LECTURE 13

Reliable Group Communications/Transactions

Need for reliable group communications

- All processes (replicas) should agree to the same transaction.
- Reliable delivery of messages from a coordinator to replicas.
  - Easy way: Send and wait for ACK (e.g., using TCP) but results in blocking at coordinator
  - ACK implosion: All the receivers send ACKs overwhelming the sender.

Reliable Multicast

- Receivers keep track of sequence numbers of transmissions and only NACK missing messages.
- A hierarchy is possible – a group of receivers with a coordinator each.
  - Coordinator performs reliable multicast to all receivers.

- Key issue: What happens when nodes fail ?

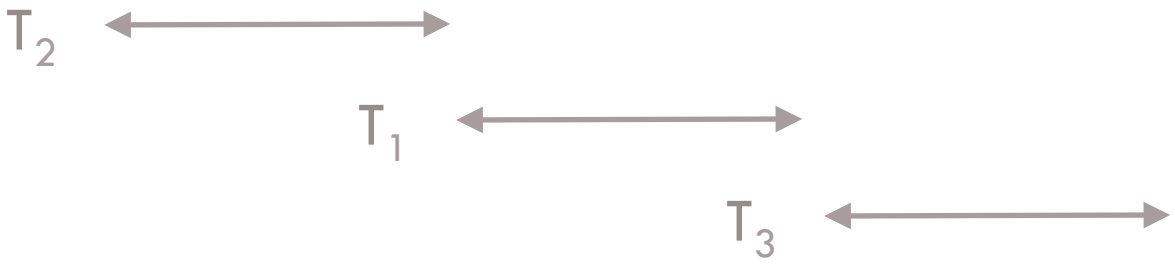
Distributed Transactions

- Partitioning of state necessary to scale
- Partitioning results in the need for transactions
  - Atomically execute operations across shards
- Examples:
  - Add meeting to calendars of two participants
  - Transfer money from one account to another
  - Looking up balance of two accounts

Concurrency + Serializability

- Execution of transactions:

- Externally visible effects:



Example of Serializability

- Concurrent execution of transactions:
  - T1: Transfer $10 from Alice to Bob
  - T2: Read balance in Alice's and Bob's accounts
  - Initial balance of $100 in both accounts

- Permissible outputs for T2:
  - (Alice: $100, Bob: $100) or (Alice: $90, Bob: $110)

- Invalid outputs for T2:
  - (Alice: $90, Bob: $100) or (Alice: $100: Bob: $110)

Atomic multicast

- Client contacts replica P for an update.
- P multicasts the update to all other replicas.
- If P crashes before multicast completes:
  - Some members may have received others may not!

- Requirement: Either all non-faulty members perform the update (equivalent to P crashing after) or none do (equivalent to P crashing before)

