# Distributed Computing III

*Murphy was an optimist.*

*— O'Toole's Commentary*

*CSSE6400*

Richard Thomas

April 22, 2024

*Question*

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- IP address not reachable – unreachable packet
- Query switches
- Timeout

*Question*

# What to do if fault is detected?

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*Answer*

- Retry
- Restart

*Definition 1.* Idempotency

Repeating an operation does not change receiver's state.

# 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
  - Send messages pretending to be another general

*Definition 2.* Byzantine Faults

Nodes in a distributed system may ‘lie’.

— Send faulty or corrupted messages or responses.

*Question*

Can we design a system to be Byzantine fault tolerant?

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Can we design a system to be Byzantine fault tolerant?

*Answer*

Yes, but, it is *challenging*.

# Limited Fault Tolerance

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  - Need strategy to handle & report errors
- Santise inputs
  - Assume any input from external sources may be malicious
- Retrieve data from multiple sources
  - If possible
  - e.g. Multiple NTP servers

*Assumption*

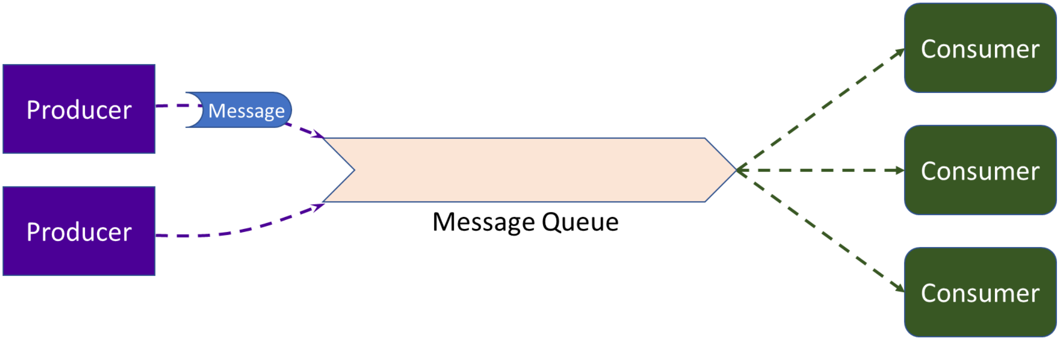
If all nodes are part of our system, we may assume there are no Byzantine faults.

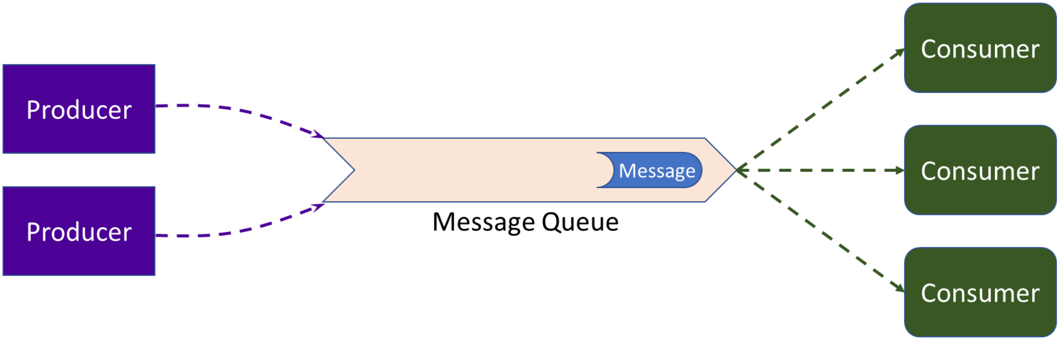
- Santise user input
- Byzantine faults may still arise
  - Logic defects
    - Same code is usually deployed to all replicated nodes, defeating easy fault tolerance solutions

*Definition 3.* Poison Message

A message that causes the receiver to fail.

