

Measurement-Based Modeling of Internet Round-Trip Time Dynamics using System Identification

Hiroyuki Ohsaki
 Department of Information Science and Technology, Osaka University, Japan
oosaki@ist.osaka-u.ac.jp
<http://www.anarg.jp/>

Research Background

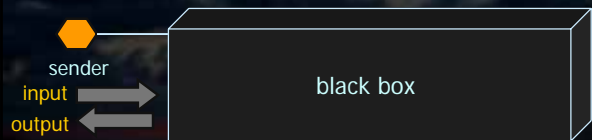


- If characteristic of **packet transmission delay** is known...
 - Can improve QoS (Quality of Services)
 - Can realize efficient congestion control
- Dynamics of packet transmission delay
 - How packet transmission delay is affected by **packet transmission rate**

Research Objectives

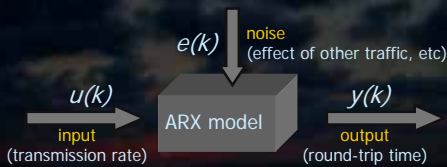
- Model dynamics of packet transmission delay
 - View network as a **black box**
 - Measure input and output to network
 - Estimate model parameters by **system identification**
- Validate model accuracy
 - Using two validation methods
 - Comparison with simulation (time domain)
 - Comparison with spectral analysis result (frequency domain)

Black-Box Modeling



- Definition of input and output
 - input → **packet transmission rate**
 - output ← **round-trip time**

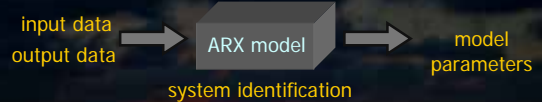
ARX (Auto-Regressive eXogenous) Model



$$y(k) = -a_1 y(k-1) - \dots - a_{n_a} y(k-n_a) + b_1 u(k-1) + \dots + b_{n_b} u(k-n_b) + e(k)$$

Determined by system identification

Modeling Procedure



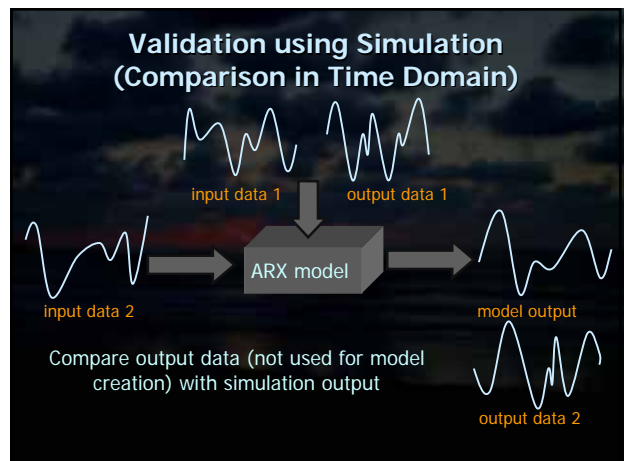
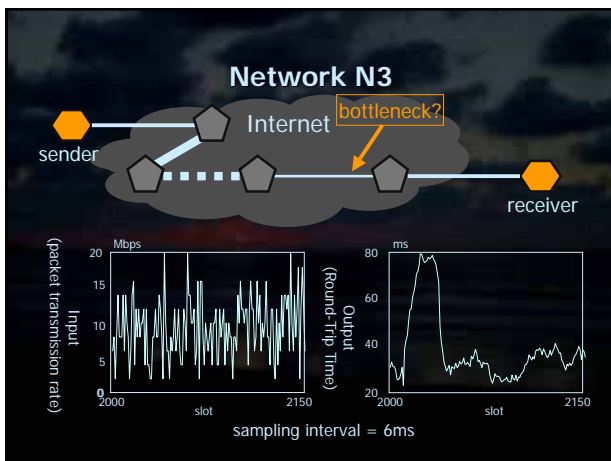
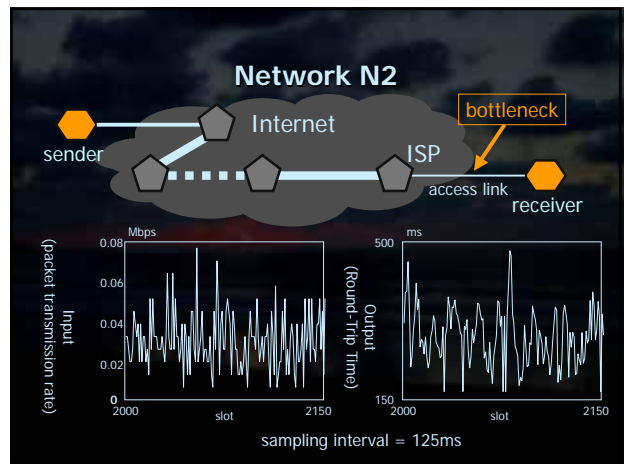
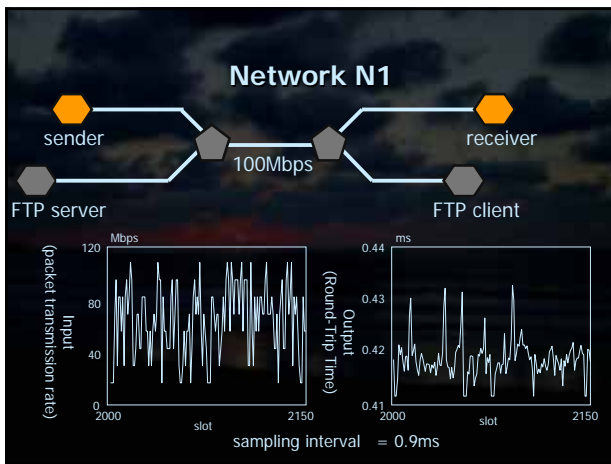
1. Measure input and output data
2. Determine ARX model parameters from measured input and output data
3. Validate accuracy of ARX model obtained

