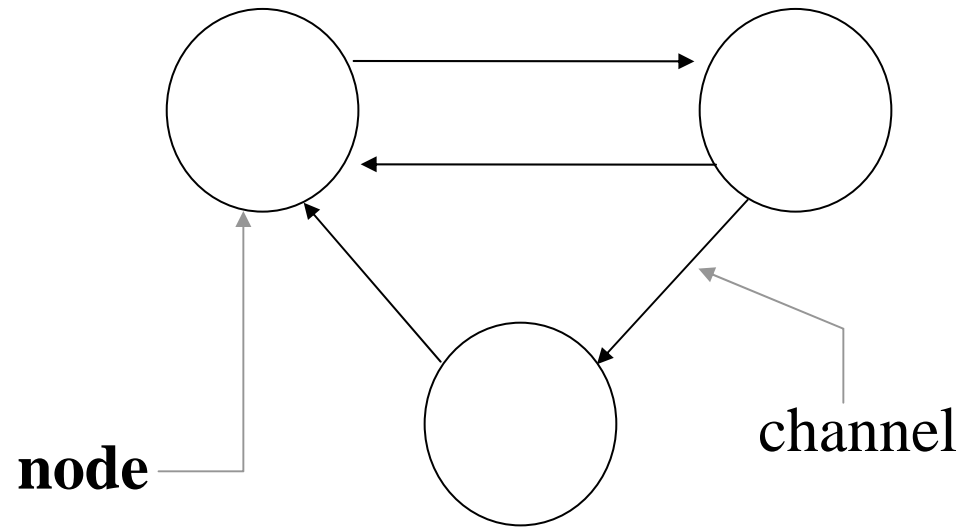


# The Model



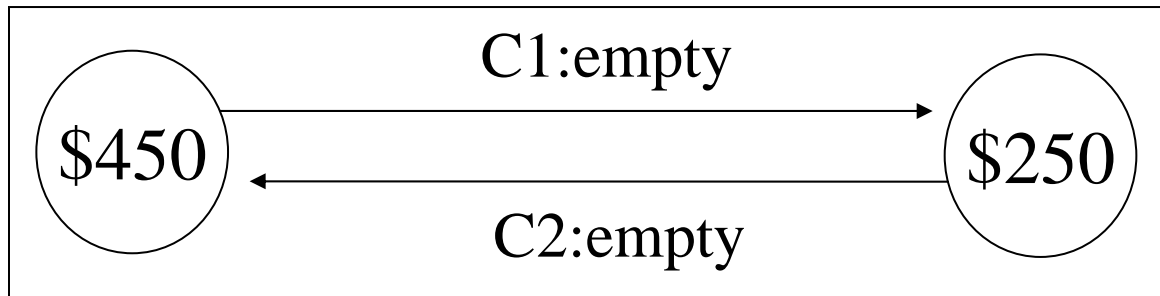
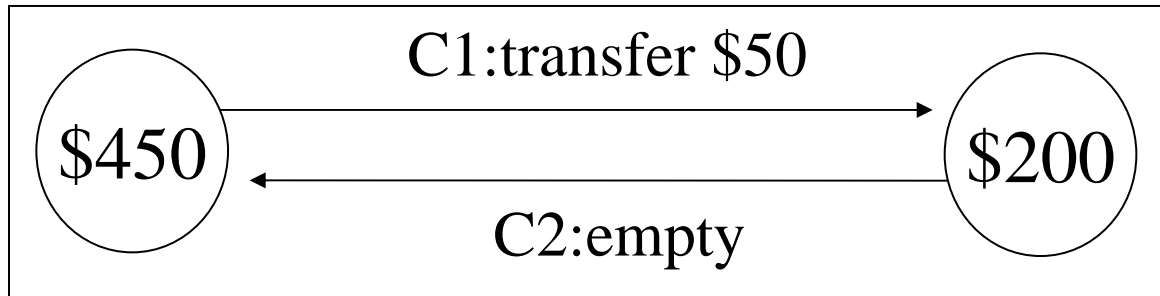
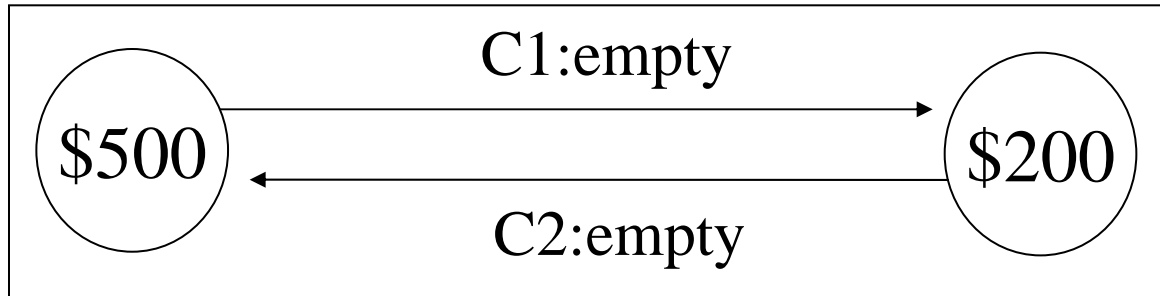
## Node properties:

- 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:

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

# 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  $p$  sends 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  $c$ .

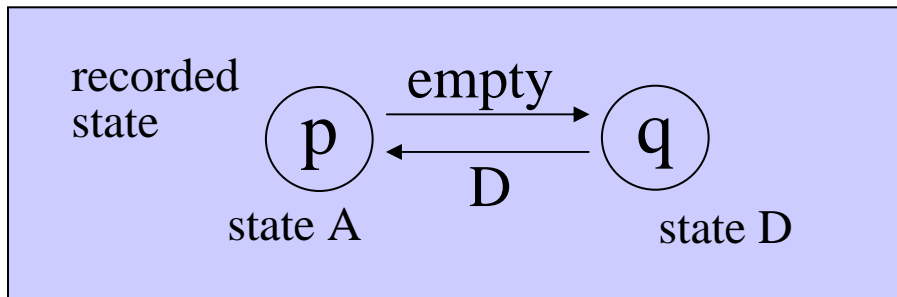
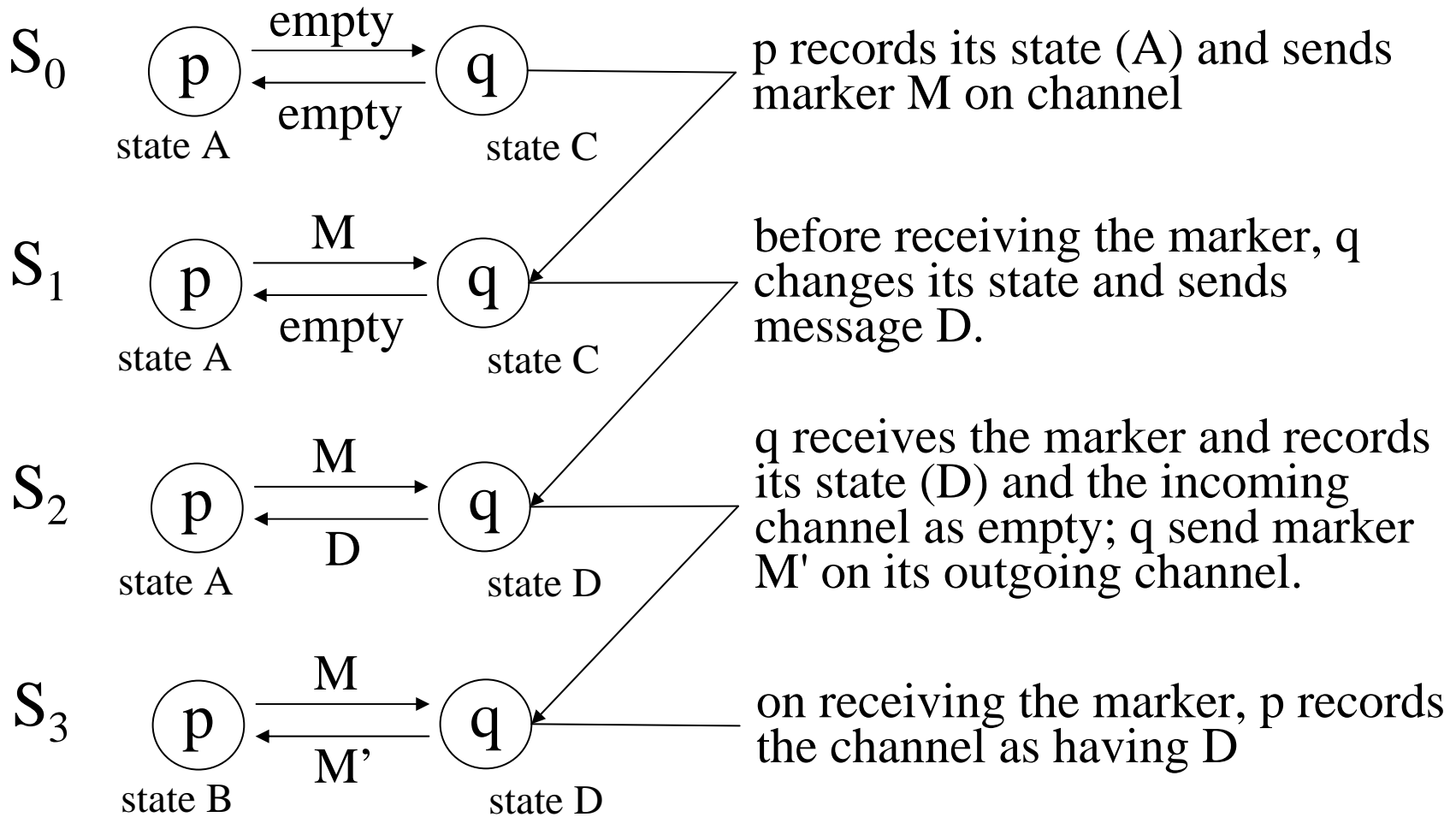
## Detecting a Stable Property

