ACID Is So Yesterday: Maintaining Data Consistency with Sagas

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Founder of Eventuate.io

Founder of the original CloudFoundry.com

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http://eventuate.io

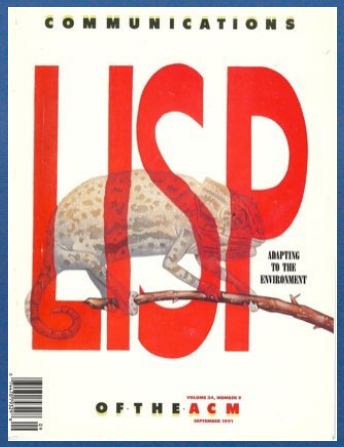
QCon SAN FRANCISCO

Presentation goal

Distributed data management challenges in a microservice architecture

Sagas as the transaction model

About Chris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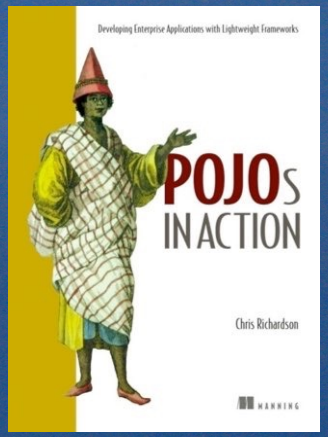
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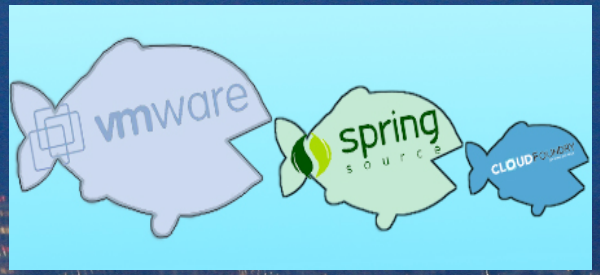
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About Chris

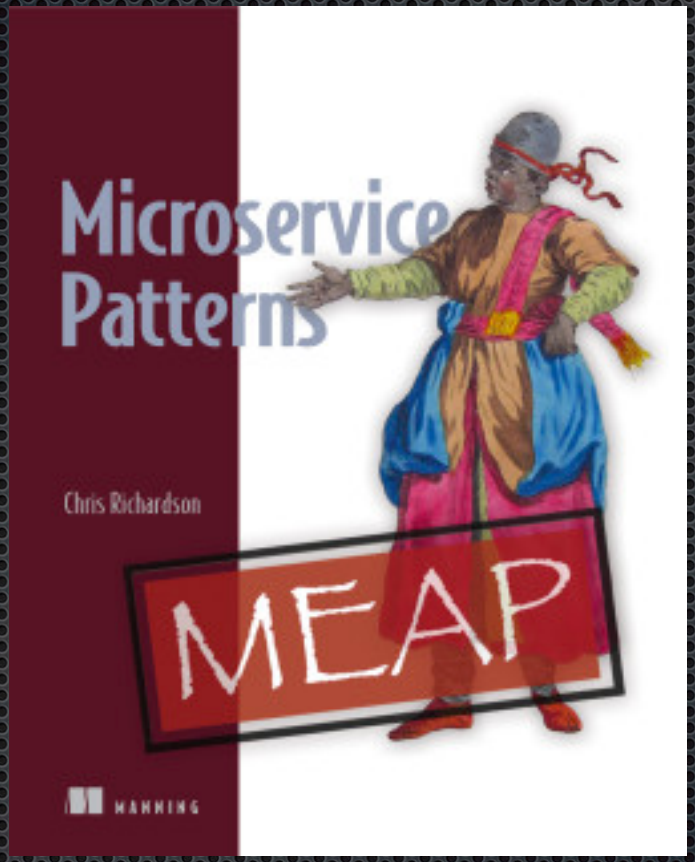
Consultant and trainer focusing on modern application architectures including microservices (http://www.chrisrichardson.net/)

About Chris

Founder of a startup that is creating an open-source/SaaS platform that simplifies the development of transactional microservices

(http://eventuate.io)

