CSci 5105

Introduction to Distributed Systems

Byzantine, Recovery

Last Time

- Fault tolerance
- Reliable multicast

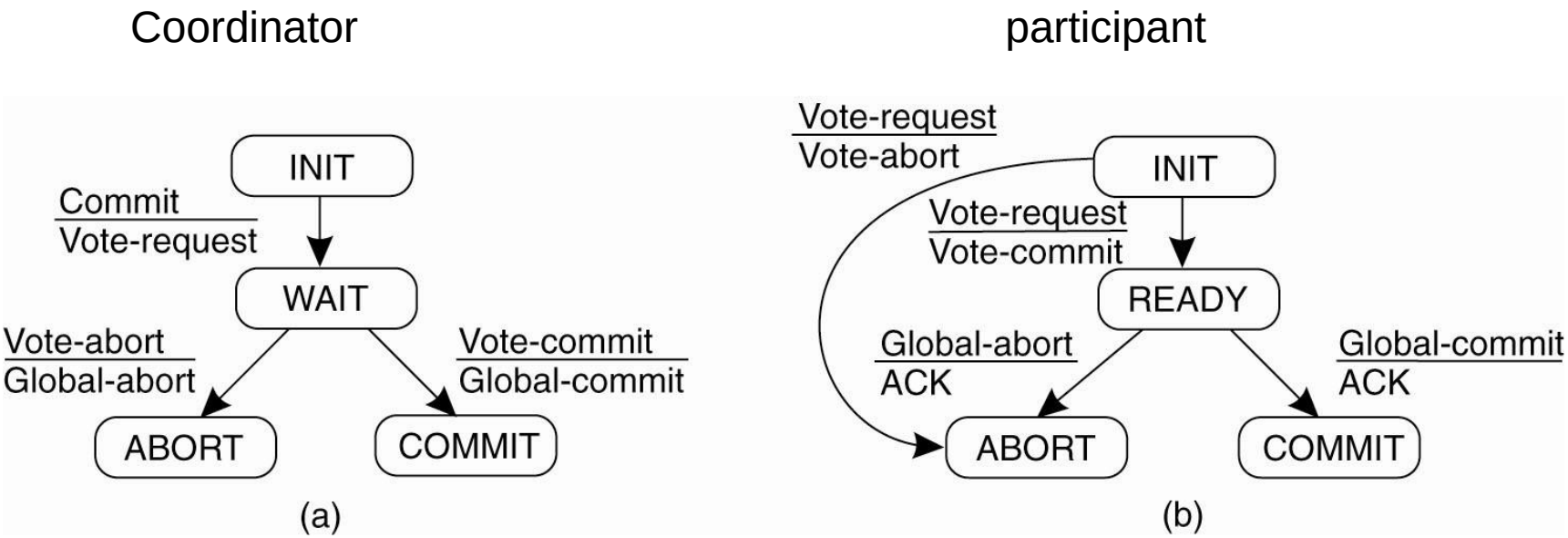
Today

- FT continued
- Recovery

Two-Phase Commit (2PC)

- General protocol to implement reliable multicast and forms of consensus
- Send message and have everyone either act on message or not
- Typical action: commit a transaction
- Multi-step (with coordinator)
  - Vote-request
  - Vote-commit or vote-abort
  - Global-commit or global-abort

Two-Phase Commit (2PC)



- Distributed commit – all or none
- Starts when someone wants to commit a value and asks coordinator if it is ok

What about failure?

