Towards Generic and Middleware-independent Support for Replicated, Distributed Objects

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Motivation

Why replication?

- Object-based distributed systems have single point of failure
- Replication provides fault-tolerance

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- High development costs
- Bigger middleware core

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State of the art

- Many middleware systems provide replication support
- All of them support group communication, replica management
- Barely re-use of existing solutions

Goal

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Provide a single replication framwork for multiple middleware systems!

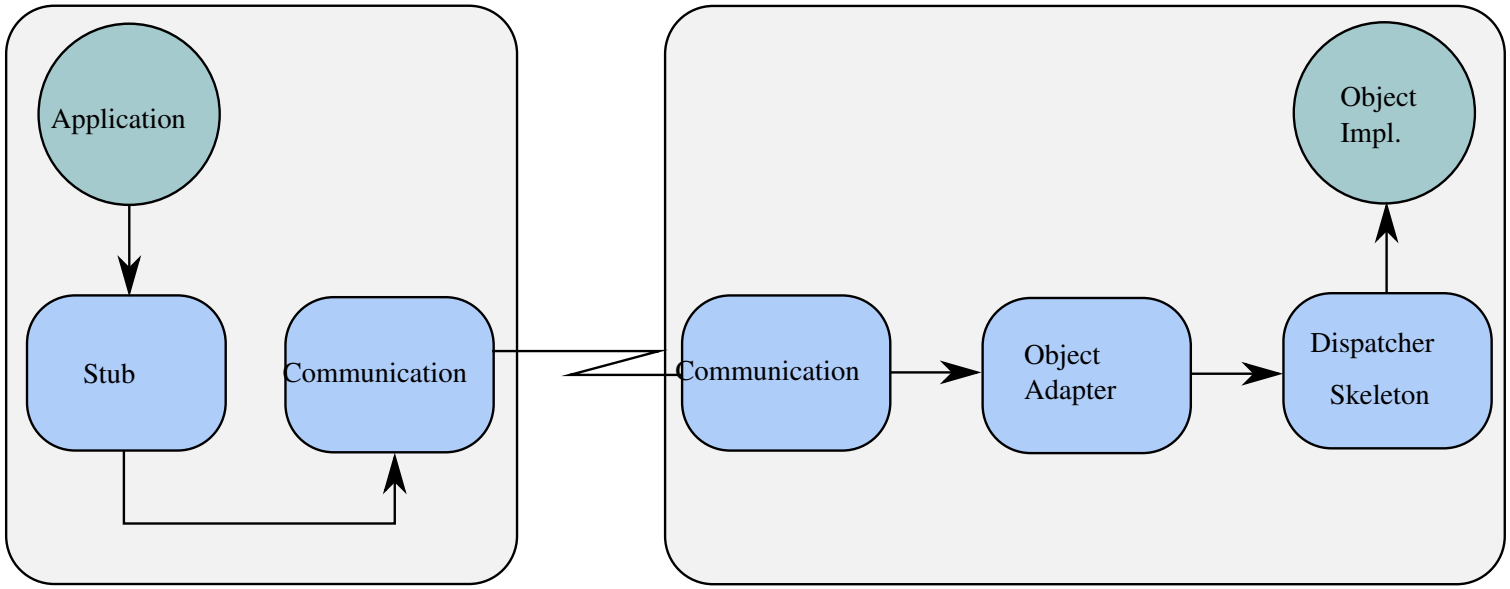
Problems to solve

- What interface does the framework have to provide?
- How to conceptually integrate the framework into the middleware systems?

Outline

Background

Middleware for Distributed Objects



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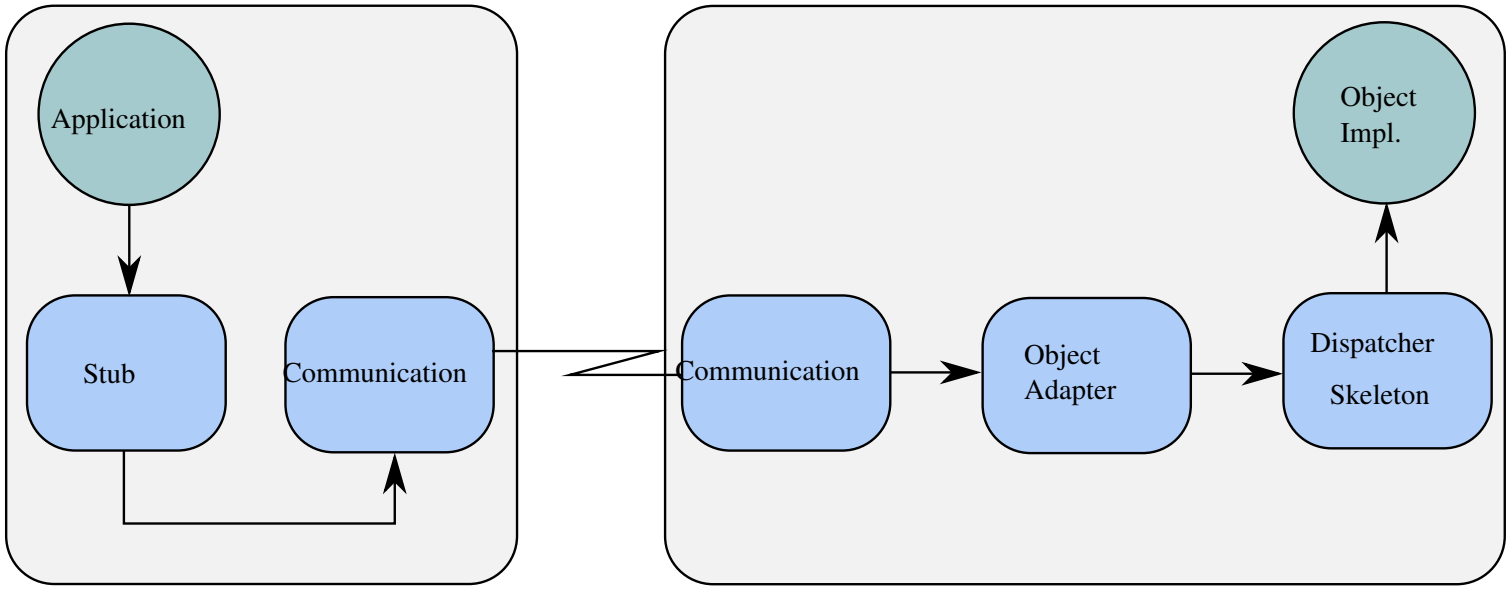
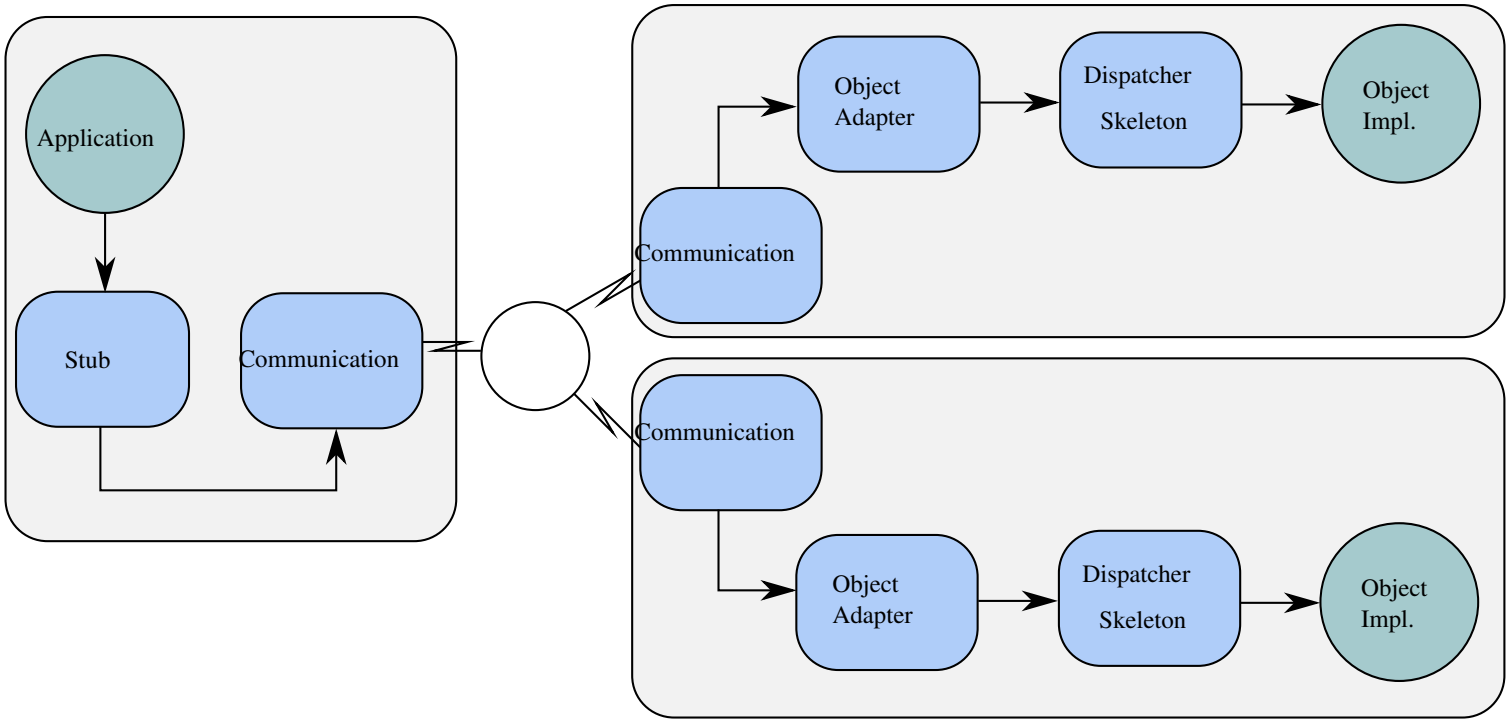


- Client accesses a single remote object
- Client-server interaction scheme
- Request followed by response

