Understanding L4S for WiFi

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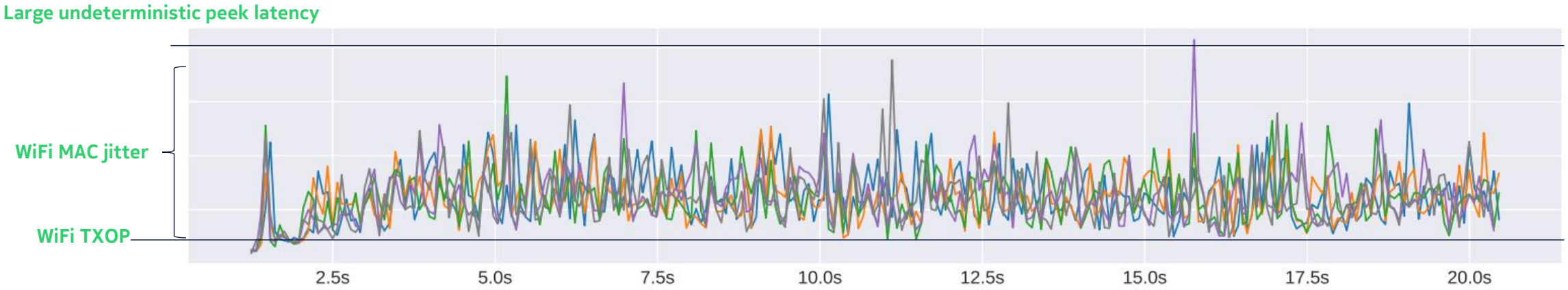
2 topics

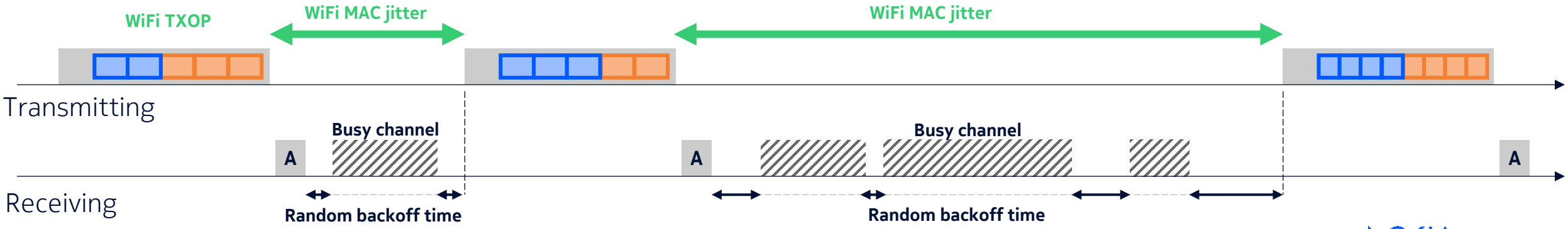
Can we adapt DualPI2 to WiFi MAC Latency?

Can we improve WiFi MAC Latency?

How to adapt the L4S AQM to the WiFi MAC?

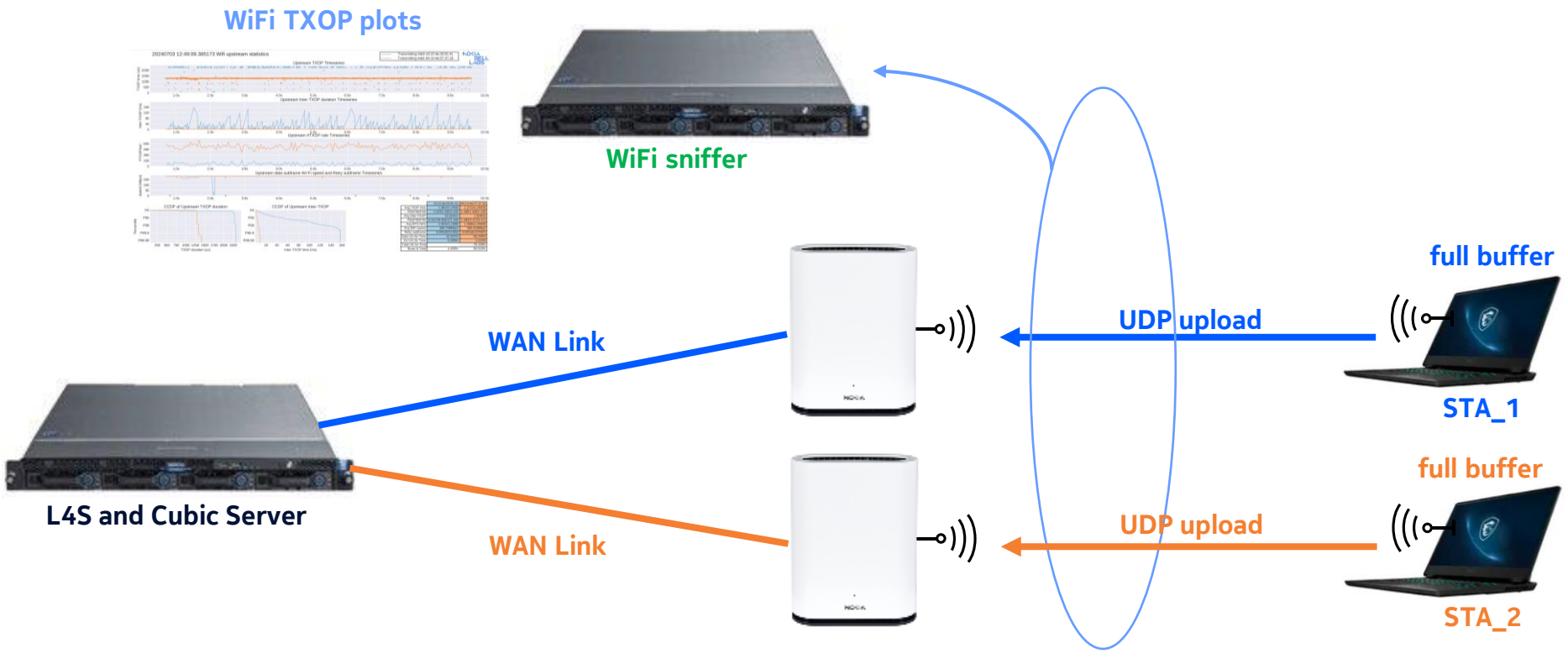
WiFi MAC latency exposed





Wi-Fi L4S Latency tests: Topology

WiFi Latency in congested (continuous contending) channel on 2 STAs, sending 200Mbps UDP (full buffer) in same channel

