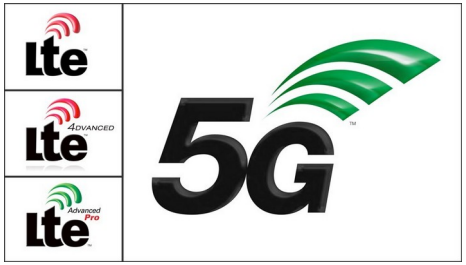
Considering return path latency in access networks

NetSatDay meets NoF

“Fast Convergence of Congestion Control”

2nd July 2021

Abstract *: Identifying the latency induced by return link in cellular radio access networks and why we need to work on it for future services and transport protocols.*



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Outline

The context of cellular networks

Observations on uplink latency and jitter

Interactions with Transport Protocols

Discussions

Conclusion

The Context of Cellular Networks

The Context of Cellular Networks

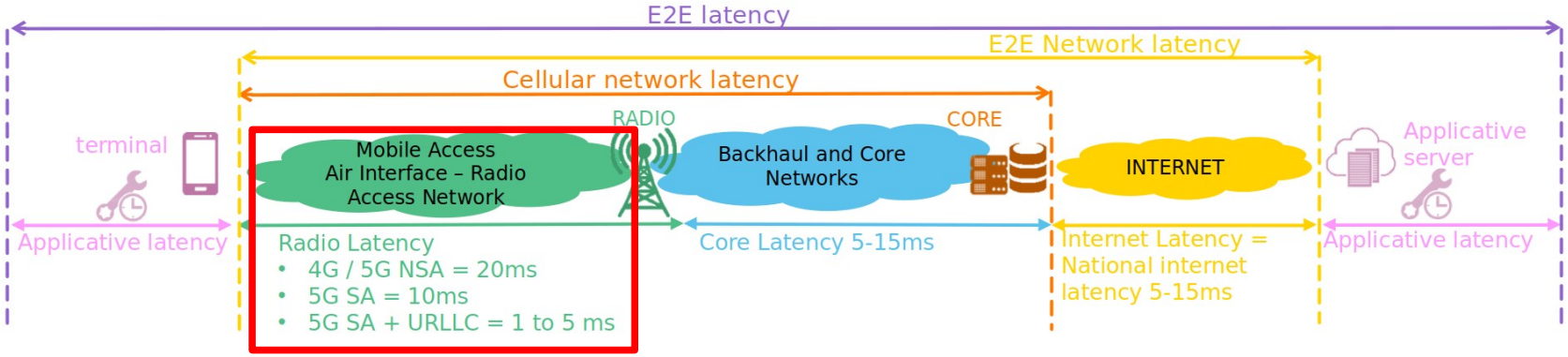


Figure: Cellular Network segments and latencies
Ref : J. Billioque (Orange Labs) 5G Program

