SDODR – CLOUD MODELS

Version 05.09.2018 – OIH Architecture Call

Susanne Braun

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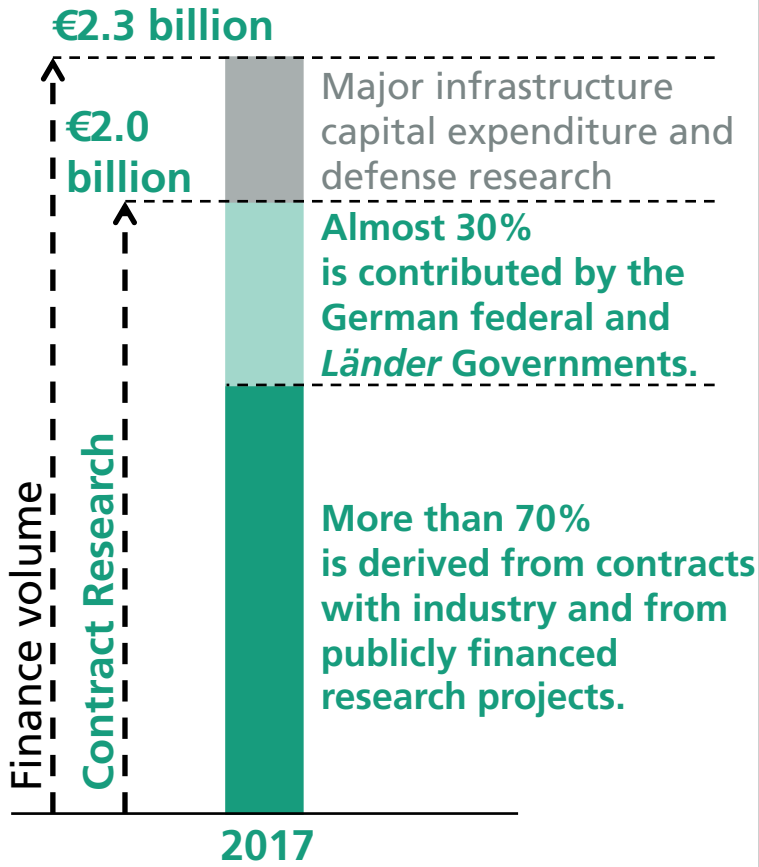

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Industry 4.0

Smart Farming

Smart Mobility

Smart Health

SMART Ecosystems

Smart Energy

Smart Rural Areas

Smart X

Project Roots

Industry Cooperation

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Cloud Models

Cloud Models

Based on
Domain Driven Design

Cloud Models
Replicated
Eventually Consistent
Built-in Conflict Management

Synchronization of High-Level
Service Operations

Cross-Platform
Model-Driven Approach

Multi-Level Transaction
Support

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Cloud Models Funding

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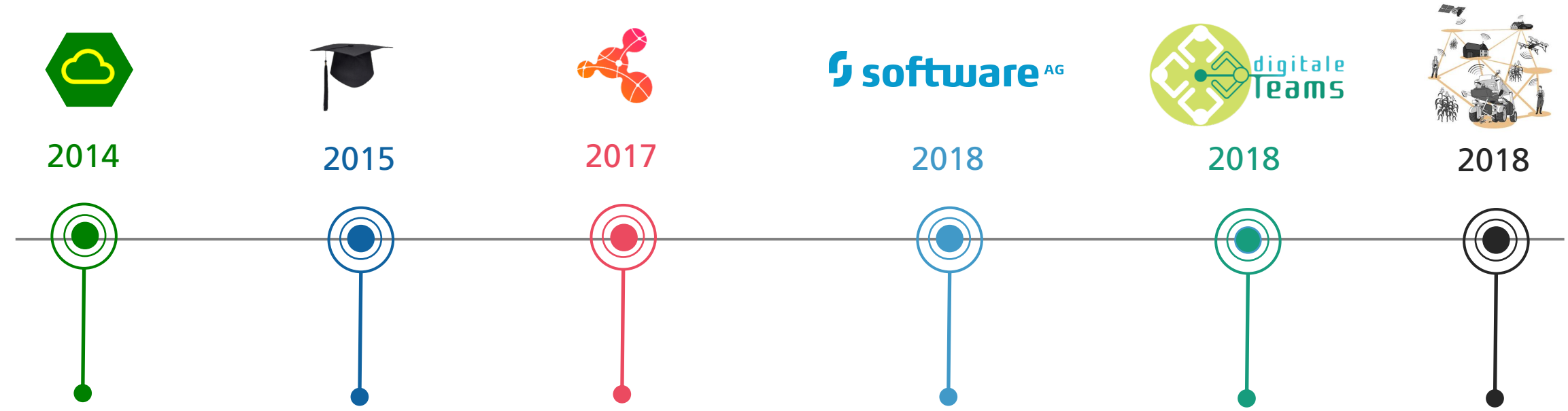

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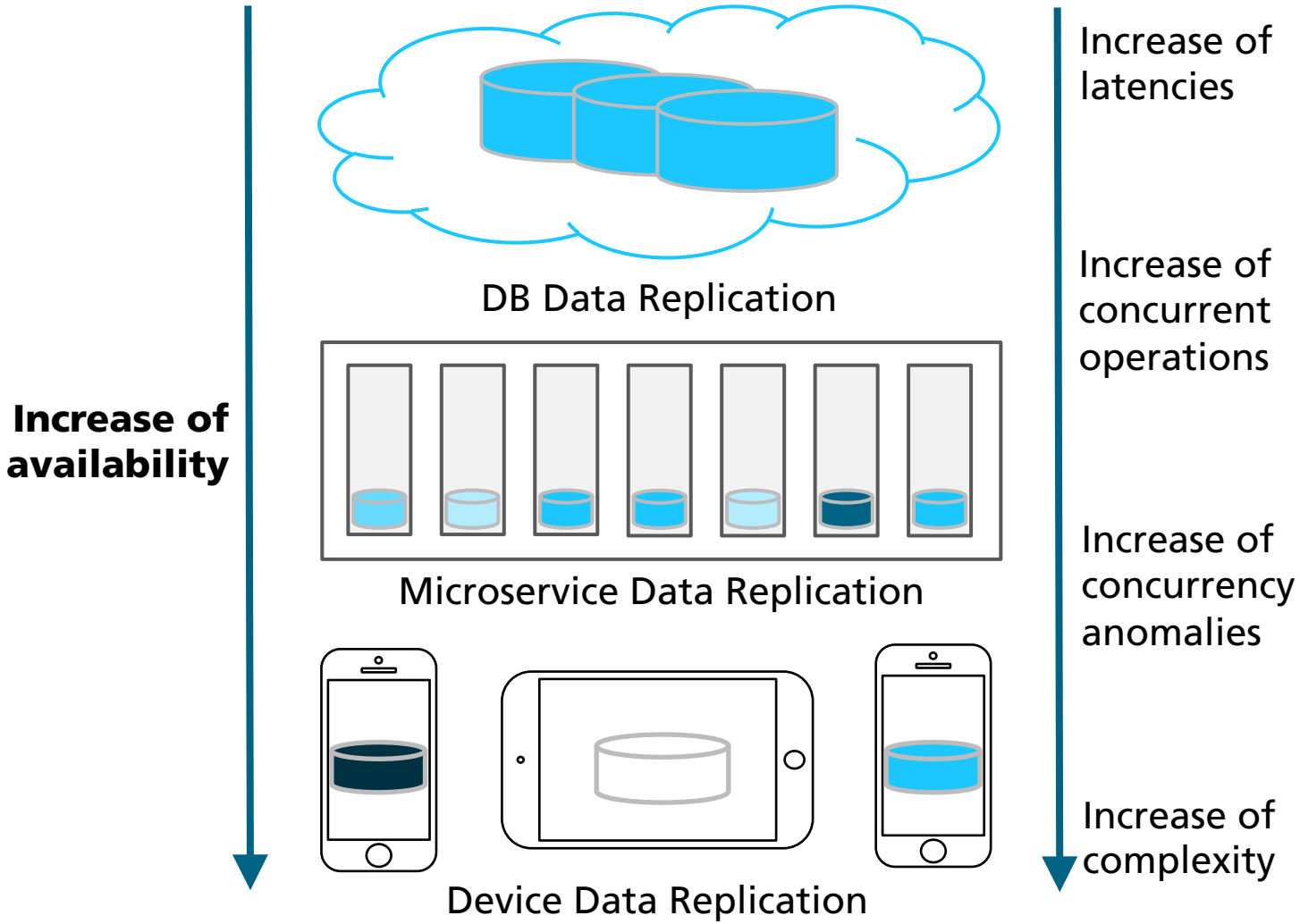
Key Requirements Replication in Ecosystems

- Offline capability of mobile apps
- Data synchronization of **core shared domain data** as platform service
- Support for standardized data models of **core shared domains**
  - No canonical data models

