SemCast: Semantic Multicast for Content-based Data Dissemination

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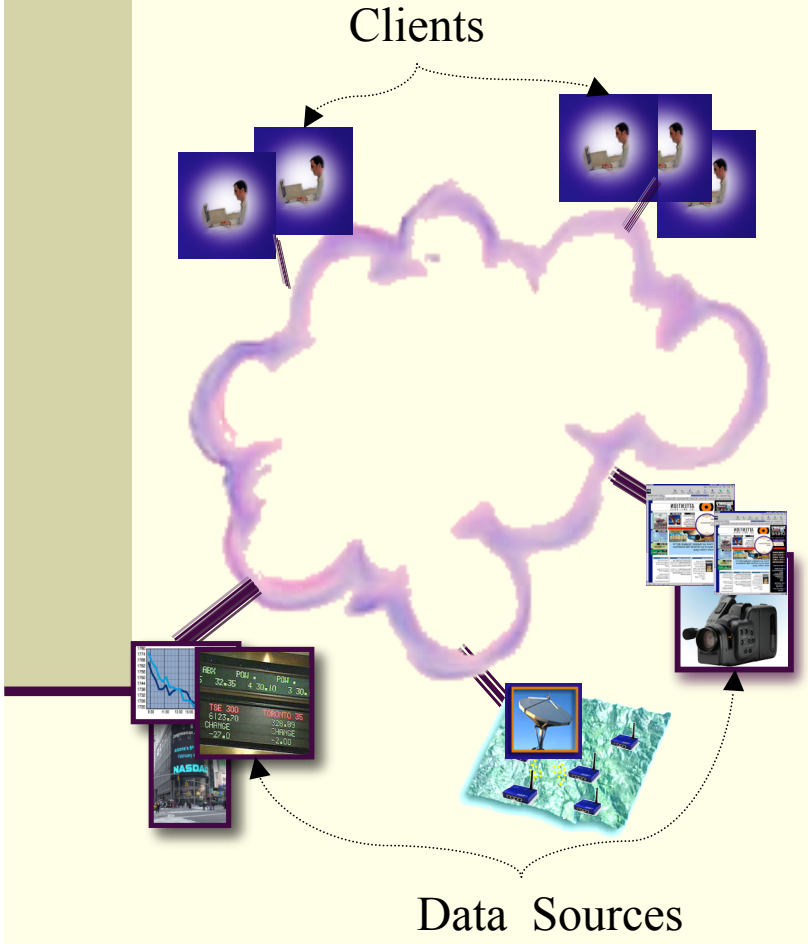
Wide Area Stream Dissemination



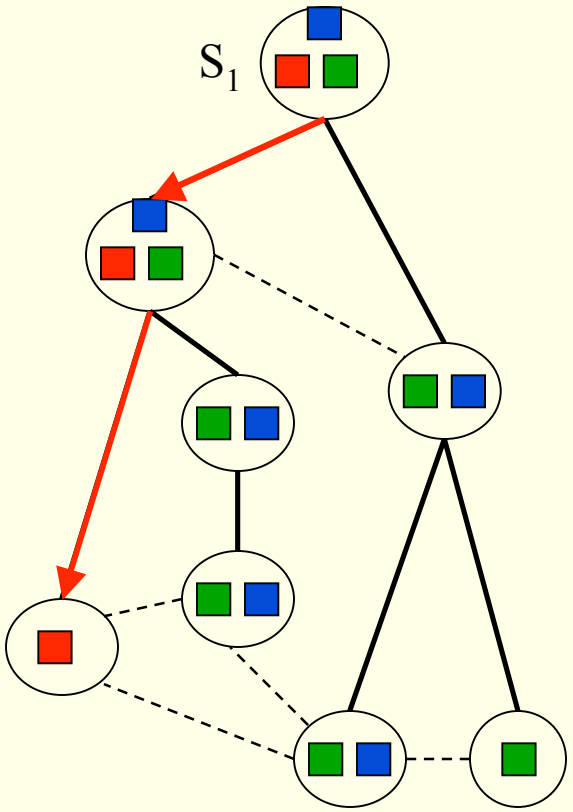
- Applications
  - Network monitoring
  - Real-time financial services/enterprise
  - News services (RSS feeds)
- Characteristics
  - High data volume
  - Highly dispersed sources & destinations
  - Low latency delivery

Content-based Dissemination

- High level of expressiveness
  - Profiles are query predicates
- Sources/destinations decoupling
  - Destinations depend on message content

