± 176) kbps SAT: 5546 (± 308) kbps SATL	G: 9234 (± 163) kbps SAT: 10174 (± 193) kbps SATL: 335 (± 47) kbps	G: 9244 (± 161) kbps SAT: 6340 (± 236) kbps SATL: 2855 (± 346) kbps	G SAT SATL	G: 9319 (± 19) kbps SAT: 8224 (± 363) kbps SATL: 6256 (± 545) kbps	G: 90 % SAT: 35 % SATL: 22 %
msquic	G: 8839 (± 49) kbps SAT	G: 8621 (± 135) kbps SAT: 3656 (± 713) kbps SATL	G: 9453 (± 140) kbps SAT: 10484 (± 592) kbps SATL: 6961 (± 625) kbps	G: 9518 (± 18) kbps SAT: 8431 (± 370) kbps SATL	G: 9428 (± 25) kbps SAT: 9014 (± 442) kbps SATL: 7274 (± 523) kbps	G: 8637 (± 56) kbps SAT: 6205 (± 2443) kbps SATL	G: 9486 (± 25) kbps SAT	G: 9550 (± 34) kbps SAT: 9394 (± 442) kbps SATL: 6640 (± 541) kbps	G: 9440 (± 41) kbps SAT: 8239 (± 1041) kbps SATL: 7531 (± 1041) kbps	G SAT: 5491 (± 557) kbps SATL	G: 9527 (± 15) kbps SAT: 9766 (± 52) kbps SATL	G: 9374 (± 112) kbps SAT: 6401 (± 452) kbps SATL: 2817 (± 290) kbps	G SAT SATL	G: 8905 (± 176) kbps SAT: 6266 (± 630) kbps SATL: 5985 (± 484) kbps	G: 92 % SAT: 38 % SATL: 31 %
mvfst	G: 8748 (± 43) kbps SAT: 1013 (± 7) kbps SATL	G: 8628 (± 168) kbps SAT: 1678 (± 16) kbps SATL	G: 9598 (± 18) kbps SAT: 2686 (± 46) kbps SATL: 1847 (± 82) kbps	G: 9431 (± 194) kbps SAT: 2978 (± 4) kbps SATL: 415 (± 58) kbps	G: 9403 (± 32) kbps SAT: 1707 (± 6) kbps SATL: 1587 (± 67) kbps	G: 4175 (± 2447) kbps SAT: 2172 (± 52) kbps SATL: 403 (± 30) kbps	G: 9524 (± 5) kbps SAT: 844 (± 2) kbps SATL: 832 (± 4) kbps	G: 9443 (± 34) kbps SAT: 829 (± 20) kbps SATL: 1389 (± 88) kbps	G: 8892 (± 51) kbps SAT: 2608 (± 34) kbps SATL: 2473 (± 197) kbps	G: 8668 (± 45) kbps SAT: 2628 (± 34) kbps SATL	G: 9559 (± 4) kbps SAT: 2779 (± 14) kbps SATL: 315 (± 33) kbps	G: 9481 (± 29) kbps SAT: 2286 (± 127) kbps SATL: 1504 (± 97) kbps	G SAT SATL	G: 9253 (± 27) kbps SAT: 2567 (± 45) kbps SATL: 1710 (± 99) kbps	G: 88 % SAT: 11 % SATL: 6 %
neqo	G SAT: 1058 (± 1) kbps	G SAT: 2527 (± 564) kbps	G SAT: 5687 (± 258) kbps	G SAT: 6649 (± 168) kbps	G SAT: 4291 (± 258) kbps	G SAT: 2965 (± 1271) kbps	G SAT: 870 (± 0) kbps	G SAT: 5176 (± 246) kbps	G SAT: 4815 (± 82) kbps	G SAT	G SAT: 7382 (± 82) kbps	G SAT: 4944 (± 302) kbps	G SAT	G SAT: 5822 (± 307) kbps	G: SATL: 22 %

SAT (20/2 Mbps, 600ms RTT)

