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

Hiroyuki Ohsaki
Graduate School of Information Science and Technology, Osaka University, Japan
oosaki@ist.osaka-u.ac.jp

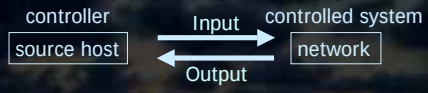
Research Background

- 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

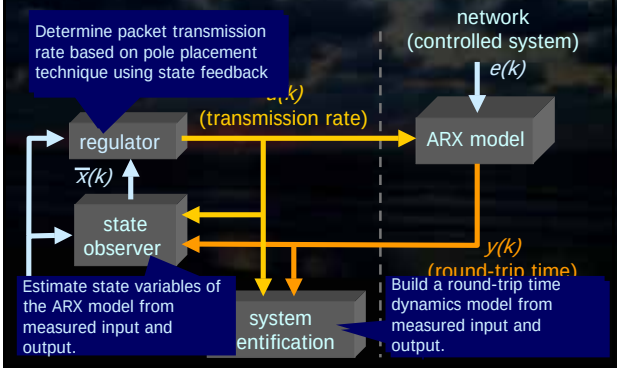
- Design a delay-based congestion control mechanism
  - Use packet delay dynamics model obtained by system identification
  - Apply classical control theory
    - Pole placement using state feedback
    - State observer
- Evaluate its performance
  - Simulation experiments in two network configrations

Problem Formulation

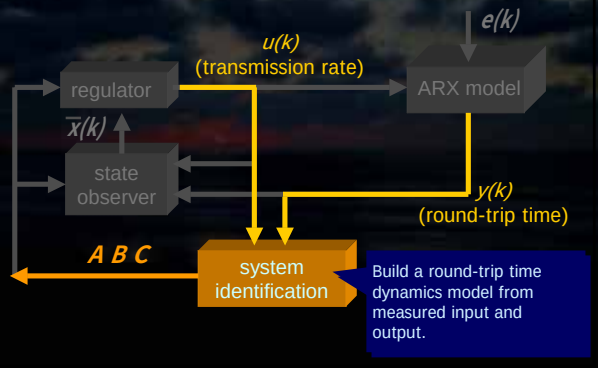


- Controlled system (i.e., plant)
  - Entire network seen by a specific source host
- Input and output definitions
  - Input u(k): packet transmission rate from source host
  - Output y(k): measured round-trip time
- Control objective
  - To achieve a constant round-trip time measured at the source host

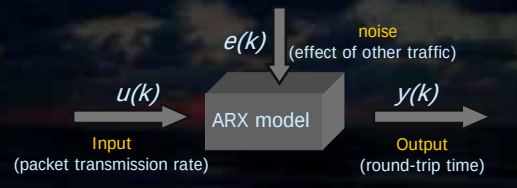
Overview of Our Delay-based Congestion Control Mechanism



System Identification Block



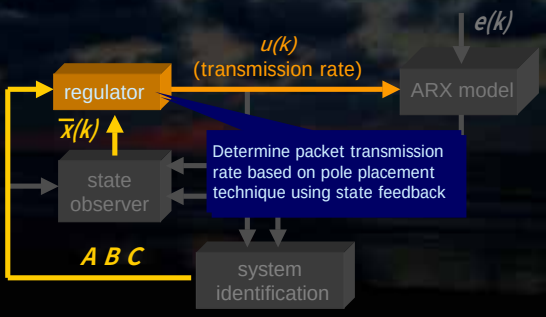
System Identification Block



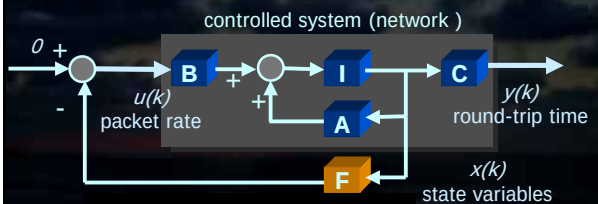
$$y(k) = -a_1 y(k-1) - \ldots - a_{n_a} y(k-n_a) + b u(k-1) + \ldots + b_{n_b} u(k-n_b) + e(k)$$

