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
# Message Queue & Event-Driven Design - 1 Hour Session

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**Duration:** 60 minutes **Level:** Intermediate

## Session Agenda

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-  Introduction to Message Queues (10 min)
  -  Message Queue Technologies (15 min)
  -  Event-Driven Patterns (15 min)
  -  Advanced Concepts: Event Sourcing & CQRS (10 min)
  -  Implementation & Best Practices (10 min)
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# Learning Objectives

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By the end of this session, you will understand:

- What message queues are and when to use them
- Key differences between Kafka, RabbitMQ, and SQS
- Pub/Sub patterns and their applications
- Event sourcing and CQRS concepts
- Choreography vs orchestration in distributed systems
- Common pitfalls and how to avoid them


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## 1. Introduction to Message Queues (10 min)

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### What is a Message Queue?

A **message queue** is a form of asynchronous service-to-service communication used in distributed systems. Messages are stored in the queue until processed and deleted.

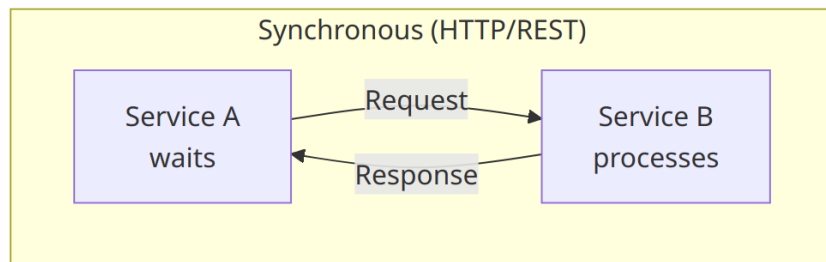
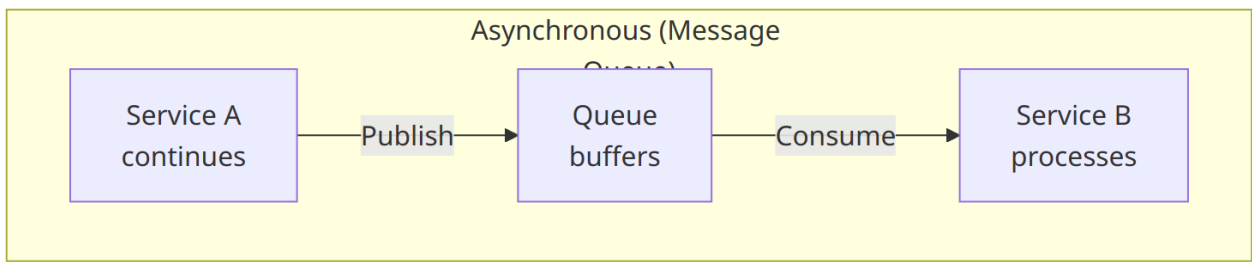
 **Quote** “Decouple components by communicating through messages rather than direct calls.”

### Why Use Message Queues?

**Key Benefits:**

-  **Decoupling:** Services don't need to know about each other
-  **Async Processing:** Non-blocking operations
-  **Scalability:** Handle traffic spikes with buffering
-  **Reliability:** Messages persist until processed
-  **Load Leveling:** Smooth out traffic bursts

## Synchronous vs Asynchronous Communication



Diagram

## Core Concepts

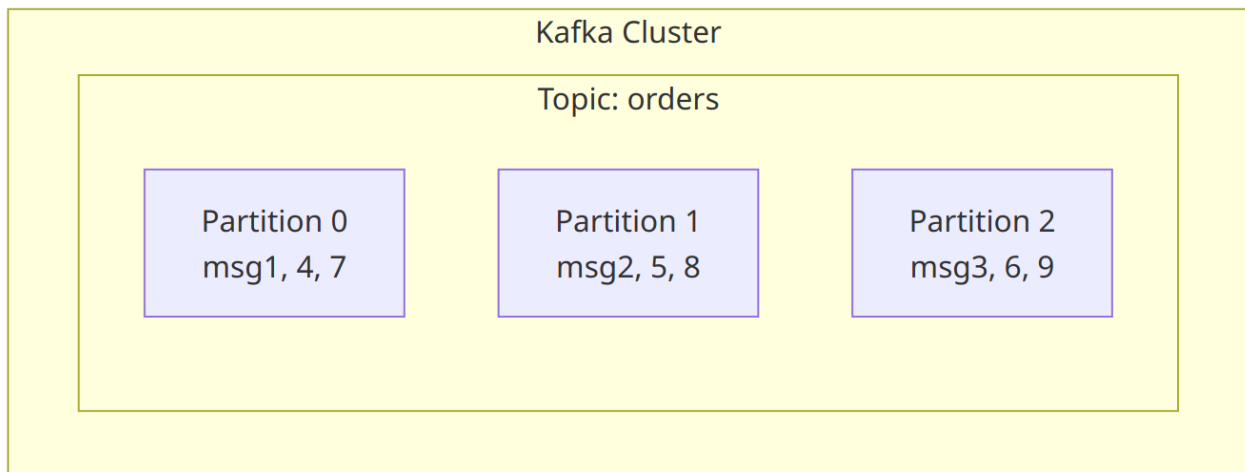
CONCEPT	DESCRIPTION
Producer	Service that sends messages
Consumer	Service that receives messages
Queue/Topic	Storage for messages
Message	Data payload with metadata
Broker	Server managing queues

