Probabilistic Multicast

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Context

- **Reliable multicast**
  - Ensure that a precise subset of processes/nodes in a group delivers a message (ideally none of the other processes receives the message)
- **In an environment characterized by**
  - Large number of processes
    - Not every process can/will know every other
    - No process is interested in every message
    - No global and static classification of interests feasible
  - No global network-level multicast protocol

Approaches

- **Deterministic schemes**
  - With **strong** reliability guarantees [HT93] do not scale sufficiently (e.g., $O(n^2)$ msgs)
- **Probabilistic, *gossip-based*, schemes**
  - Every process periodically (every *P* ms) „talks” to a subset of (*Fanout*, *F*) processes about some messages
  - Good trade-off between reliability and scalability
    - Very resilient to arbitrary crash failures
    - Usally the „time“ necessary to reach all processes in a group is *O(log n), n* being the size of the group
  - Several *broadcast* algorithms, e.g., *pbcast* [Birman et al.’99], *lpbcast* [Eugster et al.’01]

Simple Solutions?

- **„Plain broadcast“: send everything to everybody**
  - Non-interested processes receive too; ↓ network resources
  - Everybody has to know everybody; ↓ memory resources
- **„True multicast“: send only to interested processes**
  - Have to know all, *and* their interests; ↓ ↓ memory resources
- **„Subgroup broadcast“: divide process group according to interests**
  - Send data to those groups of processes manifesting corresponding interests
  - Need to know interests to create groups, groups might change as soon as interests change

Probabilistic Multicast

- **Specification**
  - **Validity**: If a correct process multicasts a message *m*, then some correct process in *Dest(m)* eventually delivers *m*
  - **Integrity**: For any message *m*, every correct process *p* delivers *m* at most once*,* and only if *m* was previously multicast by *Sender(m)*
  - **Probabilistic Agreement**: If a correct process in *Dest(m)* delivers message *m*, then every correct process in *Dest(m)* eventually delivers *m* with known, high, probability ***?.***

  Note: *Dest(m)* given implicitly by „interests“ of processes
- **Implicit requirements**
  - Scalability w.r.t. message & time complexity, membership knowledge

