E Distributed Objects in CORBA

E.1 Overview

- Motivation
- Architectural Overview
- Application Objects
- Object Request Broker
- CORBA Services

E.2 References

OMG98. Object Management Group, OMG: *The Common Object Request Broker: Architecture and Specification*. Rev. 2.2, OMG Doc. formal/98-02-01, Feb. 1998.

Pope98. A. Pope: *The CORBA Reference Guide*. Addison-Wesley. 1998.

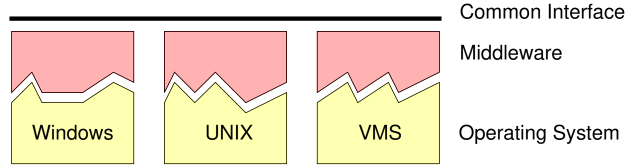
Linn98. C. Linnhoff-Popien: *CORBA, Kommunikation und Management*. Springer, 1998.

E.3 Motivation

- Location
  - Transparency of location
- Heterogeneity
  - Different hardware,
  - different operating systems, and
  - different programming languages are used in distributed systems.
  - Transparency of heterogeneity
- Services
  - Name server
  - Time server
  - ...

1 Middleware Approach

- Middleware: a piece of software between operating system and application



  - Middleware provides services for distributed programming
- **We need:** middleware for distributed object-based programming

★ CORBA – Common Object Request Broker Architecture, a standard of the OMG

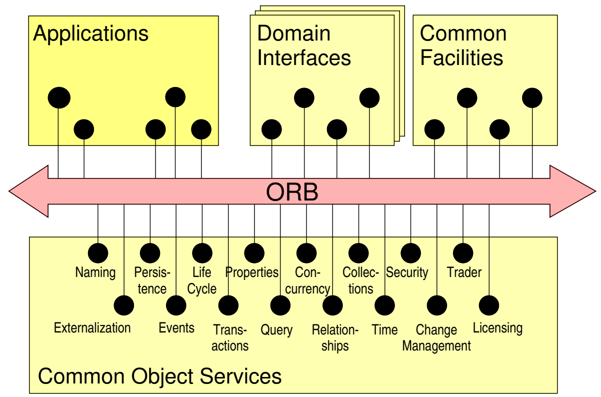
2 CORBA Design Goals

- CORBA is a standard
  - There are standard documents
  - Definition of CORBA compliance
  - Vendors build implementations of the standard (e.g., VisiBroker, Orbix, Orbacus, MICO, etc.)
- CORBA builds abstractions from
  - hardware,
  - operating system, and
  - programming language.

2 CORBA Design Goals (2)

- Interoperability
  - An application shall run on different CORBA implementations without major changes
  - Applications on different CORBA implementations shall be able to communicate
- Embedding of legacy applications
  - Legacy applications can be encapsulated and can act as CORBA objects
- Vision of business objects or components
  - CORBA objects represent all kinds of business data in a company
  - By communicating to these objects business data can be manipulated

E.4 Architectural Overview



- Object Management Architecture – OMA

1 OMA – Object Management Architecture

- Application objects
  - Centralized-object approach for distributed objects
  - Client/server architecture
- Object Request Broker (ORB)
  - Communication backbone
  - Enables objects to communicate
- CORBA Services
  - Basic services for distributed programming
  - Extends the ORB's functionality
  - Services look like objects

1 OMA – Object Management Architecture (2)

- CORBA Facilities
  - Application-specific services
  - Usable in multiple application domains
  - e.g., Compound Document Services, Graphical User Interface
- CORBA Domains
  - Application-specific services for a particular domain
  - e.g., CORBA Med

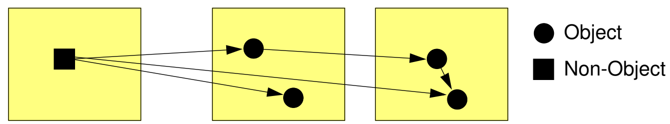
2 CORBA Implementations

- A CORBA implementation must contain
  - the implementation of the core architecture
  - one language mapping (e.g., for C++)
- A CORBA implementation may contain
  - an arbitrary number of services
  - functionality for interoperability with other CORBA implementations (GIOP/IIOP)
- The implementation is free **how** it realizes the requirements of the standard
  - Many different implementations are possible
    - Daemon-based
    - Library-based
    - ...

