Introduction

- A communication link can be characterized by a latency-reliability function [1]:

Two factors determine shape:
- Latency variability: medium access, routing, queuing and processing, etc.
- Packet loss (x>timeout): infrastructure failures, low SINR, access overload, queue overflow, etc. → \( P_f \)

- A periodically reporting M2M device (left) may have multiple connectivity options to reach the remote host (right):

For mission critical applications, the reliability of a single interface is insufficient.

Reliability can be improved by using multiple interfaces simultaneously.

Transmission strategies

- Cloning (parallel)

- 2-of-3 (triple modular redundancy)

- Weighted (series + parallel)

Full reliability model

- Latency-reliability function is calculated per state \( s \) and payload size \( B \) as \( F_{sB}(x, B) \):

\[
F_{sB}(x, B) = \begin{cases} 
1 - \left(1 - F_1 \right) \left(1 - F_2 \right) \left(1 - F_3 \right) & \text{weighted} \\
1 - \left(1 - F_1 \right) \left(1 - F_2 \right) \left(1 - F_3 \right) & \text{cloning}
\end{cases}
\]

- Thereafter, state-reliabilities \( F_s(x, B) \) are weighted by the steady-state probabilities \( \pi_s \) (i.e. fraction of time in each state):

\[
F_{s\text{-dep}}(x, B) = \sum_{s=1}^{\text{states}} \pi_s \cdot F_{sB}(x, B)
\]

Conclusion and outlook

- The model is fast to implement and evaluate and has been verified by simulation.
- Recommendations from analysis:
  - For low latency and good reliability, use weighted packet splitting strategy.
  - For highest reliability use cloning over all available interfaces.
  - In practice, latency distributions are heavy-tailed. Follow-up work has shown similar results as above for heavy-tailed latency, however with slightly less latency reduction.

Results and discussion

<table>
<thead>
<tr>
<th>Latency (x)</th>
<th>0</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1=HSDPA, C2=EDGE, B=1500, ( \gamma=0.6107 )</td>
<td>0.9999999</td>
<td>0.999999</td>
<td>0.99999</td>
<td>0.9999</td>
<td>0.999</td>
<td>0.99</td>
<td>0.9</td>
<td>0</td>
</tr>
<tr>
<td>2-par ideal (Fiber+C1)</td>
<td>0.9999999</td>
<td>0.999999</td>
<td>0.99999</td>
<td>0.9999</td>
<td>0.999</td>
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<td>0.9</td>
<td>0</td>
</tr>
<tr>
<td>3-par model (cloning)</td>
<td>0.9999999</td>
<td>0.999999</td>
<td>0.99999</td>
<td>0.9999</td>
<td>0.999</td>
<td>0.99</td>
<td>0.9</td>
<td>0</td>
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<tr>
<td>3-par model (2-of-3)</td>
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<td>0.999999</td>
<td>0.99999</td>
<td>0.9999</td>
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<tr>
<td>3-par model (weighted)</td>
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<td>Simulation</td>
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</tbody>
</table>

References