Analysis of the Increase and Decrease Algorithms for Congestion Avoidance in Computer Networks

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Congestion Control

a. Flow control concerns with resources at the destination.

b. Congestion control concerns with resources in the network.
Congestion Avoidance

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Congestion Avoidance in Computer Networks
Congestion Avoidance

Congestion control vs congestion avoidance

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Congestion Avoidance in Computer Networks
- Single shared bottleneck resource
- Synchronous feedback
- Control applied by all users
- Feedback type: binary
Feedback mechanism: set signal bit on packets, processed by destination
- Rejected alternatives: extra signal packets, induce routing changes, signal bit processed by source
- TCP Tahoe (and derivatives): signal = packet loss
Feedback

- Binary feedback

\[ y(t) = \begin{cases} 
0 & \Rightarrow \text{Increase load} \\
1 & \Rightarrow \text{Decrease load} 
\end{cases} \]

- \( x_i(t + 1) = x_i(t) + u_i(t) \)
- \( u_i \) can be an arbitrary function of \( x_i(t) \) and \( y(t) \)
- We focus on a linear model

\[ x_i(t + 1) = \begin{cases} 
a_l + b_l x_i(t) & \text{if } y(t) \Rightarrow \text{Increase} \\
a_D + b_D x_i(t) & \text{if } y(t) \Rightarrow \text{Decrease} \end{cases} \]
Criteria

1. Efficiency: load must be as close to knee point as possible

2. Fairness
   In a perfectly fair system, \( \forall i \forall j \quad x_i = x_j \)
   We use a fairness criterion:
   \[
   F = \left( \frac{\sum x_i}{n} \right)^2 \frac{\sum x_i^2}{\sum x_i^2}
   \]
   \( F \) lies between 0 and 1, higher values indicating greater fairness

3. Distributedness
   Users do not know anything about state of system
   Resource delivers only binary feedback to limit overhead

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3. **Distributedness**
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   - Resource delivers only binary feedback to limit overhead
Convergence

- Constant-state convergence unlikely since we use only binary feedback
- We use two parameters: responsiveness (how quickly the steady state is reached), and smoothness (size of oscillations)
Constraints: Fairness

- Fairness must improve in at least one of increase and decrease, and not degrade in either.
- This implies: both $\frac{a_l}{b_l}$ and $\frac{a_D}{b_D}$ must be non-negative, and at least one must be positive.
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Suppose instead $x_1(t) = x_2(t) = 10$.

Then $x_1(t+1) = x_2(t+1) = 15$ → +ve feedback.
Efficiency: Example

Consider a 2-user system with $x_1(t) = x_2(t) = 100$
Let $y(t) = decrease, \ a_D = 10, \ b_D = 1/2$
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Then \( x_1(t + 1) = x_2(t + 1) = 15 \to +\text{ve feedback} \)
Feedback must be negative no matter what the load distribution at the other users.
This implies
\[ a_I > 0 \quad b_I \geq 1 \]
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Constraints can be loosened if bounds on \( X_{goal} \) and number of users are known.
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Constraints: Efficiency + Distributedness

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Combined Constraints
Decrease

Linear decrease must be purely multiplicative
Increase must have an additive component, and optionally a multiplicative component

Multiplicative component 0 for optimal fairness convergence
Suppose

\[ x_i(t + 1) = x_i(t) + \sum_{k=-\infty}^{\infty} \alpha_k (x_i(t))^k \]

Can derive constraints on \( \alpha_k \) and \( k \) by evaluating the criteria as done for linear feedback.

- Advantage: more flexibility
- Disadvantage: less robust – higher sensitivity to system parameters like \( X_{\text{goal}} \) and \( n \)
Unresolved Issues

- Effect of delayed feedback
- Utility of non-binary feedback
- $X_{goal}$ can’t be known, but should users attempt to guess $n$?
- Asynchronous feedback
Other Issues

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- And . . . ?