Content-based Pub/Sub

- Content-based routing
  - Predefined acyclic overlay network
    - SIENA [Carzaniga *et al.*, 2001],
    - Gryphon [Banavar *et al.*, 1999]
  - Predicate-based filtering network
    - Upstream profile aggregation
- Limitations
  - Processing cost at each hop
  - Bandwidth consumption

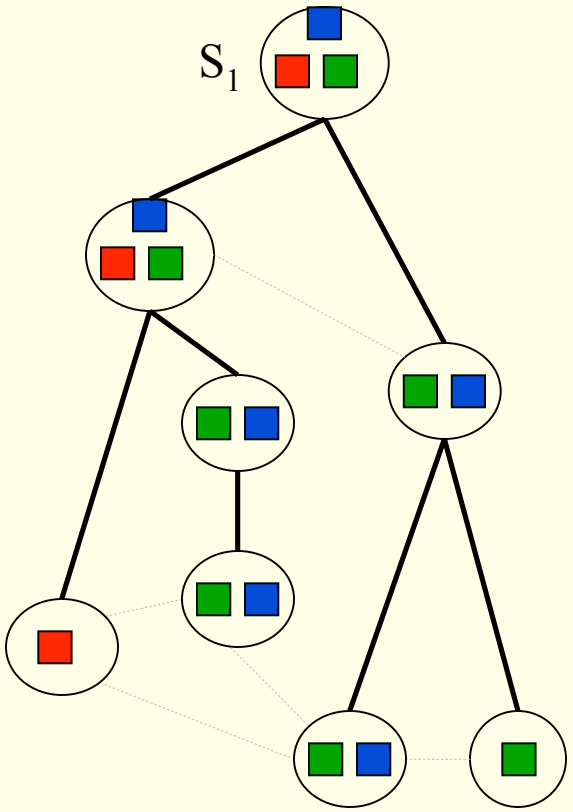


Processing cost overhead

At each level:

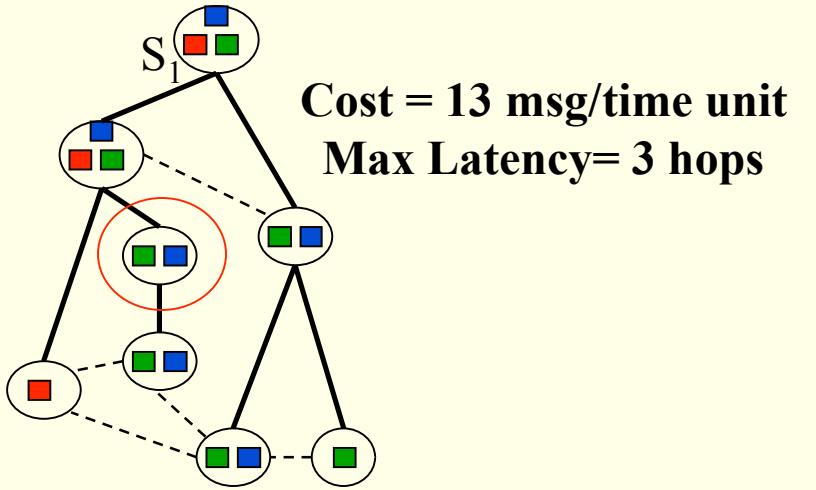
- Content-based filtering at each level
  - Maintain data structures at every broker
- Compression/decompression
  - Usually with XML streams
- Encryption/decryption
  - Integrity-critical applications (e.g., financial feeds, distributed games)

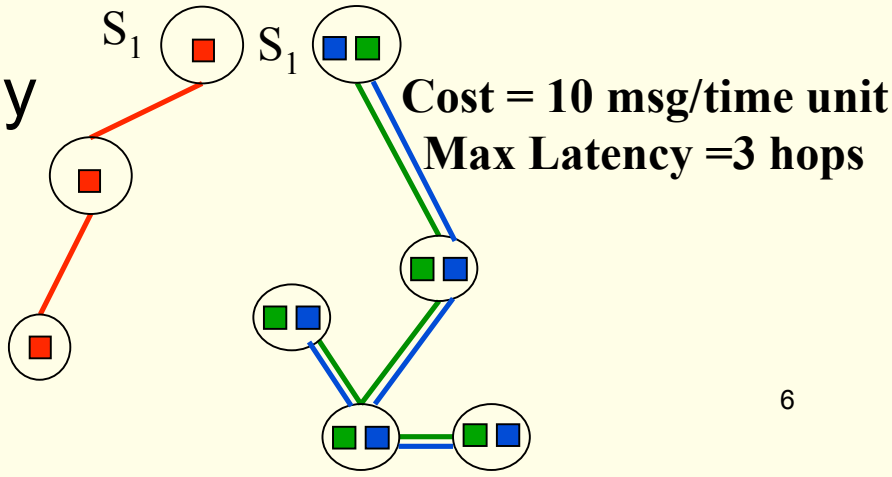
- Forwarding costs could dominate dissemination costs