The Context of Cellular Networks

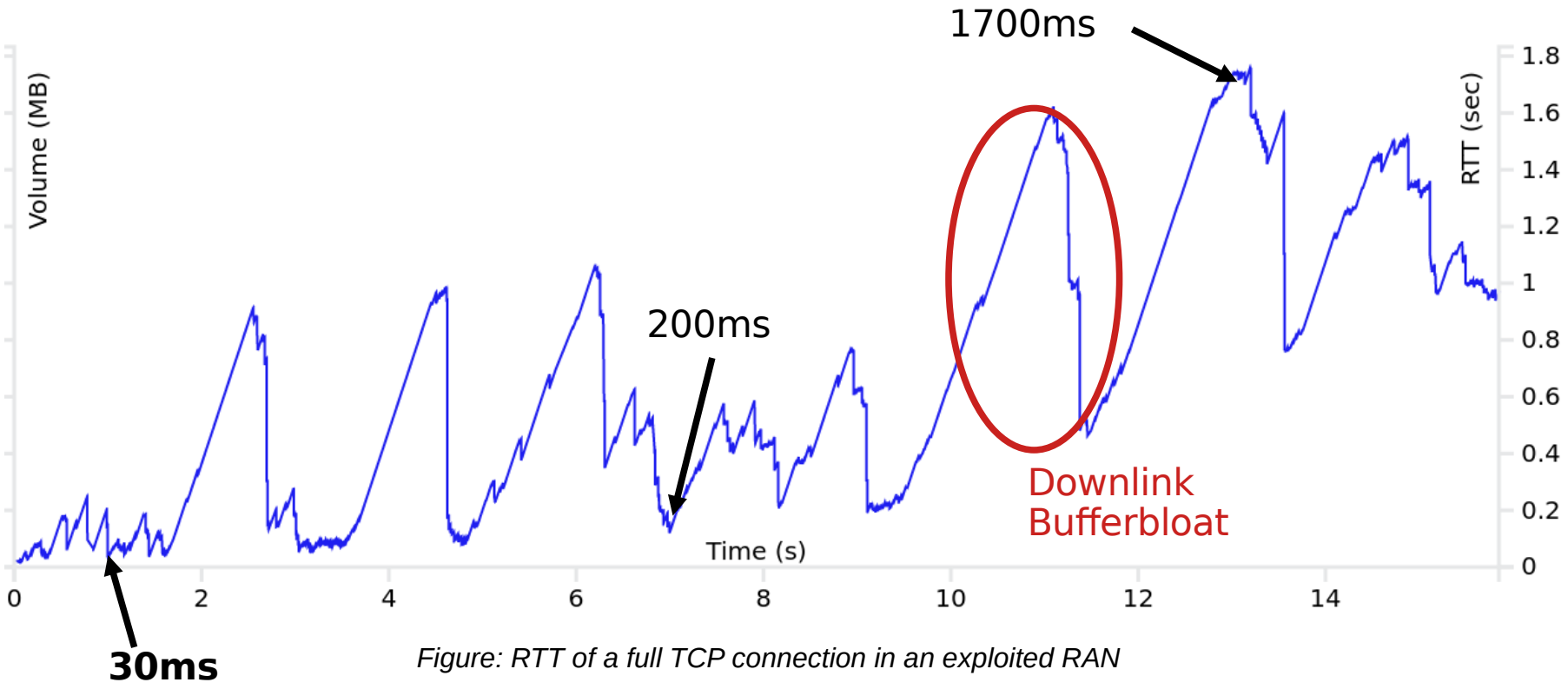


Figure: RTT of a full TCP connection in an exploited RAN

Observations on uplink latency and jitter

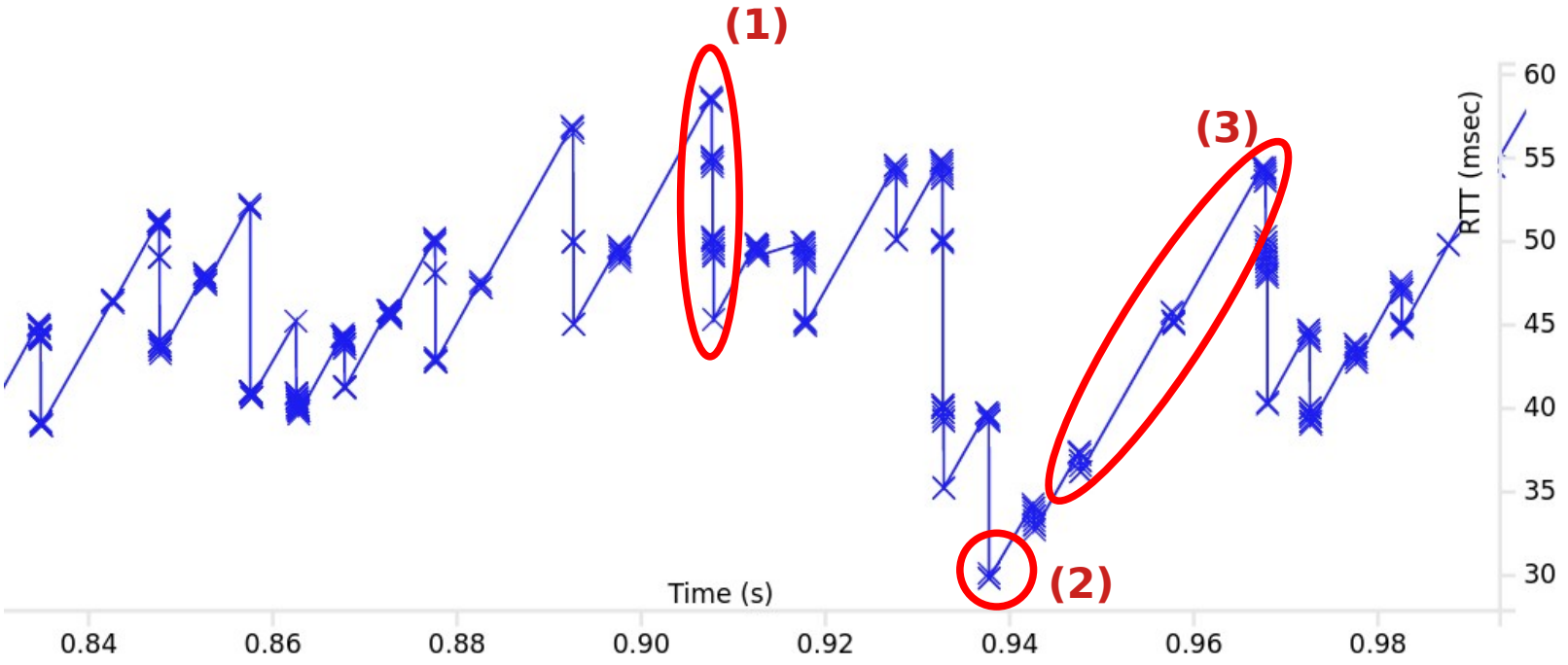


Figure: RTT in a low loaded operational Radio Access Network (RAN).

Observations on uplink latency and jitter

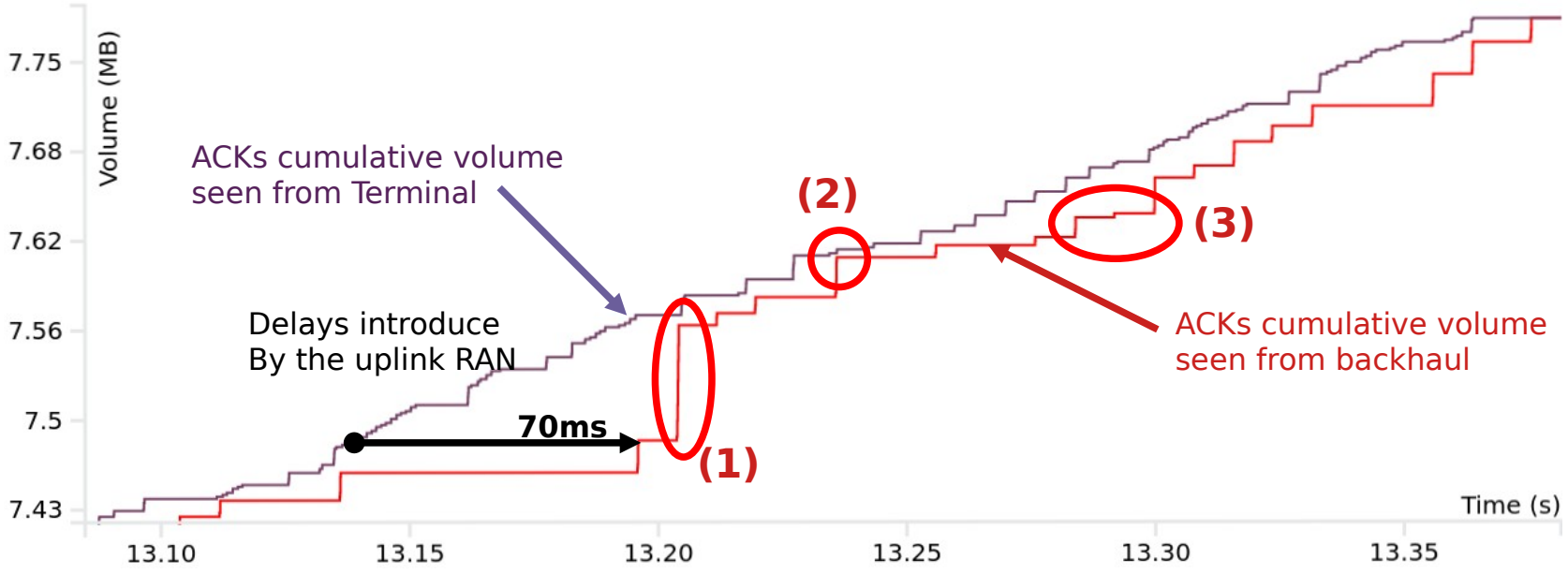


Figure: Uplink cumulated volume at in the entry and the output of an operational RAN

