# Network Management and Internet Pricing

S. Raghavan
J. Bailey
The Robert H. Smith School of Business
University of Maryland

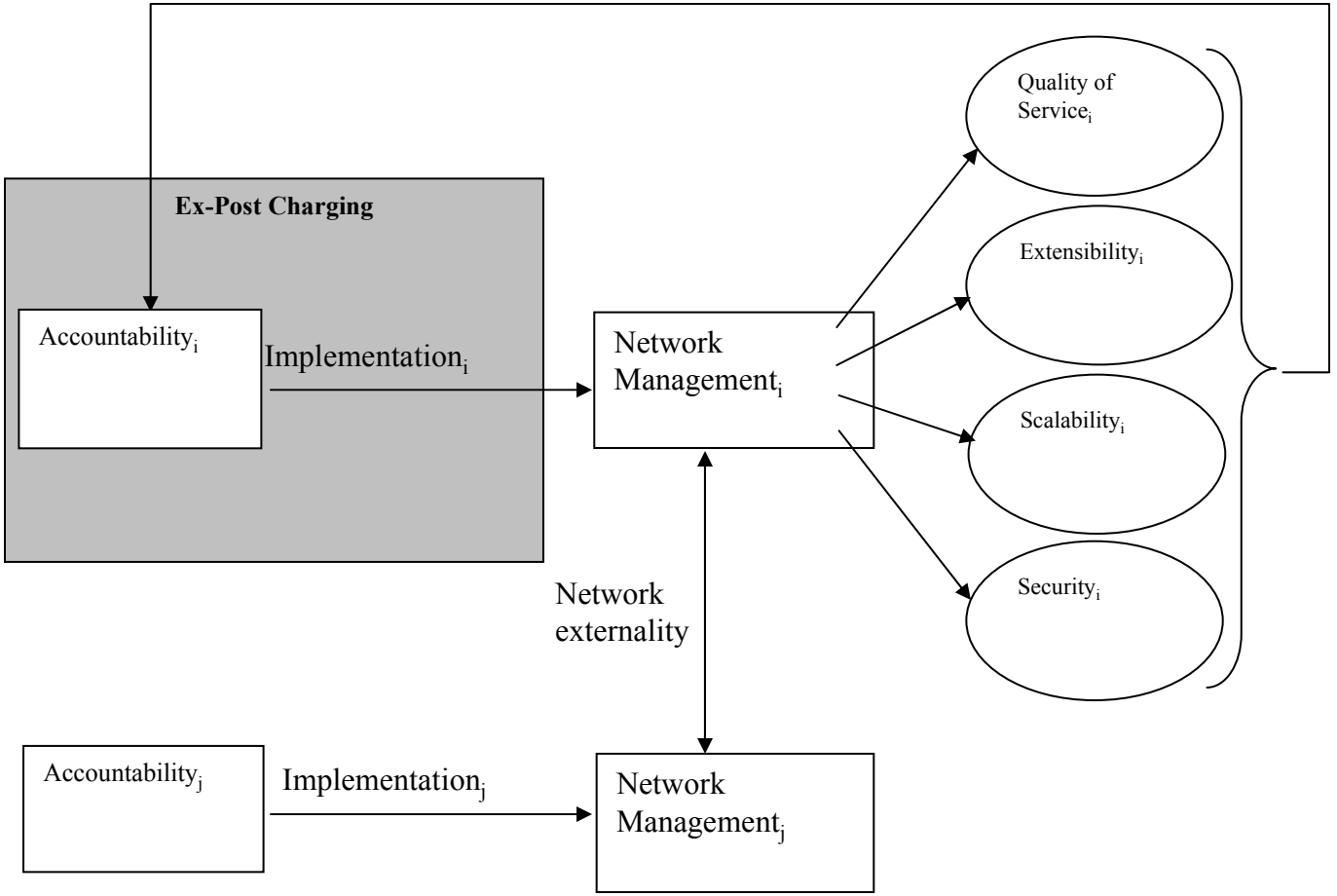
# Outline

- Goals
- Ex-Post Charging Framework
- Traffic Collection & Measurement
- Models & Experiments
  - Effective bandwidth model
  - Moment-based model
- Ex-Post Charging Diffusion
- Conclusions

# Goals

- Develop a better mechanism for giving users and network administrators feedback regarding congestion costs (imposed on other users)
- Co-locate the economic incentives with the managers of the network
- Sacrifice economic optimality to achieve a pragmatic implementation
- Subscribe to the design philosophy of the Internet of heterogeneity and interoperability

# Internet Pricing Goals



# Ex-Post Charging Concept

- Charging algorithm is known ex-ante, only utilization and burstiness metrics are unknown
- A portion of the charge may be determined ex-ante.
- ISP meters the link to collect aggregate traffic statistics.
- ISP charges the user at the end of the billing period using the charging algorithm and the utilization and burstiness statistics.

