Global States and Snapshots

Key Properties

- Multiple computers
  - Concurrent execution
  - Independent failures
  - Autonomous administrators
  - Heterogeneous capacities, properties
  - Large numbers (scalability)
- Networked communication
  - Asynchronous execution
  - Unreliable delivery
  - Insecure medium
- Common goal
  - **Consistency – can discuss whole-system properties**
  - Transparency – can use the system without knowing details

Outline

- Global States
  - Motivation
  - Definition
- Snapshots
  - Chandy-Lamport algorithm

Global State

- Want to find out a *global* property of the system
  - but can only make local observations at any time

Global State: Count

- Count the number of people in all EWS labs
- Option 1:
  - Go to each lab and count up people
  - Problems?
- Option 2:
  - Send one person to each lab to count
  - Problems?

Distributed Garbage Collection

- Newspaper on kitchen counter
  - Should you recycle it?
- Go to each roommate's room, ask if roommate done
  - When can you throw out the paper?
- Stable property
  - If someone says "not done", *may not* be safe to recycle
  - If everyone says "done", *must* be safe to recycle

Other Applications

- Detect other stable properties
  - Termination
  - Deadlock
- Save a checkpoint
  - Recover to a “known good” state

Process Histories and States

- For a process P_i , where events e_i^0, e_i^1, … occur:

  history(P_i) = h_i = $<e_i^0, e_i^1, \ldots >$

  prefix history(P_i^k) = h_i^k = $<e_i^0, e_i^1, \ldots, e_i^k >$

  S_i^k : P_i's state immediately after kth event

- For a set of processes P_1 , …,P_i , …. :

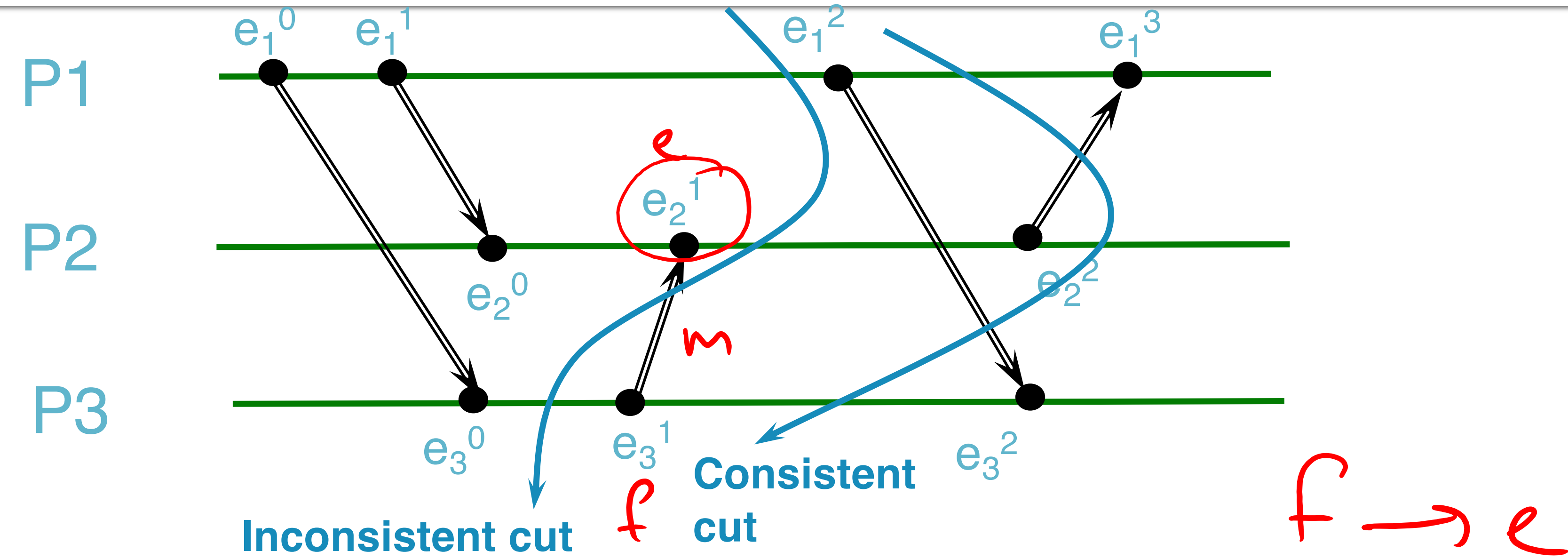
  global history: $H = \cup_i (h_i)$

  global state: $S = \cup_i (S_i^{ki})$

  a cut $C \subseteq H = h_1^{c1} \cup h_2^{c2} \cup \ldots \cup h_n^{cn}$

  the frontier of $C = \{e_i^{ci}, i = 1,2, \ldots n\}$

Consistent States



- A cut C is consistent if and only if

  $\forall e \in C$ (if $f \rightarrow e$ then $f \in C$)
- A global state S is consistent if and only if it corresponds to a consistent cut
- A consistent cut == a global snapshot

Consistent Snapshots

Snapshot: state $S_i^{T_i}$ of each process P_i at (local) time T_i

Consistent snapshot: any message m from P_i to P_j received by P_j at time t <= T_j must have been sent at time t' <= T_i

