# Effect of Time Delay in Network Trafiic Control [1]

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# Outline of the talk

- Congestion Control and AIMD
- Rate based AIMD
  - Queue length upperbound
  - Fairness
- Modified AIMD
- Window-based AIMD
- Future work

# Congestion Control and AIMD

- Congestion: Demand exceeds capacity
- Congestion Detection
  - Queue length
  - drops
  - marks
- Congestion Control Algorithm: AIMD (TCP)
  - if not in congestion increase rate additively
  - else decrease rate multiplicatively

# Previous Work

- Chiu and Jain: Synchronous updation, same RTT
- Sally Floyd: Bias against long RTT flows
  - Constant rate increase (for TCP)
- Boudec et al
  - rate proportional negative feedback
  - Stochastic model. No dynamics
  - Logarithmic utility function
- Time delays havent been generally considered in dynamical models of single-bit feedback schemes

# Model of Rate based AIMD

- Continuous time model
- Fluid flow . No averaging of queue is necessary
- Queue at bottleneck
  –

$$\dot{q}(t) = \begin{cases} max(\sum_{i=1}^{n} r_i(t) - c, 0) & q = 0 \\ \sum_{i=1}^{n} r_i(t) - c & q > 0 \end{cases}$$

- Rate adaptation by sources
  –

$$\dot{r}_j(t) = \begin{cases} \frac{a}{T_i} & \mathrm{mod}(t/T_j) \neq 0,\, q(t - T_j) < q_d \\ -\frac{lnb}{T_i} r_j(t) & \mathrm{mod}(t/T_j) \neq 0,\, q(t - T_j) \geq q_d \end{cases}$$

# Queue bound for rate based AIMD

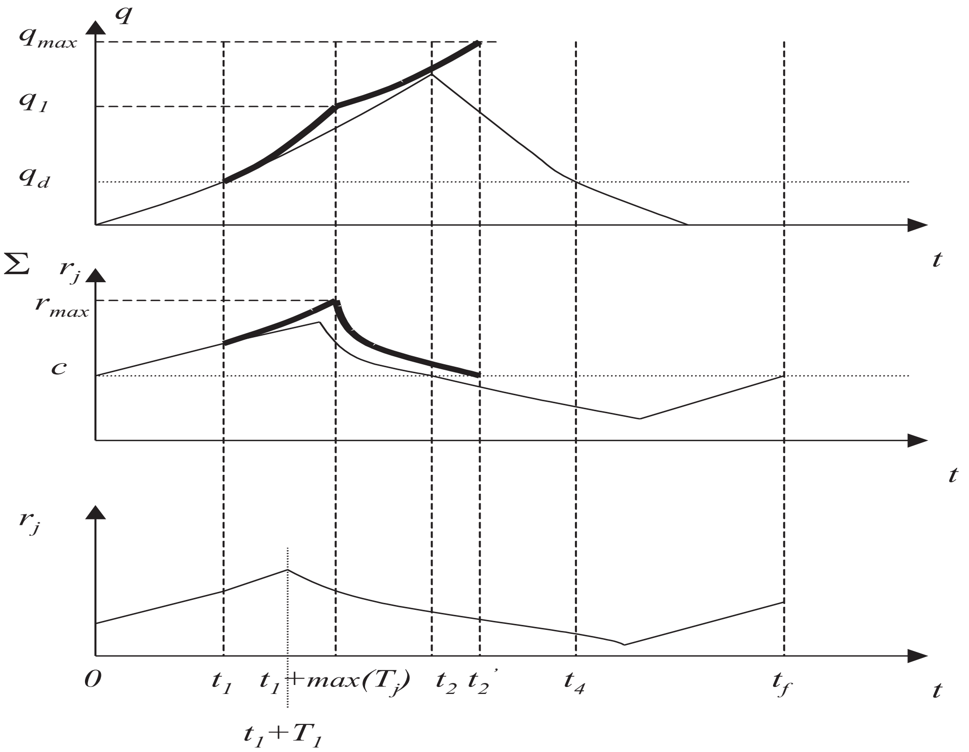


Figure 1: Estimation of Q Upperbound

$$q_{\max} = q_1 + \frac{T_{max}}{\ln b}(b^{\frac{t_2'-t_1-T_{max}}{T_{max}}} - 1)\eta - c(t_2' - (t_1 + T_{max}))$$