The Context of Cellular Networks

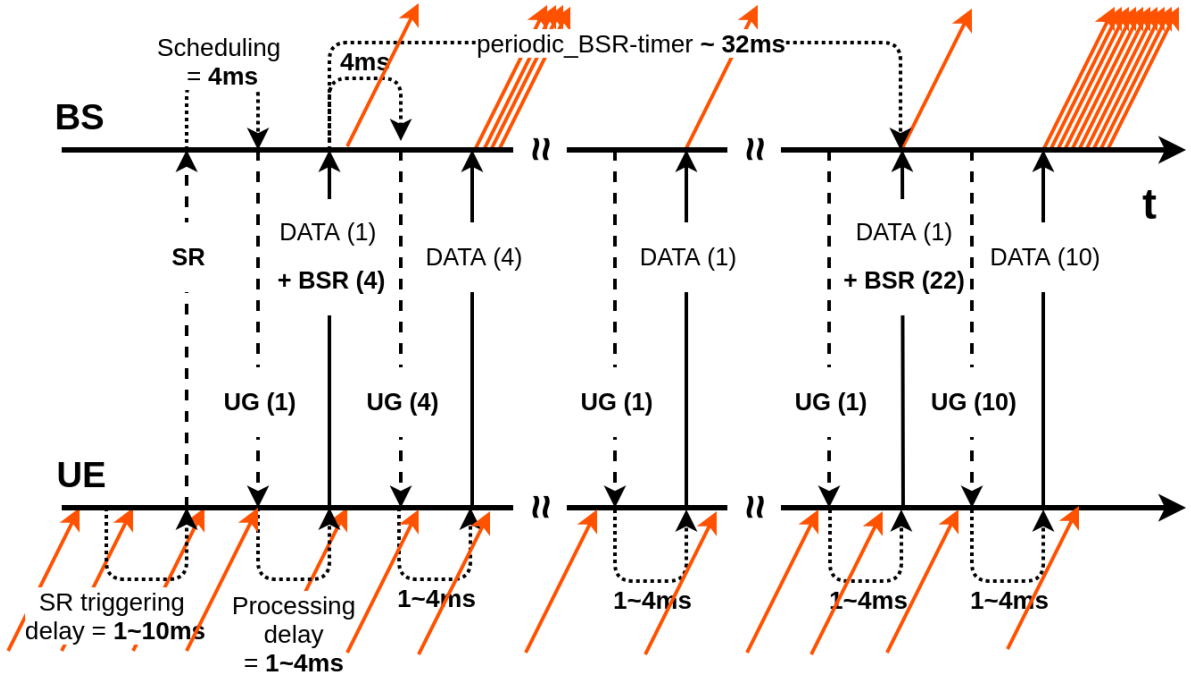


Figure: Grant-based access method timeline

Interactions with Transport Protocols

Interactions with Transport Protocols

Return link usage by TPs:

→ Acknowledgment packets

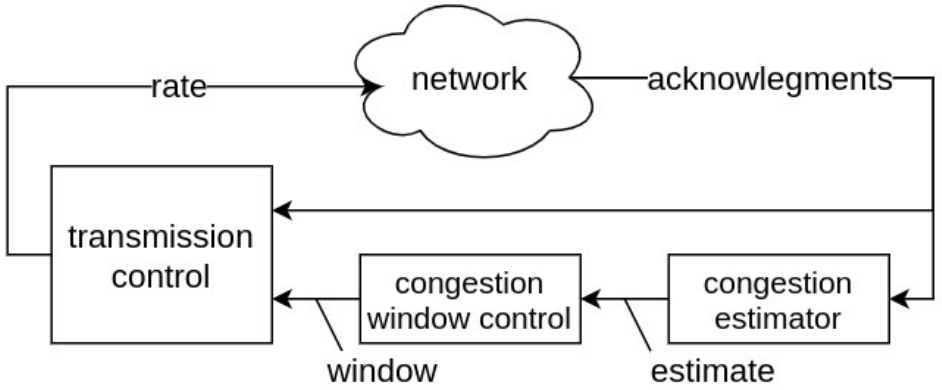
Short packets

Low datarate

Continuous during a transmission

Acknowledge data packets

Used to estimation network congestion



Ref : ACK-Clocking Dynamics, Jacobsson (2008)

Figure: Usage of acknowledgments for data transmission and rate adaptation in TCP

Interactions with Transport Protocols

TCP Cubic, downlink data transmission controlled by uplink ACKs : **clocking**

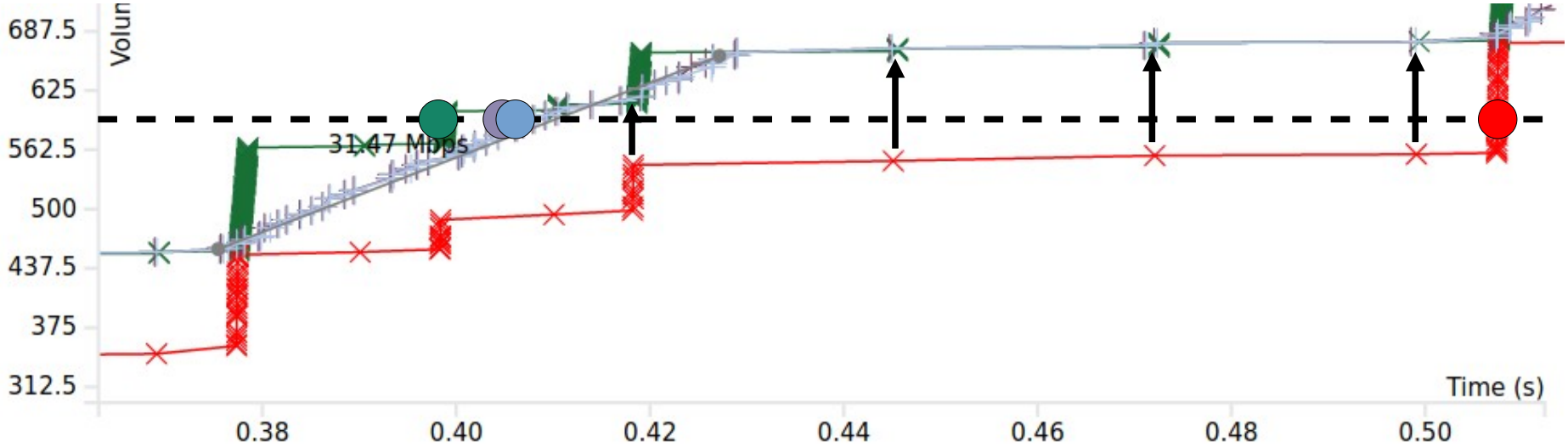
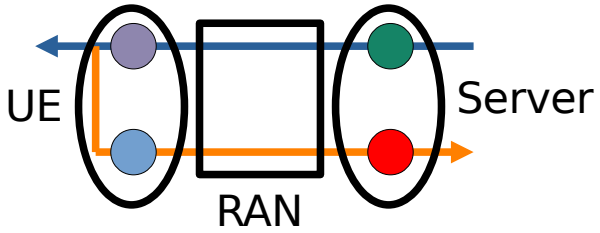


Figure: Cumulative volume of a TCP transmission at RAN entry points. Pacing is disabled.