$\Rightarrow$ Rather simple communication

Background

Replication Support in Middleware



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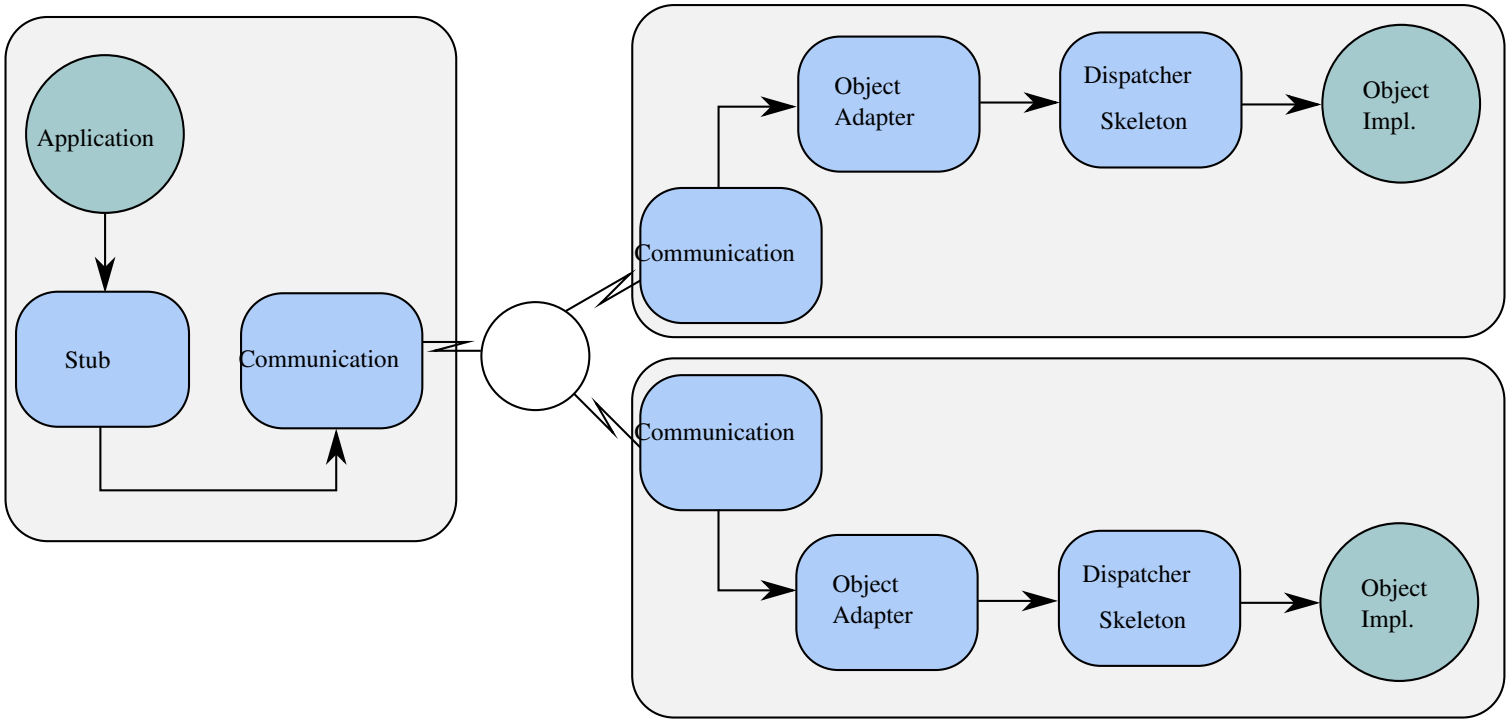
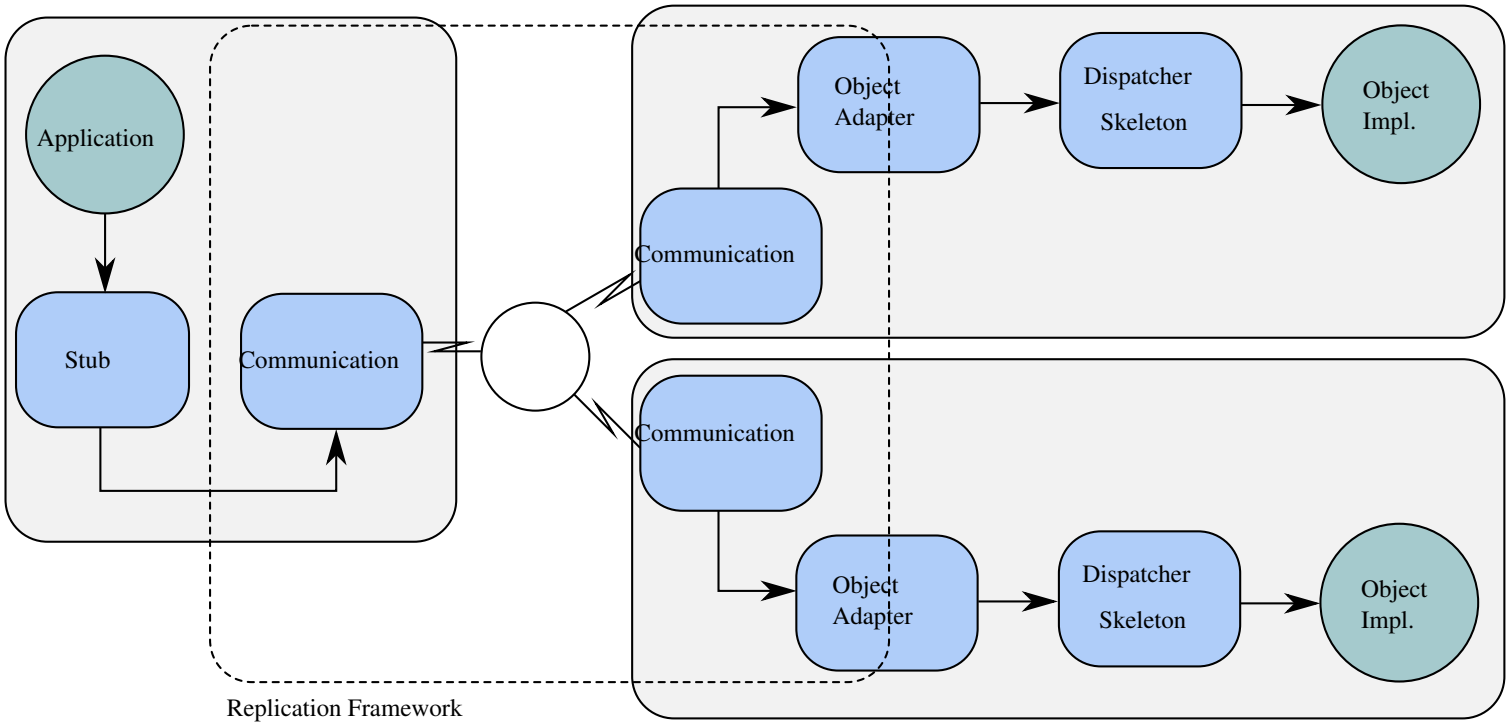


- Client accesses a group of identical remote objects
- Replica group may change
- Determinism by totally ordered multicast

$\Rightarrow$ Complex communication logic

Background

Replication support: Separation of concerns



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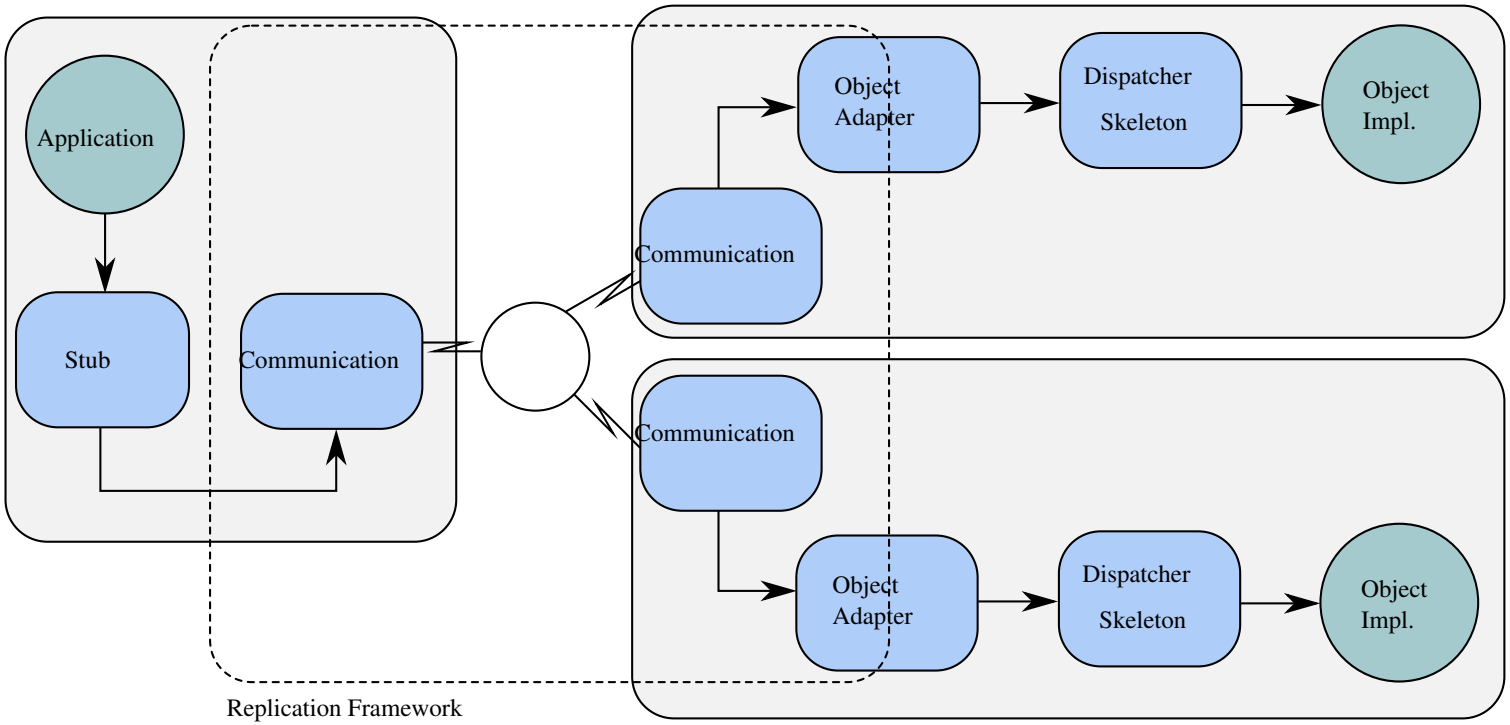
Replication support: Separation of concerns