## 2. Message Queue Technologies (15 min)

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### Apache Kafka

**Distributed event streaming platform** designed for high-throughput, fault-tolerant messaging.



Diagram

#### Key Features:

- Log-based storage (append-only)
- Consumer groups for parallel processing
- Message retention (configurable)
- Exactly-once semantics (with transactions)

```

// Kafka Producer Example
Properties props = new Properties();
props.put("bootstrap.servers", "localhost:9092");
props.put("key.serializer",
"org.apache.kafka.common.serialization.StringSerializer");
props.put("value.serializer",
"org.apache.kafka.common.serialization.StringSerializer");

Producer<String, String> producer = new KafkaProducer<>(props);
producer.send(new ProducerRecord<>("orders", "order-123", orderJson));

// Kafka Consumer Example
props.put("group.id", "order-processor");
Consumer<String, String> consumer = new KafkaConsumer<>(props);
consumer.subscribe(Arrays.asList("orders"));

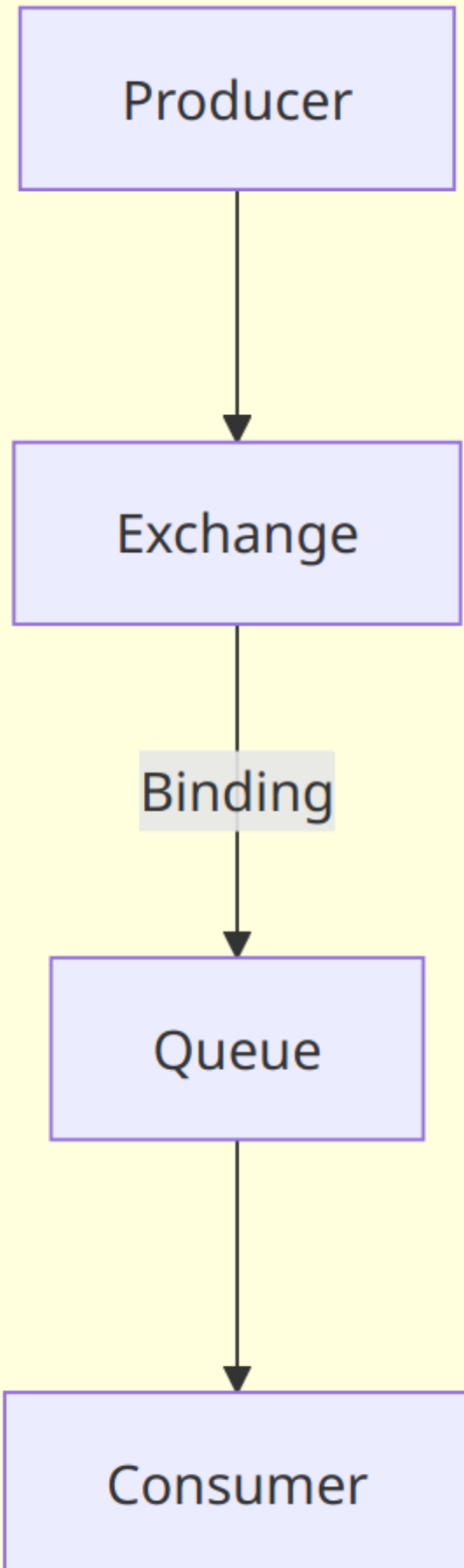
while (true) {
    ConsumerRecords<String, String> records =
consumer.poll(Duration.ofMillis(100));
    for (ConsumerRecord<String, String> record : records) {
        processOrder(record.value());
    }
}

```

## RabbitMQ

**Traditional message broker** implementing AMQP protocol with flexible routing.

## RabbitMQ



## Diagram

**Exchange Types:** - **Direct** - routing key match - **Fanout** - broadcast to all - **Topic** - pattern matching - **Headers** - header attributes

### Key Features:

- Flexible routing with exchanges
- Message acknowledgments
- Dead letter queues
- Priority queues

```
# RabbitMQ Producer Example
import pika

connection = pika.BlockingConnection(pika.ConnectionParameters('localhost'))
channel = connection.channel()

channel.queue_declare(queue='orders', durable=True)
channel.basic_publish(
    exchange='',
    routing_key='orders',
    body=order_json,
    properties=pika.BasicProperties(delivery_mode=2) # Persistent
)

# RabbitMQ Consumer Example
def callback(ch, method, properties, body):
    process_order(body)
    ch.basic_ack(delivery_tag=method.delivery_tag)

channel.basic_consume(queue='orders', on_message_callback=callback)
channel.start_consuming()
```

## Amazon SQS

Fully managed message queue service by AWS.



