Distributed Systems (ICE 601)

Distributed Transactions

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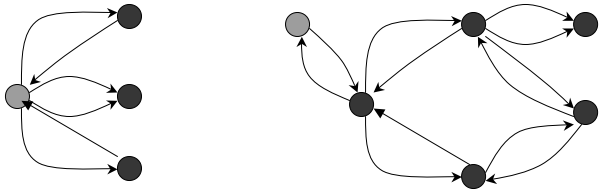
Distributed Transactions

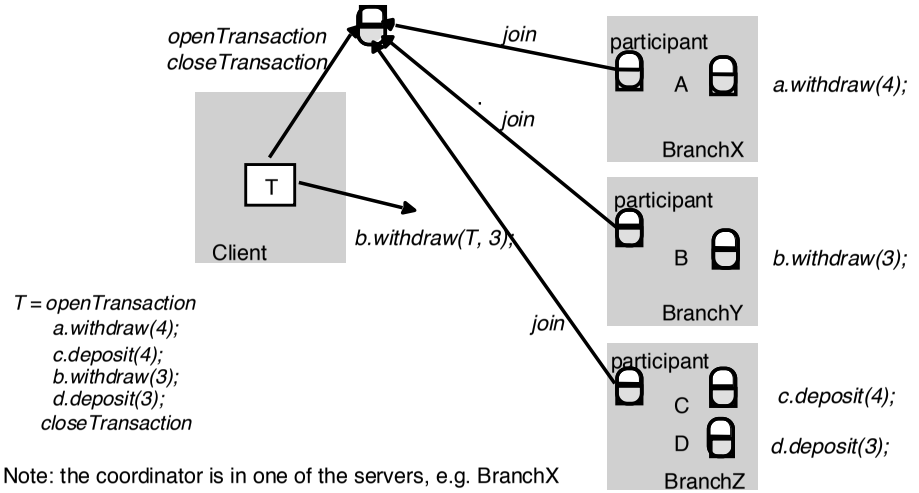
- Definition
  - a transaction in which more than one server is involved
    - multiple servers are called by a client (simple distributed transaction)
    - a server calls another servers (nested transaction)
  - execution of program accessing shared data at multiple sites [Lamport]



Class Overview

- Distributed Transactions
- Atomic Commit Protocol
- Distributed Deadlock

Distributed Transactions - example



Note: the coordinator is in one of the servers, e.g. BranchX

Atomicity in Distributed Transaction

- Requirement
  - a client requires to get congruent commitment from involved servers due to atomic property of a transaction
- Resolution
  - Coordination
  - Atomic commitment protocol

Atomic Commit Protocol

- Atomic commitment problem [Babaoglu & Toueg]
  - bring a transaction to a globally consistent conclusion despite failures
    - commit: all participants will make the transaction's update permanent
      - decision is based on unilateral agreement among all participants
    - abort: none will

  ⇒ ***atomic commit protocol*** that should satisfy these properties
    - all participants that decide reach the same decision
    - if any participant decides commit, then all participants must have voted yes
    - if all participants vote yes and no failure occur, the all participants decide commit
    - each participant decides at most once (i.e. decision is not reversible)

Coordination in Distributed Transaction

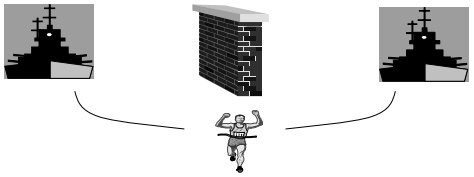
- How it works
  - one of servers become a coordinator and the others workers
    - who becomes a coordinator
      - simple transaction: first server
      - nested transaction: top-level server
  - each transaction should be globally identifiable (server id + unique #)
  - coordinator
    - maintains a list of participating servers
    - collects results from workers and makes a decision to guarantee congruent commitment of transaction
  - workers
    - aware of coordinator's existence
    - reports its result to the coordinator and follows a decision from it

Atomic Commit Protocol (cont.)

- Broadcast property
  - (validity) if a coordinator broadcasts a message m, the all participants eventually receive m
  - (integrity) for any message m, each participant receives m at most once and only if a coordinator actually broadcasts m
  - (timeliness) there exists a known constant *d* such that broadcast of m is initiated at real-time t, no participant receives m after real-time t + *d*

Atomic Commit Protocol (cont.)

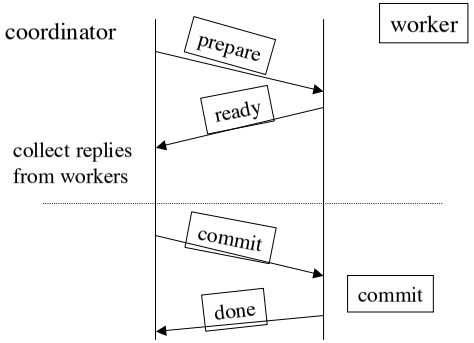
- Generals Paradox



  - There is no fixed-length protocol that will allow the generals to agree on a common time to attack

Two Phase Commit (2PC) Protocol

- Mechanism
  - commit process consists of two message passing phases
    - phase 1: voting
    - phase 2: completion of voting result



Why Multiple Phase Atomic Commit Protocol?

