



A Note on Message Ordering

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credits for the slides to:

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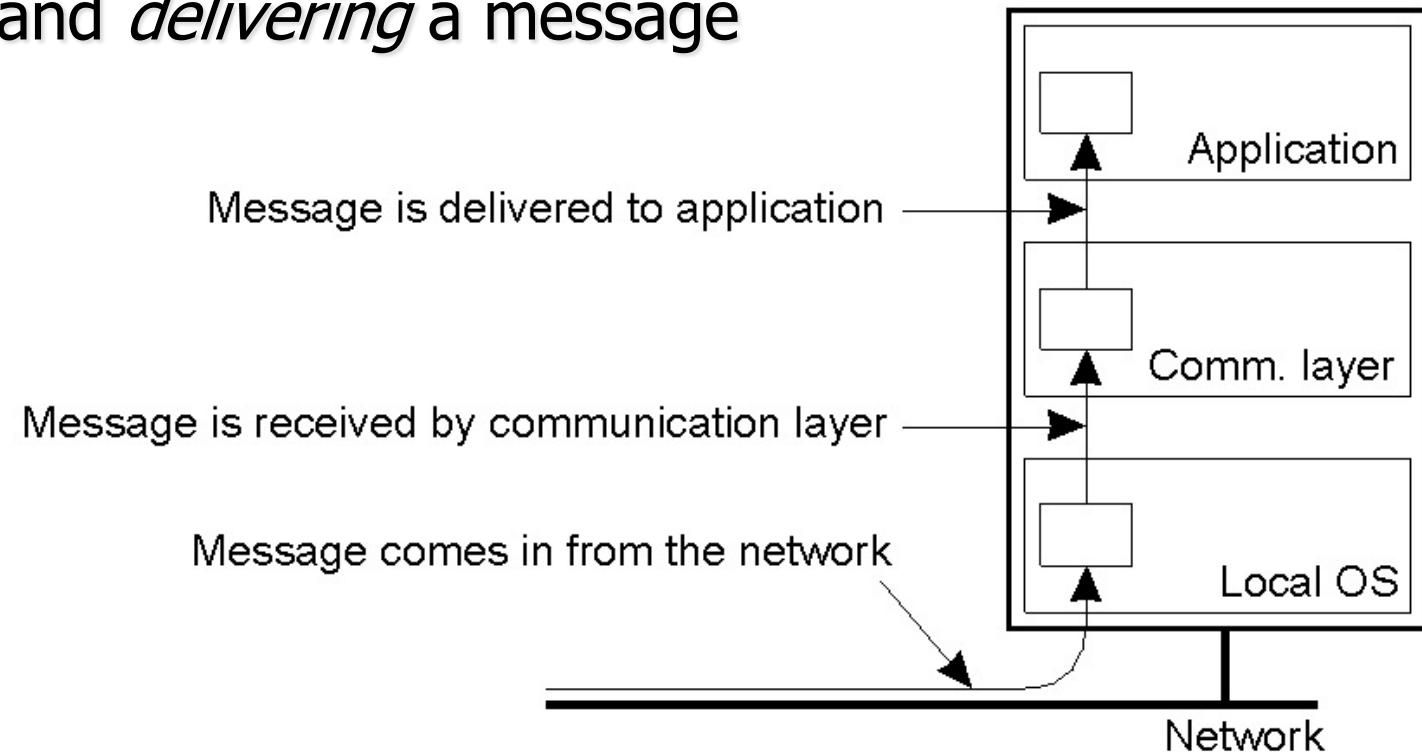
Happens-before Relation

- ◆ Let e_i and e_j be any two events in a distributed execution
- ◆ We say $e_i \rightarrow e_j$ if *any* of the following holds
 - ◆ e_i and e_j are two events on the same process and e_i comes before e_j
 - ◆ e_i is the sending event of message m , and e_j is the receive event for the same message m
 - ◆ there exist e_k such that $e_i \rightarrow e_k$ and $e_k \rightarrow e_j$
- ◆ If $e_i \rightarrow e_j$, e_j might have been caused by e_i



