Counters-Based Modified Traffic Conditioner

Maria-Dolores Cano, Fernando Cerdan, Joan Garcia-Haro, Josemaria Malgosa-Sanahuja
Department of Information Technologies and Communications
Polytechnic University of Cartagena, Spain
Outline

- Introduction
- Counters-Based Modified traffic conditioner
- Topology and scenario for simulations
- Results
- Conclusions
Introduction

- How to provide QoS in IP networks?
  - Differentiated Services
    - Complexity to the edge of the network
    - Per Hop Behavior (PHB)

**Assured Forwarding PHB**

To ensure minimum throughput
To consume excess bandwidth

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Introduction

- RIO (RED IN and OUT) and the Time Sliding Window (TSW) traffic conditioner.

- Traffic conditioners, two trends:
  - Rate estimators
    - TSW [2]
    - ETSW [3]
    - Intelligent traffic conditioner [4]
  - Tokens
    - Three colors [RFC 2698]
    - Fair marker [7] [8] [9]
    - Counters-based [10]
Counters-Based traffic conditioner:

- Strictly assures contracted rates.
- Two counters.
- No parameter configuration.
- It performs comparatively better than classical Leaky Bucket (LB) and TSW.
- It does not distribute excess bandwidth fairly.
If all sources introduce the same number of out-of-profile packets, assuming all packets have a similar size, then each source can get the same portion of excess bandwidth.

Affected by the odd characteristics of each TPC connection like different RTT, target rates, and interaction with RIO buffer management scheme.
From simulation results:

- A source with small target generates more OUT packets between consecutive IN packets than a source with higher target.
- The faster time response of the TCP sources with small RTT make them inject more traffic, i.e. more OUT packets.
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TCP source

Counters-Based marker

CBM TRAFFIC CONDITIONER

IN PACKETS INJECTED INTO THE NETWORK

OUT PACKETS INJECTED INTO THE NETWORK

OUT PACKETS DROPPED

\[
\text{If } \#\text{OUTs} < \text{min} \Rightarrow p=0
\]

\[
\text{If } \#\text{OUTs} > \text{max} \Rightarrow p=1
\]

\[
\text{if min} < \#\text{OUTs} < \text{max} \Rightarrow p
\]

\#OUTs initialized to zero after IN packet

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● Setting max and min thresholds:

- Excess bandwidth like another “TCP source” whose maximum window size would be $\Rightarrow max$
  - Source that injects a number of OUT packets close to this limit would consume almost the entire excess bandwidth.
  - If this limits is exceeded the source would steal guaranteed bandwidth from another source $\Rightarrow$ sources cannot inject more than $max$ OUT packets.
  - If only one source remains active it can consume almost the entire excess bandwidth.

$$\begin{align*}
max &= \left[ \frac{\text{bandwidth}_{\text{excess}} \cdot RTT_{\text{average}}}{MSS} \right] \\
min &= \left[ \frac{max}{2} \right]
\end{align*}$$
Estimation of the RTT:

- Periodically signaling from the router device
- No per-flow state monitoring, router does not contain information of each individual packet flow.
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Calculating the dropping probability $p$:

$$p = 2 \cdot \frac{\text{target_rate}}{\text{link_rate}} \cdot \frac{\text{link_rate}}{1 + \text{target_rate}}$$

- $p$ between 0 and 1, based on the target rate of the source.
- Small differences in the $p$ value may cause big performance differences because of the TCP congestion algorithm.
Topology for simulations

TCP SOURCES
1 T
2 T
3 T
4 T
5 T
6 T
7 T
8 T

TCP DESTINATIONS
1 T
2 T
3 T
4 T
5 T
6 T
7 T
8 T

Link rate 33Mbps

Router RIO

Round Trip Time (RTT)

Traffic Conditioner
Scenarios for simulation

- Simulation tool for the sliding window protocol of TCP Reno sources developed in [11]:
  - Greedy sources.
  - Destinations only send acknowledgements.
  - Maximum window size equals the product bandwidth delay as usual in WAN environments.

- Large IP packet size of 9,188 bytes (IP over ATM).