Diagram



```

# SQS Example
import boto3

sqs = boto3.client('sqs')
queue_url = 'https://sqs.us-east-1.amazonaws.com/123456789/orders'

# Send message
sqs.send_message(
    QueueUrl=queue_url,
    MessageBody=order_json,
    MessageAttributes={
        'OrderType': {'DataType': 'String', 'StringValue': 'standard'}
    }
)

# Receive messages
response = sqs.receive_message(
    QueueUrl=queue_url,
    MaxNumberOfMessages=10,
    WaitTimeSeconds=20 # Long polling
)

for message in response.get('Messages', []):
    process_order(message['Body'])
    sqs.delete_message(
        QueueUrl=queue_url,
        ReceiptHandle=message['ReceiptHandle']
    )

```

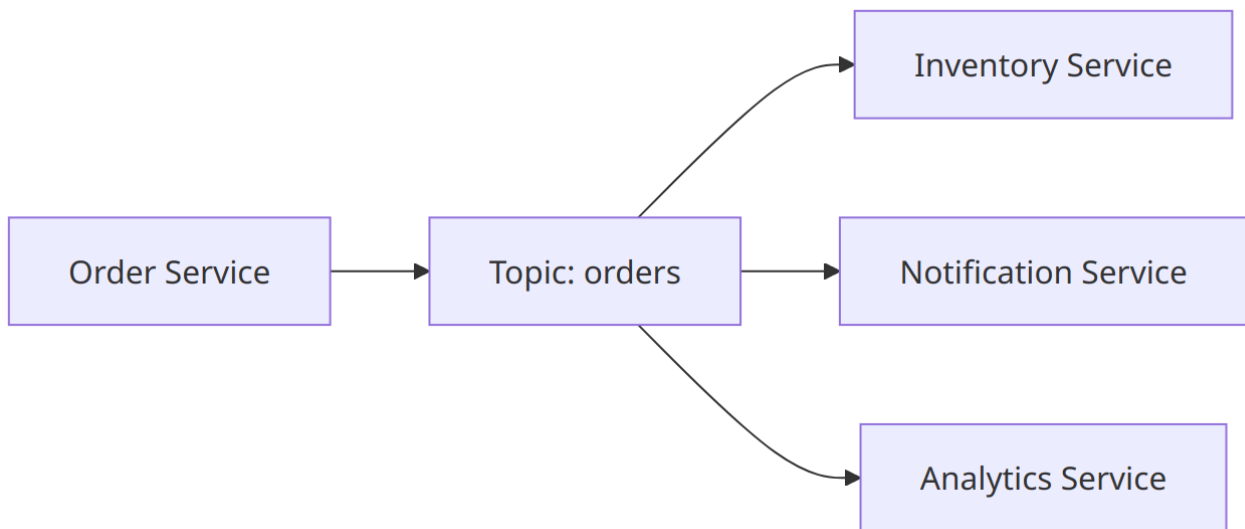
## Technology Comparison

FEATURE	KAFKA	RABBITMQ	SQS
Model	Log-based	Queue-based	Queue-based
Ordering	Per partition	Per queue	FIFO only
Throughput	Very High	High	High
Retention	Configurable	Until consumed	14 days max
Replay	Yes	No	No
Managed	No (MSK yes)	No	Yes
Best For	Event streaming	Task queues	AWS integration