- Coordinator failure
- Node P in READY state and times out
- Asks node Q

State of Q	Action by P
COMMIT	Make transition to COMMIT
ABORT	Make transition to ABORT
INIT	Make transition to ABORT
READY	Contact another participant

Safe to abort

Must block if everyone in READY state

2PC Failure/Recovery

- Nodes fail and may recover
- Use logging

Actions by coordinator:

```
    write START_2PC to local log;
    multicast VOTE_REQUEST to all participants;
    while not all votes have been collected {
        wait for any incoming vote;
        if timeout {
. . .           write GLOBAL_ABORT to local log;
                multicast GLOBAL_ABORT to all participants;
                exit;
        }
        record vote;
    }
```

2PC Failure/Recovery (cont'd)

. . .

```
if all participants sent VOTE_COMMIT and coordinator votes COMMIT {
        write GLOBAL_COMMIT to local log;
        multicast GLOBAL_COMMIT to all participants;
} else {
        write GLOBAL_ABORT to local log;
        multicast GLOBAL_ABORT to all participants;
}
```

2PC: Participant recovery

actions by participant:

```
write INIT to local log;
wait for VOTE_REQUEST from coordinator;
if timeout {
        write VOTE_ABORT to local log;
        exit;
}
if participant votes COMMIT {
        write VOTE_COMMIT to local log;
        send VOTE_COMMIT to coordinator;
        wait for DECISION from coordinator;
        if timeout {
                multicast DECISION_REQUEST to other participants;
                wait until DECISION is received; /* remain blocked */
                write DECISION to local log;
        }
        if DECISION == GLOBAL_COMMIT
                write GLOBAL_COMMIT to local log;
        else if DECISION == GLOBAL_ABORT
                write GLOBAL_ABORT to local log;
} else {
        write VOTE_ABORT to local log;
        send VOTE_ABORT to coordinator;
}
```

(a)

2PC: Participant recovery (cont'd)

Actions for handling decision requests: /* executed by separate thread */

```
while true {
    wait until any incoming DECISION_REQUEST is received; /* remain blocked */
    read most recently recorded STATE from the local log;
    if STATE == GLOBAL_COMMIT
        send GLOBAL_COMMIT to requesting participant;
    else if STATE == INIT or STATE == GLOBAL_ABORT
        send GLOBAL_ABORT to requesting participant;
    else
        skip; /* participant remains blocked */
}
```

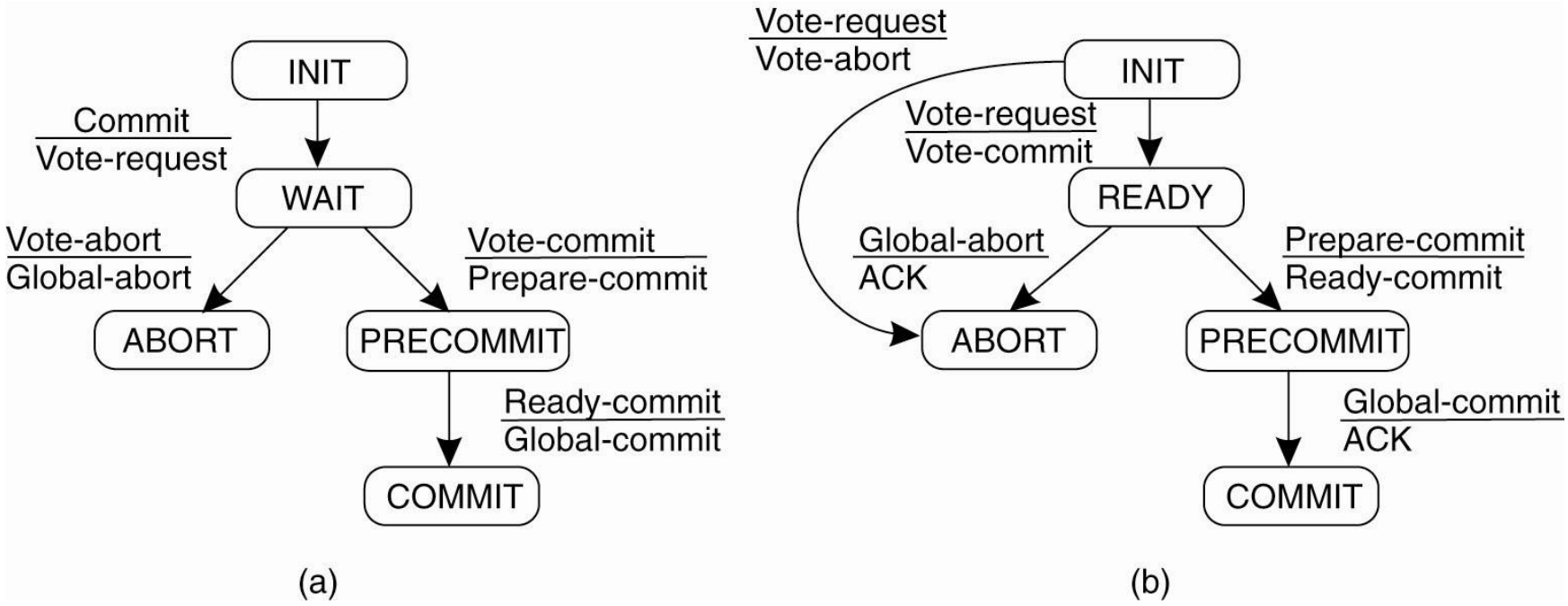
(b)