where

$$q_1 = \frac{na}{2T_{eq}}(t_1 + T_{max})^2 \quad (1)$$

$$\eta = (c + na(\frac{t_1}{T_{eq}} + 1)) \quad (2)$$

$$t_2' = T_{max}\frac{\ln(c/\eta)}{\ln b} + t_1 + T_{max} \quad (3)$$

# Simulations

Simulation setup: n=4, c=200,$q_d$=100, $a$=1 and $\beta = .98$

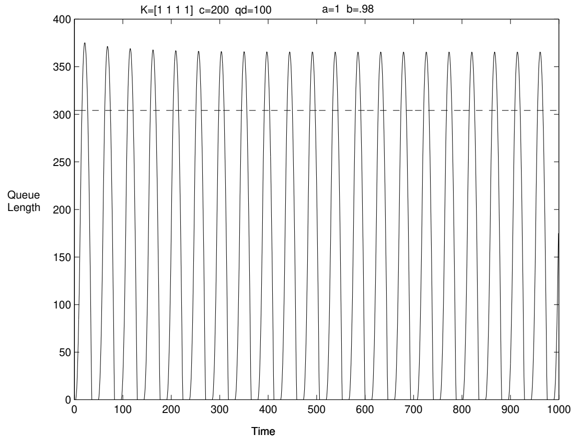


Figure 2: Q Length Vs Time and Predicted Max Q for $T = [1, 1, 1, 1]$

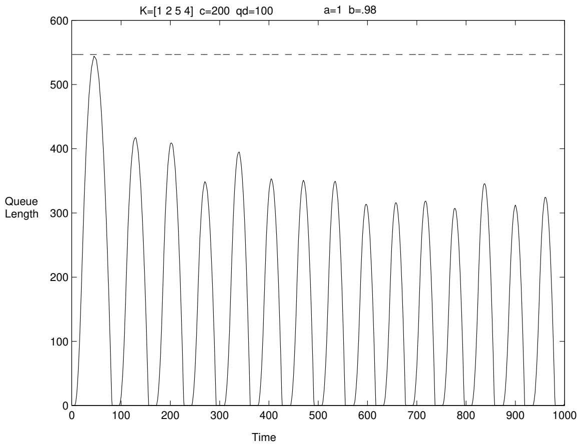


Figure 3: Q Length Vs Time and Predicted Max Q for $T = [1, 2, 5, 4]$

# Simulations (Contd)

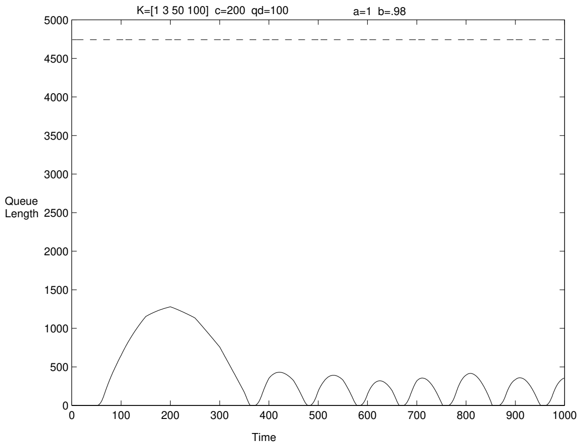


Figure 4: Q Length Vs Time and Predicted Max Q for $T = [1, 5, 30, 50]$

# Simulations: Varying parameters

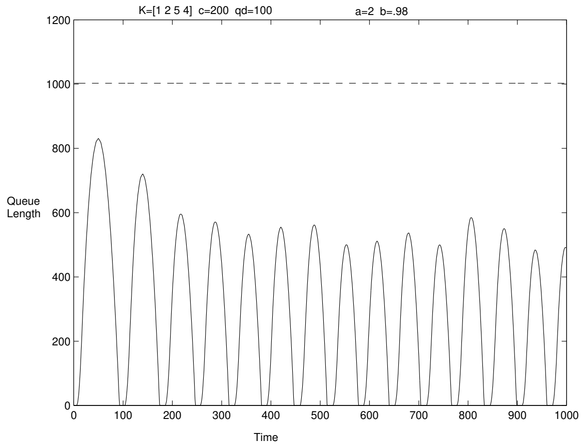


Figure 5: Q Length Vs Time and Predicted Max Q for $a = 2$

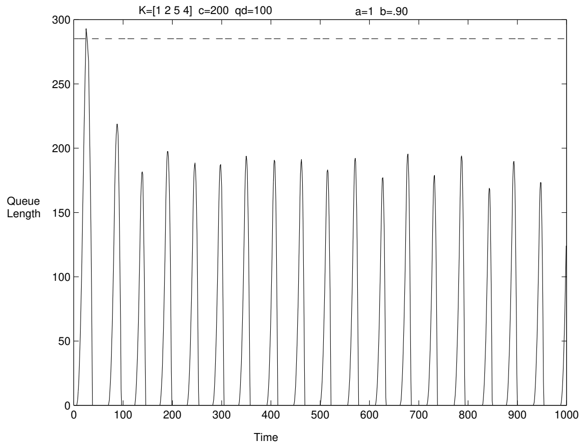