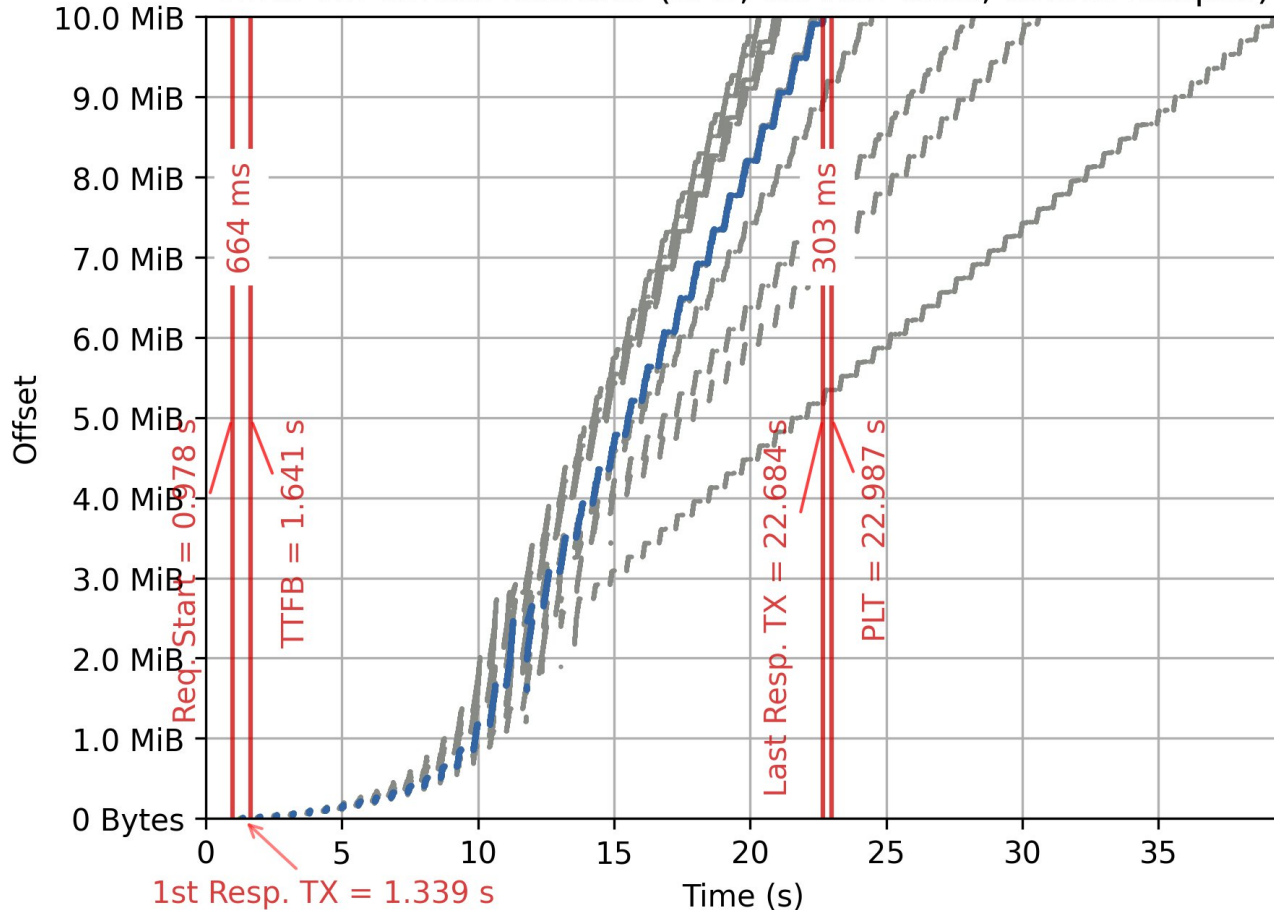


SAT (20/2 Mbps, 600ms RTT, 1% loss)



