Remoting Patterns

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Overview

- **Patterns and Pattern Languages**
- **Distributed Systems and Middleware**
- **Remoting Patterns**
  - Basic Remoting Patterns
  - Identification Patterns
  - Lifecycle Patterns
  - Extension Patterns
  - Extended Infrastructure Patterns
  - Asynchronous Invocation Patterns
- **Web Services Technology Projection**

Patterns and Pattern Languages

Pattern Definition

- **Pattern definition by Alexander:**

  A pattern is a three-part rule, which expresses a relation between a certain context, a problem, and a solution.

- **Heavily simplified definition. Bad example:**

Context	**You are driving a car.**
Problem	**The traffic lights in front of you are red. You must not run over them. What should you do?**
Solution	**Brake.**

- **Obviously this is not a pattern!**
- **Alexander's definition is much longer. Summary by Jim Coplien:**

  Each pattern is a three-part rule, which expresses a relation between a certain context, a certain system of forces which occurs repeatedly in that context, and a certain software configuration which allows these forces to resolve themselves.

Elements of a Pattern

- Name
- Context
- Problem
- Solution
- Forces
- Consequences
- Examples/Known Uses
- Pattern Relationships

Software Patterns

- **Last couple of years: Patterns have become part of the mainstream of OO SW development**
- **Different kinds of patterns:**
  - Design patterns (GoF)
  - Software architecture patterns (POSA, POSA2)
  - Analysis patterns (Fowler, Hay)
  - Organizational patterns (Coplien)
  - Pedagogical patterns (PPP)
  - Many others
- **Most of the patterns in this tutorial can be seen as falling into two categories - design patterns and architectural patterns**

From Patterns to Pattern Languages

- **Single pattern = one solution to a particular, recurring problem**
- **However: “Real problems" are more complex**
- **Pattern relationships:**
  - Compound patterns
  - Family of patterns
  - Collection or system of patterns
  - Pattern languages
- **Pattern languages:**
  - Language-wide goal
  - Generative
  - Sequences → has to be applied in a specific order
  - Pattern defines its place in the language → context, resulting context

Distributed Systems and Middleware

Distributed Systems: Application Areas

- **Some Examples:**
  - Internet
  - Telecommunication networks
  - Business-to-business (B2B) collaboration systems
  - International financial transactions
  - Embedded systems
  - Scientific applications
- **Many more …**

Distributed Systems: Reasons

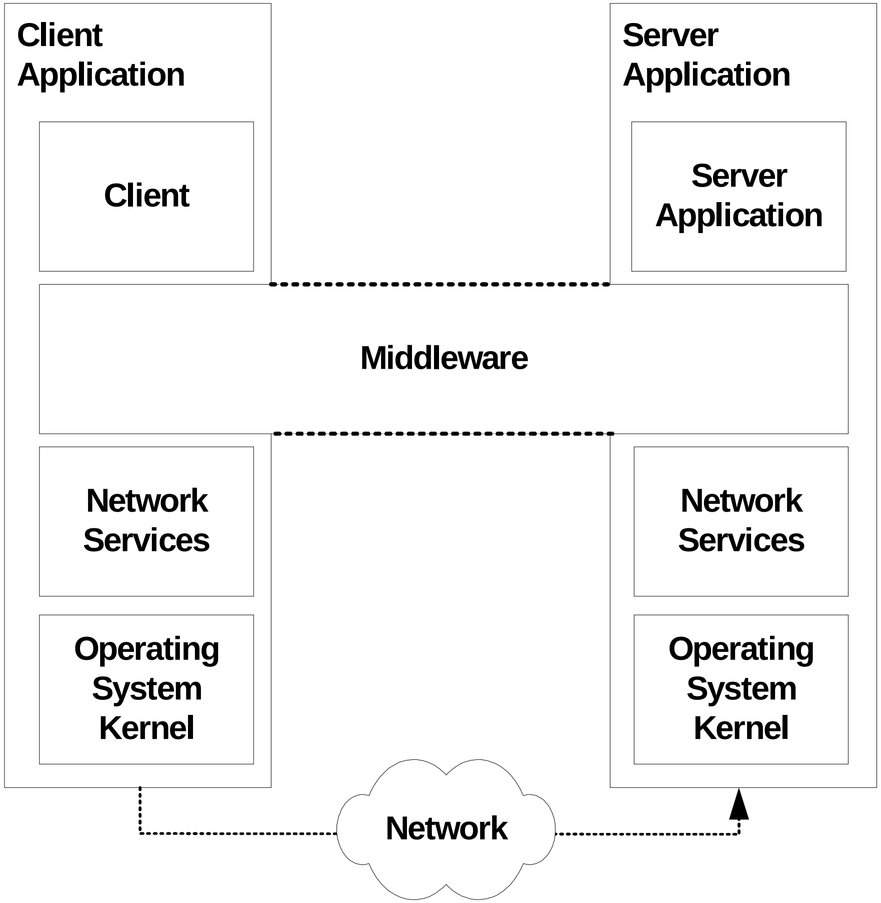
- **Reasons: Problem-related reasons**
  - “Real” distribution
- **Reasons: Property-related reasons:**
  - Performance and Scalability
  - Fault Tolerance
  - Service and Client Location Independence
  - Maintainability and Deployment
  - Security
  - Business Integration

Distributed Systems: Challenges

- Network Latency
- Predictability
- Concurrency
- Scalability
- Partial Failure

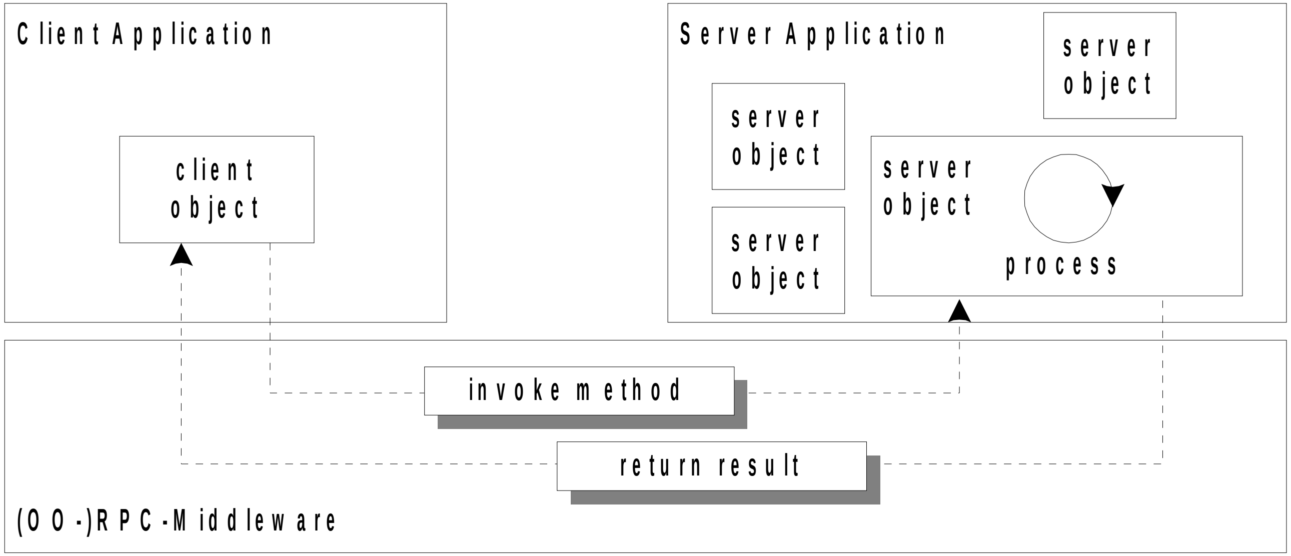
Middleware

- **Dealing with low-level networking issues yields the following problems:**
  - not easy to scale,
  - cumbersome and error prone to use,
  - hard to maintain and change, and
  - does not provide transparency of the distributed communication.
- **Solution: Communication Middleware**



Remoting Styles

- **There are systems that**
  - use the metaphor of a *remote procedure call* (RPC),
  - use the metaphor of posting and receiving *messages*,
  - utilize a *shared repository*, or
  - use continuous *streams* of data.
- **We mainly focus on object-oriented variants of the RPC style:**

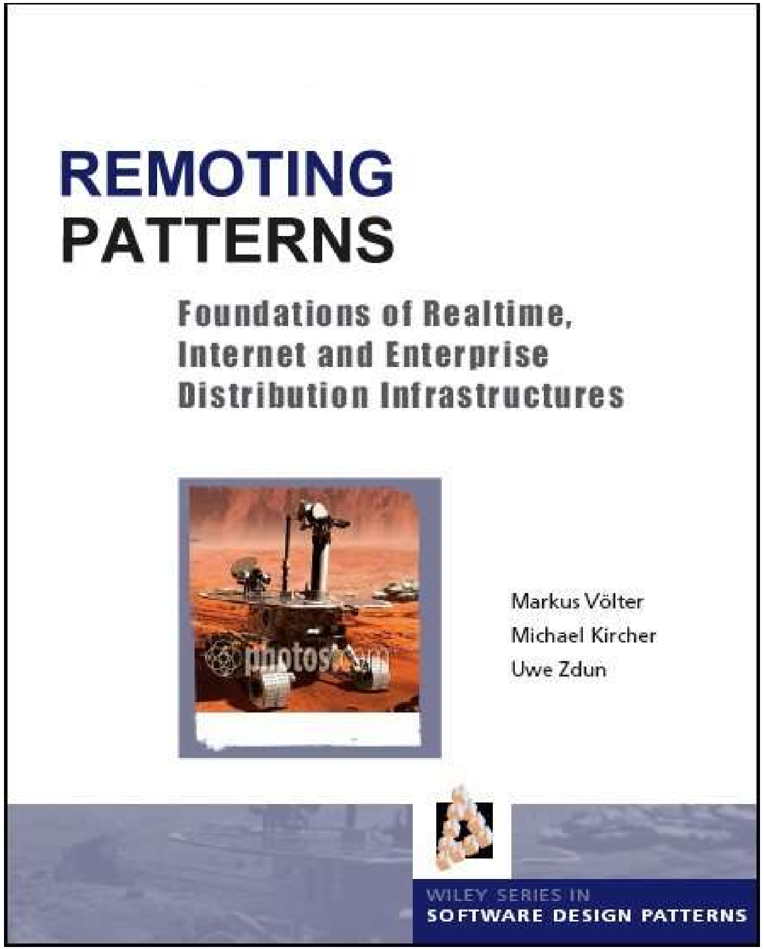


Remoting Patterns

Remoting Patterns

- **Numerous projects**
  - ***use,***
  - ***extend,***
  - ***integrate,***
  - ***customize***, and
  - ***build***

  distributed object middleware
- **Goals:**
  - illustrate the general, recurring architecture of successful distributed object middleware
  - illustrate more concrete design and implementation strategies
- **Book: to be published in Wiley‘s Pattern Series in 2004**



REMOTING PATTERNS

Foundations of Realtime, Internet and Enterprise Distribution Infrastructures

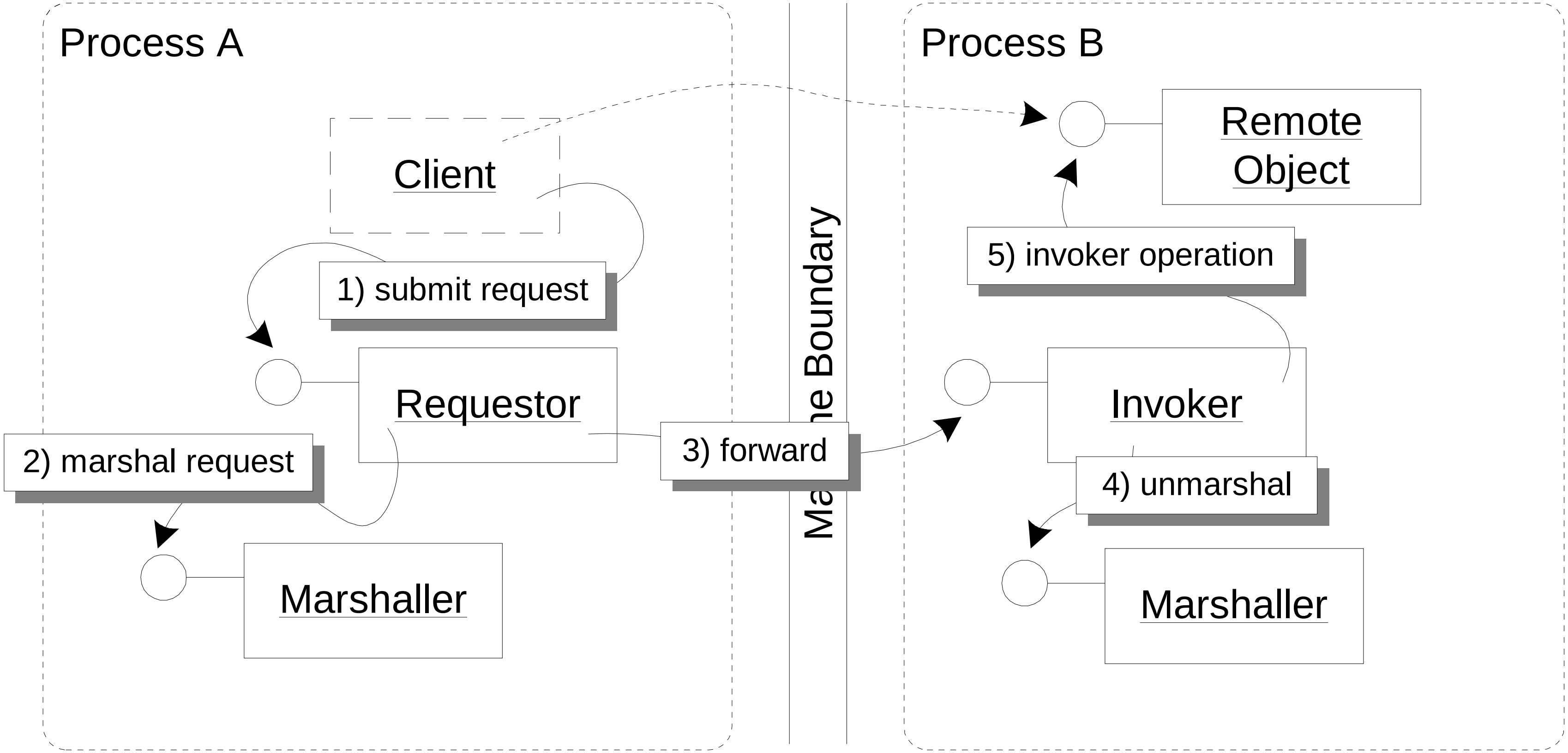
Markus Völter
Michael Kircher
Uwe Zdun

WILEY SERIES IN SOFTWARE DESIGN PATTERNS

Pattern: Broker

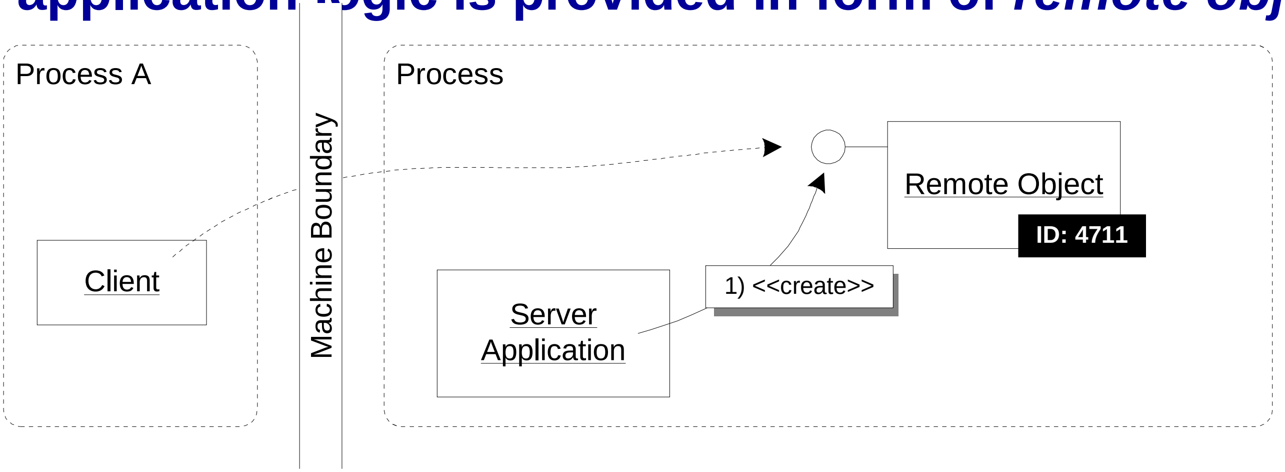
- **Context:**
  - You are designing a distributed software system
- **Problem:**
  - Many challenges that do not arise in single-process software
    - communication across networks is unreliable
    - integration of heterogeneous components into coherent applications
    - efficient usage of networking resources
  - Developers should not loose their primary focus: to develop applications that resolve their domain-specific problems.
- **Solution:**
  - Separate communication-related concerns in a Broker
  - The Broker hides and mediates all communication between the objects or components of a system
- **Details realized by other patterns**

Pattern: Broker (2)



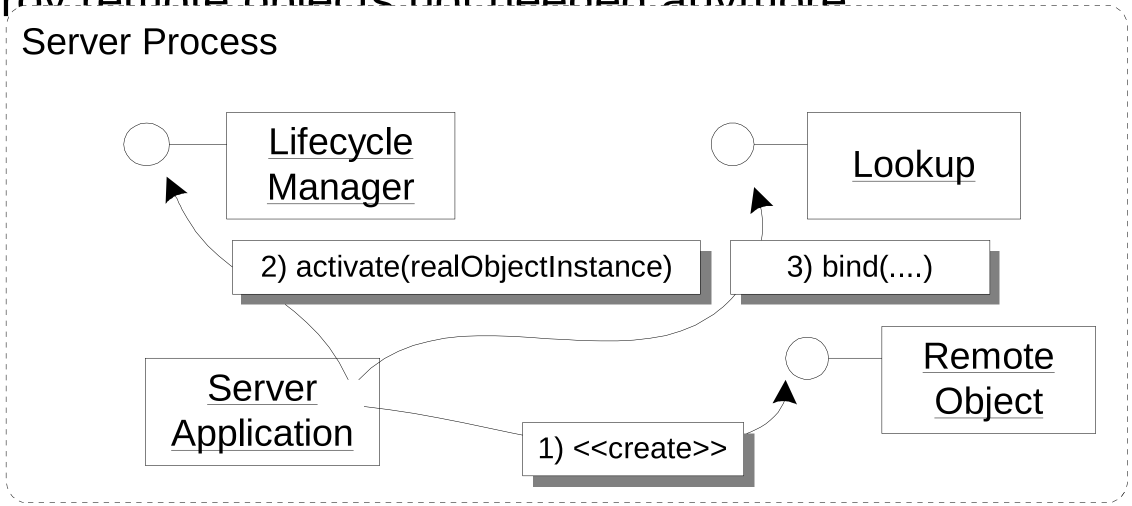
Remote Object

- **In many respects, accessing an object over a network is different from accessing a local object:**
  - Invocations have to cross process and machine boundaries
  - Network latency and network unreliability
  - Using memory addresses to define object identity will not work
  - …
- **The application logic is provided in form of *remote objects***



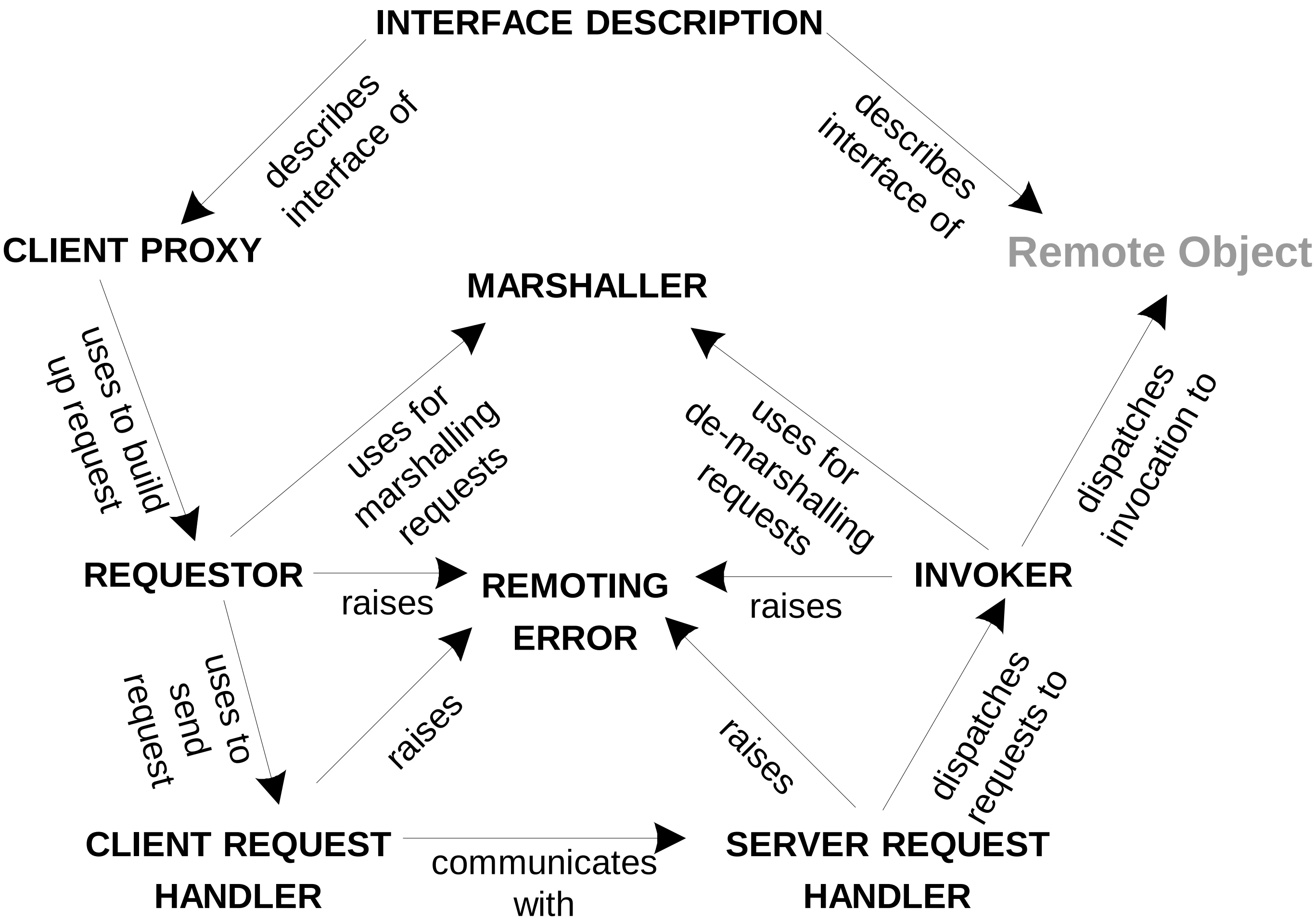
Server Application

- **Remote objects need a *server application* for the following tasks:**
  - Create and configure constituents of the distributed object middleware
  - Instantiate and configure remote objects
  - Advertise remote objects to clients
  - Connect individual remote objects to distributed applications
  - Destroy remote objects not needed anymore



Basic Remoting Patterns

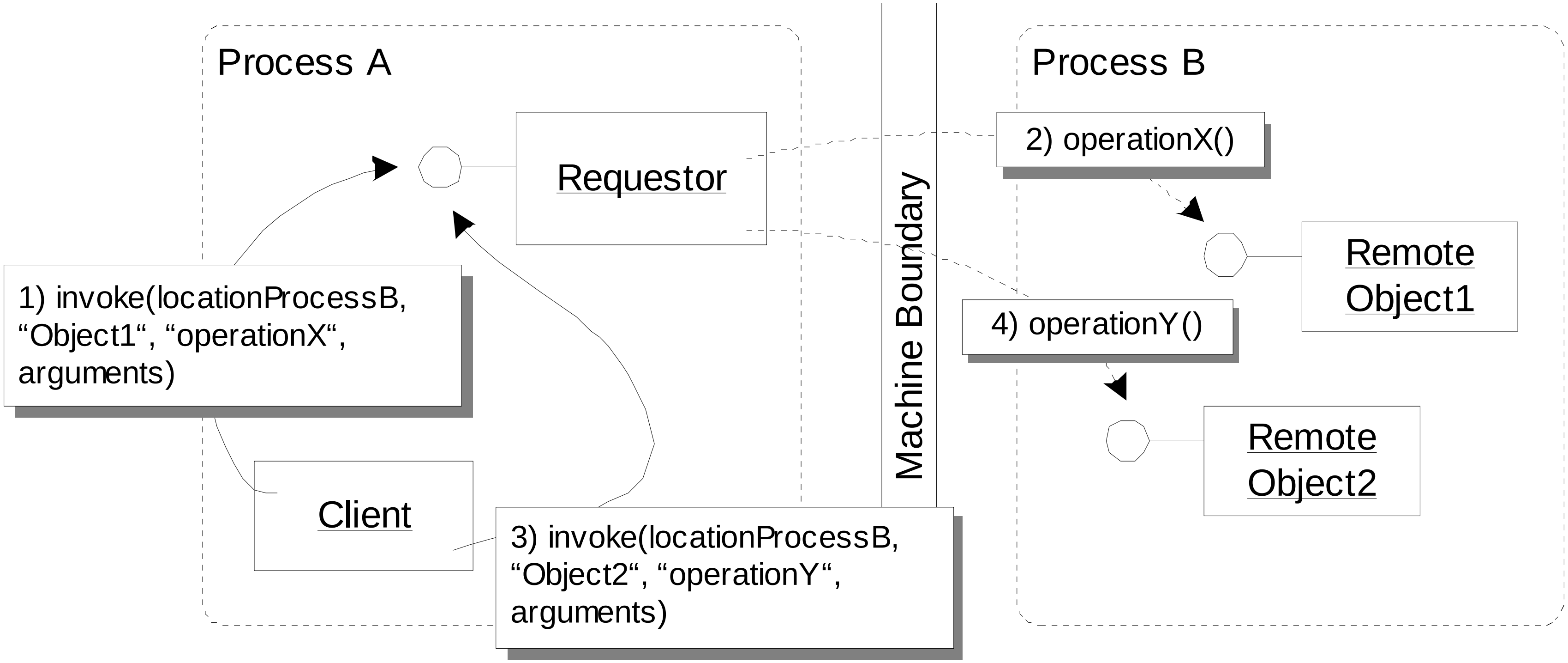
Basic Remoting Patterns



Pattern: Requestor

- **Context:**
  - A client needs to access one or more remote objects
- **Problem:**
  - For a remote invocation …
    - Marshalling must be triggered
    - A connection needs to be established
    - The request information must be sent to the target remote object
- **Solution:**
  - In the client application …
    - Use a Requestor for accessing the remote object
    - Supply it with the absolute object reference of the remote object, the operation name, and the arguments
    - The requestor constructs a remote invocation from these parameters and sends the invocation to the remote object

Pattern: Requestor (2)



Process A

Process B

Machine Boundary

Requestor

Client

Remote Object1

Remote Object2

1) invoke(locationProcessB, “Object1“, “operationX“, arguments)

2) operationX()

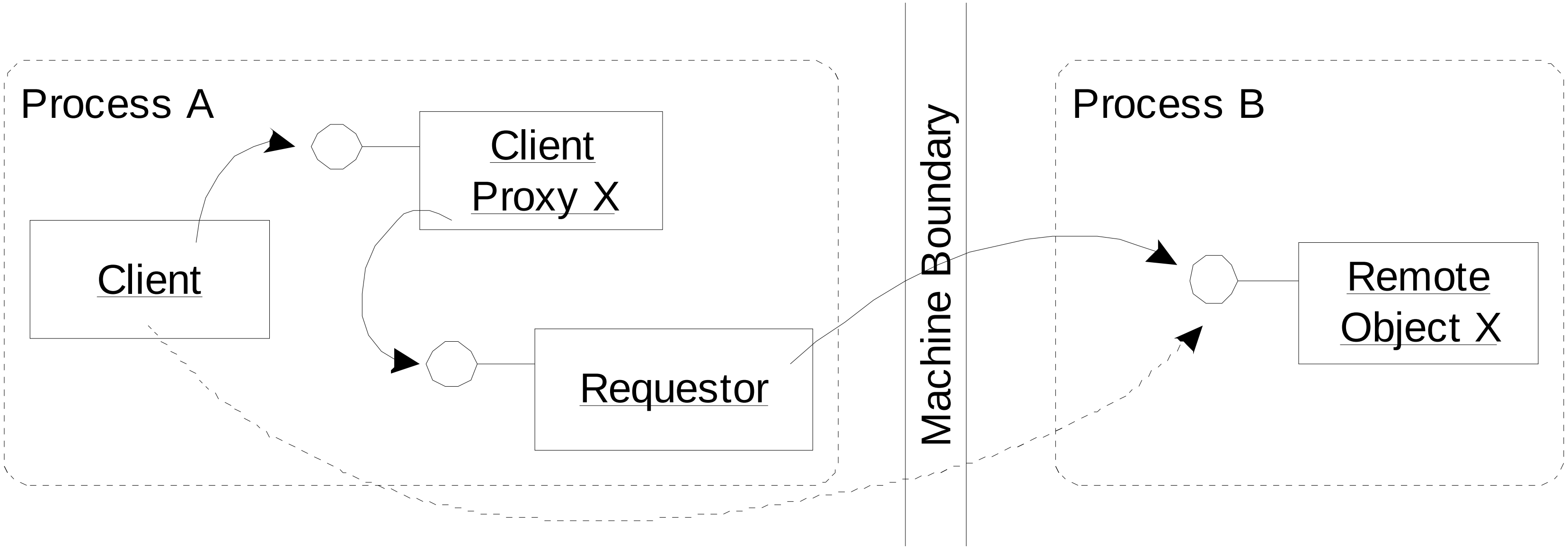
3) invoke(locationProcessB, “Object2“, “operationY“, arguments)

4) operationY()

Pattern: Client Proxy

- **Context:**
  - A Requestor is provided by the distributed object middleware
- **Problem:**
  - Goal: support remote programming model similar to accessing local objects
  - A requestor solves part of this problem by hiding many network details
  - However: the methods, arguments, location and identification information have to be passed to the requestor for each invocation
  - Requestor supports no static type checking
- **Solution:**
  - Client proxy supports the same interface as the remote object
  - Clients only interact with the local client proxy
  - Client proxy translates the local invocation into parameters for the requestor, and triggers the invocation

