21. Transparency Problems and the Decorator-Connector Pattern

A Design Pattern appearing in all classical component systems

Lecturer: Dr. Sebastian Götz

Prof. Dr. Uwe Aßmann

Technische Universität Dresden

Institut für Software- und Multimediatechnik

http://st.inf.tu-dresden.de/teaching/cbse

24. April 2017

Service-Oriented Architecture

- When the Object Management Group (OMG) was formed in 1989, interoperability was its founders primary, and almost their sole, objective:

➢ *A vision of software components working smoothly together, without regard to details of any component's location, platform, operating system, programming language, or network hardware and software.*

➢ Jon Siegel

The Ladder of Composition Systems

Software Composition Systems	**Composition Language**	***Invasive Composition Piccola Gloo***
Aspect Systems	**Aspect Separation Crosscut graphs**	***Aspect/J AOM***
View Systems	**Composition Operators**	***Composition Filters Hyperspaces***
Architecture Systems	**Architecture as Aspect Connectors**	***Darwin COSY BPMN ACME***
Classical Component Systems	**Standard Components Reflection**	***.NET CORBA Beans EJB***
Object-Oriented Systems	**Objects as Run-Time Components**	***C++ Java***
Modular Systems	**Modules as Compile-Time Components**	***Shell scripts Modula Ada-85***

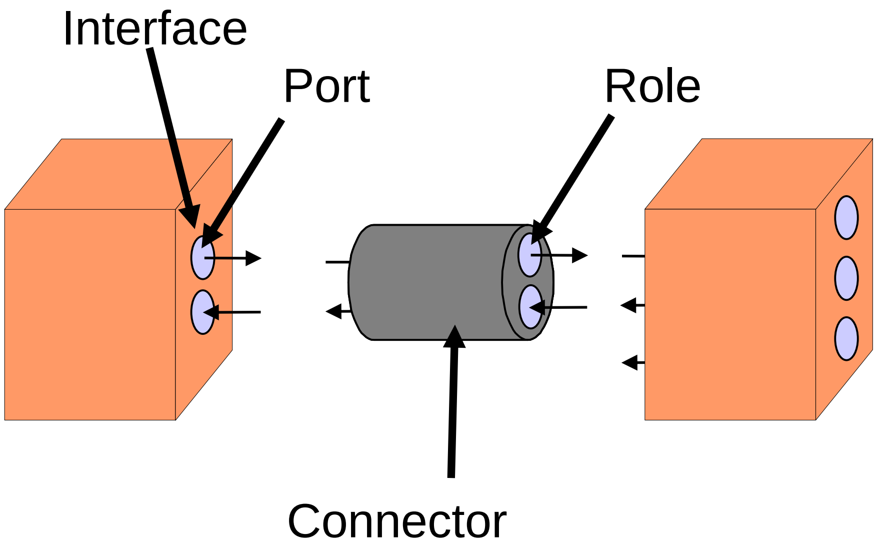
21.1. Transparency Problems for COTS

Transparency Problems (Middleware Concerns)

- **A transparency problem describes software concerns that should be transparent (invisible, hidden) when you write or deploy a component.**
  - **To solve a transparency problem, the component model requires different secrets**
- **Content secrets**
  - **Language transparency**: interoperability of components using different programming languages
  - **Persistency transparency**
    - Hide whether server has persistent memory
  - **Lifetime transparency**
    - Hide whether server has to be started
- **Connection secrets**
  - **Location transparency:** distribution of programs
    - Hiding, where a program runs
  - **Naming transparency:** naming of services
    - Hiding, how a service is called
  - **Transactional transparency**
    - Hide whether server is embedded in parallel writes

Idea: Encapsulate Transparency Problems

- *Components* encapsulate content secrets
  - *Ports* abstract required and provided interface points of components (event channels, methods)
  - Ports specify the data-flow into and out of a component
- *Connectors* are special communication components encapsulating connection secrets
  - Connectors are attached to ports
  - Connectors abstract from the concrete communication carrier
  - Can be binary or n-ary
  - Connector end is called a *role*
    - A role fits only to certain types of ports (typing)

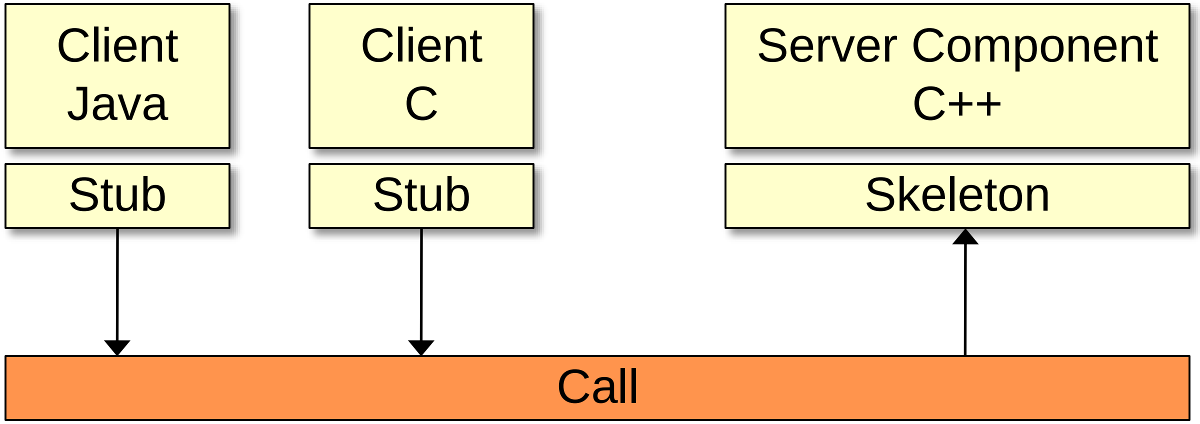


21.2 The Decorator-Connector Pattern

- Connectors can hide implementation issues for connection transparency problems

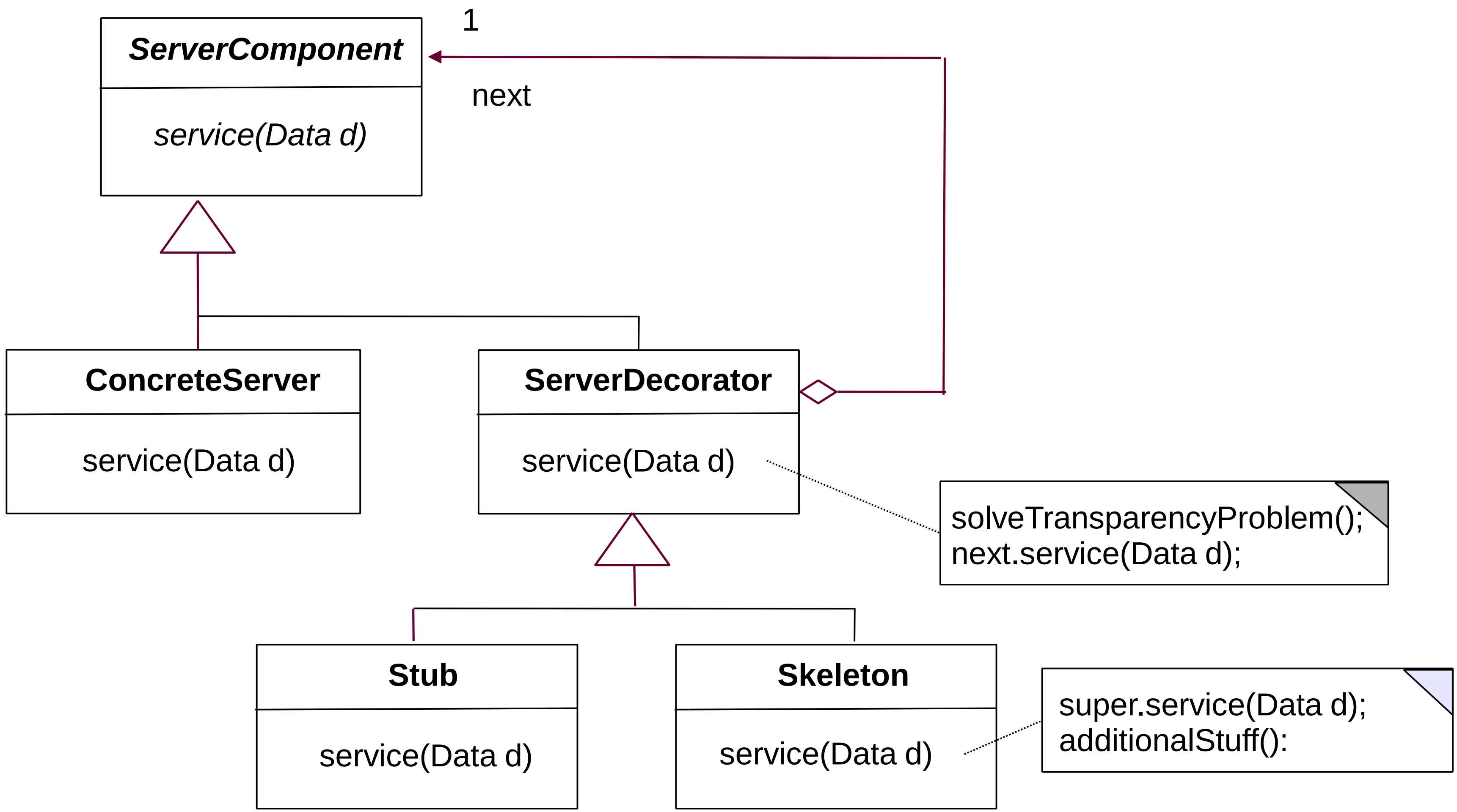
Language Transparency With the Connector Pattern

- The Connector Pattern (Double-Decorator Pattern, *n*-Decorator Pattern) can be used in a standard object-oriented language to implement connectors for classes and objects
  - Stub: Decorator of the client
    - Takes calls of clients in language $\mathcal{A}$ and sends them to the skeleton
  - Skeleton: Decorator of the server
    - Takes those calls and sends the component implementation in language $\mathcal{B}$
- Language adaptation in Stub or Skeleton (or both)
  - Adaptation deals with calling concepts, etc. (see above)
  - Based on a mapping of language constructs from both languages, defined by an Interface Definition Language (IDL)



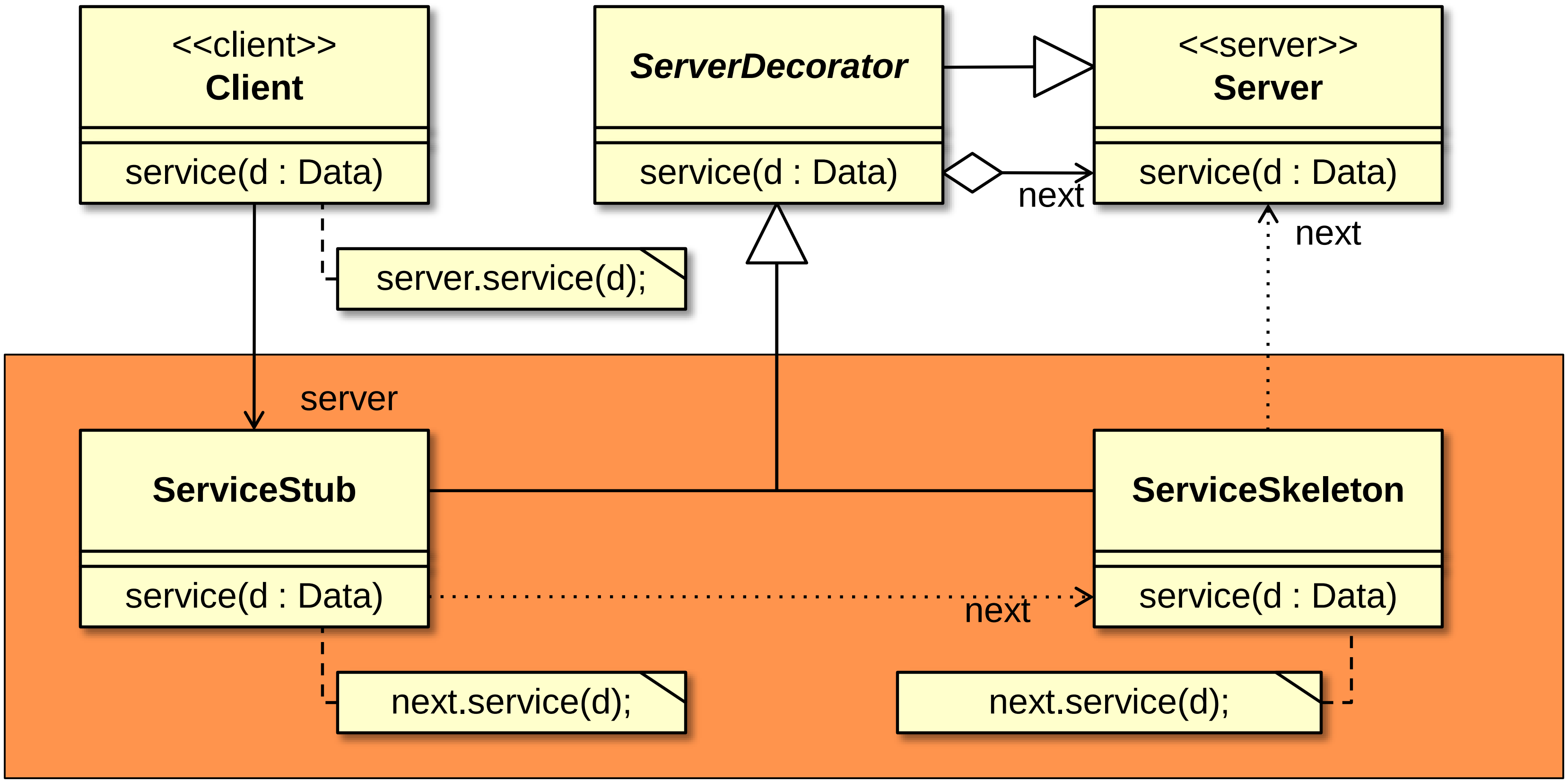
Basic Idea: Stubs and (Static) Skeletons as Decorators

- A typical instance of the Decorator pattern: two proxies on client and server
- Stub decorates skeleton, skeleton decorates server



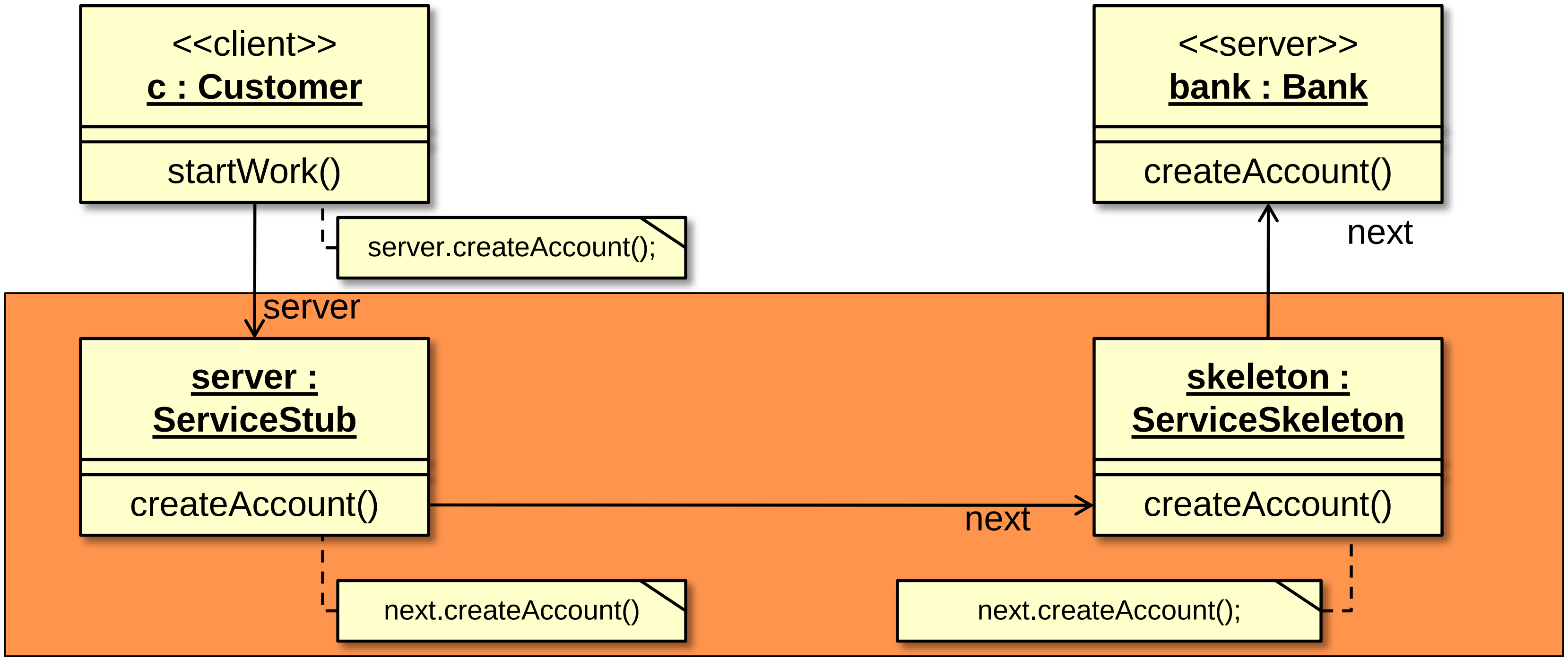
The Decorator-Connector Pattern

- Client and server are connected via a layer of stubs and skeletons (the *connector*)
- The connector consists of two decorators of the server
- Decorator chain is inherited