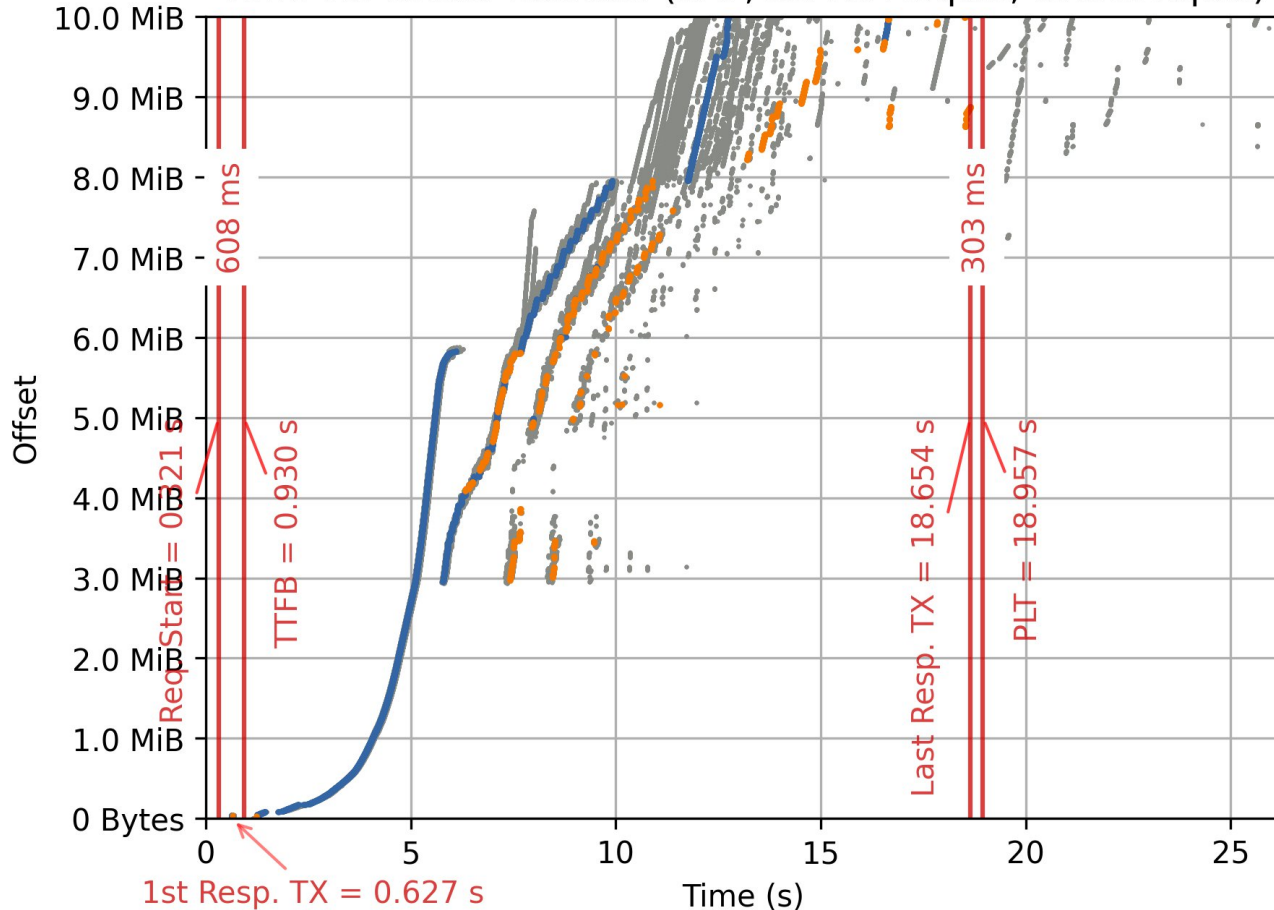


Time vs. Offset-Number (SAT, server: kwik, client: msquic)