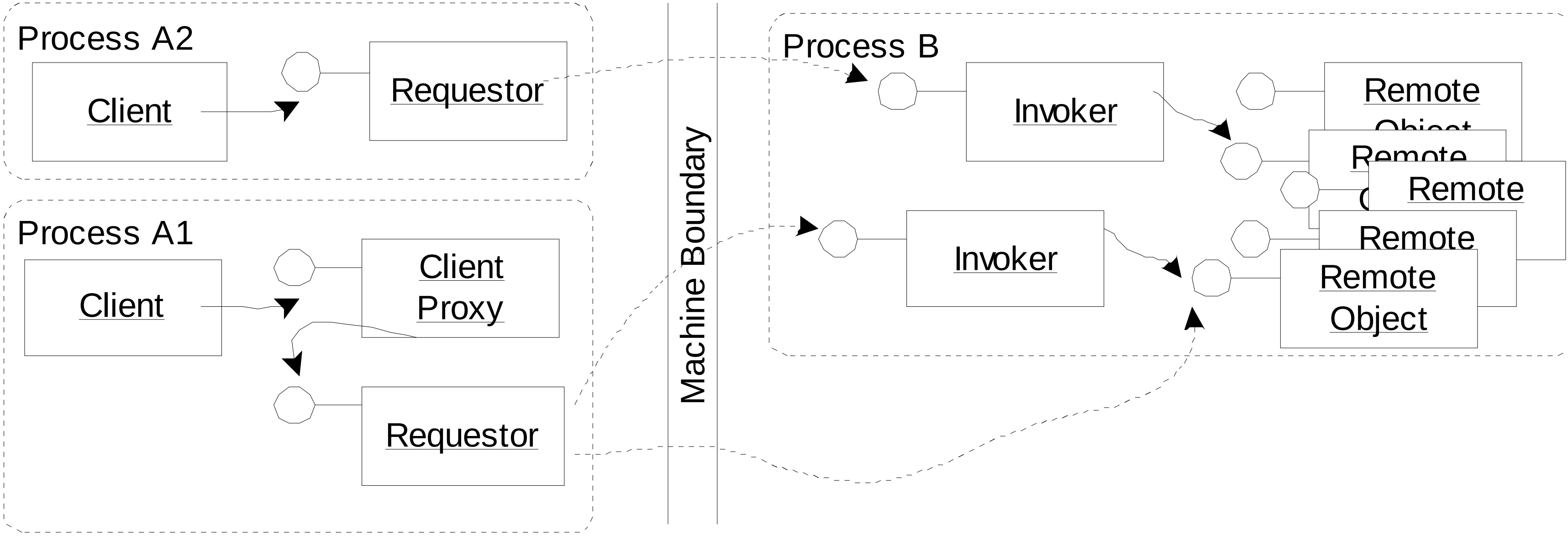
Pattern: Client Proxy (2)



Pattern: Invoker

- **Context:**
  - A requestor sends a remote invocation for a remote object to a server
- **Problem:**
  - Somehow the targeted remote object on the server has to be reached
  - Simplest solution: remote object is addressed over the network directly
    - Large number of object → not enough network endpoints
    - Remote object would have to deal with network connections, receiving and demarshalling messages, etc.
- **Solution:**
  - Invoker(s) accept(s) invocations from requestors
  - Invoker reads the request and demarshalls it
  - Looks up the correct local object & operation and
  - Performs the invocation on the targeted remote object

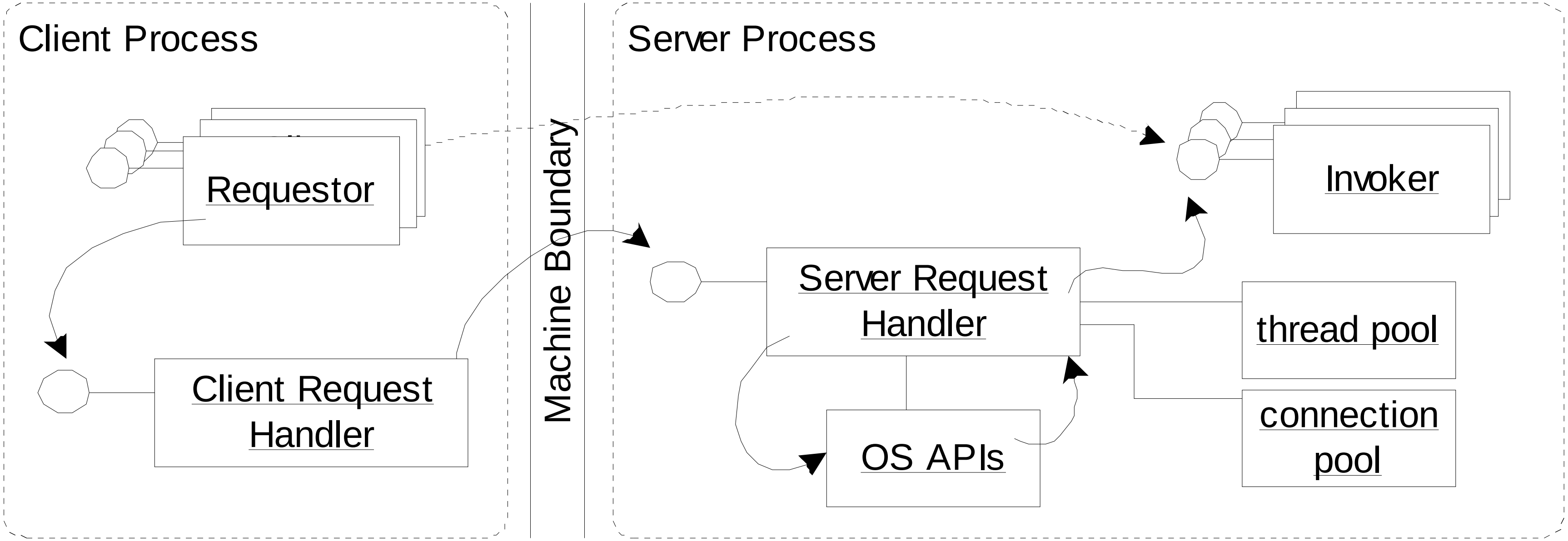
Pattern: Invoker (2)



Pattern: Server Request Handler

- **Context:**
  - You are providing remote objects in a server application, and invokers are used for message dispatching
- **Problem:**
  - The request message has to be received from the network
  - Managing communication channels efficiently and effectively is essential
  - Network communication needs to be coordinated and optimized
- **Solution:**
  - Server request handler deals with all communication issues of a server application:
    - Receives messages from the network
    - Combines the message fragments to complete messages
    - Dispatches the messages to the correct invoker
    - Manages all the required resources (connections, threads, …)

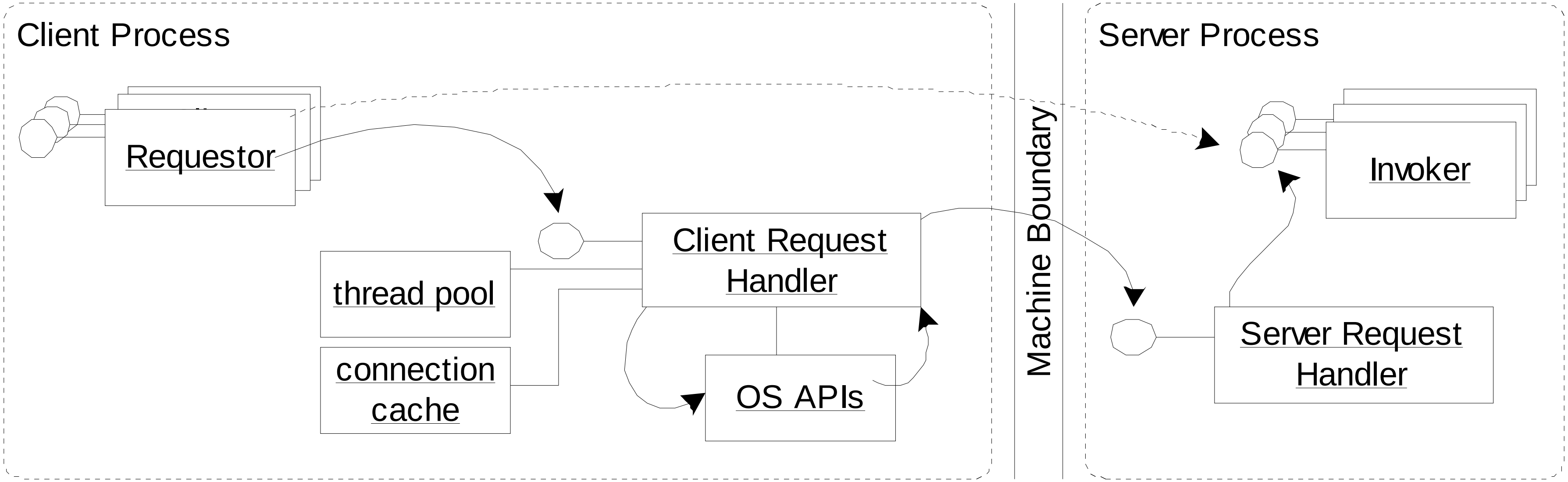
Pattern: Server Request Handler (2)



Pattern: Client Request Handler

- **Context:**
  - Requestor has to send requests to and receive responses
- **Problem:**
  - For a client request several tasks have to be performed:
    - Connection establishment and configuration
    - Result handling
    - Timeout handling
    - Error detection
  - Connection, threading, etc. need to be coordinated and optimized
- **Solution:**
  - Client request handler handles network connections for all requestors within a client:
    - Sending of requests
    - Receiving and dispatching of responses
    - Handling of timeouts, threading issues, and invocation errors

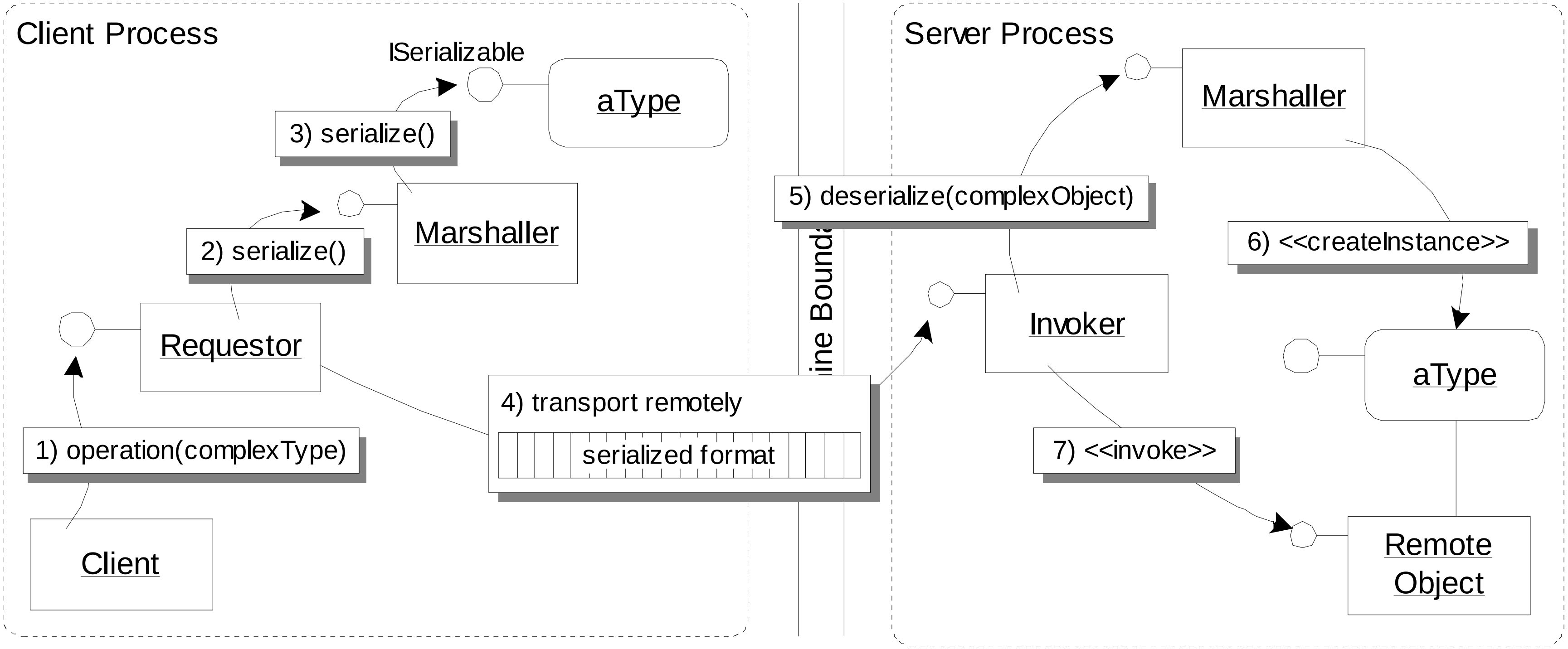
Pattern: Client Request Handler (2)



Pattern: Marshaller

- **Context:**
  - Request and response messages have to be transported over the network
- **Problem:**
  - The data to describe invocations consists of:
    - Object ID, operation name, parameters, return value, …
    - Possibly other invocation context information
  - For transportation over the network, only byte streams are suitable
- **Solution:**
  - Use compatible marshallers on client and server side that serialize invocation information
    - Primitive types and non-primitive types are serialized
    - References to remote objects are serialized as absolute object references

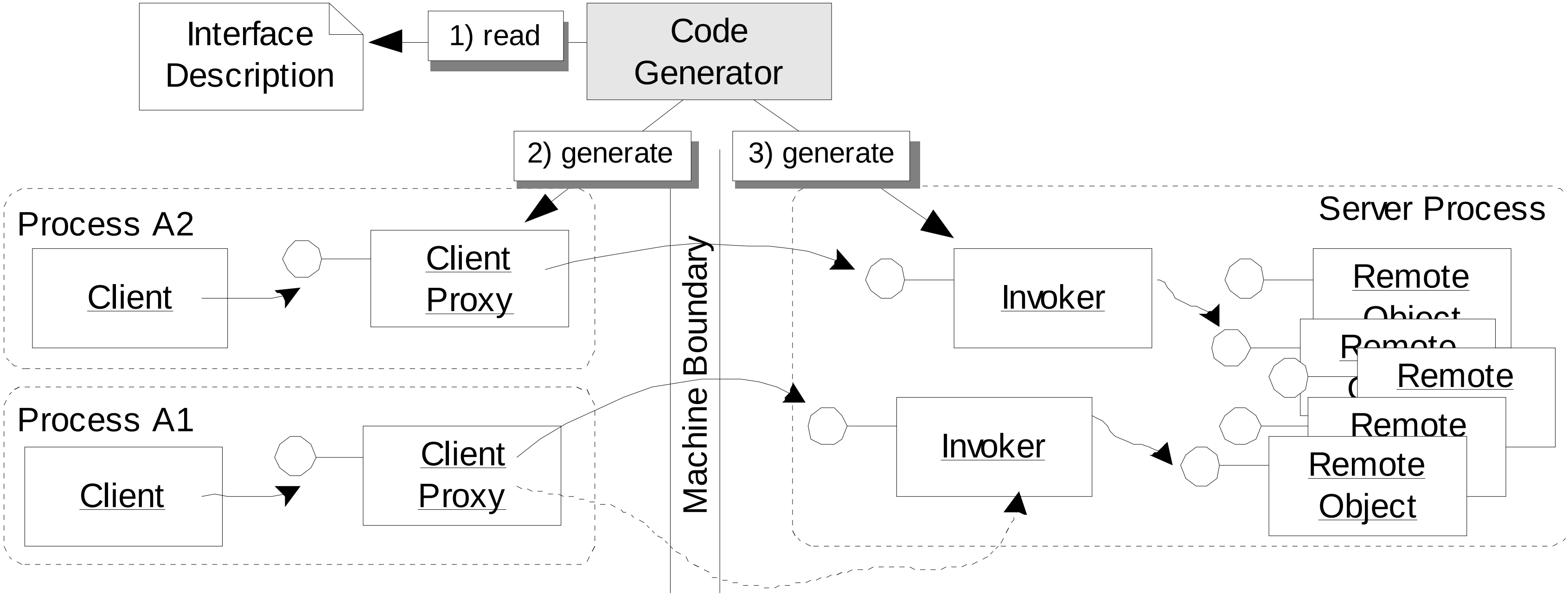
Pattern: Marshaller (2)



Pattern: Interface Description

- **Context:**
  - A client wants to invoke a remote object operation using a client proxy
- **Problem:**
  - Interfaces of client proxy and remote object need to be aligned
  - Marshalling and de-marshalling needs to be aligned
  - Client developers need to know the interfaces of the remote objects
- **Solution:**
  - Interface description describes the interface of remote objects
  - Interface description serves as the contract between client proxy and invoker
  - Client proxy and invoker use either code generation or runtime configuration techniques to adhere to that contract

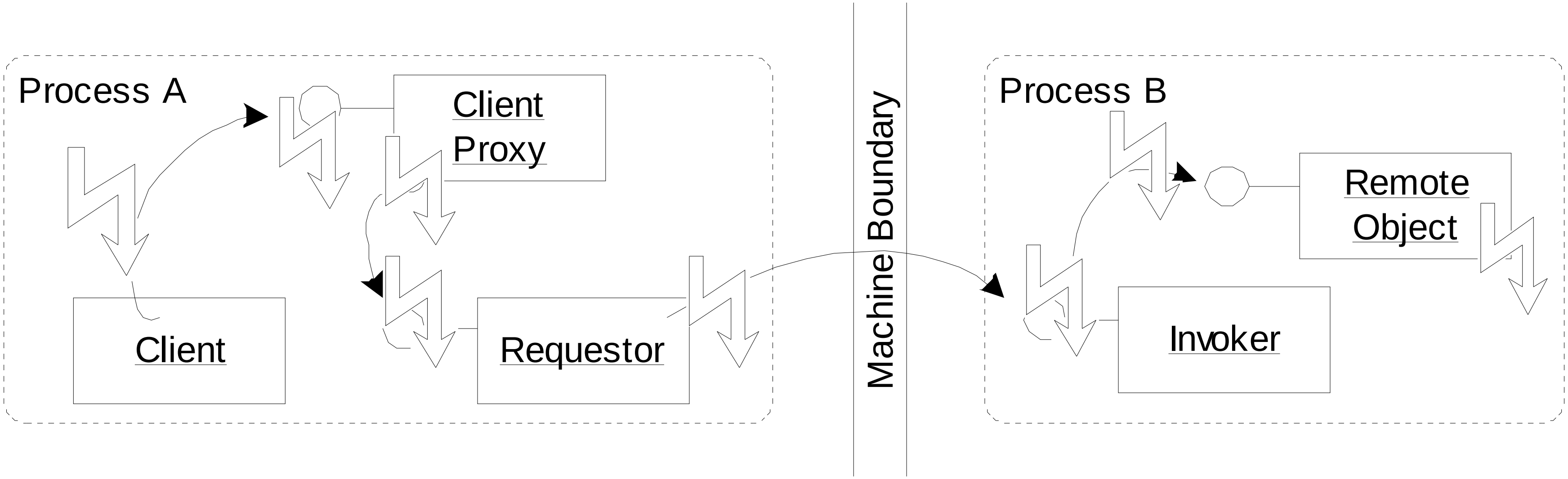
Pattern: Interface Description (2)



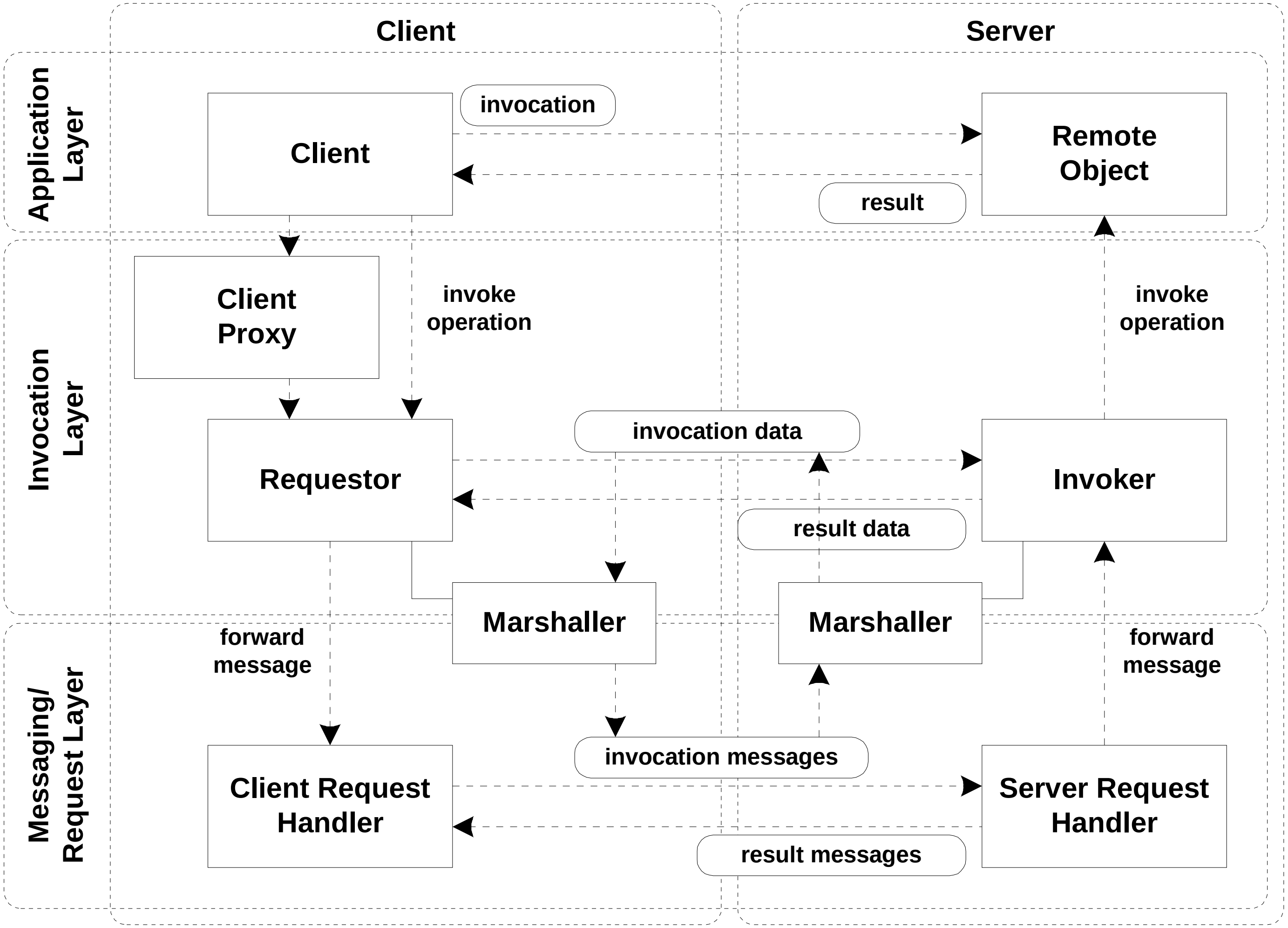
Pattern: Remoting Error

- **Context:**
  - Remote communication is inherently unreliable
- **Problem:**
  - Distributed invocations can never be completely transparent
  - Apart from errors in the remote object itself, new kinds of errors can occur, e.g.: network failures, server crashes, or unavailable objects
  - Clients need cope with such errors
- **Solution:**
  - Distinguish distribution-related errors and application-logic-related errors
  - Invoker, requestor, and request handlers detect and propagate remoting errors

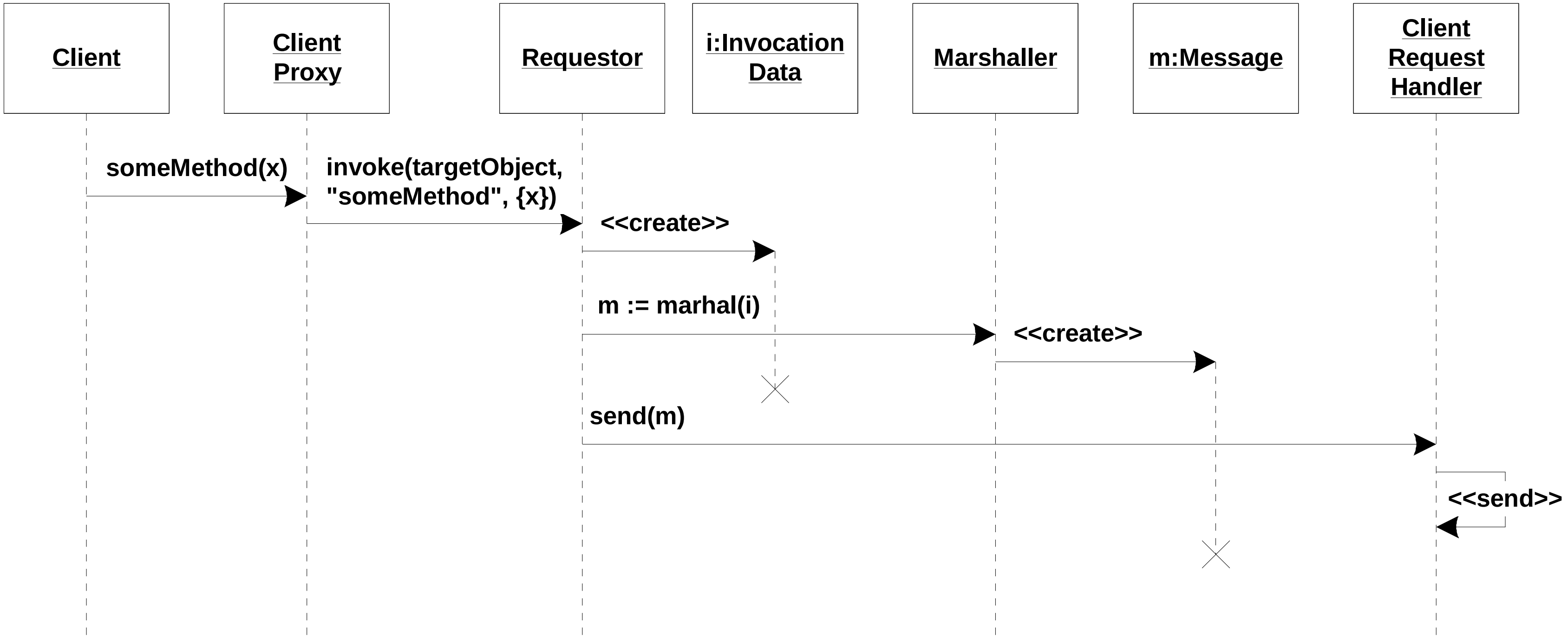
Pattern: Remoting Error (2)



