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A Scalable Protocol Architecture for End-to-End Signaling and Resource Reservation in IP Networks

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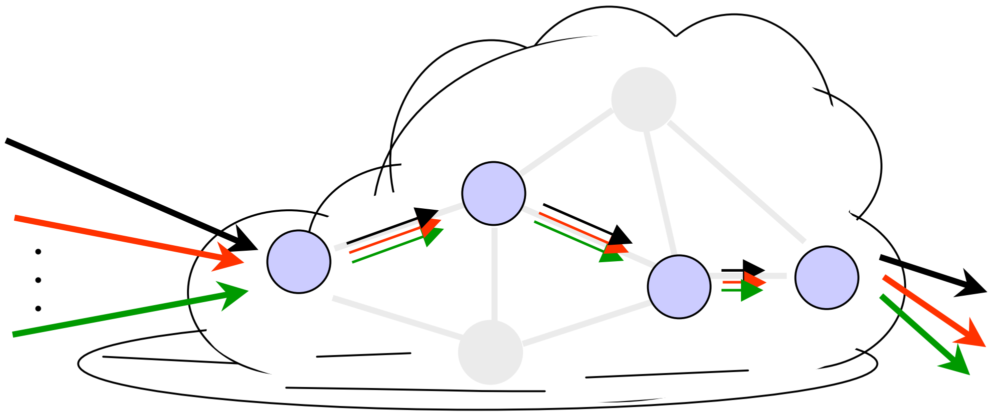
Outline

- ▷ Mechanisms for QoS support in IP networks
- ▷ A scalable protocol architecture
  - Reservation aggregation for state scalability
  - Overreservation for signaling scalability
- ▷ Signaling traffic
  - Update model with overreservation
  - Analytical performance evaluation
- ▷ Numerical results
  - Tradeoffs
  - Rule of thumb for overreservation
  - Bandwidth efficiency
- ▷ Summary
- ▷ Outlook

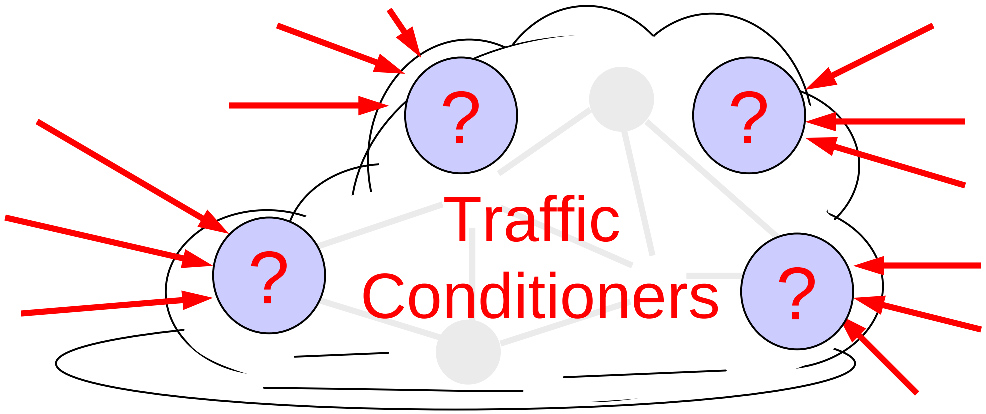
Integrated Services

- RFC1633, RFC2205, RFC2210, RFC2211, RFC2212
- Per flow treatment
  - Traffic descriptors T_{spec}
  - Reservation descriptors R_{spec}
  - Admission control (AC)
  - Number of states proportional to number of flows
- Scalability problem in large networks