E.5 Application Objects

1 Distributed Object

- Identity
- State
- Operations (methods)
- CORBA objects can be invoked (implement server side)
- CORBA objects may act as clients



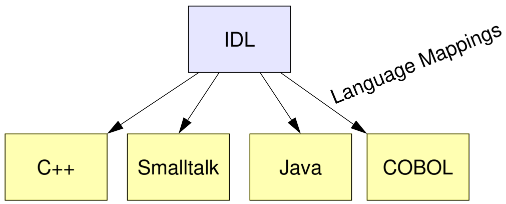
- Clients do not need to be CORBA objects
  - CORBA clients can be processes, etc.

2 Distributed Object (2)

- Distributed objects form an application
  - Objects cooperate by communicating with each other
- ★ Example: printer management system
  - Client objects
  - Spooler objects
  - Printer objects
- "Centralized object approach"
  - Client-side stub can contact the server object
  - RPC-based method invocation
  - **At-most-once** / **exactly-once** semantics

3 Interface Definition Language (IDL)

- Language for describing object interfaces
  - Independent of implementation language of an object
  - Language mapping defines how IDL primitives are mapped to the concepts of a specific programming language
  - Language mapping is part of the CORBA standard
  - Language mappings exist for C, C++, Smalltalk, COBOL, Ada, and Java
  - IDL is similar to C++



3 Interface Definition Language (2)

- Example

```
module MyModule
{
    interface MyInterface
    {
        attribute long lines;
        void printLine( in string toPrint );
    };
```

IDL to C++

```
namespace MyModule {
    class MyInterface : ... {
        public:
         virtual CORBA::Long lines();
         virtual void lines( CORBA::Long _val );
         void printLine( const char *toPrint );
        ...
    };
```


3 Interface Definition Language (3)

- Example

```
module MyModule
{
    interface MyInterface
    {
        attribute long lines;
        void printLine( in string toPrint );
    };
```

IDL to Java

```
package MyModule;
public interface MyInterface extends ... {
    public int lines();
    public void lines( int lines );
    public void printLine(java.lang.String toPrint );
    ...
};
```

```
nam
    ...
};
```


3 Interface Definition Language (4)

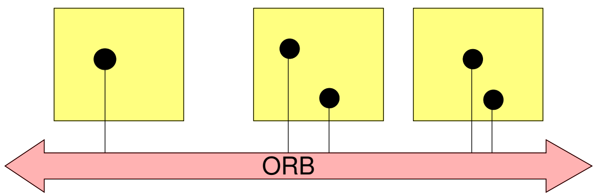
★ Advantages
  - Transparency of implementation language
  - Enables interoperability

▲ Disadvantages
  - Object interface must be defined in the target language **and** in IDL
  - IDL is quite expressive
    - Language that do not provide the right mechanisms will have a complex language mapping (e.g., sequences)
  - If a language has special features they cannot be used because they are not part of IDL

4 Process of Creation and Binding

- Creation of a server object
  - ◆ Description of the object interface in IDL
  - ◆ Programming the server object in an implementation language
  - ◆ Registration of the object at the ORB (the OA respectively)
    - The ORB creates an Interoperable Object Reference (IOR)
- Binding to the server object at client side
  - ◆ Retrieval of an object reference to the server
    - Result of a name-server query
    - Return parameter of a method call
    - Retrieval from outside of the system: user knows the reference as a string (IORs can be converted to strings and back)
  - ◆ Creation of the client stub
  - ◆ Method invocations using the stub object

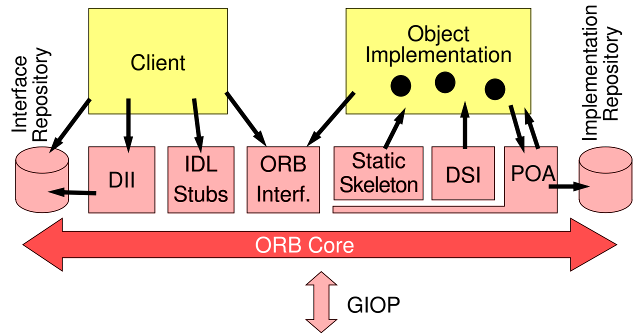
E.6 Object Request Broker – ORB



- The ORB is the communication backbone of a CORBA implementation
- All communication is handled by the ORB
  - ◆ ... within an address space / process
  - ◆ ... between address spaces / processes
  - ◆ ... between address spaces / processes of different ORBs
- The ORB implements location transparency

