Distributed Computing III

Murphy was an optimist

CSSE6400

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Question

What communication faults may occur?

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- Message not delivered
- Message delayed
- Receiver failed
- Receiver busy
- Reply not received
- Reply delayed

- Lost in transit
- Network delay or receiver overloaded, but message will be processed later
- Receiver software has crashed or node has died
- Receiver temporarily not replying (e.g. garbage collection has frozen other processes)
- Request was processed but reply lost in transit
- Reply will be received later

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- No listener on port – RST or FIN packet
- Process crashes – Monitor report failure
- IP address not reachable – unreachable packet
- Query switches
- Timeout

- Assumes node is running & reachable. OS should close or refuse connection. Error packet may be lost in transit.
- Assumes node is running & reachable. Most reliable.
- Router has to determine address is not reachable, which is no easier than for your application.
- Need permissions to do this. Will only have this in your own data centre.
- UDP reduces network transmission time guarantee – does not perform retransmission

Question

What to do if fault is detected?

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Answer

- Retry
- Restart

- How many retries? How often?
- Exponential backoff with jitter
- How long to wait to restart?
- Too long reduces responsiveness.
- Unacknowledged messages need to be sent to other nodes – reducing performance.
- Too short may prematurely declare nodes dead.
- May lead to contention – two nodes processing the same request.
- May lead to cascading failure – load is sent to other nodes, slowing them down so they are then declared dead ….

Definition 1. Idempotency

Repeating an operation does not change receiver's state.

- Idempotent consumer pattern
- Tag messages with an ID, so repeated messages can be ignored
- Or, redo messages that do not change state (e.g. queries)

Byzantine Generals Problem

- *n* generals need to agree on plan
- Can only communicate via messenger
- Messenger may be delayed or lost
- Some generals are traitors
  - Send dishonest messages
  - Pretend to have not received message

- Link analogy to Byzantine faults
- Mention idea of Byzantine fault-tolerant systems
- e.g. safety critical systems, blockchain, …

Question

How to order asynchronous messages?

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How to order asynchronous messages?

Answer

- Timestamps?
  - Can't keep clocks in sync
  - Limited clock precision

- Trying to sync with NTP is unreliable
- Network delays during sync
- Clock drift between syncs
- Finite precision – two events may end up with the same timestamp, if they occur in quick succession

Consistency

Eventual Consistency weak guarantee

Linearisability strong guarantee

Causal Ordering strong guarantee

- Once value is written, all reads see same value
  - Regardless of replica read from

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Linearisability

- Once value is written, all reads see same value
  - Regardless of replica read from
- Single-leader replication
  - Read from leader
  - Read from synchronous follower
- Multi-leader replication can't be linearised
- Leaderless replication
  - Lock value on quorum before writing

- Abstraction over replicated database
- Used when uniqueness needs to be guaranteed
- e.g. Multiple withdrawals from an account
- SLR – defeats most performance benefits
- Leaderless – similar performance cost to SLR

Causal Order

- Order is based on causality
  - What event needs to happen before another
  - Allows concurrent events

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- Single-leader replication
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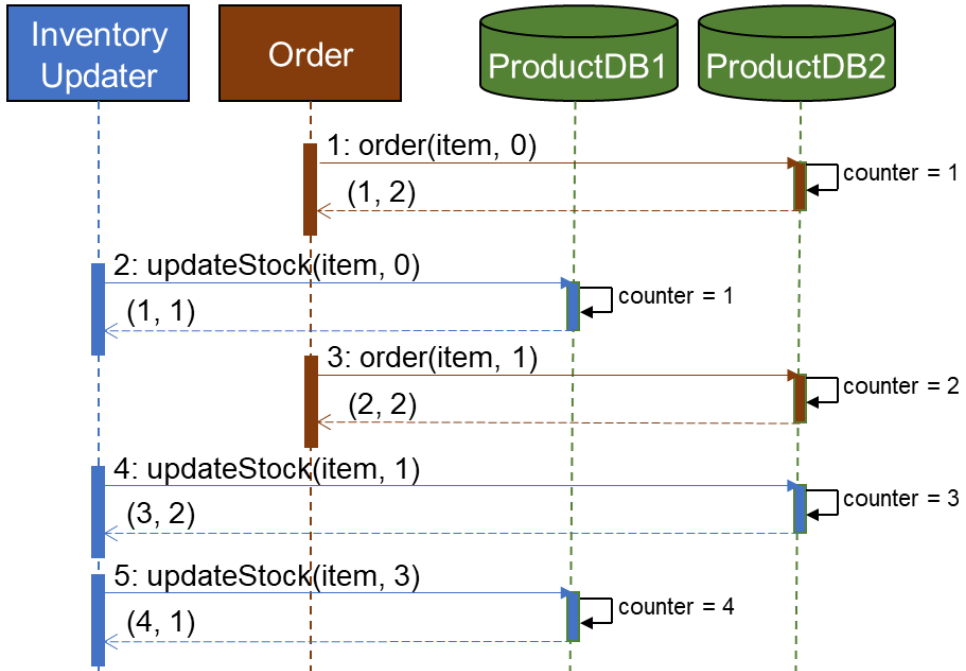
  - Followers read log to execute writes
- Lamport timestamps

