Times, Clocks, and the Ordering of Events in a Distributed System

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Main objective

In this paper Lamport discusses the partial ordering defined by the “happened before” relation, and gives a distributed algorithm for extending it to a consistent total ordering of all the events.

Distributed system

Definition (Distributed system)

A *distributed system* consists of a collection of distinct processes which are spatially separated, and which communicate with one another by exchanging messages.
A system is distributed if the message transmission delay is not negligible compared to the time between events in a single process.

Examples of distributed systems

- A worldwide network of interconnected computers
- A cluster of workstation in a data center
- Processes on a single computer

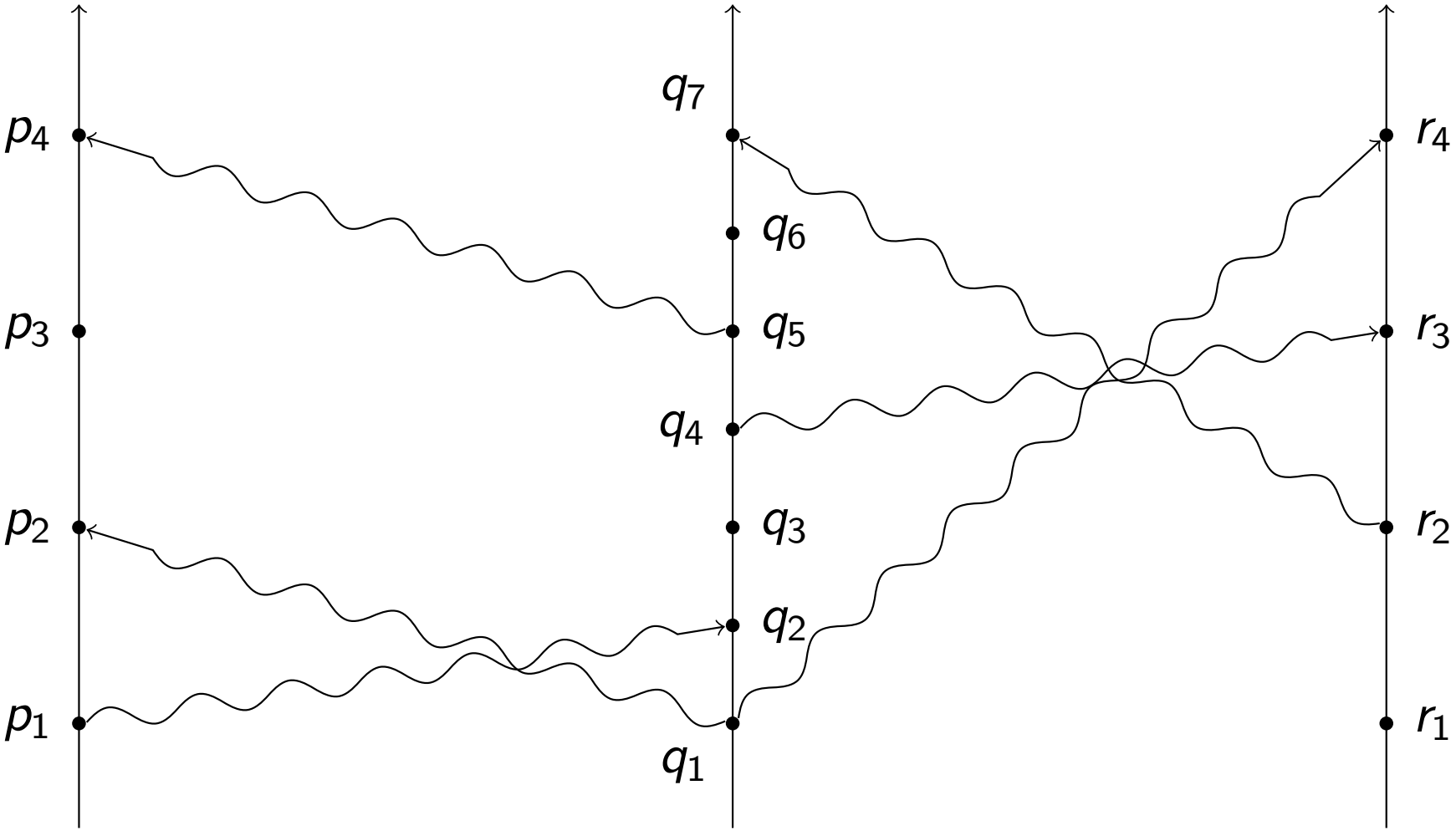
The "$\rightarrow$" relation

Definition (The "$\rightarrow$" relation)

The "$\rightarrow$" relation on the set of events of a system is the smallest relation satisfying the following three conditions:

1. If a and b are events in the same process, and a comes before b, then $a \rightarrow b$.
2. If a is the sending of a message by one process, and b is the receipt of the same message by another process, then $a \rightarrow b$.
3. If $a \rightarrow b$, and $b \rightarrow c$, then $a \rightarrow c$.

