Problems and Solutions in Classical Component Systems

- Language Transparency
- Location/Distribution Transparency
- Example: Yellow Page Service
- IDL principle
- Reflective Calls, Name Service

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Remember: Motivation for COTS

- Component definition revisited:
  Program units for composition with
  - standardized basic communication
  - standardized contracts
  - independent development and deployment
- A meaningful unit of reuse
  - Large program unit
  - Dedicated to the solution of a problem
  - Standardized in a likewise standardized domain
- Goal: economically stable and scalable software production

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Obstacles to Overcome …

- **Technical – Interoperability**
  - Standard basic communication
  - Heterogeneity:
    different platforms, different programming languages
  - Distribution:
    applications running on locally different hosts connected with different networks
- **Economically – Marketplace**
  - Standardize the domain
    to create reusable, standardized components in it
  - Create a market for those components
    (to find, sell and buy them)
    – which has some more technical implications

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Technical Motivations

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

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Heterogeneity problems to be solved by component systems

- ***Language transparency***:
  interoperability of programs
  - on the same platform, using
  - different programming languages
- ***Platform transparency***:
  interoperability of programs
  - written for different platforms using
  - the same programming language
- ***Heterogeneity***:
  - Different platforms, different programming languages
  - Requires language and platform transparency

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Language Transparency Problems

- Calling concept
  - Procedure, Co-routine, Messages, …
- Calling conventions and calling implementation
  - Call by name, call by value, call by reference, …
  - Calling implementation: Arguments on stack, in registers, on heap, ...
- Data types
  - Value and reference objects
  - Arrays, unions, enumerations, classes, (variant) records, …
- Data representation
  - Coding, size, little or big endian, …
  - Layout of composite data
- Runtime environment
  - Memory management, garbage collection, lifetime …

Options In General

For n languages:

- 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 a single format (as in .NET): $O(1)$ but very restrictive, because the languages become very similar

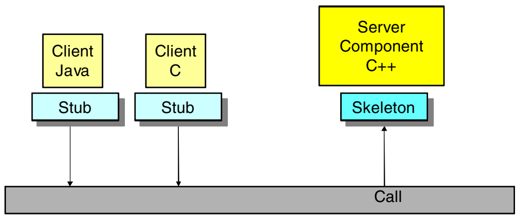
Solutions in Classical Component Systems

- Calling concept:
  - standardized by the communication library (RPC)
- Calling conventions and implementation:
  - Standardized by the communication library (EJB - Java , DCOM - C)
  - Implementation for every single language (CORBA)
- Data types:
  - Existing type system as standard (EJB – Java types)
  - New standard type system (CORBA IDL-to-Language mapping)
- Data representation:
  - Standard (EJB – Java representation, DCOM – binary standard)
  - Adaptation to a general exchange format (CORBA GIOP/IIOP)
- Runtime environment
  - Standard by services of the component systems

Language Transparency Implementation

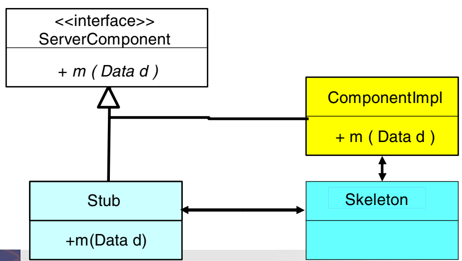
- Stubs and Skeletons
  - ***Stub***
    - Client-side proxy of the component
    - Takes calls of component clients in language A and sends them to the
  - ***Skeleton***
    - Takes those calls and sends them to the server component implementation in language B
- Language adaptation could take place in Stub or Skeleton (or both)
  - Adaptation deals with calling concepts, data formats, etc.
- Solution of distribution transparency problem postponed ...

Stubs and Skeletons



Stubs and Skeletons

- A typical instance of the **proxy pattern**
  - Stub (client-side proxy) delegates calls to Skeleton
  - Skeleton (server-side proxy) delegates to servant (implementation)



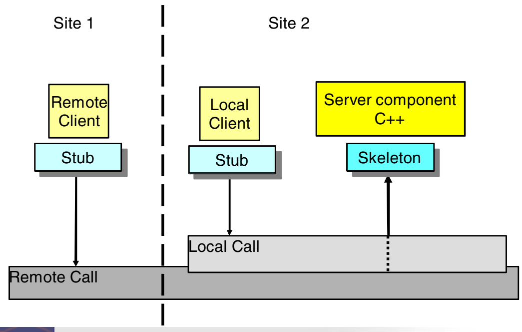
Distribution

- ***Location transparency / Distribution 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
    - How to handle references transparently?
  - Distributed systems are heterogeneous
    - So far, we handled platform-transparent design of components
  - Usual suspects in distributed systems
    - Transactions
    - Synchronization
    - …