If $e_i^k \rightarrow e_j^l$ then either $l > T_j$ or $k <= T_i$

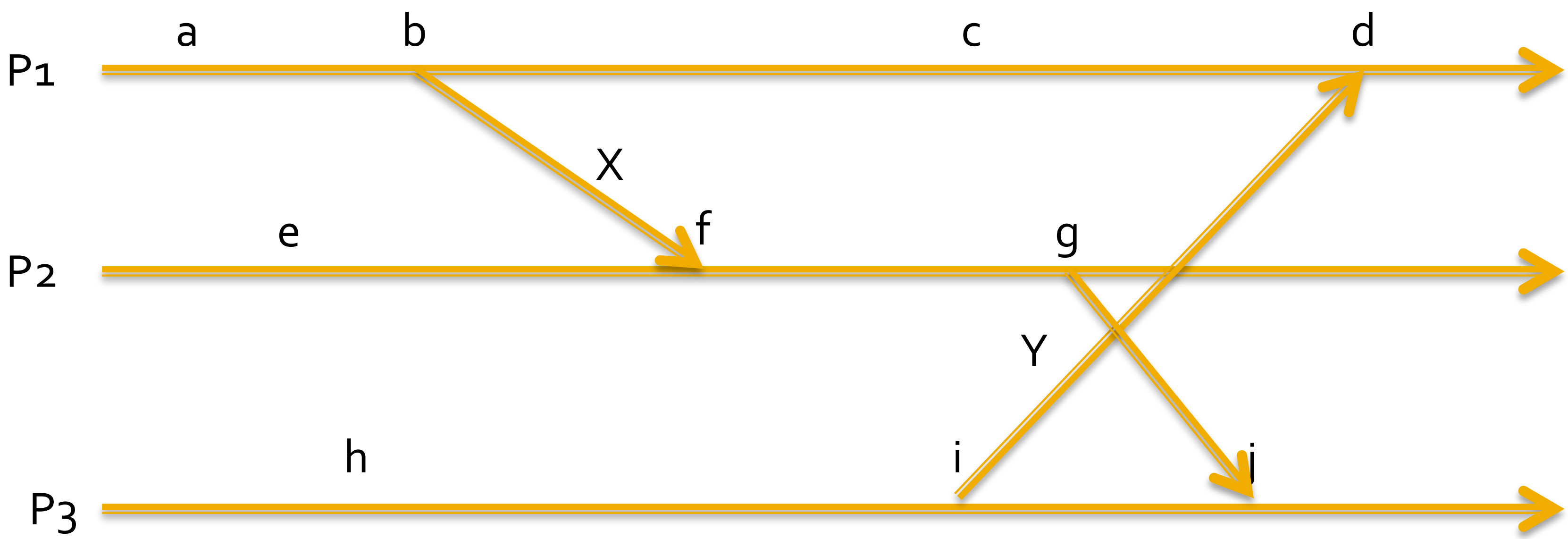
Chandy-Lamport Algorithm

- Goal: Record global snapshot
  - Process state
  - Channel state
  - Consistent cut
- System model
  - FIFO, reliable channels between any two processes
  - Each process records own state (no central collection)
  - Any process may initiate algorithm

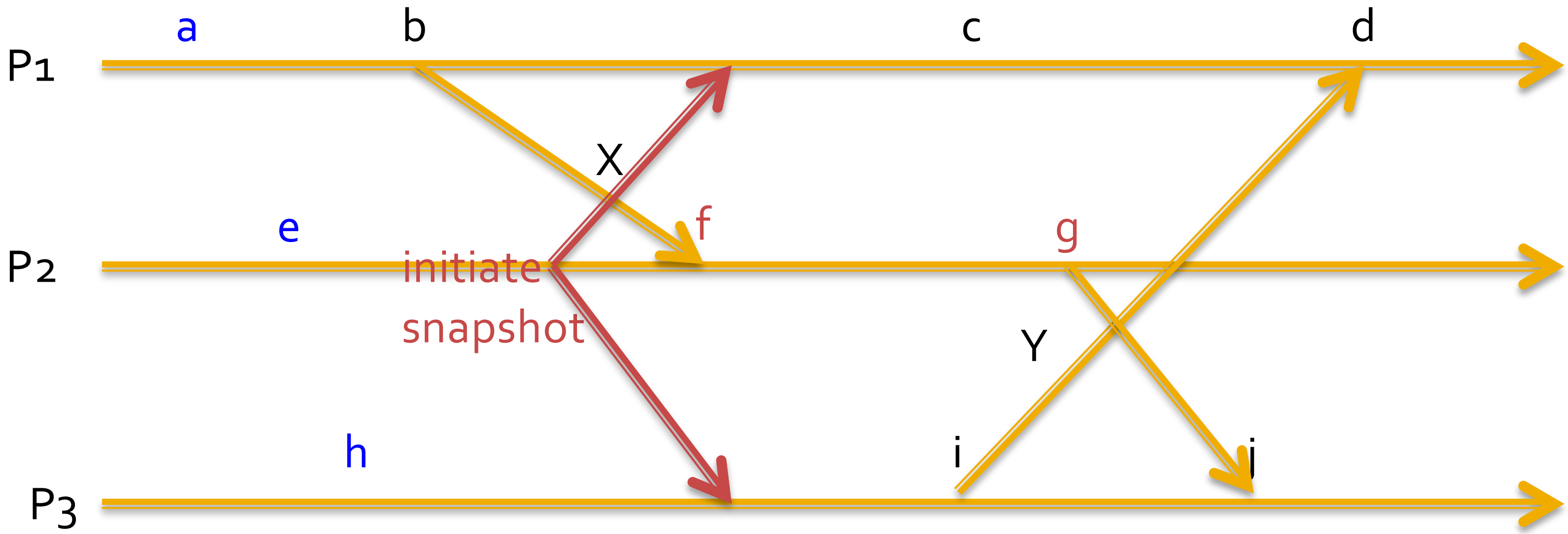
Contagion

- Two colors for processes / events / channels
  - Blue: before snapshot
  - Red: after snapshot
- To initiate:
  - Color self red
  - Send red marker to each other process
- When red marker received in blue state
  - Color self red
  - Send red marker to each other process

