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L4S: Low packet Loss and Low queuing Latency for Scalable throughput

Persistent Low Latency for the Metaverse

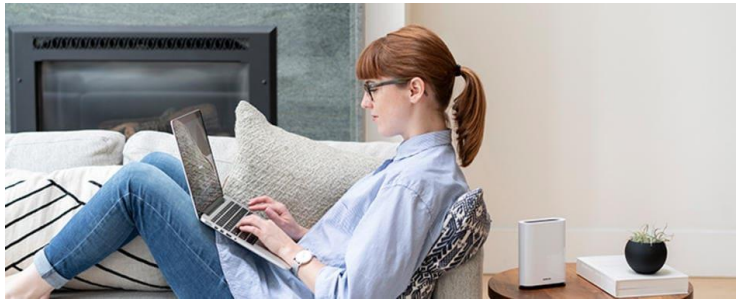
Koen De Schepper

November 2022

What problem is solved with L4S?

Why is video conferencing not working all the time perfectly??

Why are websites and documents in the cloud sometimes responding so slow??



Sometimes delays of seconds

Why is (cloud) gaming experience not optimal?

Sometimes lags of 100s of ms and freezes of seconds

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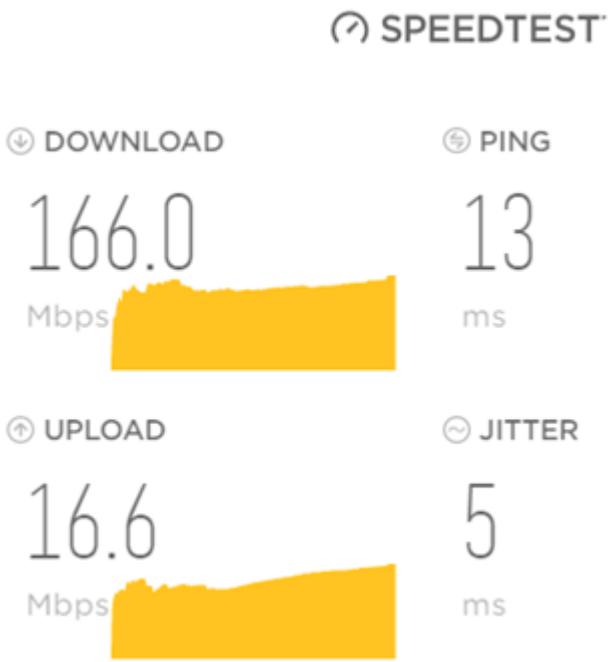
What is the reason?

Throughput?

enough available to support a lot of applications, but still…



Latency?