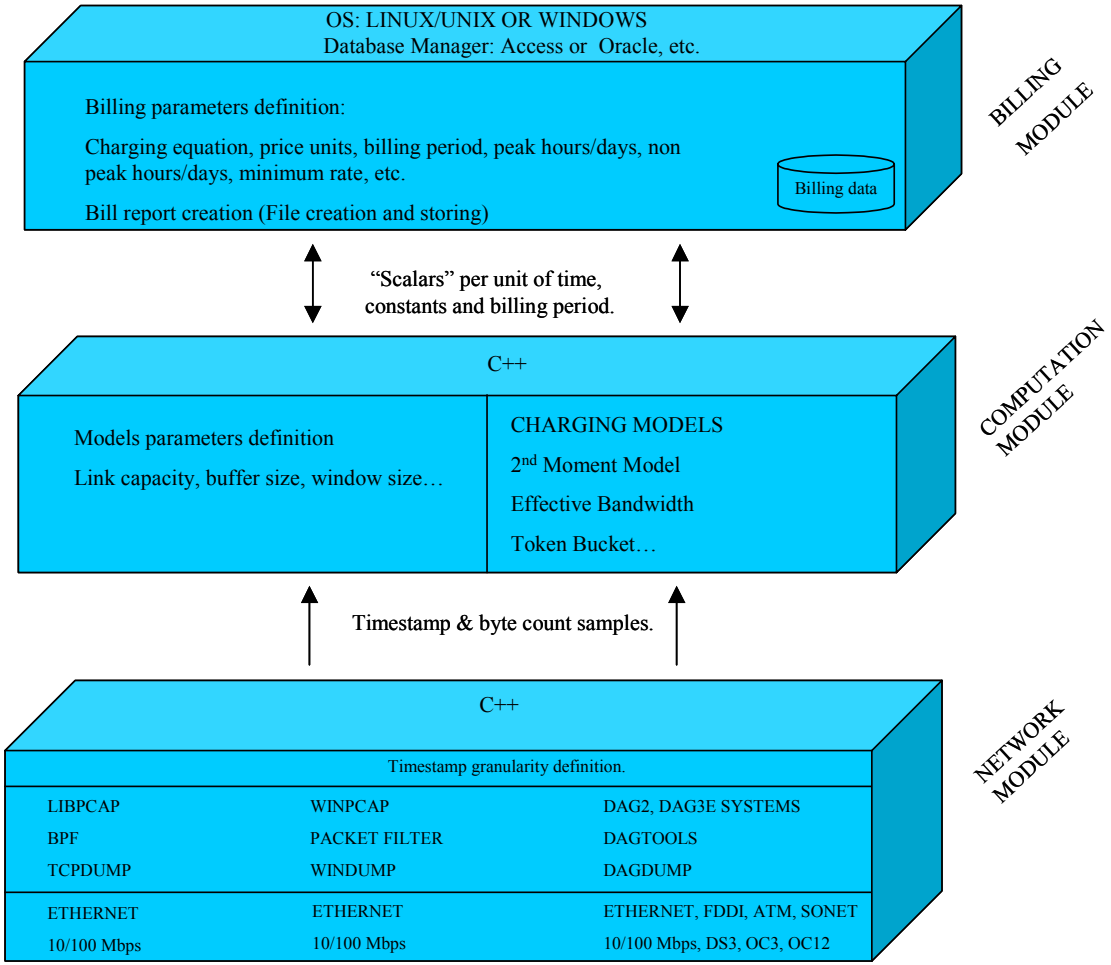
# Features of Ex-Post Charging

- Simple to explain/understand
  - To ensure feasible implementation
  - For use in Service Level Agreements
- More accurate charging of congestion costs
  - Utilization prices have been assessed before
  - Addition of burstiness parameter
- Low Burden on System
  - Bayesian Updating
    - No need for storage of gigabytes of trace data
    - Prevents potential security risk
  - Non-intrusive mechanism (to collect data and bill).

