11. Transparency Problems and the Decorator-Connector Pattern

A Design Pattern that appears in all classical component systems

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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)

- **Language transparency**: interoperability of components
  - on the same platform using different programming languages
- **Location transparency:** distribution of programs
  - Hiding, where a program runs
- **Naming transparency:** naming of services
  - Hiding, how a service is called
- **Lifetime transparency**
  - Hide whether server has to be started
- **Persistency transparency**
  - Hide whether server has persistent memory
- **Transactional transparency**
  - Hide whether server is embedded in parallel actions
- **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

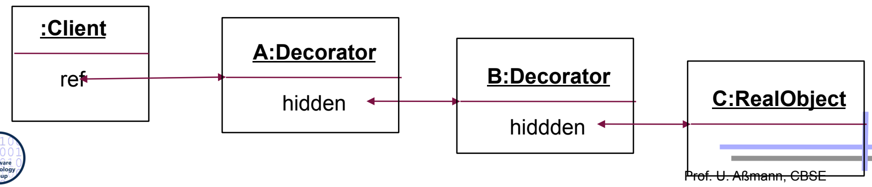
- Calling concept:
  - standardized by the communication library (RPC)
- Calling conventions:
  - Standardized by the communication library (EJB - Java , DCOM - C)
  - Implementation for every single language (Corba)
- Calling implementation:
  - Standardized by the communication library (EJB - Java , 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

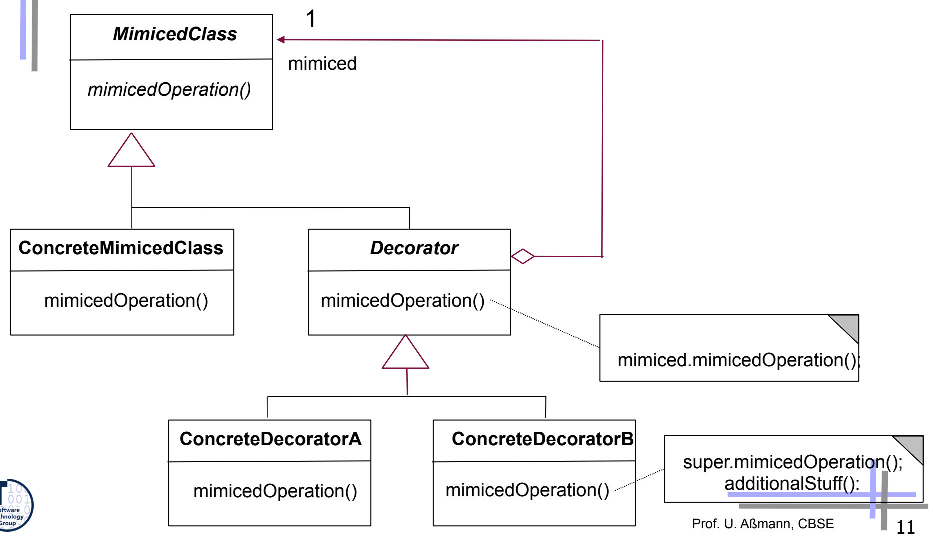
(Repetition from DPF in winter)

Decorator Pattern

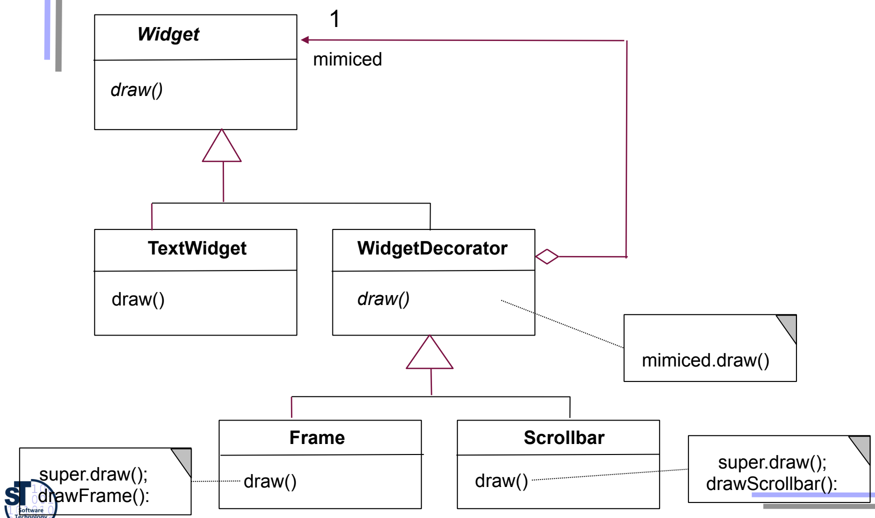
- A Decorator is a *skin* of another object
- It is a 1-ObjectRecursion (i.e., a restricted Composite):
  - A subclass of a class that contains an object of the class as child
  - However, only one composite (i.e., a delegatee)
- Combines inheritance with aggregation
  - Inheritance from an abstract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