1 Architecture

- Central components of an ORB

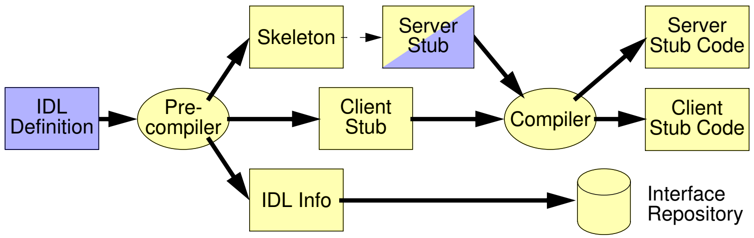


2 Static Stubs

- Stubs on client and server side
  - ◆ As soon as we exactly know the interface of an object, we can create static stubs from it.
  - ◆ Static stubs are automatically created from the IDL description
  - ◆ Server side stubs are called *skeletons*
    - CORBA skeletons have to be filled with the actual implementation
- Tasks of the stubs
  - ◆ Marshalling of parameters
  - ◆ Send and receive of request and reply messages using the ORB core

2 Static Stubs (2)

- Stub creation



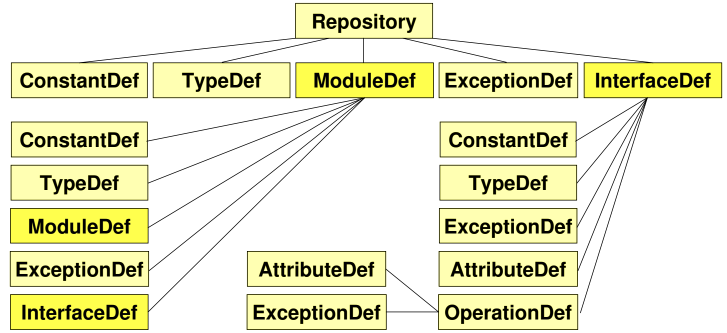
- From IDL, a precompiler generates a number of output files.
- The skeleton contains a frame for filling in the actual methods of the object implementation. The skeleton already contains the server-stub functionality.
- The client-stub file contains the code for the client stub.
- An additional file may contain data for the interface repository.
- Usually the stubs have to be compiled by the target-language compiler.

3 Interface Repository

- Database for interface definitions in IDL
- Query the database for
  - Type checking
    - Does the stub’s type match the object’s type?
    - Inter-ORB operations: insertion into multiple repositories
  - Retrieval of meta data by clients and tools
    - Dynamic invocations
    - Debugging
    - Class browser
  - Implementing method *get_interface* of each object
- Writing to the database using
  - IDL compiler
  - Write methods

3 Interface Repository (2)

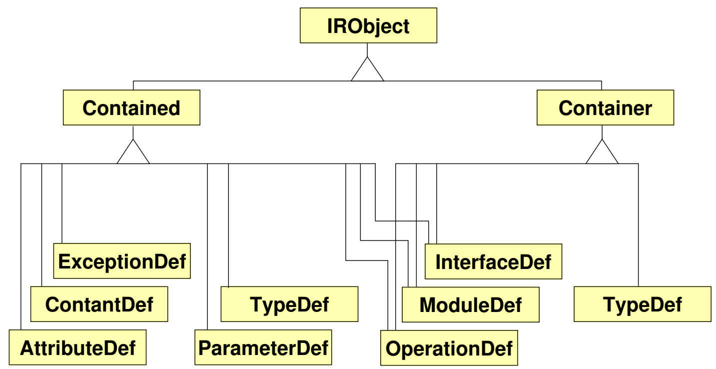
- Stored information / composition of an IDL file



- Hierarchy of the components of an IDL file, and of the interface repository respectively

