Sliding Window FEC (SWF) over Satellite Networks

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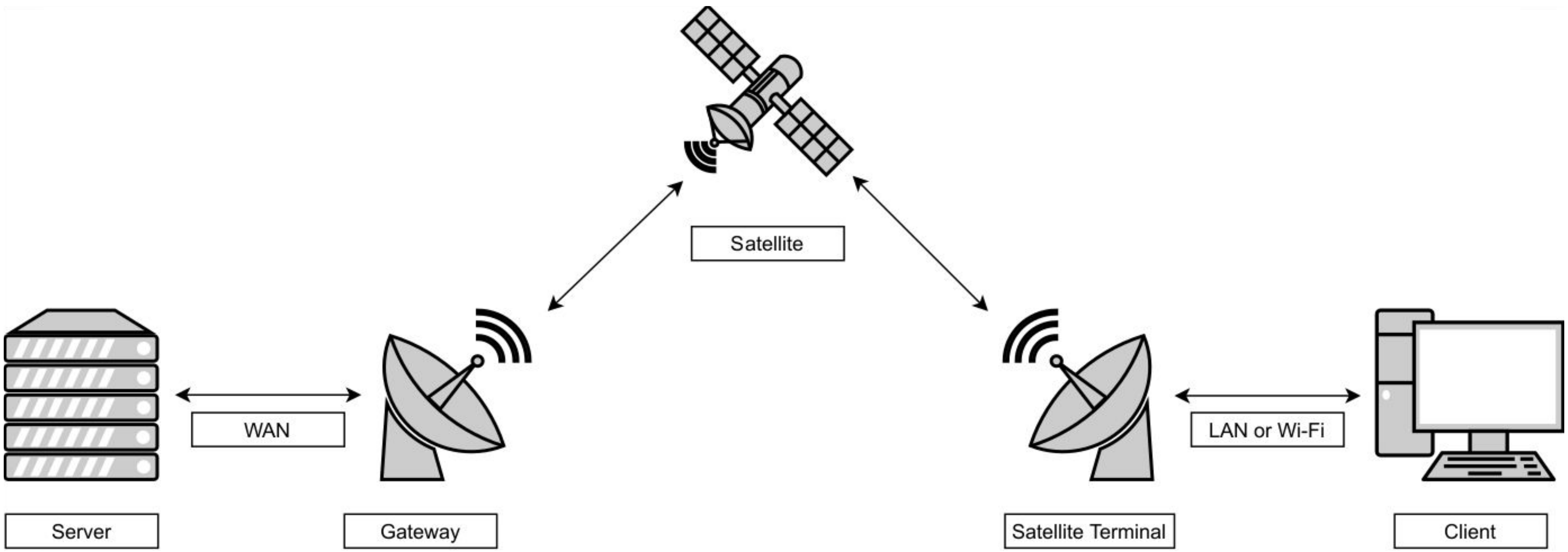
Connection over GEO satellite



TCP over SATCOM: PEP accelerates flows and handles local retransmission

QUIC over SATCOM: QUIC privacy policy prevents the use of PEP

- ➔ No acceleration
- ➔ Any loss needs a retransmission on the whole link

Sliding Window FEC

Forward Erasure Correction (FEC) on a Sliding encoding Window (SWF)

- From traffic packets, original and redundant packets are sent in a tunnel
- Any loss can be reconstructed as long as:

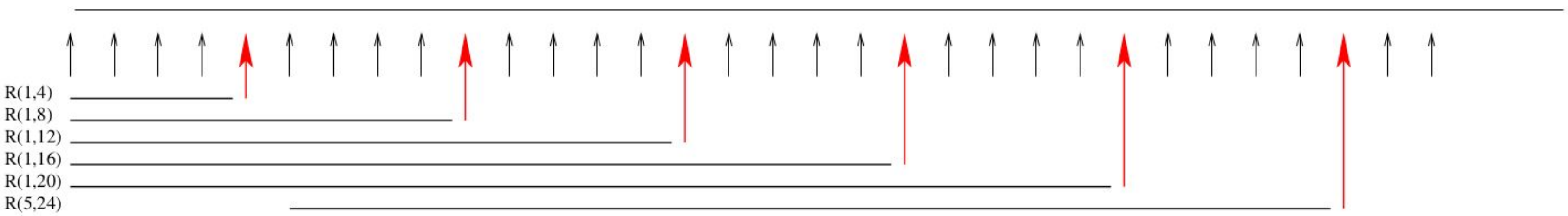
number of lost packets ≤ number of redundant packets in the sliding window