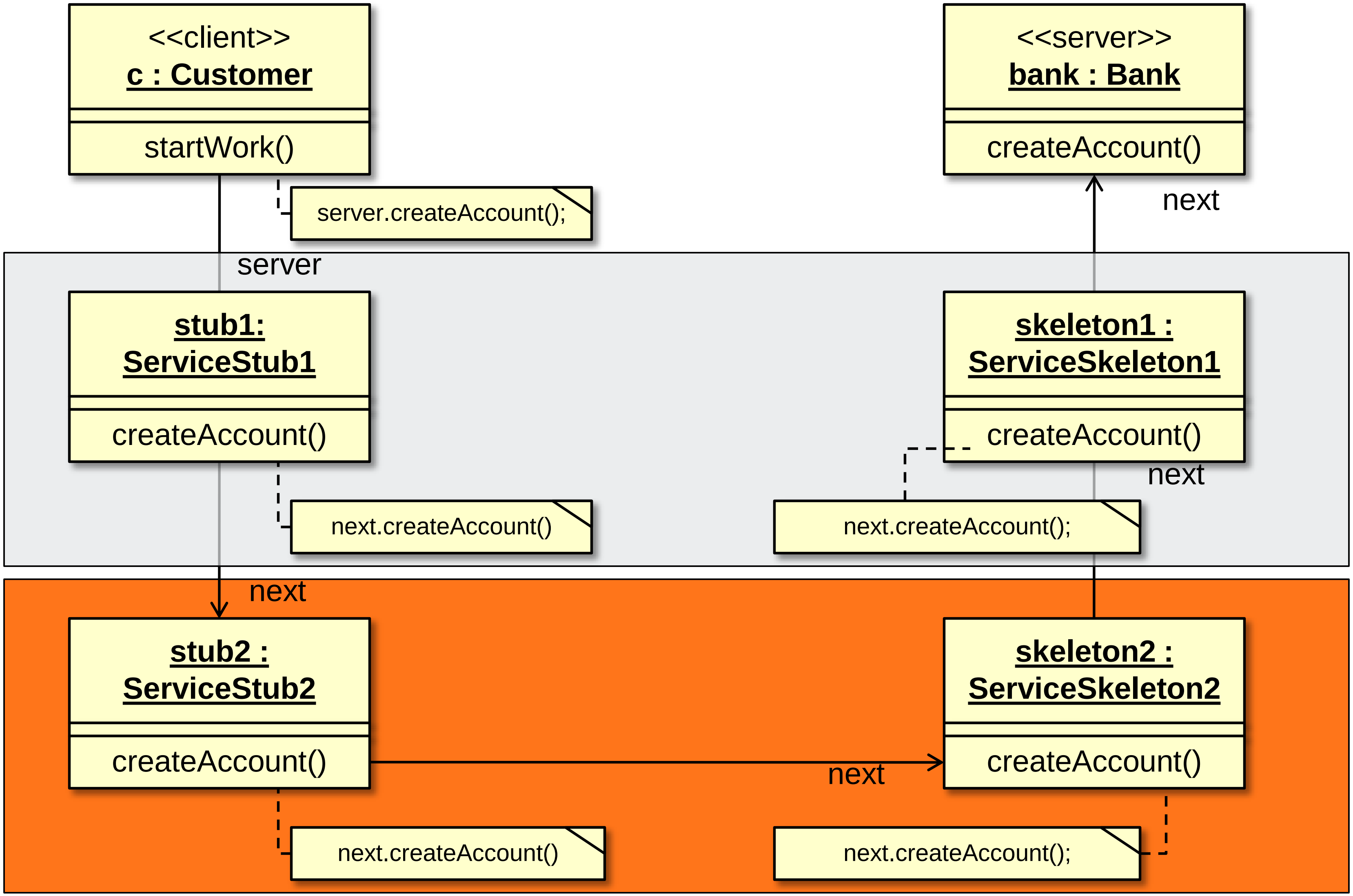
Object Diagram of Decorator-Connector Pattern

- Connector consists of a Decorator chain, in a layer



Layered Decorators (Object Diagram)

- More decorators can be stuffed into the connector in additional layers:



Decorator vs Proxy vs Adapters vs Chain

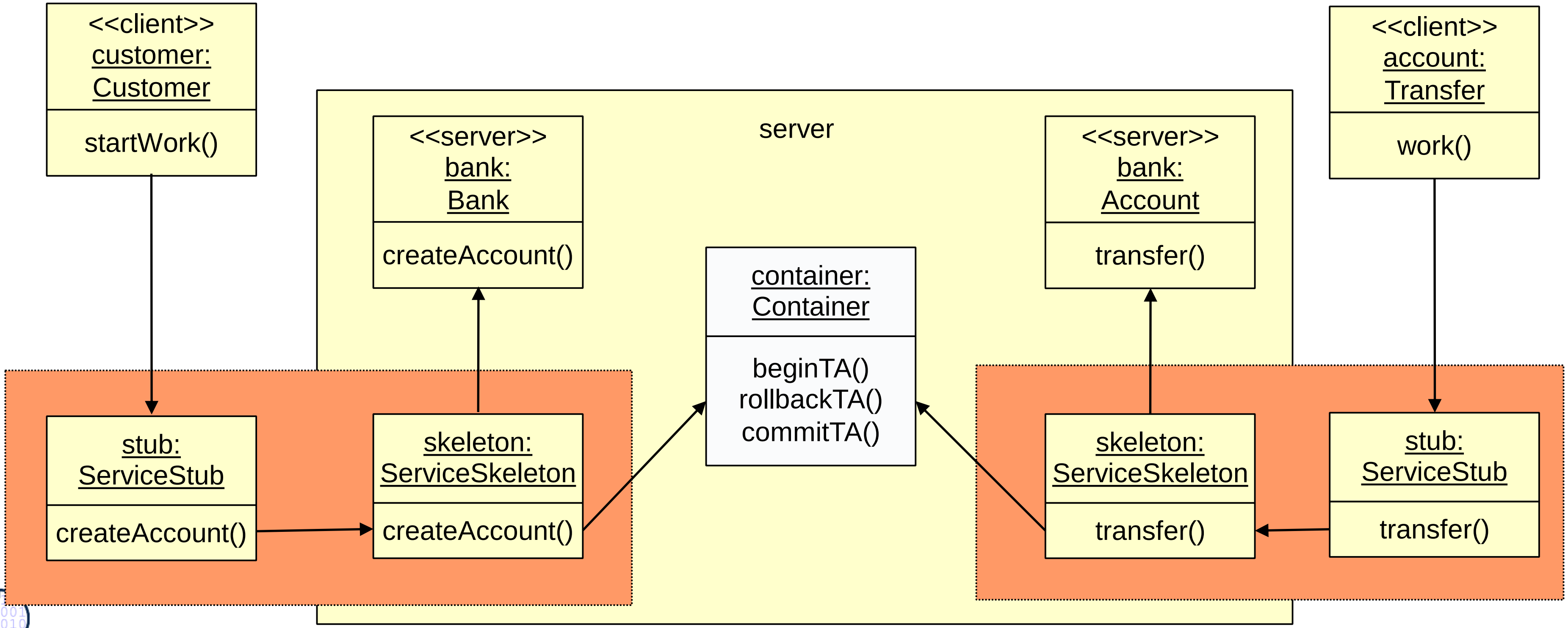
- Why should it be a Decorator?
  - Decorators allow for stacking of connectors (layering)
  - Proxy pattern: just *one* representative, no stacking possible
    - However, from the client and server's perspective, stub and skeletons are Proxies
  - Adapter: Adapted interface must be different from Adaptee
  - Chain: In a Chain, the processing may stop (not here..)
- However, Connectors can use all other basic “representer” patterns
  - Adapter-Connector: adapts required interface to server additionally
  - Chain-Connector: may stop processing
  - Proxy-Connector: just one layer possible

Tasks of the Layers

- In a component model, every layer of decorator-pairs is devoted to a specific task for *transparency (middleware concern)*
  - Language mappings (language interoperability)
  - Distribution handling (serialization, deserialization)
  - Names (name mapping, name search)
  - Persistence
  - Transactions
  - etc.
- Layers can be composed (stacked) freely

Containers – Infrastructure for all Connectors

- A **container** of a server component is an infrastructure for *all* connectors at run-time (all decorators/proxies).
  - Creation (server component factories for service families)
  - Transactions (begin, rollback, commit)
  - Persistence (activate, passivate)
- The container is an instance of the Façade design pattern (DPF)



Who Realizes Stubs and Skeletons?

- Programmer
  - Much handcrafting, using Decorator pattern. Boring and error prone
- Generator:
  - Stub
    - Export interface is component dependent, independent of source language
    - Implementation is source language dependent
  - Skeleton
    - Import interface is component dependent, independent of source language
    - Implementation is target language dependent
- Idea: Generate export and import interfaces of Stub and Skeleton out of a component interface definition
  - Take generic language adapter for the implementation

21.3 Interface Definition Languages for Mapping Different Languages

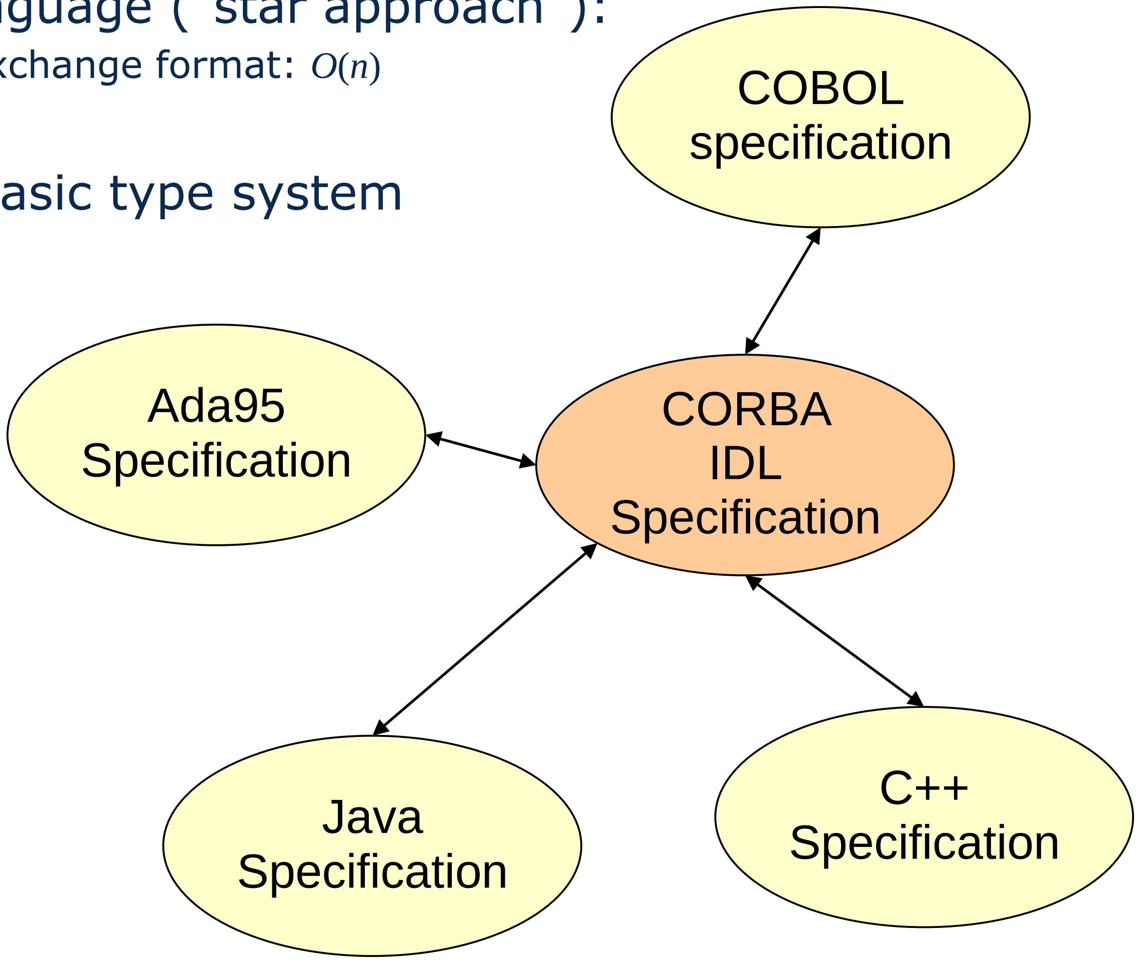
- Language mediation with the „star approach“

Transparency Problem 1: Language Transparency

- Calling concept
  - Procedure, Co-routine, Messages, ...
- Calling conventions
  - Call by name, call by value, call by reference, ...
- Calling implementation
  - Parameters on the stack, in registers, allocation and de-allocation
- Data types
  - Value and reference objects
  - Arrays, union, enumerations, classes, (variant) records, ...
  - Kind of inheritance (co-variance, contra-variance, ...)
- Data representation
  - Coding, size, little or big endian, ...
  - Layout of composite data
- Runtime environment
  - Memory management, garbage collection, lifetime ...

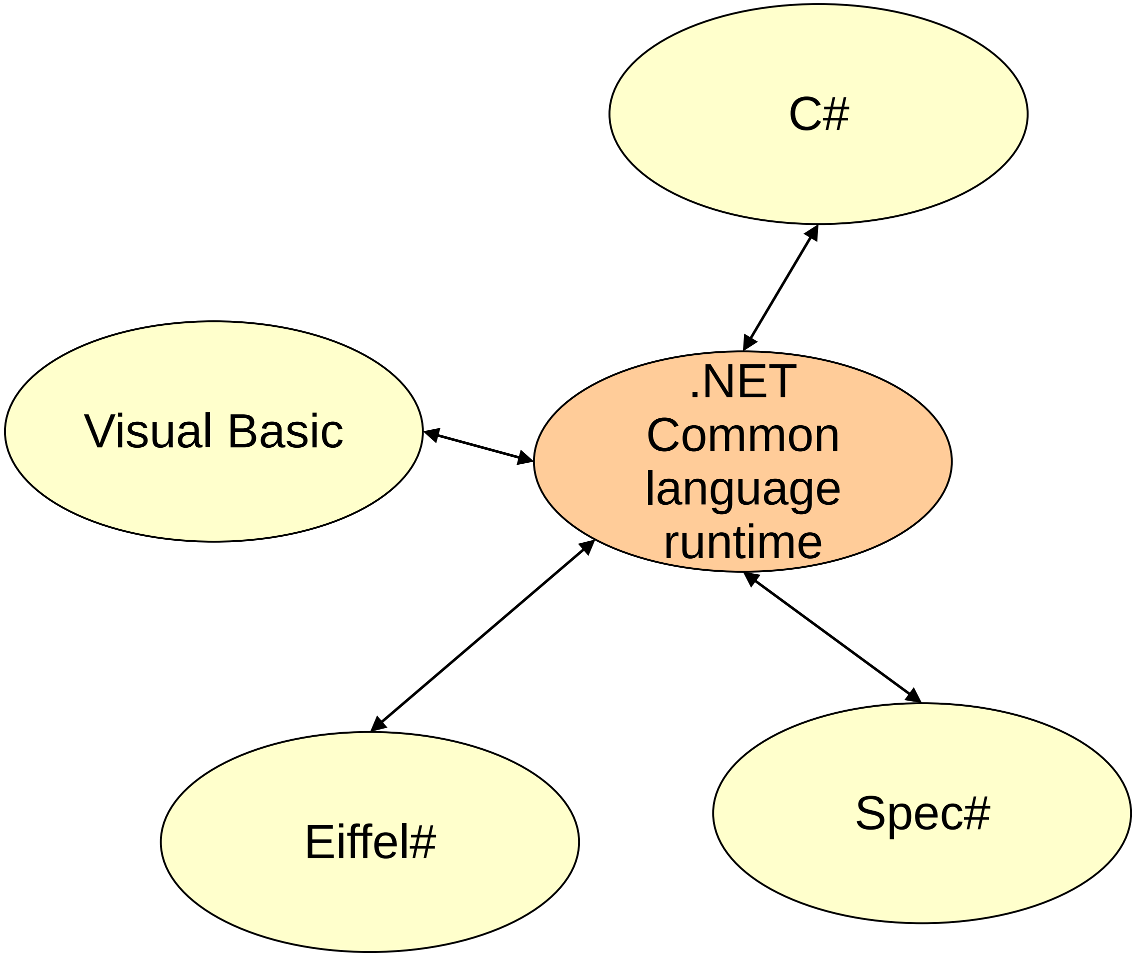
Language Mediation - Options In General

- Direct language mapping (full graph of language relationships):
  - 1:1 adaptation of pairs of languages: $O(n^2)$
- Mapping to common language (“star approach”):
  - Adaptation to a general exchange format: $O(n)$
  - CORBA IDL
- Compiling to common basic type system
  - .NET, WSDL