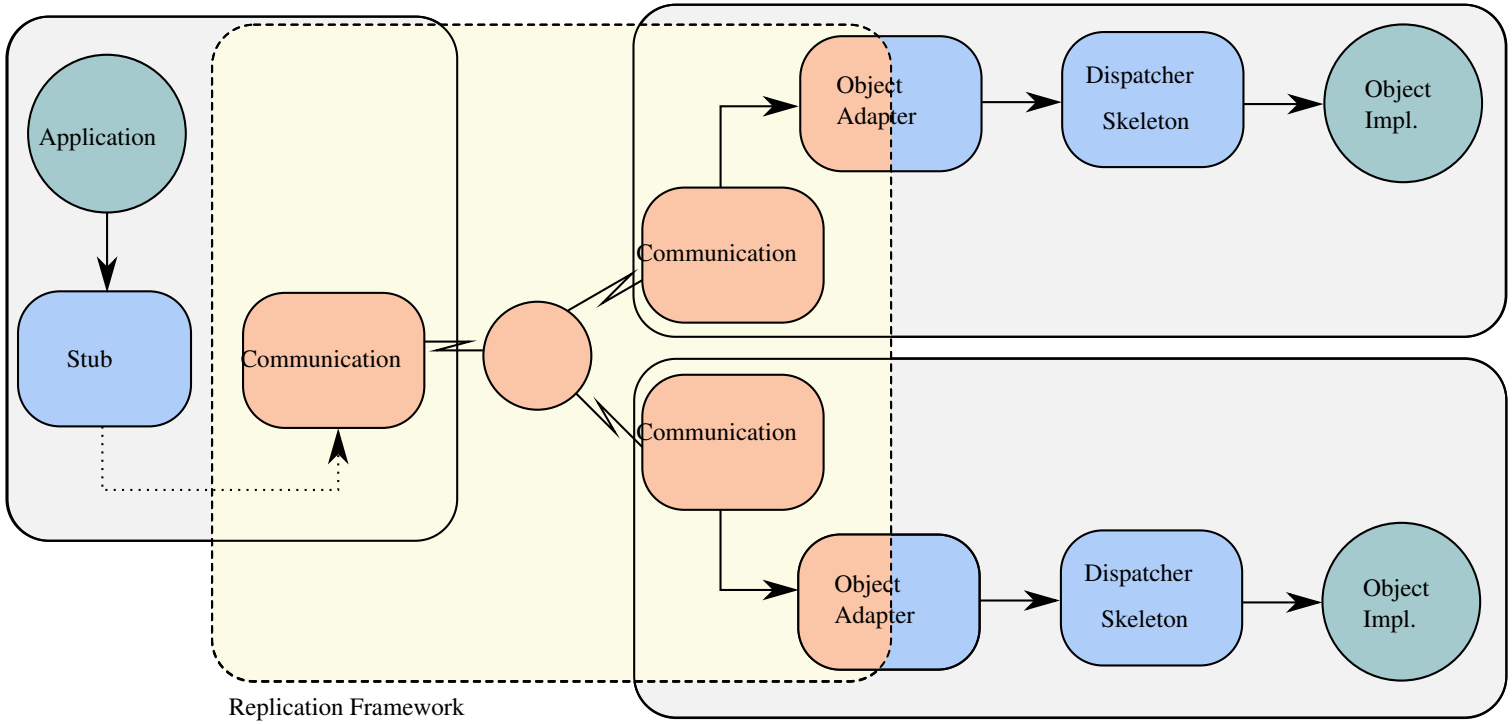


Responsibility of a replication framework

- Ensure determinism and consistency
- Follow changes of the replica group
- Ensure replication transparency

An Architecture for Replication Support

Initial step



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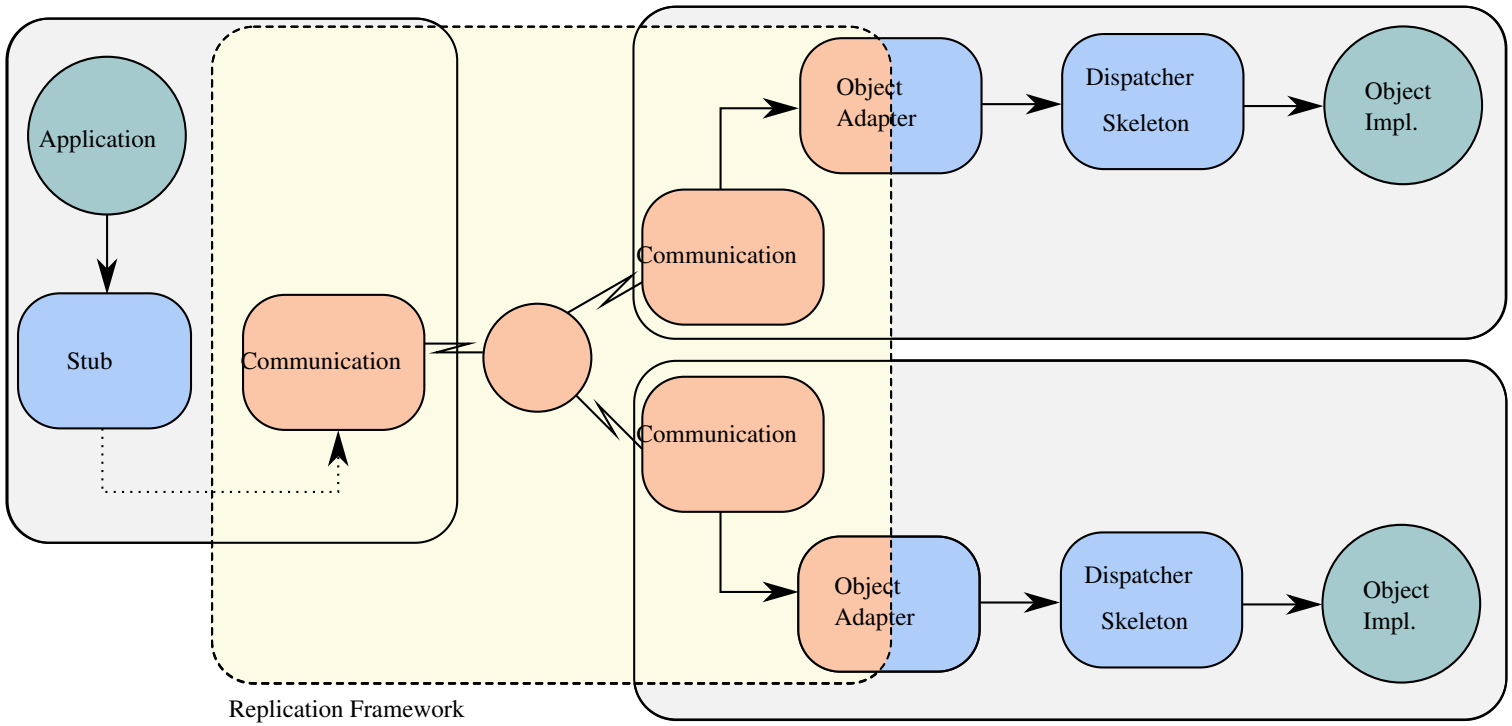

Generic replication framework:

- Transports any data
- Handles data in an opaque way

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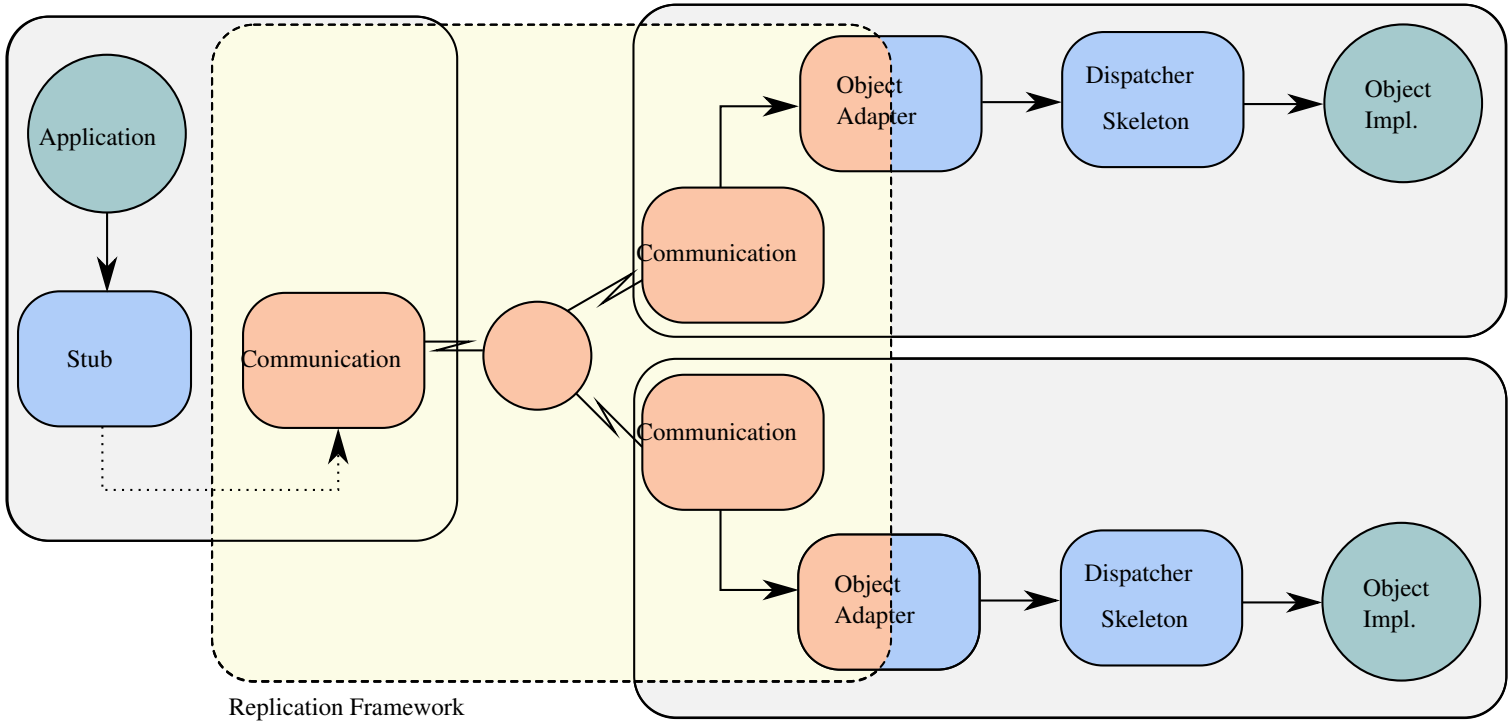