➡ Reduce the number of loss and retransmission

Sliding Window FEC - example

- $\mathbf{S}_{(4,\ 20)}$: SWF with a redundant packet every 4 source packets, on a sliding window of 20 source packets.

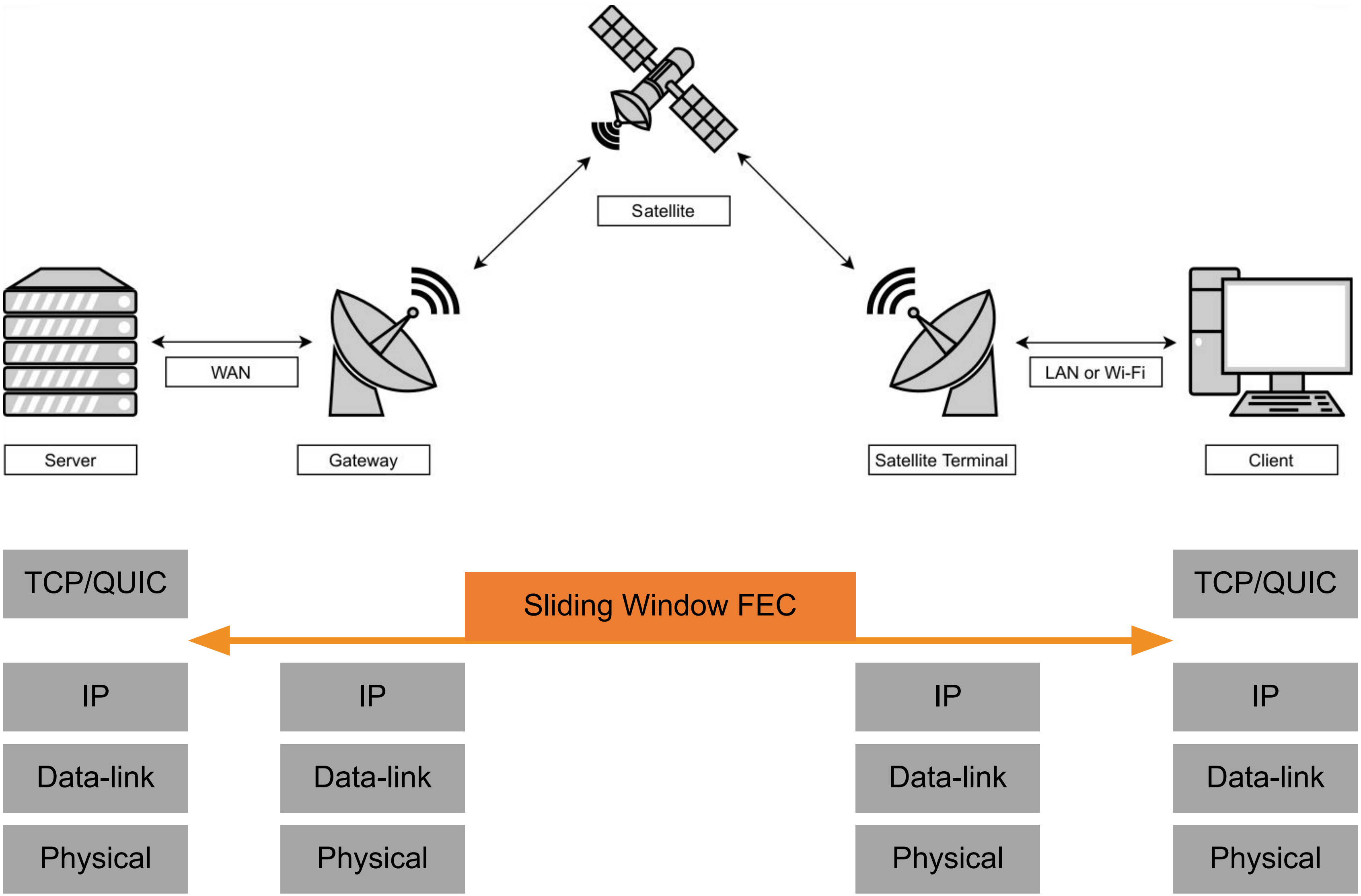
$k = 4 \quad z = 20$



Each redundant packet cover a part of source packets

- $\mathbf{R}_{(1,\ 12)}$ covers from the 1st to the 12th packets

Connection over GEO satellite



SWF impact on SATCOM

Download of 20 MB with:

- **Iperf3 (TCP/CUBIC)** (without Hystart)
- **Picoquic (QUIC/BBR)** (with Hystart of Picoquic/BBR)

30 iterations of:

- A single flow;
- Five concurrent flows.

Four configurations studied:

- **W/o SWF**;
- $\mathbf{S_{(10,100)}}$: one redundant packet every **10** original packets (**9.09%** of redundancy), with a sliding window of **100** packets;
- $\mathbf{S_{(5,100)}}$: one redundant packet every **5** original packets (**16.67%** of redundancy), with a sliding window of **100** packets;
- $\mathbf{S_{(2,100)}}$: one redundant packet every **2** original packets (**33.33%** of redundancy), with a sliding window of **100** packets.

