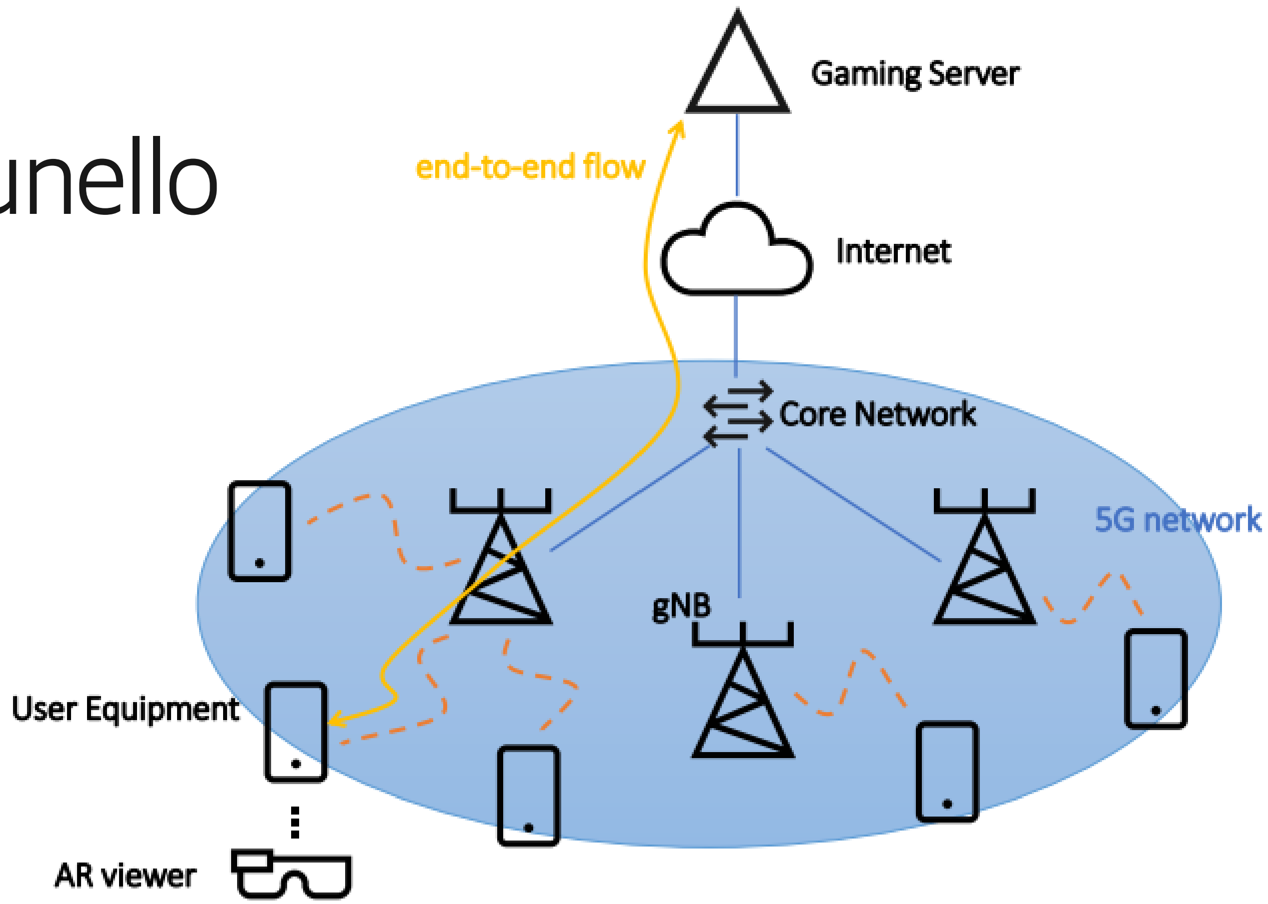
L4S in 5G

Master thesis by Davide Brunello



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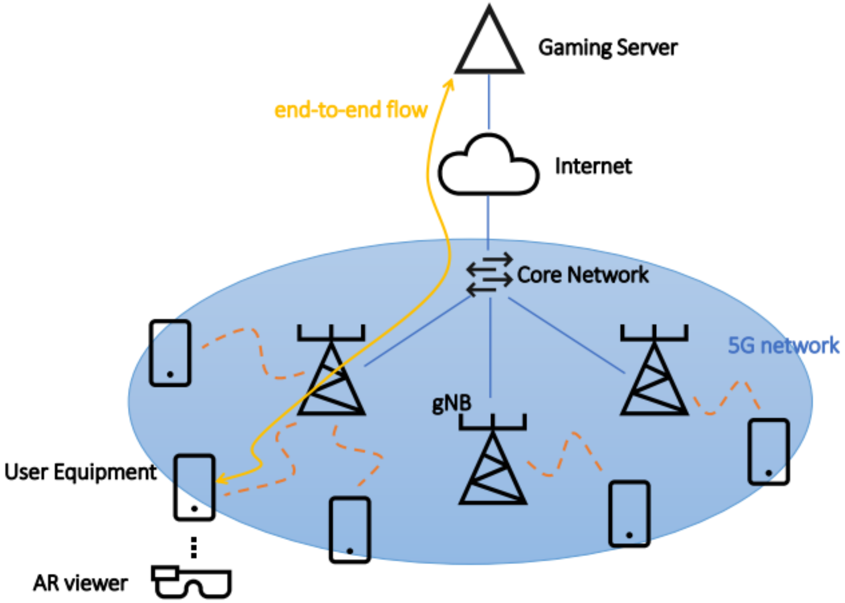
Glossary

