

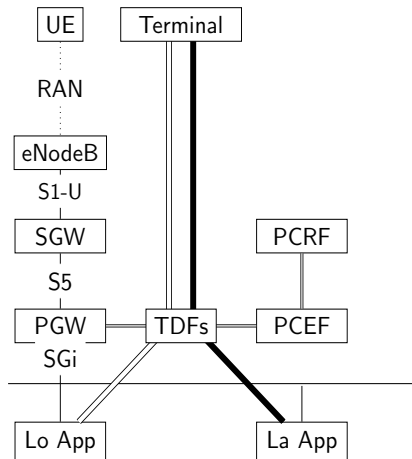
Loss Latency Tradeoff and the Mobile Network

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Experimental Setup

- ▶ LTE-uu
 - ▶ FDD SISO, 6 RB (i.e., nominal downlink peak at 4.4Mbps)
 - ▶ (measured) baseline latency: 3ms
- ▶ S1/S5/S8
 - ▶ data rate: 5Mbps
 - ▶ propagation latency: 0ms
- ▶ SGi
 - ▶ data rate: 10Gbps (basically unlimited)
 - ▶ propagation latency: 1ms
- ▶ eNB
 - ▶ proportional fair MAC scheduler
- ▶ Bearers
 - ▶ default (QCI 9)
 - ▶ dedicated low-latency (QCI 7)



Experiment one: the honest marker

Two concurrent applications on the UE resulting in two downlink flows:

- ▶ one way real-time audio (64kbps)
- ▶ one download over TCP (greedy, non application limited)

Control and experimental groups are as follows:

- ▶ control (CTL): no marking
- ▶ experimental (EXP): LLT marking applied to the real-time traffic (i.e., honest marking)

Experiment one: results

run	mean	min	max	stddev
CTL	15.48	5	24	5.18609
EXP	4.32	4	6	0.509243

Table: real-time flow latency (ms)

CTL \rightarrow EXP (mean): -72%

run	throughput
CTL	3.8073840
EXP	3.7925440

Table: TCP flow throughput (Mbps)

CTL \rightarrow EXP: -0.39%

Increased stability of the real-time flow with negligible decrease in efficiency of the throughput seeking flow (and therefore of the RAN as a whole).

Experiment two: the liar

- ▶ one way real-time audio (64kbps)
- ▶ two concurrent downloads on the UE, i.e. two TCP greedy sender (non application limited).

Control and experimental groups are as follows:

- ▶ control (CTL): TCP flows are not marked (they go through the default bearer) while the real-time audio flow is marked as low-latency and routed through the low-latency dedicated bearer
- ▶ experimental (EXP): TFT configured to route one of the TCP greedy flows (the liar) onto the low-latency dedicated bearer together with the real-time audio flow

Experiment two: results

run	honest	liar
CTL	24	25
EXP	31	140

Table: retransmissions

Liar ends up retransmitting a lot more (+460%) which implies a substantial decrease in throughput:

run	honest	liar
CTL	2.01904	1.837216
EXP	2.399816	1.332176

Table: TCP flow throughput (Mbps)

Liar gets -27.5% throughput (honest gets a 18.85% boost as a consequence)

Experiment two: results (cont)

run	mean	min	max	stddev
CTL \equiv EXP	5.37333	4	9	1.15594

Table: real-time flow latency (ms)

A throughput seeking flow that marks itself inconsistently is heavily penalised due to the increase in packet loss (basically, QCI 7's delay and packet drop budgets are not compatible with the dynamics of a bandwidth-hungry TCP flow). The aggregate throughput decreases, but because non-honest markers have no incentives, this is not a real problem. Importantly, the real-time flow is not impacted by the liar.

Conclusions

The LLT scheme has a promising future:

- ▶ Mobile operators: give your users a dedicated low-latency EPS bearer, it's safe and can effectively improve their QoE
- ▶ IETF: get together, standardise one or more LLT-like signals and let the Internet users profit!