For more information



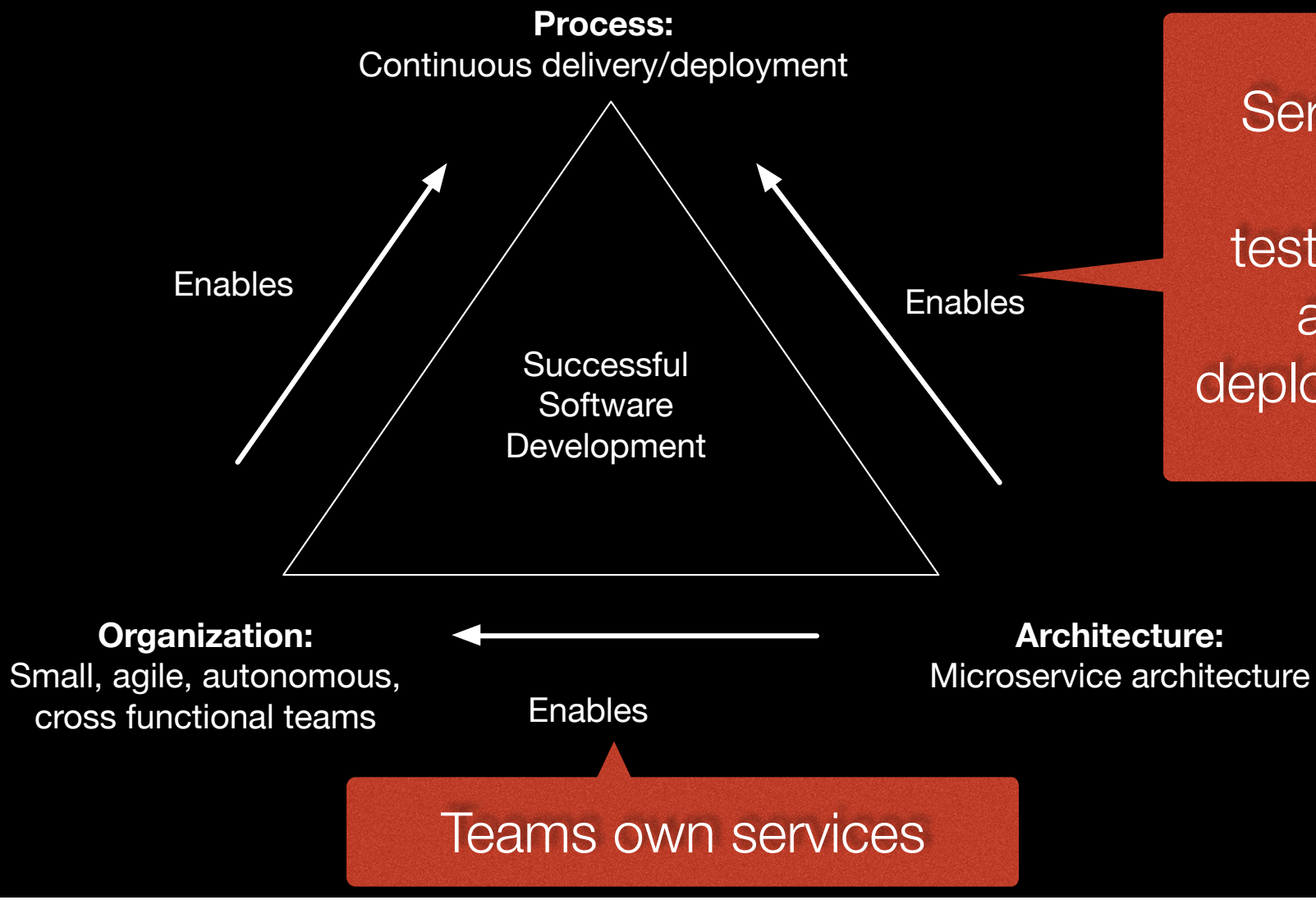
http://learnmicroservices.io

Agenda

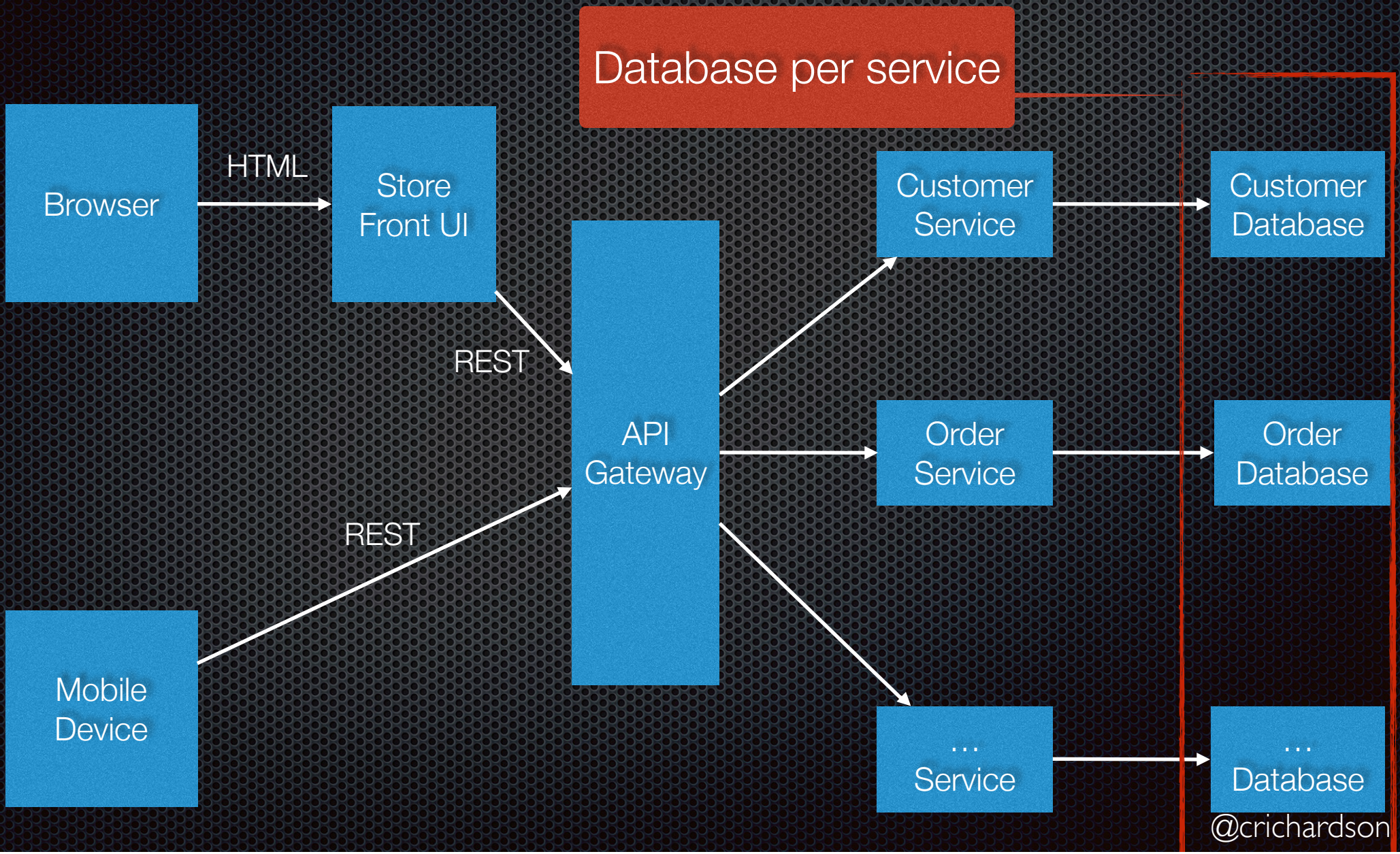
- ACID is not an option
- Overview of sagas
- Coordinating sagas
- Sagas and inter-service communication

The microservice architecture
structures
an application as a
set of loosely coupled services

Microservices enable continuous delivery/deployment



Microservice architecture

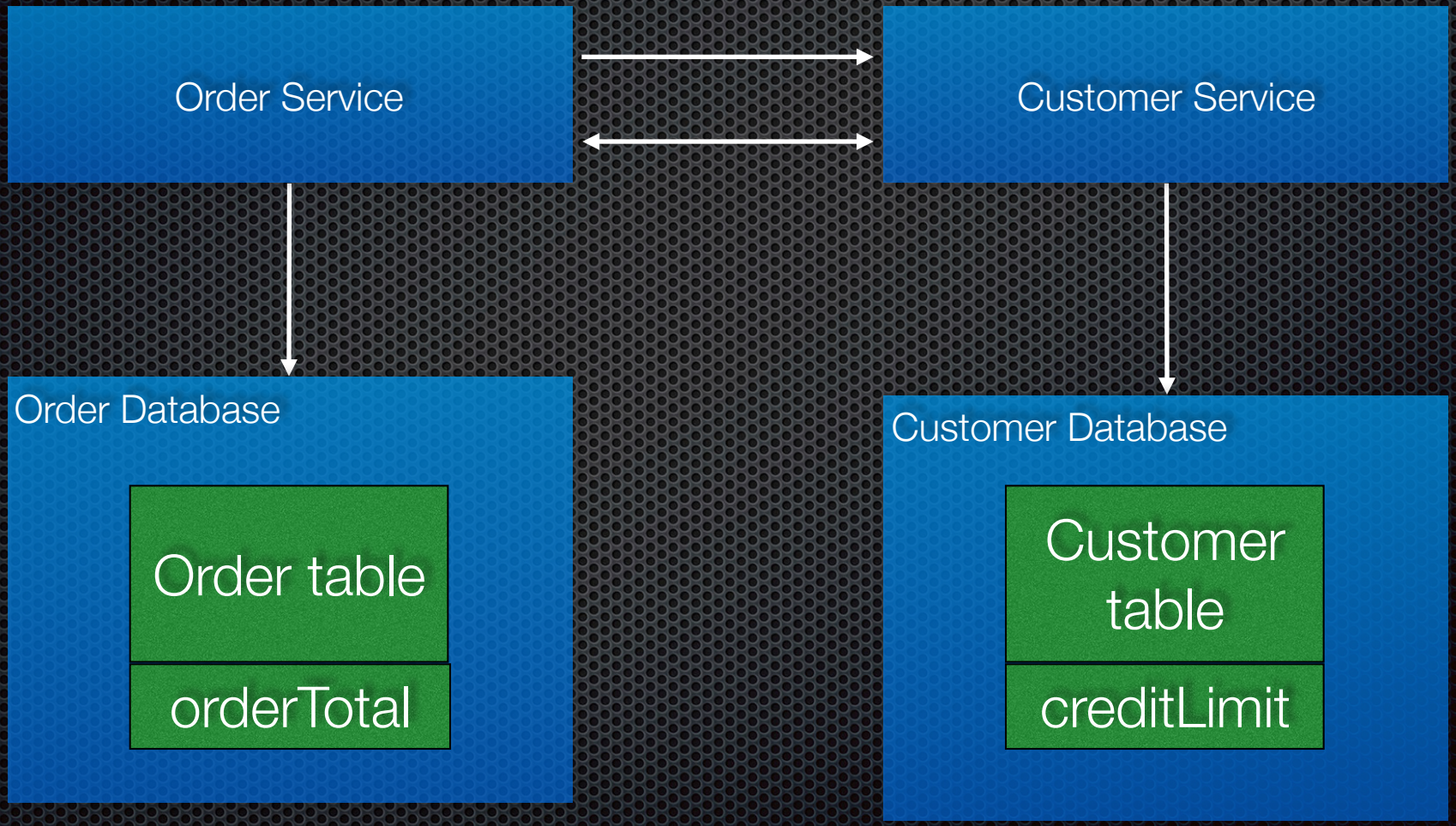


Private database

!=

private database **server**

Loose coupling = encapsulated data



How to maintain data consistency?!?!?

Invariant:
sum(open order.total) <= customer.creditLimit

Cannot use ACID transactions

Distributed transactions

```
BEGIN TRANSACTION
...
SELECT ORDER_TOTAL
 FROM ORDERS WHERE CUSTOMER_ID = ?
...
SELECT CREDIT_LIMIT
FROM CUSTOMERS WHERE CUSTOMER_ID = ?
...
INSERT INTO ORDERS ...
...
COMMIT TRANSACTION
```

Private to the Order Service

Private to the Customer Service

2PC is not an option

- Guarantees consistency

BUT

- 2PC coordinator is a single point of failure
- Chatty: at least O(4n) messages, with retries O(n^2)
- Reduced throughput due to locks
- Not supported by many NoSQL databases (or message brokers)
- CAP theorem ⇒ 2PC impacts availability
- ….

