CORBA

- Distributed Objects
- CORBA: Introduction and Overview
- CORBA Clients
- CORBA Servers
- CORBA Development Issues

- JavaIDL: *see course website*

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Distributed Objects

- Traditional enterprise apps are self-contained, monolithic apps
- Limited access to another's procedures and data
- Apply OO techniques for networked apps
- multi-tiered architecture (separation of concerns)
- 1st, 2nd, 3rd generation systems

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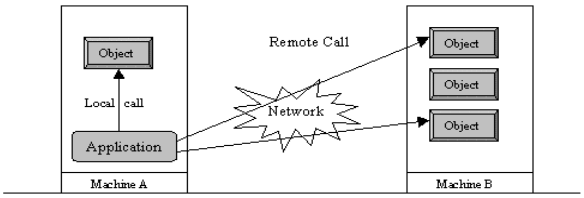
Distributed Objects

- Local vs. Remote objects



- An enterprise app is a collection of co-operating objects located on different machines

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Advantages

- Benefit from OO techniques
- Eliminates protocol design, which is error-prone
- Convenient resource sharing

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Disadvantages

- Design and Impl'n is more complex
- Multiple failure modes
- Security issues
- Use of multiple technologies
- Testing and debugging

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Available Technologies

- Many technologies available:
- Sockets (TCP, UDP) Not OO
- RPC (not OO)

- RMI
- CORBA

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CORBA Introduction

- OMG
- Current state of OMG/CORBA efforts
- Object Model
- Client Server model and issues

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OMG - Object Mgm't Group

- Non-profit consortium of software vendors
- Formed in 1989 by 8 companies
- Has more than 800 members now (?)
- http://www.omg.org
- Goals:
  - Develop specs to provide a common framework for distributed applications development
  - Promote a heterogeneous computing environment

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CORBA

- Stands for: Common Object Request Broker Architecture
- A spec for creating distributed objects
- CORBA is NOT a programming language
- Its architecture is based on the object model
- Promotes design of applications as a set of cooperating objects
- OMG Object Model: object is defined as what the client could see.

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CORBA Objects

- clients are isolated from servers by interface
- CORBA objects vs. typical objects:
  - CORBA objects run on any platform
  - CORBA objects can be located anywhere on the network
  - CORBA objects can be written in any language that has IDL mapping

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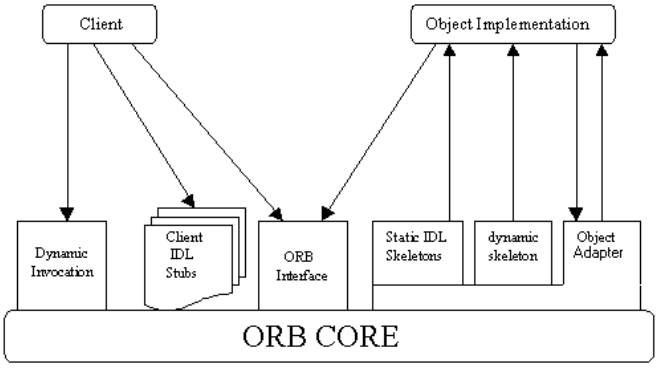
CORBA Architecture

- The structure of CORBA



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ORB

- The software that implements the CORBA specification
- Object bus that provides object location transparency
- Responsible for mechanisms to:
  - Find the object implementation of the request
  - Prepare object implem'n to receive the request
  - Communicate the data making up the request

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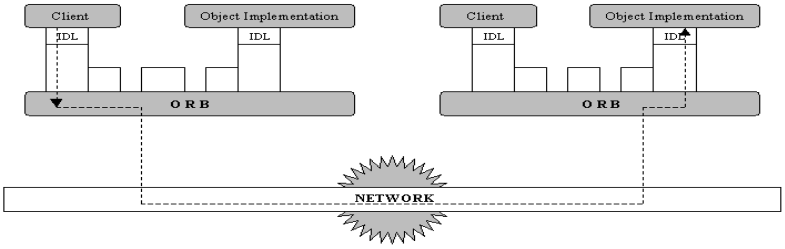
ORB

- Client and object implem'n are isolated from the ORB by an IDL interface
- all requests (local or remote) are managed by the ORB



