Performance Analysis of Practical Distributed Backpressure Protocols

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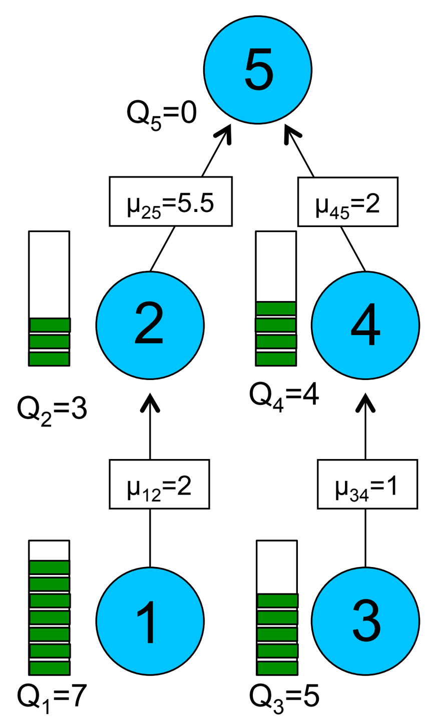
Overview

Example:

Mobile Nodes generate traffic with destination at node 5.



Notation:

Q_i = # packets in queue i

μ_{ij} = channel rate from i to j

Backpressure Routing:

Choose transmission schedule to maximize:

$$\max_{\mu_{ij}} \sum_{\forall i,j} (Q_i(t) - Q_j(t)) * \mu_{ij}(t)$$

Focus of this Work:

- How do nodes learn each others' queue backlogs and channel rates, a.k.a, *Control Information*?
- What if there are errors in these values?

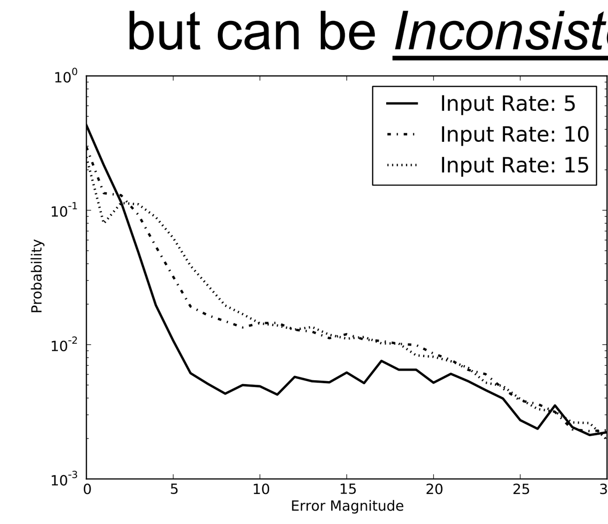
Disseminating Backlogs

Best Effort Protocol

- Schedule with most current view of network
- Information is most current, but can be *Inconsistent*

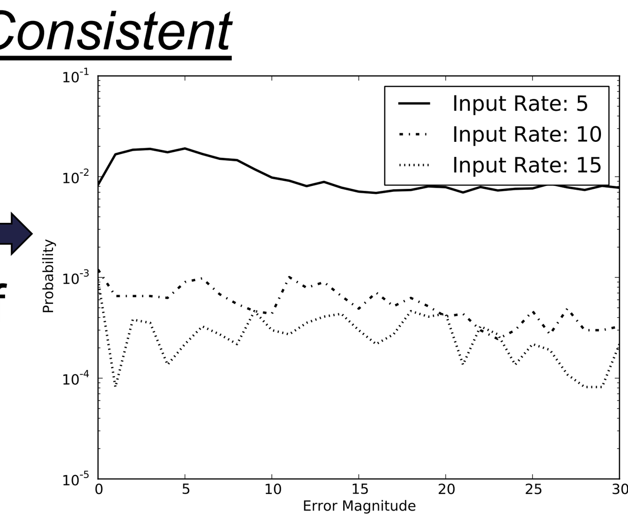
Delayed Information Protocol

- Schedule with view of network *N-1* time slots old
- Information is old, but will be *Consistent*



