CSE 486/586 Distributed Systems

Reliable Multicast (Part 2)

Slides by Steve Ko
Computer Sciences and Engineering
University at Buffalo

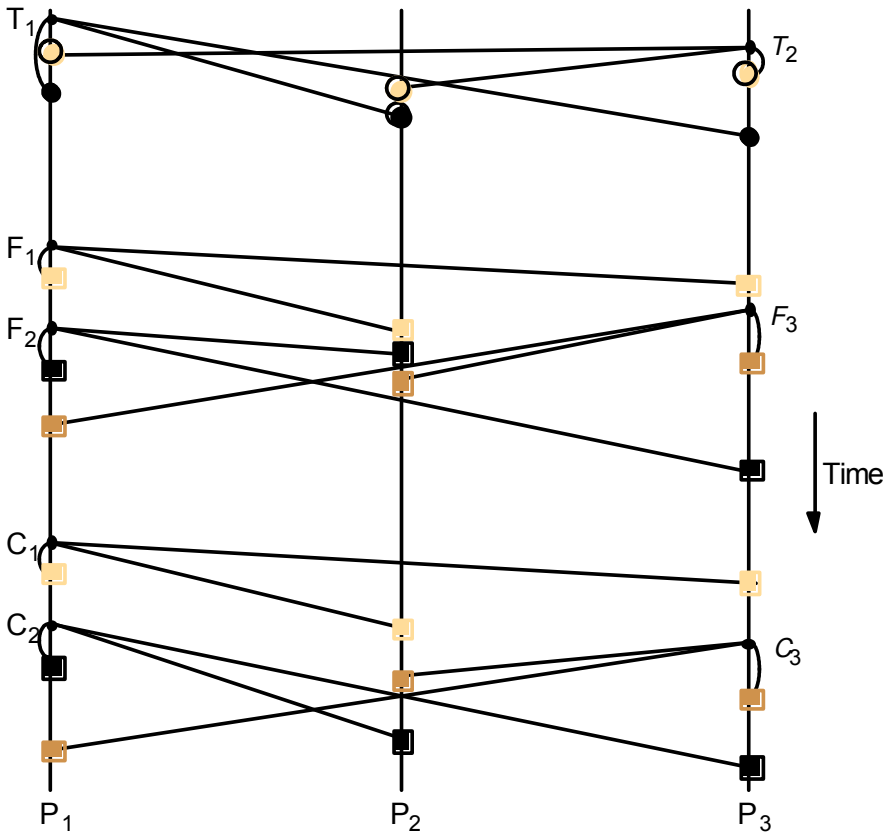
Last Time

- Multicast
  - One-to-many communication within a group of processes
- Issues to be handled
  - Processes fail
  - Messages get delayed
- B-multicast
- R-multicast
  - Integrity, Agreement, Validity
- Ordering
  - Why do we care?

