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Distributed applications based on RPC

How to implement distributed applications based on remote procedure calls?

Distributed application

In order to isolate the communication idiosyncrasy of RPCs and to make the network interfaces transparent to the application programmer, so-called ***stubs*** are introduced.

Stubs

Stub functionality

Implementing a distributed application

RPC language

Phases of RPC based distributed applications

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Phases of RPC based distributed applications

We distinguish between 3 phases:

a) design and implementation

b) binding of components

c) invocation: a client invoking a server operation.

Component binding

Mediation and brokering

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Mediation and brokering

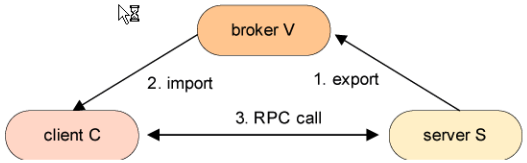
Possible terms for a mediation component are: registry, broker or trader; Corba uses the term object request broker.

Functionality of a broker

servers register their available service interfaces with the broker ("export interface").

the broker supplies the client with information in order to localize a suitable server and to determine the correct service interface ("import interface").

Client-to-server binding



Broker information

Handling client requests

Broker may either just provide the service interface to the client or act as a mediator between client and server.

direct communication between C and S.

indirect communication between C and S; communication between C and S is only possible via broker V (or several brokers).

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Broker information

A broker manages information about the available, exported interfaces.

server names ("white pages")

service types ("yellow pages")

behavioral or functional attributes

static attributes: functionality of the provided services, cost, required bandwidth.

dynamic attributes: current server state.

Phases of RPC based distributed applications

We distinguish between 3 phases:

a) design and implementation

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Component binding

Mediation and brokering

Definitions

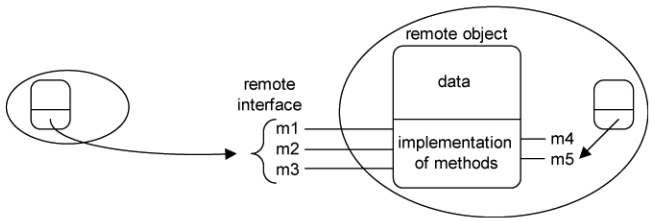
Definition: Remote object is an object whose method can be called by an object residing on another Java Virtual Machine (JVM), even on another computer.

Definition: Remote interface

is a Java interface specifying the methods of a remote object.

Definition: Remote method invocation (RMI) allows object-to-object communication between different Java Virtual Machines (JVM), i.e. it is the action of invoking a method of a remote interface on a remote object.

The method calls for local and remote objects have the same syntax.



Remote Method Invocation (RMI)

RMI supports communication among objects residing on different Java virtual machines (JVM). RMI is an RPC of the object-oriented Java environment.

Definitions

RMI characteristics

RMI architecture

Locating remote objects

Developing RMI applications

Parameter Passing in RMI

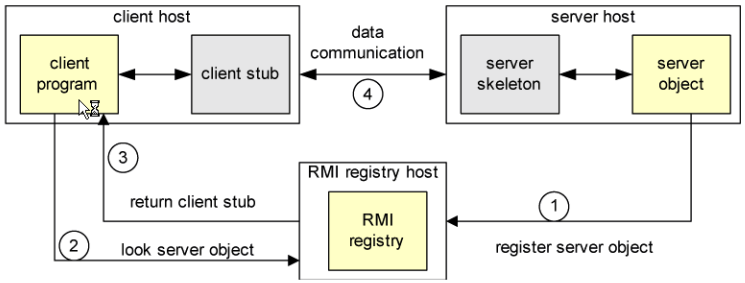
Distributed garbage collection

How does RMI work

Java RMI uses

a registry to provide naming services for remote objects,

stub and skeleton to facilitate communications between client and server.

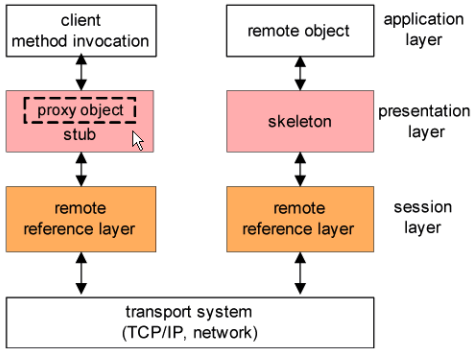


RMI works as follows

1. a server object is registered with the RMI registry
2. a client looks through the RMI registry for the remote object
3. once the remote object is located, its stub is returned to the client
4. the remote object can be used in the same way as a local object

communication between client and server is handled by stubs and skeletons.

RMI architecture



Stub/Skeleton layer

Layer intercepts method calls by the client and redirects these calls to the remote object.

Object serialization/deserialization; hidden from the application.

Remote Reference layer

Connects client and remote objects exported by the server environment by a 1-to-1 connection link.

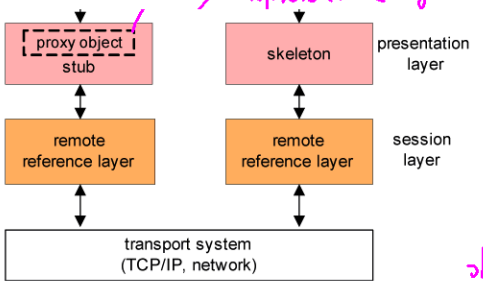
The layer provides JRMP (Java Remote Method Protocol) via TCP/IP.

Mapping of stub/skeleton operations to the transport protocol of the host; it interfaces the application code with the network communication.

The layer supports the method `invoke` .

