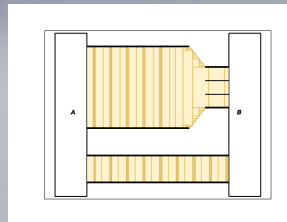


xfinity 10G

Comcast L4S Field Trial Update

12 December 2023

Presented by Jason Livingood



COMCAST

Refresher: DOCSIS and L4S/NQB



- Both queues share the same **capacity**
- Both queues are best effort **priority**
- Classifier function examines ECN and DSCP fields of packet header to select queue & can also provide queue protection
- L4S and NQB are implemented in DOCSIS, but can also be implemented in any network (5G, LEO, DSL, FTTP, etc.)

Low Latency Networking Trial: **How**

Technical Requirements:

- User connected to virtual CMTS platform (vCMTS)
- Compatible cable modem, both ISP-provided and COAM:
 - Xfinity XB8 or XB7
 - Arris S33
 - Netgear CM1000v2
- Can be located anywhere in the network geographically
- Unprecedented customer interest – several thousand volunteers
- Several waves: employees, then customer waves 1 & 2 (July, August, October)

Low Latency Networking Trial: High Level Timing

Phase 1 – July to October 2023 (Upstream + US/DS WLAN)

- Upstream support in cable modem for L4S and NQB [1]
- Upstream & downstream support for WiFi LAN (WMM: AC_VI) in XB devices [2]
- End-to-end marking use of ECN upstream & downstream – no bleaching [3]
- Manual provisioning of each cable modem (1.2 Gbps / 35 Mbps)
- Test end-to-end DSCP-45 with one network peer

Phase 2 – November 2023 – February 2023 (Downstream + Automation + Peer Edge)

- Automated provisioning (re-provision all existing customers – wide range of tiers to be tested)
- Downstream support in CMTS for L4S and NQB [4]
- Expand DSCP-45 support to all peers

[1] ECT(1), CE, and DSCP-40, 45, 46, 56 will trigger LL classification

[2] ECT(1), CE, and DSCP-45 initially, Q4 support for DSCP-40, 46, 56

[3] 100% of CMTS Service Class Names (SCNs) had to be fixed & fix DSCP leak (CS1->WMM AC_BK). Initial ECN testing was upstream – issue was discovered downstream.

[4] Features spread across two software releases

Low Latency Networking Trial: **How**

Customers Assigned Structured Weekly Activities:

1. Continue normal usage & report any issues
2. General performance tests & Apple network quality tests with L4S enabled
3. Mac: Facetime, Windows: LL DNS
4. Valve gaming, Xbox gaming

Customers submit survey forms with results for each test.

Customers also volunteered to host probes from RIPE Atlas, SamKnows, University of Chicago NetMicroscope, CableLabs.

See weekly test details at <https://github.com/jlivingood/IETF-L4S-Deployment>

High Level Observations

- No classic queue starvation issues observed (open to additional test suggestions)
- Working as expected so far – one app has identified excessive CE marking that will be fixed in an app update
- Cloud-native interactive applications seem to improve more than “legacy” apps
- More field trial work planned the next 90 days...

Next slides: some specific numbers...

Low Latency Networking Trial: **Milestones**

- 1st employee modem provisioned 7/11/23
- 1st customer modem 8/14/23
- 1st interdomain DSCP-45 packets 10/5/23 (with Valve)
- 2nd group of customers in Wave 2 added 10/11/23