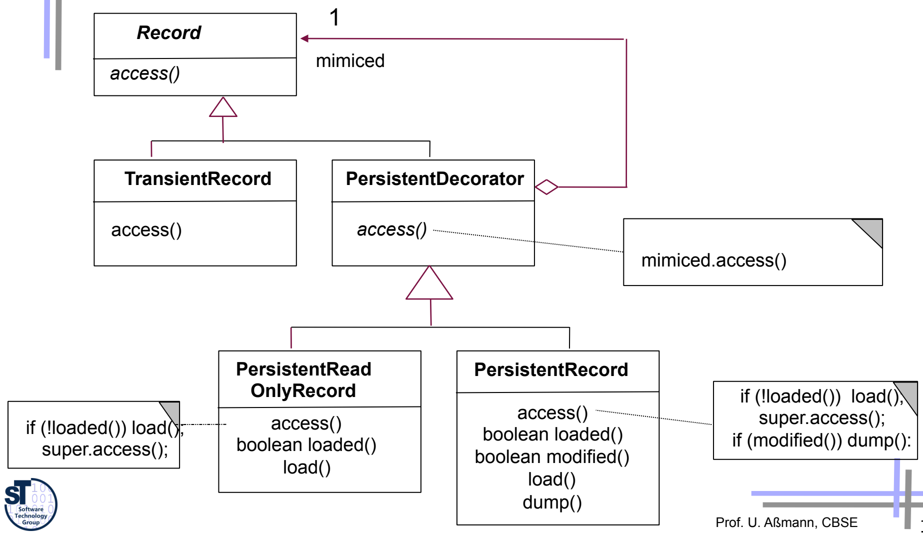
Decorator – Structure Diagram



Example: Decorator for Widgets

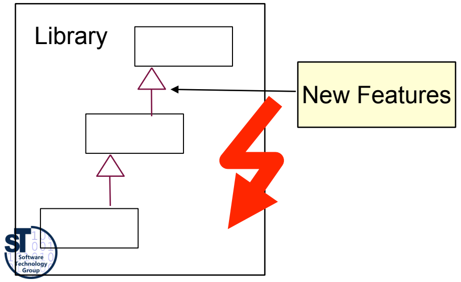


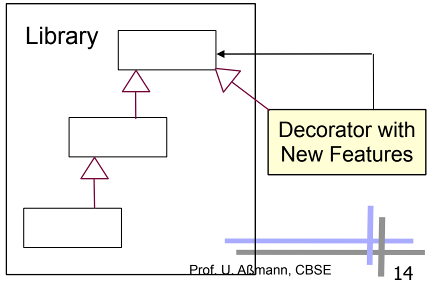
Decorator for Persistent Objects



Purpose Decorator

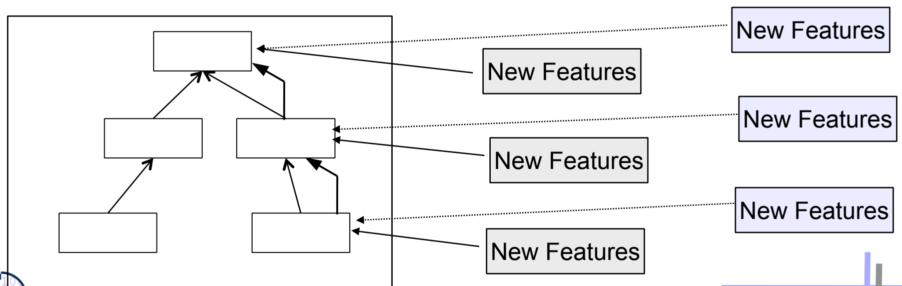
- For extensible objects (i.e., decorating objects)
  - Extension of new features at runtime
  - Removal possible
- Instead of putting the extension into the inheritance hierarchy
  - If that would become too complex
  - If that is not possible since it is hidden in a library





Variants of Decorators

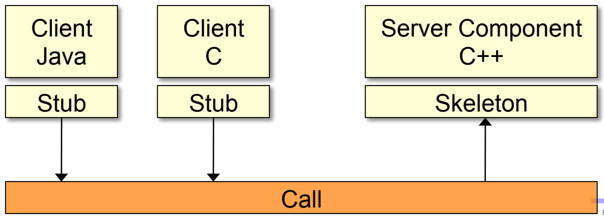
- If only one extension is planned, the abstract super class Decorator can be omitted; a concrete decorator is sufficient
- Decorator family: If several decorators decorate a hierarchy, they can follow a common style and can be exchanged together
- Decorators can be chained to each other
- Dynamically,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



11.2 The Decorator-Connector Pattern

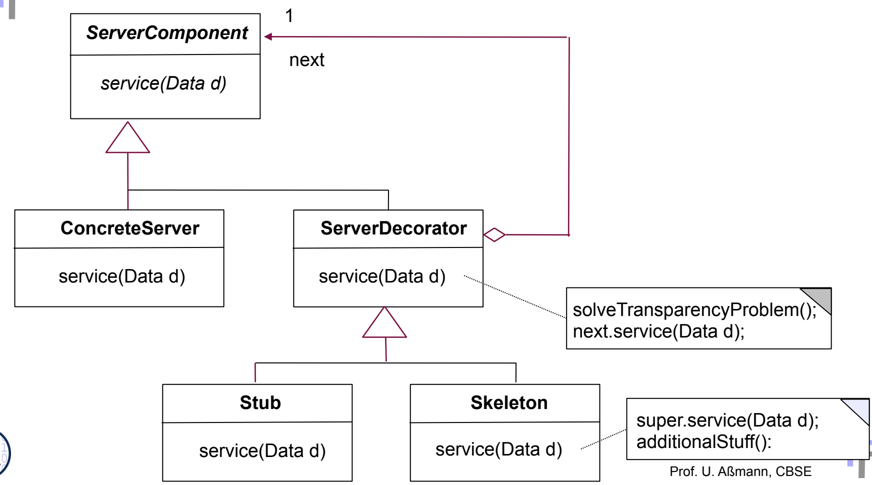
Language Transparency With the Connector Pattern

- 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)