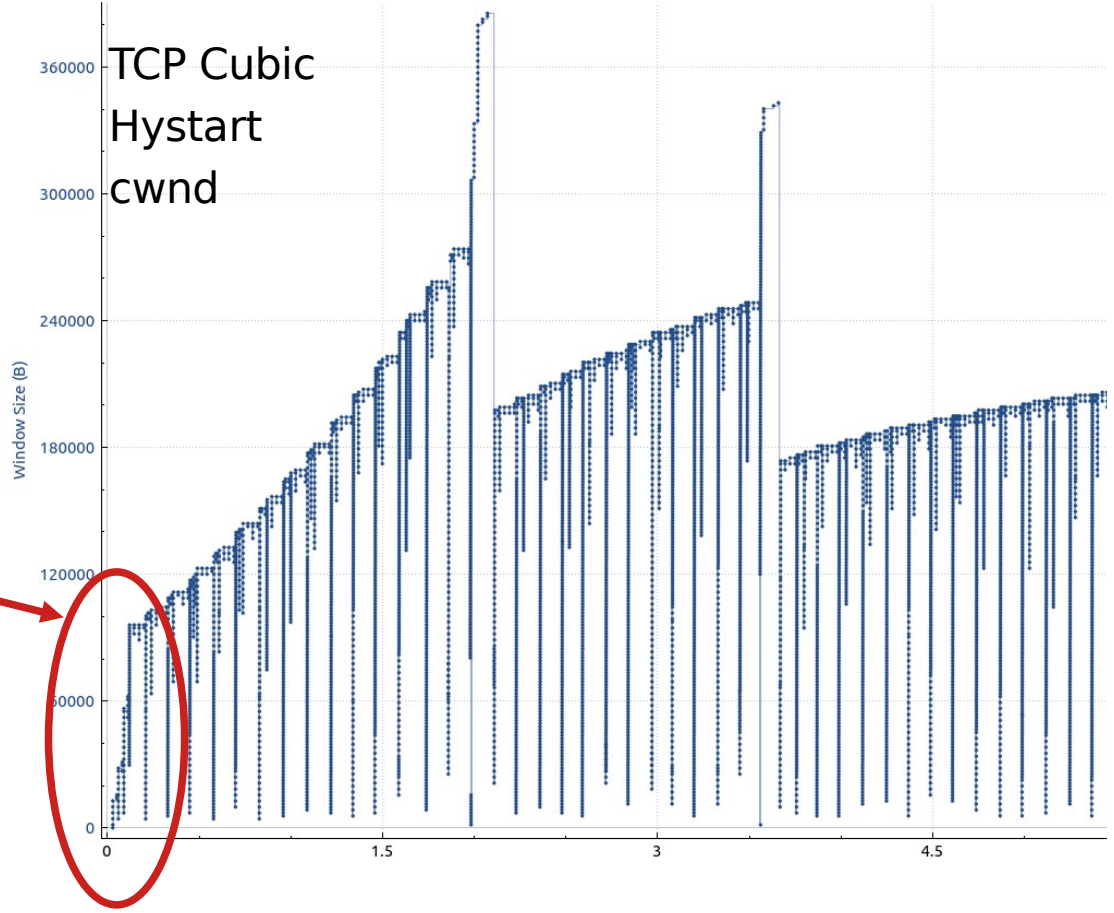


Interactions with Transport Protocols

False retransmission triggering...
(RTO = sRTT + 4*varRTT)

Early Slow Start phase exit…

→ **Under-utilization of radio capacity**

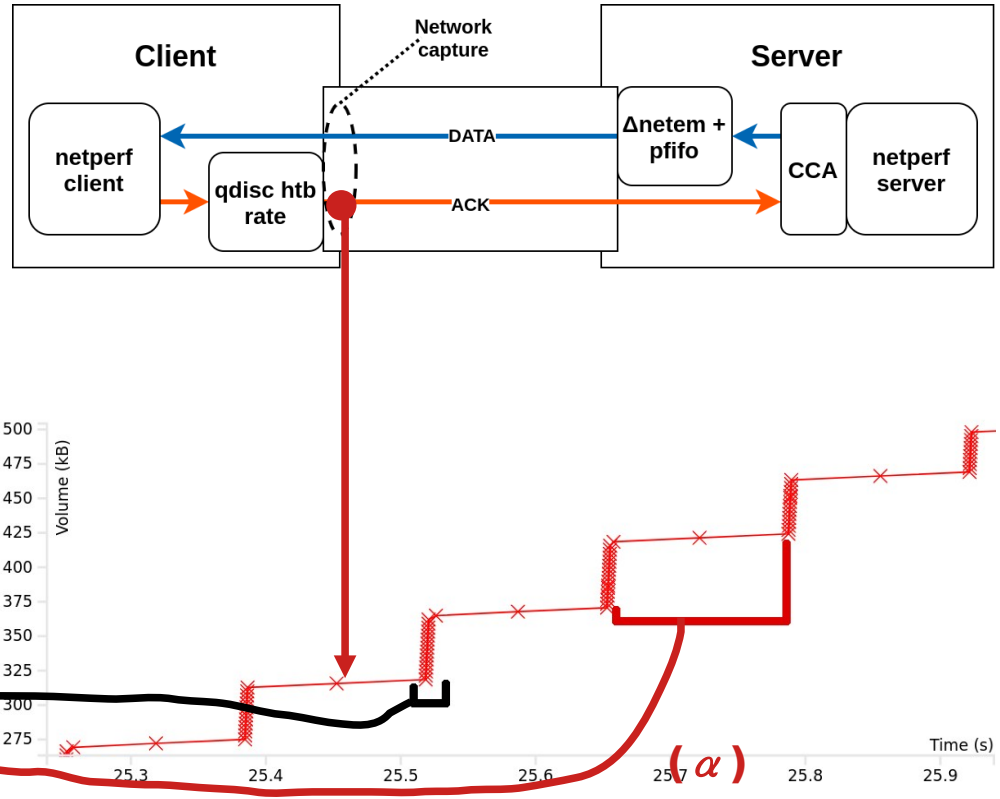


Impact of uplink on TCP BBR performance

Emulation parameters

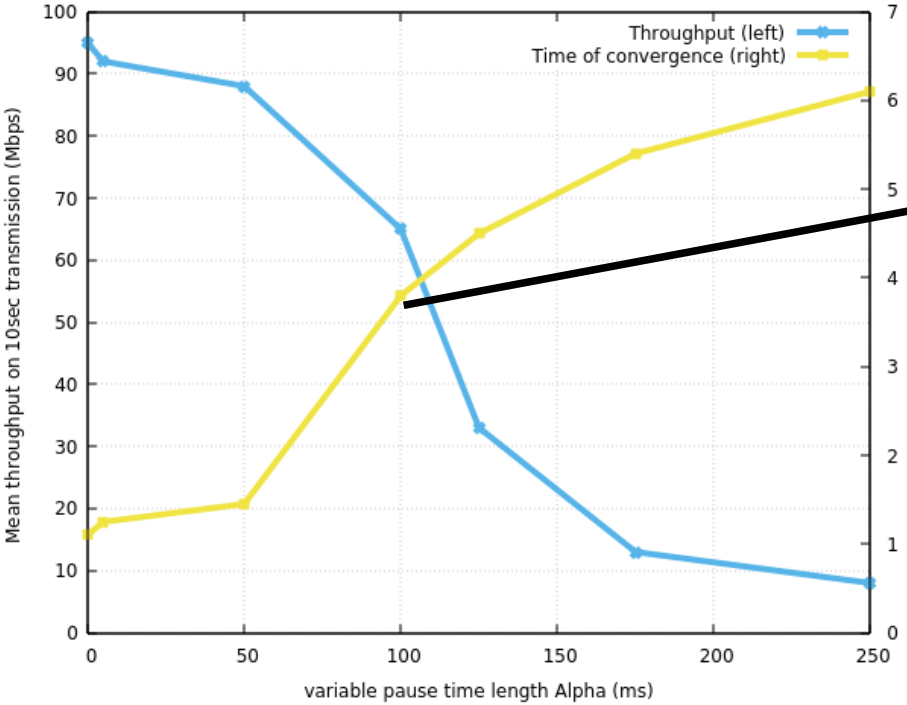
Downlink:
- Fixed 100Mbps
- Fixed 9ms min delay
- FIFO Queue, 2.000 Pkts (~3MB)