Bringing total to ~200 customers

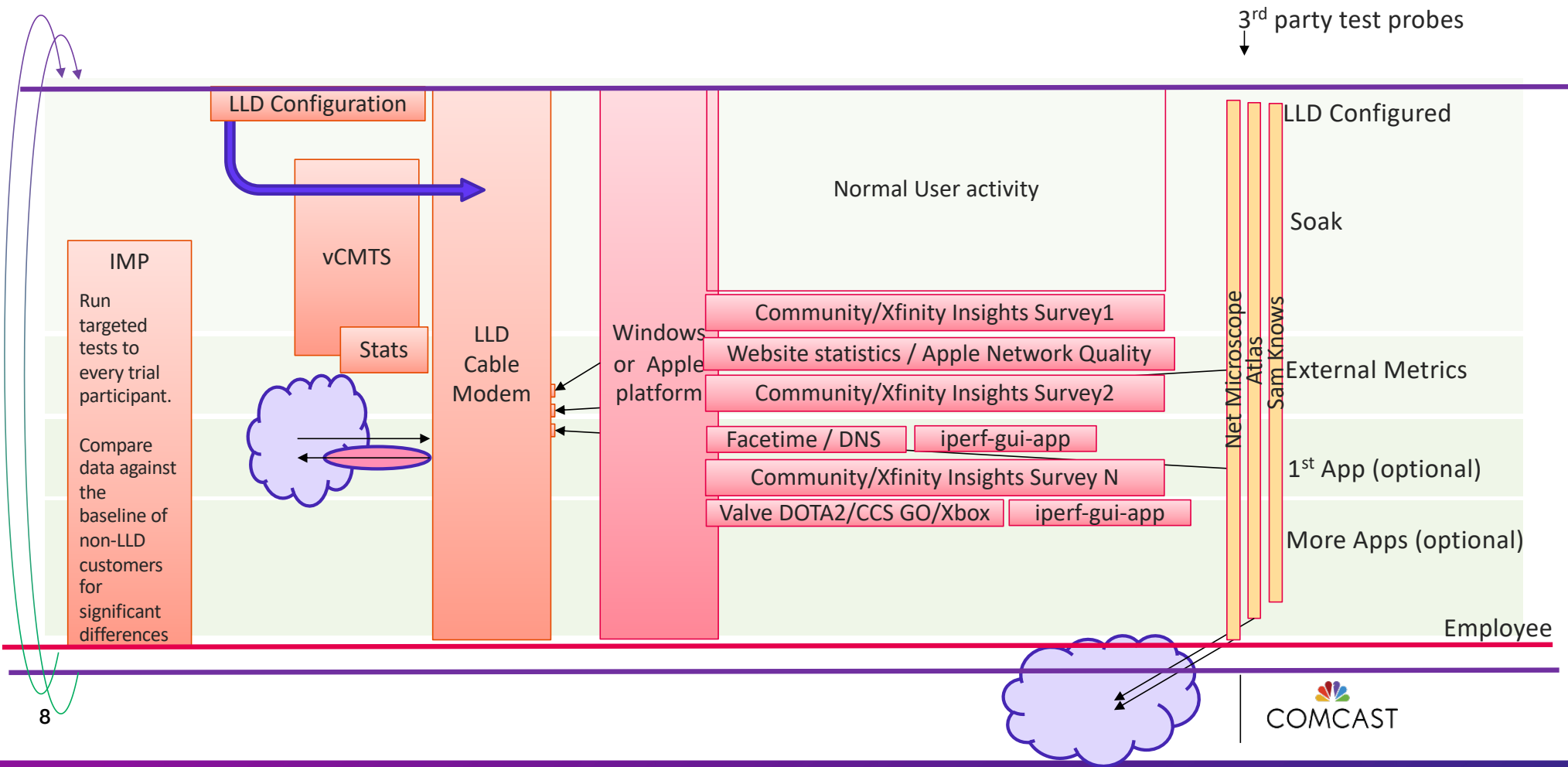
0xb7 = 101101 = NQB, DSCP-45 with CE mark

06:11:19.495711 IP (tos 0xb7,CE, ttl 108, id 64623, offset 0, flags [none], proto UDP (17), length 186)
98.52.200.237.59119 > 205.196.6.213.27027: UDP, length 158