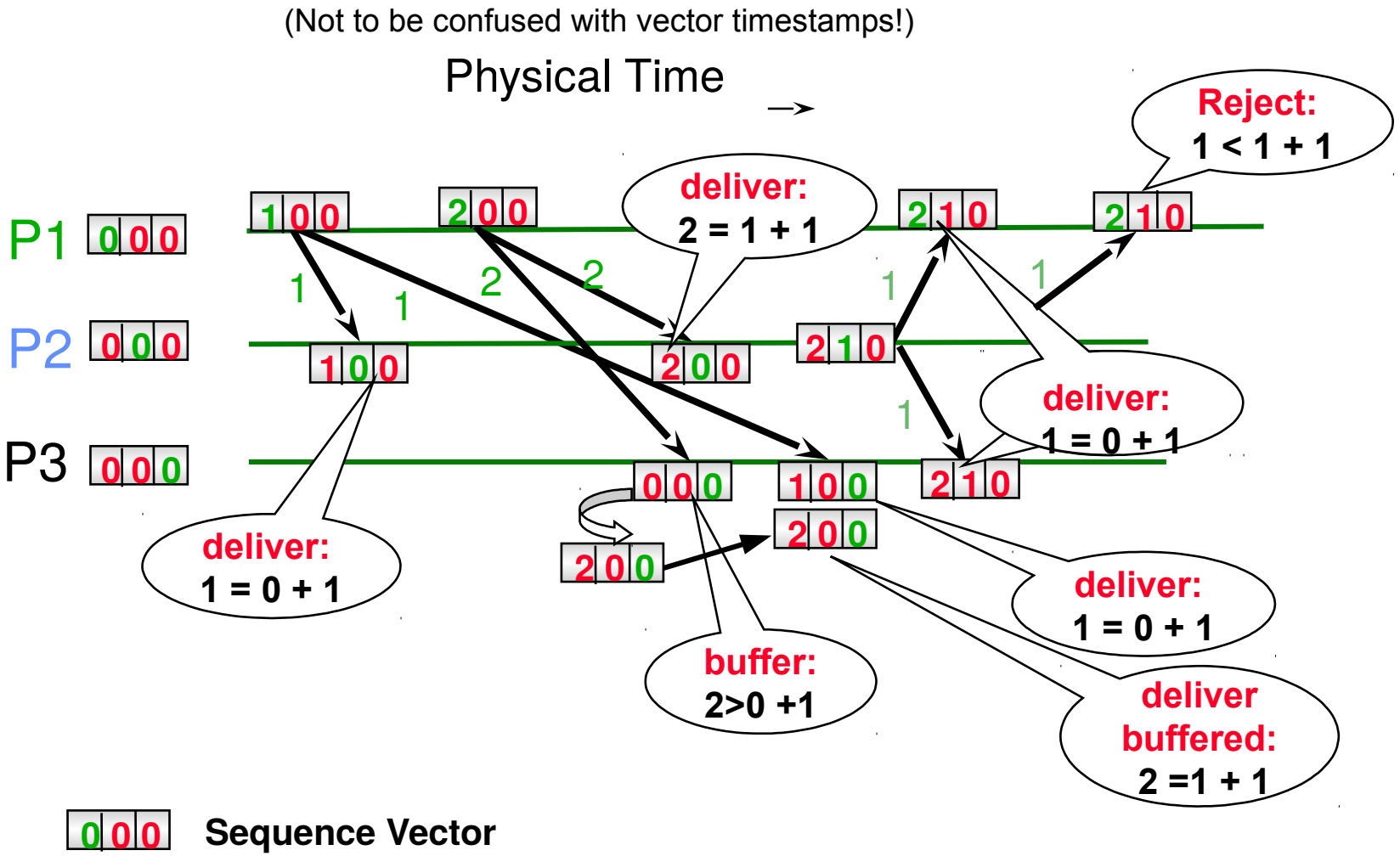
Recap: Ordering

- Totally ordered messages T_1 and T_2.
- FIFO-related messages F_1 and F_2.
- Causally related messages C_1 and C_3

- Total ordering does not imply causal ordering.
- Causal ordering implies FIFO ordering
- Causal ordering does not imply total ordering.
- Hybrid mode: causal-total ordering, FIFO-total ordering.



Example: FIFO Multicast



Totally Ordered Multicast

- Using a sequencer
  - One dedicated “sequencer” that orders all messages
  - Everyone else follows.
- ISIS system
  - Similar in result to a sequencer
  - The responsibility for sequencing is distributed to each sender

Total Ordering Using a Sequencer

1. Algorithm for group member *p*

   On initialization: $r_g := 0$

   To TO-multicast message *m* to group *g:*

   B-multicast($g \cup$ { sequencer(g) }, <*m, i*>

   On B-deliver(<*m, i*>) with *g* = group(*m*):

