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

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

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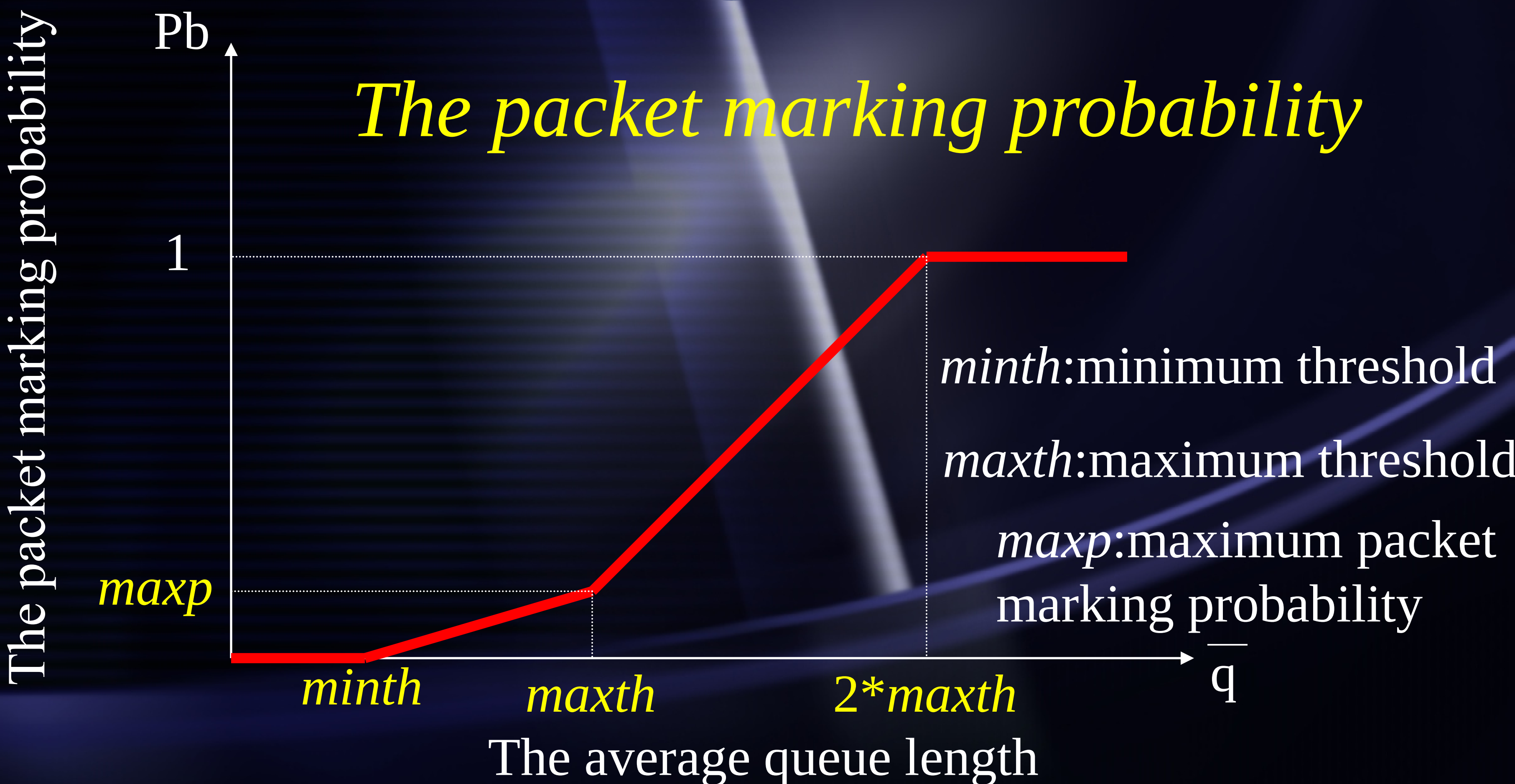
