# 11. Transparency Problems and the Decorator-Connector Pattern

A Design Pattern appearing in all classical component systems

Prof. Dr. Uwe Aßmann
Technische Universität Dresden
Institut für Software- und Multimediatechnik
http://st.inf.tu-dresden.de

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## 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



# 11.1. Transparency Problems for COTS



## Transparency Problems (Middleware Concerns)

- **A transparency problem describes software concerns that should be transparent (invisible, hidden) when you write, 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
  - **Security** scaling
    - Plug-in authentication

# 11.1.2 Language Transparency



## Language Transparency Problems

- 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 …



## Options In General

- Direct language mapping:
  - 1:1 adaptation of pairs of languages: $O(n^2)$
- Mapping to common language:
  - Adaptation to a general exchange format: $O(n)$
- Compiling to common type system:
  - Standardize to a single format (like in .NET): $O(1)$ but very restrictive, because the languages become very similar



## 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 (IDL)
- 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

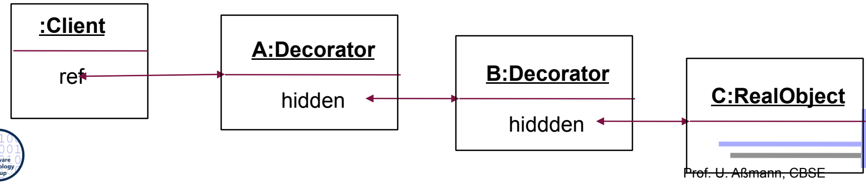
# 11.1.3 The Decorator Design Pattern

(Repetition from DPF in winter)



