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Group Communication

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Outline

Modes of communication

- unicast
  - $1 \leftrightarrow 1$
  - Point-to-point
- anycast
  - $1 \rightarrow$ nearest 1 of several identical nodes
  - Introduced with IPv6; used with BGP
- netcast
  - $1 \rightarrow$ many, 1 at a time
- multicast
  - $1 \rightarrow$ many
  - group communication
- broadcast
  - $1 \rightarrow$ all

Groups

- Groups are dynamic
  - Created and destroyed
  - Processes can join or leave
    - May belong to 0 or more groups
- Send message to one entity
  - Deliver to entire group

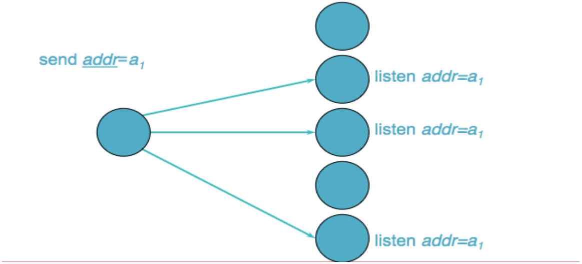
Deal with collection of processes as one abstraction

Design Issues

- Closed vs. Open
  - Closed: only group members can sent messages
- Peer vs. Hierarchical
  - Peer: each member communicates with group
  - Hierarchical: go through dedicated coordinator(s)
  - Diffusion: send to other servers & clients
- Managing membership & group creation/deletion
  - Distributed vs. centralized
- Leaving & joining must be synchronous
- Fault tolerance
  - Reliable message delivery? What about missing members?

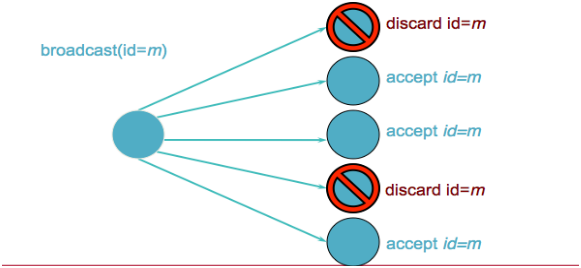
Hardware multicast

- Hardware support for multicast
  - Group members listen on network address



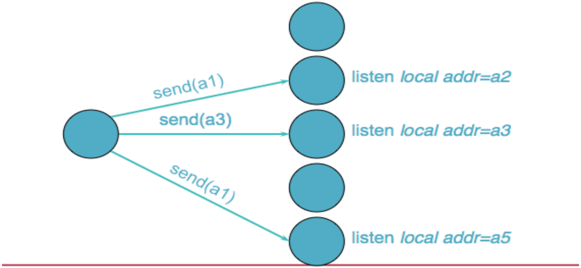
Hardware broadcast

- Hardware support for broadcast
  - Software filters multicast address • May be auxiliary address



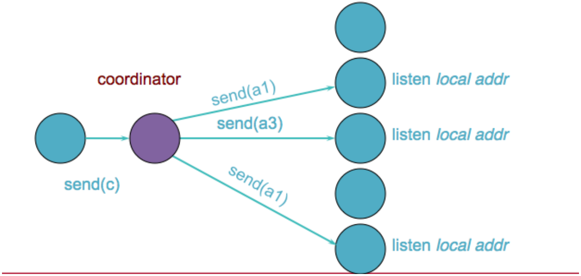
Software: netcast

- Multiple unicasts (netcast)
  - Sender knows group members



Software: hierarchical

- Multiple unicasts via group coordinator
  - coordinator knows group members



Atomic multicast

- Atomicity
  - Message sent to a group arrives at all group members
    - If it fails to arrive at any member, no member will process it.
- Problems

  Unreliable network
  - Each message should be acknowledged
  - Acknowledgements can be lost

  Message sender might die

Achieving atomicity

Retry through network failures & system downtime

- Send message to all group members
  - Each receiver acknowledges message
  - Saves message and acknowledgement in log
  - Does not pass message to application
- Sender waits for all acknowledgements
  - Retransmits message to non-responding members
    - Again and again... until responses from all are received
- Sender sends "go" message to all members
  - Each recipient delivers message to application
  - Sends reply to server