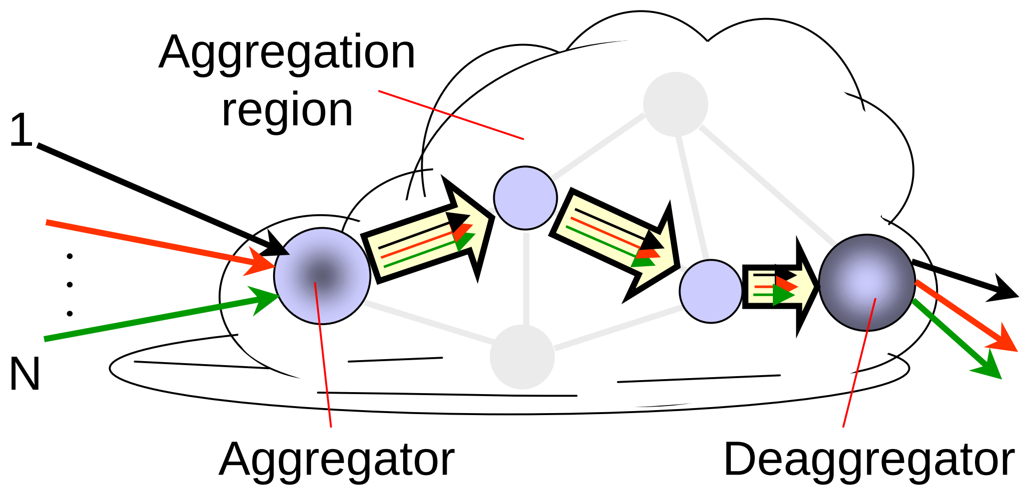
Differentiated Services

- RFC2475, RFC2597, RFC2598, RFC2638
- Per Hop Behavior (PHB) = per class treatment
  - Expedited Forwarding (EF), Assured Forwarding (AF), Best Effort (BE)
  - Traffic conditioners at edge routers, meters, policers, shapers
  - No per flow information
  - No admission control (AC)
- No QoS guarantees due to lack of AC



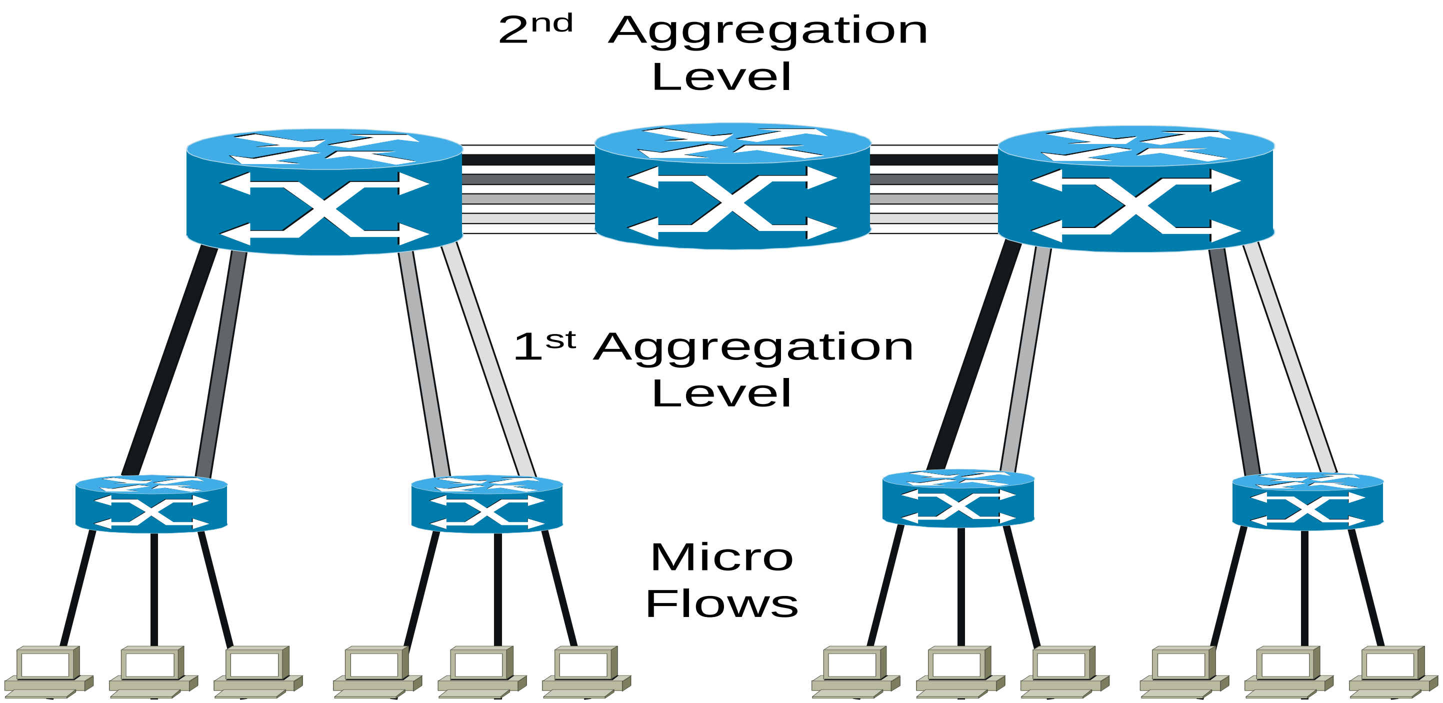
A Scalable Protocol Architecture for E2E Signaling and Resource Reservation