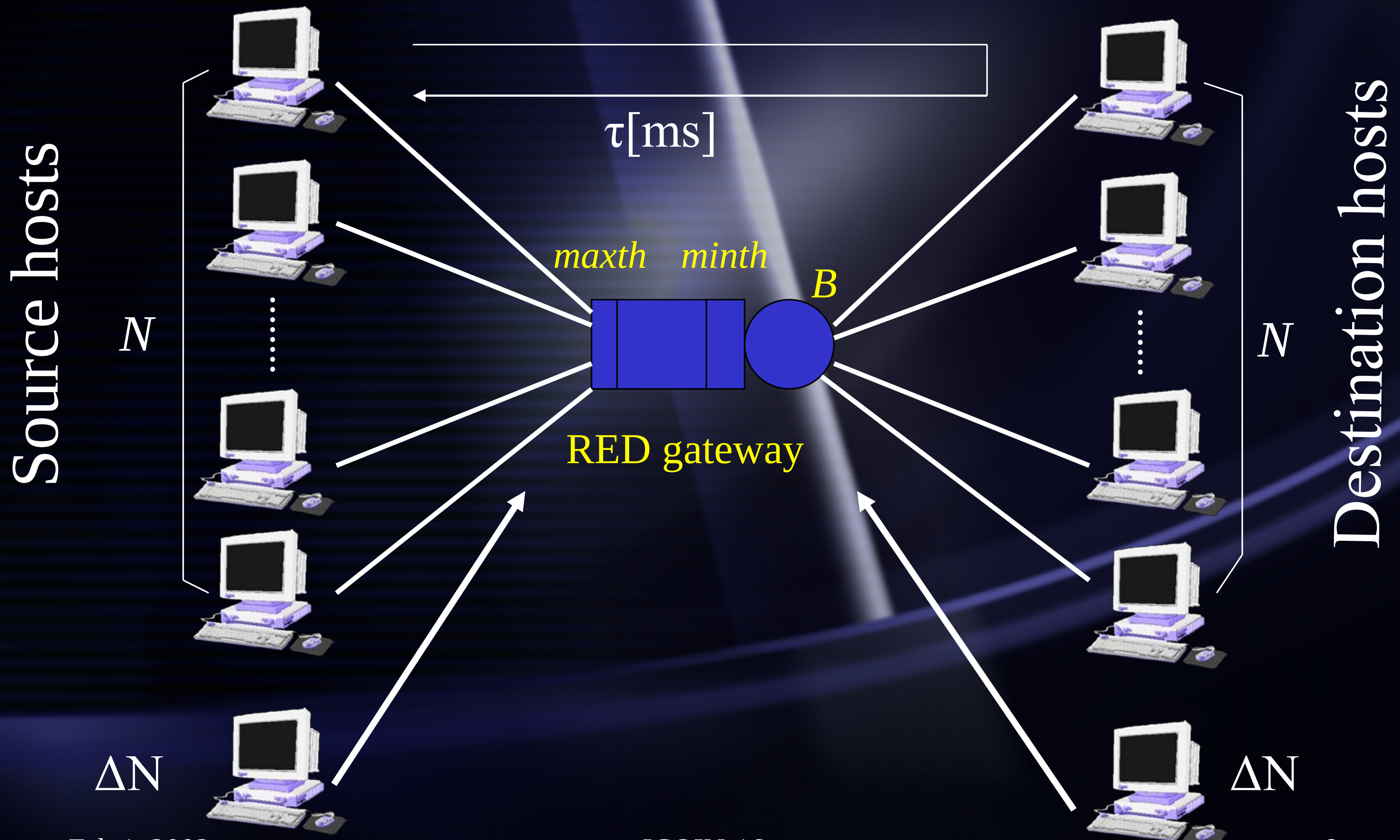
- Analyzing the transient behavior of the RED gateway
  - Taking account of the variation of TCP connections
  - Focus on the dynamics of the number of packets in the RED gateway's buffer