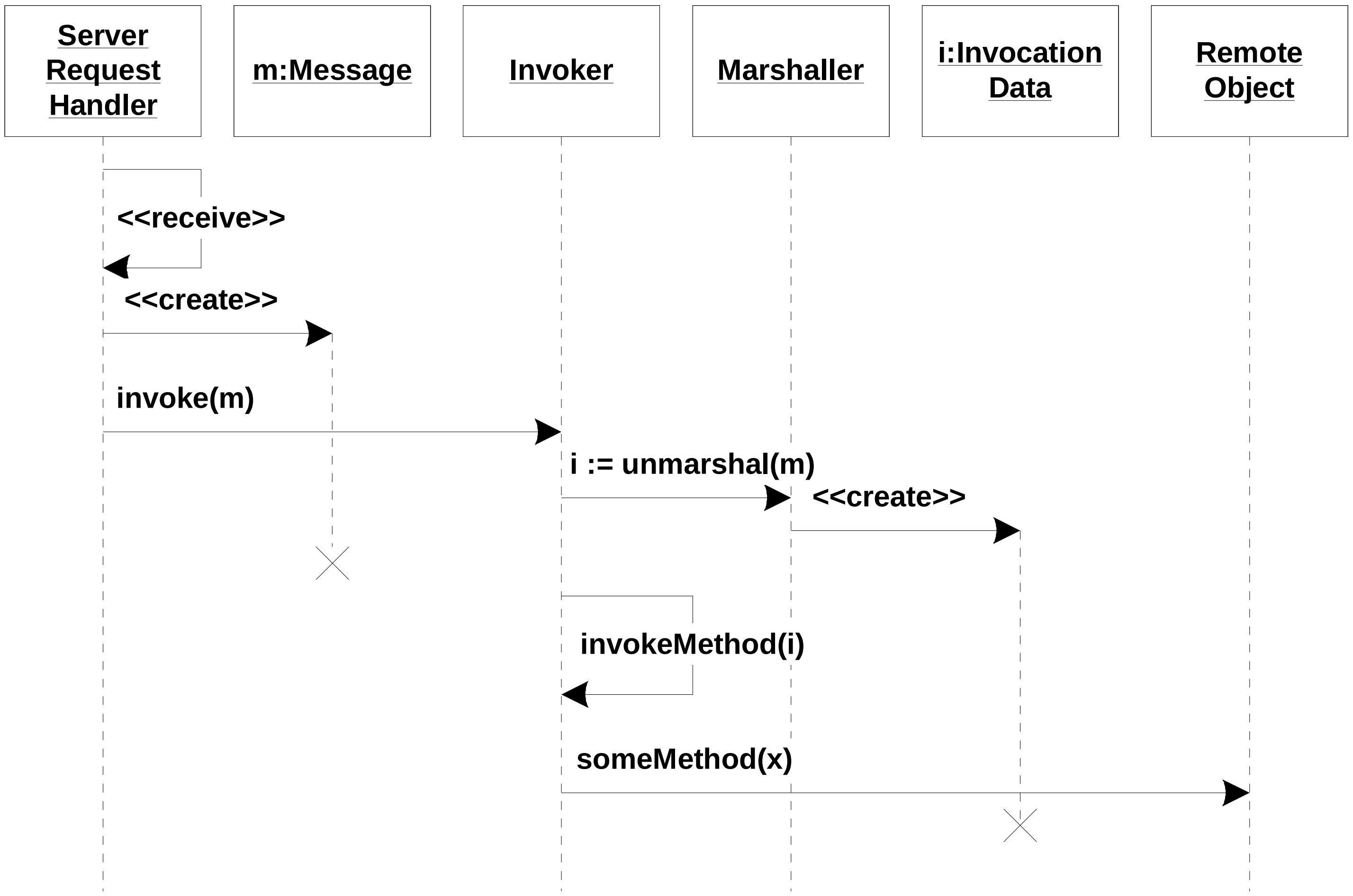
Interactions of the Patterns



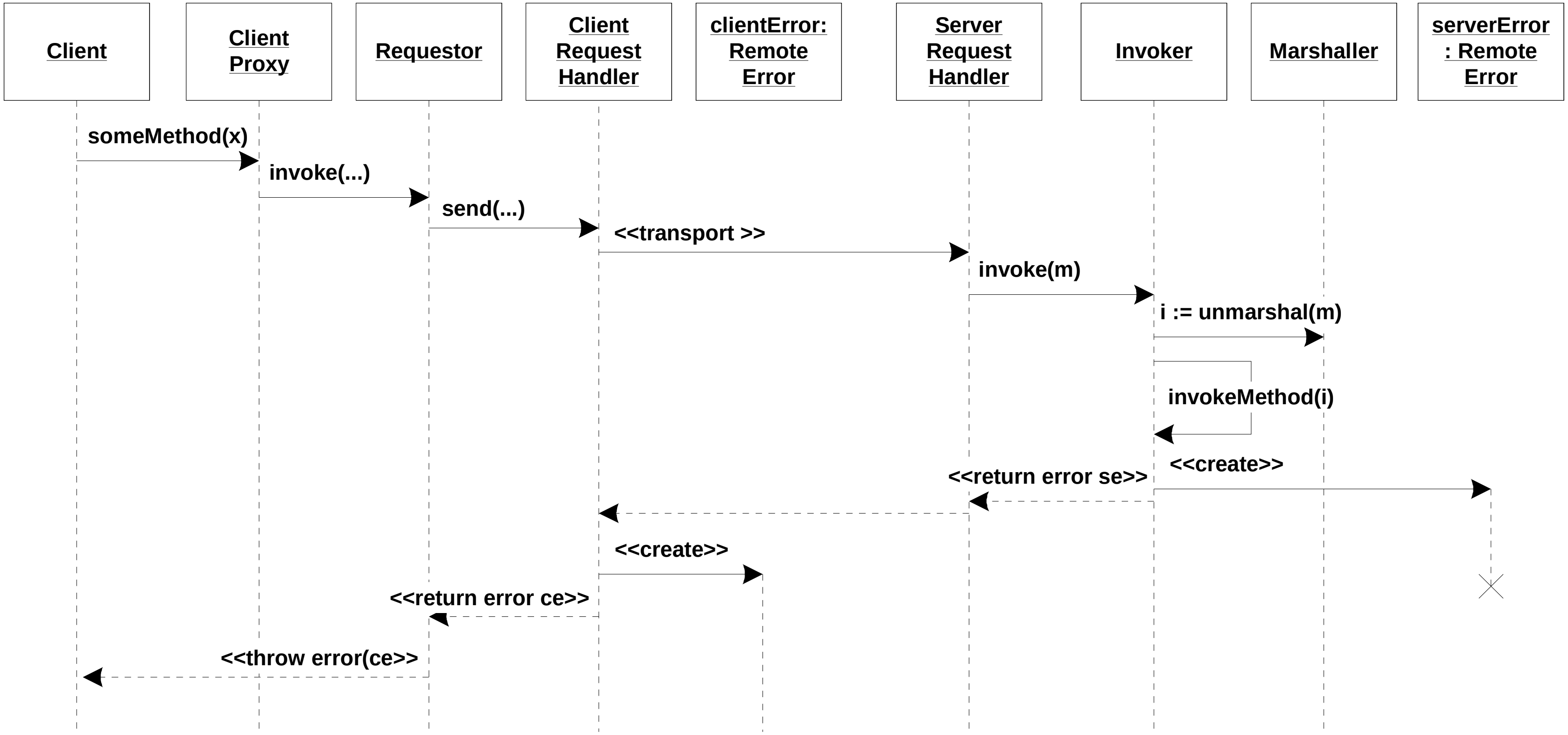
Interactions: Client-Side Invocation



Interactions: Server-Side Invocation

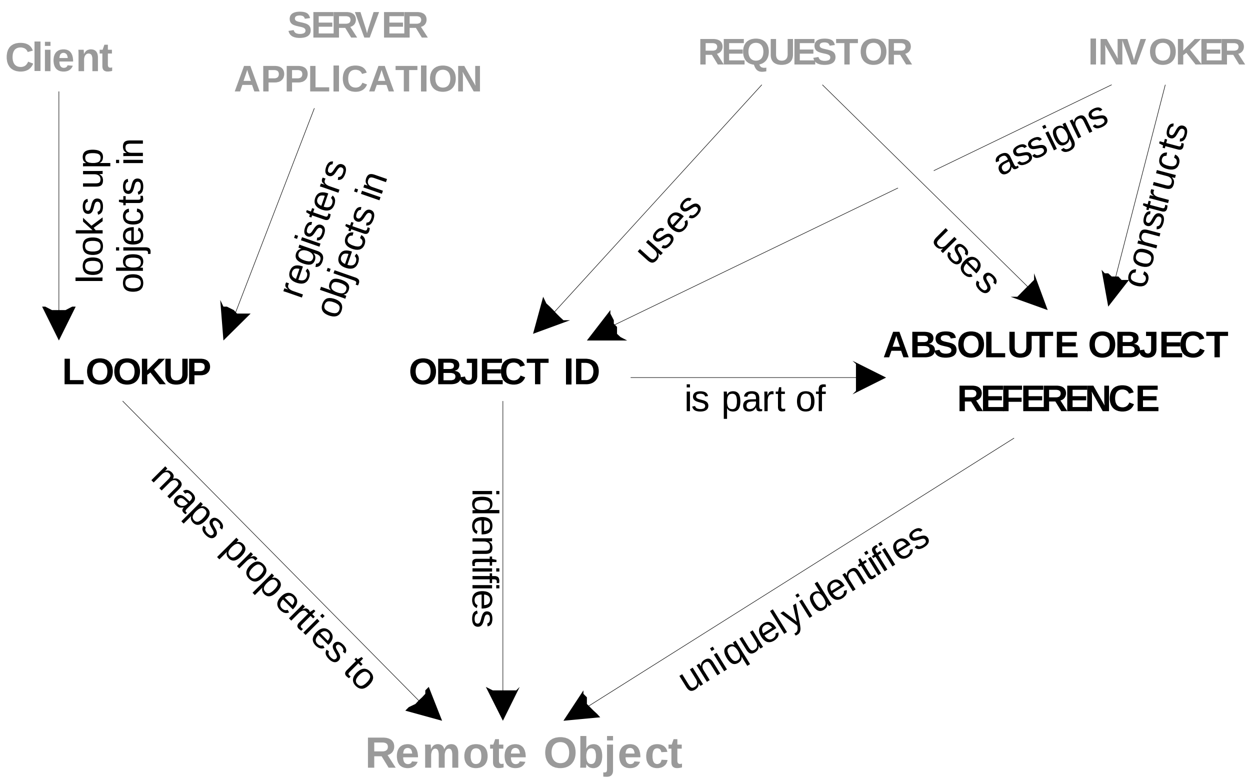


Interactions: Remoting Error Propagation



Identification Patterns

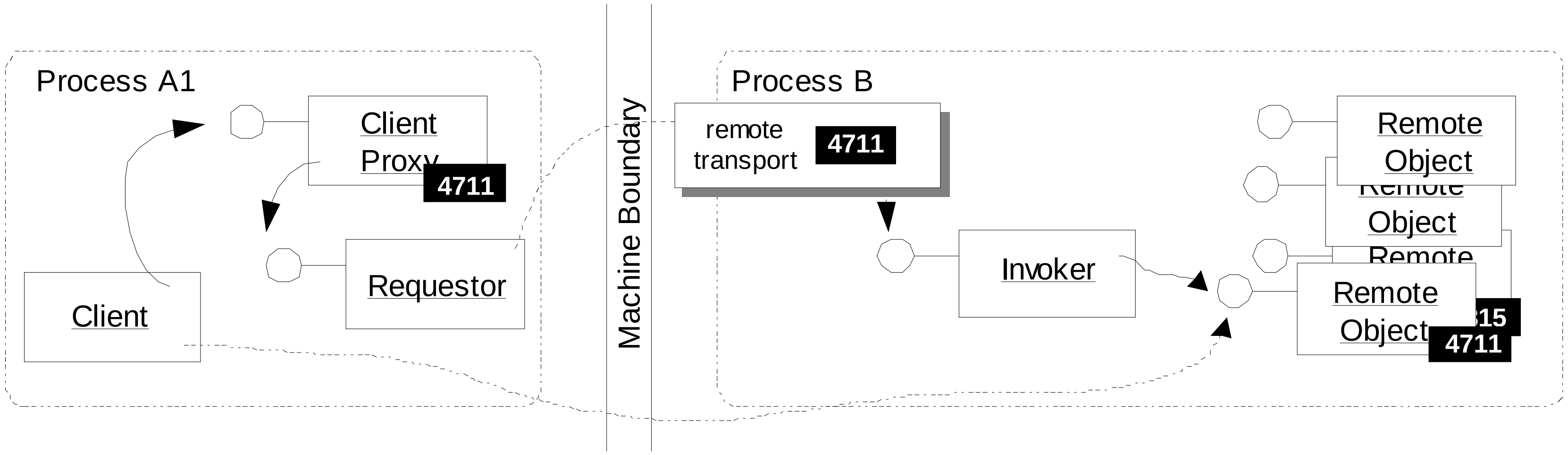
Identification Patterns



Pattern: Object ID

- **Context:**
  - The invoker has to select between registered remote objects to dispatch invocations
- **Problem:**
  - The invoker handles invocations for several remote objects
  - The invoker has to determine the remote object corresponding to a particular invocation.
- **Solution:**
  - Associate remote object instance with an object id that is unique in the context of the invoker
  - The client/client proxy have to provide the object id to the requestor

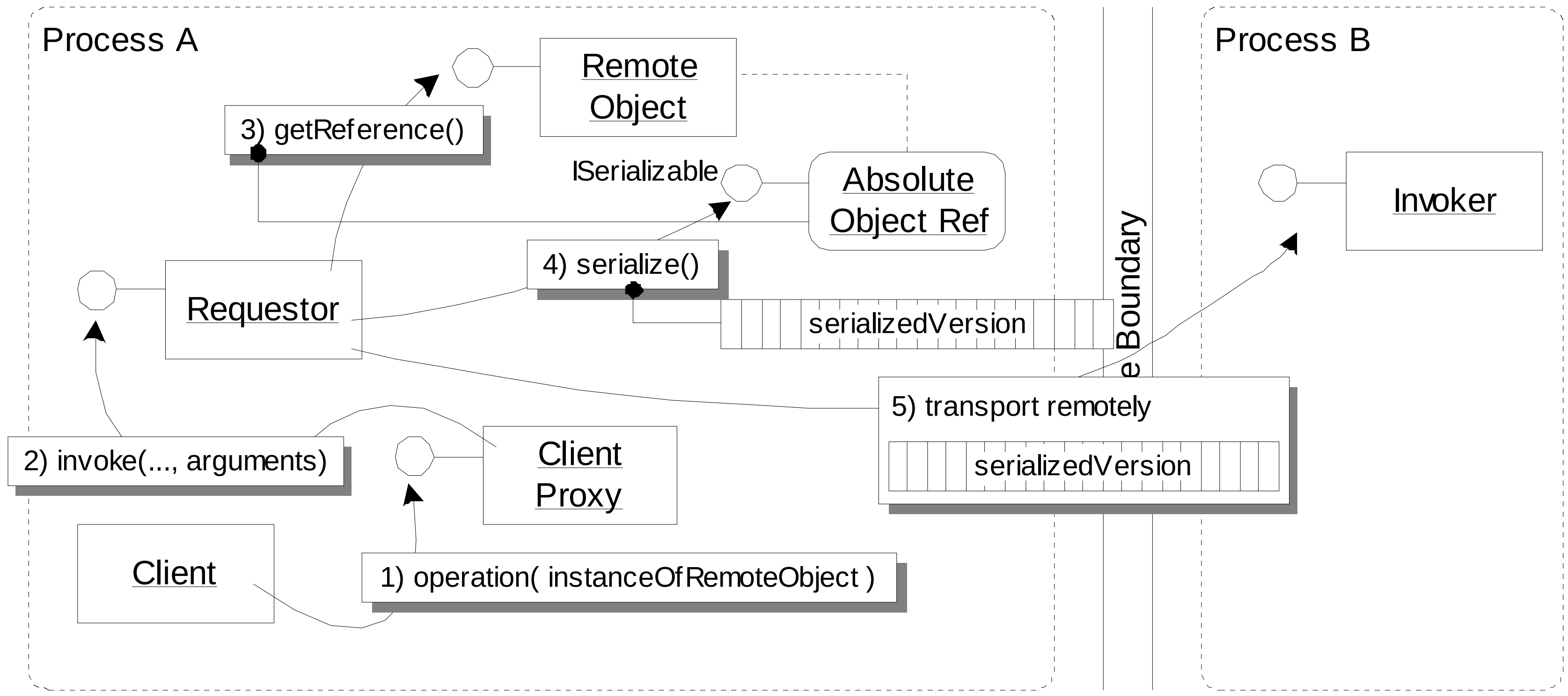
Pattern: Object ID (2)



Pattern: Absolute Object Reference

- **Context:**
  - The invoker uses Object IDs to dispatch the invocations
- **Problem:**
  - Object ID allows the invoker to dispatch the remote invocation to the correct target object
  - But first the invocation has to be delivered to the correct server request handler
- **Solution:**
  - Absolute object reference uniquely identifies invoker and remote object:
    - Endpoint information (host, port)
    - ID of the invoker
    - Object ID
  - Clients exchange references to remote objects by exchanging the absolute object references

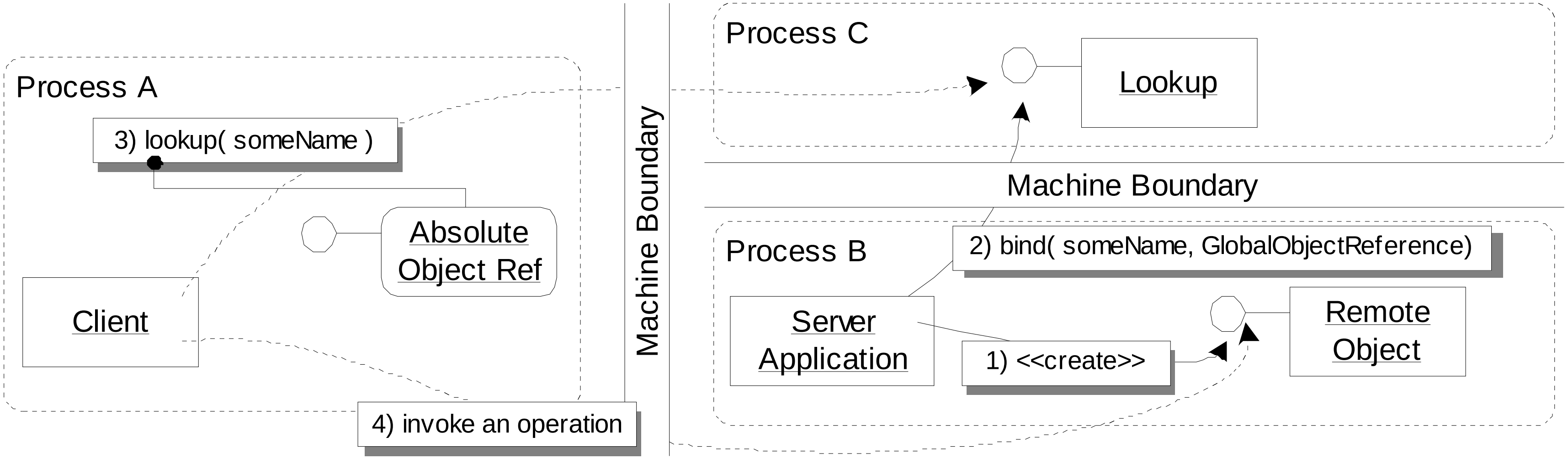
Pattern: Absolute Object Reference (2)



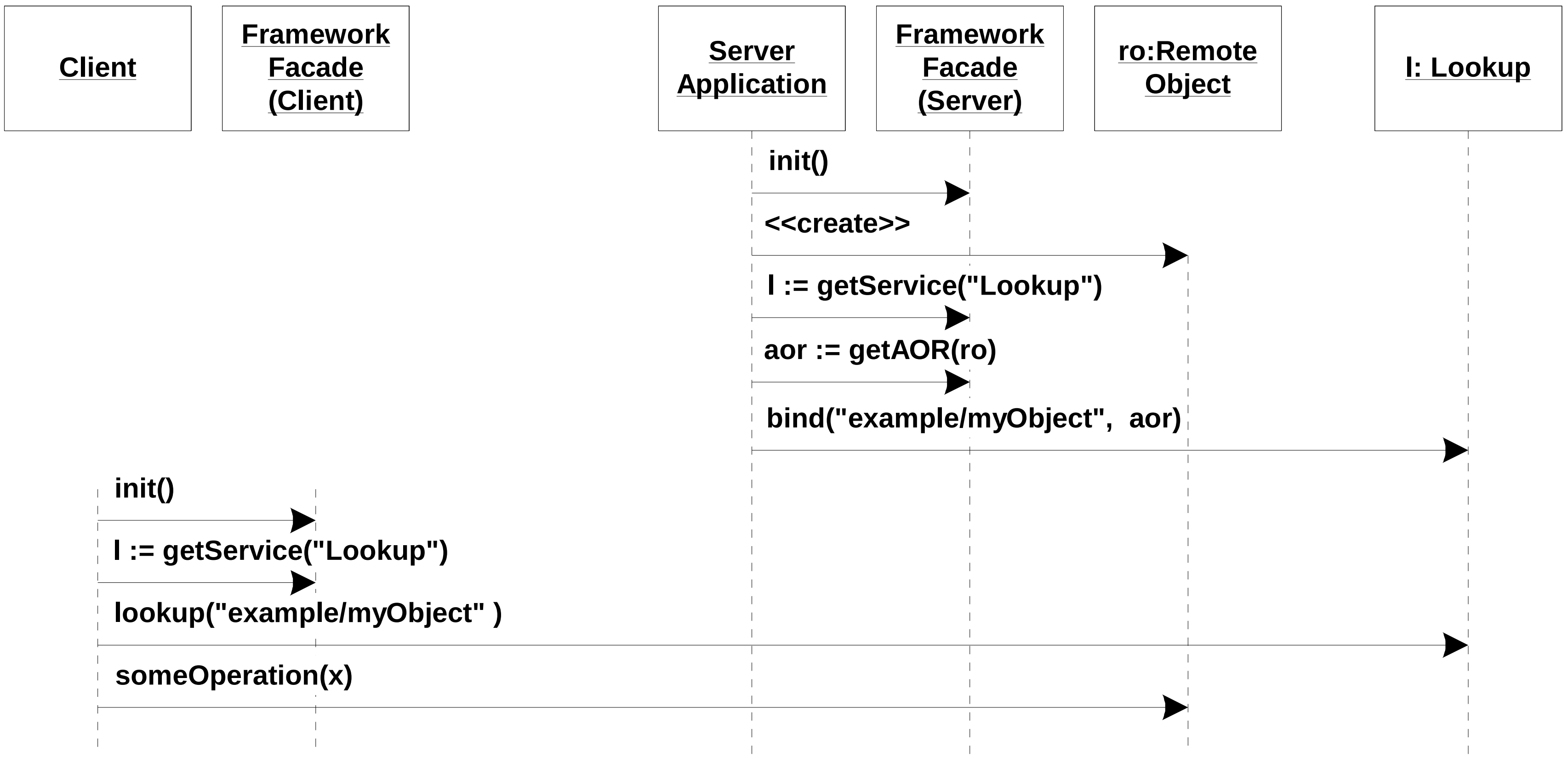
Pattern: Lookup

- **Context:**
  - Client applications want to use services provided by remote objects
- **Problem:**
  - Client has to obtain the absolute object references of the remote object
  - This remote object might change:
    - Serving instance changes
    - Location changes
    - Server restart
- **Solution:**
  - Lookup service is part of the distributed object framework
  - Server applications register references to remote objects
  - References are associated with properties (e.g. names)

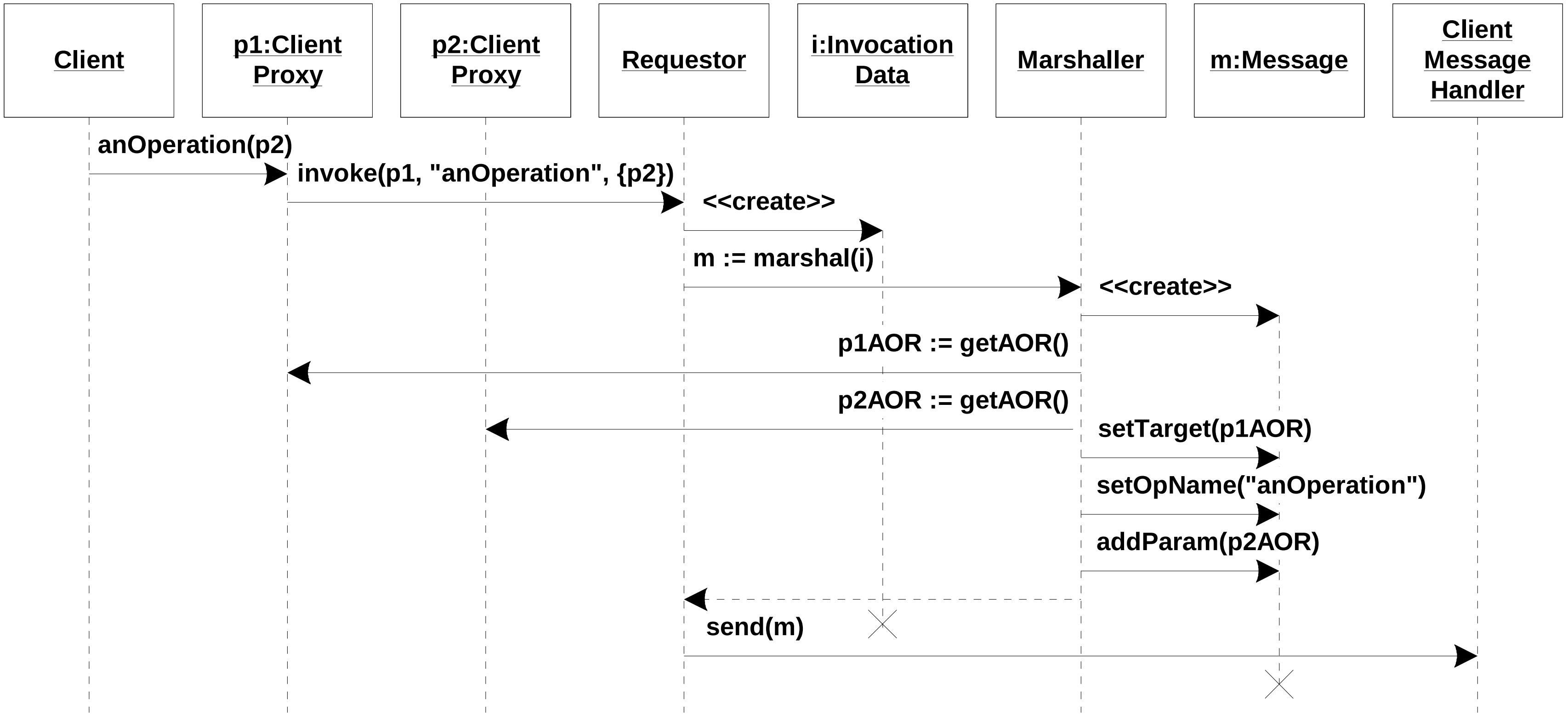
Pattern: Lookup (2)



Interactions: Registration in Lookup

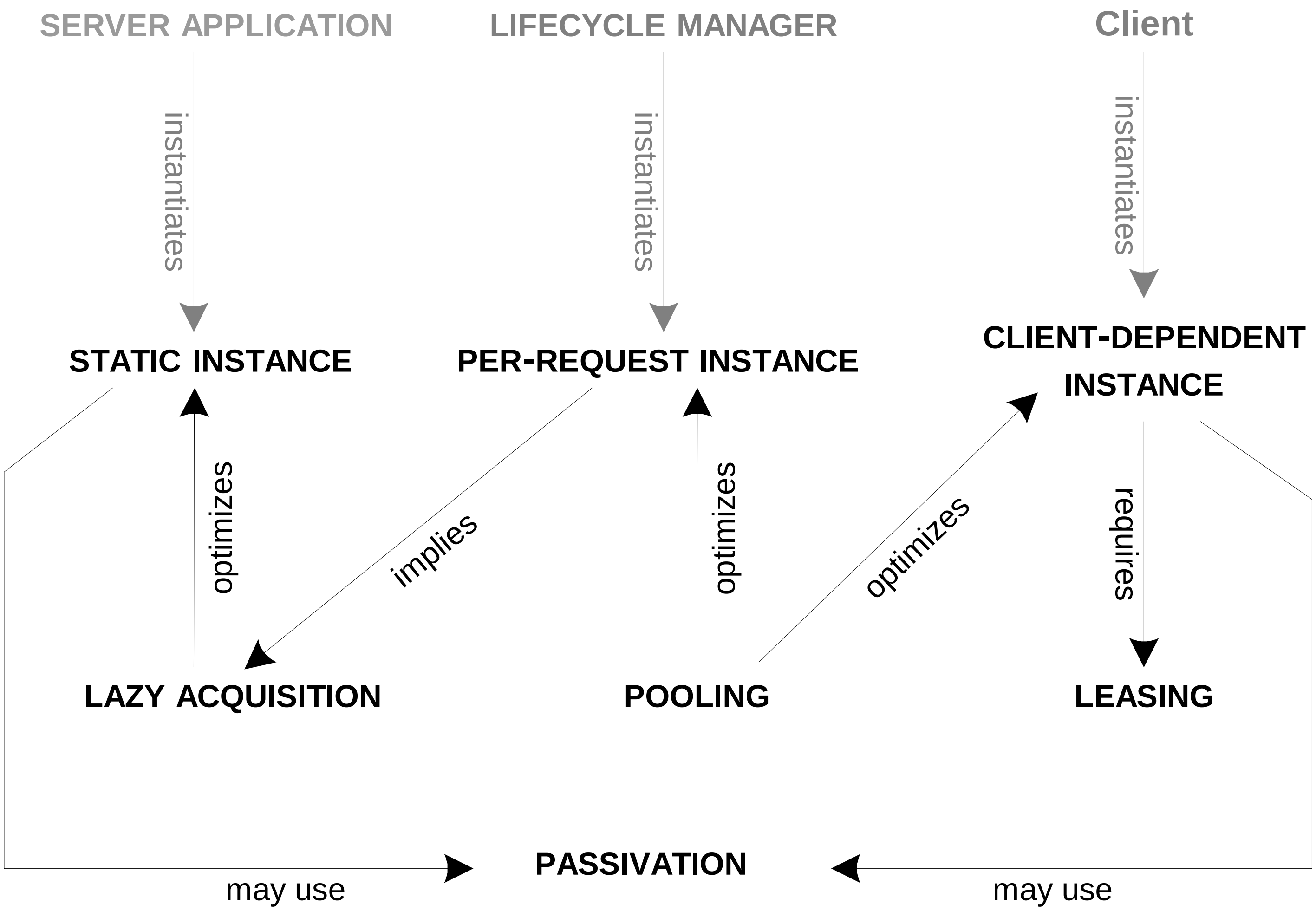

Client
Framework Facade (Client)
Server Application
Framework Facade (Server)
ro:Remote Object
l: Lookup
init()
<<create>>
l := getService("Lookup")
aor := getAOR(ro)
bind("example/myObject", aor)
init()
l := getService("Lookup")
lookup("example/myObject")
someOperation(x)

Interactions: Marshalling of Absolute Object References



Lifecycle Management Patterns

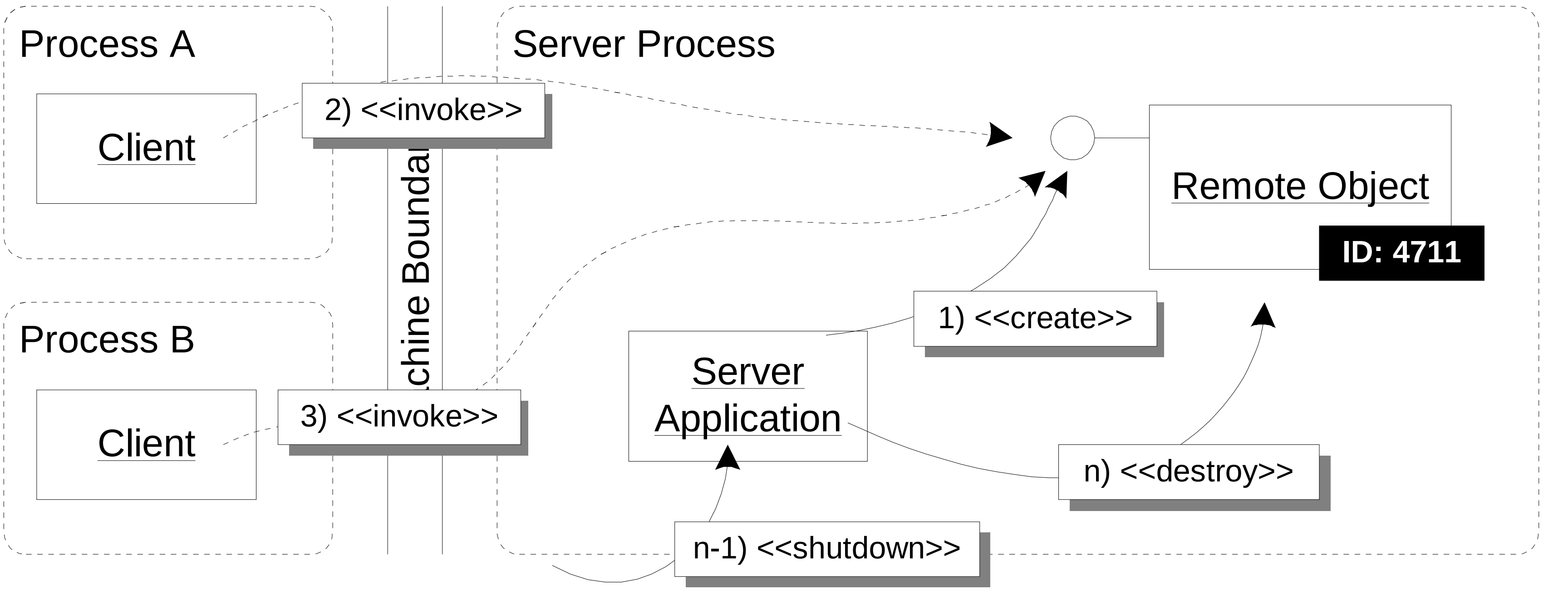
Lifecycle Management Patterns



Pattern: Static Instance

- **Context:**
  - Remote object offers a service that is independent of specific clients
- **Problem:**
  - Fixed number of previously known remote objects instances
  - Remote objects must be available for a long period
  - No predetermined expiration timeout
  - Remote object’s state must not be lost between individual invocations
- **Solution:**
  - Static instances are independent of the client’s state and lifecycle
  - Activated before any client’s usage, typically during application startup
  - Instances are registered in lookup after their activation

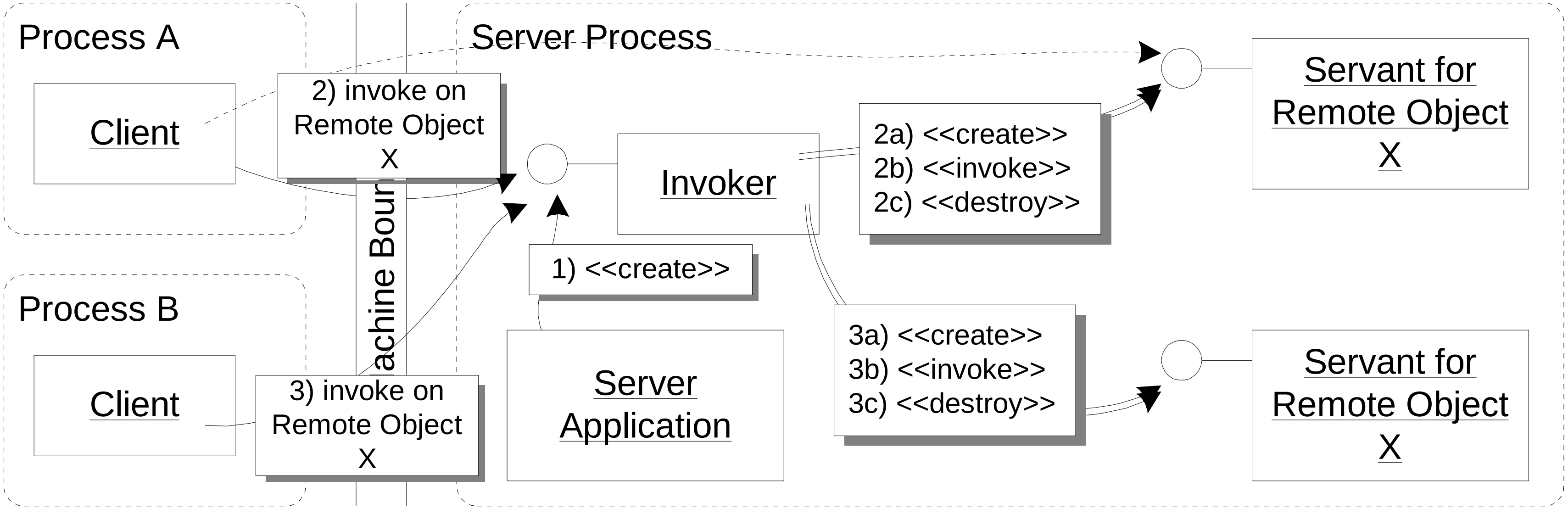
Pattern: Static Instance (2)