Uplink:
- Fixed 14ms base delay
- FIFO Queue, 1.000 Packets
- Fixed burst time length
- Variable “pause” time length



→ Reproduce the bursty behavior of uplink access network

Impact of uplink on TCP BBR performance



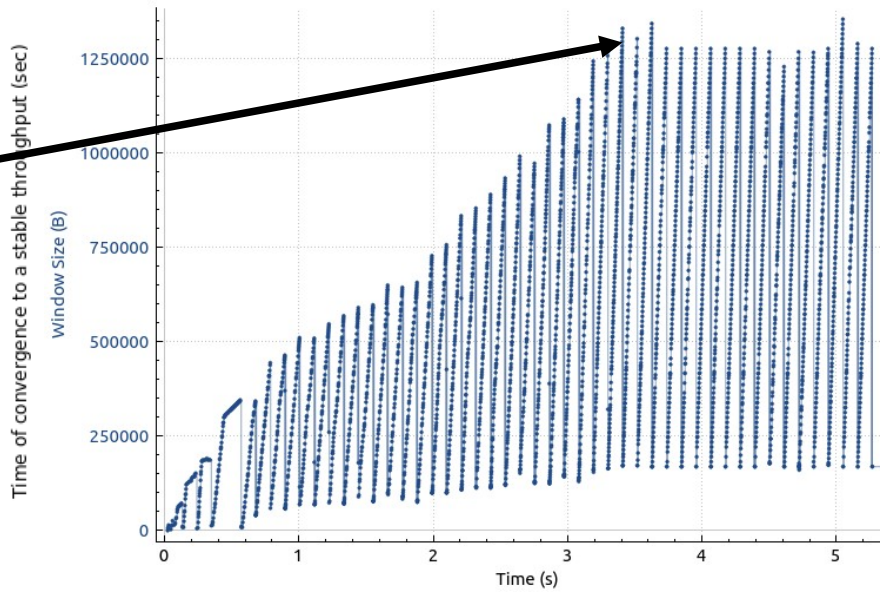
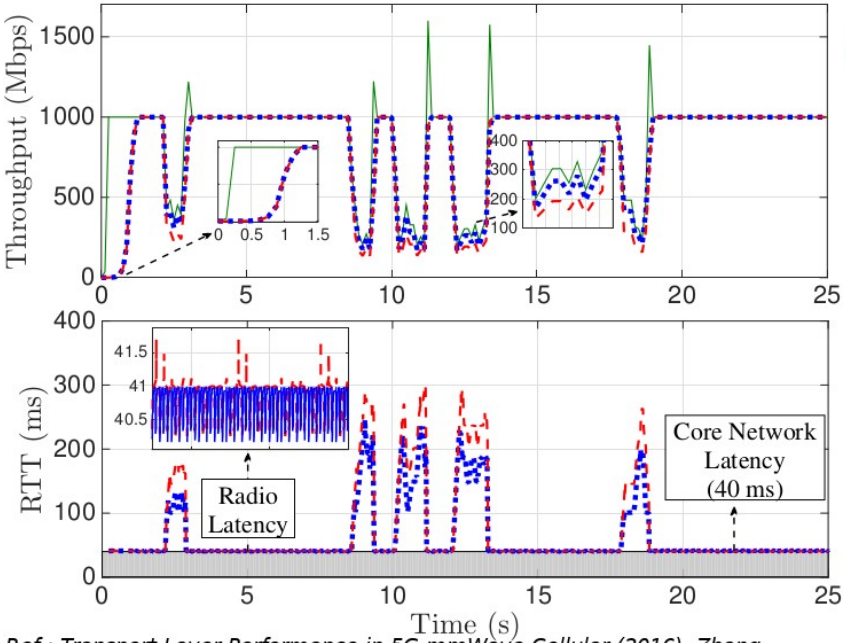


Figure: TCP BBR cwnd for alpha=100ms

Discussions

Discussion on the future of mobile access networks

Under-utilization of capacities and high variability



Ref : Transport Layer Performance in 5G mmWave Cellular (2016), Zhang

Figure: Problem of capacity variability in 5G

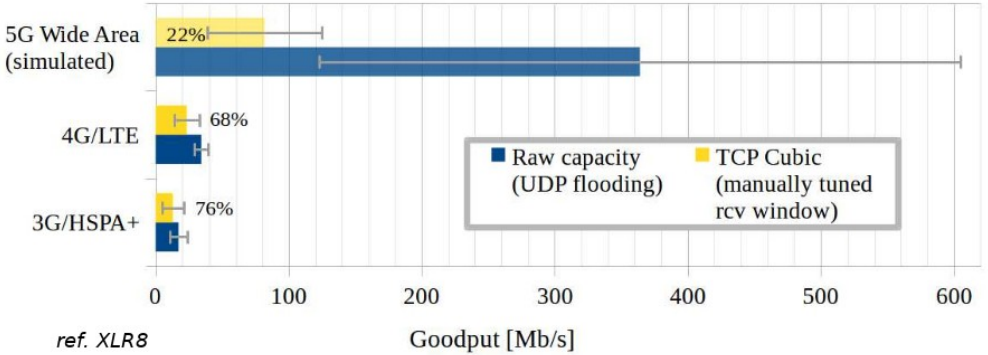


Figure: Poor radio capacity usage by TCP

Relationship with satellite transmission

Satellite for 5G :

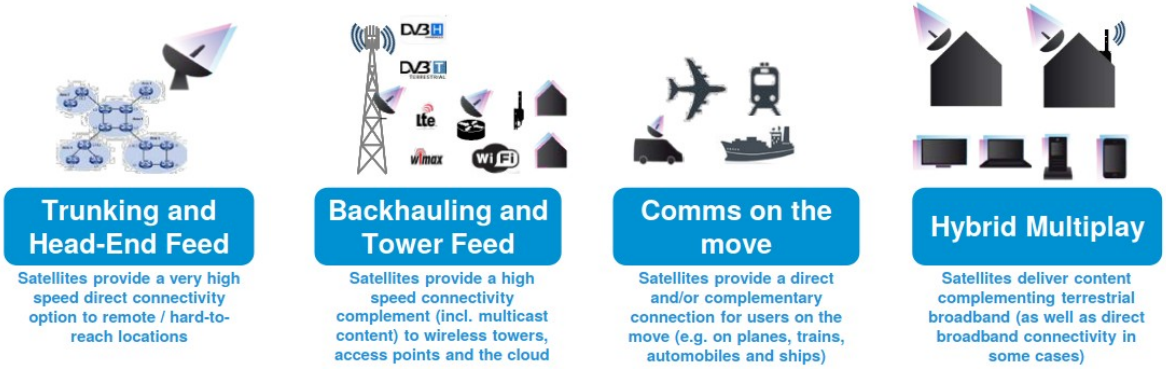


Figure: Four Satellite "Sweet Spots" in the 5G Ecosystem (The role of satellite in 5G, SES)

