Semantic Multicast for Content-based Stream Dissemination

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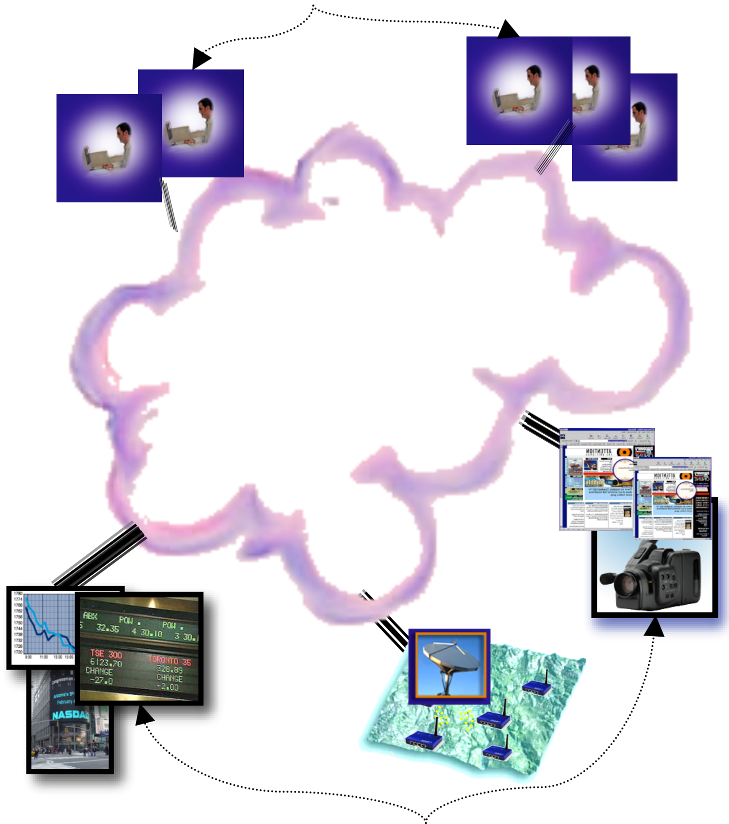
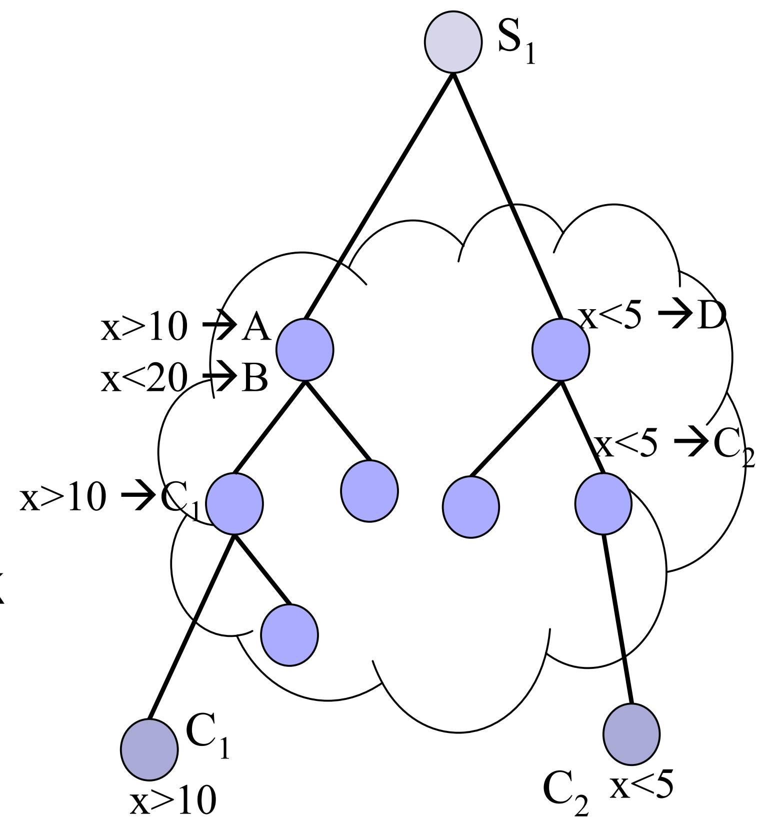
Stream Dissemination Applications