Receive vs. Deliver

- ◆ We make a distinction between *receiving* and *delivering* a message



- ◆ Already seen in TCP:
 - ◆ messages might be *received* out-of-order
 - ◆ but TCP buffers them and *delivers* them in order to the application



Message Ordering

- ◆ Let
 - ◆ $S_p(m)$ be the send event for message m by process p
 - ◆ $D_p(m)$ be the delivery event for message m by process p
 - ◆ FIFO ordering
 - ◆ $\forall p, q, m, m' : S_p(m) \rightarrow S_p(m') \Rightarrow D_q(m) \rightarrow D_q(m')$
 - ◆ Causal ordering
 - ◆ $\forall p, q, r, m, m' : S_p(m) \rightarrow S_q(m') \Rightarrow D_r(m) \rightarrow D_r(m')$
 - ◆ Total ordering
 - ◆ $\forall p, q, m, m' : D_p(m) \rightarrow D_p(m') \Leftrightarrow D_q(m) \rightarrow D_q(m')$
- Senders might be different !



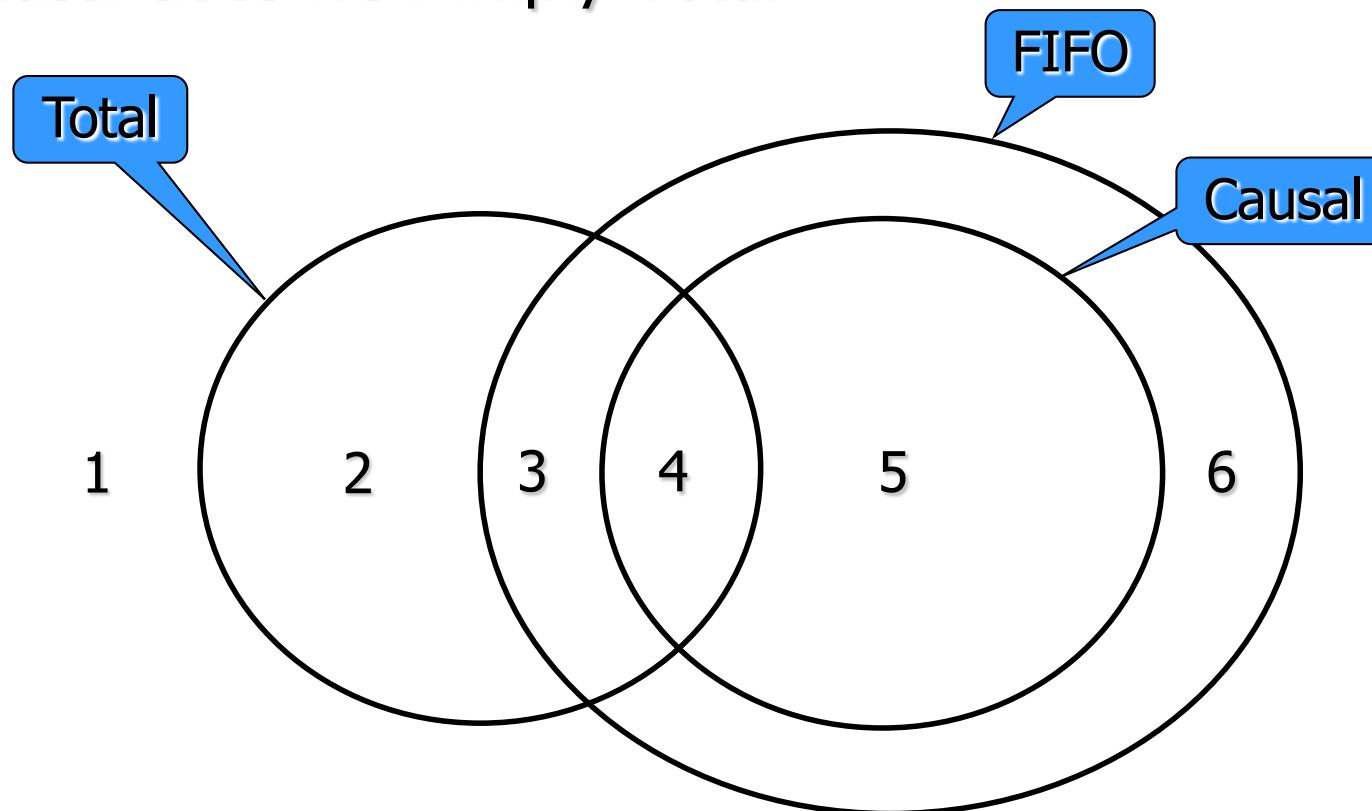
Message Ordering

- ◆ Three base flavors of a group communication service:
 - ◆ unordered;
 - ◆ FIFO ordered;
 - ◆ causally ordered;
- ◆ where each of those can be:
 - ◆ totally ordered;
 - ◆ not totally ordered;
- ◆ for a total of six flavors



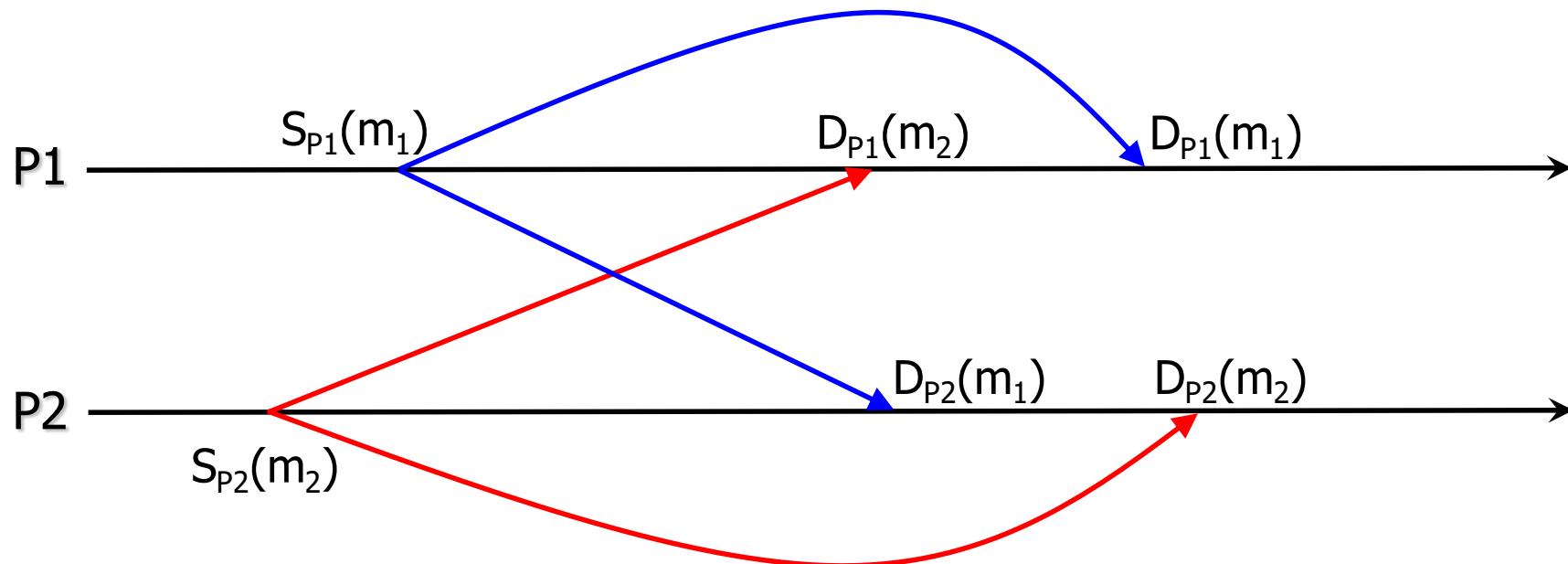
Set Containments

- ◆ Causal implies FIFO (and not FIFO implies not causal...)
- ◆ Total does NOT imply Causal
- ◆ Causal does NOT imply Total



