Ordering & Consistent Cuts

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Overview

- Same Author
  - complementary view on similar but different subjects
- Rigorous representation of distributed computation

Question

- Does this matter in implementations?
- Does this matter at all?

Terms

- Distributed System
- Distributed Computation

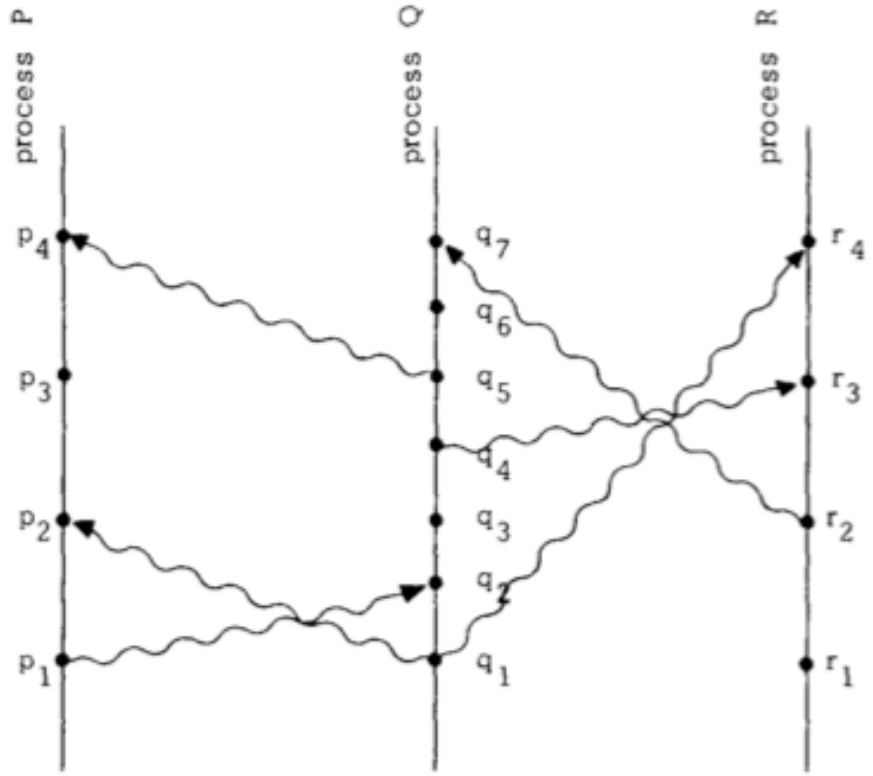
Terms

- Global State
- Stable Property

Order

- Relation to Time
- In a Distributed System

Distributed System



Happened Before

- Denoted $\rightarrow$
- Relation over Events
- Partial Order (Irreflexive)

Happened Before

- For 2 Events a & b, a→b if
  - a comes before b in the same process
  - a sends a message received by b

Happened Before

- Otherwise $a \nrightarrow b$
  - Always $a \nrightarrow a$
- If $a \nrightarrow b$ & $b \nrightarrow a$
  - a & b are Concurrent

Logical Clocks

- Monotonically Increasing Integer Counter
- $C_i\langle a\rangle < C_j\langle b\rangle$ if $a \rightarrow b$

Logical Clocks

- C_i is incremented between 2 events in P_i
- Upon receiving message with timestamp T_m, C_j is set to a value $> T_m$ & $\geq C_j$ current

Total Ordering

- $a \Rightarrow b$ if
  - $C_i\langle a\rangle < C_j\langle b\rangle$
  - $C_i\langle a\rangle = C_j\langle b\rangle$ and $P_i < P_j$

Application

- Mutual Exclusion Problem
- Single Resource
- Requests Granted In Order
- Completes

Sideband Problem

- Logical Clocks may not always agree with intuitive notions of order
- External Events are Ignored

Physical Clocks

- $C_i(t)$ is the reading of clock C_i at time t
- For All i,j $|C_i(t) - C_j(t)| < \epsilon$

Global State

- Restrict slightly the notion of a distributed system
  - messages must be delivered in order

Channels

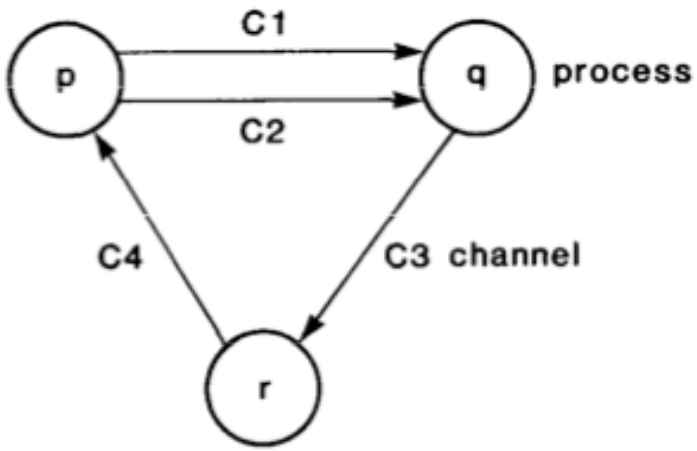


Fig. 1. A distributed system with processes p, q, and r and channels c1, c2, c3, and c4.