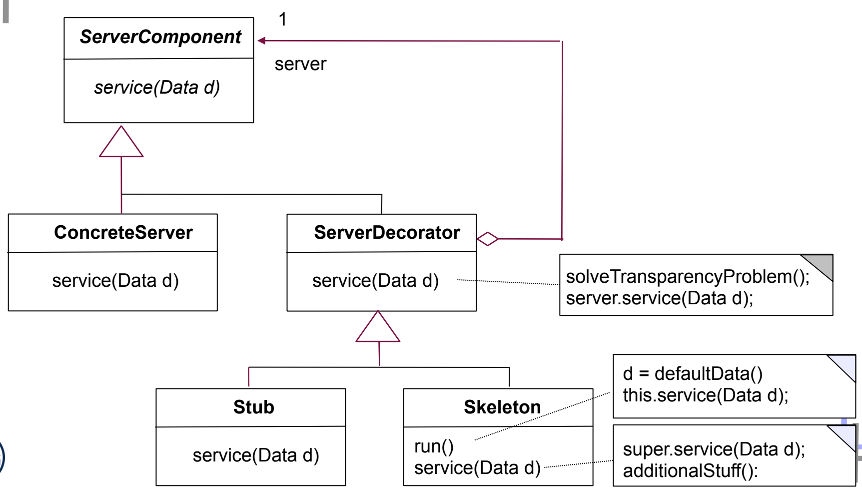
Stubs and (Static) Skeletons

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



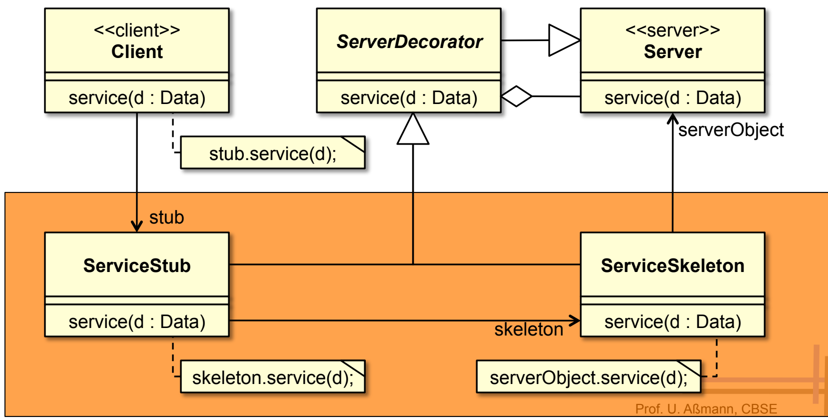
Stubs and Dynamic Skeletons

- Skeleton contains a generic method *run()*
  - Skeleton is an *Adapter*, mapping *run* to server method *service(Data)*



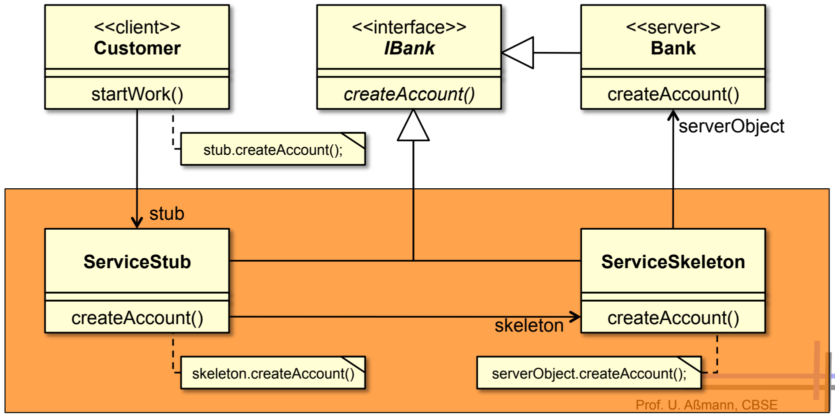
The Connector Pattern (Alt. 1, with Decorator)

- 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



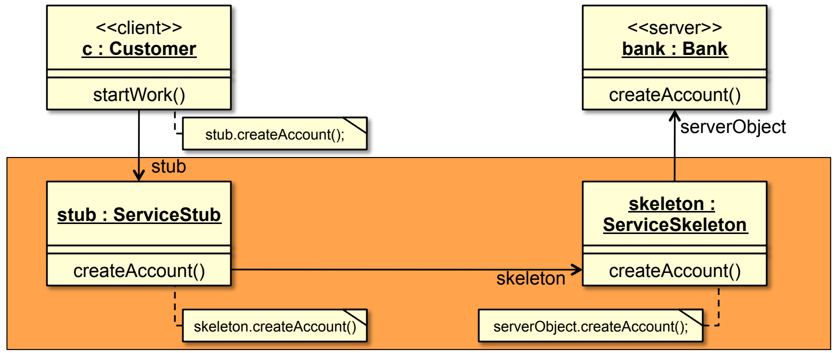
A Connector with Server Interface (Alt. 2, with Abstract Superclass)

- Client and server are connected via a layer of stubs and skeletons (the *connector*)
- Server, Stubs and Skeletons inherit from same interface



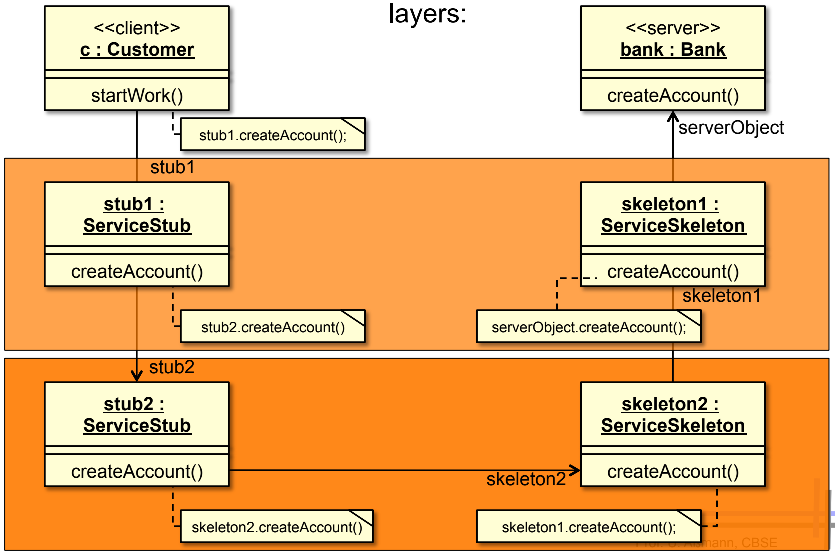
Object Diagram of Decorator-Connector Pattern

