Fault Tolerance

Causes of failure:

- process failure
- machine failure
- network failure

Goals:

- transparent: mask (i.e., completely recover from) all failures

or

- predictable: exhibit a well defined failure behavior

Elements:

- Atomic Transactions
- commitment (commit protocols)

generals paradox (message loss)

blocking vs. non-blocking protocols (non-failed sites can continue (must wait) for failed sites to recover)

independent recovery (failed sites can recover using only local information)

Transaction Model

Transaction

- A sequence of actions (typically read/write), each of which is executed at one or more sites, the combined effect of which is guaranteed to be atomic.

Atomic Transactions

- Atomicity: either all or none of the effects of the transaction are made permanent.
- Consistency: the effect of concurrent transactions is equivalent to some serial execution.
- Isolation: transactions cannot observe each other's partial effects.
- Durability: once accepted, the effects of a transaction are permanent (until changed again, of course).

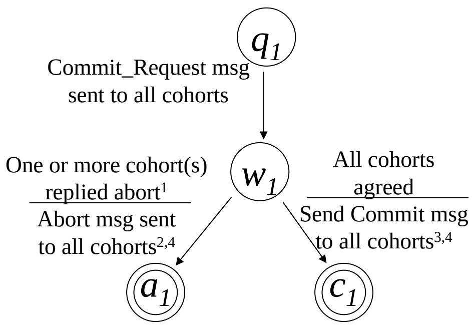
Environment

Each node is assumed to have:

- data stored in a partially/full replicated manner
- stable storage (information that survives failures)
- logs (a record of the intended changes to the data: write ahead, UNDO/REDO)
- locks (to prevent access to data being used by a transaction in progress)

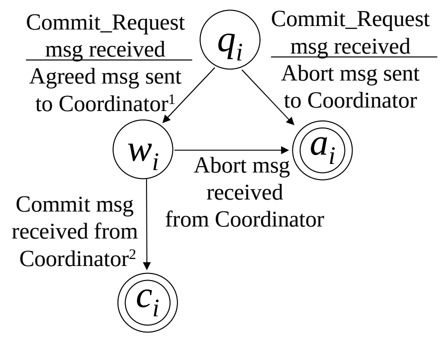
2-phase Commit Protocol

Coordinator



1. Assume ABORT if there is a timeout
2. First, writes ABORT record to stable storage.
3. First, writes COMMIT record to stable storage.
4. Write COMPLETE record when all msgs confirmed.

Cohort i (i=2,3, …, n)



1. First, write UNDO/REDO logs on stable storage.
2. Writes COMPLETE record; releases locks

Site Failures

Who Fails	**At what point**	**Actions on recovery**
Coordinator	**before writing Commit**	**Send Abort messages**
Coordinator	**after writing Commit but before writing Complete**	**Send Commit messages**
Coordinator	**after writing Complete**	**None.**
Cohort	**before writing Undo/Redo**	**None. Abort will occur.**
Cohort	**after writing Undo/Redo**	**Wait for message from Coordinator.**

Definitions

Synchronous

A protocol is synchronous if any two sites can never differ by more than one transition. A state transition is caused by sending or receiving a message.

Concurrency Set

For a given state, s, at one site the concurrency set, C(s), is the set o all states in which all other sites can be.

Sender set

For a given state, s, at one site, the sender set, S(s), is the set of all other sites that can send messages that will be received in state s.