we develop networks with lower and lower latency capabilities, but still…

latency stays the major problem for home workers and gamers

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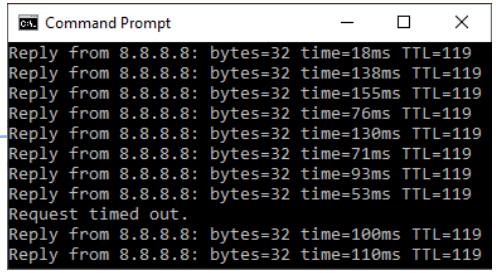
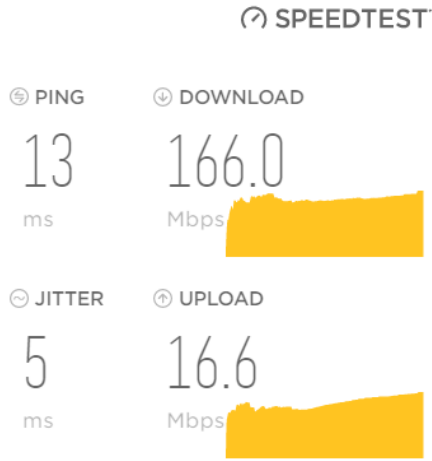
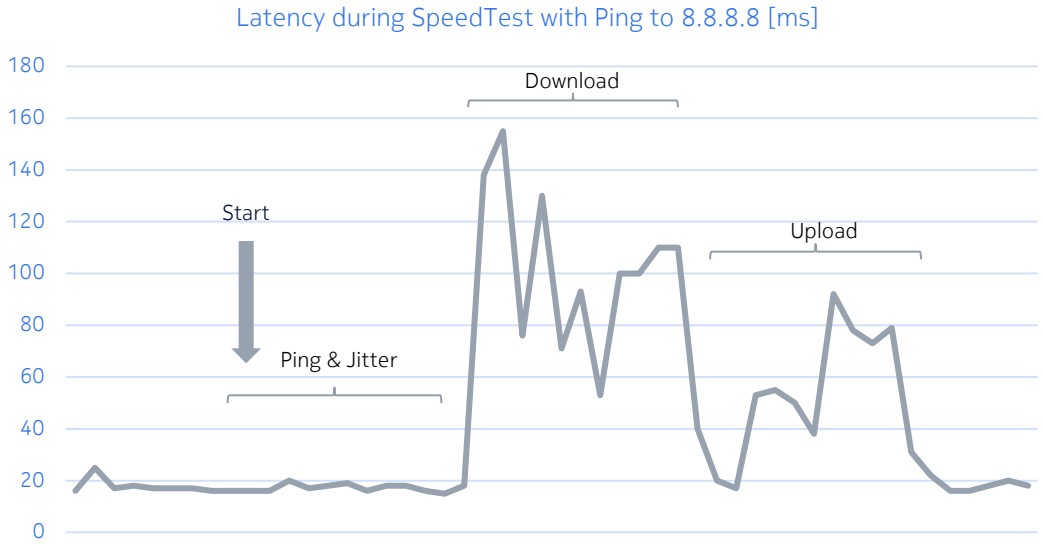
Latency under load?
SpeedTest with parallel ping

```
ping -t 8.8.8.8
```







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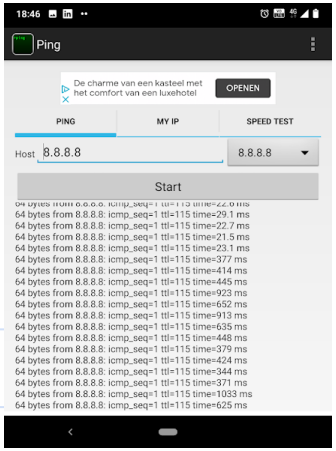
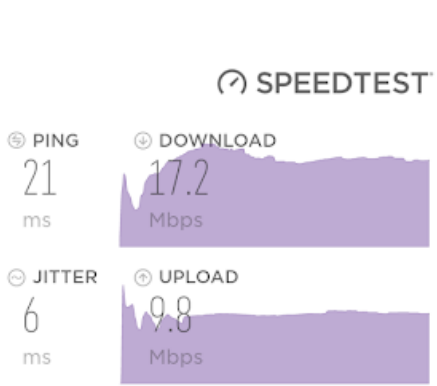
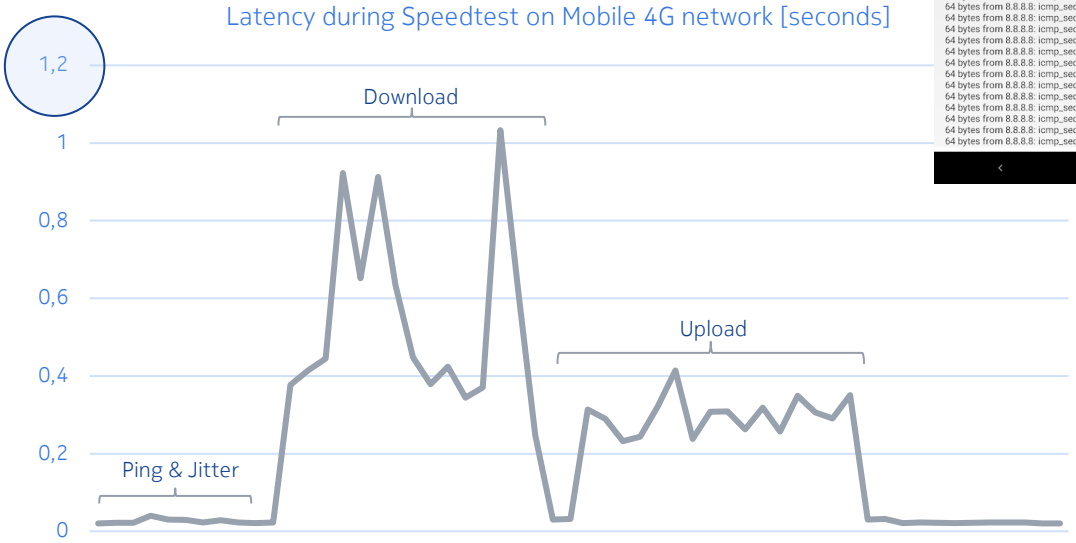
Latency under Load