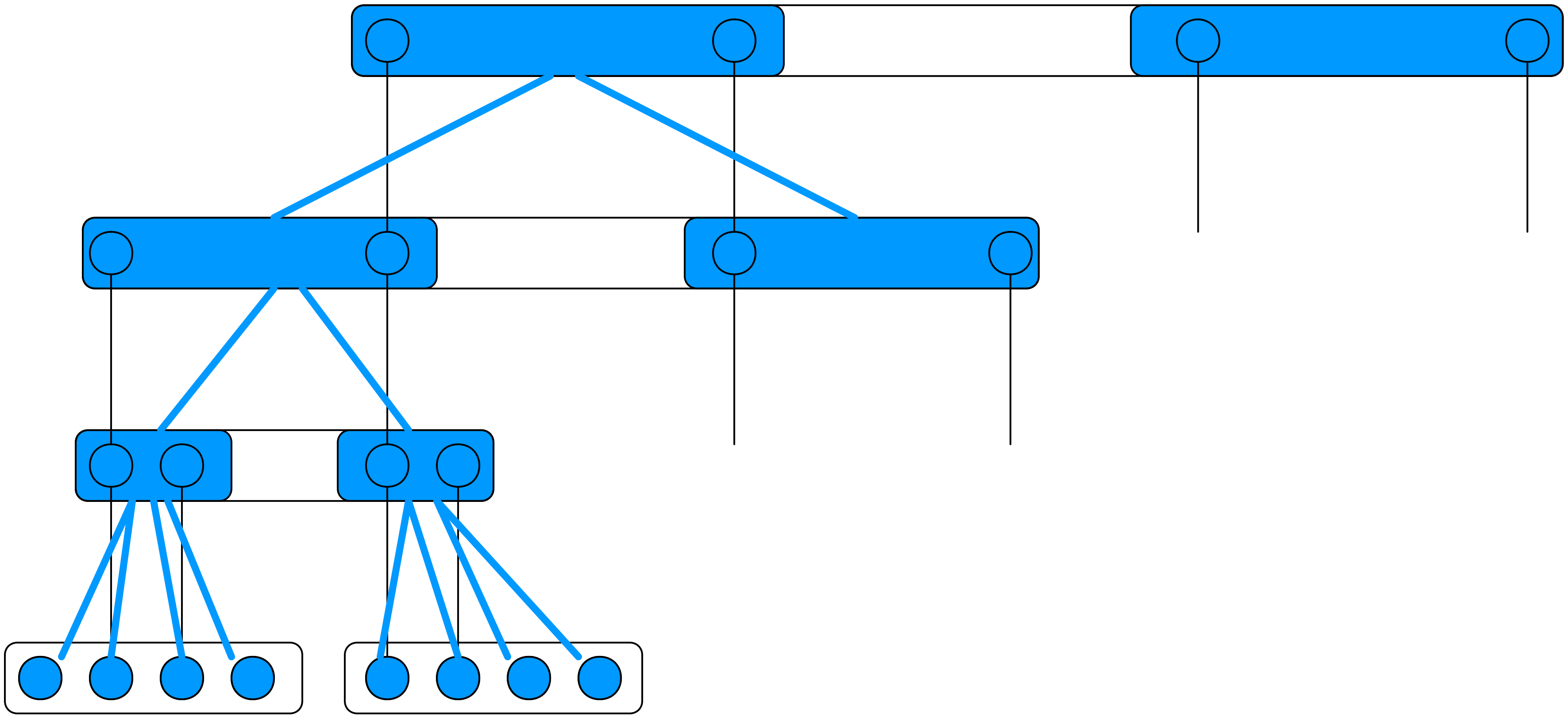
Implementing *pmcast* : An Intuition

- **Spanning tree**
  - Little to no redundant sends
  - No process has to know all the other processes in the tree
- **Gossips**
  - Good probability of success with unreliable links
    - The children of a node gossip among them, a.s.o.
    - With respect to a particular message only those interested/representing interested children
- **Fault-tolerance**
  - Every „node“ in the tree is represented by *r* >1 processes
  - A process which appears as „member“ of a given node also appears in the child nodes

Building the „Tree“

- **Bottom-up**
  - Processes have precise knowledge about „close” neighbors
  - Knowledge decreases with the „distance”
  - Processes are orchestrated in subgroups, according to distance
  - *r delegates* are chosen for each subgroup, manifest interests of all represented processes
  - Each process knows the *r* delegates of each (known) subgroup
- **Recursively**
  - Put several subgroups of level 1 together: form a group of level 2
  - Elect *r* delegates for every such supergroup
  - etc.

