Distributed Computation

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Outline

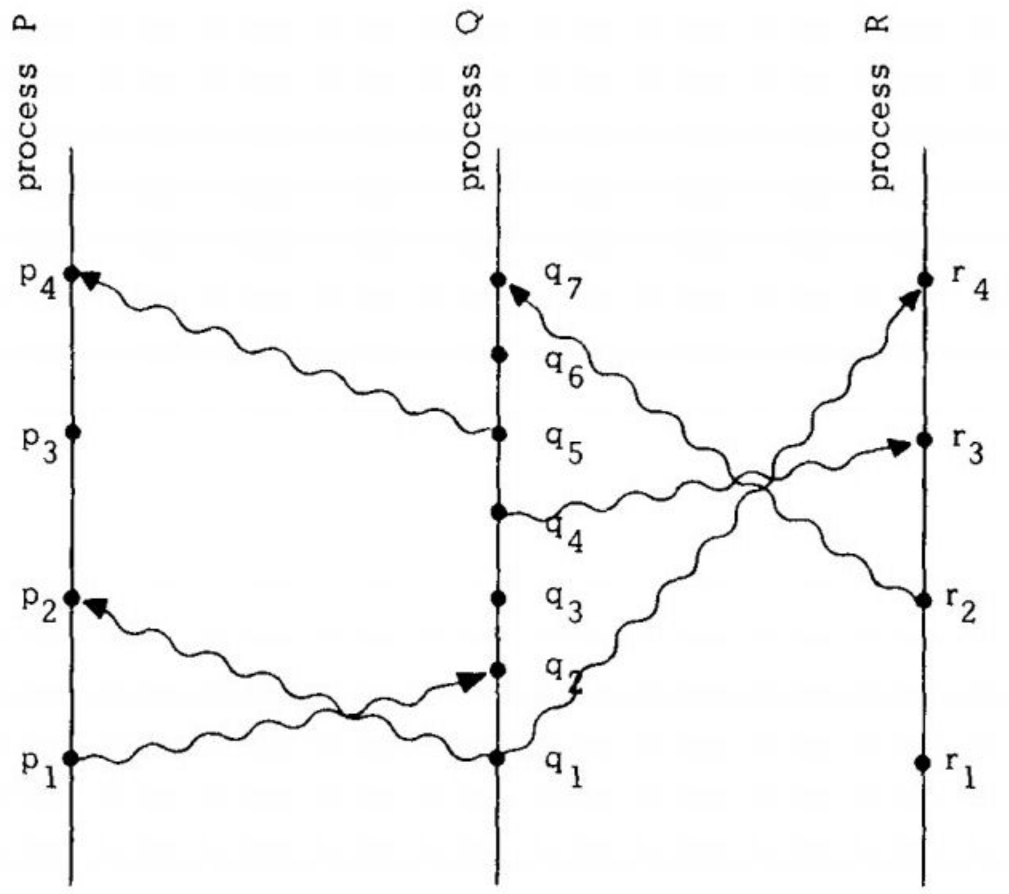
- *Time, Clocks, and the Ordering of Events in a Distributed System* by Leslie Lamport
- *Consistent Global States of Distributed Systems: Fundamental Concepts and Mechanisms* by Ozalp Babaoglu and Keith Marzullo

Distributed Sytem

- "A system is distributed if the message transmission delay is not negligible compared to the time between events in a single process."
- Spacitally separated computers
  - Multiprocessing on a single machine is similar to a distributed system but with negligible delays

Partial Order

- Process: a seqeunce of ordered events
- "Happened before" relationship (->)
  - "casually affect" relationship
- Concurrency: cannot tell which event happens first



Logical Clocks

- A function that assigns a value to each event on every process
- Clock Condition: For any events a, b: if a -> b then C(a) < C(b)
- Implementation Rules
  - At least a clock tick between two events on one process
  - Each message contains the timestamp when it was sent. Receiving event sets the clock value >= current time and > recevied timestamp

Total Order

- New “happens before” (=>) breaks the tie for concurrent events in partial order
  - Maintains the partial order relationship
  - Breaks the tie by comparing processes when two clock values are equal

Use Case: Synchronization

- Problem
  - Multiple processes request one resource
  - Only one process hold the resource at a time
  - FIFO
  - Process will relase the resource; all requests would be granted
- Assumption
  - Requests from the same process are received in the order of sent
  - Requests are broadcasted
  - All requests will be received

Algorithm

- Each process maintains a request queue initially containing T_0:P_0
- A process broadcasts T_m:P_i to request for the resource
- Upon receiving a request, the request is added to the request queue and a timestamped response is sent
- Process P_i releases a resource by removing T_m:P_i from its request queue and broadcasts release resource
- When receiving release reource, a process removes the corresponding requests from the request queue
- Resource is granted when
  - There is no other requests happening before the request
  - Response later than the request timestamp has been received from other process

Anomalous Behavior

- Late messages can have smaller timestamp than earlier messages and the receiver cannot tell
- Strong clock condition (**->**)
- Logical clocks no longer work, need physical clocks
- Physical clock conditions
  - $\left|\frac{dC}{dt} - 1\right| < \kappa, \kappa \ll 1$
  - $|C_i(t) - C_j(t)| < \epsilon$
  - $a \rightarrow b$ then b is at least μ later than a
- $\frac{\epsilon}{(1-\kappa)} \leq \mu$

Distributed System States

- Each process can be considered as a state machine
- A monitor process monitors other process states
- The global state is the union of all process states
- A wait-for graph can be a format of the global state used to detect deadlock
- Measuring global state from messages can be inconsistent

Distributed Snapshot

- Snapshot means taking pictures of current process states
- Assuming each process has in-channels and out-channels
- For systems with physical clocks, inconsistency can be avoided by scheduling snapshots far enough in the future
- For systems with logical clocks, snapshots happen when receiving messages to do so.
- Non-monitor process records its state and notifies out processes, then it record messages of in processes

Discussion

- What’s the benefit of snapshot protocol 3 over snapshot protocol 2?