- SINR : Signal to Interference/Noise Ratio
- RSRP : Reference Signal Received Power
- 99%-ile delay : 99%-ile tail latency for the 95%-ile worst off gamer
- 5%-ile bitrate : Average bitrate for the 5%-ile worst off user
- TDD : Time Division Duplex
- FDD : Frequency Division Duplex
- RLC : Radio Link Control
- PDCP : Packet Data Convergence Protocol

Outline

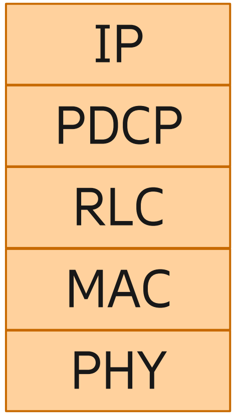
- ❑ Evaluate L4S for VR/gaming scenario with rate adaptive video in a 5G deployment
- ❑ 5G system simulator study

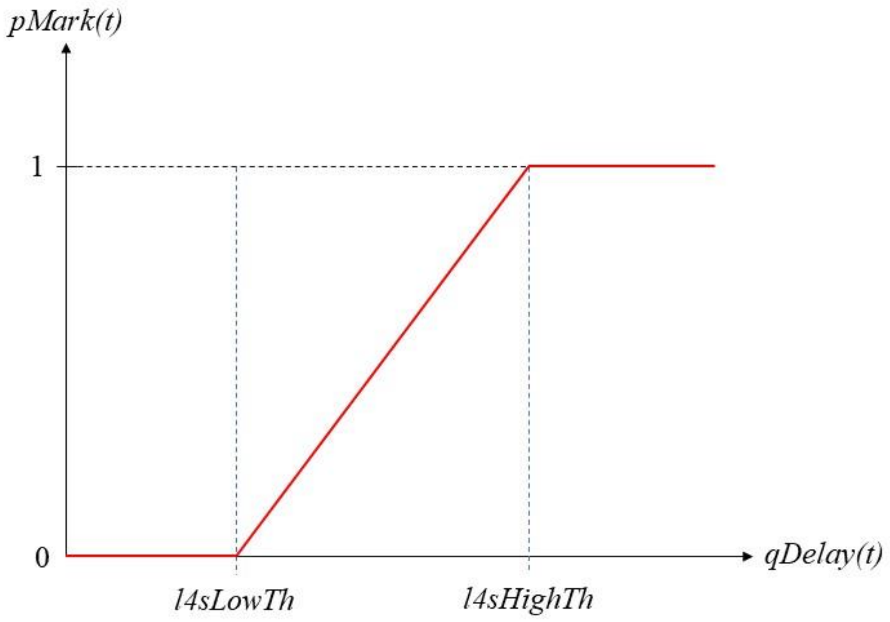


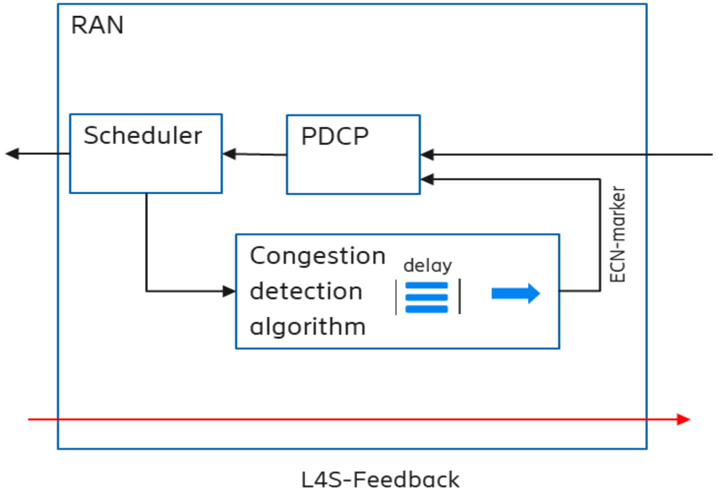
- ❑ 21 cells 3GPP case 1
- ❑ BW: 10MHz
- ❑ SCReAM congestion control (RFC8298)
  - ❑ 2-70Mbps (1080p→4K)
- ❑Variable load 2-50 video users
  - ❑ 10 times as many background (web) users
- ❑ Various scheduling algorithms
  - ❑ RR Round Robin
  - ❑ DBS Delay based scheduler (QoS)

