</ Distributed transaction using Saga pattern

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Speaker: Trung Tran

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</ Prerequisites

Must have

- Basic knowledge in software architecture
- Understanding of remote communication between servers/software components
- Understanding of concurrency concepts

Nice to have

- C#, .NET knowledge
- Understanding of async communication
- Experience of Docker

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</ Resources

Repository URL:

https://github.com/trannamtrung1st/SagaSeminar

Requirements:

- .NET SDK 6.0
- Docker Desktop

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+300 software engineers

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3 development centers (2 offices in Singapore and USA)

Website: https://saigontechnology.com/

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</ Contact

trannamtrung1st@gmail.com

(+84)76 544 1077

https://www.linkedin.com/in/trung-tran99/

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Context & problems

01

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</ Relational database & transactions

- Transaction is a single unit of logic or work
- ACID properties:
  - Atomic
  - Consistent
  - Isolated
  - Durable

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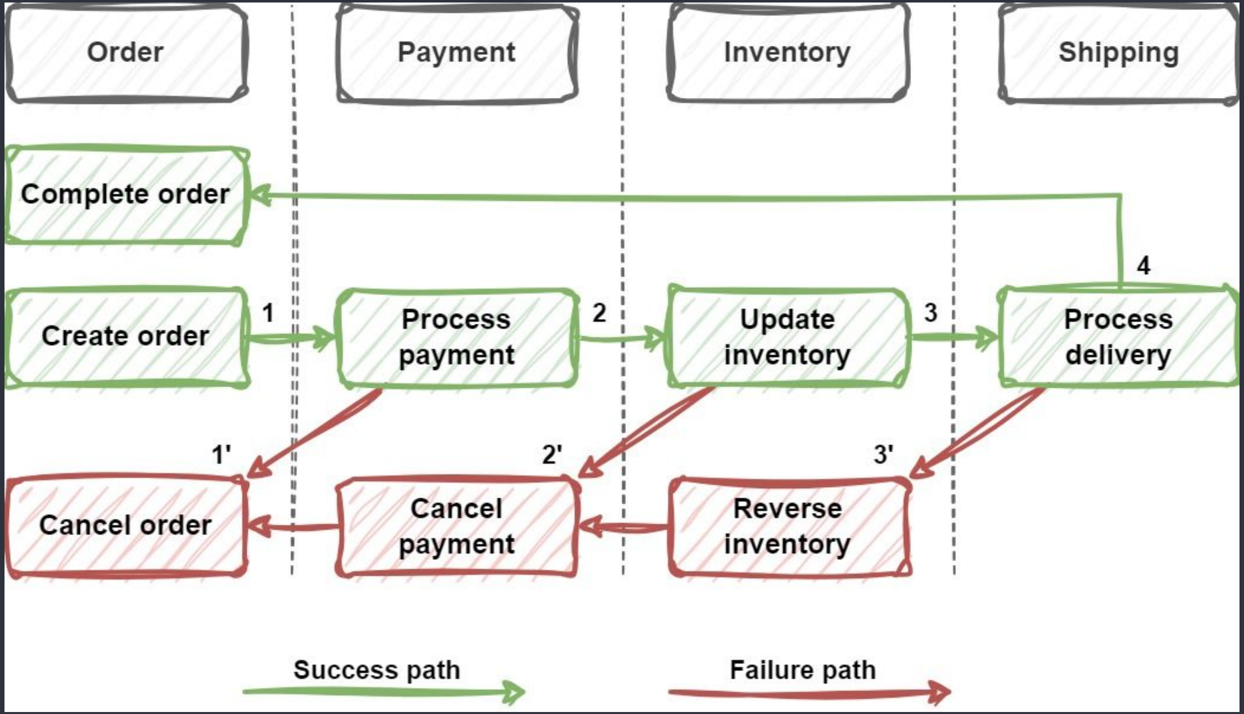
</ Transaction in a distributed system

- Atomicity: a single unit with set of operations that must all occur or none occur
- Consistency: data should only move from one state to another expected valid state in all participants
- Isolation: ensures that concurrent transactions result in the same outcome when running sequentially
- Durability: makes the commit status of transactions persistent and be able to bear with failure related to system or power outage

</ Sample order processing system



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</ Problems with a distributed transaction

Problems with transaction in a distributed environment

- Due to usage of database-per-microservice, NoSQL databases, message brokers, file storage