- ▷ Reservation aggregation (RFC2430 (MPLS), Draft-RSVP-AGGR)
  - Establish aggregate reservation
  - Forward traffic in an aggregated way
  - Bypass individual RSVP messages
- ▷ ⇒ State reduction N:1 in router MIBs



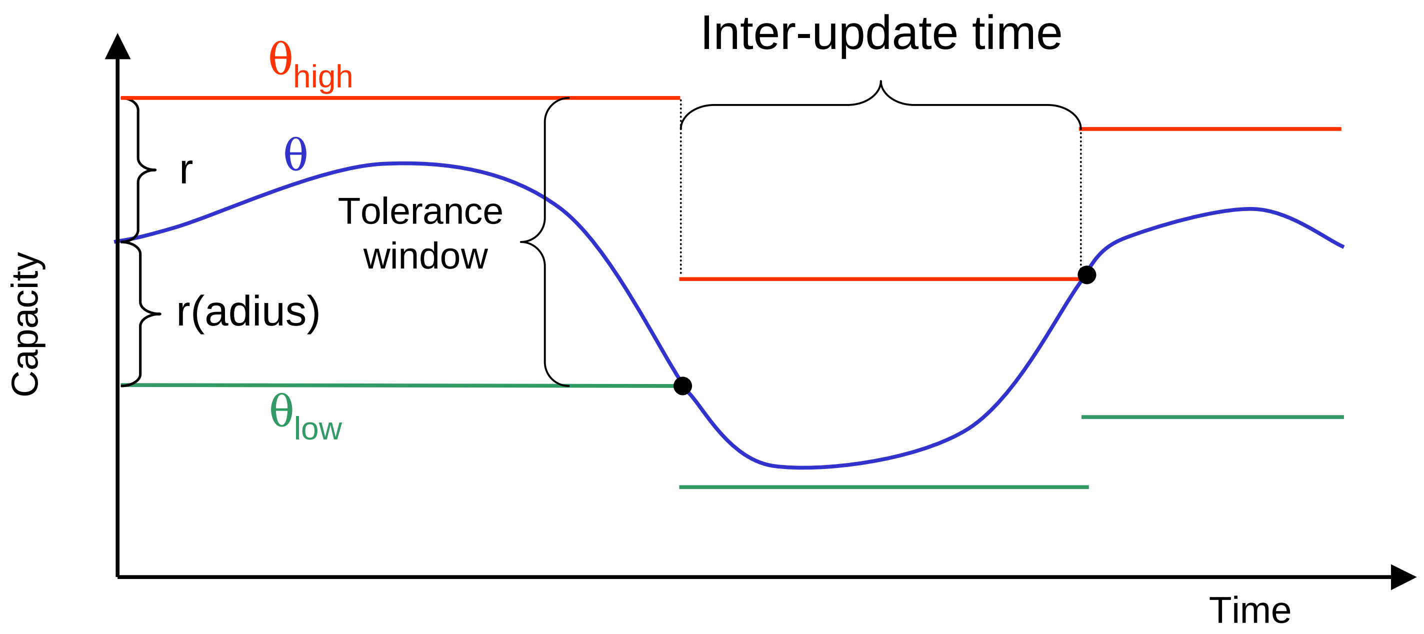
Hierarchical Aggregation for State Scalability