The queue based L4S marking strategy

- ❑ The probability to mark a packet depends on the queue delay
- ❑ Tail marking
  - ❑ Queue builds up on RLC
  - ❑ Marking on PDCP
- ❑ Typical marking thresholds
  - ❑ l4sLowTh = 5ms
  - ❑ l4sHighTh = 10ms
- ❑ Thresholds depend on numerology, TDD/FDD ...







High-level L4S solution for a 3GPP network

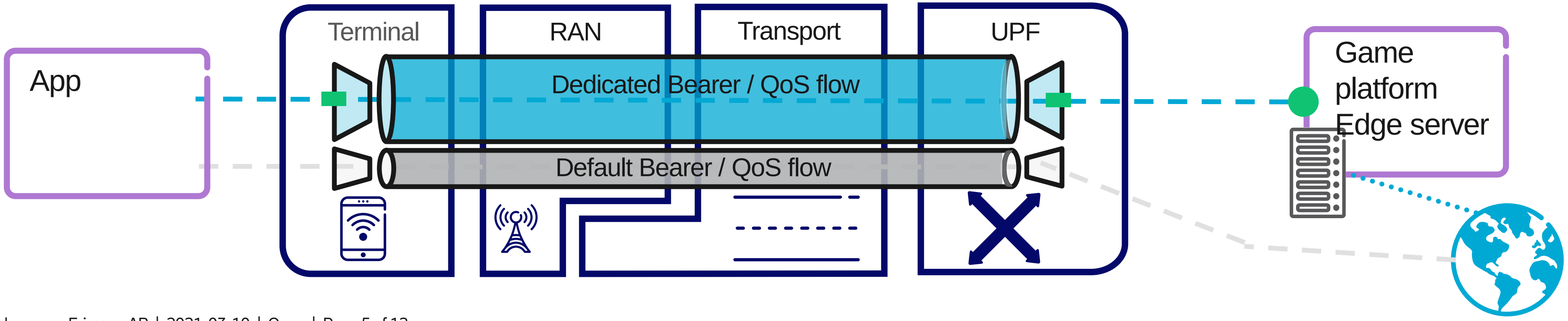
Reusing QoS/bearer features

A dedicated bearer/QoS Flow for L4S traffic ?

- Separate queue for latency-critical traffic
- Provide L4S feedback on this traffic
- Optional: provide QoS/priority
- Opportunity to tune other functions for latency

How to use dedicated bearer/QoS Flow?

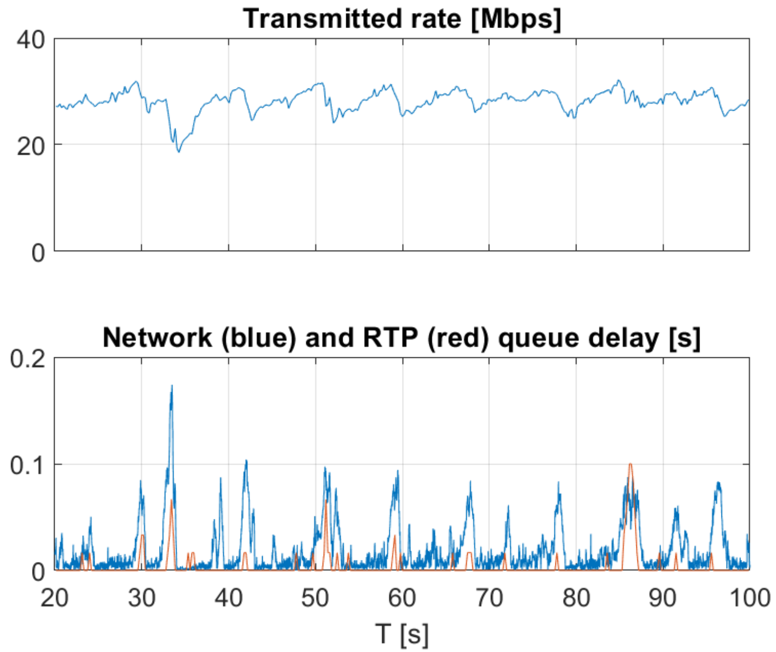
- Traffic filters map latency-critical traffic based on L4S/ECN bits
- Possibly combined with IP of Edge server