Transparent Local/Remote Calls

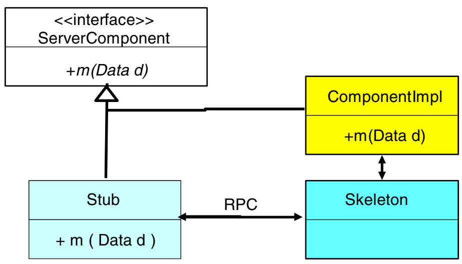
- Communication over proxies (-> proxy pattern)
  - Proxies redirect call locally or remotely on demand
  - Proxies always local to the caller
- RPC for remote calls to a handler
  - Handler always local to the callee
- Déjà vu! We reuse Stubs and Skeletons

Remote Stubs and Skeletons

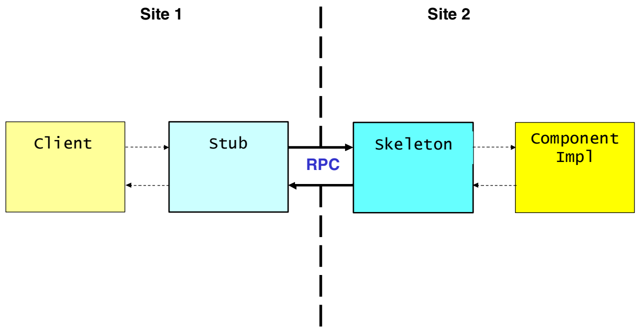


Stubs and Skeletons for Distribution

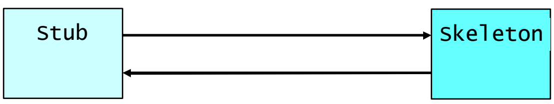
- A variant of the Proxy pattern, using remote procedure call (RPC) when forwarding requests



Stubs and Skeletons



Stubs and Skeletons so far …
(same platform)



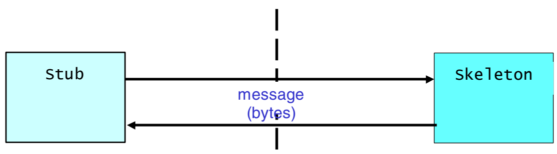
Language 1

1. Map call data to an exchange format
2. Call Skeleton

Language 2

3. Receive Call from Stub
4. Retrieve data from the exchange format

… and now



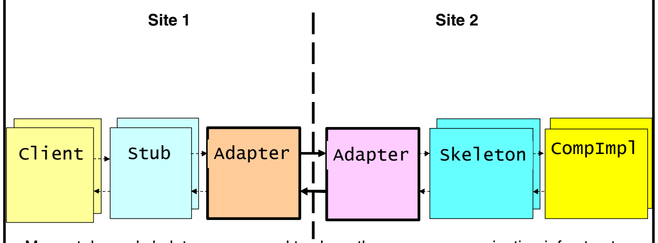
Language 1
Site 1

1. Map data / call to a byte stream exchange format
2. Send message, e.g. via TCP/IP network socket

Language 2
Site 2

3. Receive message from network socket
4. Retrieving data / call from the byte stream exchange format

Stubs, Skeletons, and Adapters



Many stubs and skeletons may need to share the same communication infrastructure (e.g., TCP/IP ports)

Stub and skeleton objects must be created and referenced by need.

Put this support functionality in a separate **Adapter** layer ("run-time system for RPC")

Remark: In CORBA, this "Adapter" functionality will be split between the ORB (communication) and the so-called Object-Adapter (multiplexing).

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Reference Problem

- Target of calls
- Call-by-reference parameters, references as 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?

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Approach

- World-wide unique addresses
  - E.g. computer address + local address
  - URL, URI (uniform resource identifiers)
- Mapping tables for local references
  - Logical-to-physical
  - Consistent change of local references possible
- (In principle) one adapter per computer manages references
  - 1:n relation adapter 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 …?")