  -> They do not support Two-phase commit (2PC) protocol

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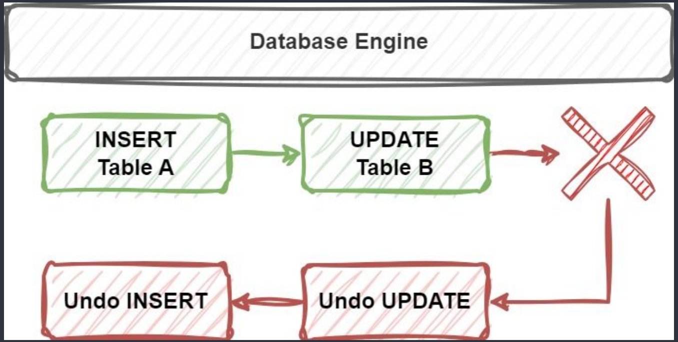
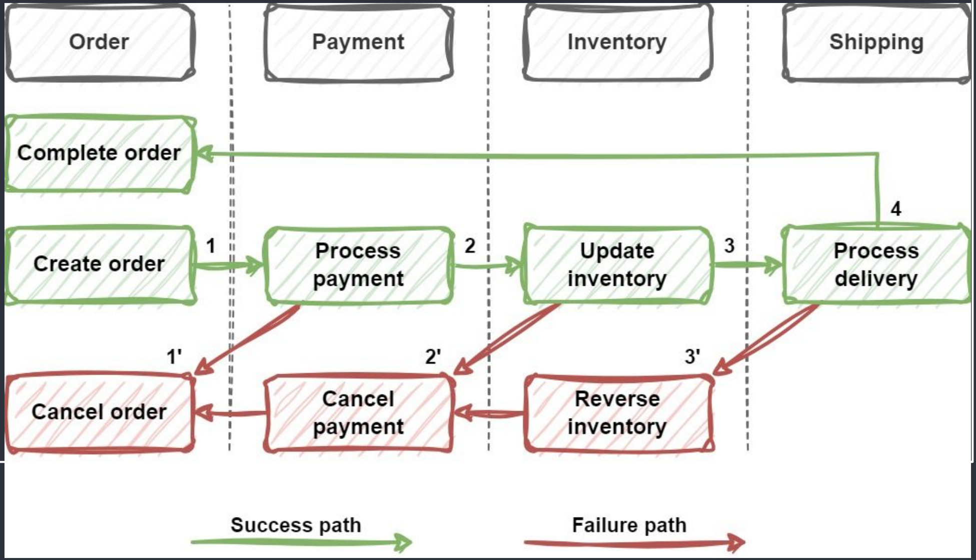
</ Problems with a distributed transaction

Problems with transaction in a distributed environment

- Complicated rollback operations





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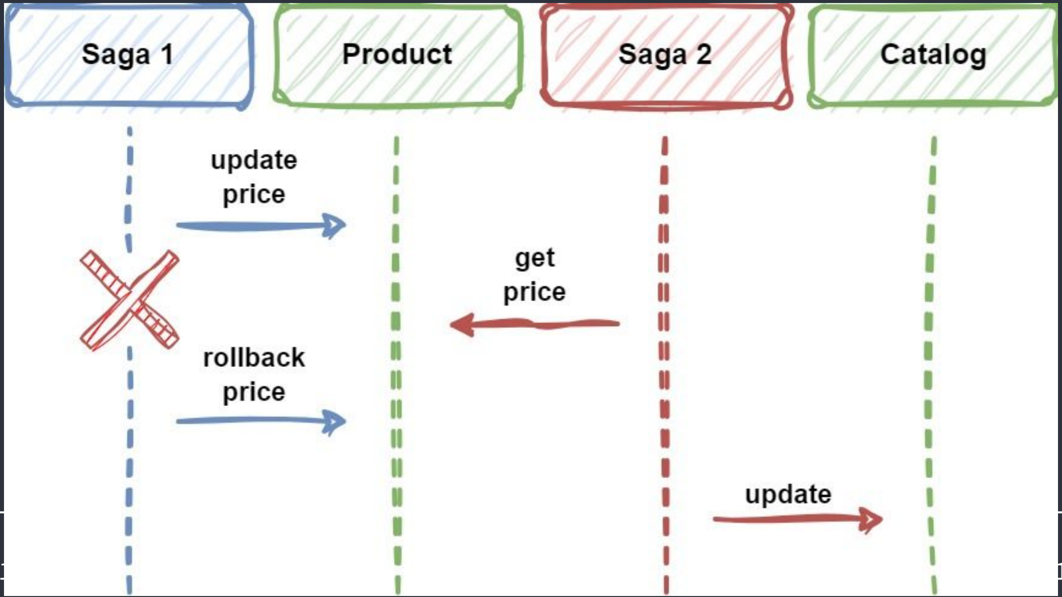
</ Problems with a distributed transaction

Problems with transaction in a distributed environment

- Atomicity, consistency and isolation is a challenge



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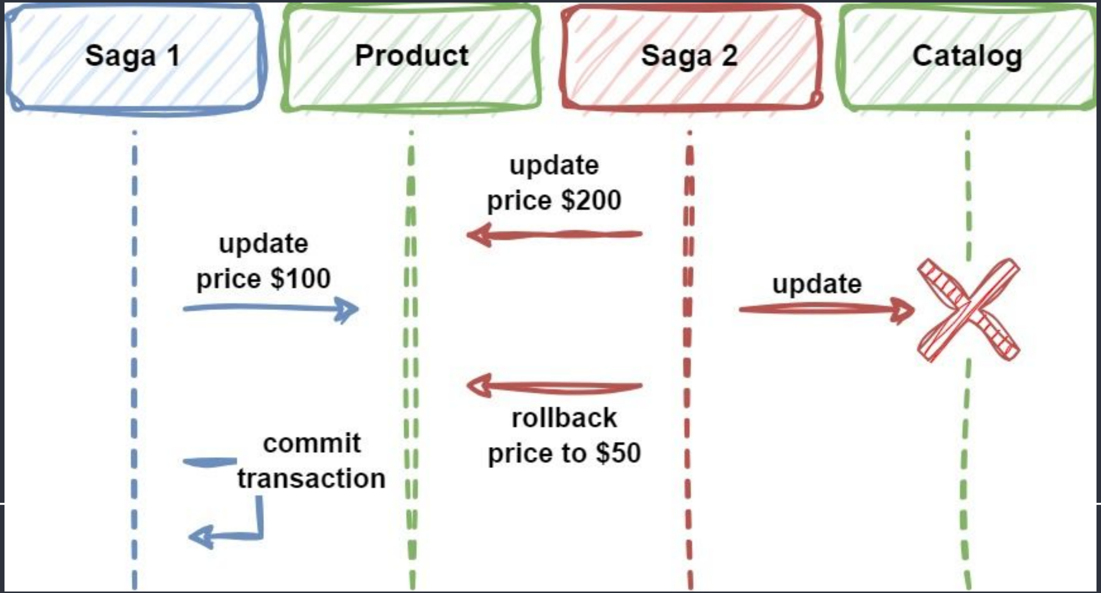
</ Problems with a distributed transaction

Problems with transaction in a distributed environment

- Limitations with synchronicity and availability



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Saga - The solution

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</ What is Saga pattern?