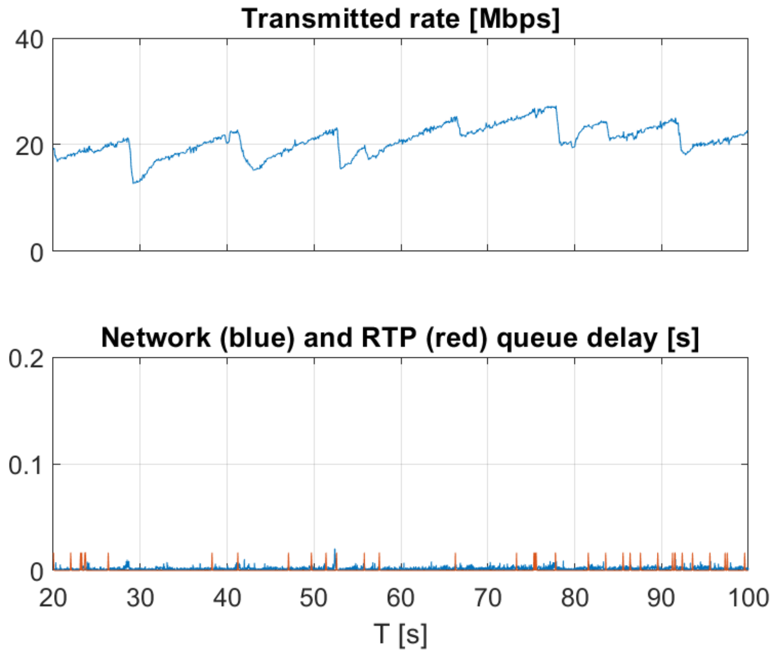
Time trace comparison

- ❑ Not-L4S → higher throughput but high RTP and Network Queue delay
- ❑ L4S → Some reduction in throughput but large reduction in Network and RTP Queue delay
  - ❑ Addition of QoS i.e. Delay based scheduler increases throughput

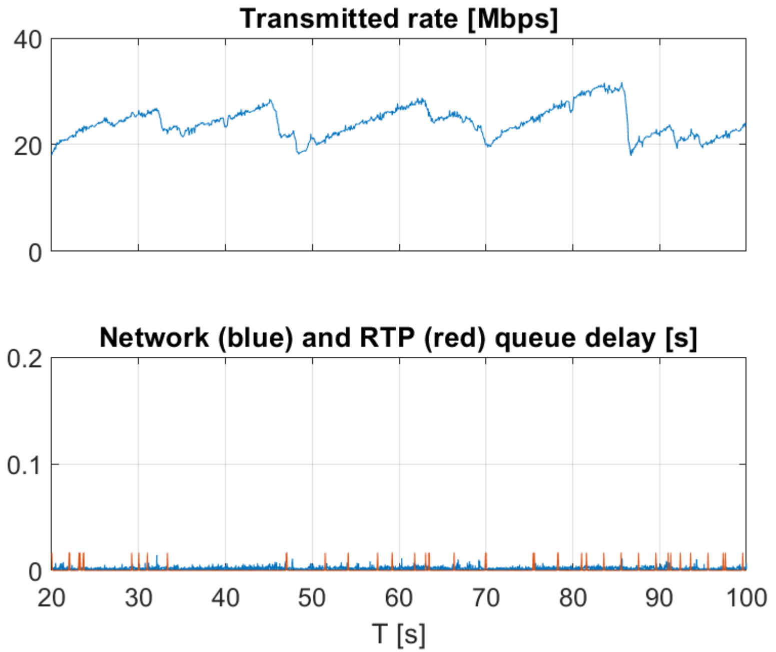
Not-L4S (RR)



L4S (RR)