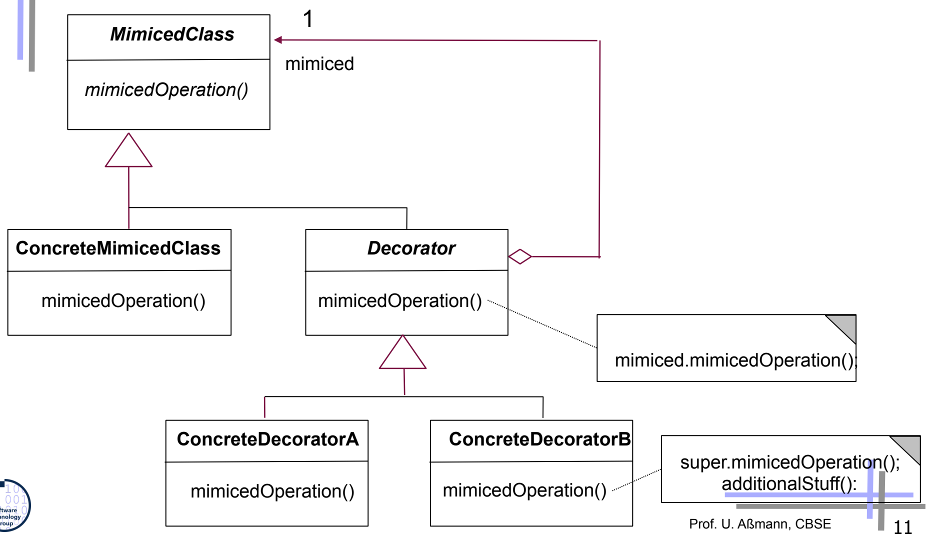
## Decorator Pattern

- 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



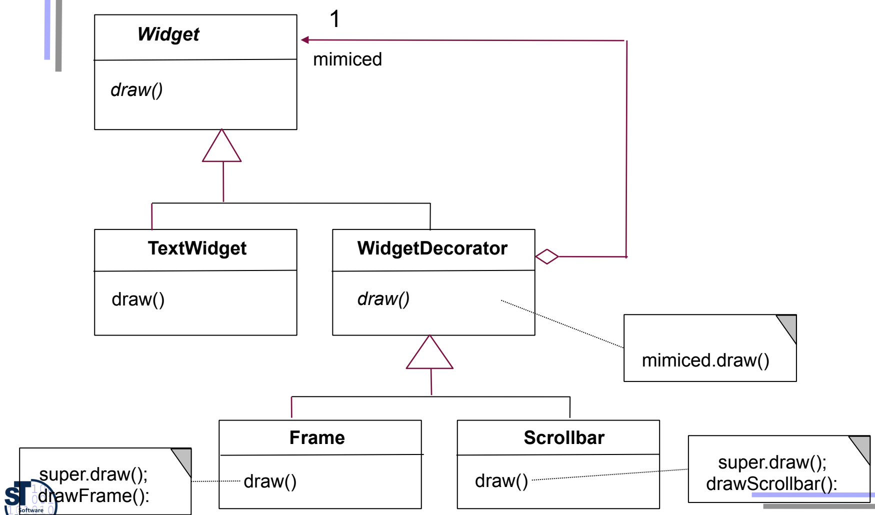



## Decorator – Structure Diagram

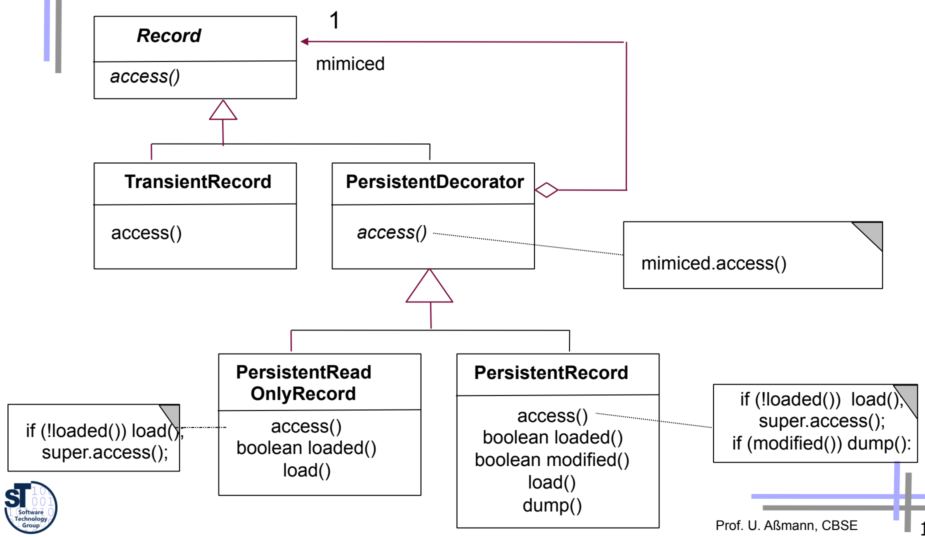





## Example: Decorator for Widgets



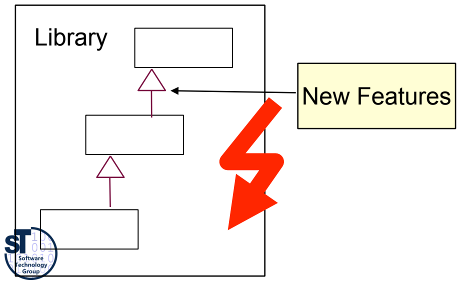
# Decorator for Persistent Objects

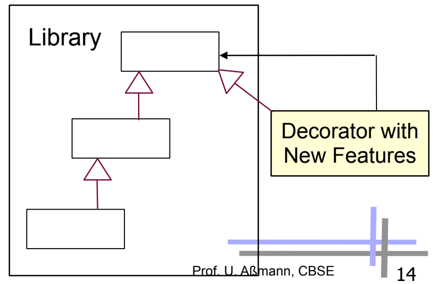





# Purpose Decorator

- 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

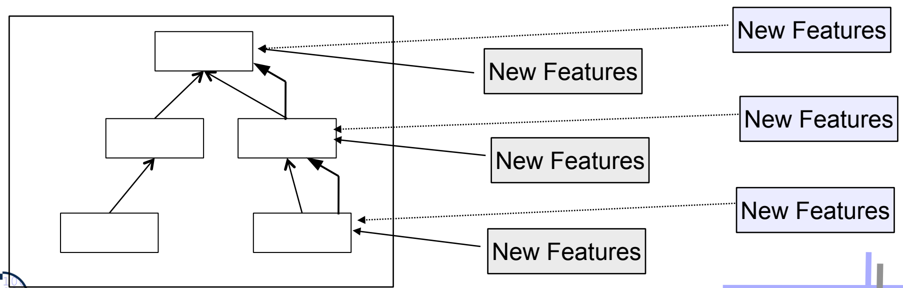





# Variants of Decorators

- 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

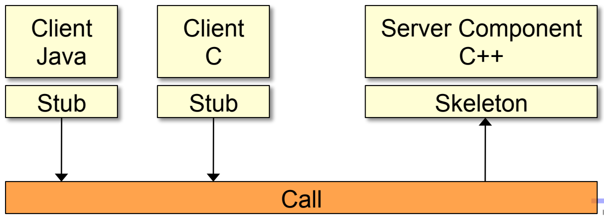





# 11.2 The Decorator-Connector Pattern

## *Language Transparency With the Connector Pattern*

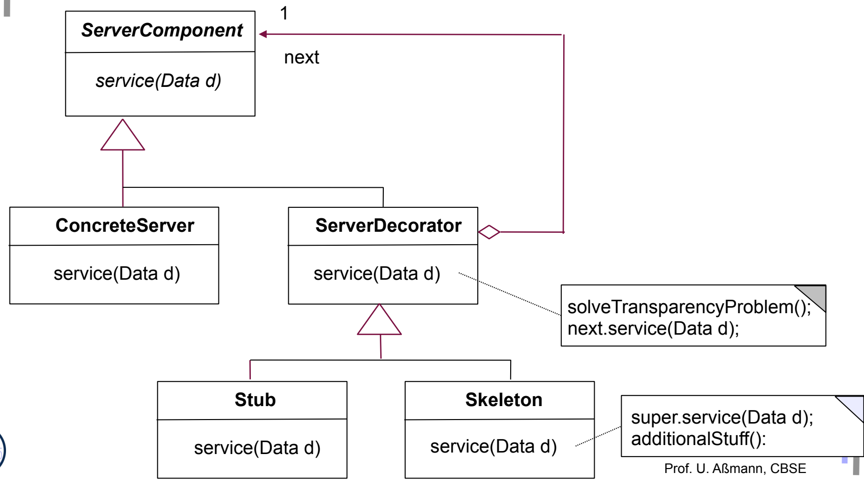
- Connector Pattern (aka Stubs and Skeletons, Double-Decorator Pattern, *n*-Decorator Pattern):
  - Stub: Proxy of the client (decorator of the skeleton)
    - Takes calls of clients in language $\mathcal{A}$ and sends them to the skeleton
  - Skeleton: Proxy (decorator) of the server
    - Takes those 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)






## *Stubs and (Static) Skeletons*

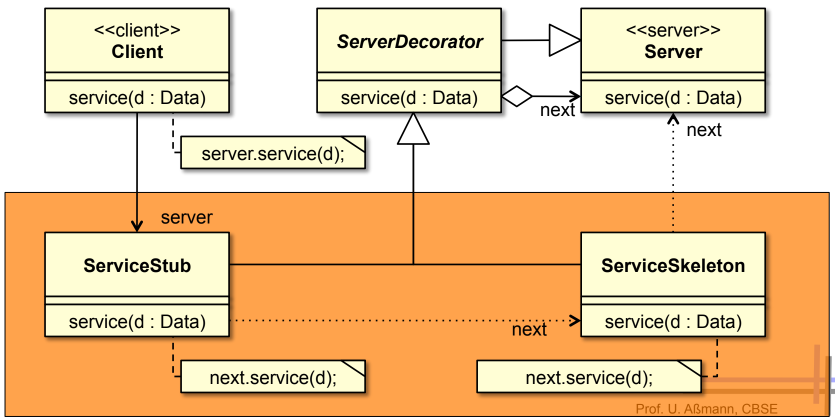
- A typical instance of the proxy or decorator pattern: two proxies on client and server
- Stub decorates skeleton, skeleton decorates server