- Used to help other participants

3PC

- 2PC is very expensive
- Blocking after a failed node recovers to make a decision
- Add one more round: PREPARE-COMMIT
- Look at 3PC

Three-Phase Commit

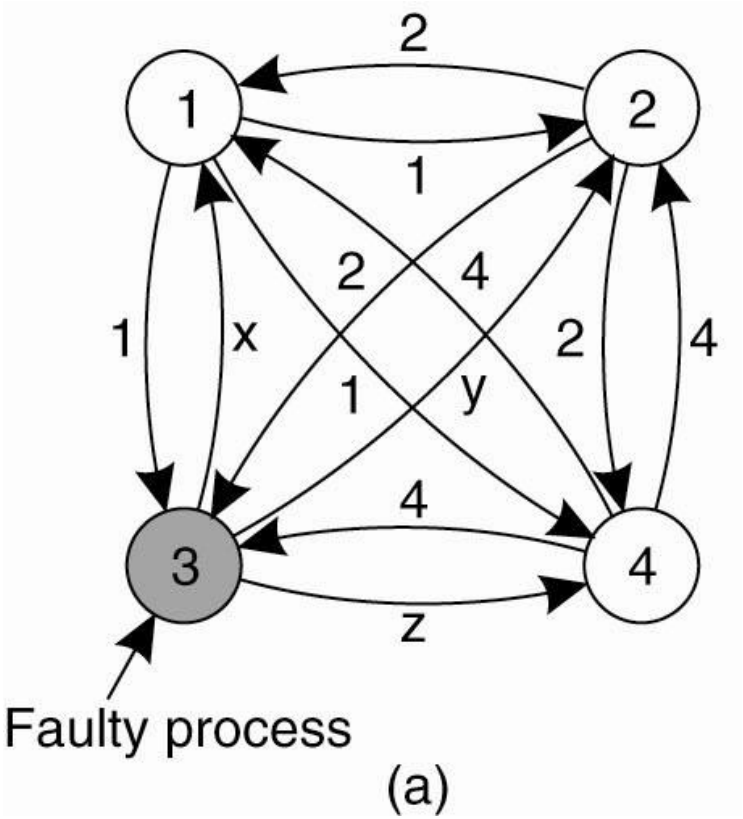


What is a Byzantine Failure?