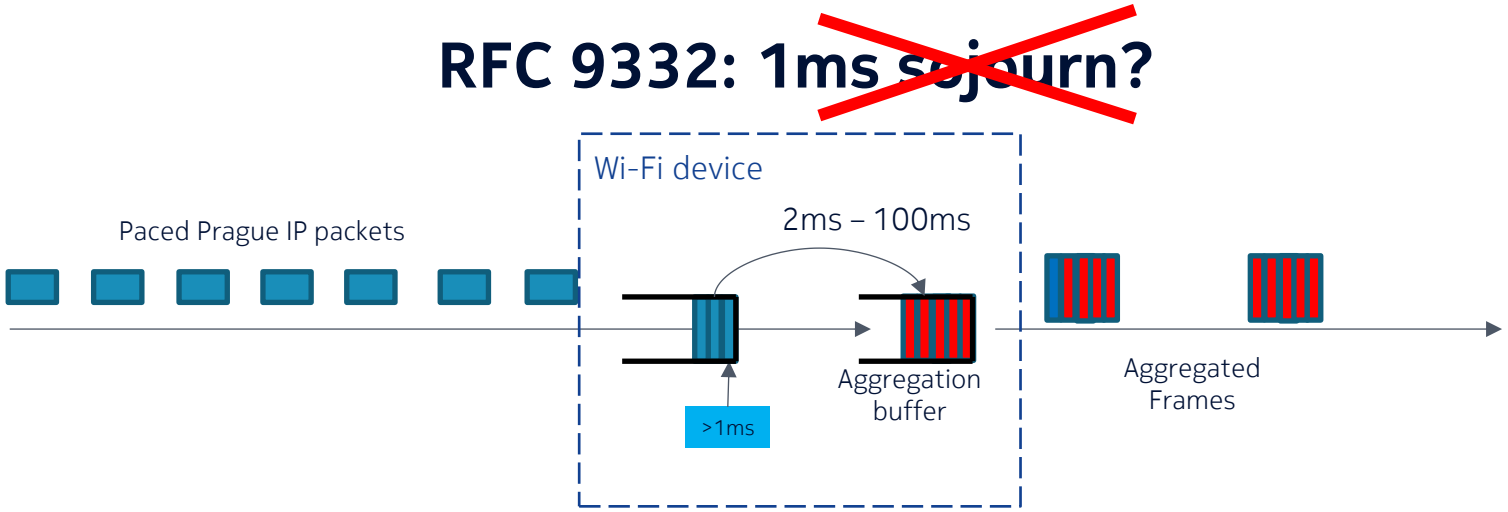


AC_BE: TXOP = 2.5ms & Inter-TXOP avg/peek = 5ms/100ms

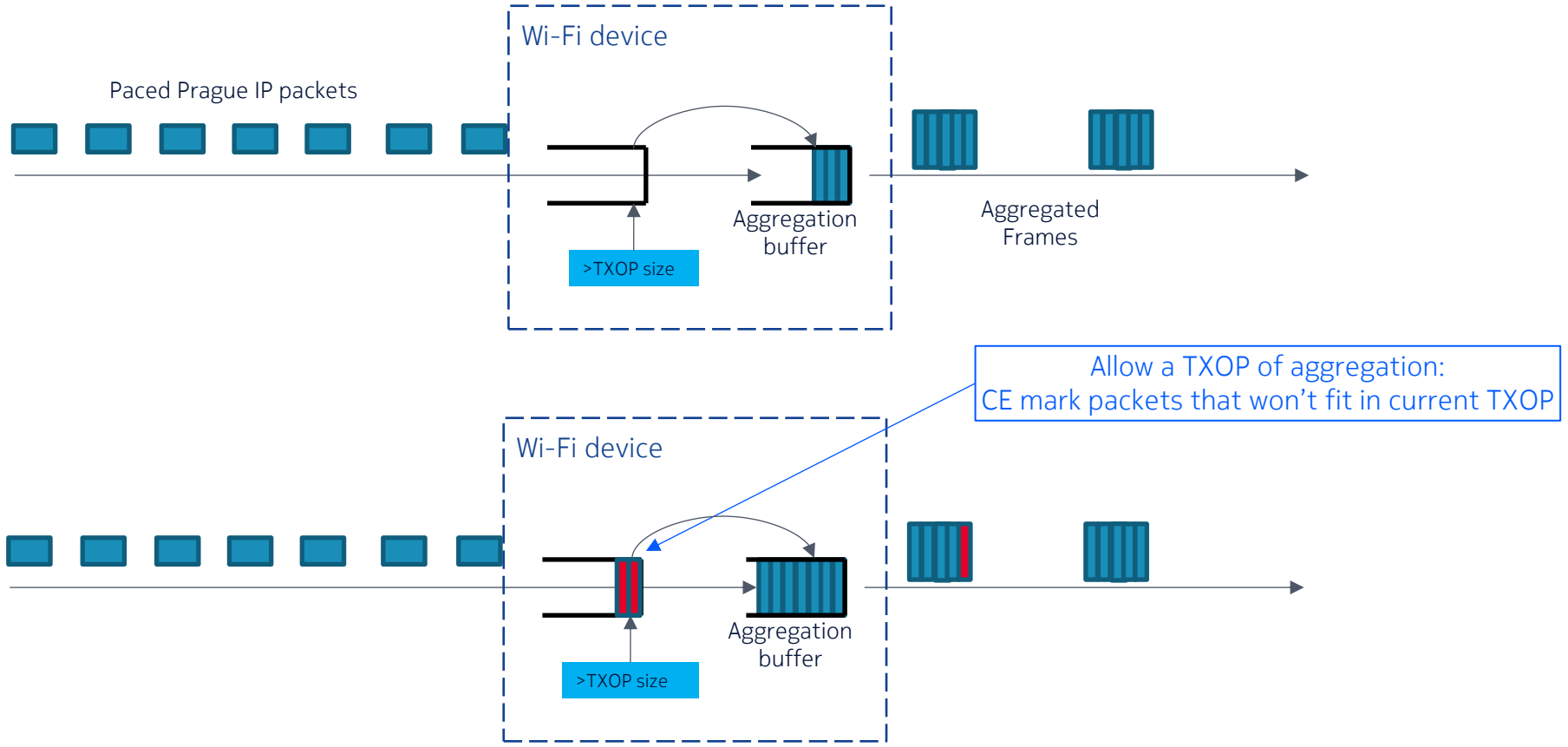
	c8:15:4e:d3:81:41	84:14:4d:07:37:26
Avg TXOP time	2.163ms (1849)	2.171ms (1769)
P50/P90/P99	2.285/2.285/2.326	2.285/2.285/2.326
Avg Inter-TXOP	5.163ms	5.396ms
P50/P90/P99	5.144/8.095/20.648	5.155/8.741/21.267
Avg RTS NAV	2.429ms (1800)	2.425ms (1755)
Avg WiFi speed	285.984Mbps	286.778Mbps
Retry subframe	0.01%(5/94171)	0.00%(1/90701)
Data US Air-Time	41.908%	40.236%
Ctrl US Air-Time	0.564%	0.545%
Total US Air-Time		83.253%
Bcast & Total	4.478%	90.309%