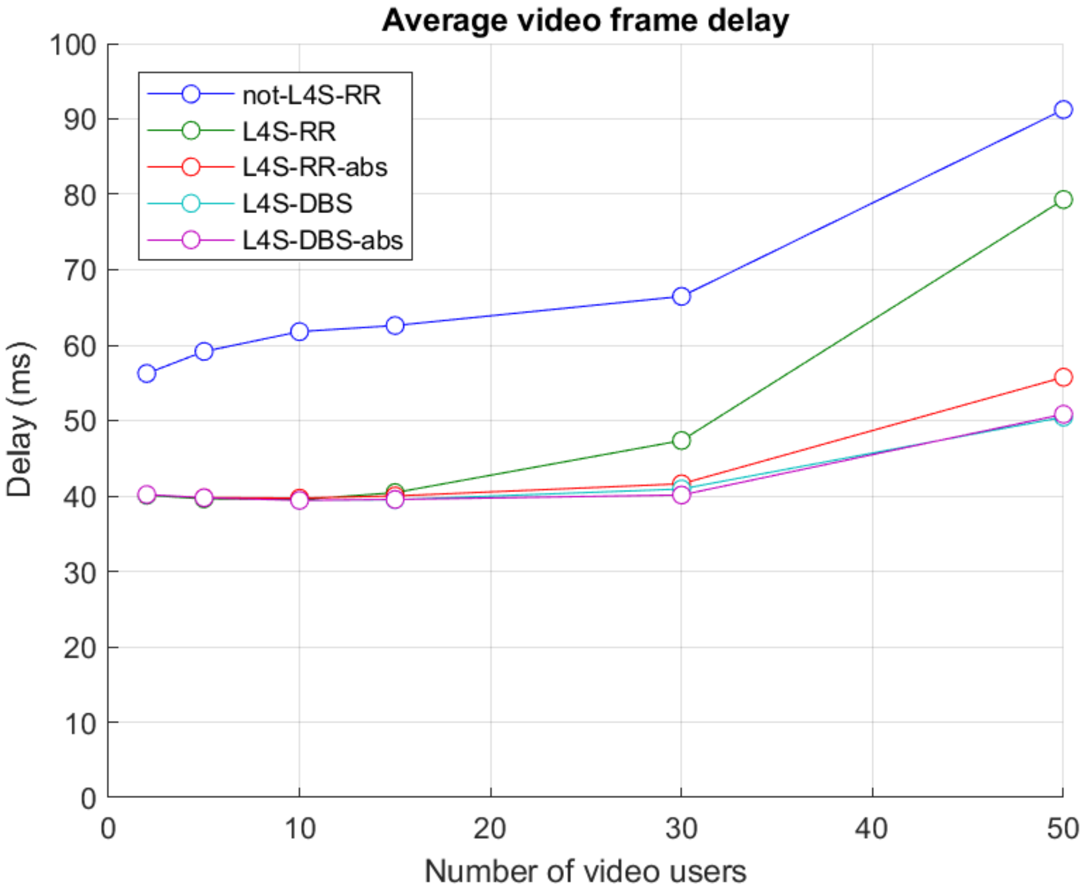


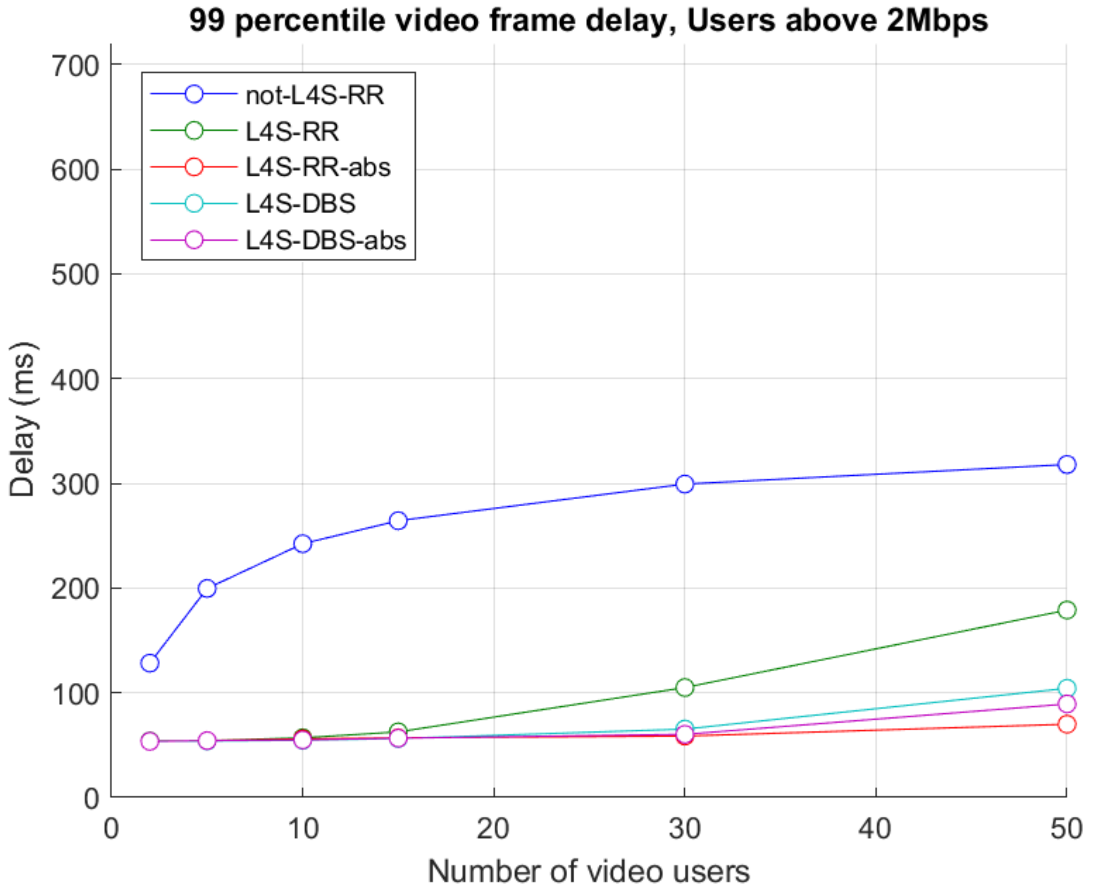
L4S (DBS)