## 3. Event-Driven Patterns (15 min)

### Pub/Sub Pattern

**Publishers** send messages to **topics**, **subscribers** receive messages from topics they're interested in.



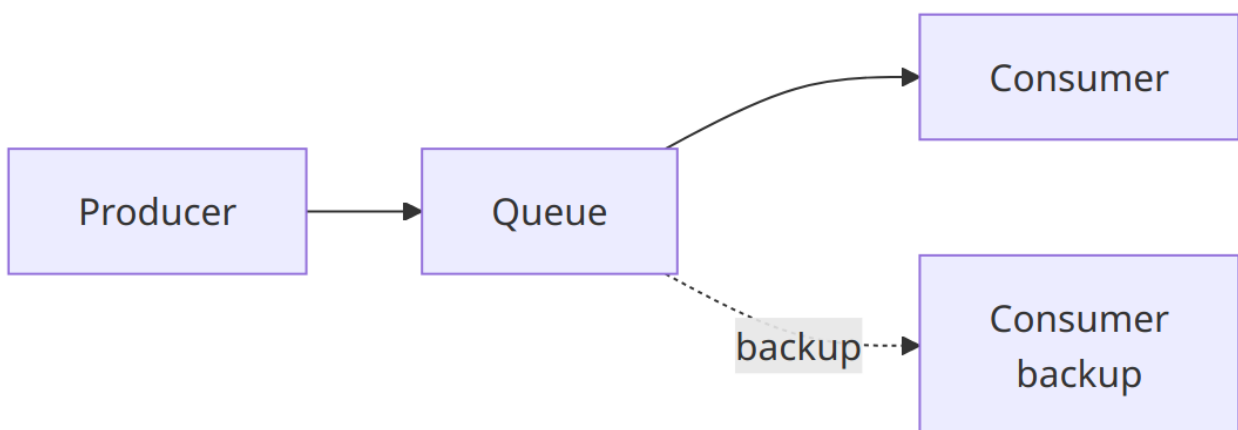
Diagram

#### Use Cases:

- Event notifications
- Real-time updates
- Fan-out processing

### Point-to-Point Pattern

**One producer, one consumer** per message. Messages are consumed once.



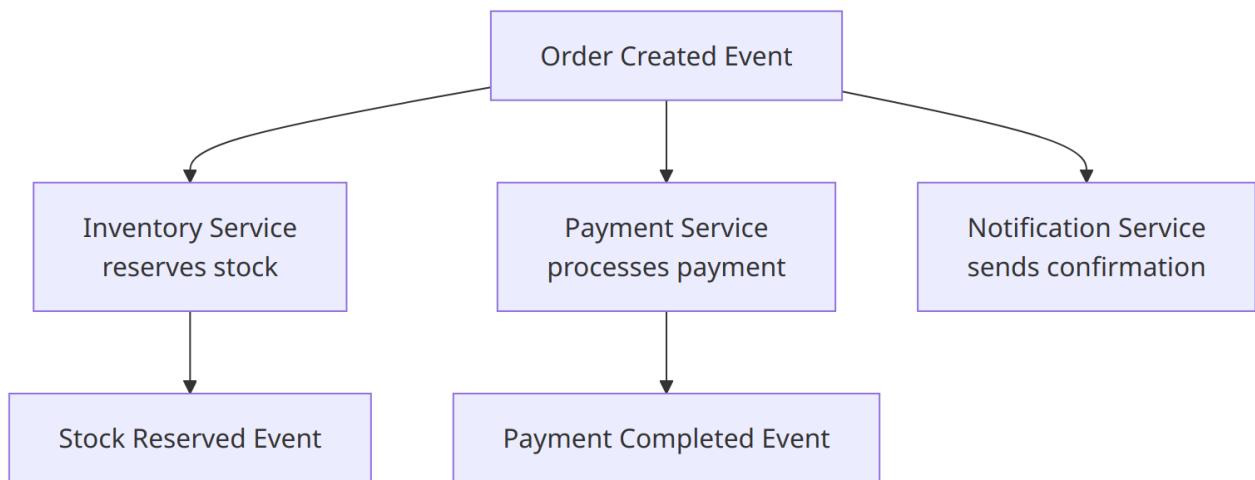
Only one consumer receives each message

## Use Cases:

- Task distribution
- Work queues
- Load balancing

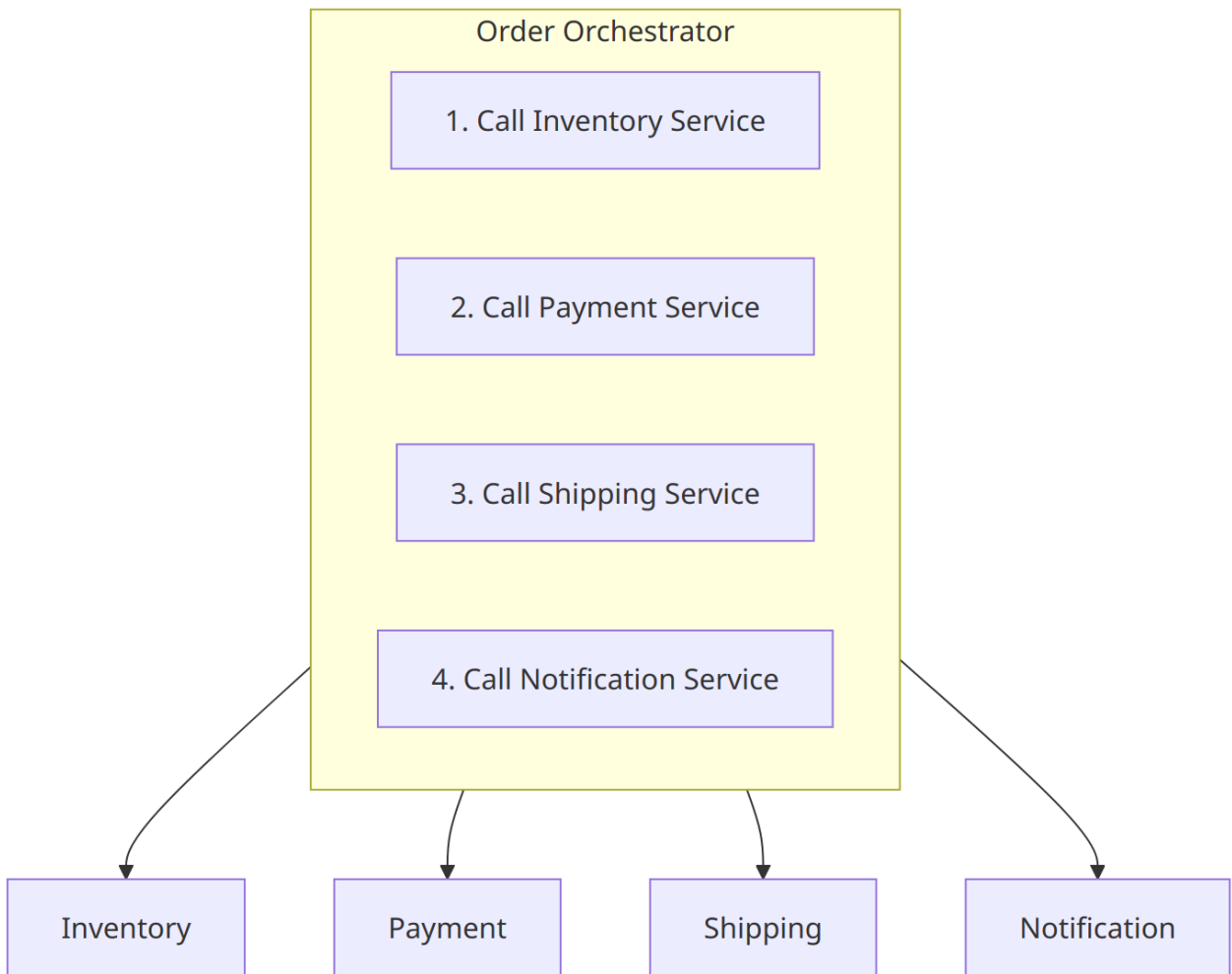
## Choreography vs Orchestration

**Choreography:** Services react to events independently (decentralized).



Diagram

**Orchestration:** Central coordinator manages the workflow.



Diagram

ASPECT	CHOREOGRAPHY	ORCHESTRATION
Coupling	Loose	Tighter
Visibility	Distributed	Centralized
Complexity	In events	In orchestrator
Failure Handling	Each service	Orchestrator
Best For	Simple flows	Complex workflows

## 4. Advanced Concepts: Event Sourcing & CQRS (10 min)

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### Event Sourcing

**Store state as a sequence of events** rather than current state.

## Event Sourcing

Event 1:  
AccountCreated(\$0)



Event 2: Deposited(\$1000)



Event 3: Withdrawn(\$300)



Event 4: Deposited(\$200)