# Traffic Measurement

- To fully develop a pricing mechanism, it is essential to understand traffic measurement and collection.
- Achievable granularity with off the shelf technologies (low cost) – around 1ms.
- Finer granularity measurement can be achieved by using GPS synchronized clock and more expensive computing power. Traces used and analyzed
  - NLANR, New Zealand, University of Maryland (Van Munching Hall)

# Schema of Billing/Ex-Post Charging System



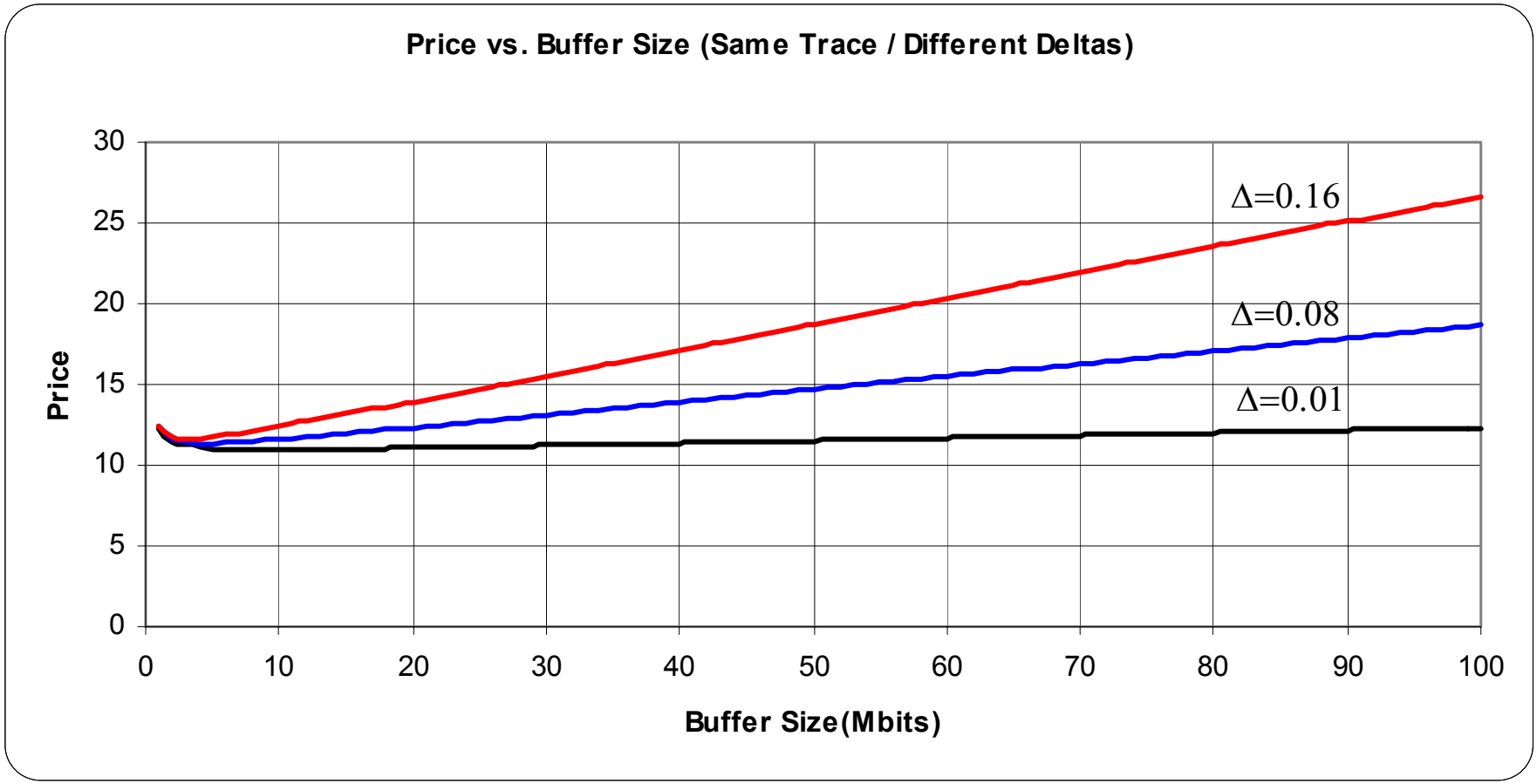