Key Requirements Replication in Ecosystems

- Modularity
- Horizontal Scalability
- Loose coupling of apps and services of the ecosystem
- High availability of apps and platform services, in particular data synchronization services
- Resilience of apps and platform services, in particular data synchronization services

Relevance for Modern Software Architectures



Goals for Cloud Models in Open Integration Hub

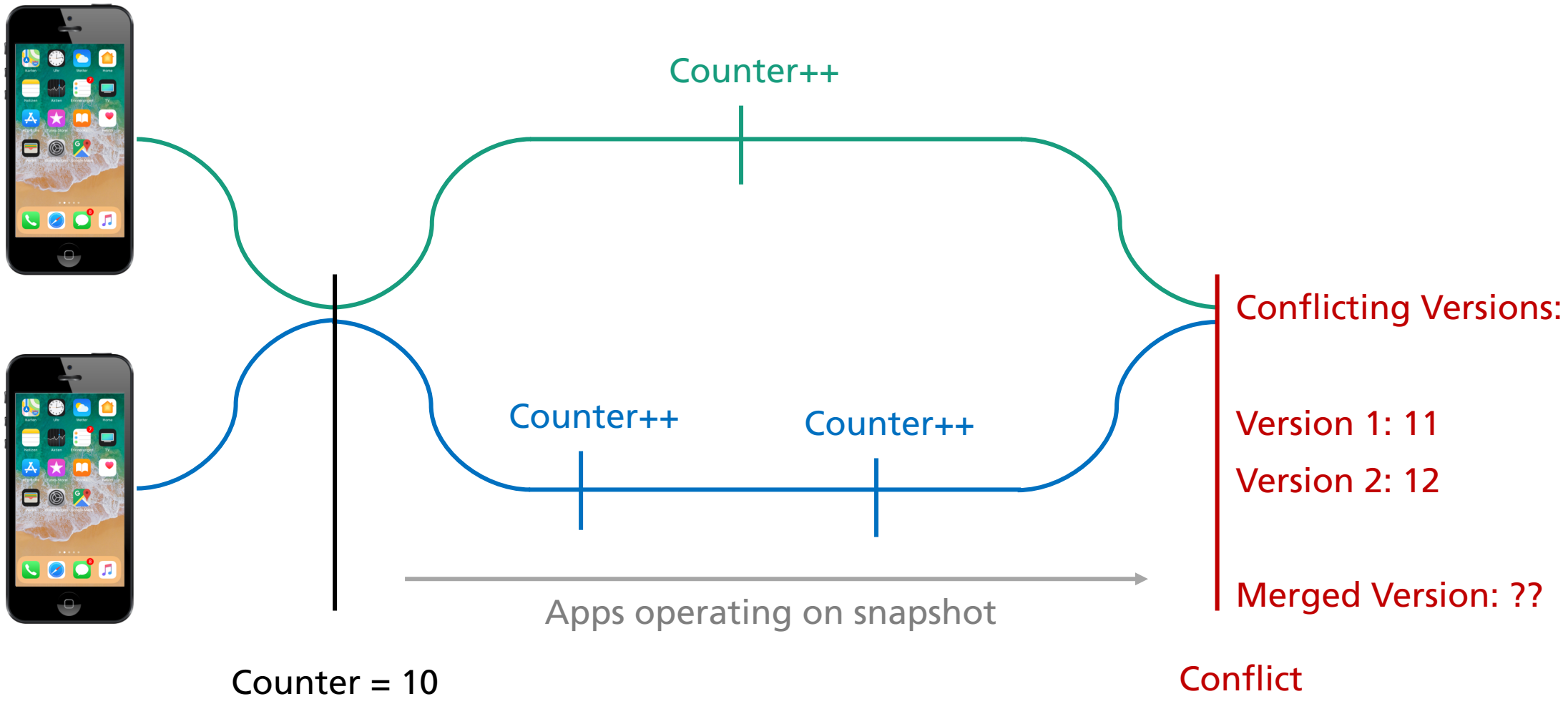
- Compare IESE approach with OIH approach
- Make small evaluation
- Publish results at scientific conferences
  - Wissenschaftliche Verwertung!

Problems

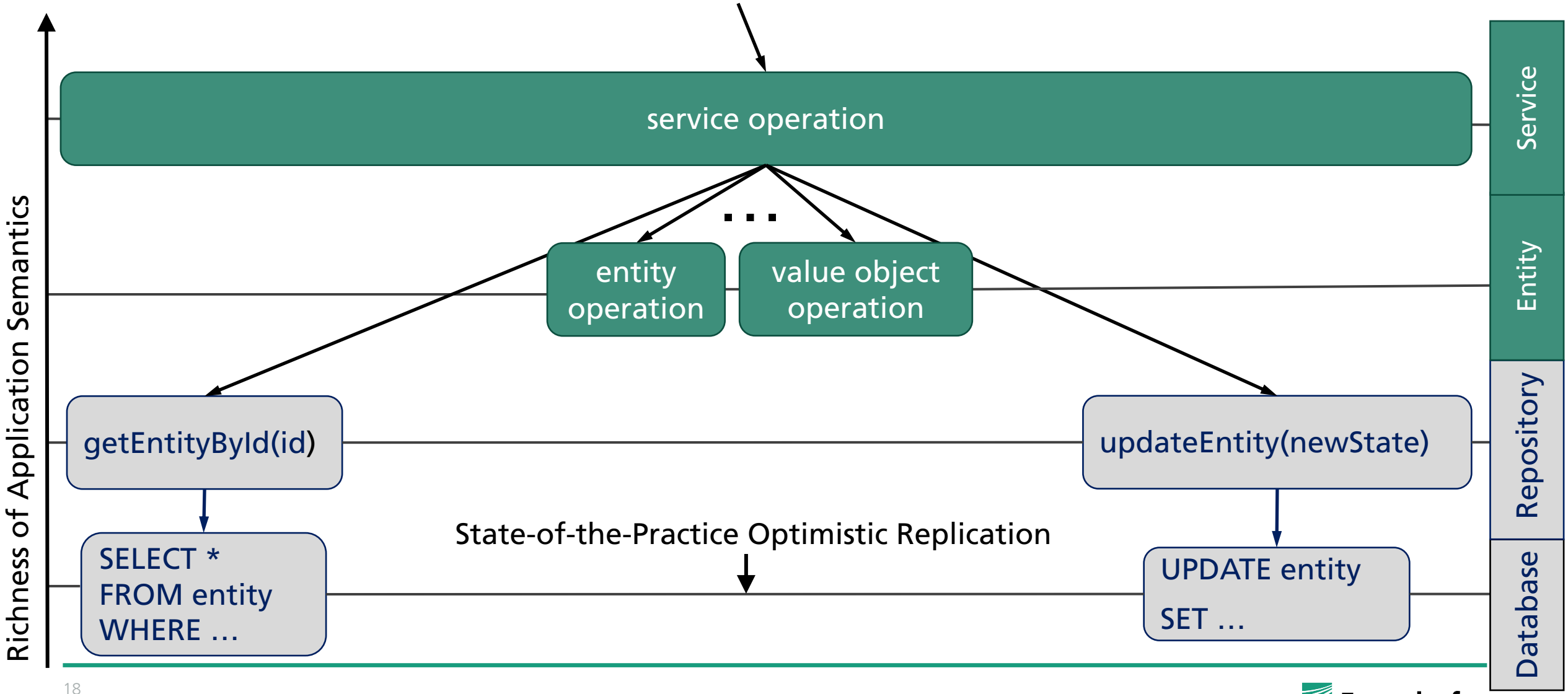
Eventual Consistency

- **Updates are propagated asynchronously (high latencies possible)**
  - Drivers: Availability, Scalability, Loose Coupling, Resilience
- Stale Data
- Conflicts
- **Merge of conflicting versions**
  - Unintuitive and error prone
  - Huge source of human error

Shared Counter Example



State-of-the-Practice Optimistic Replication



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Issues in Practice

- Conflicts that cannot be resolved correctly
  - ➡ Ultimately resulting in lost updates
- Conflicts on the semantic level that cannot be detected syntactically
  - ➡ Ultimately resulting in constraint violations
- Pseudo-conflicts detected syntactically that do not conflict on the semantic level but have to be reconciled
  - ➡ Thereby adversely impacting performance

Recap Concurrency Control in Relational DBs

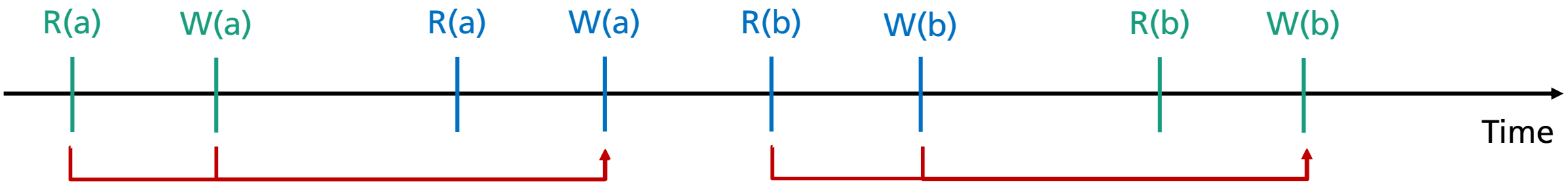
Transaction Interleaving Approach - Conflict Serializability

