96-0518R1 TCP over UBR and Its Buffer Requirements

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Performance for
- WAN
- LANs
- With and Without EPD
\(n\) Source Configuration

- All links 155 Mbps,
- WAN: 5 ms \(\Rightarrow\) RTT = 30 ms; LAN: 5 µs \(\Rightarrow\) RTT = 30 µs
- Unidirectional Infinite TCP sources.
  \(\Rightarrow\) TCP layer always has a packet to send if permitted by TCP window. Actual traffic on the network is bursty.
- No VBR

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TCP/IP Parameters

- Maximum Segment Size = 512 bytes
- Timer granularity = 100 ms
- Early packet drop (EPD)
- No TCP processing time
- One-way delay = 15 ms = 291 kB
  Used window scaling option
- No delay ack timer
- Fast retransmit/recovery not completely experimented
Performance Metrics

- Efficiency = Sum of throughputs/Maximum possible throughput
  - Maximum Segment Size = 512 data
    = 512 data + 20 TCP + 20 IP + 8 LLC + 8 AAL5
    = 12 cells = 12*53 bytes = 636 bytes in ATM Layer
  - Maximum possible throughput = 512/636 = 80.5%
    = 125.2 Mbps on a 155.52 Mbps link
- Fairness = \[ \frac{(\Sigma x_i)^2}{n \Sigma x_i^2} \]
  Where \( x_i \) = throughput of the \( i \)th TCP source
Seven Observations about UBR

- Switch queues may be as high as the sum of TCP windows.
- No cell loss for TCP if Buffers = $\Sigma$ TCP receiver window.
- Required buffering depends upon the number of sources.
- TCP receiver window $\geq$ RTT for full throughput with 1 source.
- Unfairness in many cases.
- Fairness can be improved by proper buffer allocation, drop policies, and scheduling.
- Drop policies are more critical (than ABR) for good throughput.
- No starvation $\Rightarrow$ Lower throughput shows up as increased file transfer times = Lower capacity.

Conclusion: UBR may be ok for: no VBR, Small number of sources, AND cheap implementation but not otherwise.
## LAN Results

<table>
<thead>
<tr>
<th>Buffer Size</th>
<th>Receiver Window</th>
<th>EPD</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
<th>D5</th>
<th>Efficiency</th>
<th>Fairness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>65535</td>
<td>N</td>
<td>1.8</td>
<td>1.9</td>
<td>1.8</td>
<td>1.8</td>
<td>18.1</td>
<td>20%</td>
<td>0.38</td>
</tr>
<tr>
<td>1000</td>
<td>32767</td>
<td>N</td>
<td>1.9</td>
<td>1.9</td>
<td>1.8</td>
<td>1.8</td>
<td>20.7</td>
<td>22%</td>
<td>0.36</td>
</tr>
<tr>
<td>500</td>
<td>65535</td>
<td>N</td>
<td>10.6</td>
<td>0.9</td>
<td>0.8</td>
<td>0.8</td>
<td>5.8</td>
<td>15%</td>
<td>0.48</td>
</tr>
<tr>
<td>500</td>
<td>32767</td>
<td>N</td>
<td>10.3</td>
<td>7.9</td>
<td>3.1</td>
<td>1.0</td>
<td>1.0</td>
<td>19%</td>
<td>0.60</td>
</tr>
<tr>
<td>1000</td>
<td>65535</td>
<td>Y</td>
<td>21.1</td>
<td>2.4</td>
<td>1.7</td>
<td>6.0</td>
<td>6.0</td>
<td>30%</td>
<td>0.52</td>
</tr>
<tr>
<td>1000</td>
<td>32767</td>
<td>Y</td>
<td>9.3</td>
<td>1.9</td>
<td>20.5</td>
<td>1.4</td>
<td>1.3</td>
<td>27%</td>
<td>0.46</td>
</tr>
<tr>
<td>500</td>
<td>65535</td>
<td>Y</td>
<td>3.1</td>
<td>0.8</td>
<td>8.1</td>
<td>8.1</td>
<td>10.7</td>
<td>25%</td>
<td>0.74</td>
</tr>
<tr>
<td>500</td>
<td>32767</td>
<td>Y</td>
<td>0.5</td>
<td>13.1</td>
<td>0.6</td>
<td>0.6</td>
<td>15.3</td>
<td>24%</td>
<td>0.44</td>
</tr>
<tr>
<td>10000</td>
<td>65535</td>
<td>N/A</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
<td>100%</td>
<td>1.00</td>
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<td>1000</td>
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<td>N/A</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
<td>100%</td>
<td>1.00</td>
</tr>
</tbody>
</table>