# Normal Message Flow


Producer
Message
Producer
Message Queue
Consumer
Consumer
Consumer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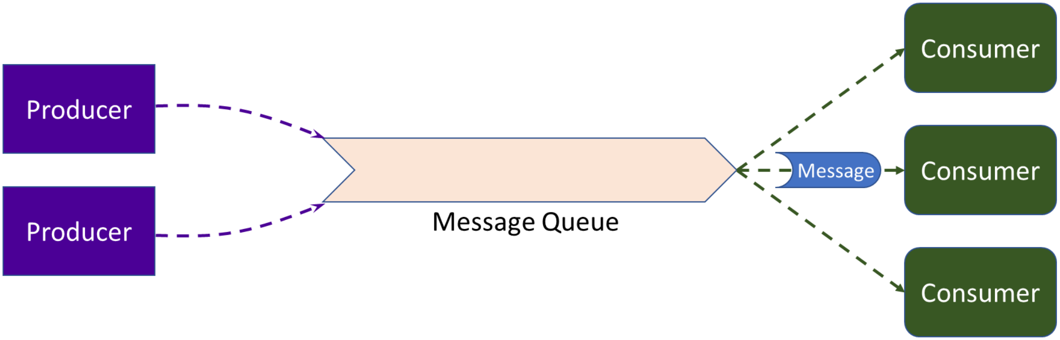
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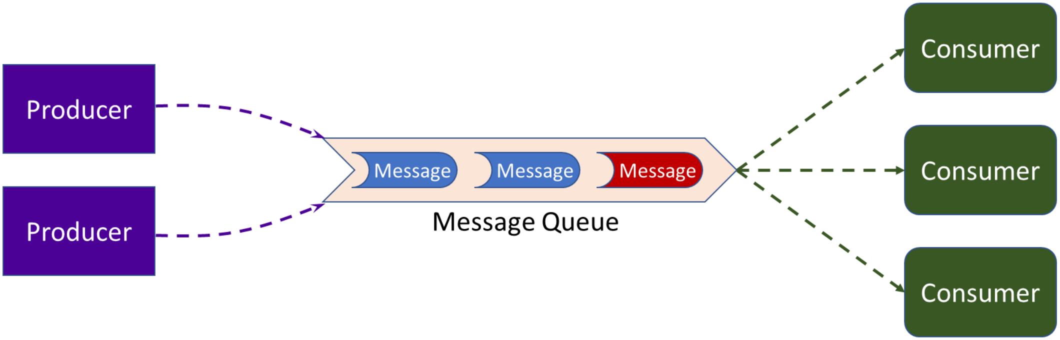
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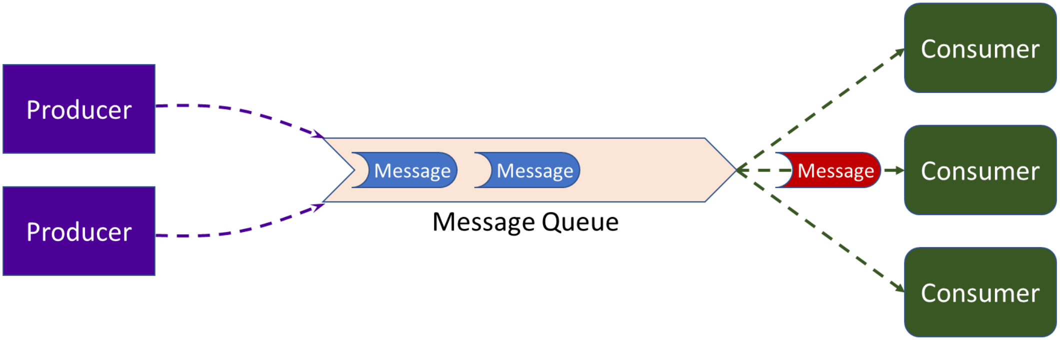