- Push-based applications
  - Environmental monitoring
  - Real-time financial services
- Characteristics
  - High data volume
  - Fast stream rates
  - Highly dispersed sources & destinations

Content-based Dissemination

- Centralized filtering
  - Single node gathers profiles
  - Unicast to destinations
  - e.g., XFilter [Altinel *et al.*, 2000]
- Distributed content-based routing
  - Interest-based routing
  - Predefined acyclic overlay network
    - e.g. SIENA [Carzaniga *et al.*, 2001]
  - Predicate-based filtering network
    - Upstream profile aggregation
  - Content filtering of each message at each hop



Content-based routing overhead

- Processing cost
  - Local filtering of each message
  - Compression/decompression for XML streams
- Bandwidth consumption
  - Missed tree optimization opportunities
    - Different client sets request different sub-streams
    - One spanning tree of the whole network is not the best solution for low cost

Our approach: Semantic Multicast

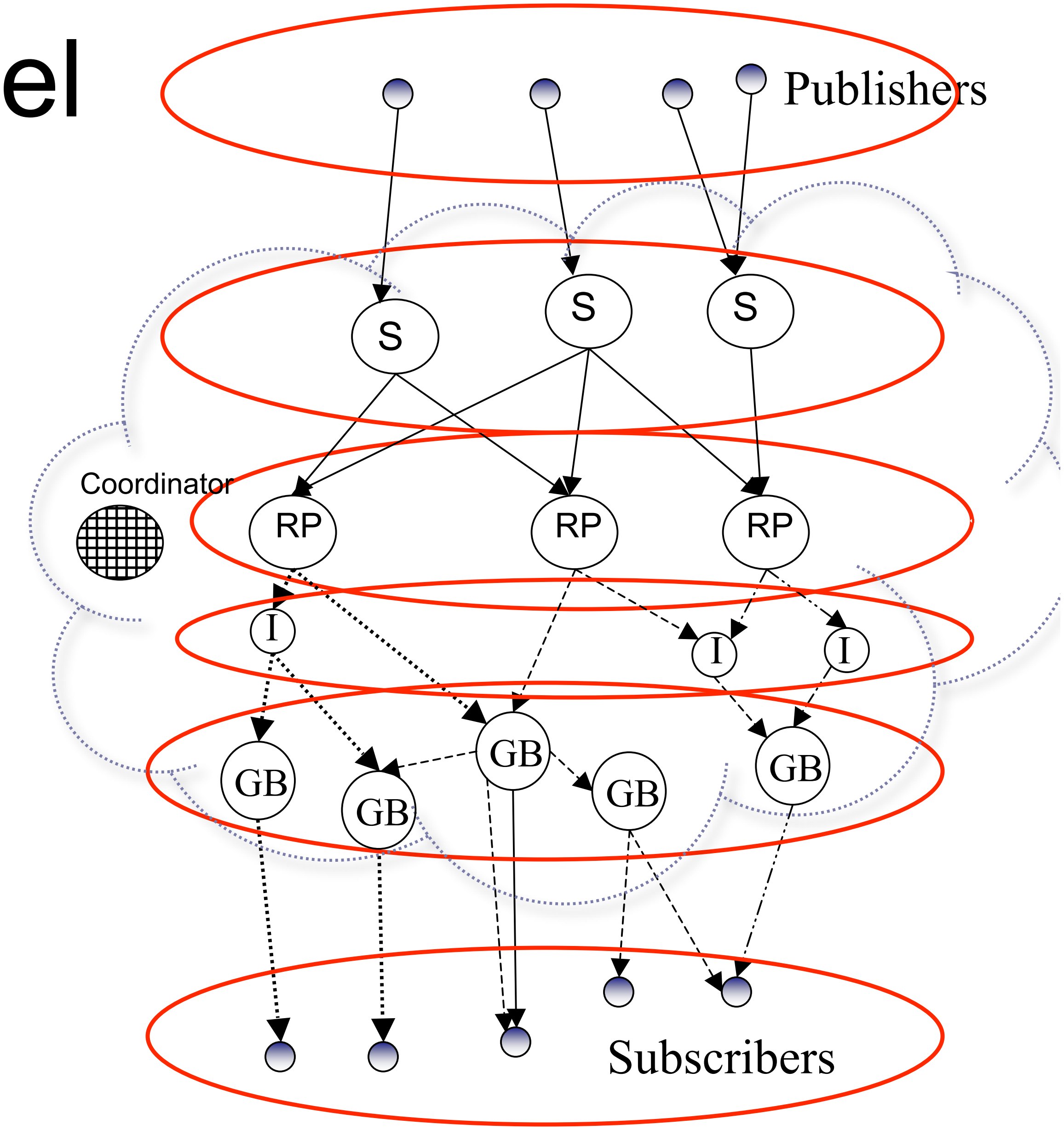
- Constructs content-based (a.k.a. *semantic*) multicast channels
  - Independent overlay dissemination trees
  - Channels characterized by their content
- Advantages
  - Decreases processing cost
    - Eliminates local filtering at interior brokers
  - Decreases overall bandwidth requirements
  - Allows QoS-aware multicast trees