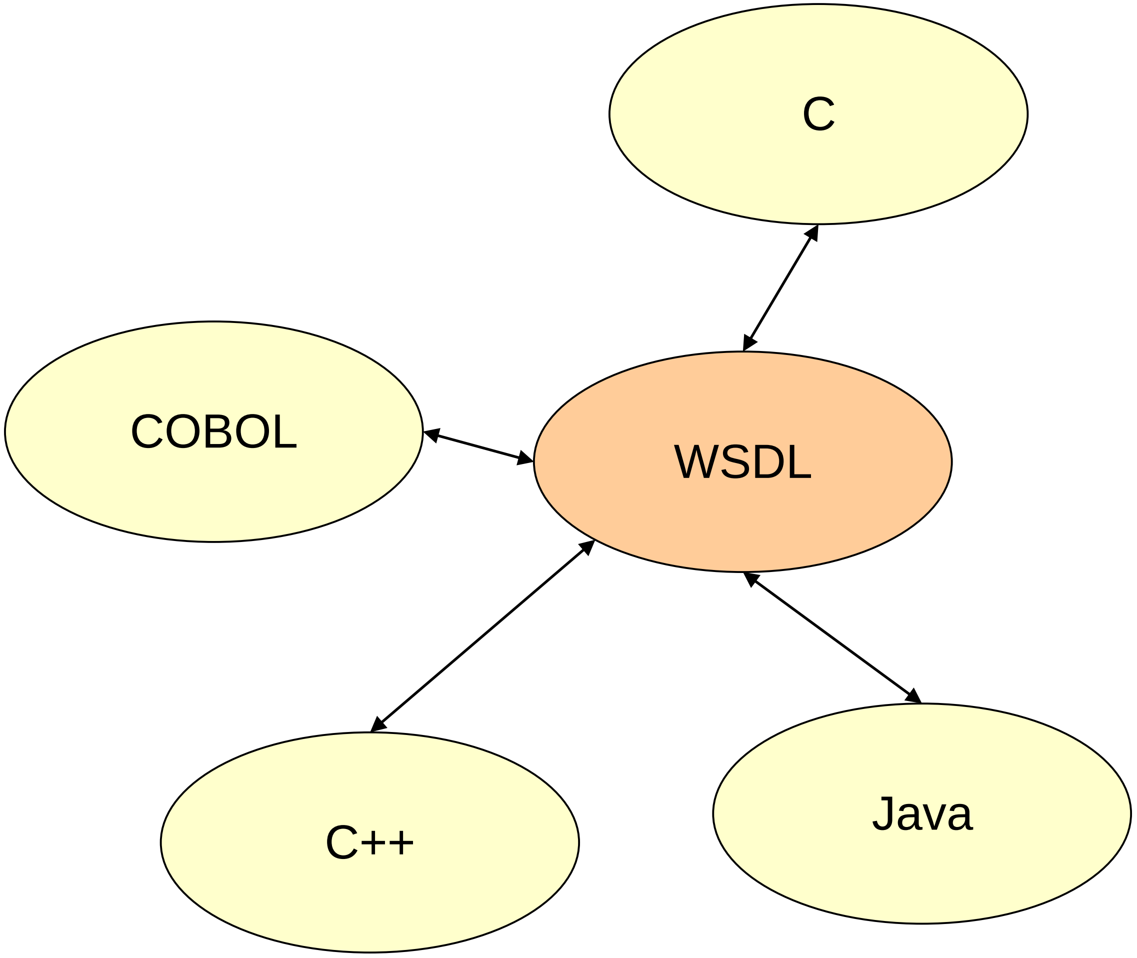
Language Mediation – Common Basic Type System

- Compiling to common basic type system:
  - Standardize to a single format (like in .NET): $O(1)$ but very restrictive, because the languages become very similar



Language Mediation – WSDL

- Web Service Definition Language (WSDL) uses a similar concept as .NET, but encodes everything as XML

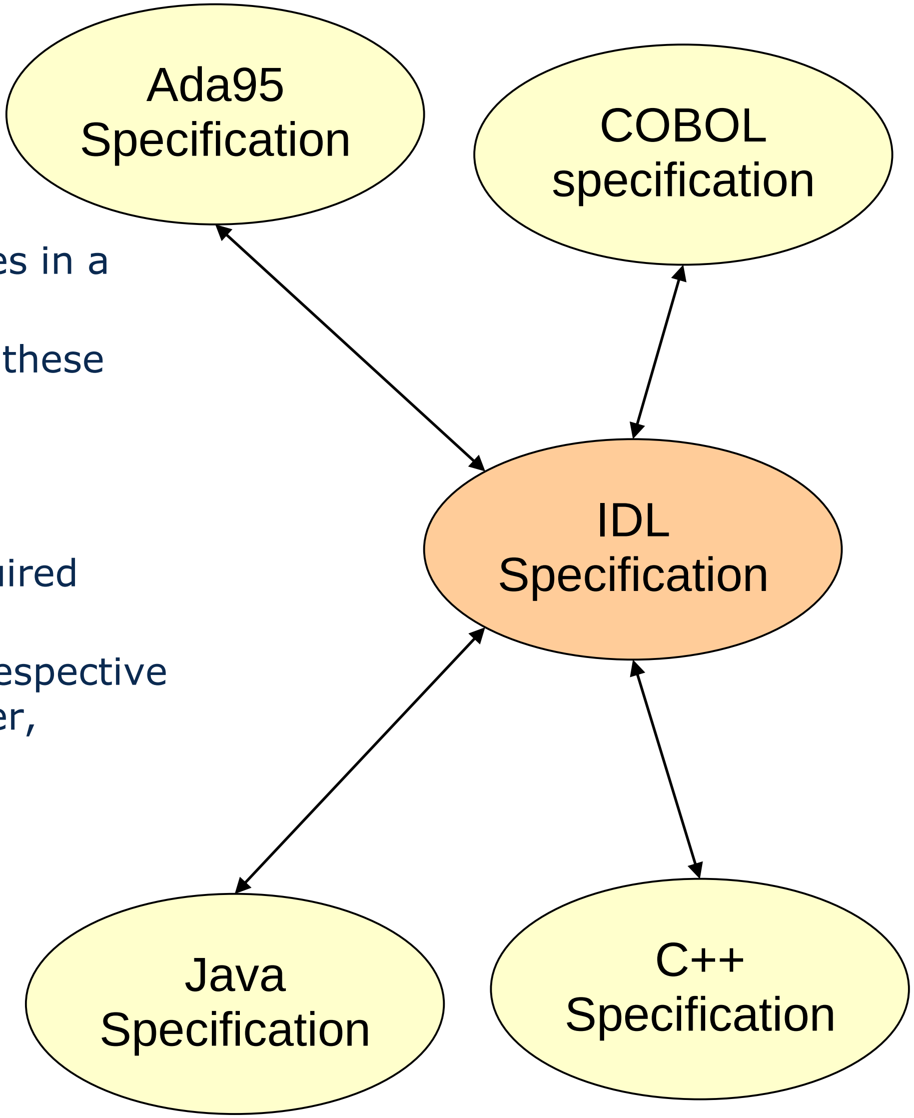


Solutions in Classical Component Systems

- Calling concept:
  - standardized by the communication library (RPC)
- Calling conventions:
  - Standardized by the communication library (EJB - Java , DCOM - C)
  - Implementation for every single language (Corba)
- Calling implementation:
  - Standardized by the communication library (EJB - Java , DCOM - C)
  - Implementation for every single language (Corba)
- Data types:
  - Standard (EJB – Java types)
  - Adaptation to a general exchange format (interface definition language, IDL)
    - CORBA IDL
    - Web Service Definition Language (WSDL)
- Data representation:
  - Standard (EJB – Java representation, DCOM – binary standard)
  - Adaptation to a general format (IDL 2 Language mapping)
- Runtime environment
  - Standard by services of the component systems

Type Mapping with the CORBA IDL

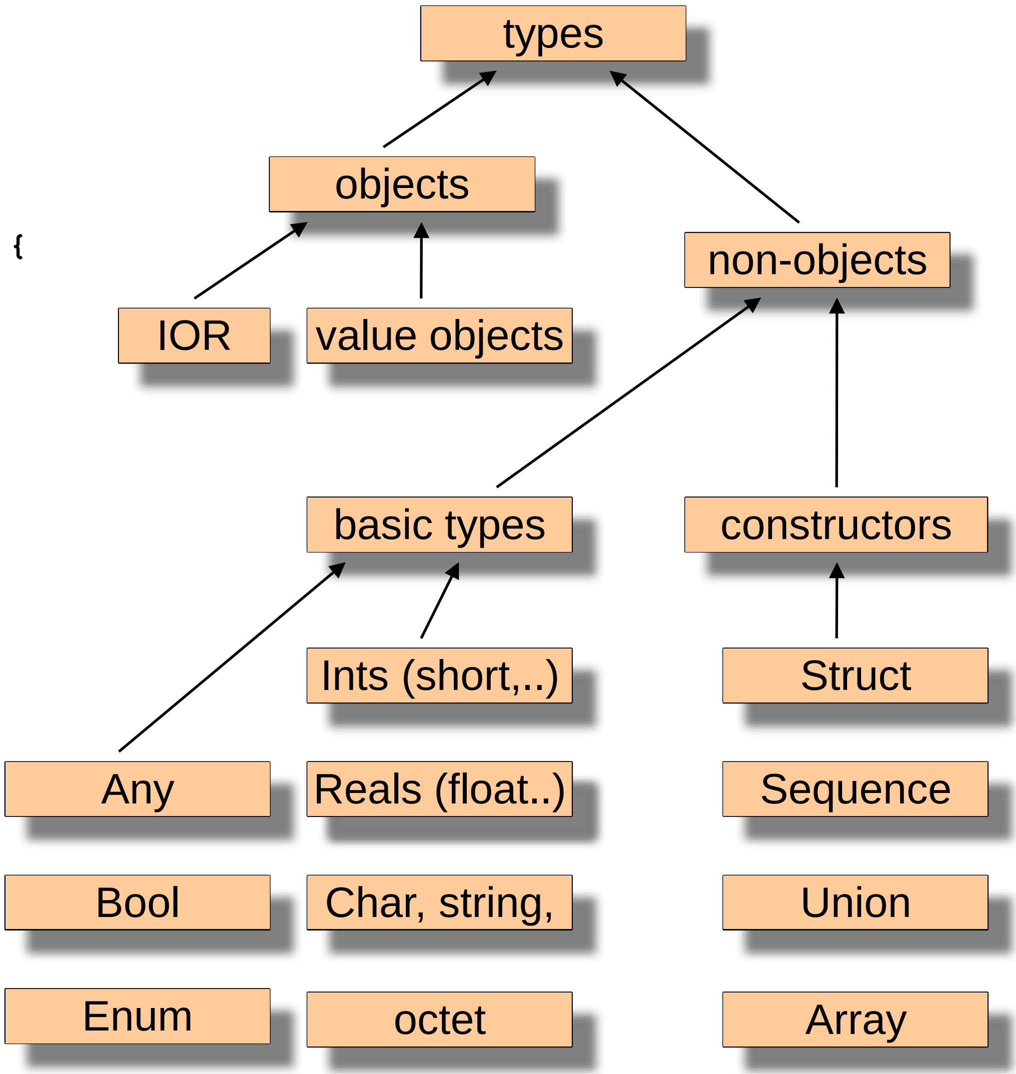
- An IDL language defines the
  - Interfaces of components
  - Data types of parameters and results
- Language independent type system
  - General enough to capture all data types in a programming language
  - IDL mediates between type systems of these languages
- Procedure of construction
  - Define component interface with IDL
  - Generate stubs and skeletons with required languages using an IDL compiler
  - Implement the frame (component) in respective language (if possible reusing some other, predefined components)



Ex.: Types in the CORBA Interface Definition Language

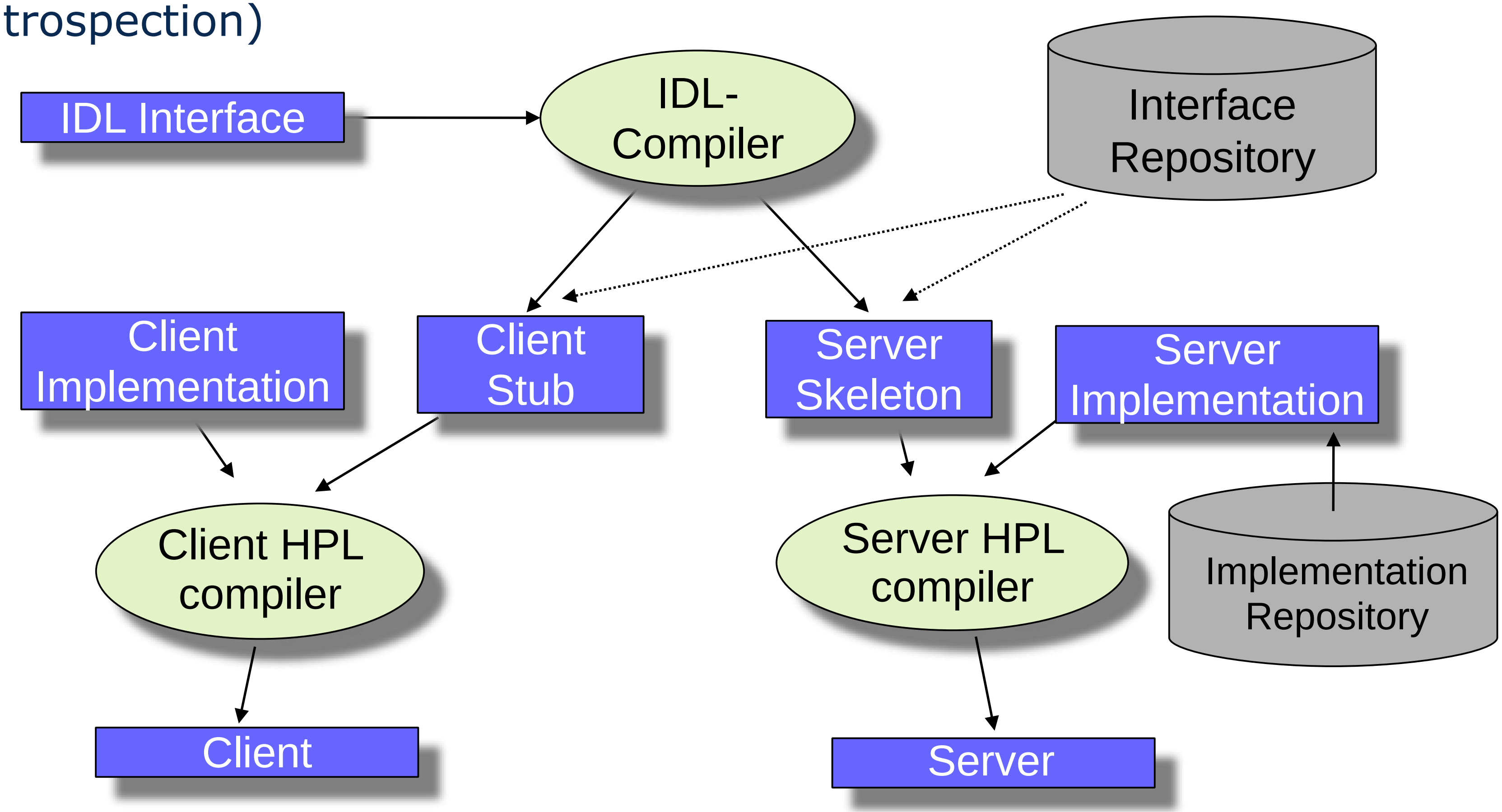

```
// IDL specification scheme
modules <identifier> {
  <type declarations>
  <constant declarations>
  <exception declarations>

  // classes
  interface <identifier> : <inheriting-from> {
    <type declarations>
    <constant declarations>
    <exception declarations>
    // methods
    optype <identifier>(<parameters>) {
              ...
    }
    ....
  }
}
```

```
module HelloWorld {
    interface SimpleHelloWorld {
        string sayHello();
    };
};
```

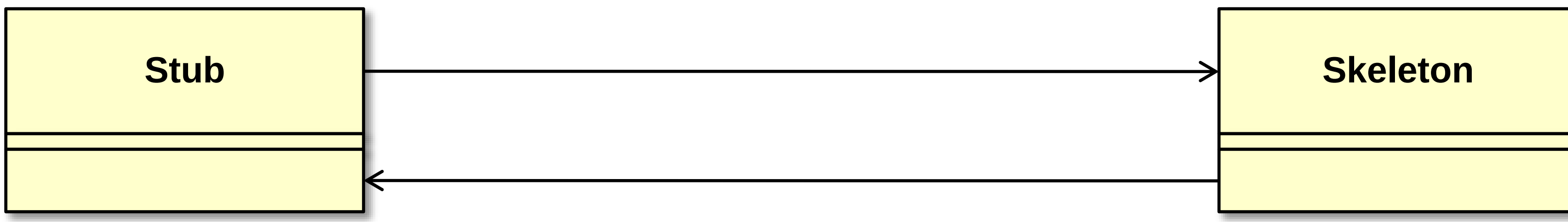


Generation of Stubs and Skeletons from CORBA IDL

- Generation is done for every involved host programming language (HPL)
- Interface Repository is queried for component interfaces (introspection)



Stubs and Skeletons for Language Mediation



Language 1

Map data to an exchange format (IDL)

Call Skeleton

Language 2

Receive call from stub

Retrieve data from the exchange format (IDL), transform it into language 2

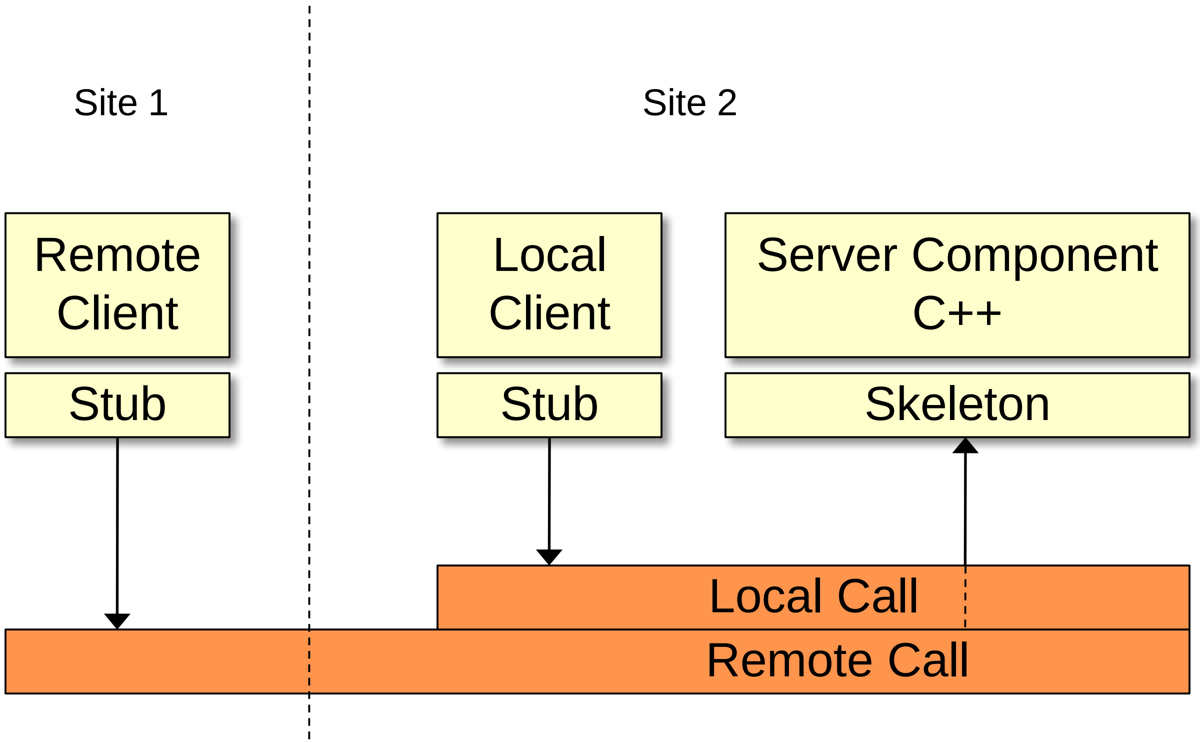
21.4 Location Transparency

Transparency Problem 2: Distribution

- *Location transparency:* interoperability of programs independently of their execution location
- Problems to solve
  - Transparent basic communication
    - Transparently initiate a local/remote call
    - Transparently transport data locally or remotely via a network
    - Transparent references
  - Distributed systems are heterogeneous
    - Platform transparent, concurrent execution?
    - So far we handled platform transparent design of components
  - Usual aspects in distributed systems
    - Transactions
    - Synchronization
    - ...

