



# CLOUD COMPUTING CONCEPTS

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## MULTICAST

Lecture A

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MULTICAST ORDERING

# MULTICAST PROBLEM

Node with a piece of information  
to be communicated to everyone



Distributed Group  
of "Nodes" =

Processes at  
Internet-based host

# OTHER COMMUNICATION FORMS

- **Multicast** → message sent to a group of processes
- **Broadcast** → message sent to all processes (anywhere)
- **Unicast** → message sent from one sender process to one receiver process

# Who Uses Multicast?

- A widely-used abstraction by almost all cloud systems
- Storage systems like Cassandra or a database
  - Replica servers for a key: Writes/reads to the key are multicast within the replica group
  - All servers: membership information (e.g., heartbeats) is multicast across all servers in cluster
- Online scoreboards (ESPN, French Open, FIFA World Cup)
  - Multicast to group of clients interested in the scores
- Stock exchanges
  - Group is the set of broker computers
  - Groups of computers for high-frequency trading
- Air traffic control system
  - All controllers need to receive the same updates in the same order

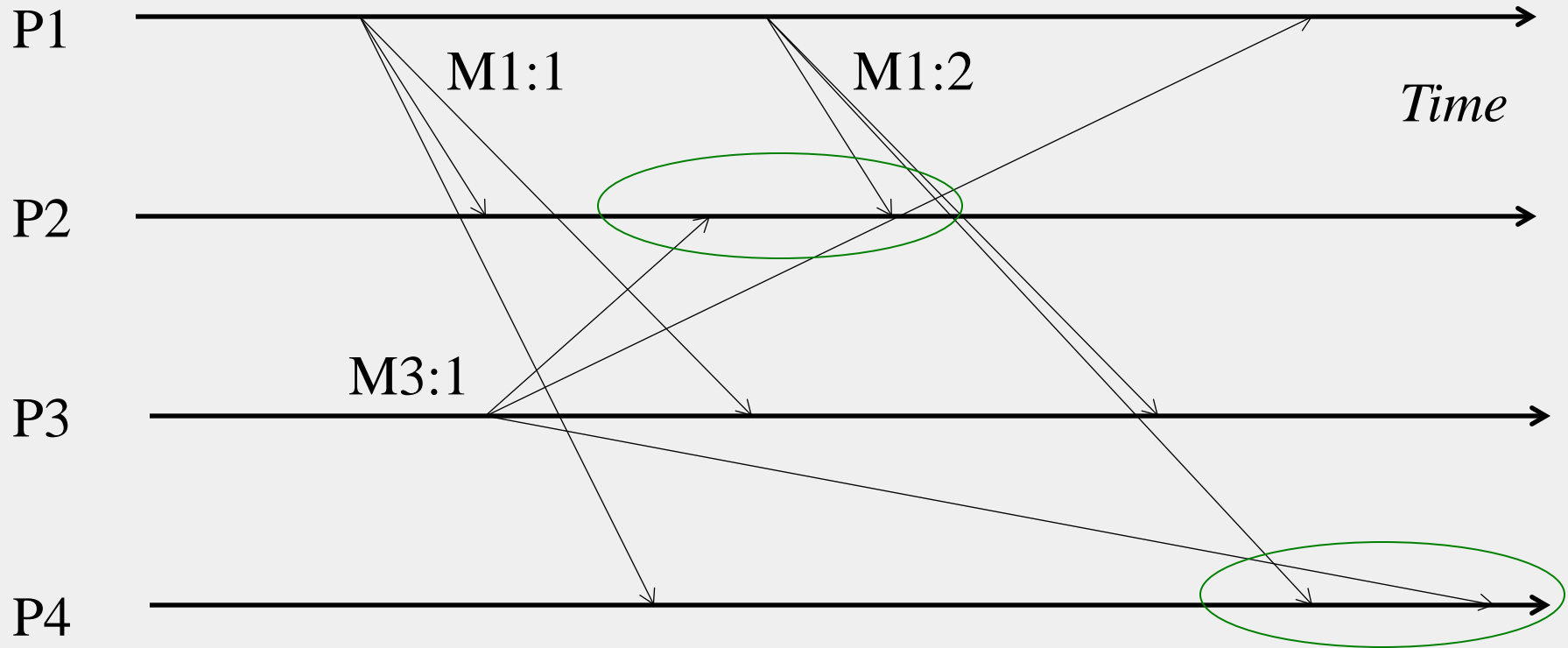
# MULTICAST ORDERING

- Determines the meaning of “same order” of multicast delivery at different processes in the group
- Three popular flavors implemented by several multicast protocols
  1. FIFO ordering
  2. Causal ordering
  3. Total ordering