Content-based Channelization

- SemCast decides:
  - Number of channels
  - Content of channels
  - Clients subscriptions to channels
  - Channel implementation
- Operational goals
  - No false exclusion
  - Low run-time cost : Overall bandwidth consumption
    - Minimize redundancy among channels’ content
    - Create efficient multicast trees

System Model

- Source brokers (S)
  - Receive XML streams from publishers
- Gateway brokers (GB)
  - Receive XPath profiles from subscribers
- Rendezvous points (RP)
  - Roots of channels
- Interior brokers (I)
  - Forward incoming messages
- Coordinator
  - Identifies content of channels



SemCast Overview

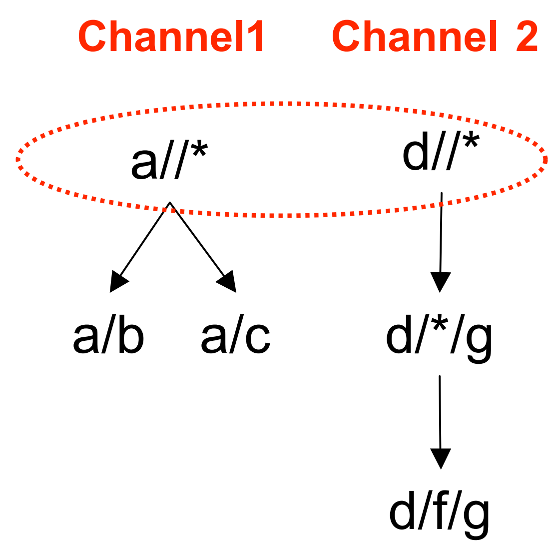
- Membership Management
  - Syntactical analysis of profiles
- Dynamic Channelization
  - Exploit statistical information
  - Reorganize channels

Membership Management

- Adding subscriptions
  - Gateway broker forwards unsatisfied subscriptions to coordinator
  - Coordinator creates a new channel for any subscription not covered by existing channels
- Removing subscriptions
  - Gateway broker forwards request to upstream brokers
  - Interior brokers remove channel entries from routing tables
  - Coordinator removes channel if there are no more remaining clients

Profile Containment Hierarchies

- Identify channels covering a profile based on profile syntax
  - Containment algorithms for XPath expressions. e.g. [Wood, 2003]
- Maintain *syntax-based containment hierarchies*
- Parent profile covers children
  - Root is the channel's content expression