- A transaction management strategy involving with multiple local transactions
- A local transaction is performed by a saga participant
- Each local transaction performs its transaction, then publishes events to trigger the next transaction
- If local transaction fails, the saga will execute a series of compensating transactions that reverse/compensate the changes made before

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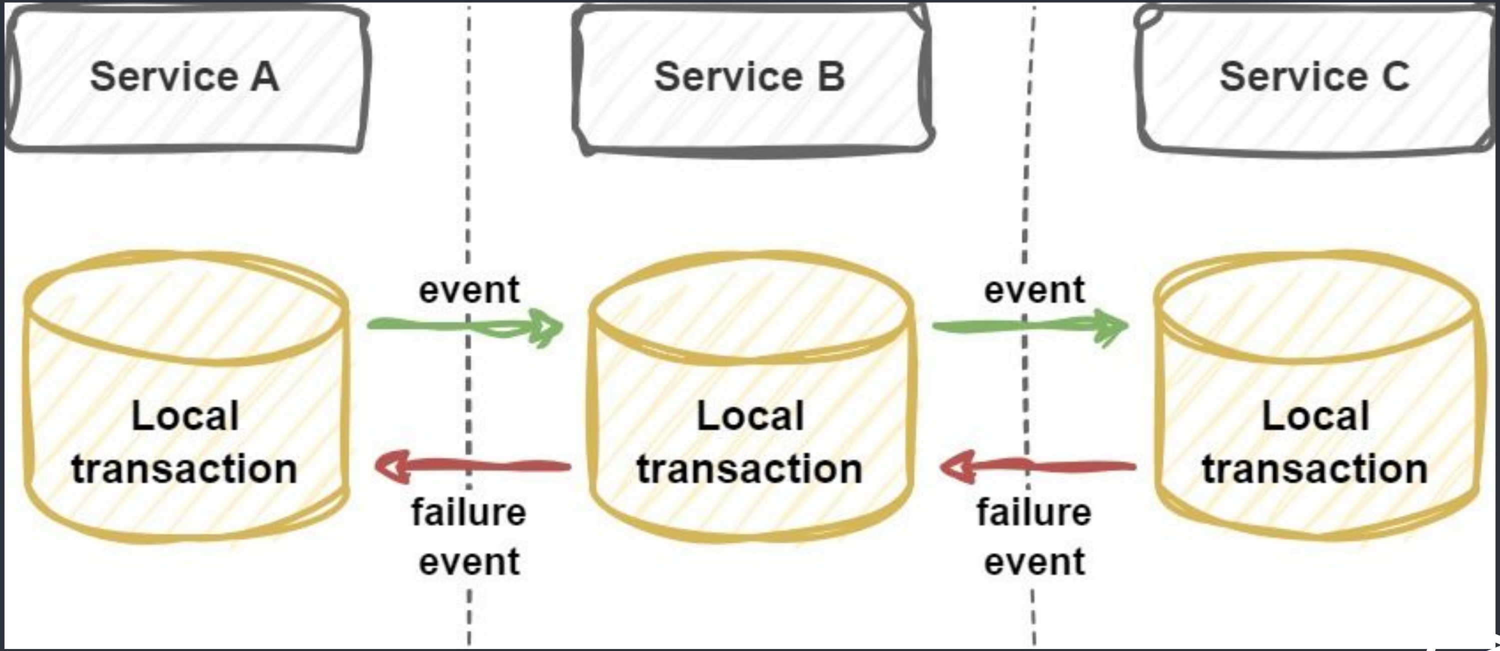
</ What is Saga pattern?



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</ Saga pattern - Concepts

- Saga participants
- Compensable & compensating transactions
- Pivot transaction
- Retryable transactions
- Transaction key

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</ Saga participants

Services/software components that are responsible for one or more local transactions in the whole saga transaction

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</ Compensable, compensating transactions

- Compensable transactions can potentially be undo by executing another transaction with the opposite effect
- Compensating transactions reverse/compensate the changes made before by the compensable transactions

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</ Pivot transaction

- The go/no-go (all or nothing) point in a saga
- If the pivot transaction commits, the saga runs the remaining transactions until done
- We can tell the saga is successful if a pivot transaction commits
- A pivot transaction can be neither compensable nor retryable, or it can be the last compensable transaction or the first retryable transaction in the saga

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</ Retryable transactions

- Follow pivot transaction and are guaranteed to succeed
- For example, in ordering application
  - Create order
    -> Compensating transaction will be Cancel order
  - Process payment
  - Update inventory
  - Delivery to customer → pivot transaction
  - Complete order → is retryable since all important steps are already successful

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</ Transaction key

- Each transaction should have a unique and consistent key across services
- Is used to retrieve the transaction's information
- Marks entities or operations as associated with a specific transaction
- Can be randomly generated and linked or must be able to construct using consistent hashing

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</ Implementation approaches

There are two common implementations:

- Choreography
- Orchestration

Each has its own set of challenges and techniques to manage the workflow

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Techniques in Saga

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</ Common techniques & design patterns

