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Microservices: An Eventually Inconsistent Architectural Style?

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WS-REST
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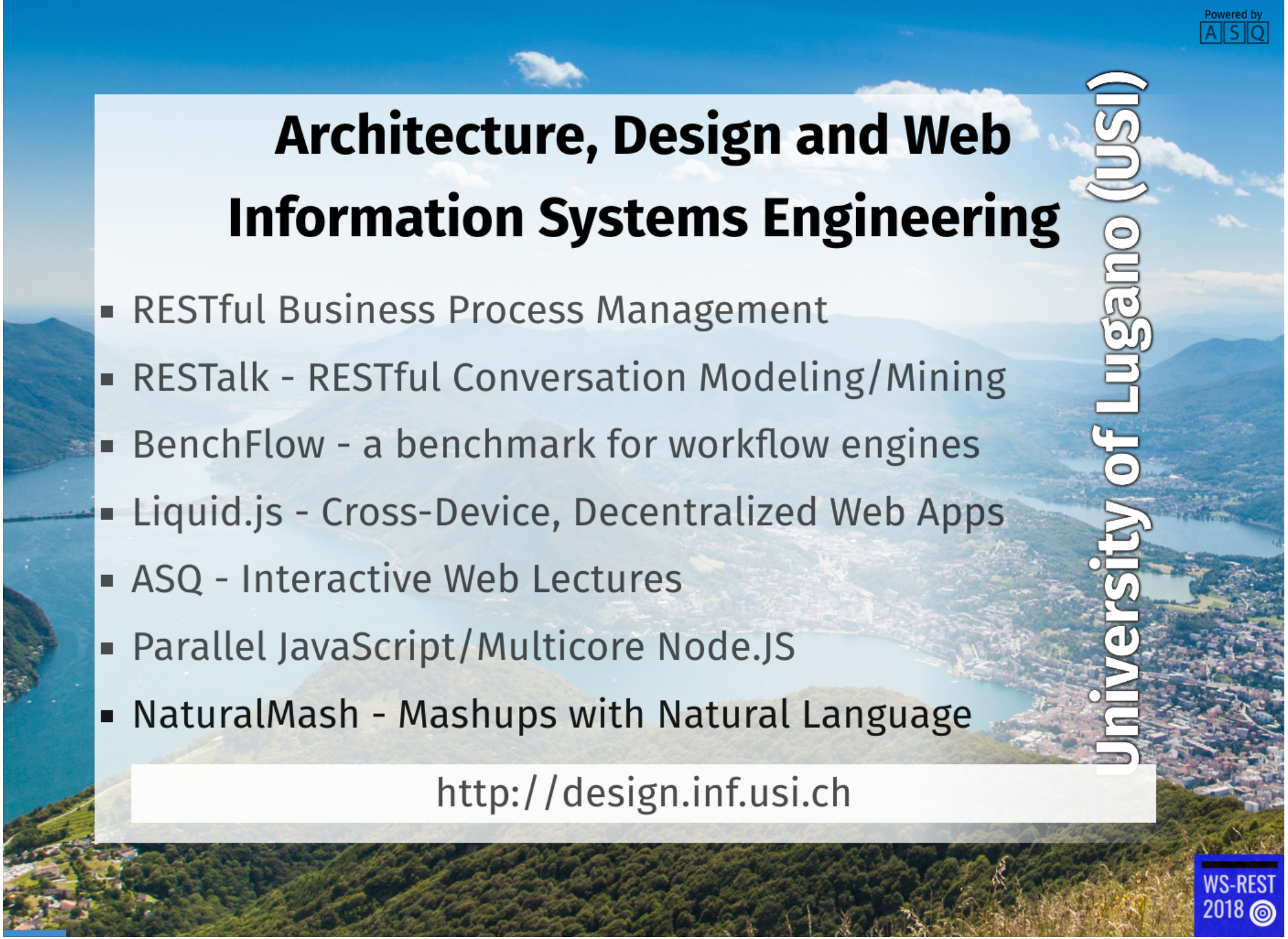
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Microservices: An Eventually Inconsistent Architectural Style?

Microservices by definition let each service independently manage its own database. In this talk we illustrate the ultimate consequences of the Polyglot persistence principle, which can be summarized using the BAC theorem: When Backing up a microservice architecture, it is not possible to have both Consistency (after recovery) and full Availability (while backing up the system). In other words, loosely coupled Microservice architectures are doomed to become inconsistent after disaster strikes. We will present and compare several coping strategies to deal with this limitation and discuss how they impact the monolith decomposition process and the corresponding service API boundary design.

Microservices

The microservice architectural style is an approach to developing a single application as a suite of **small** services, each running in its own **container** and communicating with **lightweight** mechanisms, often an **HTTP resource API**. These services are built around business capabilities and **independently deployable by fully automated deployment machinery**. There is a bare minimum of centralized management of these services, which may be written in **different programming languages** and use different data storage technologies.

Martin Fowler and James Lewis

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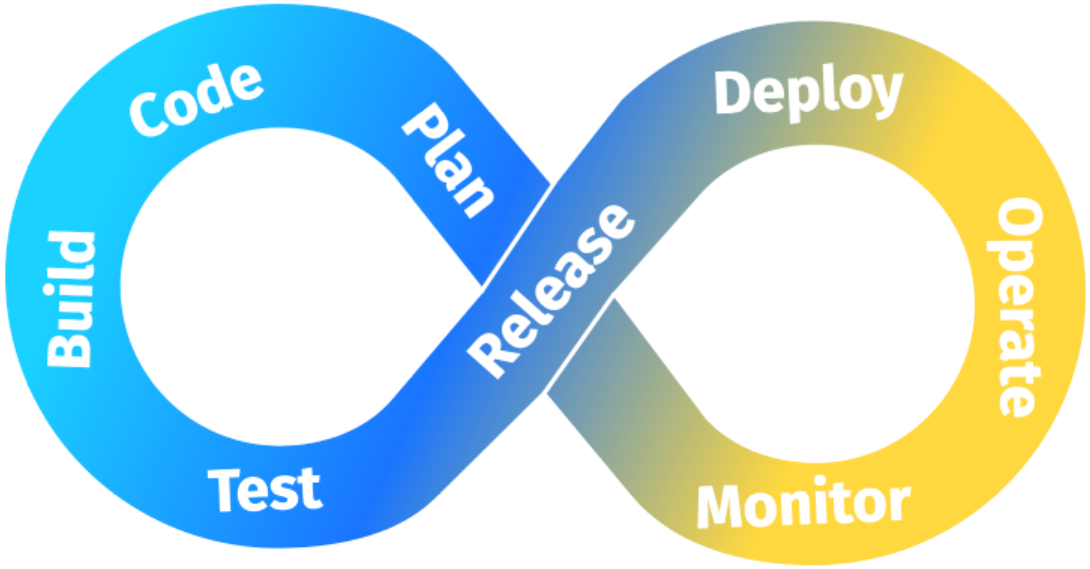
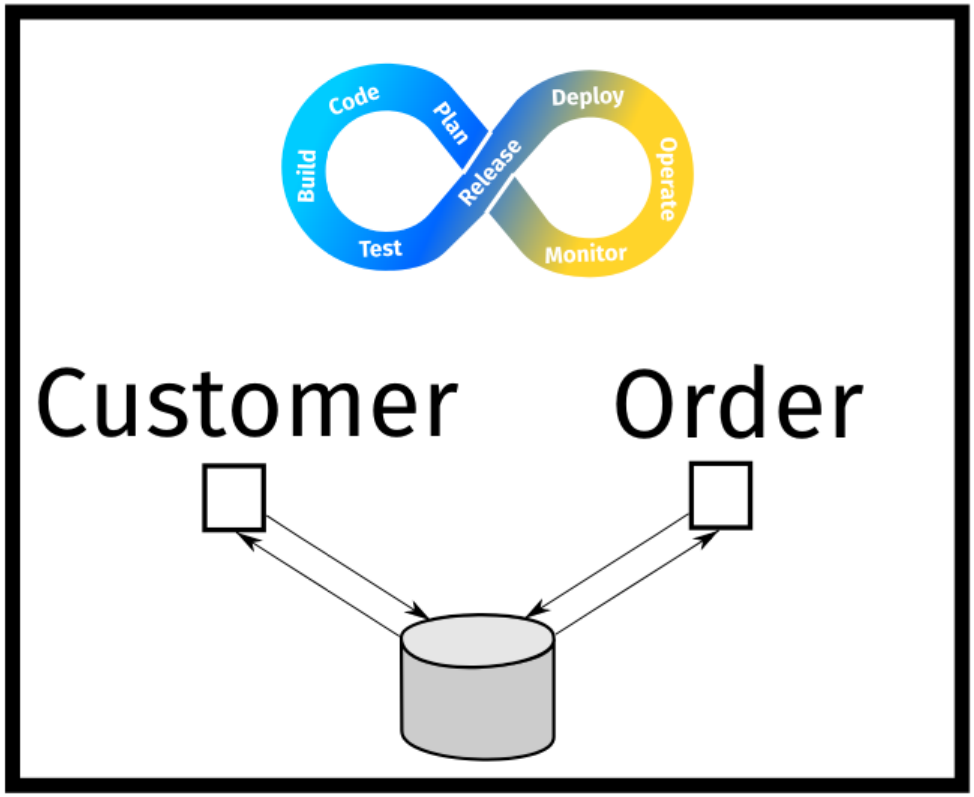
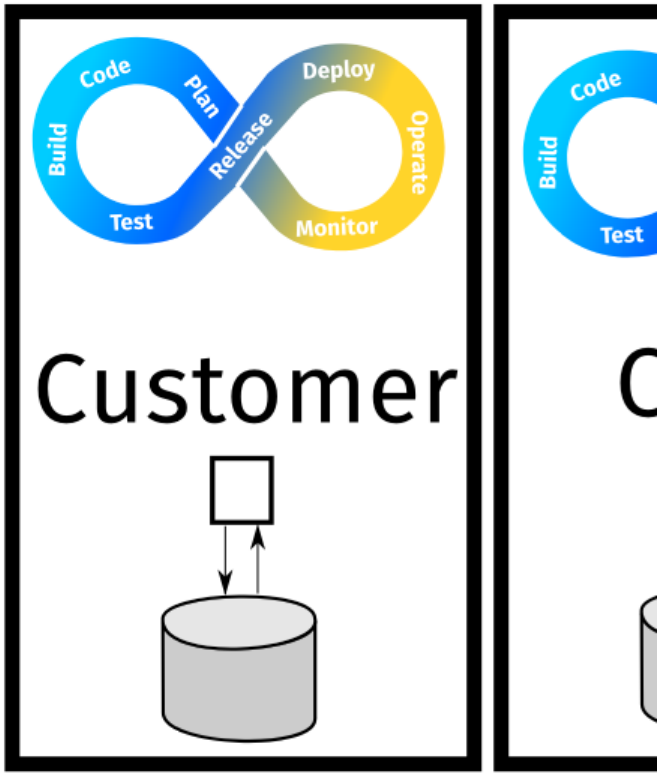
DevOps

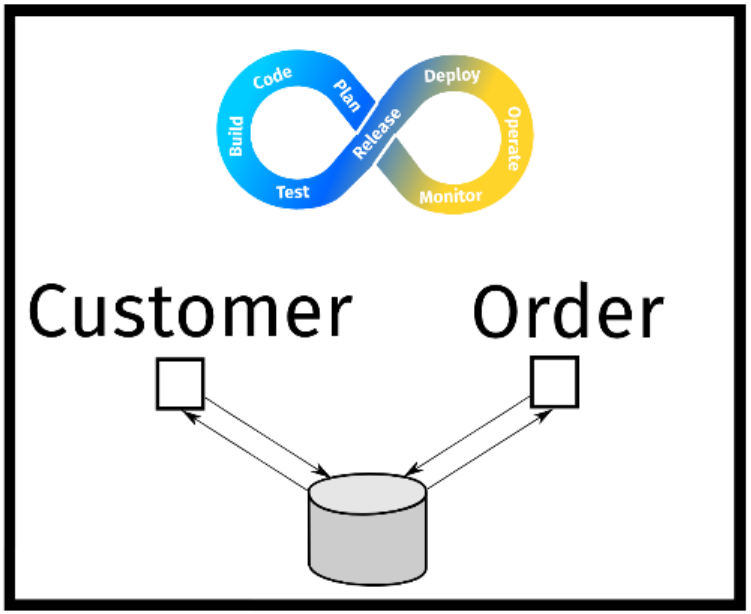




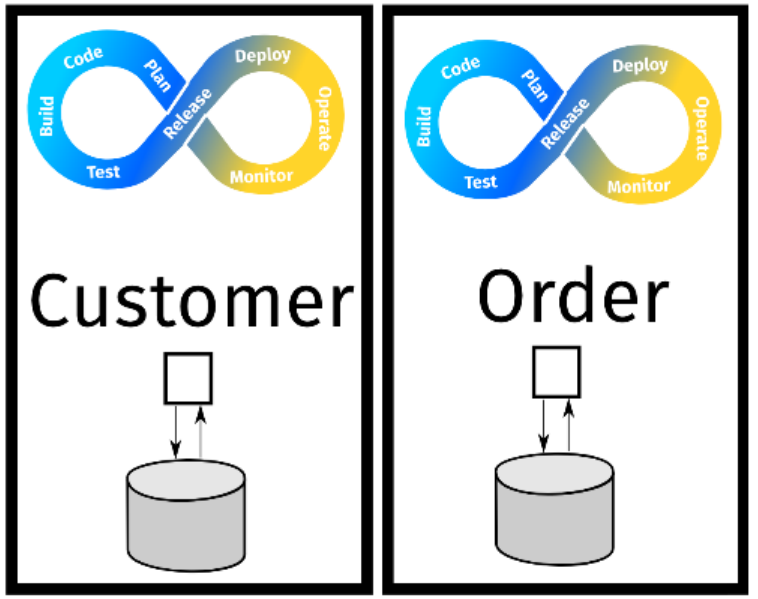
Monolith



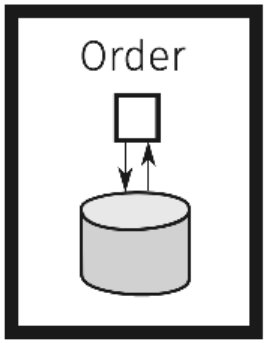
Microservi

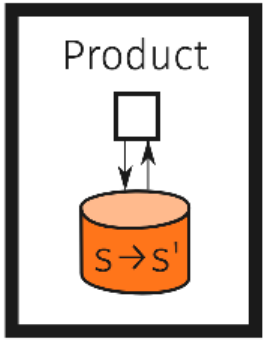


Monolith



Microservices

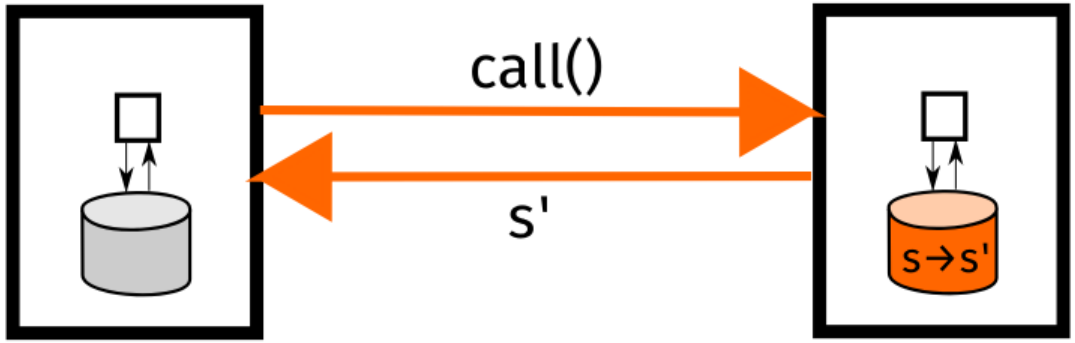




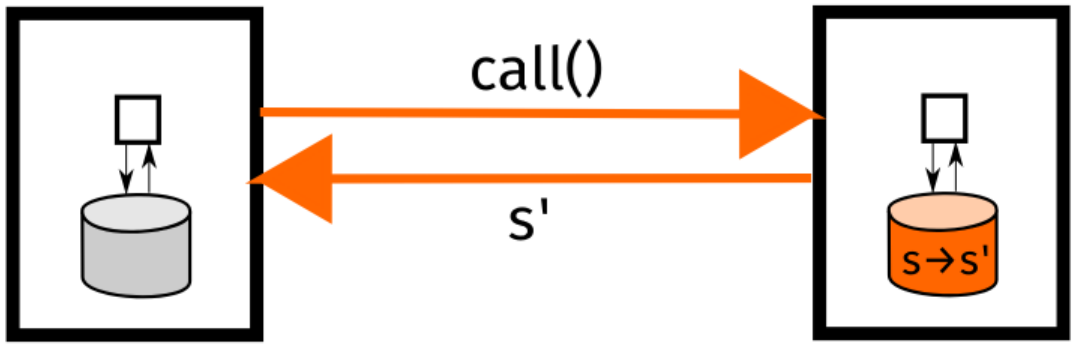
How to connect two microservices with HTTP?