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ORB

- Corba 1.0: every vendor would implement ORB differently, interoperability problems when communicating across ORBs
- Corba 2.0: specified GIOP, the General Inter-ORB Protocol:
  - collection of message requests ORBs can make over a network
  - GIOP maps ORB requests to different network transports
  - IIOP: Internet Inter-ORB Protocol maps GIOP messages to TCP/IP (mandatory for all ORBs)

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Corba 3

- Released in 2002
- Major upgrades:
  - Java and Internet Integration
  - Quality of Service Control
  - The CORBAcomponent Architecture

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CORBA Services

- Basic services that every object needs
- System level services with well-defined IDL interfaces
- They enhance functionality supported by ORBs

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CORBA Services (Examples)

- **Naming Service**: find an object by name and bind to it
- **Event service**: supports notification of events to interested objects
- **Persistent object service**: provides a common set of interfaces for managing the state of objects
- **Trader service**: an alternative location facility to the naming service, finding objects by attributes in a wide-area network
- **Security service**: restrict access to objects/groups of objects to clients with appropriate privileges

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IDL Basics

- Stands for: Interface Definition Language
- A CORBA object is specified with interface
- interface: contract between client and server
- specified in a special declarative language
- Lexical rules are same as C++ with new keywords
- IDL mapping to programming languages (e.g. C++, Java, etc) are provided in specs

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CORBA IDL Interfaces

- IDL interface provides a description of services available to clients
- IDL interface describes an object with:
  - Attributes
  - Methods with their signatures
  - Exceptions
  - Inheritance information
  - Type and constant definitions

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IDL Structure

```
module <identifier> {
  <type declarations>;
  <constant declarations>;
  <exception declarations;

   <interface definition>;
   <interface definition>;
};
```

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IDL Structure (Modules)

- At the highest level, IDL definitions are packaged into module.
- A module is analogous to a package in Java
- Example:

```
module Bank {
   // body
};
```

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IDL Structure (Interfaces)

- An IDL interface is the definition of an object
- IDL interfaces are analogous to Java interfaces
- An interface declares the operations that the CORBA object supports and its attributes

```
interface Account {
   // attributes
   // operations
};
```

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IDL Structure (Interfaces)

- An interface may inherit from multiple interfaces
- It inherits all attributes and operations of its super-interfaces

```
interface JointSavingsAccount:
  JointAccount, SavingsAccount {
    // attributes
    // operations
};
```

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IDL Structure (Attributes)

- They describe the variables (properties) of an interface
- An attribute can be **`readonly`** or read-write

```
interface Account {
   attribute string name;
   readonly attribute string sin;
   readonly attribute long accountNumber;
};
```

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IDL Structure (Operations)

- They describe the methods of an interface
- They have a return type and parameters
- Parameters are flagged as:
  - **in**: parameter is passed from client to server
  - **out**: parameter is passed from server to client
  - **inout**: parameter is passed in both directions

```
void withdraw(in unsigned long amount);
void add(in long a, in long b, out long sum);
```

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IDL Structure (Exceptions)

- IDL supports user-defined exceptions

```
exception InsufficientFunds {
  long currentBalance;
};

void withdraw(in unsigned long amount)
    raises (InsufficientFunds);
};
```

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IDL Structure (Data Types)

- IDL supports a rich variety of data types
- Primitive:
  float, double, long, short (signed, unsigned), char, long long, boolean, octet
- Complex (discussed later):
  arrays, sequences, structures

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IDL to Java Mapping

IDL	Java
boolean	boolean
octet	byte
char	char
string	String
short	short
long	int
long long	long
float	float
double	double
fixed	BigDecimal

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Object Adapters

- Mediate between CORBA objects and programming language implementations
- Provide a number of services:
  - Creation of CORBA objects and their references
  - Dispatching requests to the appropriate servant that provides implementation for the target object
  - Activation and deactivation of CORBA objects

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Object Adapters

- CORBA 2.0 defines the Basic Object Adapter (BOA)
- ORB vendors discovered that BOA is ambiguous and missing features so they developed proprietary extensions
- This resulted in poor portability between ORBs
- The new standard is: Portable Object Adapter (POA)

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Anatomy of a CORBA-based App