- Serial execution of transactions prevents occurrence of concurrency anomalies
- Conflict Serializability
  - R(x) is compatible with R(x)
  - R(x) is in **conflict** with W(x)
  - W(x) is in **conflict** with W(x)
- A schedule of concurrent transactions is conflict-serializable iff the conflict serialization graph is acyclic

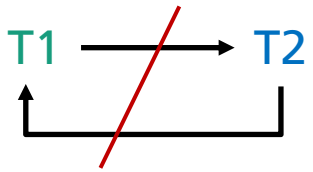
Example Conflict Serializability

- A schedule of concurrent transactions is conflict-serializable iff the conflict graph is acyclic and compatible with the execution order of the conflicting operations

Transactions T1, T2:



Conflict Graph:



Conflict Serialization Graph is cyclic

⇢ No conflict serializability

⇢ Schedule would be rejected

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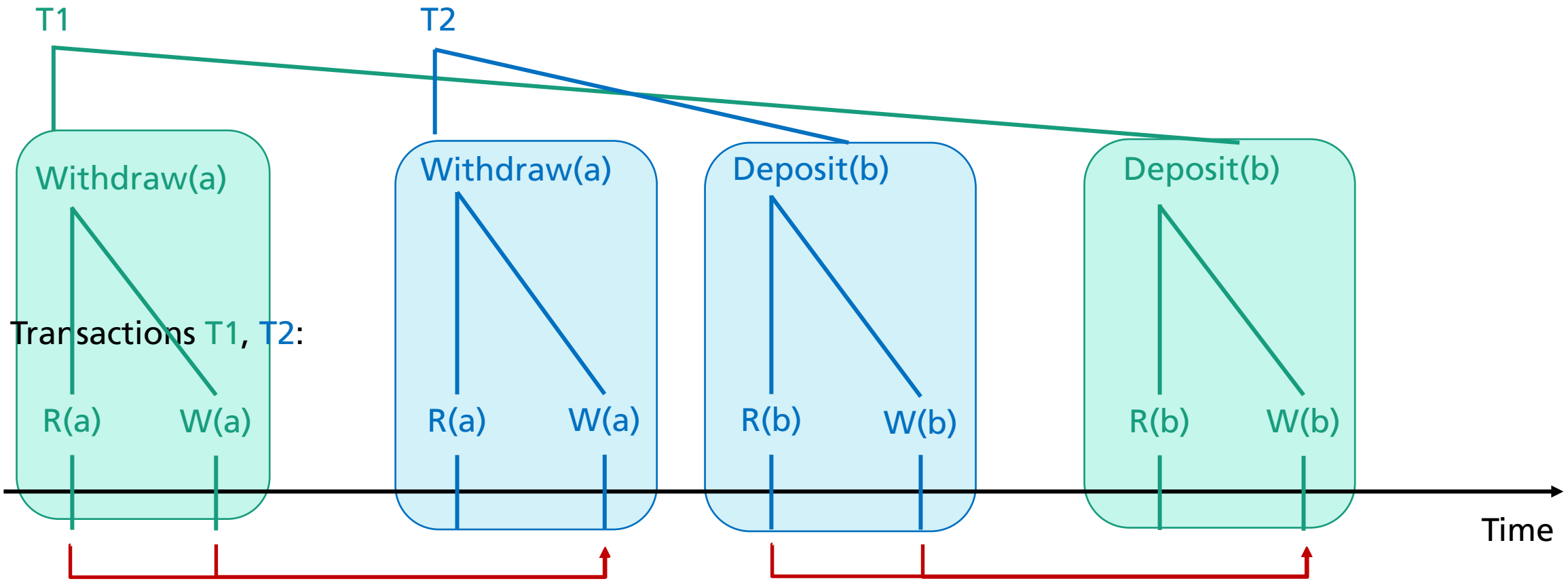
Banking Example



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Multilevel Transactions

- **Key Idea**: **Exploit the semantics of operations in level-specific conflict relations that reflect the commutativity or compatibility of operations to increase concurrency**

- Transactions are decomposed into operations and the operations again into sub-operations on multiple levels
  - Transactions, Business operations, Low-level read and write operations
- At each level a conflict relationship is defined
  - read-write conflicts and write-write conflicts on the same data item conflict at the lowest level
  - Non-commutative operations are conflicting on the level of business operations

- If at each level the conflict serialization graph is acyclic then the multilevel schedule is in total multilevel serializable

Banking Example

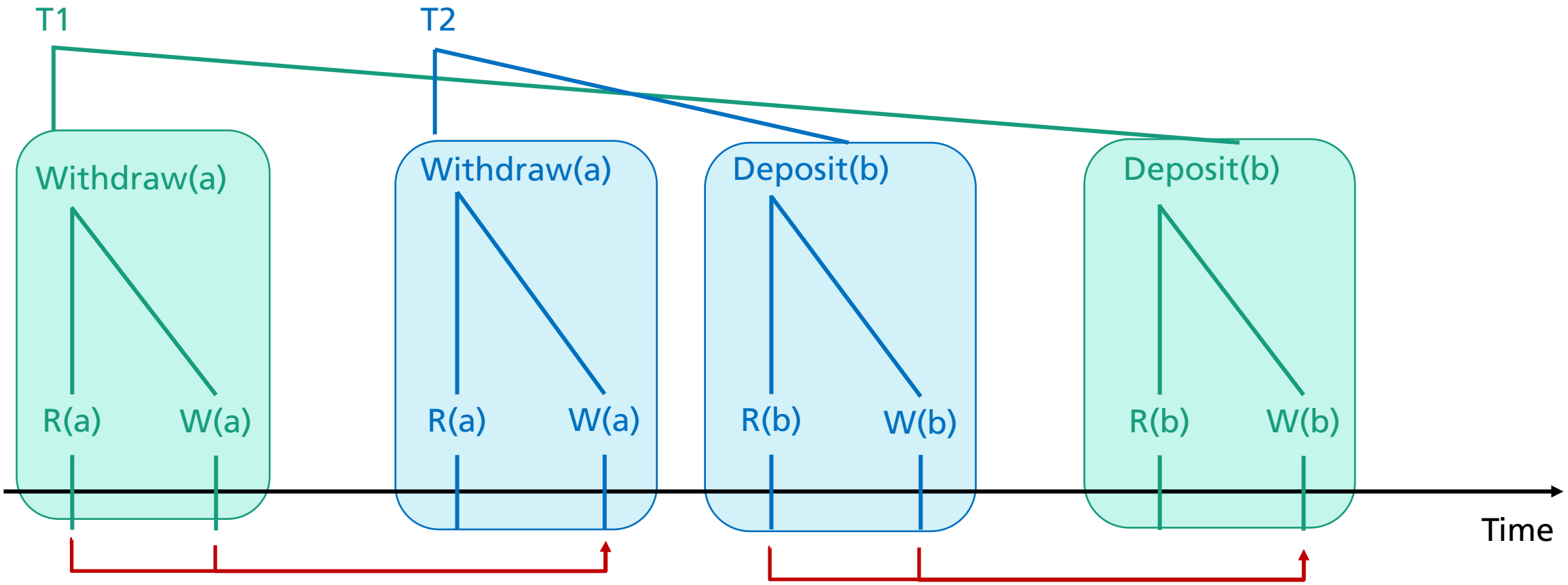
Conflict graph at level of business operations:

Withdraw(a) → Withdraw(a)

Deposit(b) → Deposit(b)

Conflict graph at level of transactions:

∅



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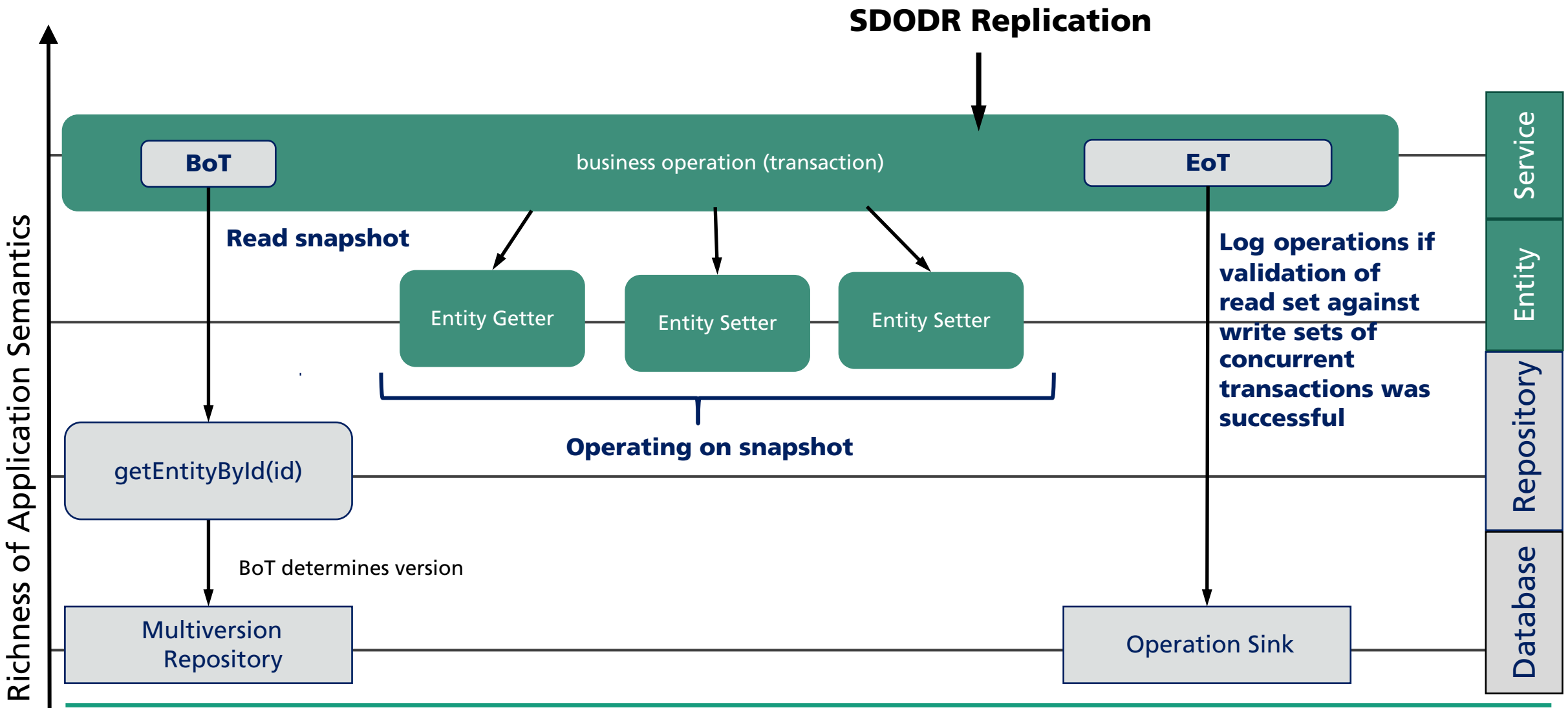
Level of SDODR Replication



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Idea

Exploit application semantics to increase number of operations that can run concurrently and conflict-free on different replication nodes

Semantics-Driven Optimistic Data Replication (SDODR)

Method

Design method based on **Domain Driven Design**

Best Practices and Design Patterns

Design for maximum compatibility of business operations

Technical Framework: Cloud Models

A cross-platform data replication framework with support for propagation and synchronization of high-level business operations and built-in conflict management

Operation approach with support for high-level business operations

Enables exploitation of semantics of high-level business operations for increased concurrency and minimization of conflicts and replication anomalies

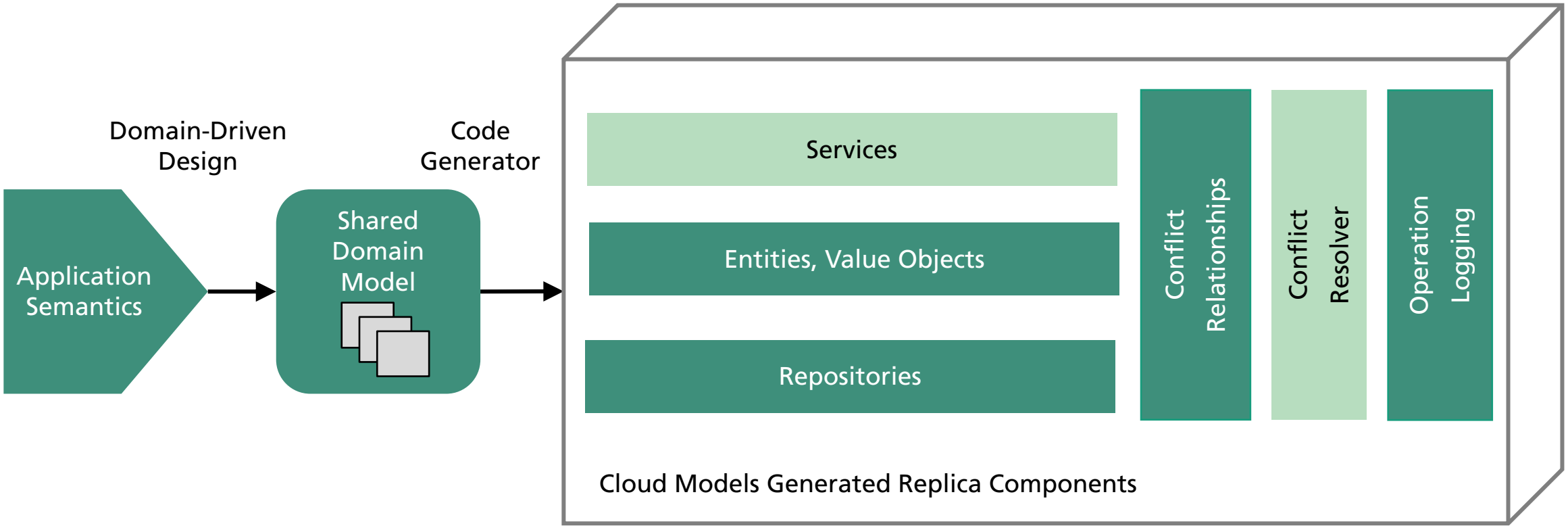
Flexible Conflict Management

- Support for management of conflict relationships of business operations
- Support for semantic reconciliation
- No lost updates

Cross-Platform Technology

Model-driven approach with code generation

How to provide a framework that can exploit application semantics for concurrency control?

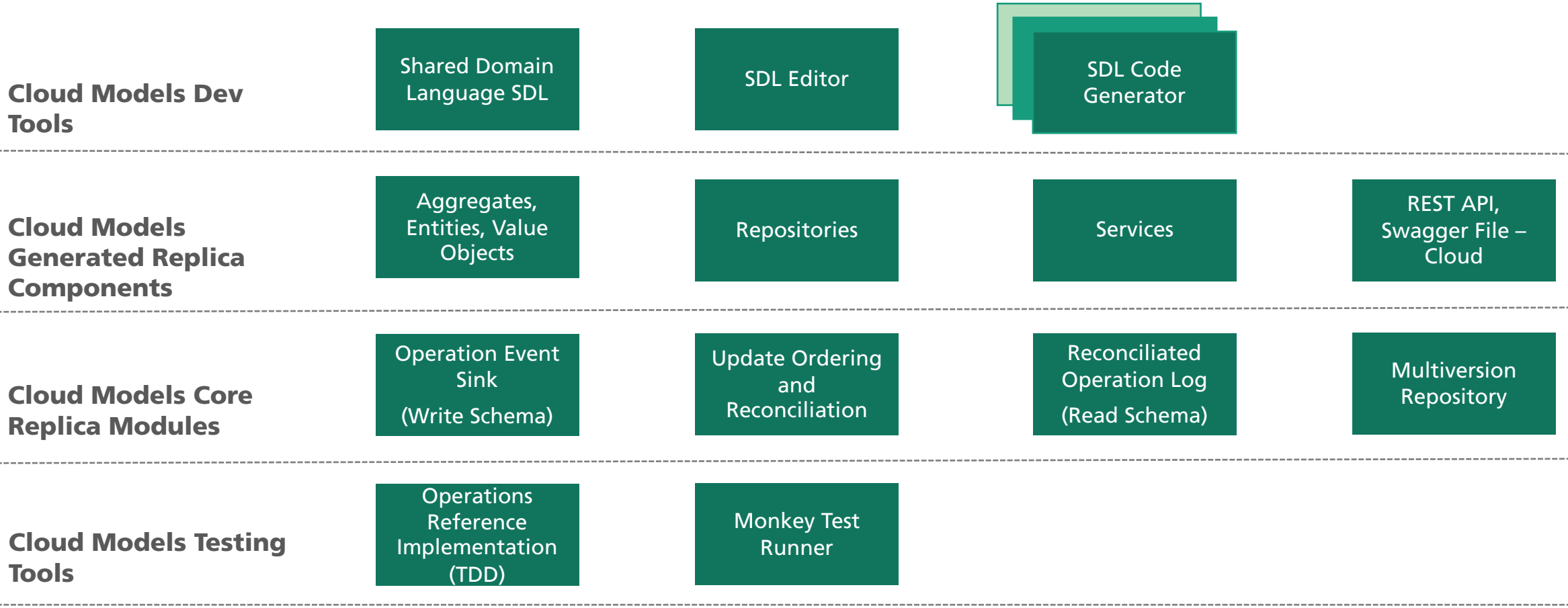


Shared Domain Model Example

```
Namespace de.fraunhofer.iese.oih
Shared Domain Contacts
Version 1.0

Entity Contact {
   person: Person
   organization: Organization
   phoneNumbers: List of PhoneNumber
}
Entity Person {
   firstName: String
   lastName: String
}
Entity Organization {
   name: String
   address: Address
}
Value Object Address {
   street: Street
   city: City
}
ValueObject PhoneNumber {
…
```

```
…

Serivce ContactsService {

   Operation deletePhoneNumber(Contact contact, Integer phoneNumberIndex): Contact
      conflicts with changePositionOfPhoneNumber
      resolve with resolveConflictOnListOfPhoneNumbers

   Operation changePositionOfPhoneNumber(Contact contact, Integer newPhoneNumberIndex): Contact
      conflicts with deletePhoneNumber
      resolve with resolveConflictOnListOfPhoneNumbers


    ConflictHandler resolveConflictOnListOfPhoneNumbers
}

…
```

