



CLOUD COMPUTING CONCEPTS

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MULTICAST

Lecture A

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

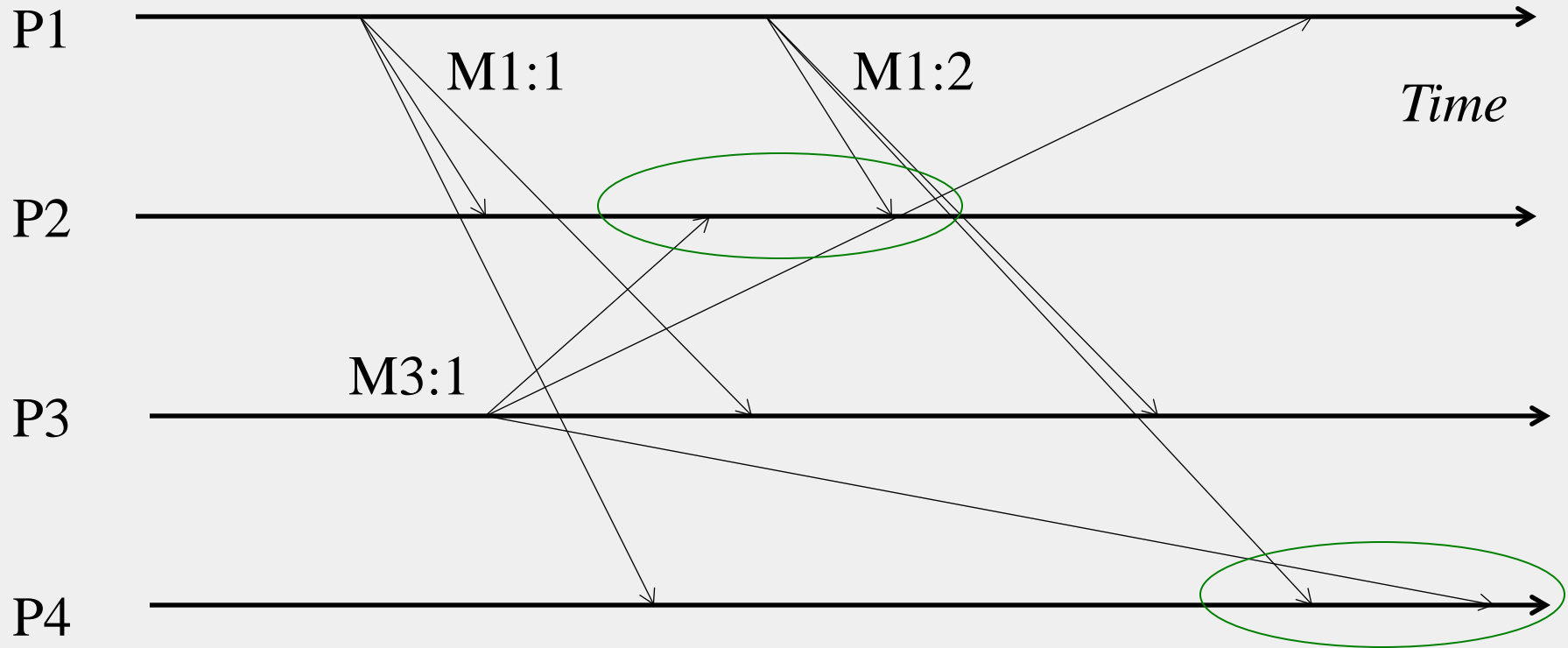
MULTICAST ORDERING

- 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