- Asynchronous communication & Message broker
- Asynchronous request-reply
- "Replay" technique
- Other techniques to ensure resiliency and target isolation, consistency issues

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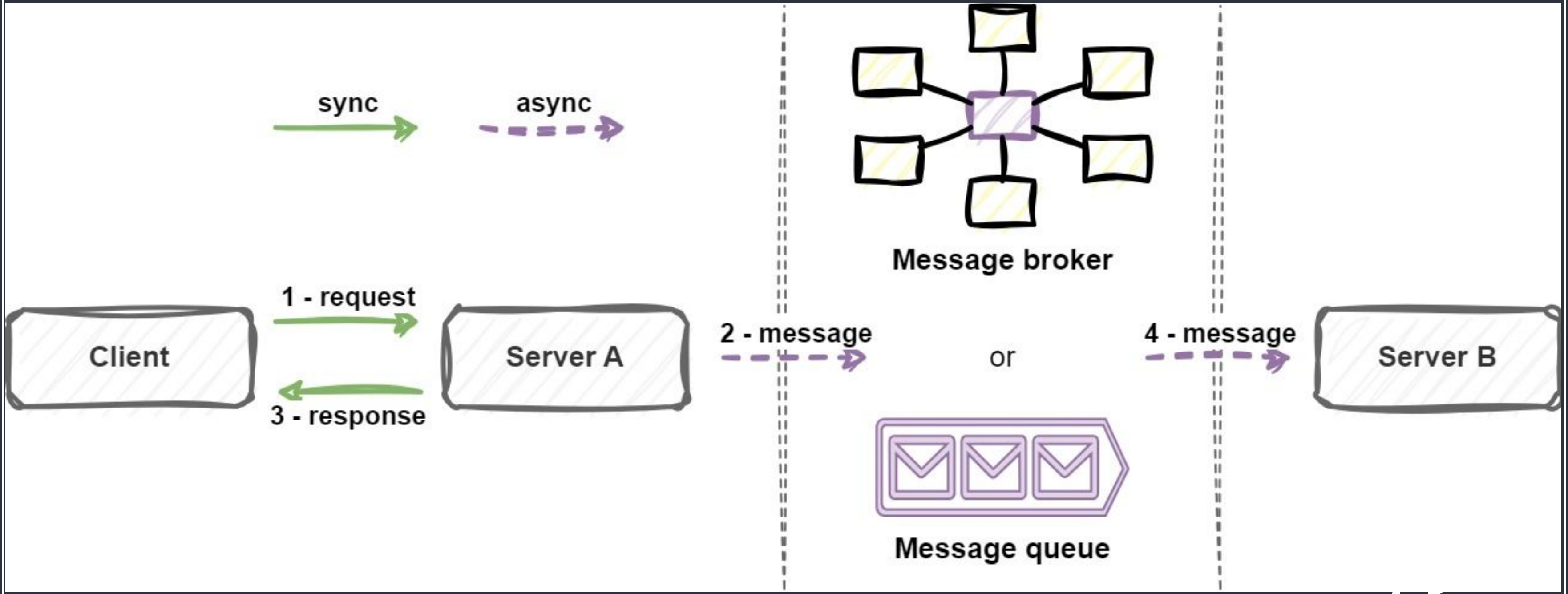
</ Asynchronous communication & Message broker



</ Synchronous vs Asynchronous communication

- Asynchronous fits Saga better

	Synchronous	Asynchronous
Technique	HTTP request	Message queue/broker
Response time	Client waits for response	Quick response
Retry	Client waits for retry	Retry in background
Throughput	Lower	Higher
Timeout	Has timeout	Almost no timeout

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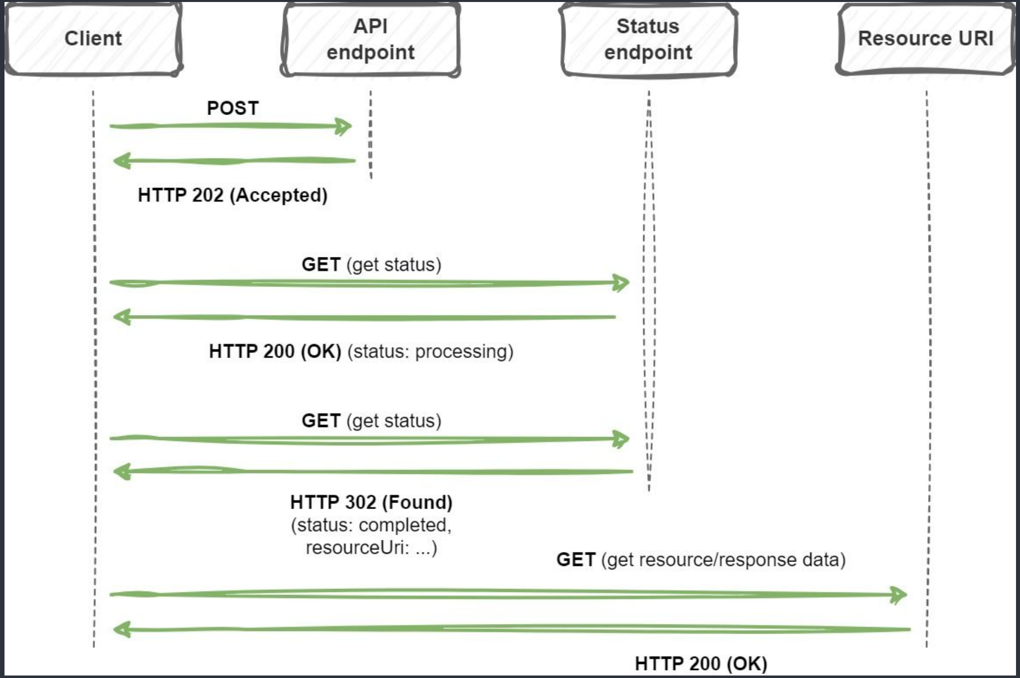
</ Asynchronous request-reply