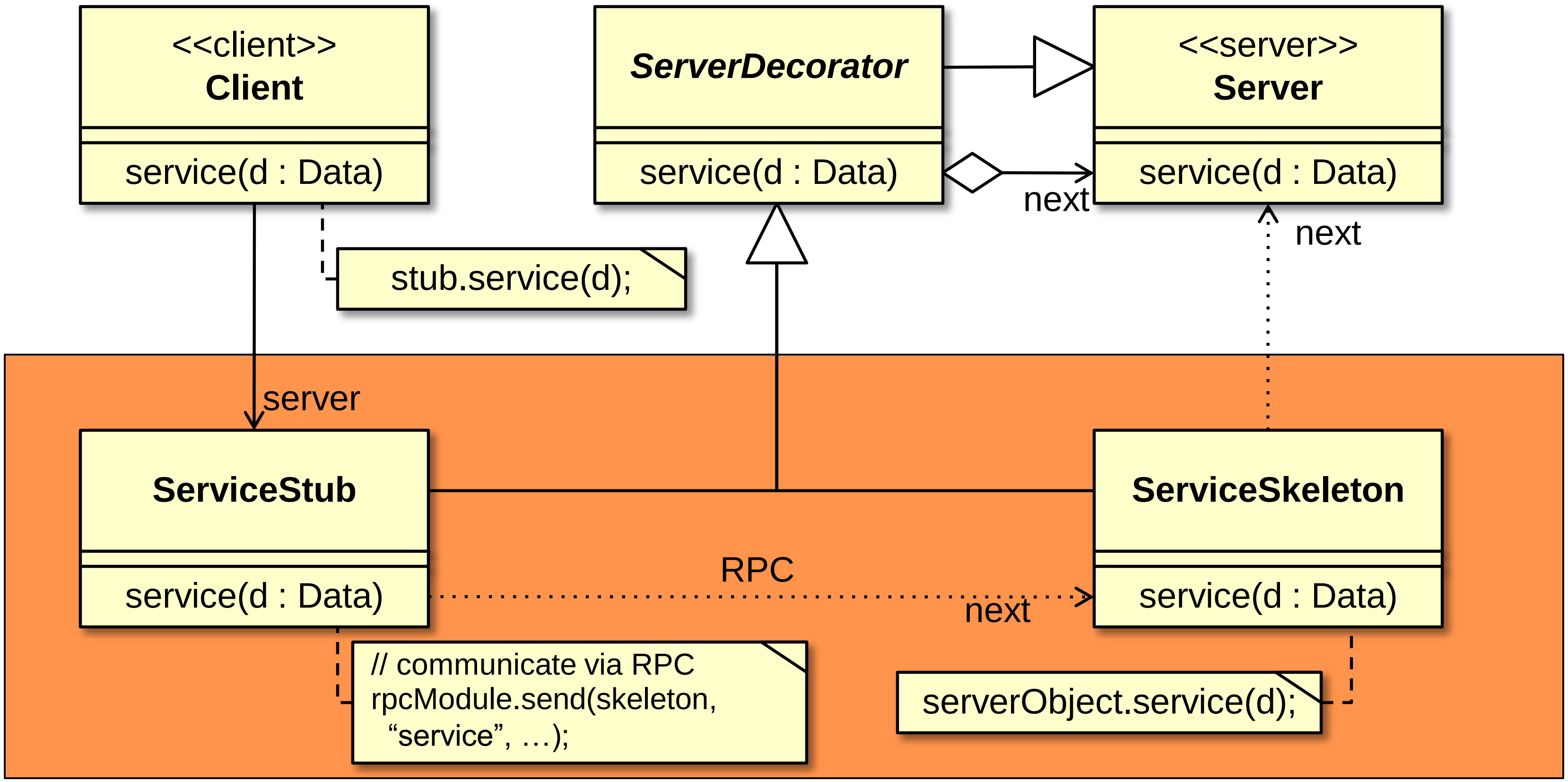
Transparent Local/Remote Calls

- Communication over proxies/decorators
  - Proxies redirect call locally or remotely on demand
  - Proxies always local to the caller
- RPC for remote calls to a handler
  - Handler always local to the callee
- We reuse Stubs and Skeletons

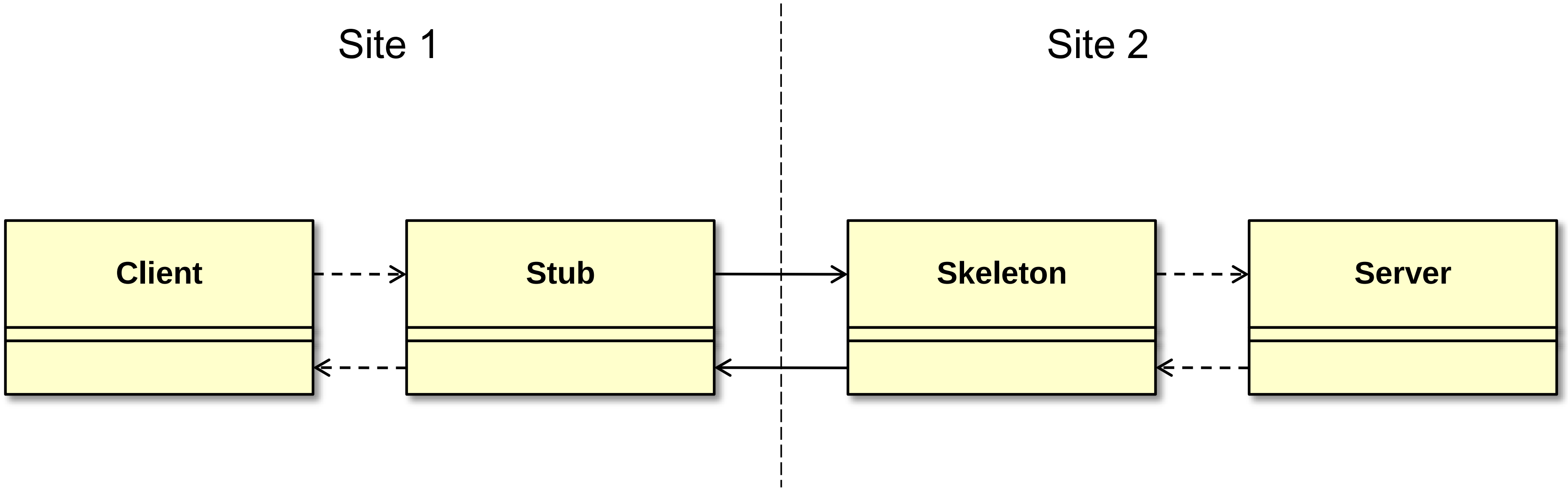


Stubs and Skeletons for Distribution

- A variant of the Connector pattern, using remote procedure call (RPC) between the decorators



Stubs and Skeletons for Distribution



RPC

Language 1

Map data / call
to a byte stream
(marshalling,serializing)
Exchange format
Send RPC

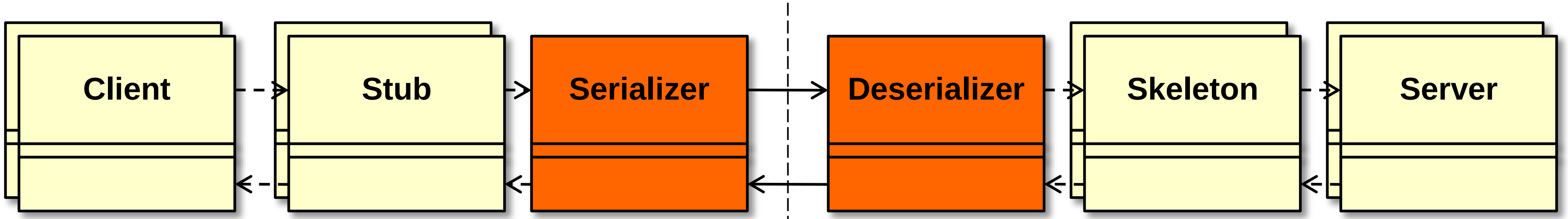
Language 2

Receive RPC
Retrieving data / call
from the byte stream
(unmarshalling,deserializing)
Exchange format

Stubs, Skeletons, and Serializers

- or with separate serializers/deserializers

Site 1 | Site 2



Language 1 | Language 2

RPC

Map data / call
to a byte stream
(marshalling,serializing)
Exchange format
Send RPC

Receive RPC
Retrieving data / call
from the byte stream
(unmarshalling,deserializing)
Exchange format

21.5 Name Transparency and Trading

- Mapping names to locations by name servers

Transparency Problem 3: The Reference Problem (Name Transparency)

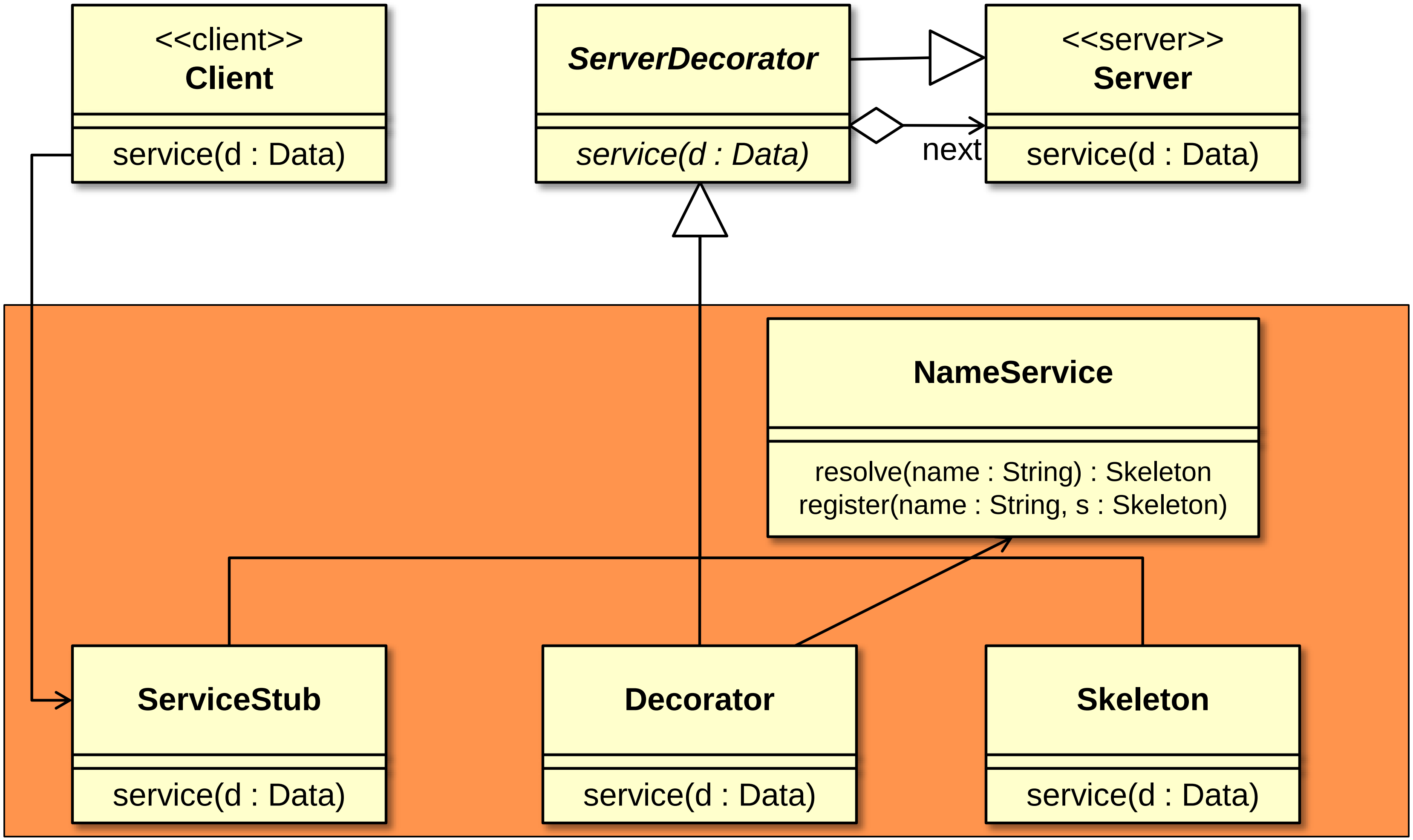
- How to reference something?
  - Target of calls (services)
  - Call by reference parameters and results
  - Reference data in composite parameters and results
- Scope of references
  - Thread/process
  - Computer
  - Agreed between communication partners
  - Net wide
- How to handle references transparently?

Approach: Global Adresses

- World wide unique *logical* addresses
  - e.g., computer address + local address
  - URL (Uniform Resource Locators), URI (Uniform Resource Identifiers)
  - CORBA IORs (Interoperable Object References)
  - Global file names, e.g., with AFS (Andrew File system)
  - Names in a global cloud file system (DropBox, Skydrive, etc.)
  - Names in a private cloud file system http://sparkleshare.org/
- Mapping tables for local references
  - Logical to physical
  - Consistent change of local references possible
- One server decorator per computer manages references
  - 1:n relation decorator to skeletons
  - 1:m relation skeletons to component objects
  - Lifecycle and garbage collection management
  - Identification (Who is this guy …)
  - Authorization (Is he allowed to do this …)

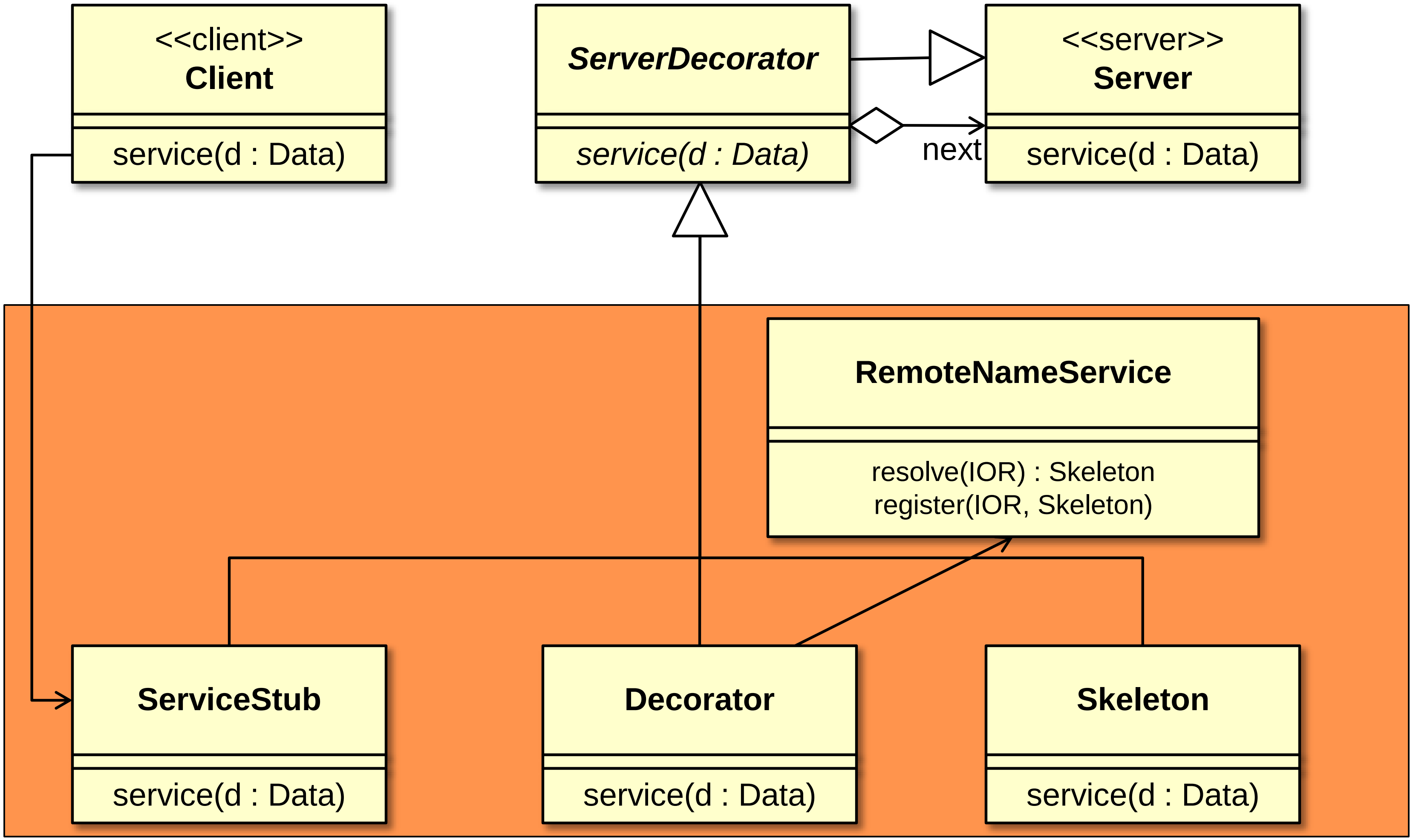
Name Service

- Name to Location
- Located in the container as an associative array (map)