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$\Rightarrow$ Interface supports only `byte[]`

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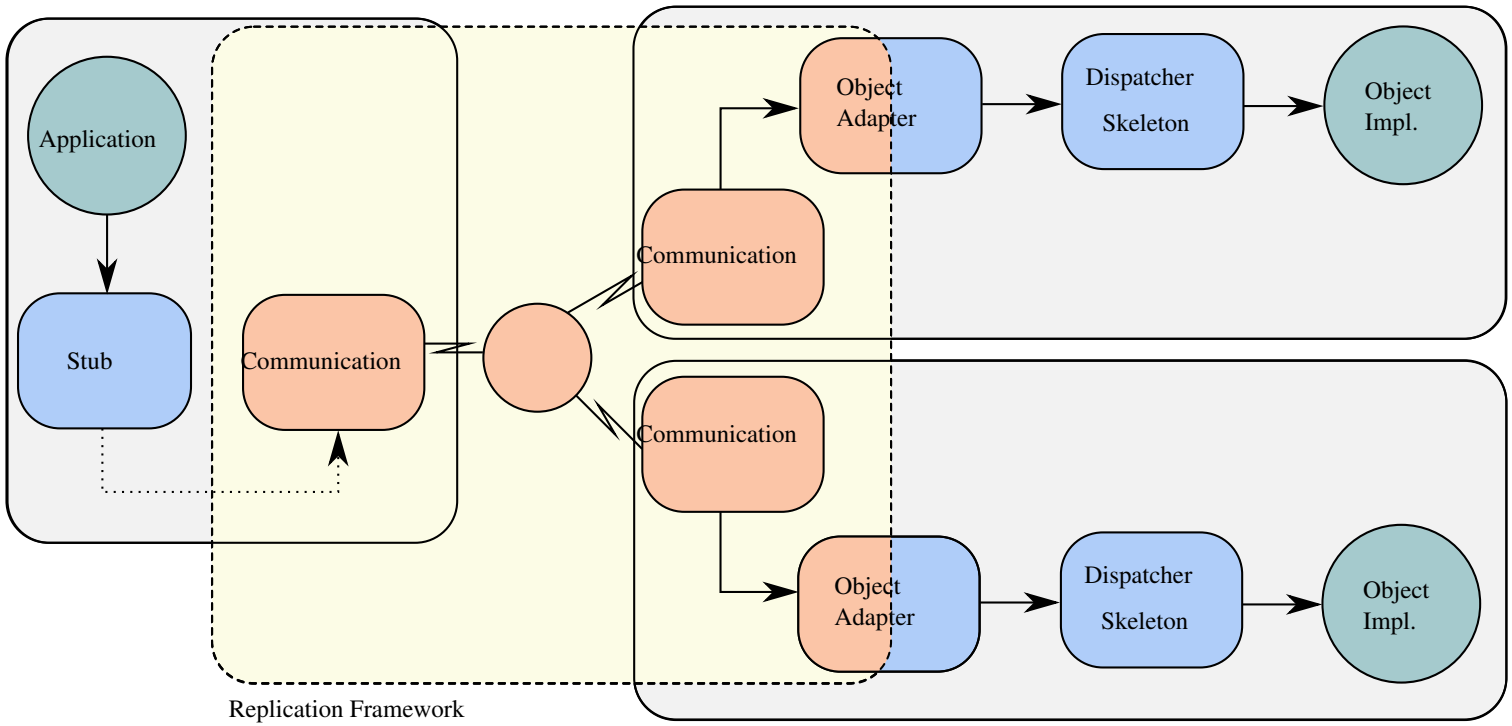

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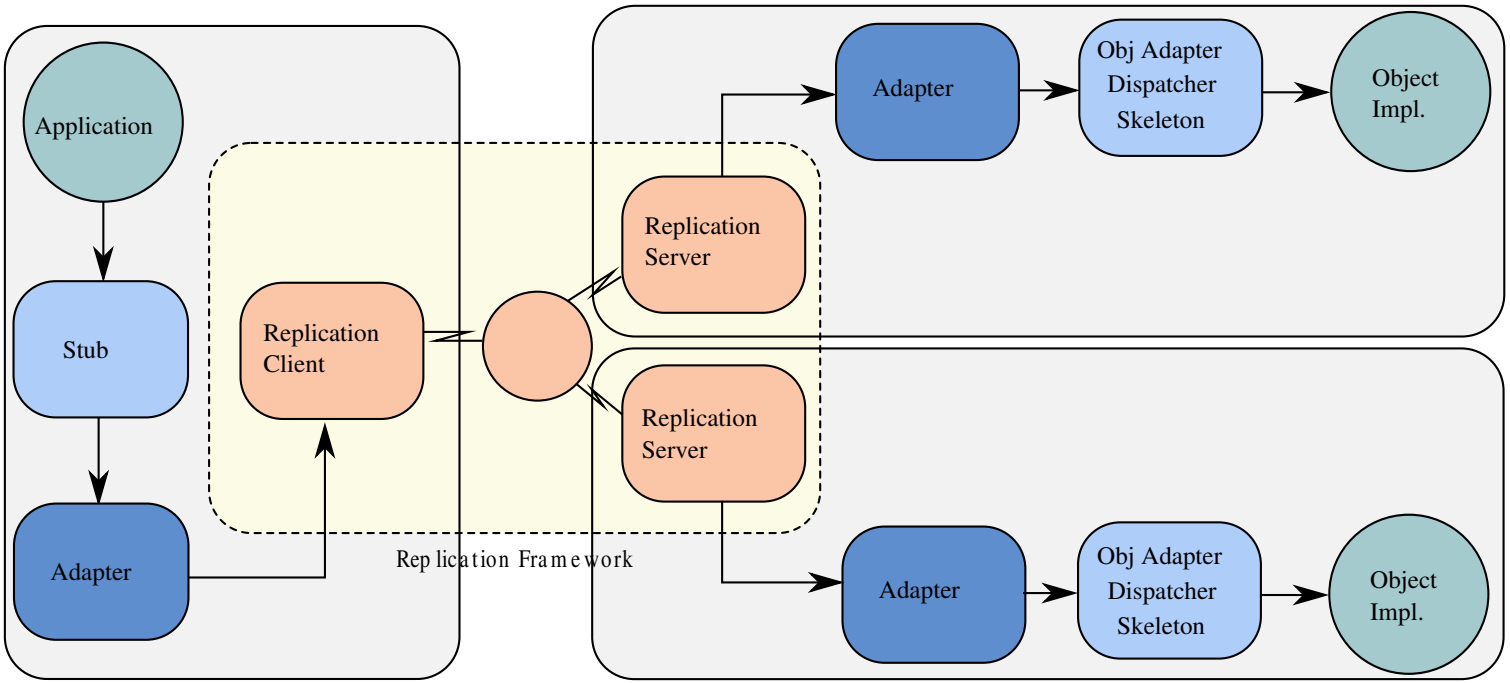
Integration into middleware

- Not all stubs support `byte[]`
- Redirecting calls to replication framework necessary

An Architecture for Replication Support

Step II: The Adapter



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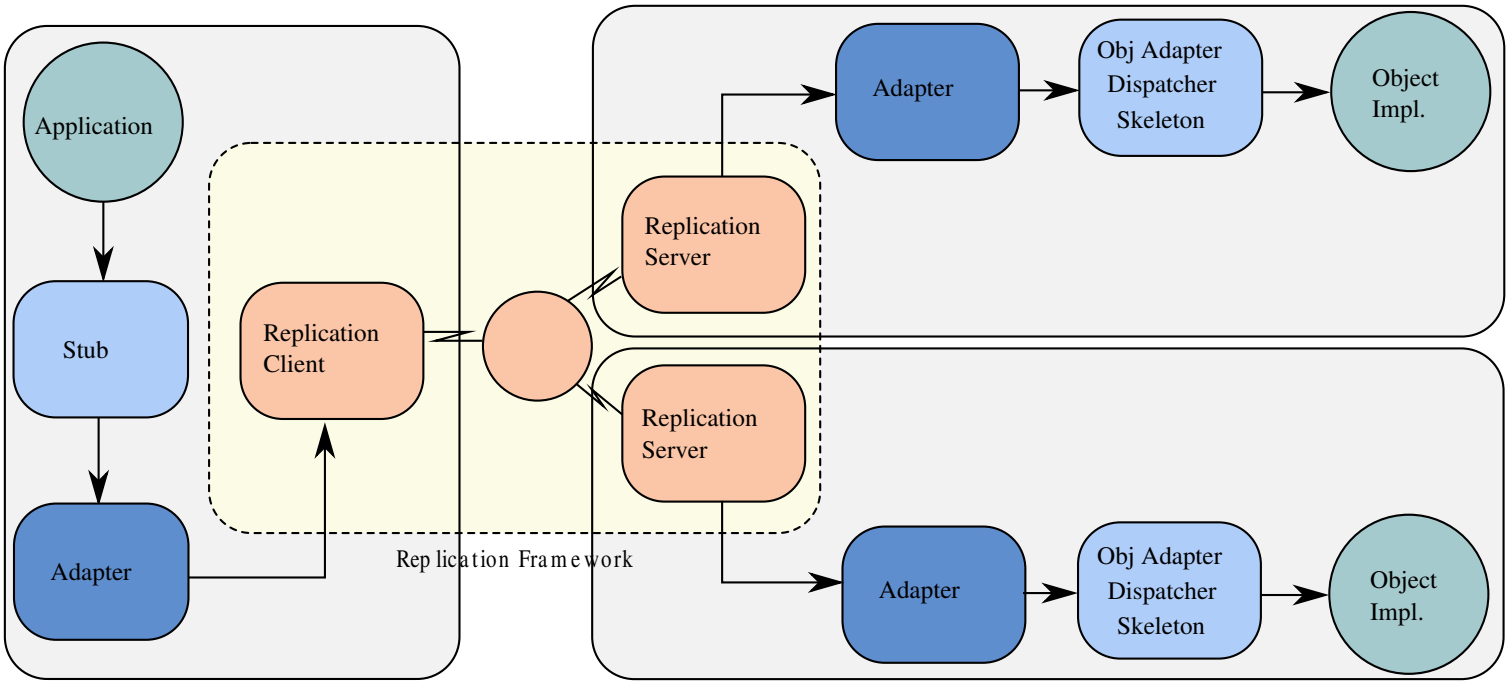

Adapter characteristics

- Conceptually part of the middleware
- Initialises replication framework
- Redirects calls to replication framework