- 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

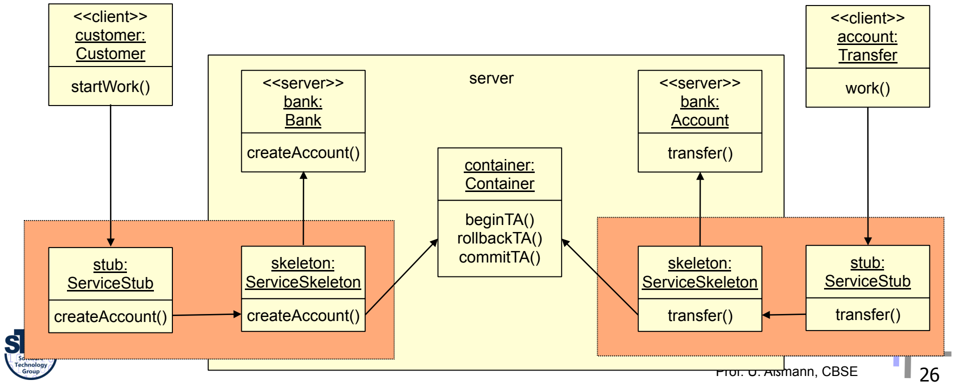
- Why is it a Decorator?
  - Decorators allow for stacking of connectors (layering)
  - Proxy pattern: just *one* representative, no stacking possible
    - However, from the client and server's perspective, stub and skeletons are Proxies
  - Adapter: Adapted interface must be different from Adaptee
  - 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

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)



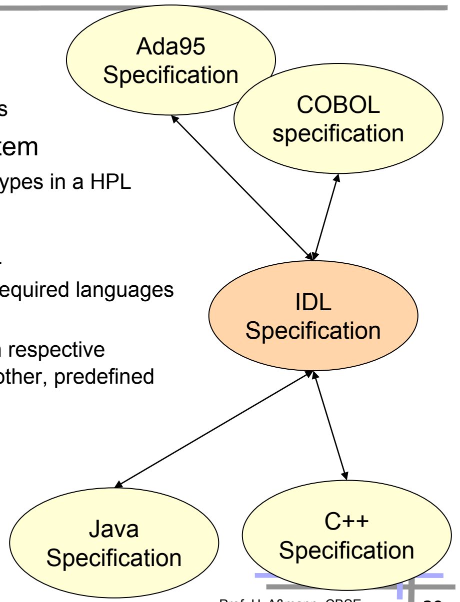
Who Realizes Stubs and Skeletons?

- 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

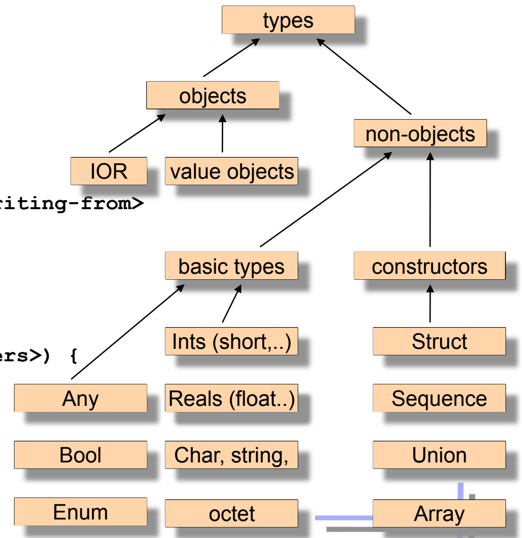
Type Mapping with the Interface Definition Language (IDL)