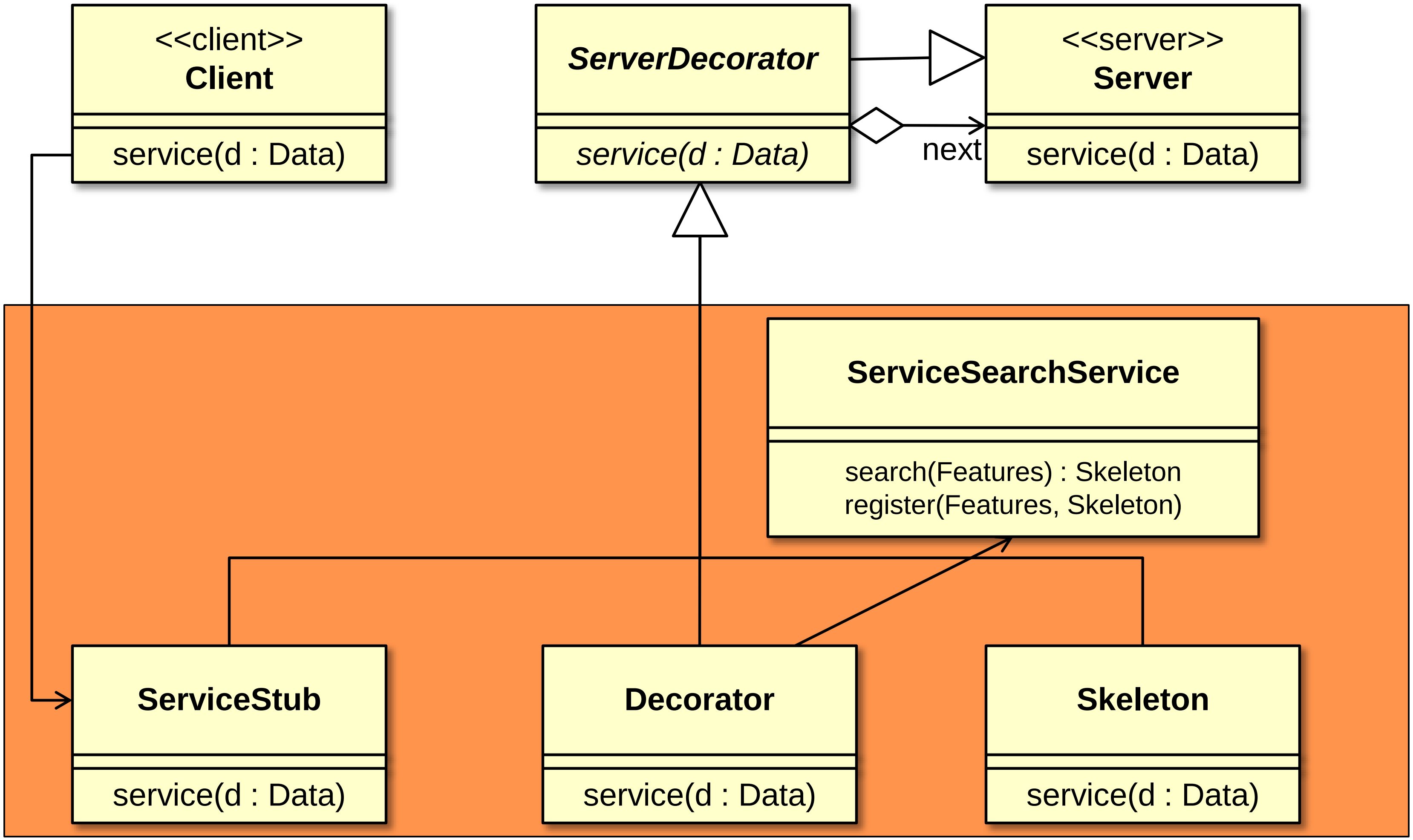
Name Service Generalized (1)

- *Distributed name service* (name to location):
  - If name of server is known, search for the right site providing a desired component



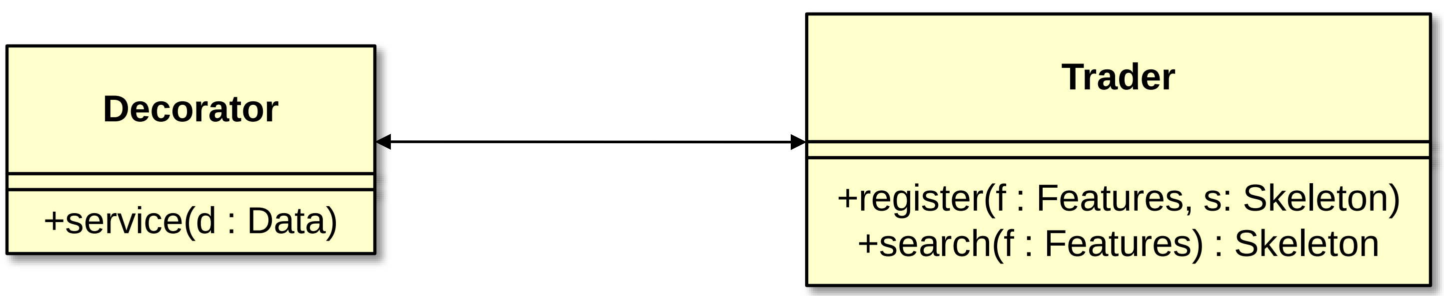
Name Service Generalized (2)

- *Extended name service, dynamic call:*
  - If name of server is **not** known, search for the right service with faceted feature description



Traders as Generalized Name Servers

- **Trader service, traded call** map symbolic service descriptions (service properties) to name or location
  - Search for a server component with known properties, but *unknown* name
  - Server components register at a *trader* with name, reference, and lookup properties (metadata)
    - The trader has a component repository (*registry)*
    - Instead of names, lookup of service matches properties (metadata)
    - Return reference (site and service)
  - Matching relies on standardized properties
    - Terminology, Ontology in facets (see “Finding components”)
    - Functional properties (domain specific functions …)
    - Non-functional properties (quality of service …)



Remark: Skeletons, NameServers, and Containers

- Can be started and consulted by skeletons
- May offer many other aid functionality
  - Transactions: consistent management of multiple clients and service requests
  - Security
  - Persistence
  - Interception (hooks into which new functionality can be entered)
  - Support for aspects

What Classical Component Systems Provide

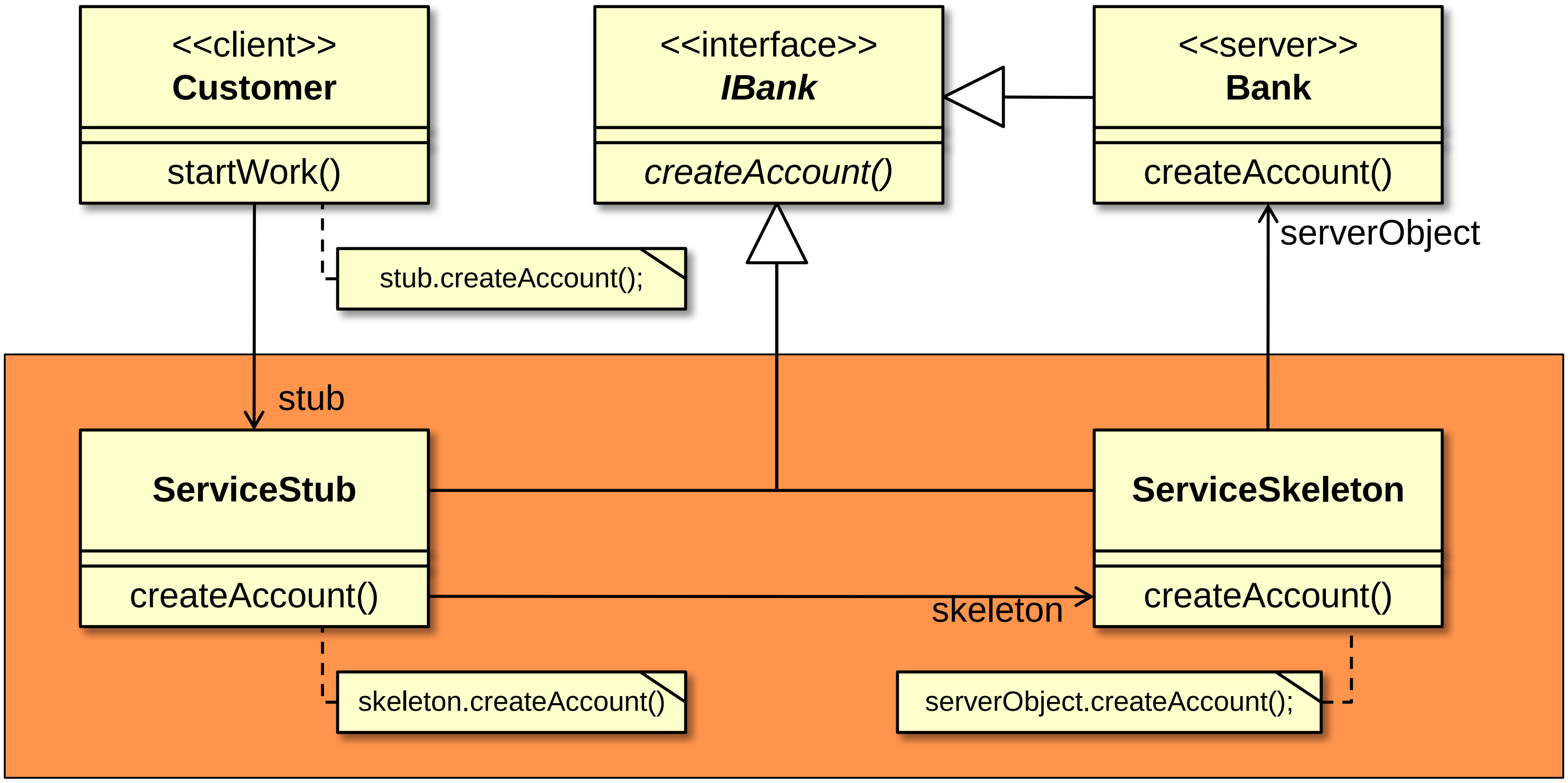
- Technical support: remote, language and platform transparency
  - Stub, Skeleton
    - One per component (technique: IDL compiler)
    - Generic (technique: reflection and dynamic invocation)
  - Decorators on client and server site
    - Individual
    - Generic (technique: Name services)
- Economically support: reusable services
  - name, trader, persistency, transaction, synchronization

Summary

- Component systems provide many component secrets
  - Location, language and platform transparency
  - Transactional, persistence, security, name service
- Component secrets are realized with the Connector Pattern (Stub, Skeleton-Pattern)
  - One pair or tuple of Decorators per component in a layer, but several layers, stacking Decorators on top of each others
  - On the server side, adapters help to make services generic
  - Decorators, Proxies, Adapters, Chains on client and server site
- Generated by IDL compiler
  - Is the IDL compiler essential?
  - No! Generic stubs and skeletons are possible, too. Technique: Reflective invocation

A More Simple Connector with Server Interface (Alt. 2, with Abstract Interface)

- Client and server are connected via a layer of stubs and skeletons (the *connector*)
- Server, Stubs and Skeletons inherit from same interface (not a Decorator!) → this cannot be layered