3 Interface Repository (3)

- Inheritance hierarchy of the IDL interfaces of IR objects



3 Interface Repository (4)

- Standard types are represented by so-called *type codes*

TypeCode

  - Representation of basic types: **int, float, boolean**
  - Representation of composite standard types: **union, struct, enum**
  - Representation of template types and complex declarators: **sequence, string, array**
  - Representation of IDL-based object types (using an interface repository ID)

- Type codes represent type and structure as objects with an standard IDL interface
  - Operation for comparing type codes
  - Operation for obtaining the description of the type

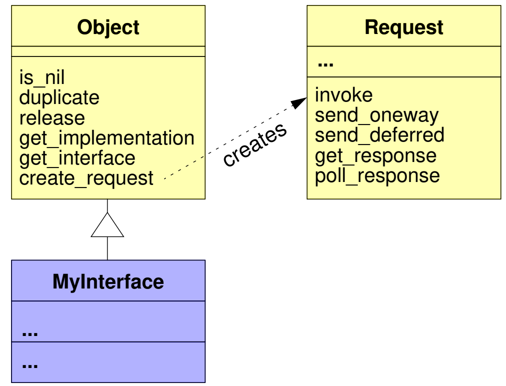
4 Dynamic Invocation Interface (DII)

- DII allows the invocation of methods whose object interface was not known at compile time
  - Interface description can be retrieved using the interface repository

- Single steps of an invocation (which have to be mapped by the language binding)
  - Retrieve signature of the method from the interface repository
  - Create list of parameters
  - Compose request
  - Invoke method
    - – with RPC (synchronous call)
    - – with asynchronous RPC (asynchronous call)
    - – with datagramm message (no reply, no reliability)

4 Dynamic Invocation Interface (2)

- IDL definitions for the DII



5 Dynamic Skeleton Interface (DSI)

- DSI allows a CORBA server to accept method invocations for objects whose interfaces are only dynamically retrievable, e.g., in
  - Bridges to other ORBs
  - CORBA-encapsulated data bases
  - Dynamically created objects and interfaces

- The DSI identifies the object for which the invocation is made for
  - A call-back function is invoked that gets all the necessary information
  - The call-back function has to invoke the corresponding object

★ **Note:**
DII and DSI are not distinguishable from static stubs, i.e., they are fully interoperable with static stubs.

6 Object Adaptor

- The object adaptor is a local representative of ORB services
  - It generates object references (for new objects)
  - It maps object references to implementations
  - It forwards incoming method calls
  - It authenticates the caller (implementing CORBA's security functionality)
  - It activates and deactivates the object and its implementation
  - It registers server classes within the implementation repository
- CORBA defines the mandatory Portable Object Adaptor
  - Basic functionality
- Another example: an OODB Adaptor
  - Connecting an object-oriented data base to CORBA
  - The OODB Adaptor represents all objects in the data base as CORBA objects and mediates invocations

7 Implementation Repository

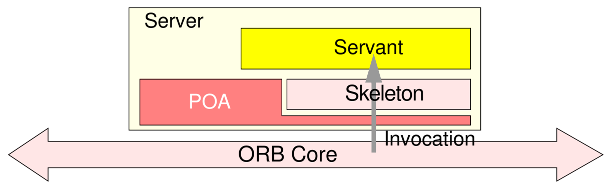
- Data base for object implementations
  - Data to localize and activate object implementations
  - Information for debugging and administration
  - etc.
- Implementation repository is highly implementation dependent.
- Query the data base
  - Implementation of the method *get_implementation* of each object
- Writing the data base by
  - External tools
  - The object adaptor at creation time of an object

8 Inter-ORB Communication

- GIOP – General Inter-ORB Protocol
  - Basic protocol for the interaction of two ORBs
  - Common Data Representation (CDR) converts IDL-compliant parameters into a serial byte stream
  - IIOP – Internet Inter-ORB Protocol
    (GIOP over TCP/IP; implementation is mandatory)
  - Other implementations of GIOP are possible
- ESIOP – Environment Specific Inter-ORB Protocols, e.g., DCE/ESIOP
  - Inter-ORB protocol on the basis of DCE RPC
- IOR – Interoperable Object Reference
  - String representation
  - Several profiles (one of it is IIOP)