- ▷ Number of required aggregates scales like $O(n^2)$
- ▷ Solution: hierarchical reservation aggregation



Overreservation for Signaling Scalability

- Update of aggregate reservation necessary for every change of aggregated flows
- Solution: overreservation for aggregate reservations



Analysis of the Inter-Update Time

- Assumptions
  - Telephone calls with holding time $1/\mu$
  - No call blocking due to lack of bandwidth
  - Call arrival rate λ
  - Call termination rate $n \cdot \mu$ for n active calls
- Tolerance window $[n_{low};n_{high}]$
- Description of the waiting process by state transition matrix Q^w

$$Q^w = \begin{pmatrix} -(\lambda + n_{low}\cdot\mu) & \lambda & 0 & \cdots & 0 \\ (n_{low}+1)\cdot\mu & \ddots & \ddots & \ddots & \vdots \\ 0 & \ddots & \ddots & \ddots & 0 \\ \vdots & \ddots & \ddots & \ddots & \lambda \\ 0 & \cdots & 0 & n_{high}\cdot\mu & -(\lambda + n_{high}\cdot\mu) \end{pmatrix}$$

Computing the Moments of the Inter-Update Time

- n^{th} moment of the inter-update time $E[W_i^n]$, $i \in [n_{low};n_{high}]$
  - First passage time of the waiting process
  - Depends on start state i within the tolerance window
- Definitions

$$m^{(n)} = \left(E[W_{n_{low}}^n], \ldots, E[W_{n_{high}}^n] \right)$$

$$m^{(0)} = \left(E[W_{n_{low}}^0], \ldots, E[W_{n_{high}}^0] \right) = (1, \ldots, 1)$$