Bandwidth overhead

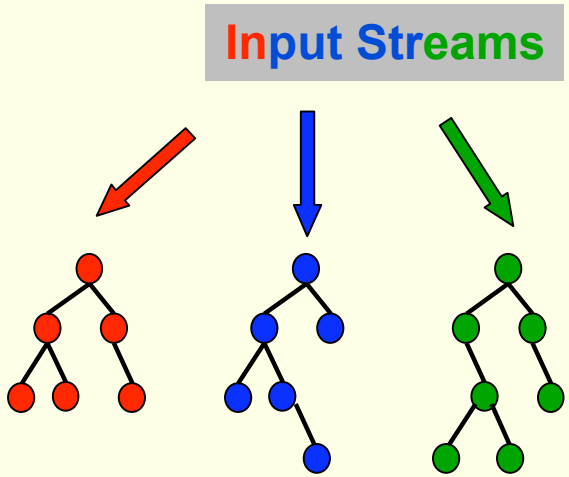
- Missed tree optimization opportunities
- Clients' profiles could overlap
- One spanning tree is suboptimal
  - Intermediate nodes may receive irrelevant data





Our approach: Semantic Multicast

- Constructs multiple content-based (a.k.a. *semantic*) dissemination channels
  - Semantic split of incoming streams
  - Channels characterized by their content
  - Independent overlay dissemination trees



SemCast's advantages

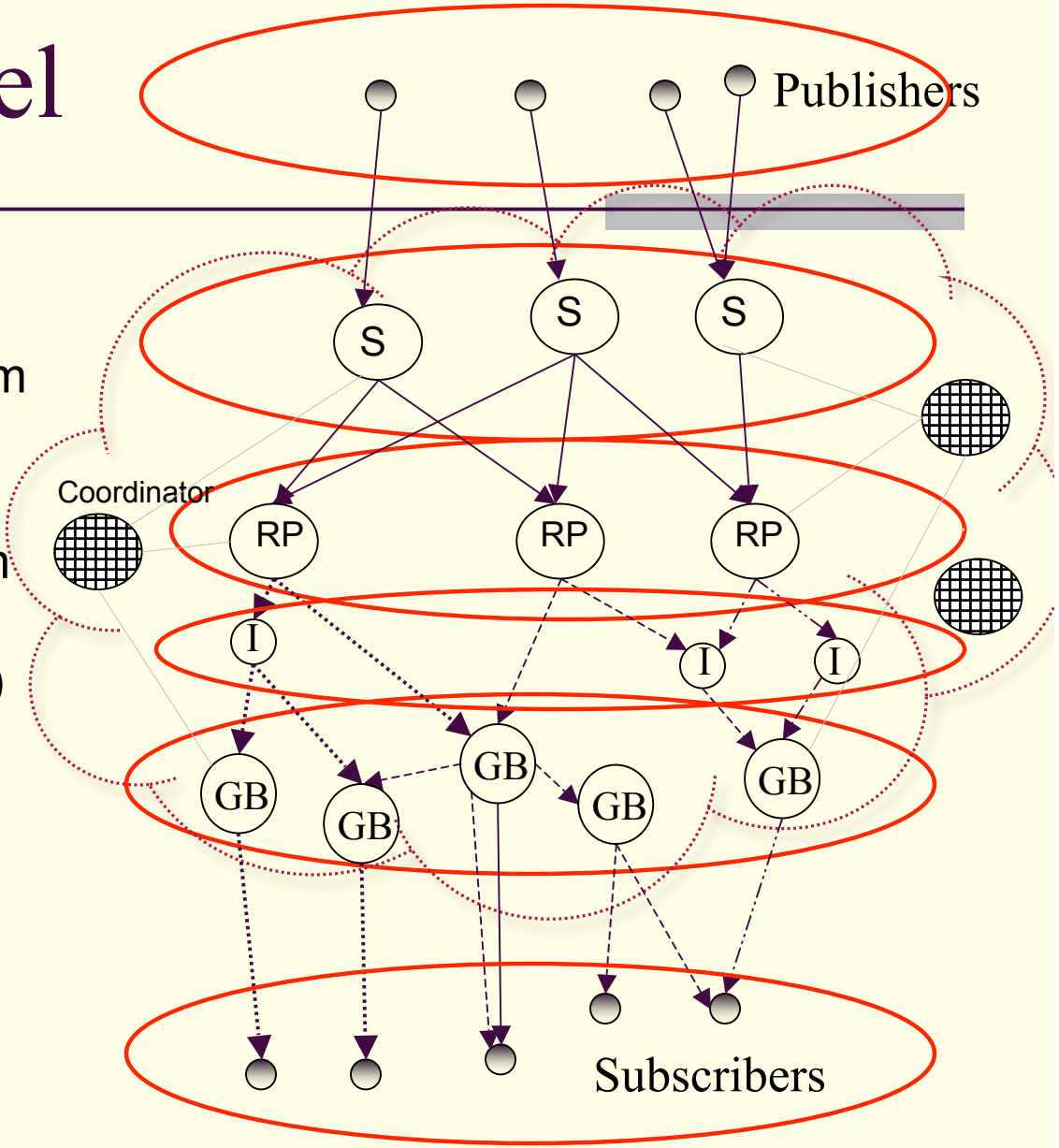
- Low processing cost
  - Eliminates local filtering at interior brokers
  - Low processing requirements for intermediate nodes
- Low overall bandwidth requirements
  - Low-cost dissemination trees
  - Enables latency-cost trade off
    - Delay-bounded trees for latency-sensitive applications