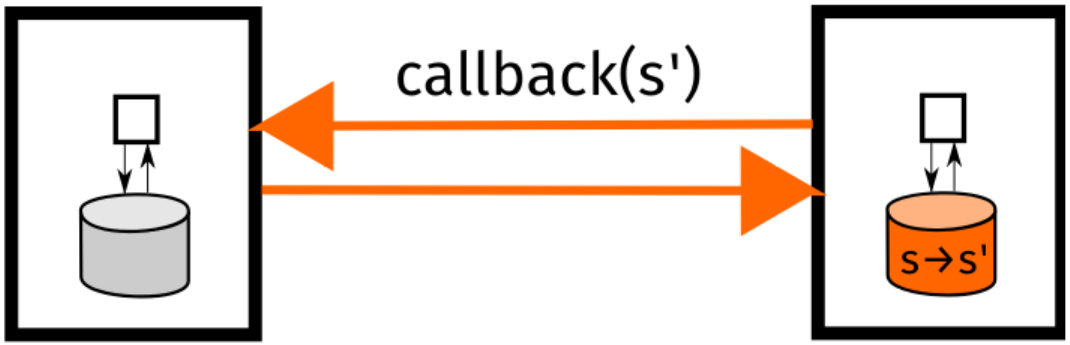
Please enter your answer and click submit

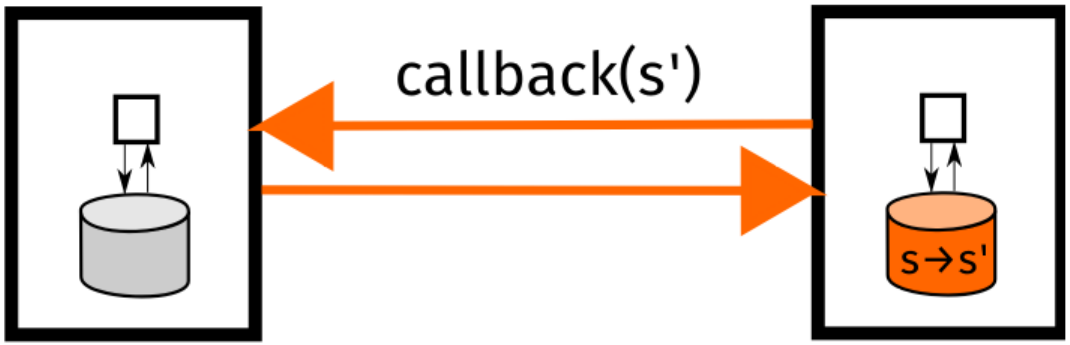
SUBMIT


call()
s'
s→s'

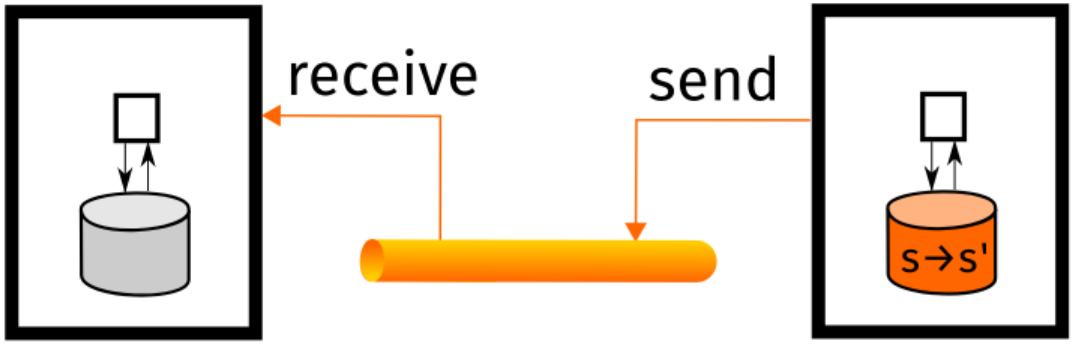
Remote Procedure Call (Poll)

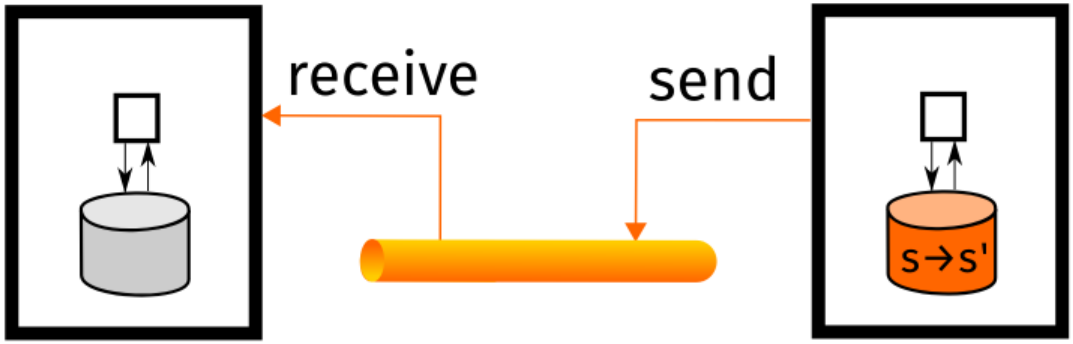



callback(s')
s→s'

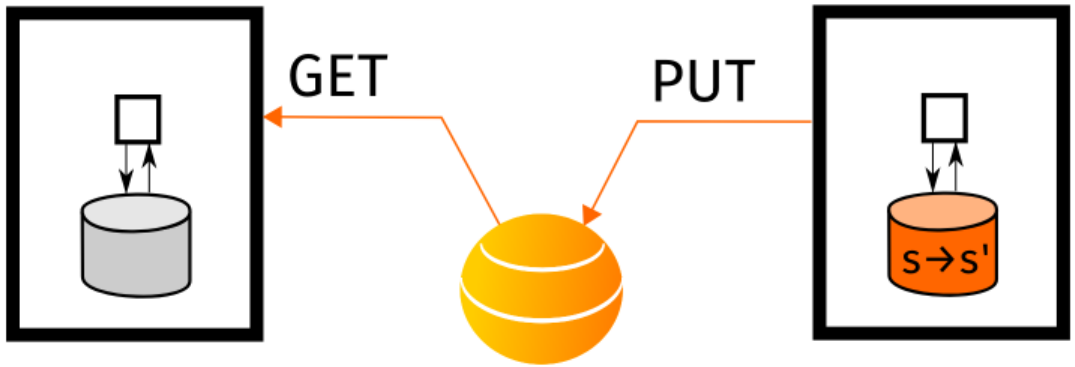


Remote Procedure Callback (Push)

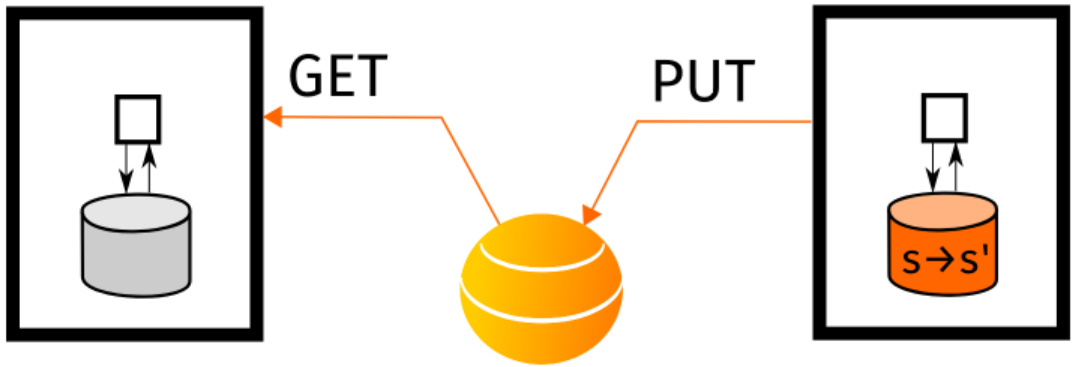

receive
send
s→s'



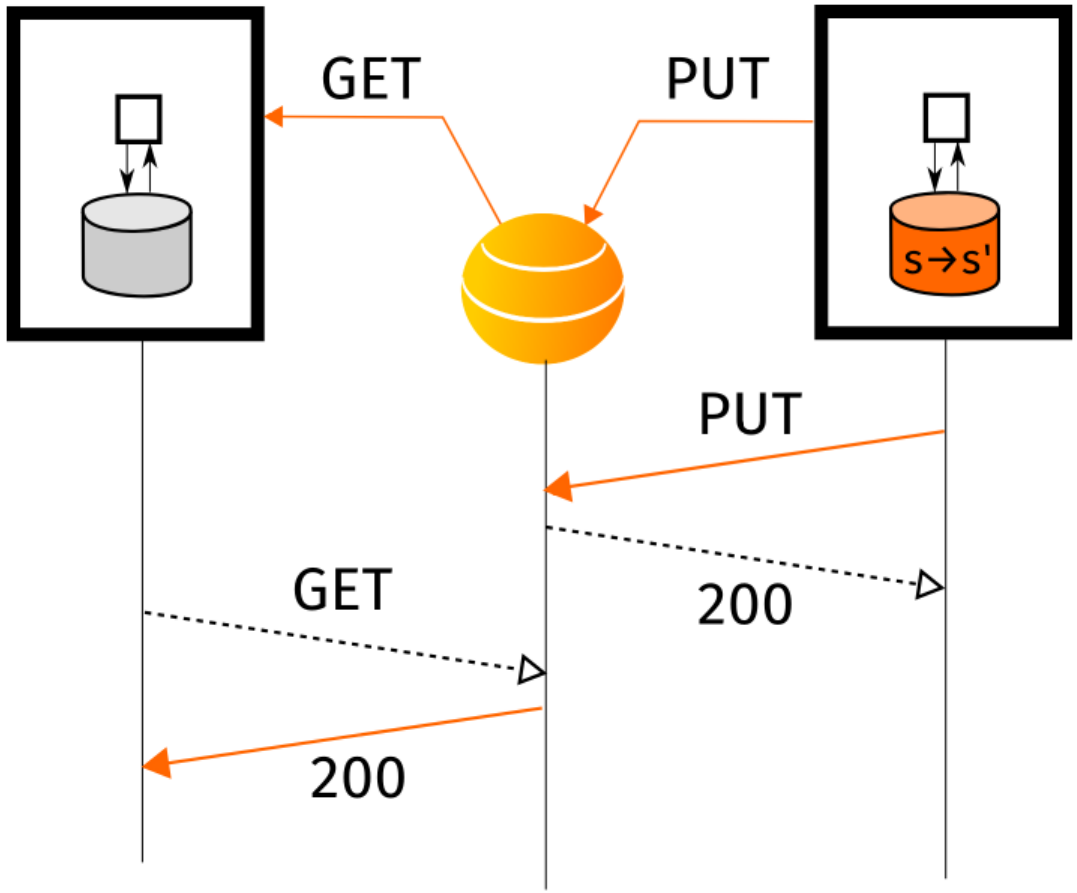
Message Bus


GET
PUT
s→s'