Grant-based access Method in SatRAN :

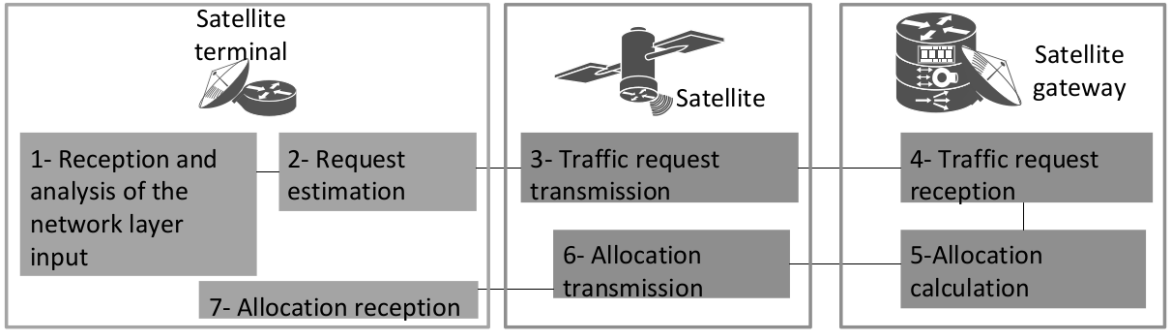


Figure: Uplink access method in SatRAN

Conclusion

LTE RAN uplink induces latency AND jitter

Impact some Transport Protocols performance → QoE

The problem still exists in 5G and worsen high capacity variability

Same for QUIC but with higher return datarate and bigger acks

Common to all shared-medium wireless system with a grant-based access method

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References

Johansson, Ingemar: **Congestion Control for 4G/5G Networks IETF 96**, 2016.

Dahlman, E., Parkvall, S.: **NR - The New 5G Radio-Access Technology** , 2018.

Jacobsson, et al.: **ACK-clocking dynamics: modelling the interaction between windows and the network**, 2008.

Atxutegi et al.: **TCP Performance over Current Cellular Access: A Comprehensive Analysis**, 2018.

Custura et al.: **Rethinking acks at the transport layer**, 2020.

Custura et al.: **Impact of Acknowledgements using IETF QUIC on Satellite Performance** , 2020.

Zhang et al.: **Transport layer performance in 5G mmWave cellular**, 2016.

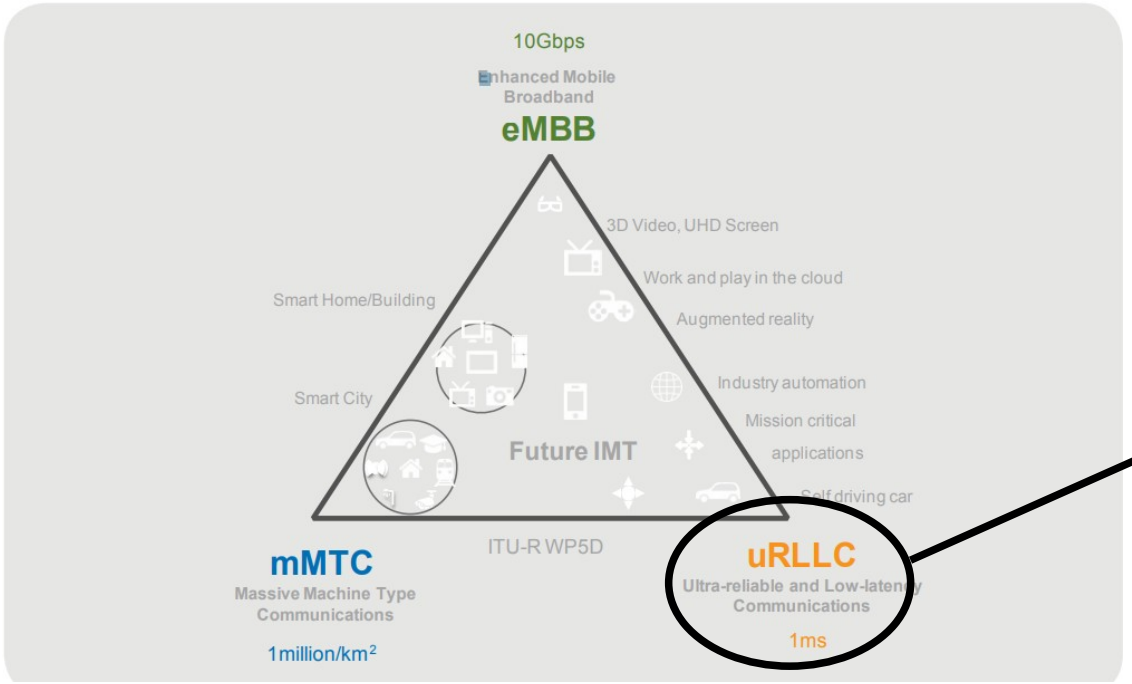
Ahmed T et al.: **Software-defined satellite cloud RAN**, 2018.

Annexes

	10/2 Mbps	50/10 Mbps	250/3 Mbps
TCP - no loss	133 - 346 kbps	650 -1,730 kbps	3,250 - 8,650 kbps
TCP - loss	346 - 560 kbps	1,730 - 2,800 kbps	8,650 - 14,000 kbps
QUIC - 1:2 ACK ratio no loss	144 -438 kbps	720 - 2,190 kbps	3,600 - 10,950 kbps
QUIC - 1:2 ACK ratio with loss	290 - Unlimited	1450 - Unlimited	7,250 - Unlimited

Figure: Return link datarate to carry ACK for TCP and QUIC. (G. Fairhust 2020)

