Designing a Delay-based Adaptive Congestion Control Mechanism using Control Theory and System Identification for TCP/IP Networks

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Research Background

- Congestion control in the Internet
  - Loss-based approach
    - Use occurrence of packet losses for congestion detection
      - TCP Tahoe and TCP Reno
      - Packet losses cannot be prevented
  - Delay-based approach
    - Use variation of packet delays for congestion detection
      - TCP Vegas
      - Packet losses can be prevented, leading higher throughput

- Our previous works
  - Modeling packet delay dynamics by ARX model using system identification

Research Objectives

- Design a delay-based congestion control mechanism
- Use packet delay dynamics model obtained by system identification
- Apply classical control theory
  - Pole placement using state feedback
- State observer
- Evaluate its performance
- Simulation experiments in two network configurations

Problem Formulation

- Controlled system (i.e., plant)
  - Entire network seen by a specific source host
- Input and output definitions
  - Input $u(k)$: packet transmission rate from source host
  - Output $y(k)$: measured round-trip time
- Control objective
  - To achieve a constant round-trip time measured at the source host

Overview of Our Delay-based Congestion Control Mechanism

- Build a round-trip time dynamics model from measured input and output.
- Estimate state variables of the ARX model from measured input and output.
- Determine packet transmission rate based on pole placement technique using state feedback
- Apply classical control theory
  - Pole placement using state feedback
- State observer

System Identification Block

- Build a round-trip time dynamics model from measured input and output.
Pole Placement using State Feedback

controlled system (network)

\[ y(k) = -a_1 y(k-1) - \ldots - a_n y(k-n) + b_1 u(k-1) + \ldots + b_m u(k-n) + e(k) \]

If feedback gain \( F \) is chosen appropriately... stability and transient behavior can be determined arbitrarily.

Overview of Our Delay-based Congestion Control Mechanism

Determine packet transmission rate based on pole placement technique using state feedback

Estimate state variables of the ARX model from measured input and output.
Simulation
- Evaluate effectiveness of our delay-based congestion control mechanism
- How the round-trip time converges to the desired value?
- How efficiently network resources are utilized?
Simulation in two network configurations
- Network N1: without background traffic
- Network N2: with background traffic

Network N1
- source host 1.0 Mbps
- destination host 1.0 Mbps
- buffer size 200 packets
- target RTT 0.177[s]
- sampling interval 0.03[s]

Network N2
- source host 1.0 Mbps
- destination host 1.0 Mbps
- buffer size 200 packets
- target RTT 0.177[s]
- sampling interval 0.03[s]

Round-Trip Time Evolution (Network N1)
- model building period
- rate control period

Round-Trip Time Evolution (Network N2)
- model building period
- rate control period

Conclusion and Future Works
- Conclusion
  - Designed a delay-based congestion control mechanism
  - Using system identification and control theory
  - Control objective is to stabilize the round-trip time
- Future works
  - Parameter tuning of control parameters
  - Performance comparison with existing TCPs
- More Information
  - http://www.anarg.jp/~oosaki/