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</ "Replay" technique

- A group of logical operations can be replayed multiple times
- Each operation is coordinated by the orchestrator
- Operation status and result will be persisted
- In the next replay, persisted result will be used if available

-> Is usually used with Event-sourcing architecture

-> More clear and readable but complicated

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</ "Replay" technique

```
try
{
    ThrowIfFailed(transaction);

    OrderModel order = await GetCreatedOrder(transaction);

    // 1st play
    PaymentModel payment = await ProcessPayment(order, transaction, transactionService, publisher);

    // 2nd play
    InventoryNoteModel inventoryNote = await InventoryDelivery(payment, transaction, transactionService, publisher);

    // 3rd play
    DeliveryModel delivery = await ProcessDelivery(inventoryNote, transaction, transactionService, publisher);

    // 4th play
    await CompleteOrder(delivery, transaction, transactionService, publisher);
}
catch (TransactionFailedException ex)
{
    // x? play (with failure)
    await Rollback(ex, transaction, transactionService, publisher);
}
catch (AsyncTransactionException ex)
{
    Console.WriteLine(ex.Message);
}
```

</ Other techniques

To ensure resiliency and target isolation, consistency issues

- Heartbeat pattern
- Retry
- Semantic lock
- Optimistic locking
- Different concurrent read techniques

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Saga - Choreography

04

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</ What is choreography-based saga?

- A way to coordinate sagas where events are exchanged using a message broker or any mechanism without a centralized controller
- Each local transaction publishes events that trigger local transactions in other participants
- Participants must know each other's events to be able to handle them

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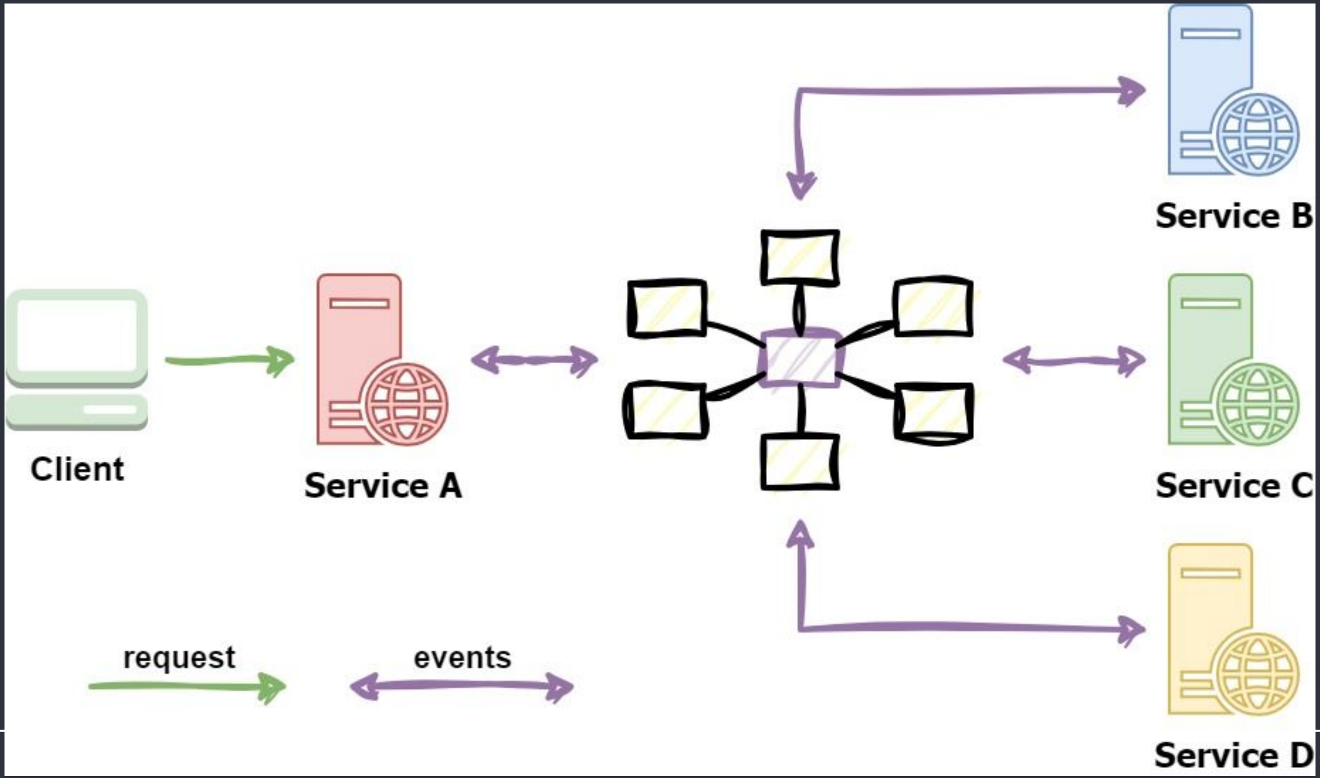
</ What is choreography-based saga?