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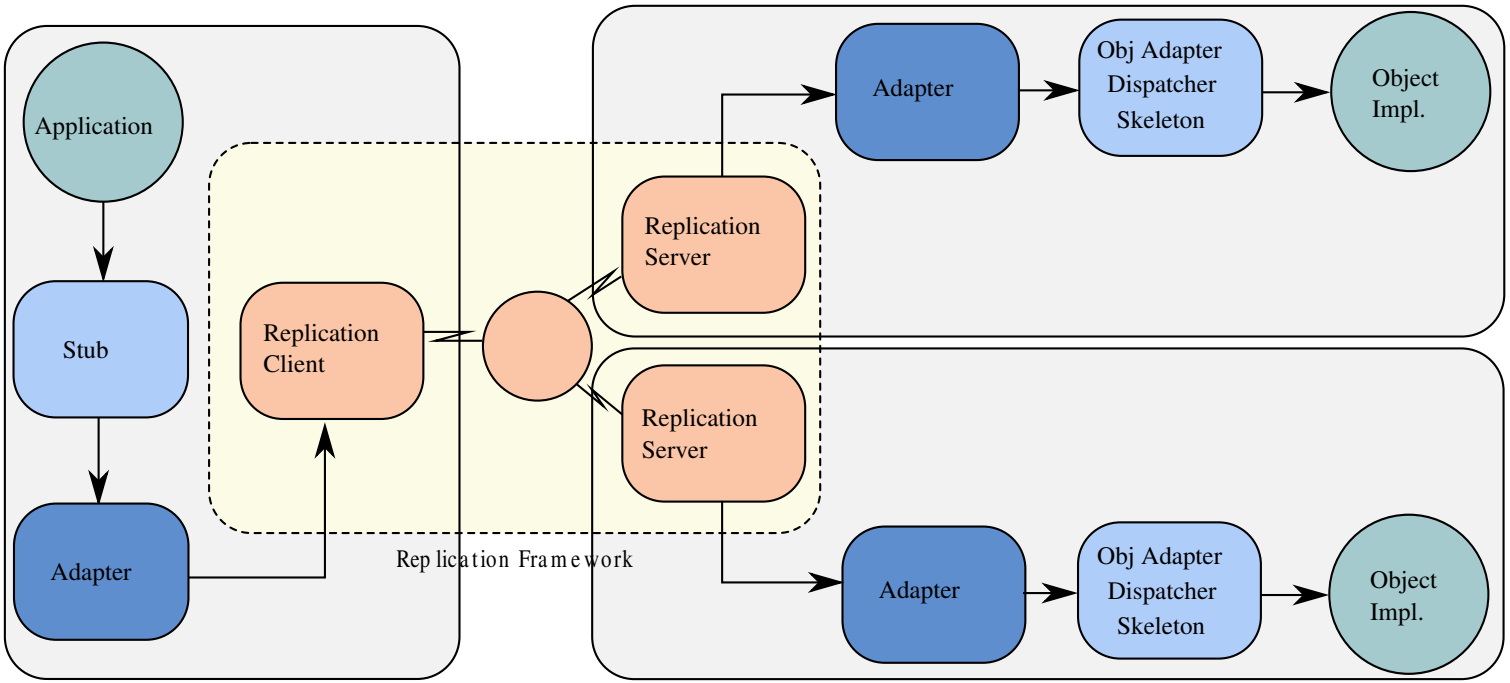
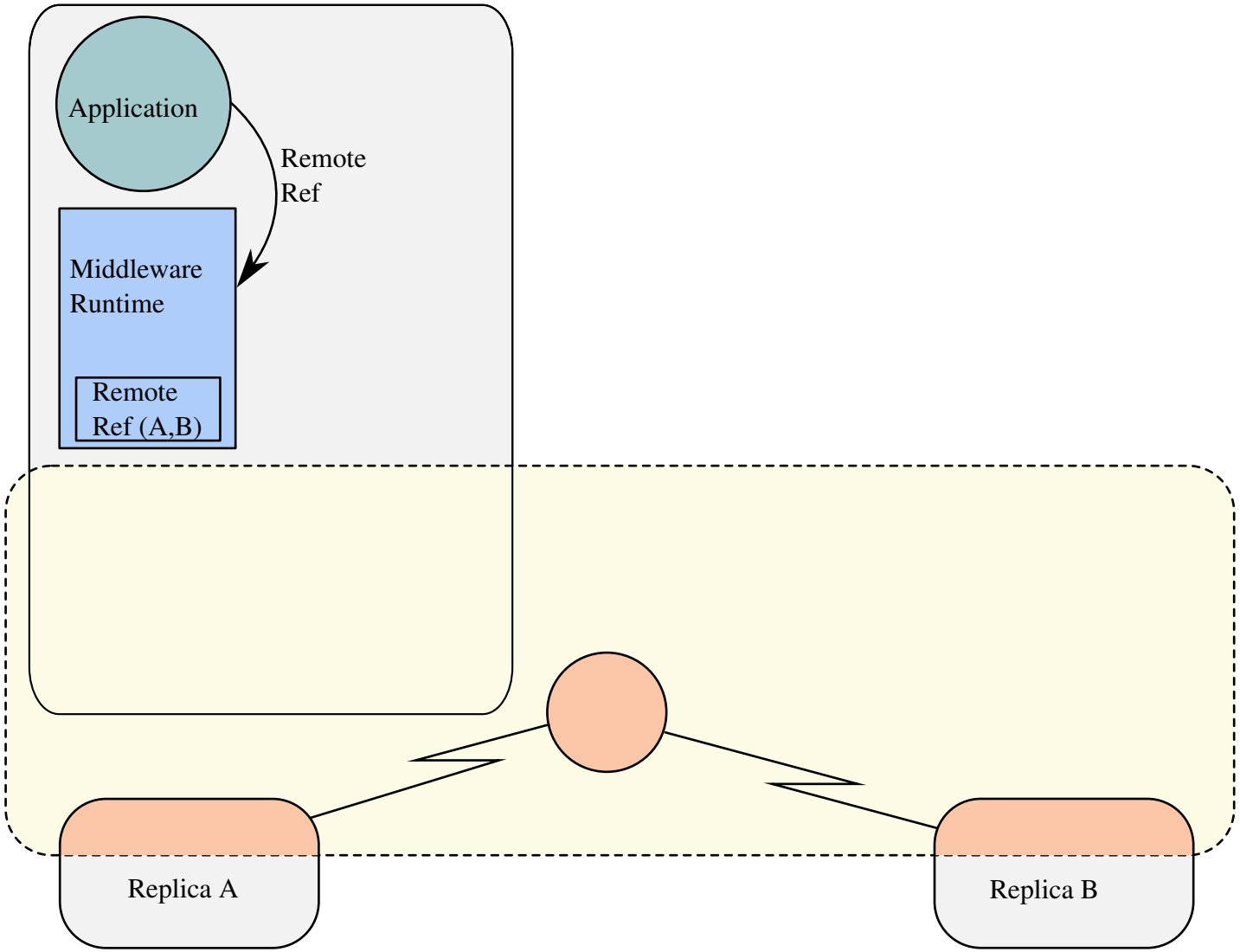


Adapter characteristics

- Conceptually part of the middleware
- Initialises replication framework
- Redirects calls to replication framework
- Does not solve all problems

An Architecture for Replication Support

The binding problem



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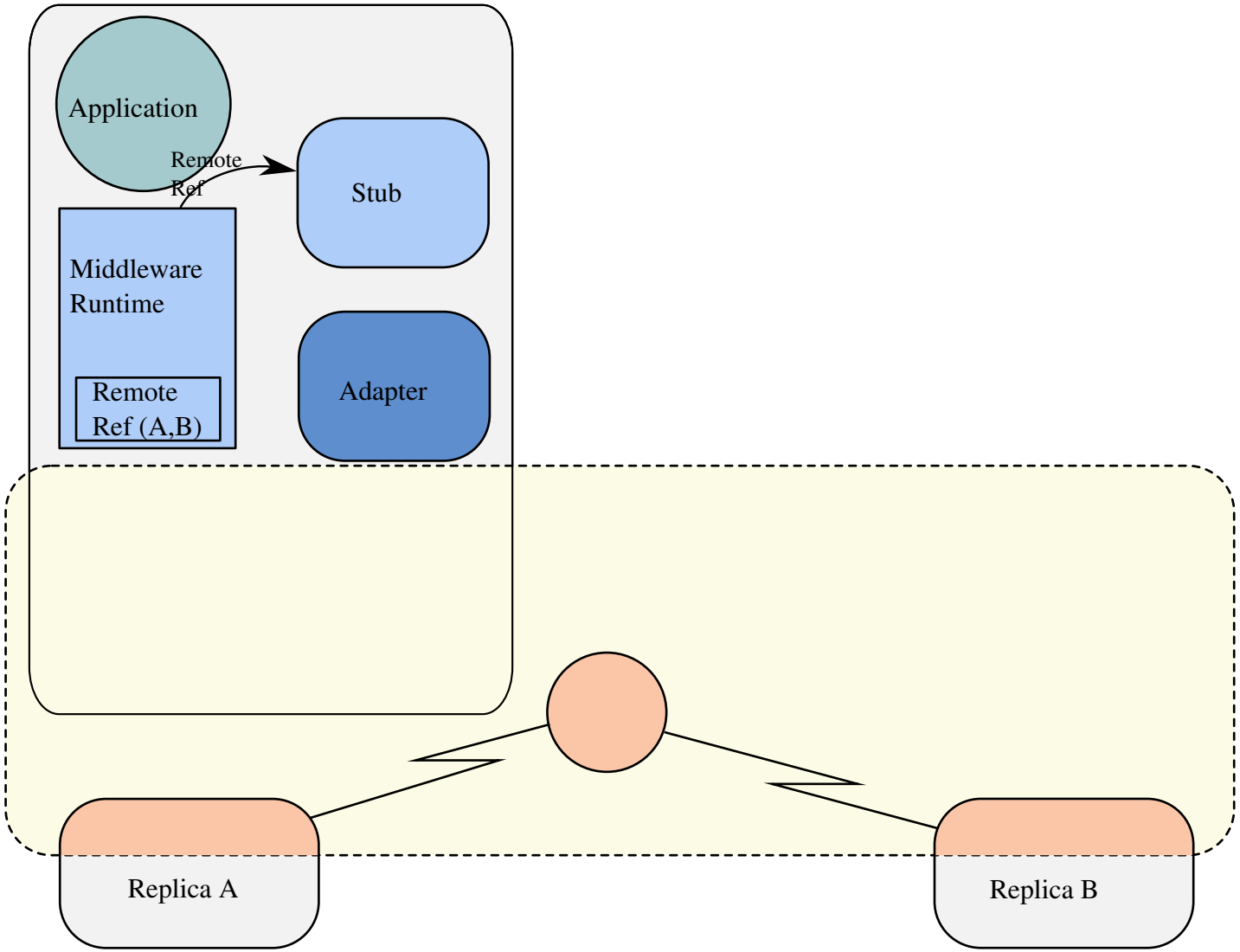