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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
  - Adapter creates or hands out reference to an arbitrary object on demand
- Need a reference to store/retrieve data service
  - Use a data base
  - Adapter creates or hands out an arbitrary object instance wrapping the accesses to the data base
- Need a reference to stated transaction to leave and resume
  - Adapter must keep correct the mapping logical-to-physical address
  - Problems with use of self reference inside and outside service

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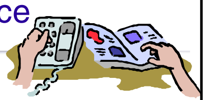
Example: Yellow-Page Service



- **Yellow Pages service**
  - Lookup of a name (database access with caching by YP object)
- Internally: **2 types of requests** (in adapter/stub/skeleton layers)
  - **Lookup Request**: given
    - Service type (Yellow pages, phone book, ...)
    - Address: specifies the YP service object (i.e., a reference)
    - Requested method (lookup, ...)
    - and array of parameter objects, e.g. name (string) to look up
  - **Creation Request**: Creation of a new YP service object on server
    - Service type
    - Address = -1 (denotes creation request)

YP service objects registered in YP skeleton in a hashtable of YP objects

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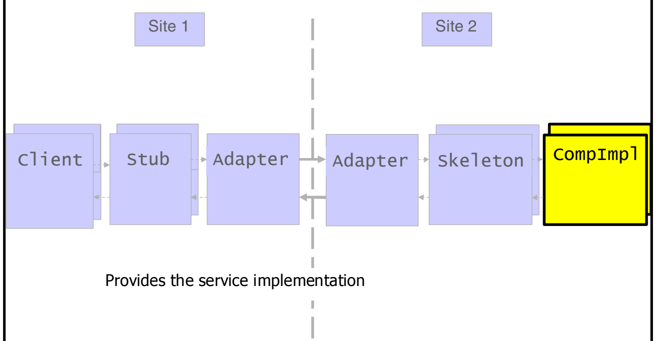
Example: Yellow Page Service (1)

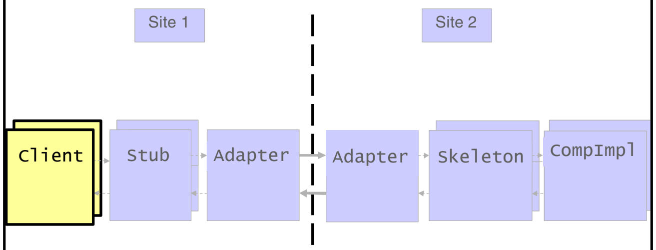
Service component



Example: Yellow Page Service (1)
Service component

```
class YellowPages extends YellowPagesInterface {
    private Hashtable cache = new Hashtable ();
    //JDBC data base connection:
    private static DataBase db = … ;
    public String lookup(String name) {
      String res;
      if ((res = cache.lookup(name)) != null)
           return (String)res;
      if ((res = db.lookup(name)) != null){
           cache.put(name,res);
           return (String)res;
      }
      return "Sorry";
    }
}
```


Example: Yellow Page Service (2)
Client

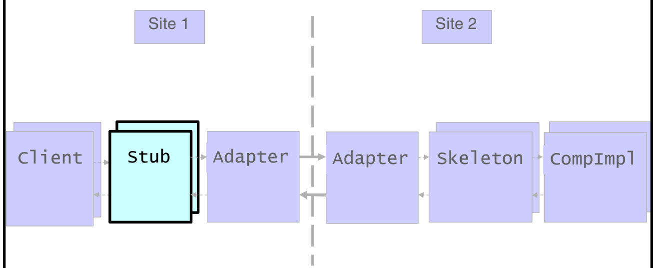


Wants to transparently use the service

Example: Yellow Page Service (2)
Client

```
class Client {
    …
    YellowPageInterface yps = YellowPageInterface.getOne();
    …
    String res = (String)yps.lookup( ...string to lookup... );
    …
}
```


Example: Yellow Page Service (3)
Stub (client site)



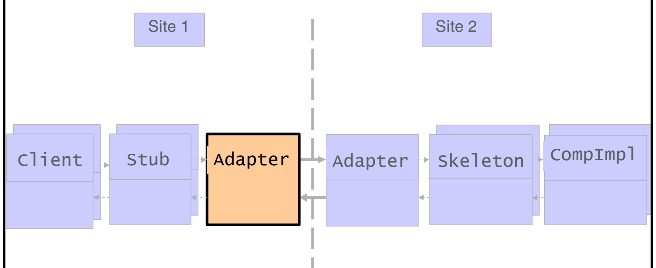
1:1 mapping to service component
Manages services objects of that component on client site
Is called from the client