Examples (1/5)

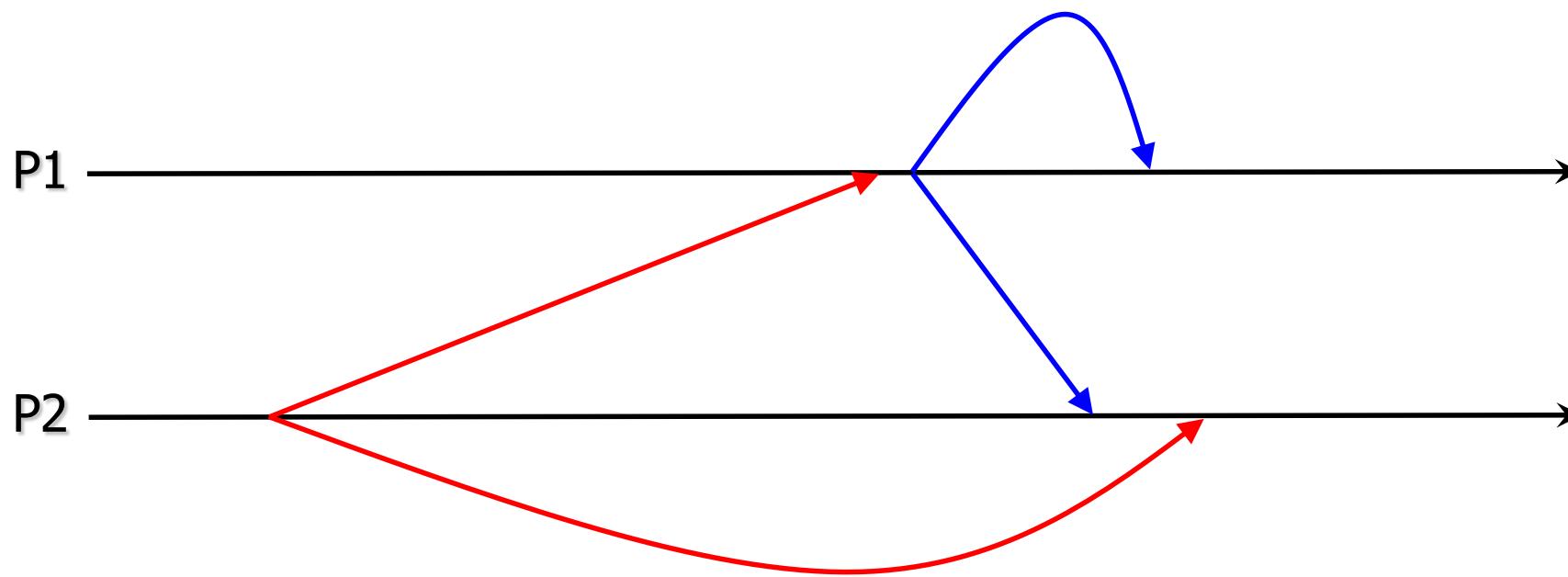
- ◆ FIFO
- ◆ Causal
- ◆ NON Total





Examples (2/5)