Congestion Control Algorithms tested

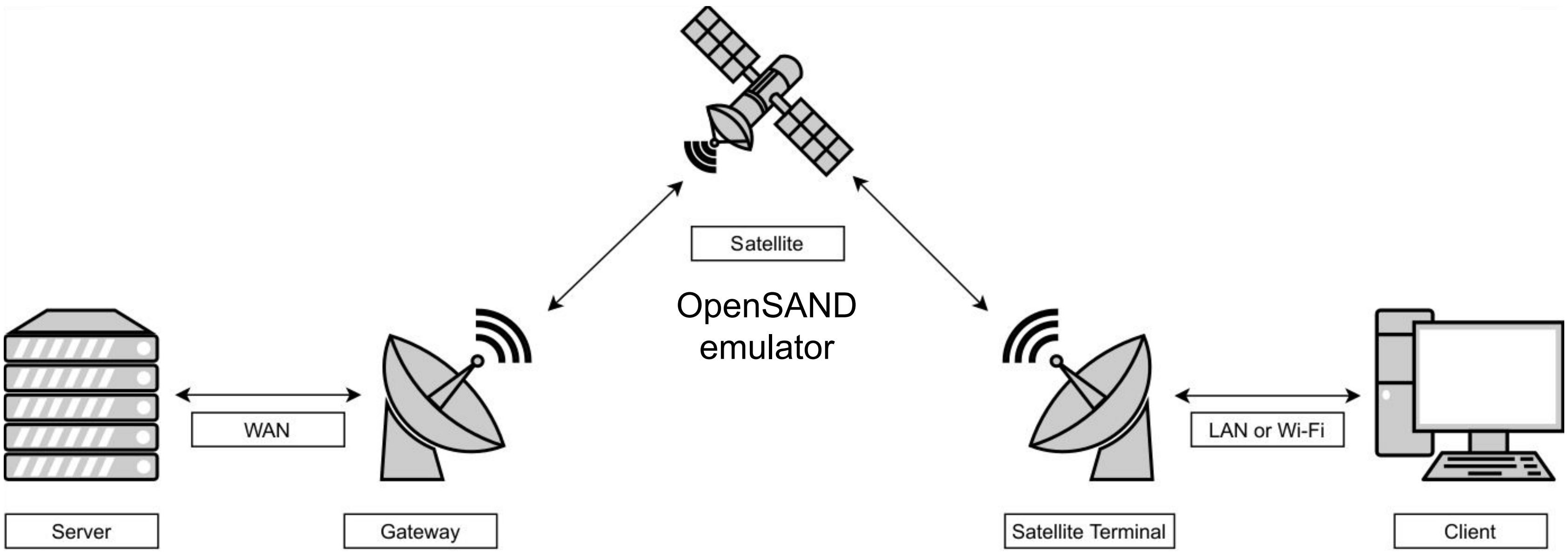
CUBIC : loss based

- Fills bottleneck buffer to its limit to set its congestion window
- Lost packets reduce congestion window

BBR : time based

- Measures available bandwidth and minimum RTT
- Does not overuse bottleneck buffer
- Does not reduce congestion window with lost packets

Topology of our tests



Satellite emulator: OpenSAND
Forward bandwidth: 12Mb/s - Return bandwidth: 3Mb/s

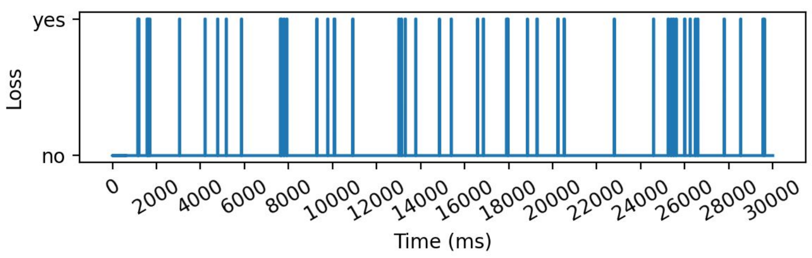
Between ST and the client:

- w/o Wi-Fi (no loss)
- w/ Wi-Fi (1% random loss)

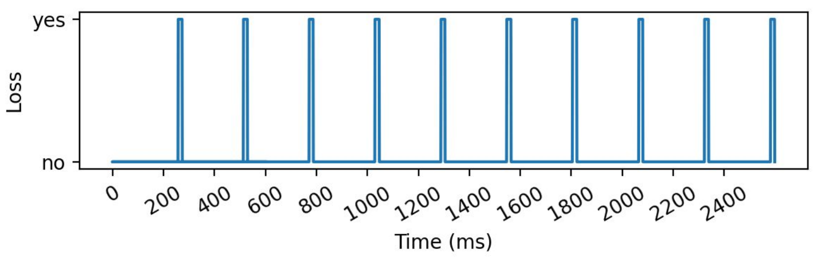
Scenarios

Ideal scenario:
Without any loss, to validate our setup

Optical satellite scenario:
Gilbert-Elliot model:
p = 0.01 and q = 0.167
Variable loss burst length
On an UDP flow: 2.70% of packet loss



DVB satellite - Mobile Receptor scenario:
Collected traces on a train
Regular loss of 15-16ms every 258ms
On an UDP flows: 6.32% of packet loss



Sub scenarios: with and without Wi-Fi between ST and client