Example: Yellow Page Service (3)
Client Stub

```
class YellowPageStub extends YellowPageInterface {
    private ClientAdapter ca = new ClientAdapter();
    private static Hashtable yellowPageObjects = new Hashtable();

    public String lookup(String name) {
      ca.invoke(    "Yellow Pages", yellowPageObjects.get(this),
                    "lookup", Object[]{name});
      return (String)ca.res;
    }
    // client-side constructor:
    public YellowPageInterface getOne() {
      ca.invoke("Yellow Pages", Integer(-1), "new", null);
      yp = new YellowPageStub();
      yellowPageObjects.put( yp, ca.res );
      return yp;
    }
}
```


Example: Yellow Page Service (4)
Client Site Adapter

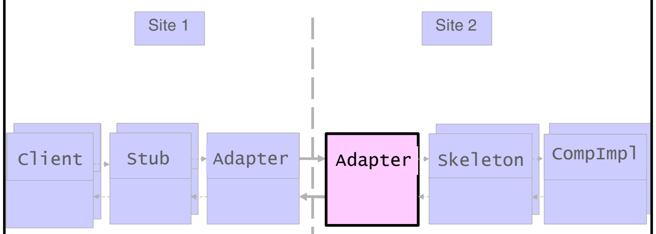


Manages the basic communication on client site
Is called from the client stubs

Example: Yellow Page Service (4)
Client Adapter

```
class ClientAdapter {
    Socket s = new Socket( serverHost, serverPort );    //magic
    public Object res;
    public void invoke( String service; Integer addr; String method; Object[] args) {
      ObjectOutputStream os = new ObjectOutputStream(s.getOutputStream());
      ObjectInputStream is = new ObjectInputStream(s.getInputStream());
      os.writeObject(service);
      os.writeObject(addr);
      os.writeObject(method);
      if ( addr==Integer(-1) && method.equals(“new”) )  {
         os.flush();
         res = is.readObject();   }
      else {
         os.writeObject(args);
         os.flush();
         res = is.readObject();}
         s.close();   }
    }
}
```


Example: Yellow-Page Service (5)
Server-side Adapter

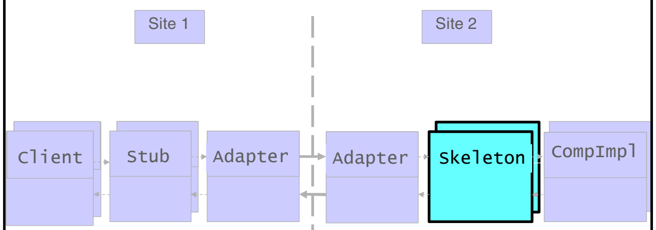


Manages the basic communication on server site
Calls the service skeletons

Example: Yellow Page Service (5)
Server-side Adapter

```
class ServiceAdapter extends Thread {
    ServerSocket ss = new ServerSocket( 0 );   //magic
    public void run() {
      while( true ) {
          try {  Socket s = ss.accept();
                    ObjectInputStream is =
                         new ObjectInputStream(s.getInputStream());
                    ObjectOutputStream os =
                         new ObjectOutputStream(s.ObjectOutputStream());
                    String service =(String) is.readObject();
                    if (service.equals(“Yellow Pages”)
                         new YellowPagesSkeleton(os,is).start();
                    else if (service.equals(“Phone Book”)
                         new PhoneBookSkeleton(os,is).start();
                    else if …
                    else System.err.println(“Unknown service.”);
          } catch( ... ) {…}
      }
    }
}
```


Example: Yellow Page Service (6)
Skeleton

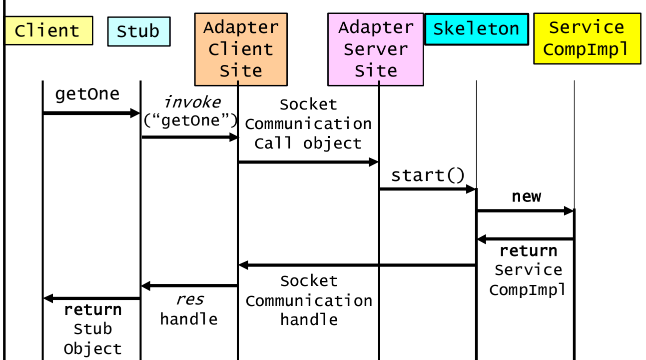


1:1 mapping to service component
Manages service objects of that component on server site