Figure 6: Q Length Vs Time and Predicted Max Q for $\beta = .9$

# Graphical Analysis of Fairness

- Synchronous updation. same RTT

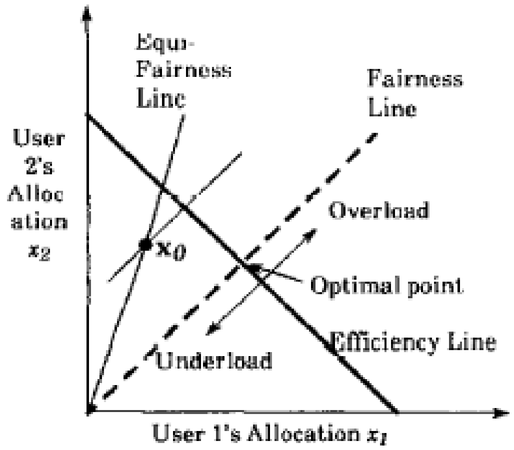


Figure 7: Representation of rates in phase space

- Different RTTs, Synchronous updation, Consistent feedback

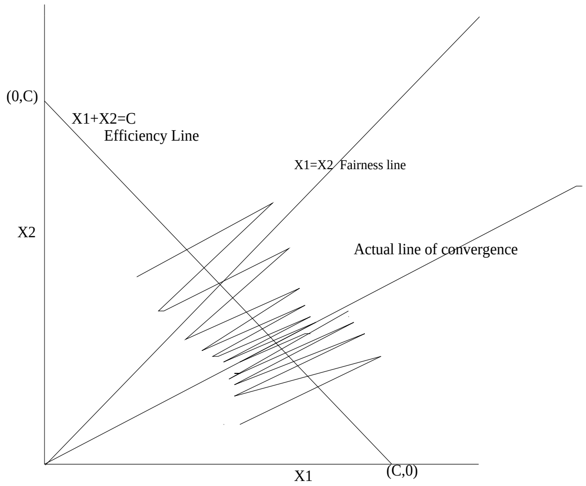


Figure 8: Convergence to Unfair steady state

- Sources converge to $x_2 = \frac{x_1(1-\beta^{nk})}{n(1-\beta^k)}$

# Modified AIMD

- Question: Can we make AIMD fair using information known only to the source
- Increase factor proportional to RTT. $a$ by $\frac{aT_i}{T}$
- Decrease factor proportional to power of RTT $\beta$ by $\beta^{\frac{T_i}{T}}$
- Not entirely equivalent to a same RTT system.
- Fails if RTT distribution is too skewed