Pattern: Per-Request Instance

- **Context:**
  - Remote objects are stateless
- **Problem:**
  - Remote objects that are accessed by a large number of clients
  - Application needs to be scalable
  - Performance might decrease dramatically because of synchronization overhead
- **Solution:**
  - Let the distributed object framework instantiate a new servant for each invocation
  - Servant handles the request, returns the results, and is then deactivated again

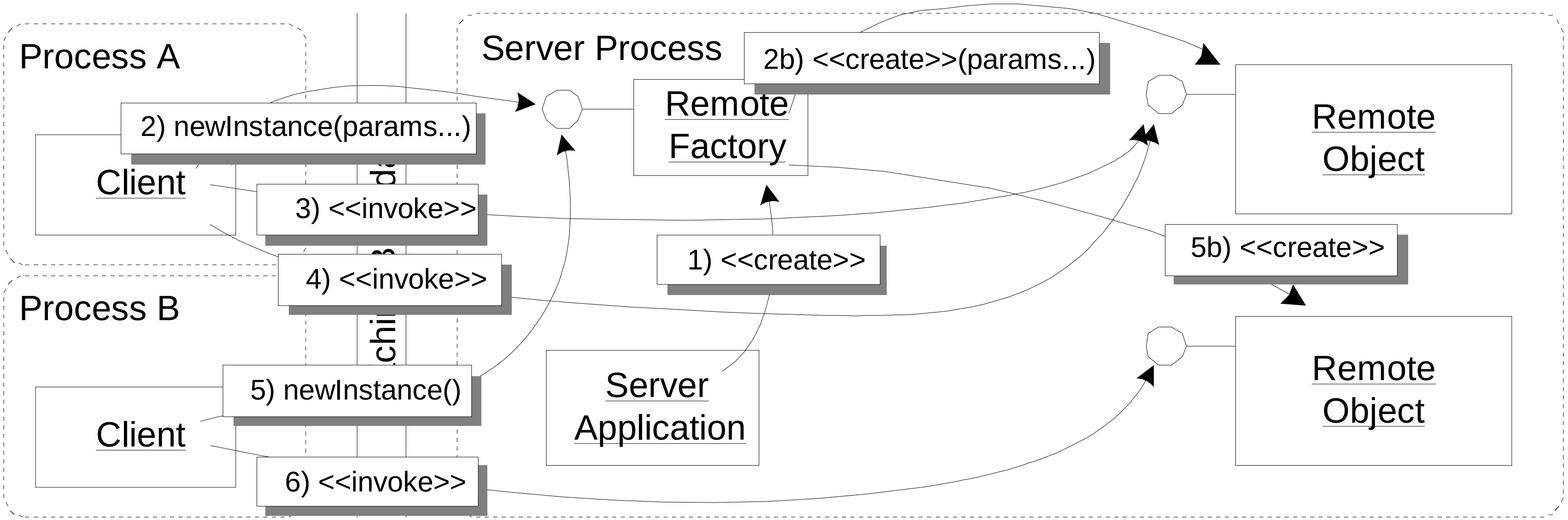
Pattern: Per-Request Instance (2)



Pattern: Client-Dependent Instance

- **Context:**
  - Clients use services provided by remote objects
- **Problem:**
  - Remote object extends application logic of the client
  - Where to put the common state of both?
- **Solution:**
  - Provide remote objects whose lifetime is controlled by clients
    - Creation
    - Destruction
  - The client can consider the state of this instance to be private

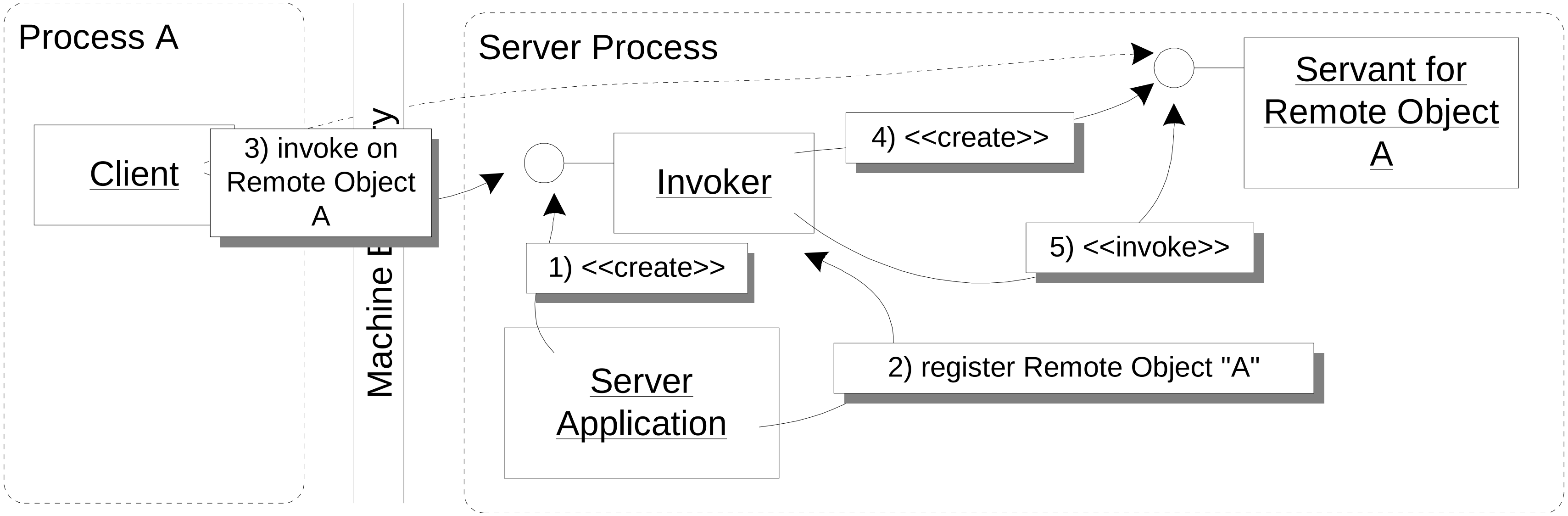
Pattern: Client-Dependent Instance (2)



Pattern: Lazy Acquisition

- **Context:**
  - Static instances must be efficiently managed
- **Problem:**
  - Creating servants for all remote objects during server application startup can result in waste of resources
  - Instantiating all servants during server application startup leads to long startup times
- **Solution:**
  - Instantiate servants when they are invoked by clients
  - Let clients assume that remote objects are always available
  - Invoker triggers the lifecycle manager to lazily instantiate the servant

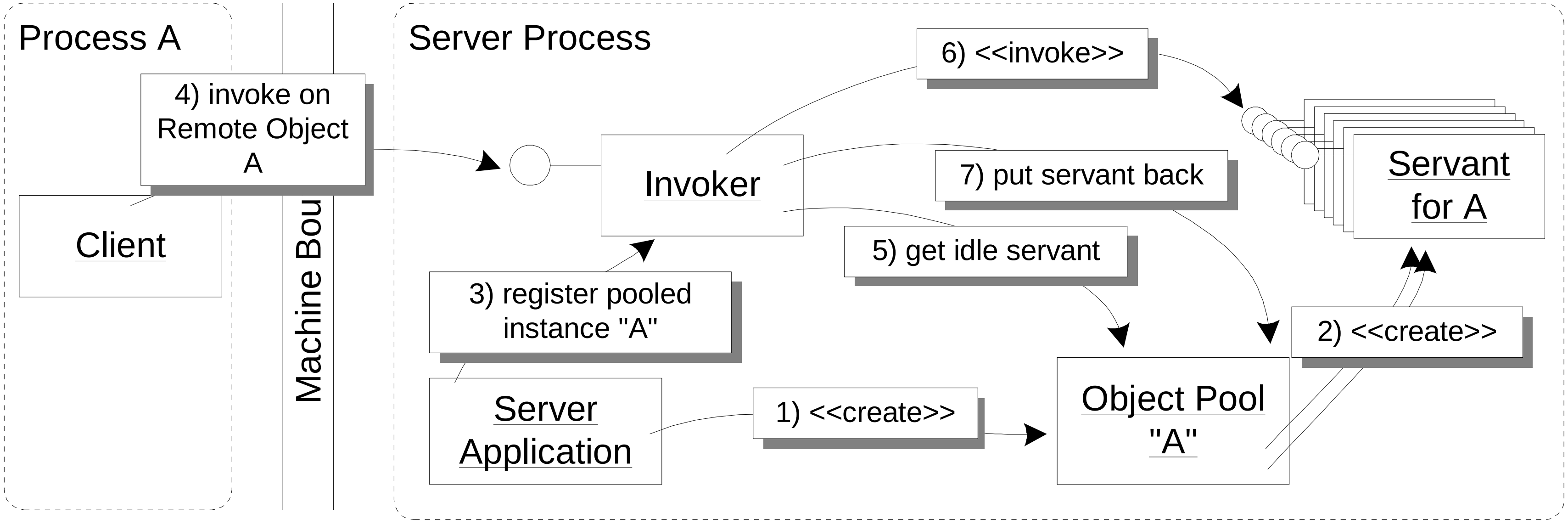
Pattern: Lazy Acquisition (2)



Pattern: Pooling

- **Context:**
  - Every remote object instance consumes server application resources
- **Problem:**
  - Instantiating and destroying servants causes a lot of overhead:
    - memory allocation
    - initializations
    - servants have to be registered with the middleware
- **Solution:**
  - Introduce a pool of servants for each remote object type
  - When an invocation arrives:
    - Take a servant from the pool
    - Initialize servant
    - Handle the request
    - Put it back to the pool

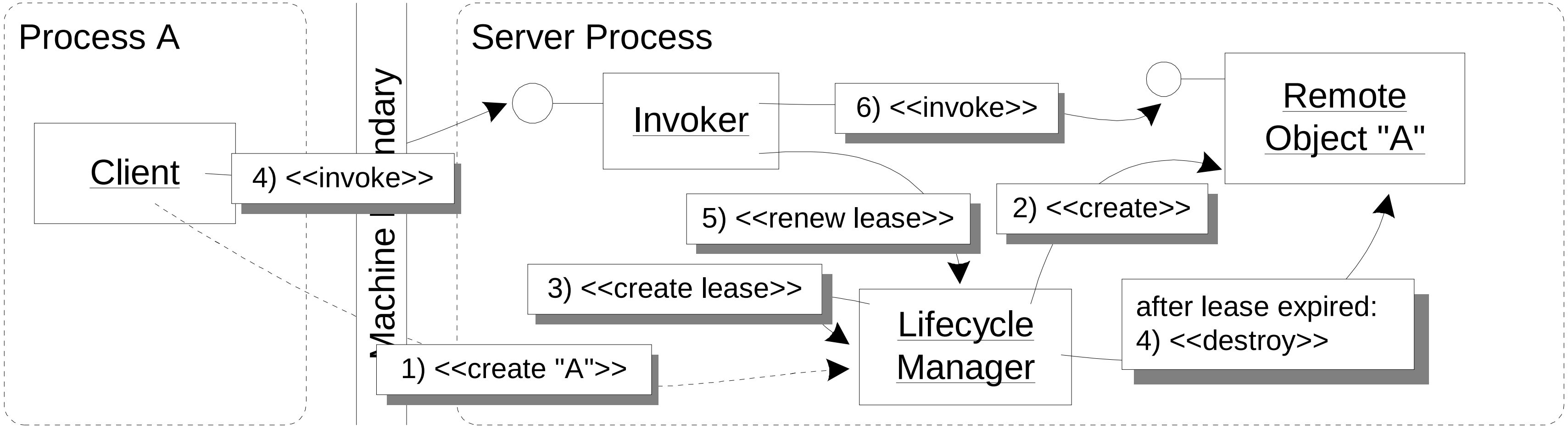
Pattern: Pooling (2)



Pattern: Leasing

- **Context:**
  - Clients use server application resources
- **Problem:**
  - Resources no longer needed should be released
  - The lifecycle manager cannot determine when a particular remote object is not used anymore
- **Solution:**
  - Associate each client’s use of a remote object with a lease
  - When the lease (or all leases) expire(s), the servant is destroyed by the lifecycle manager
  - Client can renew the lease
    - Call operation
    - Explicit renewal

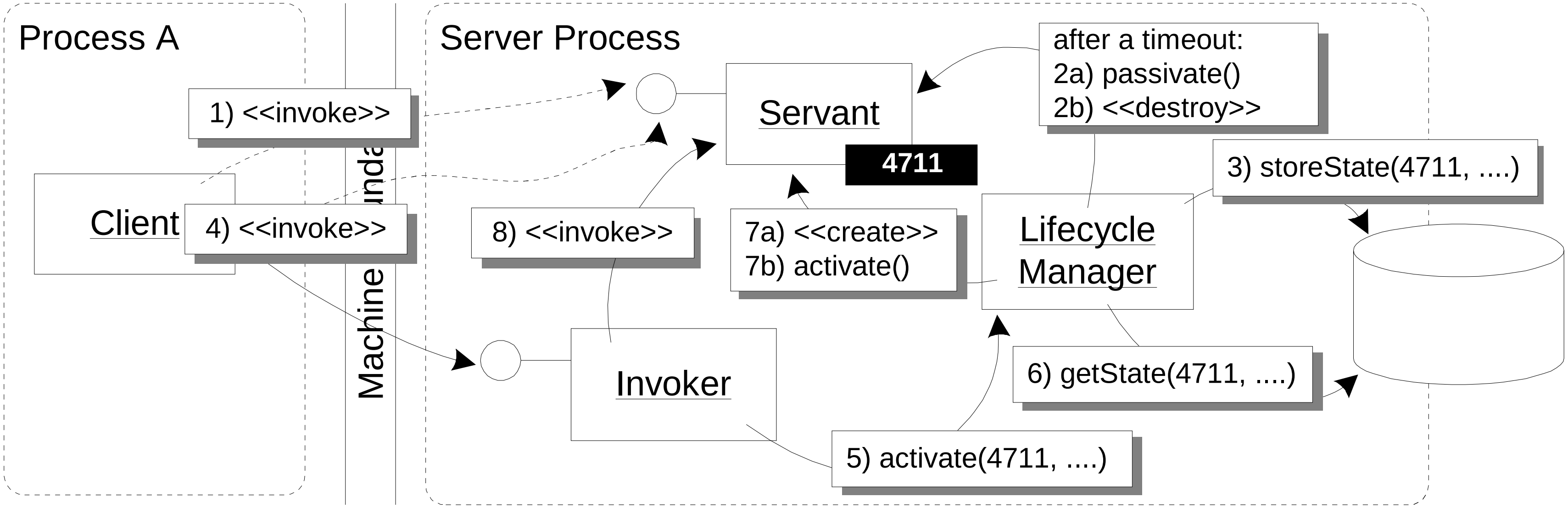
Pattern: Leasing (2)



Pattern: Passivation

- **Context:**
  - The server application provides stateful remote objects
- **Problem:**
  - Remote objects may not be accessed by a client for a long time
  - Still their servants occupy server resources
  - Problems regarding performance and stability
- **Solution:**
  - Passivation:
    - Make remote objects – not accessed for a while – persistent
    - Then remove the unused servant from memory
  - Lifecycle Manager reactivates the object again upon the next invocation

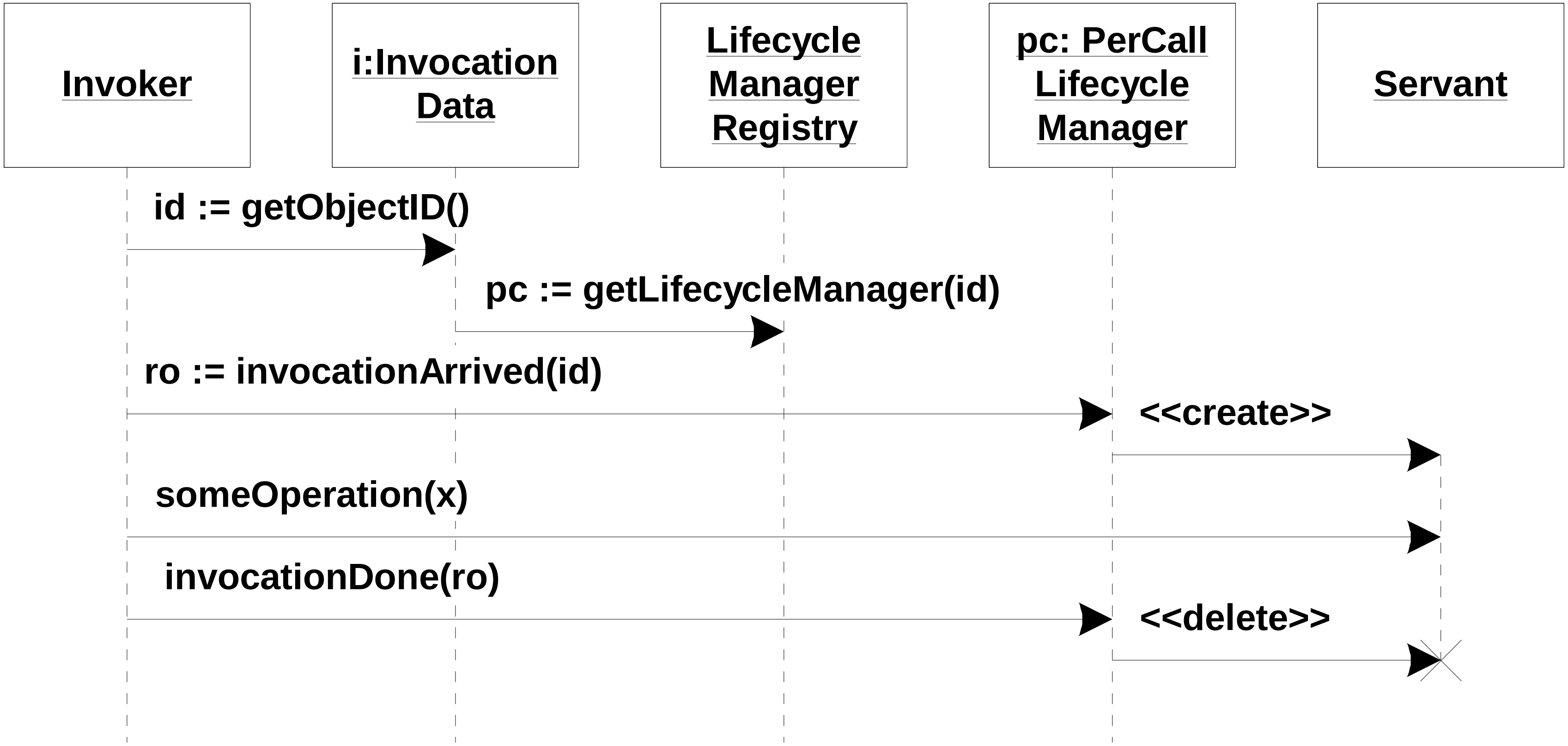
Pattern: Passivation (2)



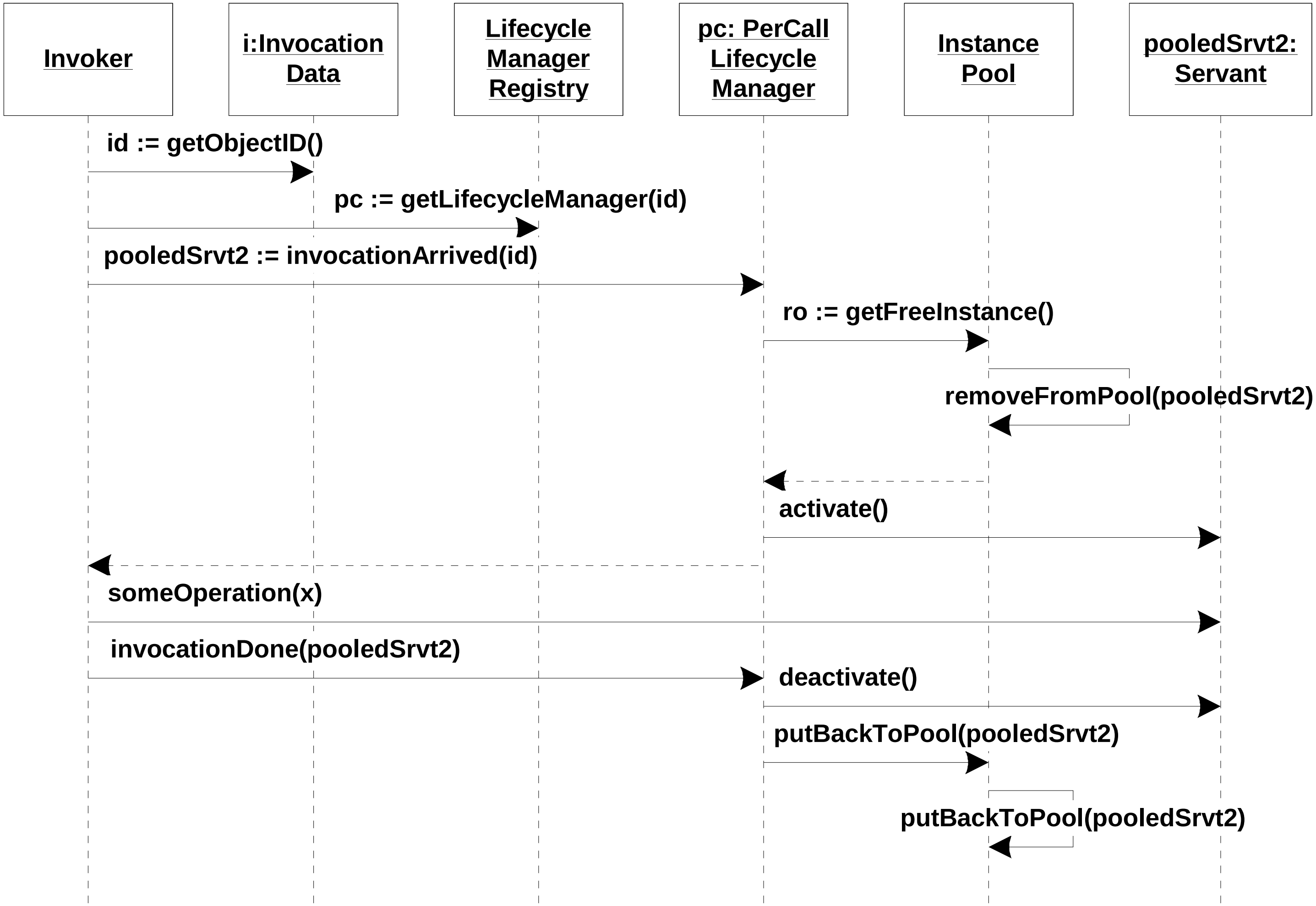
Interactions among the Patterns

	Static instance	Per-request instance	Client-dependent instance
Lazy acquisition	useful	implicitly useful	implicitly useful
Pooling	not useful	very useful	useful
Leasing	sometimes useful	not useful	very useful
Passivation	sometimes useful	not useful	very useful

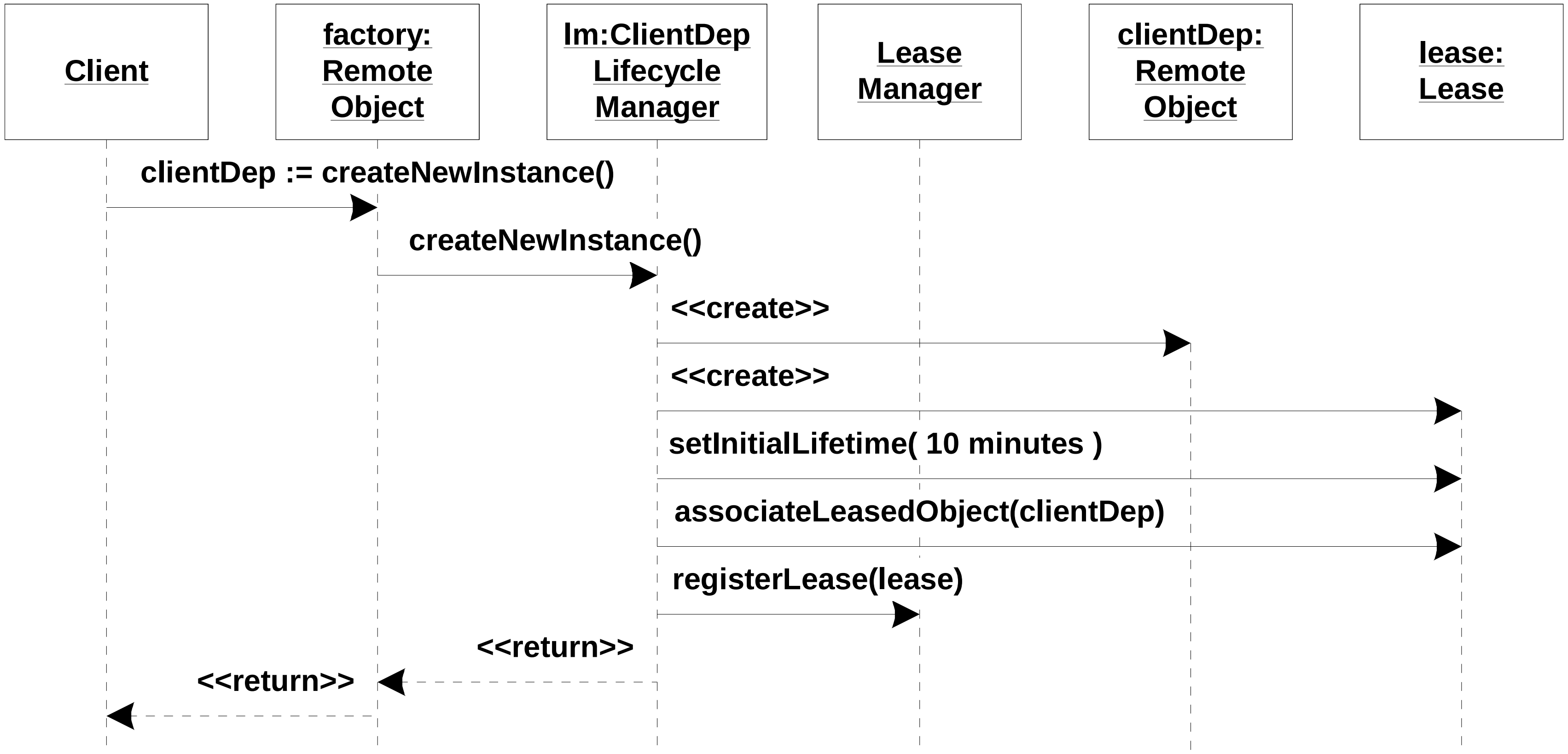
Interactions: Per-Request Instance


Invoker
i:Invocation Data
Lifecycle Manager Registry
pc: PerCall Lifecycle Manager
Servant
id := getObjectID()
pc := getLifecycleManager(id)
ro := invocationArrived(id)
<<create>>
someOperation(x)
invocationDone(ro)
<<delete>>

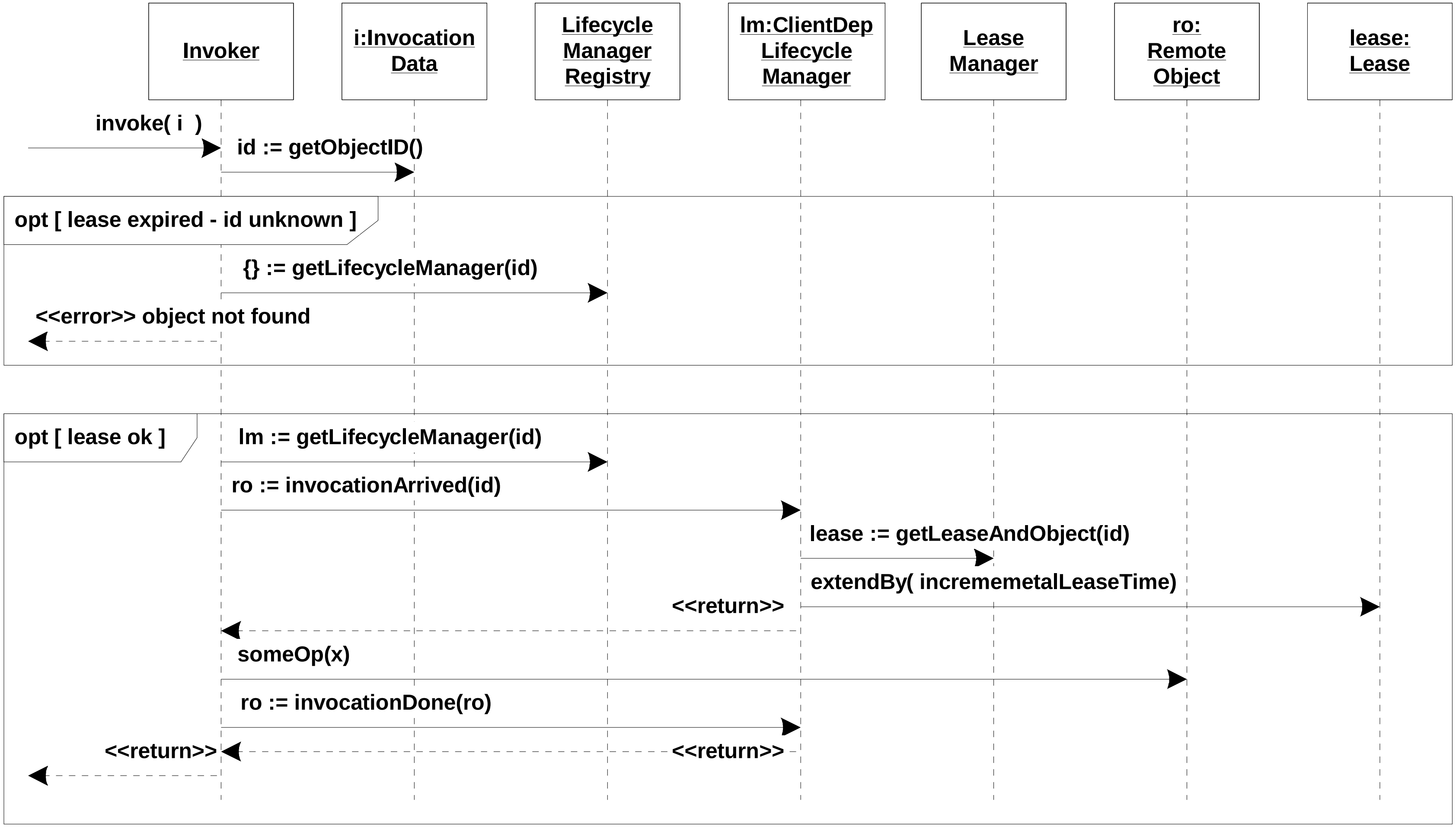
Interactions: Pooled Per-Request Instance


