Distributed Snapshots: Determining Global States of Distributed Systems

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About the Authors

- **K. Mani Chandy**
- University of Texas at Austin
- Now CS Professor at CalTech.
- Proposed new solution to Dining Philosophers Problem

- **Leslie Lamport**
- Stanford Research Inst.
- Now with Microsoft Research
- Won Turing Award in 2013

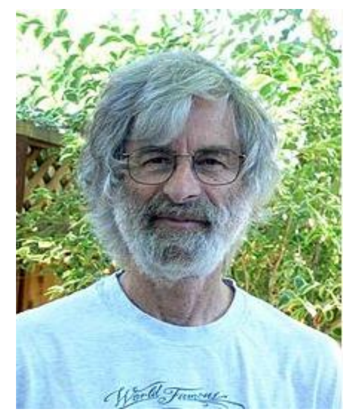


Image Source: Google images and Wikipedia

Interesting Facts

- **How the Snapshot Algorithm came to be?**
- → Wine and Dine!!!

- **Awards**
- Edsger W. Dijkstra Prize in Distributed Computing, 2014
- American Academy of Arts and Sciences, 2014
- ACM SIGOPS Hall of Fame Award, 2013

What is a Global State?

- "The global state of a distributed computation is the set of local states of all individual processes involved in the computation plus the state of the communication channels."

Why is there a need for Global State?

- Helps solve important class of problem: *Stable Property Detection*.

- **Examples**
  - computation has terminated
  - system deadlock
  - all tokens in a token ring have disappeared

Problems associated with determining global states in distributed systems?

- **Distributed systems**
  - information is spread across multiple systems
- **Local Knowledge**
  - a process in the computation only know its own state

Problems associated with determining global states in distributed systems?

- **Synchronized recording**
  - processes do not share common clocks

What is a Snapshot?

- Ex. Group of photographers observing a panoramic, dynamic scene

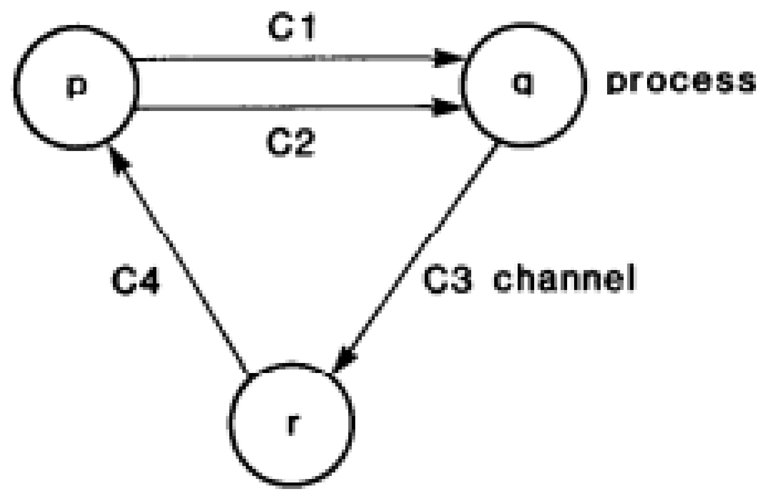


- Composite picture should be “Meaningful”

Image Source: http://www.upside-down.ca/cherry-oxford.jpg

Model of a Distributed System

- Processes: Finite
- Channels: Finite, infinite buffers, error-free, ordered delivery (FIFO)