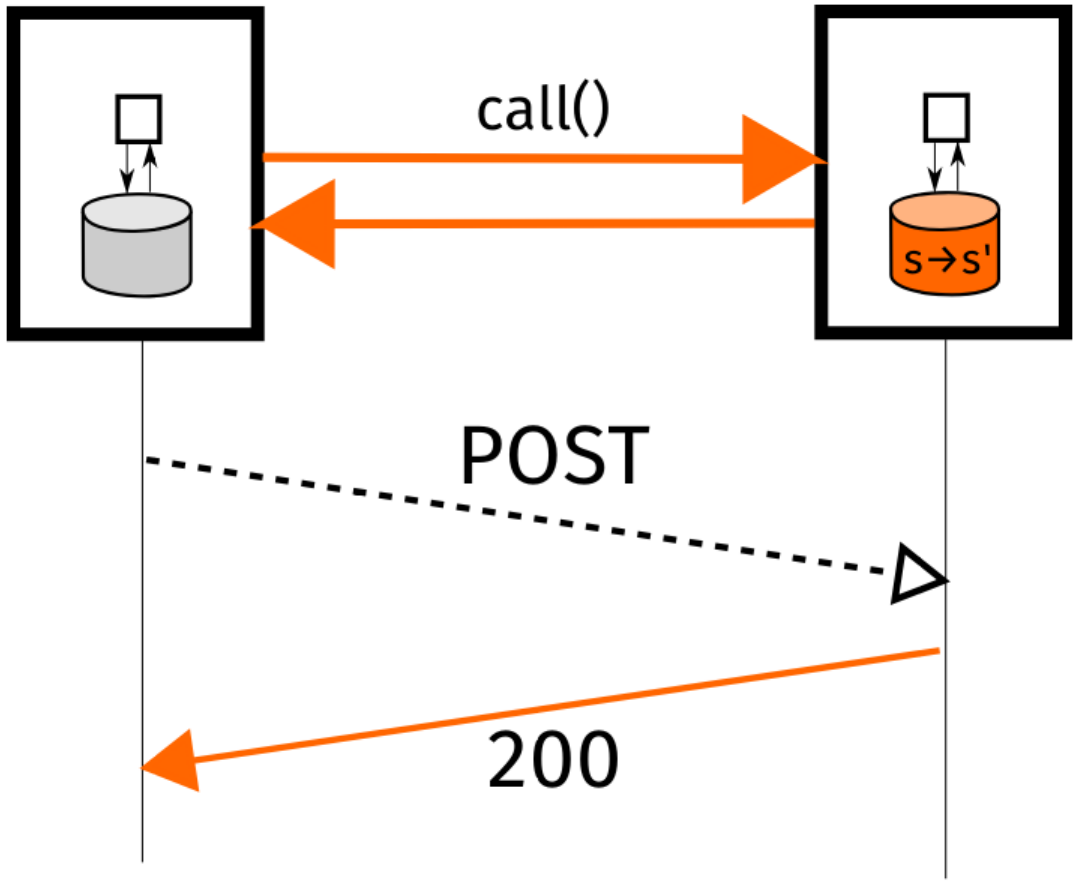
Representational State Transfer



The Web as a Software Connector

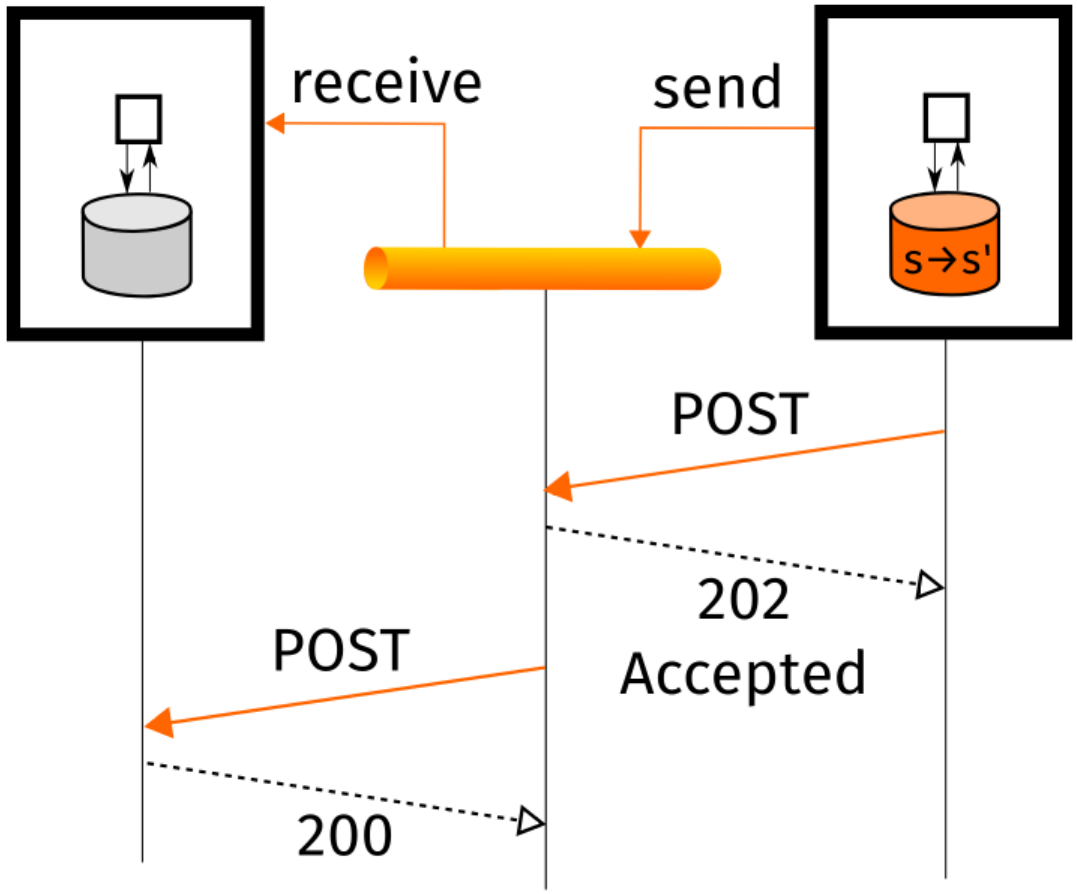


soap+xml over HTTP

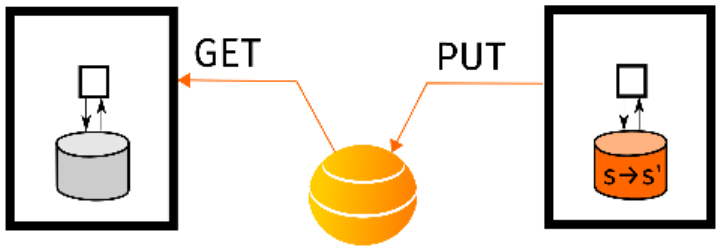


grpc+proto over HTTP/2

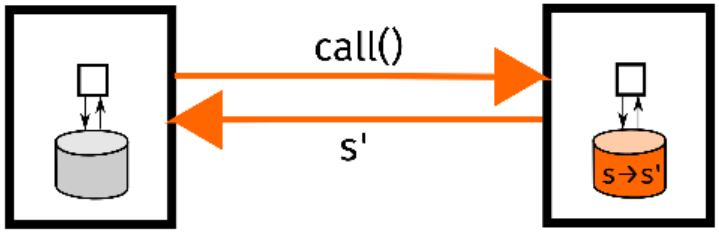
The Web as a Tunnel



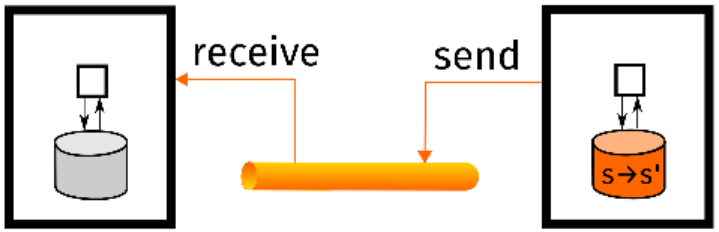
Representational State Transfer



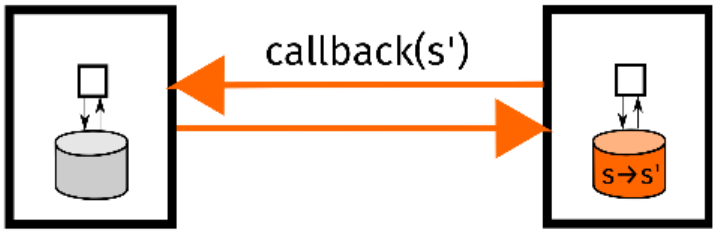
Remote Procedure Call (Poll)



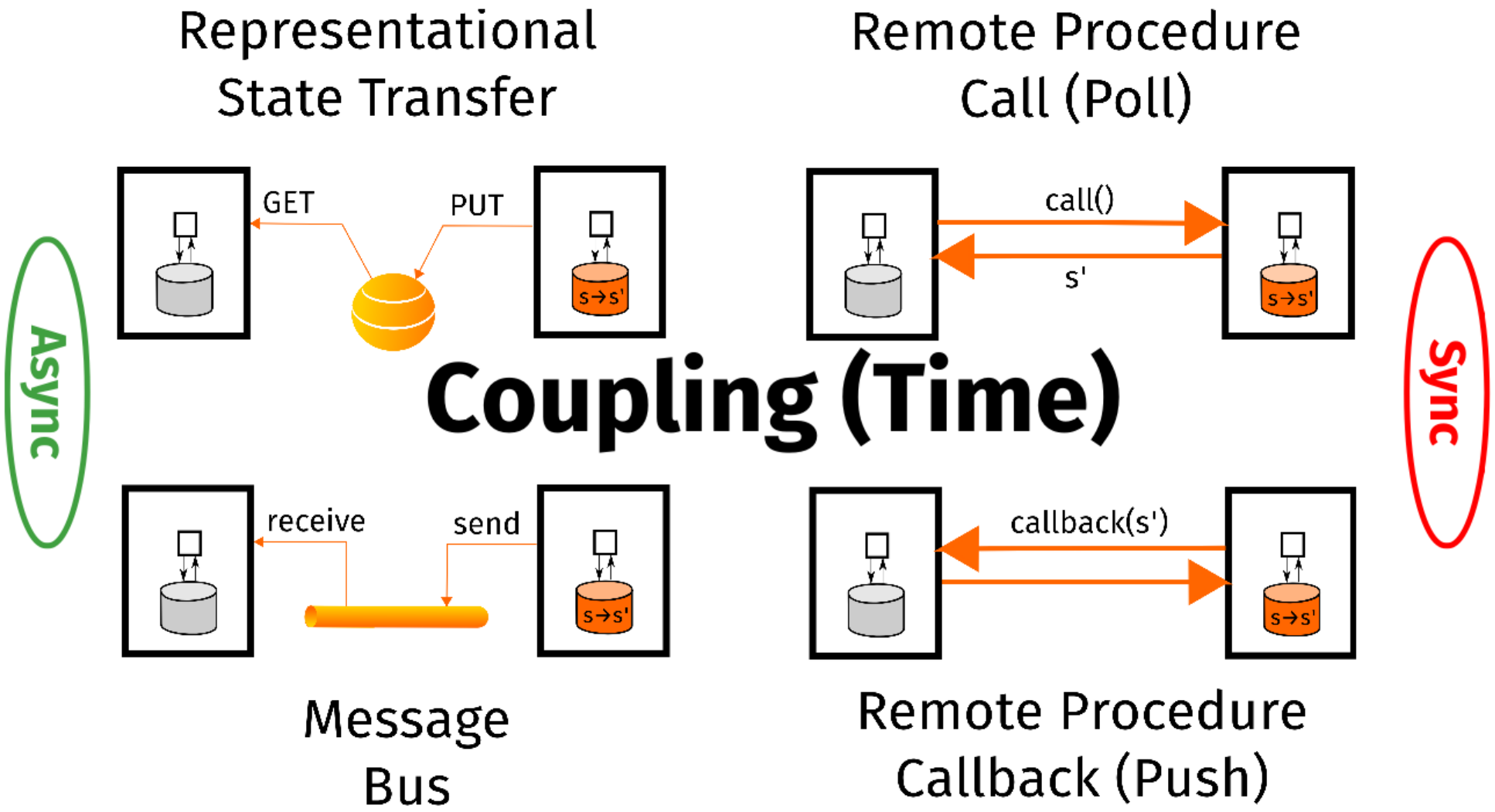
HTTP-*



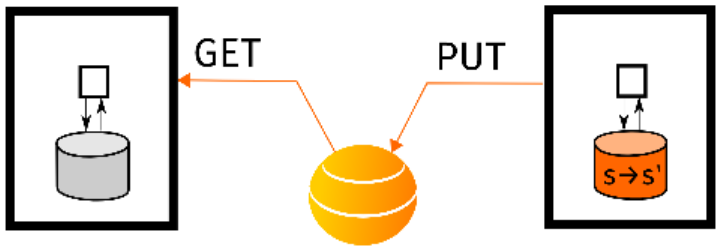
Message Bus



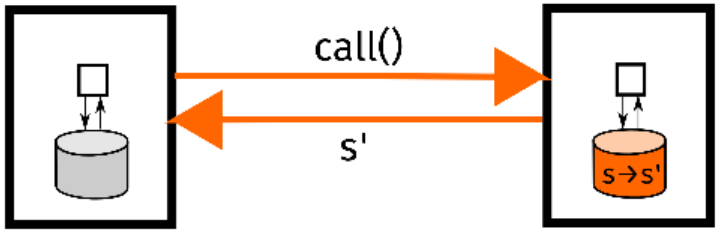
Remote Procedure Callback (Push)


Representational State Transfer
Remote Procedure Call (Poll)
GET
PUT
s→s'
call()
s'
Async
Coupling (Time)
Sync
receive
send
callback(s')
Message Bus
Remote Procedure Callback (Push)

Representational State Transfer



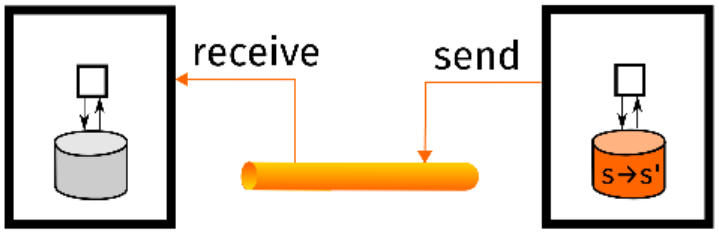
Remote Procedure Call (Poll)