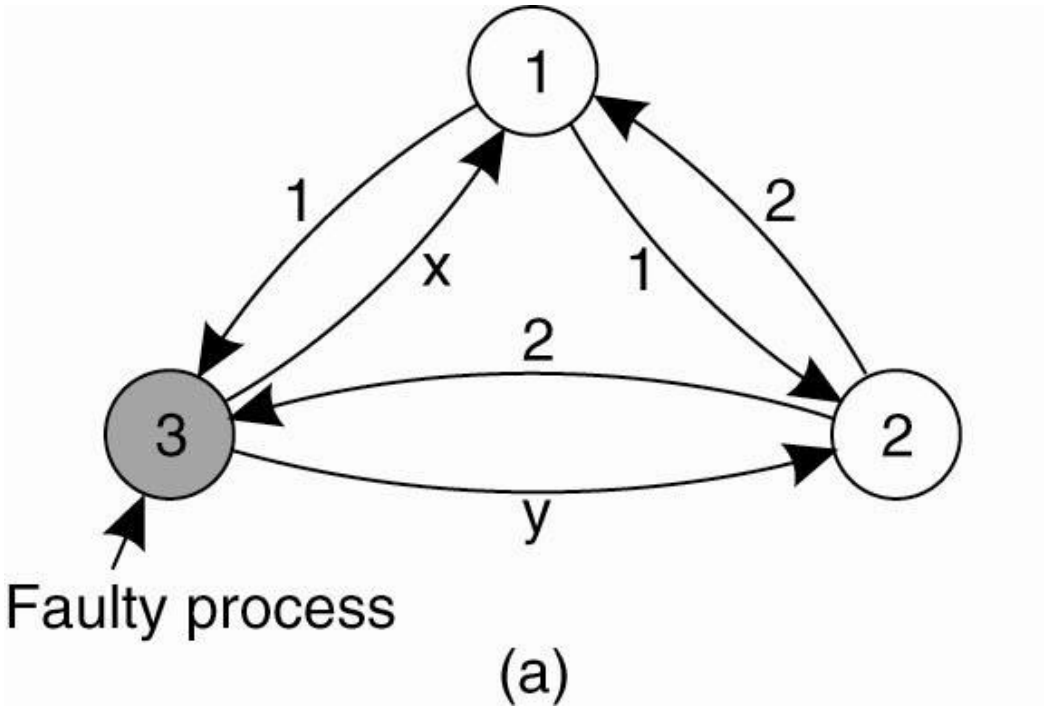
Three primary differences from Fail-Stop

1) Component can produce arbitrary output
   - Fail-stop: produces correct output or none
2) Cannot always detect output is faulty
   - Fail-stop: can always detect that component has stopped
3) Components may work together maliciously
   - No collusion across components

Agreement in Faulty Systems



Agreement in Faulty Systems



(a)

1 Got(1, 2, x)
2 Got(1, 2, y)
3 Got(1, 2, 3)

(b)

1 Got	2 Got
(1, 2, y)	(1, 2, x)
(a, b, c)	(d, e, f)

(c)

Agreement in Faulty Systems

1 Got(1, 2, x, 4)
2 Got(1, 2, y, 4)
3 Got(1, 2, 3, 4)
4 Got(1, 2, z, 4)

(b)

1 Got	2 Got	4 Got
(1, 2, y, 4)	(1, 2, x, 4)	(1, 2, x, 4)
(a, b, c, d)	(e, f, g, h)	(1, 2, y, 4)
(1, 2, z, 4)	(1, 2, z, 4)	(i, j, k, l)

(c)

General Impossibility Result

- No solution with fewer than `3m+1` generals can cope with `m` traitors

Recovery

- Recovery from failure
- Backward recovery: go back to a correct state
  - checkpointing; logging
- Forward recovery: make current or future state correct
  - plan for errors

Stable Storage

Disk data errors -> write during a crash, spontaneous bit error not handled by RAID

errors detected by ECC upon read

Operations for stable storage using 2 identical disks

(spontaneous error: 1 drive only)

Stable Storage: writes/reads

Stable writes

Write 1 disk, then read it back, check ECC, do N times until it works; get a spare disk if not

Write 2, ….