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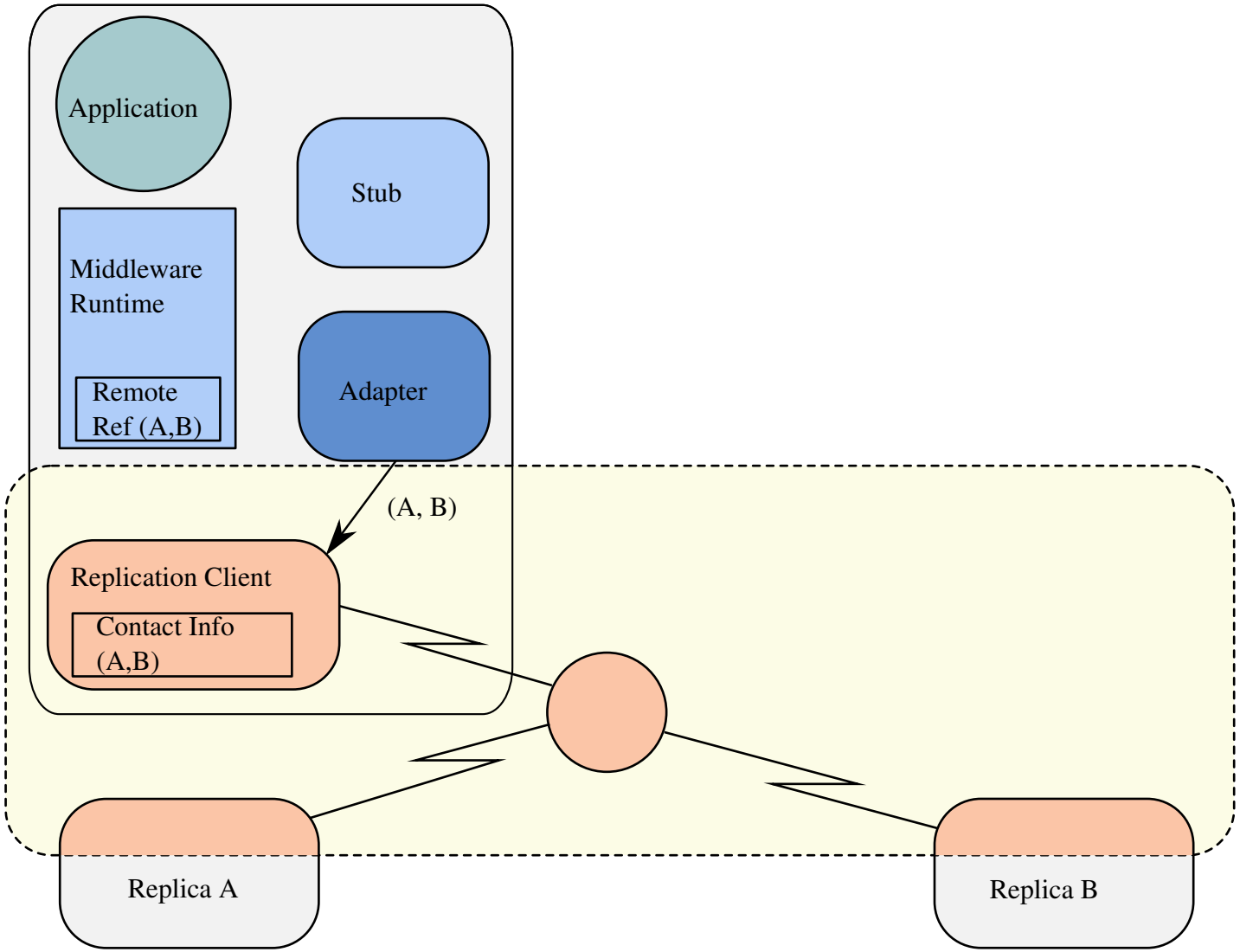

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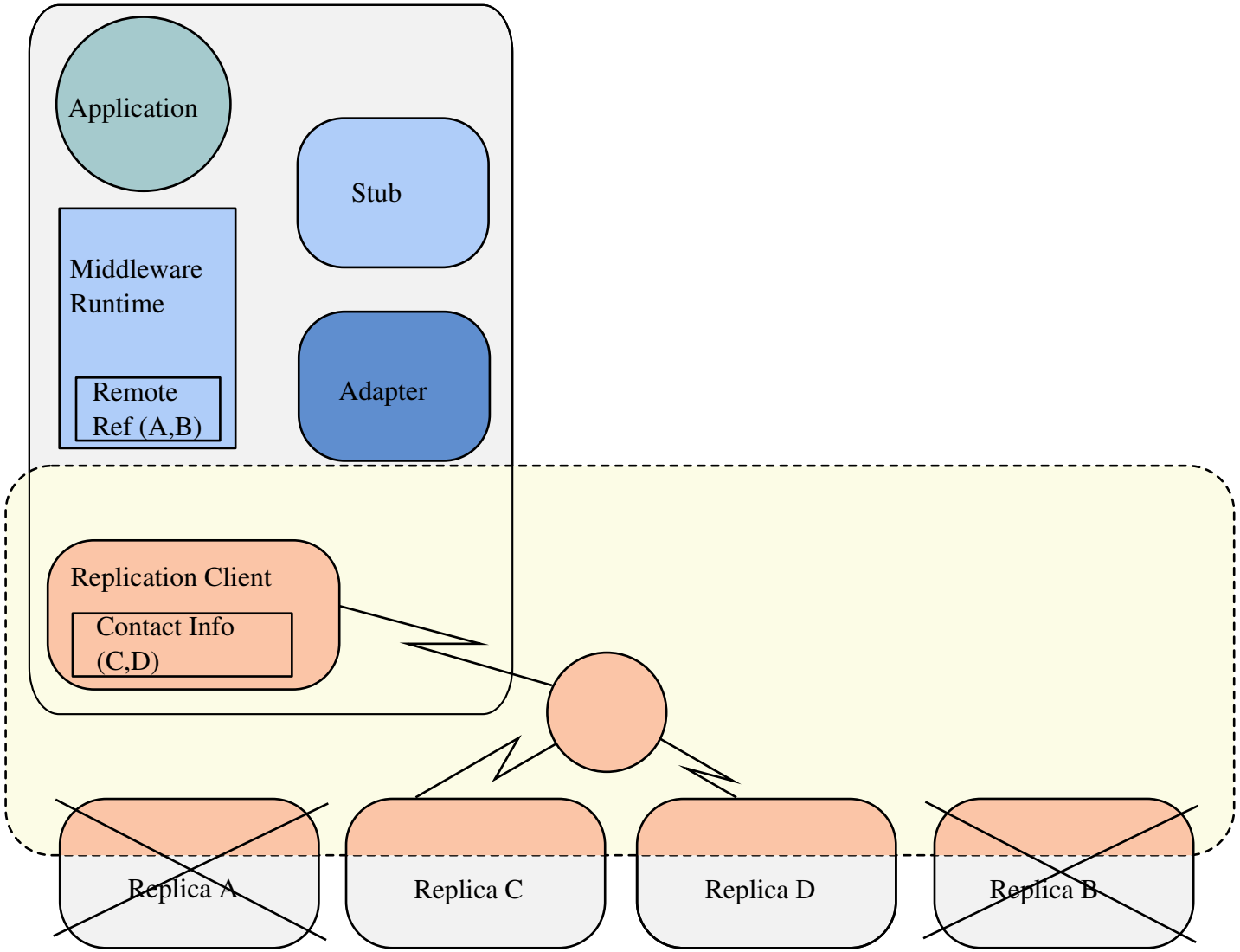

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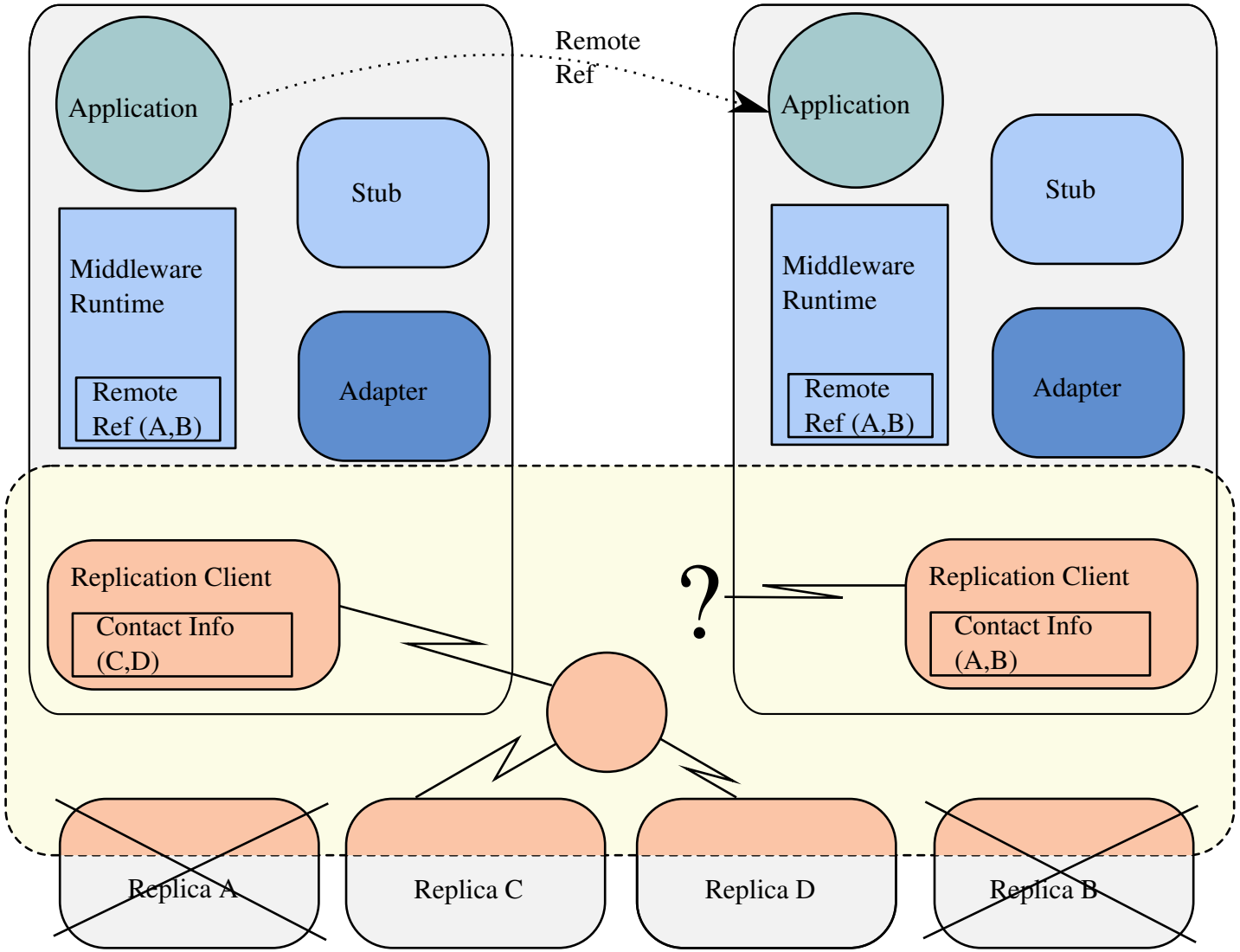