ACID ⇒

Basically
Available
Soft state
Eventually consistent

http://queue.acm.org/detail.cfm?id=1394128

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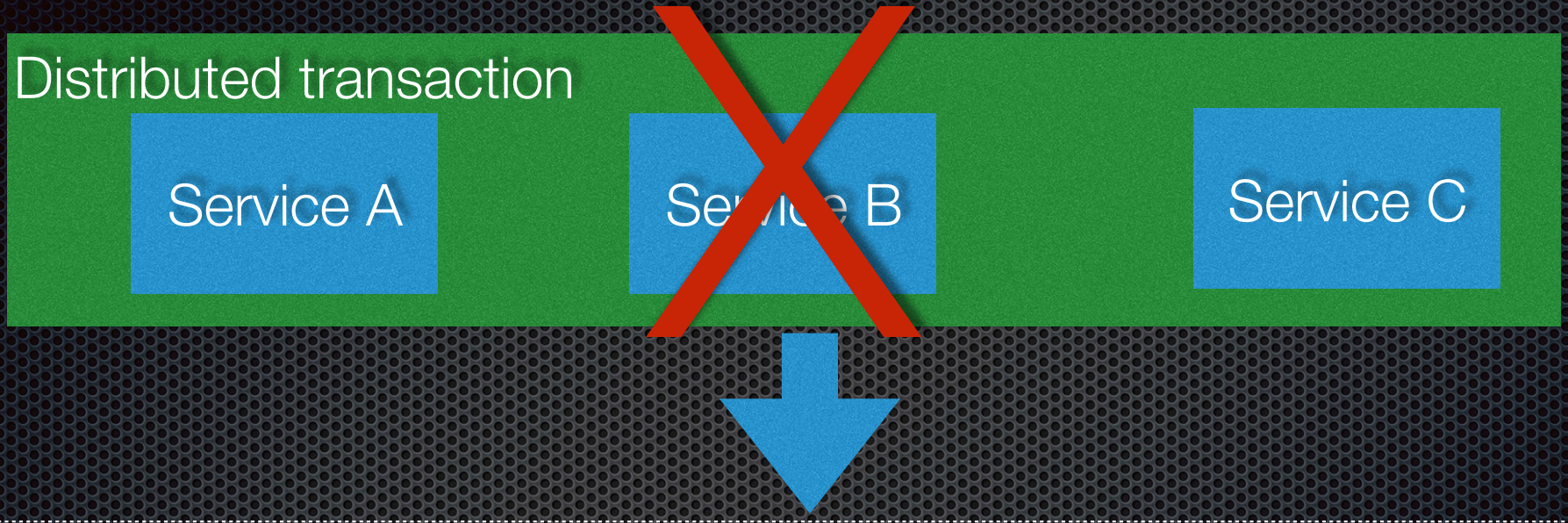
From a 1987 paper

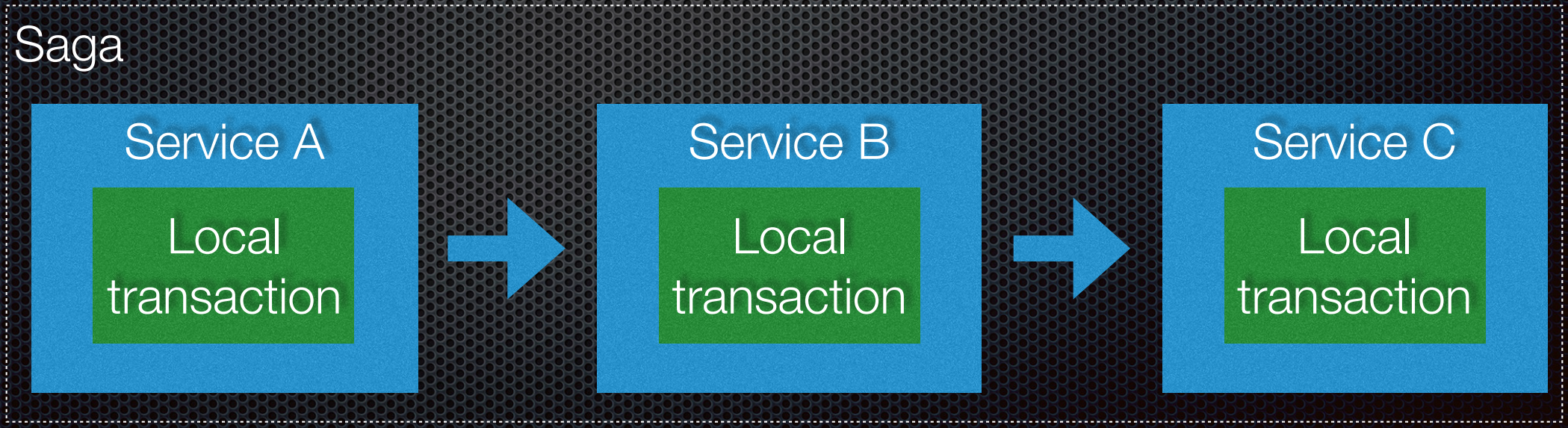
SAGAS

Hector Garcia-Molina
Kenneth Salem

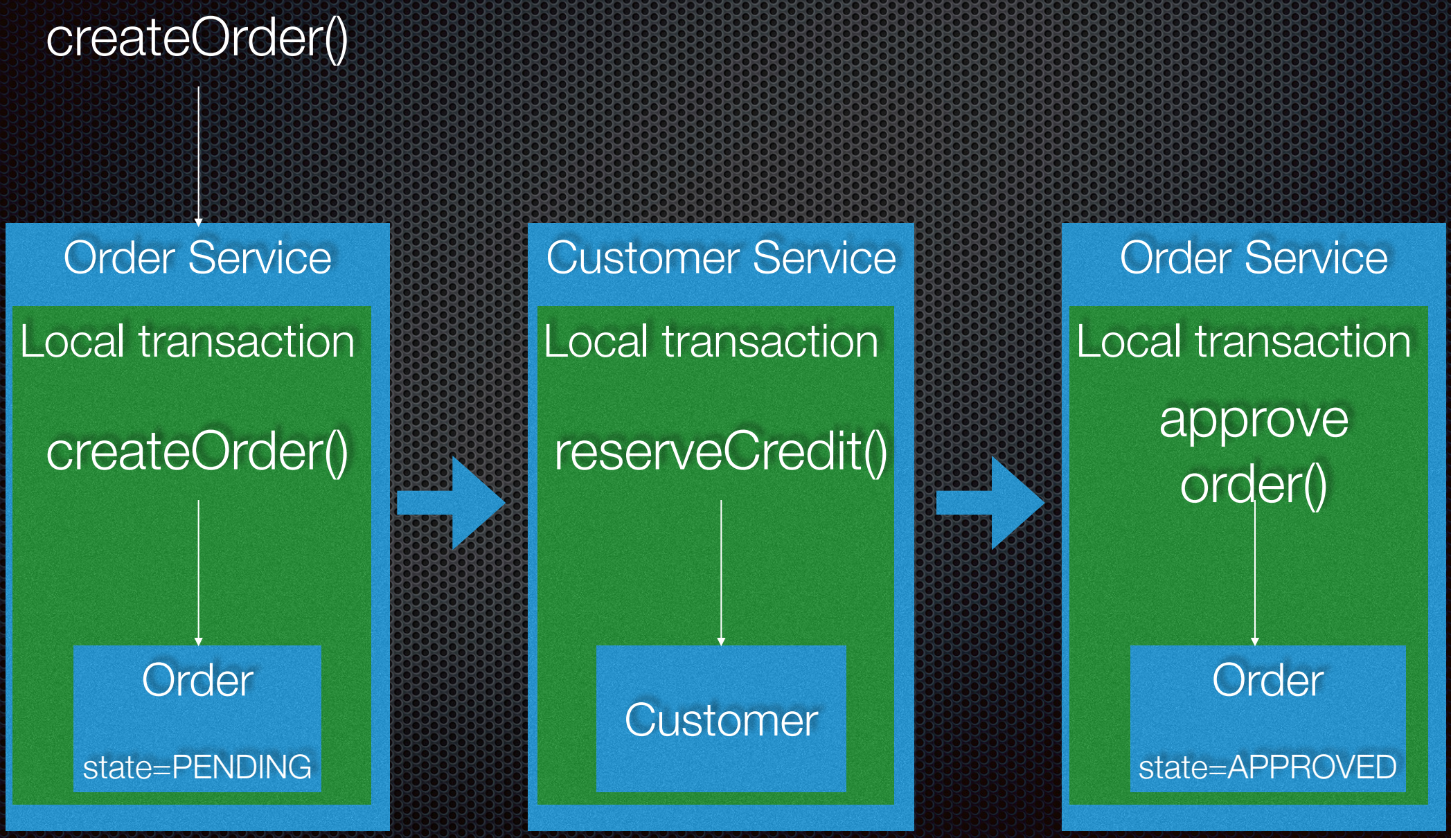
Department of Computer Science
Princeton University
Princeton, N J 08544

Use Sagas instead of 2PC





Create Order Saga



If only it were this easy....

