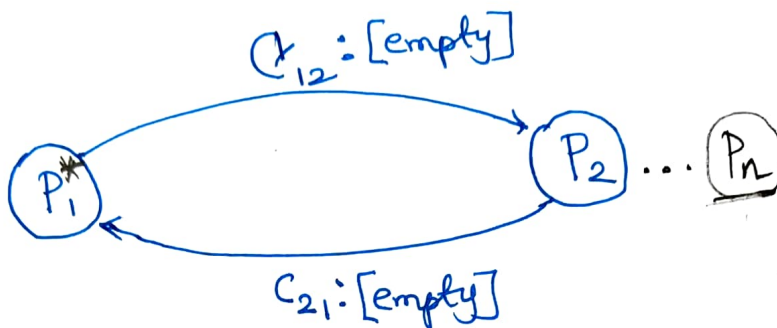


$G, S, A, R$

10  
Feb  
2022  
2-3 PM

$x_1$	0
$y_1$	0
$z_1$	0
$\vdots$	$\vdots$
$\vdots$	$\vdots$
$\vdots$	$\vdots$



$x_2$	4
$y_2$	3
$z_2$	5
$\vdots$	$\vdots$
$\vdots$	$\vdots$
$\vdots$	$\vdots$

$N=1, 2, \dots, n$

Communication: message passing

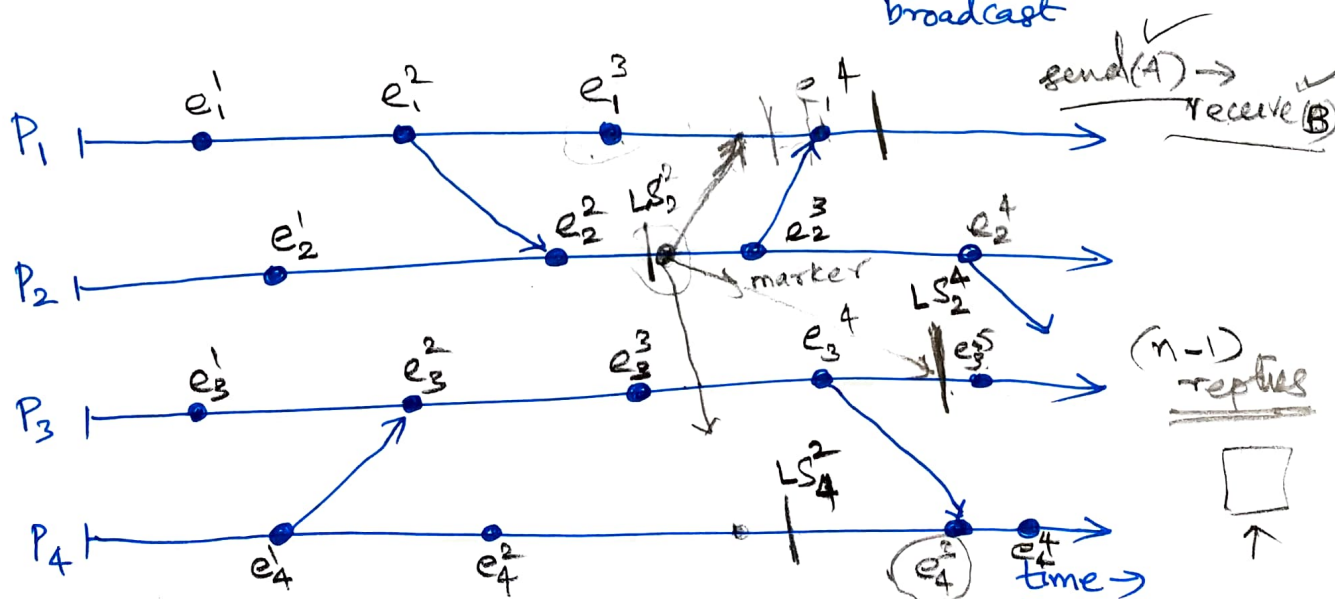
→ Application messages

→ Marker messages

\* arbitrator - Global snapshot of the entire DS

$\forall j, 1 \leq j \neq i \leq n$

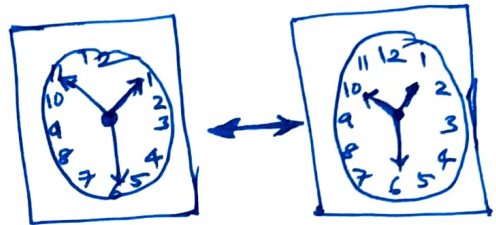
1 - arbitrator  
N-1 - processes  
broadcast



# LOGICAL CLOCKS.

Q: How do we sync. the physical clocks across  $n$  PEs (nodes)?

→ Clock rate  
"Same"



Lamport:

Counter: monotonically increasing counter...