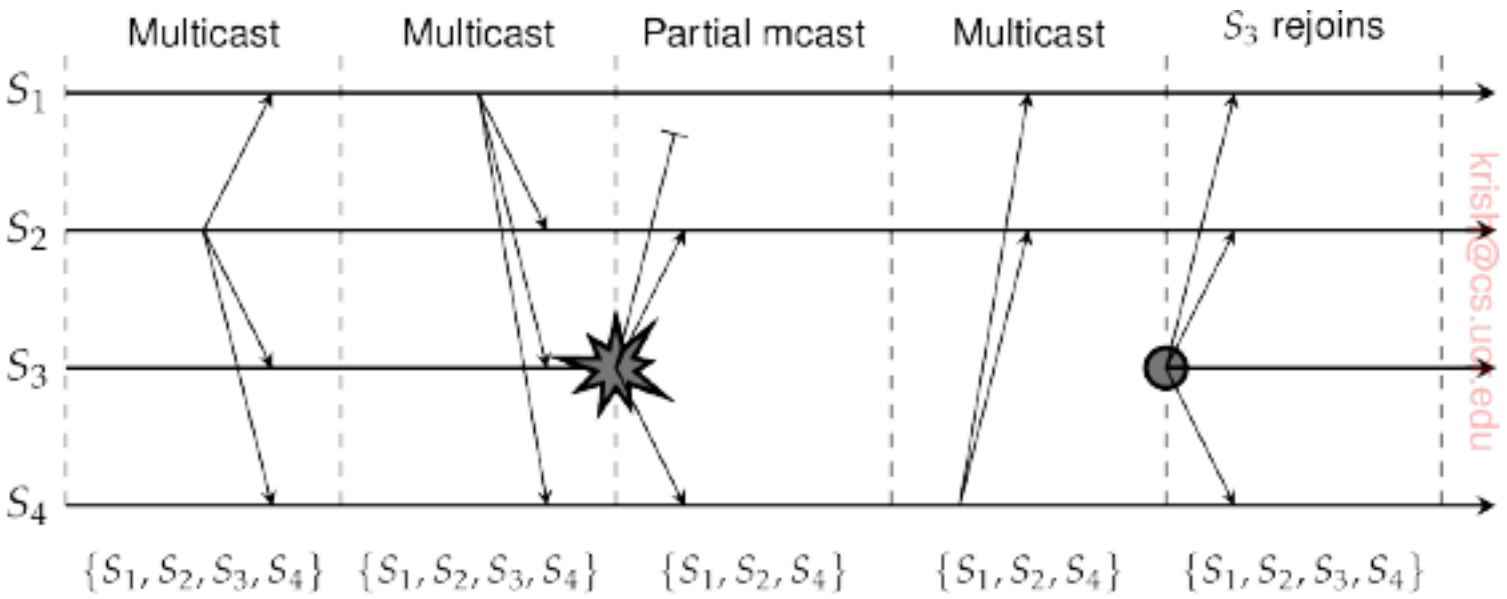
Group views

- Atomic multicasting of a message "M" is uniquely associated with a group G (Group view)
  - Processes to which M is to be delivered.
- Key question: What happens if the group changes in between (a new process Q joins or leaves group)?
- A "view change" takes place that announces this.
- However, M needs to be either delivered to all processes in group G before the view change is executed.

Virtual Synchrony

- A message multicast to a group view G is delivered to each non-faulty process in G.
- If the sender of the message crashes:
  - the message is either delivered to all the remaining processes; or,
  - ignored by all of them
- If these properties are satisfied, the reliable multicast is said to be virtually synchronous.

Example



- If virtual synchrony is satisfied, message not delivered to S2 and S4 after S3 crashes.

Categorization

- Unordered
- FIFO ordered
- Causally ordered

- Total ordered multicasts: messages are delivered in same order to all members.
  - The commits are consistent across all members.

Distributed commit

- Distributed commit problem is having an operation performed by all members of a process group or none at all.
  - Note: reliable multicasting is only delivery of a message.

- One phase commit: Coordinator tells participants whether or not to locally perform the operation.
- Drawback: If a candidate fails to perform the operation no way of telling the coordinator!

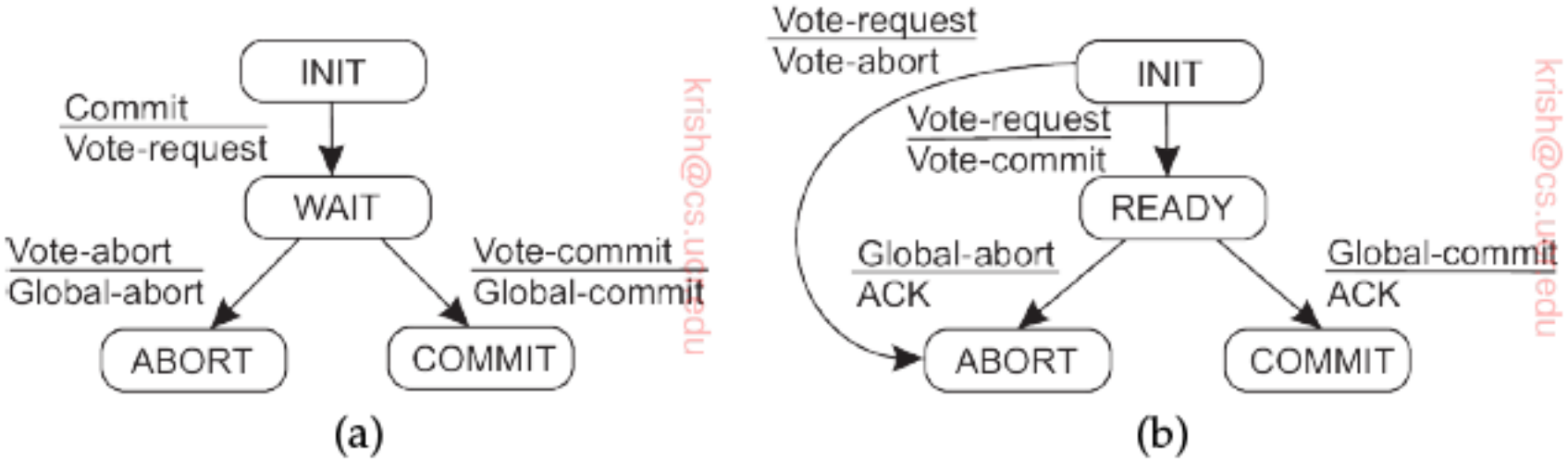
Two phase commit protocol (2PC)

- Cooridinator sends a VOTE-REQUEST to participants
- Each participant, upon receipt, either sends VOTE-COMMIT or VOTE-ABORT.
- Coordinator collects votes; if all commit, sends a GLOBAL-COMMIT; else, sends a GLOBAL-ABORT
- Participants who voted for commit, waits and does what the coordinator finally says.

Issues

- Failures can cause issues with the basic 2PC protocol.
- For example, a process may crash – and other processes may indefinitely wait for a message from that process.

2PC -- FSMs



- (a) The FSM for the coordinator
- (b) The FSM for the participant.