- The steps involved:
  - Define an interface
  - Map IDL to Java (idlj compiler)
  - Implement the interface
  - Write a Server
  - Write a Client
  - Run the application
- Example: a step-by-step *Hello* example

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Step 1: define the interface

- Hello.idl

```
module HelloApp {
  interface Hello {
    string sayHello();
  };
};
```

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Step 2: map Hello.idl to Java

- Use the idlj compiler (J2SE 1.3)

  idlj –fall Hello.idl

- This will generate:

  _HelloImplBase.java (server skeleton)
  HelloStub.java (client stub, or proxy)
  Hello.java
  HelloHelper.java
  HelloHolder.java
  HelloOperations.java

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Step 3: implement the interface

- Implement the servant:

```
import HelloApp.*;
class HelloServant extends _HelloImplBase {
   public String sayHello() {
      return "\nHello There\n";
   }
}
```

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Step 4: implement the server

- Import statements:

```
import org.omg.CosNaming.*;
import org.omg.CosNaming.NamingContextPackage.*;
import org.omg.CORBA.*;

class HelloServer {
   public static void main(String argv[]) {
     try {
```

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Step 4: implement the server….

- Create and initialize the ORB:

```
ORB orb = ORB.init(argv, null);
```

- Create the servant and register it with ORB

```
HelloServant helloRef = new HelloServant();
orb.connect(helloRef);
```

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Step 4: implement the server….

- Get the root NamingContext:

```
org.omg.CORBA.Object objRef =
    orb.resolve_initial_references("NameService");
NamingContext ncRef = NamingContextHelper.narrow(objRef);
```

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Step 4: implement the server….

- Bind the object reference in naming

```
NameComponent nc = new NameComponent("Hello", " ");
NameComponent path[] = {nc};
ncRef.rebind(path, helloRef);
```

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Step 4: implement the server….

- Wait for invocations from clients:

```
java.lang.Object sync = new java.lang.Object();
synchronized(sync) {
    sync.wait();
}
```

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Step 4: implement the server….

- Catch the exceptions

```
    } catch(Exception e) {
        System.err.println("ERROR: " + e);
        e.printStackTrace(System.out);
    } // end catch
  } // end main()
} // end class
```

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Step 5: write a client

- Import statements:

```
import HelloApp.*;
import org.omg.CosNaming.*;
import org.omg.CORBA.*;
class HelloClient {
    public static void main(String argv[]) {
      try {
```

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Step 5: write a client….

- Create and initialize the ORB:

```
ORB orb = ORB.init(argv, null);
```

- Create the root naming context:

```
org.omg.CORBA.Object objRef =
   orb.resolve_initial_references("NameService");
NamingContext ncRef =
  NamingContextHelper.narrow(objRef);
```

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Step 5: implement the client….

- Resolve the object reference in naming:

```
NameComponent nc = new NameComponent("Hello", " ");
NameComponent path[] = {nc};
Hello helloRef = HelloHelper.narrow(ncRef.resolve(path));
```

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Step 5: implement the client….

- Call the object:

```
String Hello = helloRef.sayHello();
System.out.println(Hello);
```

- Catch exception:

```
} catch(Exception e) {
   System.out.println("ERROR : " + e);
   e.printStackTrace(System.out);
} } } // end catch, main, class
```

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Step 6: run the application

- Run the naming service:

  prompt> tnameserver

- Run the server

  prompt> java HelloServer

- Run the client

  prompt> java HelloClient
  Hello There
  prompt>

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CORBA Clients (details)

- Initializing the ORB
- Helper classes
- Holder classes
- Exceptions
- The naming service

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Initializing the ORB

- Before invoking a CORBA object, you must first create an ORB object and initialize it
- public static void main(String argv[]) {
  try { ORB orb = ORB.init(argv, null); // .. }
  }
- Arguments to init():
  ORB init(String[] argv, Properties props)
  - **argv**: a list of command-line arguments to the app.
  - **props**: programmatically specify these options

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Initializing the ORB….

- Command-line arguments (options):
  -ORBClass: that class that provides your ORB implementation (JavaSoft's ORB)
  -ORBSingletonClass: the class that provides your ORB singleton implementation (JavaSoft's ORB)
  -ORBInitialHost: the host where the naming service is running (default value: localhost)
  -ORBInitialPort: the port where the naming service is running. Default value: 900

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Initializing the ORB….