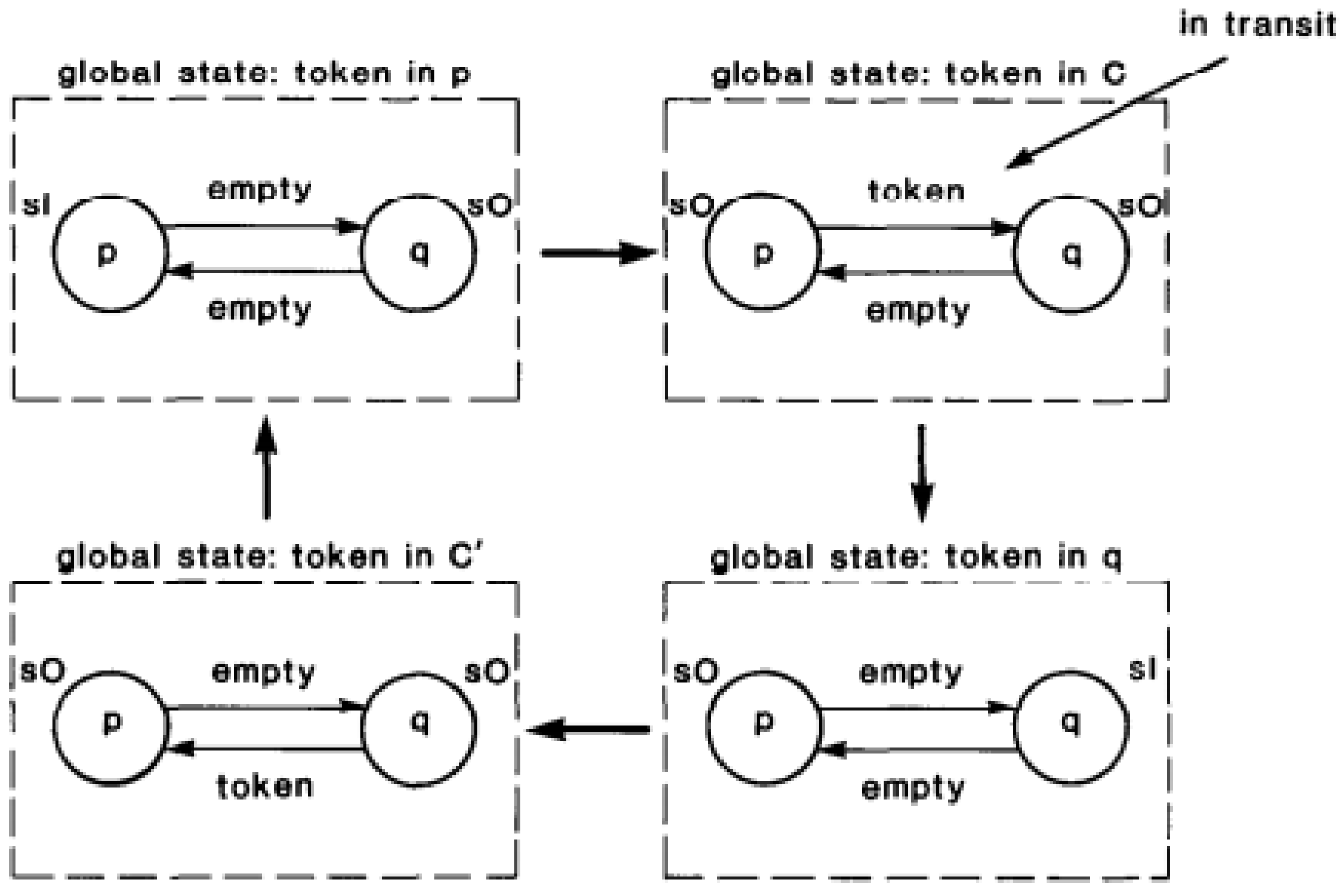
Model of a Distributed System: What is an Event?