Achieving atomicity

All members will eventually get the message

- Phase 1:
  - Make sure that everyone gets the message
- Phase 2:
  - Once everyone has confirmed receipt, let the application see it

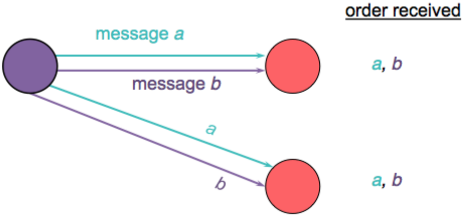
Reliable multicast

- All nonfaulty group members will receive the message
  - Assume sender & recipients will remain alive
  - Network may have glitches
    - Retransmit undelivered messages
- Acknowledgements
  - Send message to each group member
  - Wait for acknowledgement from each group member
  - Retransmit to non-responding members
  - Subject to feedback implosion
- Negative acknowledgements
  - Use a sequence # on each message
  - Receiver requests retransmission of a missed message
  - More efficient but requires sender to buffer messages indefinitely

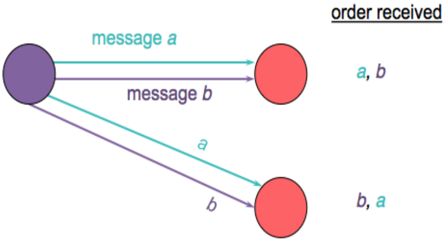
Unreliable multicast

- Basic multicast
- Hope it gets there

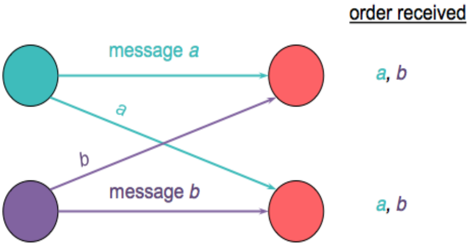
Good ordering



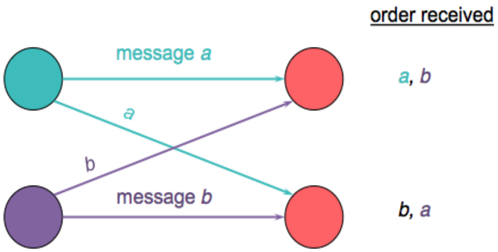
Bad ordering



Good ordering



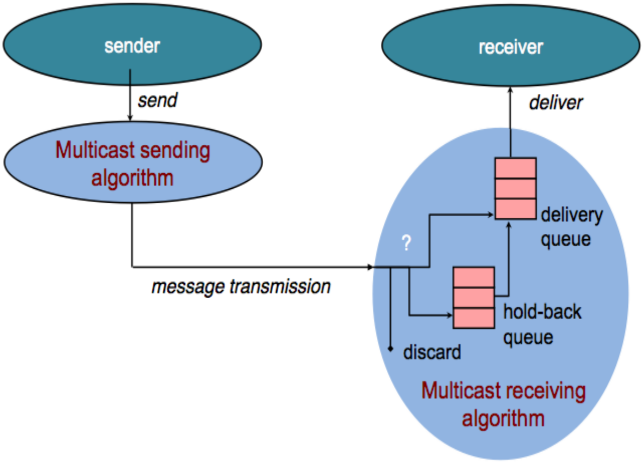
Bad ordering



Sending versus Delivering

- Multicast receiver algorithm decides when to deliver a message to the process.
- A received message may be:
  - Delivered immediately
  - Network may have glitches
    (put on a delivery queue that the process reads)
  - Placed on a hold-back queue
    (because we need to wait for an earlier message)
  - Rejected/discarded
    (duplicate or earlier message that we no longer want)

Sending, delivering, holding back



Global time ordering

- All messages arrive in exact order sent
- Assumes two events never happen at the exact same time!
- Difficult (impossible) to achieve

Total ordering

- Consistent ordering everywhere
- All messages arrive at all group members in the same order
  - If a process sends m before m' then any other process that delivers m' will have delivered m.
  - If a process delivers m' before m'' then every other process will have delivered m' before m''.
- Implementation:
  - Attach unique totally sequenced message ID
  - Receiver delivers a message to the application only if it has received all messages with a smaller ID

Total ordering

- Partial ordering
  - Messages sequenced by Lamport or Vector timestamps

- If $multicast(G, m) \rightarrow multicast(G, m')$
  then every process that delivers m' will have delivered m

- Implementation:
  - Deliver messages in timestamp order per-source.