Stable reads

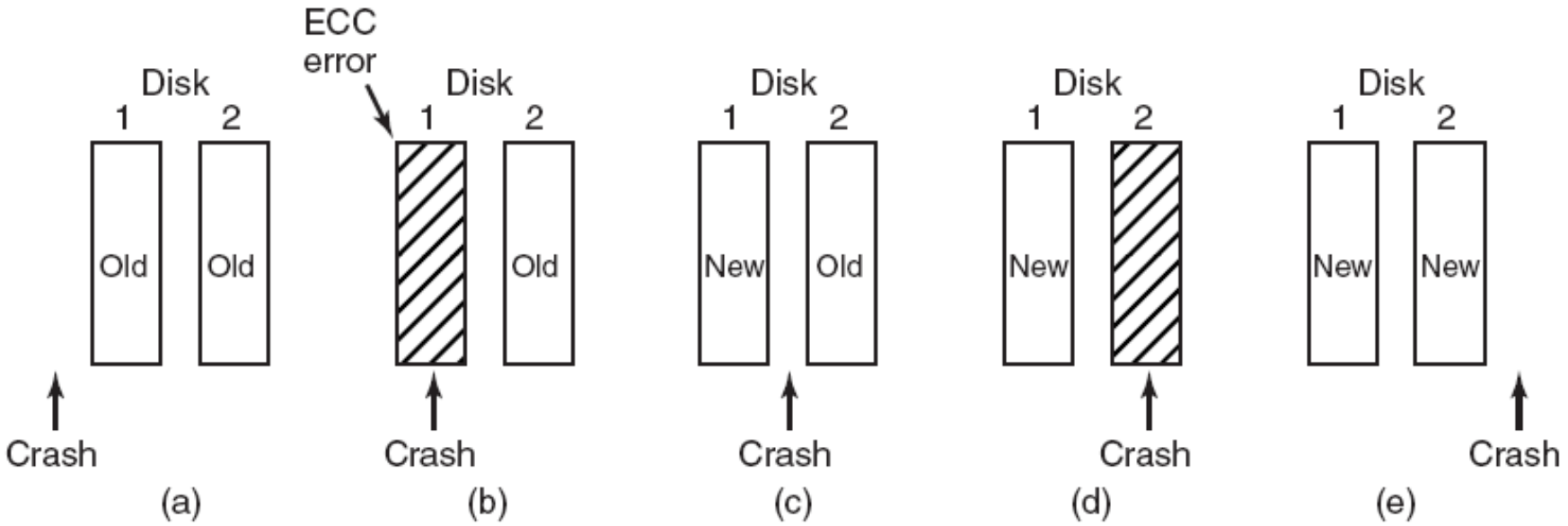
read disk 1, if ECC fails, try N times, else

read disk 2, …

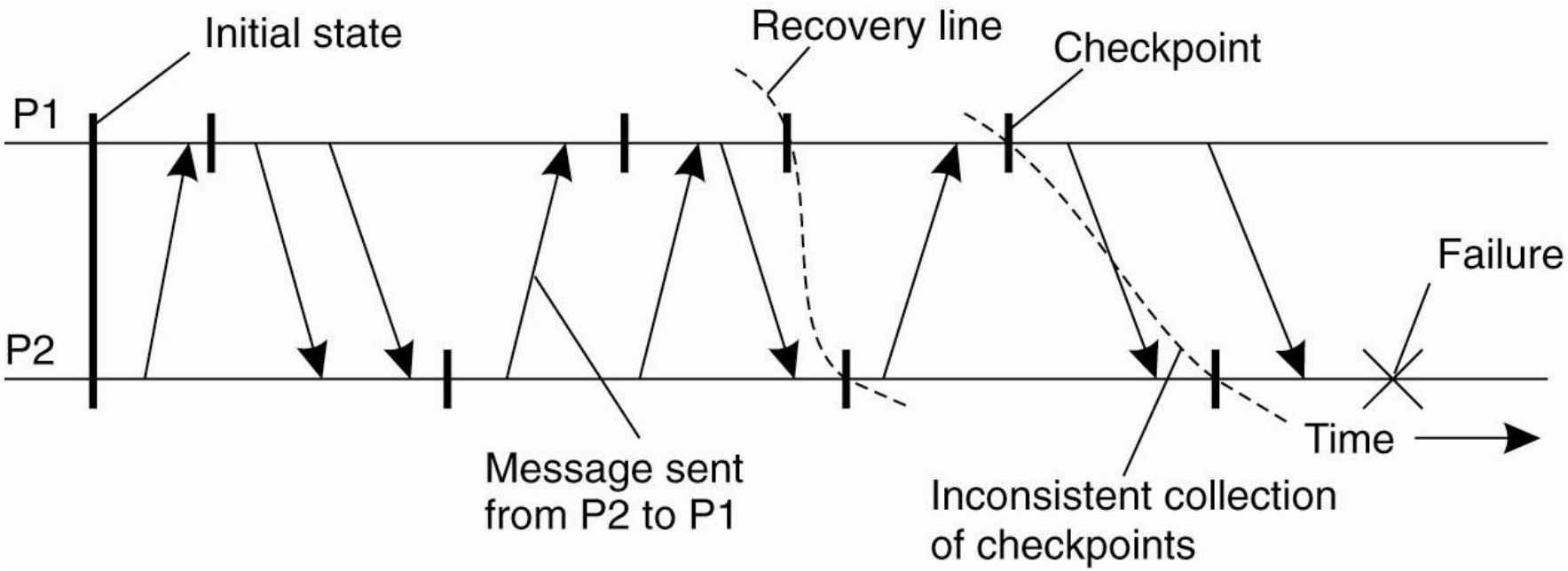
since can't have 2 disk errors, will succeed