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' contents
    - Create efficient dissemination trees
    - Optimal solution for channelization: NP-complete [Adler *et al*., 2001]

System Model

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

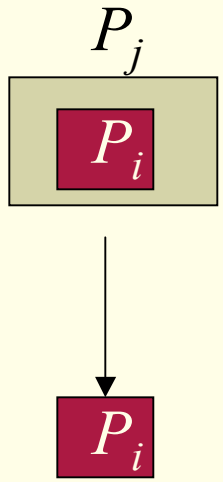


SemCast overview

- Subscription management
  - Join existing channels or create new channels
- Periodically reorganize channels
  - Exploits overlap among profiles
    - Content of channel defined by profiles assigned to it
  - Assign similar profiles to same channel
  - Identify overlap between profiles
    - Statistical & syntactical information
    - Discover containment relations
    - Merge channels with high partial overlap
    - Use cost-based model to assign profiles to channels

Containment relations

- SemCast discovers *containment hierarchies*
  - P_j *contains* P_i
    - Messages matching P_i are subset of those matching P_j
  - Profile syntax reveals containment relations
  - Statistics approximate containment relations
- Hierarchies are possible semantic channels



Cost-based Channelization

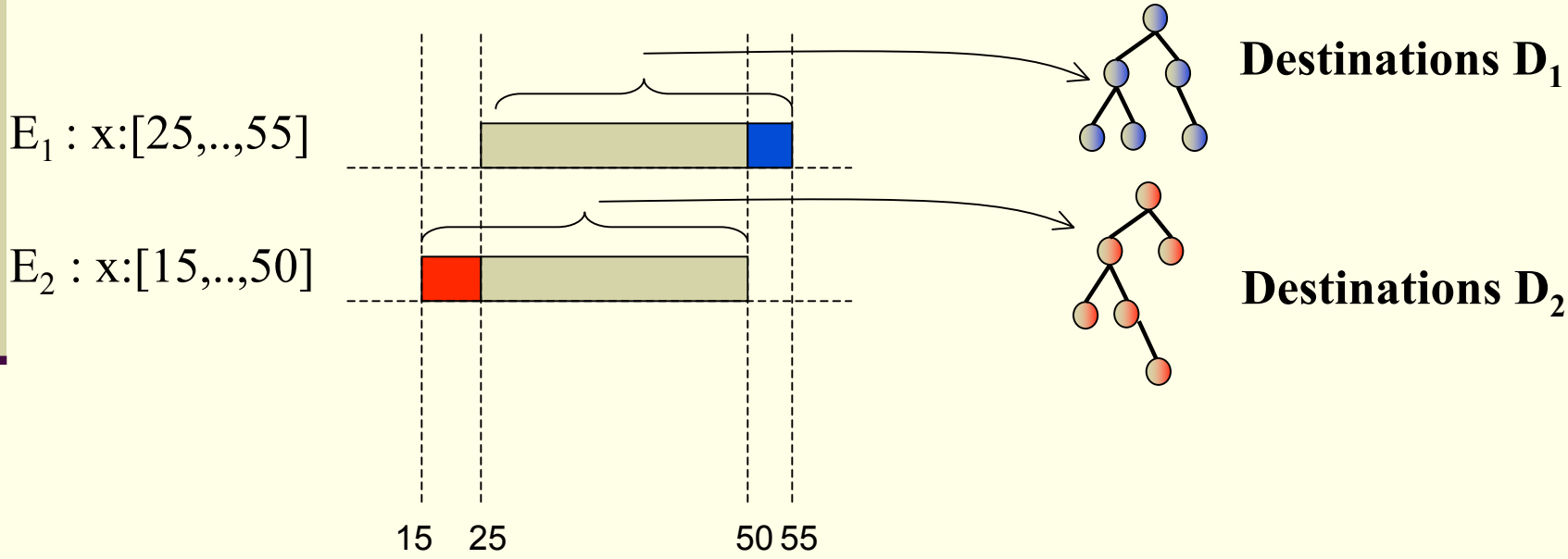
- Containment hierarchies might cause high data redundancy
  - High message rate for non-overlapping part
  - Small message rate for overlapping part
- Partial overlapping profiles may increase cost
  - Assign similar profiles to different channels
    - Forward matching messages to more than one channel
- Use cost-based model for channelization

Cost-based containment relations

- Place profiles in the same hierarchy (channel) *if* it improves bandwidth consumption
- If P_j covers P_i, compare cost
  - P_i and P_j in same channel
  - P_i on different channel
  - Apply lowest-cost scenario
- Cost estimation
  - Statistics on message rate
  - Approximate number of edges
    - Calculate edges for the Steiner tree connecting brokers

Hierarchy Merging

- Merging hierarchies with *partial overlap* reduces cost
  - Use a cost-based model
  - Send non overlapping part through “noise” channels