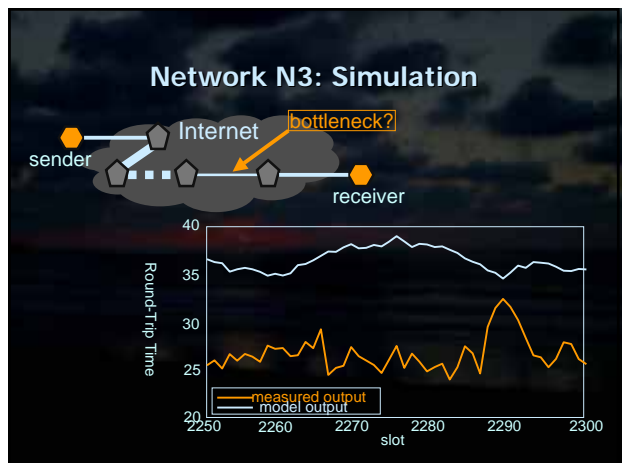
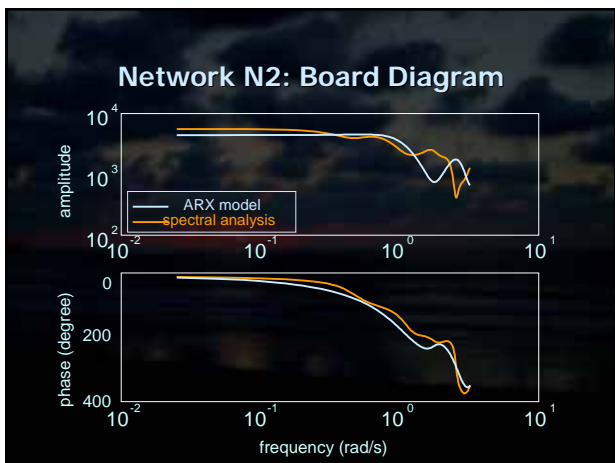
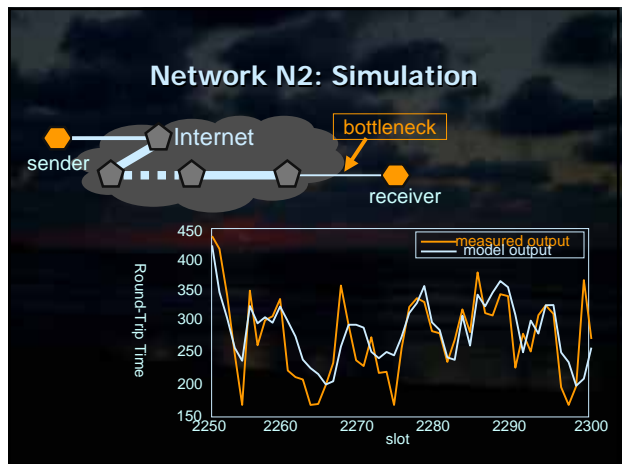
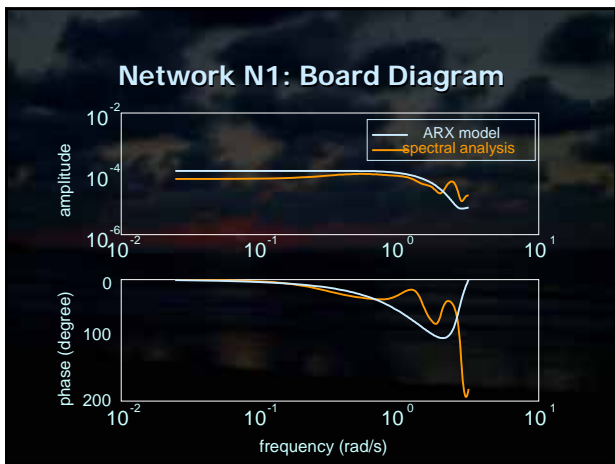
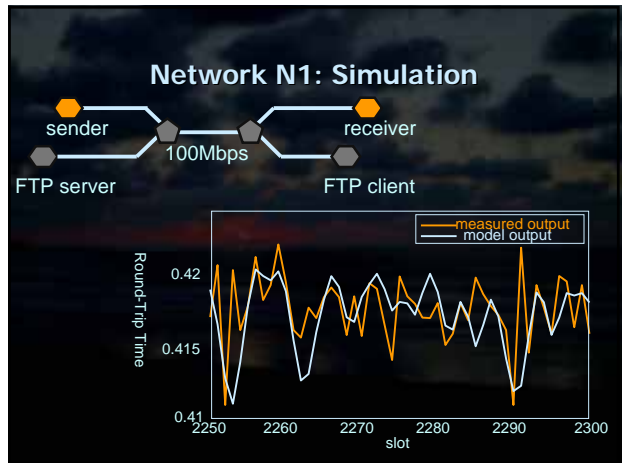
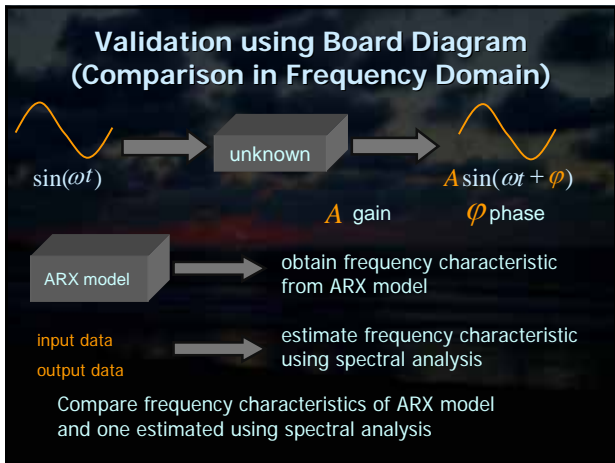
Queuing Theory vs. System Identification