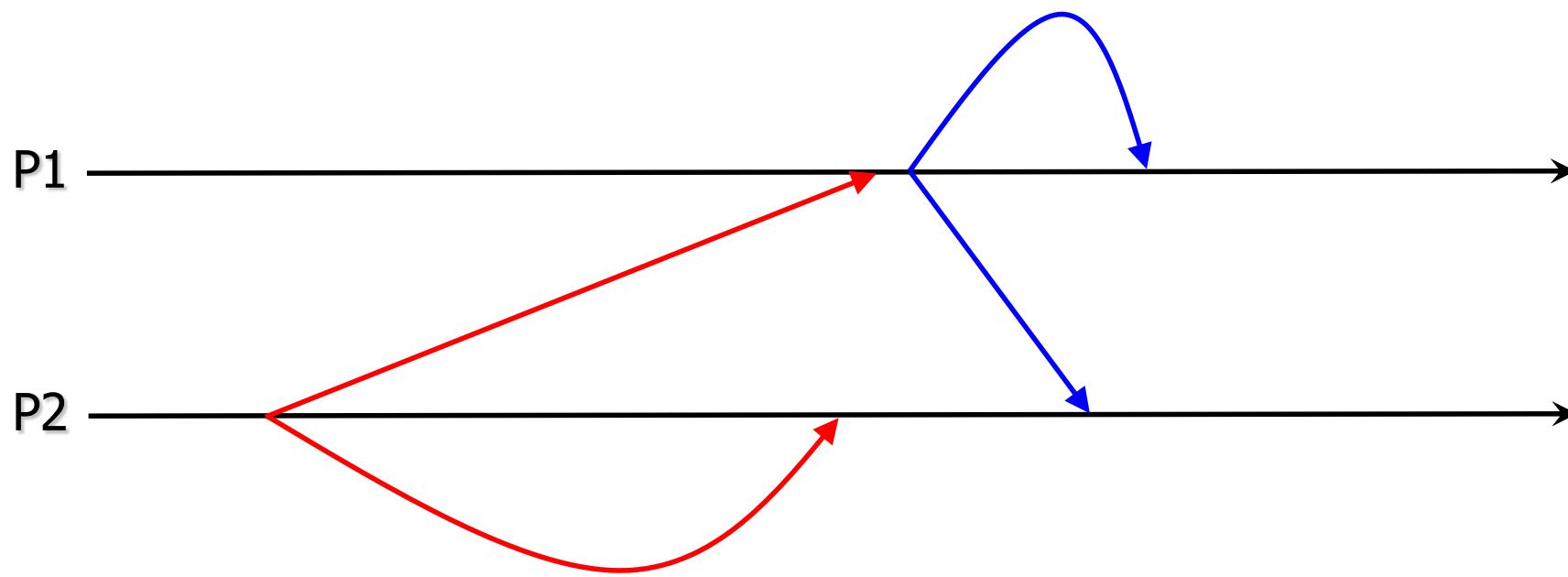
- ◆ FIFO
- ◆ NON Causal
- ◆ NON Total





Examples (3/5)