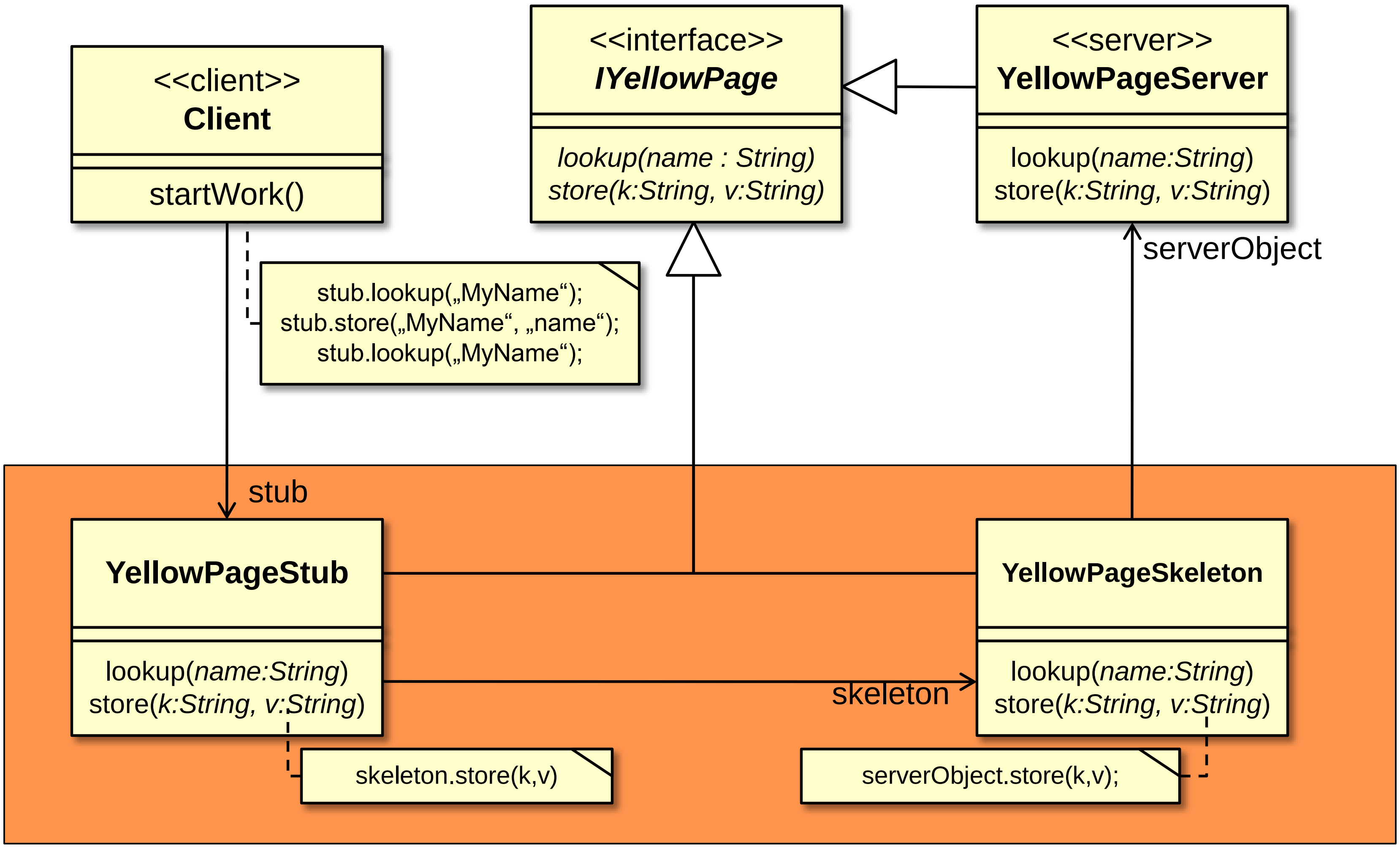


Example: A Remote Yellow Page Service

- with remote access, serialization

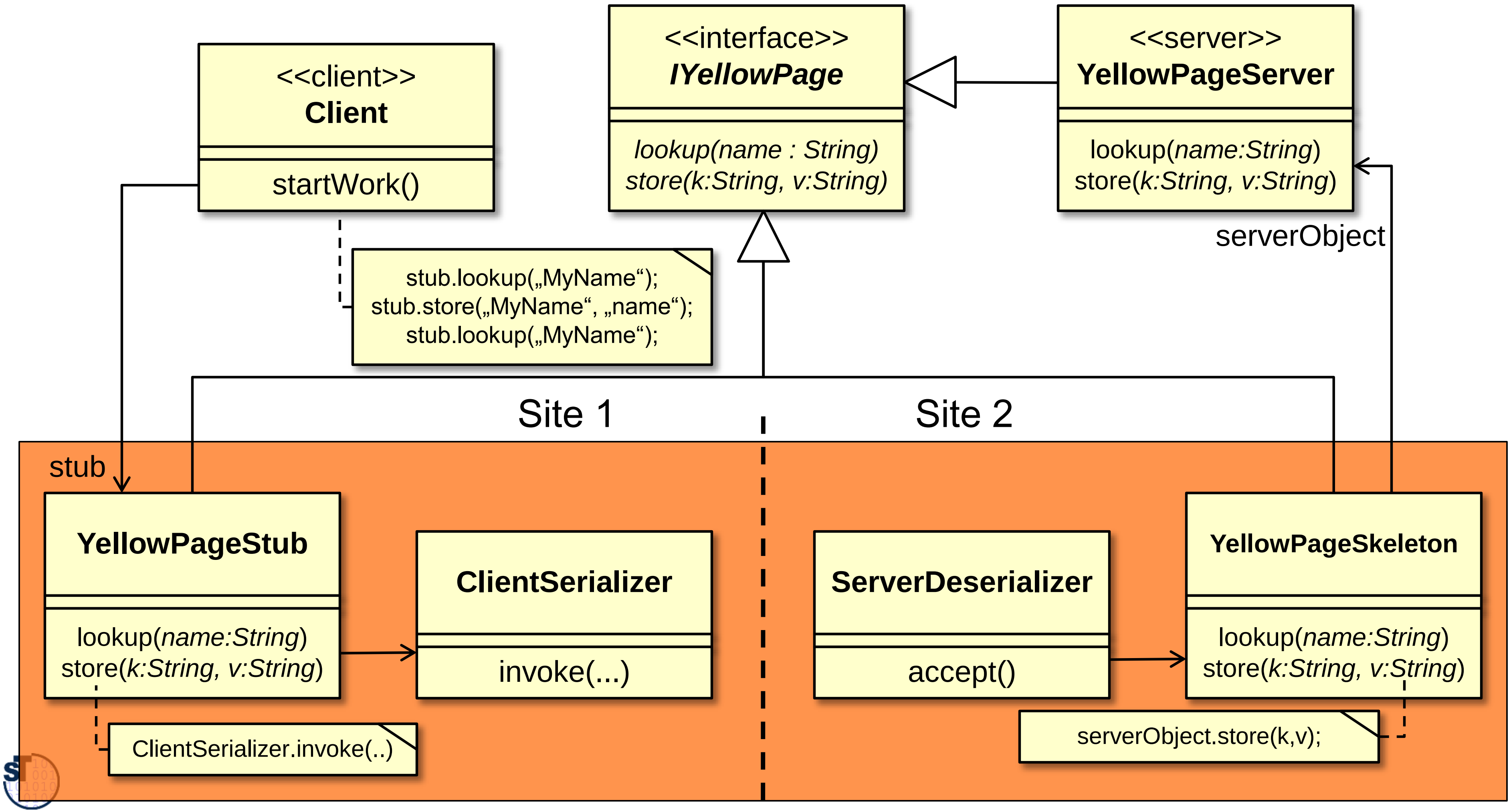
Remote Yellow Page Service

- Basic design without Serialization/Deserialization



Remote Yellow Page Service

- With Serialization/Deserialization



Service Interface

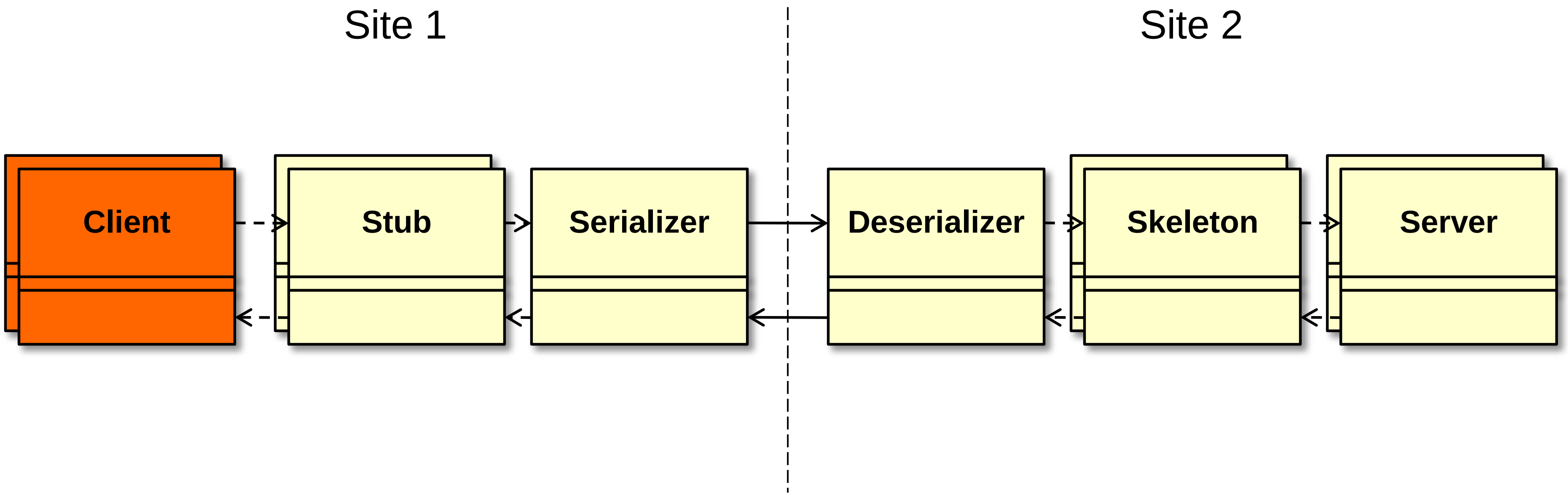

```
interface IYellowPageService {
        String SERVICE_NAME = "Yellow Pages";
        String lookup(String name);
        void store(String name, String value);
}
```

Service Implementation


```
class YellowPageService implements IYellowPageService {
        private Hashtable<String,String> cache =
                new Hashtable<String,String>();
        private DataBase db = …;
        public String lookup(String name) {
                String res = cache.get(name);
                if (res == null)
                        res = db.lookup(name);
                        if (res != null) {
                                cache.put(name,res);
                        }
                }
                return res;
        }

        public void store(String name, String value) {
                cache.put(name, value);
                db.store(name, value);
        }
}
```

Client

- Wants to transparently use the Yellow Page service



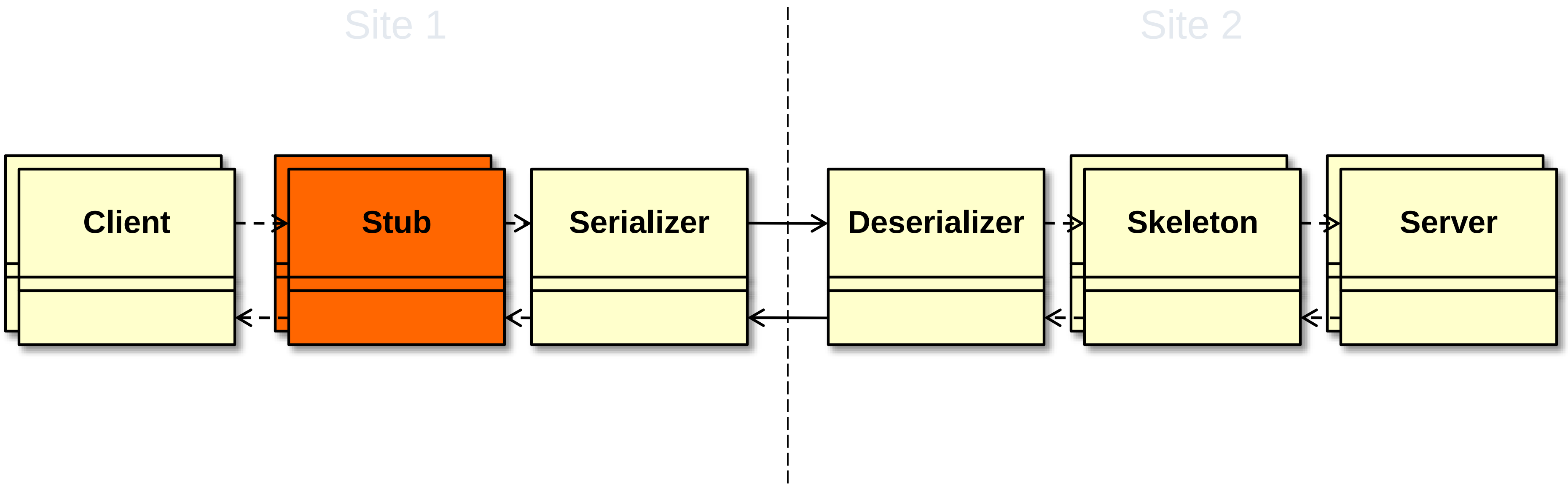
Example Client

Client calls stub with service interface:

```
class Client {
        ...
        // returns client stub
        IYellowPageService yps =
                        YellowPageFactory.create();
        ...
        String res = yps.lookup("MyName");
        ...
}

class YellowPageFactory {
        public IYellowPageService create() {
                return new YellowPageStub ();
        }
}
```

Stub (client side)

- Realizes 1:1 mapping of client to service component
- Uses 1:1 mapping of clients to stubs

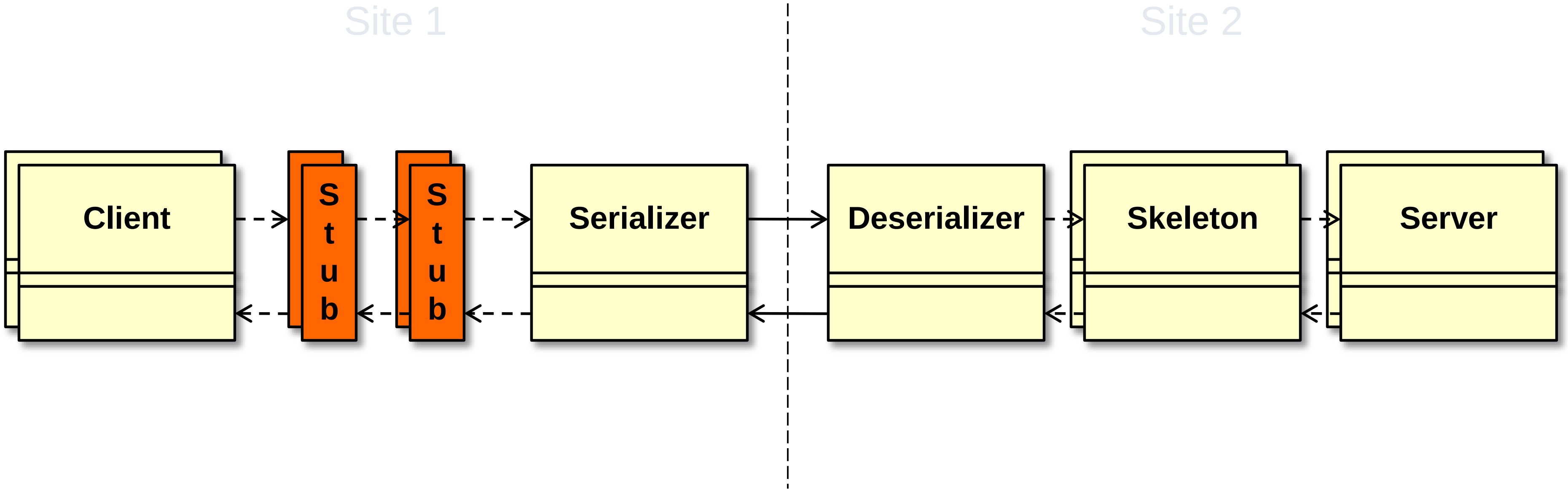


Example Client Stub - Implementation


```
class YellowPageStub implements IYellowPageService {
  private Integer logicalAddress = new Integer(-1);

  public YellowPageStub() {
    logicalAddress = (Object) ClientSerializer.invoke(
        IYellowPageService.SERVICE_NAME, logicalAddress, “new”, null);
  }

  public String lookup(String name) {
    Object res = ClientSerializer.invoke(IYellowPageService.SERVICE_NAME,
                           logicalAddress, “lookup”, new Object[]{name});
    return (String)res;
  }

  public void store(String name, String value) {
    ClientSerializer.invoke(IYellowPageService.SERVICE_NAME,
        logicalAddress, “store”, new Object[] { name, value });
  }
}
```

Scenario with Second Stub (client site)

- By using the Decorator pattern, stubs can be stacked onto each other
- Every stub solves another transparency problem (middleware concern)

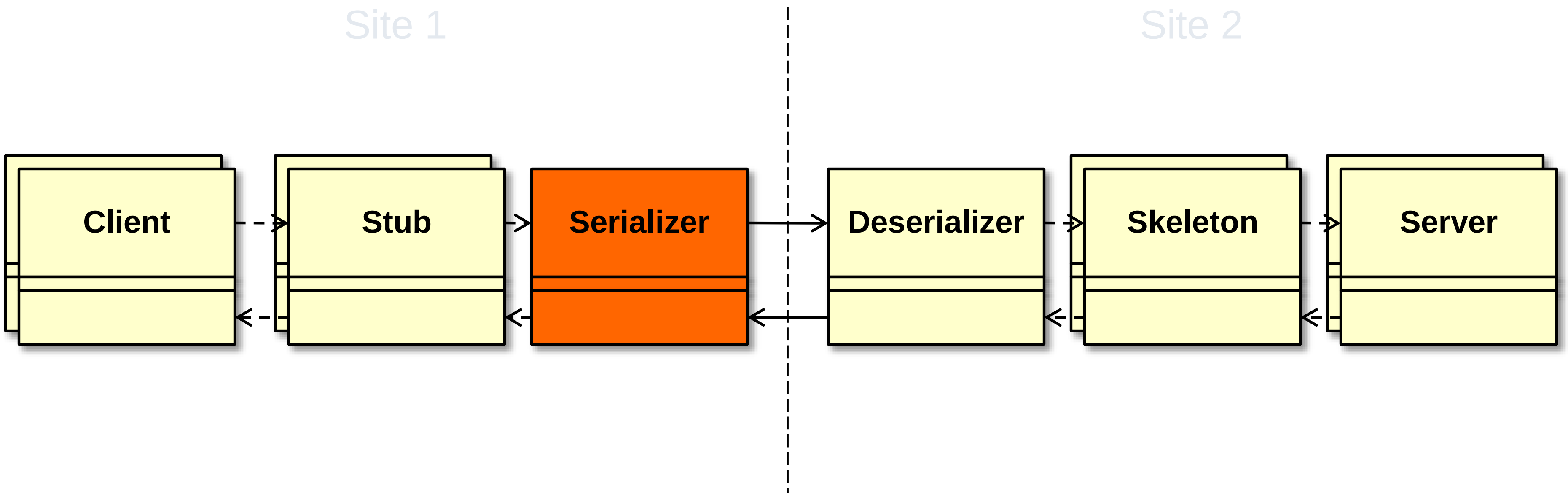


Client Stub 1 – This Time with Decorator Chain Implementation


```
// new stub: encryption decorator
class YellowPageStubEncryption implements IYellowPageService {
   private IYellowPageService clientDec;

   // Security: encryption, decryption
   private String encrypt(String name);
   private String decrypt(String name);

   // client-side constructor
   public YellowPageStubEncryption() {
     clientDec = new YellowPageStub();
   }
   // lookup function, with encryption, decryption
   public String lookup(String name) {
     String res = clientDec.lookup(encrypt(name));
     return decrypt(res);
   }
        // store
        // …
}
```

Client-side Serializer

- Manages the basic communication on client side
- Is called from the client stubs
- Can be hidden in a Decorator (1:1), but can be also shared by all stubs

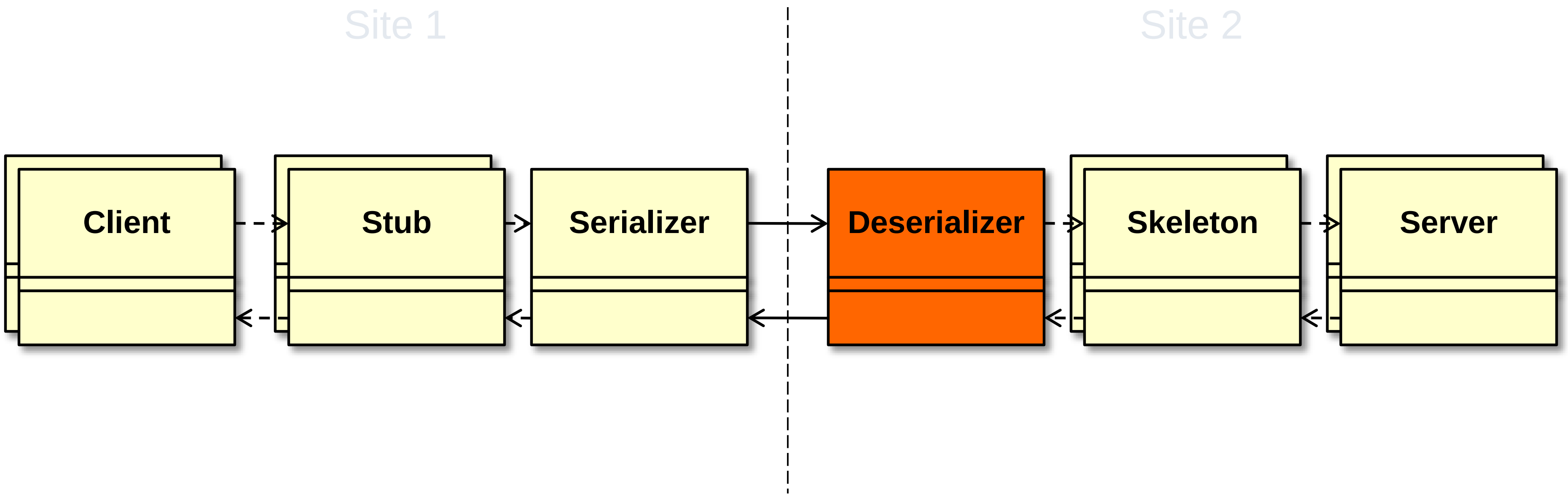


Example Client Serializer


```
class ClientSerializer {
  public static Object invoke(String service, Integer address,
                              String method, Object[] args) {

    Socket s = new Socket("yp-st.inf.tu-dresden.de", 1234);
    ObjectOutputStream os = new ObjectOutputStream(s.getOutputStream());
    ObjectInputStream is = new ObjectInputStream(s.getInputStream());
    os.writeObject(service);
    os.writeObject(address);
    os.writeObject(method);
    if (args != null) {
      os.writeObject(args);
    }
    os.flush();
    Object result = is.readObject();
    s.close();
    return result;
  }
}
```