- Linearisation defines a total order
- Causal ordering defines a partial order
- e.g. Git repo history with branching as causal order
- Not as strict as linearisability, so less performance cost


Inventory Updater
Order
ProductDB1
ProductDB2
1: order(item, 0)
(1, 2)
counter = 1
2: updateStock(item, 0)
(1, 1)
counter = 1
3: order(item, 1)
(2, 2)
counter = 2
4: updateStock(item, 1)
(3, 2)
counter = 3
5: updateStock(item, 3)
(4, 1)
counter = 4

Definition 2. Consensus

A set of nodes in the system agree on some aspect of the system's state.

Abstraction to make it easier to reason about system state.

Consensus Properties

Uniform Agreement All nodes must agree on the decision

Integrity Nodes can only vote once

Validity Result must have been proposed by a node

Termination Every node that doesn't crash must decide

- Uniform agreement and integrity are key
- Validity avoids nonsensical solutions (e.g. always agreeing to a null decision)
- Termination enforces fault tolerance, it requires that progress is made towards a solution

Definition 3. Atomic Commit

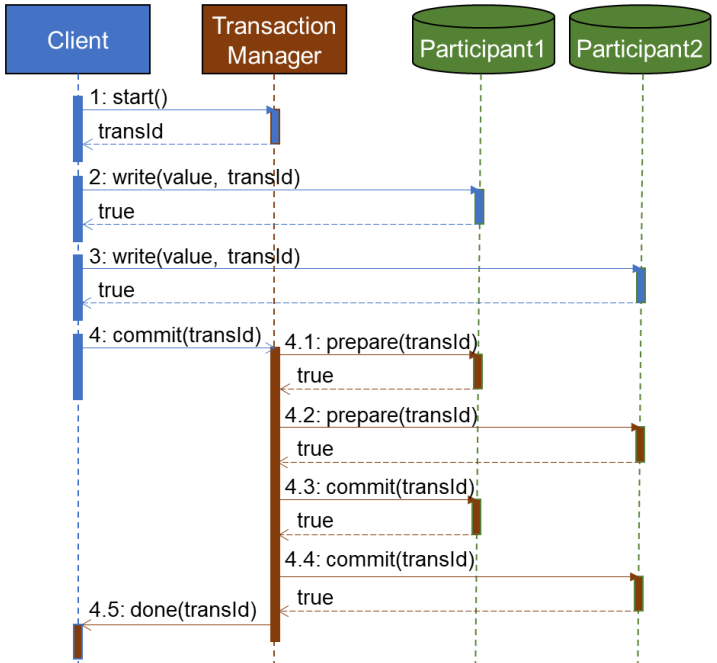
All nodes participating in a distributed transaction need to form consensus to complete the transaction.

Based on transaction atomicity from ACID.

Prepare Confirm nodes can commit transaction

Commit Finalise commit once consensus is reached

- Abort if consensus can't be reached



- Transaction ID used to track writes
- Prepare does all steps of a commit, aside from confirming it – It cannot be revoked by participant
- Commit intent is recorded in log before sending to participants
- Even if a particiant fails, commit can proceed when it recovers
- Comment on performance costs