**Benefits:**

- Complete audit trail
- Time travel (reconstruct past states)
- Event replay for debugging
- Natural fit for event-driven systems

```
# Event Sourcing Example
class BankAccount:
    def __init__(self, account_id):
        self.account_id = account_id
        self.balance = 0
        self.events = []

    def apply_event(self, event):
        if event['type'] == 'Deposited':
            self.balance += event['amount']
        elif event['type'] == 'Withdrawn':
            self.balance -= event['amount']
        self.events.append(event)

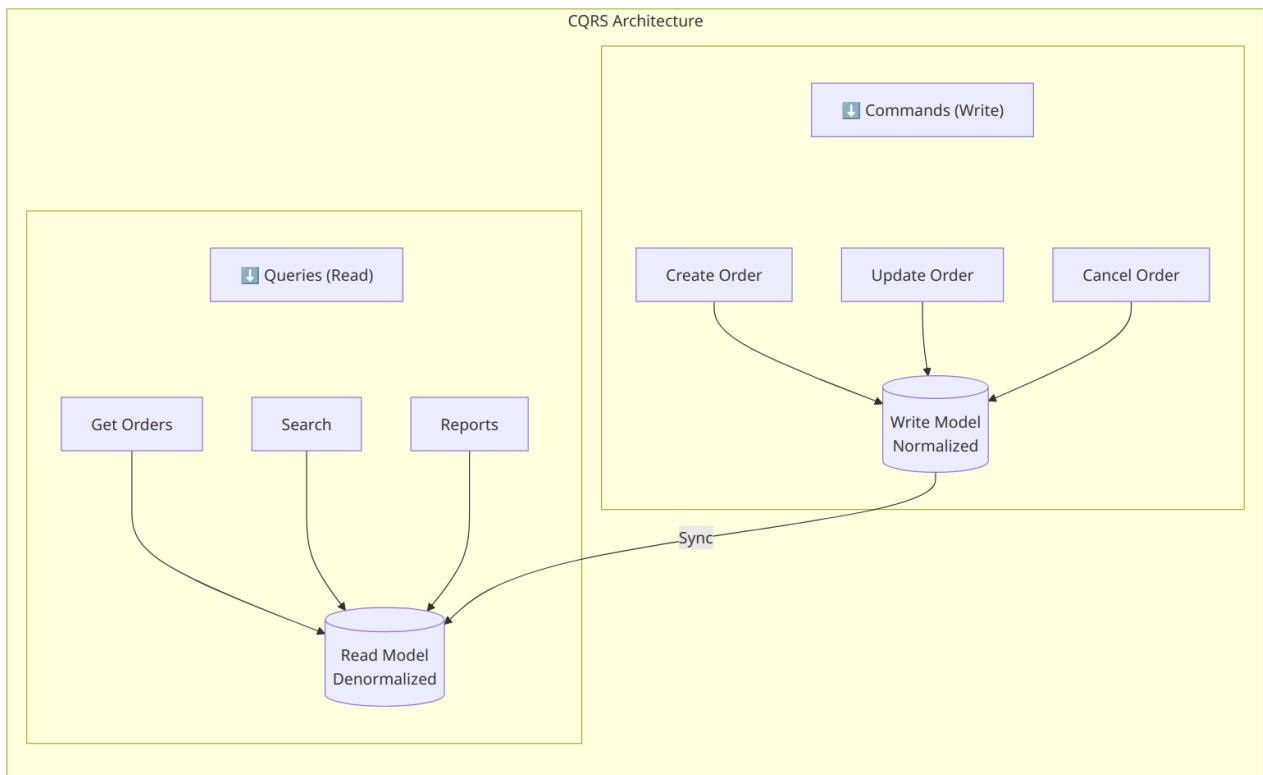
    def deposit(self, amount):
        event = {'type': 'Deposited', 'amount': amount, 'timestamp': now()}
        self.apply_event(event)
        event_store.save(self.account_id, event)

    def rebuild_from_events(self, events):
        for event in events:
            self.apply_event(event)
```

**CQRS (Command Query Responsibility Segregation)**

Separate read and write models for different optimization.





Diagram

**Benefits:** - Optimize reads and writes independently - Scale read and write sides separately - Different data models for different needs

```

# CQRS Example
class OrderCommandHandler:
    def handle_create_order(self, command):
        order = Order.create(command.data)
        order_repository.save(order)
        event_bus.publish(OrderCreatedEvent(order))

class OrderQueryHandler:
    def get_order_summary(self, order_id):
        # Read from denormalized read model
        return read_db.query(
            "SELECT * FROM order_summaries WHERE id = ?",
            order_id
        )

# Event handler updates read model
class OrderProjection:
    def handle_order_created(self, event):
        read_db.insert('order_summaries', {
            'id': event.order_id,
            'customer_name': event.customer_name,
            'total': event.total,
            'status': 'created'
        })

```

## 5. Implementation & Best Practices (10 min)

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### Message Design

```
{
  "messageId": "msg-uuid-12345",
  "type": "OrderCreated",
  "version": "1.0",
  "timestamp": "2024-01-15T10:30:00Z",
  "source": "order-service",
  "correlationId": "req-uuid-67890",
  "data": {
    "orderId": "order-123",
    "customerId": "cust-456",
    "items": [ ... ],
    "total": 99.99
  },
  "metadata": {
    "traceId": "trace-abc",
    "userId": "user-789"
  }
}
```