SpeedTest on Mobile 4G Network



Seconds (!)





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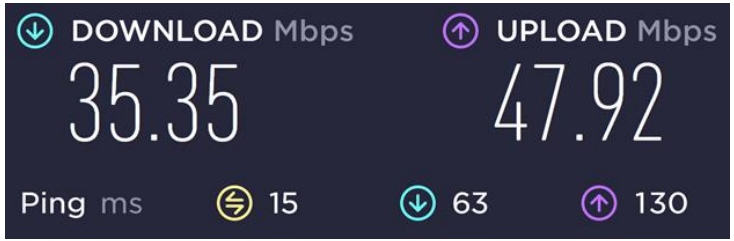
Latest Speedtest update
Isn't latency more important?

Good News:

Now latency under load is added:



Though very conservative values are used (even not yet average?)

Better for a next release?

Focus on peak latency: (or 99th percentile)

as these waiting times are today more relevant for user experience than throughput

L4S can keep peak latencies in the same order of magnitude as the idle latency… (often only 1 or a few ms queue latency higher)

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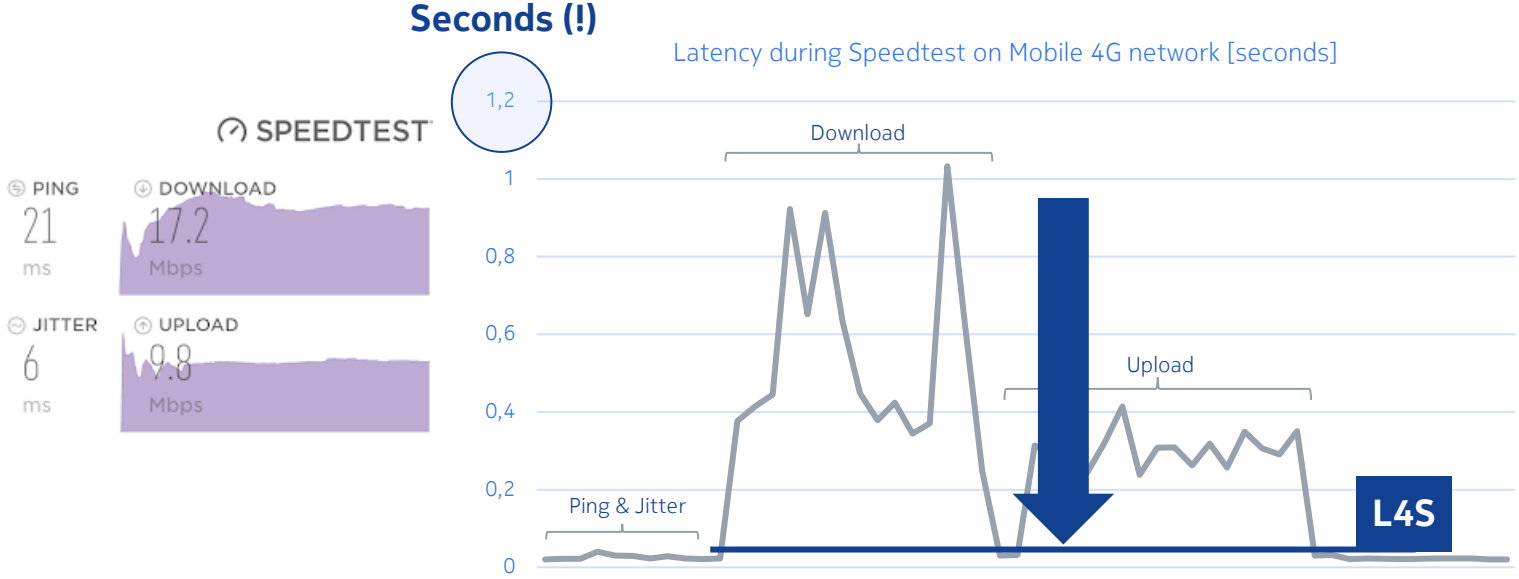
Goal of L4S
Reduce Latency under Load