Software Architecture – Major Building Blocks



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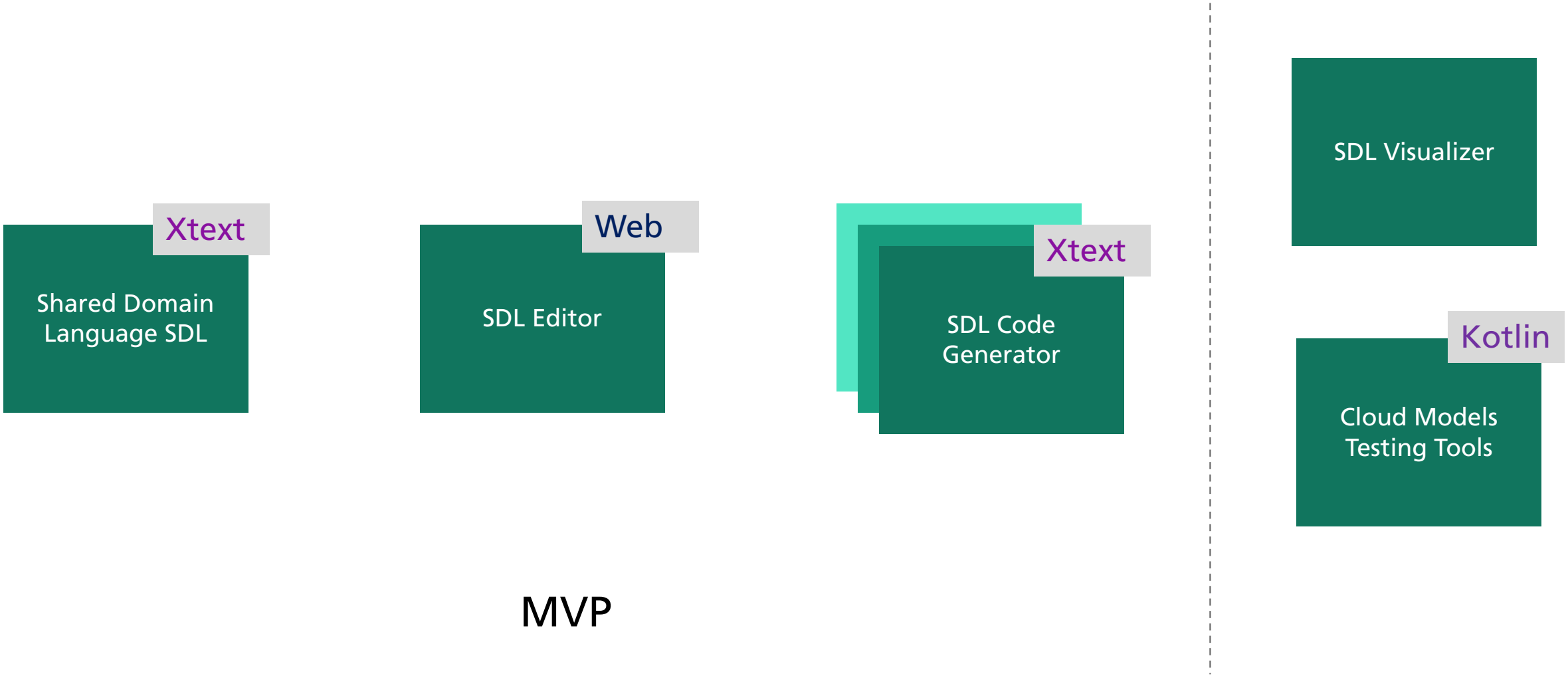
Cloud Models Dev Tools



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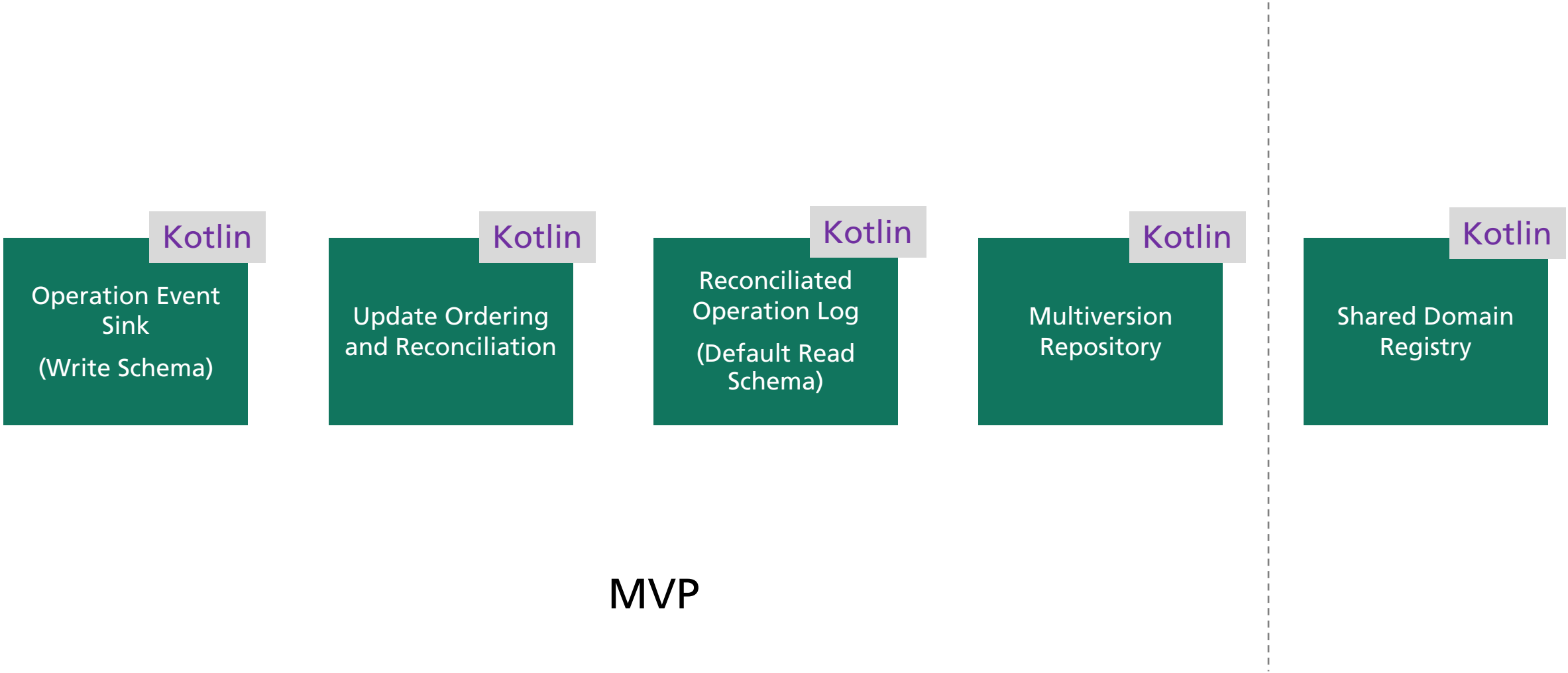
Cloud Models Core Modules (Cloud and Local)