Invoker
i:Invocation Data
Lifecycle Manager Registry
pc: PerCall Lifecycle Manager
Instance Pool
pooledSrvt2: Servant
id := getObjectID()
pc := getLifecycleManager(id)
pooledSrvt2 := invocationArrived(id)
ro := getFreeInstance()
removeFromPool(pooledSrvt2)
activate()
someOperation(x)
invocationDone(pooledSrvt2)
deactivate()
putBackToPool(pooledSrvt2)
putBackToPool(pooledSrvt2)

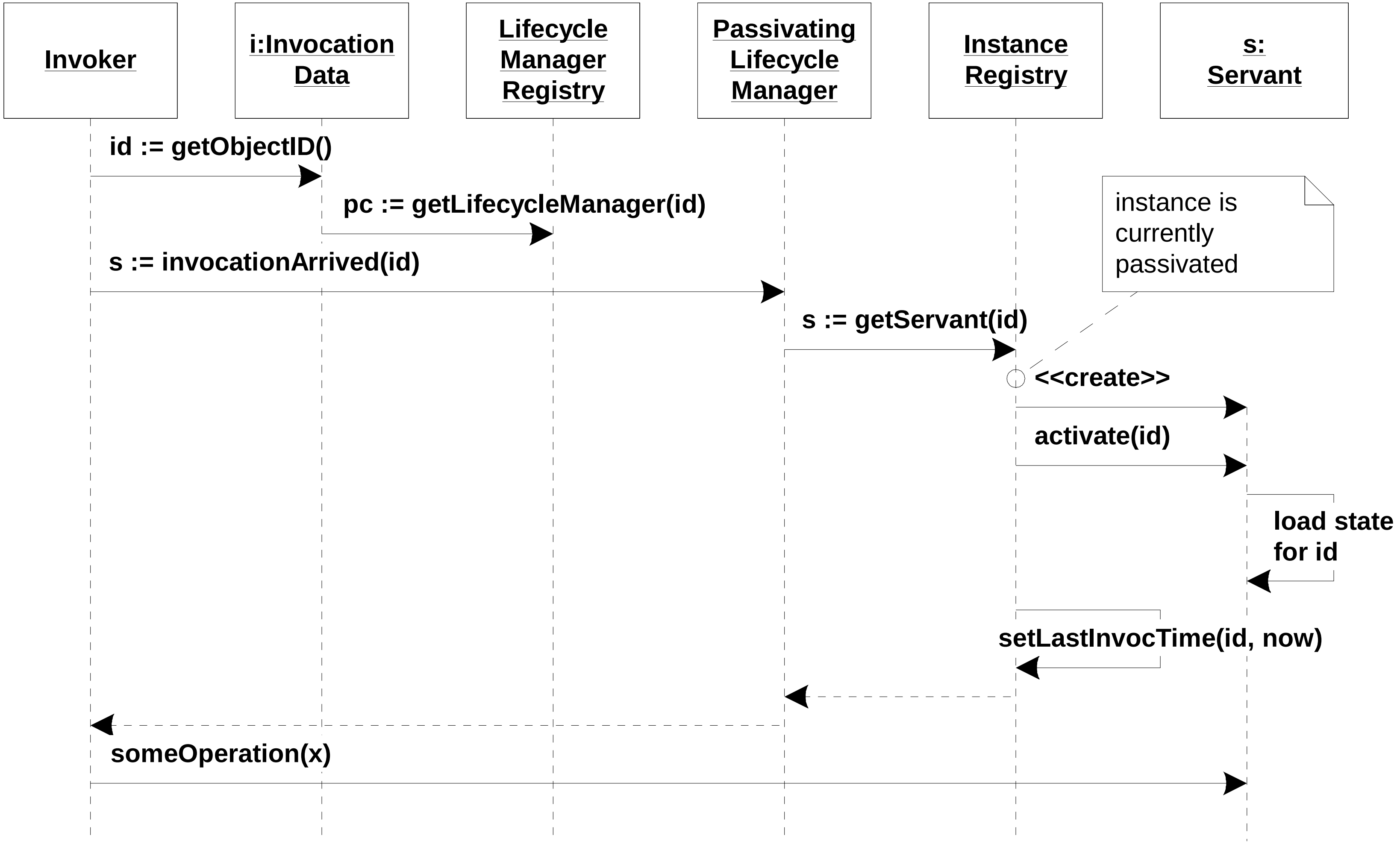
Interactions: Leased Creation



Interactions: Lease expires & Lease ok

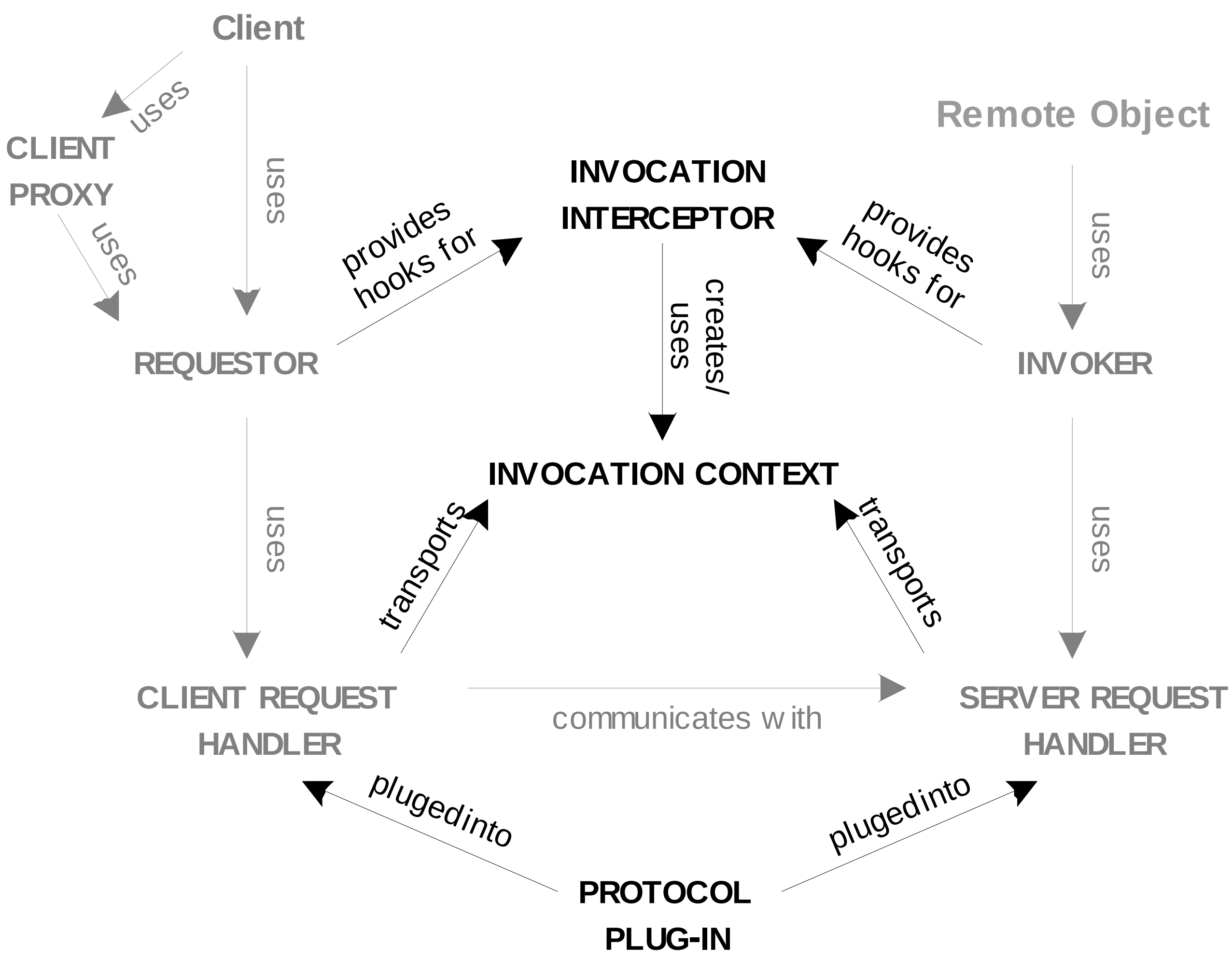

Invoker
i:Invocation Data
Lifecycle Manager Registry
lm:ClientDep Lifecycle Manager
Lease Manager
ro: Remote Object
lease: Lease
invoke(i)
id := getObjectID()
opt [lease expired - id unknown]
{} := getLifecycleManager(id)
<<error>> object not found
opt [lease ok]
lm := getLifecycleManager(id)
ro := invocationArrived(id)
lease := getLeaseAndObject(id)
extendBy(incremementalLeaseTime)
<<return>>
someOp(x)
ro := invocationDone(ro)
<<return>>
<<return>>

Interactions: Passivation


Invoker
i:Invocation Data
Lifecycle Manager Registry
Passivating Lifecycle Manager
Instance Registry
s: Servant
id := getObjectID()
pc := getLifecycleManager(id)
s := invocationArrived(id)
instance is currently passivated
s := getServant(id)
<<create>>
activate(id)
load state for id
setLastInvocTime(id, now)
someOperation(x)

Extension Patterns

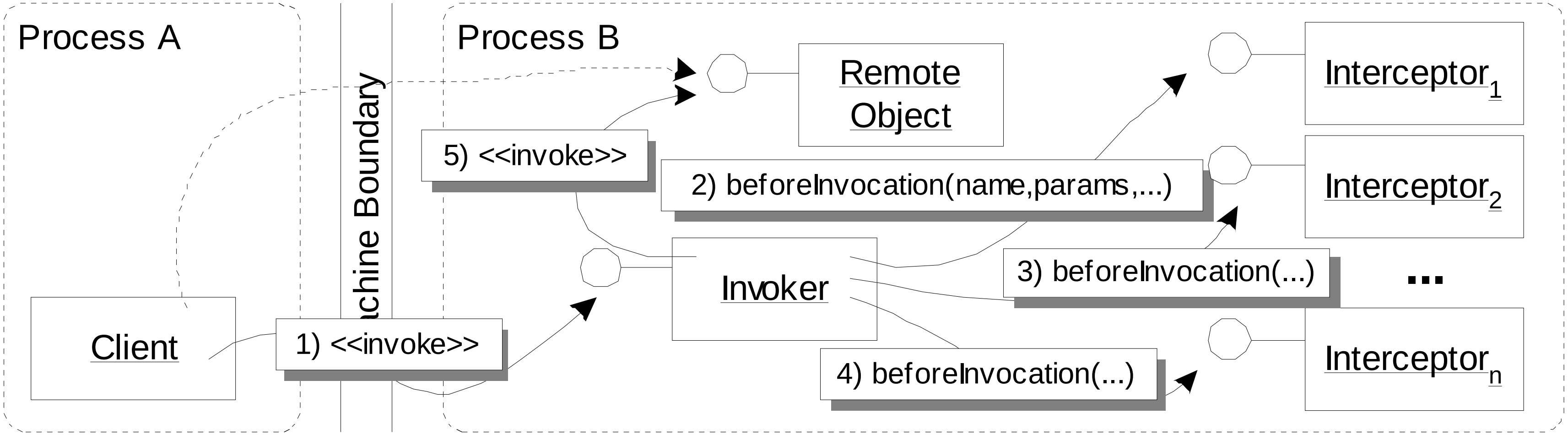
Extension Patterns



Pattern: Invocation Interceptor

- **Context:**
  - Applications need to transparently integrate add-on services
- **Problem:**
  - Client and server application have to provide add-on services, e.g.:
    - Transactions
    - Logging
    - Security
  - The clients and remote objects should be independent of add-ons
- **Solution:**
  - Hooks in the invocation path to plug in invocation interceptors
  - Invocation interceptors are invoked before and after each request and response message
  - Provide the interceptor with operation name, parameters, object id, and invocation context

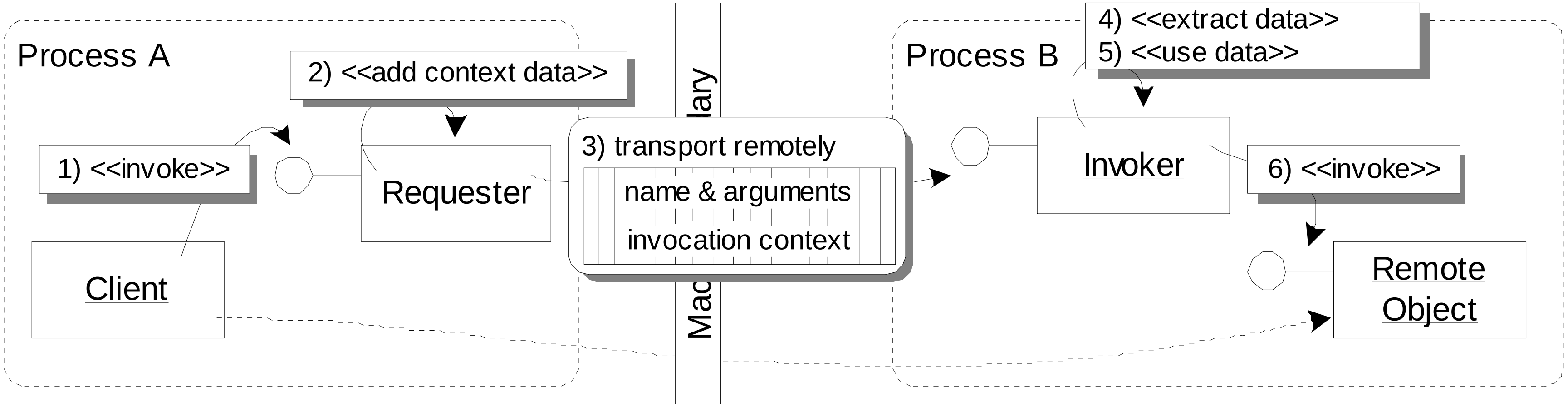
Pattern: Invocation Interceptor (2)



Pattern: Invocation Context

- **Context:**
  - Add-on services are plugged into the distributed object framework
- **Problem:**
  - Remote invocations only contain the necessary information, such as operation name, object id, and parameters
  - Invocation interceptors often need additional information in order to properly provide add-on services
  - Changing operation signatures for other reasons than business logic is tedious and error-prone
- **Solution:**
  - Bundle contextual information in an extensible invocation context
  - Invocation context is transferred between client and remote object with every remote invocation
  - Invocation interceptors can be used to add and consume this information

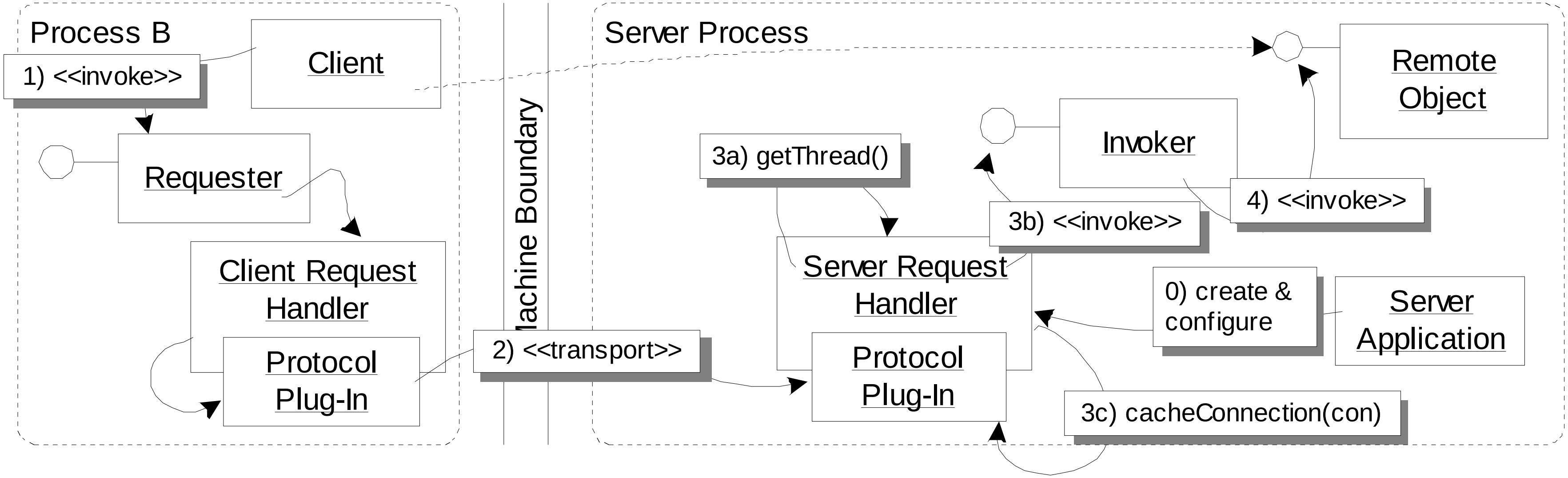
Pattern: Invocation Context (2)



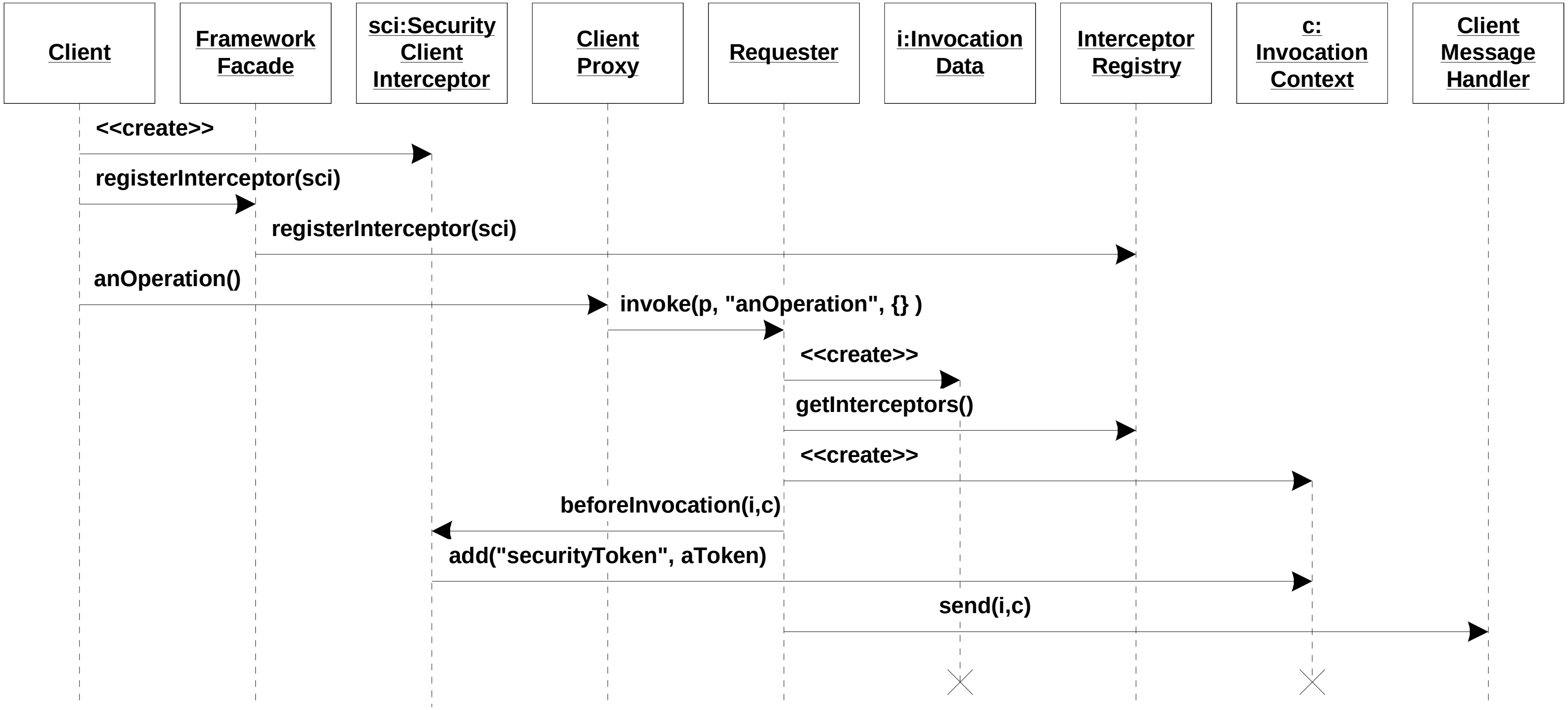
Pattern: Protocol Plug-In

- **Context:**
  - Client and server request handler adhere to the same protocol
- **Problem:**
  - The communication protocols should be configurable by developers, for instance because:
    - Multiple protocols need to be supported
    - Specialized protocols are needed
    - Existing protocols need to be optimized
- **Solution:**
  - Protocol plug-ins extend client request handlers and server request handlers
  - They provide a common interface to allow them to be configured from higher layers

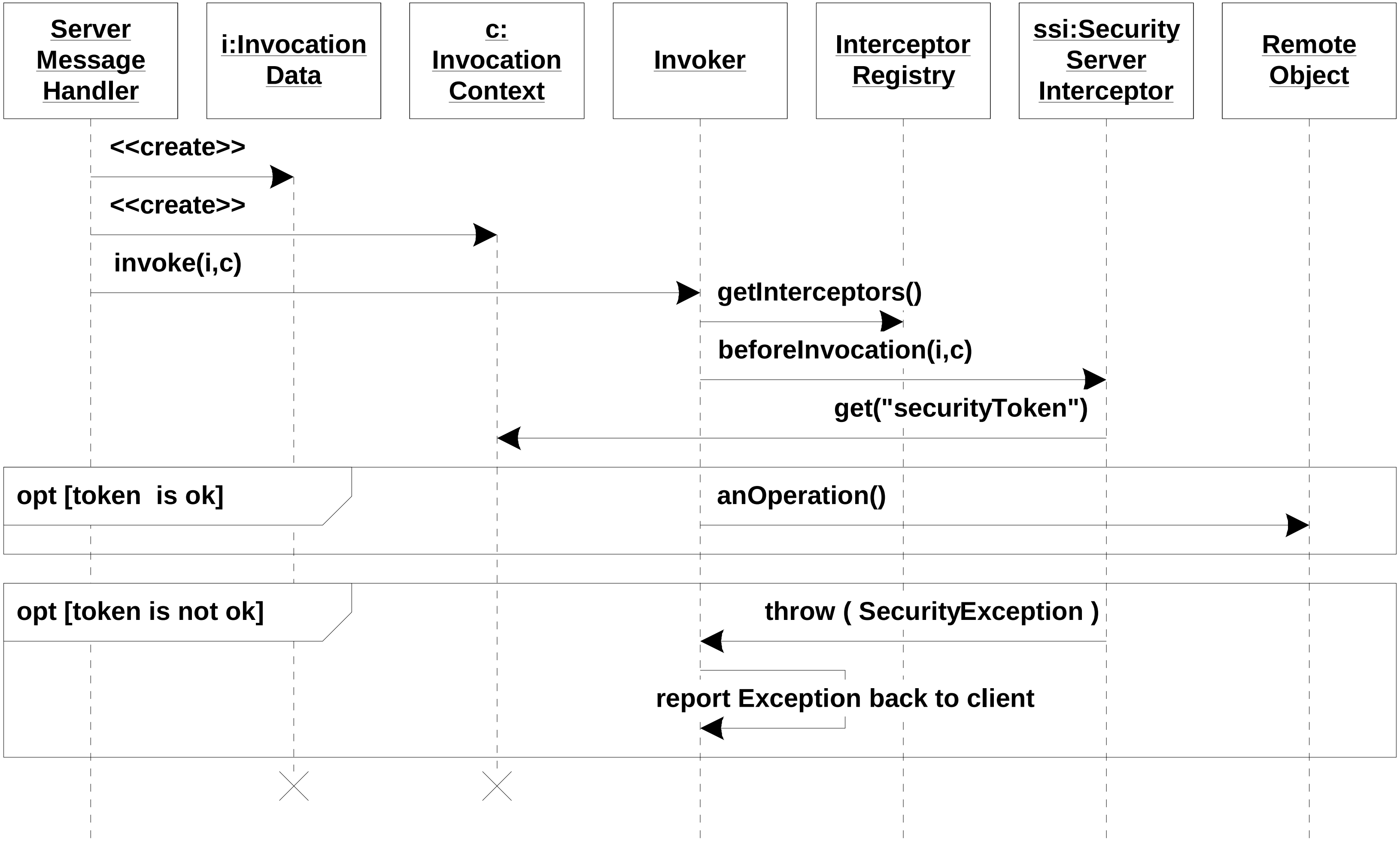
Pattern: Protocol Plug-In (2)



Interactions: Client-Side Security Interceptor

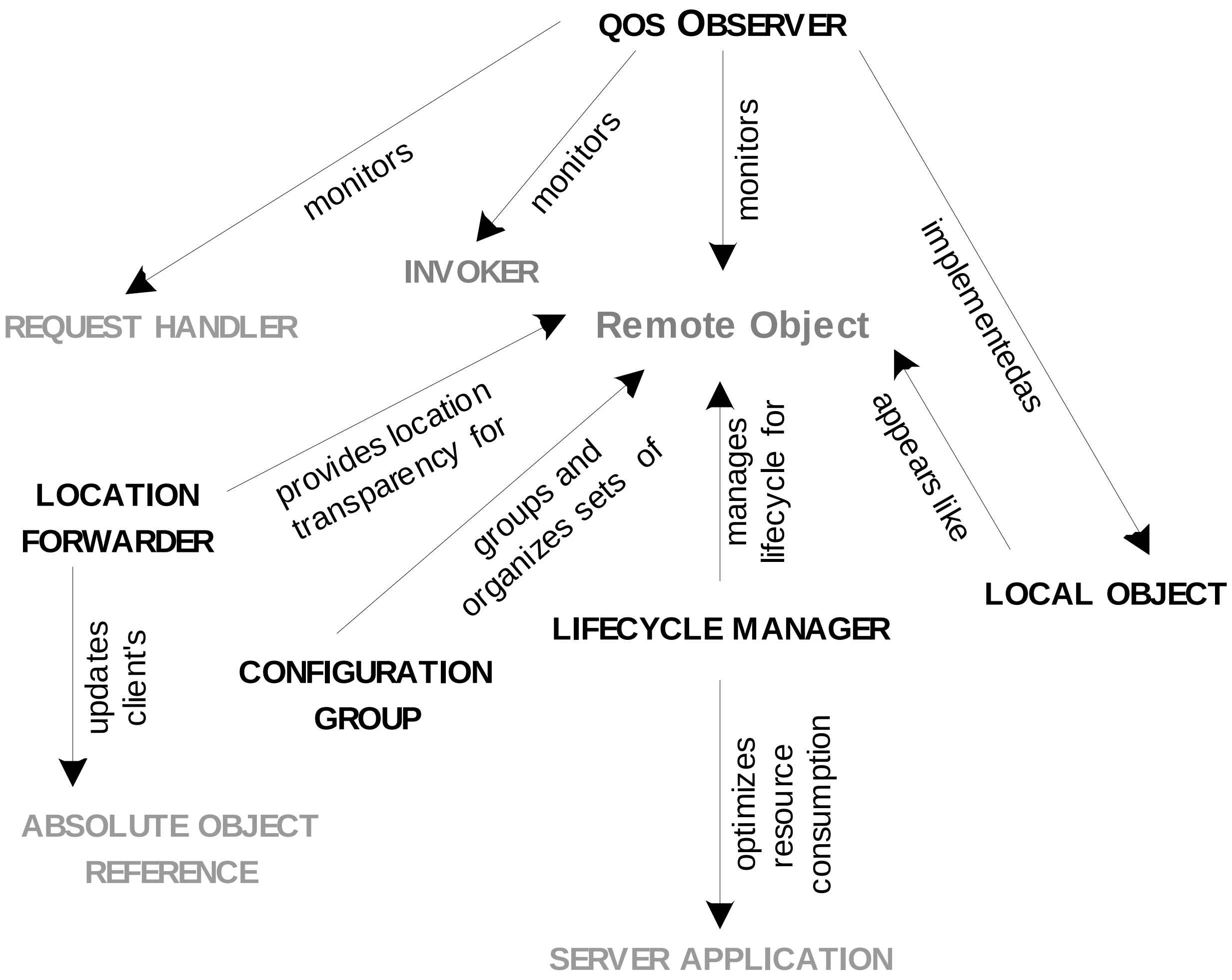


Interactions: Server-Side Security Interceptor



Extended Infrastructure Patterns

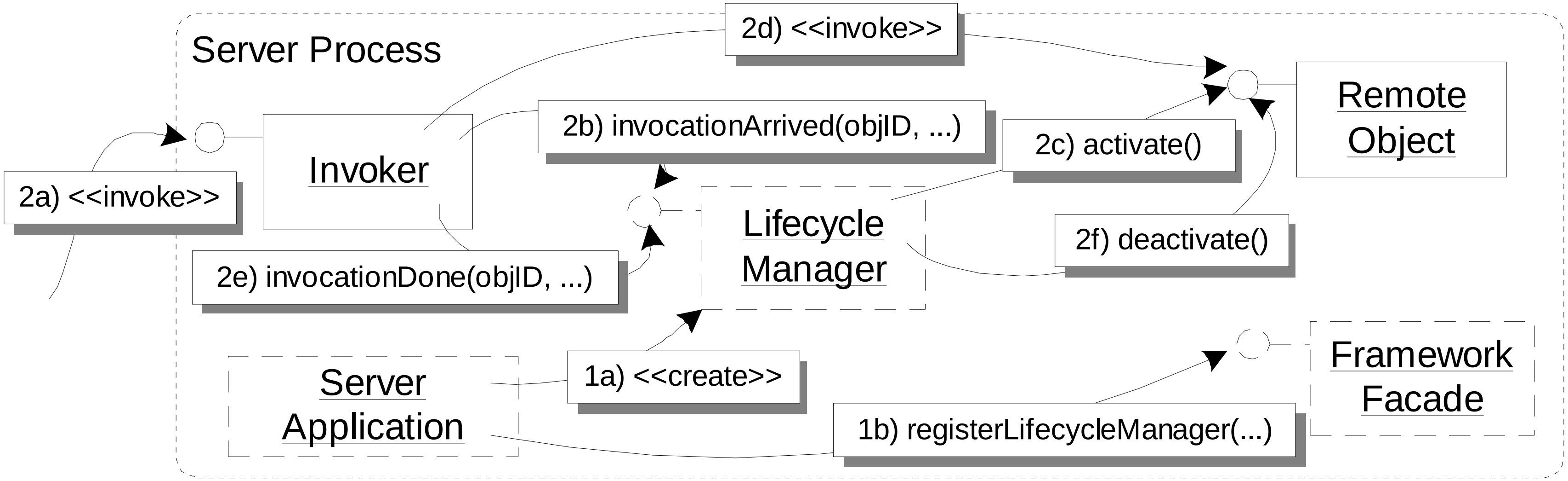
Extended Infrastructure Patterns



Pattern: Lifecycle Manager

- **Context:**
  - Different kinds of lifecycles of remote objects have to be managed
- **Problem:**
  - The lifecycle of remote objects needs to be managed by server applications
  - Based on configuration, usage scenarios, and available resources, servants have to be instantiated, initialized, or destroyed
  - All this has to be coordinated
- **Solution:**
  - Use a lifecycle manager to manage the lifecycle of remote objects
  - Lifecycle manager triggers lifecycle operations
  - Lifecycle manager implements configured lifecycle strategy