begin

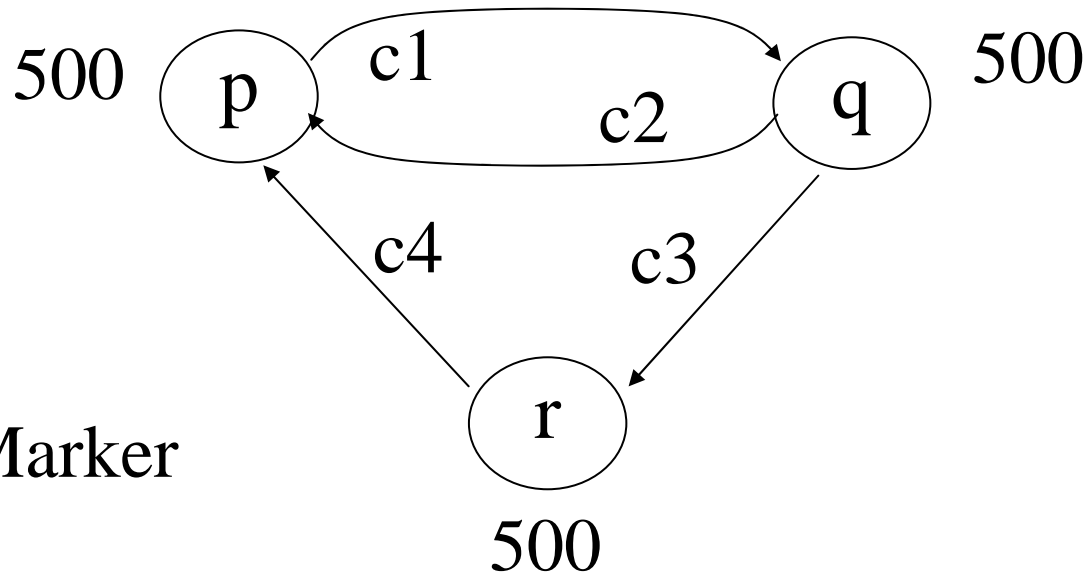
    record a global snapshot,  $S^*$ ;

    test for the stable property in  $S^*$ ;

end;