Video Frame Delay

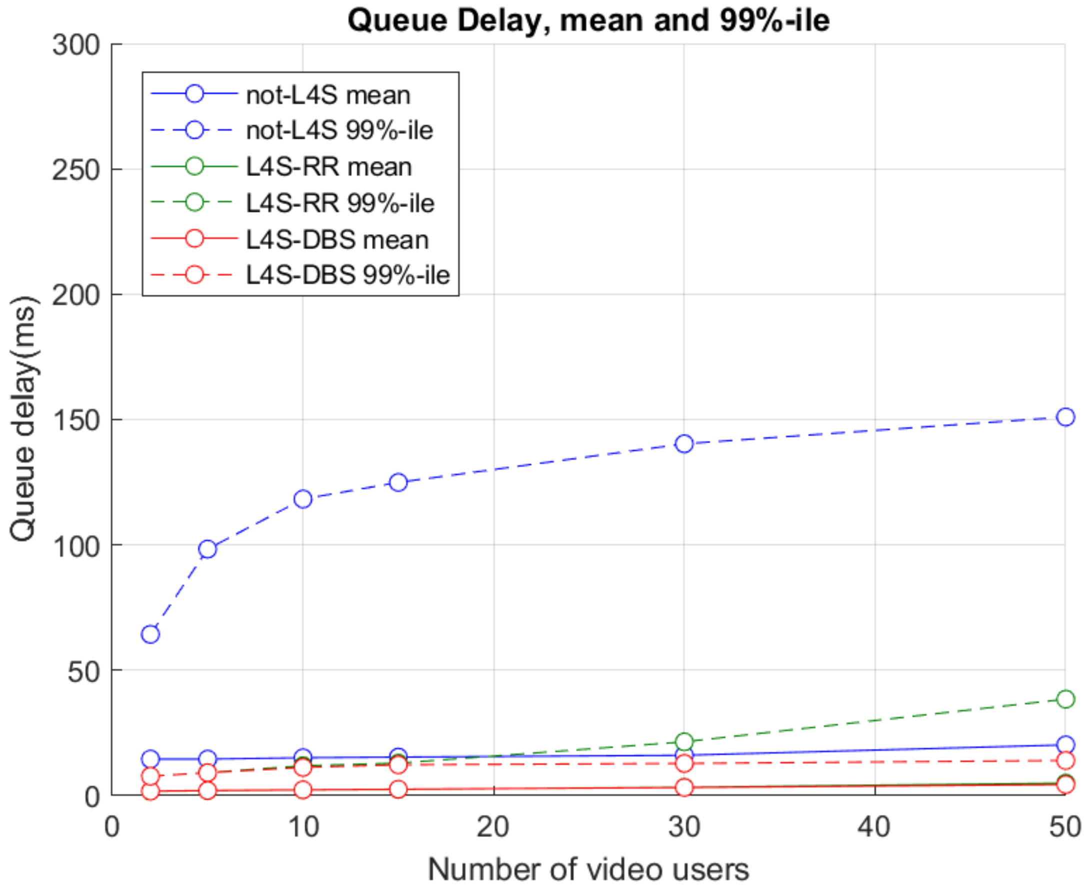
- ❑ L4S gives lower average and 99%-ile video frame delay
- ❑ L4S-RR performance degraded at higher load levels (explained earlier)
- ❑ Addition of QoS i.e. DBS gives improved average and 99%-ile delay





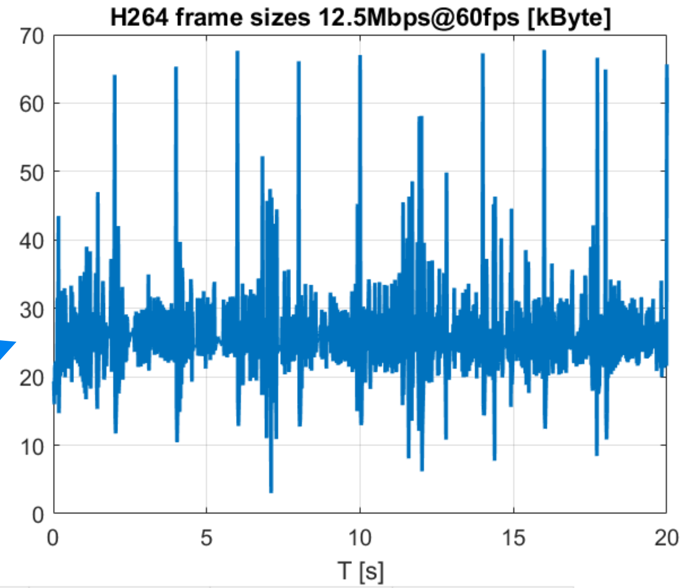
Network Queue Delay

- ❑ As expected L4S gives very low queue delay
- ❑ Additional QoS improves performance further



