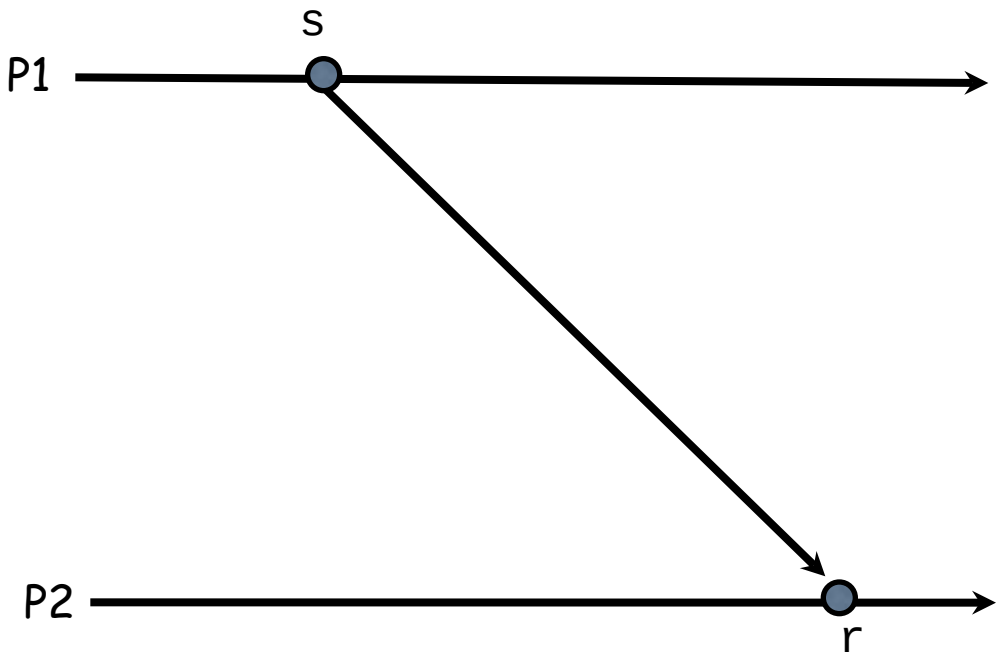
Lecture 15

- Administration


s
P1
P2
r

"happens before" Relation

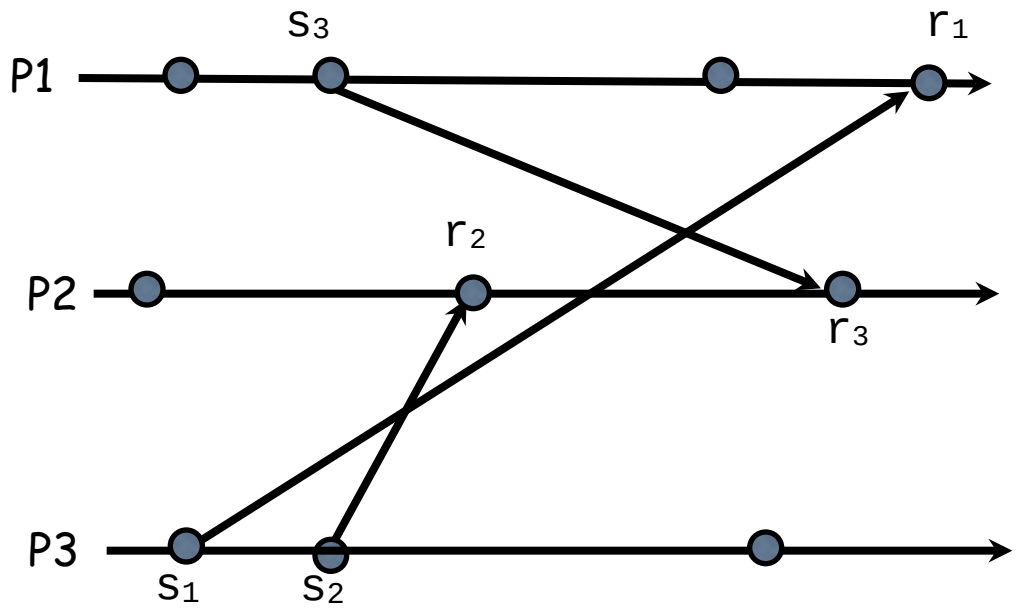
$$e_i^x \rightarrow e_j^y \Leftrightarrow \begin{cases} e_i^x \xrightarrow[i]{} e_j^y \,(i == j) \wedge (x < y) \\ e_i^x \xrightarrow[msg]{} e_j^y \\ \exists e_k^z \in H \; s.t. \; e_i^x \rightarrow e_k^z \wedge e_k^z \rightarrow e_j^y \end{cases}$$