RED Algorithm



Analytic Model



The average state transition equations

$$w(k+\bar{s}(k)) = \frac{w(k)+\bar{s}(k)-1}{2}$$

$$q(k+\bar{s}(k)) \cong n(k+\bar{s}(k))w(k+\bar{s}(k)) - B\tau$$

$$\bar{q}(k+\bar{s}(k)) \cong (1-q_w)^{\bar{X}(k)}\bar{q}(k) + \{1-(1-q_w)^{\bar{X}(k)}\}q(k)$$

reference[5]: H.Ohsaki,M.Murata,and H.Miyahara "Steady state analysis of the RED gateway: stability,transient behavior and parameter setting," to appear in IEICE Transactions on Communications, Jan. 2002.

Linear approximation

- Around their average equilibrium values
- $\mathbf{A}$ is state transition matrix

$$\delta \mathbf{x}(k+\bar{s}(k)) = \mathrm{A}\,\delta \mathbf{x}(k)$$

$$\delta \mathbf{x}(k) \equiv \begin{bmatrix} w(k) - w^{*} \\ q(k) - q^{*} \\ \bar{q}(k) - \bar{q}^{*} \\ n(k) - n^{*} \end{bmatrix}$$

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

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

$$\delta \mathbf{x}(k + \bar{s}(k)) = \mathbf{A}\delta \mathbf{x}(k) + \mathbf{B}u(k)$$

$$q(k) = \mathbf{C}\delta \mathbf{x}(k)$$

$$\mathbf{B} = [0\ 0\ 0\ 1]^T$$

$$\mathbf{C} = [0\ 1\ 0\ 0]$$

SISO model

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

$$q(k) = \sum_{i=0}^{k} u(i)\delta\mathbf{x}(k-i)$$

ΔN TCP connections are in the slow start phase

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

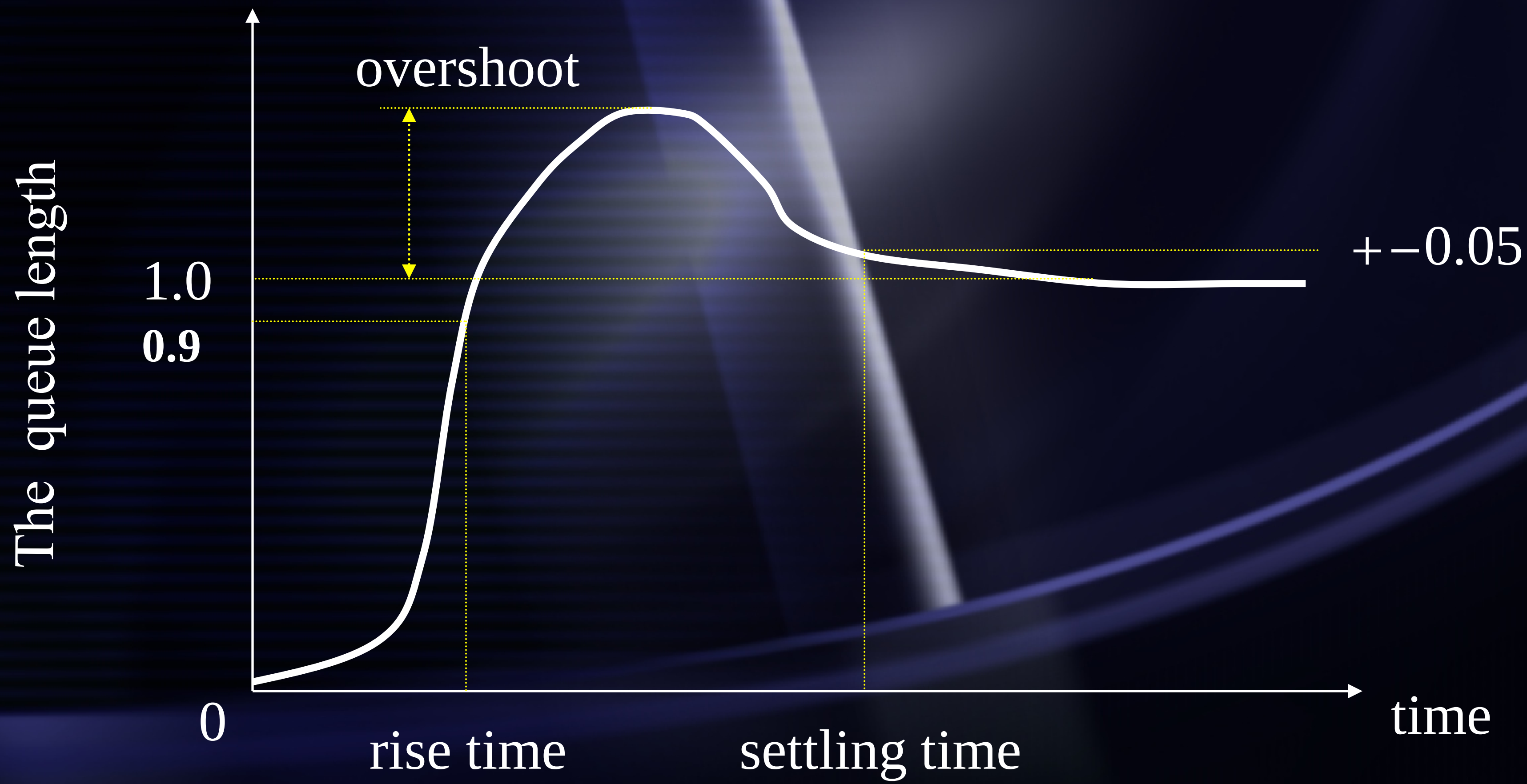
$$\delta \mathbf{x}(k + \bar{s}(k)) = \mathbf{A}\delta \mathbf{x}(k) + \mathbf{B}' u'(k)$$