Event e if defined by:

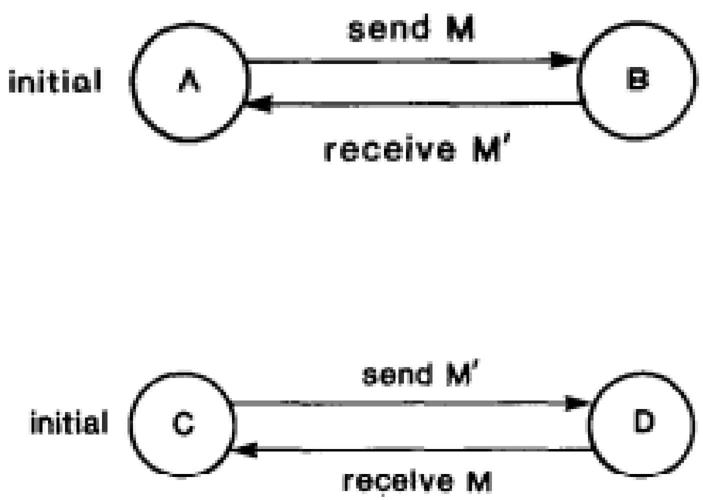
1. Process p in which event occurs
2. State s of p immediately before the event
3. State s’ of p immediately after the event
4. Channel c
5. Message M sent along c