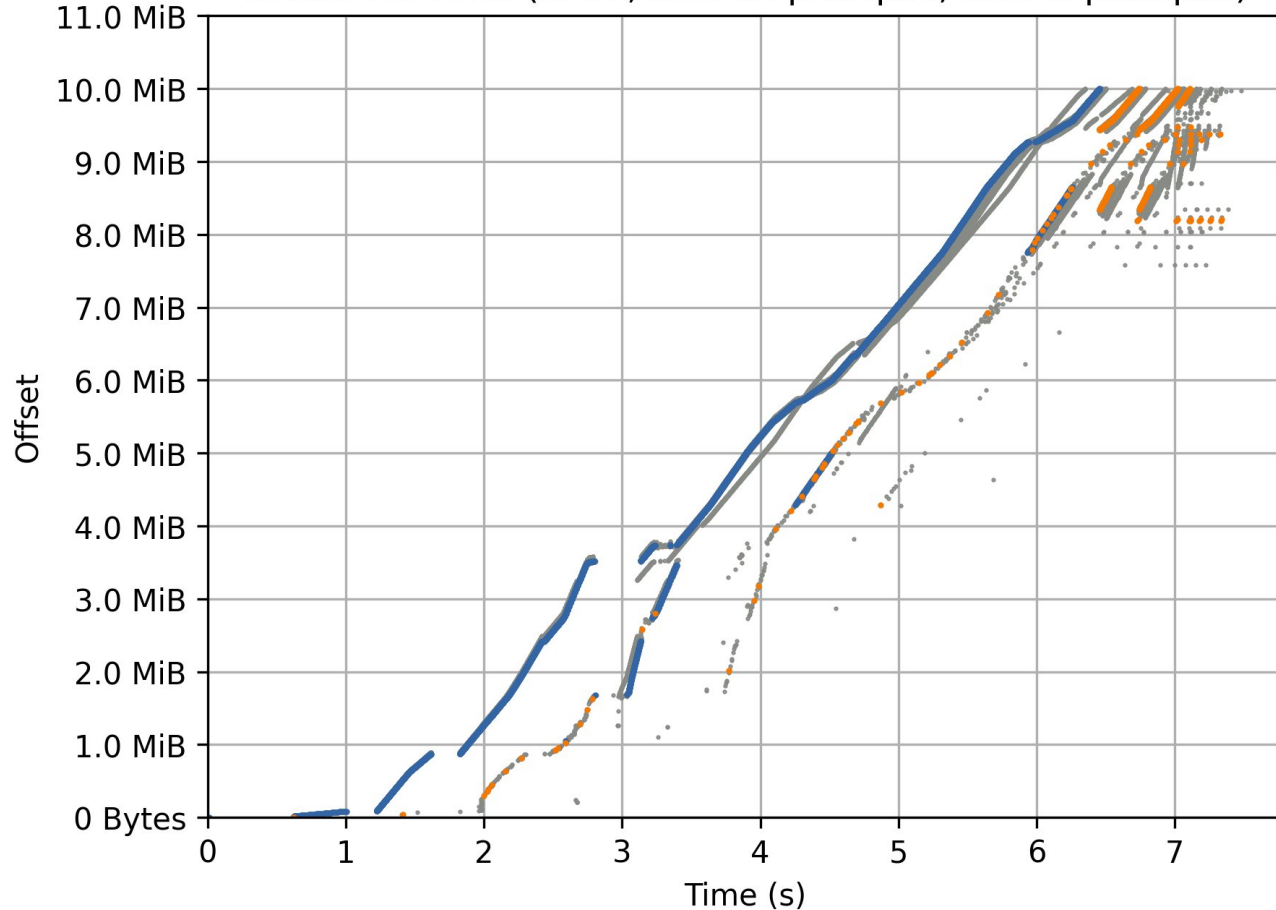
- satellite interop runner
 - 600ms RTT
 - 20/2 Mbit/s
 - no loss
- slow start-up
- varying outcomes

Time vs. Offset-Number (SAT, server: Isquic, client: xquic)