# Effective Bandwidth Model

$$P_{expost} = a * (C + \Delta B)$$

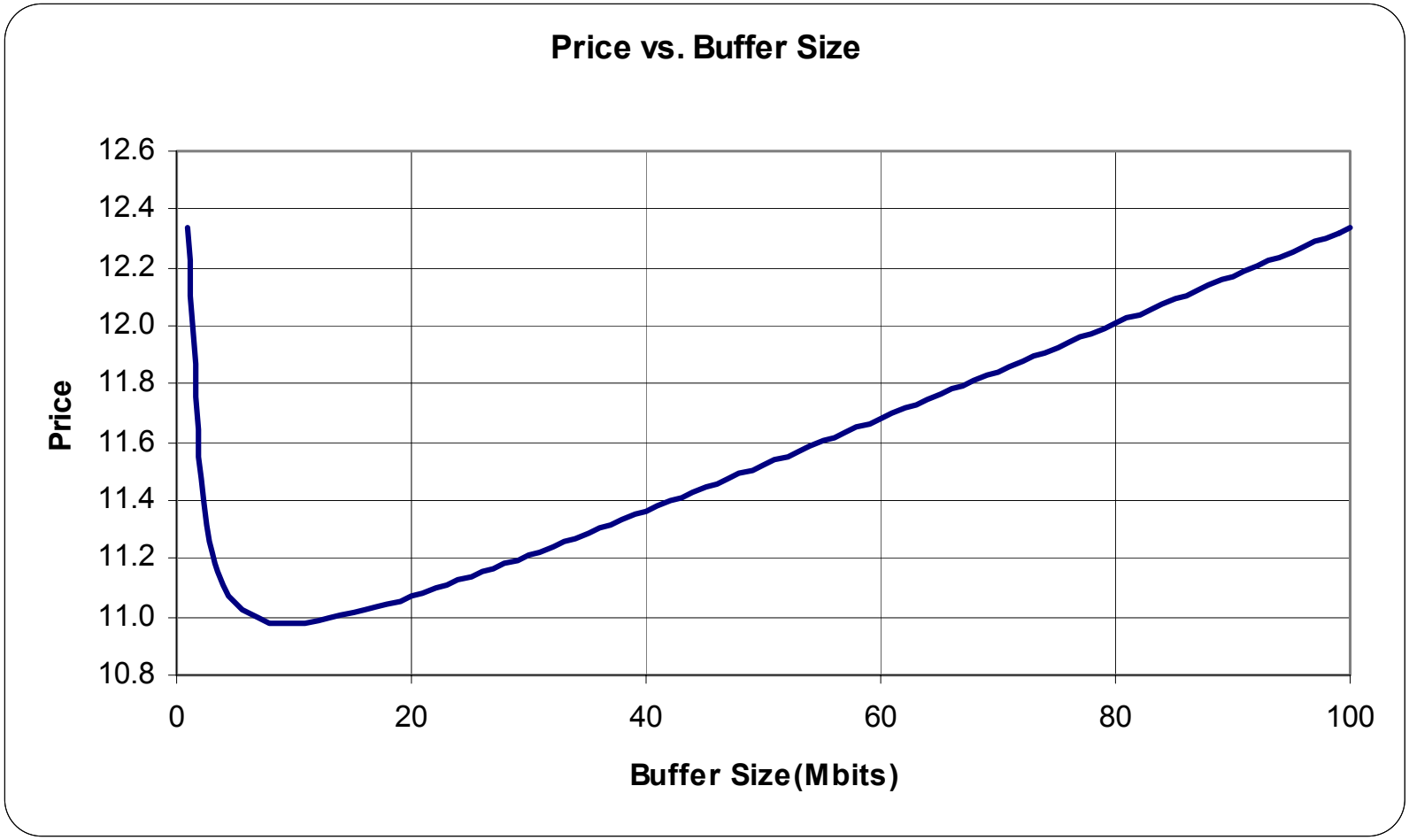
$$C = \frac{\alpha b(1-\rho)R_p - B + \sqrt{(\alpha b(1-\rho)R_p - B)^2 + 4B\alpha b\rho(1-\rho)R_p}}{2\alpha b(1-\rho)}$$

- $R_p$ peak rate, $\rho$ utilization, $b$ mean burst period, $B$ buffer size, $\alpha = \ln(1/\varepsilon)$ buffer overflow probability.
- Key variable: $\Delta$. This is the tradeoff between bandwidth and buffer. (users can purchase buffer capacity from ISP).
- $a$ scalar.
- Provides incentive for appropriate buffer size selection

