CIS 505: Software Systems
Lecture Note on Multicasting

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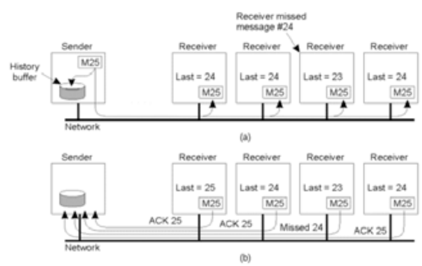
Reliable multicast

- Multicast – group communication
- States or replicas should be a deterministic function of their initial states and the sequence of operations applied to them.
- Message should be delivered to all members in a process group.
- Latency and scalability?

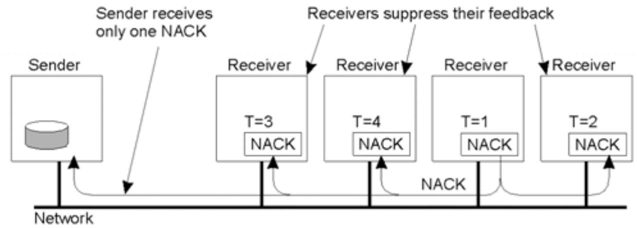
Basic Reliable-Multicasting Schemes



- A simple solution to reliable multicasting when all receivers are known and are assumed not to fail

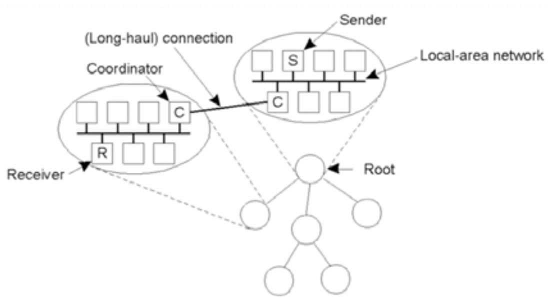
a) Message transmission
b) Reporting feedback

Nonhierarchical Feedback Control



- Several receivers have scheduled a request for retransmission, but the first retransmission request leads to the suppression of others.

Hierarchical Feedback Control

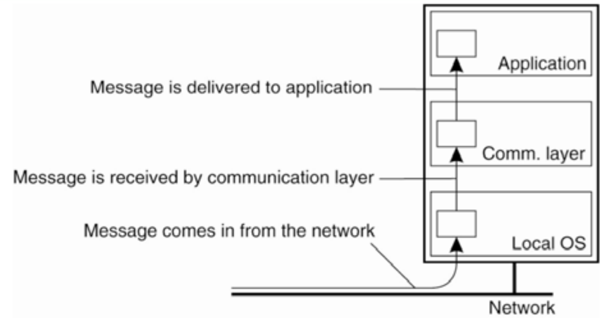


- The essence of hierarchical reliable multicasting.

a) Each local coordinator forwards the message to its children.

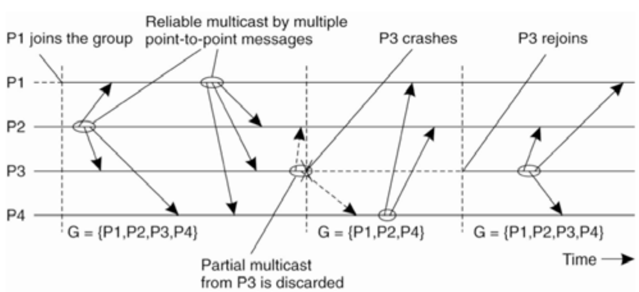
b) A local coordinator handles retransmission requests.

Atomic Multicast (Layered Architecture)



- Figure 8-12. The logical organization of a distributed system to distinguish between message receipt and message delivery.

Virtual Synchrony



- Figure 8-13. The principle of virtual synchronous multicast.

Ordered multicast

- Unordered multicasts
- FIFO ordering
  - Sender ordered
- Causal ordering
  - Happens-before
- Total ordering

- Assume no overlapping groups

Message Ordering (1)

Process P1	Process P2	Process P3
sends m1	receives m1	receives m2
sends m2	receives m2	receives m1

- Three communicating processes in the same group. The ordering of events per process is shown along the vertical axis.

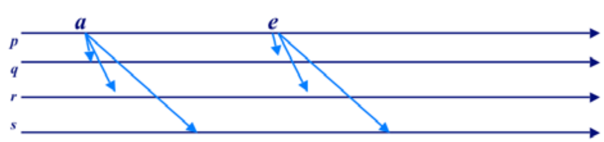
Message Ordering (2)

Process P1	Process P2	Process P3	Process P4
sends m1	receives m1	receives m3	sends m3
sends m2	receives m3	receives m1	sends m4
	receives m2	receives m2	
	receives m4	receives m4	

- Four processes in the same group with two different senders, and a possible delivery order of messages under FIFO-ordered multicasting

FIFO-ordered Multicast

- *Fifo* or *sender ordered* multicast:
  Messages are delivered in the order they were sent (by any single sender)