# 1. FIFO ORDERING

- Multicasts from each sender are received in the order they are sent, at all receivers
- Don't worry about multicasts from different senders
- More formally
  - *If a correct process issues (sends)  $\text{multicast}(g, m)$  to group  $g$  and then  $\text{multicast}(g, m')$ , then every correct process that delivers  $m'$  would already have delivered  $m$ .*

# FIFO Ordering: Example



M1:1 and M1:2 should be received in that order at each receiver

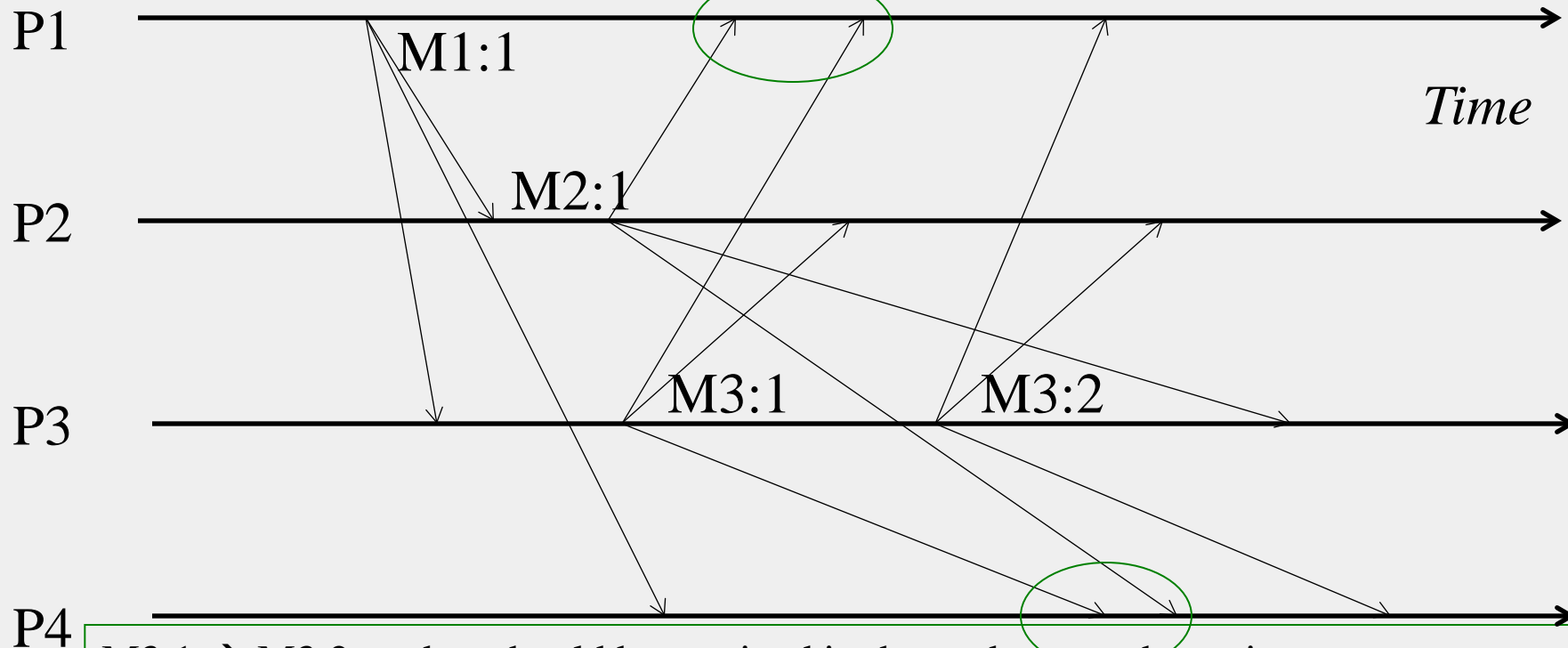
**Order of delivery of M3:1 and M1:2 could be different at different receivers**

## 2. CAUSAL ORDERING

- Multicasts whose send events are causally related, must be received in the same causality-obeying order at all receivers
- Formally
  - *If  $\text{multicast}(g, m) \rightarrow \text{multicast}(g, m')$  then any correct process that delivers  $m'$  would already have delivered  $m$ .*
  - *( $\rightarrow$  is Lamport's happens-before)*



# Causal Ordering: Example



M3:1  $\rightarrow$  M3:2, and so should be received in that order at each receiver

M1:1  $\rightarrow$  M3:1, and so should be received in that order at each receiver

**M3:1 and M2:1 are concurrent and thus ok to be received in different orders at different receivers**

# CAUSAL VS. FIFO

- Causal Ordering  $\Rightarrow$  FIFO Ordering
- Why?
  - If two multicasts  $M$  and  $M'$  are sent by the same process  $P$ , and  $M$  was sent before  $M'$ , then  $M \rightarrow M'$
  - Then a multicast protocol that implements causal ordering will obey FIFO ordering since  $M \rightarrow M'$
- Reverse is not true! FIFO ordering does not imply causal ordering.