Stable Storage: crash recovery

- Spontaneous bit errors (in 1 drive) are no problem (stable read)



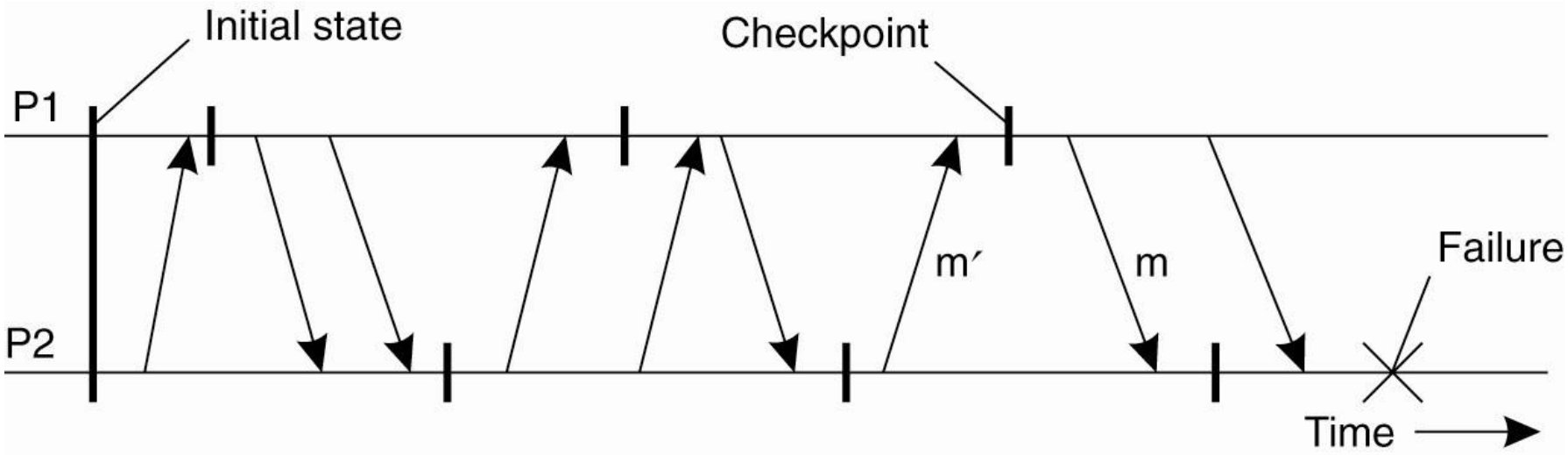
Checkpointing



Challenge: distributed
recover to most recent consistent distributed snapshot

Independent Checkpointing

- The domino effect



Coordinated Checkpoints

- Avoid cascading rollbacks
- Use 2PC – how?

- Checkpoints are large
- Instead save messages and replay

Assumptions

- Deterministic state
- Given a prior state and a log of messages
- Final state will be the same after replay