# Distributed Computing III

*Murphy was an optimist*

CSSE6400

Richard Thomas

May 9, 2022

Question

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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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## What to do if fault is detected?

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

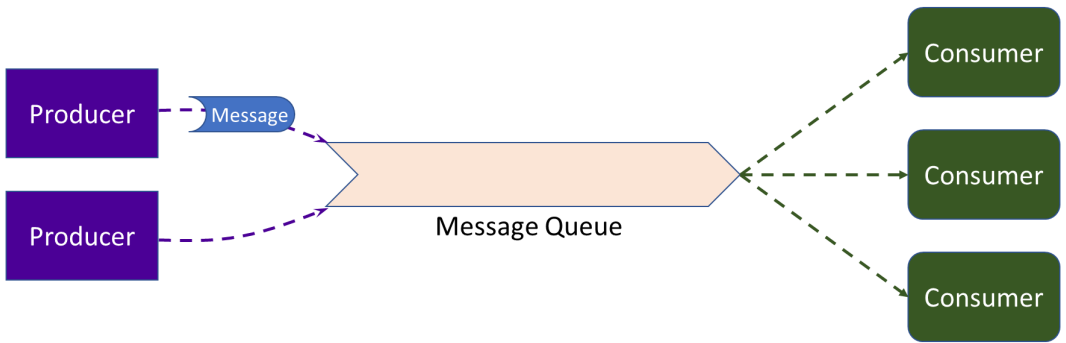
- Link analogy to Byzantine faults
- Mention idea of Byzantine fault-tolerant systems
- e.g. safety critical systems, blockchain, …

Definition 2. Poison Message

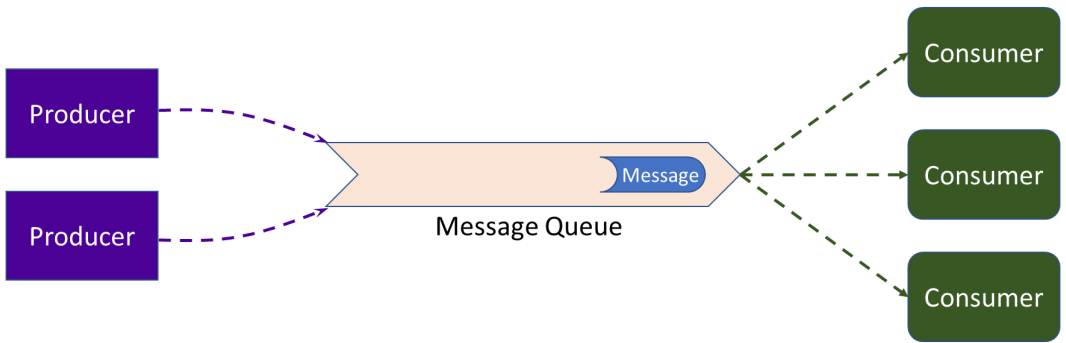
A message that causes the receiver to fail.

- Could literally cause the receiver to crash
- Often the receiver just cannot process the message and aborts processing

# Normal Message Flow




- Sequence of slides with an animation of a poison message.
- First 3 slides are an example of a message being queued and processed.
- Slides 4-8 are an example of a poison message blocking the queue.
- Should comment that poison messages block processing regardless of how they're delivered.
- A message queue or service isn't the key blocking point.
- Async messages sent directly to a consumer requires it to queue them as they're processed, leading to the same blocking issue.

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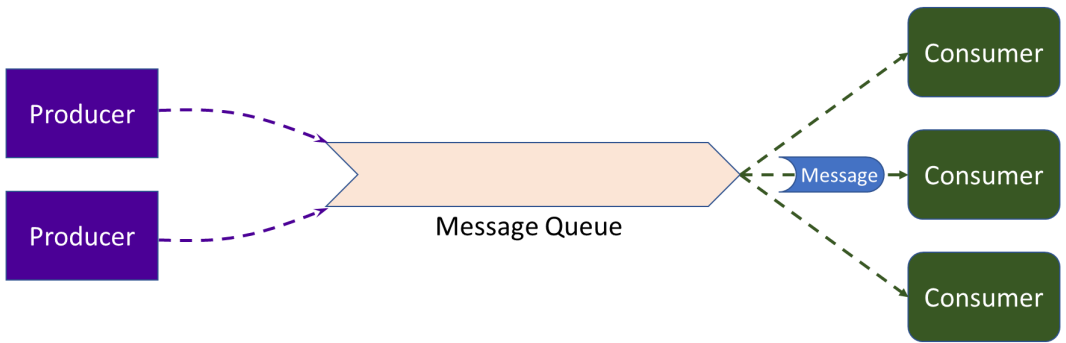


