Analyzing the Impact of TCP Connections Variation on Transient Behavior of RED Gateway

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Contents

• Background
• RED Gateway
• Analytic Model
• Transient Behavior Analysis
• Numerical Examples
• Conclusion and Future Work
Background

- **TCP (Transmission Control Protocol)**
  - Window-based congestion control
  - End-to-end congestion control
  - Assume nothing about a gateway’s operation algorithm

- **AQM (Active Queue Management)**
  - Support end-to-end congestion control mechanism of TCP
  - **RED** is one of promising gateway
Characteristic of RED

- Compare RED with conventional Drop-Tail
  - Average queue length is kept low
  - A global synchronization problem is avoided
  - RED can improve the fairness among the connections
  - Effectiveness of RED is fully dependent on a choice of control parameters
Studies on RED

- A number of studies on the steady state performance using simulation experiments
- A few studies analyzing the characteristics of RED
  - Stability and transient behavior in the steady state
  - The number of TCP connections changes in an actual network
Objective

- When the number of TCP connections is increased
  - The traffic increases temporarily
  - The possibility of buffer overflow

- When the number of TCP connections is decreased
  - The traffic decreases temporarily
  - The possibility of buffer underflow

- Analyzing the transient behavior of the RED gateway
  - Taking account of the variation of TCP connections
  - Focus on the dynamics of the number of packets in the RED gateway's buffer
RED Algorithm

The packet marking probability

\[ q \]

minth \( \leq \) \( q \) \( \leq \) maxp

minth: minimum threshold
maxth: maximum threshold
maxp: maximum packet marking probability

The average queue length

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Analytic Model

Source hosts

\[ N \]

\[ \Delta N \]

Destination hosts

\[ N \]

\[ \Delta N \]

\[ \tau [\text{ms}] \]

\[ \text{maxth minth} \]

RED gateway
The average state transition equations

\[
\begin{align*}
\bar{w}(k + s(k)) &= \frac{w(k) + s(k) - 1}{2} \\
q(k + s(k)) &\approx n(k + s(k))\bar{w}(k + s(k)) - B\tau \\
\bar{q}(k + s(k)) &\approx (1 - q_w)\bar{X}(k)\bar{q}(k) + \{1 - (1 - q_w)\bar{X}(k)\}q(k)
\end{align*}
\]

Linear approximation

- Around their average equilibrium values
- $A$ is state transition matrix

\[
\delta x(k + \bar{s}(k)) = A \delta x(k)
\]

\[
\delta x(k) \equiv \begin{bmatrix}
w(k) - w^* \\
q(k) - q^* \\
\bar{q}(k) - \bar{q}^* \\
n(k) - n^*
\end{bmatrix}
\]
Types of TCP Connections Variation

• Four types of changes in the number of TCP connections
  - All TCP connections are in the congestion avoidance phase
    • 1. End their data transmissions
    • 2. Resume their data transmissions after short idle period
  - ΔN TCP connections are in the slow start phase
    • 3. Resume their data transmissions after long idle period
    • 4. Newly start their data transmissions
All TCP connections are in the congestion avoidance phase.

\[ u(k) = \begin{cases} \Delta N & \text{if } k = i \\ 0 & \text{otherwise} \end{cases} \]

\[ \delta x(k + s(k)) = A \delta x(k) + B u(k) \]

\[ q(k) = C \delta x(k) \]

\[ B = [0 \ 0 \ 0 \ 1]^T \]

\[ C = [0 \ 1 \ 0 \ 0] \]
SISO model

- Single-Input Single-Output model
- The dynamics of the current queue length

\[ q(k) = \sum_{i=0}^{k} u(i) \Delta x(k - i) \]
TCP connections are in the slow start phase

\[ u'(k) = \sum_{i=1}^{N} (w_i(k) - w_i(k-1)) \]

\[ \delta x(k + s(k)) = A\delta x(k) + B'u'(k) \]

\[ q(k) = C\delta x(k) \]

\[ B' = [1 \ 0 \ 0 \ 0]^T \]

\[ C = [0 \ 1 \ 0 \ 0] \]
Performance measures for transient behavior

The queue length

rise time  settling time

overshoot

0 1.0 0.9 0.05

time

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15
Queue length variation \((maxp)\)

- \(B = 2\) [packet/ms]
- \(\tau = 1\) [ms], \(N = 5\), \(\Delta N = 1\)
- \(maxp = 0.025\)
- \(maxp = 0.05\)
- \(maxp = 0.1\)
- \(maxp = 0.15\)
Performance measures ($maxp$)
Queue length variation ($B$)

\[ \tau = 1 \text{[ms]}, N = 5, maxp = 0.1 \]

\[ minth = 5, maxth = 15 \]

\[ \Delta N = 1 \]
Performance Measures \( (B) \)

- Rise/Setting Time [ms]
- Queue Length Overshoot [packet]

- Overshoot
- Rise time
- Settling time

\( B \) [packet/ms]
Conclusion and Future Work

• Conclusion
  – Analyze the impact of TCP connections variation on the transient behavior of RED gateway
    • Investigate the dynamics of the current queue length
    • When the number of TCP connections is changed
  – Numerical Examples
    • The control parameters have little influence
    • The transient behavior is sensitive to the system parameters

• Future Work
  – To investigate the transient behavior for realistic TCP connections variation