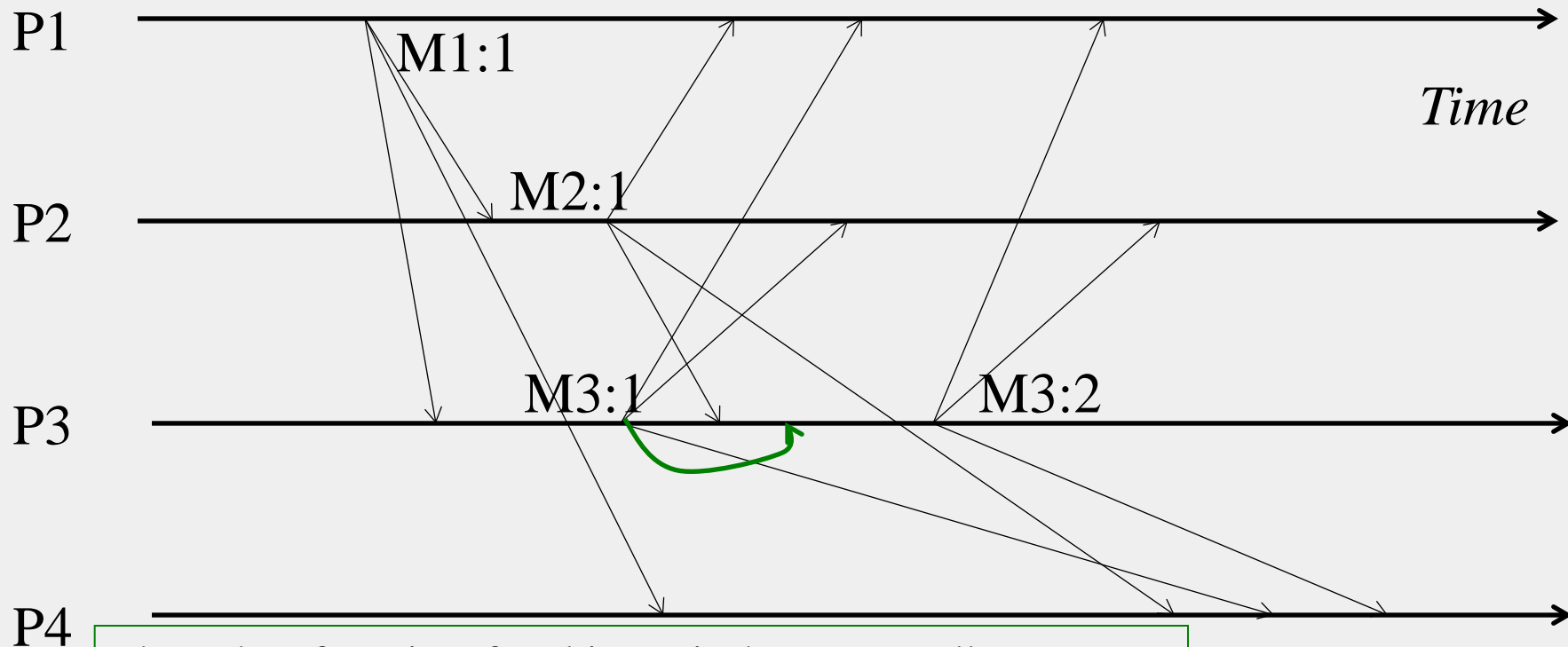
# WHY CAUSAL AT ALL?

- Group = set of your friends on a social network
- A friend sees your message  $m$ , and she posts a response (comment)  $m'$  to it
  - If friends receive  $m'$  before  $m$ , it wouldn't make sense
  - But if two friends post messages  $m''$  and  $n''$  concurrently, then they can be seen in any order at receivers
- A variety of systems implement causal ordering: Social networks, bulletin boards, comments on websites, etc.

# 3. TOTAL ORDERING

- Also known as “Atomic Broadcast”
- Unlike FIFO and causal, this does not pay attention to order of multicast sending
- Ensures all receivers receive all multicasts in the same order
- Formally
  - *If a correct process  $P$  delivers message  $m$  before  $m'$  (independent of the senders), then any other correct process  $P'$  that delivers  $m'$  would already have delivered  $m$ .*

# Total Ordering: Example



The order of receipt of multicasts is the same at all processes.

**M1:1, then M2:1, then M3:1, then M3:2**

**May need to delay delivery of some messages**

# HYBRID VARIANTS

- Since FIFO/Causal are orthogonal to Total, can have hybrid ordering protocols too
  - FIFO-total hybrid protocol satisfies both FIFO and total orders
  - Causal-total hybrid protocol satisfies both Causal and total orders

# IMPLEMENTATION?

- That was *what* ordering is
- But *how* do we implement each of these orderings?
- Next lecture