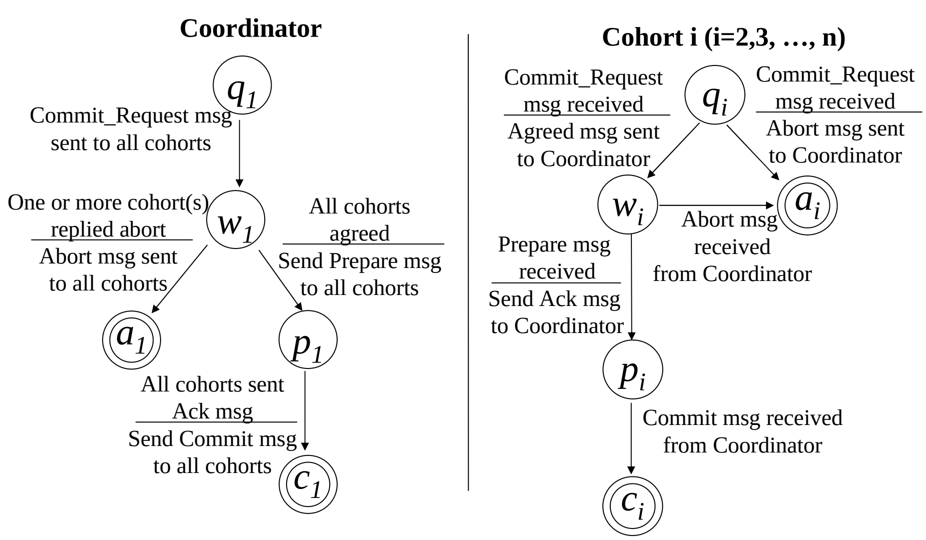
What causes blocking??

Blocking occurs when a site's state, s, has a concurrency set, C(s), that contains both commit and abort states.

Solution:

Introduce additional states. This implies adding additional messages (to allow transitions to/from these new states). This implies adding at least one more "phase".

3-phase Commit Protocol



Rules for Adding New Transitions

Failure Transition Rule

For every nonfinal state, s, in the protocol, if C(s) contains a commit, then assign a failure transition from s to a commit state; otherwise, assign a failure transition from s to an abort state.

Timeout Transition Rule

For each nonfinal state, s, if site j is in S(s), and site j has a failure transition to a commit (abort) state, then assign a timeout transition from state s to a commit (abort) state.

Using these rules in the three phase commit protocol allows the protocol to be resilient to a single site failure.

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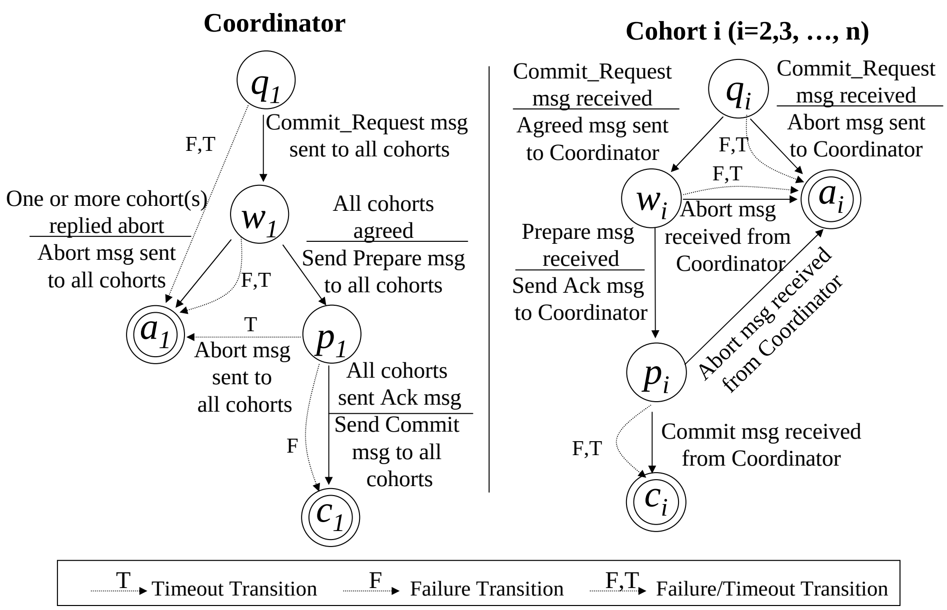
Timeout and Failure Transitions



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