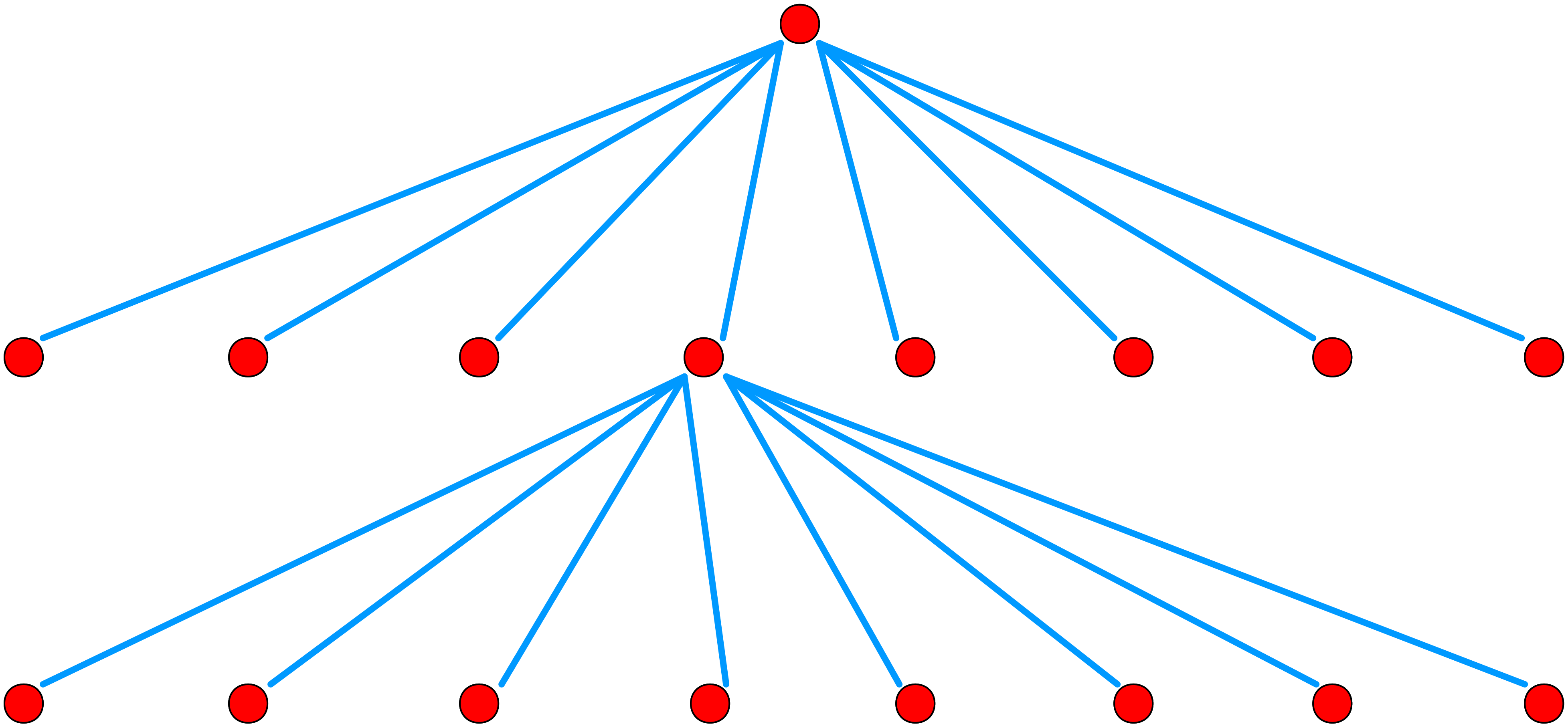
Illustration



pmcast Algorithm Overview

- **Membership „tree” maintenance**
  - Every process maintains table for its subgroup of each level
  - Periodically processes exchange membership info with others
  - Lowest level processes are „monitored“
- **Level-wise gossiping**
  - Number of nec. gossip rounds is computed through approx.
  - Gossips merged with membership info
- **Every process has a buffer for each level**
  - Periodically, every message of every buffer
    - Forwarded to the *interested* processes within a random subset (maximum number of rounds)
    - Update rounds and possibly level