- Properties:

  org.omg.CORBAClass
  org.omg.CORBA.ORBSingletonClass
  org.omg.CORBA.ORBInitialHost
  org.omg.CORBA.ORBInitialPort

- How to use these?

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Initializing the ORB….

- Properties: alternative to command-line args
- Example:

```
Properties props = new Properties();
props.put("org.omg.CORBA.ORBInitialHost", initialHost);
props.put("org.omg.CORBA.ORBInitialPort", initialPort);
String noArgs[] = null;
ORB orb = orb.init(noargs, props);
```

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Helper Classes

- They provide some utility functions (narrow)
- For interface Hello in module HelloApp, a helper class: HelloApp.HelloHelper is created
- Important method:

  Hello narrow(org.omg.CORBA.Object object)
- The naming service returns an Object, you must cast it to narrow it down….use narrow()

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Holder Classes

- Used to implement “out” and “inout” parameters to CORBA operations.
- Why do we need them?

```
void op (inout long x); // alter the value of x
```

- But in Java:

```
int x = 10; op(x); // op is not allowed to change x
```

- However, “out” or “inout” mean that the actual value of the parameter will be changed.

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Holder Classes

- Solution: use holder classes:
- For primitive data types: primitive holders

```
int x = 10;
IntHolder myx;
myx.value = x;
op(myx);
x = myx.value;
```

- BooleanHolder, CharHolder, StringHolder, etc

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Holder Classes

- For user-defined types:

```
Employee employee = …;
EmployeeHolder emp;
emp.value = employee;
op(emp);
employee = emp.value;
```

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Exceptions

- System exceptions

  org.omg.CORBA.SystemException

- User exceptions

  org.omg.CORBA.UserException

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System Exceptions

- Those implicit, unpredictable exceptions that can arise as a result of a CORBA failure
- System exceptions are all implemented as a subclass of org.omg.CORBA.SystemException
- A subclass of java.lang.RuntimeException
- Therefore, any SystemException may be implicitly thrown by a CORBA operation without being declared in a throws clause

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User Exceptions

- Those, explicit, predictable exceptions that are documented in IDL operation declarations.
- Raised by CORBA operations in response to specific situations (e.g. InsufficientFund)
- Implemented as a subclass of org.omg.CORBA.UserException
- A subclass of java.lang.Exception
- Therefore, they must be explicitly handled

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CORBA vs. RMI

- CORBA interfaces defined in IDL, RMI interfaces are defined in Java
- CORBA is language-independent, RMI is not
- CORBA objects are not garbage collected, RMI objects are garbage collected automatically.
- RMI does not support “out” and “inout” operations since local objects are copied, and remote objects passed by reference to stub
- Communication protocols: IIOP vs. RMI

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The Naming Service (Client's View)

- A tree-like directory for object references
- Much like a file system: provides directory structure for files
- Object references are stored by *name*
- Each object reference-name pair is called a *name binding*
- Name bindings may be organized under naming contexts (name binding itself)
- All bindings are stored under initial naming context (the only persistent binding)

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The Naming Service….

- Your client's ORB must know the name and port# of a host running the naming service
- The naming service can either be the JavaIDL naming service or any COS-compliant service (COS: Common Object Services)
- To start: tnameserv –ORBInitialPort port#
  - The default port number is 900
- To stop: use relevant OS command (kill, ctrl-c)
- Namespace is lost if name server halts/restarts

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The Naming Service (interfaces)

- org.omg.CosNaming:
  - **NamingContext**: primary interface to naming service
  - **NameComponent**: identify (name/kind) services
  - **BindingIterator**: iterating through the contents
  - **Binding**: a single entry in the naming service
  - **BindingList**: a list of entries in the naming service
  - **BindingType**: the type of an entry

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Naming Service (*NamingContext*)

- Analogous to a directory on a file system
- Contains a series of named objects
- An object in a NamingContext may be another NamingContext (analogous to subdirectory)
- A reference to the top level NamingContext can be obtained with the ORB method:
  resolve_initial_references()

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Naming Service (*NamingContext*)