Annexes



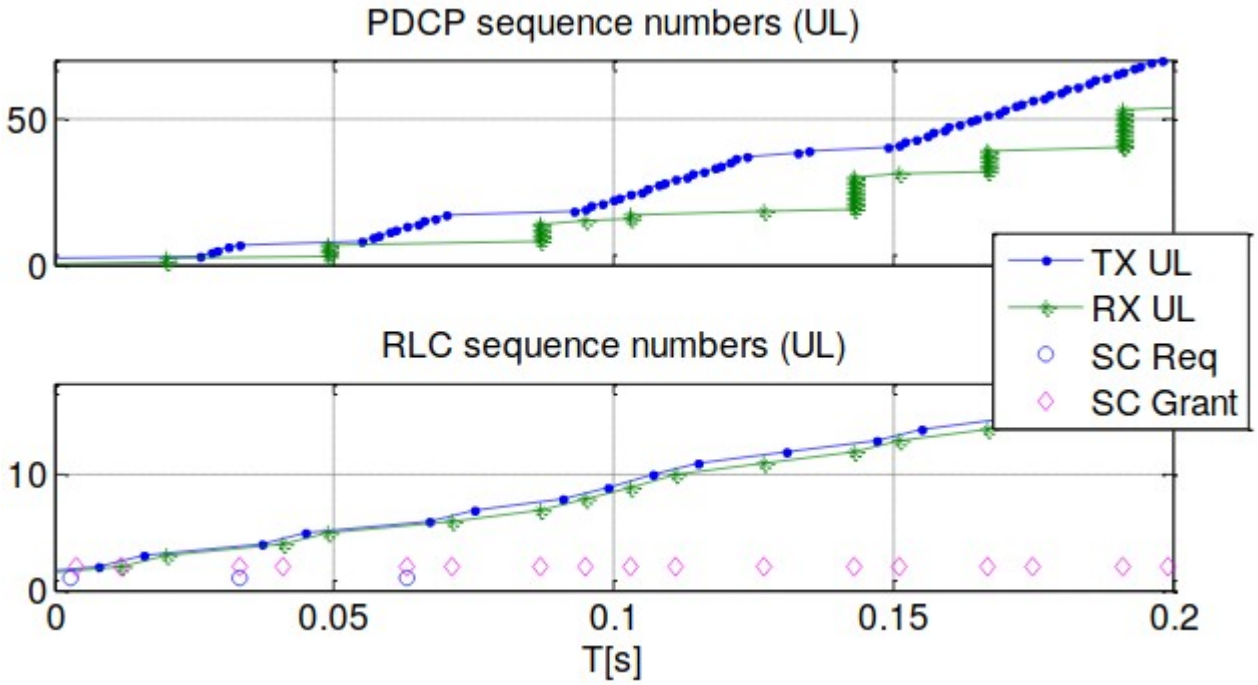
Grant-free access method

→ Contention-based (preemption)