Dynamic Channelization

- Syntactic analysis might cause high data redundancy
  - Undiscovered full/partial overlapping profiles
  - Assign similar profiles to different channels
    - Forward matching messages to more than one channel
- Use statistics to re-evaluate channelization
  - Profile overlap
  - Run-time stream rate

Profile Overlapping Relations

- SemCast exploits also partial overlap among profiles
- Partial overlap
  - P_i *k-overlaps* with P_j: $P_i \subseteq^k P_j, \quad k = \frac{match(P_i P_j)}{match(P_i)}$
- Containment
  - Special case of partial overlap, k=1
  - P_j *covers* P_i :messages matching P_i are subset of those matching P_j

Rate-based Hierarchies

- P_j is parent of P_i if

$$P_i \subseteq^1 P_j \text{ and } k = \max_{P_j, i \neq j} \{ k / r_{j-i} \mid P_j \subseteq^k P_i \}$$

$$r_{j-i} = \text{rate of non-overlapping part between } P_j \text{ and } P_i$$

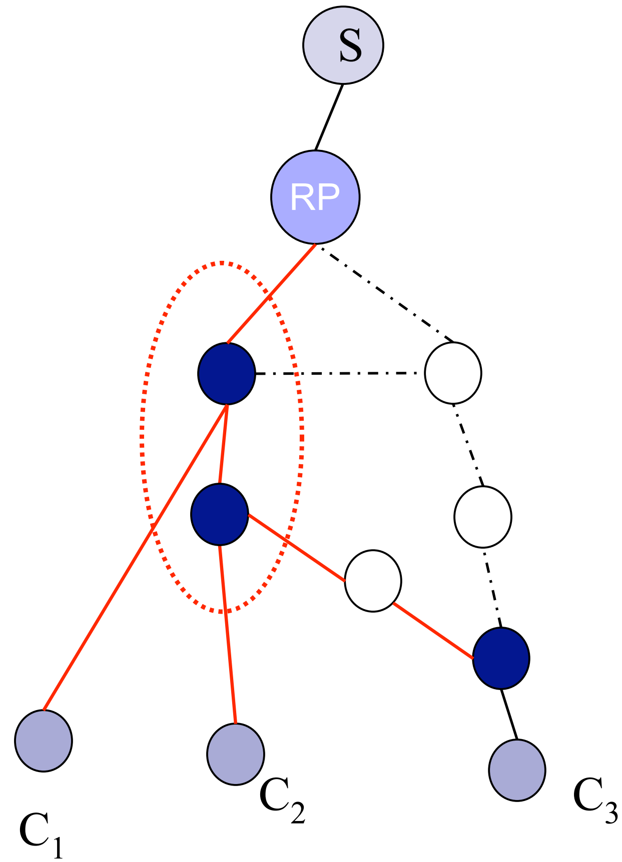
  - P_j is more general than P_i
  - If multiple candidate parents exist
    - Maximum overlap
    - Low stream rate of redundant messages

Hierarchy Merging

- Highly diverse profiles may increase cost
  - High message replication
  - Large number of channels
  - Large routing tables at interior brokers
- Merging hierarchies with partial overlap reduces cost
    - Use a cost-based model
    - Merge pairs with maximum benefit in bandwidth
      - High profile overlap
      - Efficient single multicast tree