Exiting from blocking states

- A participant may be blocked in the INIT state
  - Times out and issues VOTE-ABORT if no VOTE-REQUEST is received.
- A coordinator maybe blocked in the WAIT state.
  - Times out and issues GLOBAL-ABORT if not all votes are collected within a certain time.
- A participant maybe blocked in the READY state – waiting for the results of the global vote.
  - Now the participant cannot simply time out and abort.
  - Needs to find out what was actually sent by the coordinator.
  - Either block until coordinator recovers (delays) or
  - Contact another participant to check if a COMMIT or ABORT was received.

Blocked Participant in READY

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

- If Q is in INIT state – it means it did not receive even the VOTE-REQUEST – thus, P should abort.
- If Q is in the READY state also it has the same issue as P – so contact another participant.
  - If all participants are in READY, no choice but to wait for the coordinator to recover.

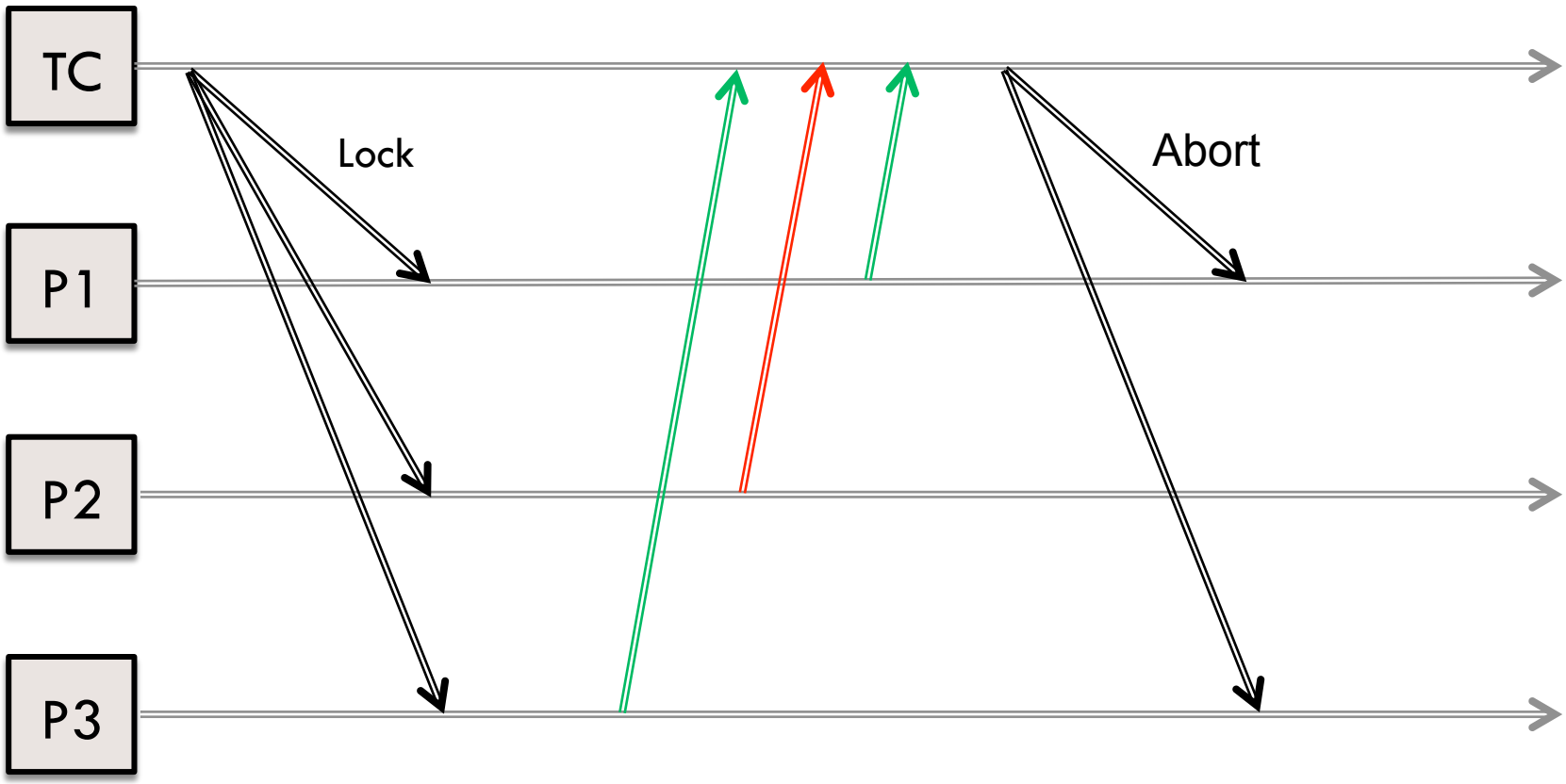
Crashes

- State information stored into persistent storage for recovery upon crashes.
- When participant crashes in READY, does not know whether to abort or commit upon recovery
  - In INIT, COMMIT or ABORT states this problem doesn't arise.
  - Needs to contact other participants
- Coordinator needs to record
  - WAIT state – retransmit VOTE-REQUEST upon recovery.
  - Decision (COMMIT or ABORT) – which is retransmitted upon recovery.