Server-side Deserializer

- Manages the basic communication on server side
- Calls the service skeletons (1:n mapping)



Example Server Deserializer (1)

Deserializer listens on the network is shared between different services

- interprets incoming service names
- can create/invoke several service skeletons
- lives always, but hides lifetime of the server

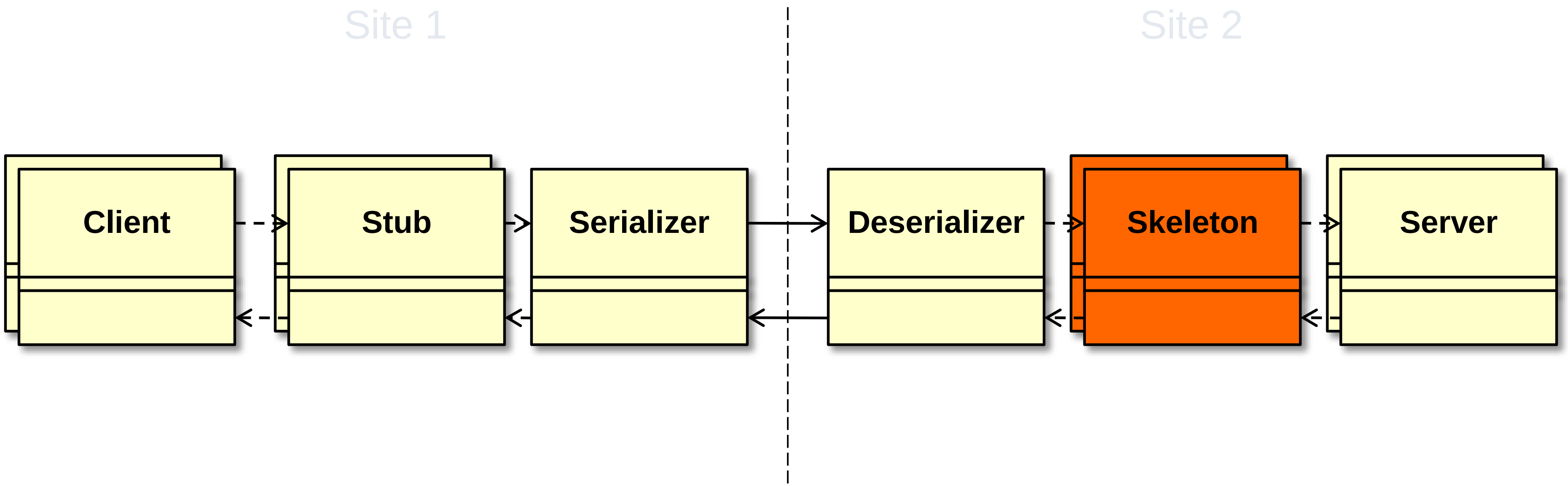
```
class ServiceDeserializer {
  public void run() {
    ServerSocket server = new ServerSocket(1234);
    Socket client = server.accept();
    ObjectInputStream is = new ObjectInputStream(client.getInputStream());
    ObjectOutputStream os = new ObjectOutputStream(client.getOutputStream());
    while (true) {
      String service = (String) is.readObject();
      if (service.equals(IYellowPageService.SERVICE_NAME)) {
        handleYellowPage(os, is);
      } else if (service.equals(IPhoneBook.SERVICE_NAME)) {
        handlePhoneBook(os, is);
      } else {
        System.err.println("Unknown service.");
      }
    }
  }
}
```

Example Server Deserializer (2)


```
private void handleYellowPage(ObjectOutputStream os, ObjectInputStream is) {
  Integer address = (Integer) is.readObject();
  if (address == -1) { // creation of the service
    YellowPageSkeleton skeleton = new YellowPageSkeleton();
    os.writeObject(skeleton.getLogicalAddress());
  } else { // service query: interpretation of the symbolic service name
    IYellowPageService yp = new YellowPageSkeleton(address);
    String method = (String) is.readObject();
    Object[] args = (Object[]) is.readObject();
    if (method.equals("lookup")) {
      String res = yp.lookup((String)args[0]); // finally: call the service
      os.writeObject(res);
    } else if (method.equals("store")) {
      yp.store((String)args[0], (String)args[1]);
      os.writeObject(null);
    } else
      System.err.println("Unknown service method.");
    }
  }
  os.flush();
}
```

Skeleton (Server side)

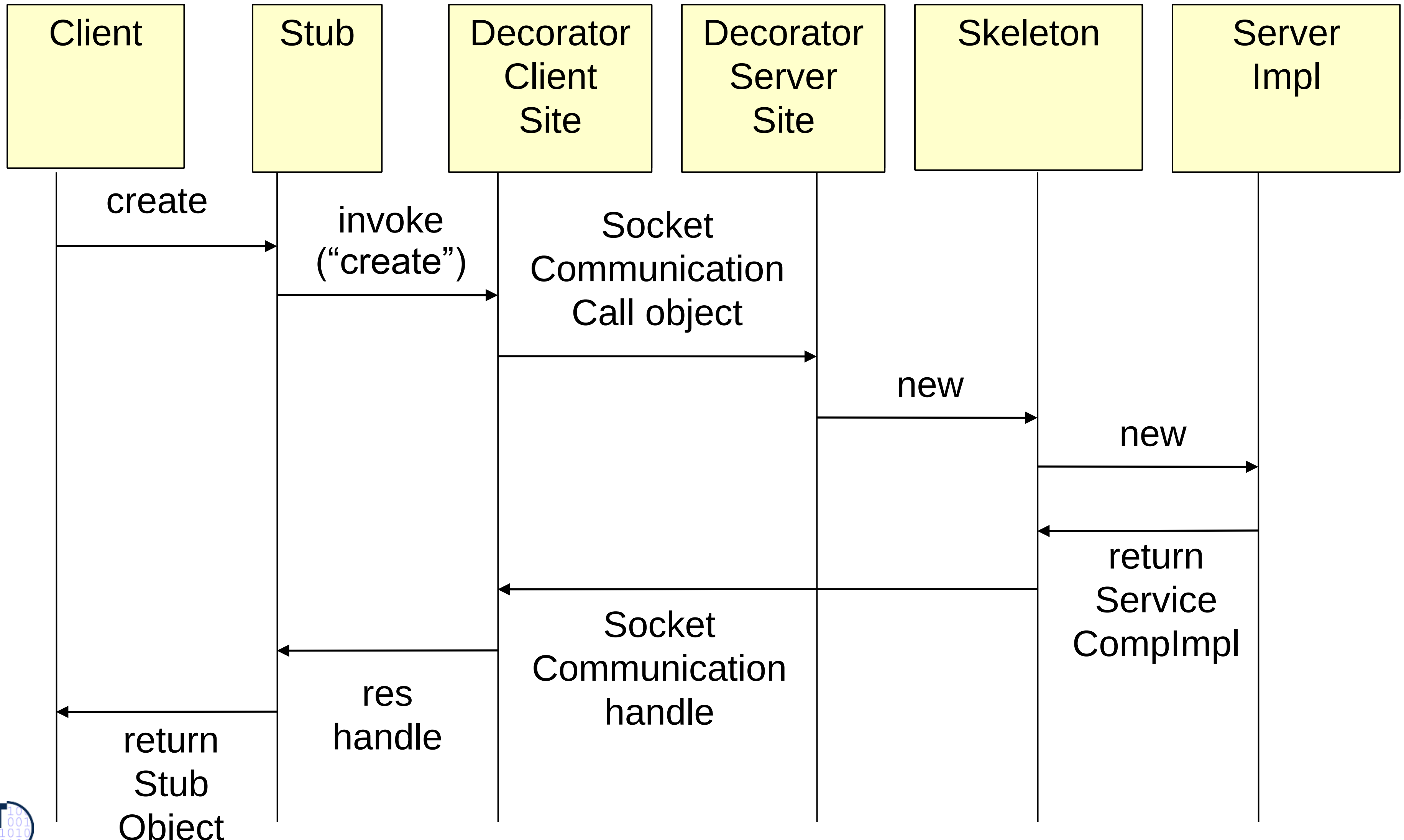
- Manages service components of server on server side
- 1:1 mapping to service component



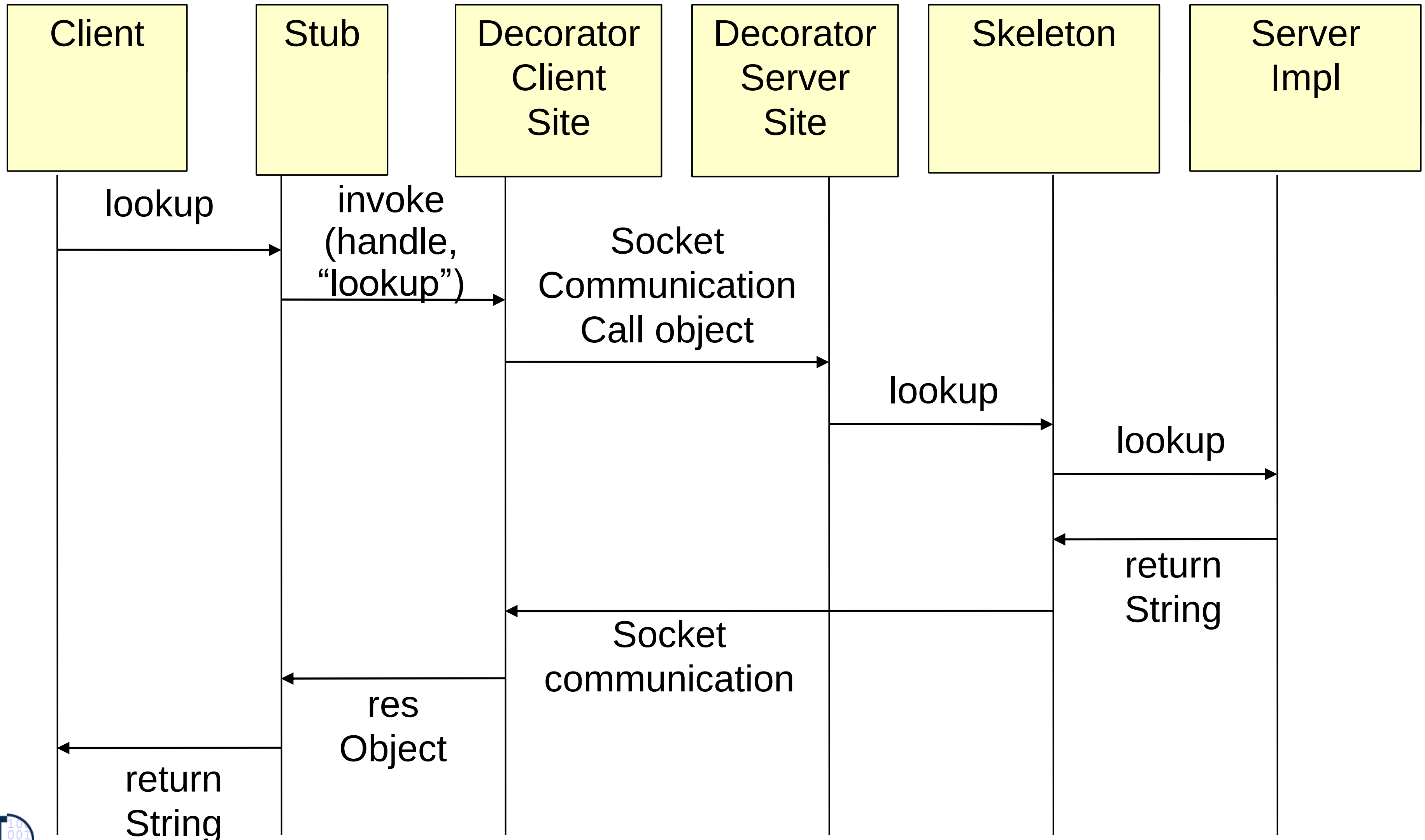
Example Yellow Pages Server Skeleton (Service Lookup and Call, Adapter)


```
public class YellowPageSkeleton implements IYellowPageService {
  private static Hashtable<Integer, IYellowPageService> yellowPageServices =
    new Hashtable<Integer, IYellowPageService>();
  private Integer logicalAddress;
  public YellowPageSkeleton() {
    this(new Integer(yellowPageServices.size()));
    yellowPageServices.put(logicalAddress, new YellowPageService());
  }
  public YellowPageSkeleton(Integer address) {
    logicalAddress = address;
  }
  public Integer getLogicalAddress() { return logicalAddress; }
  public String lookup(String name) {
    IYellowPageService service = yellowPageServices.get(logicalAddress);
    return service.lookup(name);
  }
  public void store(String name, String value) {
    IYellowPageService service = yellowPageServices.get(logicalAddress);
    service.store(name, value);
  }
}
```

Creation of YP Service



Call (Lookup) YP Service



Generic Skeletons

- Mapping names to locations by name servers

Rept.: Reflection & Reflective Invocation

- Reflection
  - to inspect the interface of an unknown component
  - for automatic/dynamic configuration of server sites
  - to call the inspected components
- Access to interfaces with IDL
  - Standardize an IDL run time representation and access
  - Define a IDL specification for IDL representation and access
  - Store IDL specifications in *interface repositories* which can be introspected

Example Generic Skeleton (Reflective Skeleton)

- A **generic skeleton** is a special case of a name service: using reflection to look up the name for a method

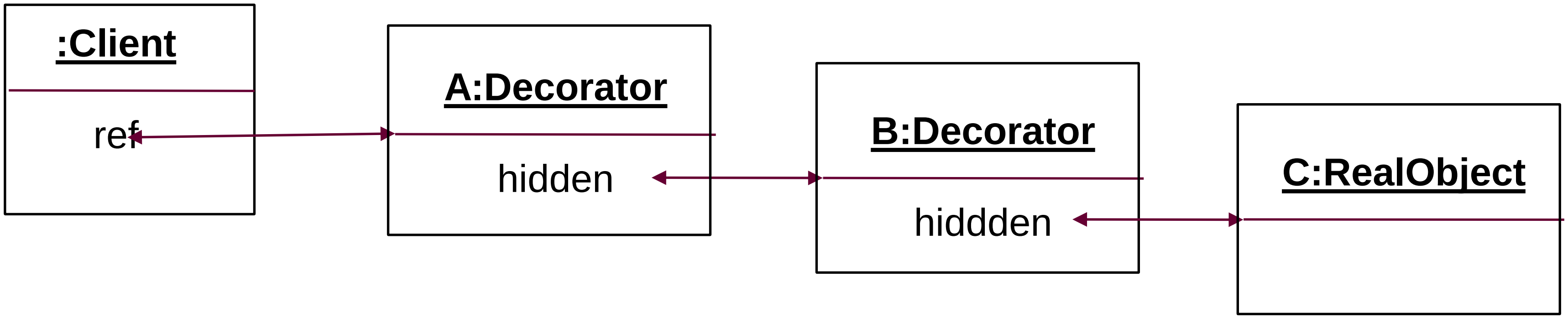
```
class ReflectiveSkeleton {

    // serverObjects is the server implementation repository
    static ExtendendHashtable serverObjects = new ExtendedHashtable();
    ObjectOutputStream os;
    ObjectInputStream is;
    …
    public Object handleGeneric() { …
          Integer  addr= (Integer)  is.readObject();//handler
          String   mn  = (String)   is.readObject();//method name
          Class[]  pt  = (Class[])  is.readObject();//parameter types
          Object[] args= (Object[]) is.readObject();//parameters

          // get server object reference by reflective call to implementation repository
          Object   o            = serverObjects.getComponent(addr);
          Method   m            = o.getClass().getMethod(mn,pt); //method object by
    reflection
          Object   res          = m.invoke(o,args);              //method call by
    reflection
          os.writeObject(res);
          os.flush();
     } …
```