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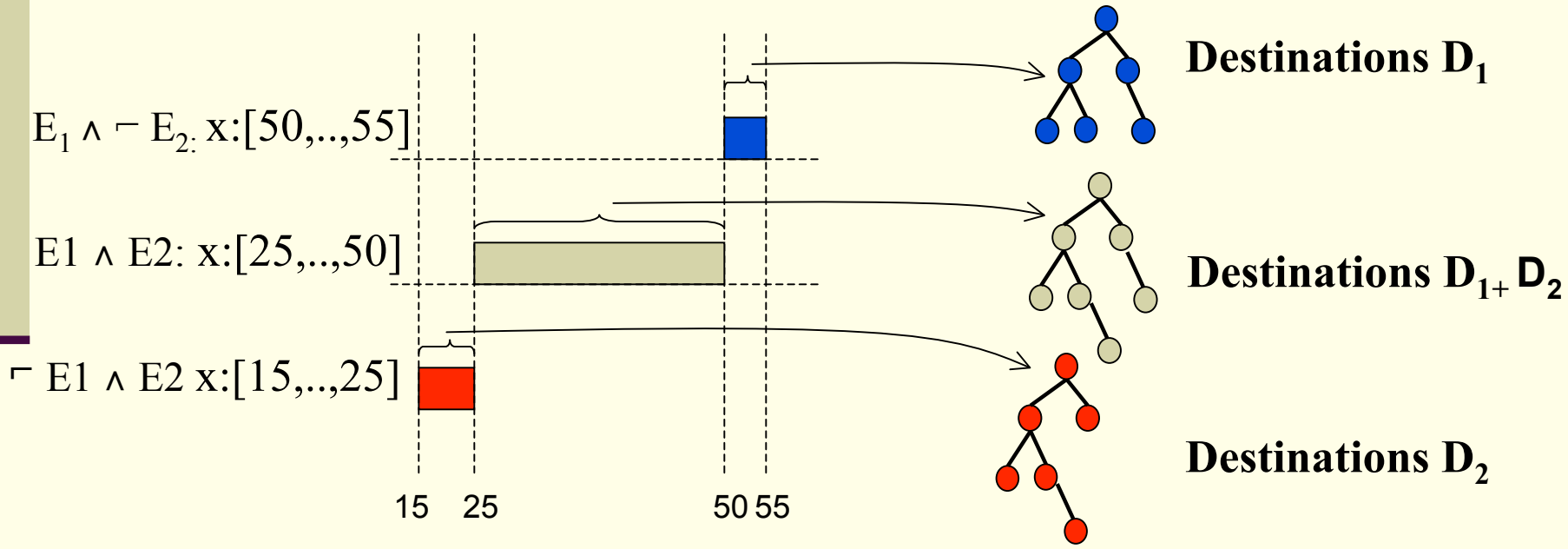
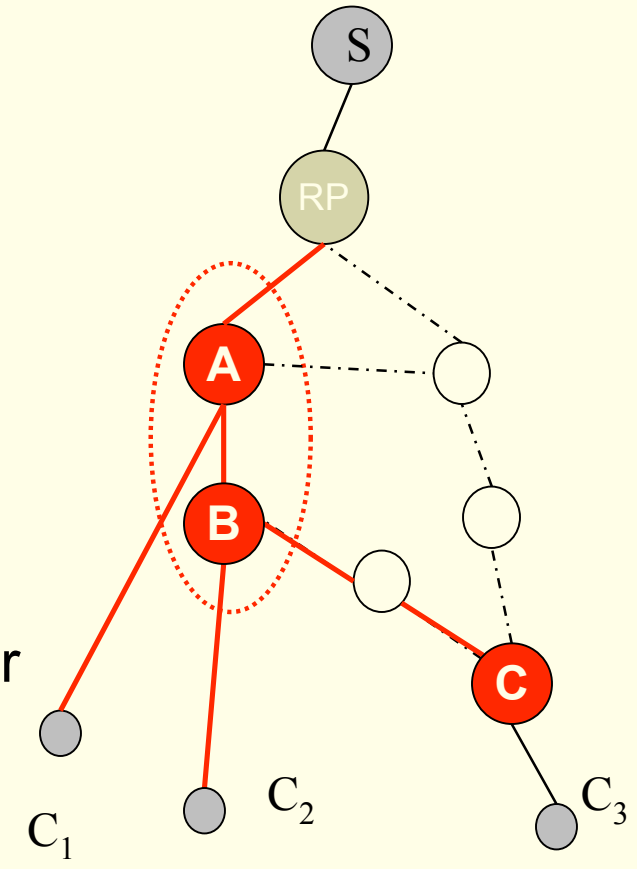


Incremental tree construction

- Base low cost heuristic
  - Request channel's gateway broker from RP
  - Find min-cost path to all destinations in the channel
  - Connect to closest one
  - Incremental Steiner tree
- Delay-bounded trees
  - Find min-cost path to one broker in the tree that covers delay bound.