The "space-time diagram"



Clocks

Definition (Clock)

For each process P_i we define a *clock* C_i to be a function that assigns a number $C_i\langle a\rangle$ to each event a in the process.

Definition (System of clocks)

A *system of clocks* is a function C that assigns to the event b in process P_j the time $C\langle b\rangle = C_j\langle b\rangle$.

The clock condition

Definition (The clock condition)

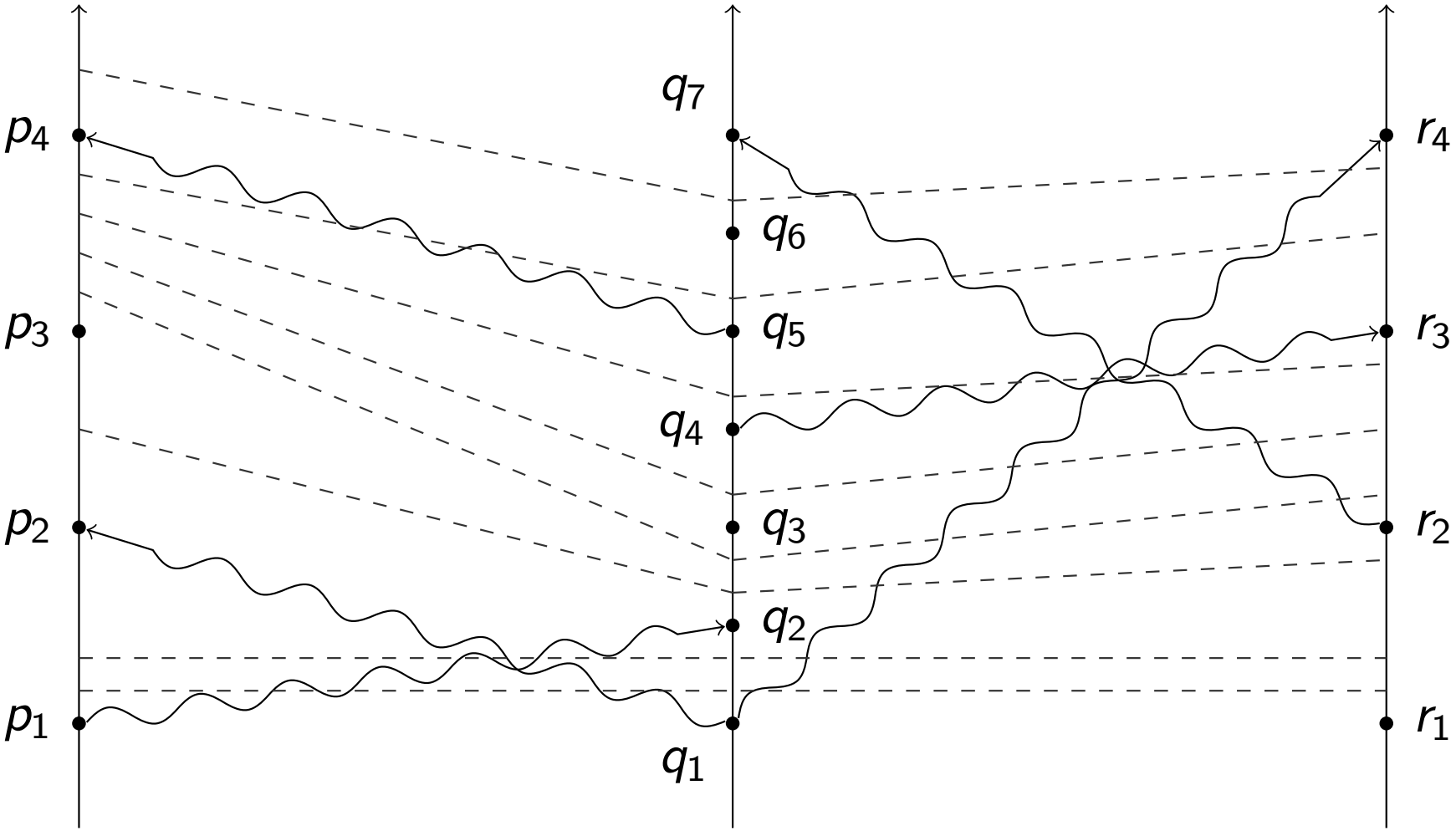
We say that a system of clocks satisfies the *clock condition* if, for any events a and b, we have: if $a \rightarrow b$ then $C\langle a \rangle < C\langle b \rangle$.

Lemma

The clock condition is satisfied if the following conditions hold:

1. *If a and b are events in process P_i and a comes before b, then $C_i\langle a \rangle < C_i\langle b \rangle$.*
2. *If a is the sending of a message by process P_i and b is the receipt of that message by process P_j, then $C_i\langle a \rangle < C_i\langle b \rangle$.*

The "space-time diagram", revisited



The "space-time diagram", rearranged