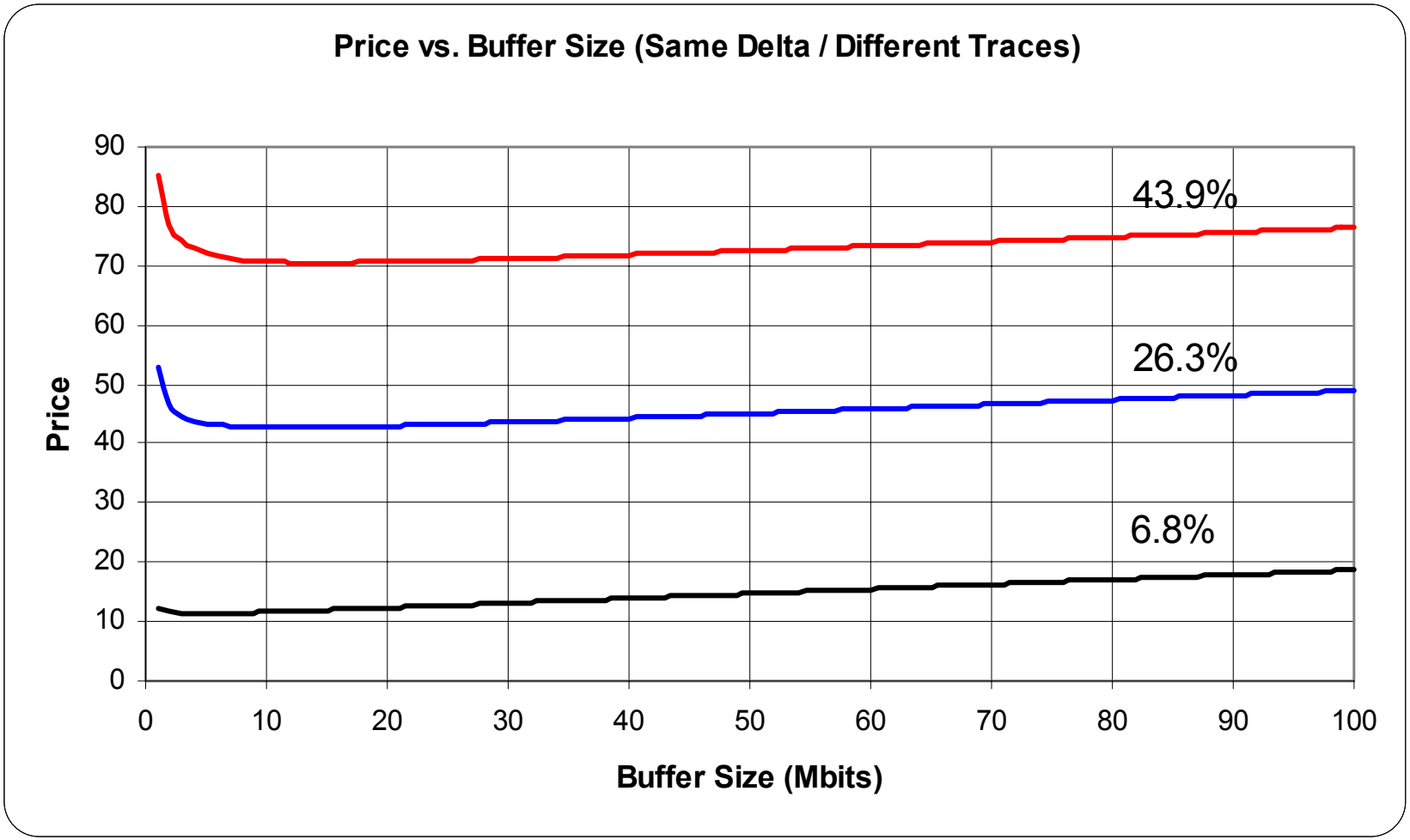
# Price vs. Buffer Size (Same Trace / Different Deltas)