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Optical scenario

CUBIC highly impacted by loss:

➔ gains a lot from SWF both with one and five flows

BBR little impacted by loss:

➔ No gain from SWF

Download time median in seconds		1 flow				5 flows			
		w/o SWF	$S_{(10,100)}$	$S_{(5,100)}$	$S_{(2,100)}$	w/o SWF	$S_{(10,100)}$	$S_{(5,100)}$	$S_{(2,100)}$
Ideal scenario	TCP CUBIC	17.84	19.04 +6.73%	20.17 +13.06%	24.12 +35.20%	65.67	73.02 +11.19%	79.78 +21.49%	96.26 +46.58%
	QUIC BBR	17.38	19.23 +10.64%	20.73 +19.28%	25.32 +45.68%	76.63	86.15 +12.42%	93.98 +22.64%	116.54 +52.08%
Optical satellite without Wi-Fi	TCP CUBIC	91.42	54.03 -40.89%	24.42 -74.38%	24.55 -73.15%	163.35	121.99 -25.32%	83.99 -48.58%	96.89 -40.68%
	QUIC BBR	19.90	21.29 +6.99%	21.72 +9.15%	25.53 +28.28%	80.90	91.44 +13.03%	94.46 +16.76%	116.86 +44.46%
Optical satellite with Wi-Fi	TCP CUBIC	244.01	72.37 -70.34%	36.30 -85.12%	24.19 -90.09%	274.18	145.91 -46.78%	100.61 -63.31%	98.24 -64.17%
	QUIC BBR	20.61	20.92 +1.53%	22.30 +8.23%	25.45 +23.50%	80.44	88.93 +10.55%	96.15 +19.53%	113.78 +41.44%