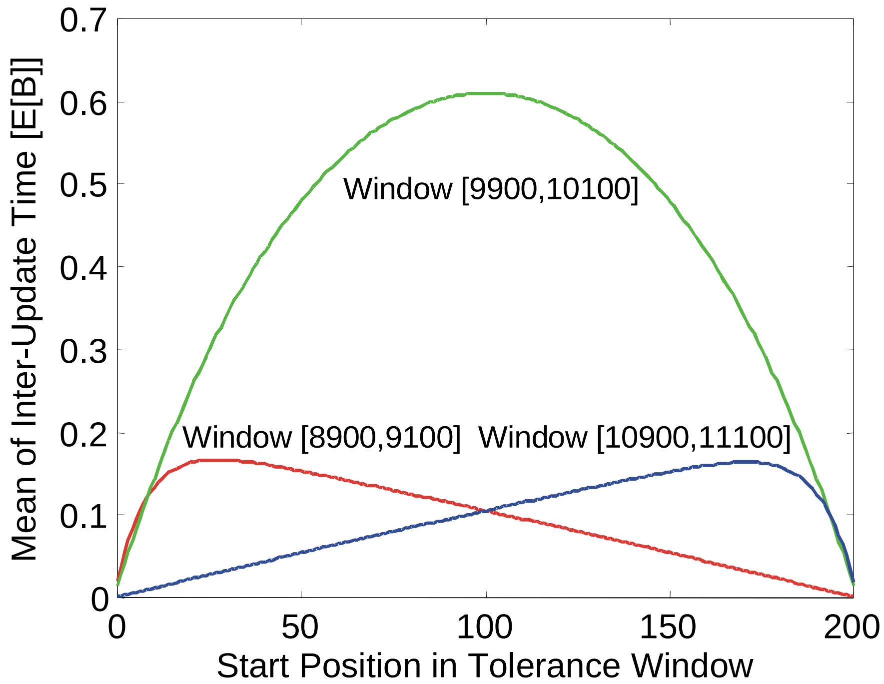
- Recursive equation

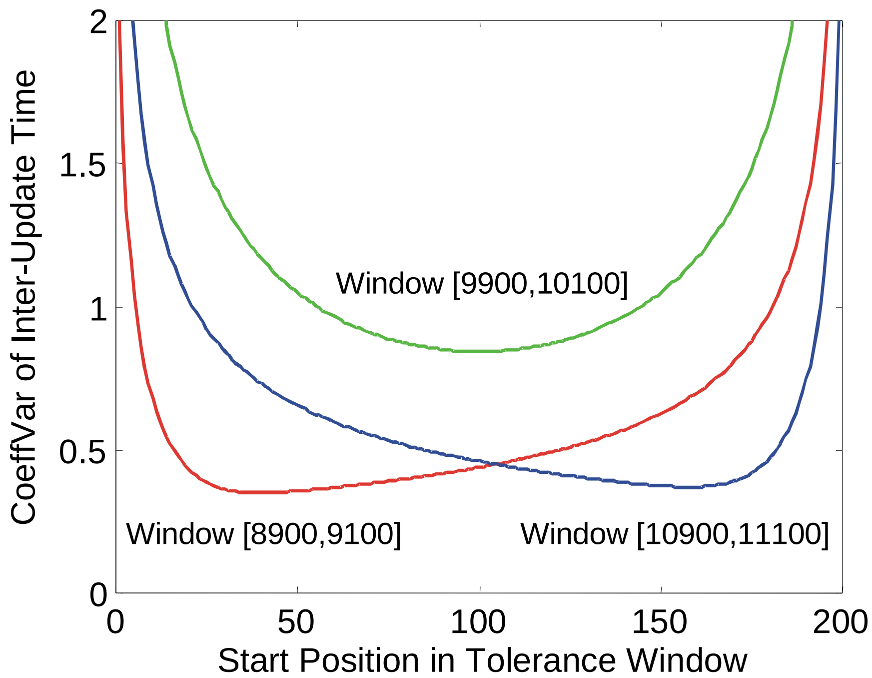
$$m^{(n)} = -\left(Q^w\right)^{-1} \cdot n \cdot \left(m^{(n-1)}\right)^T$$