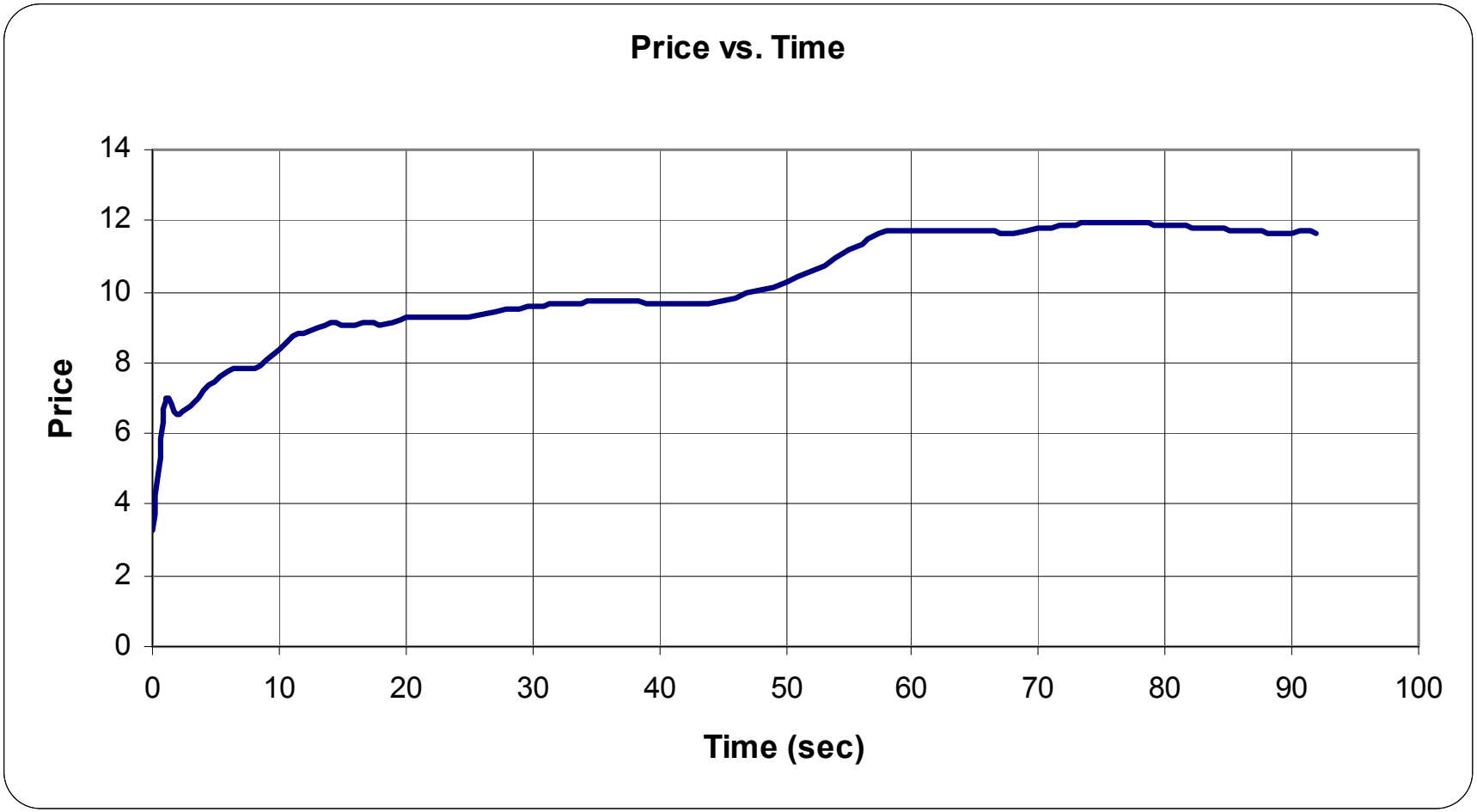
# Price vs. Buffer Size



# Price vs. Buffer Size (Same Delta / Different Traces)



# Price vs. Time



