CSE 421/521 - Operating Systems
Fall 2012

LECTURE - XXII

# DISTRIBUTED SYSTEMS - I

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## Motivation

- **Distributed system** is collection of loosely coupled processors that
  - do not share memory
  - interconnected by a communications network
- Reasons for distributed systems
  - Resource sharing
    - sharing and printing files at remote sites
    - processing information in a distributed database
    - using remote specialized hardware devices
  - Computation speedup – **load sharing**
  - Reliability – detect and recover from site failure, function transfer, reintegrate failed site
  - Communication – message passing

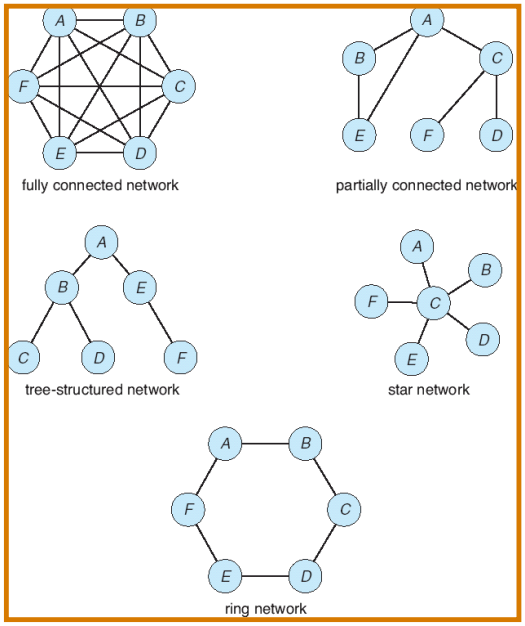
## Distributed-Operating Systems

- Users not aware of multiplicity of machines
  - Access to remote resources similar to access to local resources
- Data Migration – transfer data by transferring entire file, or transferring only those portions of the file necessary for the immediate task
- Computation Migration – transfer the computation, rather than the data, across the system

## Distributed-Operating Systems (Cont.)

- Process Migration – execute an entire process, or parts of it, at different sites
  - Load balancing – distribute processes across network to even the workload
  - Computation speedup – subprocesses can run concurrently on different sites
  - Hardware preference – process execution may require specialized processor
  - Software preference – required software may be available at only a particular site
  - Data access – run process remotely, rather than transfer all data locally

# Distributed Network Topology



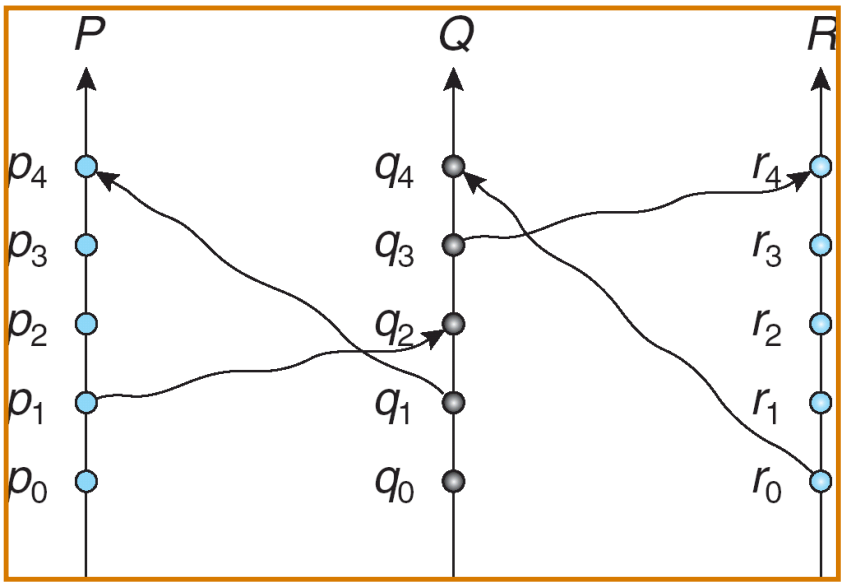

# Distributed Coordination

- Ordering events and achieving synchronization in centralized systems is easier.
  - We can use common clock and memory
- What about distributed systems?
  - No common clock or memory
  - *happened-before* relationship provides partial ordering
  - How to provide total ordering?

# Event Ordering

- Happened-before relation (denoted by $\rightarrow$)
  - If *A* and *B* are events in the same process (assuming sequential processes), 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 $A \rightarrow C$
  - If two events A and B are not related by the $\rightarrow$ relation, then these events are executed concurrently.

# Relative Time for Three Concurrent Processes

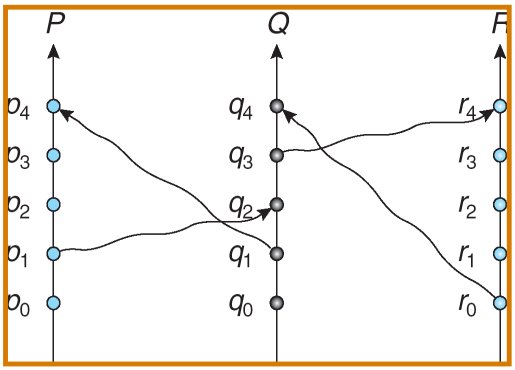



Which events are concurrent and which ones are ordered?

# Exercise

Which of the following event orderings are true?

(a) p0 --> p3 :
(b) p1 --> q3 :
(c) q0 --> p3 :
(d) r0 --> p4 :
(e) p0 --> r4 :




Which of the following statements are true?

(a) p2 and q2 are concurrent processes.
(b) q1 and r1 are concurrent processes.
(c) p0 and q3 are concurrent processes.
(d) r0 and p0 are concurrent processes.
(e) r0 and p4 are concurrent processes.



# Implementation of →

- Associate a timestamp with each system event
  - Require that for every pair of events A and B, if A → B, then the timestamp of A is less than the timestamp of B
- Within each process Pi, define a **logical clock**
  - The logical clock can be implemented as a simple counter that is incremented between any two successive events executed within a process
    - Logical clock is **monotonically increasing**
- A process advances its logical clock when it receives a message whose timestamp is greater than the current value of its logical clock
  - Assume A sends a message to B, $LC_1(A)=200$, $LC_2(B)=195$ --> $LC_2(B)=201$
- 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 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
  - Example: P1 sends a request to P2 and P3 (timestamp=10)
    P3 sends a request to P1 and P2 (timestamp=4)

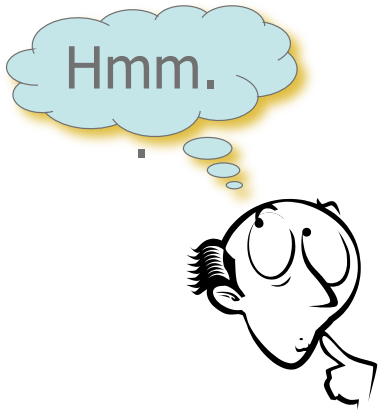
## Undesirable Consequences

- 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, and notifying all processes if a process fails

## Token-Passing Approach

- Circulate a token among processes in system
  - **Token** is special type of message
  - Possession of token entitles holder to enter critical section
- Processes *logically* organized in a **ring structure**
- Unidirectional ring guarantees freedom from starvation
- Two types of failures
  - Lost token – election must be called
  - Failed processes – new logical ring established

## Any Questions?



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