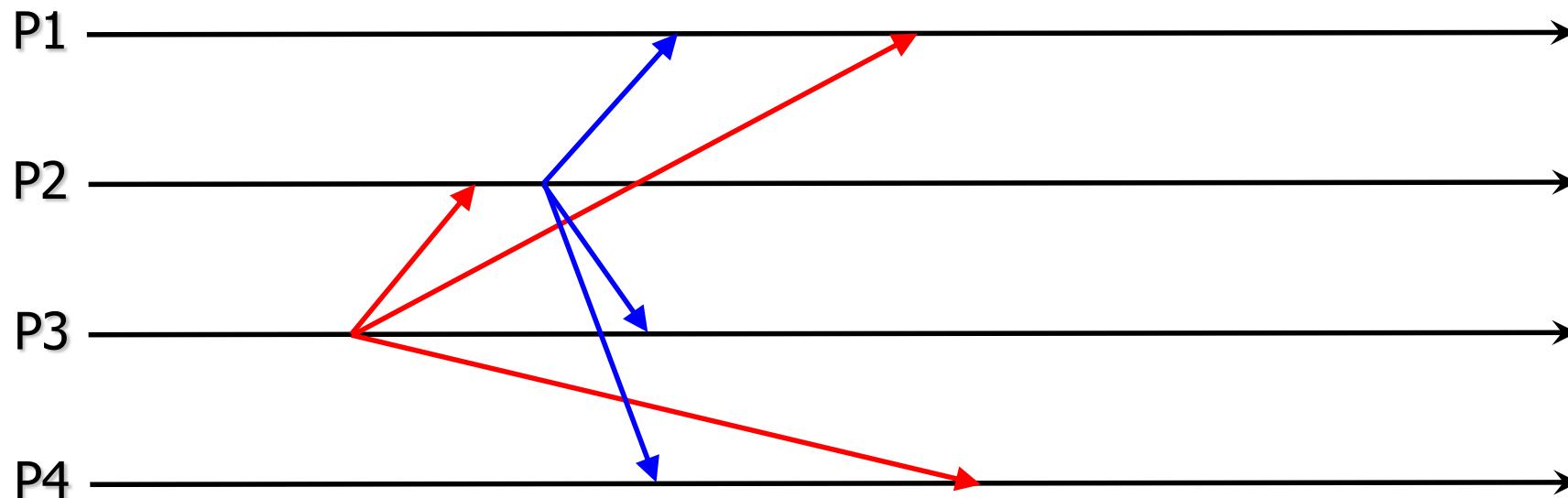
- ◆ FIFO
- ◆ Causal
- ◆ Total





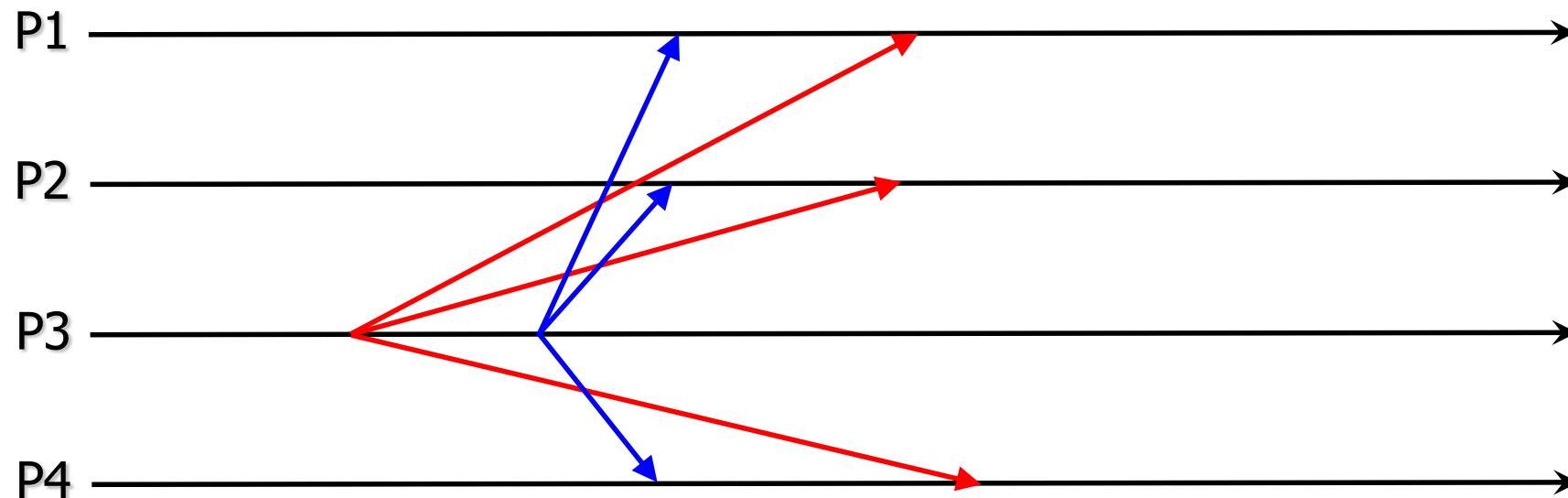
Examples (4/5)

- ◆ FIFO
- ◆ NON Causal
- ◆ Total



Examples (5/5)