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</ Apply to our problem [Success path]

1. Create order -> ?

/>

</ Apply to our problem [Success path]

1. Create order -> Order created ->
   Process payment -> Payment created ->
   Inventory delivery -> Delivery note created ->
   Process delivery -> Delivery created ->
   Complete order -> Order completed

/>

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</ Apply to our problem [Failure paths]

1. Create order -> Create order failed
2. ... Process payment -> Payment failed -> Cancel order
3. ... Inventory delivery -> Inventory delivery failed -> Cancel order, Cancel payment
4. ... Process delivery -> Delivery failed -> Cancel order, Cancel payment, Reverse inventory delivery

</ Apply to our demo [Publishing events]

```
public async Task PublishOrderCreated(OrderModel model)
{
    string message = JsonConvert.SerializeObject(new OrderCreatedEvent
    {
        Model = model
    });

    await _producer.ProduceAsync(nameof(OrderCreatedEvent),
        new Message<string, string>
        {
            Key = model.Id.ToString(),
            Value = message
        });
}
```

OrderService >

1 0 1 1 0 1 1 0 1 1 0 1 1 0 0 1 1 0 1 1 0 1 1 0 1 1 0 1 1 1 0 1 1 0 1 1 0 1 1 1 1 1 0 1

</ Apply to our demo [Handling events]

```
2 references
public async Task HandleCreatePaymentWhenOrderCreated(CancellationToken cancellationToken)
{
    await StartConsumerThread(nameof(OrderCreatedEvent), async (message) =>
    {
        using IServiceScope scope = serviceProvider.CreateScope();

        OrderCreatedEvent @event = JsonConvert.DeserializeObject<OrderCreatedEvent>(message.Message.Value);

        IPaymentService paymentService = scope.ServiceProvider.GetRequiredService<IPaymentService>();

        await paymentService.CreatePaymentFromOrder(@event.Model);

    }, cancellationToken: cancellationToken);
}
```

PaymentService

/>

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</ Choreography - Pros & Cons

Pros

- Good for simple, few participants, no need coordination logic workflows
- No need to maintain orchestrator service
- No single point of failure
- Responsibilities are shared and distributed

Cons

- Cumbersome when adding new participants and steps
- Complicated dependencies (cyclic, tight coupling) between participants
- All services must be running to simulate a transaction -> difficult to do integration testing

Saga - Orchestrator

05

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</ What is orchestrator-based saga?

- Orchestrator coordinates sagas using a centralized controller
- Trigger participants local transactions to perform in case of events
- Handle failures by running compensating transactions/actions
- Status can be managed and persisted for monitoring and management purposes

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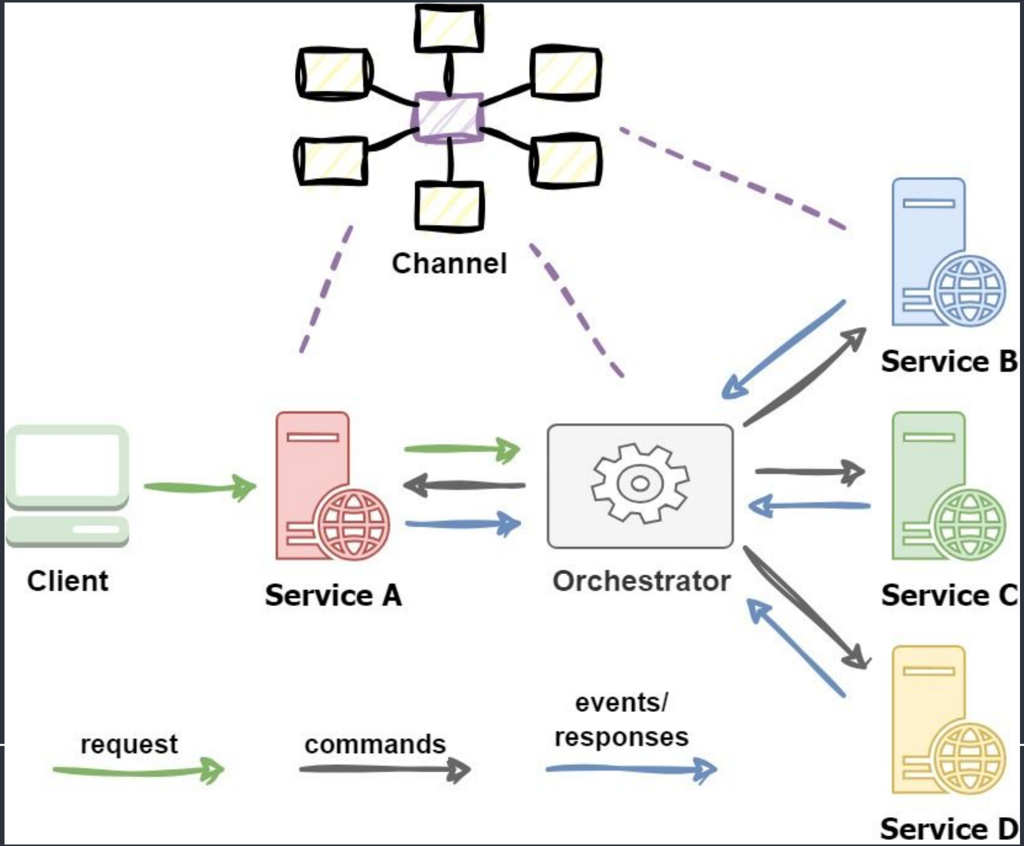
</ What is orchestrator-based saga?