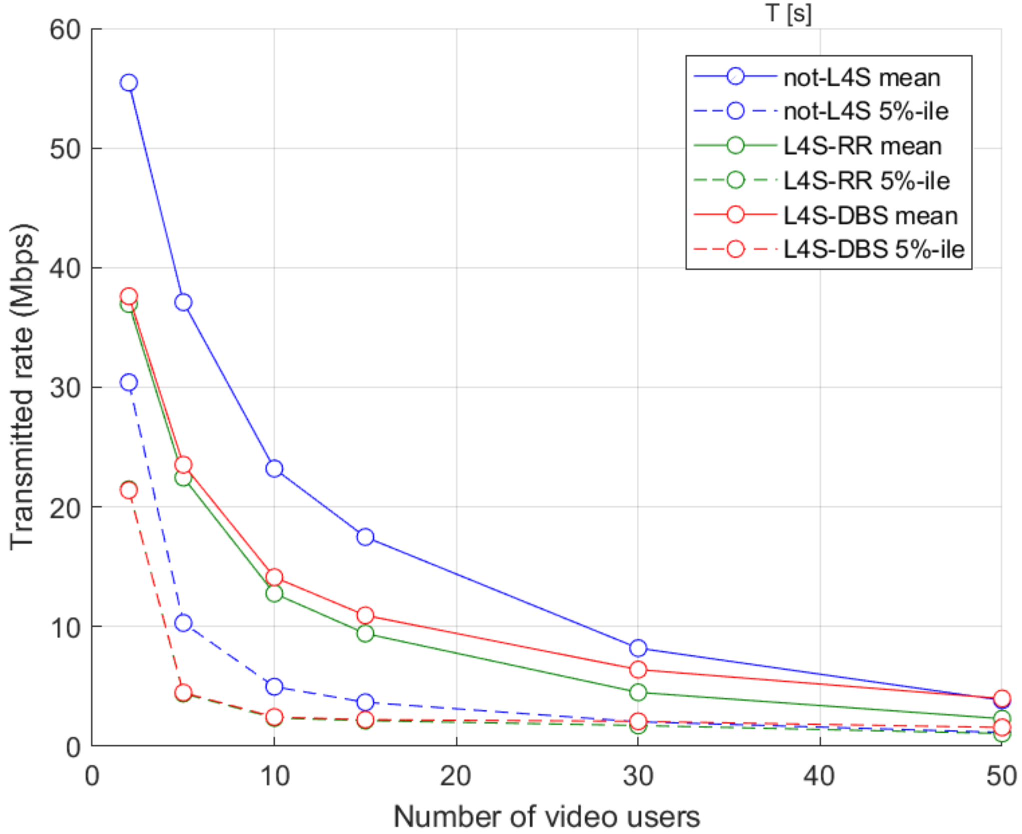
Transmitted Rate

- ❑ Not-L4S gives higher throughput
  - ❑ Direct consequence of the tradeoff between throughput and delay
  - ❑ Adaptation to source characteristics



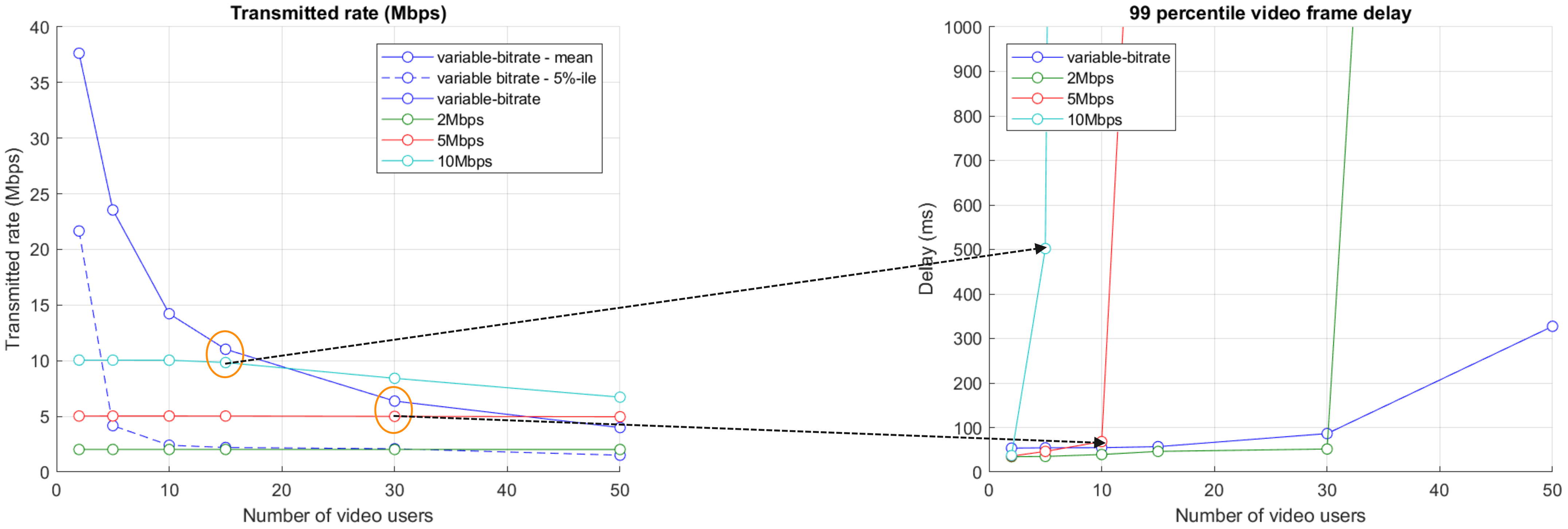
- ❑ At high load the average throughput is almost the same with and without L4S