*Approximated as Normal

Empirically Found Distributions of Errors

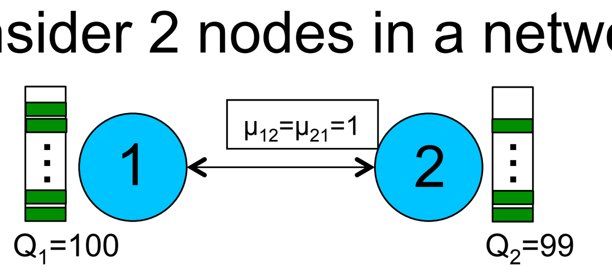


*Approximated as Uniform

Scheduling with Inconsistent vs. Consistent Information

Motivating Example

Consider 2 nodes in a network:



Optimal Schedule

Node 1 Trx at μ_{12}

Node 2 Silent

Inconsistent Errors (Best Effort Protocol):

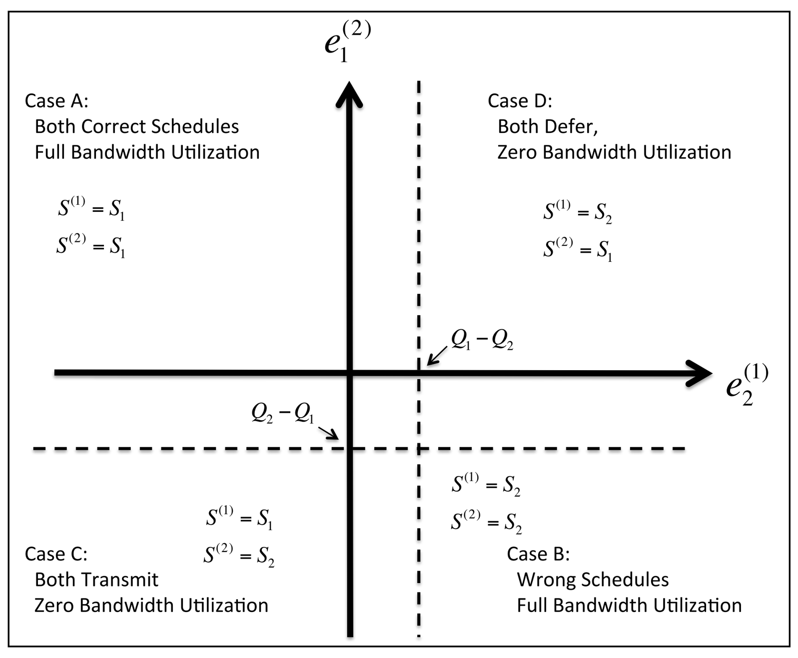
- Let $e_i^{(j)}$ be the error in Queue i at Node j
- Each node chooses whether or not to transmit based on its view of the network.