- Router buffers and forwards aggregated traffic using RIO with parameters [40/70/0.02] for IN packets and [10/40/0.2] for OUT packets.
## Scenarios for simulation

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Link rate (Mbps)</strong></td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td><strong>TRsrc#0 to 7 (Mbps)</strong></td>
<td>2.4</td>
<td>1-1-2-2-3-3-4-4</td>
<td>2.4</td>
<td>1-1-2-2-3-3-4-4</td>
<td>4-4-3-3-2-2-1-1</td>
</tr>
<tr>
<td><strong>RTT src#0 to 7 (ms)</strong></td>
<td>50</td>
<td>50</td>
<td>10-20-30-40-50-70-80</td>
<td>10-20-30-40-50-70-80</td>
<td>10-20-30-40-50-70-80</td>
</tr>
<tr>
<td><strong>Σ target rates (Mbps)</strong></td>
<td>19.2</td>
<td>20</td>
<td>19.2</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td><strong>BW&lt;sub&gt;excess&lt;/sub&gt; (Mbps)</strong></td>
<td>13.8</td>
<td>13</td>
<td>13.8</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td><strong>RTT&lt;sub&gt;average&lt;/sub&gt; (ms)</strong></td>
<td>50</td>
<td>50</td>
<td>45</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td><strong>max (#OUT packets)</strong></td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td><strong>min (#OUT packets)</strong></td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
Results

- Out packets dropping
  - The CBM traffic conditioner is able to control the number of OUT packets injected into the network by each source.

![Graphs showing packet drops over time](image-url)
Results

- Fairness index:
  - We understand fairness as the even distribution of excess bandwidth among all connections that compose the aggregate.

  \[
  f = \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{n \cdot \sum_{i=1}^{n} x_i^2} \leq 1
  \]

  \(x_i\) • Excess throughput of source \(i\)

  \(n\) • Number of sources
Results

- Fairness index:
  - It is possible to assure fairness in the excess bandwidth sharing with CBM, achieving an $f$ value close to 0.95.
Results

How does the CBM behave when best-effort sources compete with Assured Service sources for available excess bandwidth?

- BE sources generate only OUT packets.
- BE sources do not have target rates.
- Simulations in same scenarios A through E with slight variations.
Results

- Fairness in scenario A, $f = 0.906$
- AS sources have target rate of 5 Mbps
- Excess bandwidth = $33 - 5 \times 4 = 13$ Mbps
- Fair share of excess bandwidth
  - $13 / 8 = 1.625$ Mbps
- RTT 50 ms for all sources

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Results

- Fairness in scenario C, $f = 0.847$

- AS sources have target rate of 5 Mbps
- Fair share of excess bandwidth
  - $13 / 8 = 1.625$ Mbps

- Excess bandwidth: $33 - 5 * 4 = 13$ Mbps
- RTT from 10 ms (src1) to 80 ms (src8)

For source AS at 5 Mbps; Four sources best effort; RTT of 10–20–30–40–50–60–70–80 ms; Link rate 33 Mbps
Results

- Fairness in scenario E, $f = 0.811$
  - AS sources have target rate of 7-4 Mbps
  - Excess bandwidth: $33 - 22 = 11$ Mbps
  - Fair share of excess bandwidth
    $\Rightarrow 11 / 8 = 1.375$ Mbps

Four sources AS at 7-6-5-4 Mbps; Four sources best effort; RTT of 10-20-30-40-50-60-70-80 ms; Link rate 33 Mbps

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Results

- Target rate is guaranteed for AS sources even when best-effort sources compete in the same topology.

Conclusions

- We have introduced a modification of the Counters-Based traffic conditioner, the Counters-Based Modified (CBM), which fulfills a fair distribution of excess bandwidth and guarantees target rates.

- CBM controls the number of OUT packets that each source introduces in the aggregate
  - Discarding OUT packets with a probability that depends on the target rate, the excess bandwidth and an estimation of the RTT.
Conclusions

- We have presented simulation results in miscellaneous TCP environments (different target rates, different RTT and sharing of resources with best-effort connections):
  - Results show that CBM can assure fairness (f > 0.9).
  - CBM comparatively better than classical LB or TSW with RIO.
  - When best-effort sources coexist with AS sources, CBM is robust enough and keeps its good behavior.
- Further work: more complex topologies, different packet sizes, and “errors” in RTT estimation.
Thank you!

mdolores.cano@upct.es