$$q(k) = \mathbf{C}\delta \mathbf{x}(k)$$

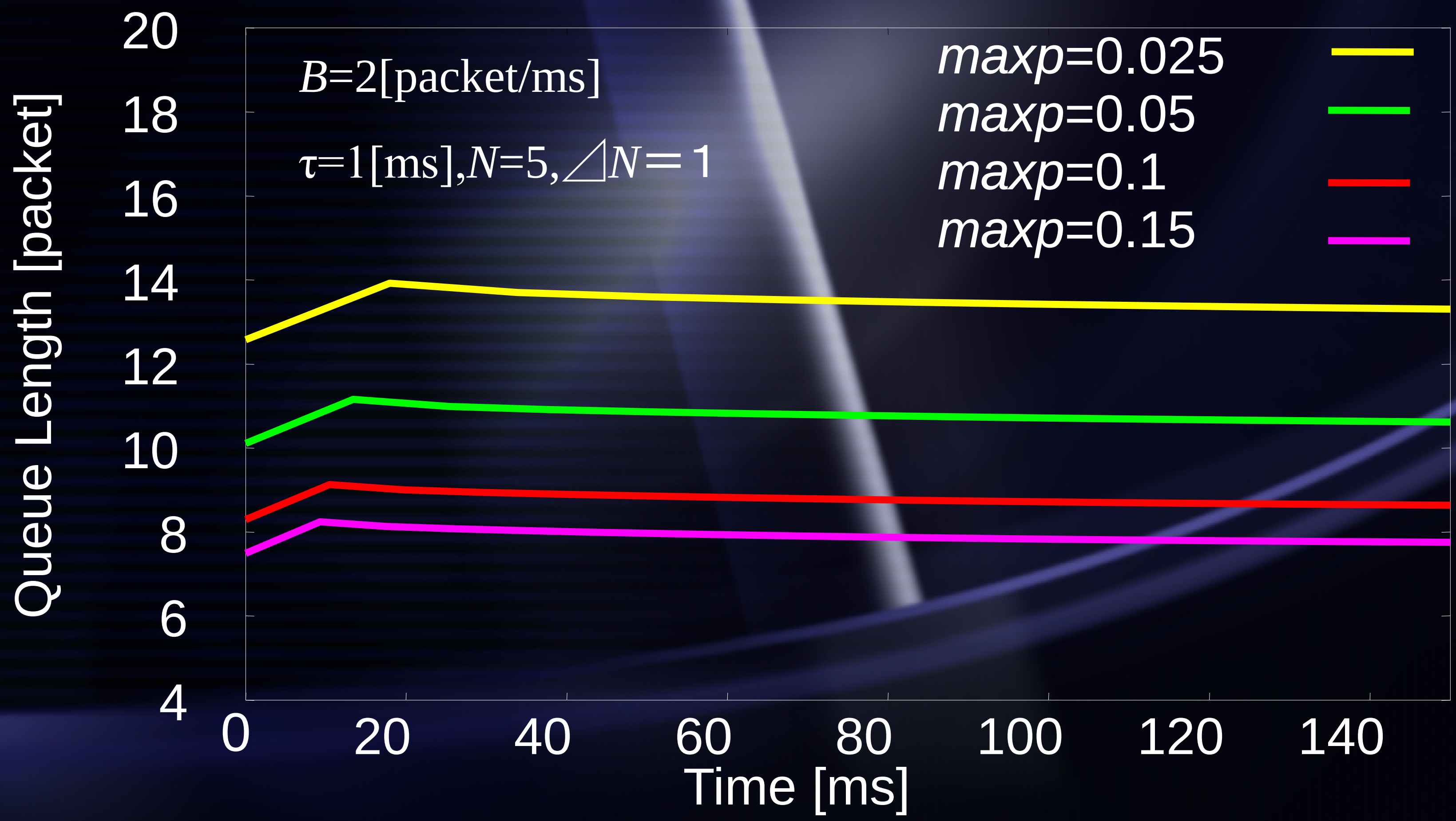
$$\mathbf{B}' = [1\ 0\ 0\ 0]^T$$