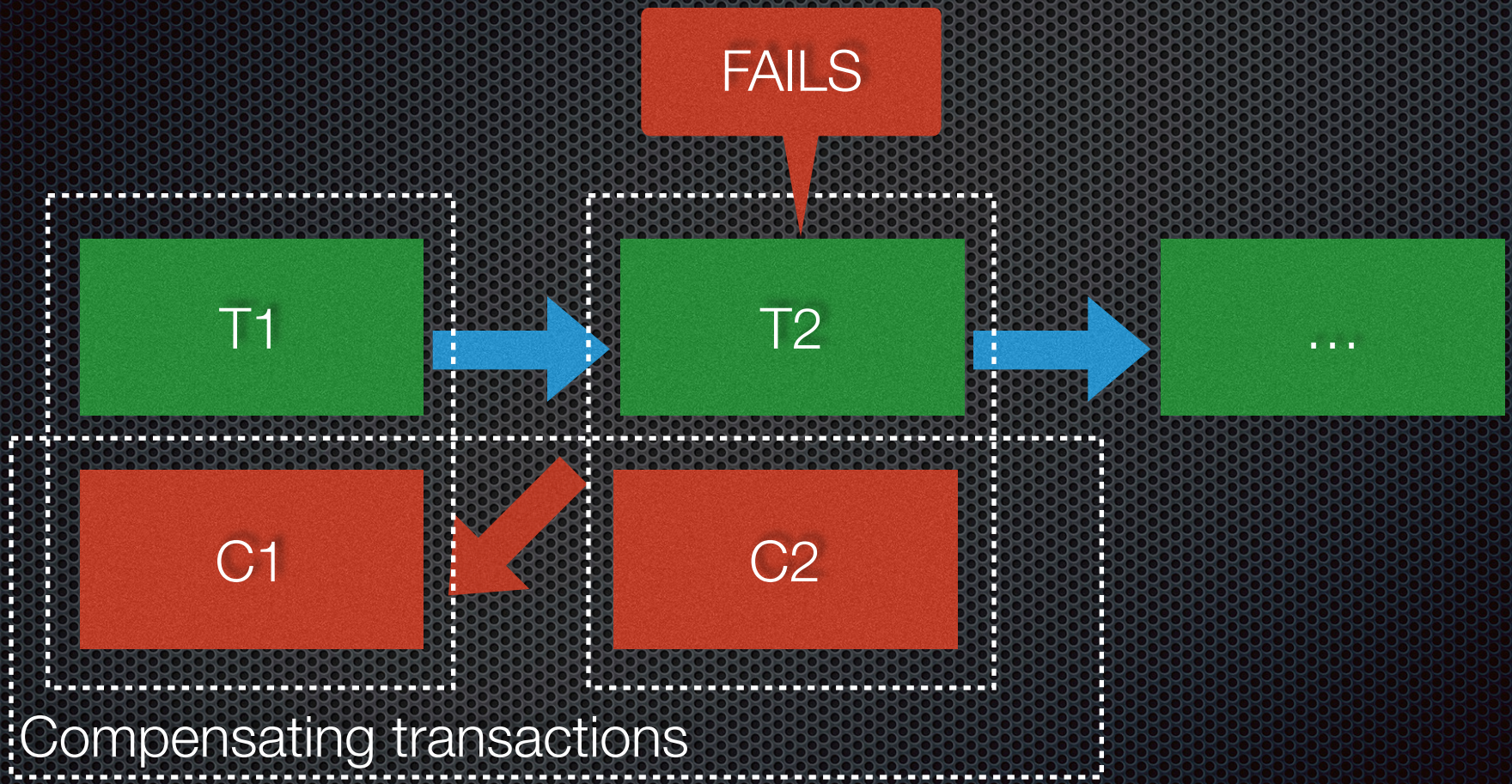
Rollback using compensating transactions

- ACID transactions can simply rollback

BUT

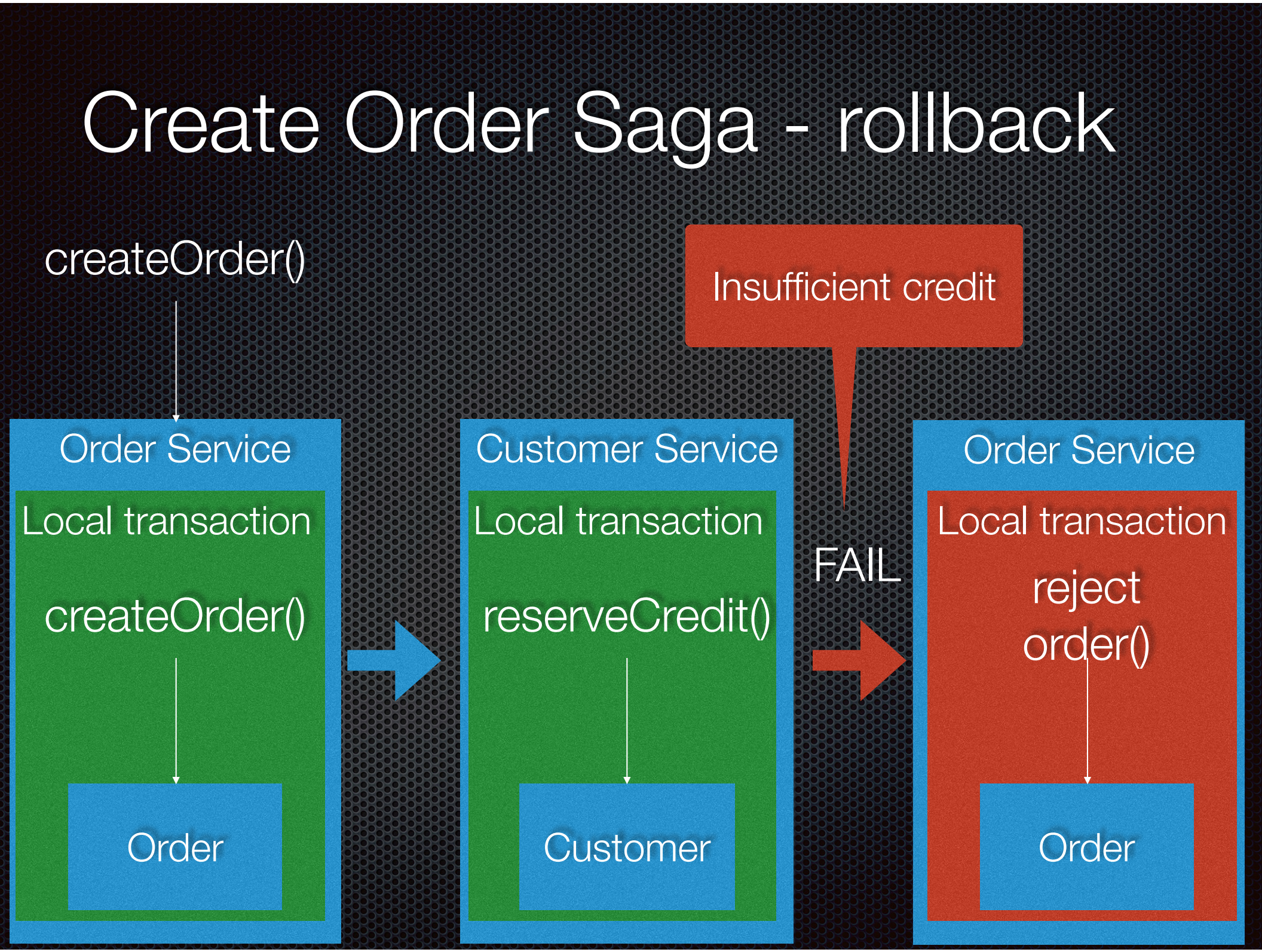
- Developer must write application logic to “rollback” eventually consistent transactions
- Careful design required!

Saga: Every Ti has a Ci



T1 ⇒ T2 ⇒ C1

Create Order Saga - rollback



Sagas complicate API design

- Synchronous API vs Asynchronous Saga
- Request initiates the saga. When to send back the response?
- Option #1: Send response when saga completes:

  + Response specifies the outcome

  - Reduced availability

- Option #2: Send response immediately after creating the saga **(recommended)**:

  + Improved availability

  - Response does not specify the outcome. Client must poll or be notified

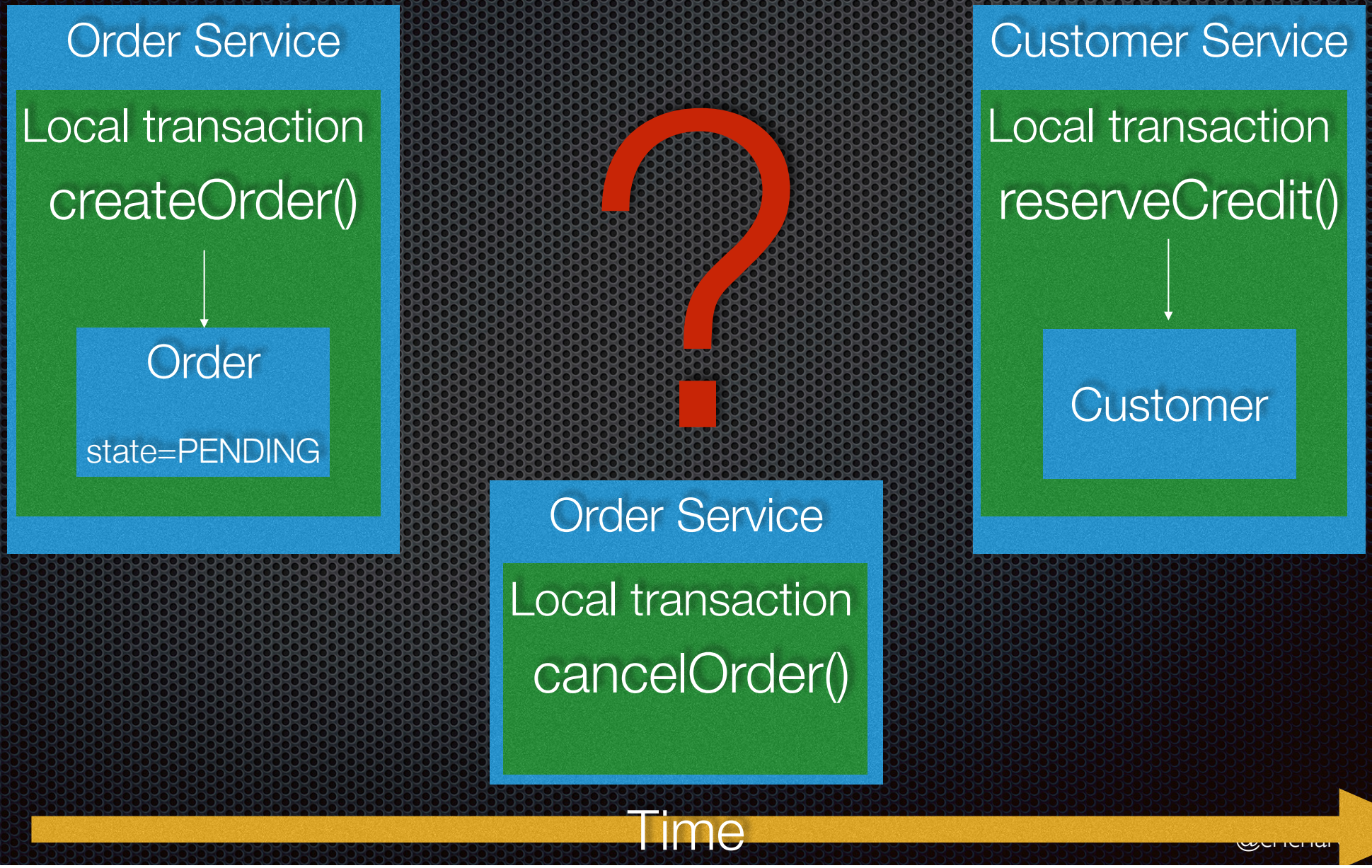
Revised Create Order API

- createOrder()
  - returns id of newly created order
  - **NOT** fully validated
- getOrder(id)
  - Called periodically by client to get outcome of validation

Minimal impact on UI

- UI hides asynchronous API from the user
- Saga will usually appear instantaneous (<= 100ms)
- If it takes longer ⇒ UI displays “processing” popup
- Server can push notification to UI

Lack of isolation ⇒ complicates business logic



How to cancel a PENDING Order?

- Don't ⇒ throw an OrderNotCancellableException
  - Questionable user experience
- "Interrupt" the Create Order saga?
  - Cancel Order Saga: set order.state = CANCELLED
  - Causes Create Order Saga to rollback
  - But is that enough to cancel the order?
- Cancel Order saga waits for the Create Order saga to complete?
  - Suspiciously like a distributed lock
  - But perhaps that is ok

Countermeasure Transaction Model

SOFTWARE—PRACTICE AND EXPERIENCE, VOL. 28(1), 77–98 (JANUARY 1998)

Semantic ACID Properties in Multidatabases Using Remote Procedure Calls and Update Propagations

lars frank[1] and torben u. zahle[2]

Saga structure

- Series of compensatable transactions (Ti,Ci)
- Pivot transaction (Ti)
  - “not compensatable or retriable”
  - Execute compensating transactions if it fails
  - **GO/NO GO point**
- Set of retriable transactions (Ti)
  - Can't fail

Sagas are ACD

- **Atomicity**
  - Saga implementation ensures that all transactions are executed **OR** all are compensated
- **Consistency**
  - Referential integrity within a service handled by local databases
  - Referential integrity across services handled by application
- **Durability**
  - Durability handled by local databases

Lack of I ⇒ anomalies

- Lost update
  - Ti reads ⇒ other transaction writes ⇒ Tj (or Ci) writes
- Dirty reads
  - Ti writes ⇒ other transaction reads ⇒ Ci writes
- non-repeatable/fuzzy read
  - Ti reads ⇒ other transaction writes ⇒ Tj reads

Countermeasures for reducing impact of isolation anomalies...

- Commutative updates
  - e.g. debit account can compensate for a credit account
- Version file
  - Record history of changes
  - Use them to make updates commutative
  - e.g. record cancel reservation so that create/cancel = cancel/create
  - Sounds suspiciously like event sourcing

…Countermeasures for reducing impact of isolation anomalies…

- Re-read value
  - Before modifying value, Ti re-reads value that was read by a previous Ti
  - Abort if the value has changed (and possibly restart)
- Pessimistic view
  - Minimize the business risk
  - Reduce available credit in compensatable transaction
  - Increase available credit in retriable transaction, which will never be compensated

...Countermeasures for reducing impact of isolation anomalies

- Countermeasures by value
  - Business risk determine strategy
  - High risk => use 2PC/distributed transaction
- Semantic lock
  - Compensatable transaction sets flag, retriable transaction releases it
  - Flag = lock - prevents other transactions from accessing it
  - Flag = warning - treat the data differently, e.g. a pending deposit
  - Require deadlock detection, e.g. timeout

Agenda

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- Overview of sagas
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How to sequence the saga transactions?

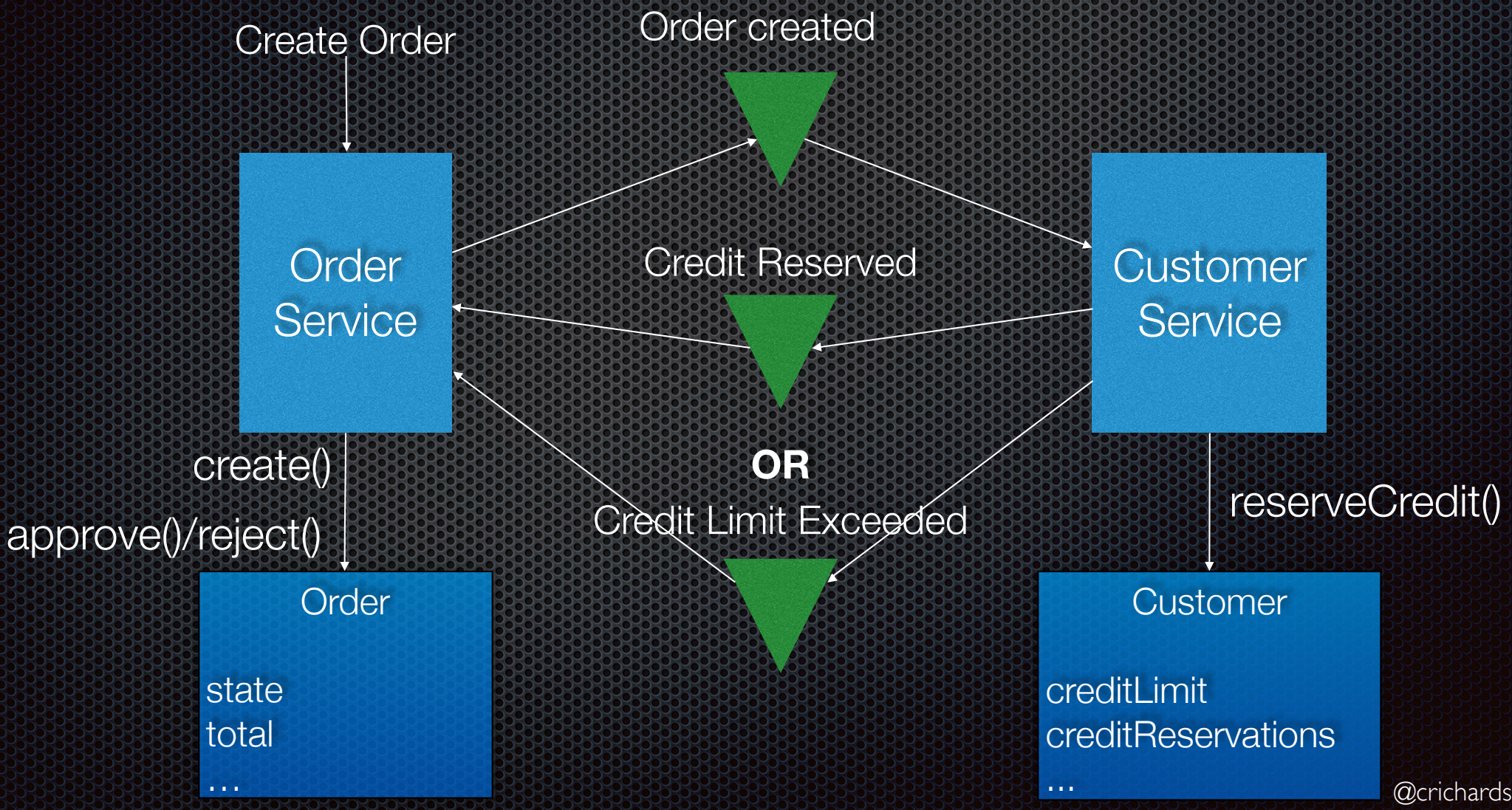
- After the completion of transaction Ti “something” must decide what step to execute next
- Success: which T(i+1) - branching
- Failure: C(i - 1)

Choreography: **distributed** decision making

vs.