L4S using 1ms sojourn is not going to work at all…

All packets exceed 1ms sojourn, so different marking strategy



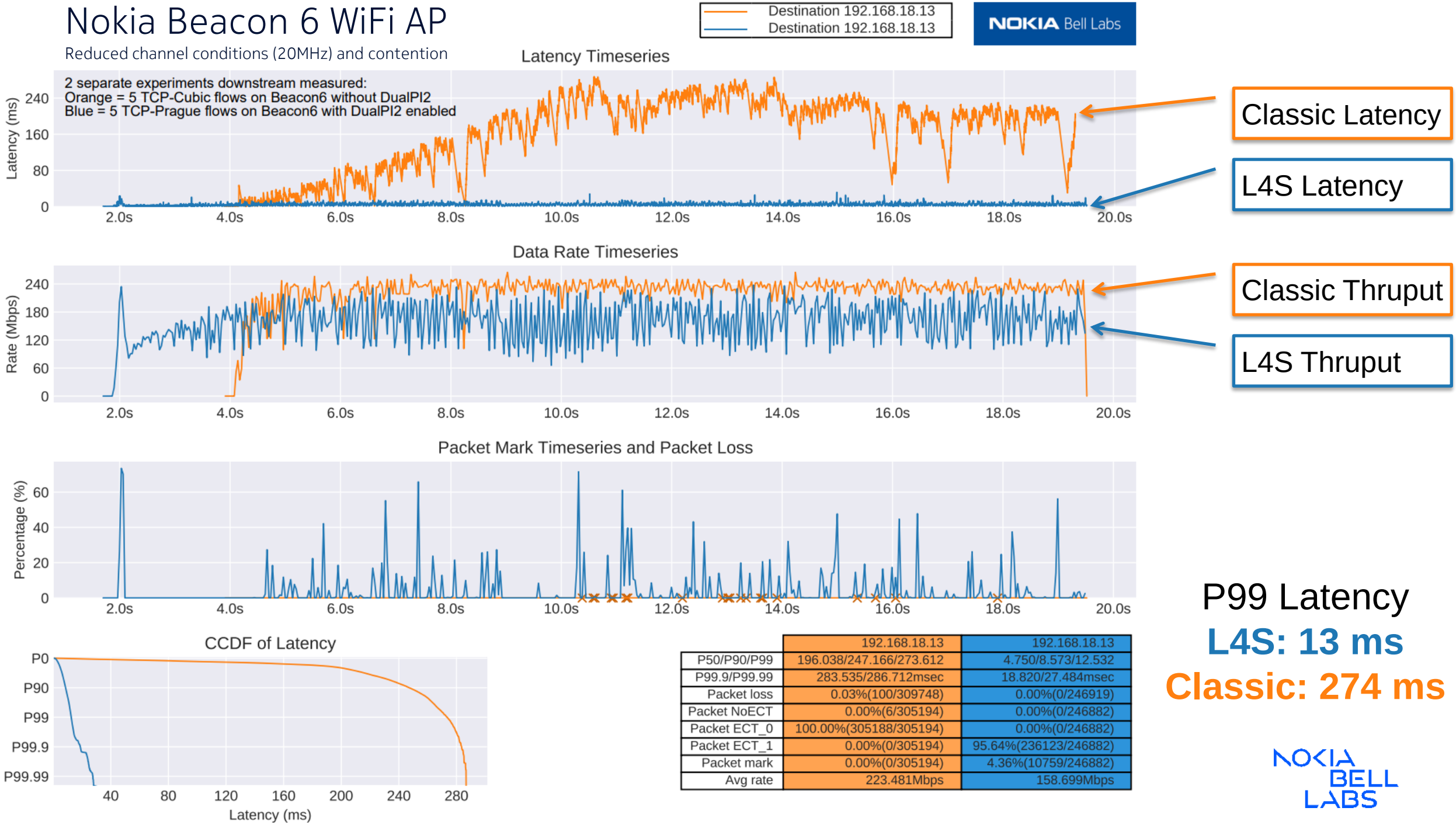
L4S AQM for Wi-Fi



AQM threshold set based on TXOP size = dependent on MCS and TXOP time

Nokia Beacon 6 WiFi AP

Reduced channel conditions (20MHz) and contention



	192.168.18.13	192.168.18.13
P50/P90/P99	196.038/247.166/273.612	4.750/8.573/12.532
P99.9/P99.99	283.535/286.712msec	18.820/27.484msec
Packet loss	0.03%(100/309748)	0.00%(0/246919)
Packet NoECT	0.00%(6/305194)	0.00%(0/246882)
Packet ECT_0	100.00%(305188/305194)	0.00%(0/246882)
Packet ECT_1	0.00%(0/305194)	95.64%(236123/246882)
Packet mark	0.00%(0/305194)	4.36%(10759/246882)
Avg rate	223.481Mbps	158.699Mbps

P99 Latency

L4S: 13 ms

Classic: 274 ms

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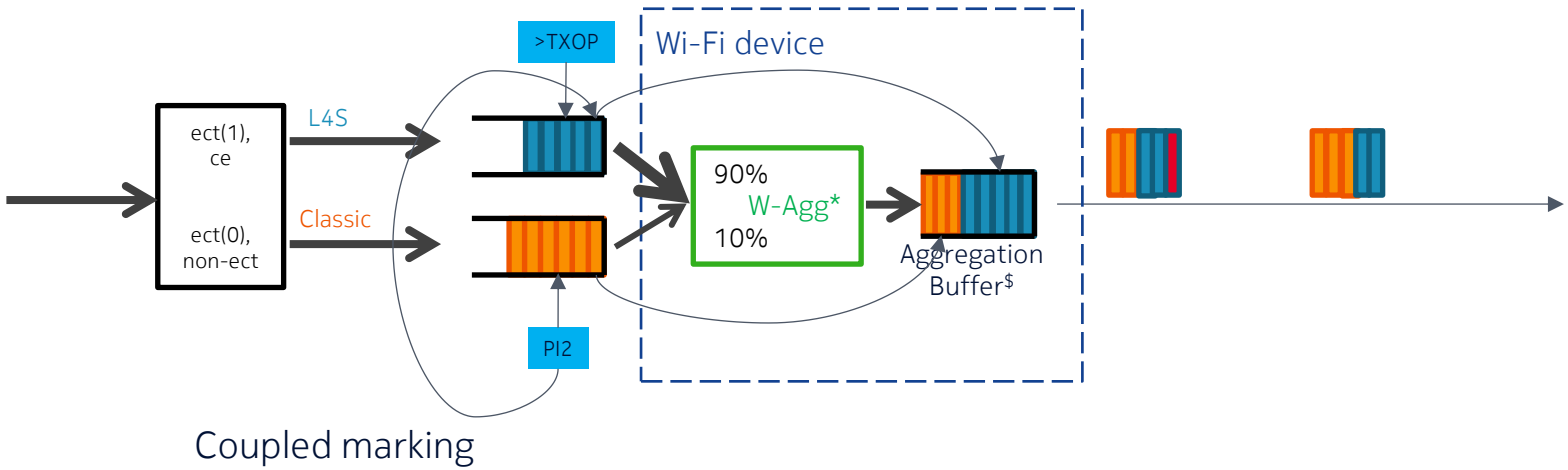
L4S Coupled AQM for Wi-Fi