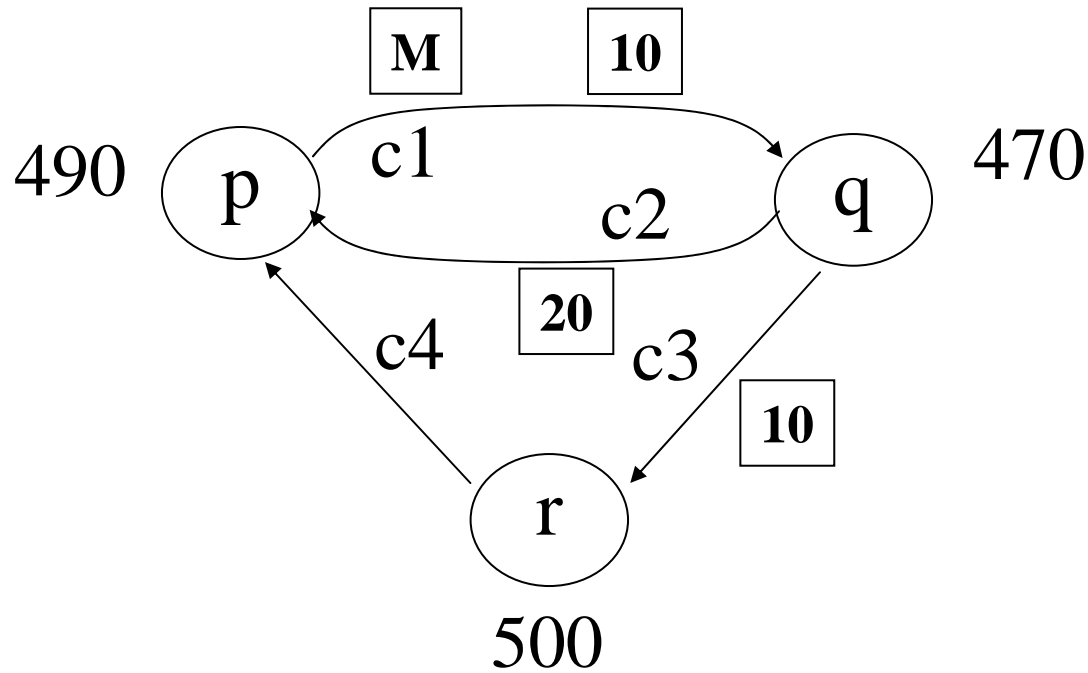
# Snapshot/State Recording Example



**M** = Marker

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

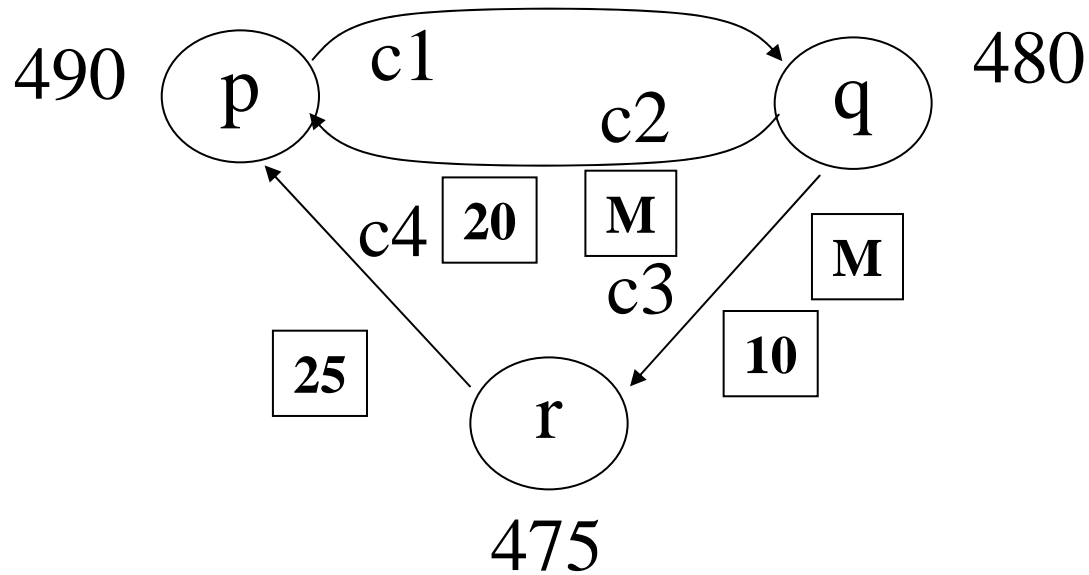
# Snapshot/State Recording Example (Step 1)



