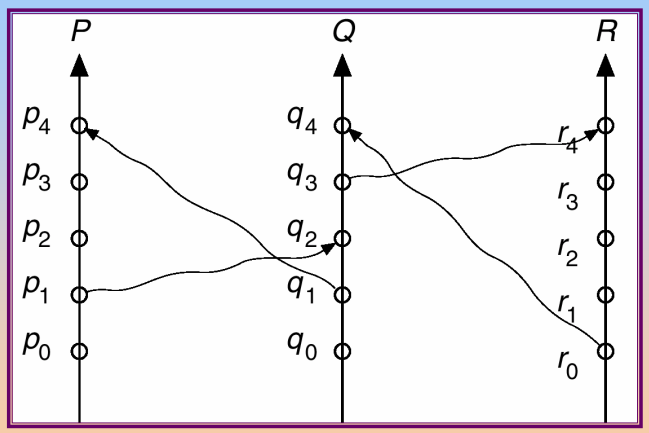
Chapter 17 Distributed Coordination

- Event Ordering
- Mutual Exclusion
- Atomicity
- Concurrency Control
- Deadlock Handling
- Election Algorithms
- Reaching Agreement

Event Ordering

- *Happened-before* relation (denoted by $\rightarrow$).
  - If A and B are events in the same process, and A was executed before B, then $A \rightarrow B$.
  - If A is the event of sending a message by one process and B is the event of receiving that message by another process, then $A \rightarrow B$.
  - If $A \rightarrow B$ and B $\rightarrow C$ then $A \rightarrow C$.

Relative Time for Three Concurrent Processes



Implementation of $\rightarrow$

- Associate a timestamp with each system event. Require that for every pair of events *A* and *B*, if $A \rightarrow B$, then the timestamp of *A* is less than the timestamp of *B*.
- Within *each* process P_i a *logical clock*, LC_i is associated. The logical clock can be implemented as a simple counter that is incremented between any two successive events executed within a process.
- A process advances its logical clock when it receives a message whose timestamp is greater than the current value of its logical clock.
- If the timestamps of two events *A* and *B* are the same, then the events are concurrent. We may use the process identity numbers to break ties and to create a total ordering.

Distributed Mutual Exclusion (DME)

- Assumptions
  - The system consists of *n* processes; each process P_i resides at a different processor.
  - Each process has a critical section that requires mutual exclusion.
- Requirement
  - If P_i is executing in its critical section, then no other process P_j is executing in its critical section.
- We present two algorithms to ensure the mutual exclusion execution of processes in their critical sections.


DME: Centralized Approach

- One of the processes in the system is chosen to coordinate the entry to the critical section.
- A process that wants to enter its critical section sends a *request* message to the coordinator.
- The coordinator decides which process can enter the critical section next, and its sends that process a *reply* message.
- When the process receives a *reply* message from the coordinator, it enters its critical section.
- After exiting its critical section, the process sends a *release* message to the coordinator and proceeds with its execution.
- This scheme requires three messages per critical-section entry:
  - request
  - reply
  - release


DME: Fully Distributed Approach

- When process P_i wants to enter its critical section, it generates a new timestamp, *TS*, and sends the message *request* (P_i, *TS*) to all other processes in the system.
- When process P_j receives a *request* message, it may reply immediately or it may defer sending a reply back.
- When process P_i receives a *reply* message from all other processes in the system, it can enter its critical section.
- After exiting its critical section, the process sends *reply* messages to all its deferred requests.


DME: Fully Distributed Approach (Cont.)

- The decision whether process P_j replies immediately to a *request*(P_i, *TS*) message or defers its reply is based on three factors:
  - If P_j is in its critical section, then it defers its reply to P_i.
  - If P_j does *not* want to enter its critical section, then it sends a *reply* immediately to P_i.
  - If P_j wants to enter its critical section but has not yet entered it, then it compares its own request timestamp with the timestamp *TS*.
    - If its own request timestamp is greater than *TS*, then it sends a *reply* immediately to P_i (P_i asked first).
    - Otherwise, the reply is deferred.


Desirable Behavior of Fully Distributed Approach

- Freedom from Deadlock is ensured.
- Freedom from starvation is ensured, since entry to the critical section is scheduled according to the timestamp ordering. The timestamp ordering ensures that processes are served in a first-come, first served order.
- The number of messages per critical-section entry is

$$2 \times (n - 1).$$

This is the minimum number of required messages per critical-section entry when processes act independently and concurrently.

Three Undesirable Consequences

- The processes need to know the identity of all other processes in the system, which makes the dynamic addition and removal of processes more complex.
- If one of the processes fails, then the entire scheme collapses. This can be dealt with by continuously monitoring the state of all the processes in the system.
- Processes that have not entered their critical section must pause frequently to assure other processes that they intend to enter the critical section. This protocol is therefore suited for small, stable sets of cooperating processes.