- Coefficient of variation

$$\sigma_{W_i} = \frac{\sqrt{E[W_i^2] - E[W_i]^2}}{E[W_i]}$$

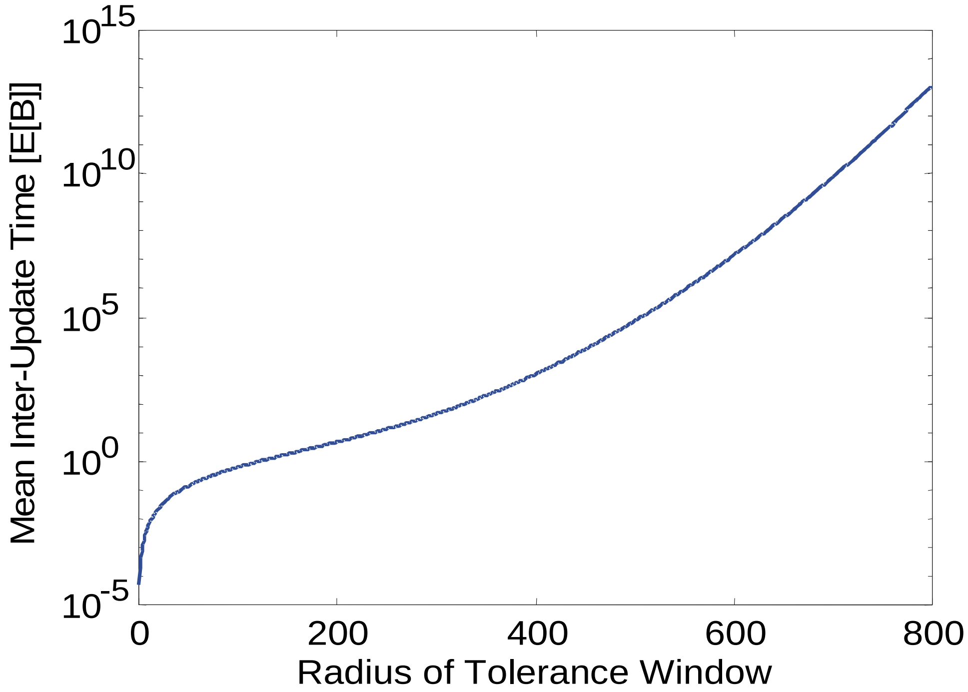
Impact of the Tolerance Window Position





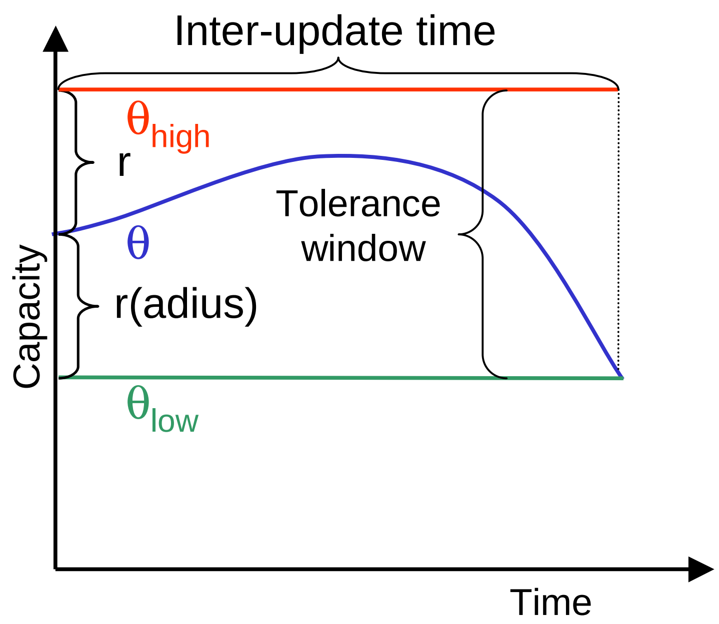
- Mean aggregate size $\bar{n}=10000$
- Radius of tolerance window $r=100$
- Best performance if window is symmetric around mean queue length

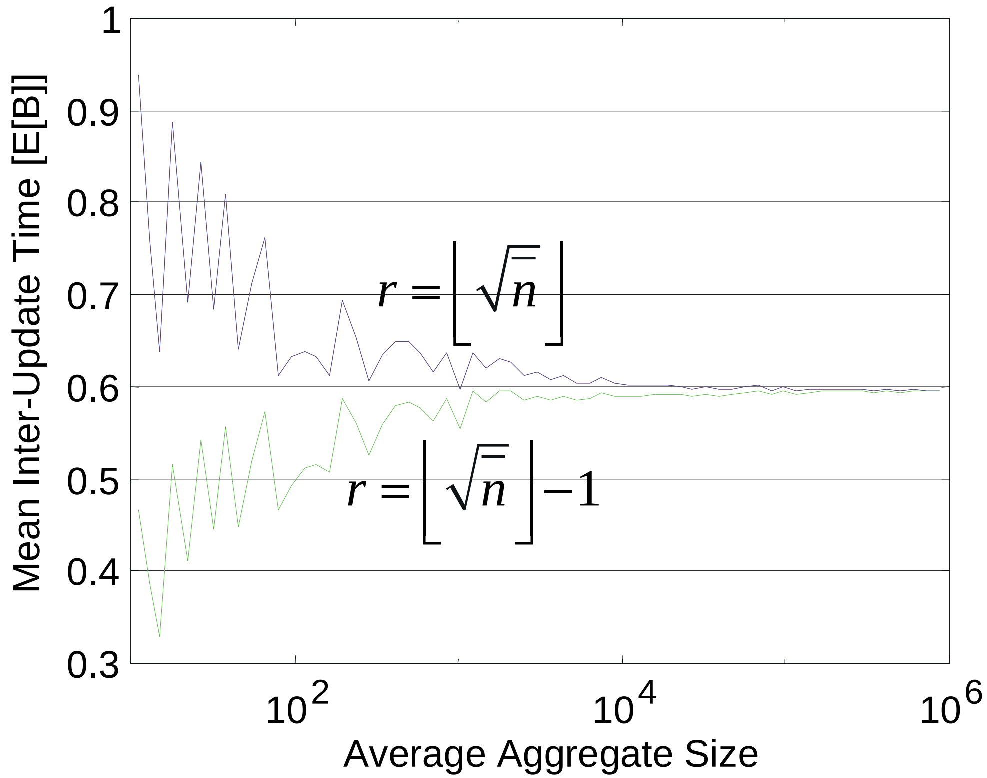
Impact of the Tolerance Window Radius



- ▷ Growth of the inter-update time
  - Mean aggregate size $\overline{n}=10000$
  - Quadratic for small window sizes
  - Exponential for large window sizes