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DVB Mobile scenario

CUBIC even more impacted by loss:

➔ SWF can reduce download time by 20 (1 flow w/ Wi-Fi)

BBR still little impacted by loss:

➔ No gain from SWF

Download time median in seconds		1 flow				5 flows			
		w/o SWF	$S_{(10,100)}$	$S_{(5,100)}$	$S_{(2,100)}$	w/o SWF	$S_{(10,100)}$	$S_{(5,100)}$	$S_{(2,100)}$
Ideal scenario	TCP CUBIC	17.84	19.04 **+6.73%**	20.17 **+13.06%**	24.12 **+35.20%**	65.67	73.02 **+11.19%**	79.78 **+21.49%**	96.26 **+46.58%**
	QUIC BBR	17.38	19.23 **+10.64%**	20.73 **+19.28%**	25.32 **+45.68%**	76.63	86.15 **+12.42%**	93.98 **+22.64%**	116.54 **+52.08%**
DVB satellite - mobile receptor without Wi-Fi	TCP CUBIC	405.91	291.02 **-28.30%**	31.11 **-92.34%**	24.67 **-93.92%**	454.30	313.26 **-31.04%**	88.61 **-80.61%**	96.74 **-78.71%**
	QUIC BBR	23.56	23.67 **+0.45%**	23.68 **+0.51%**	25.51 **+8.28%**	83.49	93.56 **+12.07%**	87.78 **+17.13%**	114.67 **+37.35%**
DVB satellite - mobile receptor with Wi-Fi	TCP CUBIC	507.10	416.56 **-17.85%**	83.82 **-83.47%**	24.52 **-95.16%**	547.56	444.55 **-18.81%**	135.51 **-75.25%**	97.13 **-82.23%**
	QUIC BBR	24.96	24.98 **+0.07%**	24.09 **-3.50%**	25.35 **+1.54%**	84.76	92.86 **+9.56%**	102.92 **+21.41%**	115.18 **+35.88%**

Discussion about results

Results could have been expected:

CUBIC : loss based

➔ SWF hides loss

- ➢ CUBIC does not reduce its congestion window

BBR: time based

➔ SWF is almost a UDP congestion flow for BBR

- ➢ BBR reduces its congestion window to avoid “SWF congestion”

Conclusion

SWF improve download time depending on the congestion control

If applied on all flows:

➢ Would help CUBIC flows

➢ Popular services, like Google or Facebook, would be negatively affected

➡ Need to detect the congestion control to only apply SWF on specific flows

Annexes

Ideal scenario

Ideal Scenario			TCP/CUBIC median download time (s)	TCP/CUBIC standard deviation (s)	QUIC/BBR median download time (s)	QUIC/BBR standard deviation (s)
without SWF with Hystart		1 flow	21.27	3.81	17.38	0.13
		5 flows	65.67	10.26	76.63	11.18
without SWF without Hystart		1 flow	17.84	0.34	19.24	7.36
		5 flows	65.29	8.73	76.18	11.26
TCP w/o Hystart and QUIC with Hystart	w/o SWF with tunnel	1 flow	17.94	0.34	17.66	0.14
		5 flows	66.73	7.83	75.97	11.93
	$S_{(10,100)}$	1 flow	19.04	0.34	19.23	0.15
		5 flows	73.02	10.28	86.15	13.86
	$S_{(5,100)}$	1 flow	20.17	0.32	20.73	0.14
		5 flows	79.78	9.00	93.98	15.47
	$S_{(2,100)}$	1 flow	24.12	0.29	25.32	0.10
		5 flows	96.26	9.67	116.54	17.44