- Low efficiency. High Unfairness.
  ⇒ Do not use default (high) windows.
- EPD improves efficiency and fairness
- For full throughput: Need buffers = Σ receive windows

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### WAN Results

<table>
<thead>
<tr>
<th>Buffer Size</th>
<th>Receiver Window</th>
<th>EPD</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
<th>D5</th>
<th>Efficiency</th>
<th>Fairness</th>
</tr>
</thead>
<tbody>
<tr>
<td>12000</td>
<td>600000</td>
<td>N</td>
<td>16.9</td>
<td>17.9</td>
<td>17.9</td>
<td>19.2</td>
<td>17.4</td>
<td>71%</td>
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<tr>
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<td>1800000</td>
<td>N</td>
<td>16.9</td>
<td>17.9</td>
<td>17.9</td>
<td>19.2</td>
<td>17.4</td>
<td>74%</td>
<td>1.00</td>
</tr>
<tr>
<td>36000</td>
<td>600000</td>
<td>N</td>
<td>21.3</td>
<td>21.3</td>
<td>21.3</td>
<td>21.3</td>
<td>21.2</td>
<td>85%</td>
<td>1.00</td>
</tr>
<tr>
<td>36000</td>
<td>1800000</td>
<td>N</td>
<td>27.2</td>
<td>28.1</td>
<td>11.0</td>
<td>12.1</td>
<td>27.9</td>
<td>85%</td>
<td>0.88</td>
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<td>600000</td>
<td>Y</td>
<td>31.8</td>
<td>15.9</td>
<td>15.3</td>
<td>15.8</td>
<td>15.4</td>
<td>75%</td>
<td>0.89</td>
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<tr>
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<td>1800000</td>
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<td>31.8</td>
<td>15.9</td>
<td>15.3</td>
<td>15.8</td>
<td>15.4</td>
<td>75%</td>
<td>0.89</td>
</tr>
<tr>
<td>36000</td>
<td>600000</td>
<td>Y</td>
<td>21.1</td>
<td>21.1</td>
<td>21.7</td>
<td>21.2</td>
<td>20.8</td>
<td>85%</td>
<td>1.00</td>
</tr>
<tr>
<td>36000</td>
<td>1800000</td>
<td>Y</td>
<td>13.3</td>
<td>31.9</td>
<td>14.5</td>
<td>14.5</td>
<td>31.7</td>
<td>85%</td>
<td>0.86</td>
</tr>
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<td>12000</td>
<td>120000</td>
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<td>24.0</td>
<td>24.1</td>
<td>24.0</td>
<td>24.1</td>
<td>24.0</td>
<td>96%</td>
<td>1.00</td>
</tr>
<tr>
<td>36000</td>
<td>360000</td>
<td>N/A</td>
<td>23.9</td>
<td>24.2</td>
<td>23.9</td>
<td>24.2</td>
<td>23.9</td>
<td>96%</td>
<td>1.00</td>
</tr>
</tbody>
</table>

- Default windows are ideal for WANs.
  ⇒ EPD has less effect..

- For full throughput: Need buffers = Σ receive windows
Other Observations

- Setting EPD threshold as a fraction of buffer size is not useful. Better to set EPD Threshold = buffer size - n packets
- EPD improves fairness. But UBR+EPD is still unfair.
Packet loss results in a significant degradation in TCP throughput. For best throughput, TCP needs no loss.

For zero loss, need buffers = Σ receiver windows

With enough buffers, ABR may guarantee zero loss for any number of TCP sources. With UBR there is no such guarantee.

TCP + ABR is better than TCP + UBR. But, UBR may be OK for low-end products.
REFERENCES


All our past ATM forum contributions/presentations, and recent papers can be obtained on-line:
http://www.cis.ohio-state.edu/~jain/