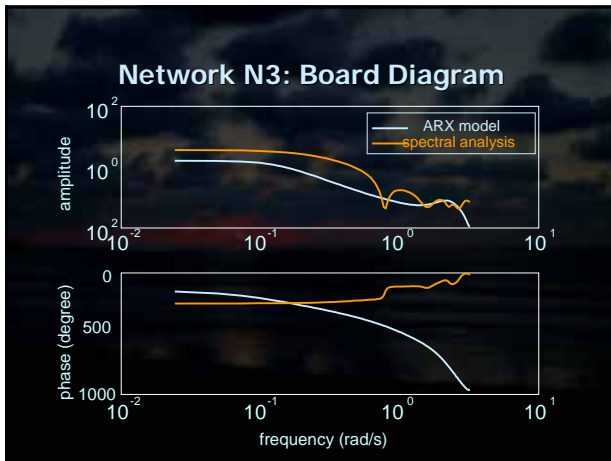
	queuing theory	system identification
modelling approach	white box	black box
dynamics	cannot model	can model
control theory applicability	no	yes
statistical characteristic	can model	cannot model
model information	required	not required
model accuracy	good	?

Network Configurations

- Build model in three network configurations
 - Complexity of network topology
 - Effect of **noise** (e.g., background traffic)
 - Location of **bottleneck link**
- N1: LAN**
 - Simple network topology
- N2: WAN**
 - Complex network topology
 - Access link is **bottleneck**
- N3: WAN**
 - Complex network topology
 - Access link is **not bottleneck**







- ### Conclusion
- Model dynamics of **packet transmission delay**
 - View network as a **black box**
 - Measure input and output data
 - Determine model parameters by **system identification**
 - Validate model accuracy
 - Simulation (comparison in time domain)
 - Bode diagram (comparison in frequency domain)
 - Show effectiveness of black-box modeling
 - When network is **not so noisy**

- ### Future Works
- More accurate modeling of packet transmission delay
 - Model structures
 - **Parametric model**
 - Non-parametric model
 - Linearity
 - **Linear model**
 - Non-linear model
 - Noise assumption
 - **white noise**
 - colored noise
 - Design a delay-based congestion control using control theory
 - More info: <http://www.anarg.jp/>