### Idempotency

Ensure processing a message multiple times has the same effect as once.

```

def process_order(message):
    message_id = message['messageId']

    # Check if already processed
    if processed_messages.exists(message_id):
        return # Skip duplicate

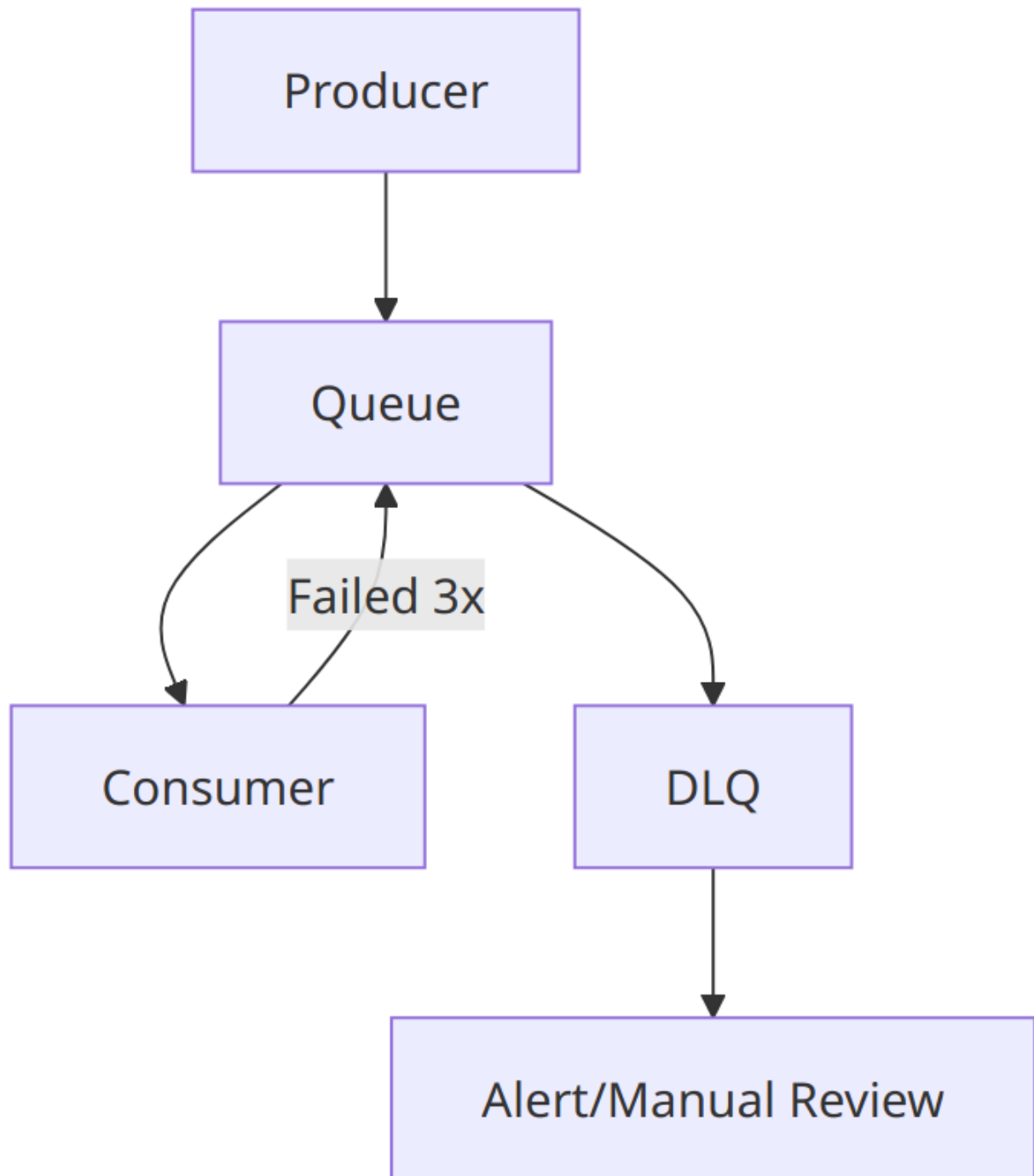
    try:
        # Process the order
        create_order(message['data'])

        # Mark as processed
        processed_messages.add(message_id, ttl=7*24*60*60) # 7 days
    except Exception as e:
        # Don't mark as processed - allow retry
        raise e

```

## Dead Letter Queues

Handle messages that can't be processed.



Diagram

## Monitoring & Observability

**Key Metrics:** - Queue depth (messages waiting) - Processing latency - Error rate - Consumer lag (Kafka) - Message age

```
# Structured logging for tracing
import logging

def process_message(message):
    logger.info("Processing message", extra={
        'message_id': message['messageId'],
        'correlation_id': message['correlationId'],
        'trace_id': message['metadata']['traceId'],
        'message_type': message['type']
    })
```