Multicast Tree Construction

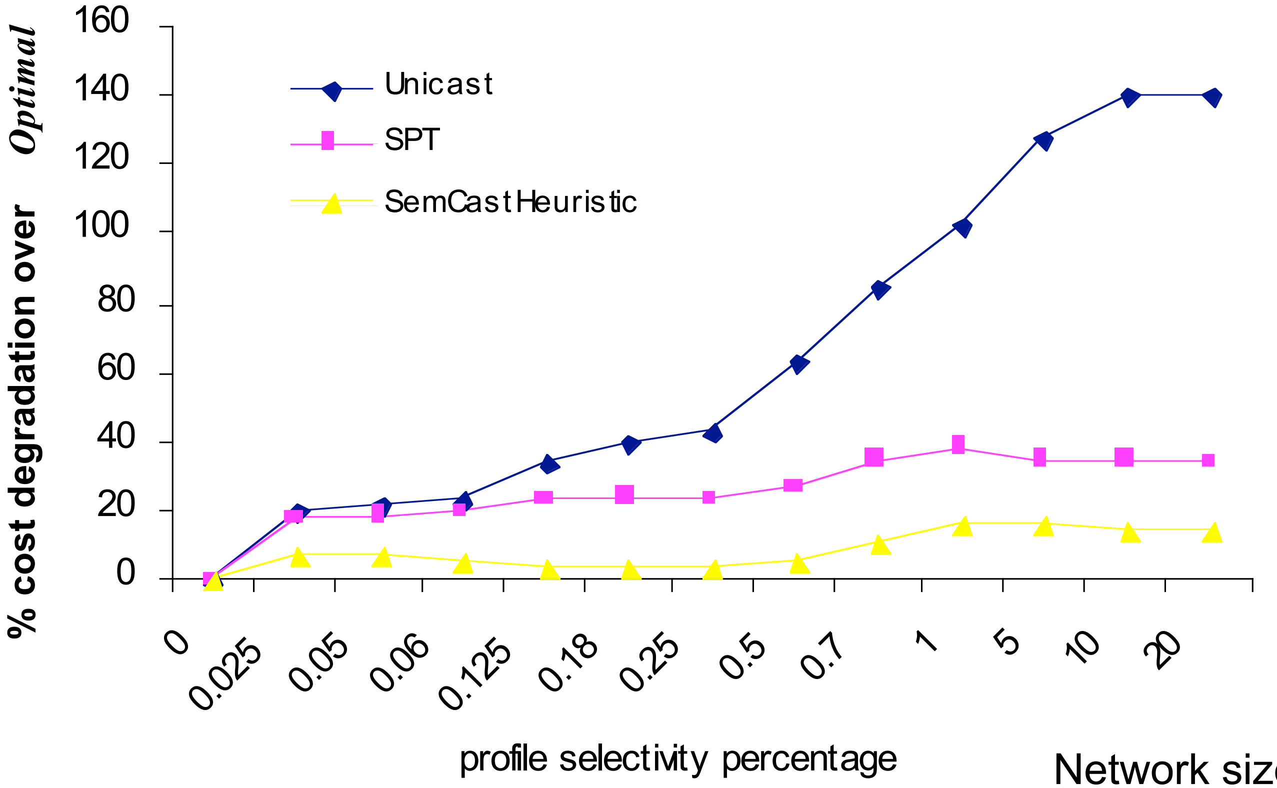
- Base low cost heuristic
  - Request channel's destinations from RP
  - Find min-cost path to all destinations in the channel
  - Connect to closest one