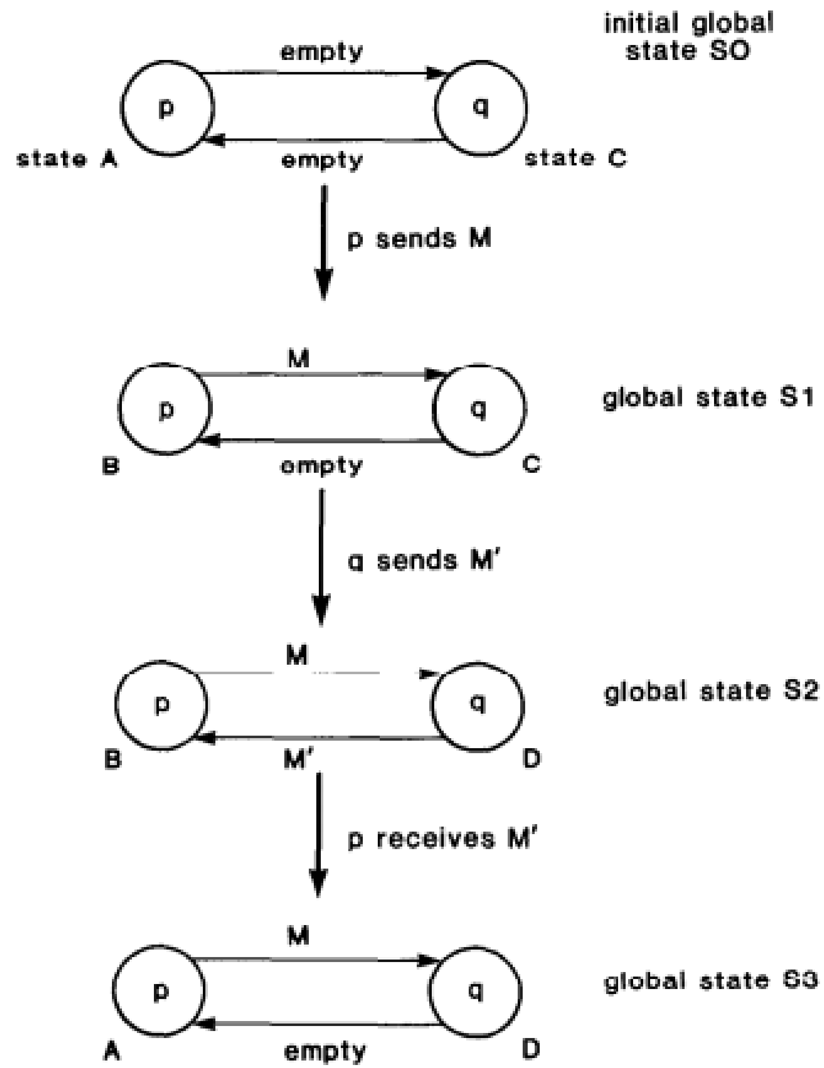
- Defined by 5-tuple <p, s, s’, M, c>

Model of a Distributed System: Single-token conservation system



Model of a Distributed System: Non Deterministic Computation