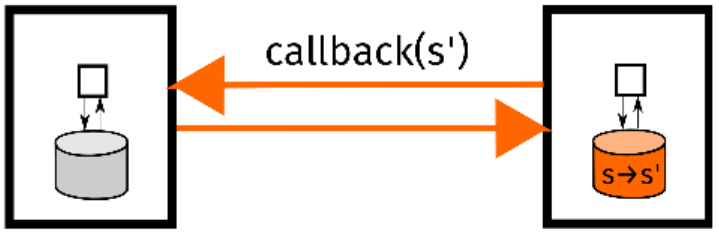
1:N

Cardinality

1:1

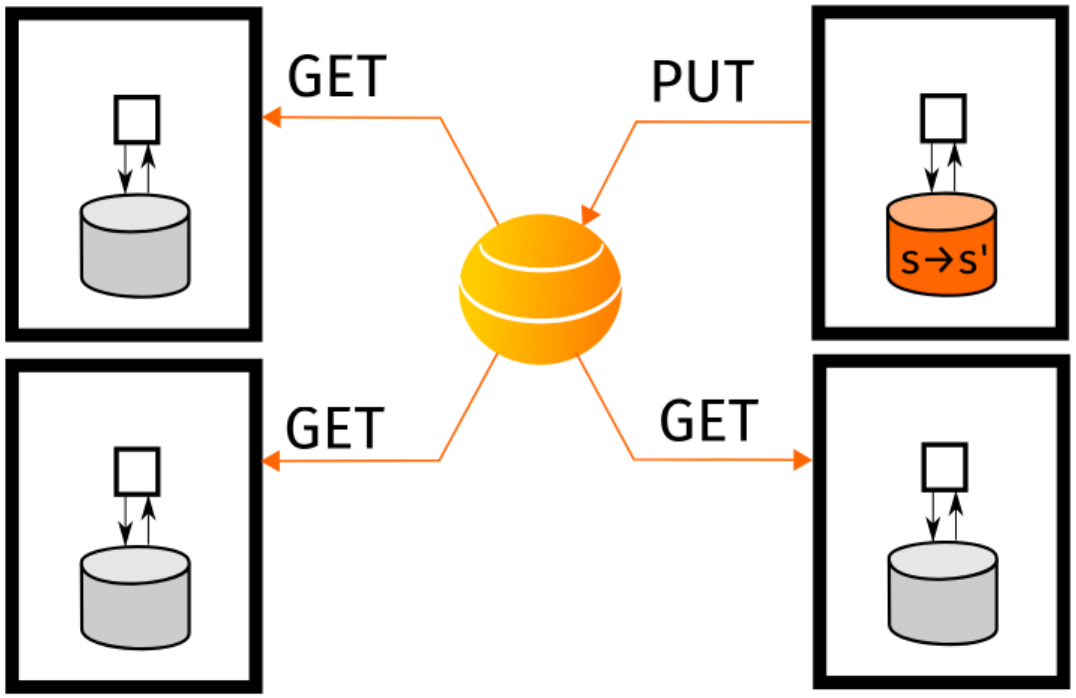


Message Bus

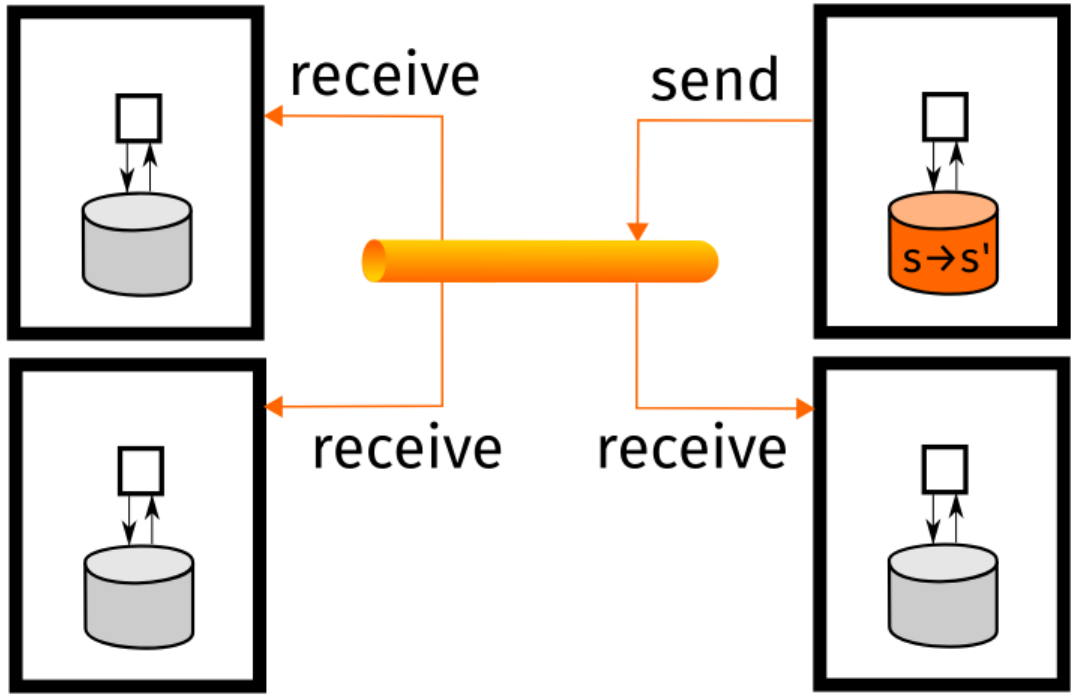


Remote Procedure Callback (Push)

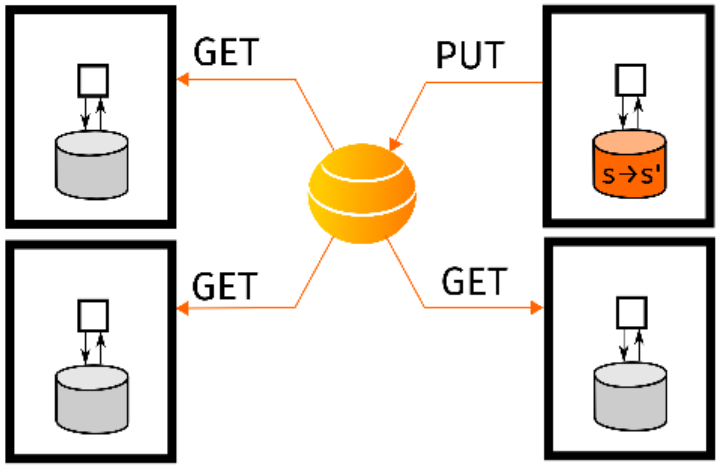
Shared Web Resource

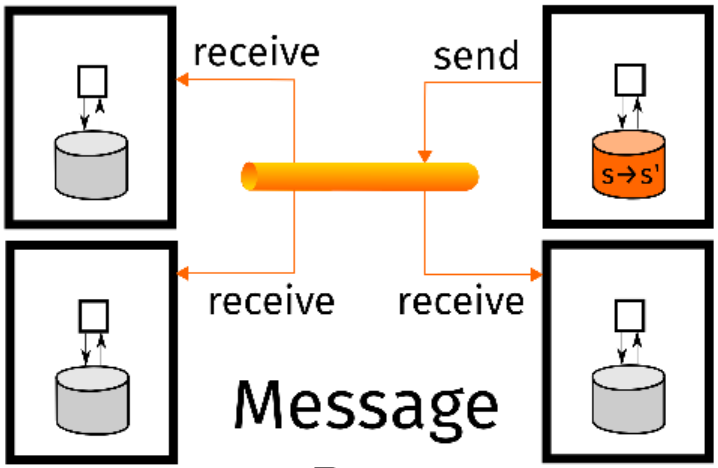


Multicast



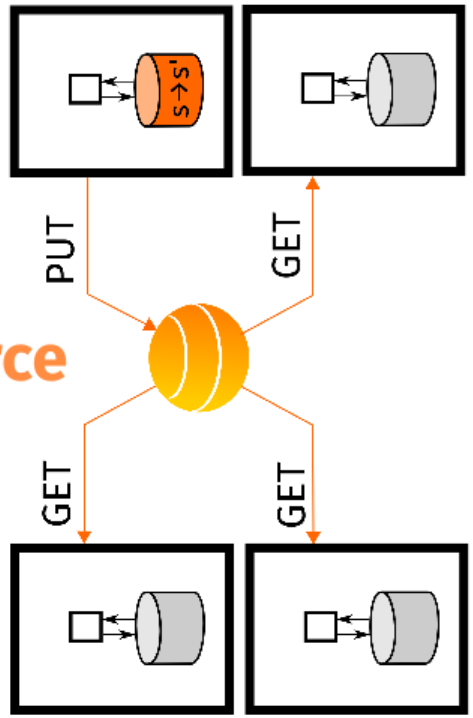
Representational State Transfer





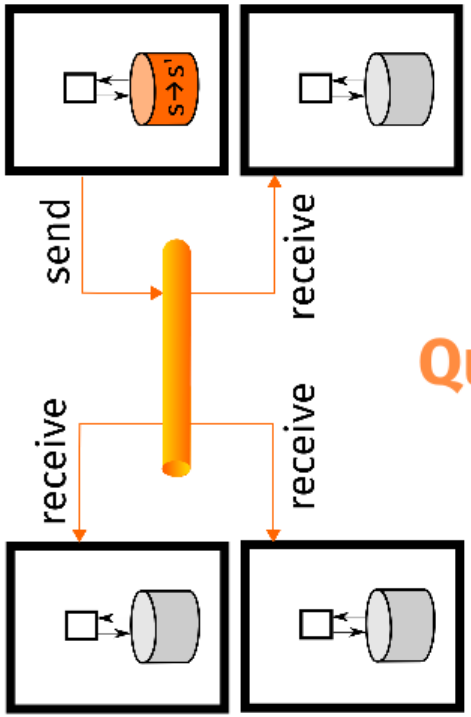
Message Bus (Multicast)

REST/WWW



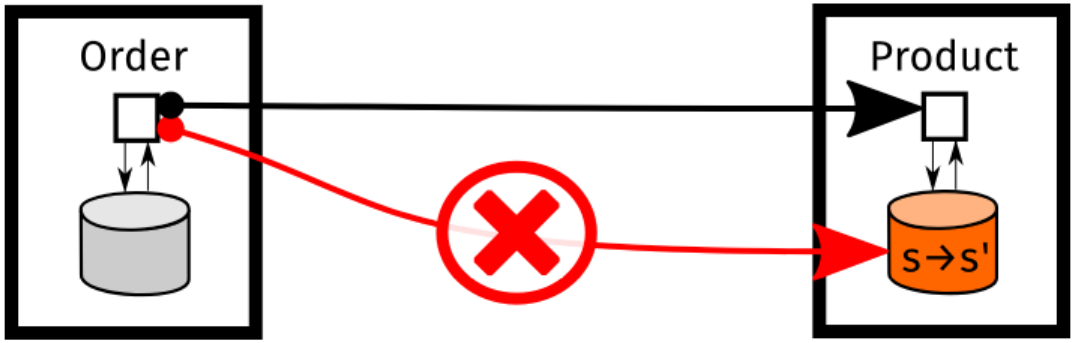
Shared Memory

MEST/ESB



Message Passing

How not to connect two microservices



For us service orientation means encapsulating the data with the business logic that operates on the data, with the only access through a published service interface. No direct database access is allowed from outside the service, and there's **no data sharing among the services**.

Werner Vogels, Interviews Web Services: Learning from the Amazon technology platform , ACM Queue, 4(4), June 30, 2006

Do you:

- ☐ Operate more than one microservice?
- ☐ Use polyglot persistence?
- ☐ Avoid storing everything in the same database?
- ☐ Assume eventual consistency?

SUBMIT

Stateful Microservices

Microservices prefer letting **each service manage its own database**, either different instances of the same database technology, or entirely different database systems - an approach called **Polyglot Persistence**.

M. Fowler, J. Lewis https://www.martinfowler.com/articles/microservices.html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Eventual Inconsistency
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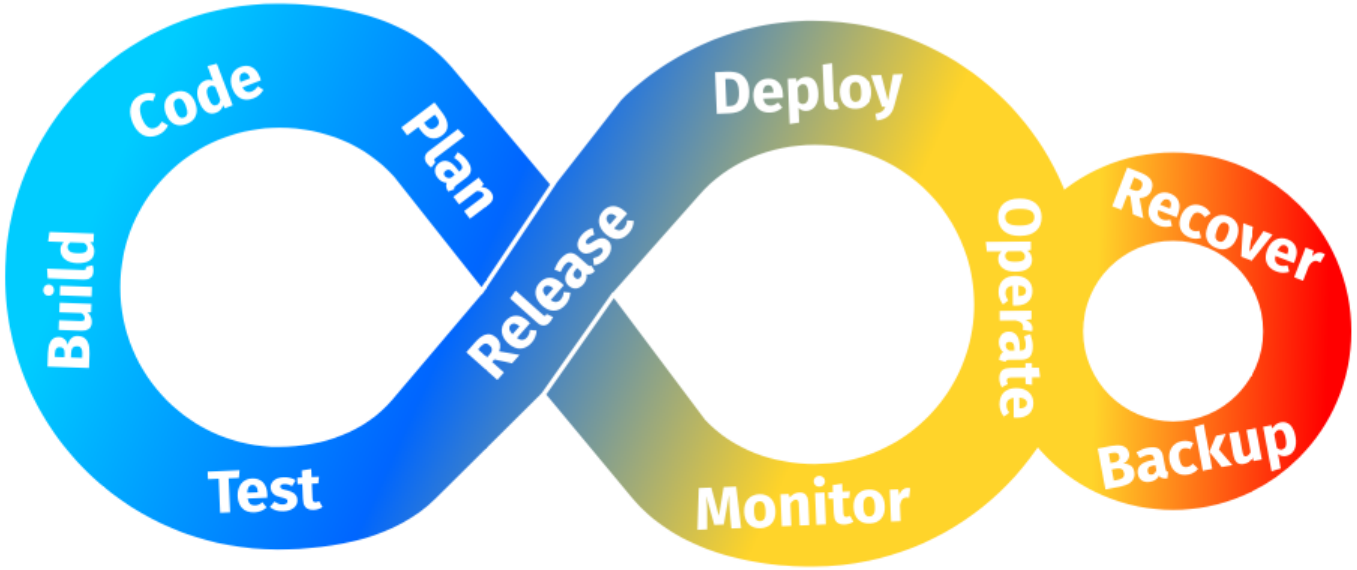
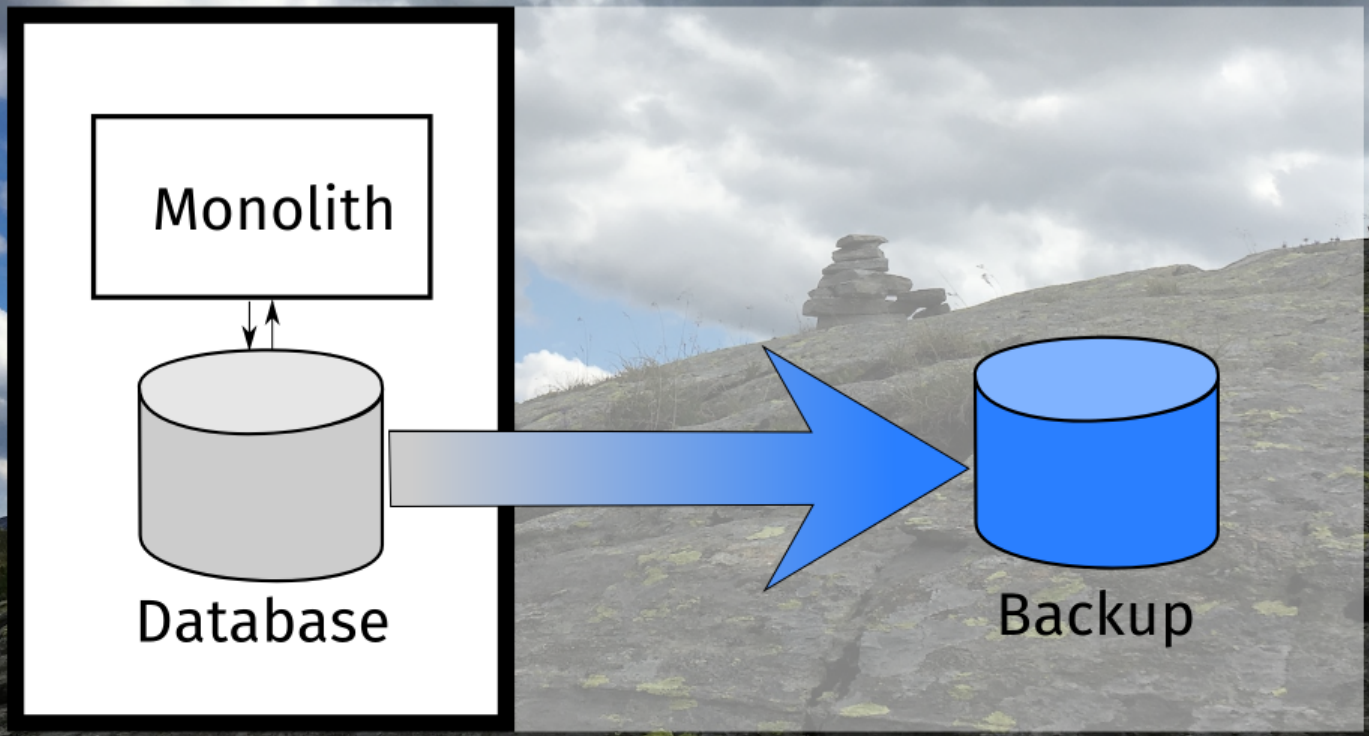
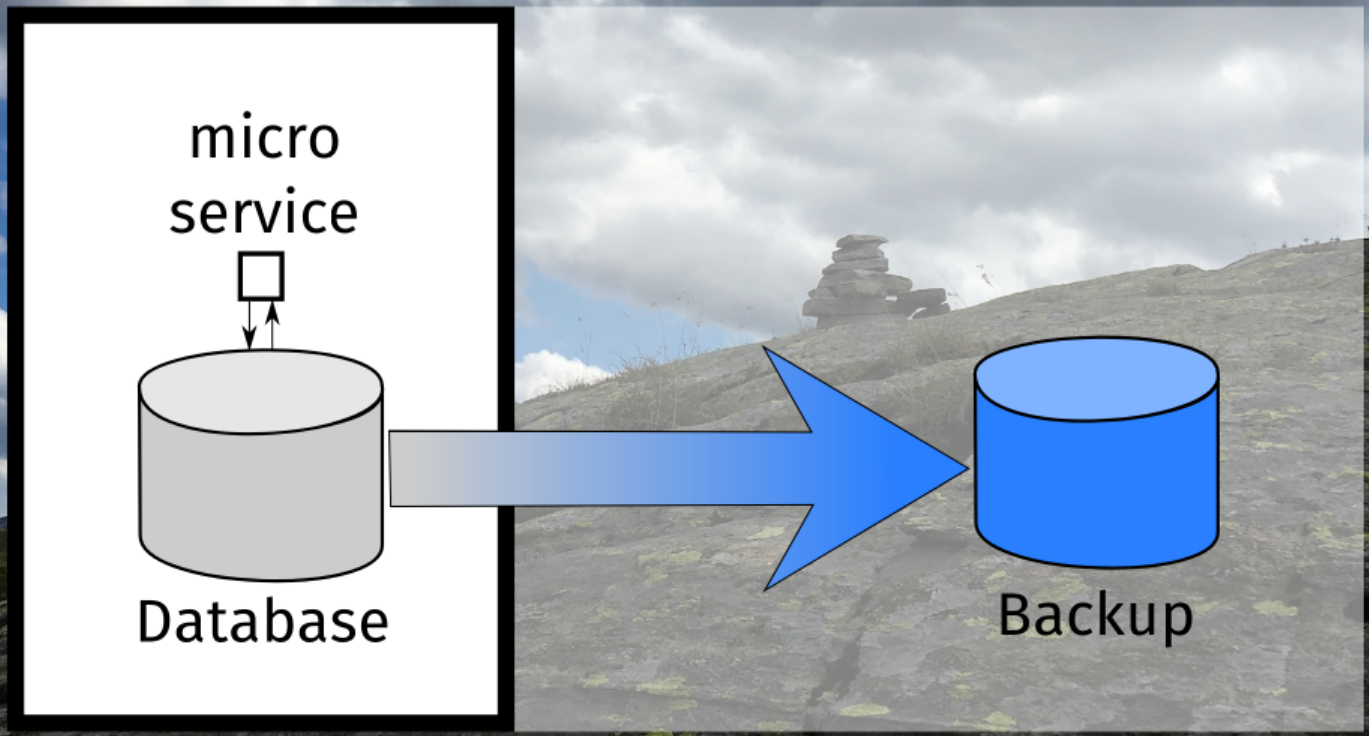
Devops meets Disaster Recovery