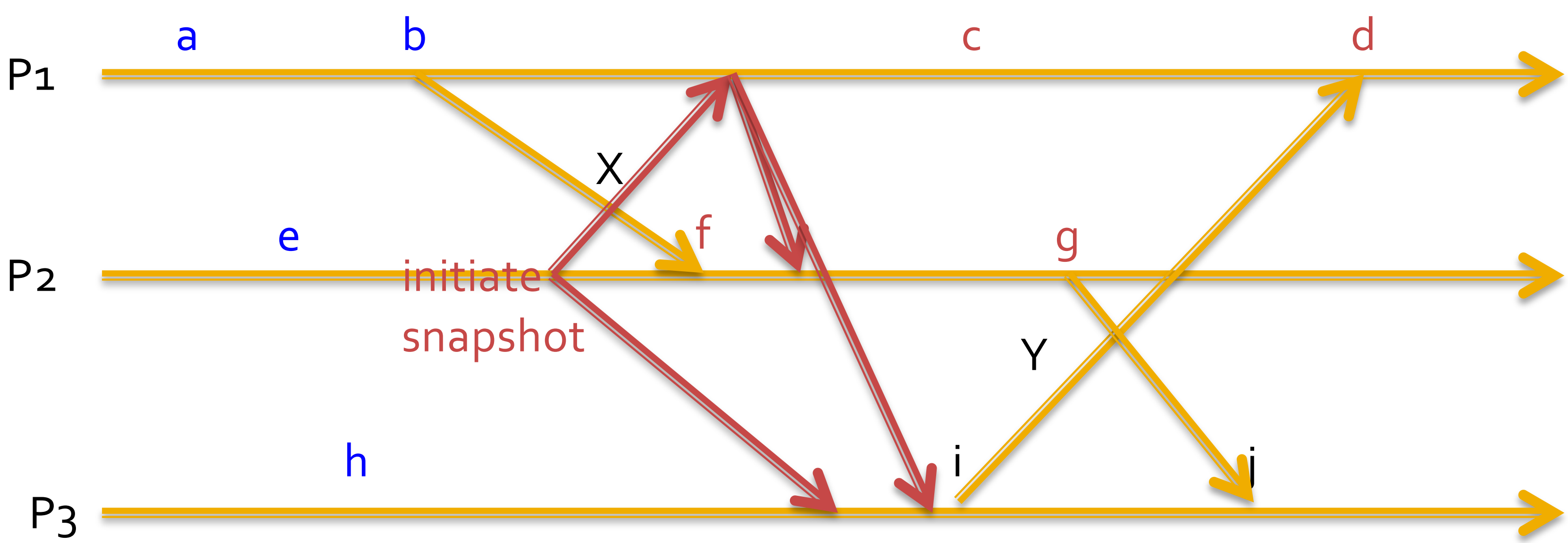
Example



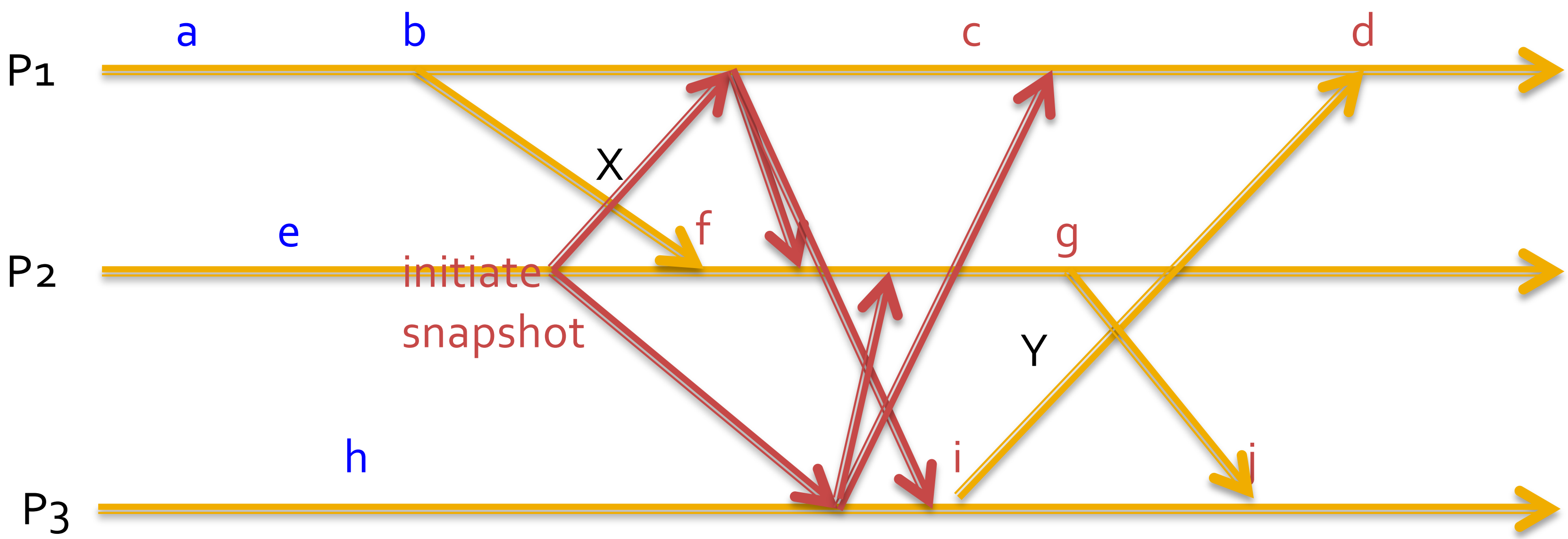
Example



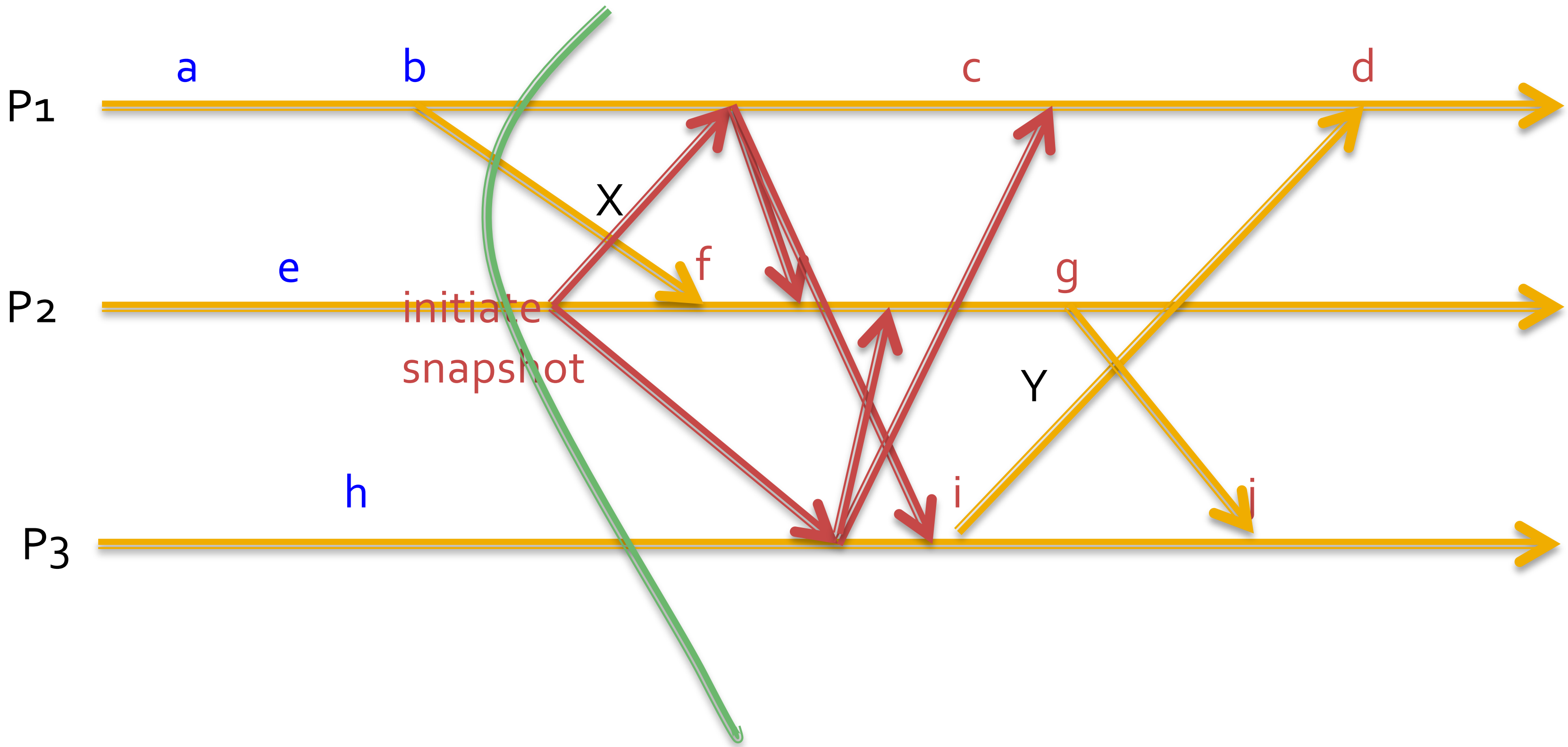
Example



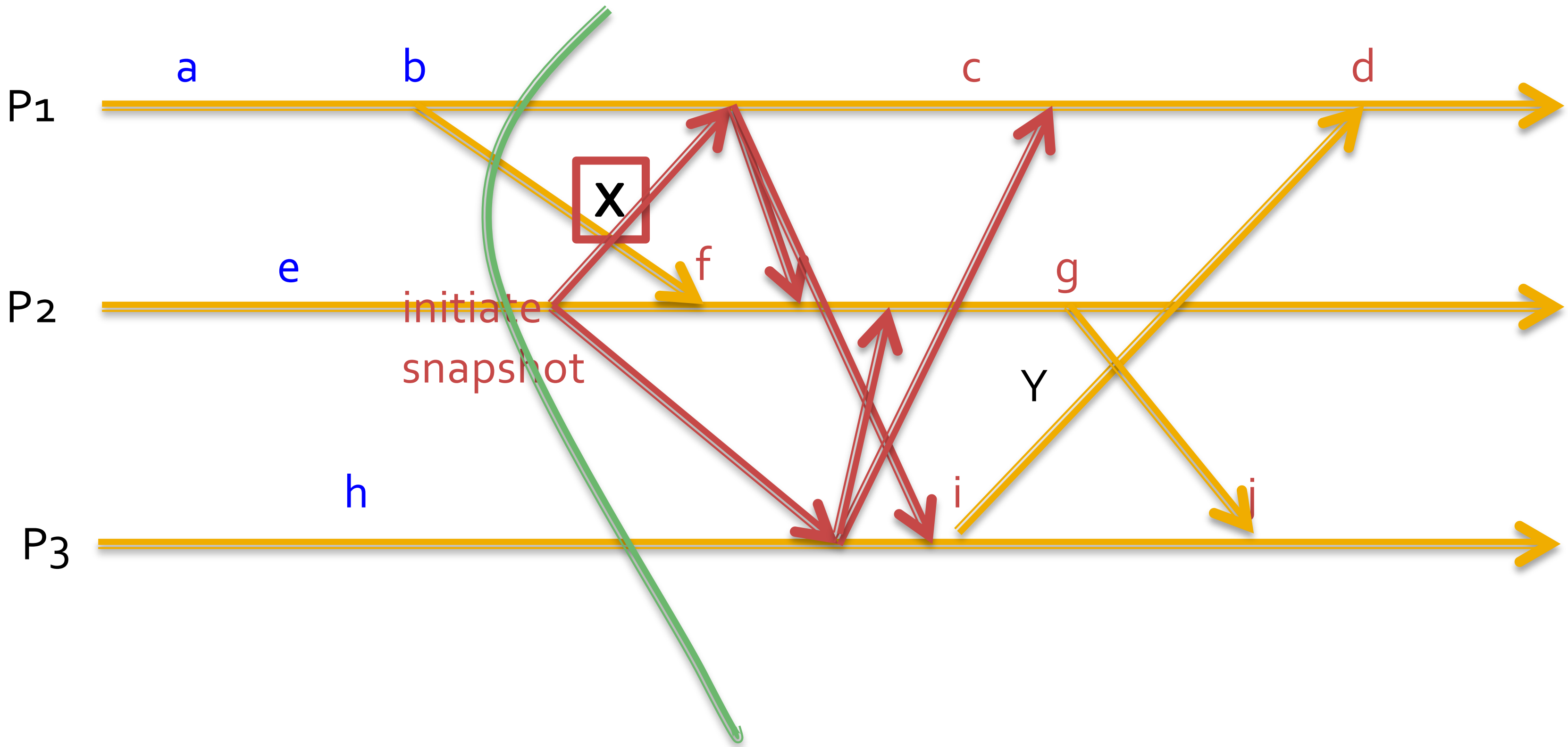
Example



Example



Example



Chandy and Lamport's 'Snapshot' Algorithm

Marker receiving rule for process p_i

On p_i's receipt of a *marker* message over channel c:

if (p_i has not yet recorded its state) it

records its process state now;

records the state of c as the empty set;

turns on recording of messages arriving over other incoming channels;

else

p_i records the state of c as the set of messages it has received over c since it saved its state.