## *The Connector Pattern (Alt. 1, with Decorator)*

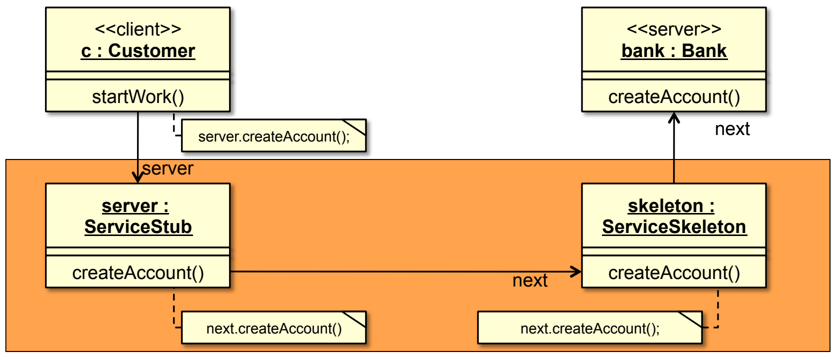
- Client and server are connected via a layer of stubs and skeletons (the *connector*)
- The connector consists of two decorators of the server
- Decorator chain is inherited





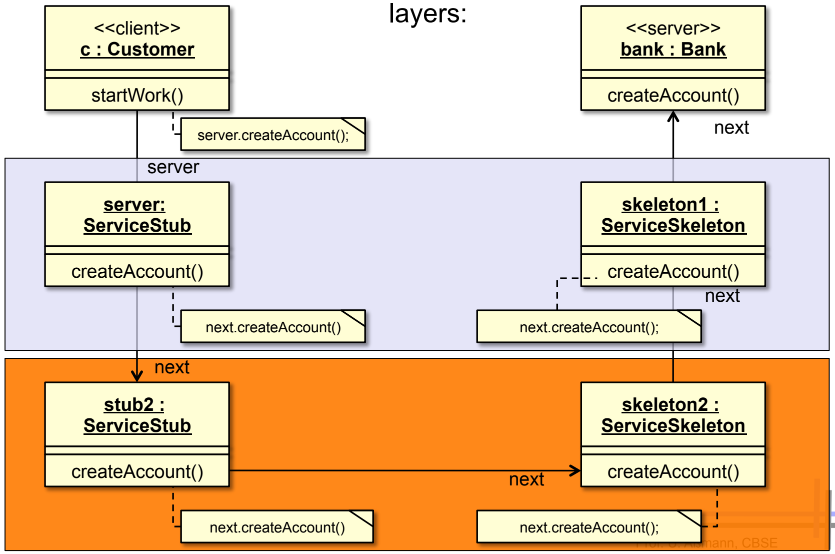

## *Object Diagram of Decorator-Connector Pattern*

- Connector consists of a Decorator chain, in a layer



# Layered Decorators

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






# Decorator vs Proxy vs Adapters vs Chain

- Why is it 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 “representant” patterns
  - Adapter-Connector: adapts required interface to server additionally
  - Chain-Connector: may stop processing
  - Proxy-Connector: just one layer possible



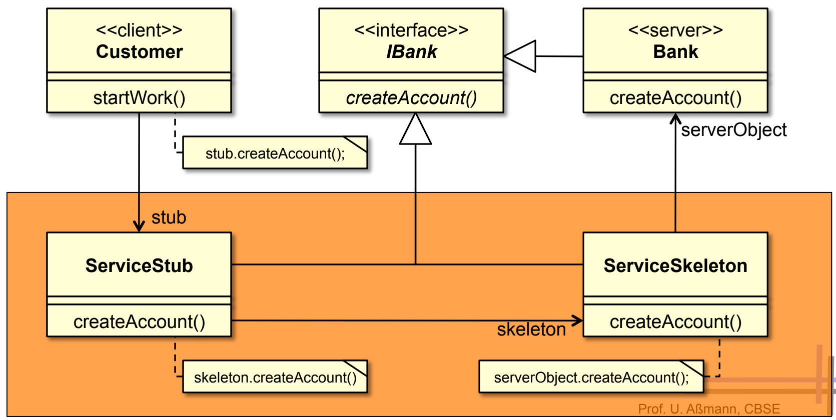
# Tasks of the Layers

- 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



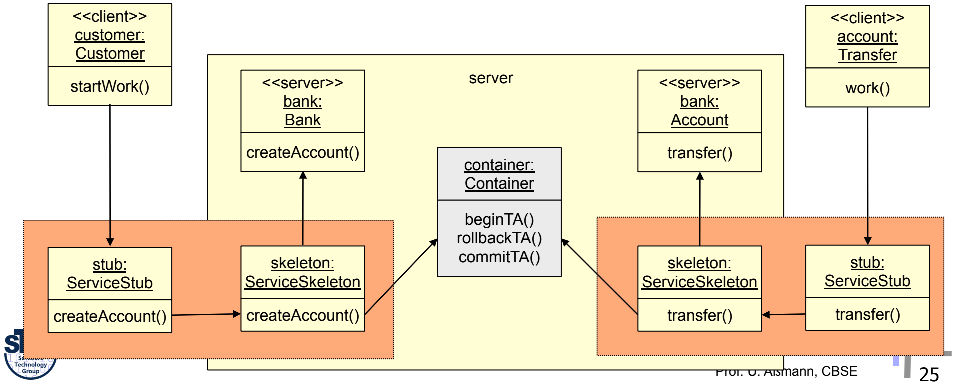
# A Connector with Server Interface (Alt. 2, with Abstract Interface)

- 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!)