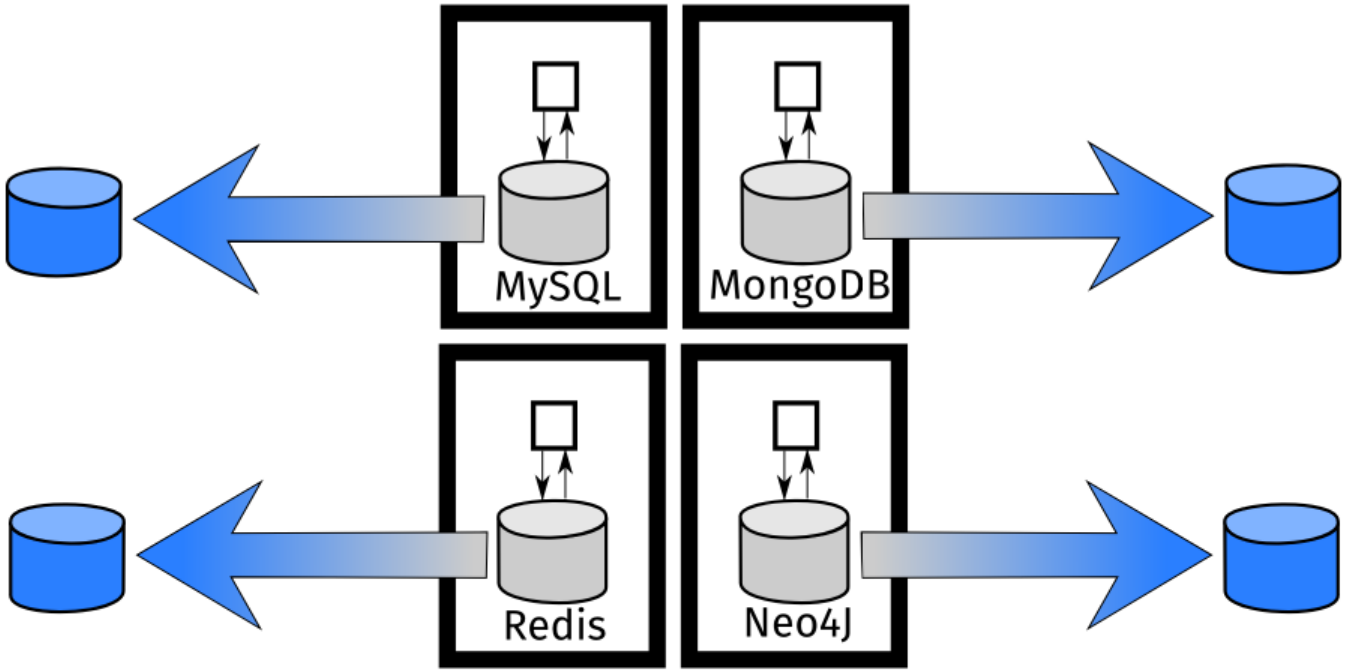
How do you back up a monolith?



How do you back up one microservice?

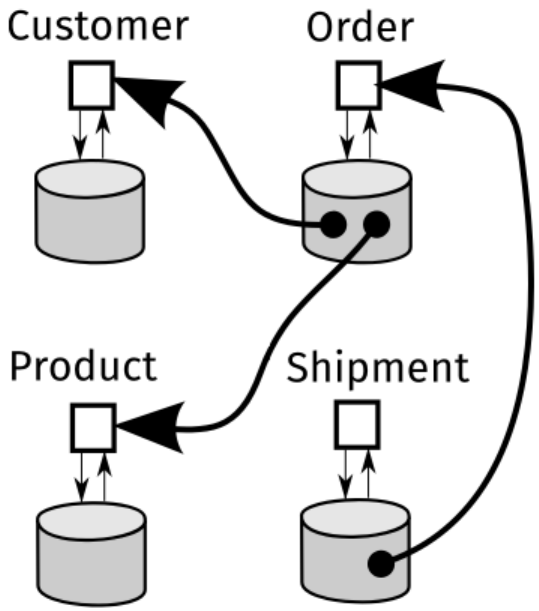


How do you back up an entire microservice architecture?



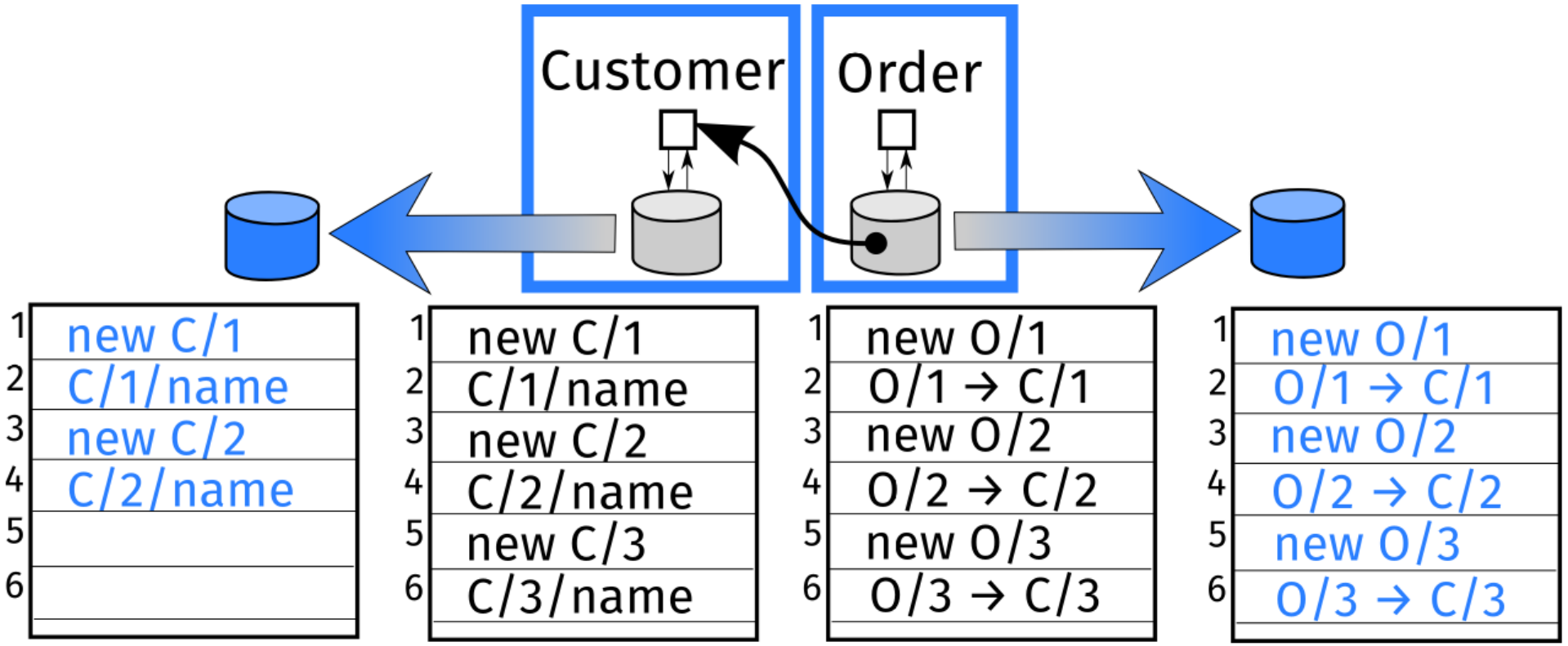
Are you sure?

Example



Data relationships across microservices =
Hypermedia

Independent Backup



Backups taken independently at different times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Disaster Strikes
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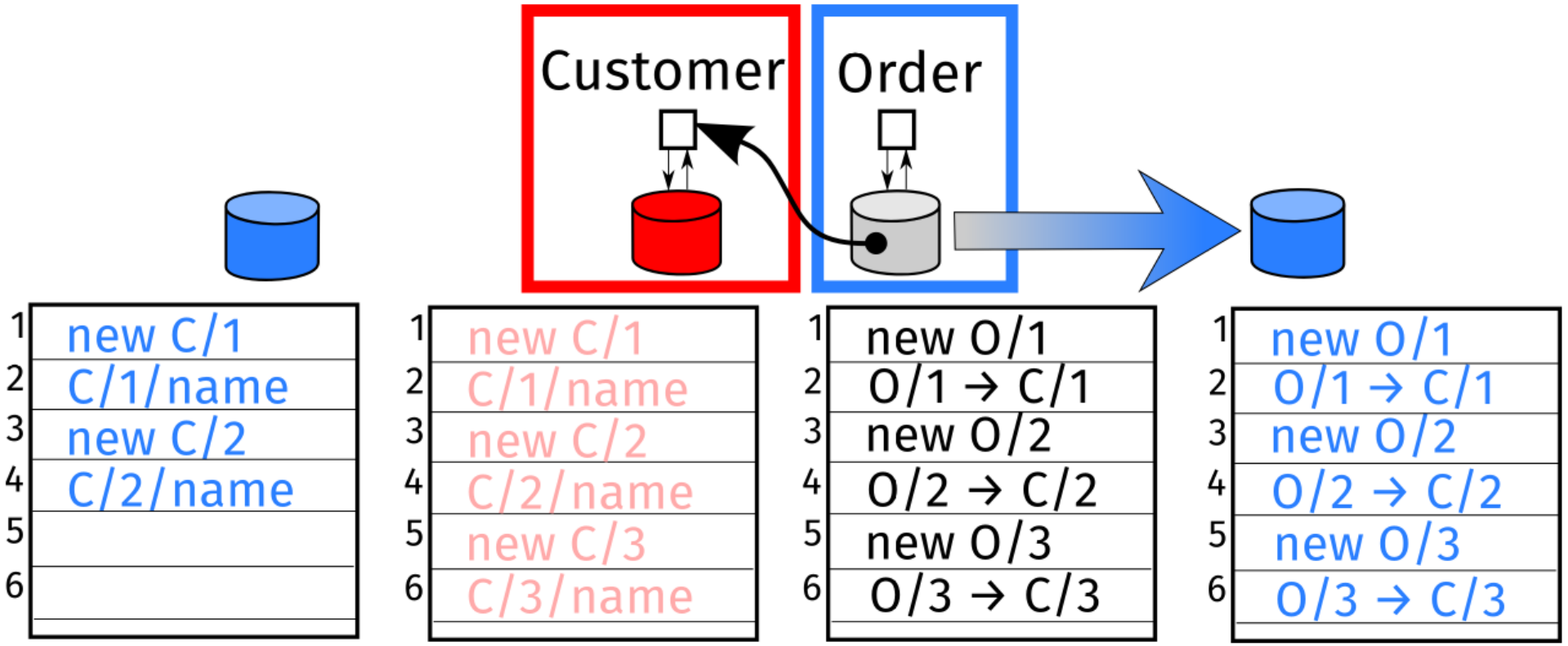
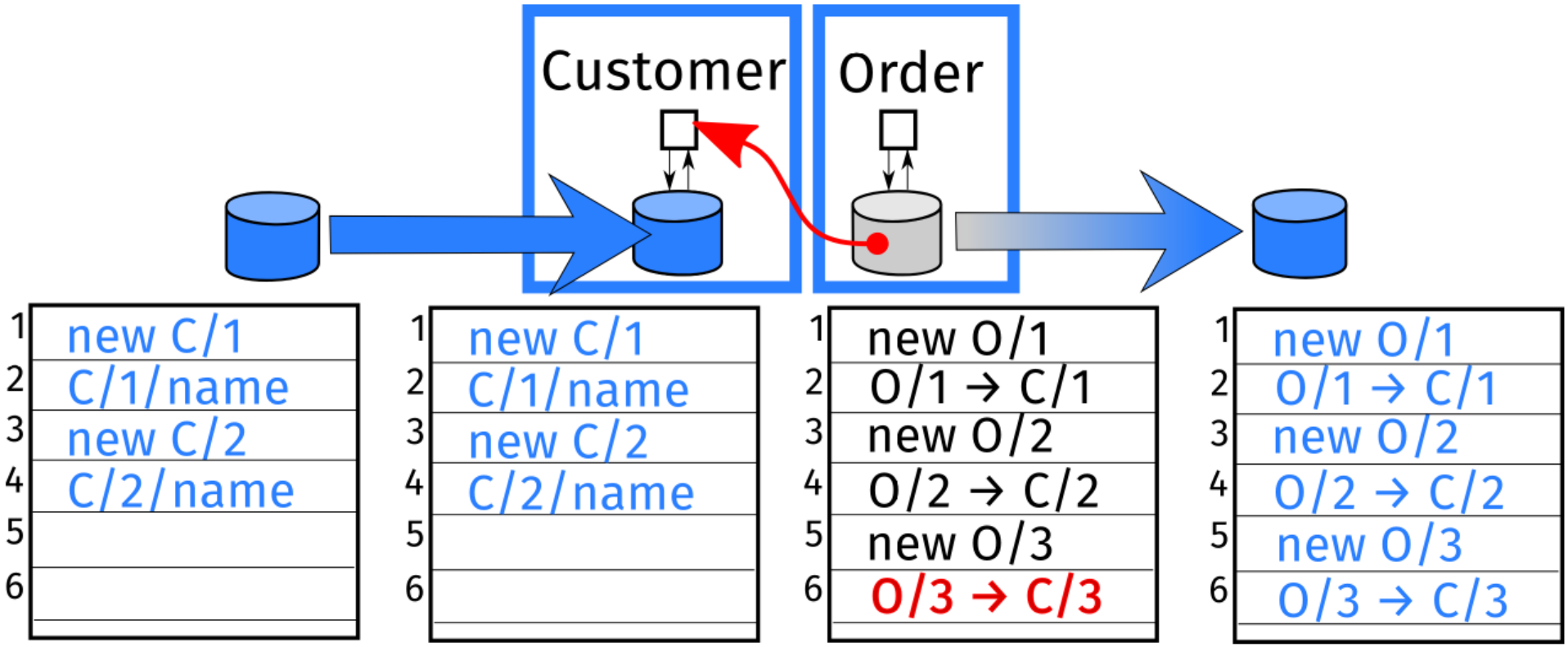
2018