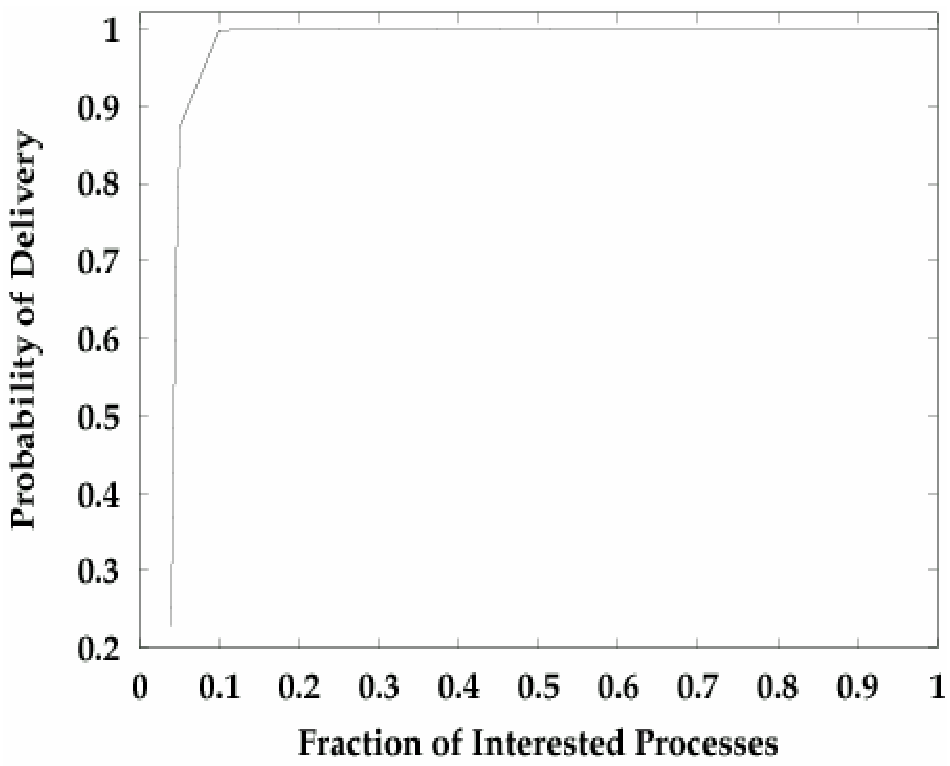
Illustration

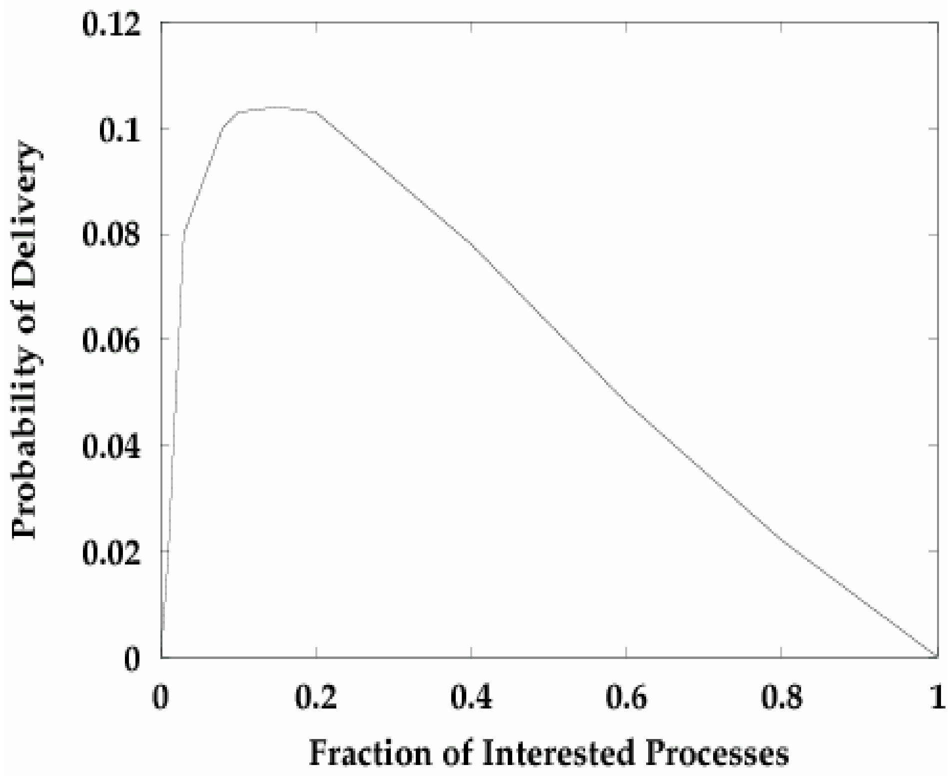


Performance

- **Number of processes that a given process knows**
  - *O(log n)*
- **„Worst“ case: broadcast**
  - Same „time“ to complete as when every process knows every other process: *O(log n)*
  - Same message complexity: *O(n log n)*
- **Probability *?* of delivery for interested processes**
  - Comes very close to 1
- **Probability of receiving for non-interested processes**
  - Very small for cases where „enough“ processes are interested in a given message