- 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 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>) {
              ...
    }
    ....
  }
}
```

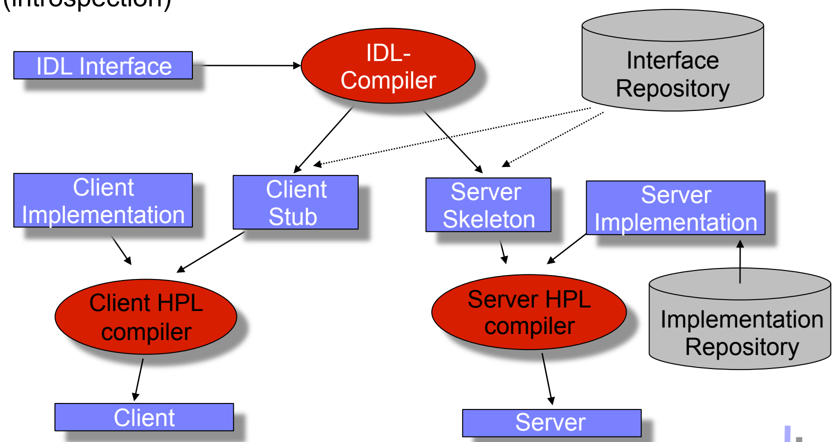


Hello World IDL

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


Generation of Stubs and Skeletons from IDL

- Generation is done for every involved 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 ι_{IDL}
   $\forall\ PL : \tau_{PL} \circ \tau_{PL}^{-1}: TS_{PL} \rightarrow TS_{PL}$ is ι_{PL}

IDL Can Also Be Generated from Host Language

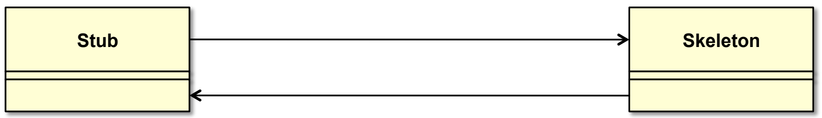
Specification of IDL and host language

- 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

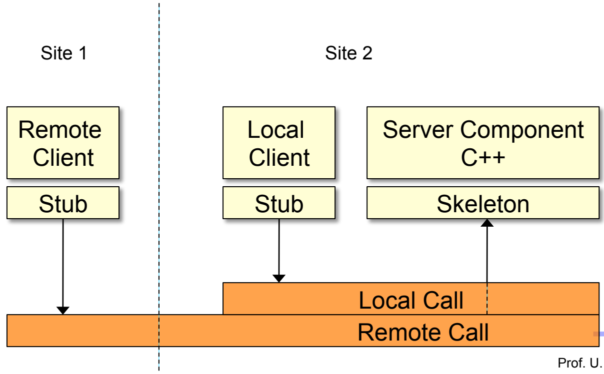
11.4 Location Transparency

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
    - …

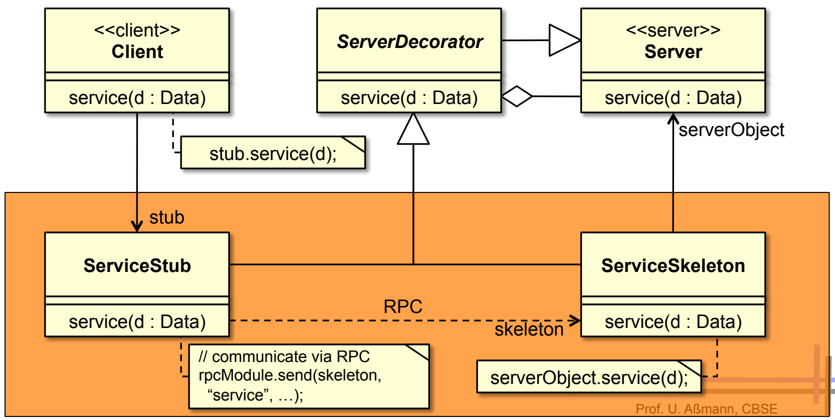
Transparent Local/Remote Calls

- 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

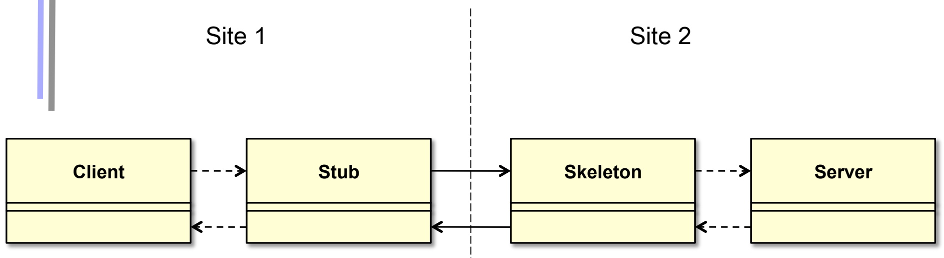


Stubs and Skeletons for Distribution

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



Stubs and Skeletons for Distribution



RPC

Language 1

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

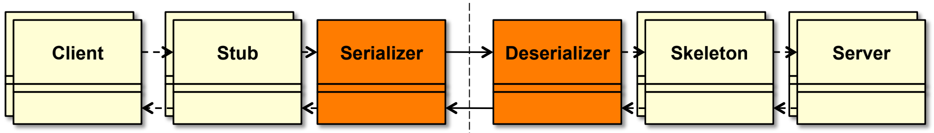
Language 2

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

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

RPC

Language 2

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

Problem 3: The Reference Problem (Name Transparency)

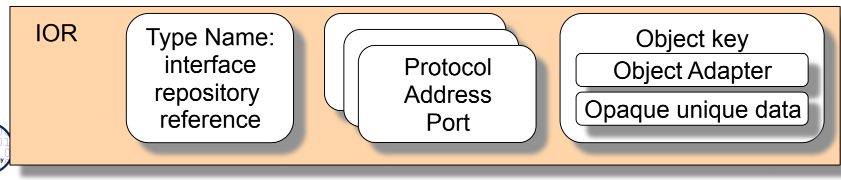
- How to reference something?
  - Target of calls (services)
  - Call by reference parameters and results
  - Reference data in composite parameters and results
- Scope of references
  - Thread/process
  - Computer
  - Agreed between communication partners
  - Net wide
- How to handle references transparently?

Approach: Global Adresses

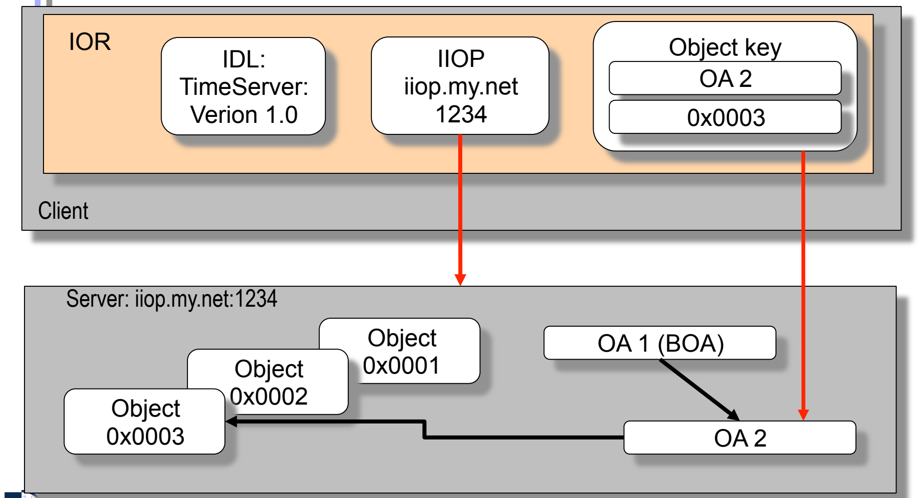
- World wide unique addresses
  - e.g., computer address + local address