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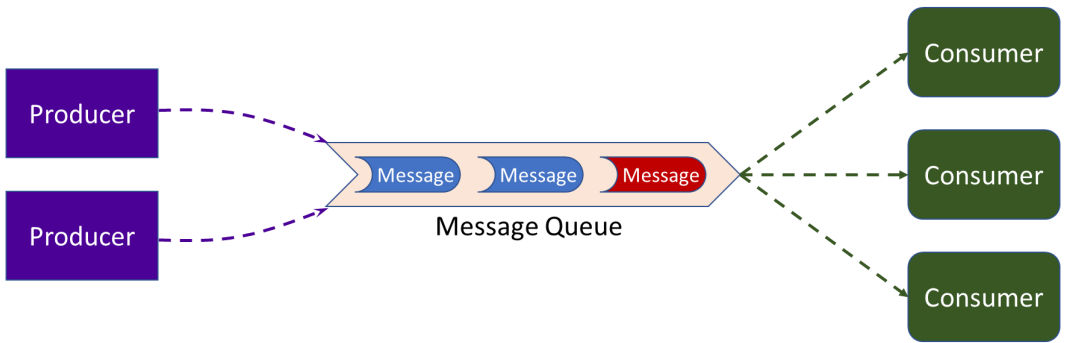
# Poison Message

- Receiver can't process message.
- Always fails – Not due to transient failure.
- Failed messages are retried.
- Returned to front of queue – Preserve message order.
- Next receiver fails to process message – Infinite loop.
- Blocks sending of following messages.

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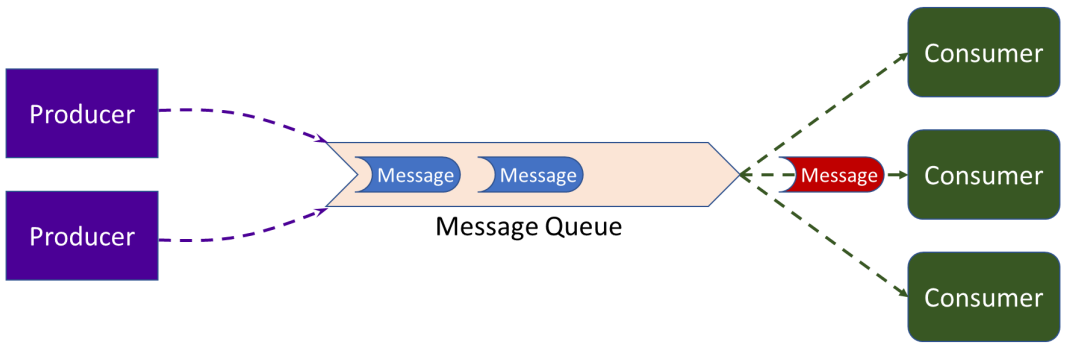


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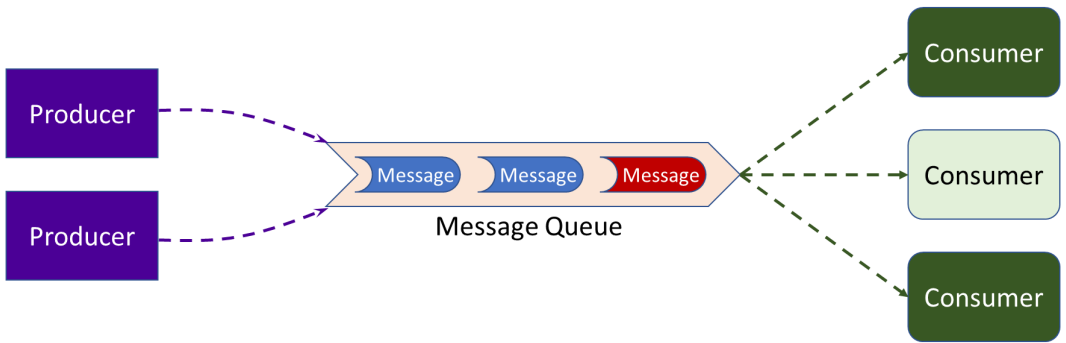