# 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 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

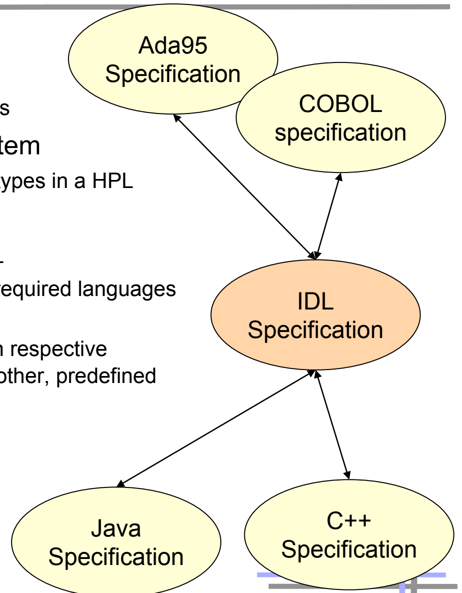


# 11.3 Interface Definition Languages for Mapping Different Languages



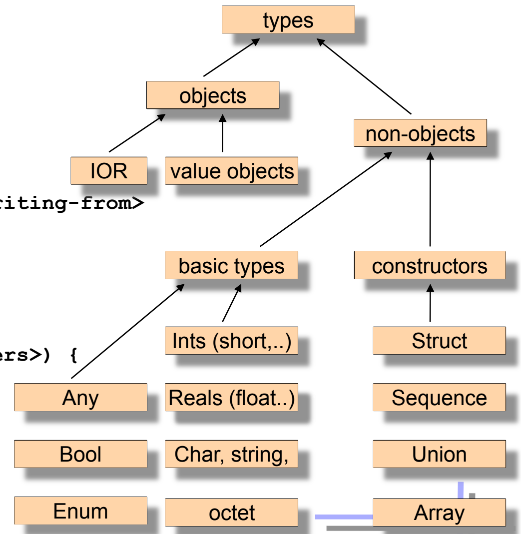
# Type Mapping with the Interface Definition Language (IDL)

- Language to define the
  - Interfaces of components
  - Data types of parameters and results
- Language independent type system
  - General enough to capture all data types in a HPL
- 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)



## Types in the Interface Definition Language

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

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





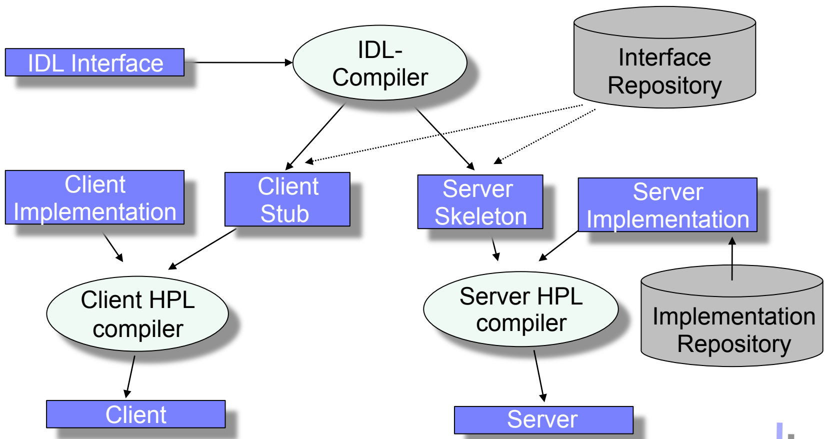

## Hello World IDL

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



## Generation of Stubs and Skeletons from IDL

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






## Required Formal Properties of the IDL-To-Language Mapping

- Let $\tau_{PL}: IDL \rightarrow TS_{PL}$ be the mapping from an interface definition language $IDL$ to the type system $TS$ of a programming language $PL$

1. Well-definedness
   $\forall\ PL : \tau_{PL}: IDL \rightarrow TS_{PL}$ is well defined
2. Completeness
   $\forall\ PL : \tau_{PL}^{-1}: TS_{PL} \rightarrow IDL$ is well defined
3. Soundness
   $\forall\ PL : \tau_{PL}^{-1} \circ \tau_{PL}: IDL \rightarrow IDL$ is $\iota_{IDL}$
   $\forall\ PL : \tau_{PL} \circ \tau_{PL}^{-1}: TS_{PL} \rightarrow TS_{PL}$ is $\iota_{PL}$

## IDL Can Also Be Generated from Host Language

*Specification of IDL and host language*

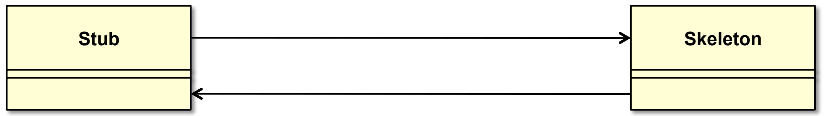
- Determined language binding,
- standardized IDL-to-Language mapping
- Generation of stubs and skeleton is IDL compiler independent
- Language specific IDL compilers
- OMG Corba

*Specification of host language*

- Retrieve the IDL out of the interface definitions (e.g., Java classes)
- Have only one source of IDL compilers guaranteeing round-trip property of retrieval and generation for all languages
- Quasi standard
- Java, DCOM, .Net