\* Each  $P_i$  has a logical clock  $L_i$

\*  $LC_1$ :  $L_i$  is incremented by 1 before each event @  $P_i$

\*  $LC_2$ :

a) when  $P_i$  sends message:  $m_{ij}$

$$\boxed{m_i} + (t = \underline{L_i})$$

(m, t)

b) When  $P_j$  receives  $(m, \underline{t})$ :  $t = \underline{L_i}$

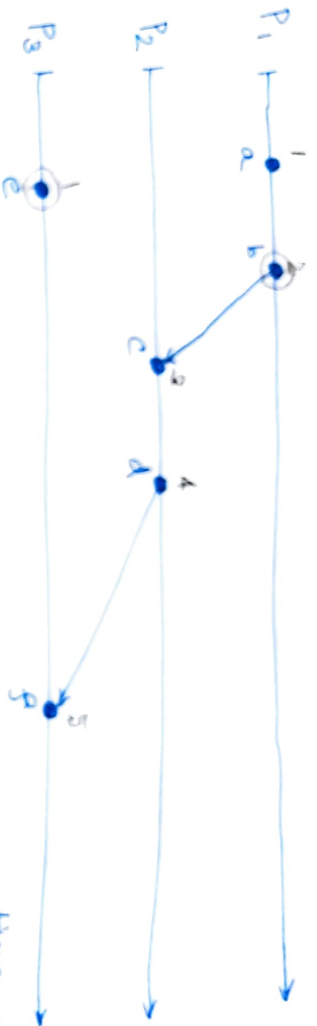
$$\underline{L_j} = \max(L_j, t)$$

and

$$\underline{L_j} = \max(L_j, L_i)$$

Apply  $LC_1$ :  $L_j = L_j + 1$

$$L_j = \max(L_j, L_i) + 1$$



Causal events:

$e \rightarrow e' \Rightarrow L(e) < L(e')$  but not vice versa

$a \rightarrow b$

$a \rightarrow c$  ( $\exists b \Rightarrow a \rightarrow b$  and  $b \rightarrow c$ )

$c \rightarrow d$

$c \rightarrow f$

$b \rightarrow f$

$\vdots$

Concurrent Events:

$x \not\rightarrow y$  and  $y \not\rightarrow x \Rightarrow x \parallel y$

$a \parallel e$

$b \parallel e$

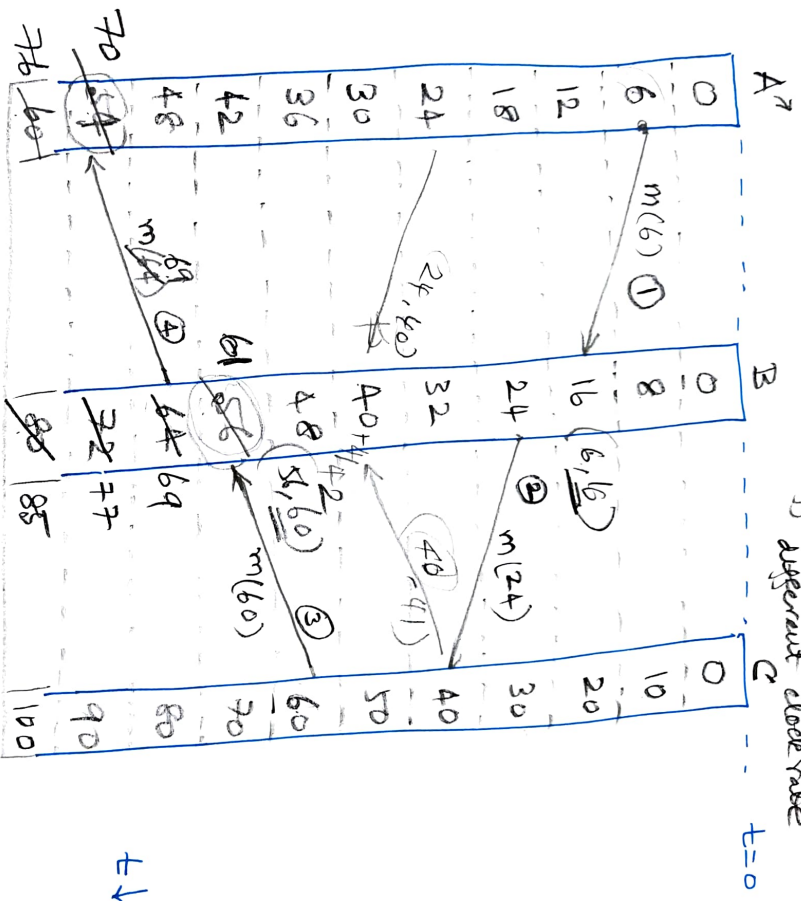
$c \parallel e$

$d \parallel e$

~~$e \not\rightarrow f$~~  ( $\because$  They happen on the same  $P_i$ )

# Example: Clock Correction

different clocks  
different clock rate



$t \uparrow$

$$\begin{aligned}
 L_A &= 54, L_B = 69 \\
 L_A &= \max(54, 69) + 1 \\
 &= 69 + 1 \\
 &= 70 \\
 L_B &= 56, L_C = 60 \\
 L_B &= \max(56, 60) + 1 \\
 &= 61
 \end{aligned}$$