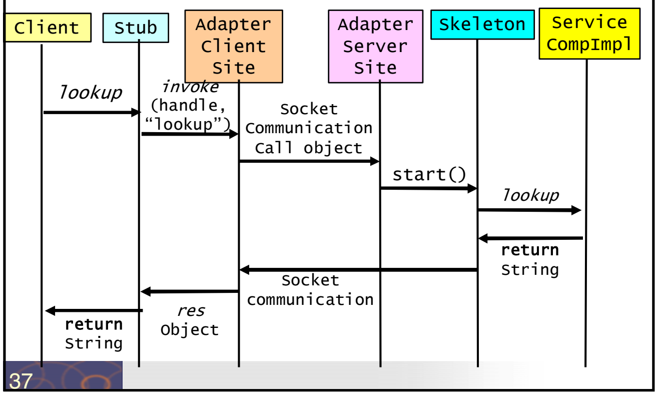
Example: Yellow Page Service (6)
Skeleton

```
class YellowPagesSkeleton extends Thread implements Skeleton {
    static Hashtable yellowPageObjects = new Hashtable();
    YellowPagesSkeleton( ObjectOutputStream os, ObjectInputStream is ) { … }
  public void run() { …
      Integer addr = (Integer) is.readObject();
      if (addr == Integer(-1)) {  // creation of the service:
           Integer address = new Integer( yellowPageObjects.size() ) ;
           yellowPageObjects.put( address, new YellowPage() );
           os.writeObject( address );}
      else {  // service query:
           YellowPage yp = (YellowPage) yellowPageObjects.get( addr );
           String method = (String) is.readObject();
           if (method.equals(“lookup”) {
                String name = (String) is.readObject();
                String res = yp.lookup( name );  // finally: the call to the service
                os.writeObject(res); }
           else if (method.equals(“store”) { … }
           else System.err.println(“Unknown service method.”); }
      os.flush(); s.close();
    }}
```


Sequence Diagram, Creation

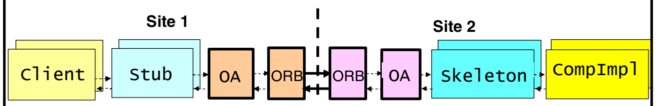


Sequence Diagram, Call



Technical remark

Note: **This was a simplification!**
Some issues are solved differently e.g. in CORBA or Java RMI.



"Adapter" functionality is, in CORBA, split up between ORB (communication/run-time system) and Object Adapter.

The communication mechanism, here Java sockets etc., is in CORBA provided by the ORB (which abstracts from language or platform specific communication mechanism/API).

The server object registry (static hashtable yellowPageObjects), here in the Skeleton, which is used to direct a call to the "right" server object, would in CORBA reside in the Object Adapter (who is responsible for activating / terminating "its" server processes and objects, resolving interoperable object references, and directing calls from the ORB to the right target object).

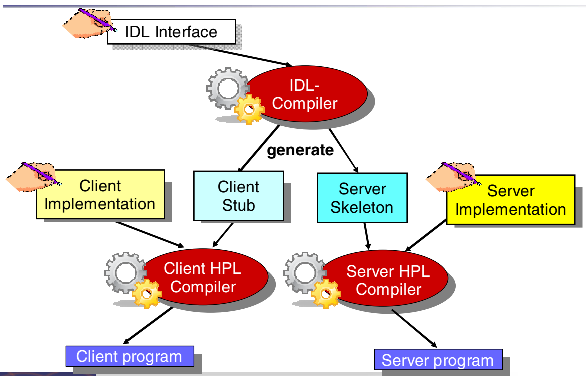
Who Realizes Stubs and Skeletons?

- Programmer ?
  - Much handcraft, boring and error prone
- Insight
  - Stub
    - Export interface is component dependent
    - Implementation is source language dependent
  - Skeleton
    - Import interface is component dependent
    - Implementation is target language dependent
- Idea
  - Generate export and import interfaces of Stub and Skeleton from a component interface definition
  - Take a generic language adapter for the implementation

Interface Definition Language (IDL)

- Language to define the
  - Interfaces of components
  - Data types of parameters and results
- Programming-language independent type system
  - General enough to capture all data types in HPL (host progr. lang.)
- Procedure of construction
  - Define component 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)

Automatic Generation of Stubs and Skeletons



IDL Interface Can Be Generated

Specification in 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
- CORBA

Specification in host language only

- Retrieve the IDL spec from the HPL interface definitions (see lecture on metaprogr.)
- Have only one source of IDL compilers, guaranteeing consistency
- Quasi standard
- Java, DCOM, .NET