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

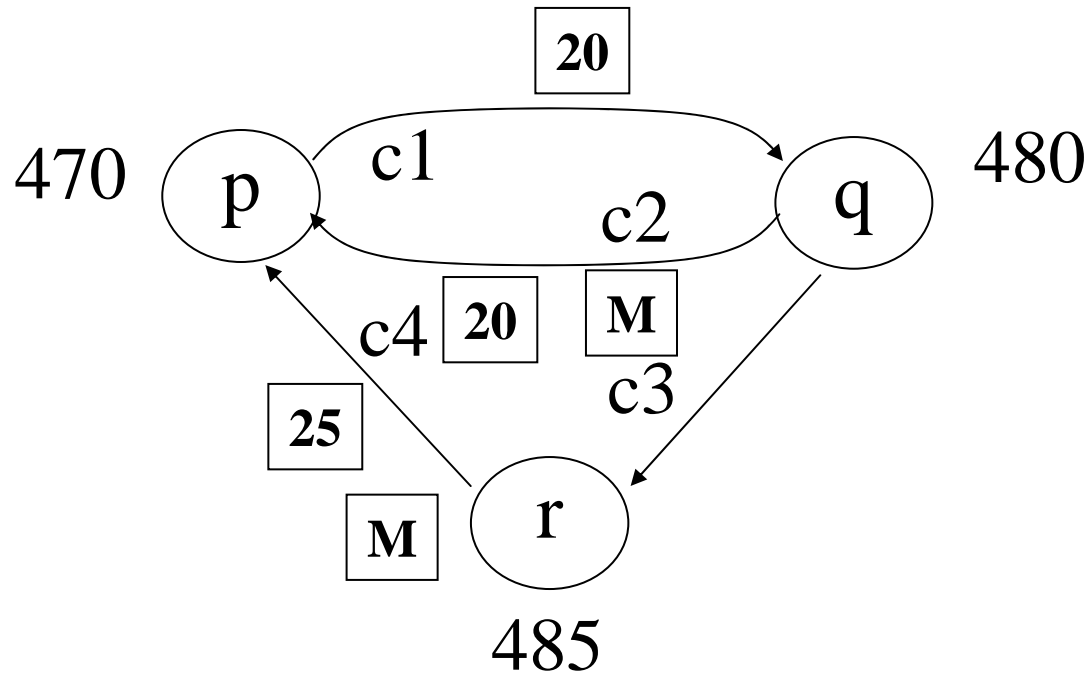


# Snapshot/State Recording Example (Step 2)



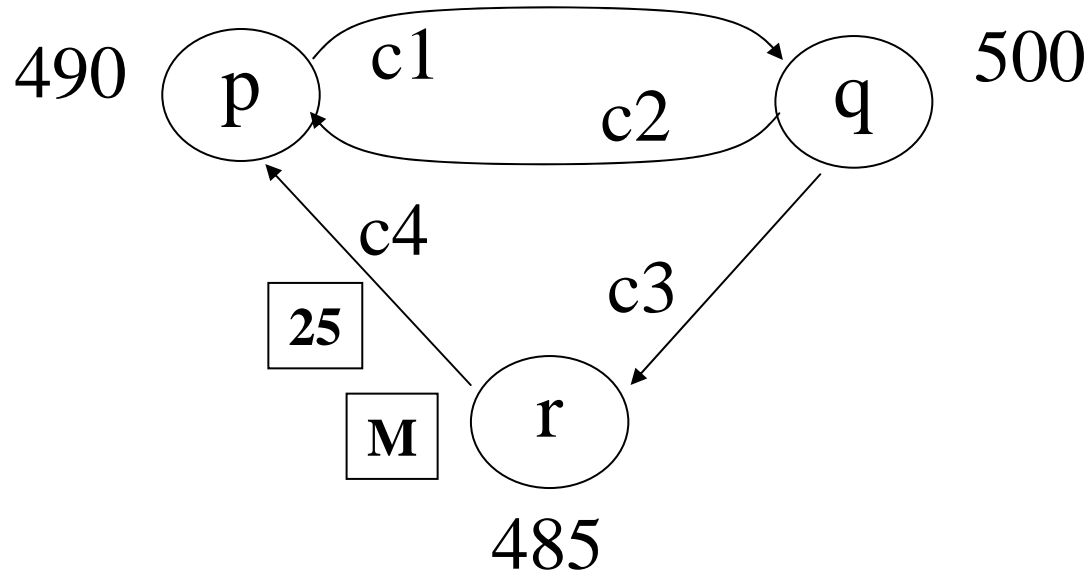
Node	Recorded state				
	state	c1	c2	c3	c4
p	490		{}		{}