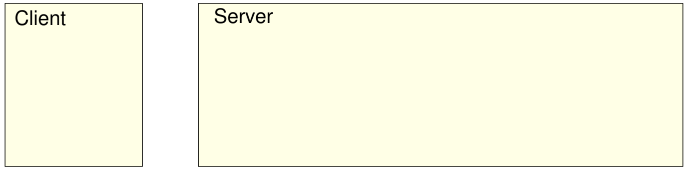
E.7 Portable Object Adaptor (POA)

- Terminology
  - **Server:** Process hosting CORBA objects
  - **Servant:** Language object representing the implementation of a CORBA objec
- Each servant knows one POA instance within a server
  - The object reference includes the identifier of this POA instance
  - The POA creates and identifies ***its*** CORBA objects
  - The POA forwards requests to its objects



1 Creation of an Object

- Application creates an object



1 Creation of an Object

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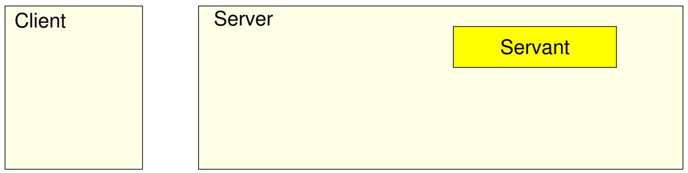
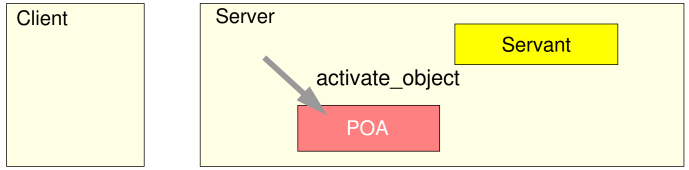


- First, the servant is created

1 Creation of an Object

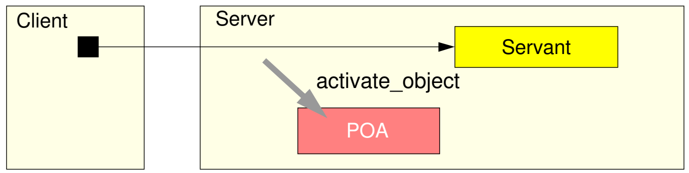
- Application creates an object



- First, the servant is created
- Second, the CORBA object is activated (can now be remotely invoked)

1 Creation of an Object

- Application creates an object



- First, the servant is created
- Second, the CORBA object is activated (can now be remotely invoked)
- Then, the servant can be passed as parameter or returned as a result, which creates a client stub (CORBA object reference) at the receiver side

2 Alternative Activations

- Implicit activation
  - POA automatically creates an object reference if servant reference is passed as parameter or result
- Activation on demand
  - Object references can be created without having an active servant
  - In case of incoming requests some alternatives are possible:
    - A registered default servant handles the request (e.g., for wrapping database objects)
    - A user-supplied servant manager returns a servant (servant manager can create the servant on demand)

3 Deactivation and Activation

- Objects may survive a POA instance: persistent objects
  - Servant can be deactivated
  - POA can be deactivated
  - Server can be shut down
- POA cooperates with a location forwarding service and the implementation repository
  - On deactivation the necessary information for activation is retained in the implementation repository
  - Requests for deactivated servants trigger a forwarding service to launch a new server
  - The server gets the forwarded requests and activates a POA for it
  - The POA activates a servant for the request

4 Policies

- Policies apply to one POA instance
  - There may be many (named) POA instances within a server each with different policies
- Activation method is encoded in such policies
  - Servant retention policy
  - Request processing policy
  - Implicit activation policy
- Other policies
  - Thread policy: multi-threaded or single-threaded
  - ID uniqueness policy: unique IDs or not
  - ID assignment policy: user- or system-provided IDs
  - Object lifespan policy: transient or persistent