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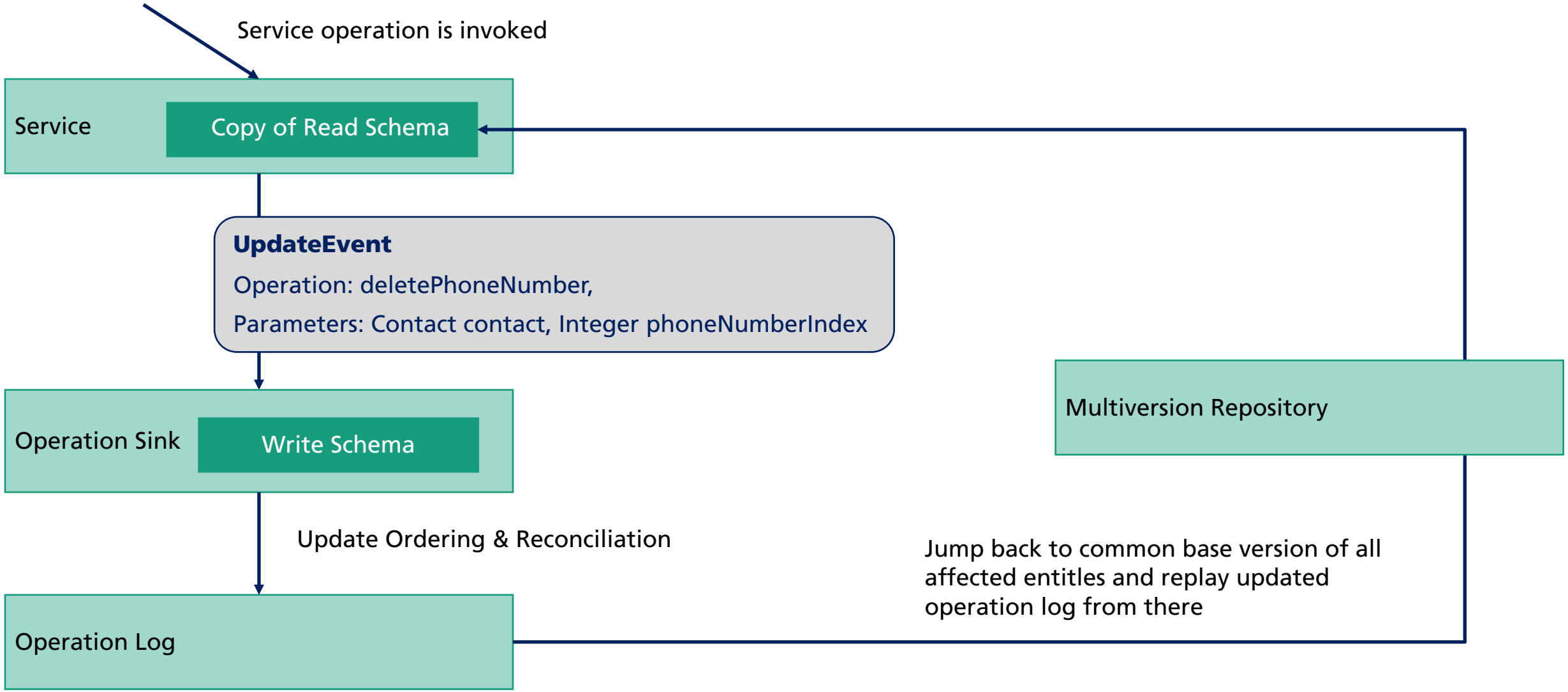
Distributed CQRS With Local Update Event



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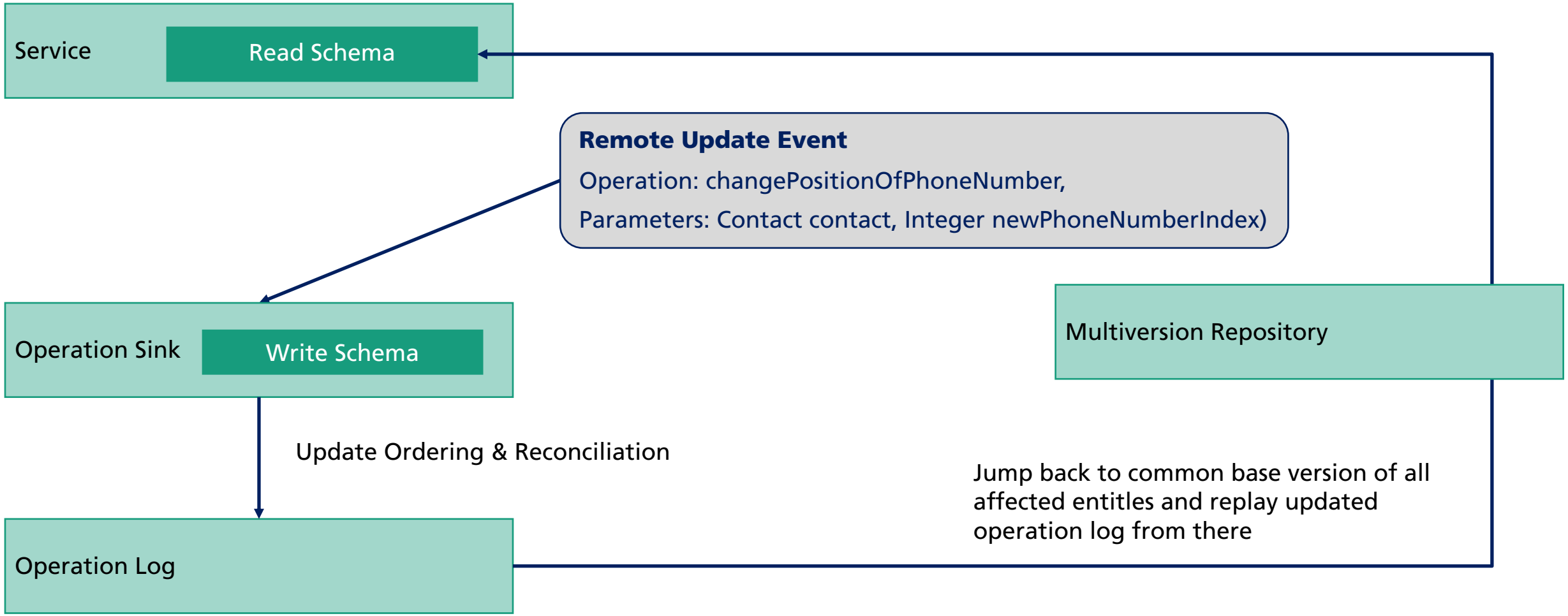
Distributed CQRS with Remote Updates



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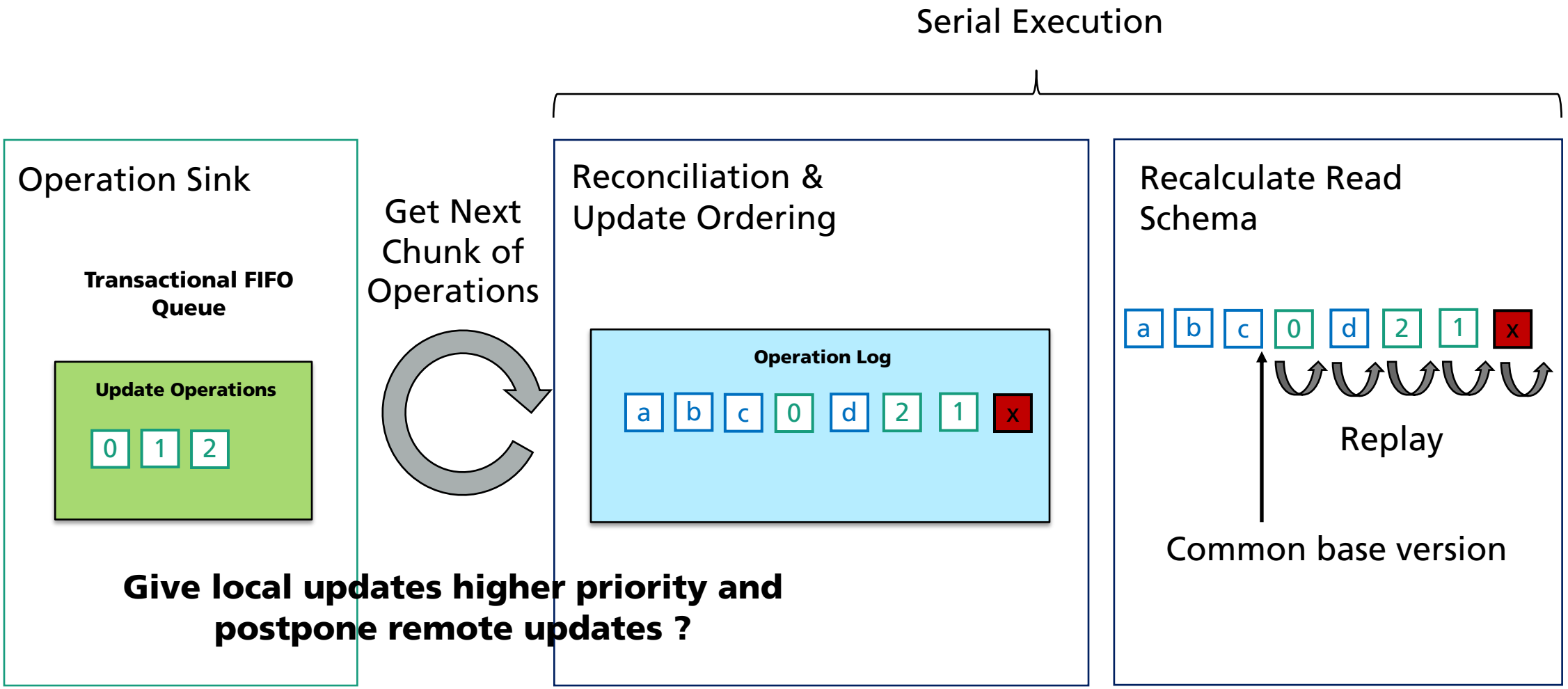
CQRS Performance Considerations (App / Microservice)