- To get a reference to an object stored under NamingContext, use:

  resolve(NameComponent namePath)
- It throws: *NotFound*, *CannotProceed*, *InvalidName*
- This method returns org.omg.CORBA.Object
- Therefore, it must be narrowed to a particular interface using a helper's *narrow()*

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Browsing the Naming Service

- The top level only….

```
import org.omg.CORBA.*;
import org.omg.CosNaming.*;
public class Browser {
  ORB orb = ORB.init (args, null);
  // obtain a reference to the naming service
  org.omg.CORBA.Object nc =
    orb.resolve_initial_references ("NameService");
   NamingContext namingContext =
    NamingContextHelper.narrow (nc);
```

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Browsing the Naming Service….

```
BindingListHolder b1 = new BindingListHolder ();
BindingIteratorHolder b2 = new BindingIteratorHolder ();

// get initial content-list (retrieve up to 10, rest can be accessed
// by iterator)
namingContext.list (10, b1, b2);
// print out bindings
Binding[] bindings = b1.value;
if(bindings.length == 0) return;
```

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Browsing the Naming Service….

```
for (int i = 0; i < bindings.length; i++) {
  Binding binding = bindings[i];
  NameComponent[] name = binding.binding_name;
  BindingType type = binding.binding_type;
  if (type == BindingType.nobject) {
     System.out.println (name[0].id + "-" + name[0].kind);
  } else { // BindingType.ncontext
   System.out.println (name[0].id + "-" + name[0].kind + "/");
  }
 }
```

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CORBA Servers

- Implement the IDL interfaces by subclassing the appropriate pre-generated skeleton class
- Each class is called a *servant*
- The HelloServer Example
  - Initialize the ORB
  - Create initial objects (servants)
  - Connect each servant to the ORB
  - Bind the servants in the naming service
  - Wait for connections

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CORBA Servers (ObjectImpl)

- When a servant extends the _interfaceObjectImpl, it is actually extending the orb.omg.CORBA.Portable.ObjectImpl class
- This class provides a variety of helper methods (including all methods of CORBA Object)

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Naming Service (Server's View)

- Registering/Unregistering services:
  - **bind**: register the object under the specified name
  - **rebind**: identical to bind(), but an **AlreadyBound** exception won't be thrown – existing object replaced
  - **unbind**: unregister a CORBA object
- Creating new naming contexts:
  - **bind_new_context, new_context, bind_context**
- Destroying a naming context:
  - **destroy**: destroy an empty **NamingContext**

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Clearing the Naming Service

- Steps:
  - Get a reference to initial naming context
  - Recursively iterate through the sub naming contexts
  - Call unbind
  - Call destroy

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Advanced IDL

- IDL supports C/C++ style comments:
  // This is a comment
  /* This is another comment */
- Also, it supports:
  - conditionals (#if)
  - defines (#define)
  - includes (#include)
- idlj requires access to a C preprocessor (cpp)

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Advanced IDL: Arrays

- IDL provides multidimensional fixed-size arrays
- The array size is fixed at compile time
- IDL arrays map directly into Java arrays
- Example:

```
interface Customer {
  attribute string address[4]; // 1-D array
  attribute short table[5][7];   // 2-D array
}
```

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Advanced IDL: Sequences

- A sequence is a 1-D array that can be of variable size
- Two types:
  - Bounded sequences

```
sequence<long, 15>employee;
```

  - Unbounded sequences

```
sequence<long> employee;
```

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Advanced IDL: Enumerations

- The *enum* data type defines an enumeration
  - A user-defined data type that can hold one of a fixed set of values
- Example:

```
enum CreditCard { visa, amex, discover };
interface Bank {
    void applyForCreditCard(CreditCard cc);
};
```

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Enumerations (mapping to Java)

- An enum is mapped to a Java class with static variables representing the set of values
- Example:

```
// IDL
    enum EnumType {first, second, third};
// generated Java
    public class EnumType
    implements org.omg.CORBA.portable.IDLEntity {
        public static final int _first = 0;
        public static final EnumType first = new EnumType(_first);
        public static final int _second = 1;
        public static final EnumType second = new EnumType(_second);
        public static final int _third = 2;
        public static final EnumType third = new EnumType(_third);
        public int value() {...}
        public static EnumType from_int(int value) {...};
        // constructor
        protected EnumType(int) {...}
    };
```