Appendix
The Decorator Design Pattern

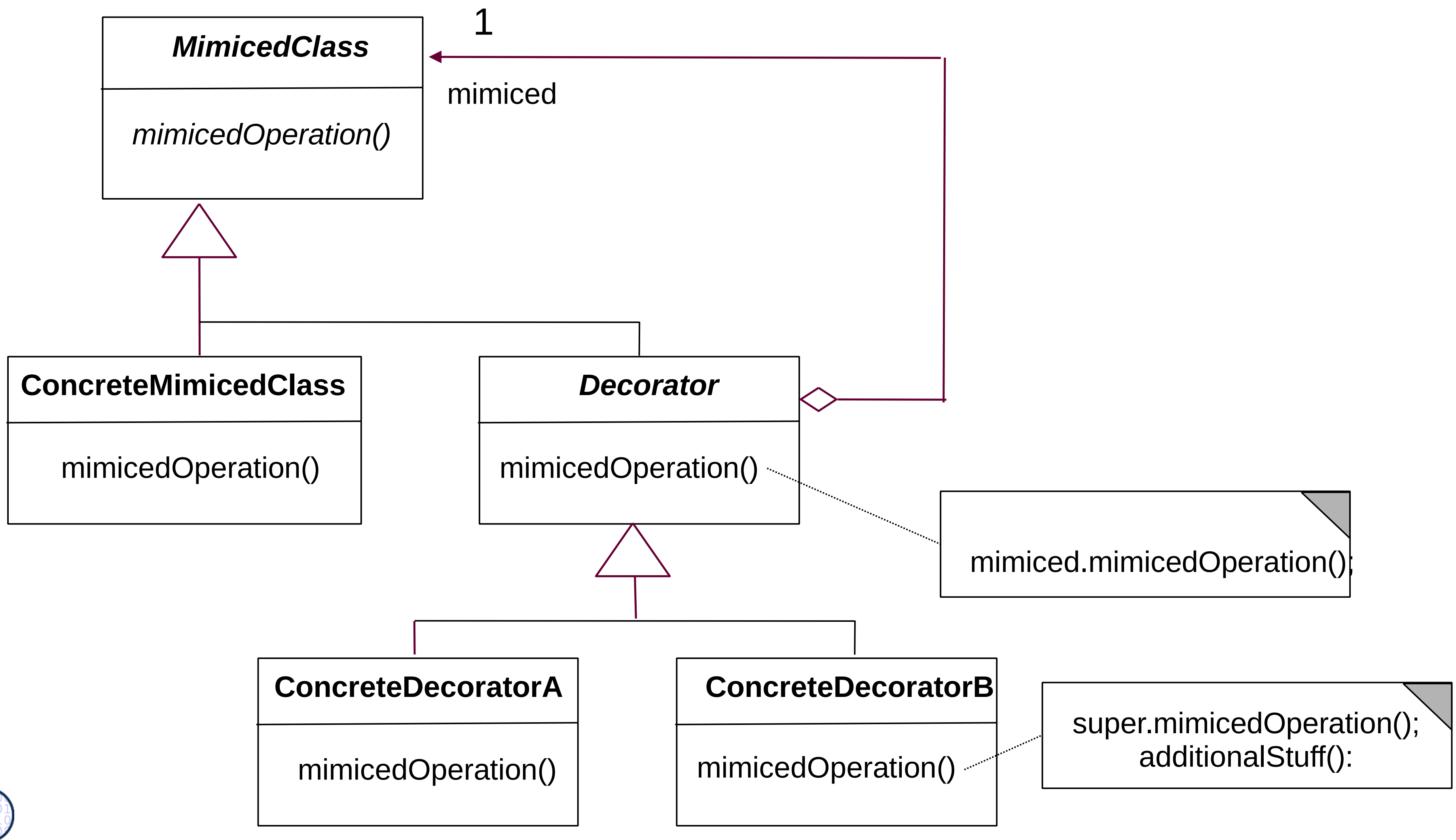
- (Repetition from DPF in winter)

Decorator Pattern

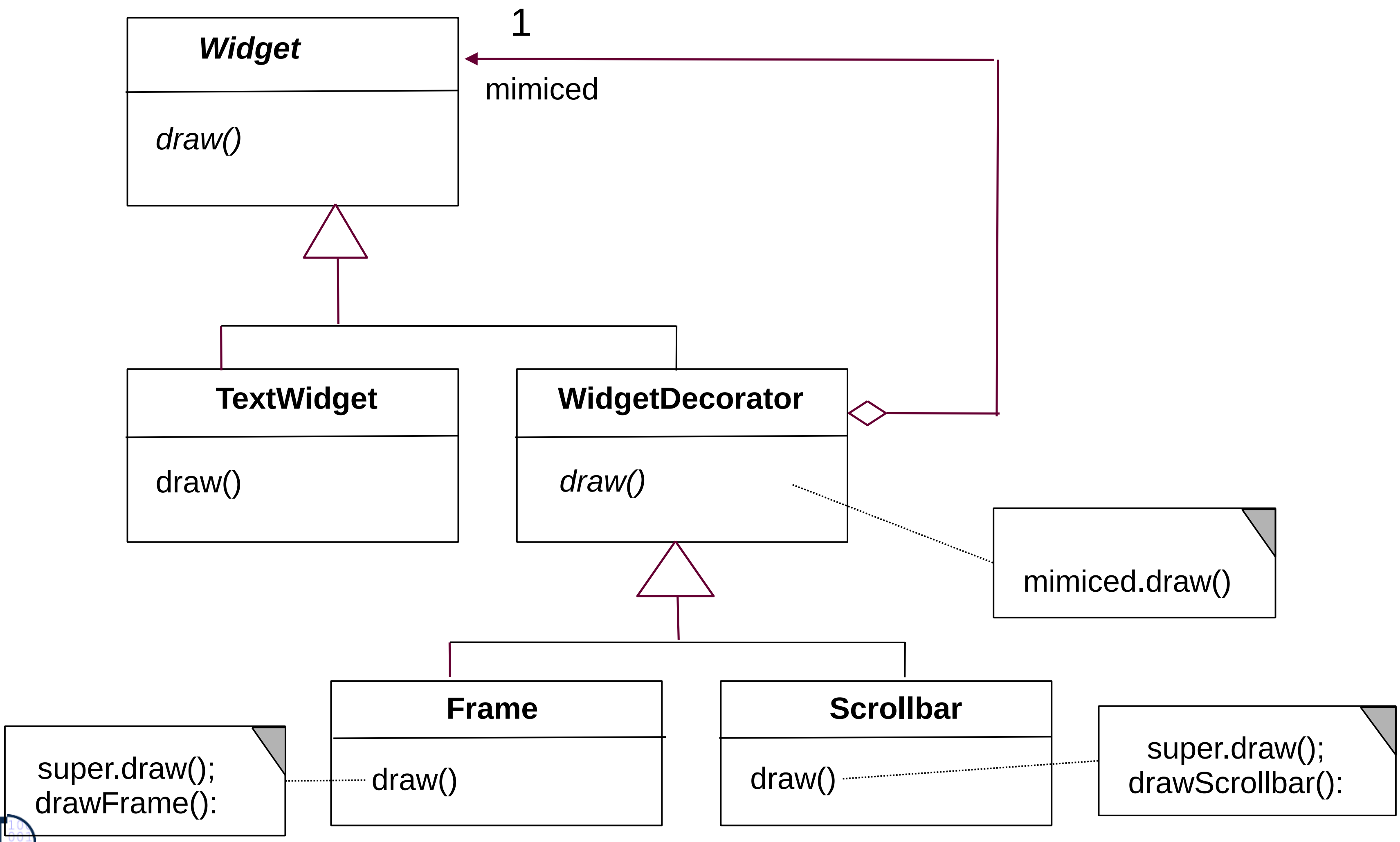
- A Decorator is a *skin* of another object
- It is a 1-ObjectRecursion (i.e., a restricted Composite):
  - A subclass of a class that contains an object of the class as child
  - However, only one composite (i.e., a delegatee)
- Combines inheritance with aggregation
  - Inheritance from an abstract Handler class
  - That defines a contract for the mimiced class and the mimicing class



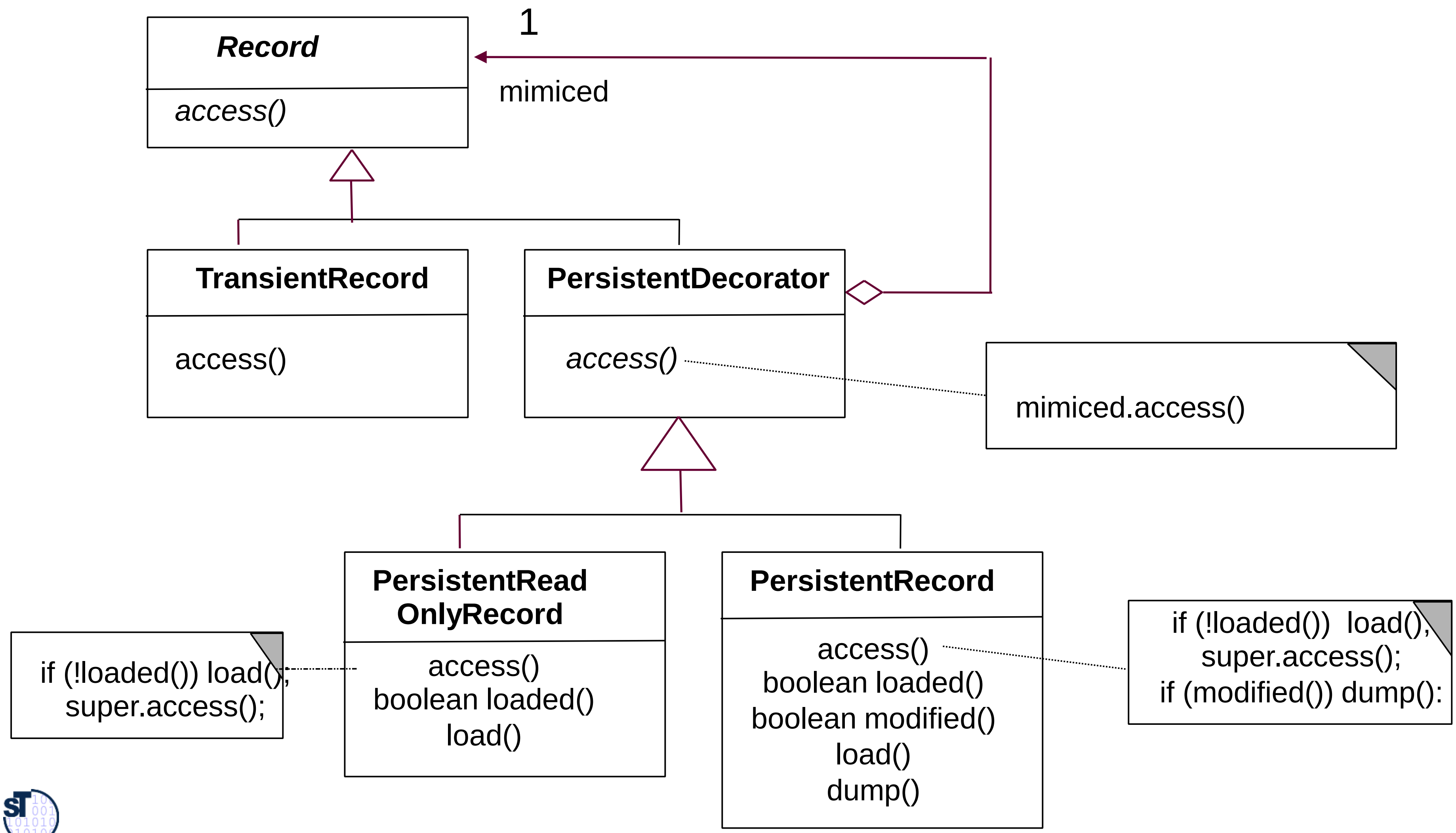
Decorator – Structure Diagram



Example: Decorator for Widgets

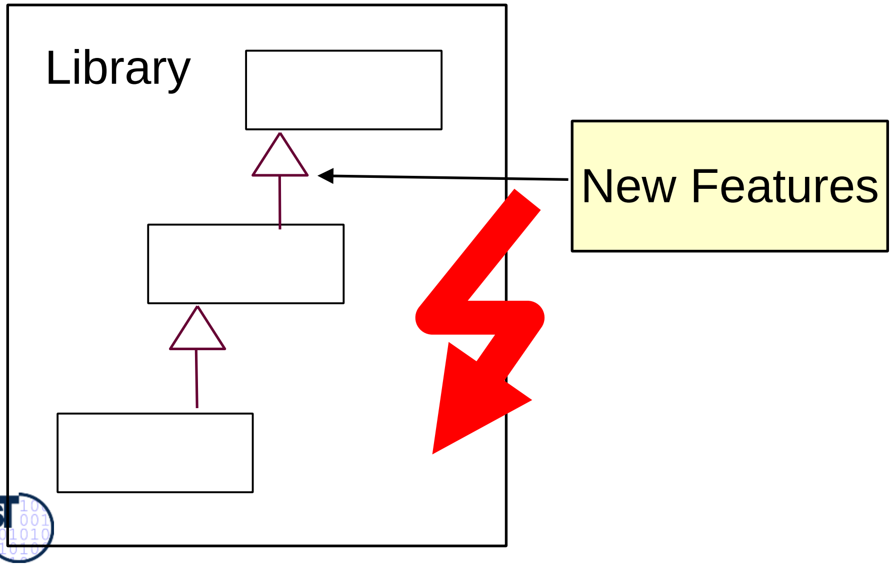


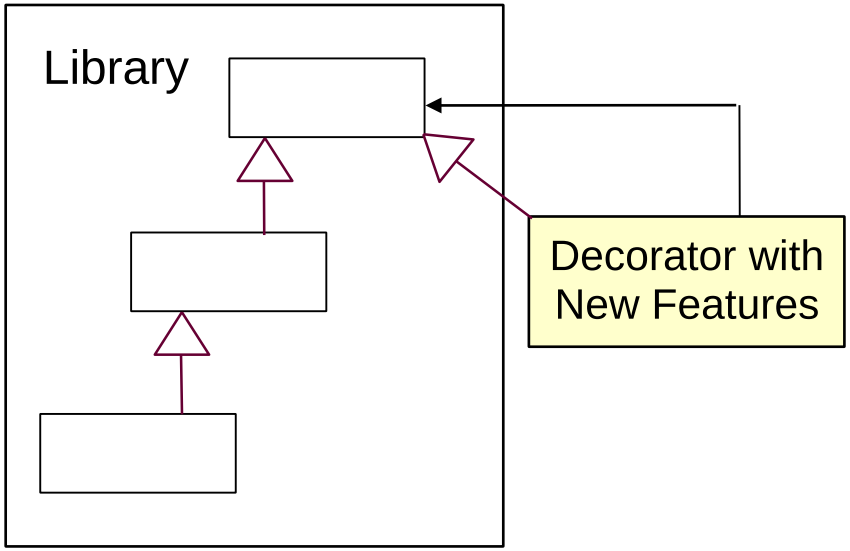
Decorator for Persistent Objects



Purpose Decorator

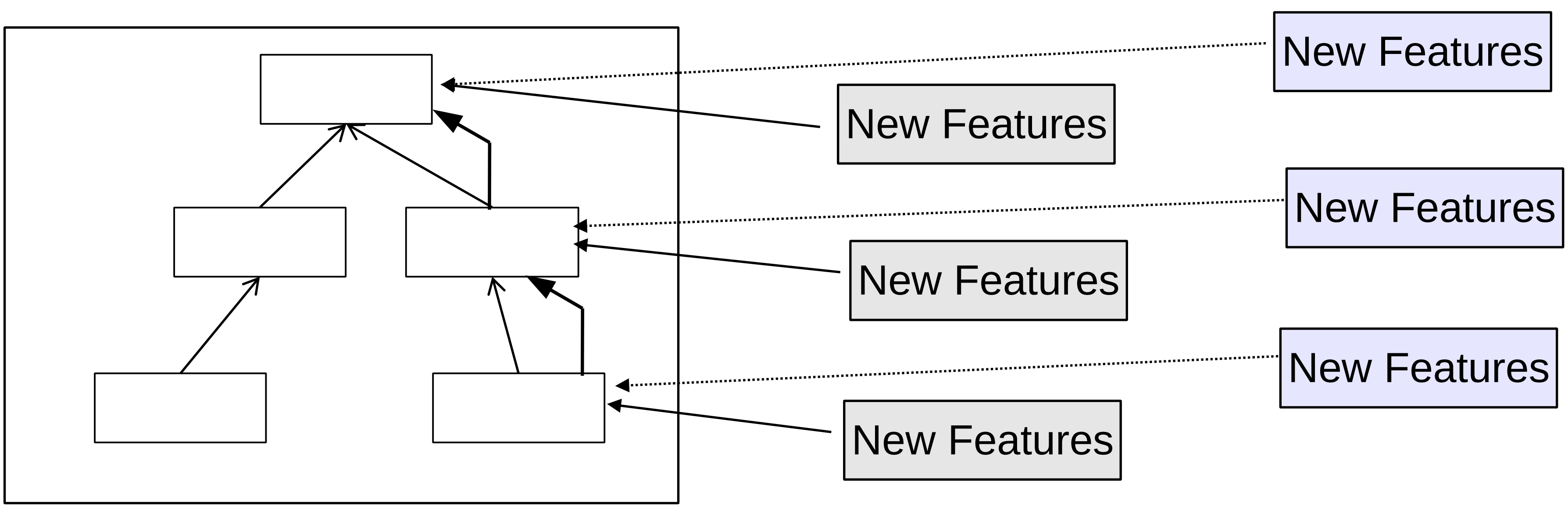
- For extensible objects (i.e., decorating objects)
  - Extension of new features at runtime
  - Removal possible
- Instead of putting the extension into the inheritance hierarchy
  - If that would become too complex
  - If that is not possible since it is hidden in a library





Variants of Decorators

- If only one extension is planned, the abstract super class Decorator can be omitted; a concrete decorator is sufficient
- Decorator family: If several decorators decorate a hierarchy, they can follow a common style and can be exchanged together
- Decorators can be chained to each other
- Dynamically, arbitrarily many new features can be added



The End

- Many slides courtesy to Prof. Welf Löwe, Växjö University, Sweden.