- Example: one phase atomic commit
  - mechanism
    - coordinator keeps sending workers a commit or abort request until all of them acknowledged that they had carried it out
  - does not allow a coordinator to make a unilateral decision to abort a transaction when a client requests a commit
    - there's no room for servers to have decision consensus process among themselves
    - it is caused mainly by concurrency control

➲ allow one or more preparation phases before making a final decision

  - two phase commit protocol is most widely used
    - general and inexpensive
    - window of time during which servers are not allowed to abort the transaction is small

2PC Protocol (cont.)

- Phase 1
  - coordinator
    - send "prepare (CanCommit?)" message to each worker
    - wait until
      - a response ("ready" or "no" is received from each worker, or
      - timeout occurs
  - workers
    - wait until "prepare" message is received from coordinator
    - if transaction is ready to commit
      - then, send "ready" message to coordinator
      - otherwise, send "no" message to coordinator and abort
- Phase 2
  - coordinator
    - if "ready" message was received from every worker
      - send "commit" message to each worker
      - otherwise, send "abort" message to each worker
    - wait until
      - acknowledgement is received from each worker
  - workers
    - wait until "commit" or "abort" message is received from coordinator
    - do appropriate work according to the message
    - send acknowledgement

2PC Protocol for Nested Transactions

- Why extra care?
  - sub-transactions can make an independent decision to commit provisionally or to abort
  - transaction can commit only if all of its provisionally committed child transactions can commit
- Extra steps
  - assumption
    - servers for sub-transactions record information regarding what sub-transactions have committed provisionally or aborted => top-level will get a list of all sub-transactions with their status
  - phase 1
    - if worker has any provisionally committed sub-transactions
      - then, check whether they do not have aborted ancestors
        - » if yes, send "no" and abort
        - » otherwise, send "yes"
      - otherwise, send "no"

Timeout in 2PC Protocol (cont.)

- Worker timeout
  - coordinator failed to send "ready" message
    - workers unilaterally abort
  - coordinator failed to send decision
    - workers send a coordinator a probing message (GetDecision) or
      - sub-transaction can ask its parent in case of nested transaction
    - workers cooperatively obtain a decision
- Coordinator timeout
  - workers failed to send "yes" messages
    - coordinator decides to abort transaction

Timeout in 2PC Protocol

- Objective
  - make 2PC protocol non-blocking in the presence of
    - coordinator failure
    - worker failure
- Additional properties
  - atomic commit protocol properties
    - every correct participant that executes atomic commit protocol eventually decides
  - broadcast properties
    - (uniform agreement) if any participant (correct or not) receives a message m, then all correct participants eventually receive m

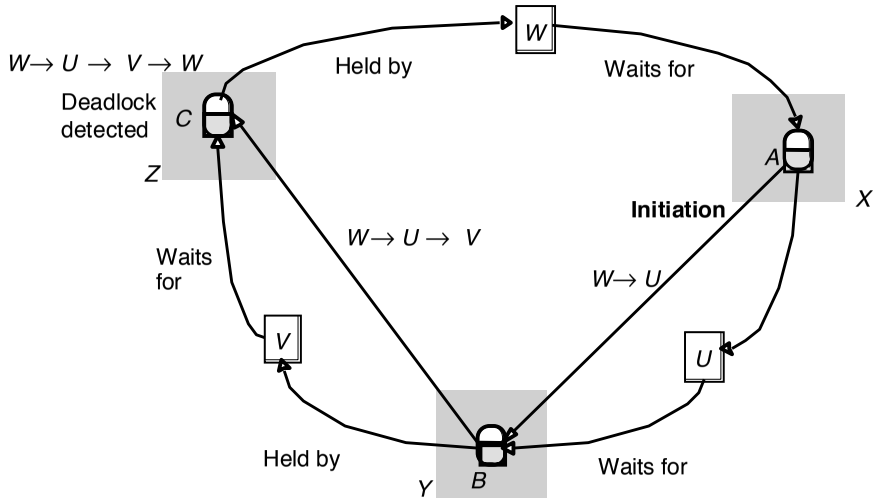
Concurrency Control in Distributed Transactions

- Locking
  - distributed deadlock may occur
- Timestamp ordering concurrency control
  - if two transactions access the same data items on various servers, they must commit them in the same order
    - to achieve this, servers should agree on the ordering of their timestamp using synchronized physical clock
- Optimistic concurrency control
  - parallel validation
    - resolve commitment deadlock

Distributed Deadlock

- Centralized deadlock detection
  - each server sends its local wait-for graph and the central deadlock detector checks a cycle by global wait-for graphs
  - phantom deadlocks
    - happens when one of transactions that holds a lock (and creates deadlock) will have aborted during deadlock detection phase

Distributed Deadlock (cont.)



Distributed Deadlock (cont.)

- Distributed deadlock detection
  - called edge chasing or path pushing
  - no global wait-for graph
  - mechanism
    - lock manager informs the coordinator when transactions start waiting and when they become active again
    - three phases
      - initiation
        - » if transaction A starts waiting for transaction B waiting to access a data item at another server, transaction B's server sends a probe containing the wait-for relationship to the server of data item where transaction B is blocked and all the servers in which transactions share lock with transaction B
      - detection
        - » if the data item is hold by another transaction (by consulting with coordinator), add this relationship to the probe and forward the probe in the same manner as above
      - resolution
        - » when cycle is detected, a transaction in a cycle is aborted to break the deadlock