$$\mathbf{C} = [0\ 1\ 0\ 0]$$

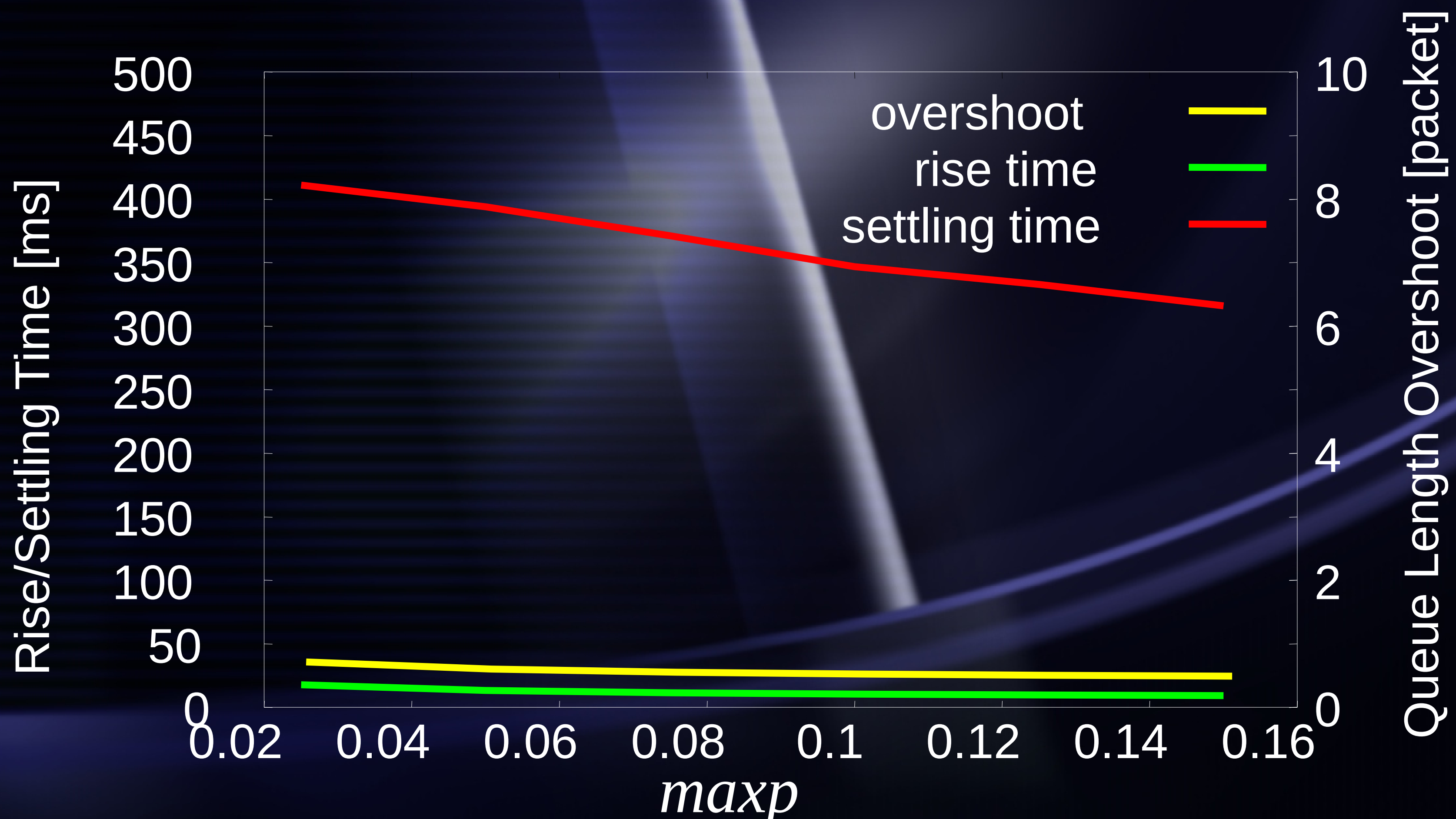
Performance measures for transient behavior