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</ Apply to our problem [Success path]

1. Create order -> Order created -> ?

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</ Apply to our problem [Success path]

1. Create order -> Order created -> Orc ->
   C:Process payment -> Payment created -> Orc ->
   C:Inventory delivery -> Delivery note created -> Orc ->
   C:Process delivery -> Delivery created -> Orc ->
   C:Complete order -> Order completed -> Orc

Annotation

Orc: Orchestrator		*C:{action}: command that triggers action*

1 0 1 1 0 1 1 0 1 1 0 1 1 0 0 1 1 0 1 1 0 1 1 0 1 1 0 1 1 1 0 1 1 0 1 1 0 1 1 1 1 1 0 1

</ Apply to our problem [Failure paths]

1. ... Process payment -> Payment failed -> Orc -> C:Cancel order
2. ... Inventory delivery -> Inventory ... failed -> Orc -> C:Cancel order, C:Cancel payment
3. ...

Annotation

Orc: Orchestrator *C:{action}: command that triggers action*

1 0 1 1 0 1 1 0 1 1 0 1 1 0 0 1 1 0 1 1 0 1 1 0 1 1 0 1 1 1 0 1 1 0 1 1 0 1 1 1 1 1 0 1

</ Apply to our demo [Orchestrator handles events]

```
1 reference
protected async Task HandleOrderCreated(CancellationToken cancellationToken)
{
    await StartConsumerThread(nameof(OrderCreatedEvent), async (message) =>
    {
        using IServiceScope scope = serviceProvider.CreateScope();

        IOrderProcessingPublisher publisher = scope.ServiceProvider.GetRequiredService<IOrderProcessingPublisher>();

        OrderCreatedEvent @event = JsonConvert.DeserializeObject<OrderCreatedEvent>(message.Message.Value);

        await publisher.ProcessPayment(@event.Model);

    }, cancellationToken: cancellationToken);
}
```

Orchestrator

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</ Apply to our demo [Orchestrator publishes commands]

```
3 references
public async Task ProcessPayment(OrderModel order)
{
    string message = JsonConvert.SerializeObject(new ProcessPaymentCommand
    {
        FromOrder = order,
    });

    await _producer.ProduceAsync(nameof(ProcessPaymentCommand),
        new Message<string, string>
        {
            Key = order.Id.ToString(),
            Value = message
        });
}
```

Orchestrator

</ Apply to our demo (Services handle commands)

```
2 references
public async Task HandleProcessPayment(CancellationToken cancellationToken)
{
    await StartConsumerThread(nameof(ProcessPaymentCommand), async (message) =>
    {
        using IServiceScope scope = serviceProvider.CreateScope();

        ProcessPaymentCommand command = JsonConvert.DeserializeObject<ProcessPaymentCommand>(message.Message.Value);

        IPaymentService paymentService = scope.ServiceProvider.GetRequiredService<IPaymentService>();

        await paymentService.CreatePaymentFromOrder(command.FromOrder);

    }, cancellationToken: cancellationToken);
}
```

PaymentService

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</ Orchestrator - Pros & Cons

Pros

- Suitable for complex, many participants or new participants added over time workflows
- Good when flow of tasks and activities are under control
- No cyclic dependencies
- Separation of concerns

Cons

- Additional effort to maintain, implement coordination logic
- Single point of failure

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Issues & considerations

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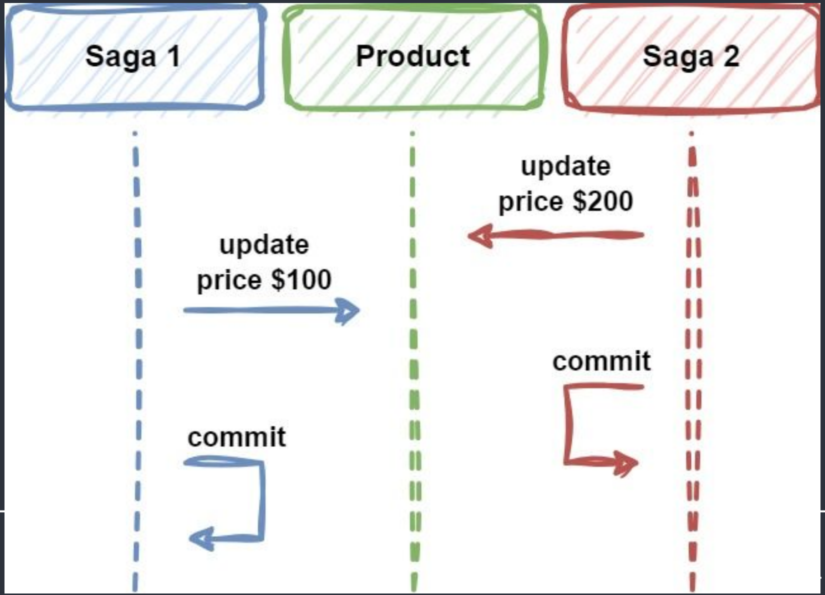
</ Some considerations

- Can be challenging in the beginning
- Hard to debug
- Complexity grows when there are more participants
- Consistency is relative only, because changes are committed to local databases
- Improper transient failures handling can cause side-effects
- Difficult to manage without proper monitoring and observability implemented