end if

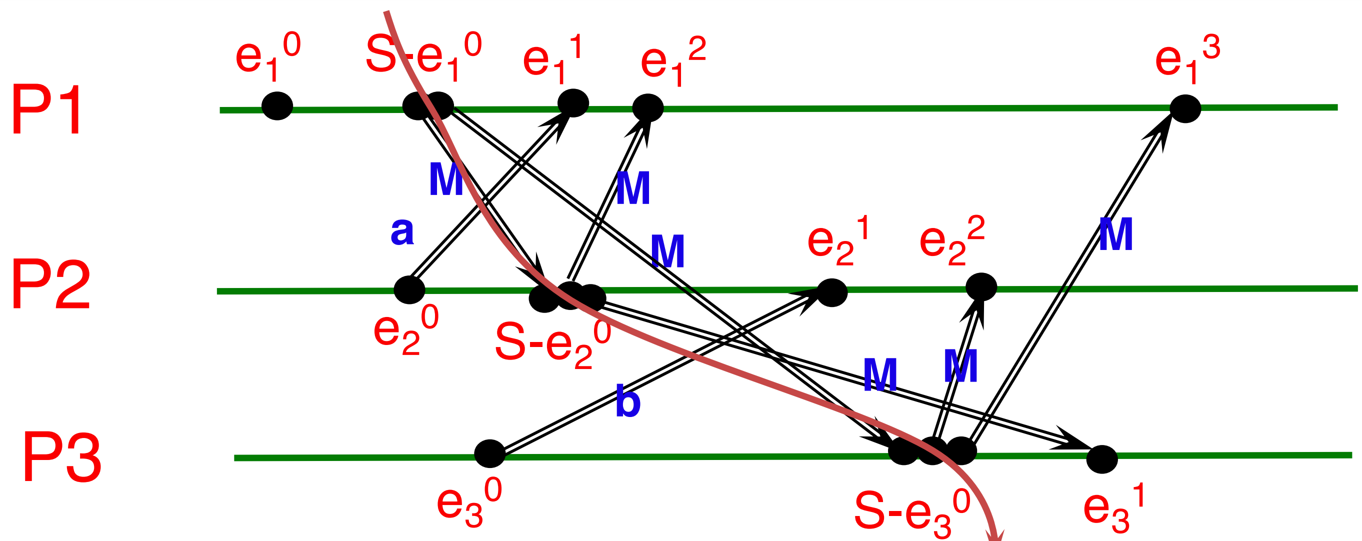
Marker sending rule for process p_i

After p_i has recorded its state, for each outgoing channel c:

p_i sends one marker message over c (before it sends any other message over c).

Note: initiating the snapshot is like receiving a marker from yourself

Snapshot Example



1- P1 initiates snapshot: records its state (S1); sends Markers to P2 & P3; turns on recording for channels C21 and C31

- 2- P2 receives Marker over C12, records its state (S2), sets state(C12) = {} sends Marker to P1 & P3; turns on recording for channel C32

- 3- P1 receives Marker over C21, sets state(C21) = {a}

4- P3 receives Marker over C13, records its state (S3), sets state(C13) = {} sends Marker to P1 & P2; turns on recording for channel C23

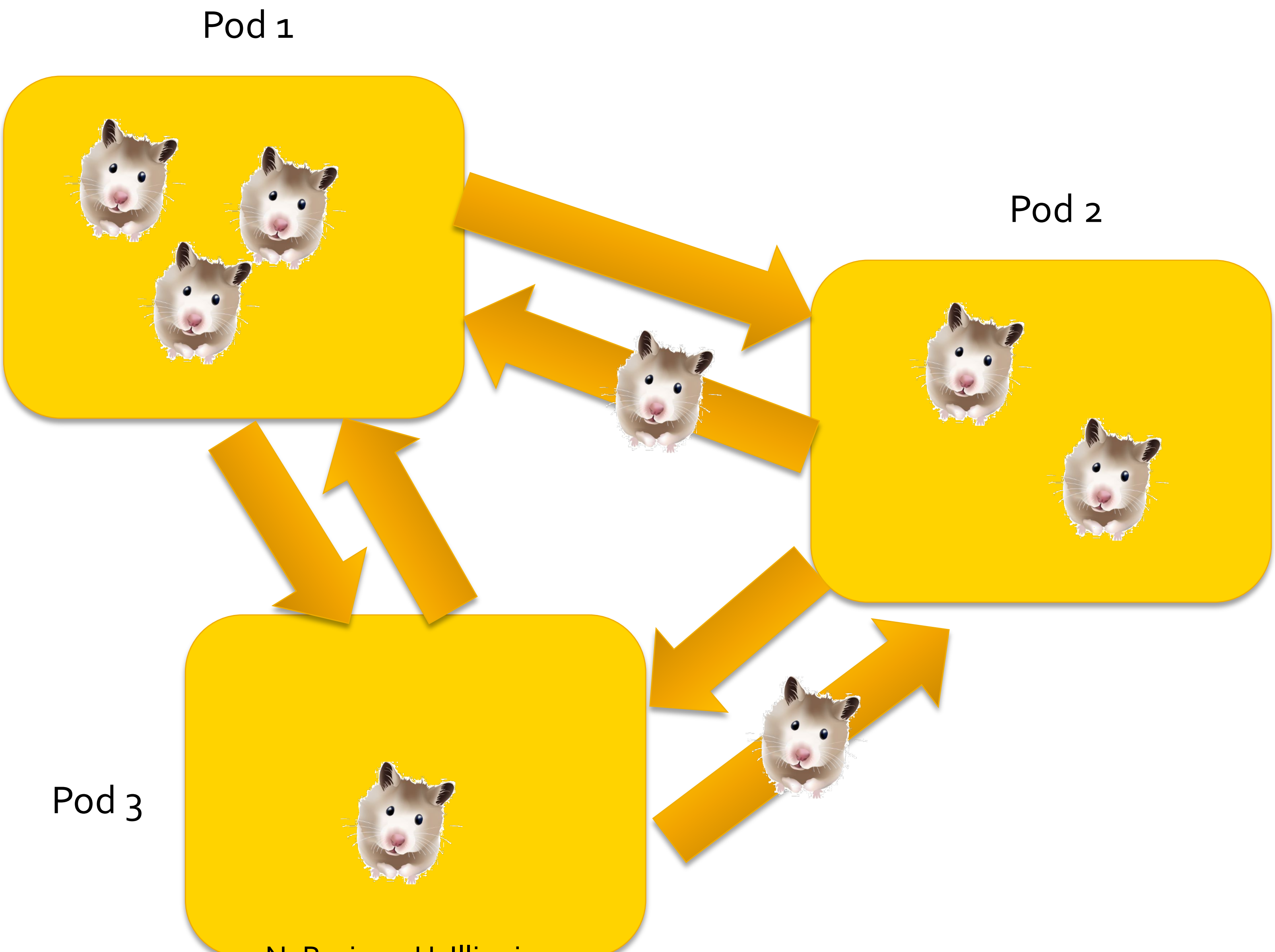
5- P2 receives Marker over C32, sets state(C32) = {b}