Achieving Serializability

- When is concurrent execution of transactions safe?
  - Data read/written is disjoint
- When must two transactions execute in order?
  - Intersection in data read/written
- Solution for serializability:
  - Fine-grained locks
  - Transaction coordinator first acquires locks for all data
  - Execute transaction and release locks

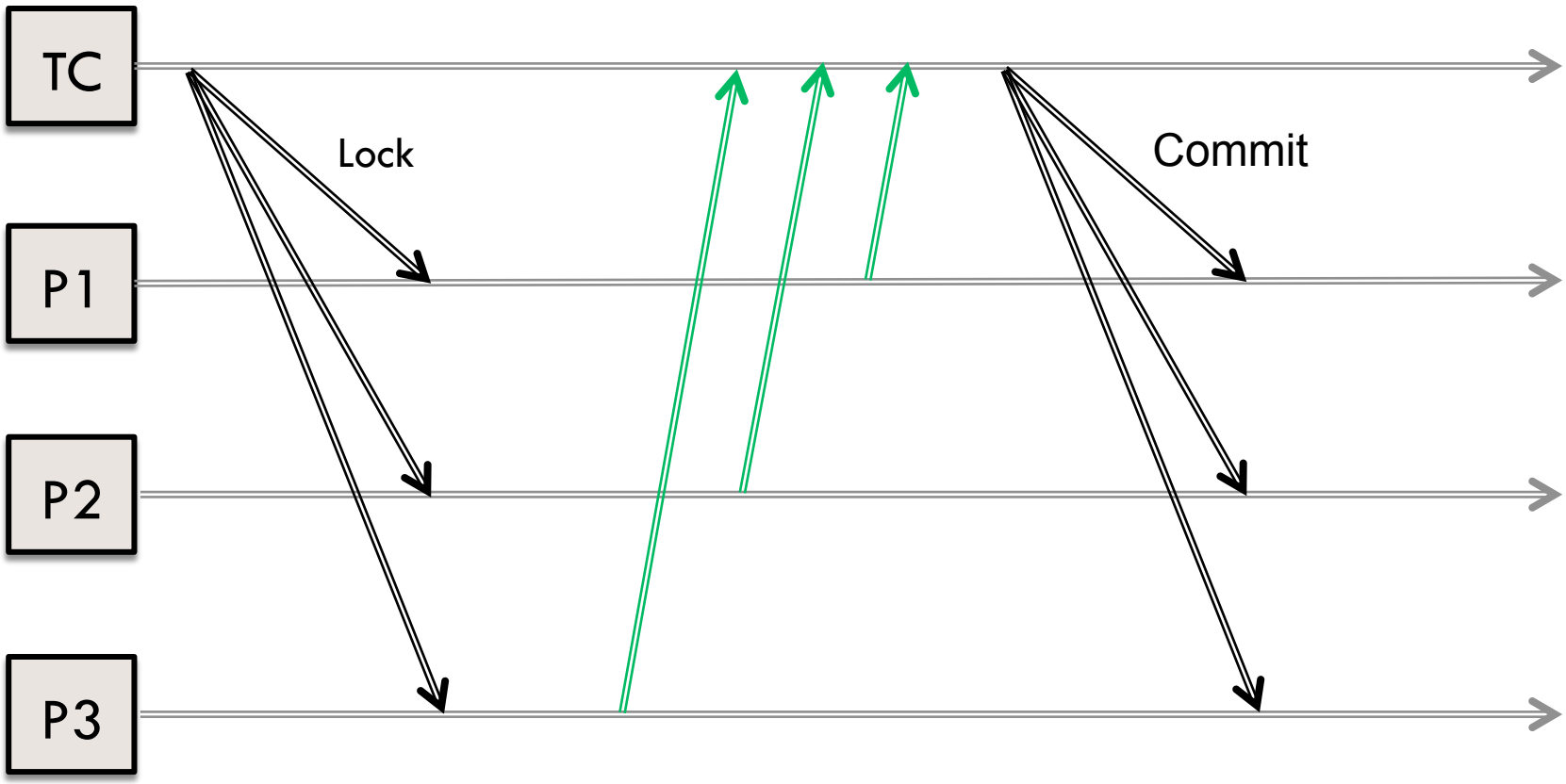
Two Phase Locking



- Transaction aborted since P2 did not commit to lock

Two Phase Locking

Can we reduce latency for read-only transactions?