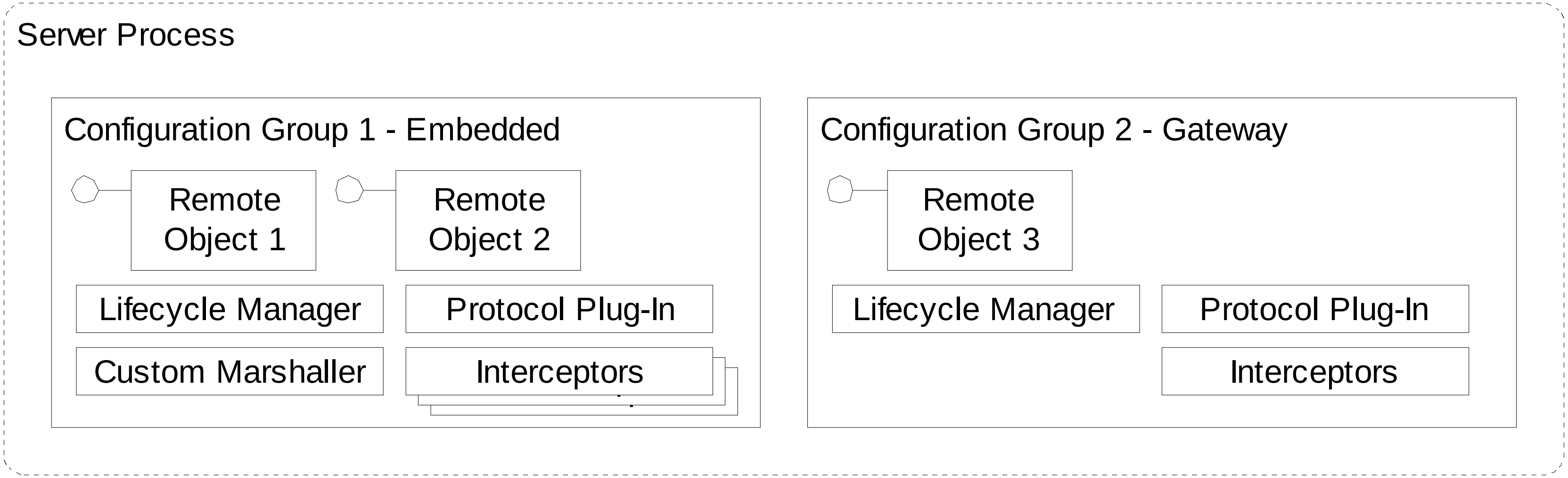
Pattern: Lifecycle Manager (2)



Pattern: Configuration Group

- **Context:**
  - Some remote objects require similar configurations
- **Problem:**
  - Remote objects need to be configured with various properties, such as:
    - quality of service (QoS)
    - Interceptor tasks
    - lifecycle management
    - protocol support.
  - Configuring per server application is not flexible enough
  - Configuring for each remote object leads to implementation overhead
- **Solution:**
  - Provide configuration groups which group remote objects with common properties

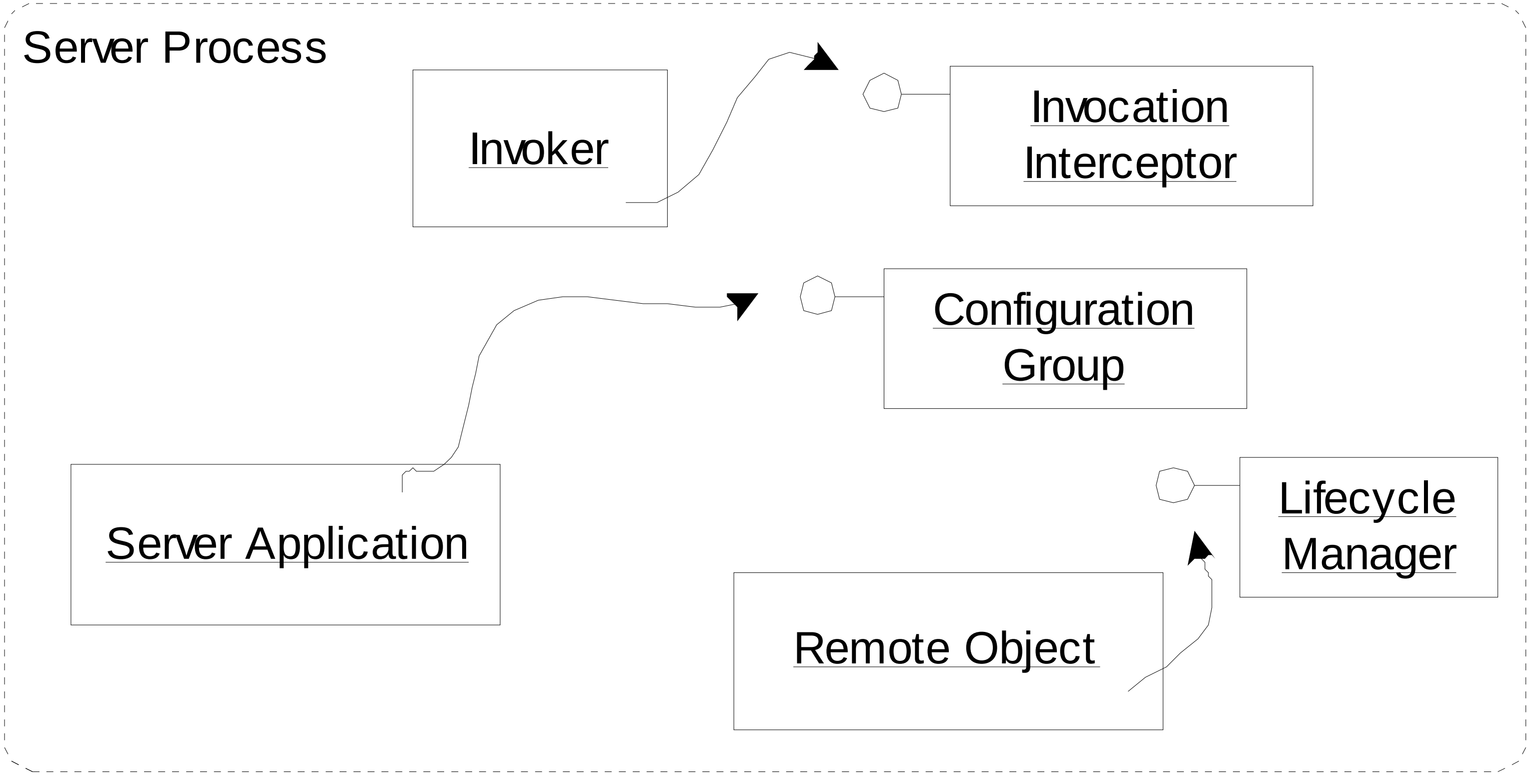
Pattern: Configuration Group (2)



Pattern: Local Object

- **Context:**
  - Middleware constituents need to be configured
- **Problem:**
  - To configure protocol plug-ins, configuration groups, or lifecycle managers, interfaces are needed
  - These interfaces must not be accessible remotely
  - For consistency reasons, the interfaces should behave similarly as those of remote objects
- **Solution:**
  - Local objects allow application developers to access configuration and status parameters of the middleware
  - Local objects adhere to the same parameter passing rules, memory management, and invocation syntax as remote objects
  - They cannot be accessible remotely

Pattern: Local Object (2)



Server Process

Invoker

Invocation Interceptor

Configuration Group

Server Application

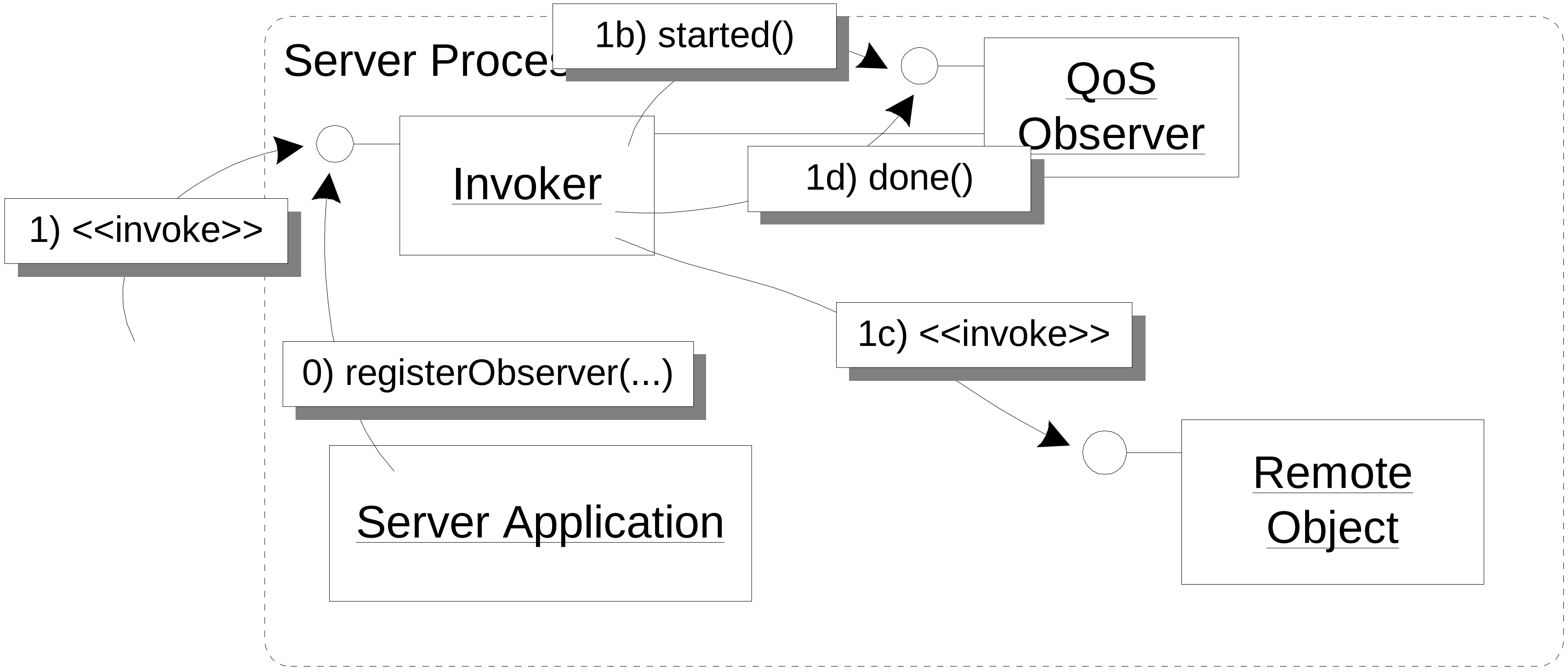
Lifecycle Manager

Remote Object

Pattern: QoS Observer

- **Context:**
  - You want to control application-specific quality of service properties, such as bandwidth, response times, or priorities
- **Problem:**
  - Request handlers, marshallers, protocol plug-ins, configuration groups, provide hooks to implement a variety of QoS characteristics
  - Applications might want to react on changes in QoS
  - The application-specific code to react on those changes should be decoupled from the framework itself
- **Solution:**
  - Provide hooks in the middleware constituents where application developers can register QoS Observers.
  - The observers are informed about relevant QoS parameters, such as message sizes, invocation counts, or execution times.
  - QoS observers contain code to react if service quality gets worse.

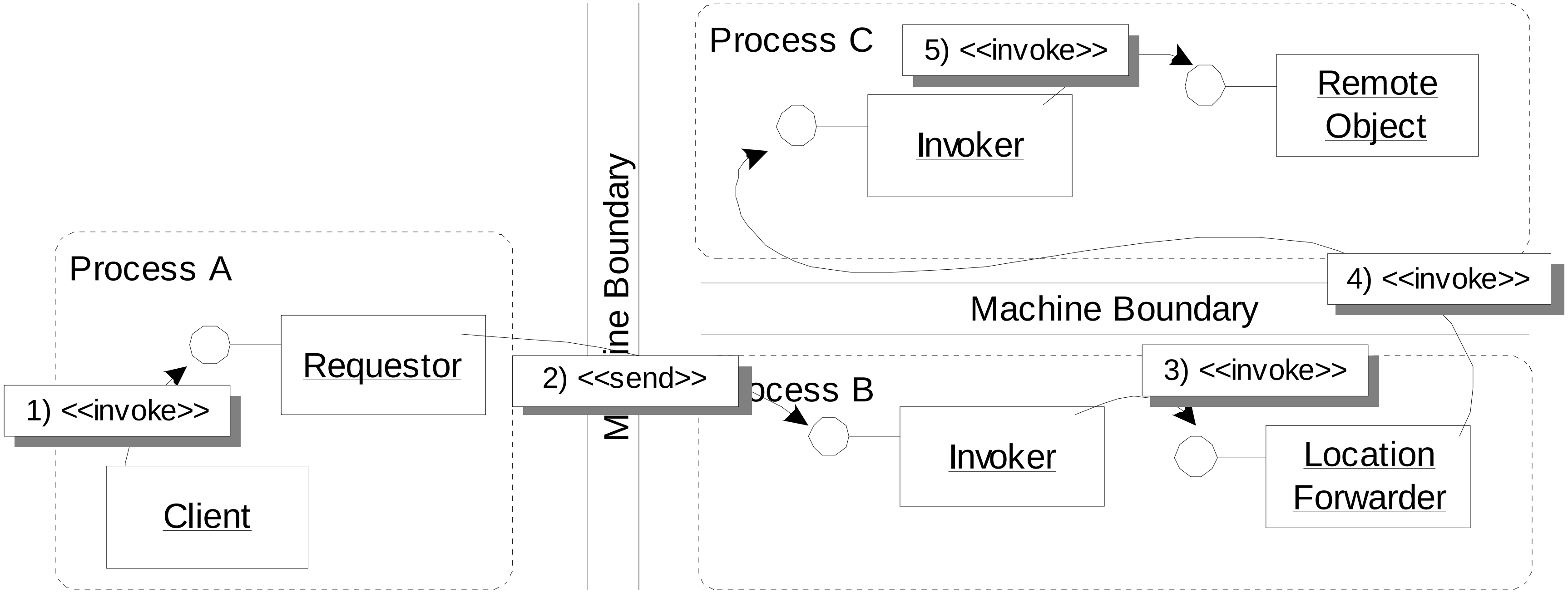
Pattern: QoS Observer (2)



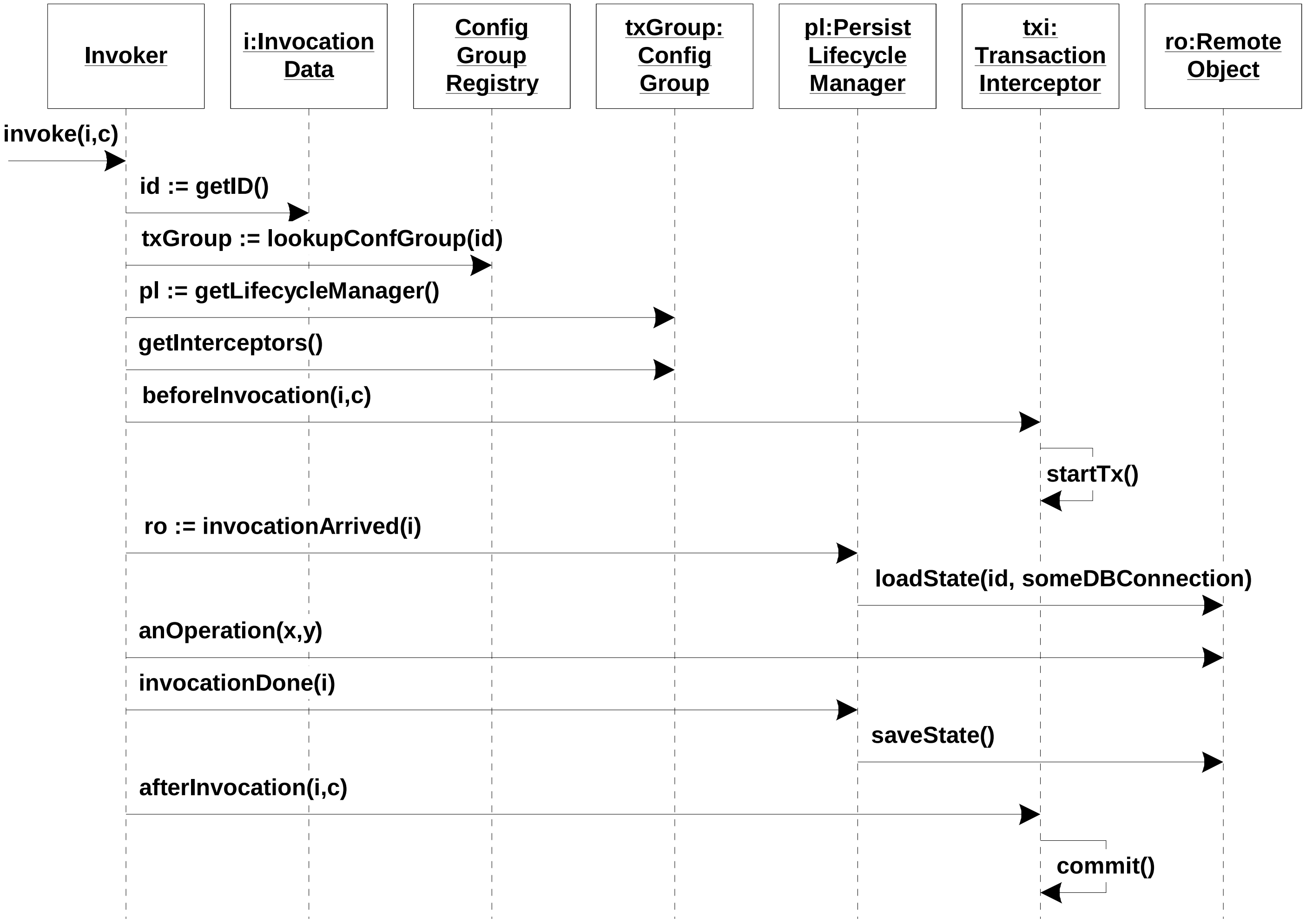
Pattern: Location Forwarder

- **Context:**
  - Invocations of remote objects arrive at the invoker to be dispatched
- **Problem:**
  - Remote objects might be located in a different server application than the one where the invocation arrives
    - Load balancing and fault tolerance
    - Remote objects were moved to other server applications
  - Invocations should transparently reach the correct remote object
- **Solution:**
  - A location forwarder can forward invocations to a remote object in other server applications
  - The location forwarder maps the object id to an absolute object references of another remote object

Pattern: Location Forwarder (2)

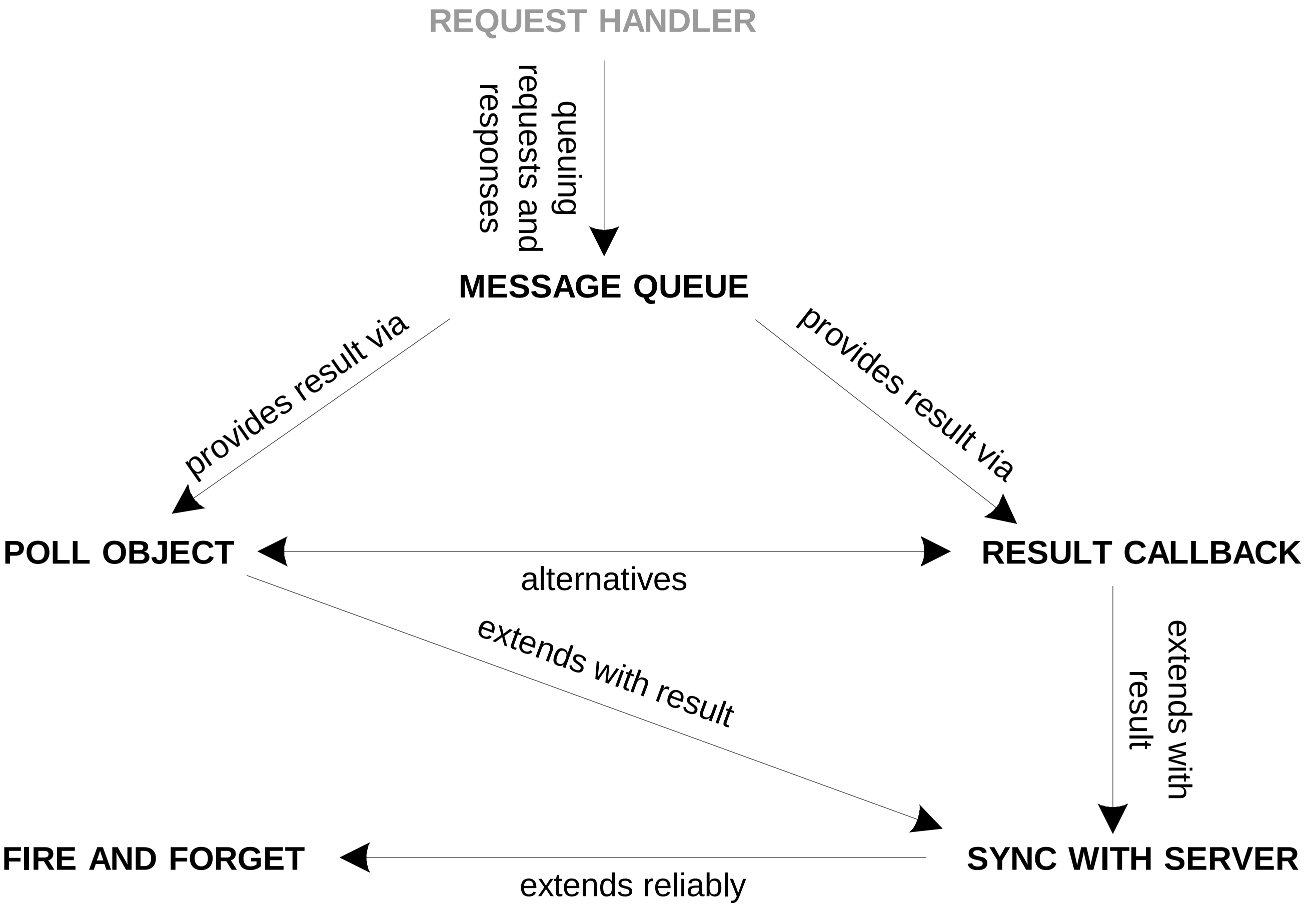


Interactions: Transaction Configuration Group



Invocation Asynchrony Patterns

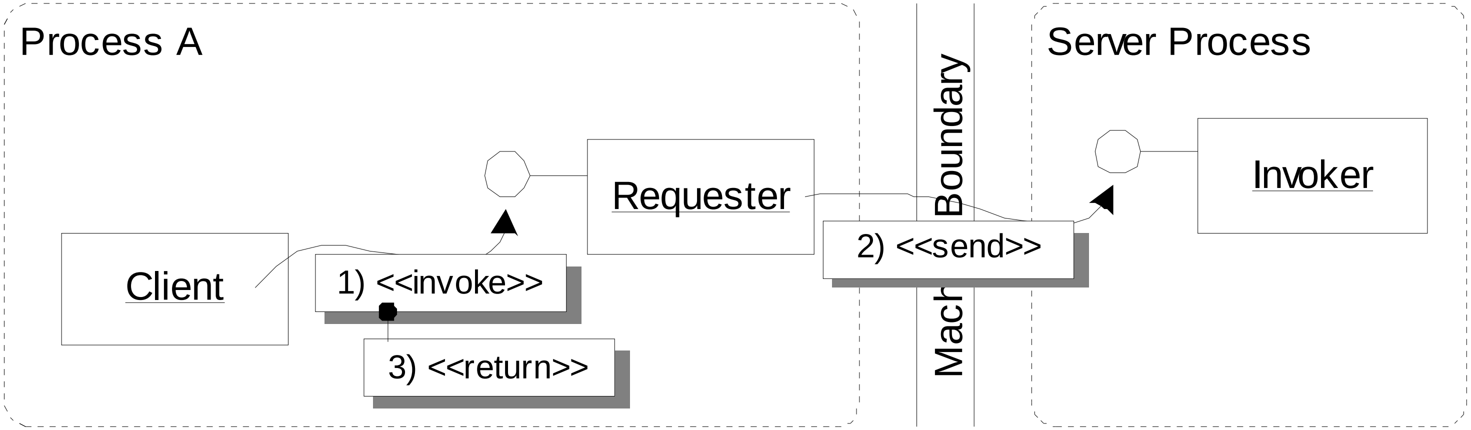
Invocation Asynchrony Patterns



Pattern: Fire and Forget

- **Context:**
  - Operations have neither a return value nor report any exceptions
- **Problem:**
  - A client simply needs to notify the remote object of an event
  - The client does not expect any return value
  - Reliability of the invocation is not critical
- **Solution:**
  - For fire and forget operations, the requestor
    - sends the invocation across the network
    - returns control to the calling client immediately
  - The client does not get any acknowledgement from the remote object

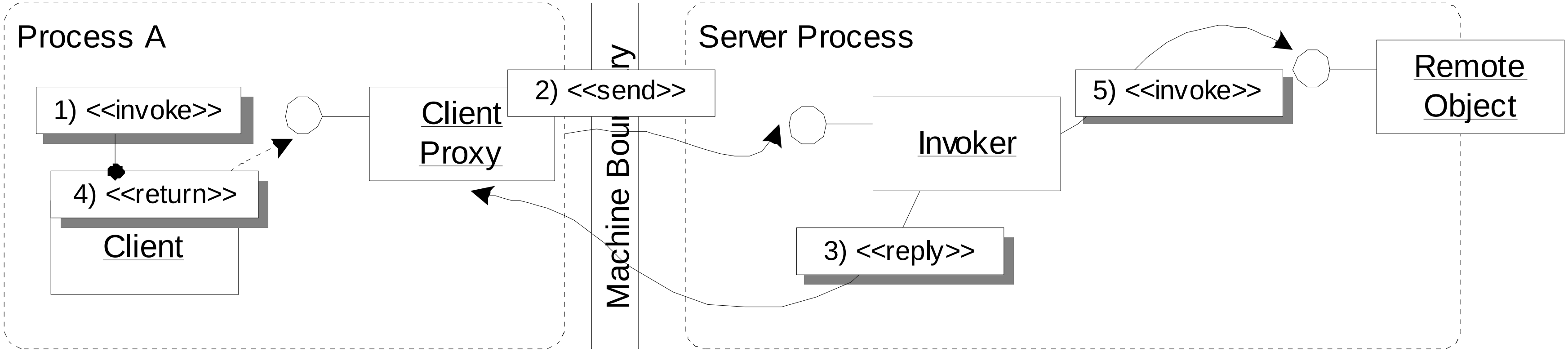
Pattern: Fire and Forget (2)



Pattern: Sync with Server

- **Context:**
  - Operations have neither a return value nor report any exceptions
- **Problem:**
  - Fire and forget is too unreliable
  - A synchronous call should not be used because it blocks the client until the server responds
- **Solution:**
  - Provide sync with server semantics for remote invocations
  - The client sends the invocation and waits for a reply from the server application informing it about the successful reception of the invocation
  - After the reply is received by the requestor, it returns control to the client and execution continues
  - The server application independently executes the invocation

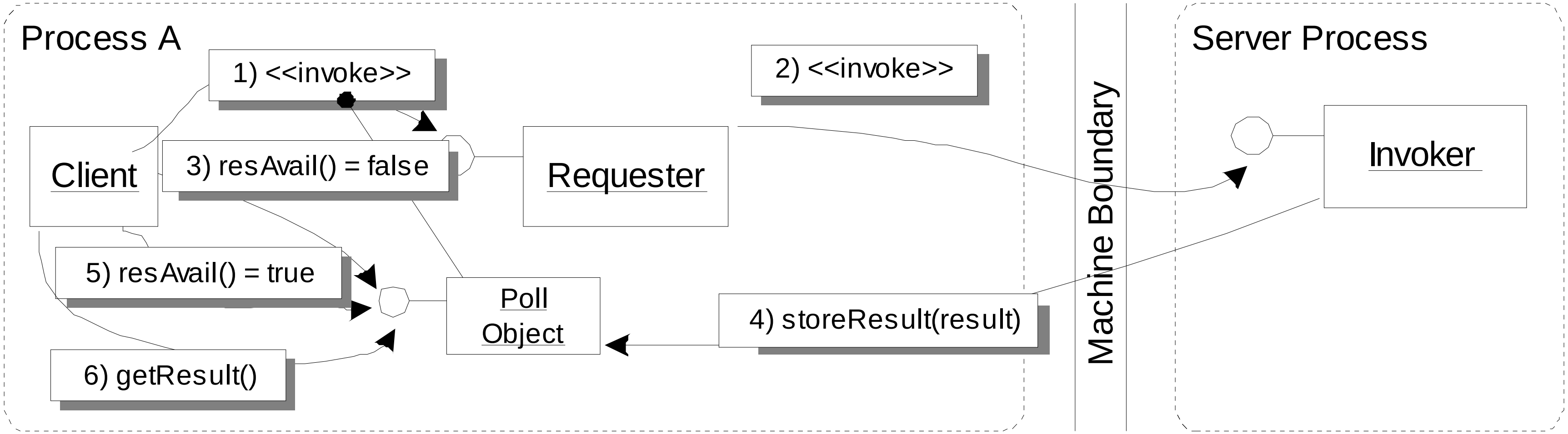
Pattern: Sync with Server (2)



Pattern: Poll Object

- **Context:**
  - Invocations should execute asynchronously and clients depend on the results
- **Problem:**
  - The client does not necessarily need the results immediately to continue its execution
  - It can decide for itself when to use the returned results
- **Solution:**
  - Provide poll objects that receive the result of remote invocations on behalf of the client
  - The client subsequently uses the poll object to query the result:
    - query (“poll”) whether the result is available or
    - block on the poll object until the result becomes available
  - As long as the result is not available on the poll object, the client can continue with other tasks asynchronously.