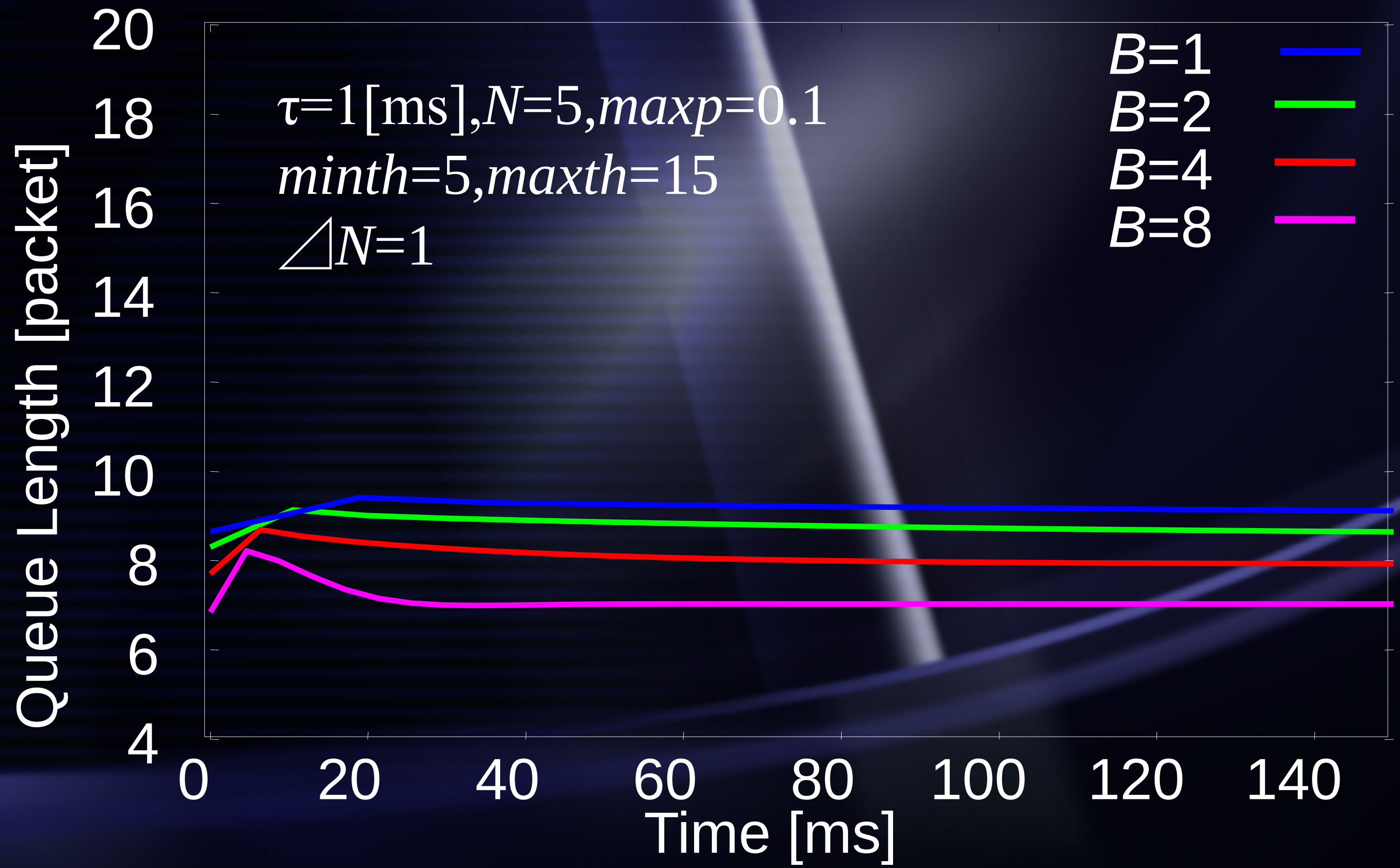
Queue length variation (*maxp*)