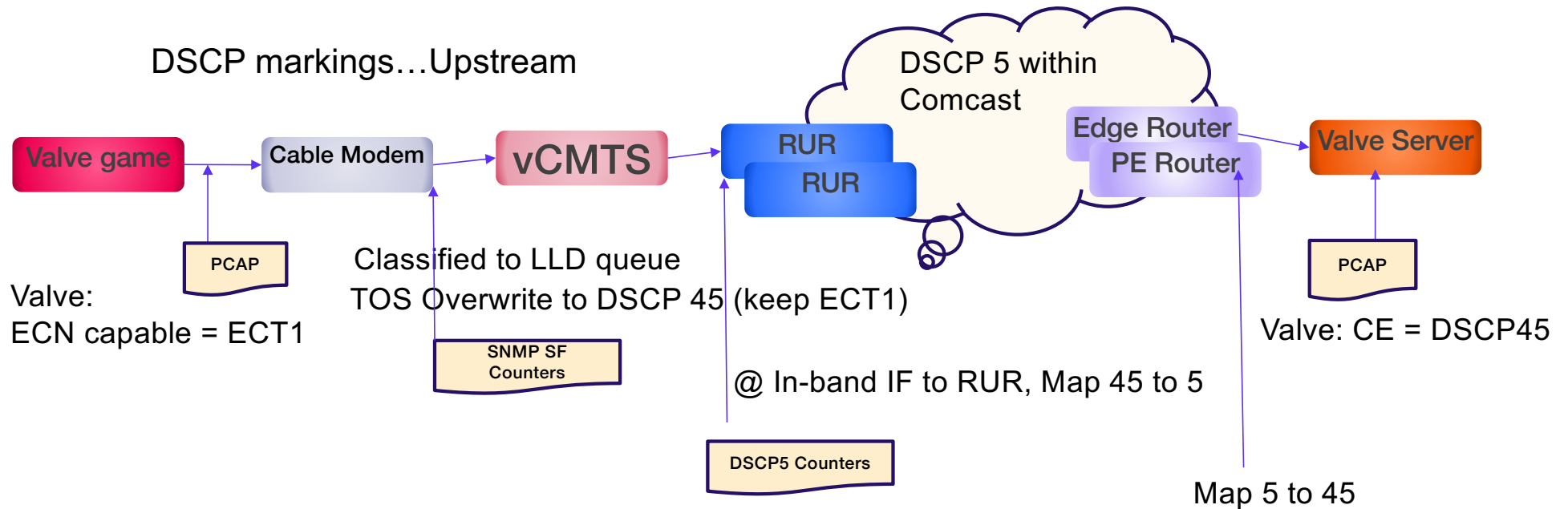
0xb5 = 10110101 = NQB, DSCP-45 with ECT(1) mark

06:11:19.639254 IP (tos 0xb5,ECT(1), ttl 108, id 64627, offset 0, flags [none], proto UDP (17), length 186)
98.52.200.237.59119 > 205.196.6.213.27027: UDP, length 158

Approach to Test & Measurement



End-to-End NQB Marking Test (DSCP-45)



IMP US LLD Results --> 50%+ lag reduction

LLD Production Testing

About the Testing

This dashboard represents the data acquired from **Ultra-Low-Latency (ULL)** tests run on the list of employee and customer devices participating in the **Low-Latency-DOCSIS (LLD)** trial. Devices must be at a firmware version of at least 6.5 and either CGM4331COM (TCH XB7) or CGM4981COM (TCH XB8).

Each device will have six runs per day. One run consists of three different IMP measurements:

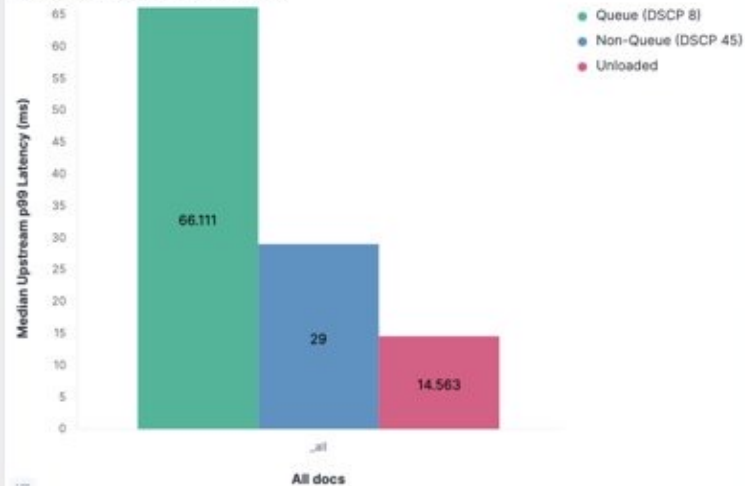
1. Latency-only DSCP 8
2. Latency-only DSCP 45
3. ULL upstream with DSCP 8 and 45

The latencies from the ULL measurements represent the Netperf metrics collected while consuming 100% of the device's upstream bandwidth. In contrast, the latency-only measurements do not congest the upstream bandwidth at all. We focus on the 99th percentile latency as that is the most accurate metric for determining customer experience.