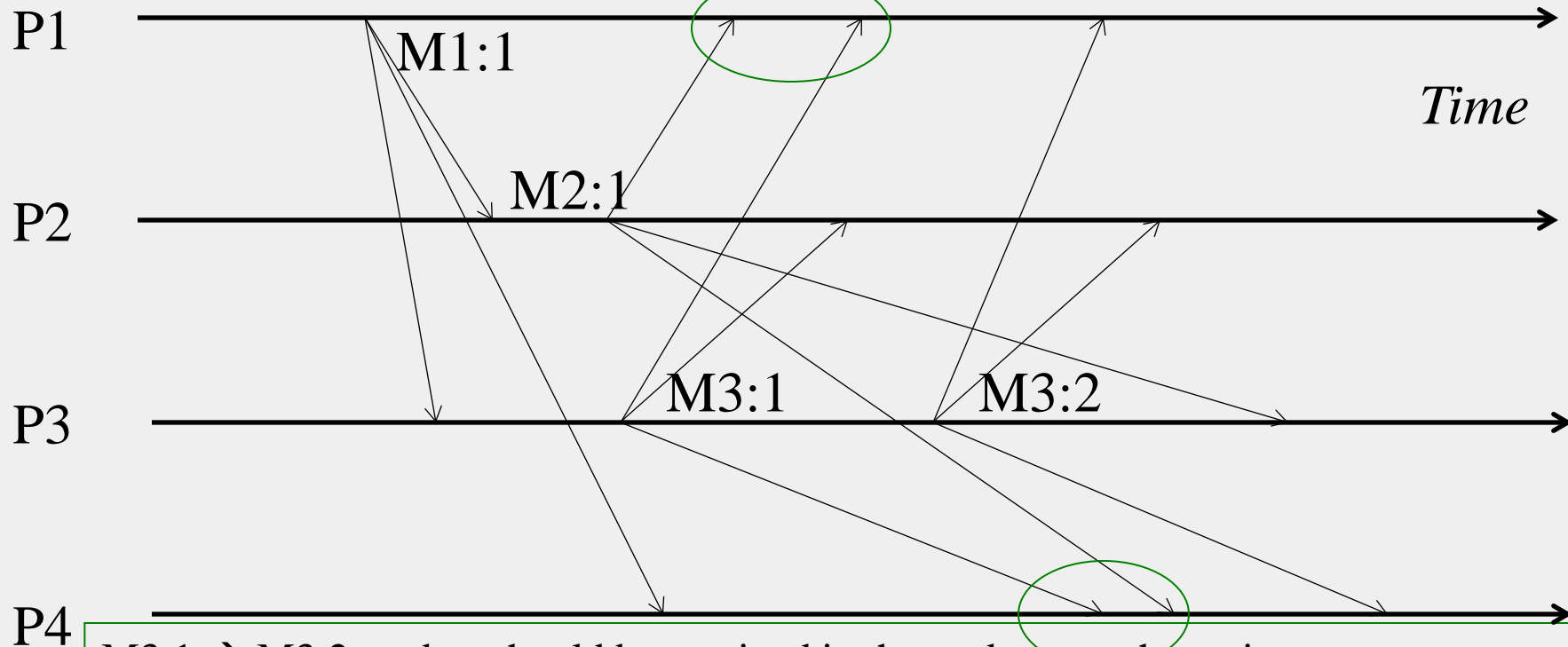
M1:1 and M1:2 should be received in that order at each receiver

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.

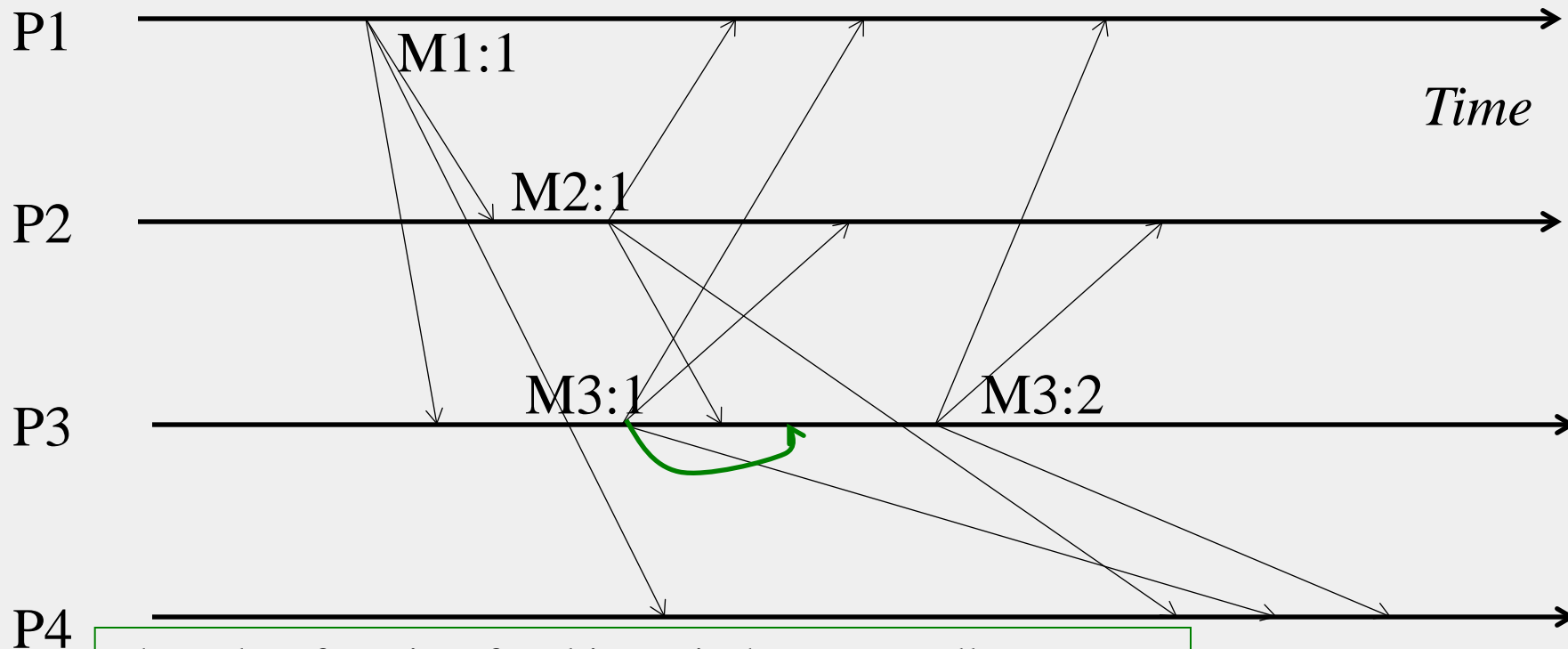
WHY CAUSAL AT ALL?

- 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