   Place <*m, i*> in hold-back queue

   On B-deliver(m_{order} = <"order", *i, S*>) with *g* = group(m_{order}):

   Wait until <*m, i*> in hold-back queue and $S = r_g$

   TO-deliver *m*

   $r_g = S + 1$

2. Algorithm for sequencer of *g*

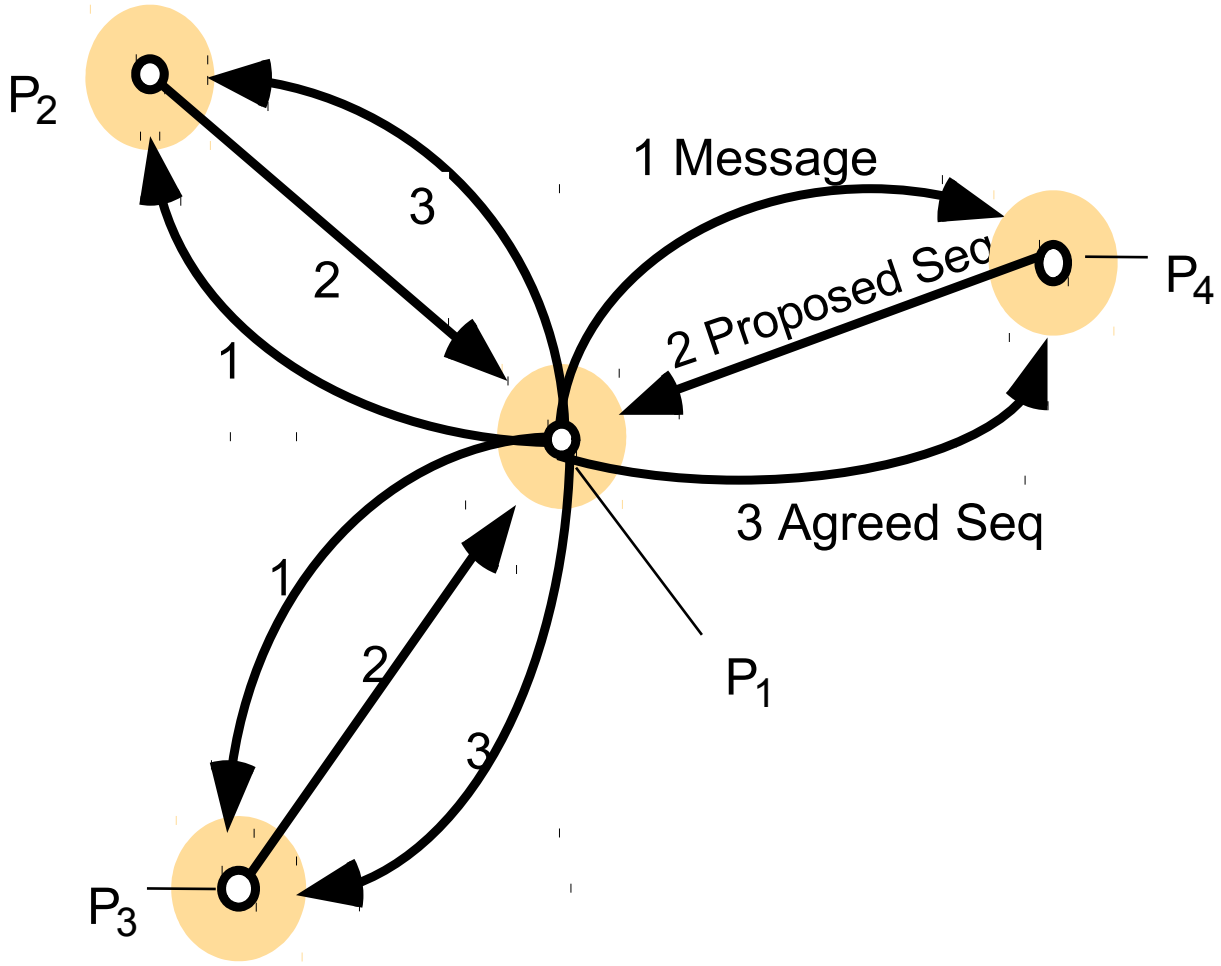
   On initialization: $s_g := 0$

   On B-deliver(<*m, i*>) with *g* = group(*m*):