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Operation Event Sink and Global Operation Log in the Cloud

- Transactional Queue System (e.g. Kafka) shared by different services (that scales well horizontally)
  - One “operation event sink” queue **per** “Master Data Model” (**shared by all cloud replicas**)
  - Updates can be ”submitted” via generated REST API (similar to the one I proposed)
    - Example: POST to /contacts/update-events
  - Updates can be polled via the same generated REST API (similar to the one I proposed)
    - Example: GET /contacts/update-events
    - services maintain their own pointer in the transactional log (compare to how Linkedin does it, Kappa Architecture)
  - REST endpoints can easily be generated
  - Each service has its own “global operation log” queue
  - services / global operation logs being eventually consistent

Response of GET /contacts/update-events?snapshot=<causal history>

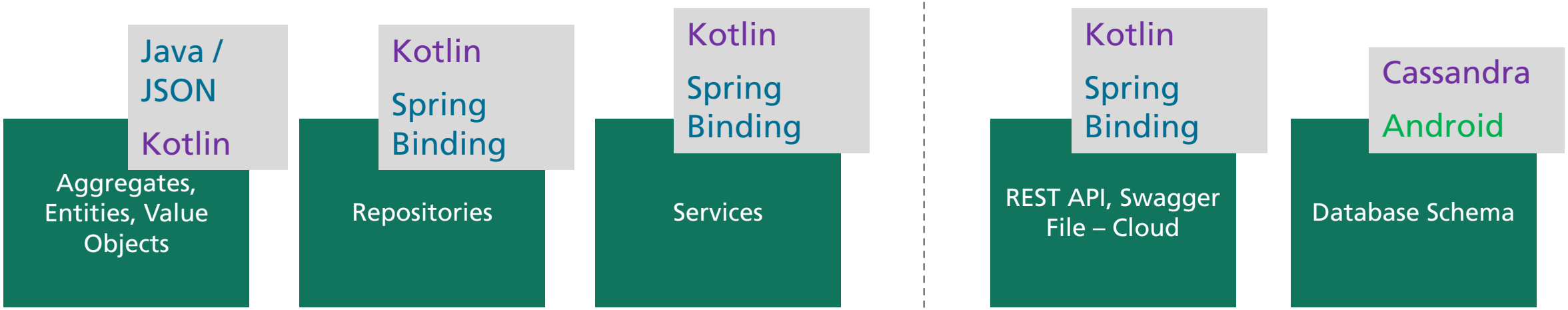
```
[
  {
    "id": "d10b642c-6e76-11e8-adc0-fa7ae01bbebc",
    "readVersion": [ecfe3992-b0e4-11e8-96f8-529269fb1459, 080c2a0a-b0e5-11e8-96f8-529269fb1459, ...],

    "operation": "de.fraunhofer.iese.oih.Contact.delete()",
    "operationTime": "2007-04-05T12:30-02:00",
    "operationOriginAppUuid": "com.snazzycontacts.SnazzyContacts",

    "securityUserUuid": "bc9c46fe-238b-11e8-b467-0ed5f89f718b",
    "securityUserRole": "some-role",

    "parameters": []
  },
  {
    "id": "7d2817e6-6e77-11e8-adc0-fa7ae01bbebc",
    "readVersion": [ecfe3992-b0e4-11e8-96f8-529269fb1459, 080c2a0a-b0e5-11e8-96f8-529269fb1459, ...],

    "operation": "de.fraunhofer.iese.oih.Contact.update(de.fraunhofer.iese.oih.Contact)",
    "operationTime": "2007-04-05T12:30-02:00",
    "operationOriginAppUuid": "com.snazzycontacts.SnazzyContacts",

    "securityUserUuid": "bc9c46fe-238b-11e8-b467-0ed5f89f718b",
    "securityUserRole": "some-role",

    "parameters": [
      {
        "firstName": "Torsten",
        "lastName": "Kuhn"
      }
    ]
  }
]
```

Causal Histories

Operation Event Sink and Global Operation Log – Mobile Sync Scenario

- One (horizontally scalable) Central Service Replica in the Cloud functioning as a hub
  - designed similar to services of the cloud scenario from the previous slide
  - mobile apps use it to poll remote updates
  - mobile apps use it to transmit local updates
  - -> API of the central replica can again be generated (same approach as in cloud scenario)
- Apps have operation event sink and global operation log on the mobile device

Cloud Models Generated Replica Components



MVP

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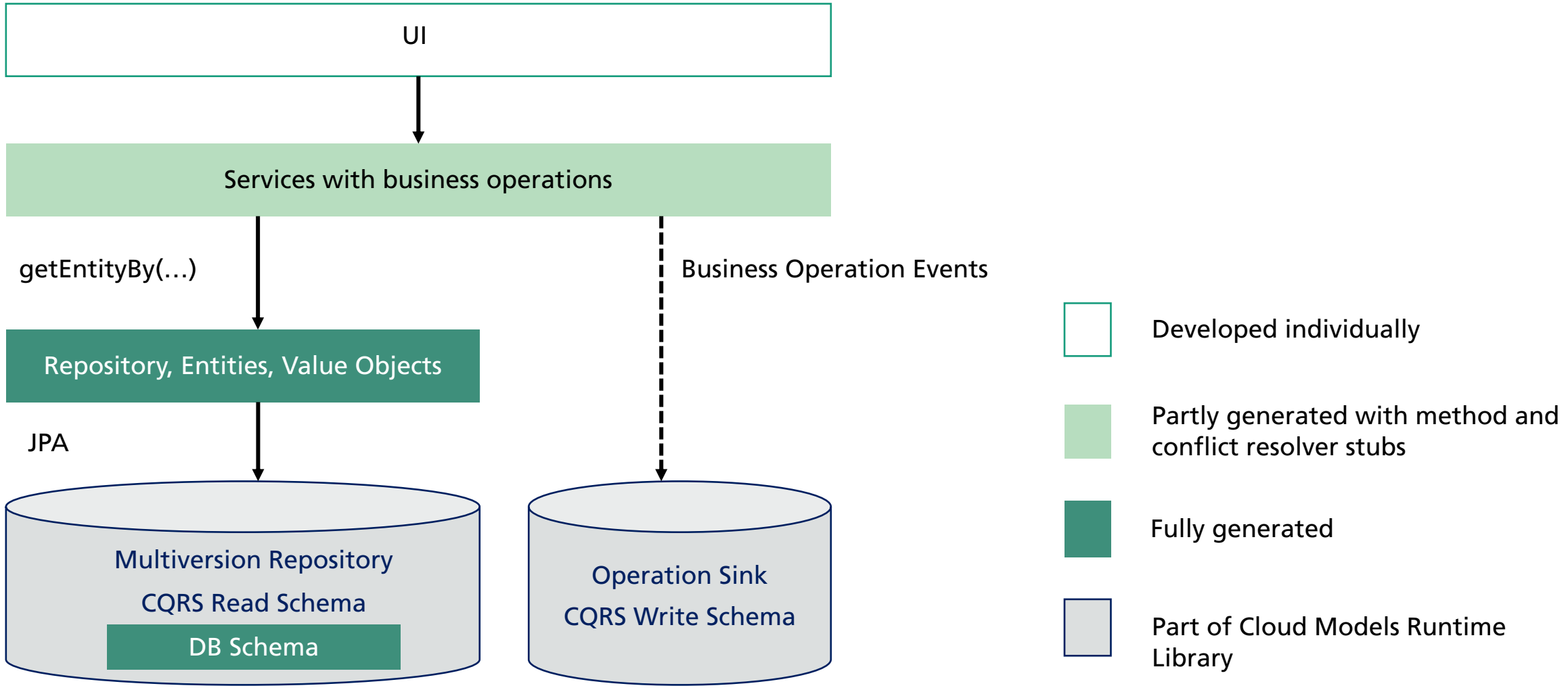
Layered Architecture of Microservices / Mobile Apps



