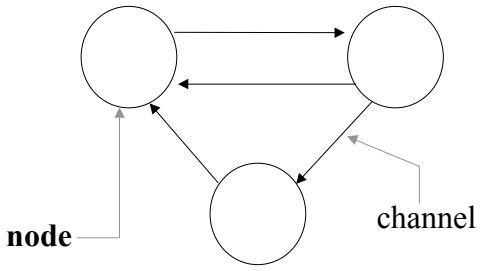
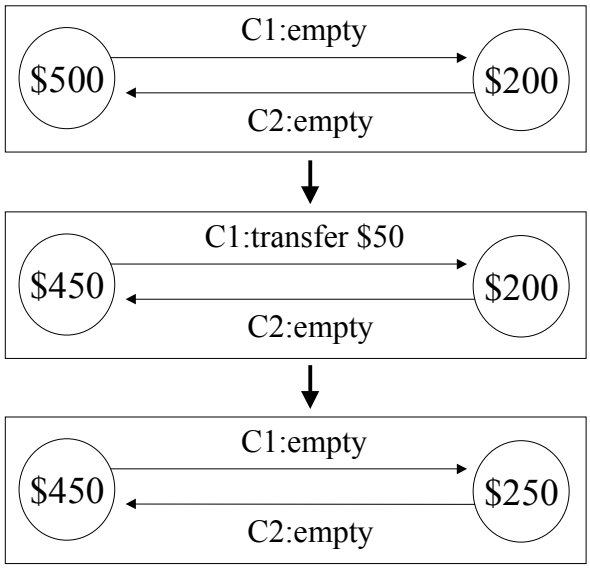
The Model



Node properties
- No shared memory
- No global clock

Channel properties:
- FIFO
- loss free
- non-duplicating

The Problem



Distributed Snapshot
(Global State Recording)

Problems:

- recording a "consistent" state of the global computation
  - checkpointing for fault tolerance (rollback, recovery)
  - testing and debugging
  - monitoring and auditing
- detecting stable properties in a distributed system via snapshots. A property is "stable" if, once it holds in a state, it holds in all subsequent states.
  - termination
  - deadlock
  - garbage collection

Definitions

Local State and Actions:

local state: LS_i

message send: $send(m_{ij})$

message receive: $rec(m_{ij})$

time: $time(x)$

$send(m_{ij}) \in LS_i$ iff $time(send(m_{ij})) < time(LS_i)$

$rec(m_{ij}) \in LS_j$ iff $time(rec(m_{ij})) < time(LS_j)$

Predicates:

$transit(LS_i, LS_j) =$

$\{m_{ij} \mid send(m_{ij}) \in LS_i \wedge !(rec(m_{ij}) \in LS_j)\}$

$inconsistent(LS_i, LS_j) =$

$\{m_{ij} \mid !(send(m_{ij}) \in LS_i) \wedge rec(m_{ij}) \in LS_j\}$

Consistent Global State:

$\forall i, \forall j : 1 <= i, j <= n :: inconsistent(LS_i, LS_j) = \Phi$

Global-State-Detection Algorithm

Marker-Sending Rule for a Process p:

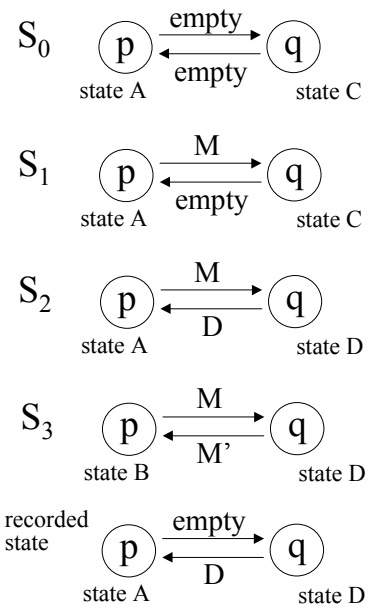
For each channel c, incident on, and directed away from p: p sends one marker along c after p records its state and before p send further messages along c.

Marker-Receiving Rule for a Process q:

if (q has not recorded its state) then
begin q records its state;
q records the state of c as the empty sequence;
end
else q records the state of c as the sequence of message received along c after q's state was recorded and before q received the marker along c.