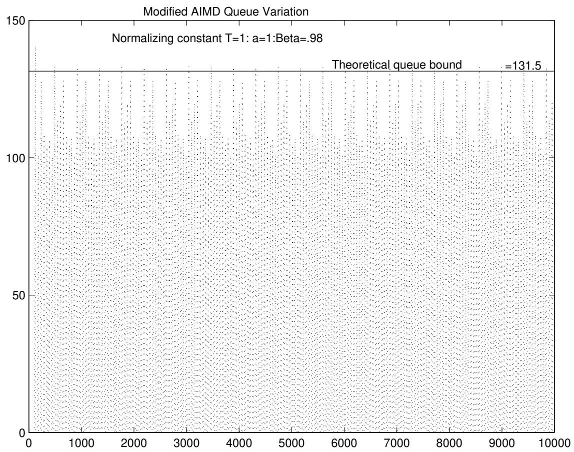


Figure 9: Queue variation in fair AIMD

T=[1 5] c=200 $a$=1, $\beta$=.98 and $q_d = 20$

# Fairness Simulations

T=[1 5] c=200 $a$=1, $\beta$=.98 and $q_d = 20$

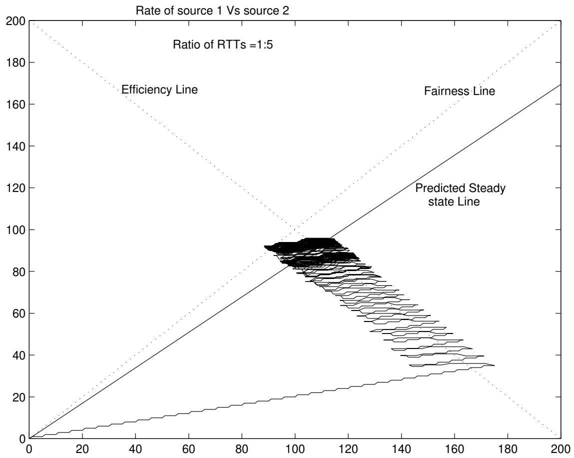


Figure 10: Phase Plot of AIMD with $T = [1, 5]$

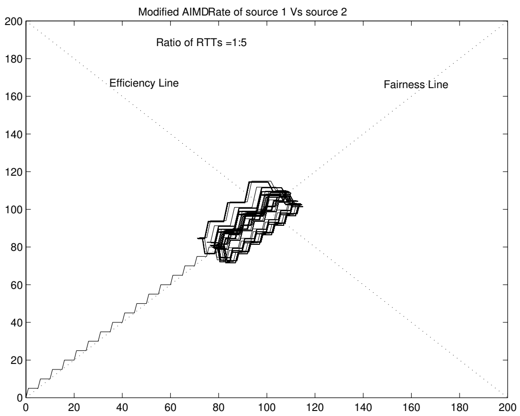


Figure 11: Phase Plot of Modified AIMD

# Fairness Simulations: Anamolous Behavior

$q_d = 100$, c=500,$a$=1 and $\beta$=.98

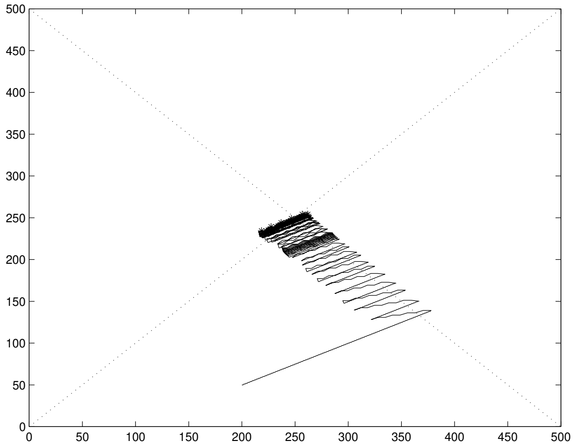


Figure 12: Phase Plot of AIMD: $T = [1, 4]$,

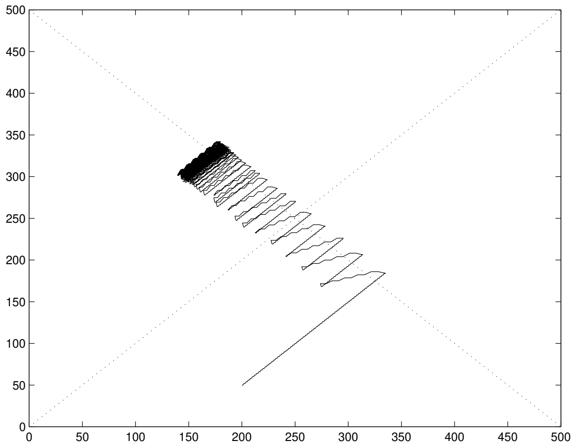


Figure 13: Floyd's Modification: $T = [1, 4]$ $q_d = 100$

# Fairness Simulations: Skewed RTTs

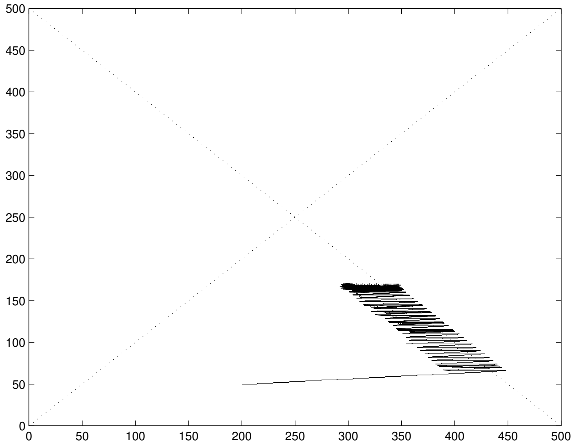


Figure 14: Phase Plot of AIMD: $T = [2, 20]$

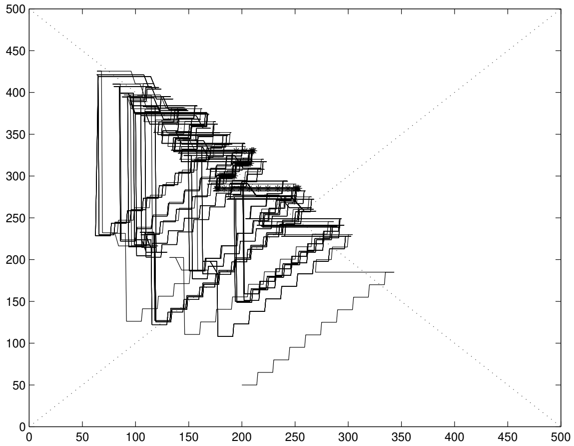


Figure 15: Phase Plot of AIMD: $T = [2, 20]$

# Fairness Simulations: Skewed RTTs (contd)

$\beta = .9999$

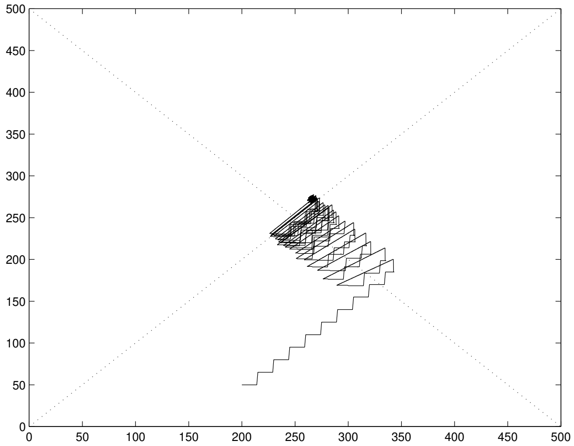


Figure 16: Phase Plot of AIMD: $T = [2, 20]$

Max queue length $= 10^4$ !

# Window-based AIMD

- Intractable with different propagation delays. Queueing delays are considered
- Discrete time formulation. unit of time = RTT - variable
- Dynamics
  - $$q(k+1) = q(k) + \sum_{i=1}^{n} w(k) - cRTT(k)$$
  - $$RTT(k) = T + \frac{q(k) + q(k+1)}{2c}$$
  - $$w_i(k+1) = w_i(k) + a \quad q(k) <= q_d$$
  - $$w_i(k+1) = \beta w_(k) \quad q(k) > q_d$$
- Features:
  - Linear queue growth (quadratic for rate-based)
  - c=10Mbps, T=100ms, n=12, a=512 bytes. Queue decreases within 2 RTTs =¿ Smoother queue variation
- Fairness
  - approximate equivalent rate as window/RTT
  - Steady state line: $$x_2 = \frac{x_1(1-\beta^{nk})}{n^2(1-\beta^k)}$$

# Conclusions and future work

- Summary
  - Queue bound for rate and window-based AIMD
  - Unfairness of AIMD with time delays
  - Proposed modifications and showed range of applicability
- Future Work
  - Anamolous behavior: Continuous time, continuous feedback model not adequate ?
  - Discretization of update times and discrete queue sizes
  - Extension to multiple bottleneck