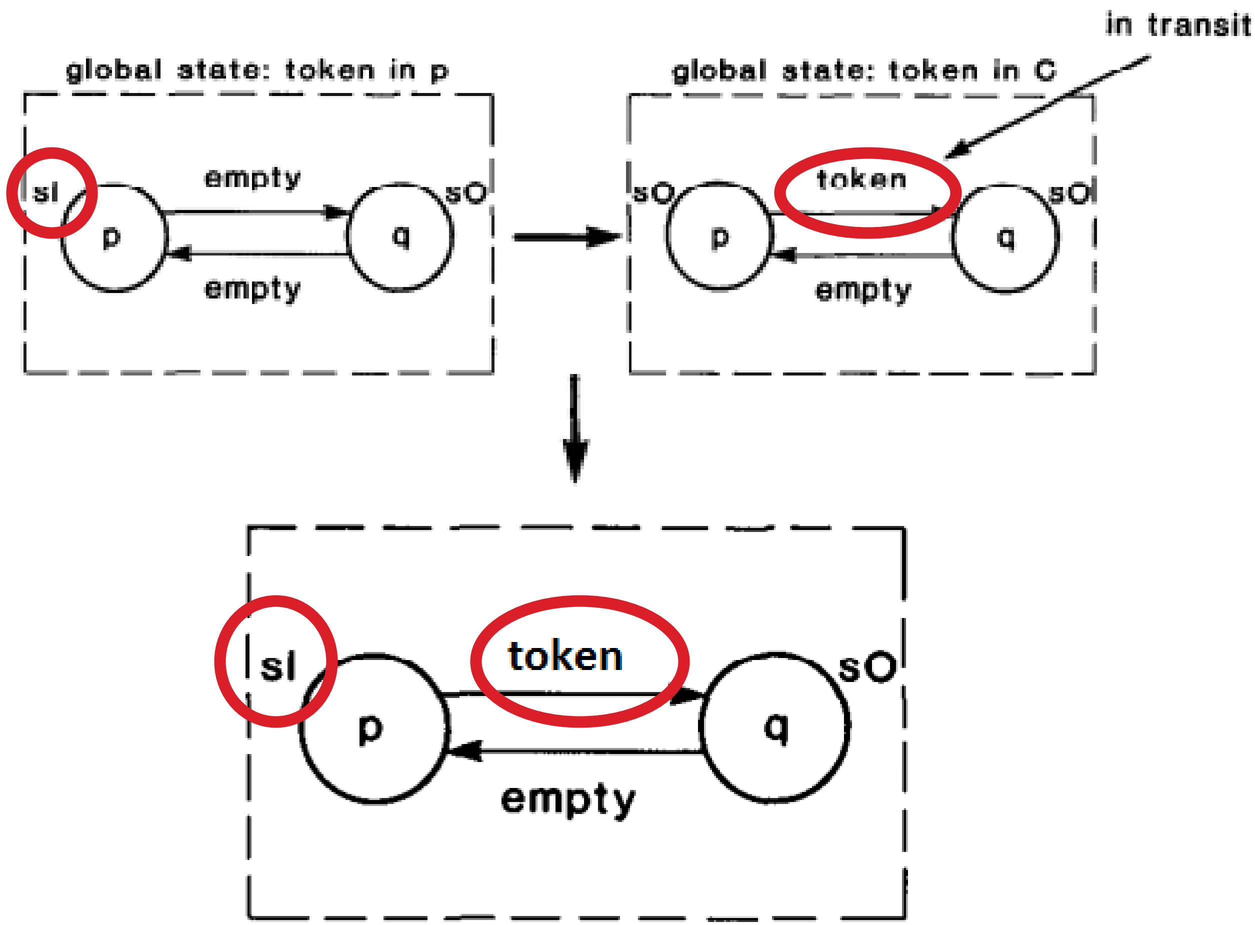




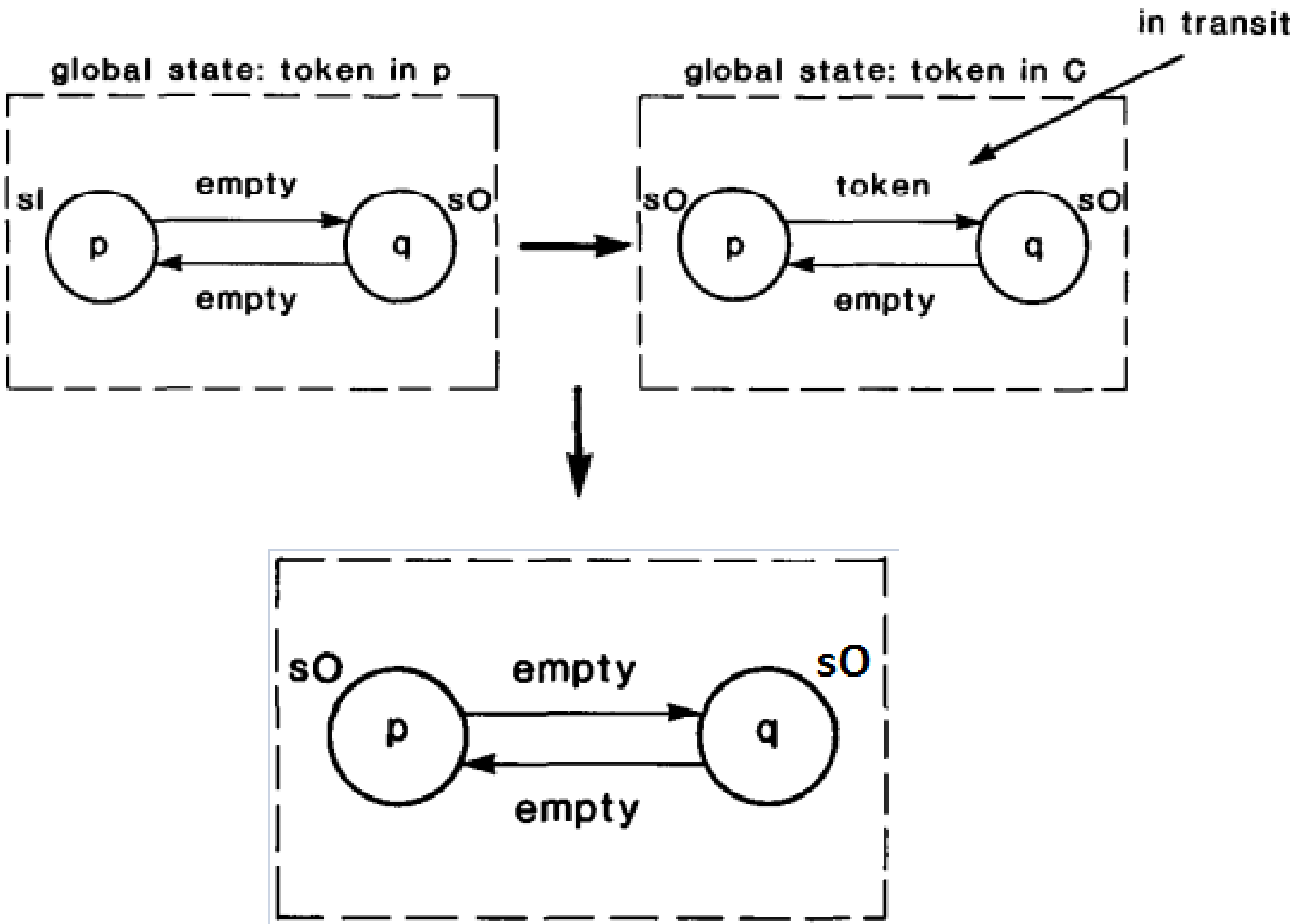
Snapshot Algorithm

- The global-state recording algorithm is superimposed on underlying computation without interfering with the underlying computation