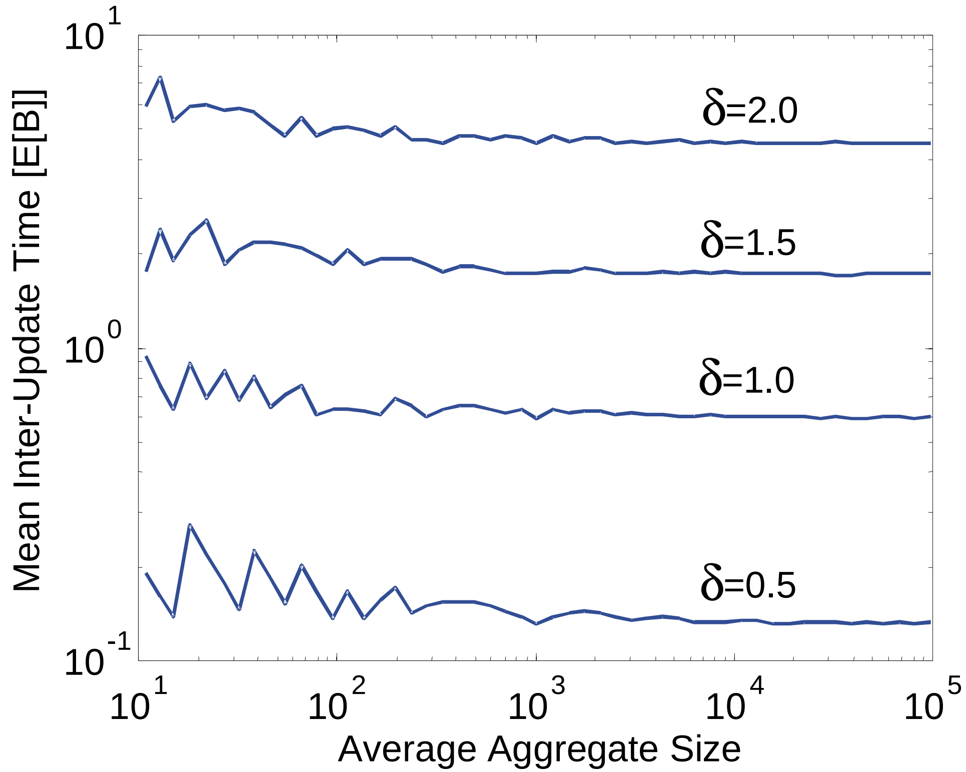
A Rule of Thumb for Overreservation





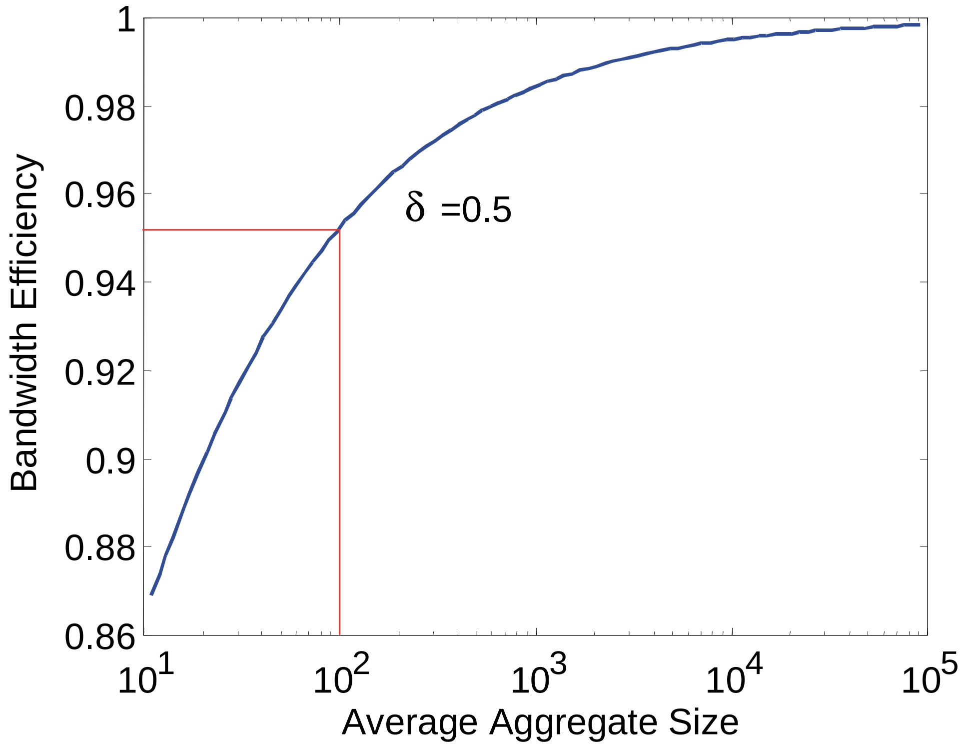
- Rule of thumb
  - Constant inter-update time for various aggregate sizes
  - Sharp upper bound