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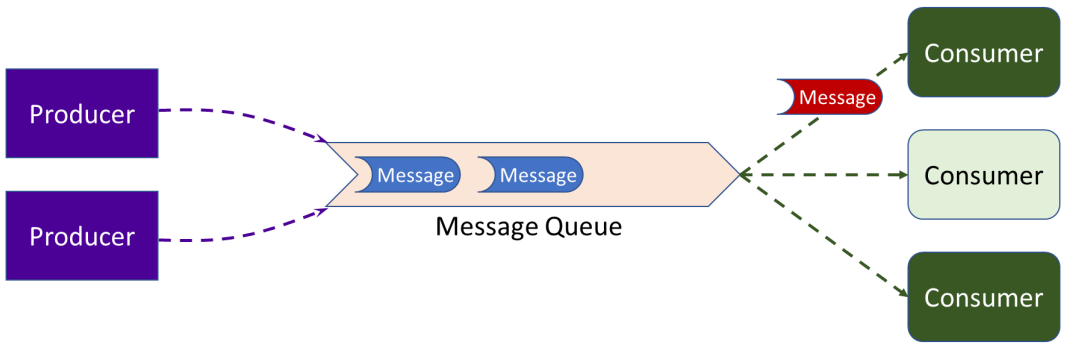


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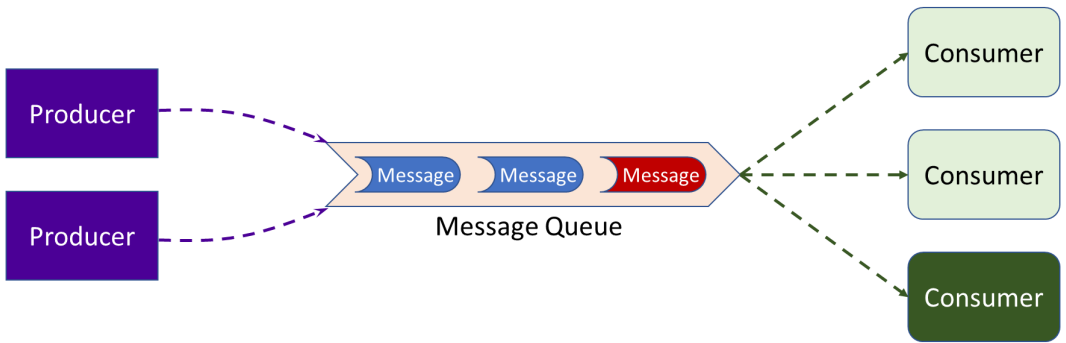


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- Content is invalid
  - e.g. Invalid product id sent to purchasing service
  - Error handling doesn't cater for error case

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Answer

- Content is invalid
  - e.g. Invalid product id sent to purchasing service
  - Error handling doesn't cater for error case
- System state is invalid
  - e.g. Add item to shopping cart that has been deleted
  - Logic doesn't handle out of order messages
    - Insidious asynchronous faults

- Invalid content may be
- corrupted data,
- old version of data structure,
- incorrect data, or
- malicious data.
- Invalid state may be
- events out of order (e.g. delete then update),
- logic error making state invalid, or
- external corruption of persistent state.

# Detecting Poison Messages

## Retry counter – with limit

- Where is counter stored?
  - Memory – What if server restarts?
  - DB – Slow
  - Must ensure counter is reset, regardless of how message is handled
    - e.g. Message is manually deleted

# Detecting Poison Messages

## Retry counter – with limit

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    - e.g. Message is manually deleted

## Message service may have a timeout property

- Message removed from queue
  - Pending messages get older while waiting for poison message
  - Transient network faults may exceed timeout

# Detecting Poison Messages

## Monitoring service

- Trigger action if message stays at top of queue for too long
- Can check for queue errors
  - No messages are being processed
  - Restart message service

## Discard message

- System must not require guarantee of message delivery
- Suitable when message processing speed is most important

# Handling Poison Messages

## Discard message

- System must not require guarantee of message delivery
- Suitable when message processing speed is most important

## Always retry

- Requires mechanism to fix message
  - Often requires manual intervention
- Suitable when message delivery is most important
- Very long delays in processing

## Dead-letter queue

- Long transient failures result in adding many messages
  - e.g. Network failure
- Requires manual monitoring and intervention
- System must not require strict ordering of messages
- Suitable when message processing speed is important

## Retry queue

- Transient failures also added
- Use a previous strategy to deal with poison messages
- System must not require strict ordering of messages
- Suitable when message processing speed is very important
  - Main queue is never blocked
  - Receivers need to process from two message queues

Definition 3. Poison Pill Message

Special message used to notify receiver it should no longer wait for messages.