Properties of H:

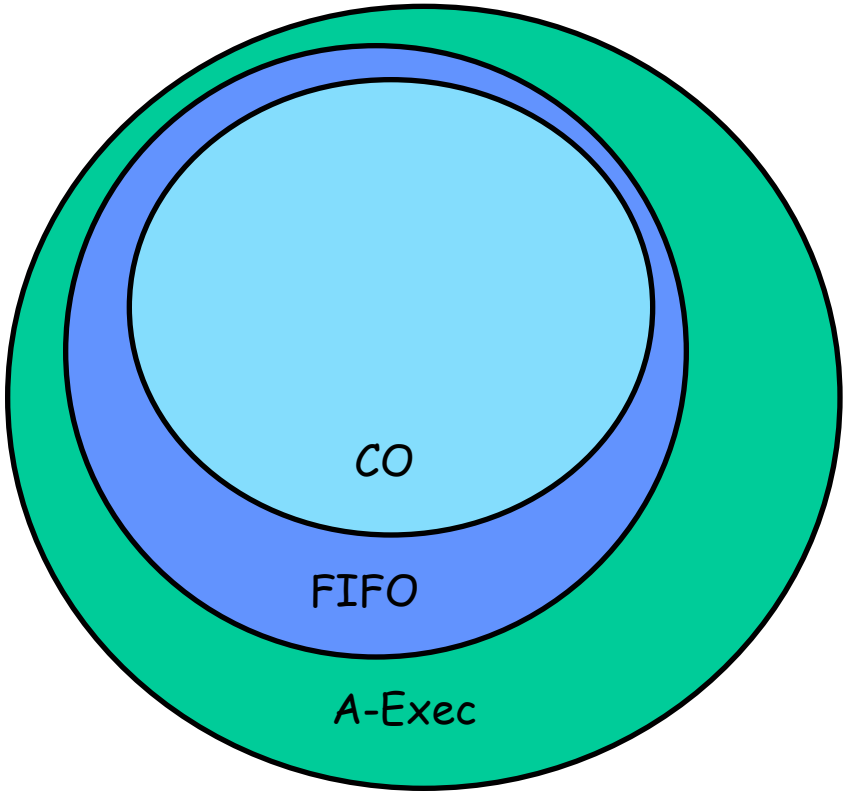
1. NOT a < a (irreflexive)
2. If a < b Then NOT b<a (asymmetric)
3. Transitive