Disaster Strikes



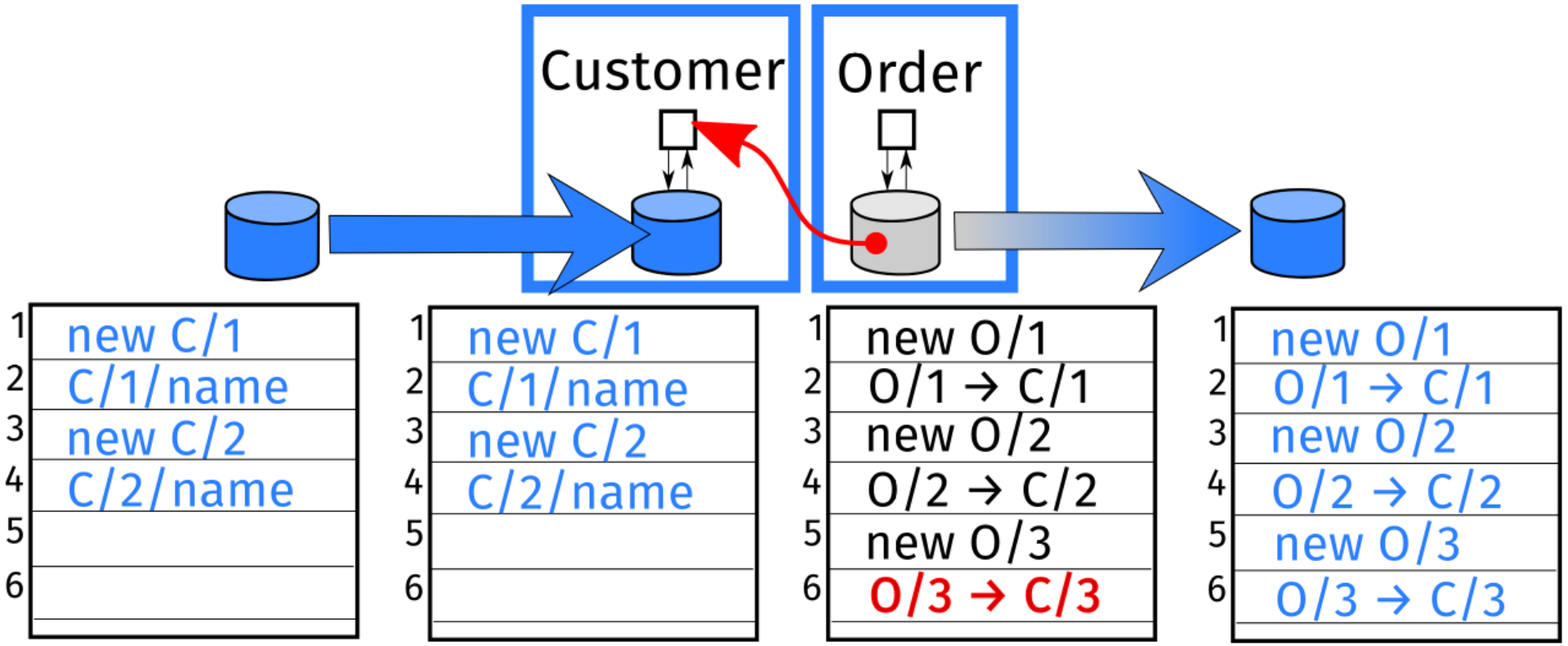
One microservice is lost

Recovery from Backup



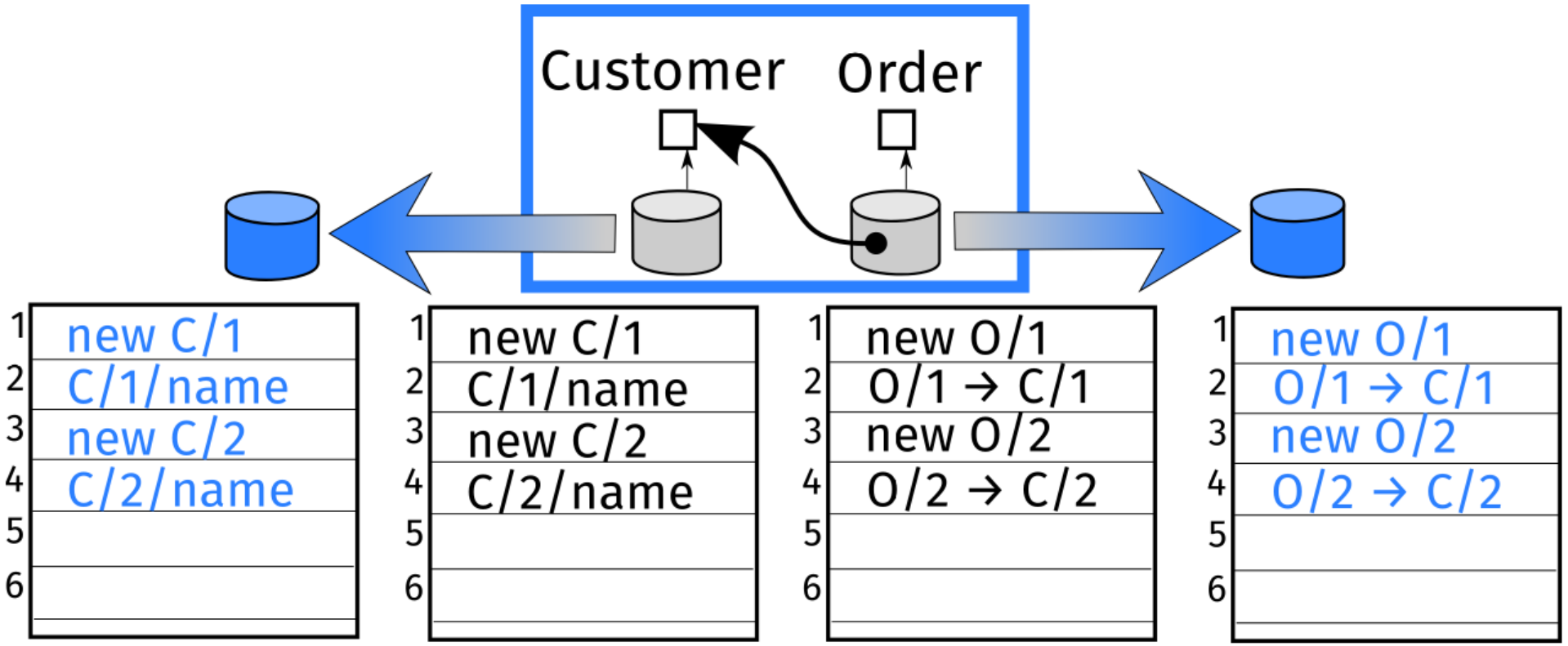
Broken link after recovery

Eventual Inconsistency



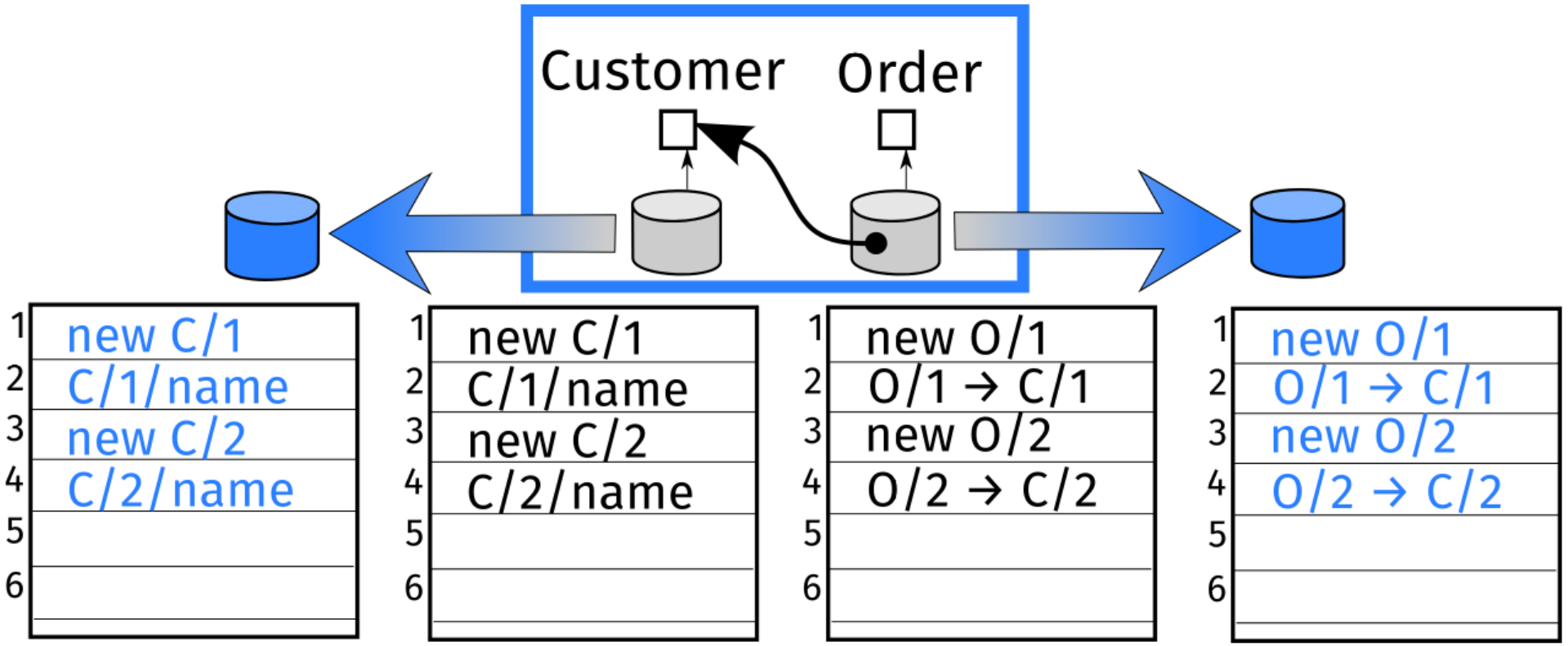
Broken link after recovery

Synchronized Backups



Backups of all microservices taken at the same time.

Limited Availability



No updates allowed anywhere while backing up the microservices

The BAC theorem

When **B**acking up a
microservice architecture,
it is not possible to have
both
Consistency and **A**vailability

Consistency

During normal operations, each microservice will eventually reach a consistent state

Referential integrity: links across microservice boundaries are guaranteed eventually not to be broken

Availability

It is possible to both read **and update** the state of any microservice at any time

Backup

While backing up the system, is it possible to take a consistent snapshot of all microservices without affecting their availability?

No.

Backup + Availability

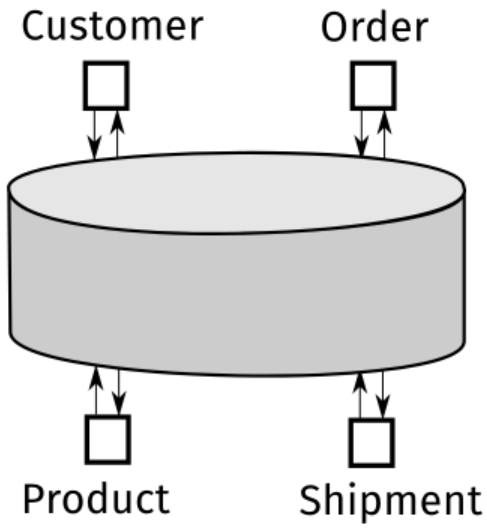
Backing up each microservice independently will eventually lead to inconsistency after recovering from backups taken at different times

Backup + Consistency

Taking a consistent backup requires to:

- disallow updates anywhere during the backup (limited availability)
- wait for the slowest microservice to complete the backup
- agree among all microservices on when to perform the backup (limited autonomy)

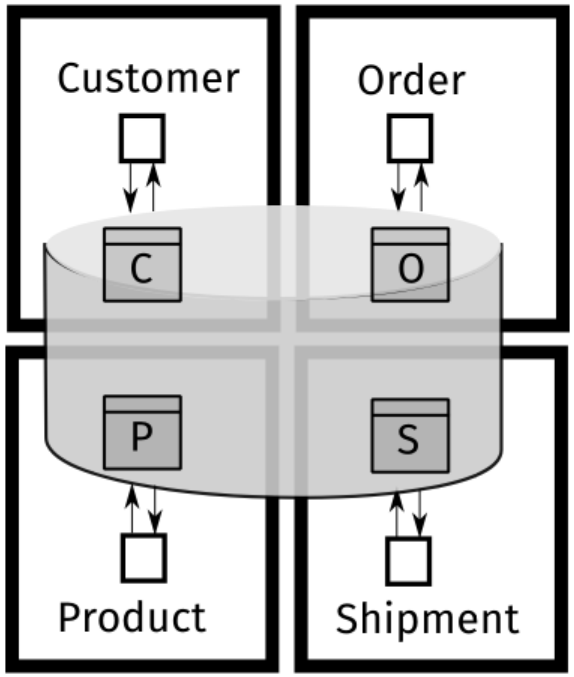
Shared Database



A centralized, shared database would require only one backup

Is this still a microservice architecture?