   B-multicast(*g,* <"order", *I,* s_g>)

   $s_g := s_g + 1$

ISIS algorithm for total ordering



ISIS algorithm for total ordering

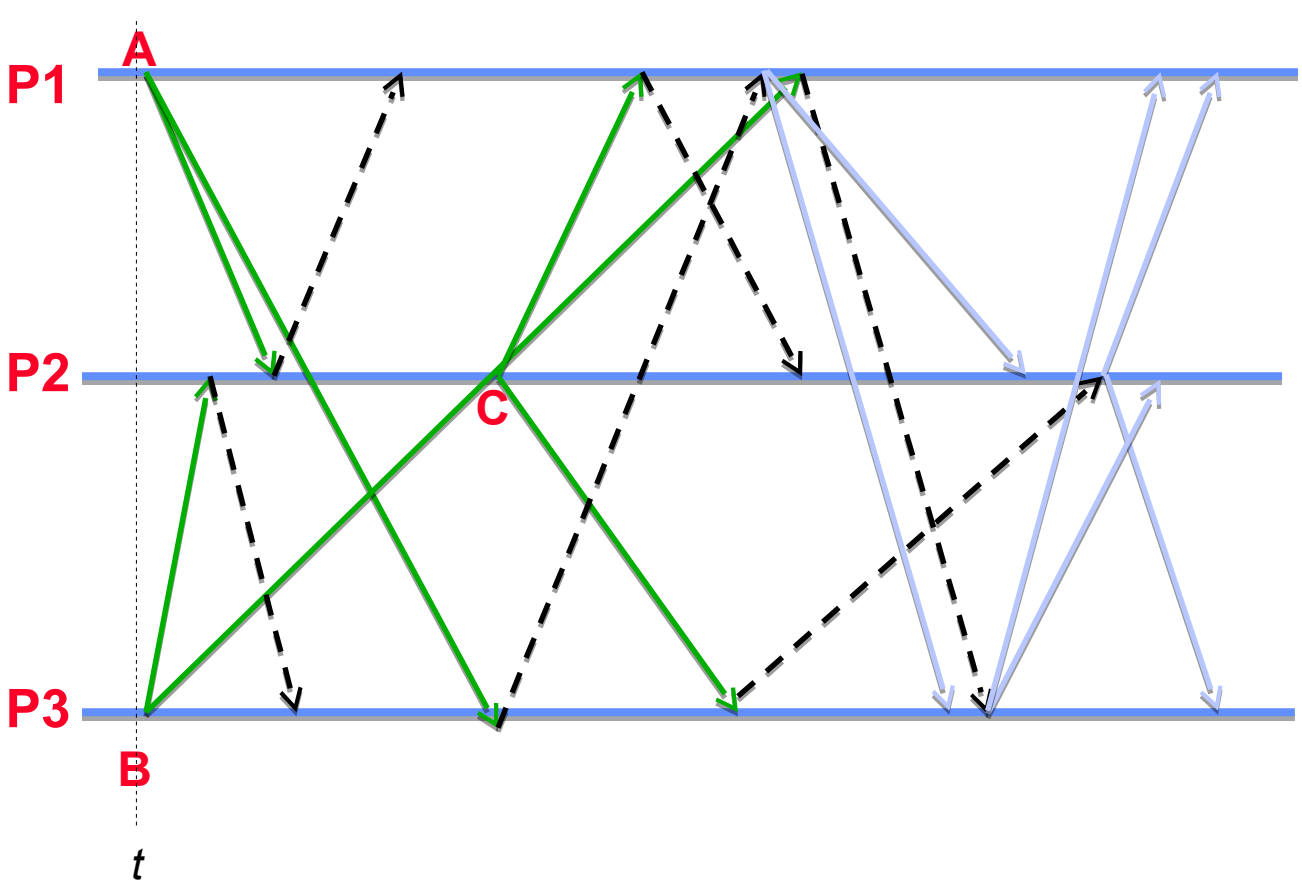
1) Sender multicasts message to everyone
2) Each process replies with its proposed priority (seq. no.)
   - Larger than all observed agreed priorities
   - Larger than any priority previously proposed by this process
3) Store messages in a priority queue
   - Ordered by priority (proposed or agreed)
   - Mark message as undeliverable
4) Sender chooses agreed priority, multicasts message
   - Agreed priority = maximum of all proposed priorities
5) Upon receiving agreed priority
   - Mark message as deliverable
   - Deliver any deliverable messages at the front of priority queue