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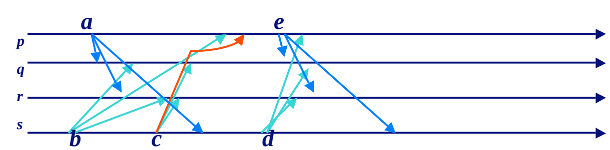

delivery of c to p is delayed until after b is delivered

Implementing FIFO order

- Basic reliable multicast algorithm has this property
  - Without failures all we need is to run it on FIFO channels (like TCP)
  - With failures need to be careful about the order in which things are done but problem is simple

Causally-ordered multicast

- *Causal* or *happens-before* ordering:
  If send(a) → send(b) then deliver(a) occurs before deliver(b) at common destinations

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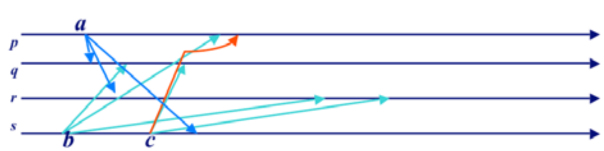

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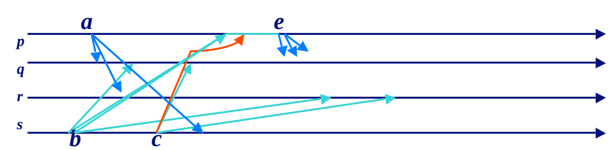

delivery of c to p is delayed until after b is delivered

e is sent (causally) after b

Causally-ordered multicast

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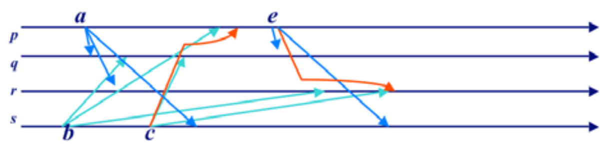


delivery of c to p is delayed until after b is delivered

delivery of e to r is delayed until after b&c are delivered

Implementing causal order

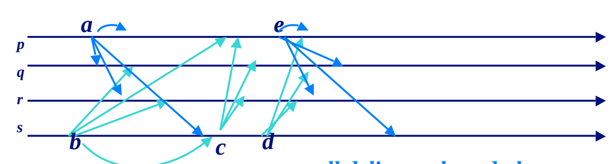
- Start with a FIFO multicast
- Frank Schmuck showed that we can always strengthen this into a causal multicast by adding vector time (no additional messages needed)
  - If group membership were static this is easily done, small overhead
  - With dynamic membership, at least abstractly, we need to identify each VT index with the corresponding process.

Observations

- These two orderings are for *asynchronous:*
  - Sender doesn't get blocked and can deliver a copy to itself without "stopping" to learn a safe delivery order
  - If used this way, the multicast can seem to sit in the output buffers a long time, leading to surprising behavior
  - But this also gives the system a chance to concatenate multiple small messages into one larger one.
- Sometimes, we want a replicated object or service that advances through a series of transitions in the same order
  - Clearly will need all copies to make the same transitions
  - Leads to a need for totally ordered multicast

Totally-ordered multicast

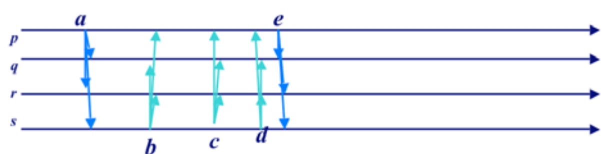
- *Total* or *locally total* multicast:
  Messages are delivered in same order to all recipients (including the sender)



all deliver a, b, c, d, then e

Totally-ordered multicast

- Can visualize as "closely synchronous"
- *Real* delivery is less synchronous, as on the previous slide



all deliver a, b, c, d, then e

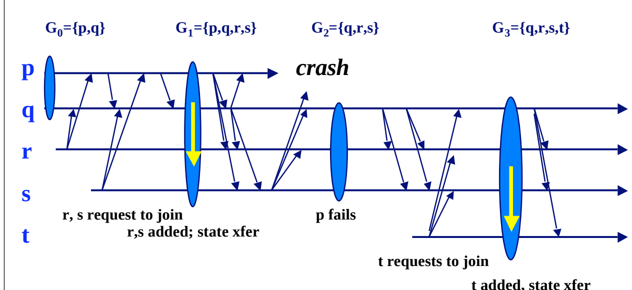
Implementing Total Order

- Many ways have been proposed
  - o Centralized sequencer
  - o Just have a token that moves around
    - Token has a sequence number
    - When you hold the token you can send the next burst of multicasts

What about membership changes?

- Virtual synchrony model synchronizes membership change with multicasts
- Idea is that:
  - o Between any pair of successive group membership views…
  - o … same set of multicasts are delivered to all members
- If you implement distributed code, this makes algorithms *much* simpler for you!

Process groups with joins, failures



Asynchrony

- Notice that FIFO-order and causally-order can be used asynchronously, while total-order always "stutters"
  - Insight is that the first two can always be delivered to the sender at the time the multicast is sent
  - Total-order delivery ordering usually isn't known until a round of message exchange has been completed
- Results in a tremendous performance difference
  - With asynchrony, we gain concurrency at the sender side, but this helps mostly if remainder of group is idle or doing a non-conflicting task
  - Too much asynchrony
    - Means things pile up in output buffers
    - If a failure occurs, much is lost
    - And we could consume a lot of sender-side buffering space