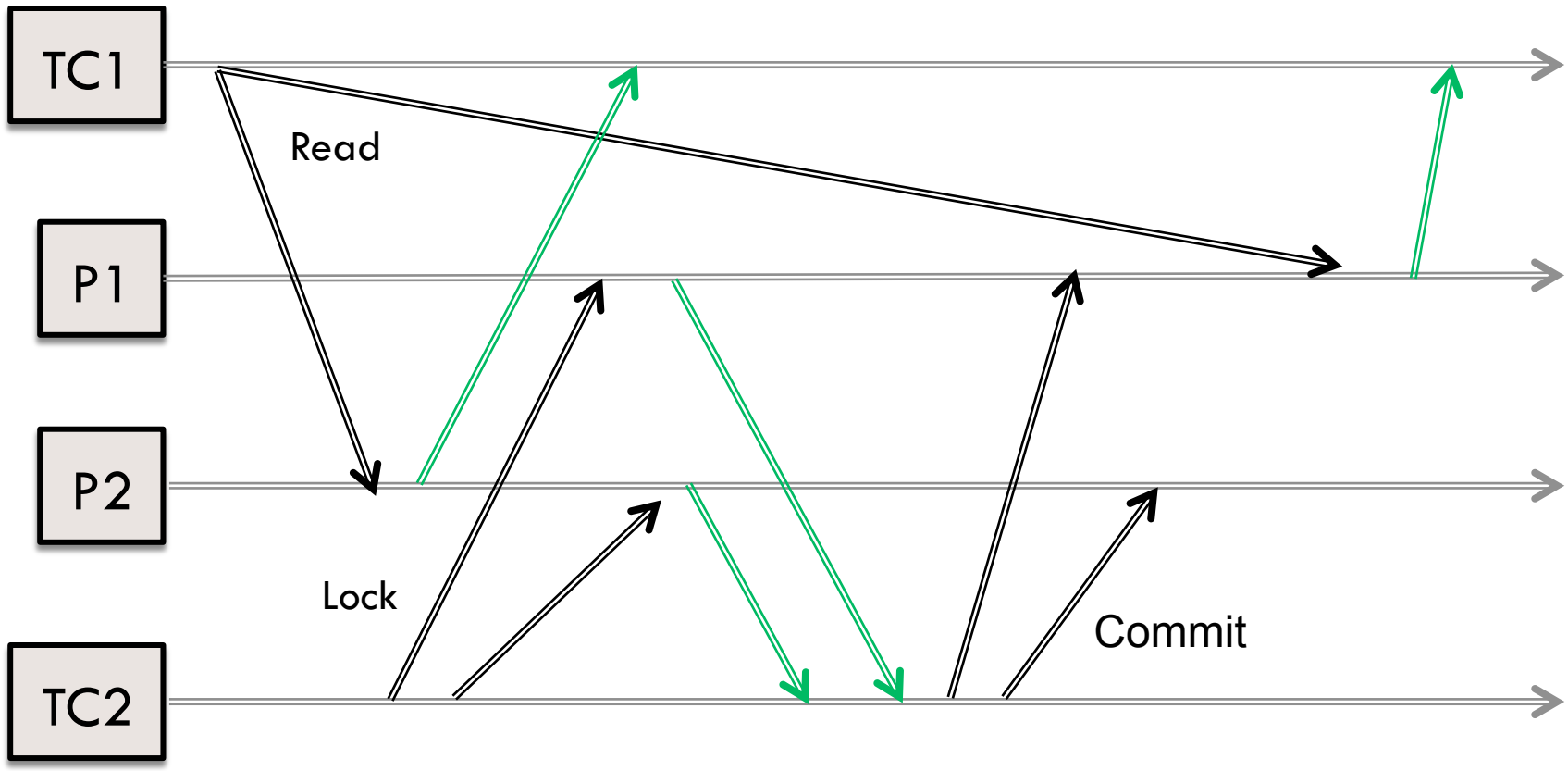
Return data in first round if lock not held