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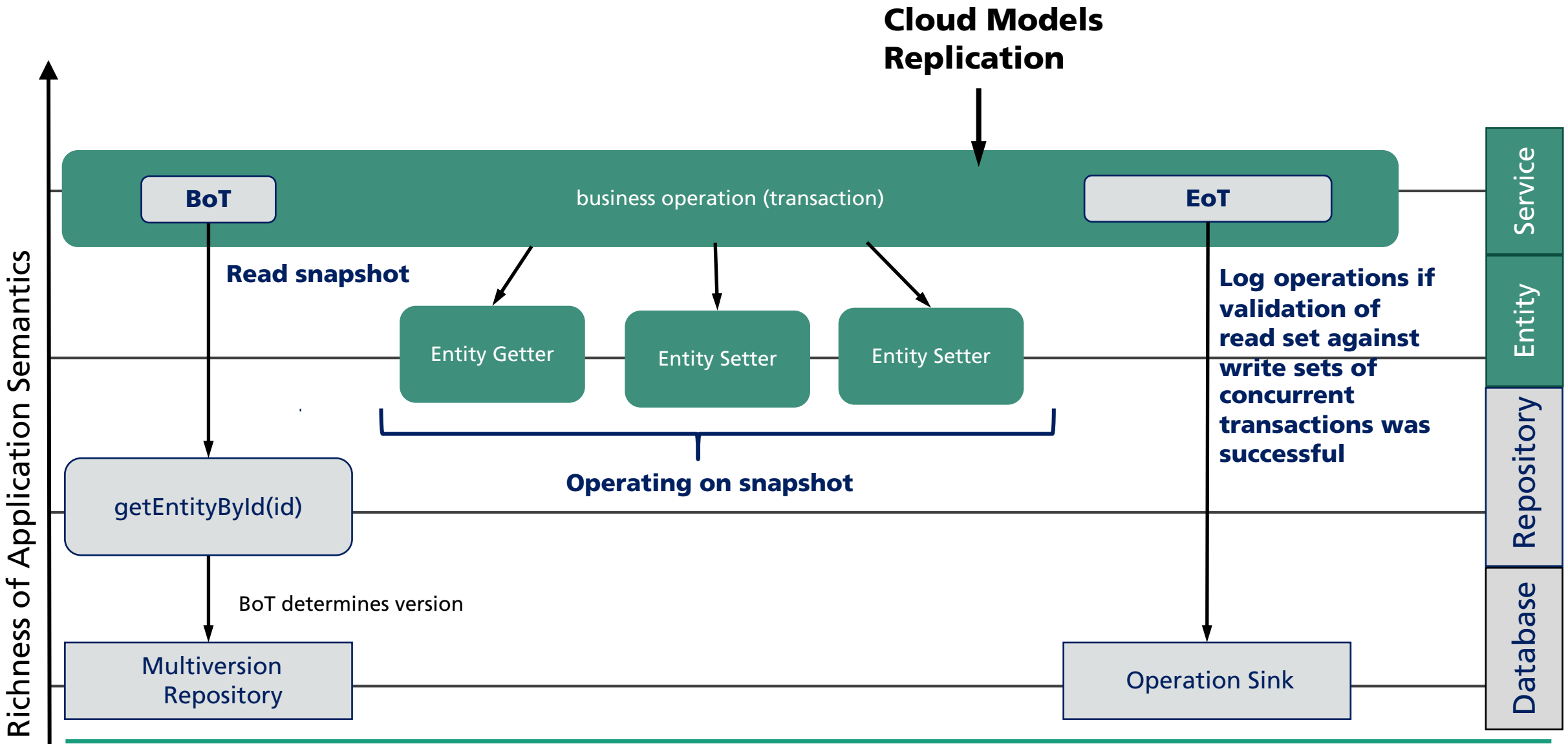
Level of Cloud Models Replication



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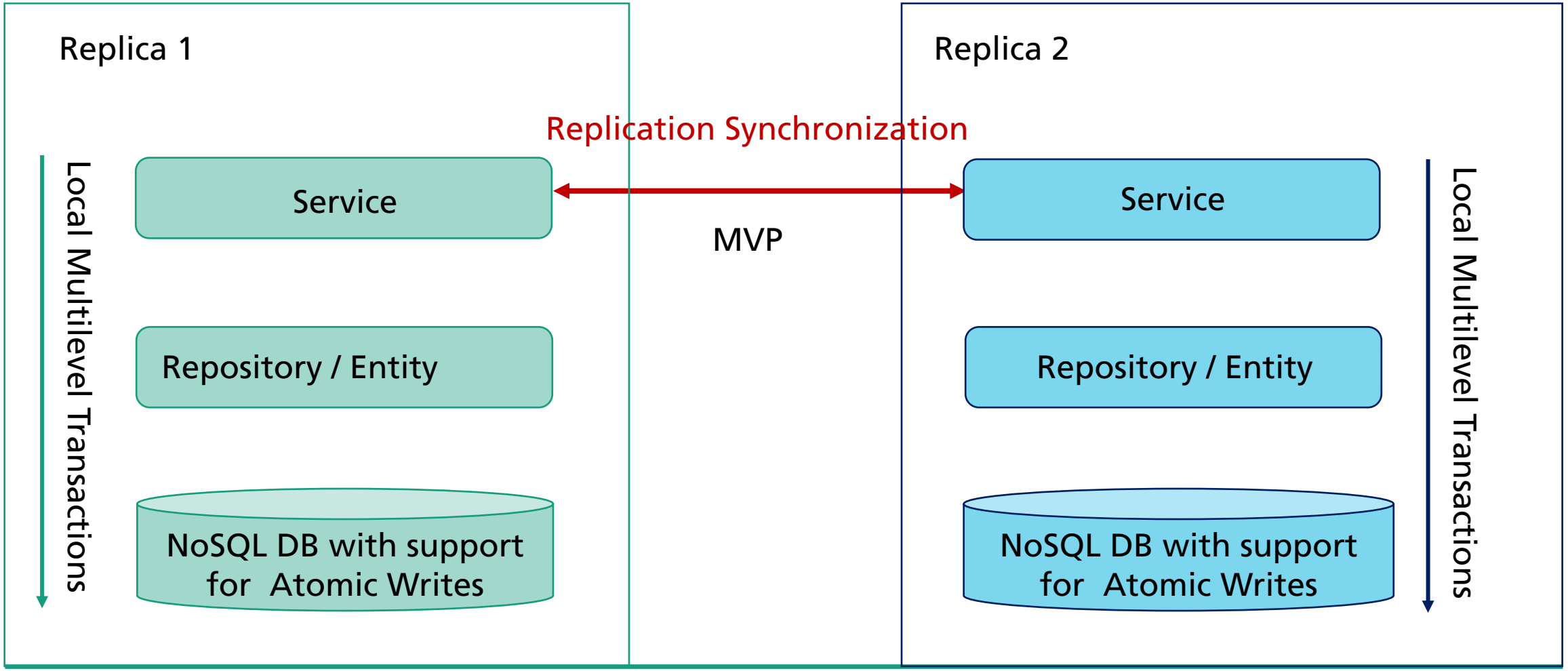
Outlook: Cloud Models Multilevel Transactions



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Cloud Models Testing Tools

Cloud Models Roadmap

- Ecosystem Data Sync: Lessons Learned, Best Practices, First Ideas & State of the Art Analysis -> John Deere Cooperation
- Cloud Models Core Library & Code Generator -> Software Campus Project (cloud-models.de), Digitale Teams Project (digitale-teams.de)
- Methodology & Design Guidelines -> PhD
- **OIH Connector for Cloud Model Apps -> OIH Project**

Integration Issues & Challenges OIH Connector

- OIH /data REST endpoint can be used and data can be taken directly from the multi-version repository of the cloud-models framework
  - How is versioning treated in OIH ?
  - -> Connector will maintain pending operations that need to be scheduled for synchronization with OIH

- Remote updates polled from /webhooks endpoint
  - Problem: No operations can be queried via /webhooks endpoint
  - Again: How is versioning treated in OIH ?
  - CRUD operations need to be derived by the connector
    - **how to determine the identity of a (derived) CRUD operation ?**
      - **what happens if a update-events are delivered more than once?**
      - **how to prevent "update cycles"?**
      - remote updates events need to be treated differently, than locale ones that are scheduled for propagation
  - Cloud Models Replication can only run on level of basic CRUD operations. No support for high-level service operations. No sophisticated conflict handling.
    - **Adaption of the cloud models framework necessary**, s.t. replication level is configurable **(basic CRUD operations vs. service operations (preferred))**
    - **Conflicts will be resolved by the replicas with the deterministic conflict resolution algorithm of cloud models framework (based on the conflict relationships of basic read-and-write operations)**
    - **cloud model apps will be able to register conflict resolvers via DSL of the cloud models framework**
    - **Consequence: cloud models apps might not be eventually consistent with OIH apps, in case OIH applies a different reconciliation algorithm.**

Susanne Braun

Tel.: +49 631 6800 2138

susanne.braun@iese.fraunhofer.de

Twitter: @susannebraun