Orchestration: **centralized** decision making

Option #1: Choreography-based coordination using events



Benefits and drawbacks of choreography

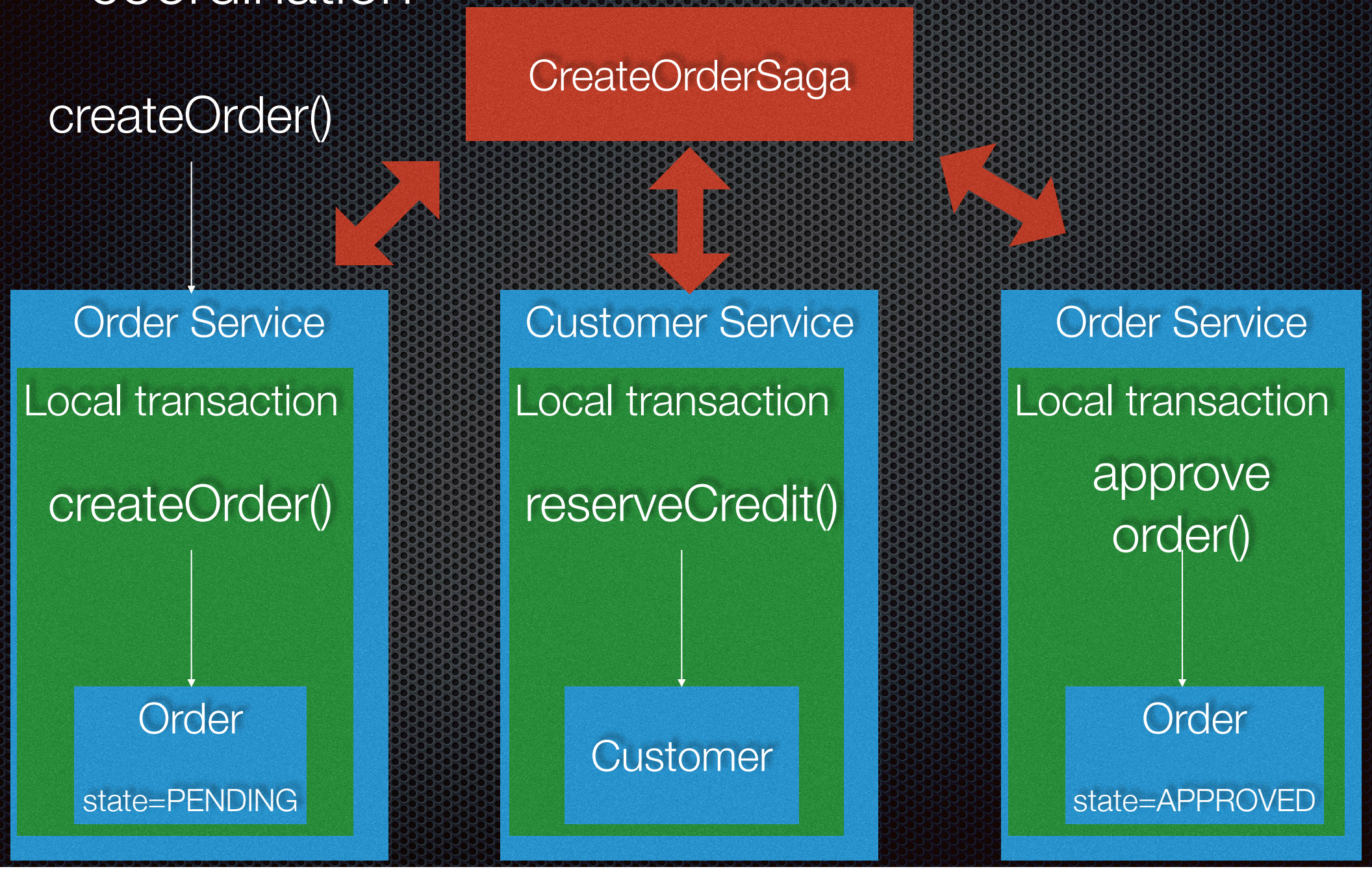
Benefits

- Simple, especially when using event sourcing
- Participants are loosely coupled

Drawbacks

- Cyclic dependencies - services listen to each other's events
- Overloads domain objects, e.g. Order and Customer **know** too much
- Events = indirect way to make something happen

Option #2: Orchestration-based saga coordination

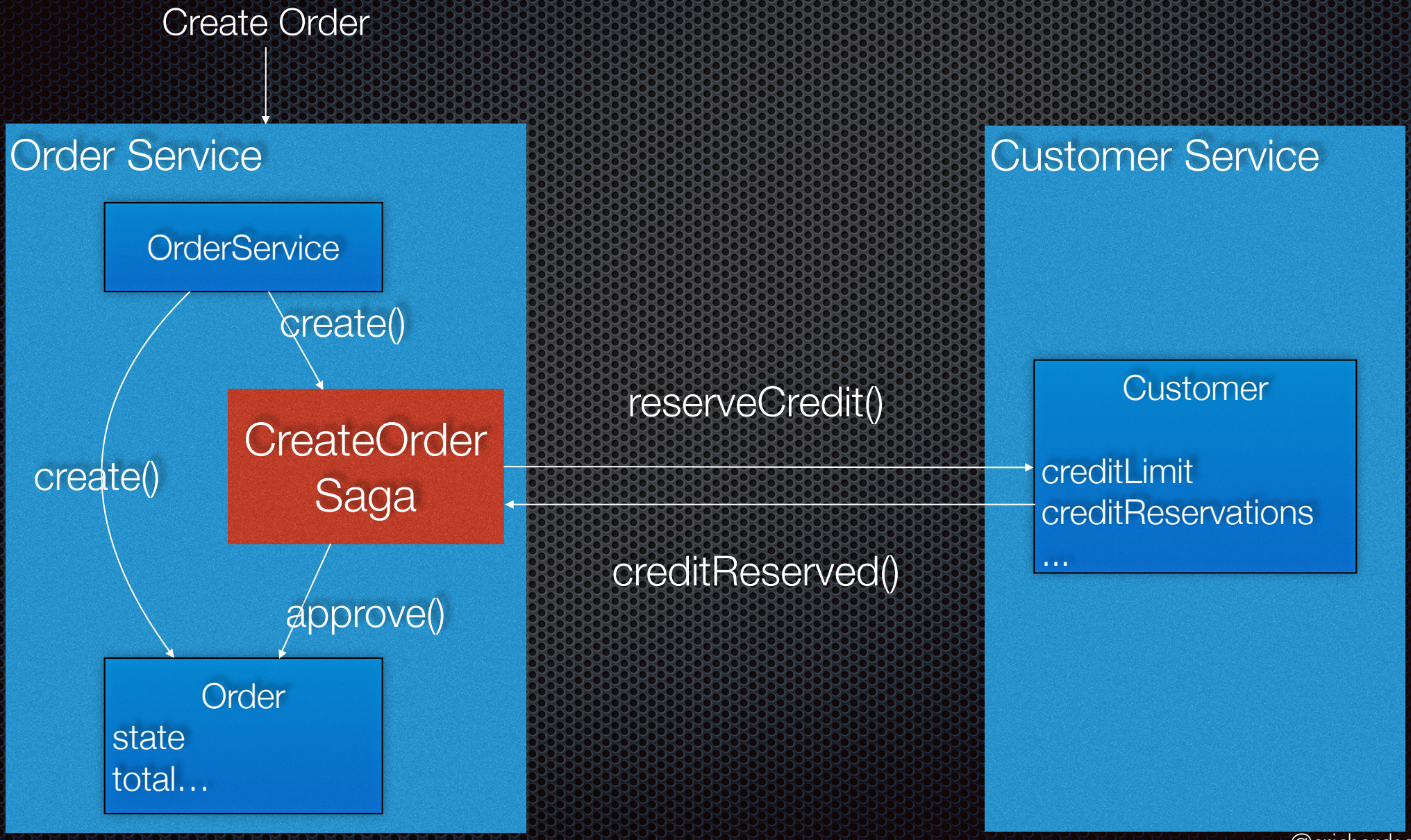


A saga (orchestrator)
is a **persistent object**
that
tracks the state of the saga
and
invokes the participants

Saga behavior

- On create:
  - Invokes a saga participant
- On reply:
  - Determine which saga participant to invoke next
  - Invokes saga participant
  - Updates its state
  - …

CreateOrderSaga orchestrator



CreateOrderSaga definition

```
public class CreateOrderSaga implements SimpleSaga<CreateOrderSagaData> {

  private SagaDefinition<CreateOrderSagaData> sagaDefinition =
          step()
            .withCompensation(this::reject)
          .step()
            .invokeParticipant(this::reserveCredit)
          .step()
            .invokeParticipant(this::approve)
          .build();


  @Override
  public SagaDefinition<CreateOrderSagaData> getSagaDefinition() { return this.sagaDefinition; }


  private CommandWithDestination reserveCredit(CreateOrderSagaData data) {
    long orderId = data.getOrderId();
    Long customerId = data.getOrderDetails().getCustomerId();
    Money orderTotal = data.getOrderDetails().getOrderTotal();
    return send(new ReserveCreditCommand(customerId, orderId, orderTotal))
            .to("customerService")
            .build();
  }
```

Saga's Data

Sequence of steps

step = (T_i, C_i)