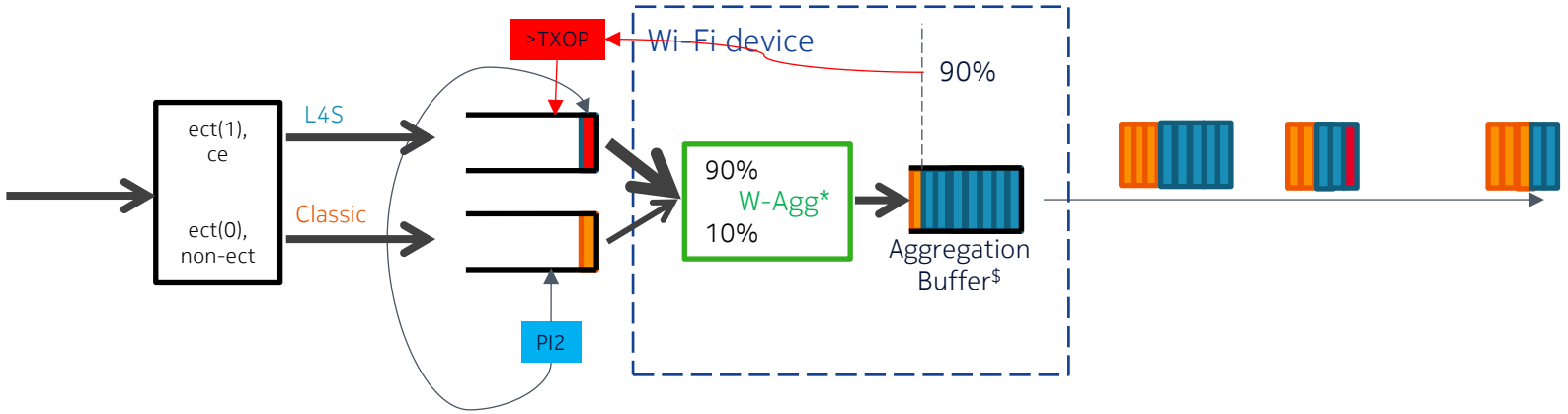
Loading L4S packets with priority, top-up with Classic packets



* W-Agg = a Weighted Aggregator, making sure that L4S can fill up to 90% of the next TXOP
$ Aggregation should optimally be limited to one TXOP

L4S Coupled AQM for Wi-Fi

Above 90% loaded, Classic Packets get priority and L4S AQM is triggered



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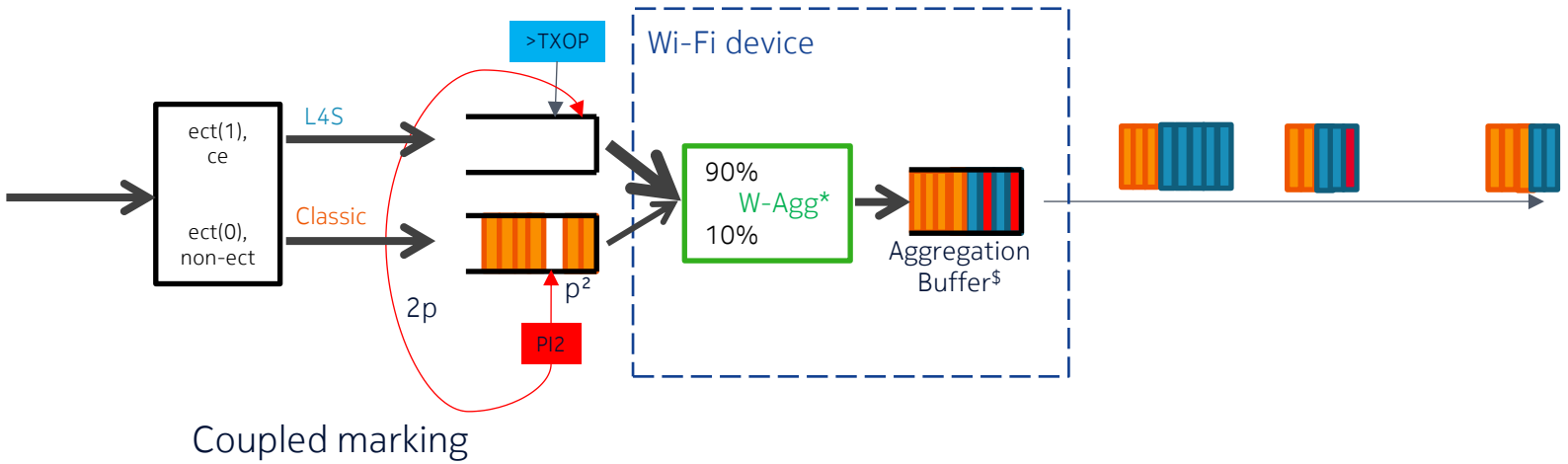
L4S Coupled AQM for Wi-Fi

If Classic AQM is triggered, also pushing back L4S with marks



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L4S is implementable and very important for Wi-Fi

Wi-Fi is very important for L4S

- L4S drastically reduces Latency-under-Load
  - Benefit is easily10x lower latencies
  - Cost is less than 2x rate reduction

- Proven technology
  - L4S in Nokia Wi-Fi APs since 2019 on top of many existing chipsets