About the Results

We look into standard bandwidth metrics such as PoA (percent of the advertised tier reached). Most importantly, we want to analyze the performances between queue (DSCP 8) and non-queue building (DSCP 45) upstream loaded latencies.

Overall Median Upstream p99 Latencies



Unique Device Count - No Errors

30

CGM4331COM -

8

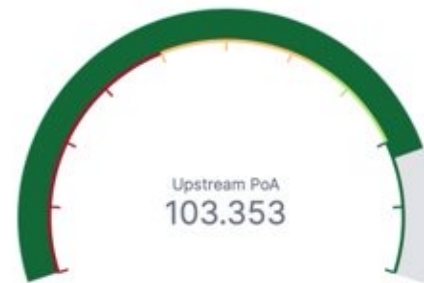
CGM4981COM -

Total ULL Test Count

4,752

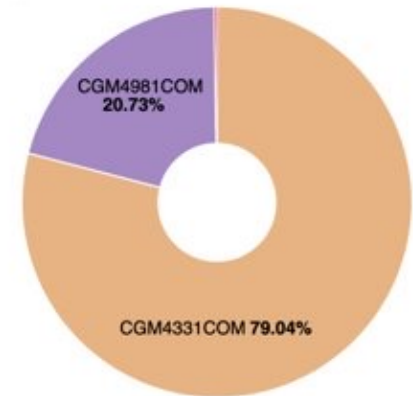
Total Test Count - No Errors

Upstream Avg PoA: ratio of actual to advertised speeds



Upstream PoA

Device Type Distribution of All Tests





**GEFORCE
NOW**

Lag Spikes ~20 ms vs 225 ms!

SUMMARY:

NVIDIA EXPERIMENTS WITH DIFFERENT MARKING

Low Latency Queue

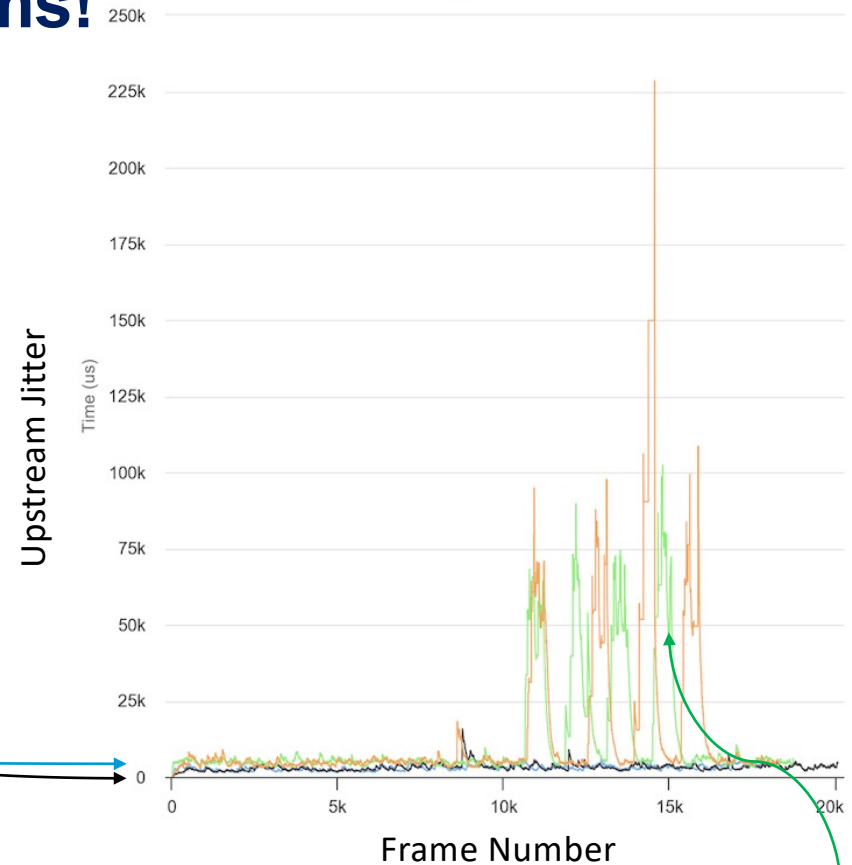
- Significantly lower jitter – MUCH more consistent and reliable QoE
- Very low working latency for classic traffic AND low latency traffic
- Strong independent validation
- Makes cloud gaming truly viable