Required Formal Properties of the IDL-to-Language mapping

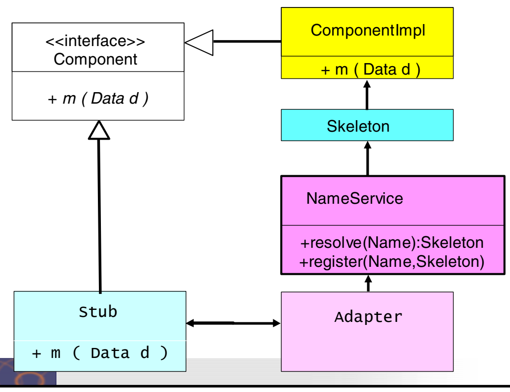
Let $\tau_{PL}: IDL \to TS_{PL}$ be the mapping from an interface definition language IDL to the type system TS of a programming language PL

- ***Well-definedness***
  for all PL : $\tau_{PL}: IDL \to TS_{PL}$ is well defined
- ***Completeness***
  for all PL : $\tau_{PL}^{-1}: TS_{PL} \to IDL$ is well defined
- ***Soundness***
  for all PL : $\tau_{PL}^{-1}\,\tau_{PL}: IDL \to IDL$ is ι_{IDL}
  for all PL : $\tau_{PL}\tau_{PL}^{-1}: TS_{PL} \to TS_{PL}$ is ι_{PL}

Example revisited

- IDL compiler must generate code for server-side adapter (example code contained the service dispatcher)
  - This is very nasty
  - One server-side adapter per site – should be independent of client components provided
  - Current solution prevents dynamic loading of services
- Idea:
  - Decoupling of adapter and skeletons
  - Provide a basic (name) service for identifying the components (skeletons) of a site
  - Components register with name and reference
  - Generic adapter provides this service

Name Service



Example: Generic Server Adapter

```
class ServiceAdapter extends Thread {
   ServerSocket ss = new ServerSocket( 0 );
   NameService ns = new NameService();
   public void run() {
     while( true ) {
      try {
        Socket s = ss.accept();
        ObjectInputStream is  =  new ObjectInputStream ( s.getInputStream() );
        ObjectOutputStream os  = new ObjectOutputStream (s.getOutputStream());
        String service = (String) is.readObject();
        Skeleton sk = null;
        if ((sk = ns.resolve(service)) != null) {
               sk.init( os, is );
               sk.start(); }
        else System.err.println("Unknown service.");
      } catch(...) {...} ...
     }
   }
```


Name Server Generalized

- Search for the right site providing a desired component (*extended name service*)
- Search for a component with known properties, but unknown name (*trader service*)
  - Like an extended name service
  - Components register with name, reference, and properties
  - Match properties instead of names
  - Return reference (site and service)
  - Needs standardized properties (Terminology, Ontology)
    - Functional properties (domain specific functions …)
    - Non-functional properties (quality of service …)

Summary

- Component systems provide location, language and platform transparency
  - Stub, Skeleton
    - One per component
    - Technique: IDL compiler
  - Adapters on client and server site
    - Generic
    - Technique: Name services
- Is the IDL compiler essential?
  - No! Generic stubs and skeletons are possible, too.
  - Technique: Reflection and dynamic invocation

Reflection & Dynamic Invocation

- Reflection
  - to inspect the interface of an unknown component
  - for automatic / dynamic configuration of server sites
- Dynamic invocation
  - to call the components
- Problem
  - Language incompatibilities (solved)
  - Access to interfaces (open)
- Solution: IDL is already the standard
  - Standardize an IDL run time representation and access
  - Define a IDL for IDL representation and access

Example: Generic Server Skeleton Using Reflection

```
class GenericSkeleton extends Thread {
   static ExtendendHashtable objects = new ExtendedHashtable();
   ObjectOutputStream os;
   ObjectInputStream is;
   …
   public void run() { …
     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
     Object o = objects.getComponent( addr );
                         //object reference by reflective call
     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(); s.close();
   }
```


Services

- Predefined functionality standardized
  - Reusable
- Distinguish
  - Basic
    - Useful (only) with component services
    - Examples discussed: name and trader service
    - Further: multithreading, persistency, transaction, synchronization
  - General (*horizontal services*)
    - Useful (per se) in many domains
    - Examples: Printer and e-mail service
  - Domain specific (*vertical services*)
    - Result of domain analysis
    - Examples: Business objects (components)

Summary: 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)
  - Adapters on client and server site
    - Generic (technique: Name services)
- Economically support: reusable services
  - Basic: name, trader, persistency, transaction, synchronization
  - General: print, e-mail, …
  - Domain specific: business objects, …
- More on these issues in the next lecture: CORBA