Global State

- Single Token Conservation System
- Consistency

Snapshot

- A Consistent Global State
- The only way to check for Stable Properties

Consistent States

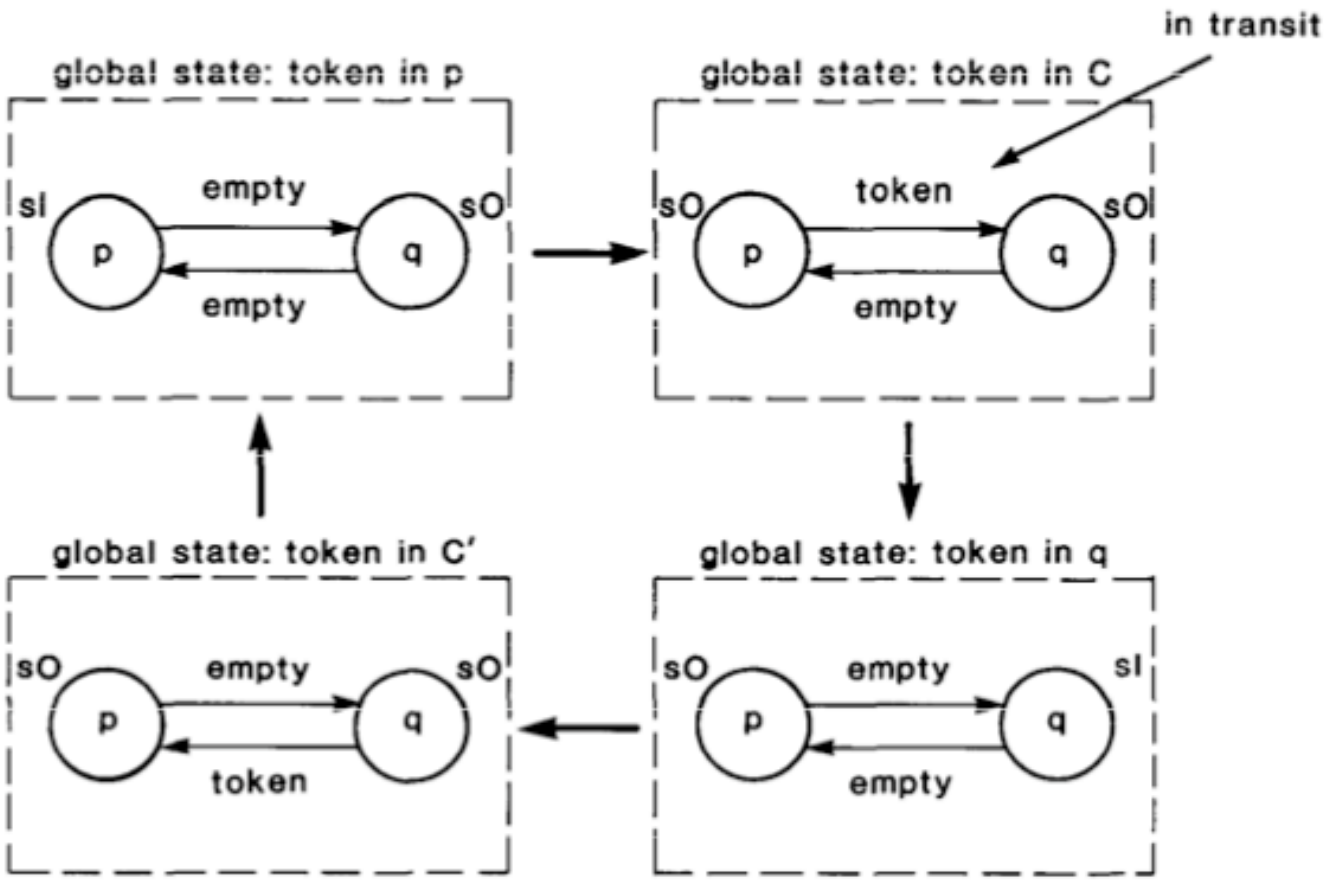


Fig. 4. Global states and transitions of the single-token conservation system.

Recording

- Each process records its own state
- Both processes on a channel record the state of the channel
- Ordering?

Recording Algorithm

- Ensure that messages only appear once in the global state
  - avoid recording a message at multiple processes
  - avoid recording a message at a process and in a channel

Recording Algorithm

- Initiated by some process deciding to record its state
- Terminates when all processes have recorded their states

Recording Algorithm

- Use marker
- After recording state, send marker on all incident, outgoing channels

Recording Algorithm

- On receiving marker
  - Record state of process if not yet done
  - Otherwise, record state of channel which marker came on

Recorded Global State

- May not have happened at the same time
- But could have

Recorded Global State

- The recorded Global State S* is reachable from the initial Global State and the final Global State is reachable from it
- There exists a permutation of the actual computation which does contain S*

Stability Detection

- Record the Global State
- Apply the given predicate to the Global State
- Return value of TRUE means property holds at termination of recording
- Return value of FALSE means that property does not hold at initiation of recording

Summary

- Elegant, provable properties of distributed systems.
- Unquestionably helpful for reasoning about distributed systems

Summary

- Practical for real implementations?
- Scalable to geographically large systems and / or high number of processes?

Summary

- Is relaxing the same ideas even helpful for designing larger scale / higher performance systems?