## Stubs and Skeletons for Language Adaptation




Language 1

Map data to an exchange format

Call Skeleton

Language 2

Receive call from stub

Retrieve data from the exchange format



# 11.4 Location Transparency

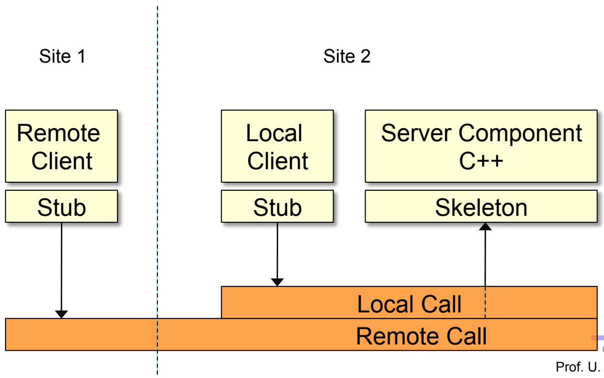


## Problem 2: Distribution

- *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

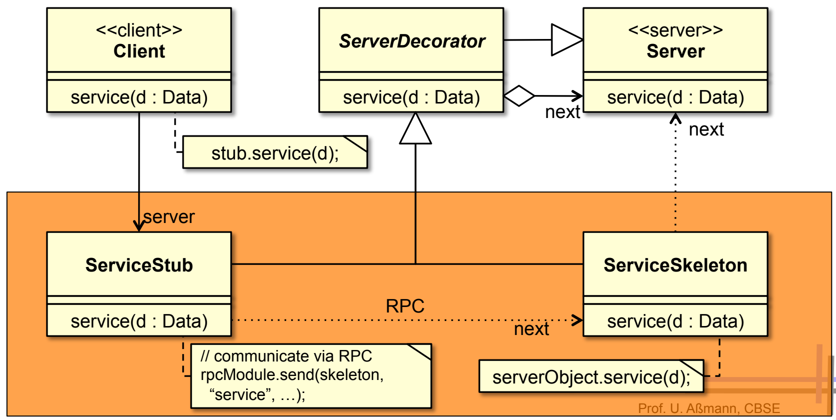
- Communication over proxies/ decorators
  - Proxies redirect call locally or remotely on demand
  - Proxies always local to the caller
- RPC for remote calls to a handler
  - Handler always local to the callee
- Déjà vu! We reuse Stubs and Skeletons





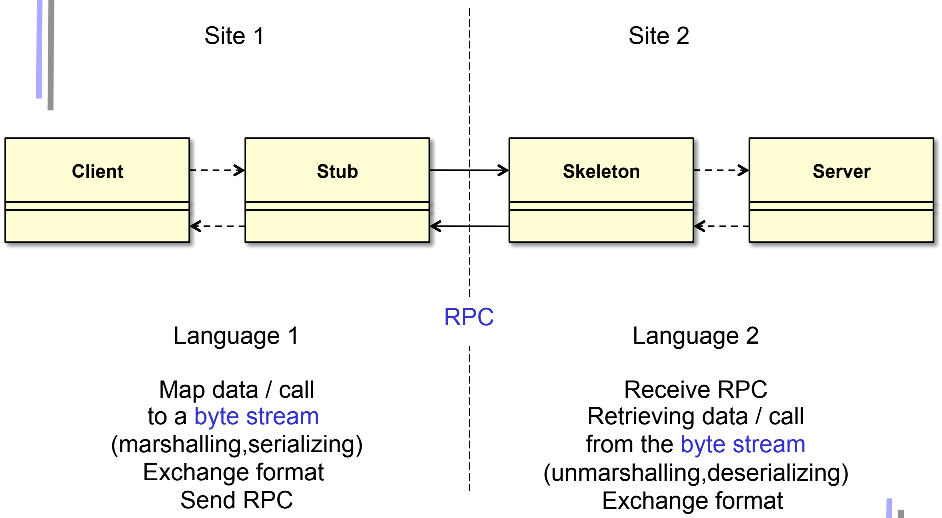

## Stubs and Skeletons for Distribution

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





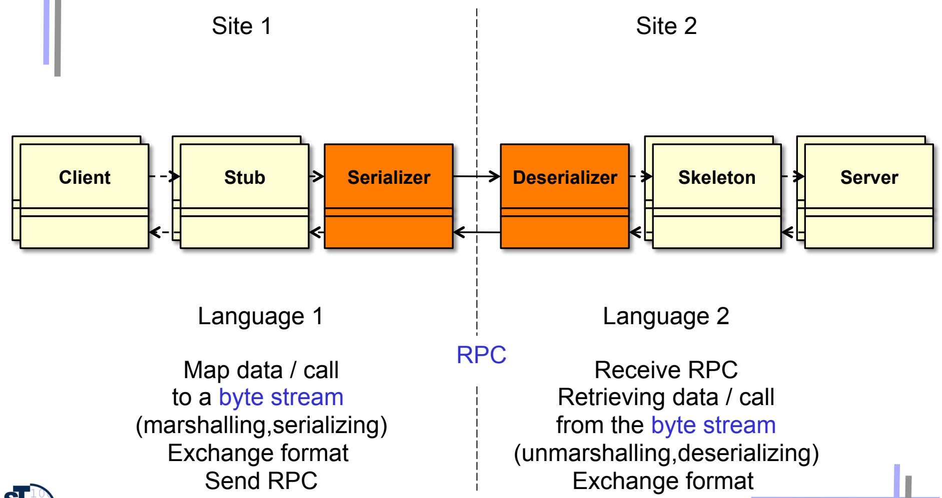

## Stubs and Skeletons for Distribution






## Stubs, Skeletons, and Serializers

- or with separate serializers/deserializers



## 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 addresses
  - e.g., computer address + local address
  - URL, URI (Uniform Resource Identifiers)
  - CORBA IORs (Interoperable Object References)
  - AFS (Andrew File system) directory names
- 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 …)



## Change of Local References

- Why are you interested in a reference?
  - Need a reference to computation service (function)
    - Sufficient to have a reference to the component
    - Decorator creates or hands out an arbitrary object instance on demand
  - Need a reference to store/retrieve data service
    - Use a data base
    - Decorator creates or hands out an arbitrary object instance wrapping the accesses to the data base
  - Need a reference for transaction to leave and resume
    - Decorator must keep correct mapping logical 2 physical address
    - Problems with use of self reference inside and outside service