q	480	{}			
r				{}	

# Snapshot/State Recording Example (Step 3)



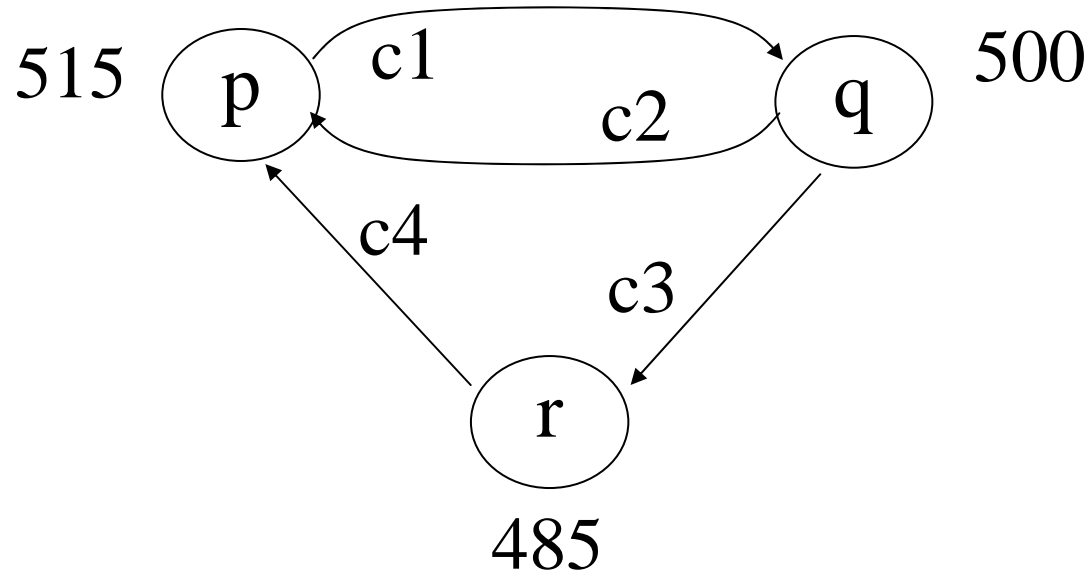
Node	Recorded state				
	state	c1	c2	c3	c4
p	490		{}		{}
q	480	{}			
r	485			{}	

# 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			{}	