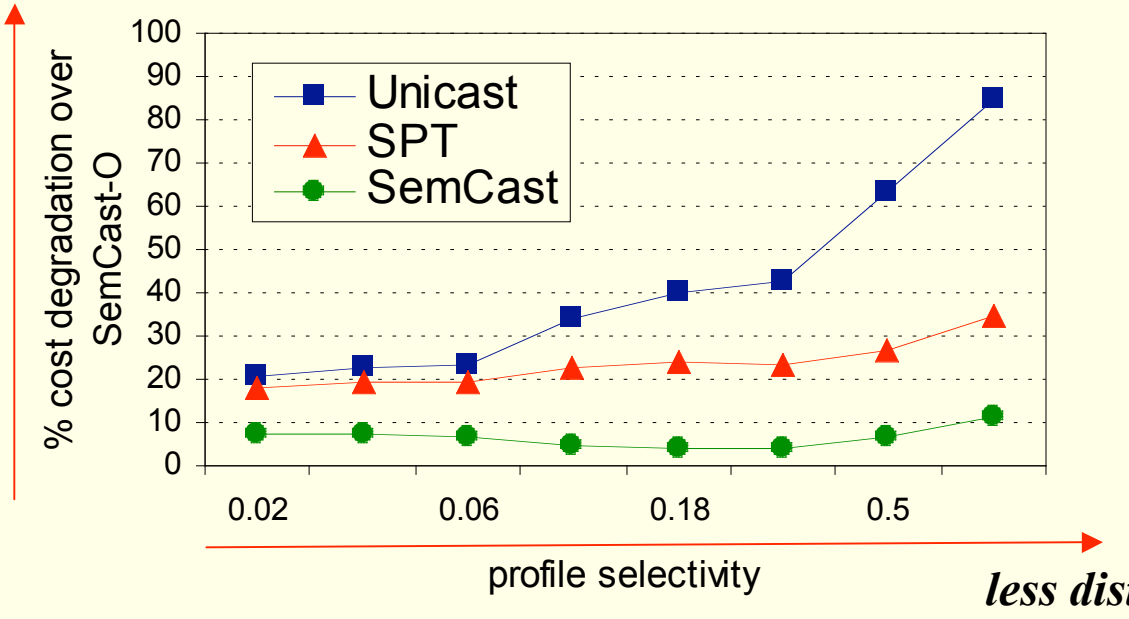


Experimental study

- Metrics
  - Processing cost
  - Bandwidth efficiency
- Approaches
  - *Unicast* approach
  - *SPT*: Shortest Path Tree approach
    - Distributed pub-sub system [Carzaniga *et al.*, 2001]
  - *SemCast:* Distributed content-based channelization
    - *SemCast-O*: Centralized Steiner tree construction