Optimizing Read-Only Txns

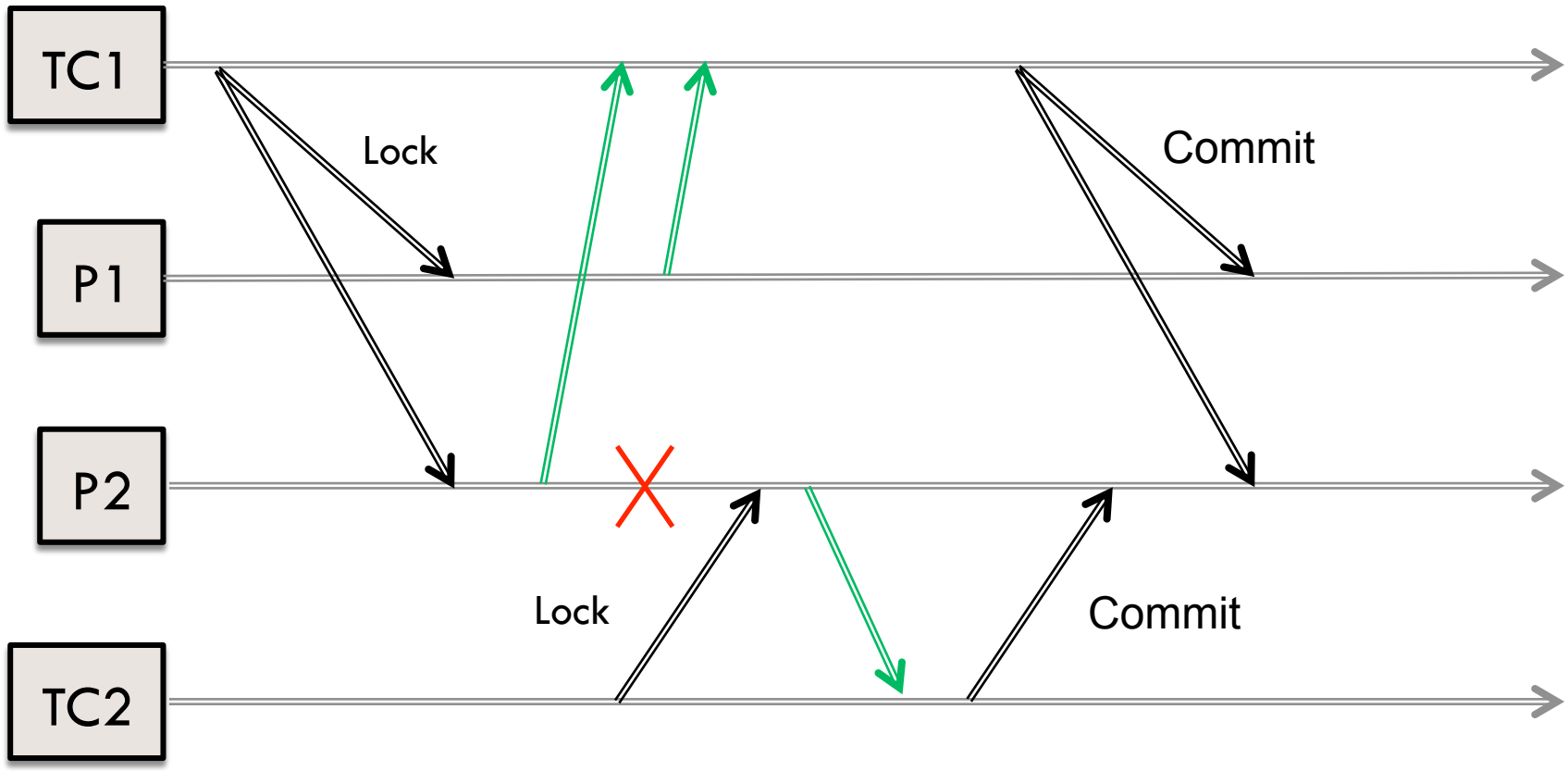
- Concurrent execution of transactions:
  - T1: Transfer $10 from Alice to Bob
  - T2: Read balance in Alice's and Bob's accounts
  - Initial balance of $100 in both accounts

- Problematic sequence of concurrent execution?
  - TC2 reads Alice's account balance as $100
  - TC1 executes 2PL to acquire locks on both accounts, transfer $10, and release locks
  - TC2 reads Bob's account balance as $110