Detecting a Stable Property

begin
record a global snapshot, S*;
test for the stable property in S*;
end;



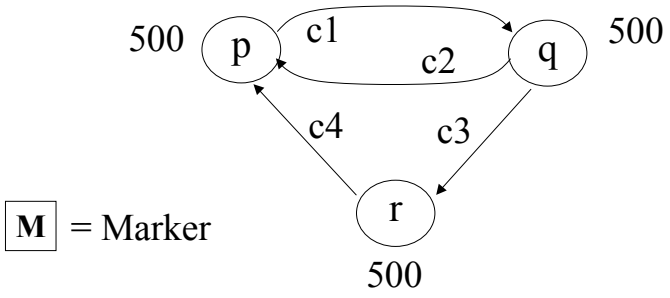
p records its state (A) and sends marker M on channel

before receiving the marker, q changes its state and sends message D.

q receives the marker and records its state (D) and the incoming channel as empty; q send marker M' on its outgoing channel.

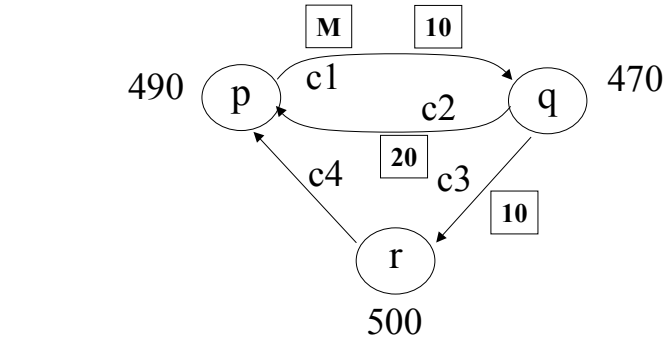
on receiving the marker, p records the channel as having D

Snapshot/State Recording Example



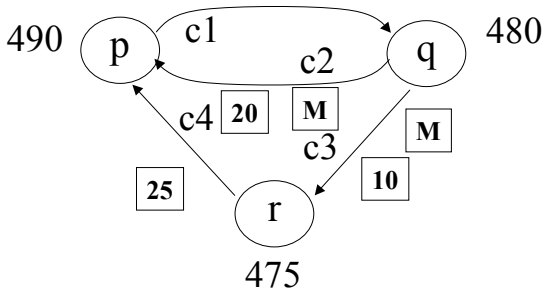
Node	Recorded state				
		c1	c2	c3	c4
p			{}		{}
q		{}			
r				{}	

Snapshot/State Recording Example (Step 1)



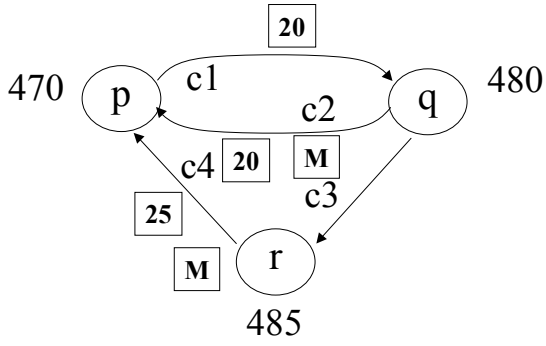
Node	Recorded state				
	state	c1	c2	c3	c4
p	490		{}		{}
q		{}			
r				{}	

Snapshot/State Recording Example (Step 2)



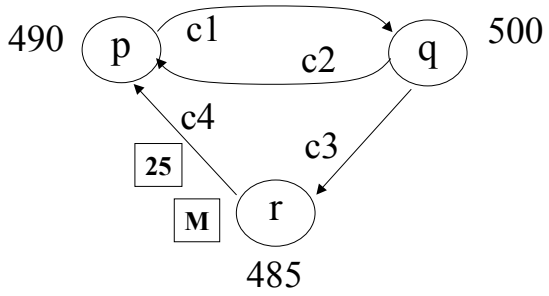
Node	Recorded state				
	state	c1	c2	c3	c4
p	490		{}		{}
q	480	{}			
r				{}	

Snapshot/State Recording Example (Step 3)



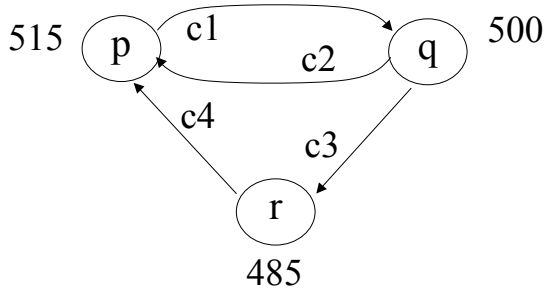
Node	Recorded state				
	state	c1	c2	c3	c4
p	490		{}		{}
q	480	{}			
r	485			{}	

Snapshot/State Recording Example (Step 4)



Node	Recorded state				
	state	c1	c2	c3	c4
p	490		{20}		{}
q	480	{}			
r	485			{}	

Snapshot/State Recording Example (Step 5)



Node	Recorded state				
	state	c1	c2	c3	c4
p	490		{20}		{25}
q	480	{}			
r	485			{}	