L4S ECT(1) flows show nominal latency increases

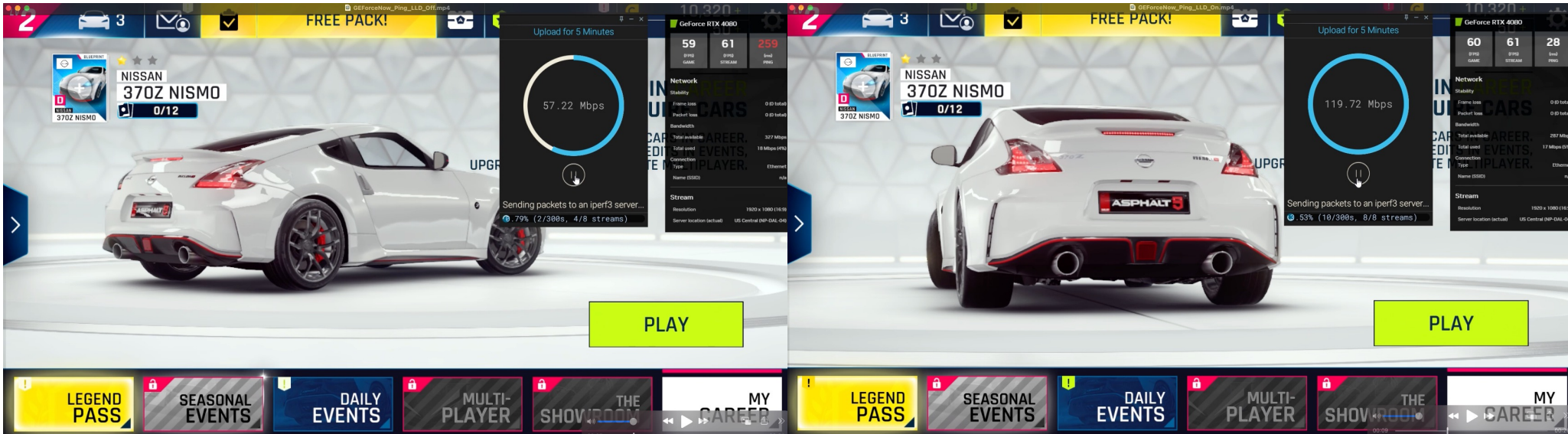
Flow Marking

- Orange = Downstream no marking – normal working conditions
- Green = Upstream no marking – normal working conditions
- Black & Blue = DS & US with LLD marking – normal working conditions

NVIDIA Working Latency



Flow loaded with classic queue traffic including several TCP file transfers with no L4S Congestion Experienced (CE) in DS vCMTS queues