Solving the Binding Problem

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    $\Rightarrow$ Not supported by all middleware systems
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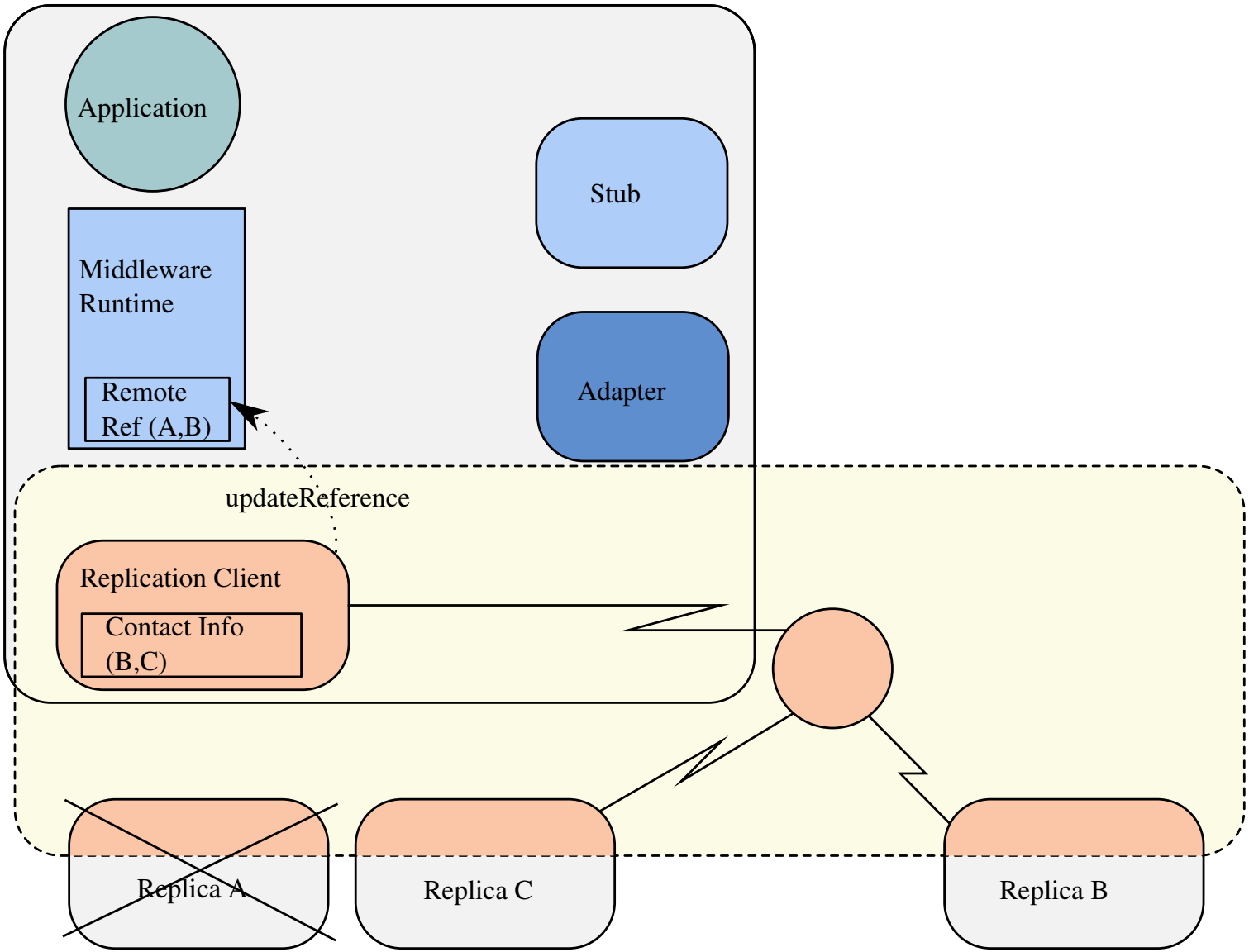
    $\Rightarrow$ No generic middleware interface
- Conversion step required
  - Converter as callback handler

An Architecture for Replication Support

Step III: The Converter



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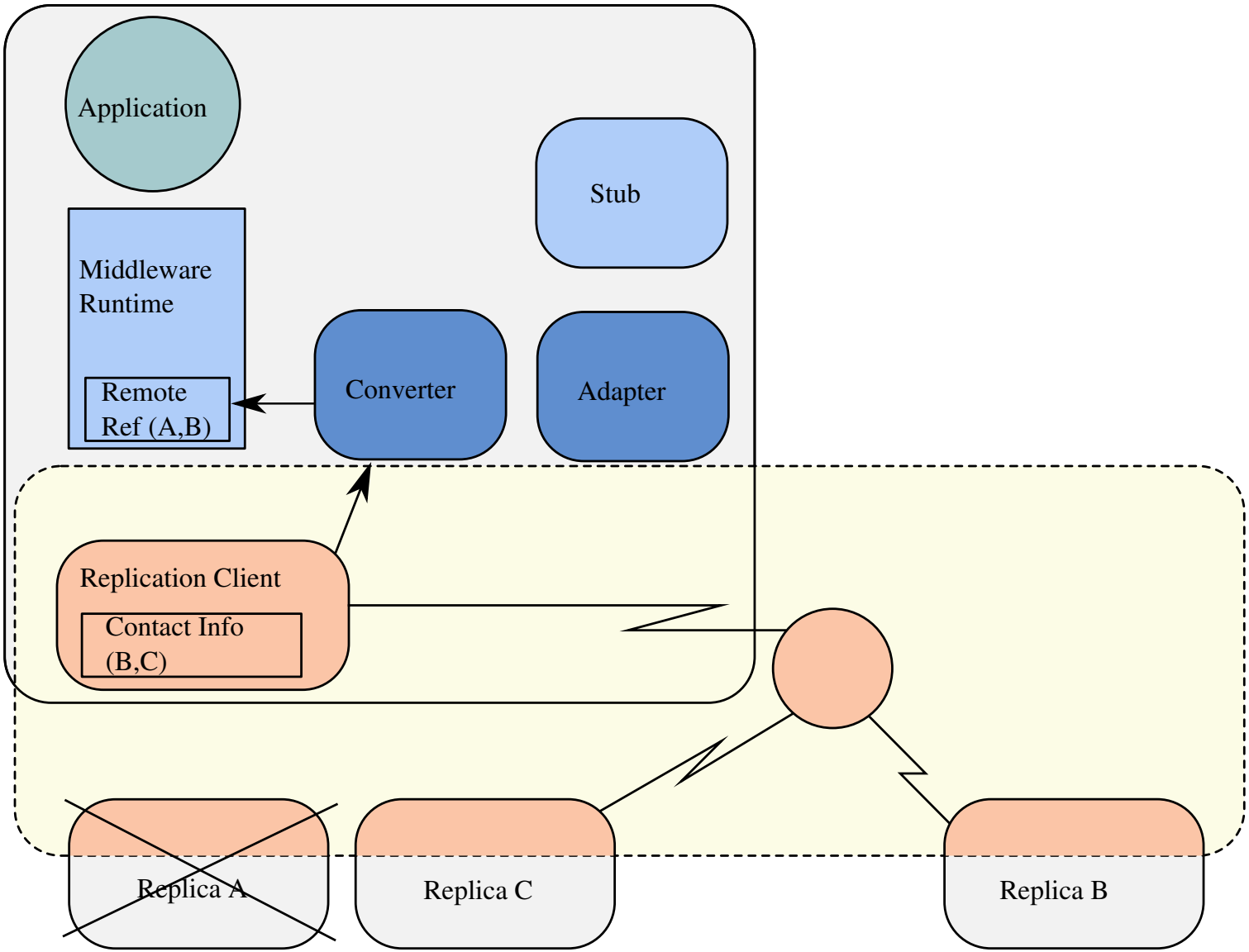