- ❑ Additional QoS gives higher throughput



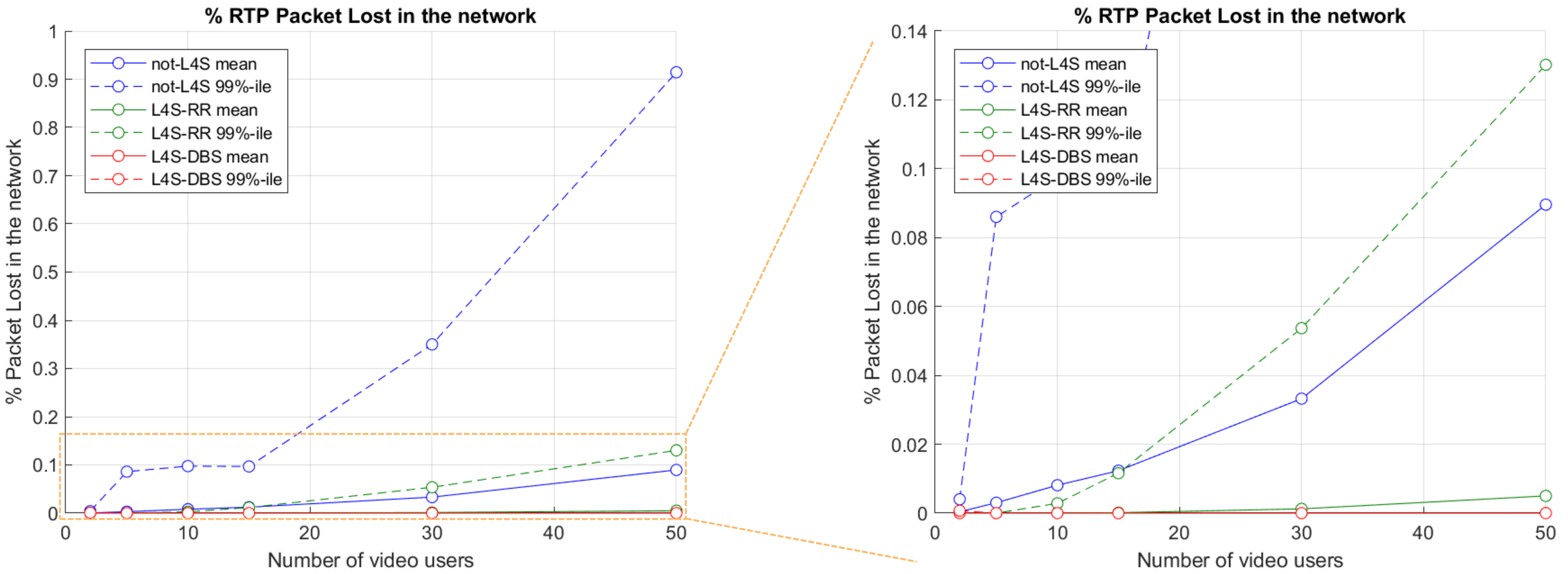
Adaptive vs Fixed video bitrate

- ❑ Adaptive bitrate → larger operating range (SINR and RSRP)
- ❑ Example below :
  - ❑ 10Mbps fixed → breaking point is less than 5 users
  - ❑ Rate adaptive → Max 15 users with average bitrate 12Mbps



Packet loss rate for video gaming traffic

- ❑ Considerable reduction in packet loss with L4S
- ❑ L4S with DBS gives nearly zero packet loss



Conclusion

L4S makes it possible to achieve low latency, low packet loss and good throughput for videogaming traffic also at high load

Additional QoS can improve the performance further

Packet loss is drastically decreased with L4S

Throughput-delay trade-off, low latency → reduced throughput