## Common Pitfalls & Solutions

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### 1. Message Ordering

**Problem:** Messages processed out of order.

**Solutions:** - Use partition keys (Kafka) - FIFO queues (SQS) - Sequence numbers in messages

### 2. Duplicate Processing

**Problem:** Same message processed multiple times.

**Solutions:** - Idempotent consumers - Deduplication with message IDs - Exactly-once semantics (where available)

### 3. Poison Messages

**Problem:** Messages that always fail processing.

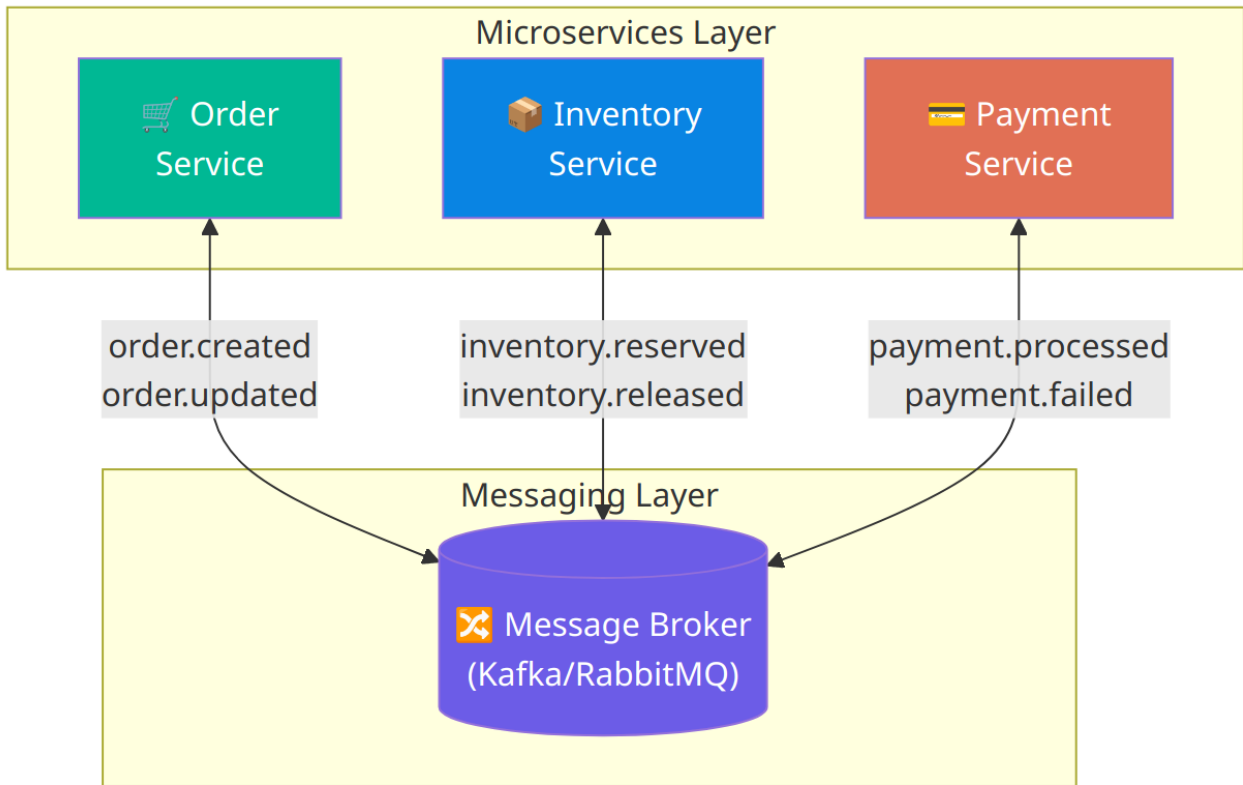
**Solutions:** - Dead letter queues - Retry limits - Circuit breakers

### 4. Consumer Lag

**Problem:** Consumers can't keep up with producers.

**Solutions:** - Scale consumers horizontally - Increase batch size - Optimize processing logic

## Event-Driven Microservices



## Compensation (on failure)

PaymentFailed



ReleaseInventory



CancelOrder

## Order Saga

OrderCreated



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## Key Takeaways

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1. **Message queues enable loose coupling** and async communication
  2. **Choose the right tool:** Kafka for streaming, RabbitMQ for routing, SQS for simplicity
  3. **Pub/Sub vs Point-to-Point** depends on your use case
  4. **Choreography vs Orchestration** - trade-offs in visibility and coupling
  5. **Event Sourcing** provides audit trails and time travel
  6. **CQRS** optimizes reads and writes separately
  7. **Always design for idempotency** and handle failures gracefully
- 

## Practical Exercise

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**Scenario:** Design an e-commerce order processing system.

**Requirements:** - Order placement - Inventory check - Payment processing - Shipping notification - Email confirmation

**Questions:** 1. Which message queue technology would you choose? 2. Choreography or orchestration? 3. How to handle payment failures? 4. How to ensure exactly-once processing?

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**Session End - Thank You!** 🎉

#message-queue #event-driven #kafka #rabbitmq #sqs #architecture #session-notes