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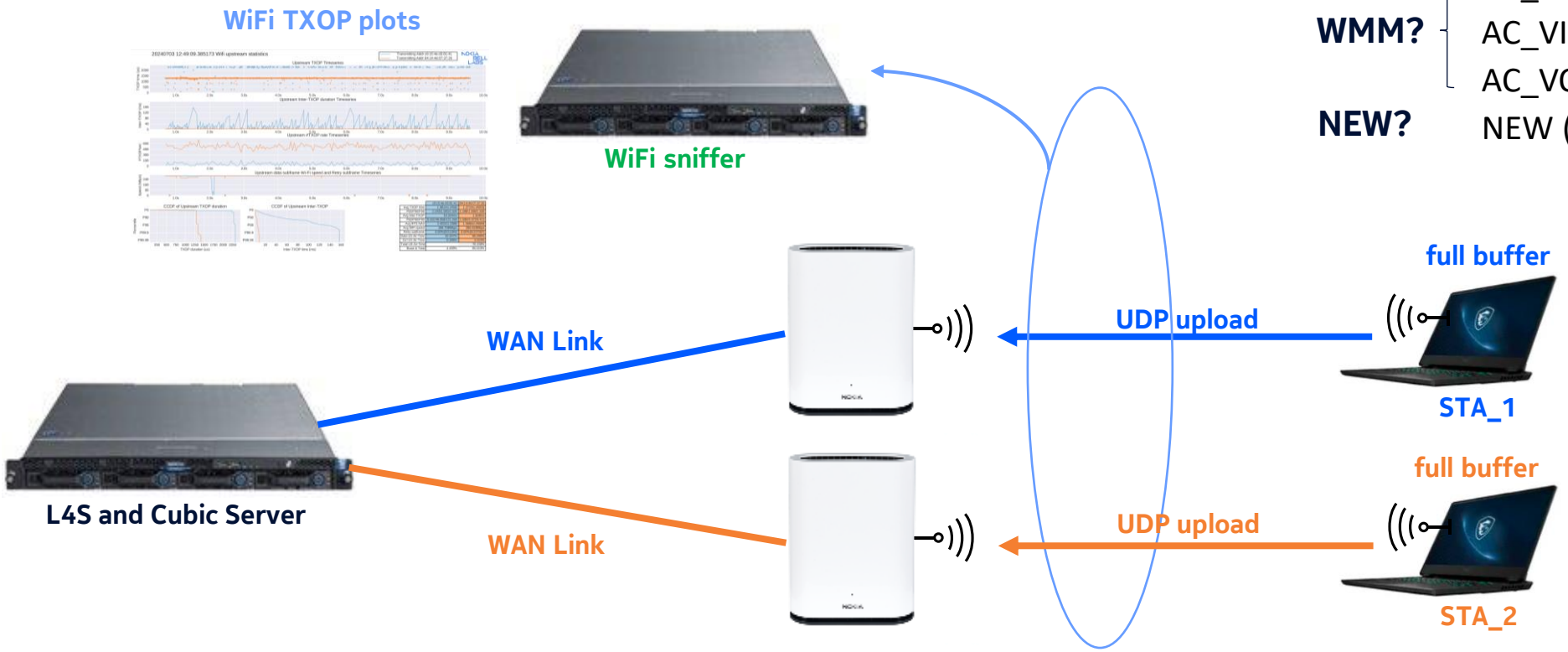
Wi-Fi L4S Latency tests: Topology with different EDCA configs

WiFi Latency in congested (continuous contending) channel on 2 STAs, sending 200Mbps UDP (full buffer) in same channel

EDCA configurations:

WMM?
- AC_BE (3/15/1023/2.5ms)
- AC_VI (2/7/15/3ms)
- AC_VO (2/3/7/1.5ms)

NEW?
- NEW (1/15/15/1ms)



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AC_BE: TXOP = 2.5ms & Inter-TXOP avg/peek = 5ms/100ms

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EDCA configurations:

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- AC_VI (2/7/15/3ms)
- AC_VO (2/3/7/1.5ms)
- NEW (1/15/15/1ms)

AC_VI: TXOP = 3ms & Inter-TXOP avg/peek = 6ms/30ms

	c8:15:4e:d3:81:41	84:14:4d:07:37:26
Avg TXOP time	2.625ms (1468)	2.633ms (1508)
P50/P90/P99	2.783/2.783/2.824	2.783/2.783/2.824
Avg Inter-TXOP	6.325ms	6.153ms
P50/P90/P99	6.123/11.007/17.475	6.114/9.568/18.450
Avg RTS NAV	2.914ms (1425)	2.925ms (1504)
Avg WiFi speed	286.763Mbps	286.800Mbps
Retry subframe	0.00%(3/91321)	0.00%(1/94096)
Data US Air-Time	41.524%	42.777%
Ctrl US Air-Time	0.493%	0.525%
Total US Air-Time		85.320%
Bcast & Total	4.327%	91.873%

EDCA configurations:

- AC_BE (3/15/1023/2.5ms)
- AC_VI (2/7/15/3ms)
- AC_VO (2/3/7/1.5ms)
- NEW (1/15/15/1ms)

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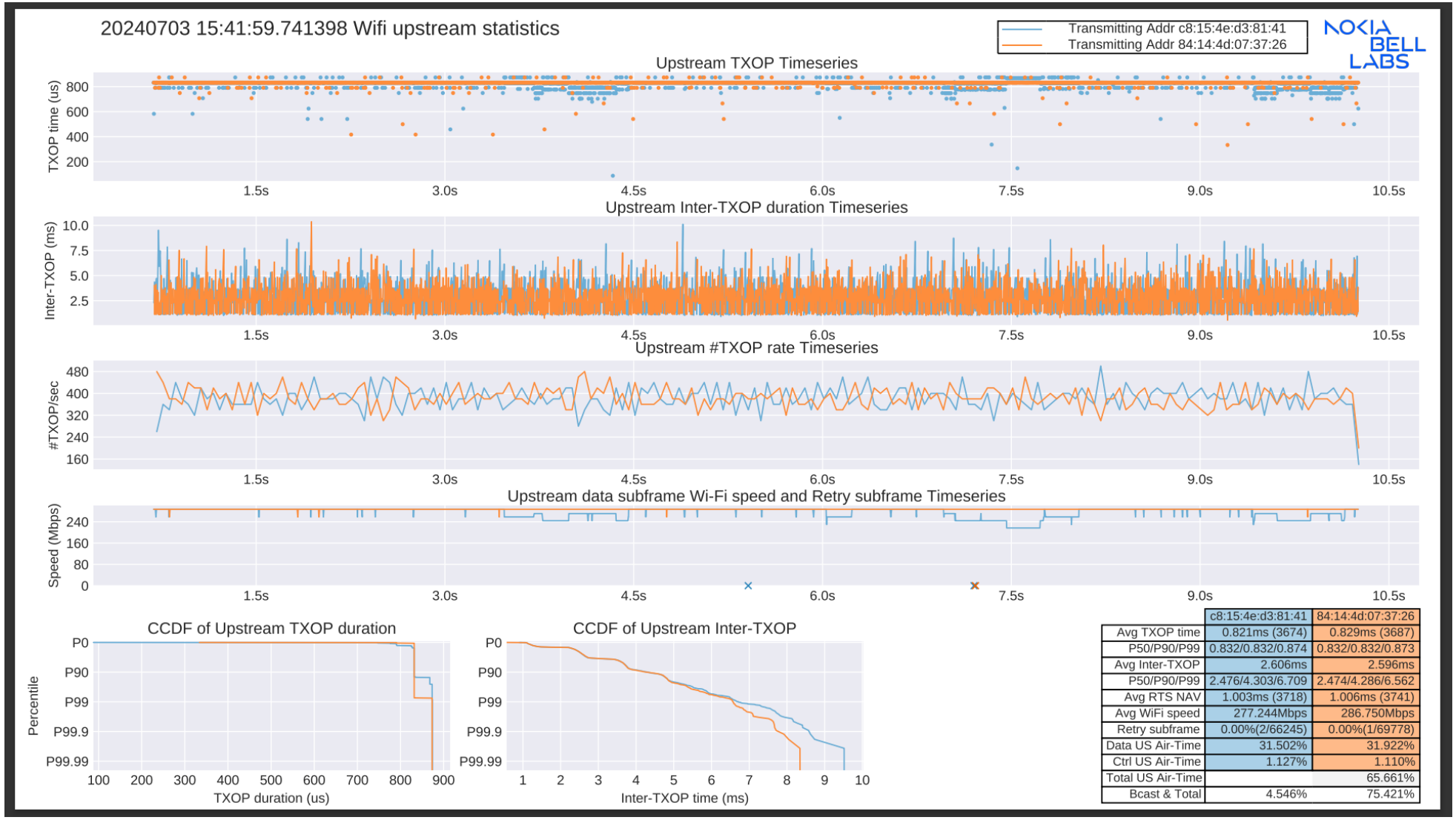
AC_VO: TXOP = 1.5ms & Inter-TXOP avg/peek = 3ms/15ms