# 11.5 Name Transparency and Trading

Mapping names to locations by name servers

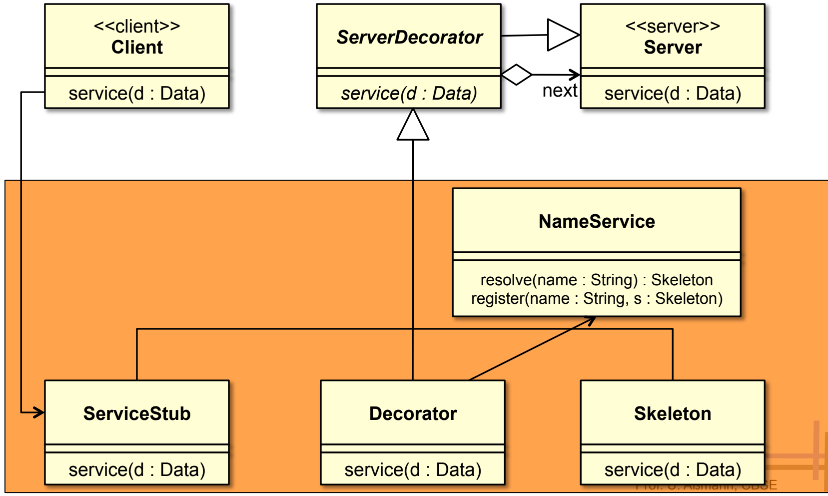
## More Flexible Service Management

- How to spare server skeletons?
  - IDL compiler must generate code for server decorator deserizalizer (example code contained the service dispatcher)
  - Solution: only one server side Decorator per site – independent of client components provided
    - flexible service method with name lookup
    - the current solution prevents dynamic loading of services, because code has fixed names; requires regeneration of Decorator
- Solution: *name service*
  - Decoupling of decorator and skeletons
  - Provide a basic name service for identifying the components (skeletons) of a site, so that the number of services is dynamically extensible
  - Server components register in a service directory (name service) with name and reference
  - Generic adapter looks up, creates, and provides the appropriate service



## Name Service

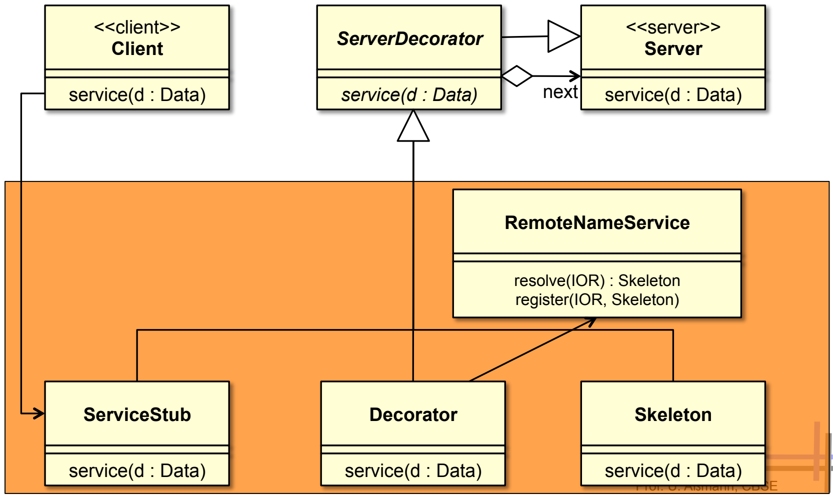
- Name to Location
- Located in the container as an associative array (map)






## Name Service Generalized (1)

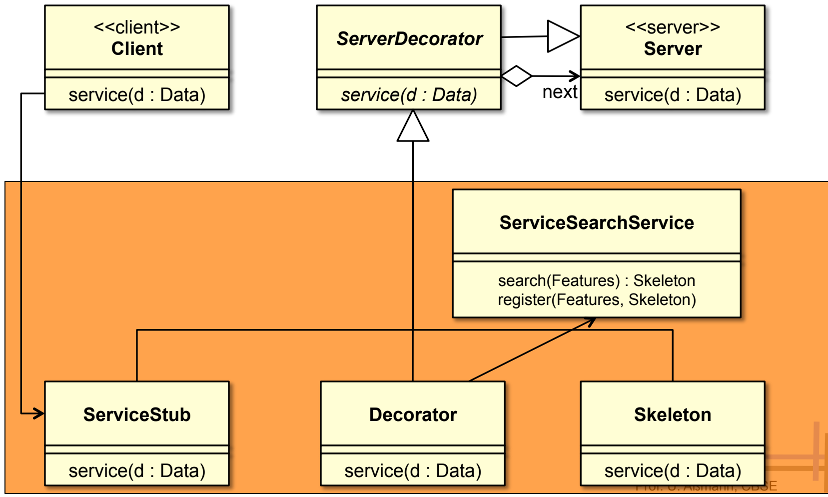
- *Distributed name service* (name to location):
  - If name of server is known, search for the right site providing a desired component





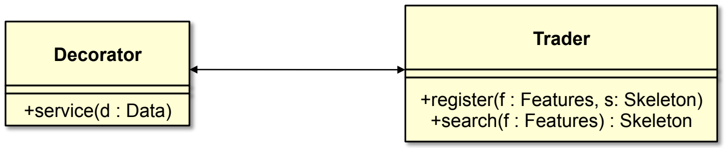

## Name Service Generalized (2)

- *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 properties to name or properties to 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
  - Basic: name, trader, persistency, transaction, synchronization
  - General: print, e-mail, …
  - Domain specific: business objects, …