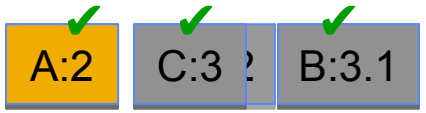
Problematic Scenario

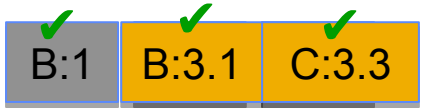
- Two processes *P1* & *P2* at their initial state.
- P1 sends m_1 & *P2* sends m_2.
- *P1* receives m_1 (its own) and proposes priority 1. *P2* does the same for m_2.
- *P2* receives m_1 (*P1*'s message) and proposes priority 2. *P1* does the same for m_2.
- *P1* picks 2 for m_1 & *P2* also picks 2 for m_2.
- Same sequence number for two different messages!
- How do you want to solve this?

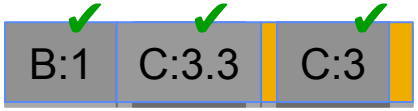
Example: ISIS algorithm [1]

Showing the process id only when necessary









Proof of Total Order

- For a message m_1, consider the first process p that delivers m_1
- Let m_1 be deliverable & at the head of the queue at p
- Let m_2 be another message that has not been delivered

  finalpriority(m_2) >=
  proposedpriority(m_2) >=
  finalpriority(m_1)

  Due to "max" operation at sender

  Since queue ordered by increasing priority

- Let p' be a process that delivers m_2 before m_1. At p':

  finalpriority(m_1) >=
  proposedpriority(m_1) >=
  finalpriority(m_2)