	c8:15:4e:d3:81:41	84:14:4d:07:37:26
Avg TXOP time	1.247ms (2622)	1.258ms (2646)
P50/P90/P99	1.288/1.288/1.330	1.288/1.288/1.330
Avg Inter-TXOP	3.421ms	3.390ms
P50/P90/P99	3.149/5.301/10.005	3.148/5.158/9.494
Avg RTS NAV	1.453ms (2645)	1.456ms (2891)
Avg WiFi speed	285.345Mbps	285.957Mbps
Retry subframe	0.00%(0/75624)	0.00%(0/77216)
Data US Air-Time	36.455%	37.106%
Ctrl US Air-Time	1.039%	1.166%
Total US Air-Time		75.766%
Bcast & Total	4.426%	84.420%

EDCA configurations:

- AC_BE (3/15/1023/2.5ms)
- AC_VI (2/7/15/3ms)
- AC_VO (2/3/7/1.5ms)
- NEW (1/15/15/1ms)

NEW: TXOP = 1ms & Inter-TXOP avg/peek = 2ms/10ms



	c8:15:4e:d3:81:41	84:14:4d:07:37:26
Avg TXOP time	0.821ms (3674)	0.829ms (3687)
P50/P90/P99	0.832/0.832/0.874	0.832/0.832/0.873
Avg Inter-TXOP	2.606ms	2.596ms
P50/P90/P99	2.476/4.303/6.709	2.474/4.286/6.562
Avg RTS NAV	1.003ms (3718)	1.006ms (3741)
Avg WiFi speed	277.244Mbps	286.750Mbps
Retry subframe	0.00%(2/66245)	0.00%(1/69778)
Data US Air-Time	31.502%	31.922%
Ctrl US Air-Time	1.127%	1.110%
Total US Air-Time		65.661%
Bcast & Total	4.546%	75.421%

EDCA configurations:

- AC_BE (3/15/1023/2.5ms)
- AC_VI (2/7/15/3ms)
- AC_VO (2/3/7/1.5ms)
- NEW (1/15/15/1ms)

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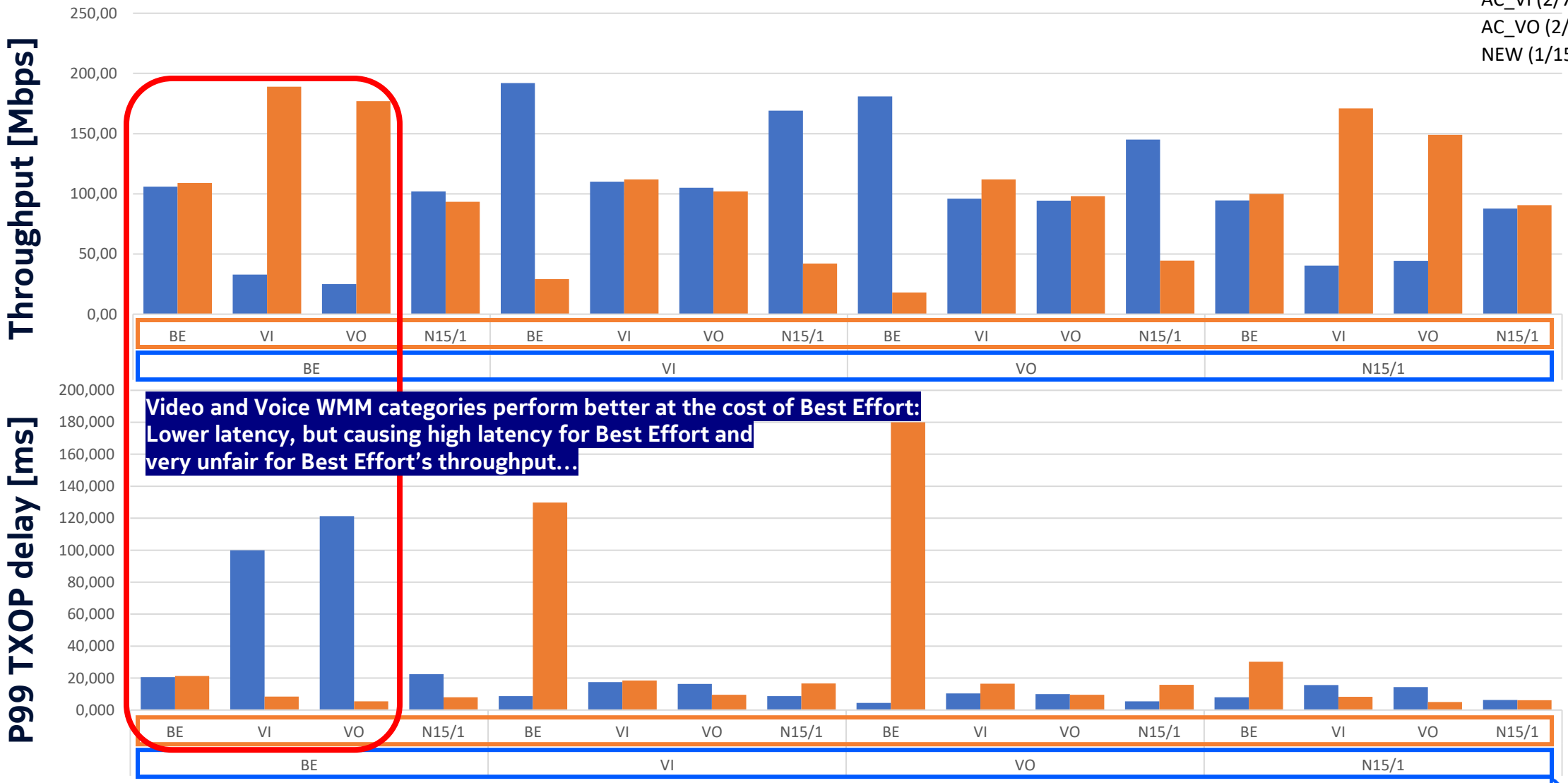
Overview of all combinations