# 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

# 11.6 Example: A Remote Yellow Page Service

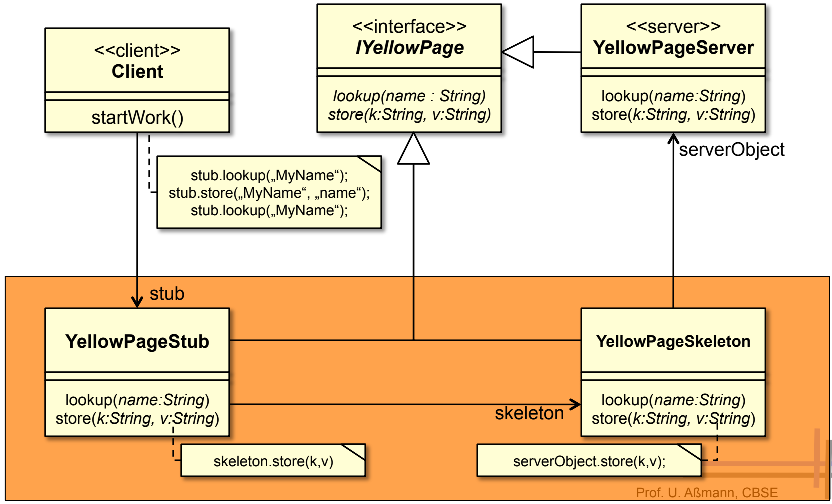
with remote access, serialization

For your own study



## Remote Yellow Page Service

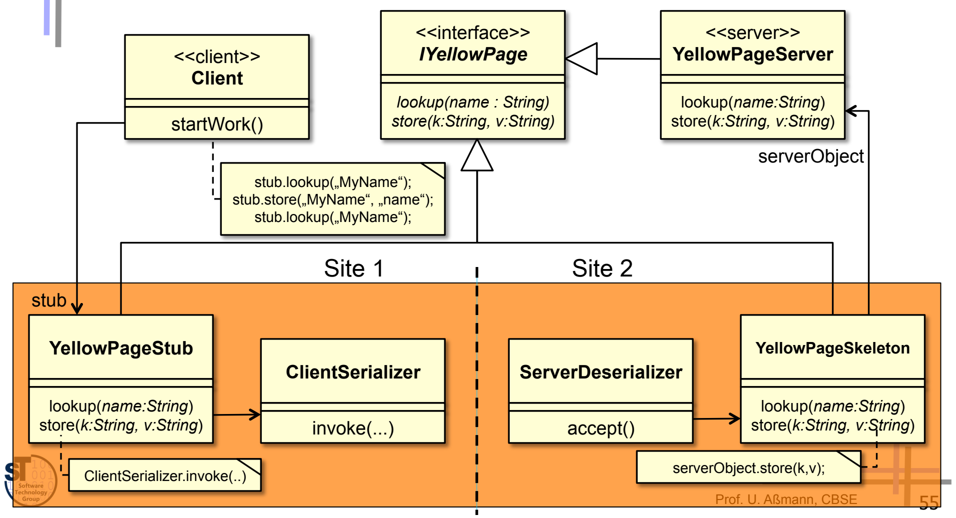
- Basic design without Serialization/Deserialization






## 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);
}
```

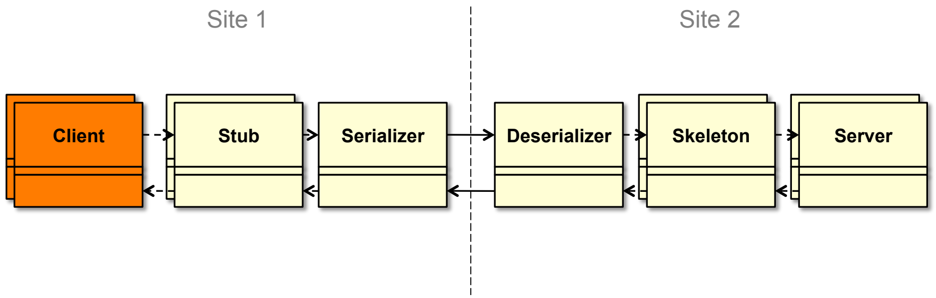
# Service Implementation

```
class YellowPageService implements IYellowPageService {
   private Hashtable<String,String> cache =
                              new Hashtable<String,String>();
   private DataBasis 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

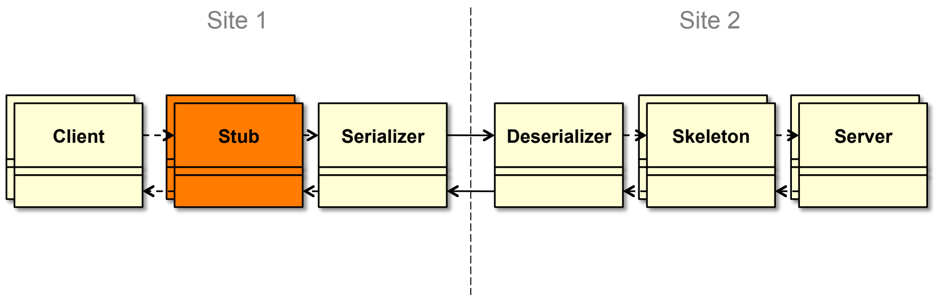
- Client calls stub with service interface:

```
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



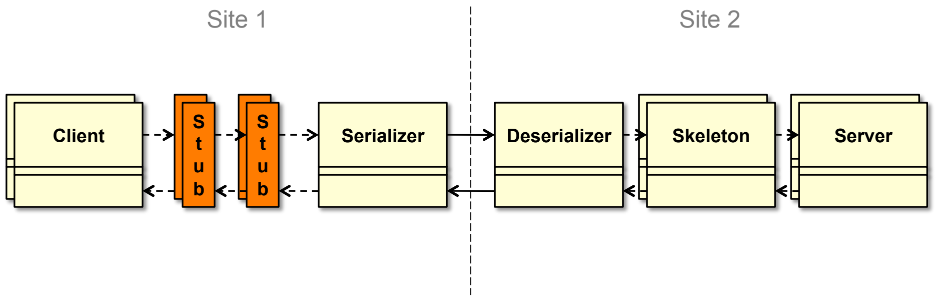
# Example Client Stub - Implementation

```
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)





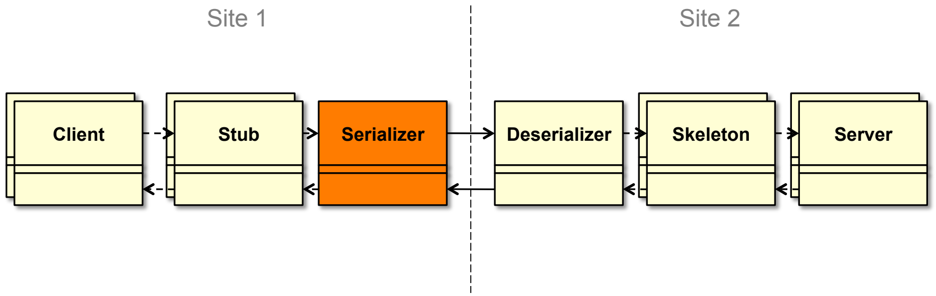

# Client Stub 1 – This Time with Decorator Chain Implementation

```
// 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



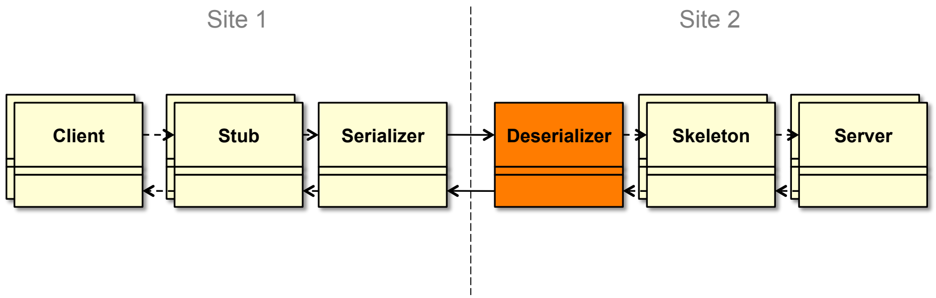
# Example Client Serializer