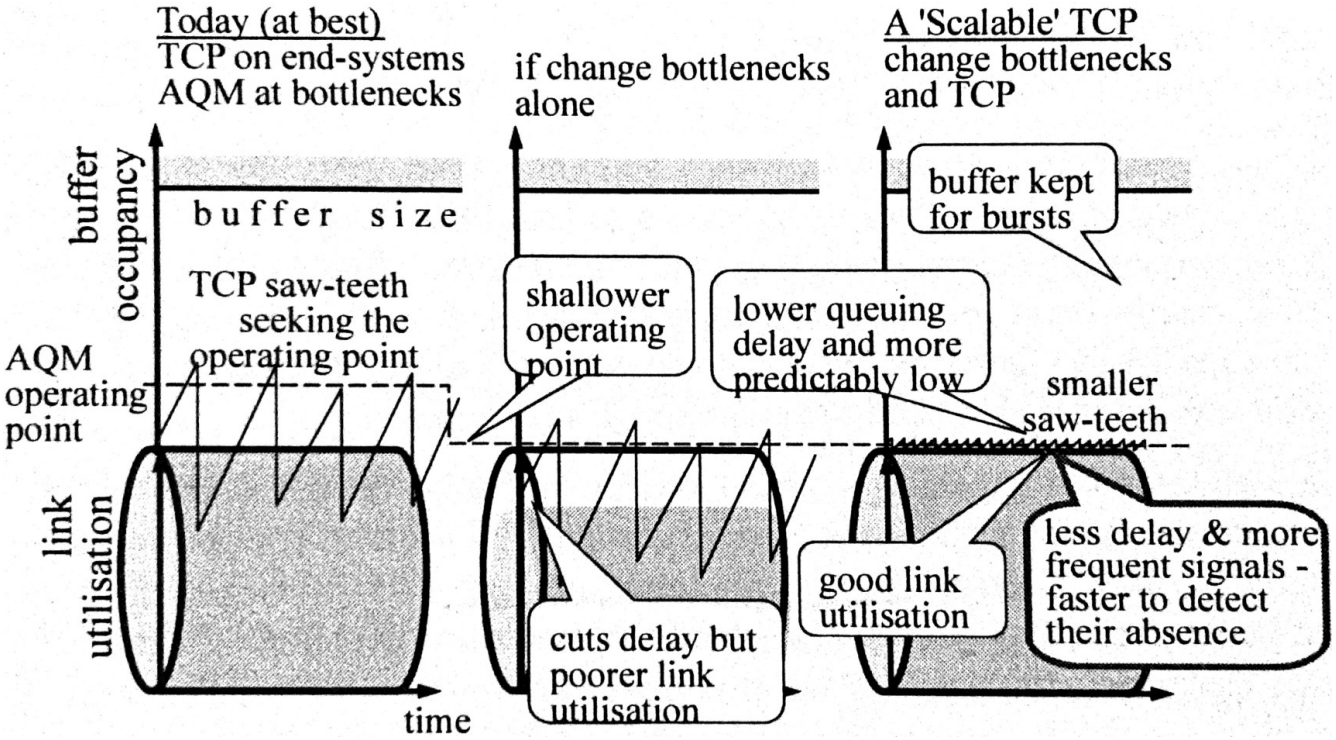
→ Pre-scheduling

→ Semi-Persistent Scheduling

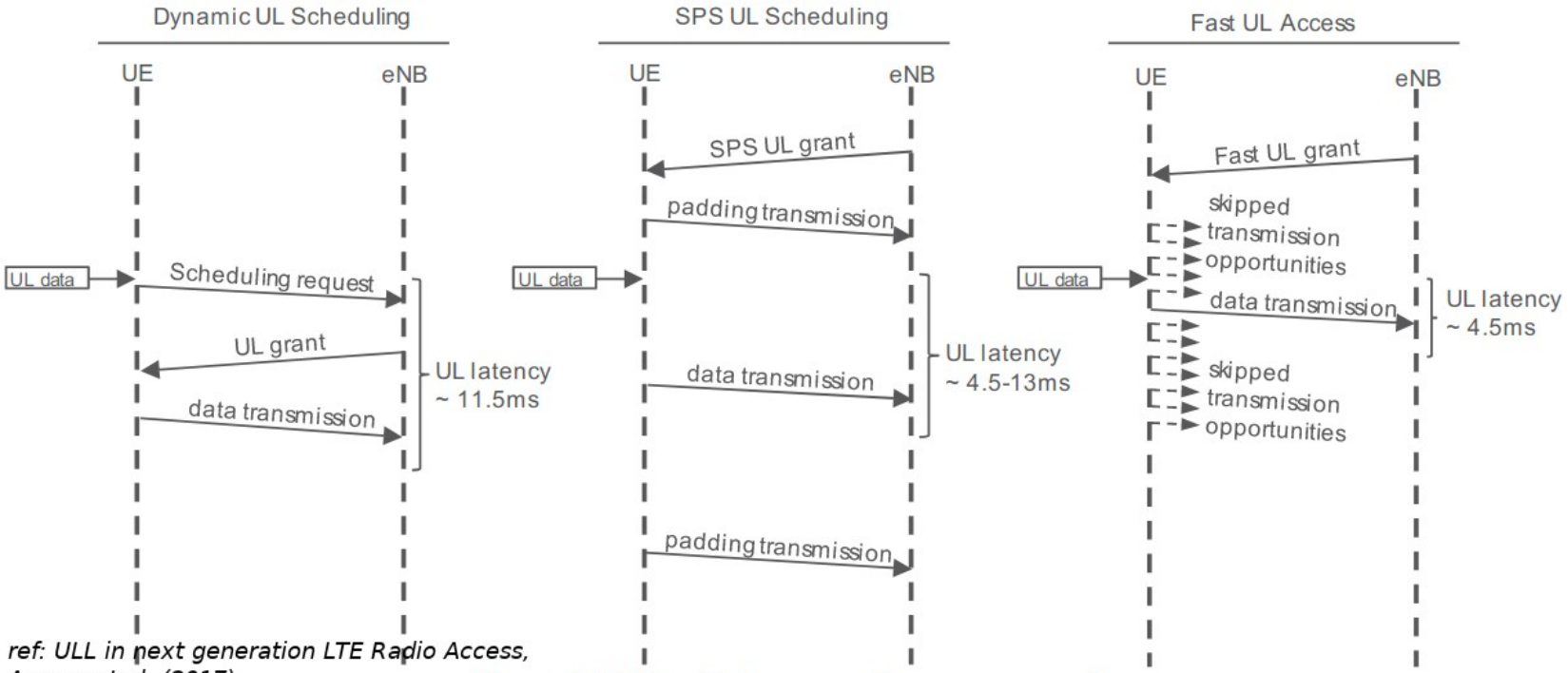
Annexes


PDCP sequence numbers (UL)
50
0
RLC sequence numbers (UL)
10
0
0
0.05
0.1
0.15
0.2
T[s]
TX UL
RX UL
SC Req
SC Grant

Annexes


Today (at best)
TCP on end-systems
AQM at bottlenecks
if change bottlenecks alone
A 'Scalable' TCP
change bottlenecks and TCP
buffer occupancy
buffer size
buffer kept for bursts
TCP saw-teeth seeking the operating point
shallower operating point
lower queuing delay and more predictably low
AQM operating point
smaller saw-teeth
link utilisation
less delay & more frequent signals - faster to detect their absence
good link utilisation
cuts delay but poorer link utilisation
time

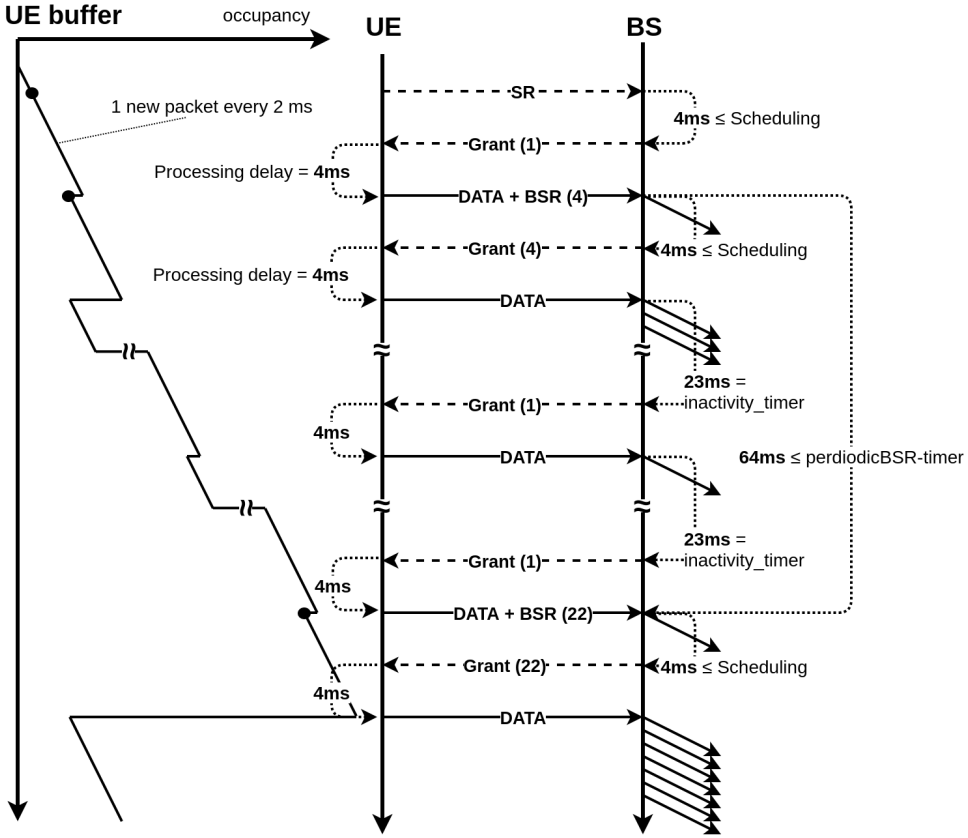
Annexes



ref: ULL in next generation LTE Radio Access, Arenas et al. (2017)

Figure 1: LTE uplink access schemes compared.

Annexes


UE buffer
occupancy
UE
BS
1 new packet every 2 ms
SR
4ms ≤ Scheduling
Grant (1)
Processing delay = 4ms
DATA + BSR (4)
Grant (4)
4ms ≤ Scheduling
Processing delay = 4ms
DATA
23ms = inactivity_timer
Grant (1)
4ms
DATA
64ms ≤ perdiodicBSR-timer
23ms = inactivity_timer
Grant (1)
4ms
DATA + BSR (22)
Grant (22)
4ms ≤ Scheduling
4ms
DATA

Annexes

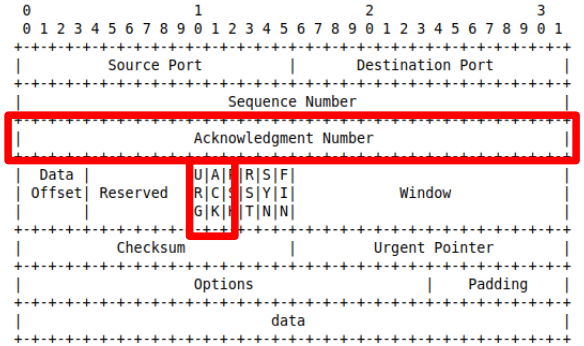


Figure: TCP ACK packet

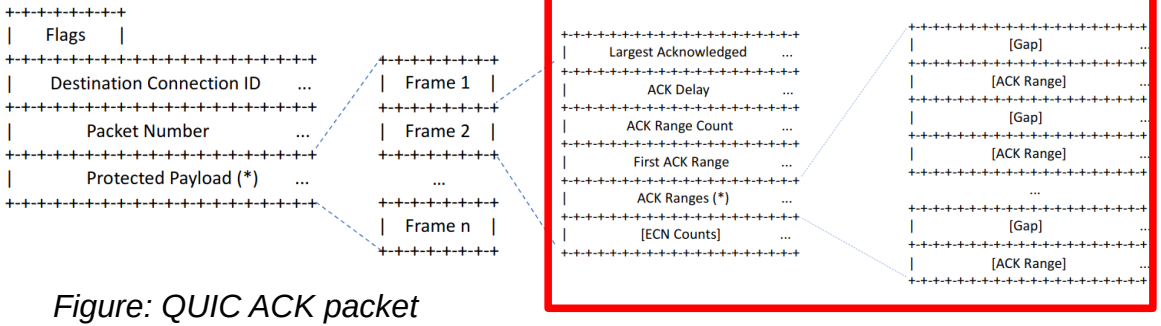


Figure: QUIC ACK packet