EDCA configurations:
AC_BE (3/15/1023/2.5ms)
AC_VI (2/7/15/3ms)
AC_VO (2/3/7/1.5ms)
NEW (1/15/15/1ms)



Video and Voice WMM categories perform better at the cost of Best Effort: Lower latency, but causing high latency for Best Effort and very unfair for Best Effort's throughput…

Overview of all combinations

EDCA configurations:
- AC_BE (3/15/1023/2.5ms)
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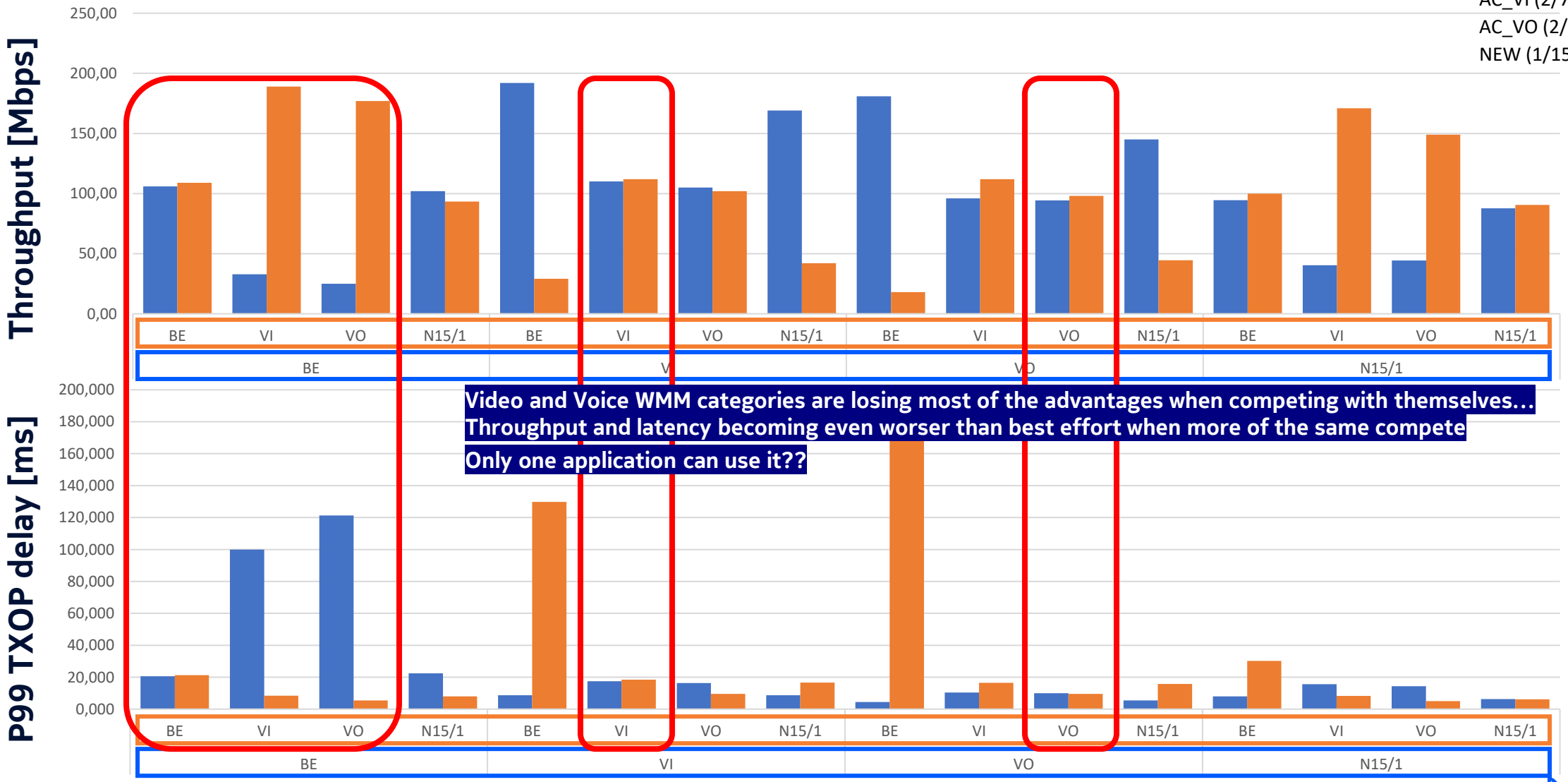

Overview of all combinations

EDCA configurations:
AC_BE (3/15/1023/2.5ms)
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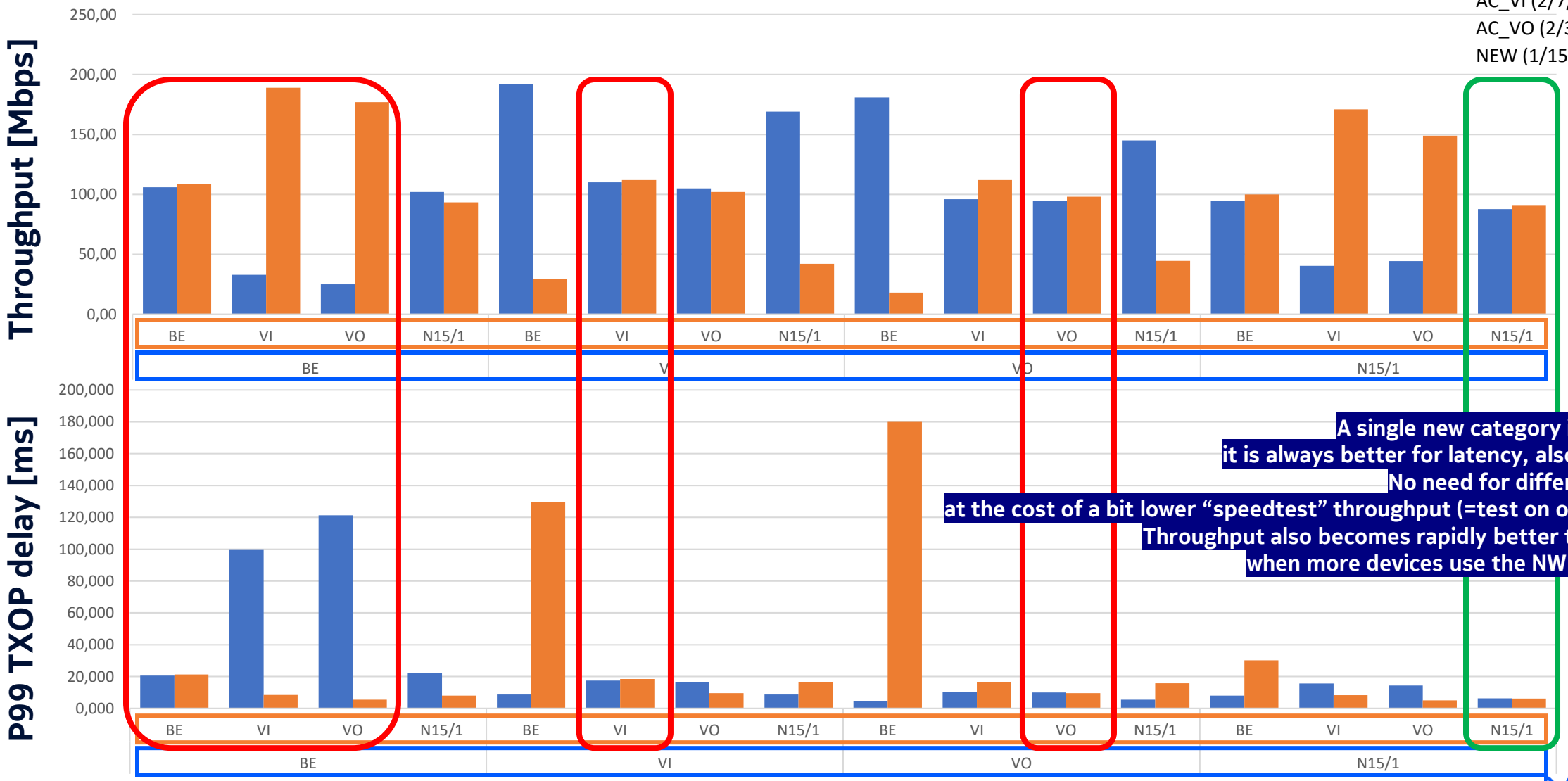