6- P3 receives Marker over C23, sets state(C23) = {}

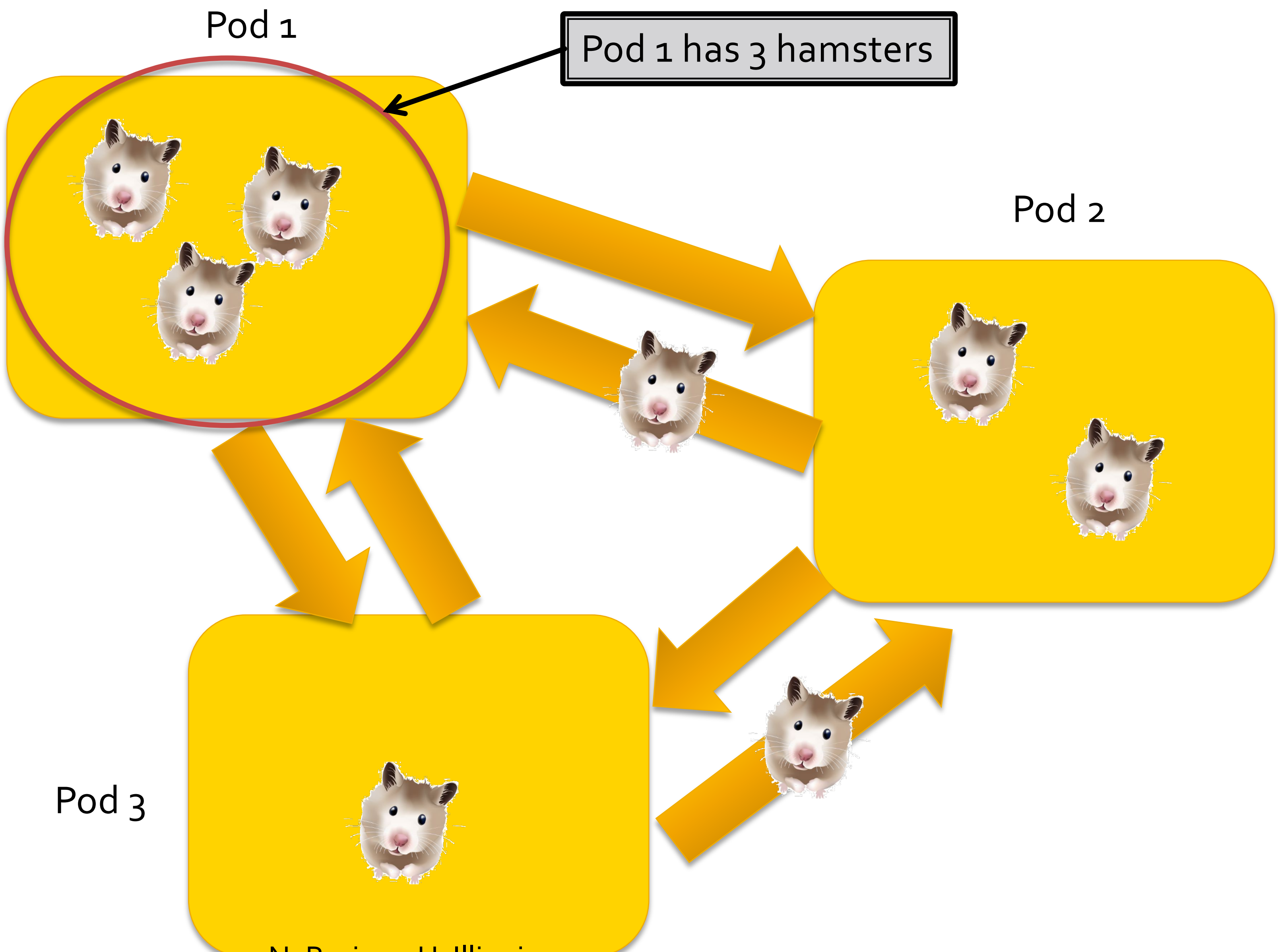
7- P1 receives Marker over C31, sets state(C31) = {}