</ Common issues - Lost updates

- Lost updates, a participant updates data without reading latest changes



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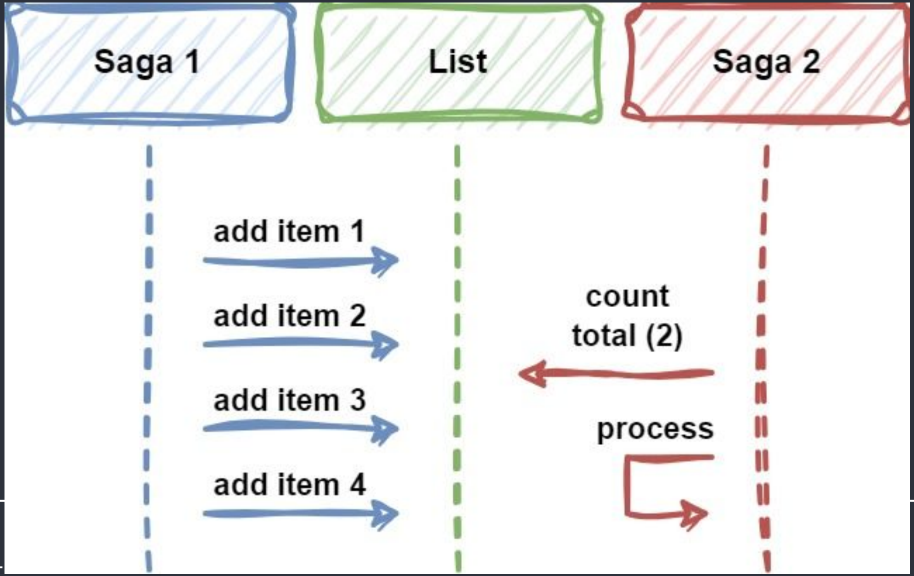
</ Common issues - Dirty reads

- Dirty reads, when a participant reads data that is just partially updated by another saga



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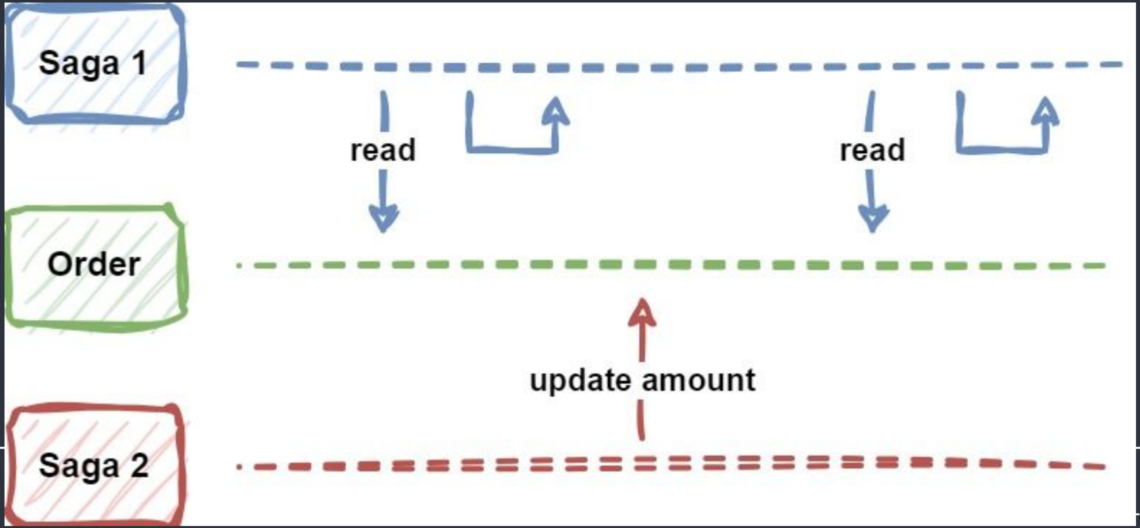
</ Common issues - Fuzzy/non-repeatable reads

- Fuzzy/non-repeatable reads, data is not consistent across participants since data can be updated at some points throughout the entire saga workflow



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</ Countermeasures against isolation issues

- Semantic lock
- Commutative updates
- Pessimistic view
- Reread value and restart if data changed
- Record operations in arriving order to execute sequentially
- Low-risk requests use sagas, high-risk requests favor distributed transactions (2PC, 3PC distributed transaction commit/rollback protocol)

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</ Solutions for resiliency

- Rate limiting
- Delay & retry
- Idempotency

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Practical usage

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</ When to use

- Ensure data consistency in a distributed system without tight coupling
- Efficiently execute compensating actions if one of the operations fails in the distributed action sequence

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</ When to use

- Microservices
- Cloud-based applications
  - Saga pattern - AWS Prescriptive Guidance (amazon.com)
  - Saga pattern - Azure Design Patterns | Microsoft Learn
  - Saga pattern - IBM Cloud Architecture Center

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</ When to use

- Banking applications: Patterns and implementations for a banking cloud transformation - Azure Architecture Center | Microsoft Learn
- Media processing system: Gridwich saga orchestration - Azure Reference Architectures | Microsoft Learn

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</ When to NOT use

- Monolithic architecture
- Tightly coupled operations and transactions
- Cyclic dependencies

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</ Summary

- So far, we have learned that:
  - The use of Saga pattern in distributed transaction
  - Some common techniques used in Saga
  - Two Saga implementations: Choreography & Orchestrator
  - Some common issues and challenging when apply Saga

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Discussion & QnA

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</ References

- Saga pattern - Azure Design Patterns | Microsoft Learn
- Patterns and implementations for a banking cloud transformation - Azure Architecture Center | Microsoft Learn
- Gridwich saga orchestration - Azure Reference Architectures | Microsoft Learn
- Saga Pattern in Microservices | Baeldung on Computer Science
- Saga Pattern for Microservices Distributed Transactions | by Mehmet Ozkaya | Design Microservices Architecture with Patterns & Principles | Medium
- Distributed transaction - SAGA pattern (viblo.asia)
- Implement a distributed transaction in microservices software system using Saga pattern | Careers Saigon Technology

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Do you have any questions?

trannamtrung1st@gmail.com

(+84)76 544 1077

https://www.linkedin.com/in/trung-tran99/

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