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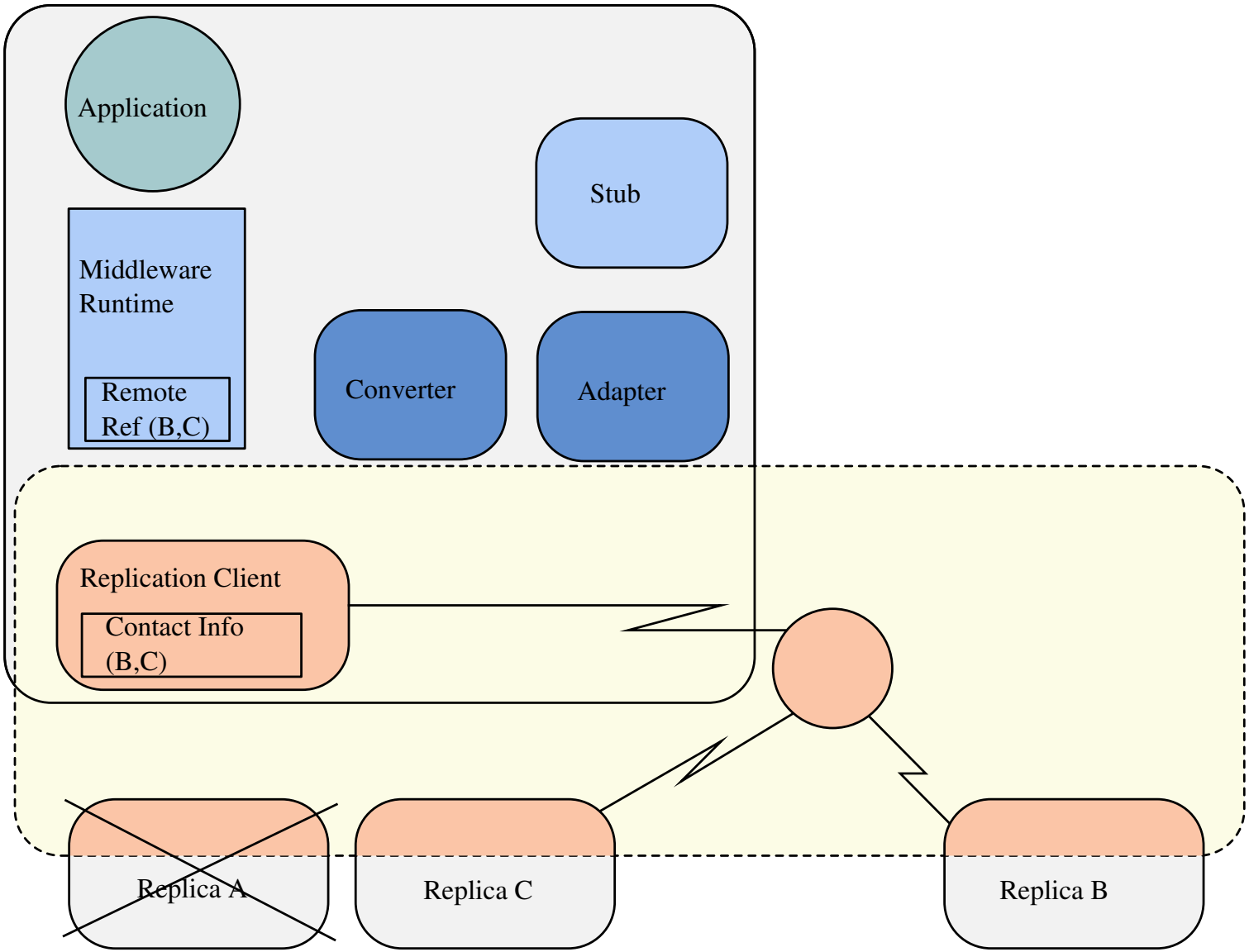

Separation in Practice

Starting Point:

FT*flex* replication framework integrated into Aspectix middleware

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Coupling:

- IOR
  - Aspectix: Remote reference, binding
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- Coupling code: Code in framework unrelated to replication

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FT*flex* replication framework integrated into Aspectix middleware

Coupling:

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Separation

- IOR
  - Used for binding only
  - Extended FT*flex* with a *replication state management* facility
  - Converter translates between both systems
- Coupling Code: Moved to adapter

Support for Arbitrary Middleware Architectures

- Adapter and converter heavily depend on middleware
- In general four approaches to include the adapter
  - Integration: modify the middleware source code
  - Interception: intercept messages at OS level
  - Service approach: application calls replication services
  - Customised stub: All further stubs are copies of the first one
- Existing adapters
  - Aspectix-FT*flex* adapter
  - Java RMI-FT*flex*

Evaluation

Replication:

Java RMI	81.7 μs
RMI-FT*flex*	126.7 μs
Costs	55 %

Separation:

FT*flex* integrated	124.9 μs
FT*flex* adapter	130.4 μs
Costs	4 %

Set-up:

- One client, one replica
- On a single physical machine
- Different virtual machines

Conclusion

Conclusion:

- Middleware-independent replication support is feasible
  - Genericity by the use `byte[]` at interface
  - Handle data in an opaque way
- Light-weight Integration into middleware
  - Adapter and Converter
- Overhead introduced by replication logic

Ongoing work:

- Adapter for JacORB
- Comparison with FT-CORBA implementation

Separation of Concerns

Object reference, Interface definition, Object adapter, Binding, Code generation, Consistency management, Replication management

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Object reference

Middleware concerns

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Interface definition

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  - Dispatching
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Replication concerns

- Object adapter
- Consistency management
  - Message ordering
  - Determinism

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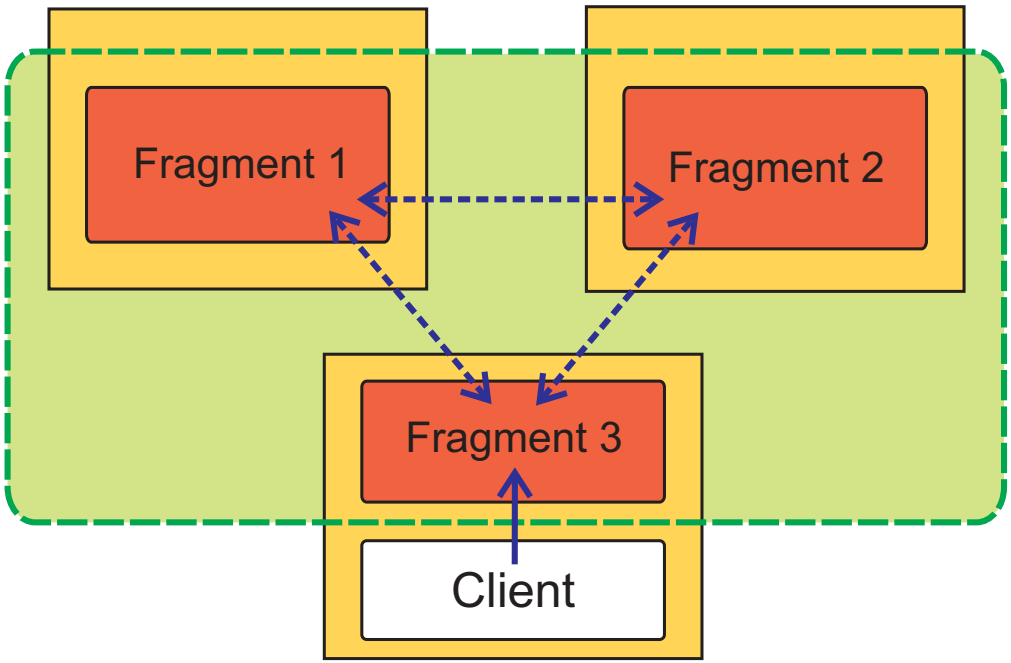
Replication concerns

- Object adapter
- Consistency management
  - Message ordering
  - Determinism
- Replication Management
  - Monitoring of replicas
  - Start new replicas
  - migrate replicas

Aspectix

- CORBA-based
- Supports fragmented objects
  - An object consits of multiple fragments
  - Fragments are arbitrarily distributed over multiple address spaces
  - Distribution of state and functionality is arbitrary
  - Communication is an object-internal issue



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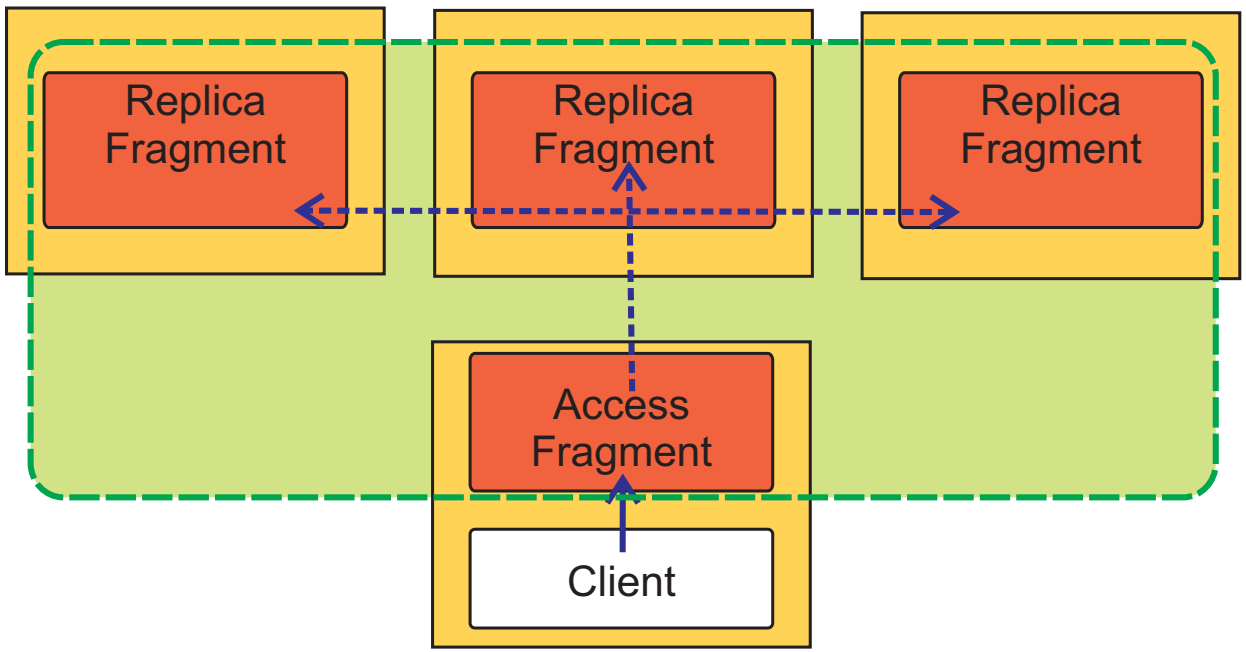
  - Distribution of state and functionality is arbitrary
  - Communication is an object-internal issue
- Features
  - Implicit binding
  - Interface Definition
  - Code generation
- but arbitrary distribution of state and functionality disables generation of marshalling and dispatching

FT*flex*

- Replication infrastructure based on Aspectix
  - Fragmented objects
- Has a more concrete object structure
  - Access fragments
  - Replica fragments
  - Code generation results in marshalling and dispatching code



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  - Fragmented objects
- Has a more concrete object structure
  - Access fragments
  - Replica fragments
  - Code generation results in marshalling and dispatching code
- Object adapter part of replica fragment
  - Message Management
  - Dispatching
  - Error handling
- Own group communication system