  Due to "max" operation at sender

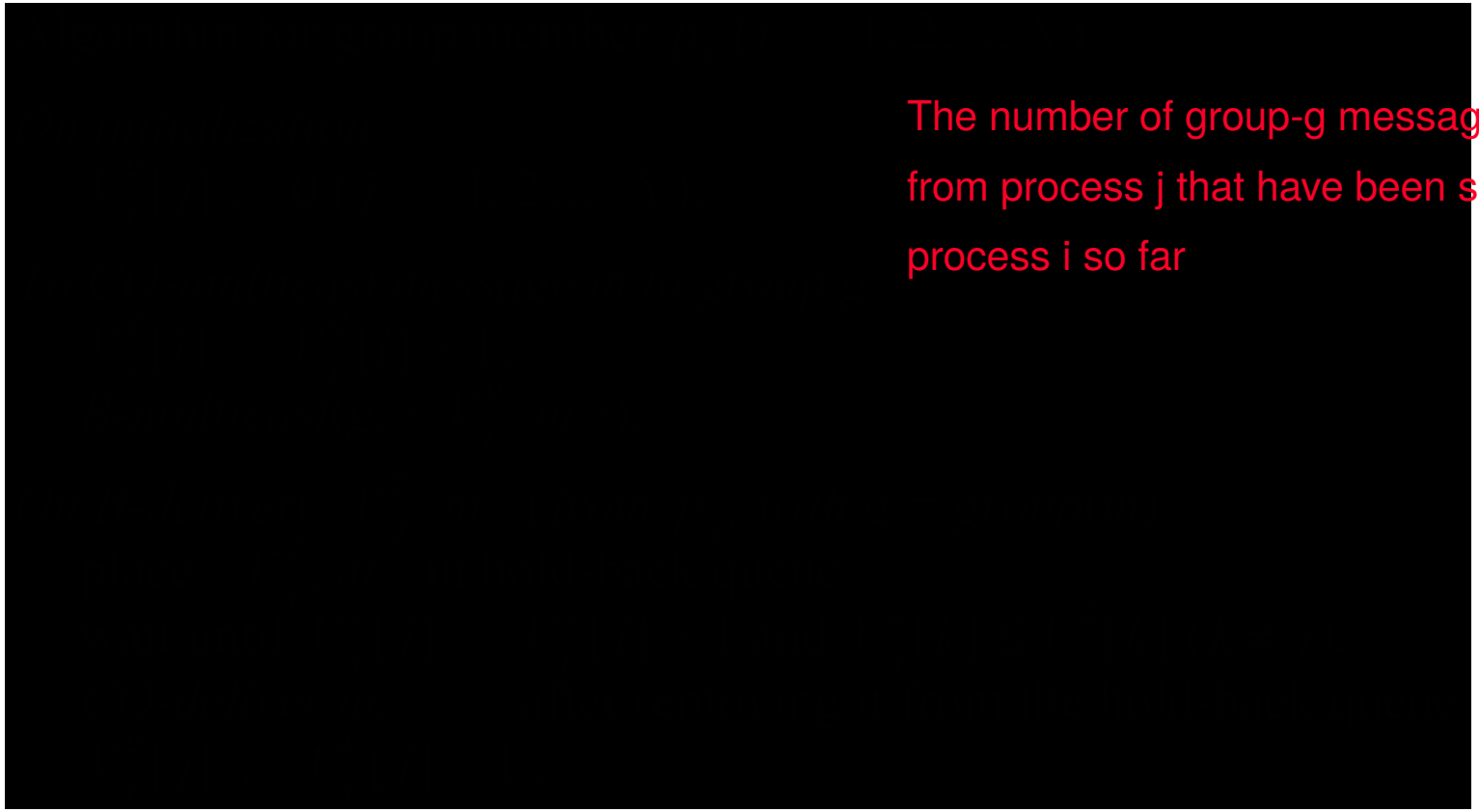
  Since queue ordered by increasing priority

- **a contradiction**!

