Loss Latency Tradeoff and the Mobile Network

Pedro A. Aranda Gutiérrez, Thomas Fossati, Mirja Kühlewind, Diego R. Lopez

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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
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

<table>
<thead>
<tr>
<th>run</th>
<th>mean</th>
<th>min</th>
<th>max</th>
<th>stddev</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTL</td>
<td>15.48</td>
<td>5</td>
<td>24</td>
<td>5.18609</td>
</tr>
<tr>
<td>EXP</td>
<td>4.32</td>
<td>4</td>
<td>6</td>
<td>0.509243</td>
</tr>
</tbody>
</table>

**Table:** real-time flow latency (ms)

CTL $\rightarrow$ EXP (mean): -72%

<table>
<thead>
<tr>
<th>run</th>
<th>throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTL</td>
<td>3.8073840</td>
</tr>
<tr>
<td>EXP</td>
<td>3.7925440</td>
</tr>
</tbody>
</table>

**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

Two concurrent downloads on the UE, i.e. two TCP greedy sender (non application limited).

Control and experimental groups are as follows:

- control (CTL): no marking
- experimental (EXP): TFT configured to route one of the flows (the liar) onto the low-latency dedicated bearer
Experiment two: results

<table>
<thead>
<tr>
<th>run</th>
<th>honest</th>
<th>liar</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTL</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>EXP</td>
<td>31</td>
<td>140</td>
</tr>
</tbody>
</table>

**Table:** retransmissions

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

<table>
<thead>
<tr>
<th>run</th>
<th>honest</th>
<th>liar</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTL</td>
<td>2.01904</td>
<td>1.837216</td>
</tr>
<tr>
<td>EXP</td>
<td>2.399816</td>
<td>1.332176</td>
</tr>
</tbody>
</table>

**Table:** TCP flow throughput (Mbps)

Liar gets -27.5% throughput (honest gets a 18.85% boost as a consequence)
Experiment two: results (cont)

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.
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!