Shared Database, Split Schema

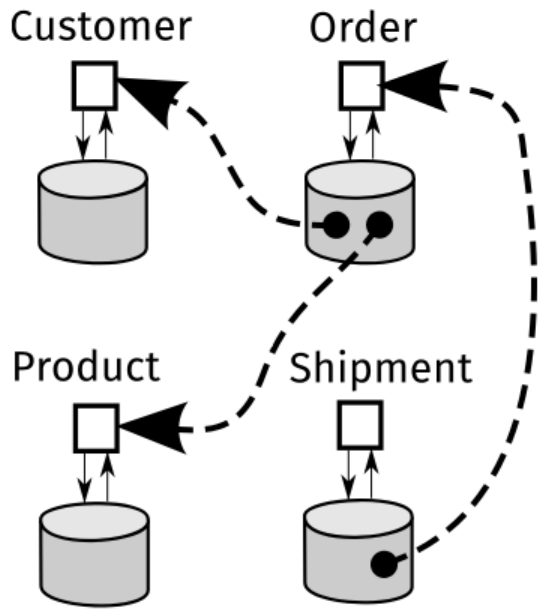


A centralized, shared database would require only one backup

Each microservice must use a logically separate schema

What happened to polyglot persistence?

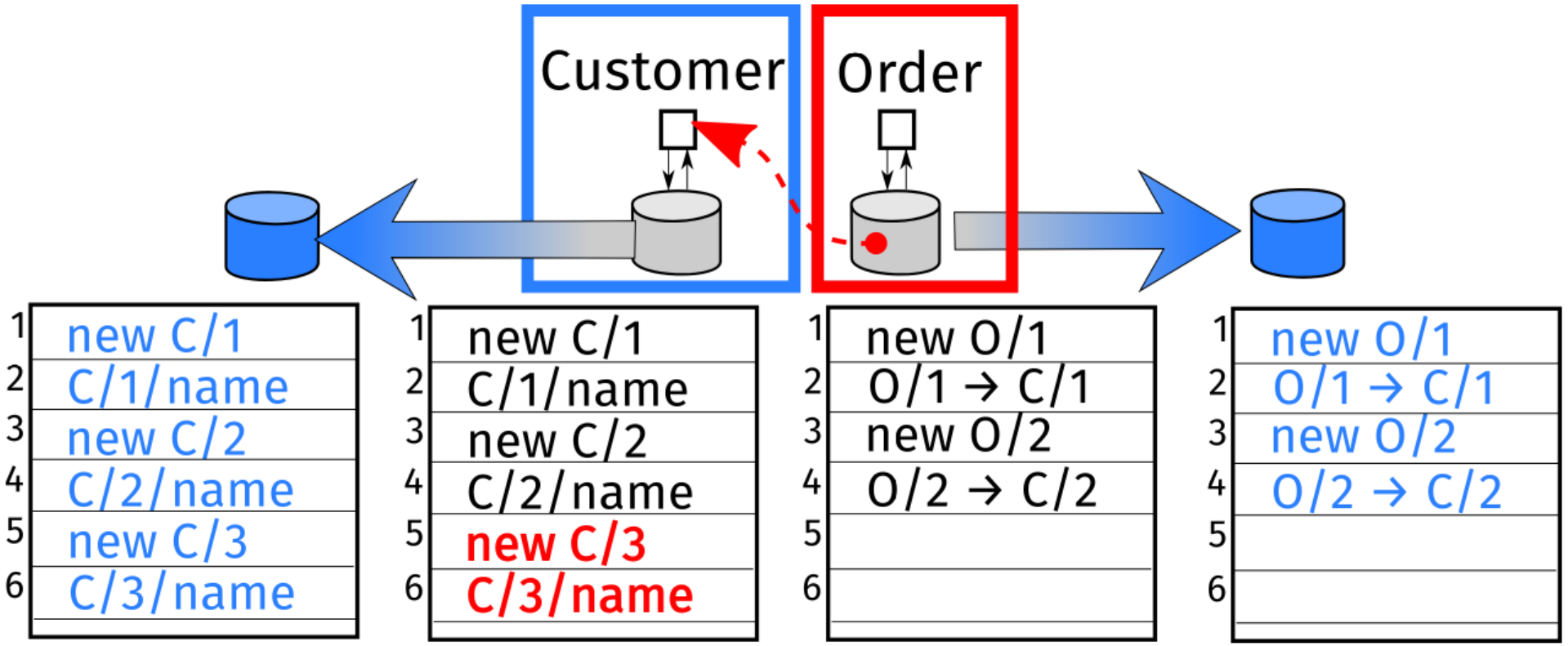
Links can break



No guarantees for references crossing microservice boundaries

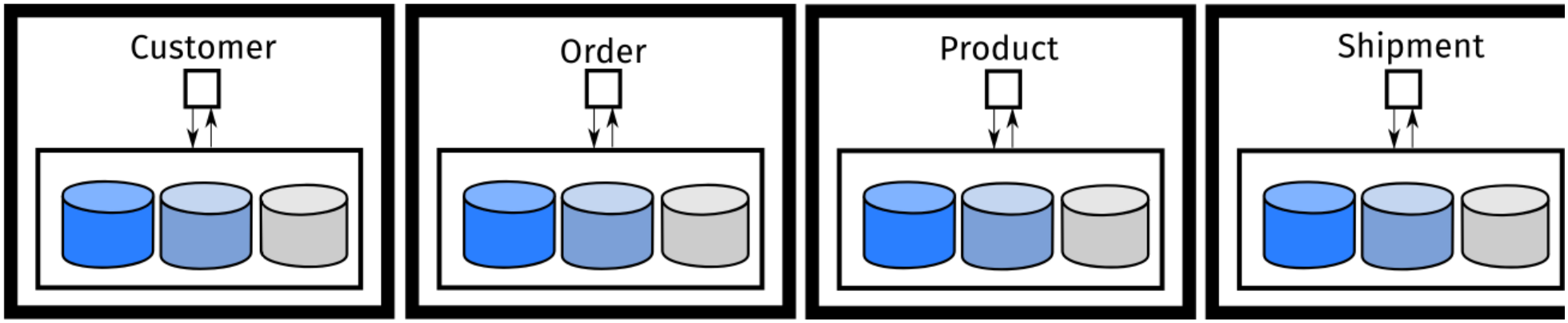
Microservices inherit a fundamental property of the Web

Orphan State



Orphan state is no longer referenced after recovery

Unstoppable System



An expensive, replicated database with high-availability for every microservice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Unstoppable System
How do you restart an unstoppable system?
WS-REST
2018

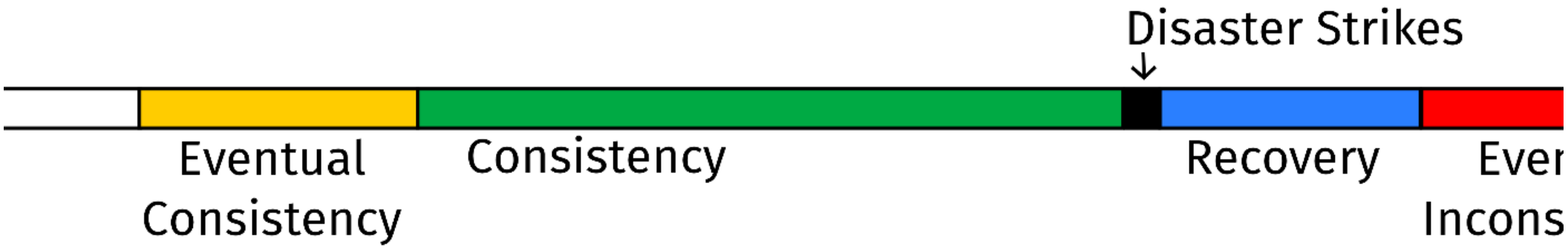
Eventual Consistency

Consistency


Disaster Strikes
Eventual Consistency
Consistency
Recovery
Eventual Inconsistency

Eventual Consistency

Retries are **enough** to deal with **temporary** failures of read operations, eventually the missing data will be found

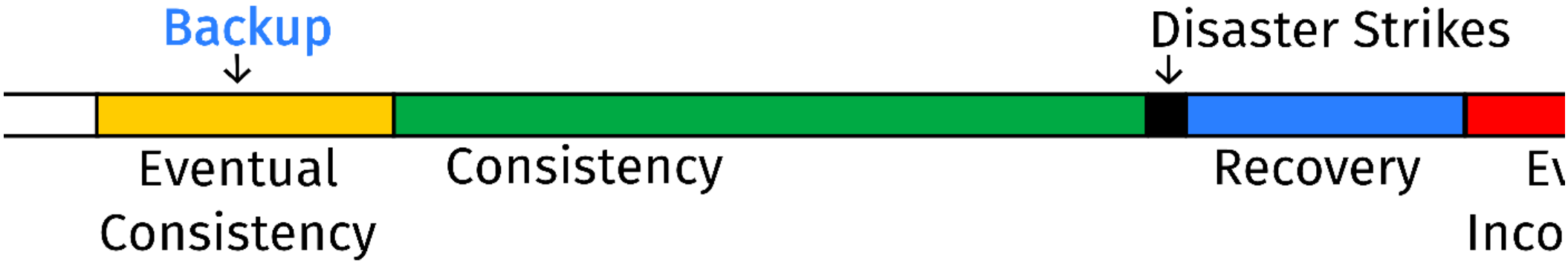


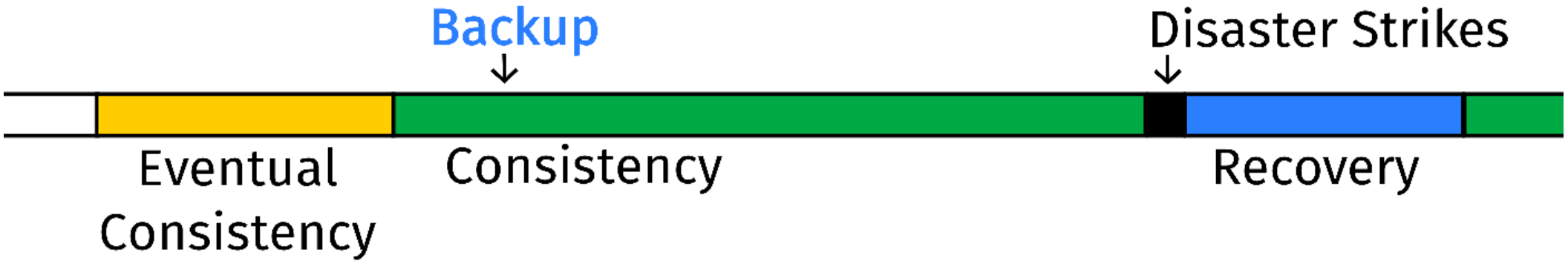
Eventual Consistency

Retries are **enough** to deal with **temporary** failures of read operations, eventually the missing data will be found

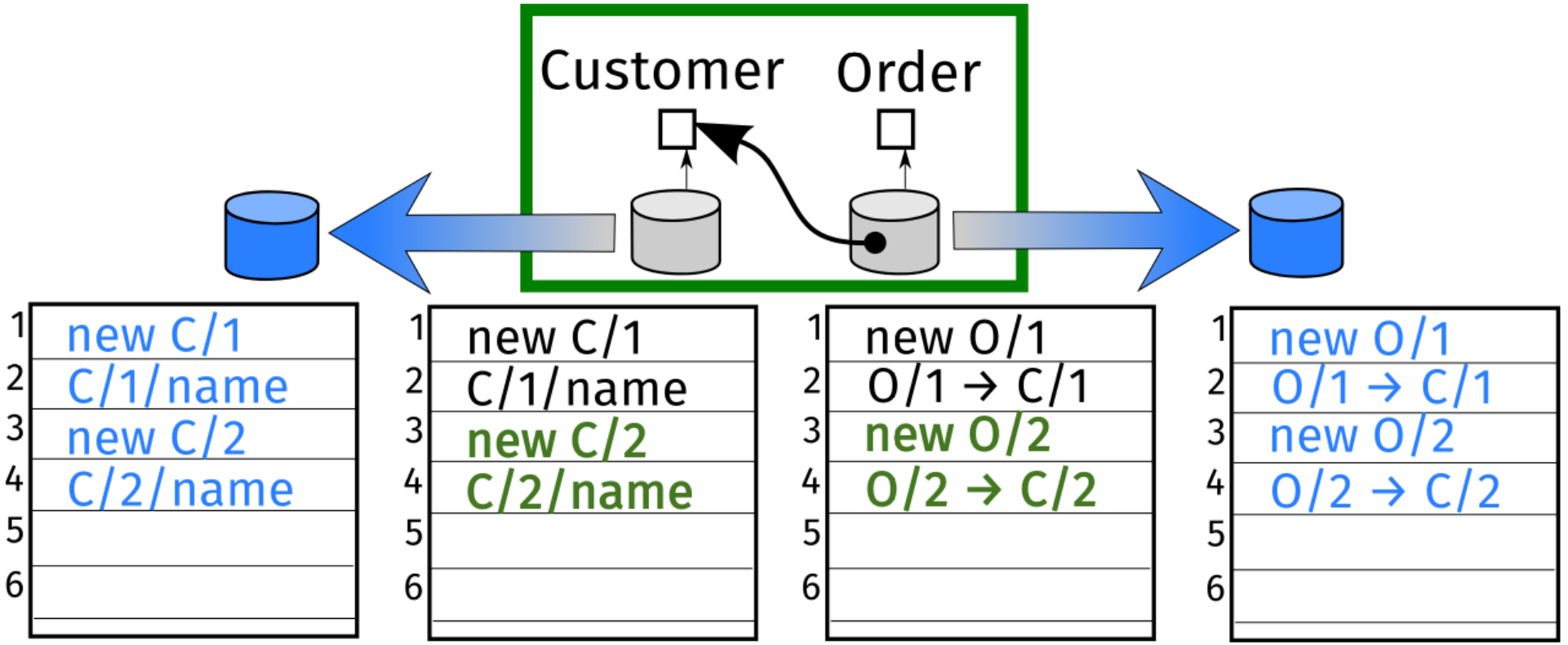
Eventual Inconsistency

Retries are **useless** to deal with **permanent** failures of read operations, which used to work just fine before disaster recovery





Distributed Transactions



Take snapshots only when all microservices are consistent

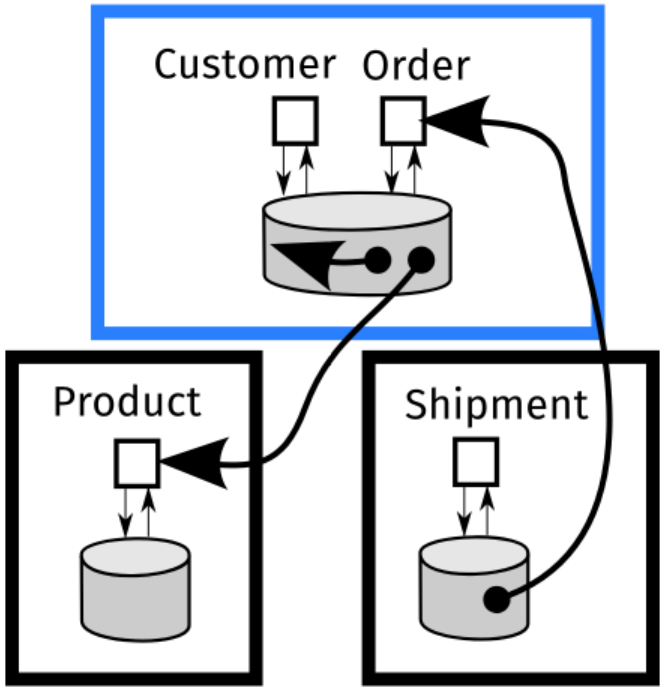
Avoid eventual consistency

Microservices

Distributed transactions are notoriously difficult to implement and as a consequence **microservice architectures emphasize transactionless coordination** between services, with explicit recognition that **consistency may only be eventual consistency** and problems are dealt with by compensating operations.