E.8 CORBA Services

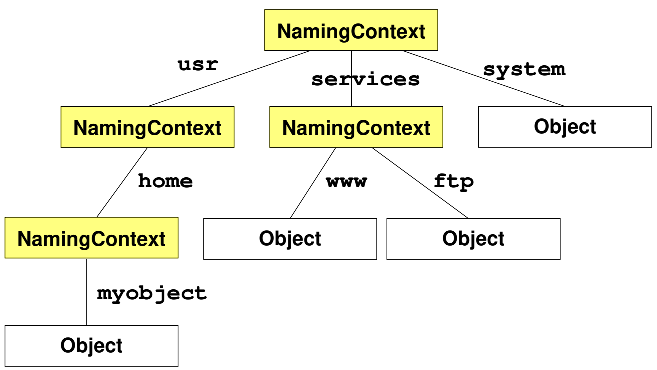
- Basic services of a distributed system as extensions of the ORB
  - Naming service
  - Transaction service
  - Persistent object service
  - Life cycle service
  - etc.
- Services are accessible by IDl interfaces
  - No additional primitives necessary; method invocation is enough

1 Naming Service

- CORBA defines an hierarchical naming service similar to the UNIX file system
  - ◆ Name space forms a tree
  - ◆ Names consist of multiple components (syllables)
    e.g., < "usr"; "home"; "myobject" >
    (UNIX: "/usr/home/myobject")
  - ◆ Interface to the naming service is defined by IDL

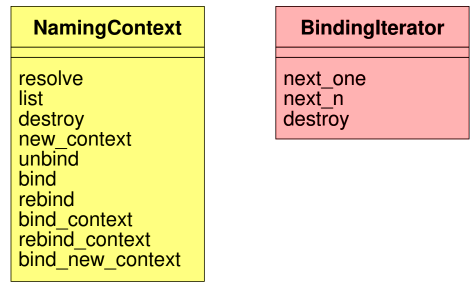
1 Naming Service (2)

- Example of a name tree



1 Naming Service (3)

- Interface of a Naming Context and the Binding Iterator

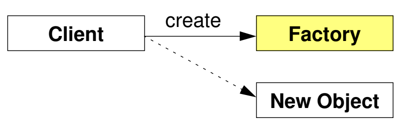


  - ◆ Naming Context acts like a directory
  - ◆ Objects or other contexts can be bound to a name
  - ◆ Listing the context returns an array and an iterator that allows you to look at the next entries

2 Life Cycle Service

- Controls the life cycle of an object
  - ◆ Creation
  - ◆ Copying, Migration
  - ◆ Deletion
- Life Cycle Service defines the common interface for controllable objects

★ Modell des Lebenszyklus
  - ◆ Creation of an Object:

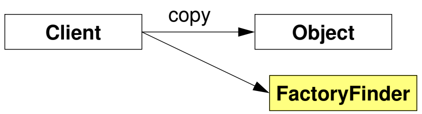


Call of a create method at a factory object

  - • Protocol and interface of the factory is not defined and probably dependent on the kind of object to create

2 Life Cycle Service (2)

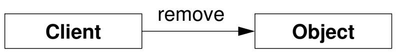
◆ Copying and migration:



FactoryFinder determines the location

- Locations can be a specific computer or a group of computers, etc.

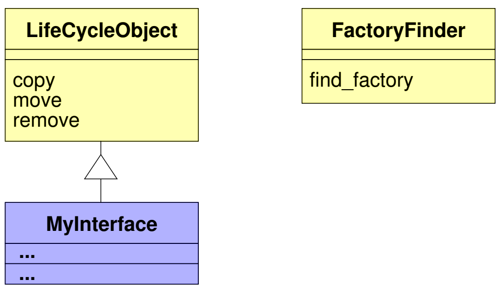
◆ Deletion:



- With the call of remove the object is deleted.

2 Life Cycle Service (3)

■ Objects need to implement the LifeCycleObject interface



◆ copy and move need a FactoryFinder object to find a factory object which in turn will create the copy or migrated object

2 Life Cycle Service (4)

■ Example: implementation of the copy meethod

◆ Client invokes copy method and passes a reference to a FactoryFinder

◆ The copy method is provided by the programmer **or** by the CORBA implementation

◆ The copy methode calls the FactoryFinder and selects a suitable factory that is used to create a new object

◆ The new object will be initialized with the data of the existing object

▲ To the outside: clearly defined interface

▲ To the inside: open and implementation dependent, e.g., protocol between copy method and factory

■ In CORBA 2.0 relationship between objects is considered for copying and mobility: part-of relationship, etc.

◆ Parts of the object are also copied or migrated (deep copy vs. shallow copy)