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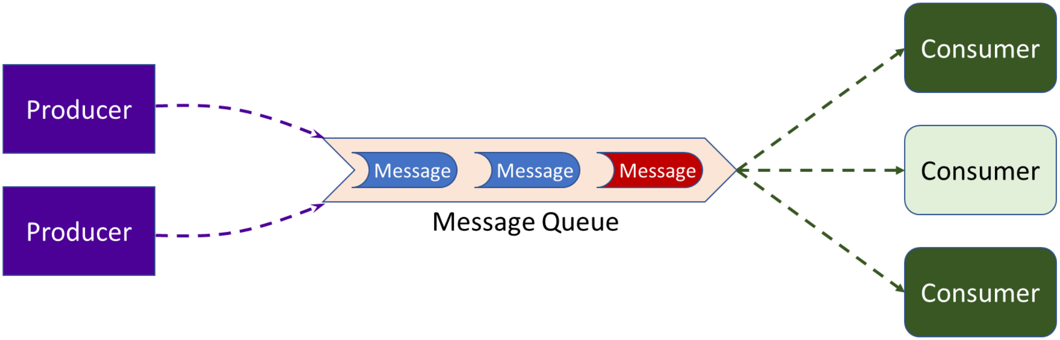
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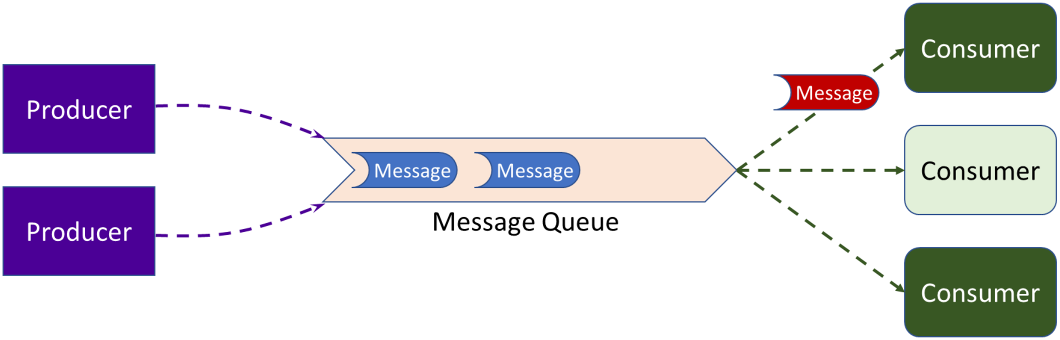
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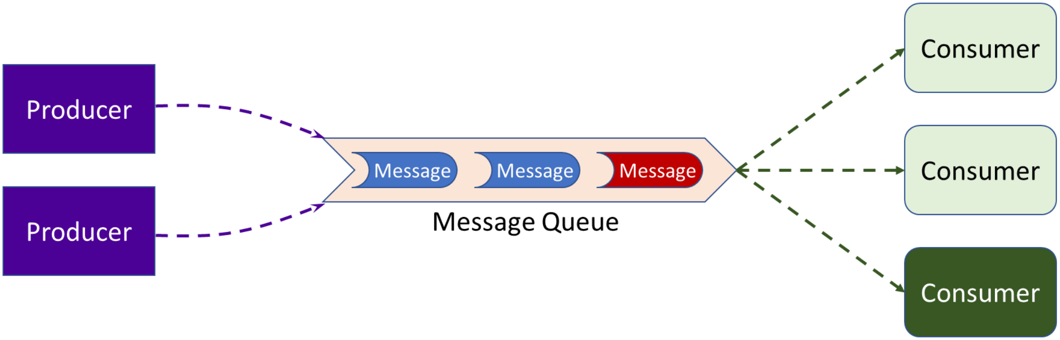
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# What causes a message to be poisonous?