  - URL, URI (Uniform Resource Identifiers)
  - CORBA IORs (Interoperable Object References)
  - AFS (Andrew File system) directory names
- Mapping tables for local references
  - Logical to physical
  - Consistent change of local 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 …)

Example: CORBA Interoperable Object Reference – IOR

- A unique key for an object
  - Uniquely mapped per language (for all ORBs)
  - Hides object references of programming languages
- Consists of:
  - Type name (code), i.e., index into Interface Repository
  - Protocol and address information (e.g., TCP/IP, port #, host name), could support more than one protocol
  - Object key:
    - Opaque data only readable by generating ORB (pointer)
    - Object decorator (adapter) name (for BOA)



IOR Example



Change of Local References

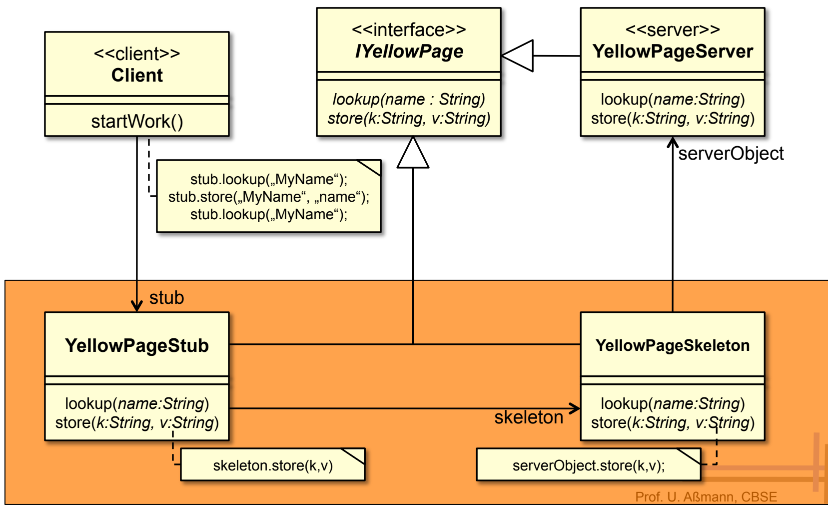
- Why are you interested in a reference?
  - Need a reference to computation service (function)
    - Sufficient to have a reference to the component
    - Decorator creates or hands out an arbitrary object instance on demand
  - Need a reference to store/retrieve data service
    - Use a data base
    - 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 Example: A Remote Yellow Page Service

with remote access, serialization

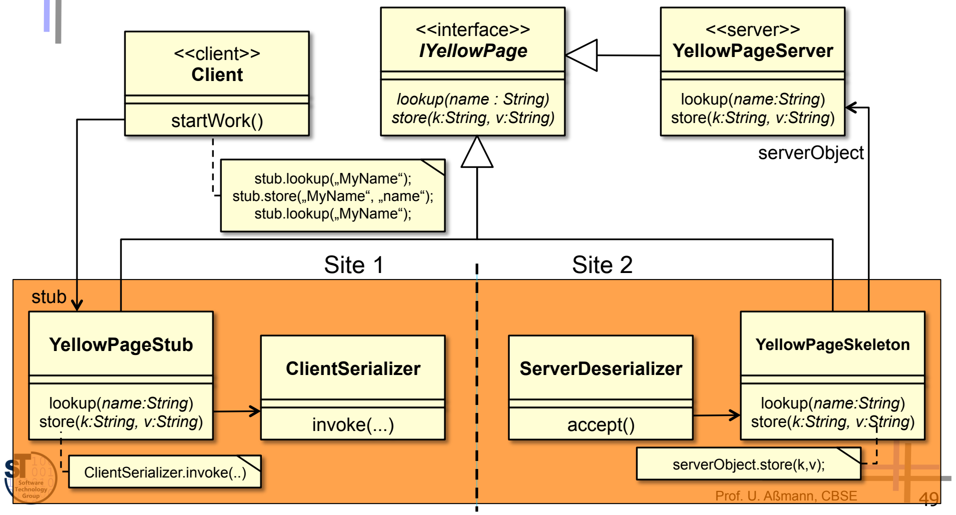
Remote Yellow Page Service

- Basic design without Serialization/Deserialization



Remote Yellow Page Service

- With Serialization/Deserialization



Service Interface

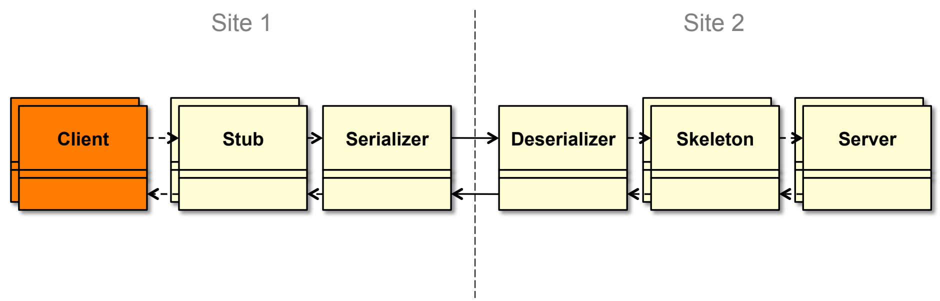
```
interface IYellowPageService {
   String SERVICE_NAME = "Yellow Pages";
   String lookup(String name);
   void store(String name, String value);
}
```


Service Implementation

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



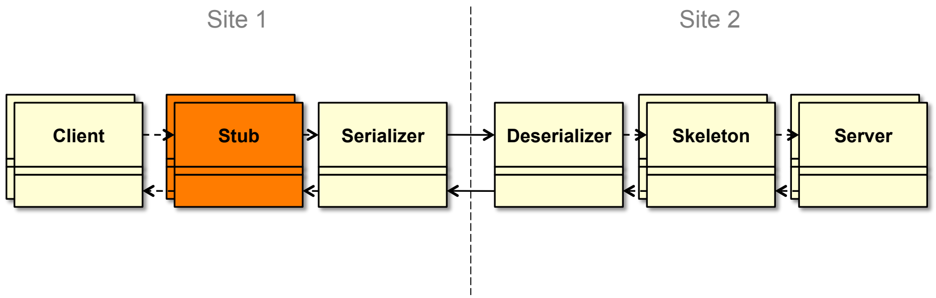
Example Client

- 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

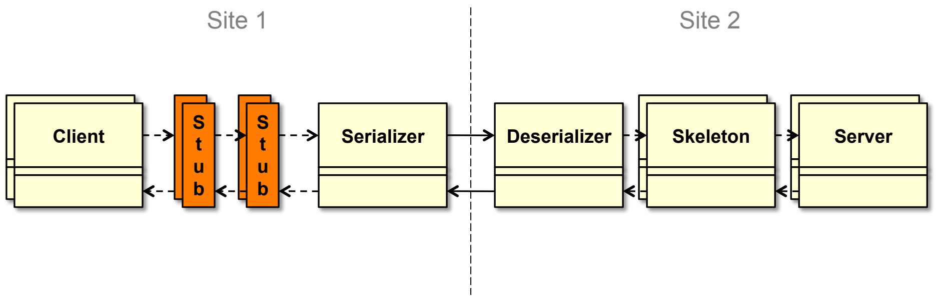


Example Client Stub - Implementation