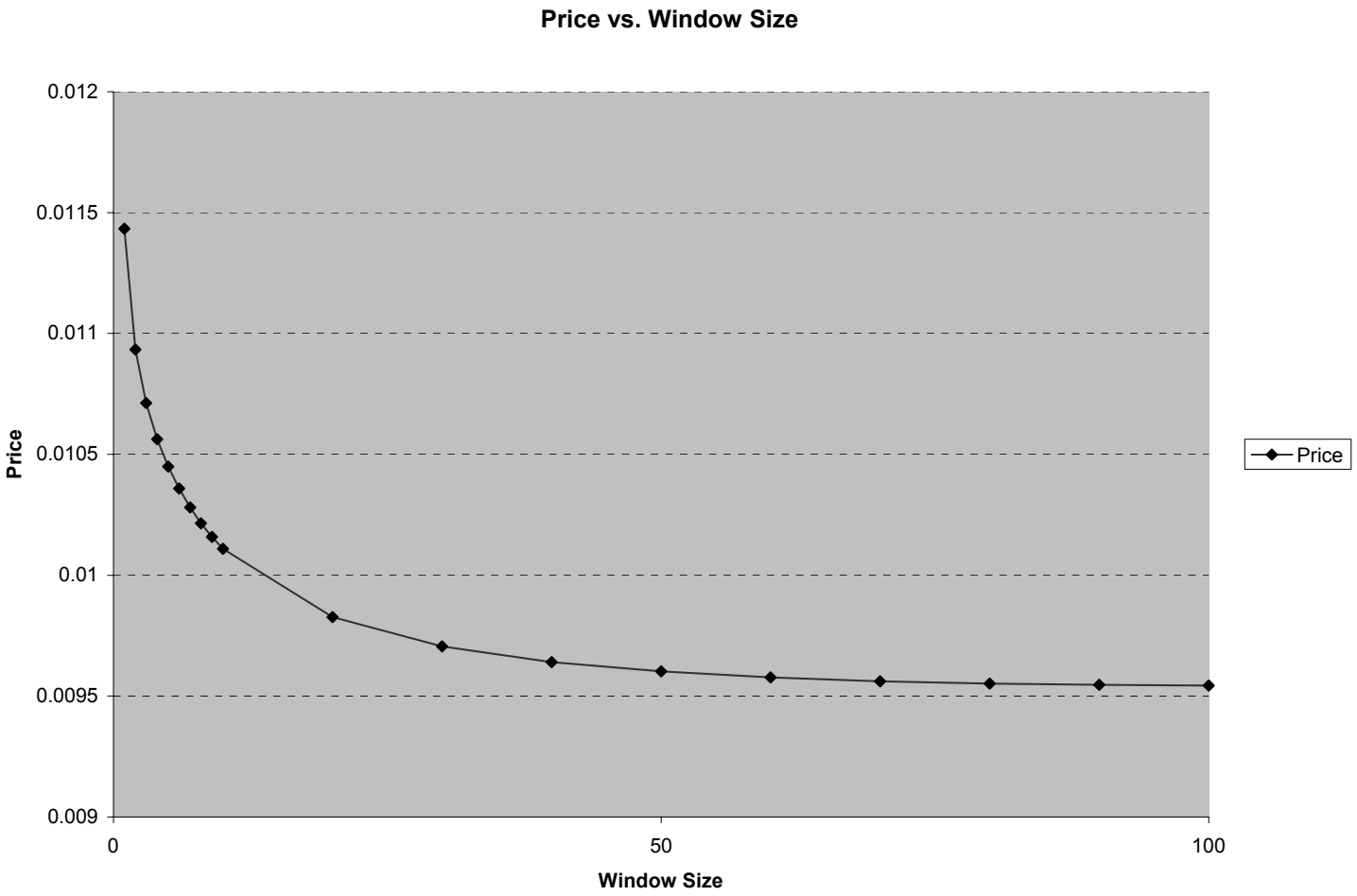
# Moment-Based Model

$$P_{ex\text{-}post} = a \,\mathrm{Ln}\,(b\rho + 1)\left(e^{c\sqrt{r^2+l^2}} - 1\right)$$