Causally Ordered Multicast

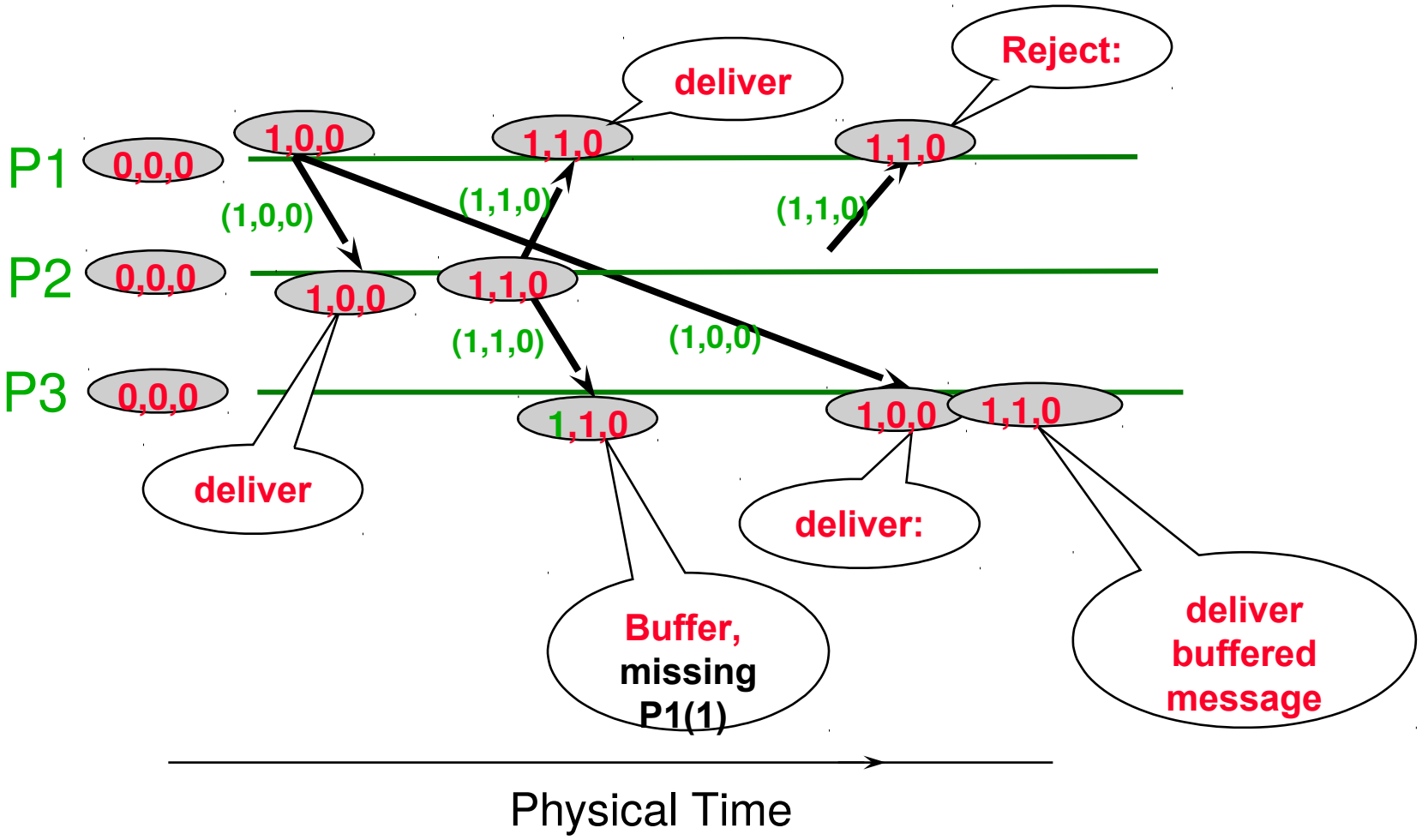
- Each process keeps a vector clock
  - Each entry *i* in the vector clock counts the number of messages delivered from process P_i
  - Each process's own entry in its vector represents the number of messages it has sent
- When sending a multicast message *m*, process P_i increments its own entry, then sends its vector with *m*
- When receiving a message *m*, from process P_j process P_i waits to deliver *m* until it can preserve causal ordering:
  - It has delivered all previous messages from P_j
  - It has delivered all messages that P_j had delivered before *m*

Causal Ordering



The number of group-g messages from process j that have been seen at process i so far

Example: Causal Ordering Multicast



Summary

- Total Ordering Multicast
  - Sequencer
  - ISIS
- Causal Ordering Multicast
  - Uses vector timestamps

References

[1] Kenneth Birman, Andre Schiper, and Pat Stephenson. *Fast Causal Multicast.* Technical Report. http://www.dtic.mil/dtic/tr/fulltext/u2/a220910.pdf

[2] Textbook section 15.4. **Required Reading.**

Acknowledgements

- These slides are by Steve Ko, used and lightly modified with permission by Ethan Blanton.
- These slides contain material developed and copyrighted by Indranil Gupta (UIUC).