Simulation

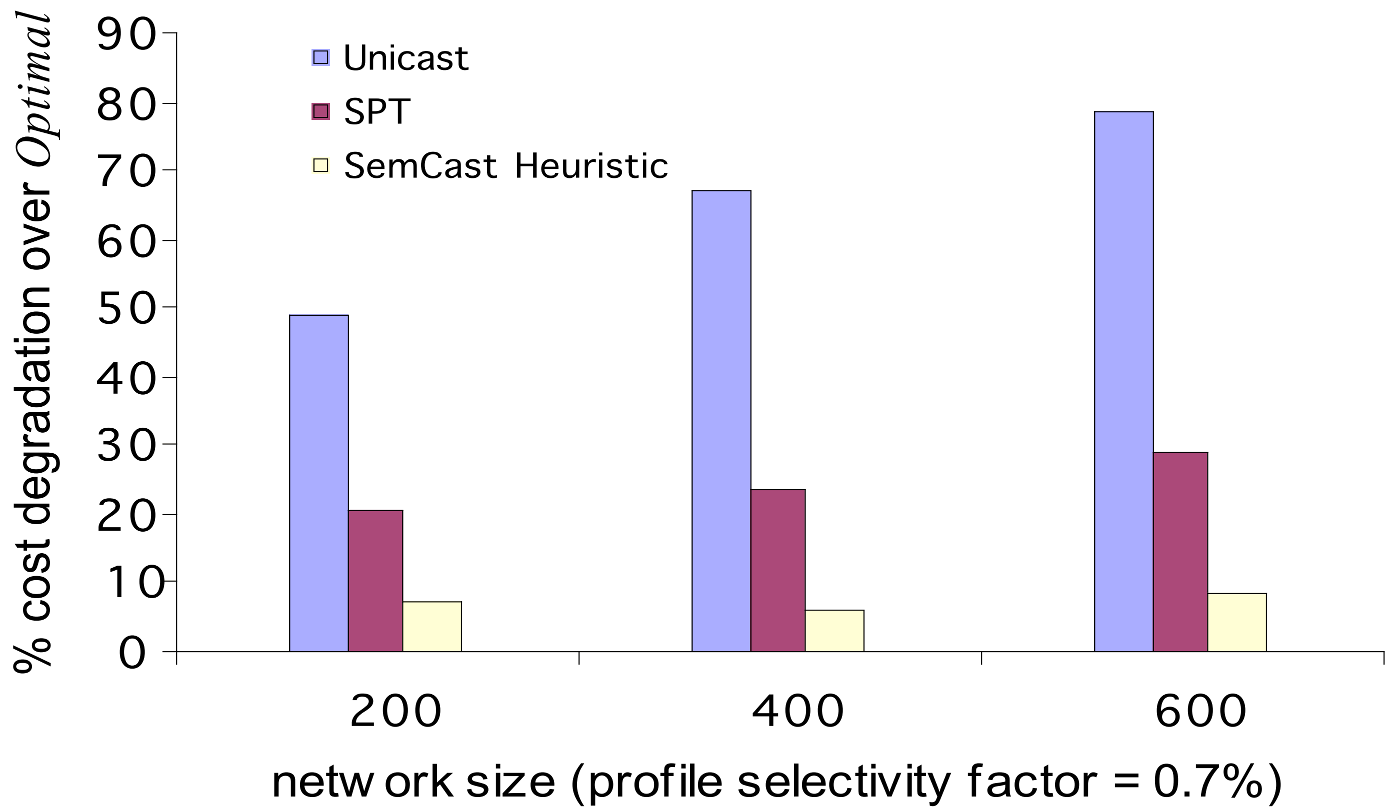
- Metrics
  - Processing cost
    - Eliminate need for local filtering (not in this paper)
  - Bandwidth efficiency
- Approaches
  - *Unicast* approach
  - *SPT*: Shortest Path Tree approach
    - Distributed pub-sub system [Carzaniga *et al.*, 2001]
  - *SemCast:* Distributed content-based channelization
  - *Optimal*: Centralized Steiner tree construction
- Simulation environment
  - Random graph generated by GT-ITM
  - Up to 700 nodes and 7000 profiles

Bandwidth efficiency



Network size =700
#profiles =7000

Scalability



Related Work

- Publish-Subscribe Systems
  - Centralized approaches: XML Filtering
    - XFilter [Altinel *et al.*, 2000] , YFilter [Diao *et al.*, 2002]
    - XTrie [Chan *et al.*, 2002]
  - Distributed approaches: Content- based Routing
    - Gryphon [Opyrchal *et al.*, 2000]
    - SIENA [Carzaniga *et al.*, 2001]
- Application-Level Multicast
    - SCRIBE [Castro *et al.*, 2002]
    - CAN-based Multicast [Ratnasamy *et al.*, 2001]

Conclusions & Ongoing Work

- SemCast
  - Performs semantic split of incoming streams
  - Eliminates local filtering in interior brokers
  - Improves bandwidth consumption
- Ongoing work
  - SemCast prototype
  - Demonstrate processing cost benefit
  - Investigate affects of network topology
  - Storage-oriented model: caching XML nodes