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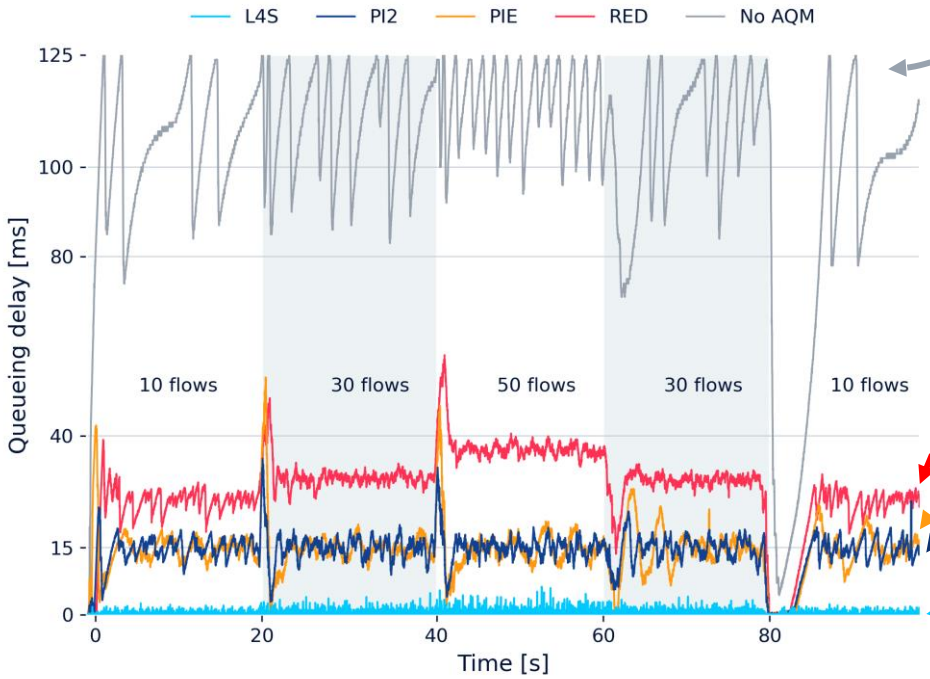
L4S
AQM and CC evolution



No AQM

First-Gen AQM

RED: difficult to tune,
cannot keep target, unstable

Second-Gen AQM

PIE: PI Enhanced with heuristics

PI2: PI Improved with a Square

Delay is kept around 15ms target

Classic CC (Reno)

L4S AQMs

STEP 1ms marking barrier
Mark don't Drop
Full utilization, ultra low latency

L4S (Prague)

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How to control both L4S CCs and Classic CCs

App/NW interaction

Interactive applications set L4S bit in IP header and use L4S CCs

Mark bit set by NW | L4S bit set by app

ECN bits

Prague Compiant

Mark twice as hard

Echo Marks in ACKs

$r \approx 2/p$

$r \approx 2/(2p) \approx 1/p$

Mark

L4S-ECN Capable Receiver TCP/UDP/...