Build command to send

Customer Service command handler

```
public class CustomerCommandHandler {

  @Autowired
  private CustomerRepository customerRepository;

  public CommandHandlers commandHandlerDefinitions() {
    return SagaCommandHandlersBuilder
            .fromChannel("customerService")
            .onMessage(ReserveCreditCommand.class, this::reserveCredit)
            .build();
  }

  public Message reserveCredit(CommandMessage<ReserveCreditCommand> cm) {
    ReserveCreditCommand cmd = cm.getCommand();
    long customerId = cmd.getCustomerId();
    Customer customer = customerRepository.findOne(customerId);
    try {
      customer.reserveCredit(cmd.getOrderId(), cmd.getOrderTotal());
      return withSuccess(new CustomerCreditReserved());
    } catch (CustomerCreditLimitExceededException e) {
      return withFailure(new CustomerCreditReservationFailed());
    }
  }
```

Route command to handler

Reserve credit

Make reply message

Eventuate Tram Sagas

- Open-source Saga framework
- Currently for Java
- https://github.com/eventuate-tram/eventuate-tram-sagas

Benefits and drawbacks of orchestration

Benefits

- Centralized coordination logic is easier to understand
- Reduced coupling, e.g. Customer knows less
- Reduces cyclic dependencies

Drawbacks

- Risk of smart sagas directing dumb services

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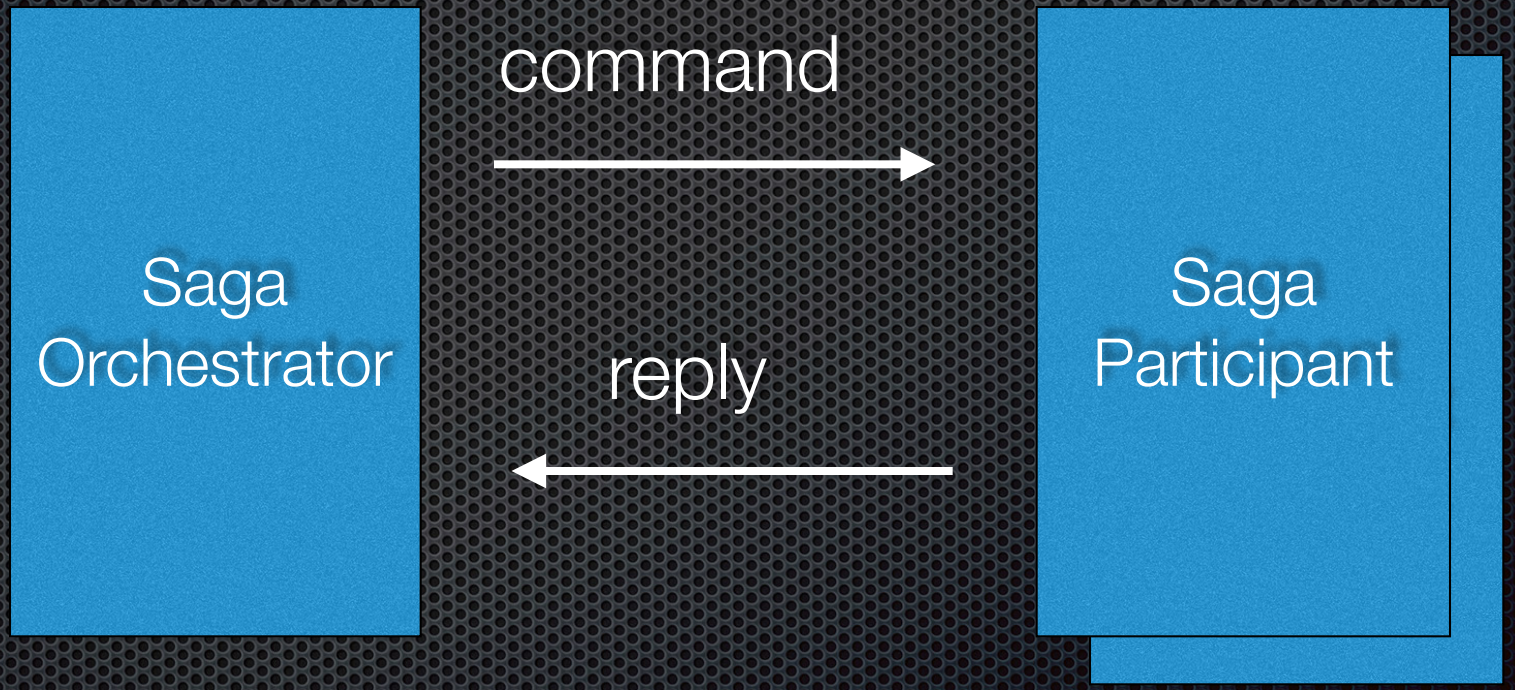
About Saga orchestrator ⇔ participant communication