- Network environment
  - Graphs generated by GT-ITM

Bandwidth efficiency- Disjoint profiles

higher bandwidth consumption



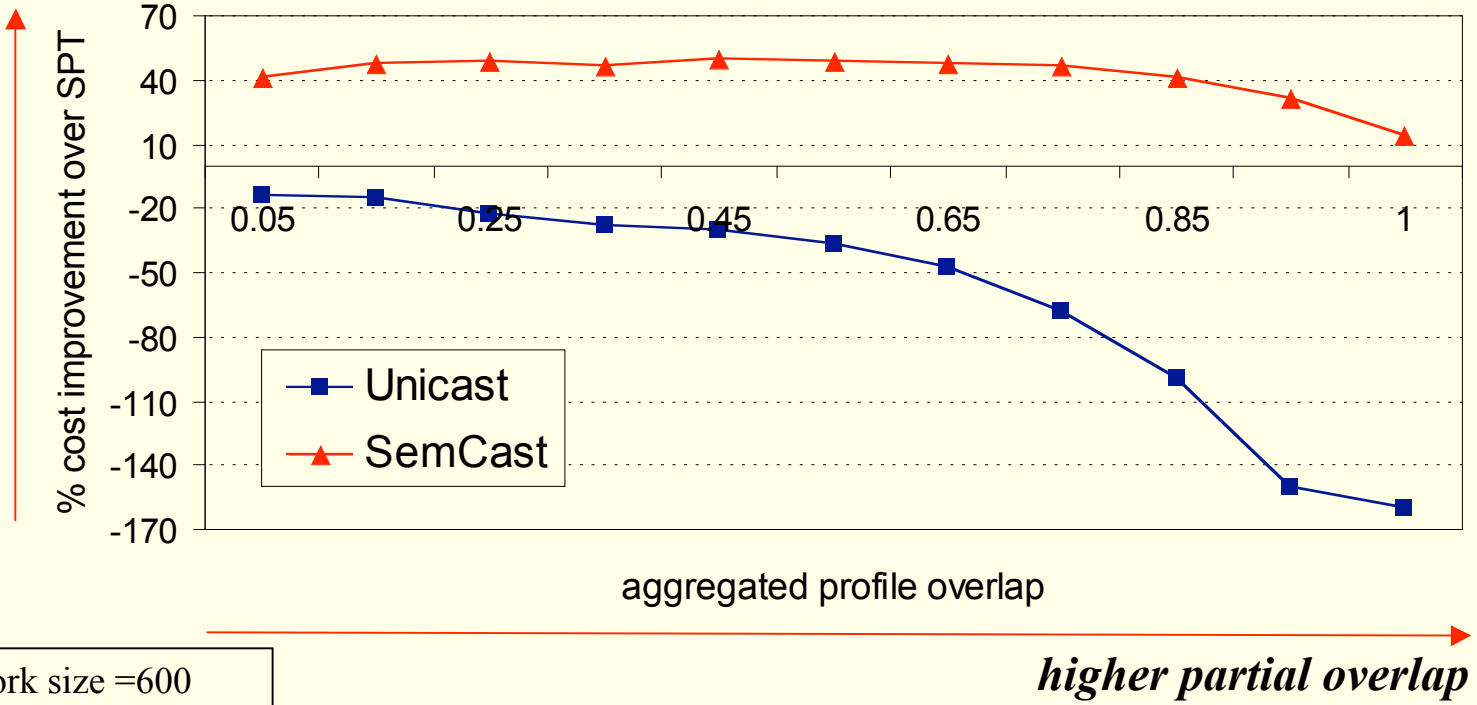
less distinct profiles

Network size = 600 nodes
Profiles= 7000

- *SemCast's trees are close to Steiner trees*
- *SemCast performs better than SPT, Unicast with no overlapping profiles*