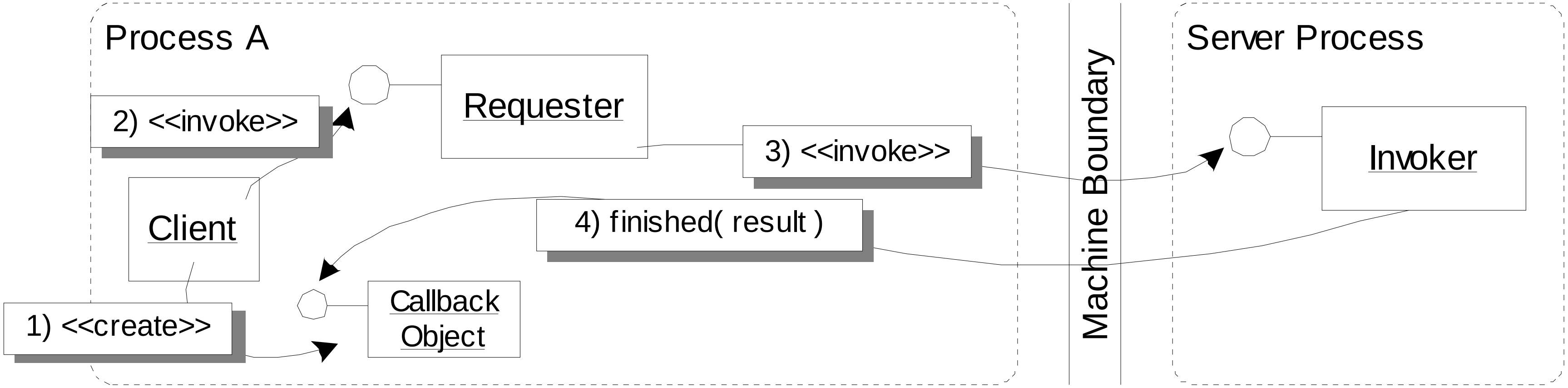
Pattern: Poll Object (2)



Pattern: Result Callback

- **Context:**
  - Invocations should execute asynchronously and clients depend on the results
- **Problem:**
  - If the result becomes available to the requestor, the client wants to be informed immediately to react on it
  - In the meantime the client executes concurrently.
- **Solution:**
  - Provide a callback-based interface for remote invocations on the client
    - The client passes a result callback object to the requestor
    - The invocation returns immediately after sending the invocation
    - Once the result is available, the distributed object framework invokes a predefined operation on the result callback object

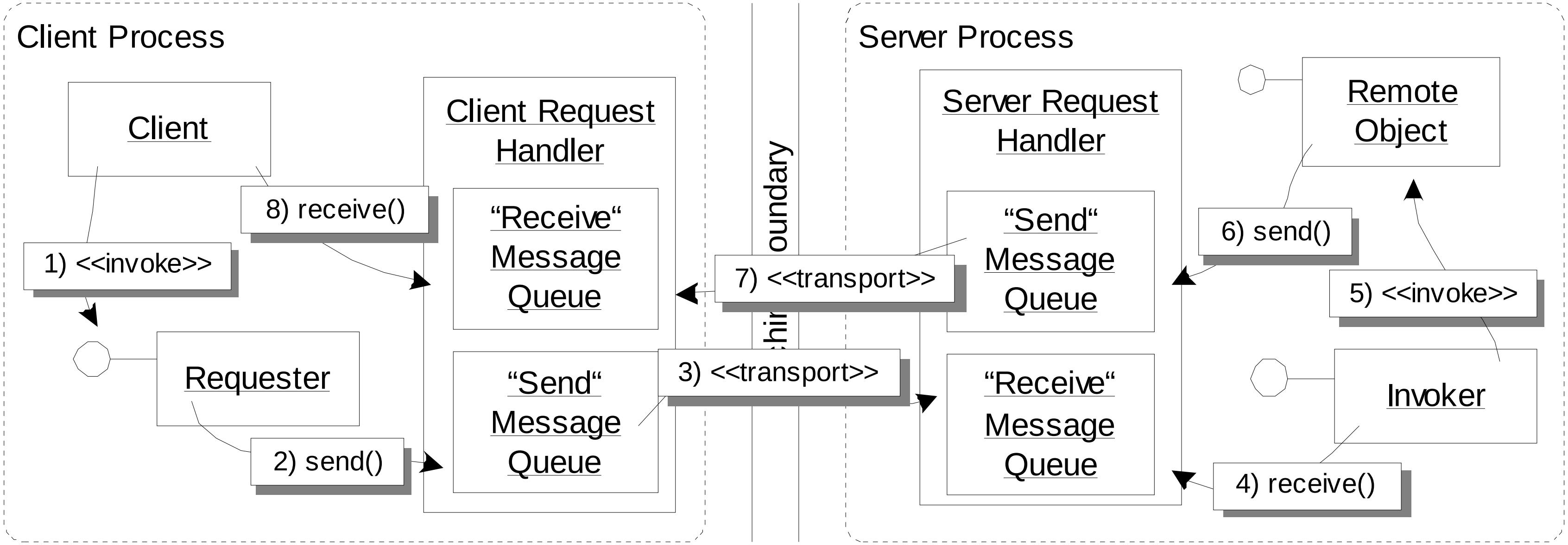
Pattern: Result Callback (2)



Pattern: Message Queue

- **Context:**
  - The result of the invocation can be handled asynchronously
- **Problem:**
  - Poll object and result callback require a separate process or thread for receiving the result asynchronously
  - Perhaps you want to deal with (temporal) problems of the networked environment
  - None of the synchronous or asynchronous invocation variants can handle the order of invoking or receiving messages.
- **Solution:**
  - Add message queues to the request handlers (or protocol plug-ins)
  - Perhaps as part of a larger Messaging system

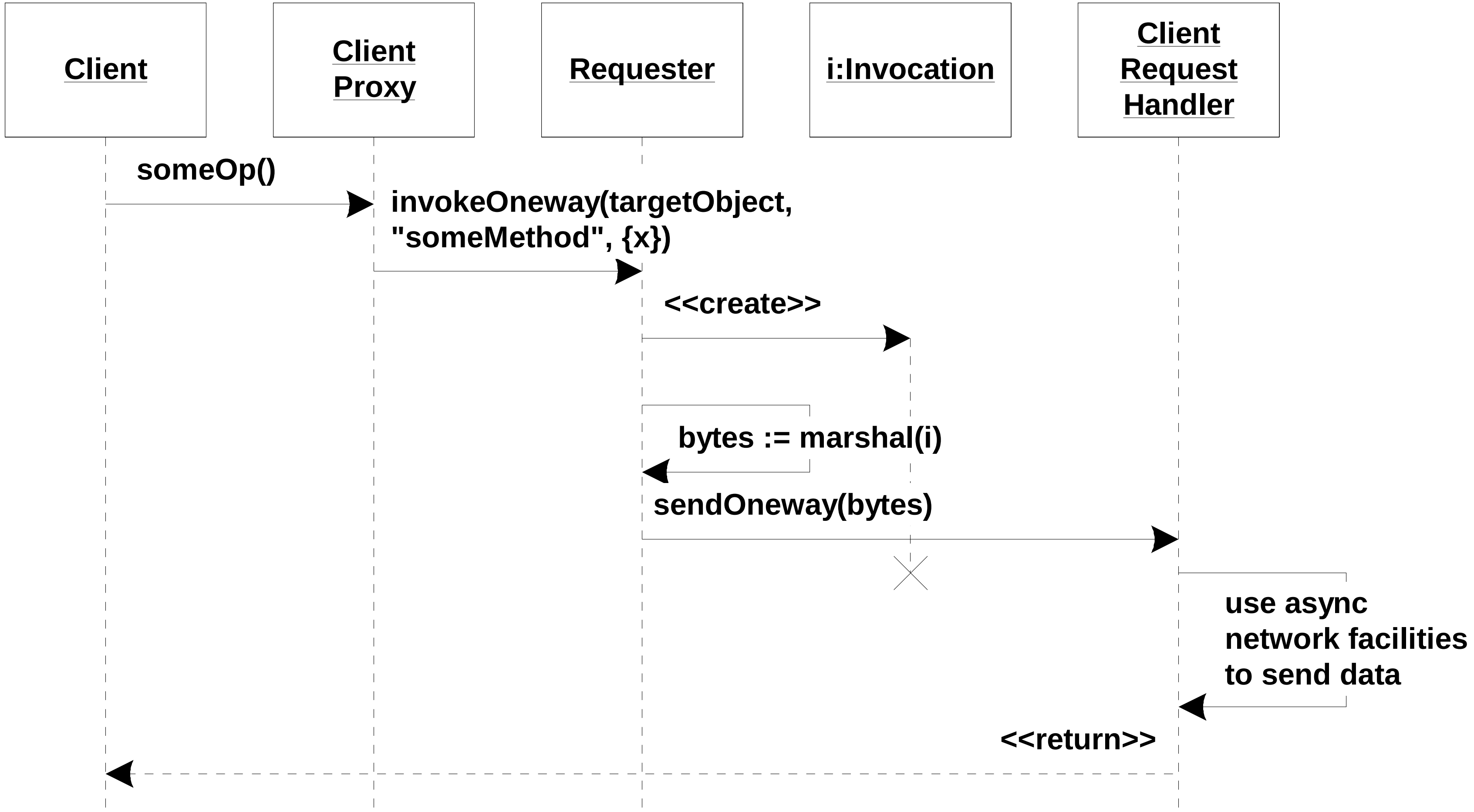
Pattern: Message Queue (2)



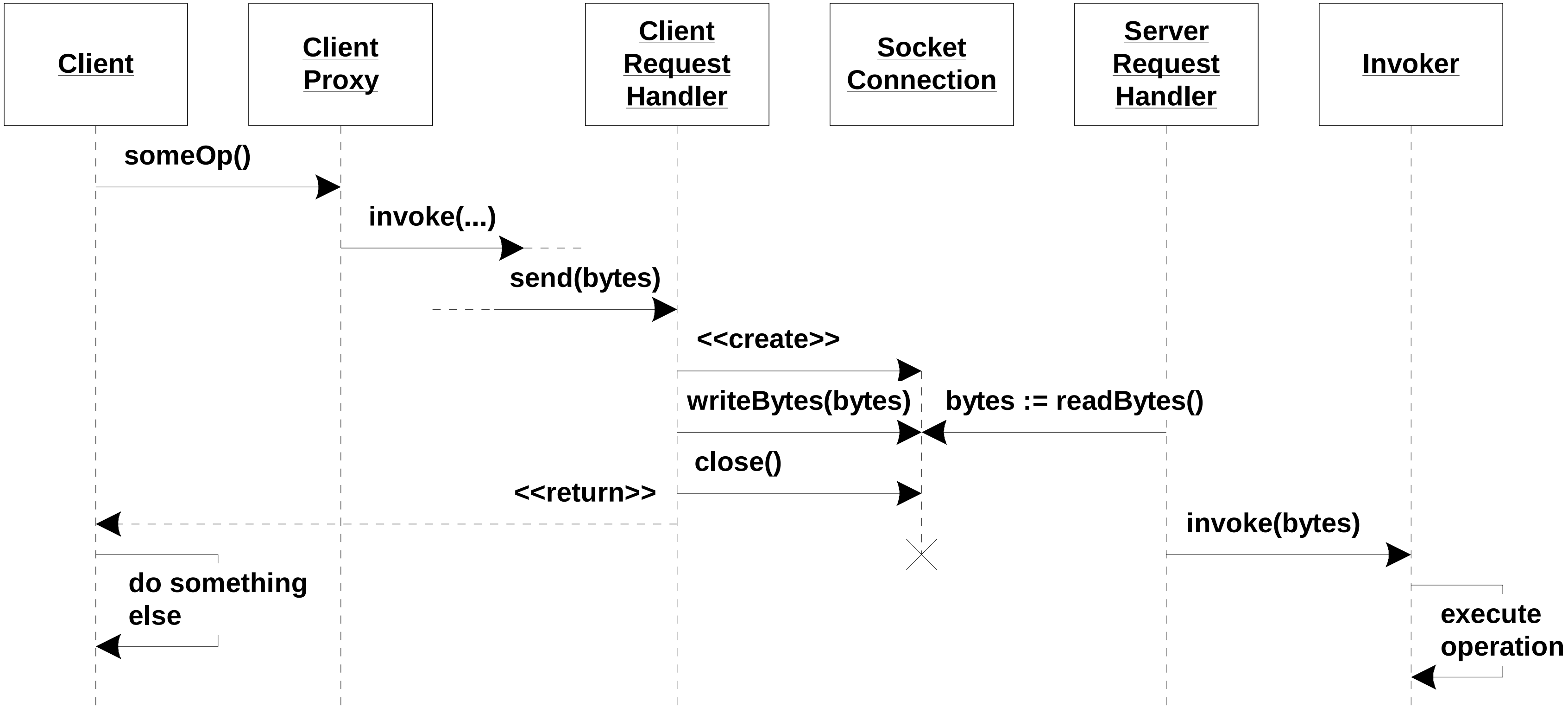
Relations among the Patterns

	Acknow-ledgement to client	Result to client	Responsibility for result
Fire and forget	No	No	-
Sync with server	Yes	No	-
Poll object	Yes	Yes	Client gets the result
Result callback	Yes	Yes	The client is informed via callback
Message Queue	Yes	Yes	Sync, Poll Object or Result Callback

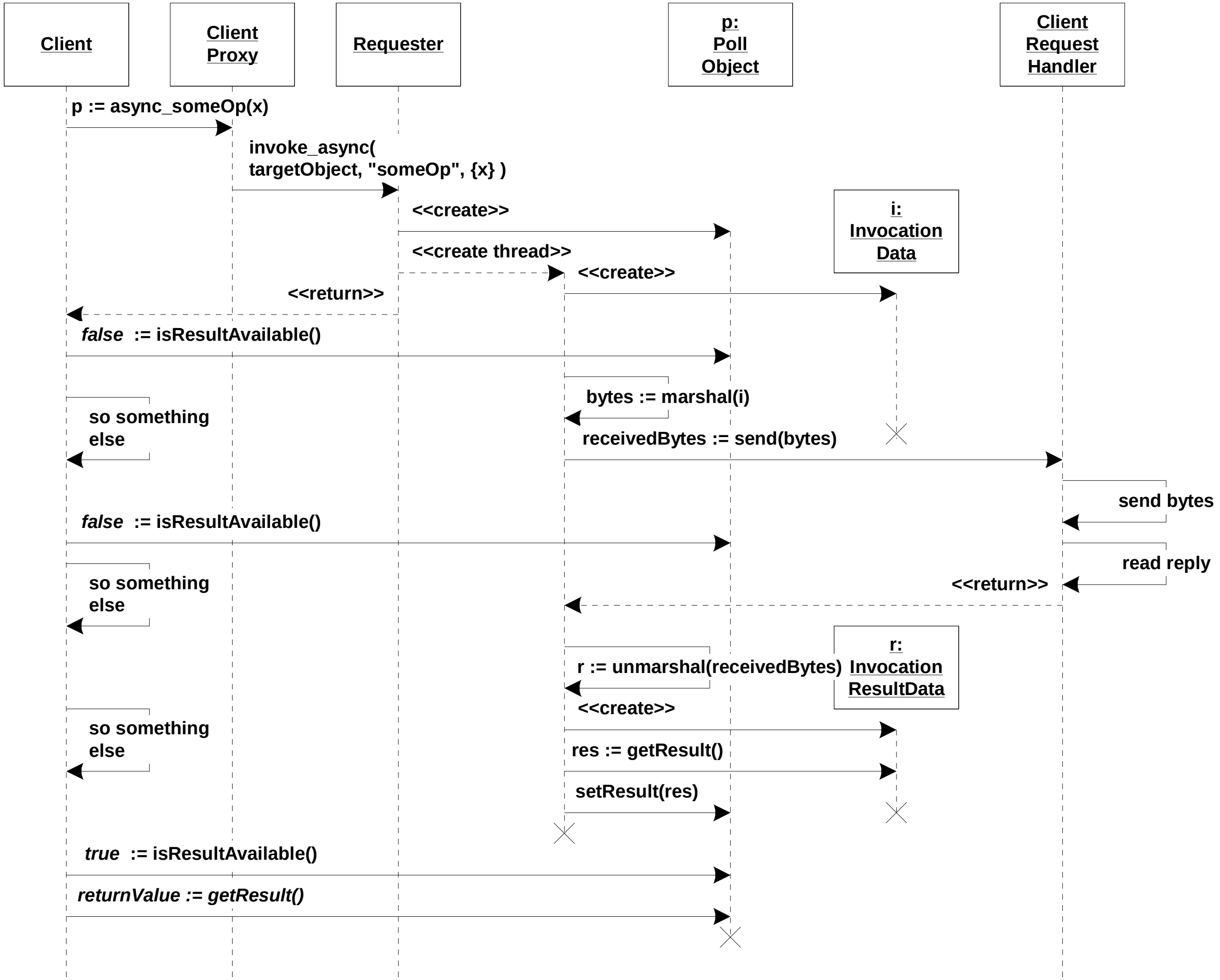
Interactions: Fire and Forget



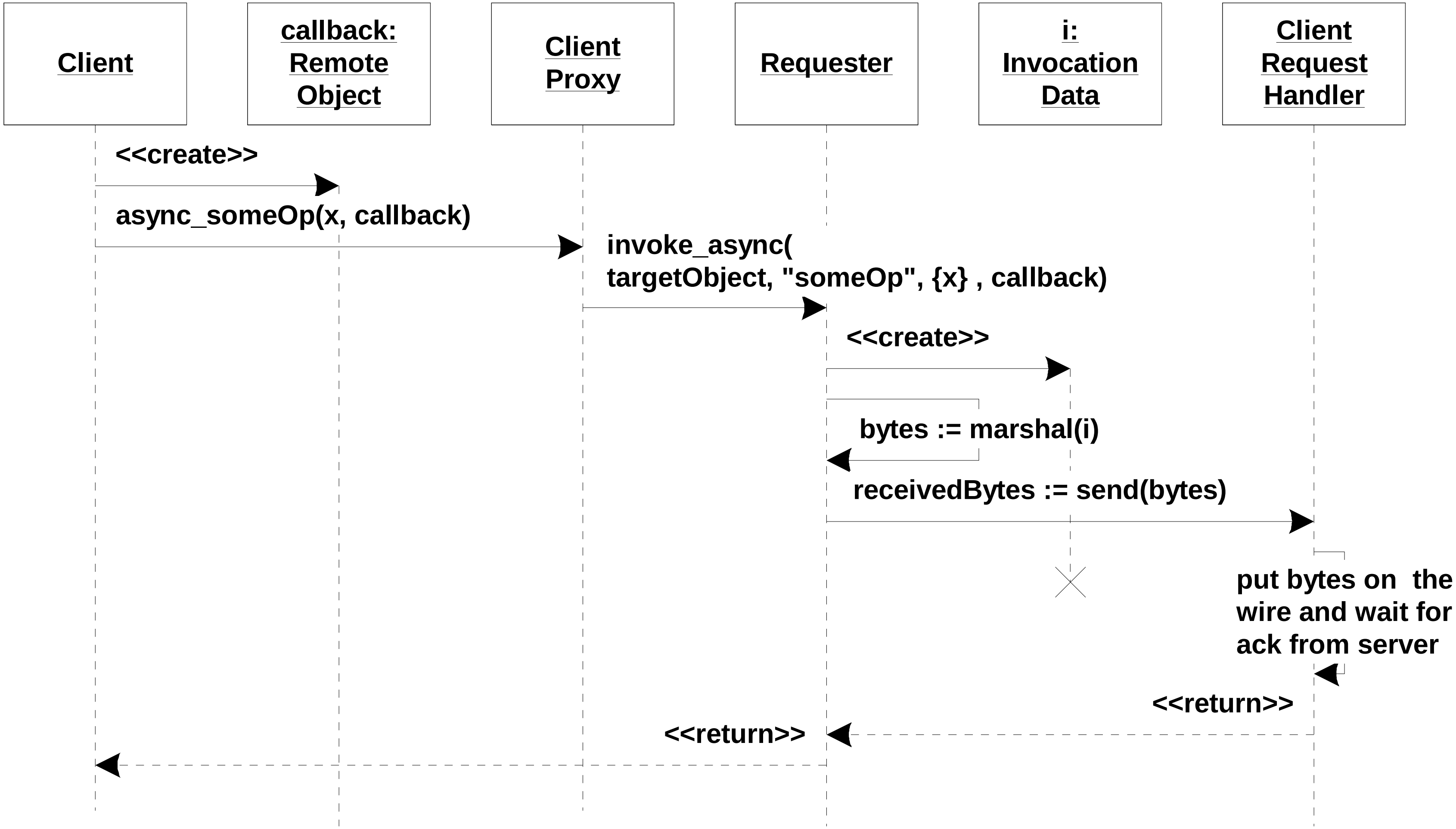
Interactions: Sync with Server



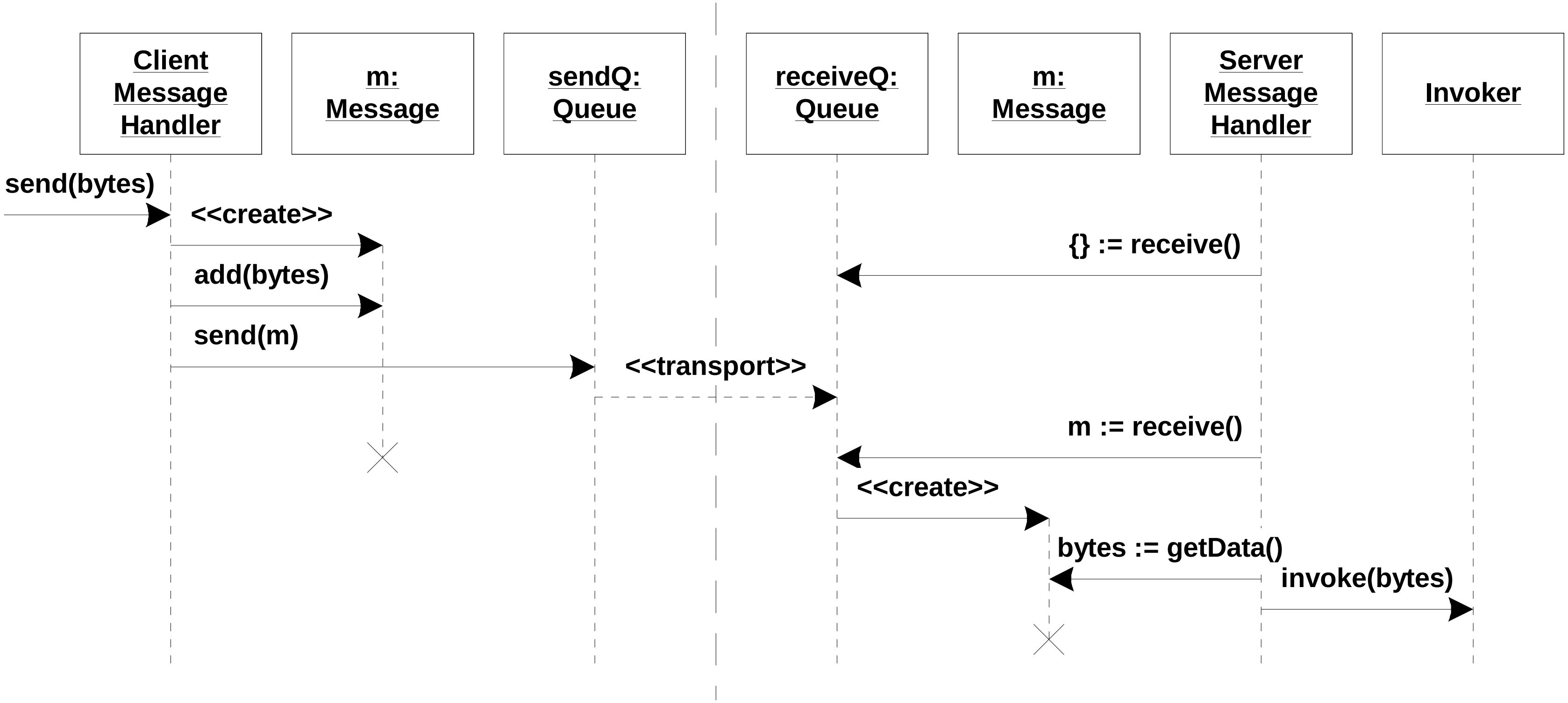
Interactions: Poll Object



Interactions: Result Callback

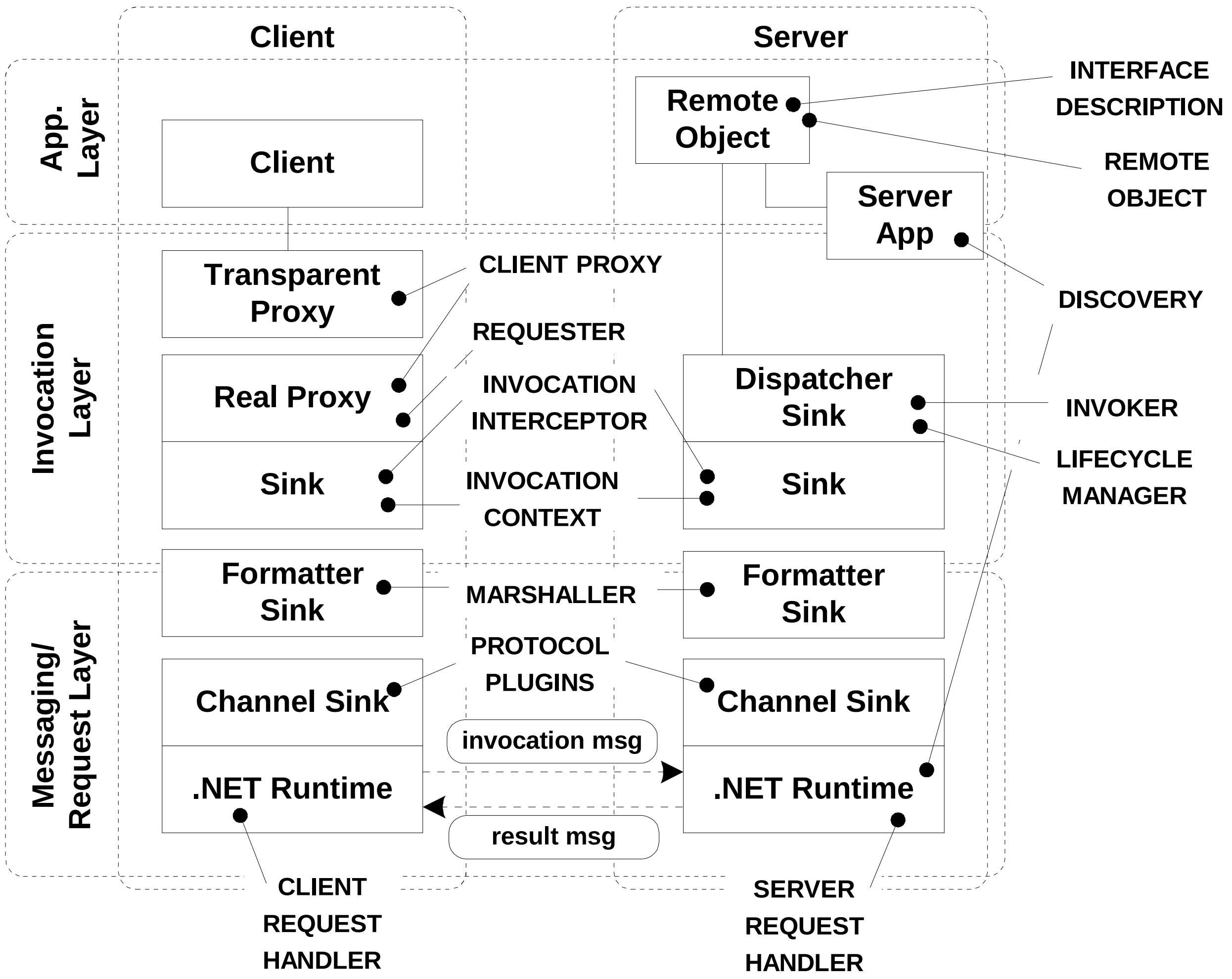

Client
callback: Remote Object
Client Proxy
Requester
i: Invocation Data
Client Request Handler
<<create>>
async_someOp(x, callback)
invoke_async(targetObject, "someOp", {x} , callback)
<<create>>
bytes := marshal(i)
receivedBytes := send(bytes)
put bytes on the wire and wait for ack from server
<<return>>
<<return>>