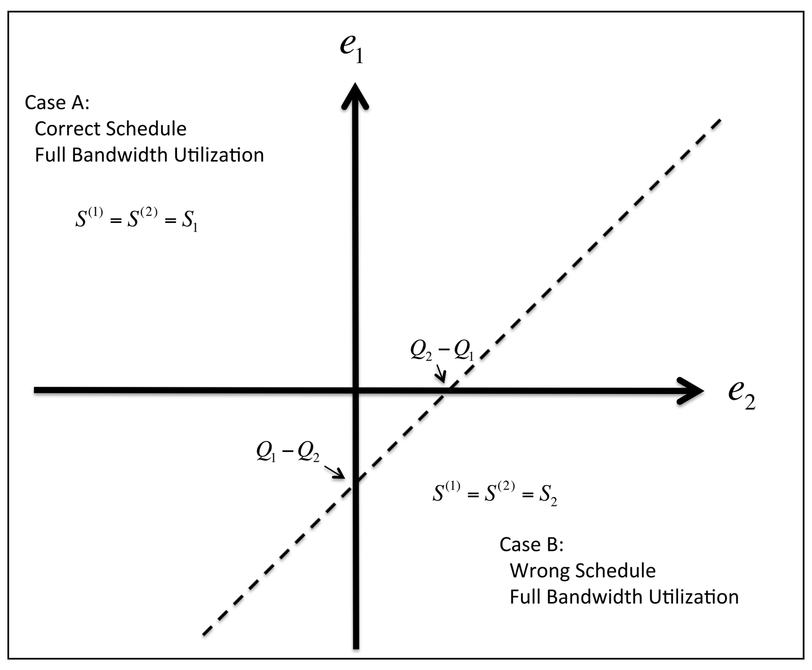
Case	$e_1^{(2)}$	$e_2^{(1)}$	Node 1: Q_1, Q_2	Node 2: Q_1, Q_2	Node 1 Result	Node 2 Result	Overall Result
A	1	0	100, 99	101, 99	Trx	Silent	Full Tput
B	-2	2	100, 101	98, 99	Silent	Trx	Full BW
C	-2	0	100, 99	98, 99	Trx	Trx	Collision
D	0	2	100, 101	100, 99	Silent	Silent	Dead Air

Consistent Errors (Delayed Info Protocol):

- Let e_i be the error in Queue i at all nodes
- Each node chooses whether or not to transmit based on the same, possibly erroneous view of the network

Case	e_1	e_2	Node 1: Q_1, Q_2	Node 2: Q_1, Q_2	Node 1 Result	Node 2 Result	Overall Result
A	2	0	102, 99	102, 99	Trx	Silent	Full Tput
B	0	2	100, 101	100, 101	Silent	Trx	Full BW





Takeaway: Using Consistent Information results in zero collisions or dead air = full utilization of bandwidth

Probability of Outcomes

Inconsistent Information:

- Using Normal RV with standard deviation, E_{StdDev}
- CDF of error becomes:

$$F_{e_i^{(j)}}(x) = \Phi\left(\frac{x}{E_{StdDev}}\right)$$

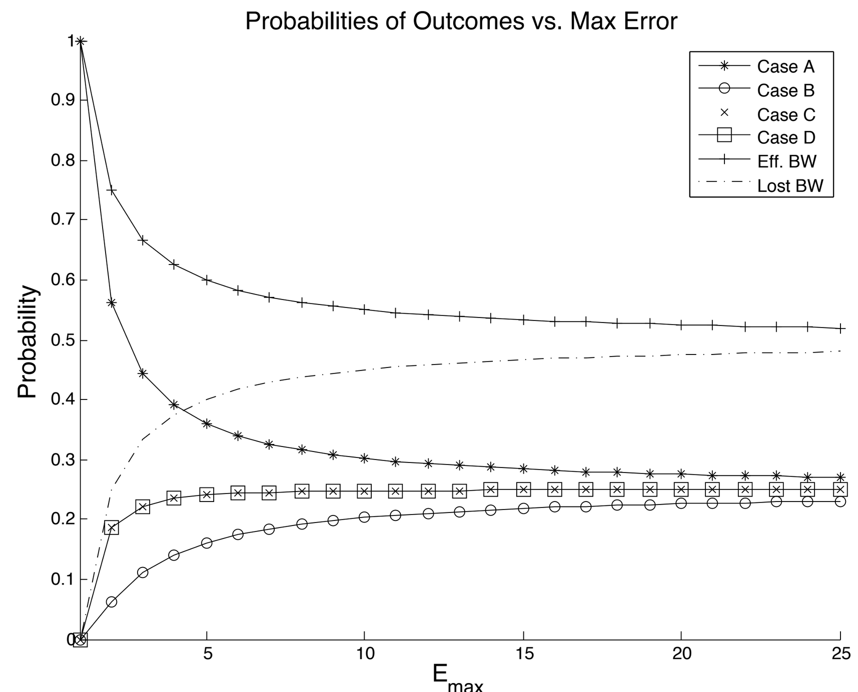
Probability of each case

$$P(CaseA) = \left(1 - \Phi\left(\frac{-Q_{diff}}{E_{StdDev}}\right)\right) * \Phi\left(\frac{Q_{diff}}{E_{StdDev}}\right)$$