Scaling the Rule of Thumb



- Control for tradeoff between
  - Bandwidth efficiency
  - Signaling reduction

Overreservation and Bandwidth Efficiency



▷ Performance of the update scheme

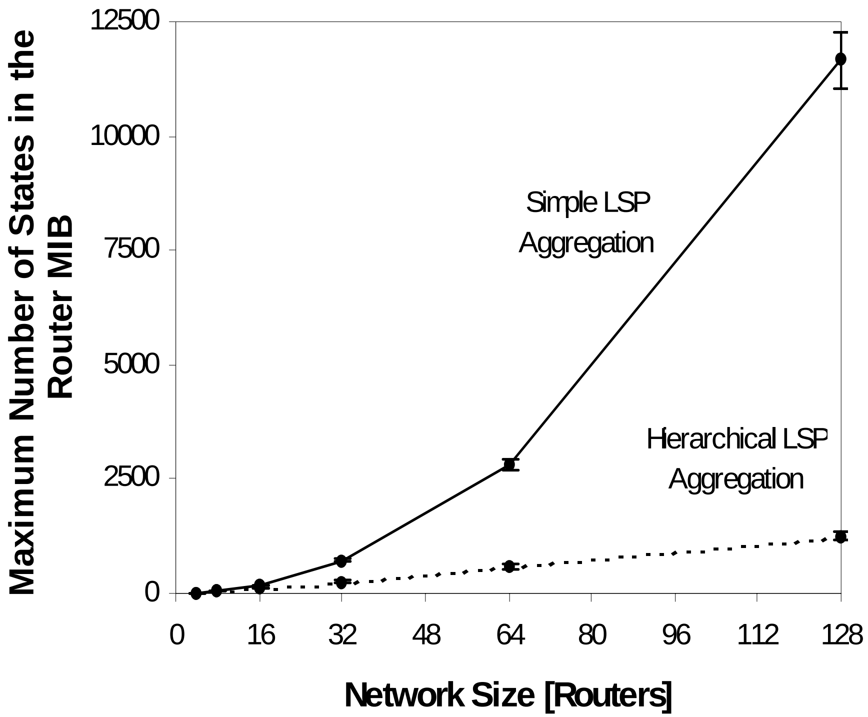
- $r = 0.5 \cdot \sqrt{n}$: inter -update time: 15 seconds
- Bandwidth efficiency: 95 % for aggregate size 100

Summary

- ▷ Scalable protocol architecture
  - Synthesis of
    - IntServ
    - DiffServ
  - Based on aggregate reservations
  - Scalability with respect to
    - States in router MIBs
    - Signaling traffic
- ▷ Update scheme using overreservation
  - Analytical performance evaluation of inter-update time of aggregate reservations
  - Rule of thumb: recommendation for overreservation
  - Good bandwidth efficiency in spite of overreservation

Outlook

- Creation of suited reservation hierarchies in general network structures
  - Decreases average growth of state number in router MIBs from $O(n^2)$ to $O(n)$



- Integration of
  - Hierarchically aggregated reservations
  - Traffic engineering methods