TCP AND ATM IN WIDE AREA NETWORKS

Benjamin J. Ewy, Joseph B. Evans, Victor S. Frost, Gary J. Minden
Telecommunications & Information Sciences Laboratory
Department of Electrical Engineering & Computer Science
University of Kansas
Lawrence, KS 66045-2228
evans@eeecs.ukans.edu

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MAGIC Network

- 2.4 Gb/s Wide-Area Network (1000 kilometers)
- support for 622 Mb/s (OC-12c) and 155 Mb/s (OC-3c) circuits
- hosts at KU, BCBL, Sprint, EDC used for tests
Overview of Results

- default TCP/IP performance over ATM WAN is poor
  - buffer overflow caused by bandwidth mismatch, multiple sources
  - TCP rate control not working?
  - TCP windows must be large enough for WAN

- solutions
  - ATM
  - TCP
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Experiment 1

- question: WAN performance limited by TCP window size?
- experiment: DEC Alpha with a DEC OTTO OC-3c interface to DEC Alpha over a 600 km link, 8.8 ms round-trip delay
- results

<table>
<thead>
<tr>
<th>TCP Window Size</th>
<th>0.5k</th>
<th>1k</th>
<th>2k</th>
<th>4k</th>
<th>8k</th>
<th>16k</th>
<th>32k</th>
<th>64k</th>
<th>128k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput (Mb/s)</td>
<td>0.47</td>
<td>0.93</td>
<td>1.8</td>
<td>3.7</td>
<td>7.4</td>
<td>14.9</td>
<td>29.8</td>
<td>59.6</td>
<td>119</td>
</tr>
</tbody>
</table>

- comments
  - consistent with the theoretical limits caused by latency
  - pacing not needed because no rate mismatch
  - large windows necessary for acceptable throughput
Experiment 2

- questions: high bandwidth TCP sources will overrun ATM switch buffers at points of bandwidth mismatch? improved by pacing?
- experiment: Alpha (OC-3c) in Lawrence, Kansas to SPARC-10 (TAXI) in South Dakota (600 km) - a single host to another host
  - Alphas - DEC OTTO cards, SPARC-10 - Fore Systems 100 Mb/s TAXI
  - switches - Fore Systems ASX-100
  - 128 kB TCP windows, 64 kB write buffers
  - ATM pacing at 70 Mb/s
- results:

<table>
<thead>
<tr>
<th></th>
<th>No Pacing</th>
<th>Pacing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.87 Mb/s</td>
<td>68.20 Mb/s</td>
</tr>
</tbody>
</table>
Experiment 3

- questions: multiple high bandwidth TCP sources will overrun ATM switch buffers at multiplexing points? improved using pacing?

- experiment: Two Alphas (OC-3c) in Lawrence, Kansas to SPARC-10 (TAXI) in South Dakota (600 km) - two hosts to a third host
  - Alphas - DEC OTTO cards, SPARC-10 - Fore Systems 100 Mb/s TAXI, switches - Fore Systems ASX-100
  - 128 kB TCP windows, 64 kB write buffers
  - ATM pacing at 35 Mb/s each

- results:

<table>
<thead>
<tr>
<th></th>
<th>No Pacing</th>
<th>Pacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.66 Mb/s</td>
<td>52.36 Mb/s</td>
<td></td>
</tr>
</tbody>
</table>
Experiment 4

- questions: interoperability? packet losses? pacing effects?
- experiment:
  - scenario a: two SPARC-10s (TAXI) in Kansas and South Dakota to SGI Onyx (TAXI) in Kansas City - Fore interfaces only
  - scenario b: two Alphas (OC-3c) in Lawrence, Kansas to SGI Onyx (TAXI) in Kansas City - two hosts supporting pacing to a third host
- results:

<table>
<thead>
<tr>
<th></th>
<th>No Pacing</th>
<th>Pacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>scenario a</td>
<td>46.71 Mb/s</td>
<td>-</td>
</tr>
<tr>
<td>scenario b</td>
<td>-</td>
<td>61.17 Mb/s</td>
</tr>
</tbody>
</table>
- comments:
  - two to four packet losses per second observed in scenario a
  - no packet losses observed in scenario b
Experiment 5

- question: will TCP rate control be more effective if TCP segment size small relative to buffers?

- experiment: Alpha (OC-3c) in Lawrence, Kansas to SPARC-10 (TAXI) in South Dakota (600 km), vary TCP segment size

- results:

![Throughput and TCP Segment Size](image)
Experiment 6

- question: does TCP performance trade-off exist due to congestion limits versus machine processing limits?

- experiment: Alpha (OC-3c) in Lawrence, Kansas to Alpha (OC-3c) at same location, vary TCP segment size

- results:
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EXTRAPOLATION

Buffer Size Effects

- segment size and buffers (Fore ASX-100 has 12 kB buffer)
- assume given cell loss rate, find buffers needed for given load

![Graph showing Allowable Load versus ATM Switch Buffer Capacity]

Ewy, Evans, Frost, Minden
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TCP Processing Bounds

- throughput limits due to segment size and machine speed
- extrapolate from measured data to higher machine capabilities
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- congestion limitations
- WAN limitations
- processing limitations
- ATM pacing
- TCP pacing