$$P(CaseB) = \Phi\left(\frac{Q_{diff}}{E_{StdDev}}\right) * \left(1 - \Phi\left(\frac{Q_{diff}}{E_{StdDev}}\right)\right)$$

$$P(CaseC) = \Phi\left(\frac{-Q_{diff}}{E_{StdDev}}\right) * \Phi\left(\frac{-Q_{diff}}{E_{StdDev}}\right)$$

$$P(CaseD) = \left(1 - \Phi\left(\frac{-Q_{diff}}{E_{StdDev}}\right)\right) * \left(1 - \Phi\left(\frac{Q_{diff}}{E_{StdDev}}\right)\right)$$



Consistent Information:

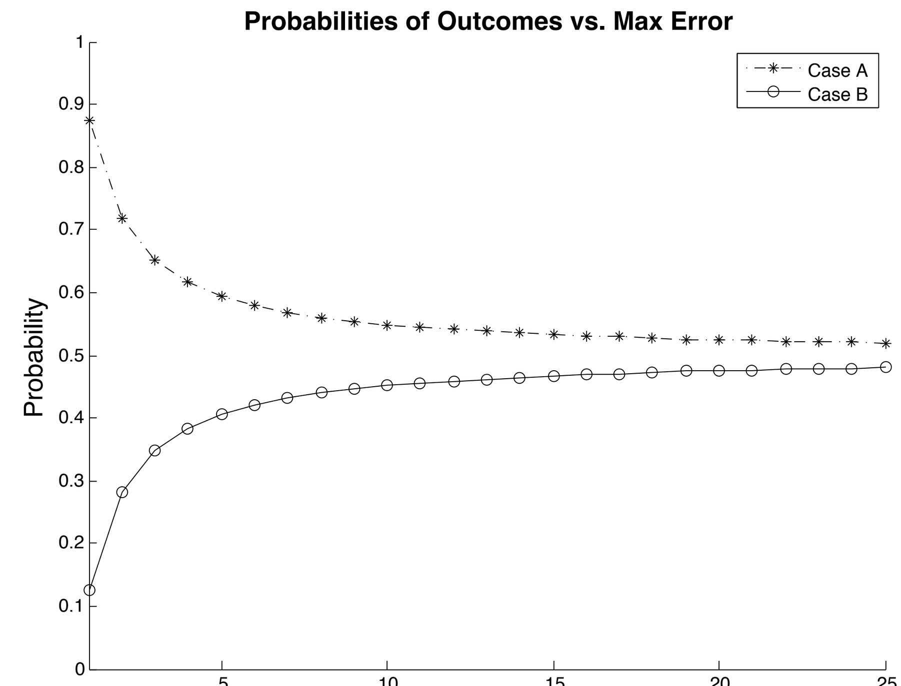
- Using Uniform RV with maximum error, E_{max}
- CDF of error becomes:

$$F_{e_1 - e_2}(x) = \begin{cases} 0 & x < -2E_{\max} \\ \frac{(2E_{\max} + x)^2}{8E_{\max}^2} & -2E_{\max} < x < 0 \\ 1 - \frac{(2E_{\max} - x)^2}{8E_{\max}^2} & 0 < x < 2E_{\max} \\ 1 & x > 2E_{\max} \end{cases}$$