```
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 (yellow page, phone book, ..)
  - lives always, but hides lifetime of the server

```
class ServiceDeserializer {
   public void run() {
    ServerSocket server = new ServerSocket(1234);
    while (true) {
        Socket client = server.accept();
        ObjectInputStream is = new ObjectInputStream(client.getInputStream());
        ObjectOutputStream os = new ObjectOutputStream(client.getOutputStream());
        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.");
        }
   }}
```

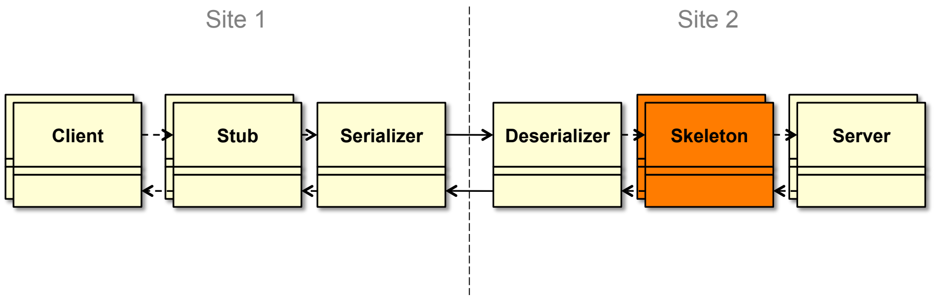


# Example Server Deserializer (2)

```
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



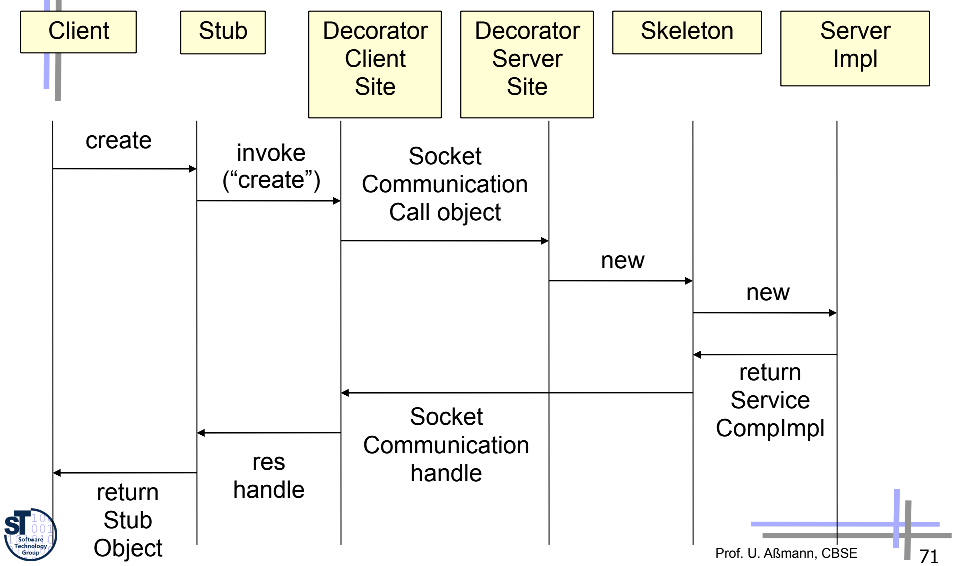



# Example Yellow Pages Server Skeleton (Service Lookup and Call, Adapter)

```
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);
}  }
```

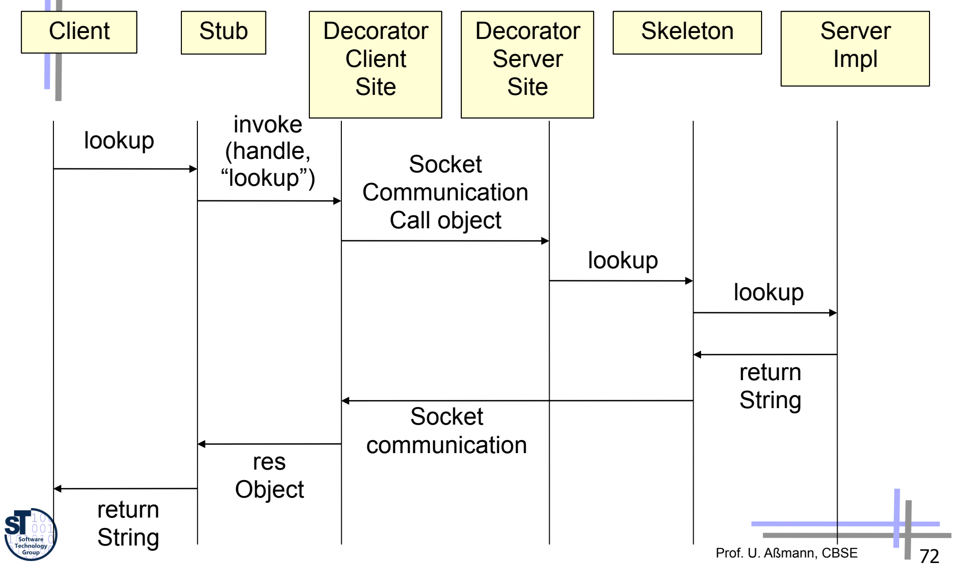


# Creation of YP Service






# Call (Lookup) YP Service



# 11.7 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();
    } …
```



## The End

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