$r \approx 1/\sqrt{p}$

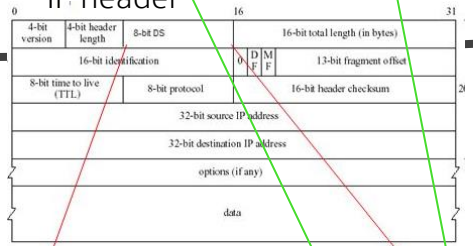
Drop (Delay)

$r \approx 1/\sqrt{(p^2)} \approx 1/p$

Reno Cubic

RTT delay

IP header



L4S capable Network node

Drops not ACKed

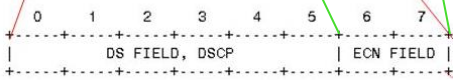
Think twice to drop

For all CCs:

$r \approx 1/p$

Download applications don't set L4S bit and use Classic CCs

TOS byte



DSCP: differentiated services codepoint
ECN: Explicit Congestion Notification

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IETF
L4S drafts are ready and will become RFC soon

Architecture explained in draft-ietf-tsvwg-l4s-arch

Requirements specified in the L4S-ID draft draft-ietf-tsvwg-ecn-l4s-id :

- for NW: L4S identification protocol (ECN bits) and mark/drop relationship (squaring classic drops and doubling L4S marks)
- for End-Systems: Prague requirements (Low Latency congestion control)

Example reference NW AQM implementation: DualPI2 draft

- IETF draft: draft-ietf-tsvwg-aqm-dualq-coupled
- Open-source code: linux/sch_dualpi2.c at testing · L4STeam/linux (github.com)

Example reference TCP CC implementation: TCP-Prague draft

- IETF draft: draft-briscoe-iccrg-prague-congestion-control
- Open-source code: linux/tcp_prague.c at testing · L4STeam/linux (github.com)

L4STeam/linux: Kernel tree containing patches for TCP Prague and the dualpi2 qdisc (github.com) (also including BBRv2 and Accurate ECN implementations)

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First IETF L4S Interop was a big success