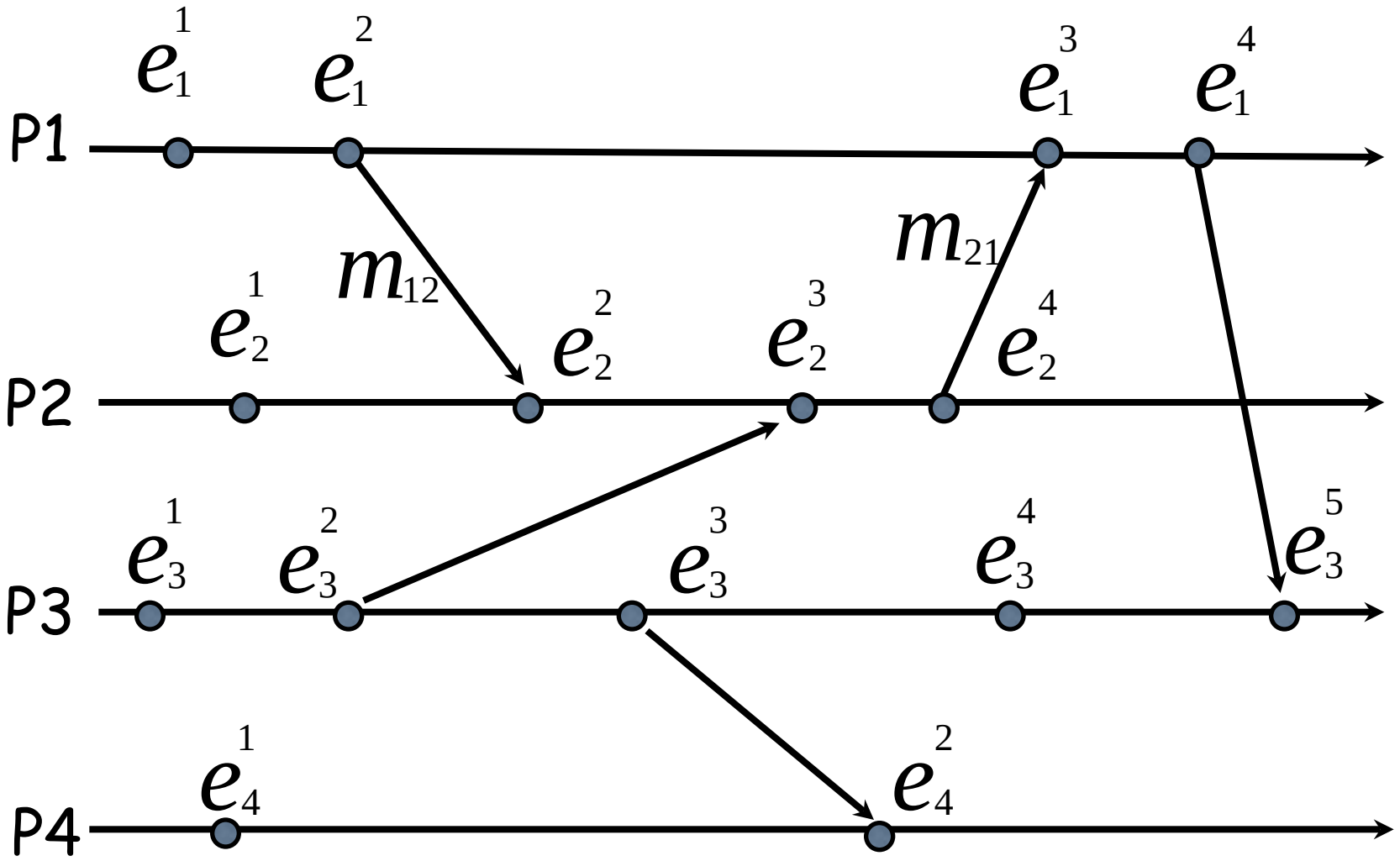
Defines a strict partial order on events (causal ordering)

Asynchronous Communication



Ordered Communication Hierarchy




P1
P2
P3
P4
e_1^1
e_1^2
e_1^3
e_1^4
e_2^1
e_2^2
e_2^3
e_2^4
e_3^1
e_3^2
e_3^3
e_3^4
e_3^5
e_4^1
e_4^2
m_{12}
m_{21}

Communication

- Not a POSET

$$e_i^x \rightarrow e_j^y \wedge e_j^y \rightarrow e_i^x$$

- ASYNC (a POSET)

- FIFO

$$e_i^x \rightarrow e_j^y \wedge e_i^{x'} \rightarrow e_j^{y'}; e_i^x \rightarrow e_i^{x'} \Rightarrow e_j^y \rightarrow e_j^{y'}$$

- Causal Order

$$\text{send}(m_{ij}) \rightarrow \text{send}(m_{kj}) \Rightarrow \text{recv}(m_{ij}) \rightarrow \text{recv}(m_{kj})$$

- SYNC

State of Channel

All messages that have been sent but not yet received.

$$S_{ij}^{x,y} = \left\{ m_{ij} : \text{send}(m_{ij}) \leq \text{recv}(m_{i,j}) > LS_j^y \right\}$$

LS_j^y The state of process j after the occurrence of event e_j^y

Global State

$$GS = \left\{ \bigcup_{i} LS_i^{x_i}, \bigcup_{j,k} S_{jk}^{y_j, z_k} \right\}$$

Consistent or Inconsistent

Terms

- Concurrent
- Cut some Global State
- Consistent, transitless (no outstanding messages), strongly consistent (consistent and transitless)

Logical clocks

Assign sequence numbers to messages

- All cooperating processes can agree on order of events
- vs. **physical clocks**: time of day

Assume no central time source

- Each system maintains its own local clock
- No total ordering of events
  - No concept of *happened-when*