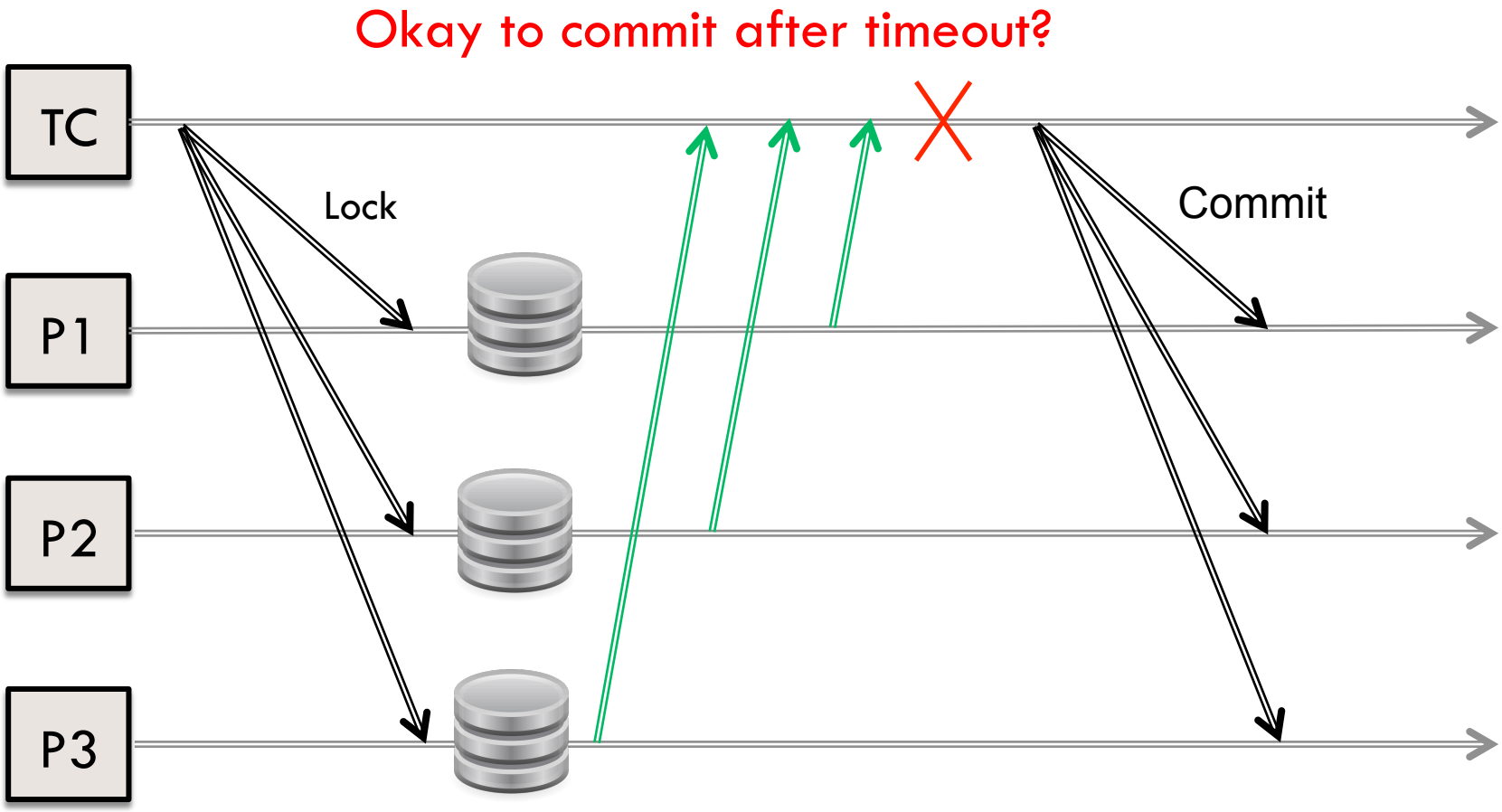
Lock-free Read-Only Txns



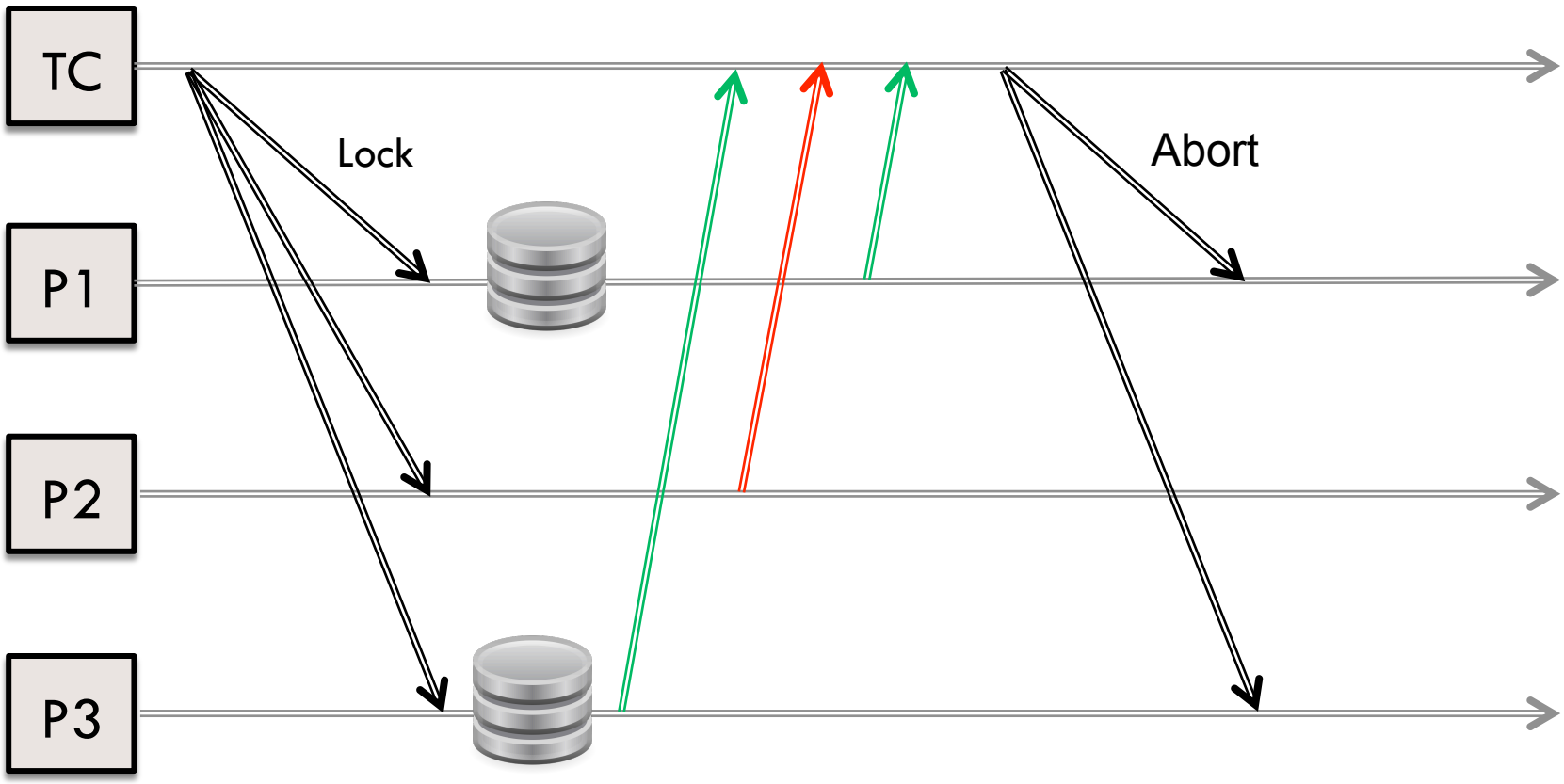
Fault Tolerance of 2PL



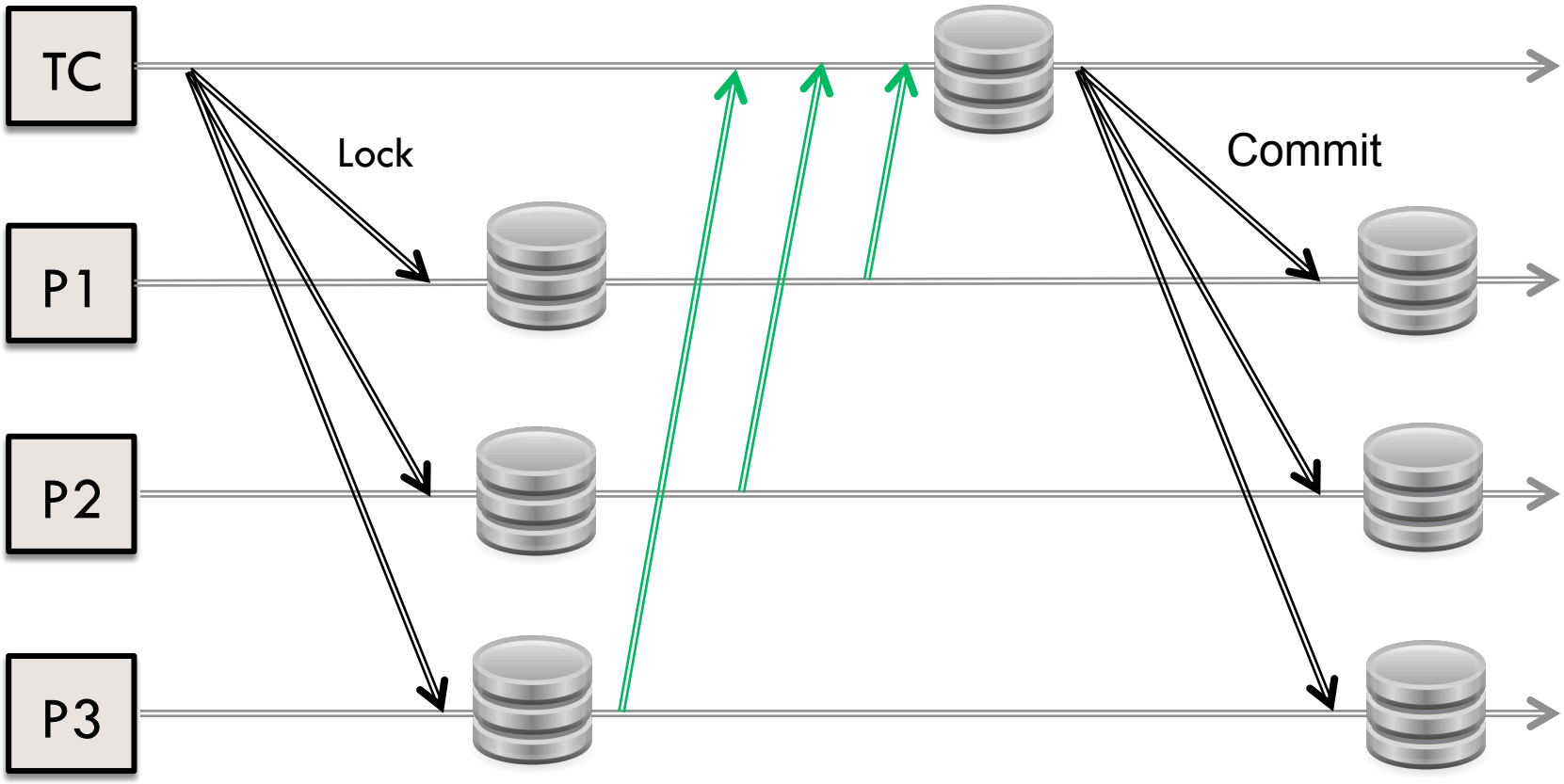
Fault Tolerance of 2PL



Fault Tolerance of 2PL



Fault Tolerance of 2PL



When can we garbage collect transaction log?

Garbage Collection

- Lock acquisition in node log:
  - Node receives commit from TC and writes to its log
- Commit operation in TC log:
  - After all nodes say transaction committed
- Commit operation in node log:
  - Upon applying operation to local state

Fault Tolerance

Transaction cannot succeed if any partition unavailable