Sync ordering

- Messages can arrive in any order
- Special message type
  - Synchronization primitive
  - Ensure all pending messages are delivered before any additional (post-sync) messages are accepted

FIFO ordering

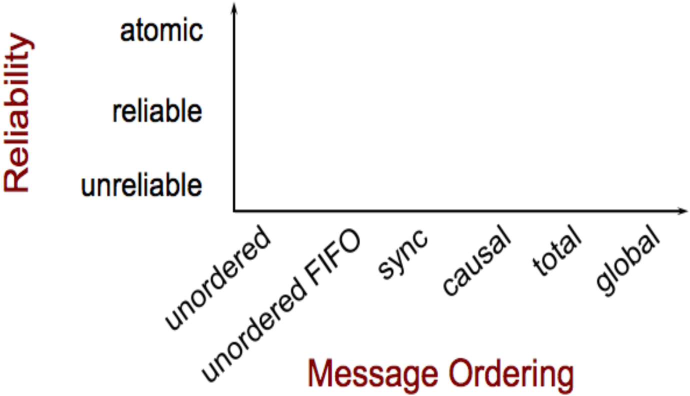
- Messages can be delivered in different order to different members
- Message m must be delivered before message m' iff m was sent before m' from the same host

If a process issues a multicast of m followed by m', then every process that delivers m' will have already delivered m.

Unordered multicast

- Messages can be delivered in different order to different members
- Order per-source does not matter.

Multicasting considerations



IP multicasting routing

- Deliver messages to a subset of nodes
- How do we identify the recipients?
  - Enumerate them in the header?
    - What if we don't know?
    - What if we have thousands of recipients?
- Use a special address to identify a group of receivers
  - A copy of the packet is delivered to all receivers associated with that group
  - Host group=set of machines listening to a particular multicast address

IP multicasting

- Can span multiple physical networks
- Dynamic membership
  - Machine can join or leave at any time
- No restriction on number of hosts in a group
- Machine does not need to be a member to send messages
- Efficient: Packets are replicated only when necessary

IGMP

- Internet Group Management Protocol (IGMP)
  - Operates between a host and its attached router
  - Goal: allow a router to determine to which of its networks to forward IP multicast traffic
  - IP protocol
- Three message types
  - Membership_query
    - Sent by a router to all hosts on an interface to determine the set of all multicast groups that have been joined by the hosts on that interface
  - Membership_report
    - Host response to a query or an initial join or a group
  - Leave_group
    - Host indicates that it is no longer interested
    - Optional:router infers this if the host does not respond to a query

Multicast Forwarding

- IGMP allows a host to subscribe to a multicast stream
- What about the source?
  - There is no protocol for the source!
  - It just sends to a class D address
  - Routers have to do the work

Multicast Forwarding

- IGMP: Internet Group Management Protocol
  - Designed for routers to talk with hosts on directly connected networks
- PIM: Protocol Independent Multicast
  - Multicast Routing Protocol for delivering packets across routers
  - Topology discovery is handled by other protocols

Flooding: Dense Mode Multicast

- Relay multicast packet to all connected routers
  - Use a spanning tree and use reverse path forwarding (RPF) to avoid loops
  - Feedback & cut-off if there are no interested receivers on a link
    - A router sends a prune message.
    - Periodically, routers send messages to refresh the prune state
  - Flooding is initiated by the sender's router
- Reverse path forwarding (RPF): avoid routing loops
  - Packet is duplicated & forwarded ONLY IF it was received via the link that is the shortest path to the sender
  - Shortest path is found by checking the forwarding table to the source address

Flooding: Dense Mode Multicast

- Advantage:
  - Simple
  - Good if the packet is desired in most locations
- Disadvantage:
  - wasteful on the network, wasteful extra state & packet duplication on routers

Sparse Mode Multicast

- Initiated by the routers at each receiver
- Each router needs to ask for a multicast feed with a PIM Join message
  - Initiated by a router at the destination that gets an IGMP join
  - Spanning tree constructed
    - Join messages propagate to a defined rendezvous point
    - Sender transmits only to the rendezvous point
  - A Prune message stops a feed
- Advantage:
  - Packets go only where needed
  - Creates extra state in routers only where needed