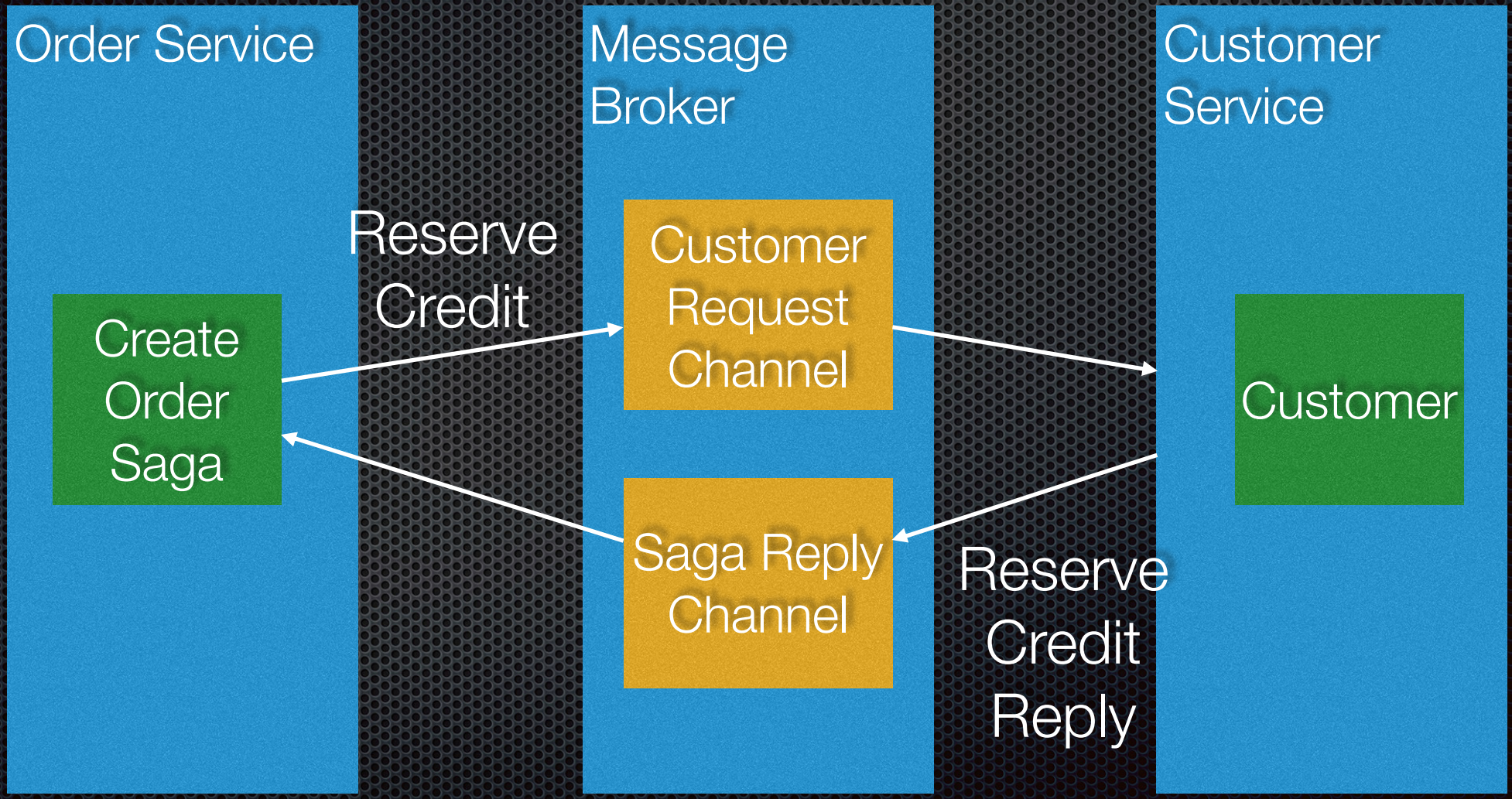


Saga must complete even if there are transient failures

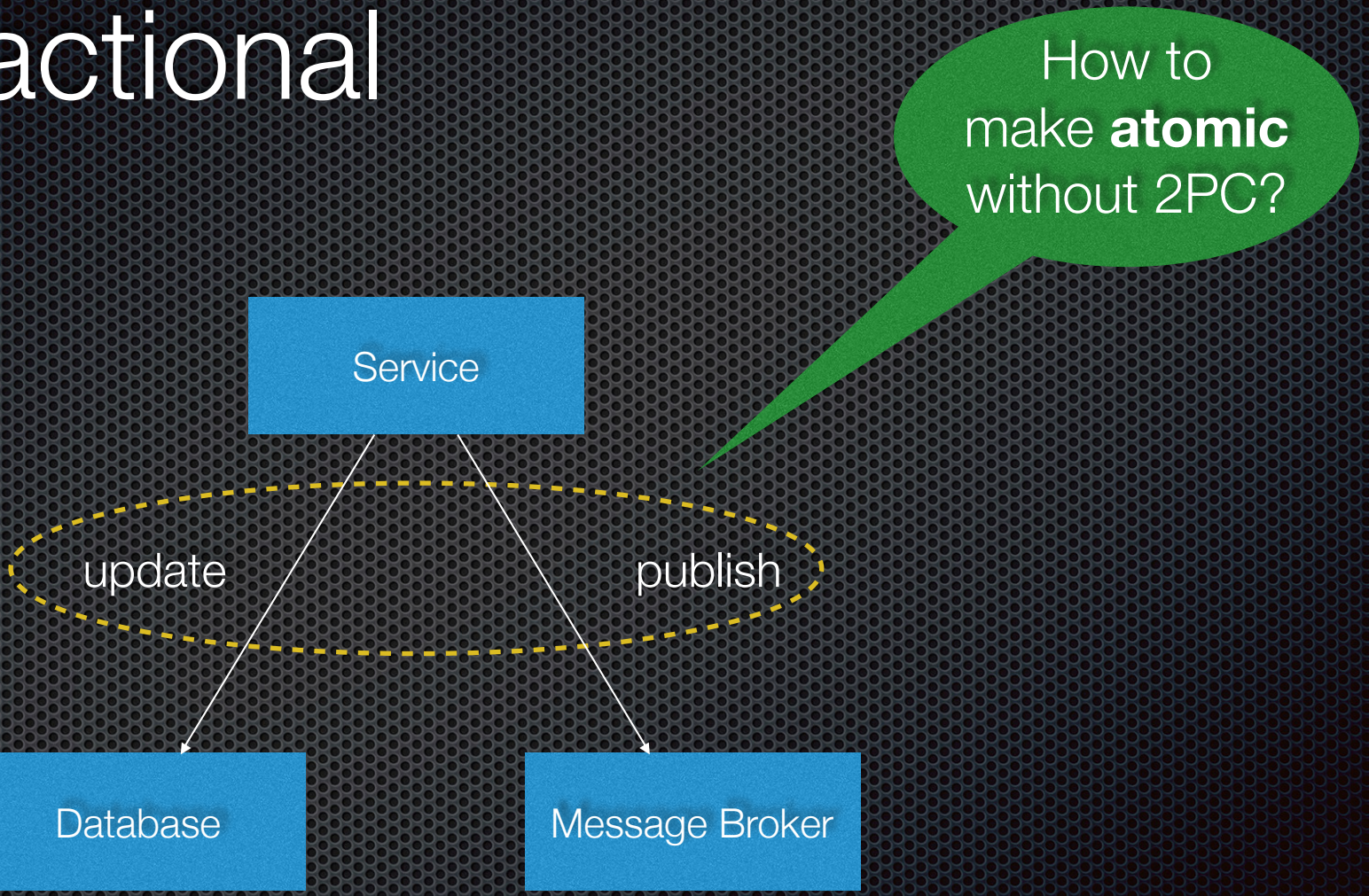
Use asynchronous messaging

Ensures sagas complete when participants are temporarily unavailable

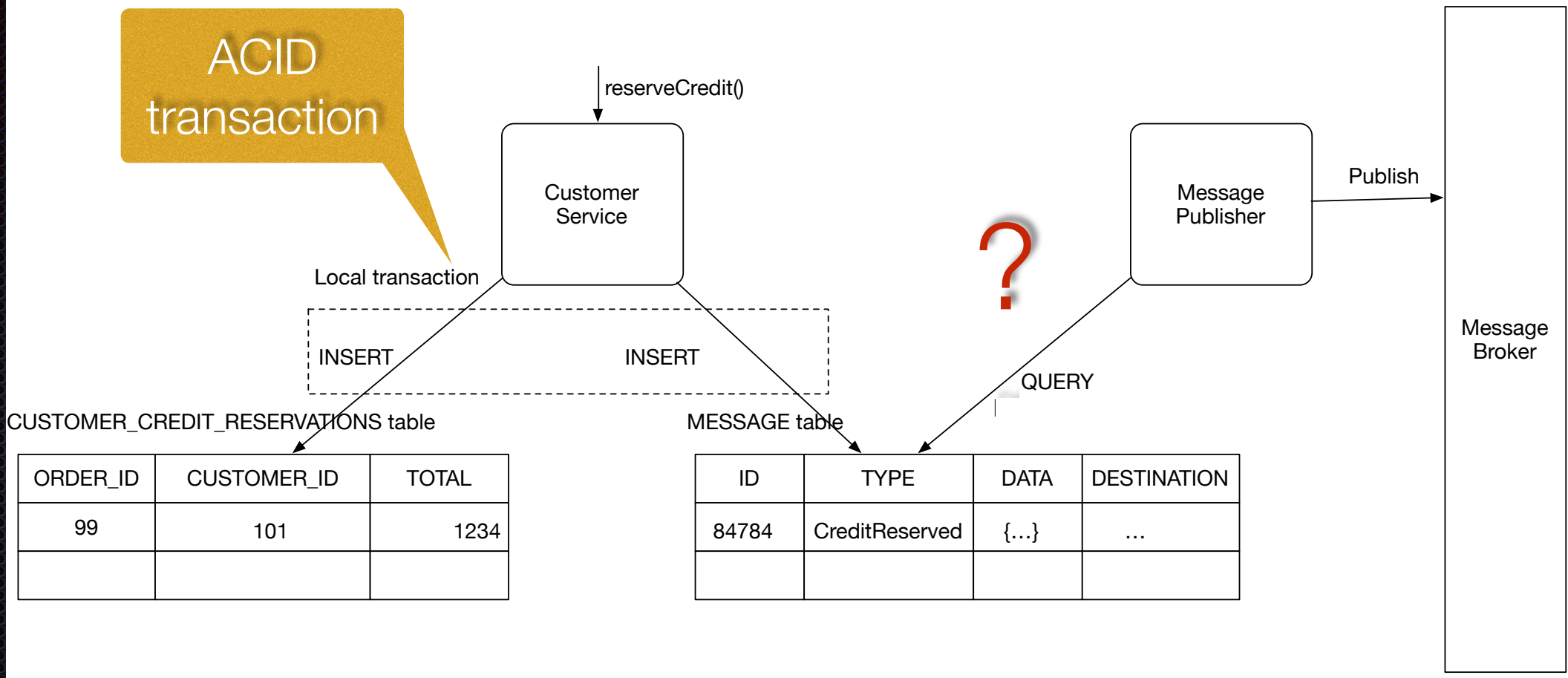
Create Order Saga - messaging



Messaging must be transactional



Option #1: Use database table as a message queue



- See BASE: An Acid Alternative, http://bit.ly/ebaybase

Publishing messages

Poll the MESSAGE table (ok)

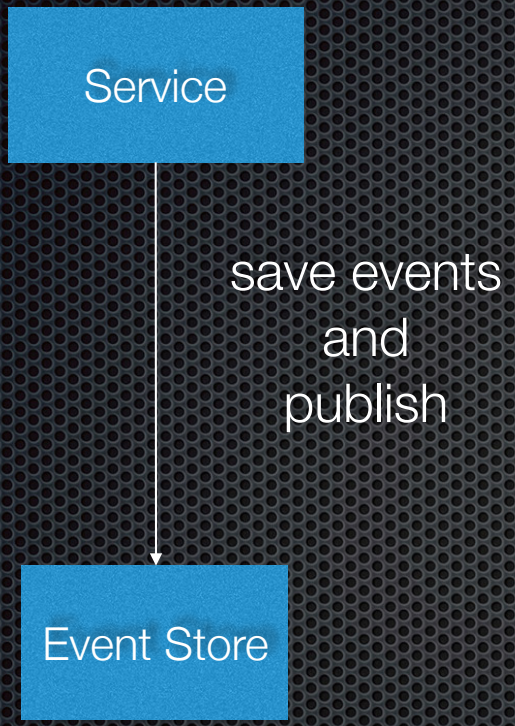
OR

Tail the database transaction log (better)

Eventuate Tram

- Open-source framework for transactional messaging
  - Send and receive messages
  - Publish and subscribe to domain events
  - Send commands and replies
- Currently, for Java
- https://github.com/eventuate-tram/eventuate-tram-core

Option #2: Event sourcing: event-centric persistence



Event table

Entity id	Entity type	Event id	Event type	Event data
101	Order	901	OrderCreated	…
101	Order	902	OrderApproved	…
101	Order	903	OrderShipped	…

Every state change ⇒ event

Summary

- Microservices tackle complexity and accelerate development
- Database per service is essential for loose coupling
- Use sagas to maintain data consistency across services
- Use transactional messaging to make sagas reliable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Questions?
http://learnmicroservices.io