M. Fowler, J. Lewis https://www.martinfowler.com/articles/microservices.html

Splitting the Monolith



Keep data together for microservices that cannot tolerate eventual inconsistency

Does it apply to you?

- ☐ More than one stateful microservice
- ☐ Polyglot persistence
- ☐ Eventual Consistency
- ☐ (Cross-microservice references)
- ☐ Disaster recovery based on backup/restore
- ☐ **Independent** backups

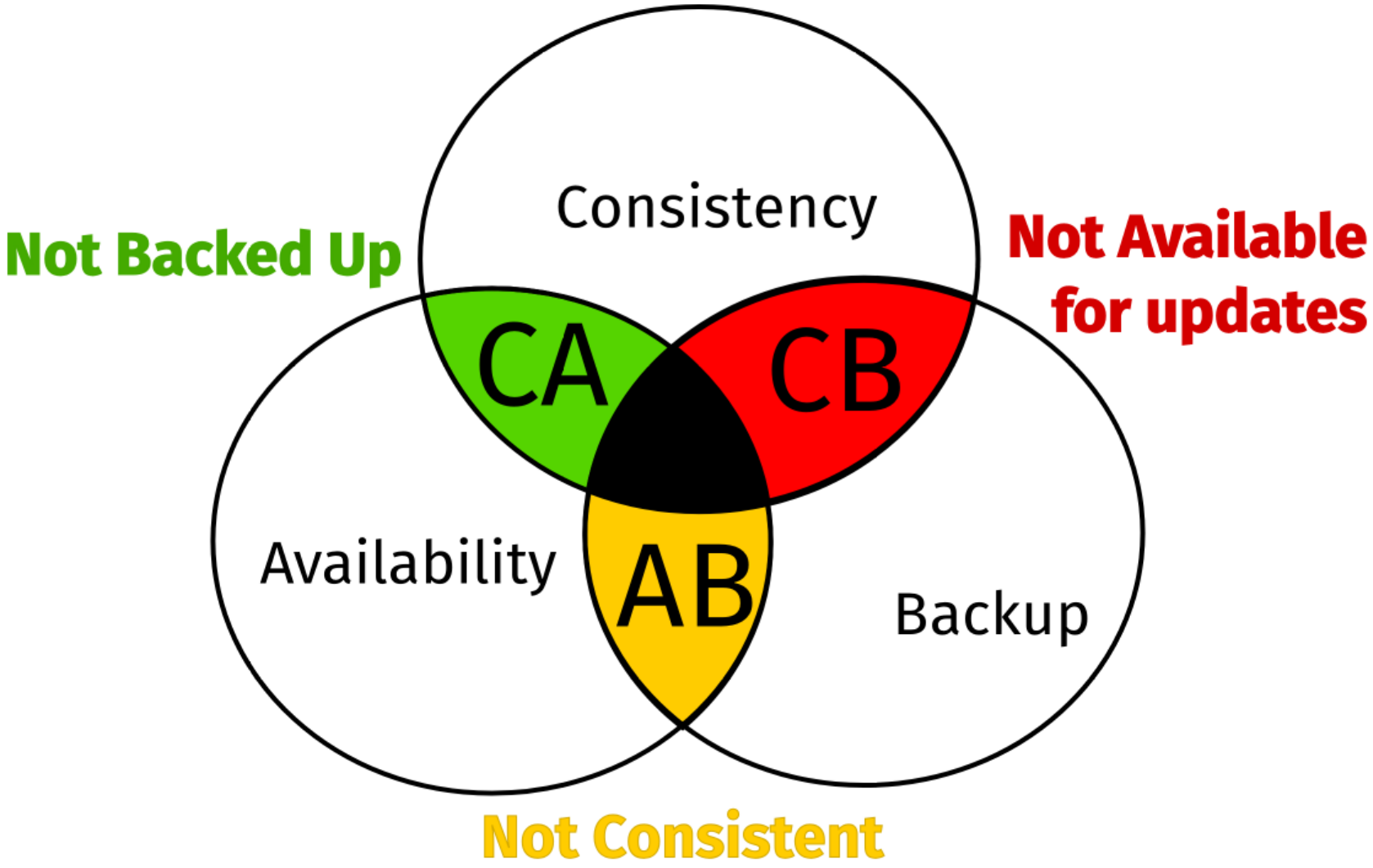
⇒ Eventual inconsistency (after disaster recovery)

Does it apply to you?

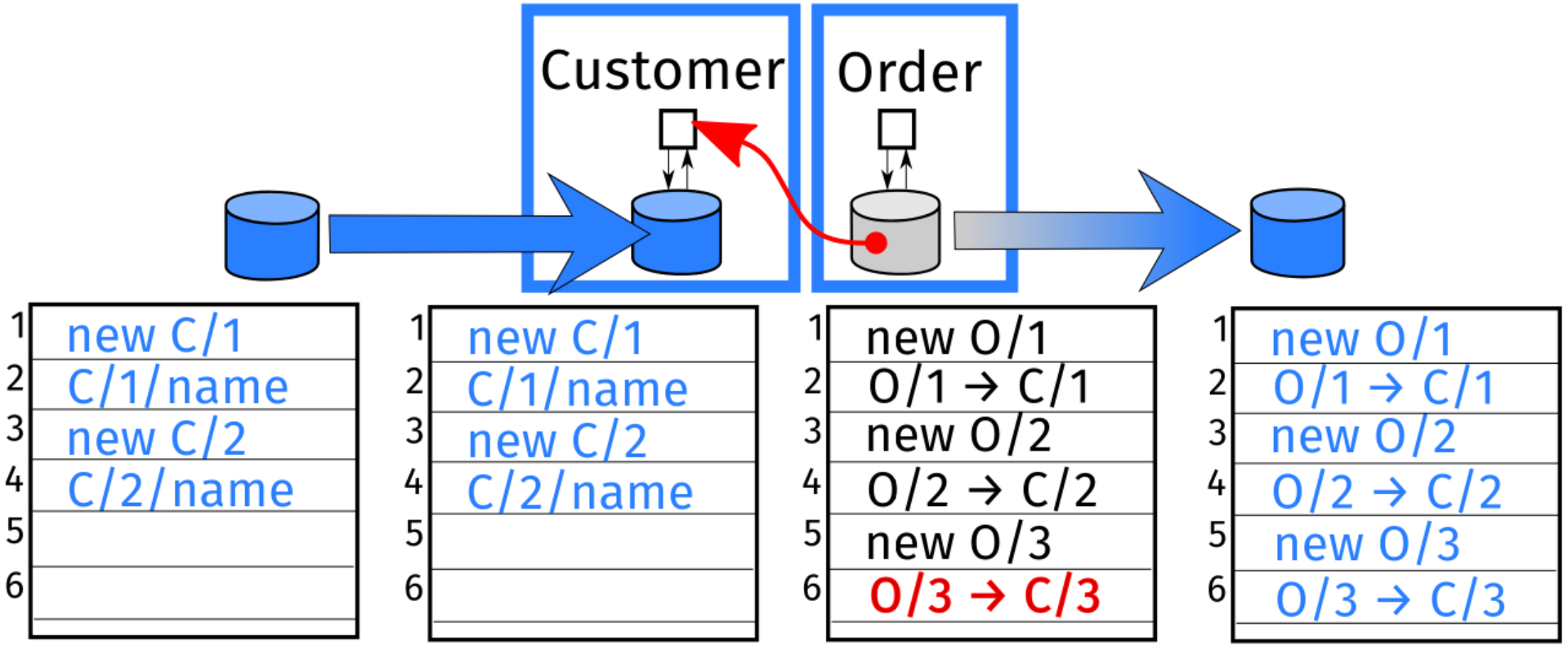
- ☐ More than one stateful microservice
- ☐ Polyglot persistence
- ☐ Eventual Consistency
- ☐ (Cross-microservice references)
- ☐ Disaster recovery based on backup/restore
- ☐ **Synchronized** backups (limited availability/autonomy)

⇒ Consistent Disaster Recovery

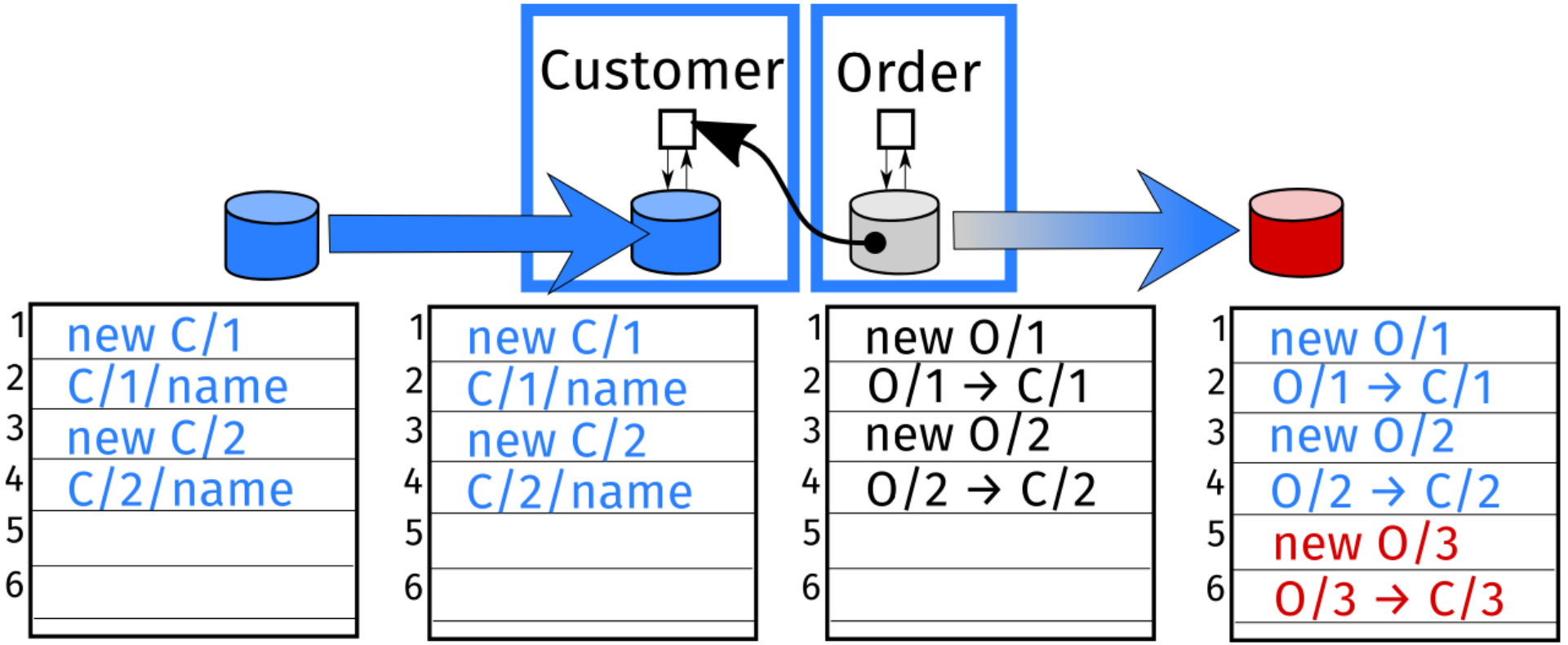
The BAC Theorem



No Backup



No Backup



Trim to the oldest backup

Loose even more data!

The BAC Theorem

When Backing up a whole microservice architecture, it is not possible to have both Consistency and Availability

Corollaries

1. Microservice architectures eventually become inconsistent after disaster strikes when recovering from independent backups
2. Achieving consistent backups can be attempted by limiting the full availability/autonomy of the microservices and synchronizing their backups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Dealing with the Consequences of BAC
1. Eventual Consistency breeds Eventual Inconsistency
2. Trade off: Cost of Recovery vs. Prevention
3. Cluster microservices to be backed up together
WS-REST 2018

Consistent Disaster Recovery for Microservices: the BAC Theorem

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How do you back up a microservice? You dump its database. But how do you back up an entire application decomposed into microservices? In this article, we discuss the tradeoff between the availability and consistency of a microservice-based architecture when a backup of the entire application is being performed. We demonstrate that service designers have to select two out of three qualities: backup, availability, and/or consistency (BAC). Service designers must also consider how to deal with consequences such as broken links, orphan state, and missing state.

Microservices are about the design of fine-grained services, which can be developed and operated by independent teams, ensuring that an architecture can organically grow and rapidly evolve.[1] By definition, each microservice is independently deployable and scalable; each stateful one relies on its own polyglot persistent storage mechanism. Integration at the database layer is not recommended, because it introduces coupling between the data representation internally used by multiple microservices. Instead, microservices should interact only through well-defined APIs, which—following the REST architectural style[2]—provide a clear mechanism for managing the state of the resources exposed by each microservice. Relationships between related entities are implemented using hypermedia,[3] so that representations retrieved from one microservice API can include links to other entities found on other microservice APIs. While there is no guarantee that a link retrieved from one microservice will point to a valid URL served by another, a basic notion of consistency can be introduced for the microservice-based application, requiring that such references can always be resolved, thus avoiding broken links. As the scale of the system grows, such a guarantee can be gradually weakened, as is currently the case for the World Wide Web.

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