A single new category is enough:
it is always better for latency, also for itself
No need for differentiation,
at the cost of a bit lower "speedtest" throughput (=test on one device)
Throughput also becomes rapidly better than WMM
when more devices use the NW in parallel

Overview of all combinations

EDCA configurations:
AC_BE (3/15/1023/2.5ms)
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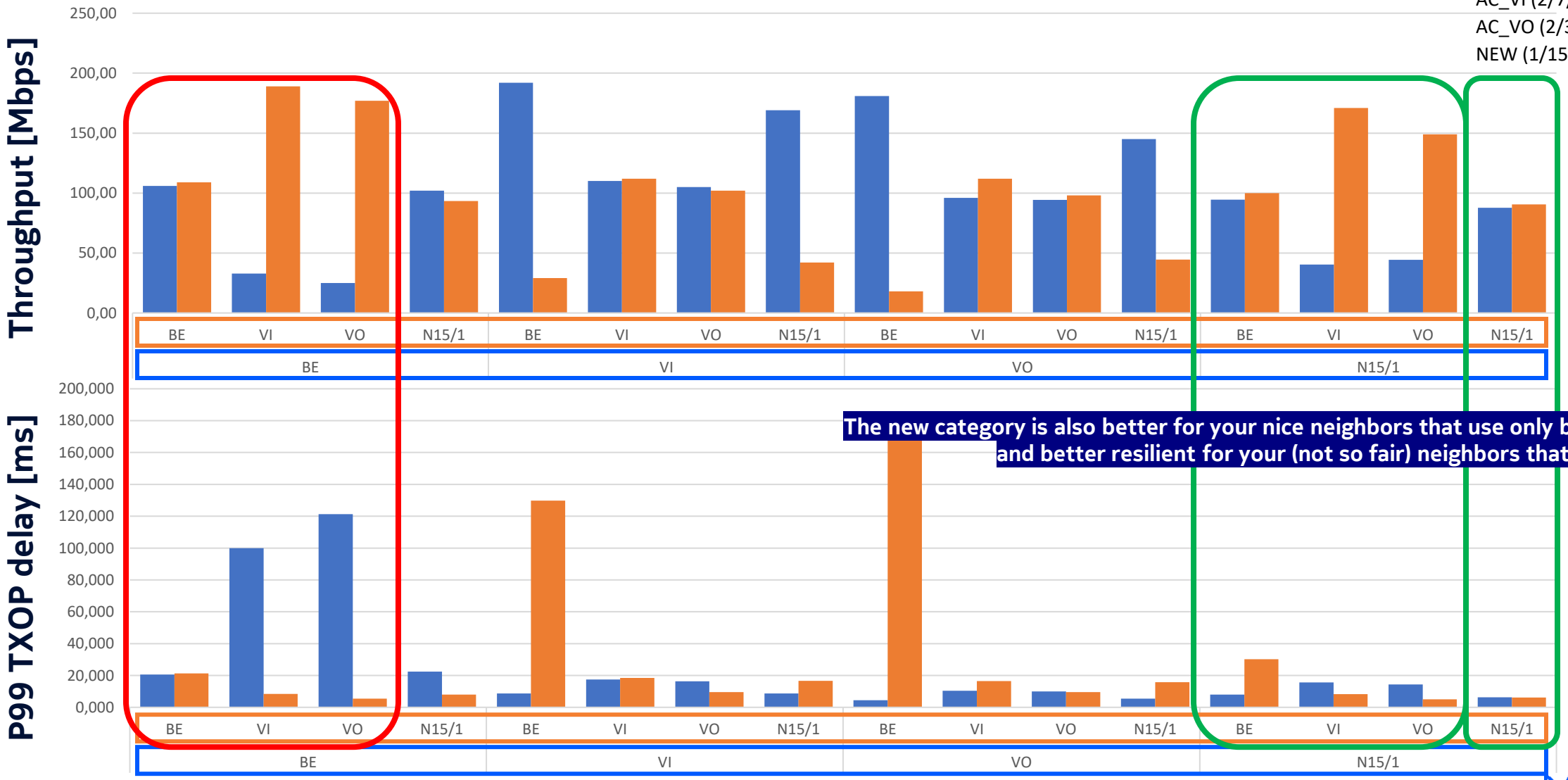
NEW (1/15/15/1ms)



The new category is also better for your nice neighbors that use only best effort and better resilient for your (not so fair) neighbors that use WMM

Conclusion?

Forget WMM: (avoid using AC_VI and AC_VO ?)

Very unfair and not a scalable solution!

Part of the problem, not the solution…

Define better MAC,

Rethink MAC with lowest Latency and jitter as objective

instead of highest Throughput

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Understanding L4S for WiFi

Questions?

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Low Loss, Low Latency and Scalable Throughput
RFC 9330, RFC 9331 and RFC 9332

Linux Open-Source repository, many contributors

L4STeam/linux: Kernel for TCP Prague and Dualpi2 (github.com)
L4STeam/udp_prague: Prague congestion control protocol for UDP-based very interactive apps

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