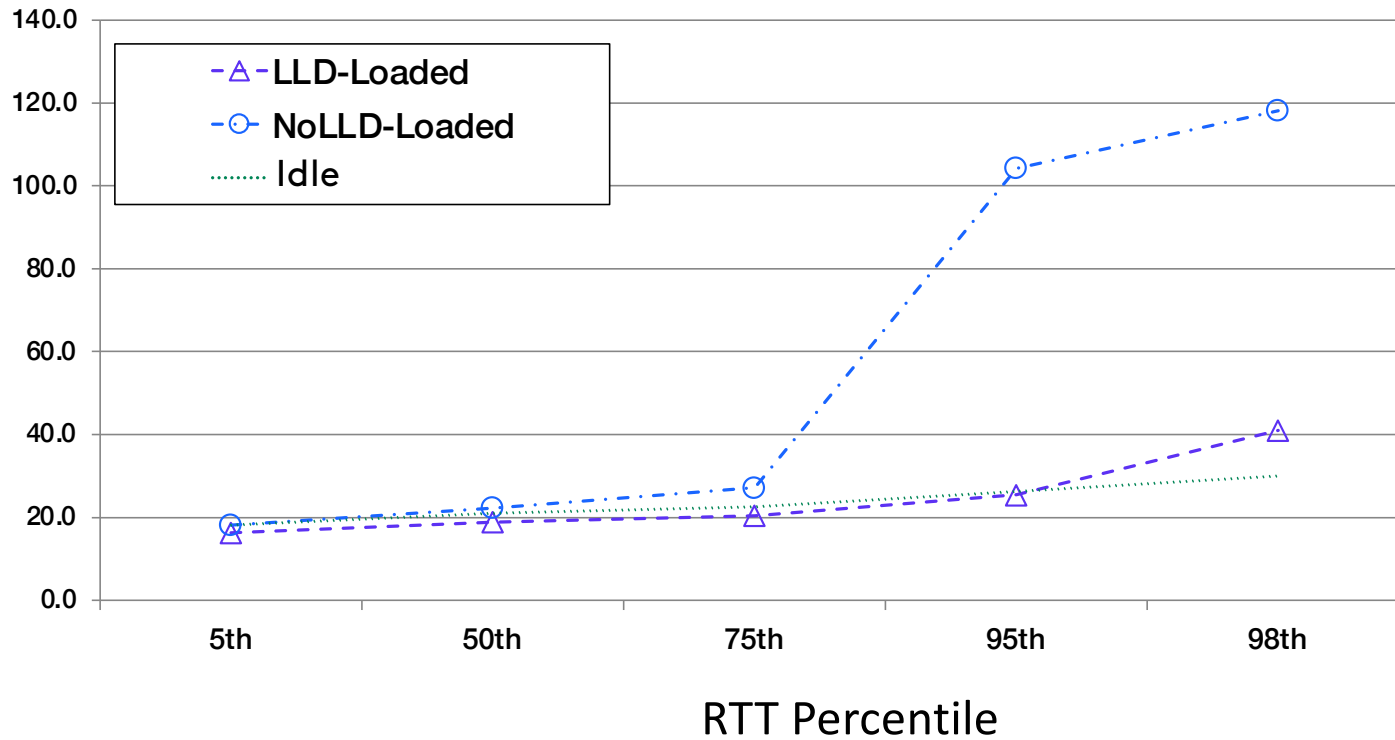


Example cloud game:

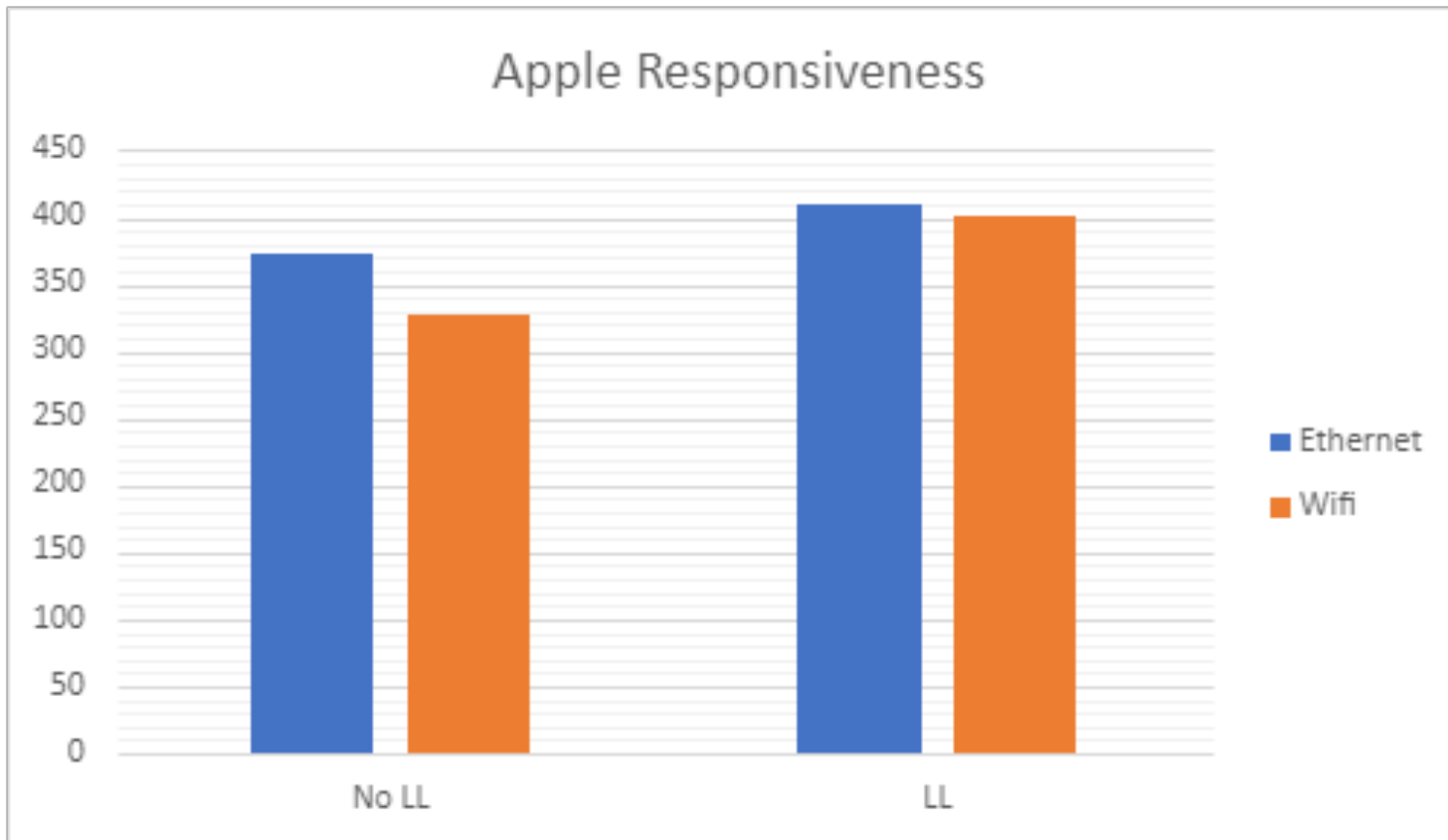
- Upstream traffic generator – creates bursty, variable upstream flows
- Left is without L4S – ping spiking to 259 ms, music & video out of sync and generally buffering
- Right is with L4S – stable ping and seamless QoE

Valve/Steam Counterstrike Results – Down to Roughly Idle!

Ping Distribution - End-to-End



Apple Network Quality Test



Classic queue testing

Working to collect L4S data

- 76 RPMs → 997 RPMs
- 250 RPMs → 967 RPMs
- 325 RPMs → 955 RPMs

University of Chicago NetMicroscope Platform

- Implemented a LUL test
- Pending implementation of DSCP or ECN marking to compare to baseline classic queue



SamKnows Platform

- Implemented the Apple Network Quality test
- Future implementation of DSCP marking to compare to baseline classic queue

Responsiveness - Uplink

Responsiveness - Uplink

1st Percentile ↓↑	Median ↓↑	99th Percentile ↓↑	Sample Count ↓↑
877.00 RPM	1682.00 RPM	4138.00 RPM	1617

Conclusions & Next Steps

- Testing to continue through March 2024
- Cable modem configuration updates coming soon
- Adding downstream dual queue (field validated 10/30/2023), automated provisioning, other OAM stuff needed to deploy & scale
- Still soliciting tests for users / applications – reach out if you'd like us to add something!
- Preparing to operationally scale to **millions** of users