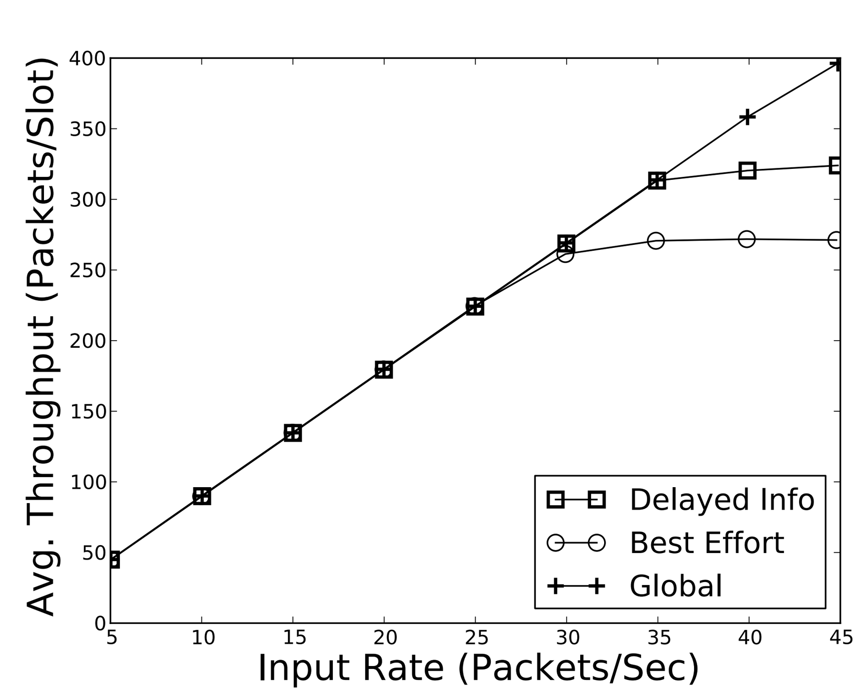
Probability of each case

$$P(CaseA) = 1 - \frac{(2E_{\max} - Q_{diff})^2}{8E_{\max}^2}$$

$$P(CaseB) = \frac{(2E_{\max} - Q_{diff})^2}{8E_{\max}^2}$$

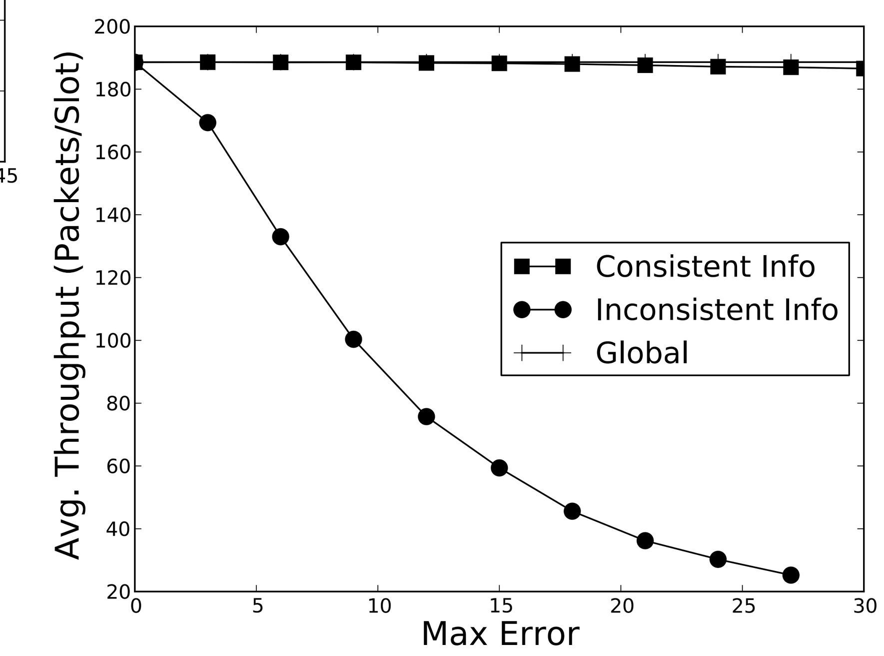


Experimental Results



Result 1:
No wasted bandwidth means higher network capacity for Delayed Info

Result 2:
Impact of errors diminishes with magnitude



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