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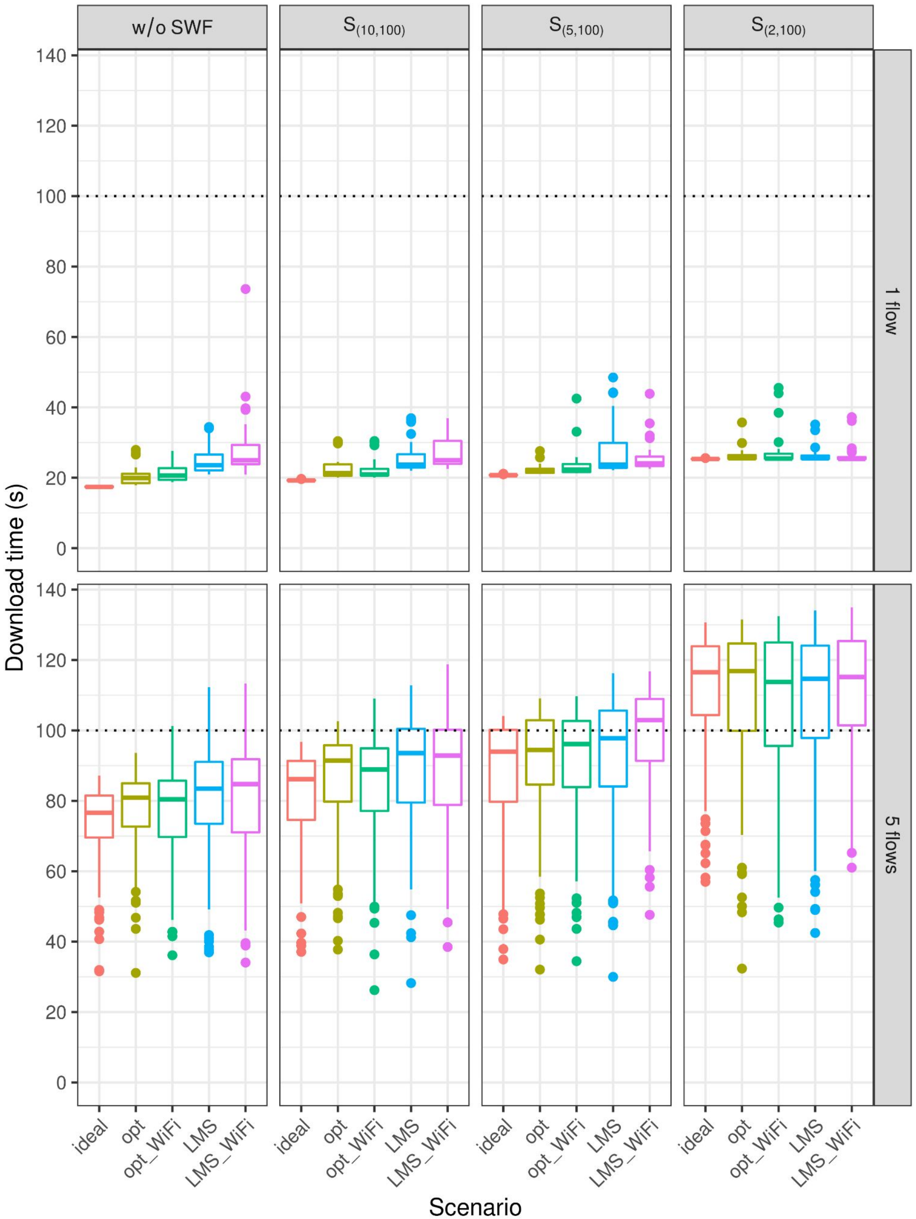
QUIC/BBR



TCP/CUBIC