- ◆ NON FIFO
- ◆ NON Causal
- ◆ Total





Exercise

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	

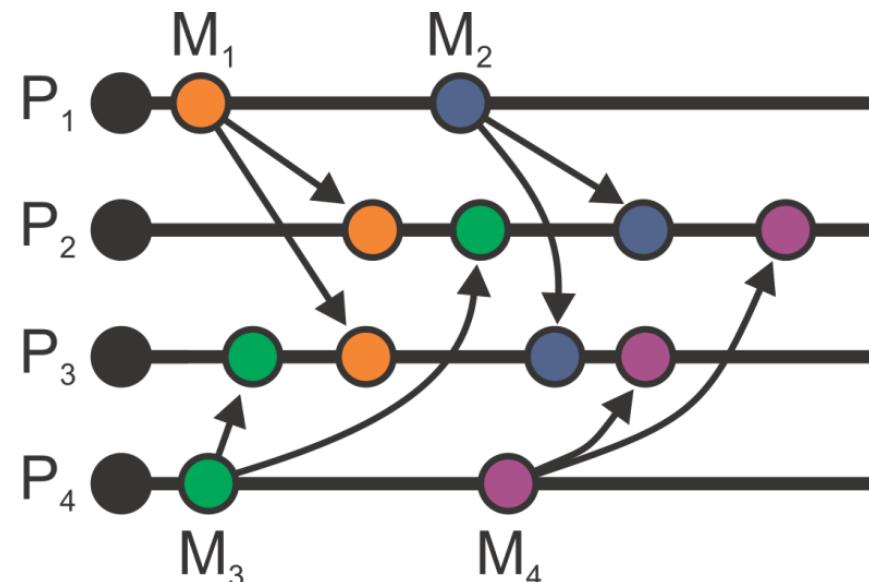
Is this total ordered? Causal? Draw the time diagram!



Exercise

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	

Is this total ordered? Causal? Draw the time diagram!



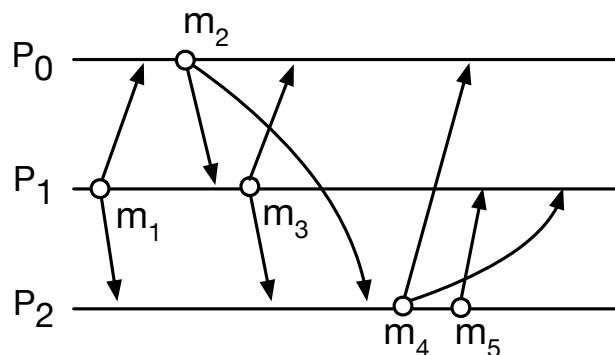
FIFO
Causal
Non Totally ordered



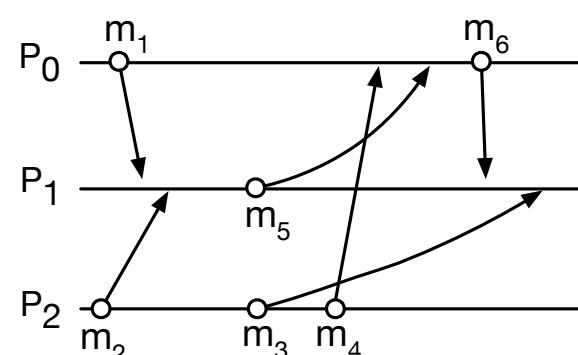
Exercise

◆ In the context of message ordering schemes:

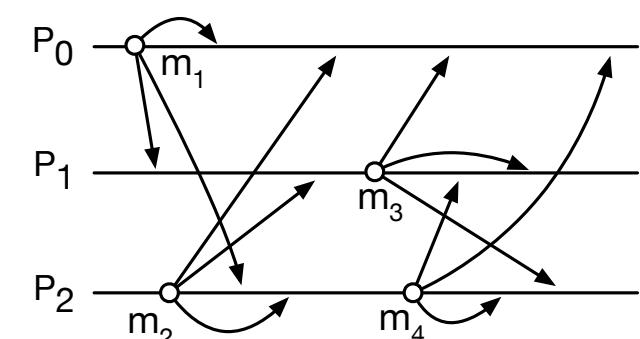
1. provide the definitions for the three delivery schemes we have seen in class: *FIFO*, *causal*, and *total*. Briefly discuss the relationship between these schemes (e.g. are they independent? Does one imply the other?).
2. For each of the executions depicted below, indicate whether or not they satisfy the delivery schemes of item (1). Should they not satisfy one or more of the schemes, indicate the first message(s) that causes *each scheme* to be violated, as well as the reason why they cause the violation.



(E1)



(E2)



(E3)