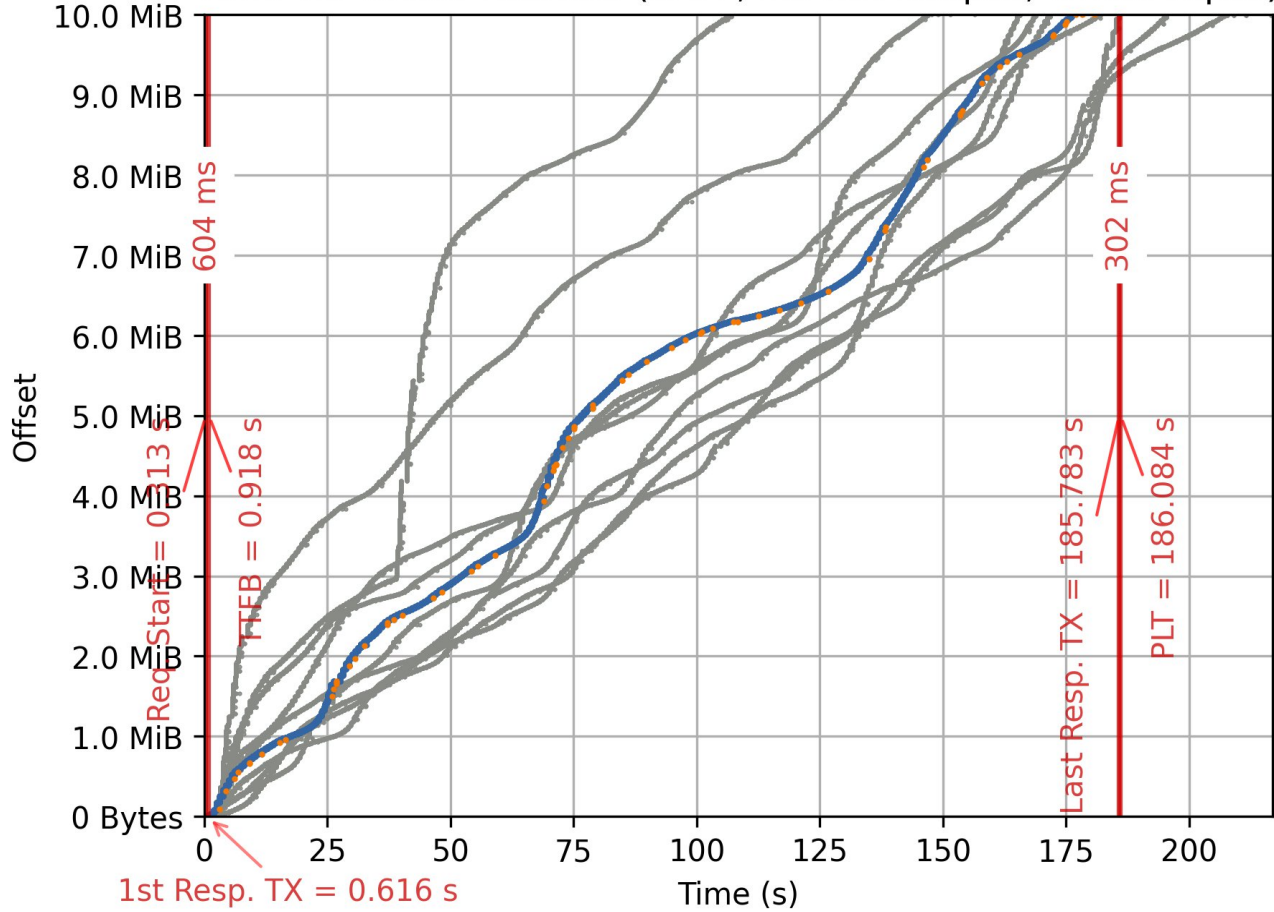
- satellite interop runner
 - 600ms RTT
 - 20/2 Mbit/s
 - no loss
- many retransmissions (orange points)
- non-sequential offset numbers? (parallel lines)

Offset vs. Time (SATL, server: picoquic, client: picoquic)



- **satellite interop runner**
 - 600ms RTT
 - 20/2 Mbit/s
 - 1% loss
- **good performance** (unlike other implementations in the SATLOSS scenario)

Time vs. Offset-Number (SATL, server: msquic, client: xquic)



- satellite interop runner
 - 600ms RTT
 - 20/2 Mbit/s
 - 1% loss
- very poor performance

Part 3

QUIC interop runner with geostationary satellite links

- Preliminary results
 - Broad testing of many QUIC implementations
 - **Work in progress**
 - Some combinations fail due to timeouts or other reasons
 - Performance depends on client and server implementation
 - QUIC implementations are work in progress, too
 - maybe not all implementations strive for high-performance bulk data transfer and/or may only be used as proof of concept?
 - Time-offset plots
 - not always available due to faulty pcap traces
 - provide some insights into the behavior of the implementations
 - Will announce updates on EToSat mailing list

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