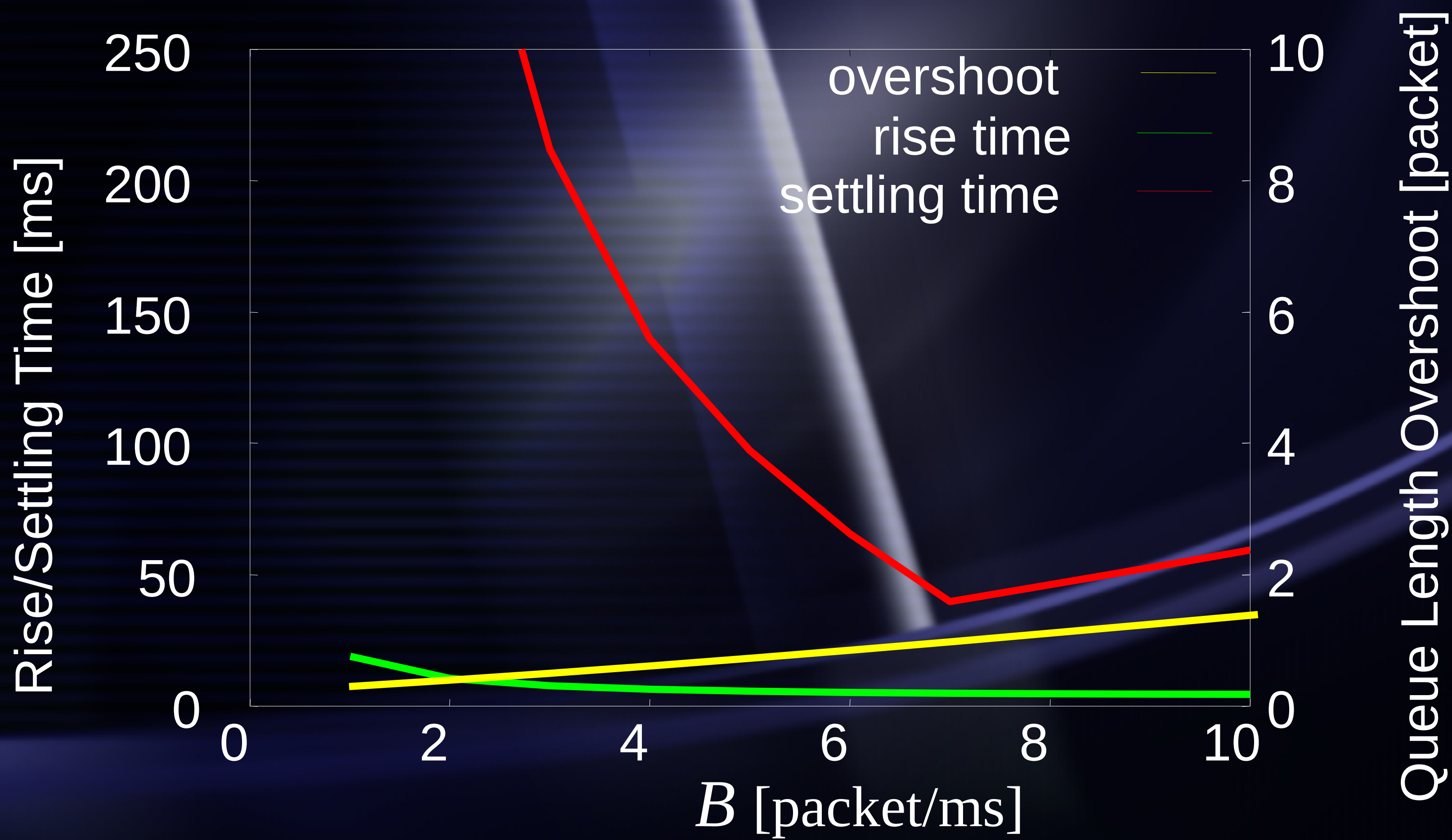
Performance measures (*maxp*)



Queue length variation (*B*)



Performance Measures (B)



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