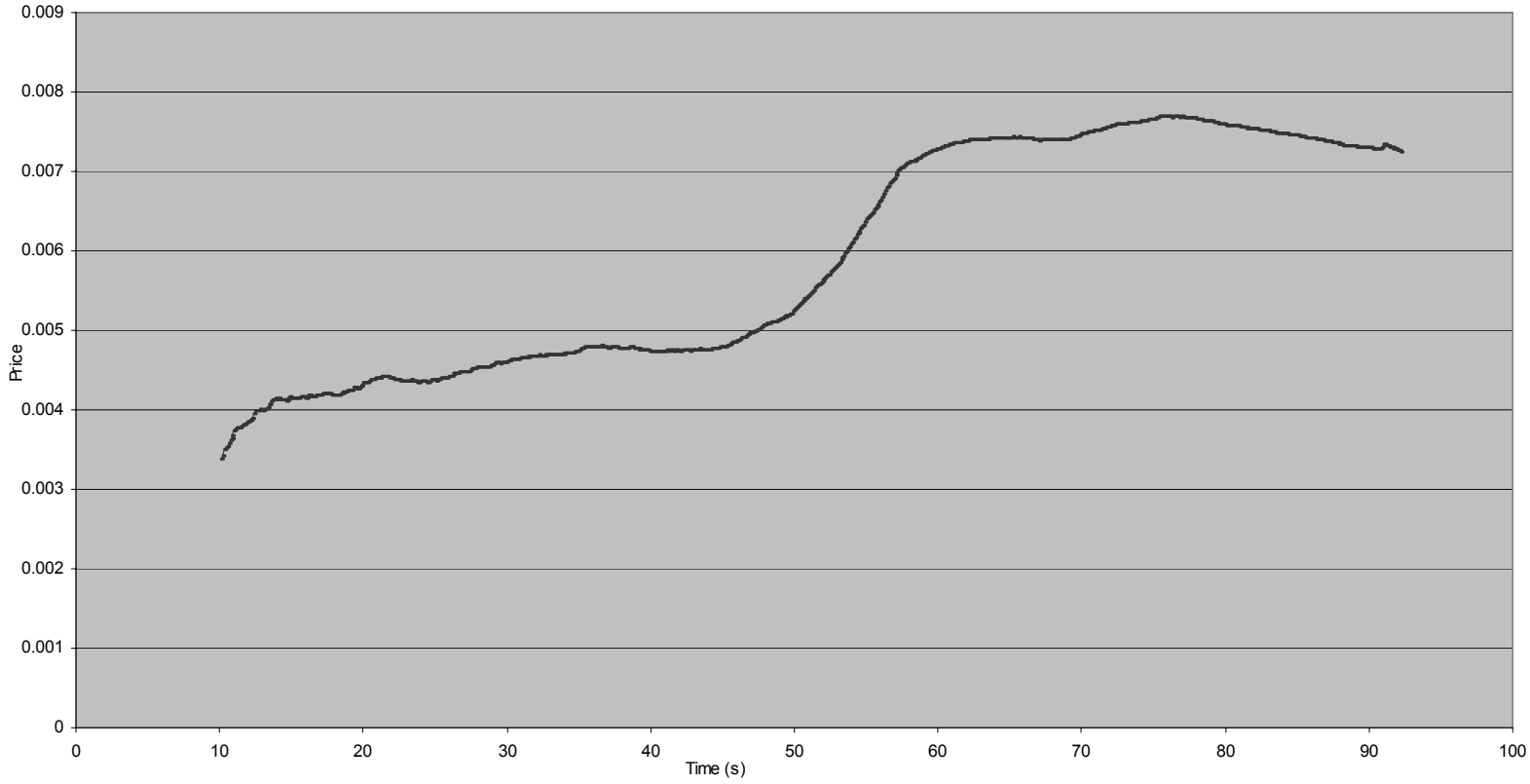
$$r = \frac{\sqrt{\mathrm{E}[x^2]}}{B} \qquad l = \frac{\sqrt{\mathrm{E}[y^2]}}{B}$$

- x is original trace. y is smoothed trace, obtained by taking a simple moving average (with moving average window size w).
- ρ utilization. B bandwidth of link. a, b, c, scalars.
- Uses basic statistical measures. Easy to understand for non-engineers.

# Moment-Based Model: Window Size Sensitivity



# Moment-Based Model: Price Convergence



# Ex-Post Charging Diffusion

- user i, a light user of Internet resources, who currently subsidizes some of the heavier users, switches from an ex-ante charging model to an ex-post charging model to lower their costs.
- user j, a medium user of Internet resources, is now faced with larger costs because they are no longer subsidized by user i, chooses to manage their network better and adopt an ex-post charging model.
- user k, a heavy user of Internet resources, is now faced with larger costs because they are no longer subsidized by users i and j, so they switch to an ex-post charging model.

# Quality of Service

$$P_{expost} = a_1*(C_1 + \Delta_1 B_1) + a_2*(C_2 + \Delta_2 B_2)$$

- Users get more specific about QoS needs, then ex-post algorithms could be more specific (SLAs)
- But, to have an environment where guaranteed end-to-end QOS applications can be provided over the internet there must be overall adoption of better network management among all users.
- Ingress and Egress is where the bottlenecks are and this is where the charging algorithms will be working

# Security (Benefits)

- Accounting gives network managers metrics to identify potential security problems
- Charging based on these metrics gives network managers an incentive to monitor their networks.

# Research Dissemination

- *Ex-Post Internet Charging*, J. Bailey, J. Nagel, and S. Raghavan to appear in Internet Services, L. McKnight and J. Wroclawski, eds., MIT Press
- *Ex-Post Internet Charging Models Using Effective Bandwidth*, I. Gamvros, C. Hernandez, J. Bailey, S. Raghavan, working paper to be completed summer 2001.
- *A Prototype Ex-Post Internet Charging System*, J. Noda, S. Raghavan, and J. Bailey, working paper to be completed shortly.
- *Second Moment Model for Ex-Post Internet Charging*, C. Lapuerta, J. Bailey, and S. Raghavan, working paper to be completed summer 2001.

# Conclusions

- Simple pricing scheme, implementable in practice, provides incentives to users to manage and monitor their networks. Result is a more stable/secure network where it is easy to provide QOS guarantees.
- Pushes responsibility to edges of networks..
- Determination of scalars. Develop (ISP) cost models to provide guidelines on how to set scalars.