Habitrail

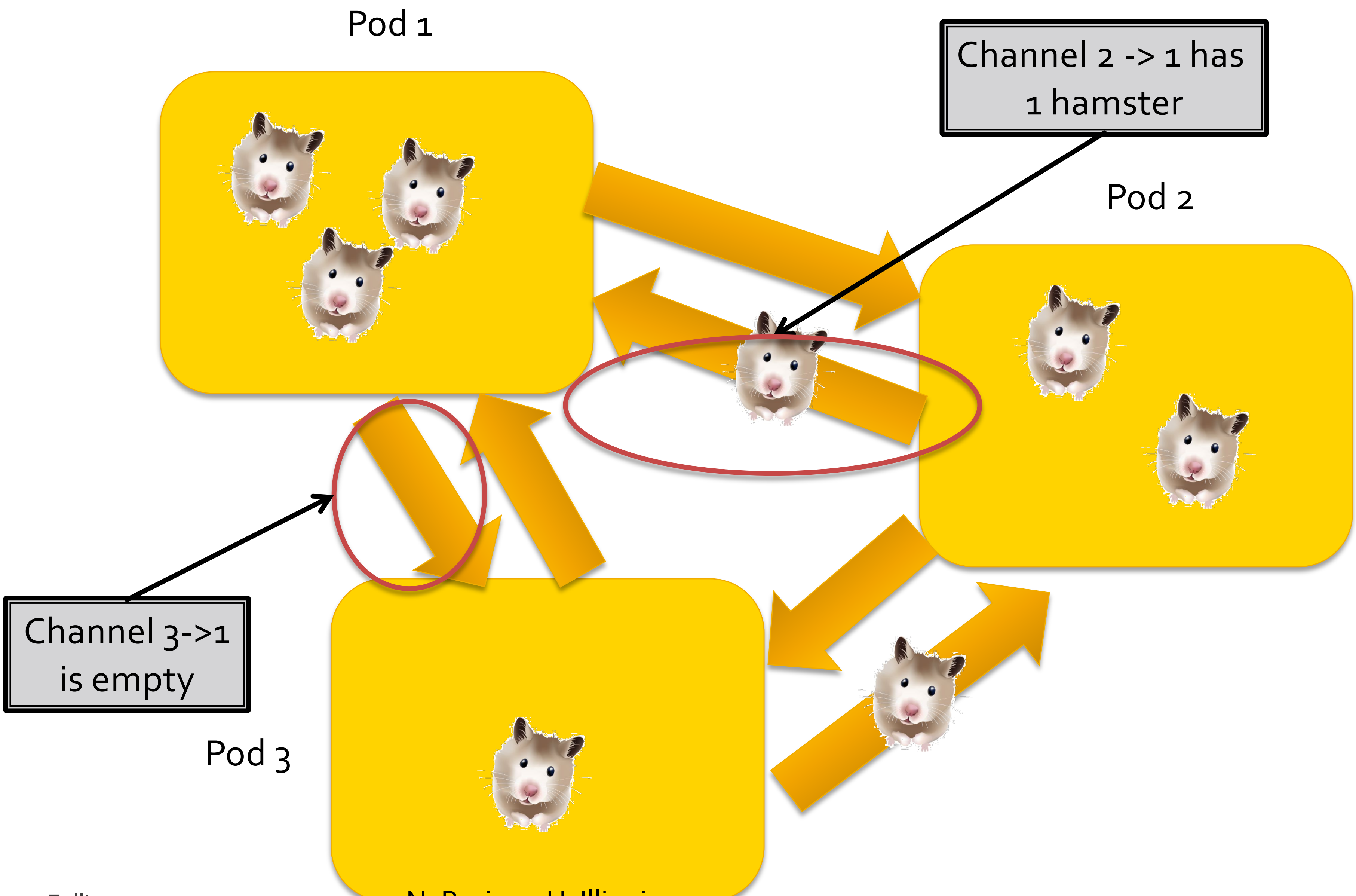
Habitrail



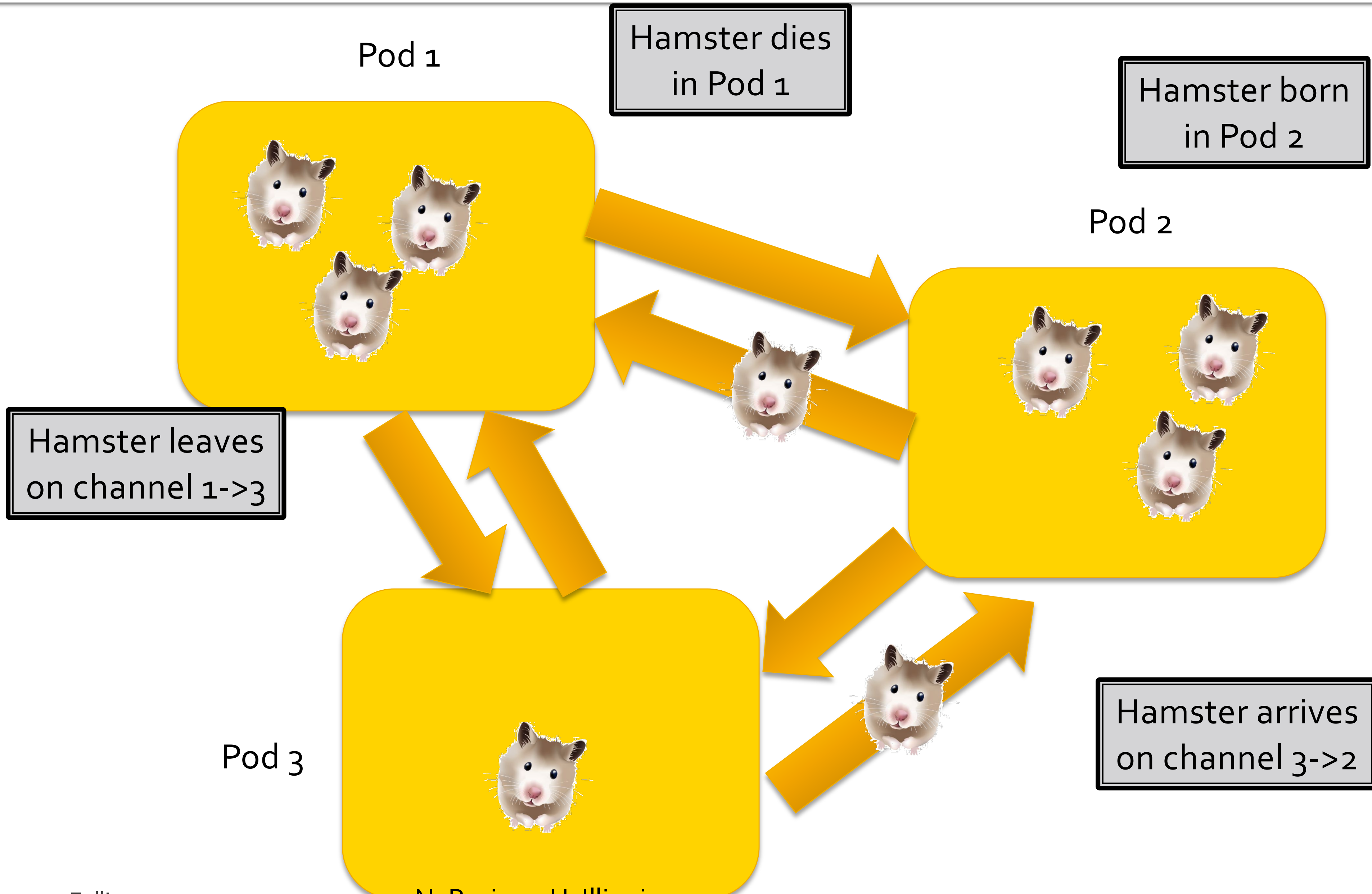
Process State



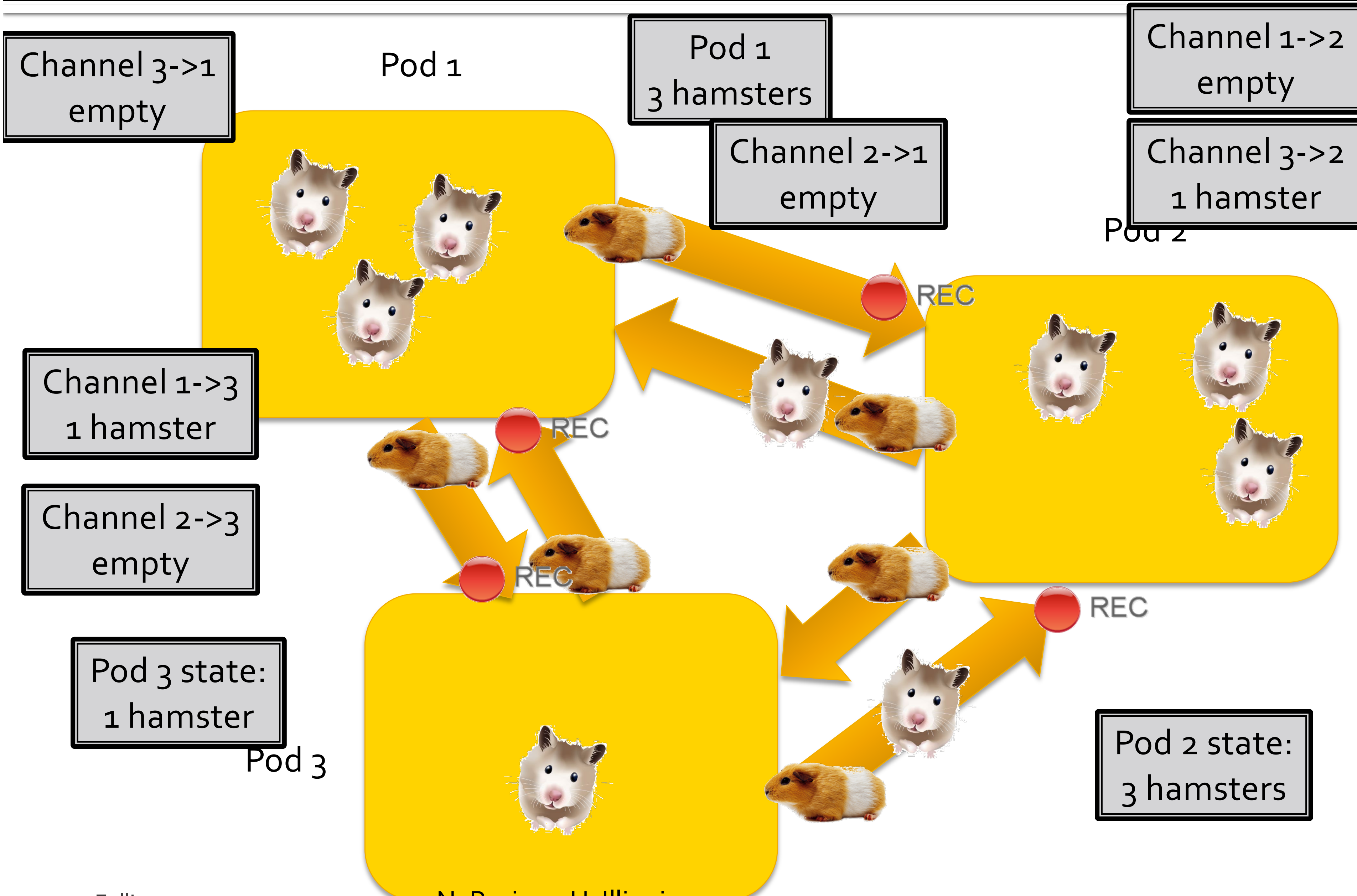
Channel State



Events


Pod 1
Hamster dies
in Pod 1
Hamster born
in Pod 2
Pod 2
Hamster leaves
on channel 1->3
Pod 3
Hamster arrives
on channel 3->2

Chandry-Lamport Algorithm



Chandry-Lamport proof

- Let e_i and e_j be events occurring at p_i and p_j, respectively such that $e_i \rightarrow e_j$
- The snapshot algorithm ensures that

  if e_j is in the cut then e_i is also in the cut.
- if $e_j \rightarrow$ <p_j records its state>, then it must be true that $e_i \rightarrow$ <p_i records its state>.
  - By contradiction, suppose <p_i records its state> $\rightarrow e_i$
  - Consider the path of app messages (through other processes) that go from $e_i \rightarrow e_j$
  - Due to FIFO ordering, markers on above path precede regular app messages
  - Thus, since <p_i records its state> $\rightarrow e_i$, it must be true that p_j received a marker before e_j
  - Thus e_j is not in the cut => contradiction