Interactions: Message Queue

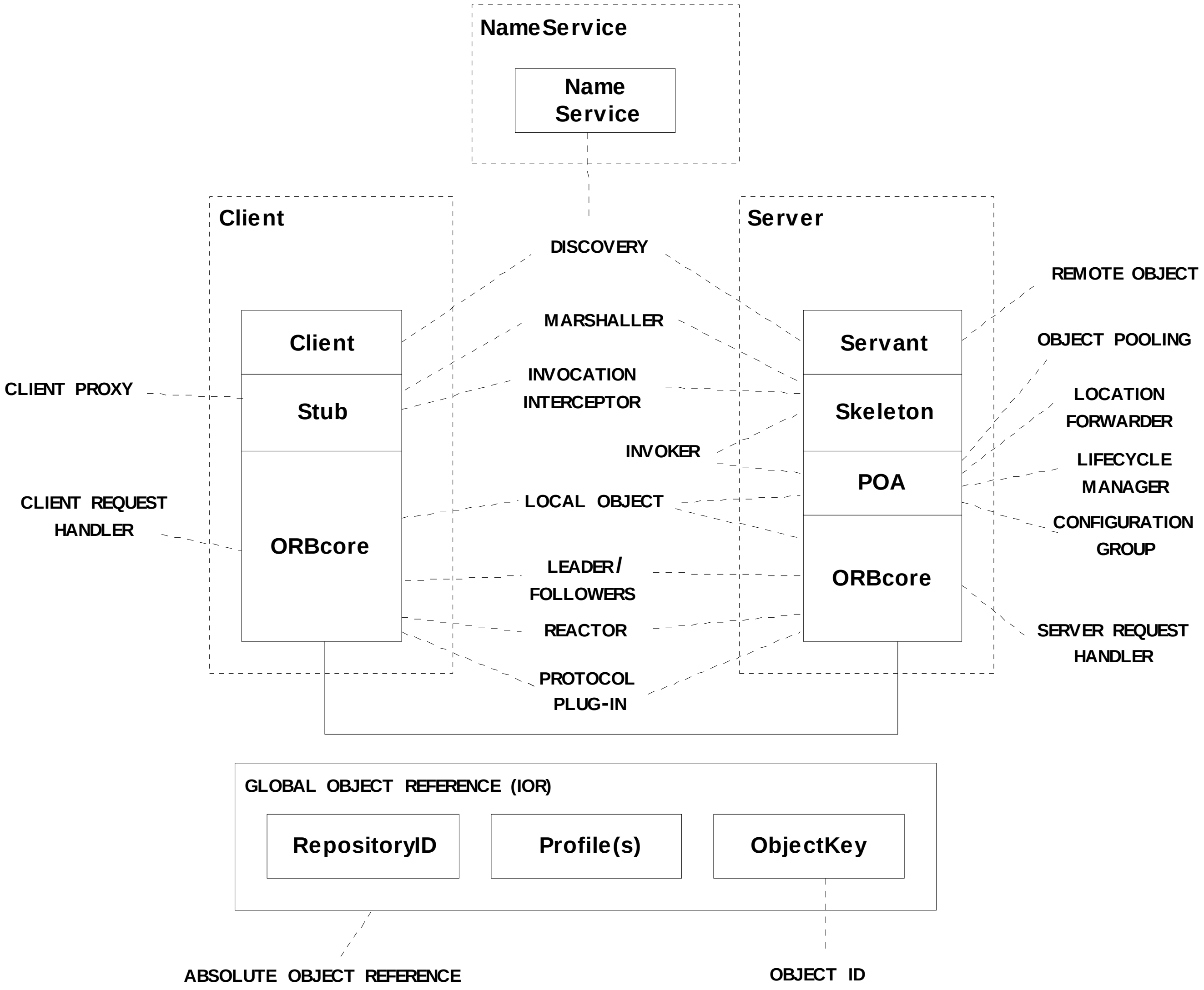


Technology Projections

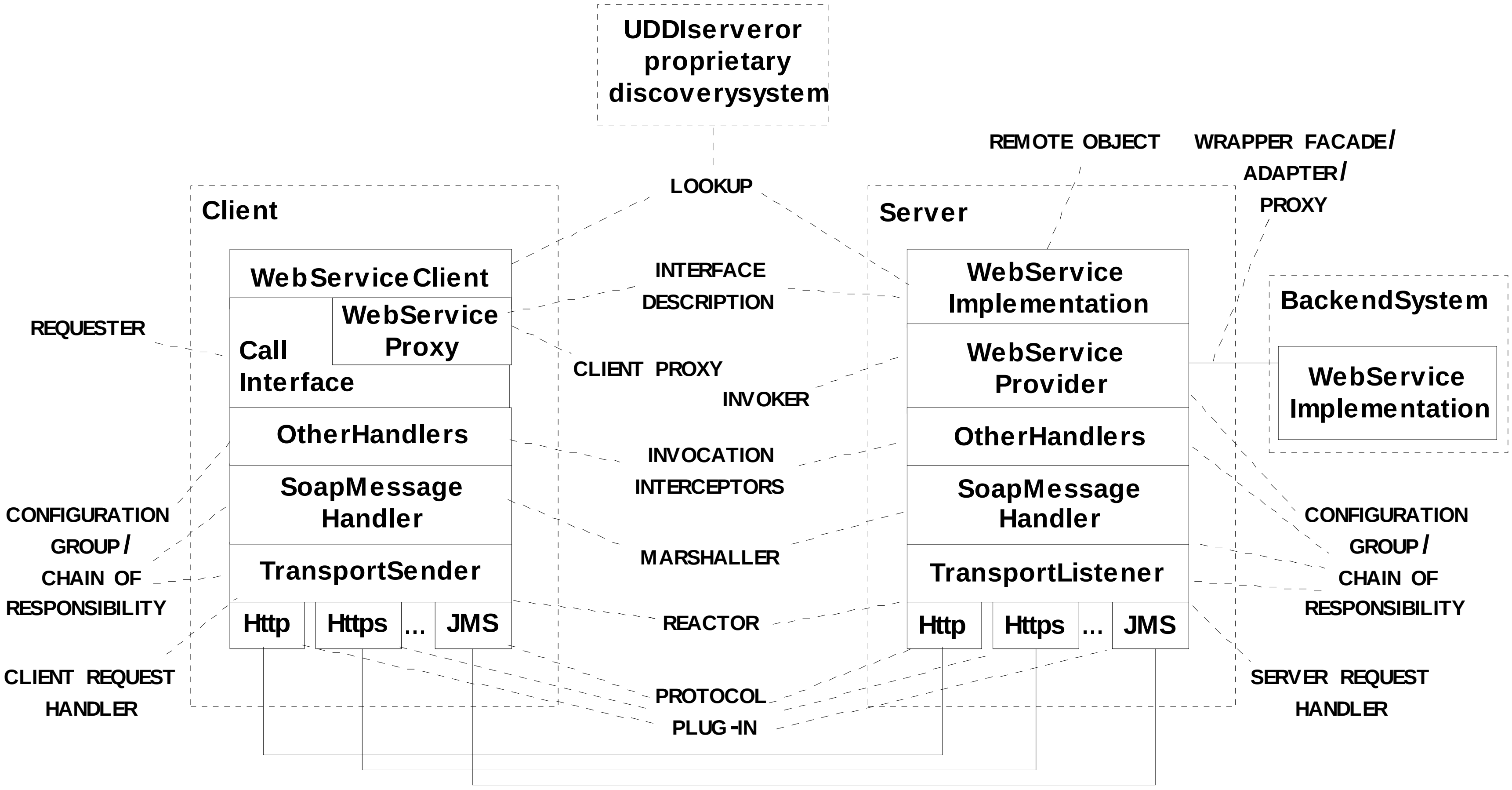
.NET Remoting Technology Projection



CORBA Technology Projection



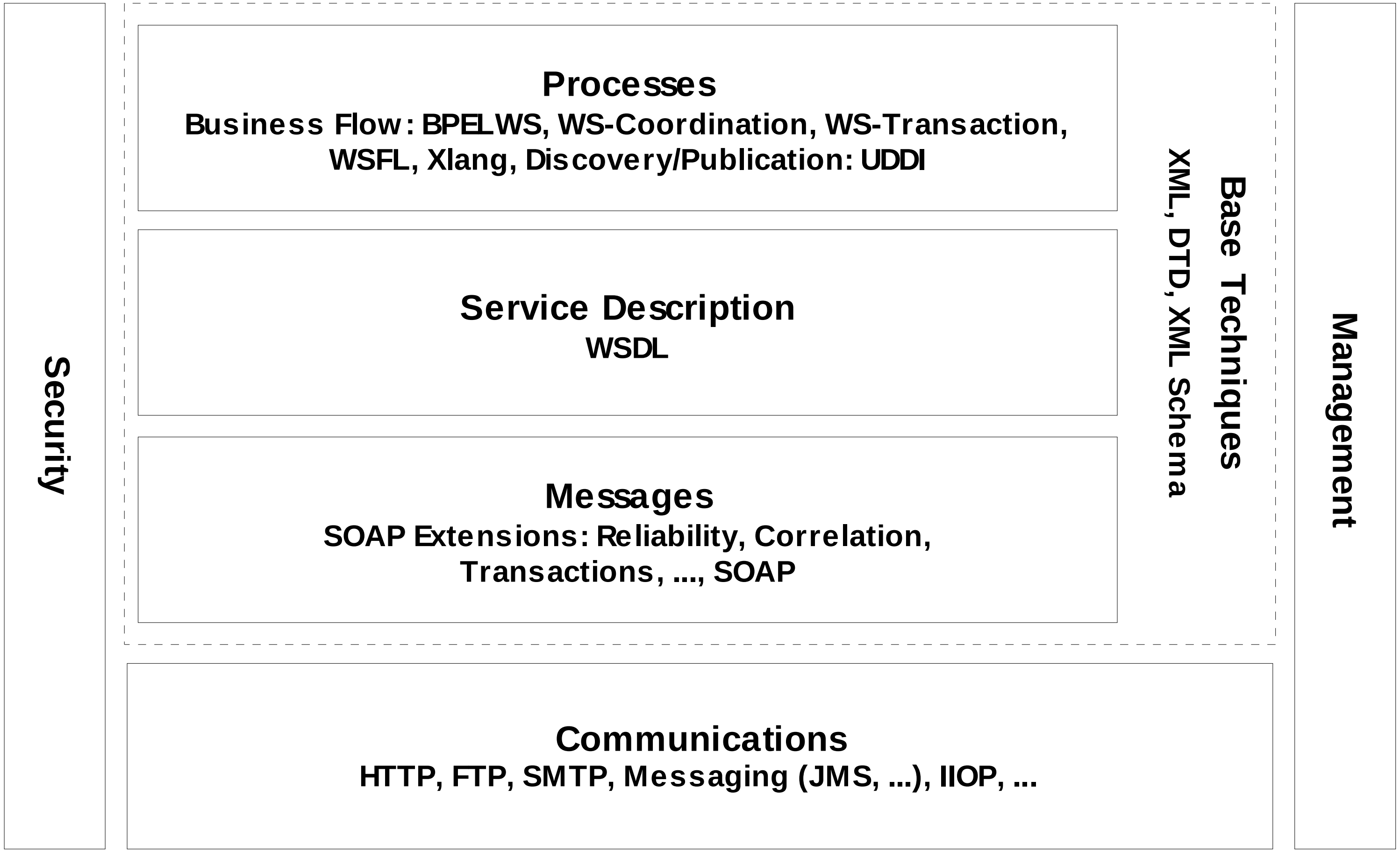
Web Services Technology Projection



Web Services

- **Definition:**
  - ***A Web Service is a software system designed to support interoperable machine-to-machine interaction over a network.***
  - ***It has an interface described in a machine-processable format (specifically WSDL).***
  - ***Other systems interact with the Web Service in a manner prescribed by its description using messages (specifically SOAP messages).***
  - ***Messages are typically conveyed using HTTP with an XML serialization in conjunction with other Web-related standards, but any other communication protocol can be used for message delivery as well.***
- **Here: Apache Axis**

Web Service Stack



Security

Processes

Business Flow: BPELWS, WS-Coordination, WS-Transaction, WSFL, Xlang, Discovery/Publication: UDDI

Service Description

WSDL

Messages

SOAP Extensions: Reliability, Correlation, Transactions, ..., SOAP

Base Techniques

XML, DTD, XML Schema

Management

Communications

HTTP, FTP, SMTP, Messaging (JMS, ...), IIOP, ...

Dynamic Invocation on Server Side

Ordinary Java class as Remote Object:

```
public class DateService {
   public String getDate (String format) {…}
   public String getDate () {…}
}
```

Invoker is set up by XML configuration file (used for dynamic deployment):

```
<deployment xmlns="http://xml.apache.org/axis/wsdd/"
  xmlns:java="http://xml.apache.org/axis/wsdd/providers/java">
        <service name="DateService" provider="java:RPC">
               <parameter name="className"
                value="simpleDateService.DateService"/>
               <parameter name="allowedMethods" value="getDate"/>
        </service>
</deployment>
```

Dynamic Invocation on Server Side (2)

- **Service name is used as Object ID: `DateService`**
- **Per default: Per-Request Instance as activation strategy**
- **URL as Absolute Object Reference, e.g.:**

```
http://localhost:8080/axis/services/DateService
```

- **Invoker performs mapping and invocation**
  - In the SOAP request the operation name and parameters are encoded
  - Before invocation:
    - check that invocation is an “allowed method”
    - check that the parameter number and types are valid
  - If so: return result as SOAP message
  - Otherwise: SOAP Remoting Error is returned to the client

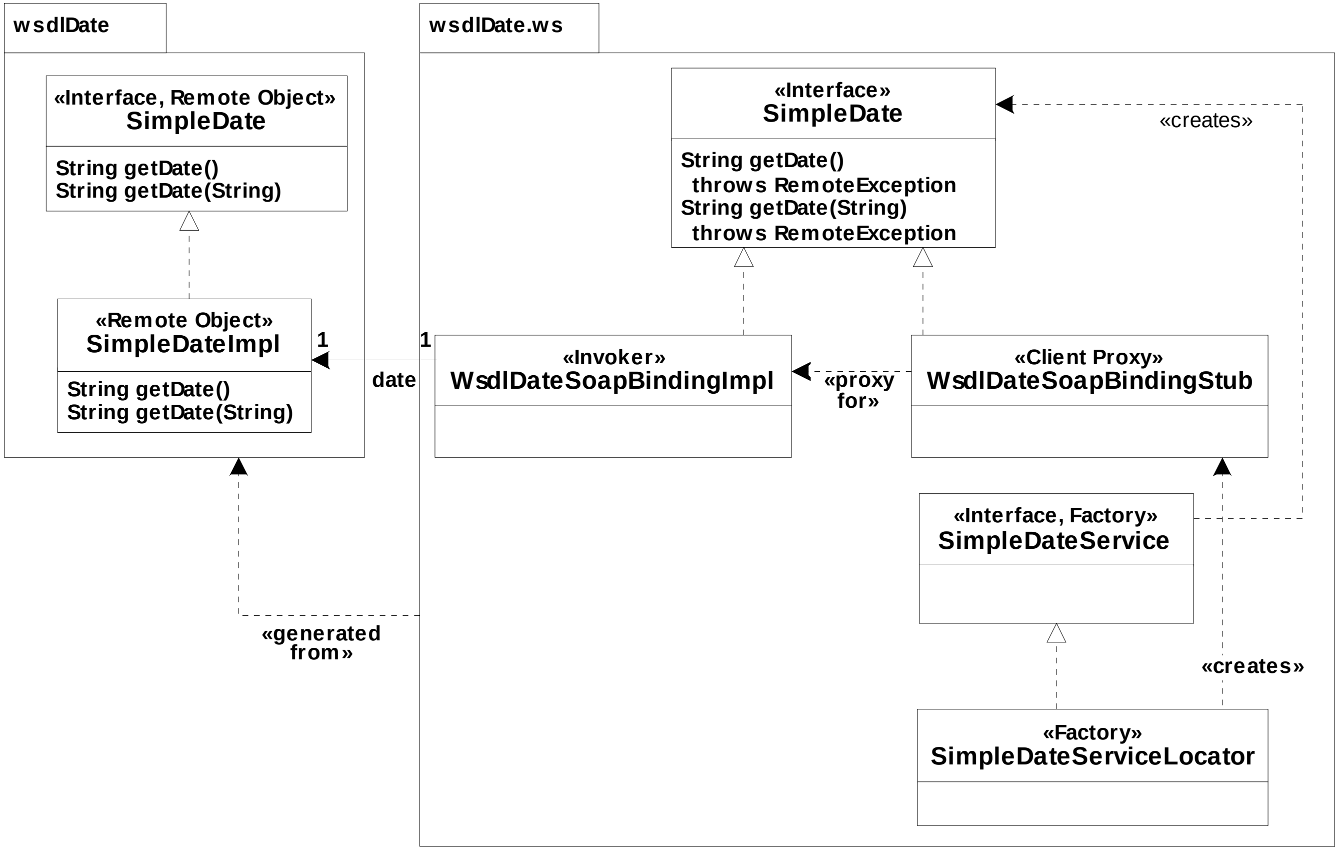
Constructing an Invocation with a Requestor on Client Side

```
Service service = new Service();
Call call = (Call) service.createCall();

call.setTargetEndpointAddress(
     new java.net.URL(endpointURL));
call.setOperationName("getDate");
call.addParameter( "format",
   XMLType.XSD_STRING,
  ParameterMode.IN);
arguments = new Object[] { formatString };
call.setReturnType(
  org.apache.axis.encoding.XMLType.XSD_STRING);
String result =
       (String) call.invoke( arguments );
System.out.println("Date: " + result);
```

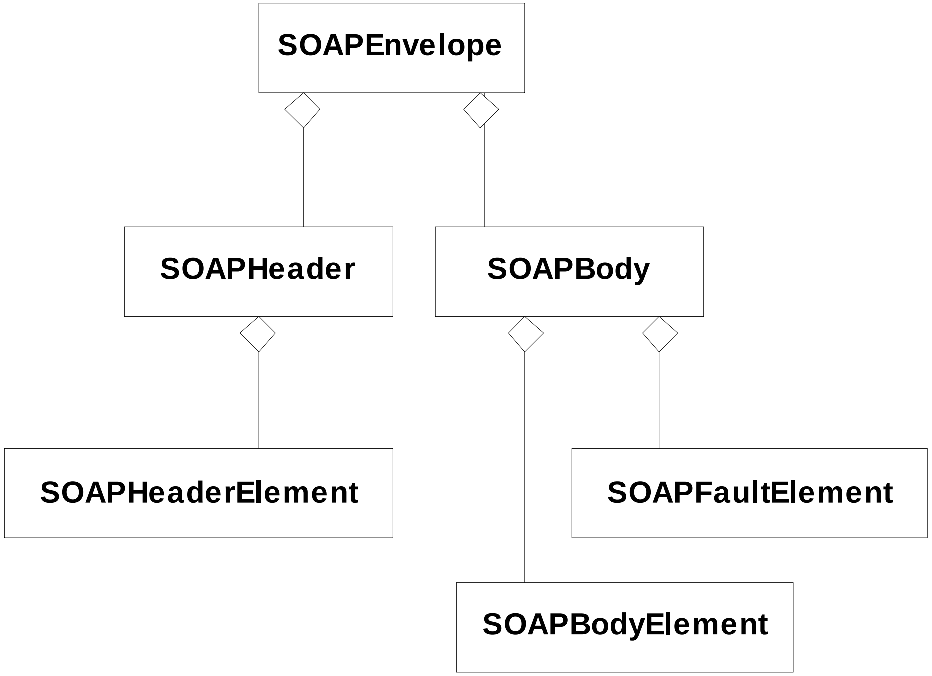
Generating Invoker and Client Proxy Code with WSDL

From an WSDL Interface Description we can generate Client Proxy and Invoker code:



Marshalling

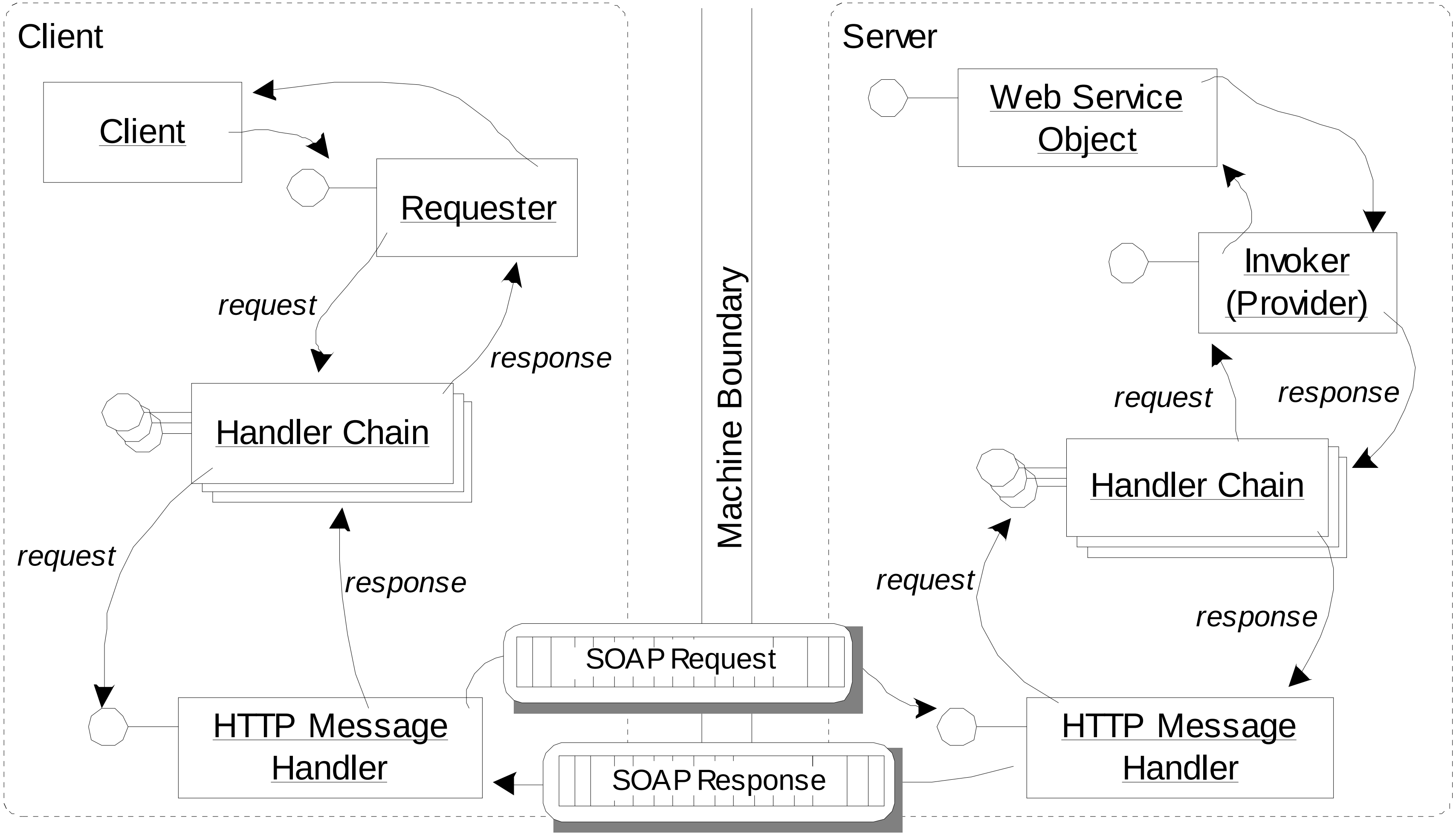
- **Conversion to SOAP**
  - Type conversion to/from strings, XSD types, …
  - Automatic type conversion for standard types



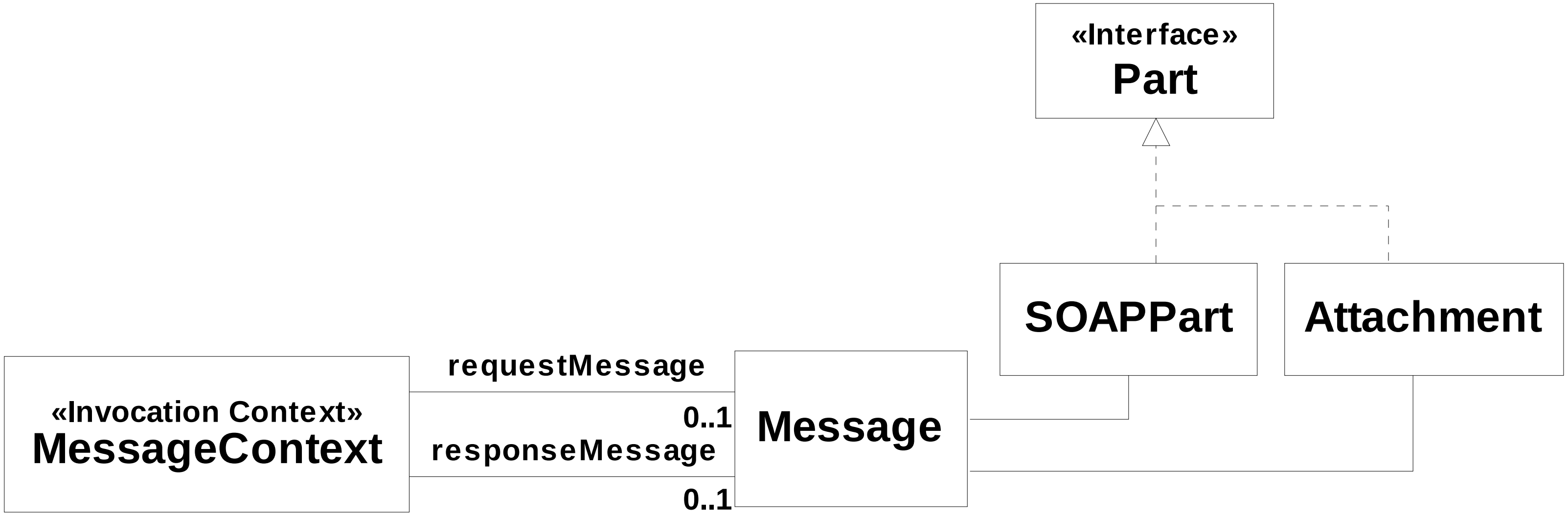
Message Processing

- **On client and server side:**
  - there are many different, orthogonal tasks to be performed for a message,
  - there is a symmetry of the tasks to be performed for request and response,
  - similar problems occur on client side and server side, and
  - the invocation scheme and add-ons have to be flexibly extensible.
- **Combination of the patterns**
  - requestor,
  - invoker,
  - invocation context,
  - invocation interceptor, and
  - client/server request handler
- **Interceptors as Commands are ordered in a Chain of Responsibility**

Message Processing (2)



Message Context



Example: Log Handler

```
public class LogHandler extends BasicHandler {
  ...
  public void invoke(MessageContext msgContext)
    throws AxisFault {
      ...
      if (msgContext.getPastPivot() == false) {
        start = System.currentTimeMillis();
      } else {
        logMessages(msgContext);
      }
      ...
  }
  ...
}
```

Configuration Groups in Deployment Descriptors

```
<handler
  name="logger"
   type="java:org.apache.axis.handlers.LogHandler"/>
...
<chain name="myChain"/>
   <handler type="logger"/>
   <handler type="authentication"/>
</chain>
...
<service name="DateService" provider="java:RPC">
   ...
   <requestFlow>
       <handler type="myChain"/>
  </requestFlow>
</service>
```

Protocol Integration

- **Heterogeneity of communication protocols of Web Service frameworks**
    - Most Web Service frameworks provide for some extensibility at this layer
    - Slightly different request handler/protocol plug-in architectures
- **In the default case HTTP is used as a communication protocol**
- **SOAP also allows for other communication protocols**
    - Implemented with protocol plug-ins
    - Same invoker can used for all protocols
- **Axis supports protocol plug-ins for HTTP, Java Messaging Service (JMS), SMTP, and local Java invocations**
- **Protocol plug-ins are responsible for implementing a message queue, if needed (e.g. JMS-based messaging)**

Lifecycle Handling and Identification

- **Axis supports the following lifecycle patterns using a scope option chosen in the deployment descriptor**
  - Per-Request Instance: Default, “request” scope
  - Static instance: “application” scope
  - Client-dependent instance: “session” scope,
    - Sessions are supported either by HTTP cookies or by - communication protocol independent - SOAP headers
    - Each session object has a timeout (which can be set to a certain amount of milliseconds). After the timeout expires, the session is invalidated. A method touch can be invoked on the session object, which re-news the lease.

Client-Side Asynchrony

- **Axis does not support client-side asynchrony patterns without using a messaging protocol**
- **Simple Asynchronous Invocation Framework for Web Services (SAIWS)**
  - Asynchrony layer on top of synchronous invocation layer provided by Axis
  - `http://saiws.sourceforge.net`

SAIWS - Requestors

Two kinds of requestors one for synchronous invocations:

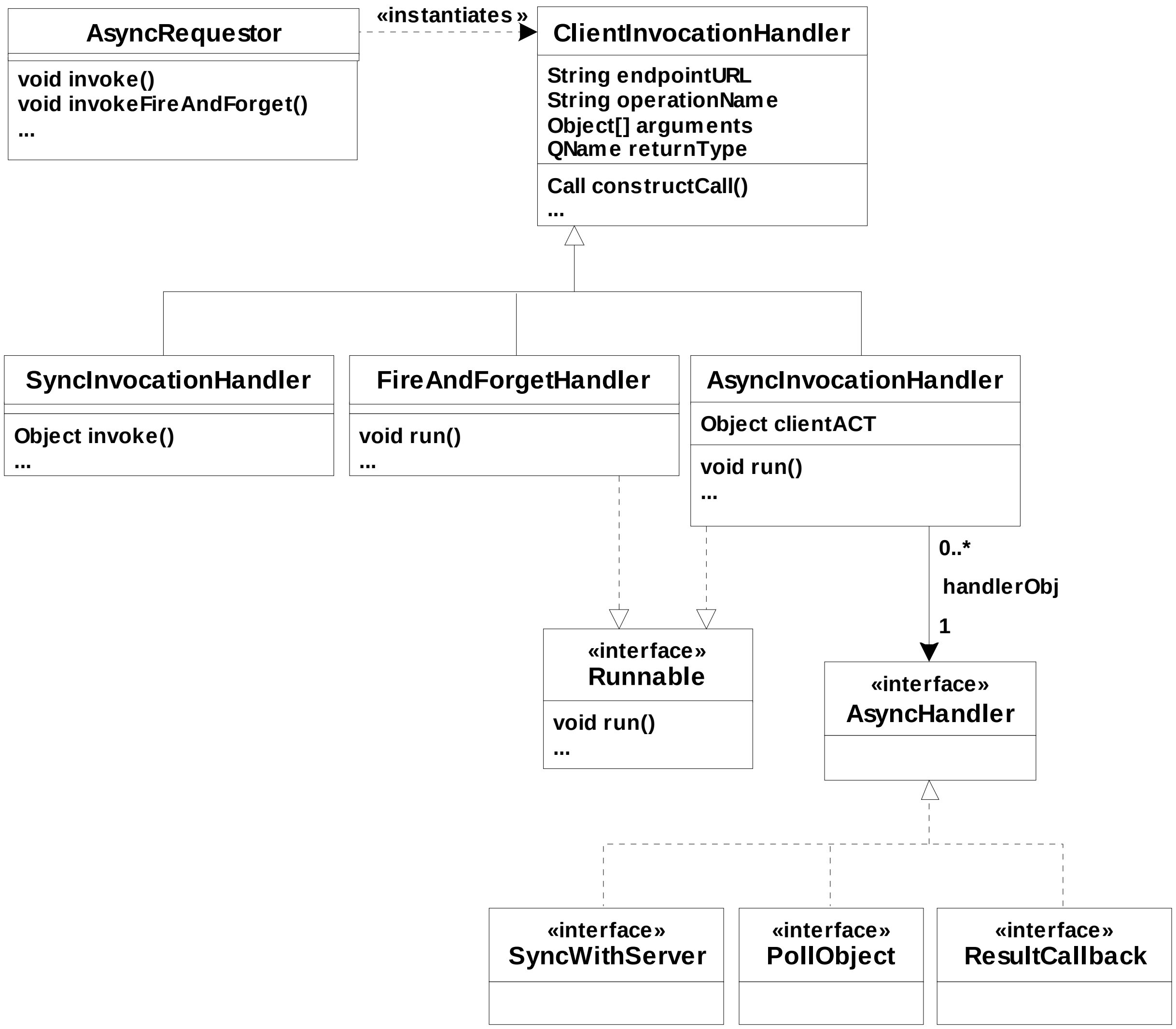
```
SyncRequestor sr = new SyncRequestor();
String result =
      (String) sr.invoke(endpointURL, operationName,
                                   null, rt
```

… and one for asynchronous invocations:

```
AsyncHandler ah = ...;
Object clientACT = ...;
AsyncRequestor ar = new asyncRequestor();
ar.invoke(ah, clientACT, endpointURL, operationName,

          null, rt);
// ... resume work
```

SAIWS - Invocation Handlers



AsyncRequestor

void invoke()
void invokeFireAndForget()
...

«instantiates»

ClientInvocationHandler

String endpointURL
String operationName
Object[] arguments
QName returnType

Call constructCall()
...

SyncInvocationHandler

Object invoke()
...

FireAndForgetHandler

void run()
...

AsyncInvocationHandler

Object clientACT

void run()
...

0..*
handlerObj
1

«interface»
Runnable

void run()
...

«interface»
AsyncHandler

«interface»
SyncWithServer

«interface»
PollObject

«interface»
ResultCallback

SAIWS - Example: Poll Object Invocation

```
AsyncRequestor requestor = new AsyncRequestor();
PollObject p = (PollObject) new SimplePollObject();
requestor.invoke(p, null, endpointURL,
                 operationName, null, rt);
while (!p.resultArrived()) {
      // do some other task ...
}
System.out.println("Poll Object Result Arrived = " +
                   p.getResult());
```

SAIWS - Example: Result Callback Invocation

```
AsyncRequestor requestor = new AsyncRequestor();
ResultCallback r = (ResultCallback) new
      ResultCallbackQueue();
for (int i = 0; i < 10; i++) {
      String id = "invocation" + i;
      requestor.invoke(r, id, endpointURL,
                       operationName,
                       null, rt);
}
```

Lookup of Web Services: UDDI

- **Many possible ways to realize lookup with Web Services**
- **UDDI is an automated directory service that allows one to register services and lookup services**
  - All UDDI specifications use XML to define data structures
  - An UDDI registry includes four types of documents:
    - A business entity is a UDDI record for a service provider.
    - A business service represents one or more deployed Web Services.
    - A technical model (tModel) can be associated with business entities or services.
    - A binding template binds the access point of a Web Service and its tModel.
  - UDDI allows a service provider to register information about itself and the services it provides

Other Web Service Frameworks Discussed

- **GLUE is a commercial Web Service implementation in Java that is optimized for ease-of-use and performance**
- **Microsoft’s .NET Web Services:**
  - .NET remoting
  - ASP.NET Web Services
- **IONA’s Artix**
- **Tcl SOAP**

Thanks for your attention!