Emphasise that this is different to a poison message

Question

# Why use a poison pill message?

Question

## Why use a poison pill message?

Answer

## Graceful shutdown of system.

- Implementation is challenging with multiple producers and/or consumers
- It must be the last message received by all consumers

Question

# How to order asynchronous messages?

Question

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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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  - Read from leader
  - Read from synchronous follower

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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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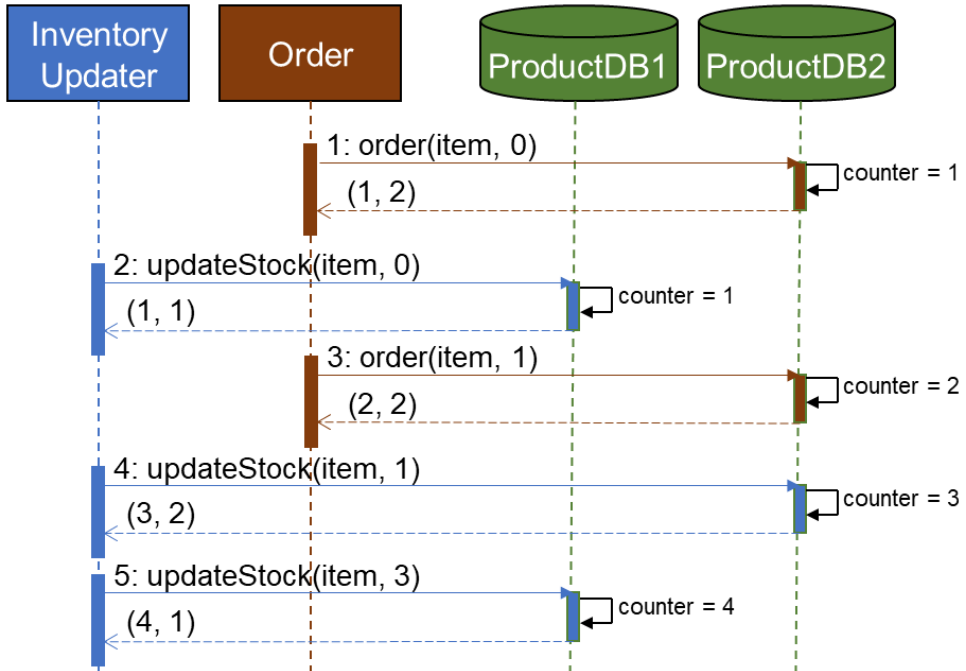
- Single-leader replication
  - Record sequence number of writes in log
  - Followers read log to execute writes
- Lamport timestamps

- 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 4. 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 5. Atomic Commit

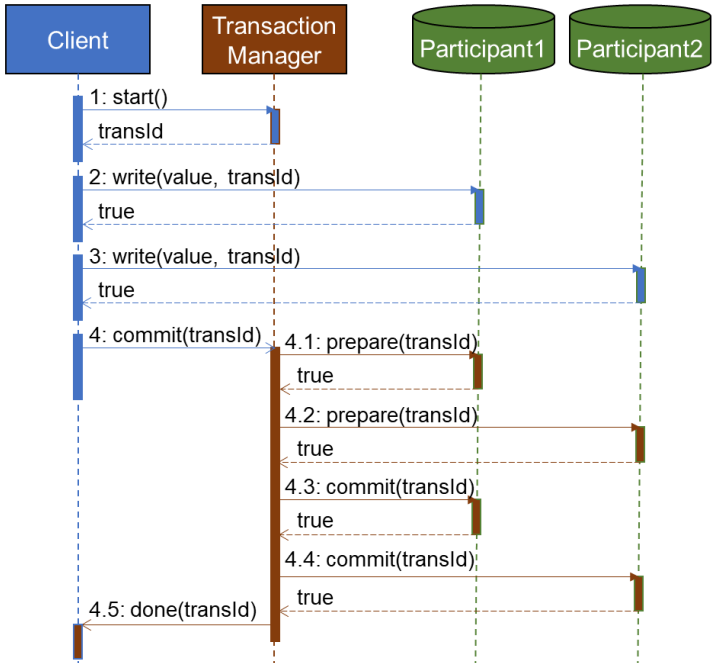
All nodes participating in a distributed transaction need to form consensus to complete the transaction.

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