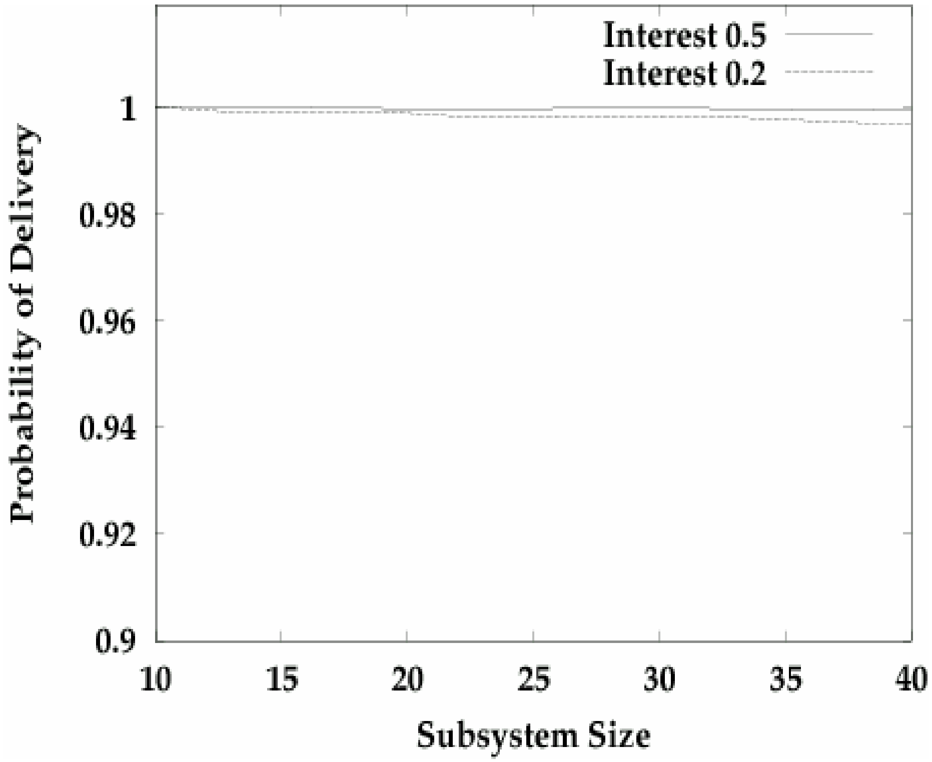
Delivery and Unvoluntary Delivery



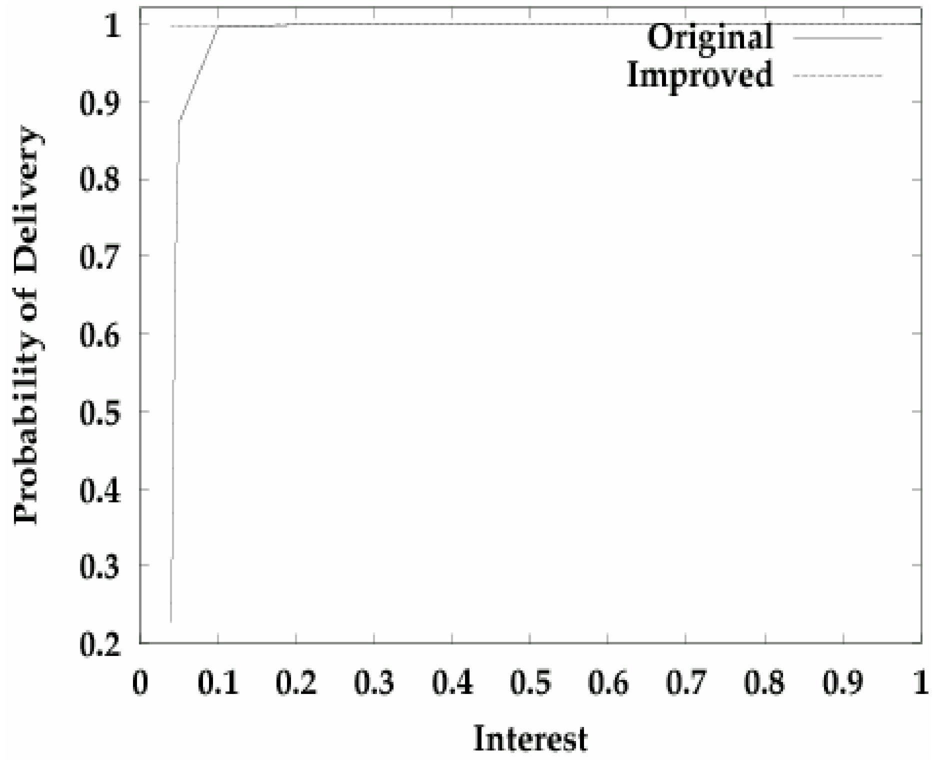


10000 processes, 3 levels, redundancy and fanout of 3

Scalability and Tuning



3 levels, redundancy 4, fanout 3



?10000 processes, 3 levels, redundancy and fanout of 3

Conclusions and Ongoing Efforts

- **„Natural“ tradeoffs**
  - Increasing the number of levels
    - Reduces the membership knowledge each process has
    - Increases the average filtering load, etc.
  - Approximations for the number of rounds at each level
    - Small vs large fractions of interested processes
- **Root processes**
  - Require more computing power
    - Use approximate matching to reduce filtering load
  - Require more memory
    - Hash functions to compact space for „interests“

Questions