Snapshot Algorithm: Single-token system, Scenario 1 (2 tokens)



Snapshot Algorithm: Single-token system, Scenario 2 (No tokens)



Snapshot Algorithm

- Inconsistency in 2-token problem

  $n < n'$
- Inconsistency in No token problem

  $n > n'$
- To ensure consistent global state

  $n = n'$

n = #messages sent along c before p's state is recorded

n' = #messages sent along c before c's state is recorded

Snapshot Algorithm

- Similarly,

  $$m = m'$$

m = #messages received along c before q's state is recorded

m' = #messages received along c before c's state is recorded

In every state,

$$n' \geq m'$$

Which implies

$$n \geq m$$

Snapshot Algorithm: Marker

- Process p sends special message called "*marker*" along c, after the nth message and before sending further messages

- Marker has no effect on underlying computation

Snapshot Algorithm

- Marker-Sending Rule for process p:

  p sends one marker along c after p records its own state and before p sends further messages along c

- Marker-Receiving Rule for process q:

  if q has not recorded its state

  begin q records its state

  q records the state c as empty sequence

  end

  else q records the state of c as the sequence of messages received along c after q's state is recorded and before q receives marker along c

Snapshot Algorithm Overview

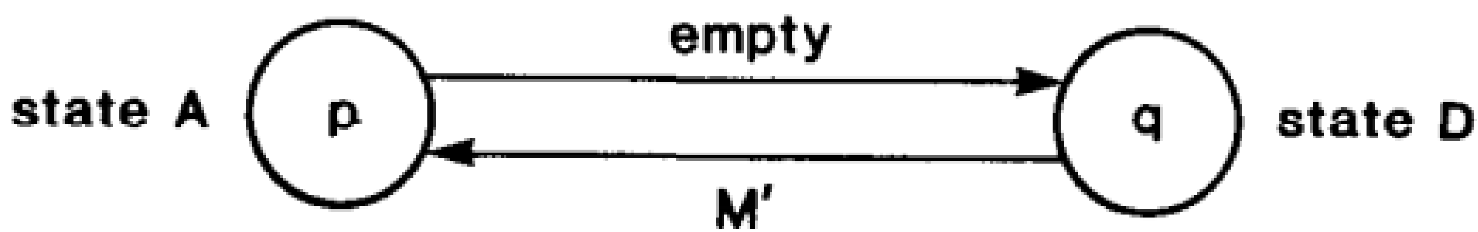
- Initiator (process p)
  - save its local state
  - send marker tokens along channel
- Other processes (process q)
  - on receiving first marker, save state and propagate markers along outgoing channels
- Terminate algorithm after every process saves its state

Snapshot Algorithm: Example

- p records global state in $S_{0,}$ state A
- p sends marker along c
- System goes to global state S_1, S_2, and S_3 while marker is in transit
- Marker received by q in global state S_3
- q records its state, state D
- q records state c to be empty space
- After recording its state, q sends marker along c'
- On receiving marker, p records state of c' as message M'

Snapshot Algorithm: Example

- Recorded global state S*
- Algorithm is initiated in global state S_0 and terminated in global state S_3



- Global state S* is not identical to any of the global states S_0, S_1, S_2, S3

Properties of Snapshot Algorithm

- S* is reachable from initial global states
- Final global state is reachable from S*
- y(S) → y(S') for all S' (stable property definition)

References

[1] “Distributed Snapshots: Determining Global States of Distributed Systems, K. Mani Chandy and Leslie Lamport, ACM Transcations on Computer Systems, Feb 1985

[2] “Global States of a Distributed System”, Michael J. Fischer, 1981 IEEE

[3] http://research.microsoft.com/en-us/um/people/lamport/pubs/pubs.html

Thank you!