- **To compare (using switch): (unknown.value() == _first)**

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Advanced IDL: Structures

- The IDL type *struct* defines a structure
- Use a struct to group related data together
- Example:

```
struct Name {
    string firstName;
    string lastName;
};
interface Customer { attribute Name name; };
```

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Structures (mapping to Java)

- A struct is mapped to a Java class that provides instance variables for the fields, and a constructor for all values, and a null constructor
- Example:

```
public class Name {
    public String firstName;
    public String lastname;
    public Name();
    public Name(String firstName, String lastName);
}
```

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Advanced IDL: typedefs

- A typedef is an alias, or another name for an existing data type
- Example:

```
typedef long age;
interface Customer {
   age howOld;
}
```

- Typedefs of simple data types are mapped to the original (I.e. replaced by the more basic type)

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Advanced IDL: Constants

- **1. Within an interface**:
  interface Foo { const long aLong = -32; };
- Mapped to: public interface Foo {
  public static final int aLong = (int) –32L; };
- **2. Not within an interface**:
  const string Message="hello";
- Mapped to: public interface Message {
  public static final String Message="hello"; };

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Advanced CORBA Topics

- The Tie Mechanism
- Dynamic Invocation Interface (DII)
- Dynamic Skeleton Interface (DSI)
- Interface Repository (IR)

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The Tie Mechanism

- All CORBA-based server programs we have seen so far extend a CORBA skeleton (ImplBase class) generated by the idlj compiler
- Since Java doesn't support multiple inheritance, we cannot inherit from a CORBA skeleton and another class
- Inheriting from a CORBA skeleton is not appropriate/uses up your one inheritance chance
- The tie mechanism offers an alternative to inheritance

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How to use the tie mechanism?

- Implementation inheritance (Hello example)
  - HelloServant inherits its entire implementation from another class
  - Method requests for HelloServant are delegated to another idlj-generated class

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Programming Example (Hello)

- Compile the IDL interface (Hello.idl) with the command: idlj –fall –tie Hello.idl
- This will generate two additional classes in the HelloApp directory
  1. _HelloOperations.java (the servant implements this interface)
  2. _HelloTie.java (acts as a skeleton, receiving requests from the ORB and delegating them to the servant that does the actual work

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HelloBasic

- A new class: HelloBasic.java

```
public class HelloBasic {
   public String sayHello() {
      return “Hello World\n”;
   }
}
```

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HelloServant

- HelloServant.java

```
class HelloServant extends HelloBasic implements
   _HelloOperations {
}
```

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HelloServer

- HelloServer.java

```
class HelloServer {
   public static void main(String argv[]) {
      // create and initialize ORB
      …
      // Create servant and register it with ORB
      HelloServant servant = new HelloServant();
      Hello helloRef = new _HelloTie(servant);
      // connect ….etc
}
```

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The Tie Mechanism vs. Inheritance

- Inheritance is easier as implementation objects look like normal object references
- If object implementations are in the same process as the client then method invocations are cheaper (because no delegation)

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Dynamic Invocation Interface (DII)

- IDL interfaces used by a client are determined when the client is compiled
- Therefore, the developer is limited to using servers that contain objects that implement those interfaces
- This is not enough if an application (e.g. a distributed debugger) requires the use of interfaces that are not defined at the time the application was developed

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DII

- The solution is provided by CORBA's DII
- DII allows an application to invoke operations from any interface (clients use the IR to learn about unknown object interfaces).
- Static operation requests are more efficient but DII is good for:
  - Clients issue requests for any operation (which may not be known as compile time)
  - Client operations don't need to be recompiled in order to access newly activated object implmnt's

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Dynamic Skeleton Interface (DSI)

- DSI provides a way to deliver requests from an ORB to an object implementation without any compile-time knowledge of the objects it is implementing
- DSI is analogous to DII:
  - DII is for the client-side
  - DSI is for the server-side

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Interface Repository (IR)

- IR is like a database that contains data that describes CORBA interfaces or types
- The data in the IR is equivalent to that in an IDL file except that data in the IR is represented in a such a way that makes it easier for clients to use
- Clients use the IR to learn about unknown object interfaces and they use DII to invoke methods on that object

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