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
  - Adaptively controls sending rate according to control equation
  - Slow response to the congestion

End-to-End Congestion Control

	Advantage	Disadvantage
AIMD (TCP congestion control)	Effective for bulk data transfer	Multiplicative decrease is not suitable for real-time applications (e.g. streaming multimedia)
Equation-based congestion control	Change of transmission rate is smooth over time (appropriate for real-time applications)	Not able to respond to the abrupt increase immediately

- TCP-friendly Rate Control (TFRC)
  - Proposed equation-based congestion control for unicast application
  - Smooth change of sending rate in response to 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

TFRC Protocol

TCP response function

$$T = \frac{s}{R\sqrt{\frac{2p}{3}} + t_{RTO}\left(3\sqrt{\frac{3p}{8}}\right)p\left(1+32p^2\right)}$$

T: upper bound of sending rate

R: round-trip time
computed by sender or receiver

p = steady-state loss event rate
computed by receiver

t_{RTO} = retransmit timeout
can be computed using R

TFRC Protocol

$$T = \frac{s}{R\sqrt{\frac{2p}{3}} + t_{RTO}\left(3\sqrt{\frac{3p}{8}}\right)p\left(1+32p^2\right)}$$

- Receiver
  - Computes *p* (loss event rate) and transfer it to the sender
- Sender
  - Compute *T* based on *p* and *R*
  - Controls transmission rate based on *T*

TFRC Protocol

- Loss event rate (*p*)
  - Different from loss fraction which is $\frac{\text{\# packets lost}}{\text{\# packets transferred}}$
  - Loss event rate counts a 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 sender and used to compute *T*
- TFRC provides congestion control mechanism which is less variable in response to congestion