Second is active now

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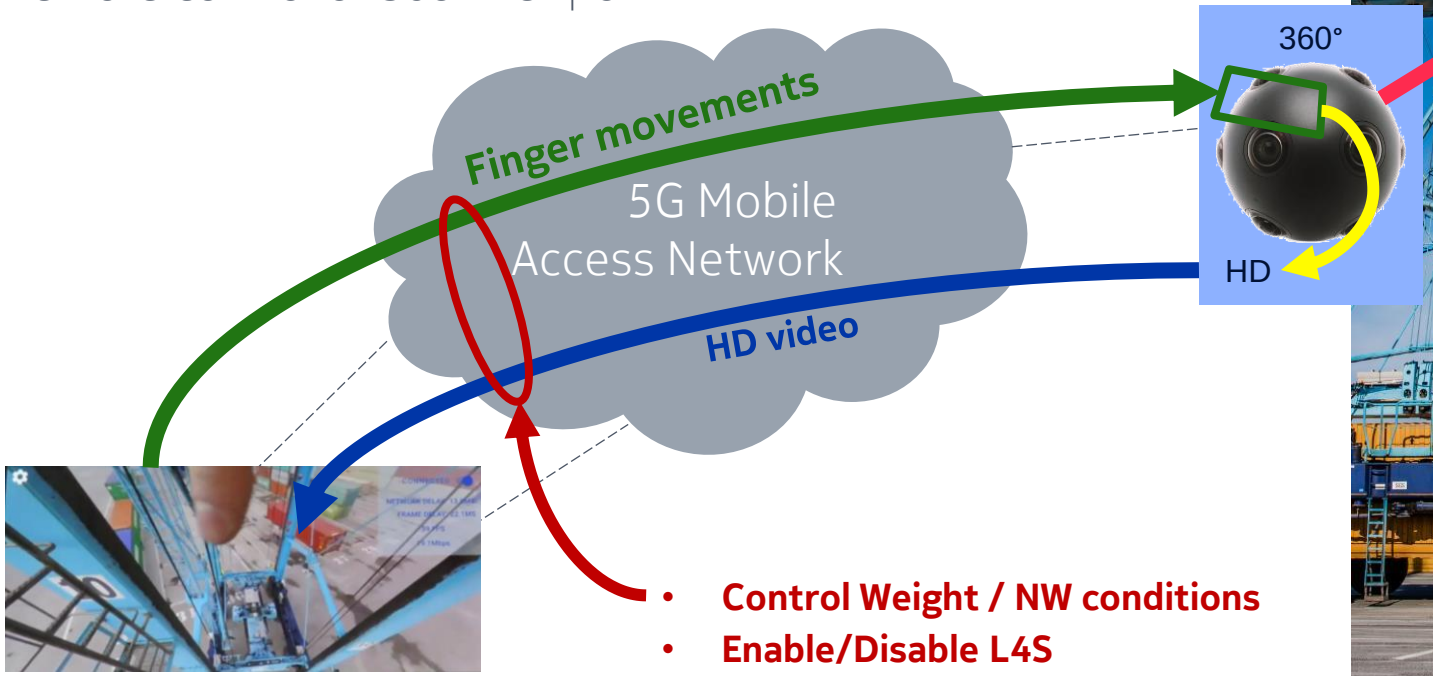
Effect on Remote Control use cases

Remote control of 360° viewpoint



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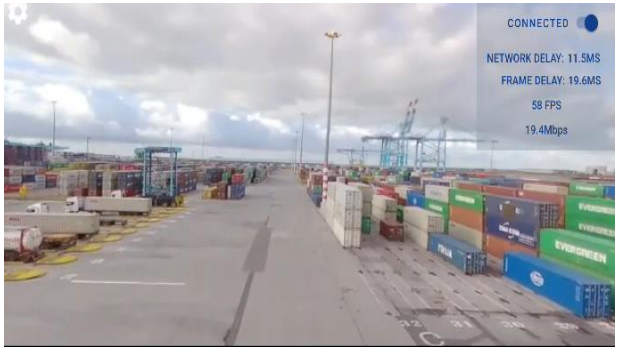
Latency is key for interactive applications

Safety-critical applications must still work even if the SLA is degraded

SLA of 25Mbps & 30ms, app uses 20Mbps



High Video Resolution
User has full remote control

SLA degraded to ~15Mbps and **no L4S**

Video slows down, delays and skips fragments
User loses control

SLA degraded to <7Mbps and **L4S**

Slightly Reduced Video Resolution
User keeps full remote control

Setup: Cloud-rendered/encoded video towards lightweight client sending motion events to control the view position

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Latency is key for interactive applications

Safety-critical applications must still work even if the SLA is **drastically** degraded

SLA degraded to <0.5Mbps and **no L4S**

Video stops, applications often crash
Total loss of control

SLA degraded to <0.5Mbps and **L4S**

Like bad weather conditions
User keeps full remote control

Setup: Cloud-rendered/encoded video towards lightweight client sending motion events to control the view position

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Conclusions

Collaboration between NW and Applications with L4S:

- ✓ allows graceful degradation, preserving low latency
- ✓ improves scalable deployment of interactive applications (more peak users)
- ✓ Improved latency performance of link technologies are directly exploitable (today queuing spoils all efforts below 10s of ms)

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Gaming

Remote presence / Teleoperation

Questions?

Home Working

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