```
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)

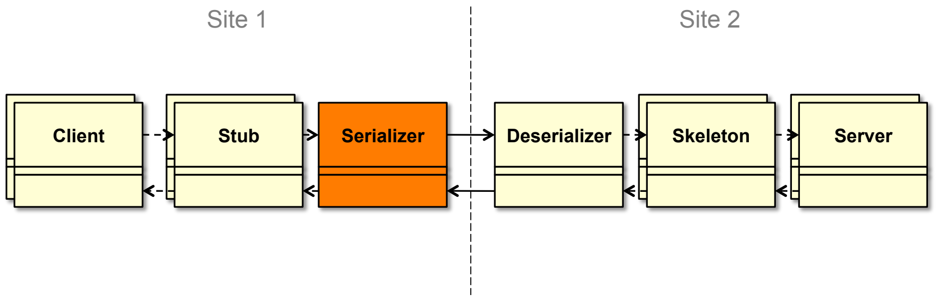


Client Stub 1 – This Time with Decorator Chain Implementation

```
// 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

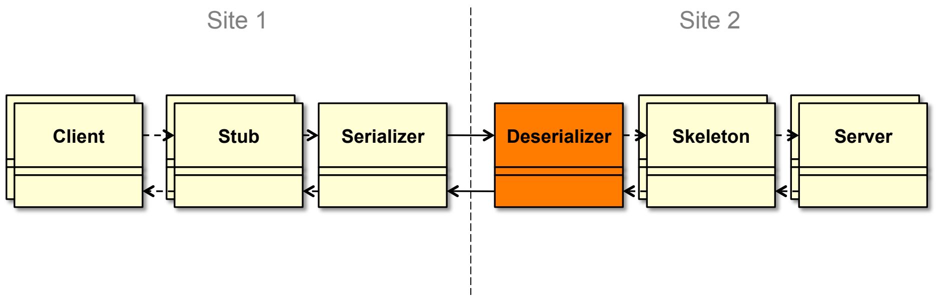


Example Client Serializer

```
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

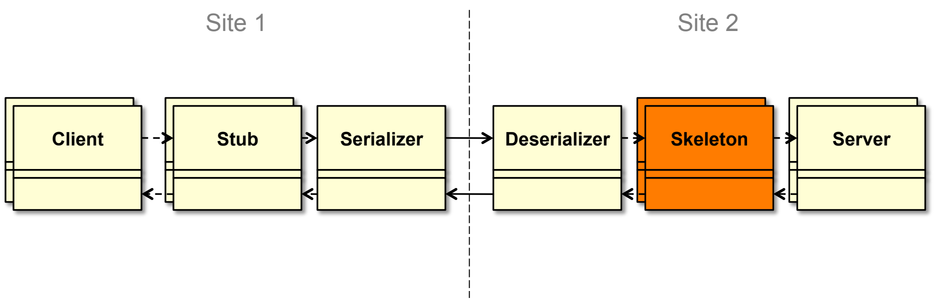
```
class ServiceDeserializer {
   public void run() {
    ServerSocket server = new ServerSocket(1234);
    while (true) {
        Socket client = server.accept();
        ObjectInputStream is = new ObjectInputStream(client.getInputStream());
        ObjectOutputStream os = new ObjectOutputStream(client.getOutputStream());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

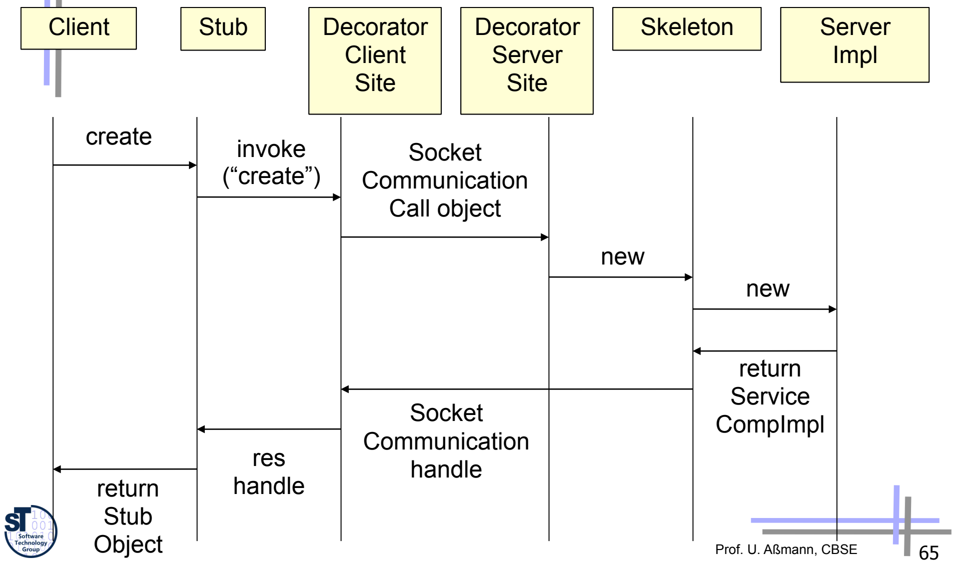
- Manages service components of server on server side
- 1:1 mapping to service component



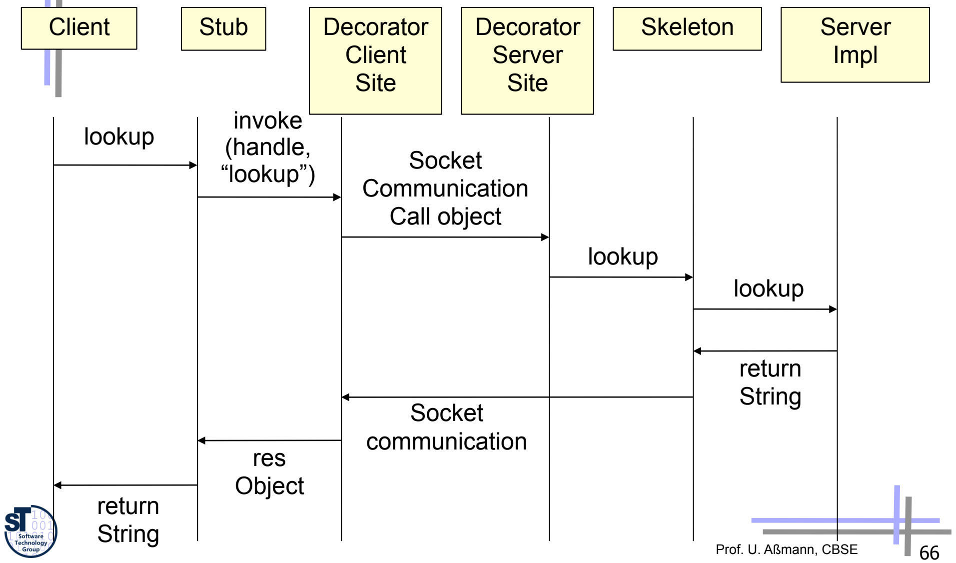
Example Yellow Pages Server Skeleton (Service Lookup and Call, Adapter)

