Equation-Based Congestion Control for Unicast Applications

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End-to-End Congestion Control

• Additive Increase/Multiplicative Decrease approach
  – Congestion control used by TCP
  – If congestion is detected (e.g., packet drop), multiplicatively decrease congestion window size (\(CWZ = CWZ / 2\))
  – Otherwise, additively increases congestion window size (\(CWZ = CWZ + 1\))

• Equation-based congestion control approach
  – Adapts to sending rate according to control equation
  – Slow response to the congestion

TCP-Friendly Rate Control (TFRC)

• TFRC is “TCP-compatible”
  – If TCP and TFRC were competing, there is no significant starvation in FIFO queue
  – TFRC uses TCP response function (it reflects the steady-state sending rate of TCP)

• Design principles
  1. Not aggressive for sending more data
  2. Be responsive to packet losses in sufficiently long term

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<thead>
<tr>
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<th>Advantage</th>
<th>Disadvantage</th>
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<tbody>
<tr>
<td>AIMD (TCP congestion control)</td>
<td>Effective for bulk data transfer</td>
<td>Multiplicative decrease is not suitable for real-time applications (e.g., streaming multimedia)</td>
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<tr>
<td>Equation-based congestion control</td>
<td>Change of transmission rate is smooth over time (appropriate for real-time applications)</td>
<td>Not able to respond to the abrupt increase immediately</td>
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• TCP-friendly Rate Control (TFRC)
  – Proposed equation-based congestion control for unicast application
  – Smooth change of sending rate in response to congestion
TFRC Protocol

TCP response function

\[ T = \frac{s}{R \sqrt{\frac{2p}{3}} + \frac{4}{R^2} \left( \frac{3p}{8} \right) R_T O + \frac{4}{R^2} (s + 32p^2)} \]

- **T**: upper bound of sending rate
- **R**: round-trip time
- **p**: steady-state loss event rate computed by receiver
- **R_T O**: retransmit timeout can be computed using R

TFRC Protocol

- **Loss event rate (p)**
  - Different from loss fraction which is \( \frac{\text{# packets lost}}{\text{# packets transferred}} \)
  - Loss event rate counts an event loss per packet round-trip time
  - Loss event rate models TCP protocols
  - Average Loss Interval method is used.
    - (Averaging the loss rate over the previous loss intervals with dynamic weights)
  - \( p = \frac{1}{\text{Average Loss Interval}} \)

Summary

- Equation-based Congestion control is proposed for real-time applications
- Sender determines the transfer rate (T) based on the control equation
- Receiver computes loss event rate which is transferred to the sender and used to compute T
- TFRC provides congestion control mechanism which is less variable in response to congestion