*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

# 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

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## 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

# Handling Poison Messages

## Discard message

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## Always retry

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

# Handling Poison Messages

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

# Handling Poison Messages

## 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 4.* Poison Pill Message

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

*Question*

# Why use a poison pill message?

*Question*

Why use a poison pill message?

*Answer*

Graceful shutdown of system.

*Question*

# How to order asynchronous messages?

*Question*

How to order asynchronous messages?

*Answer*

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

# § Data Issues

*Consistency*

Eventual Consistency weak guarantee

Linearisability strong guarantee

Causal Ordering strong guarantee

## *Eventual Consistency*

- Allows stale reads
- May be appropriate for some systems
  - e.g. Social media updates[1]

[1] See Distributed II slides 41 - 46.

*Linearisability*

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  - Regardless of replica read from
- Single-leader replication
  - Read from leader
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- Multi-leader replication can't be linearised
- Leaderless replication
  - Lock value on quorum *before* writing

## *Causal Order*

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  - What event needs to happen before another
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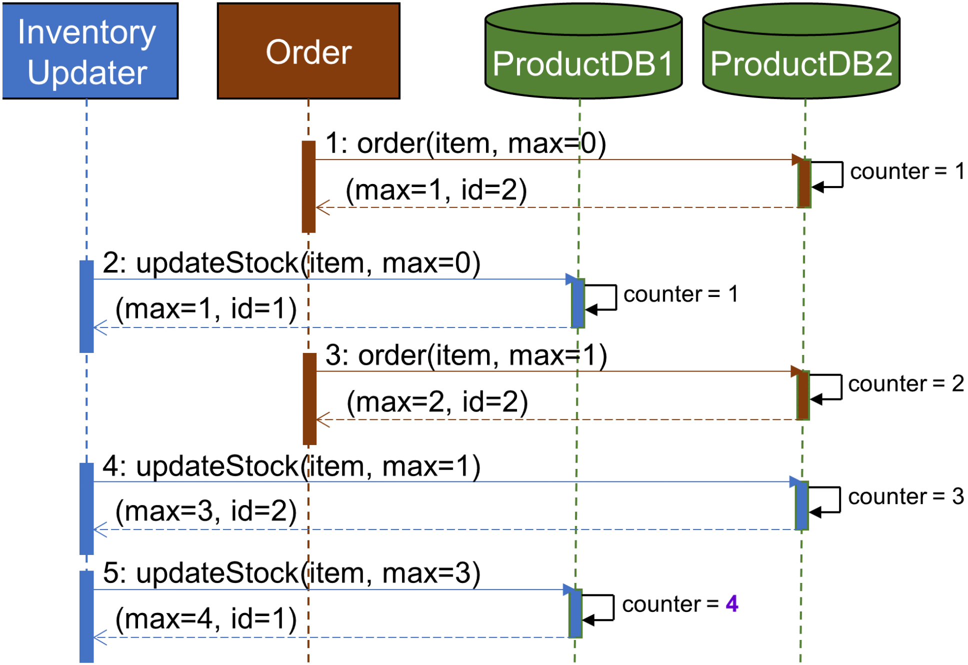
- Lamport timestamps


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

*Definition 5.* Consensus

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

*Definition 6.* Atomic Commit

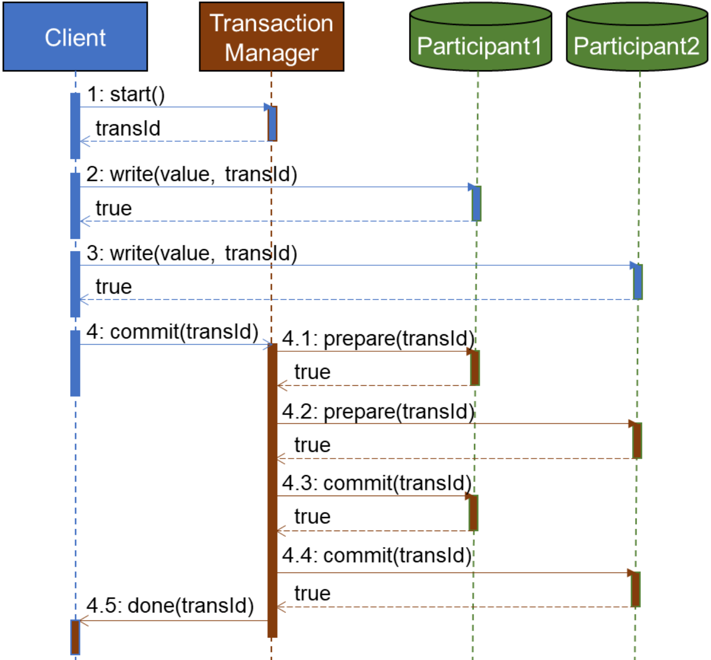
All nodes participating in a distributed transaction need to form consensus to complete the transaction.

*Two-Phase Commit*

**Prepare** Confirm nodes can commit transaction

**Commit** Finalise commit once consensus is reached

- Abort if consensus can't be reached



Client
Transaction Manager
Participant1
Participant2
1: start()
transId
2: write(value, transId)
true
3: write(value, transId)
true
4: commit(transId)
4.1: prepare(transId)
true
4.2: prepare(transId)
true
4.3: commit(transId)
true
4.4: commit(transId)
true
4.5: done(transId)

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- Synchronous System
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  - Assumes most faults are rare & transient
  - Error handling to catch faults

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- Partially Synchronous System
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  - Error handling to catch faults
- Asynchronous System
  - No timing assumptions
  - Important message order managed by application
  - Difficult & limited design

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- Crash Stop
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- Crash Recovery
  - Node fails and restarts
    - Requires persistent memory for recovery close to prior state
- Arbitrary Failure
  - Nodes may perform spurious or malicious actions
    - Byzantine faults

- Distributed systems are hard to build
- Large systems have to be distributed
  - Monoliths can't scale to millions of users
- Use environments, tools & libraries
  - Leaverage others' experience
- CSSE7610 Concurrency: Theory & Practice
  - Prove correctness of concurrent & distributed systems