Bandwidth efficiency- Overlapping profiles

higher bandwidth improvement



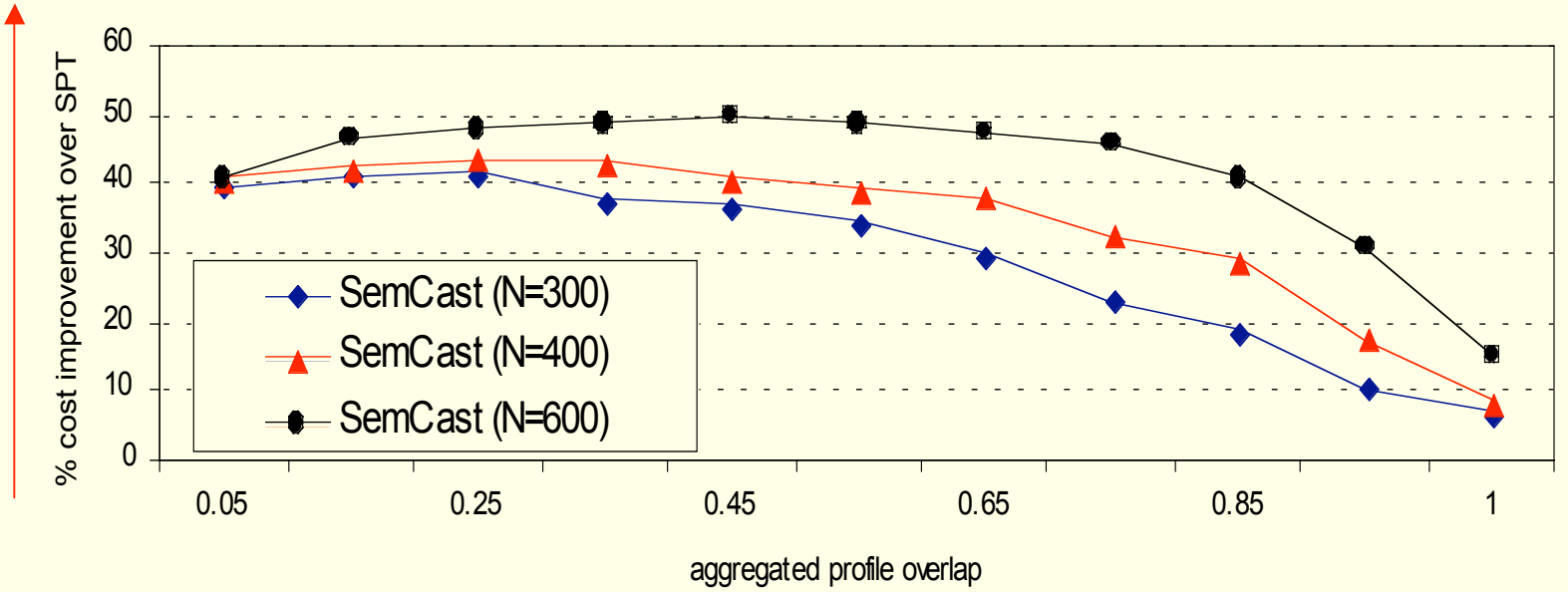
higher partial overlap

Network size =600
Profiles =7000
Profile selectivity =2%

- *SemCast performs better than SPT with overlapping profiles*

Scalability

higher bandwidth improvement



higher partial overlap

N = Network size
Profiles =5 × N
Selectivity factor =2

- *SemCast's improvement increases with the network size*

Related Work

- Publish-Subscribe Systems
  - Distributed approaches: Content- based Routing
    - Gryphon [Opyrchal *et al.*, 2000]
    - SIENA [Carzaniga *et al.*, 2001]
    - ONYX [Diao *et al*, 2004]
  - Centralized approaches: XML Filtering
    - XFilter [Altinel *et al.*, 2000] , YFilter [Diao *et al.*, 2002]
    - XTrie [Chan *et al*., 2002]
- Application-Level Multicast
    - SplitStream [Castro *et al*., 2003]
    - 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
  - More expressive profiles
    - Statefull subscriptions
  - Wireless environment