```
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



11.6 Name Transparency and Trading

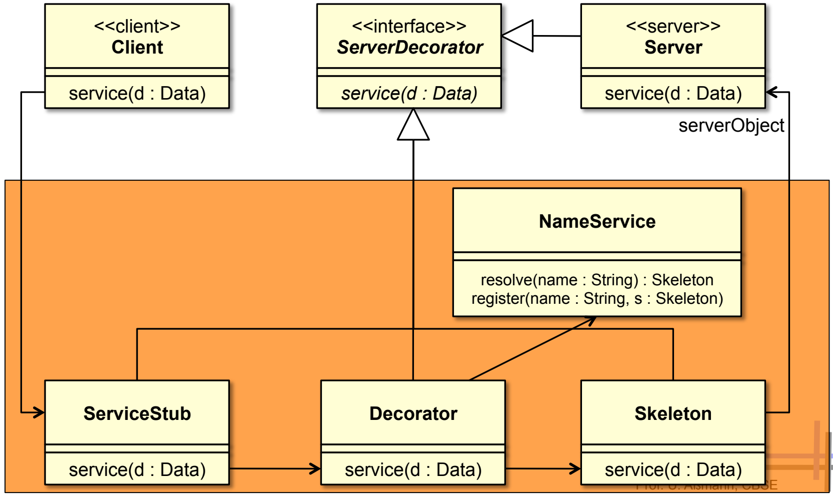
Mapping names to locations by name servers

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

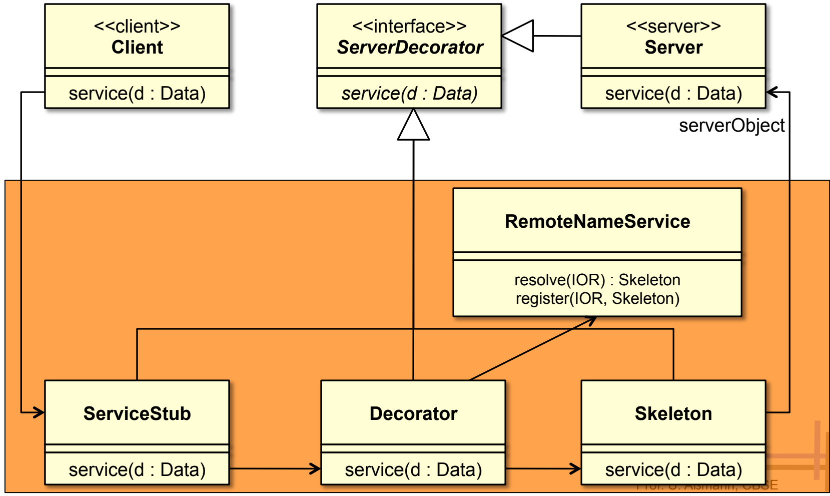
Name Service

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



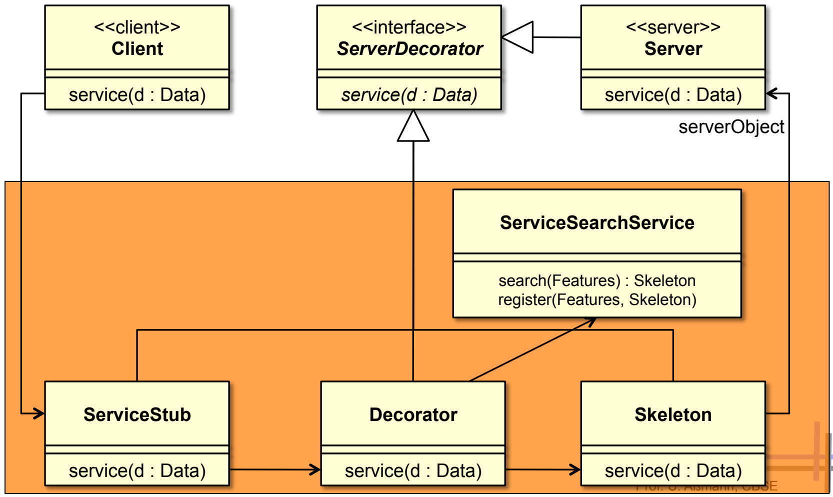
Name Service Generalized (1)

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



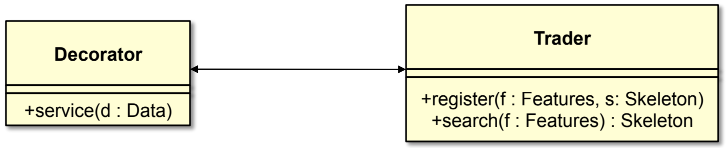
Name Service Generalized (2)

- *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 …)



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();
     } …
```


Remark: Skeletons 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

The End

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

Prof. U. Aßmann, CBSE 78