Parameters are determined by system identification

Control Block: Regulator



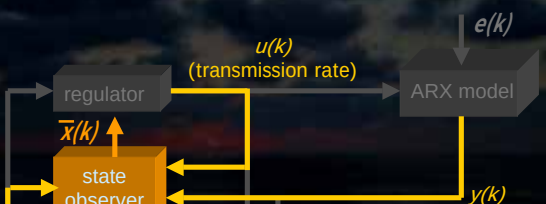
Pole Placement using State Feedback



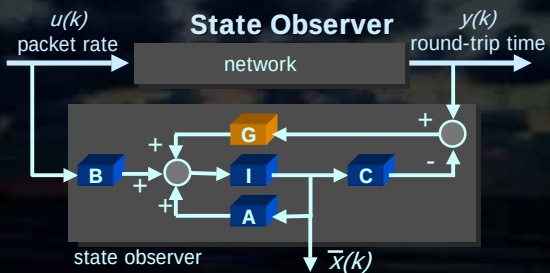
$$x(k+1) = (A - BF)\,x(k)$$
$$y(k) = C\,x(k)$$

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

Control Block: State Observer



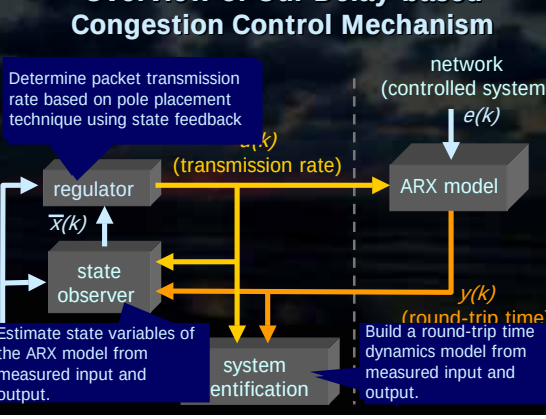
State Observer



$$\bar{x}(k+1) = (A - GC)\bar{x}(k) + G\,y(k) + B\,u(k)$$
$$x(k+1) - \bar{x}(k+1) = (A - GC)\{x(k) - \bar{x}(k)\}$$

If G is chosen appropriately... $x(k) - \bar{x}(k)$ converges to 0.

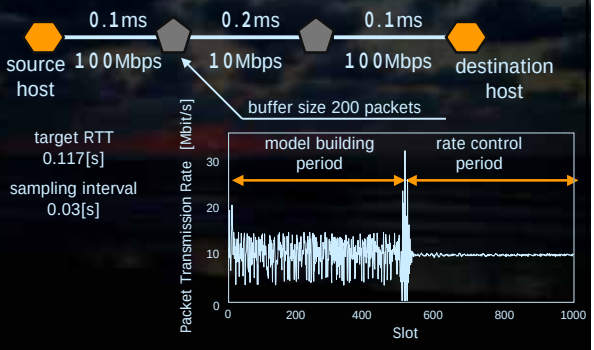
Overview of Our Delay-based Congestion Control Mechanism



Simulation

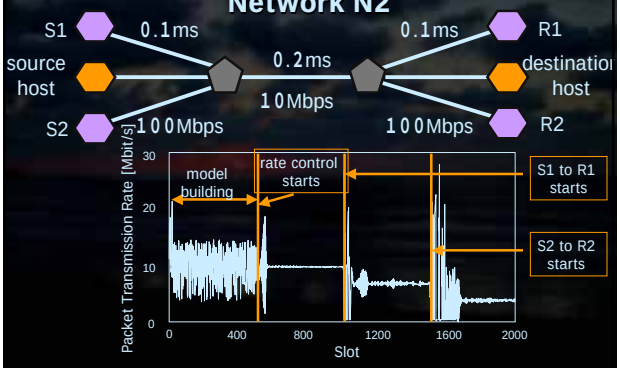
- Evaluate effectiveness of our delay-based congestion control mechanism
  - How the round-trip time converges to the desired value?
  - How efficiently network resources are utilized?
- Simulation in two network configurations
  - Network N1: without background traffic
  - Network N2: with background traffic

Network N1

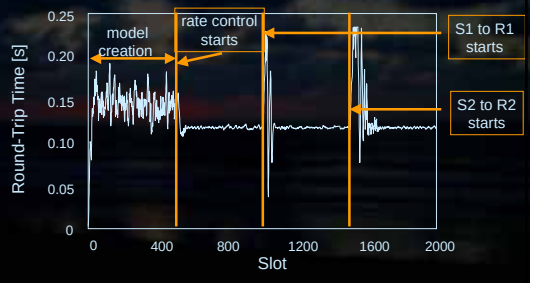


Round-Trip Time Evolution (Network N1)

Network N2



Round-Trip Time Evolution (Network N2)



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/