RMI architecture

representative of remote object



stub realizes remote server object method interface

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```
Object invoke (Remote obj, java.lang.reflect.Method method, Object
[ ] params, long opnum) throws Exception
```

RMI architecture

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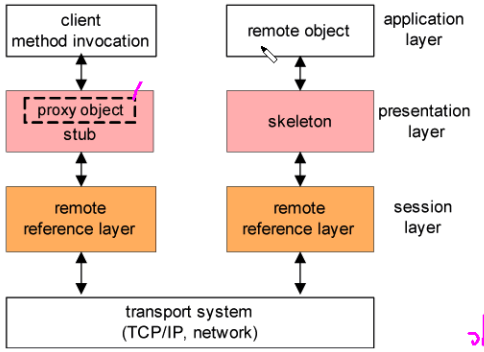

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hash code of method signature

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Remote Method Invocation (RMI)

RMI supports communication among objects residing on different Java virtual machines (JVM). RMI is an RPC of the object-oriented Java environment.

Naming interface methods

public static void `bind (String name, Remote obj)`

Throws AlreadyBoundException, java.net.MalformedURLException, RemoteException.

associates the remote object obj with name (in URL format).

example for name: rmi: //host[:service-port]/service-name

if name is already bound to an object, then AlreadyBoundException is triggered.

public static void `rebind (String name, Remote obj)`

Throws java.net.MalformatURLException, RemoteException.

associates always the remote object obj with name (in URL format).

public static `Remote lookup (String name)`

Throws NotBoundException, java.out.MalformedURLException, RemoteException.

returns as a result a reference (a stub) to the remote object.

if name is not bound to an object, then NotBoundException is triggered.

public static void `unbind (String name)`

Throws NotBoundException, RemoteException.

public static `String [ ] list (string name)`

Throws java.net.MalformedURLException, RemoteException.

Naming interface methods

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public static void `unbind (String name)`

Throws NotBoundException, RemoteException.

public static `String [ ] list (string name)`

Throws java.net.MalformedURLException, RemoteException.

as a result, it returns all names entered in the registry.

Registry-Lookup

The client invokes a lookup for a particular URL, the name of the service (rmi://host:port/service). The following describes the steps:

1) a socket connection is opened with the host on the specified port.

2) a stub to the remote registry is returned.

3) the method Registry.lookup() on this stub is performed. The method returns a stub for the remote object.

4) the client interacts with the remote object through its stub.

Remote Method Invocation (RMI)

RMI supports communication among objects residing on different Java virtual machines (JVM). RMI is an RPC of the object-oriented Java environment.

1 Defining a remote interface

A remote interface is the set of methods that can be invoked remotely by a client.

- The remote interface must be declared public.
- The remote interface must extend the `java.rmi.Remote` interface.
- Each method must throw the `java.rmi.RemoteException` exception.
- If the remote methods have any remote objects as parameters or return types, they must be interfaces rather than implementation classes.
- **Example: remote interface definition**

```
public interface HelloInterface extends java.rmi.Remote {
    /* this method is called by remote clients and it is implemented by
    the remote object */
    public String sayHello ( ) throws java.rmi.RemoteException
}
```


2 Implementing the remote interface

Definition of an implementation class that defines the methods of the remote interface;

the abstract class `java.rmi.server.RemoteServer` provides the basic semantics to support remote references.

`java.rmi.server.RemoteServer` has subclasses

`java.rmi.server.UnicastRemoteObject` : defines a non-replicated remote object whose references are valid only while the server process is alive.

`java.rmi.activation.Activatable` : defines a remote object which can be instantiated on demand (if it has not been started already).

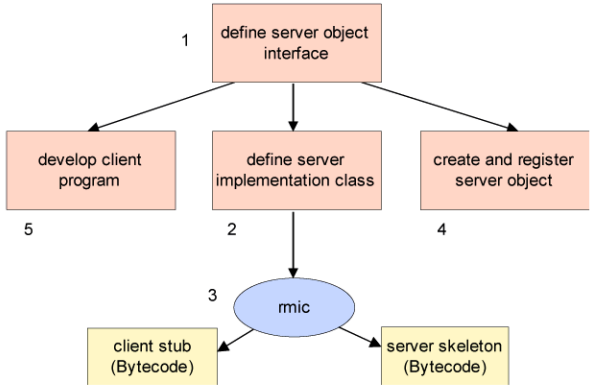
- **Example: Remote interface implementation**

```
import java.io.*;
import java.rmi.* ;
import java.rmi.server.* ;
import java.util.Date.* ;
public class HelloServer extends UnicastRemoteObject implements
HelloInterface{
    public HelloServer( ) throws RemoteException {
       super( );
       /* call superclass constructor to export this object */
    }
    public String sayHello( ) throws RemoteException {
       return "Hello World, the current system time is " + new Date( );
```

3 Generating stubs and skeletons

The tool rmic generates stub and skeleton from the implemented class (up to Java version 5).

```
rmic HelloServer
```



4 Remote object registration

Every remotely accessible object must be registered in a registry in order to make it available;

stubs are needed for registration.

the registry is started at the host of the remote object.

- **Example for object registration**

```
import java.rmi.* ;

public class RegisterIt {

    public static void main (String args [])
        try { // Instantiate the object
           HelloServer obj = new HelloServer( );
           System.out.println ("Object instantiated: " + obj);
           Naming.rebind("/HelloServer", obj);
           System.out.println("HelloServer bound in registry");
        } catch (Exception e) {
           System.out.println(e)
        }
    }

}
```


5 Client implementation

This step encompasses the writing of the client that uses remote objects.

The client must incorporate a registry lookup in order to obtain a reference to the remote object.

The client interacts with the remote interface, ***never*** with the object implementation.

- **Example: Client implementation**

```
import java.rmi.*;
public class HelloClient {
    public static void main (String args [ ]) {
        if (System.getSecurityManager( ) == null)
        System.setSecurityManager (new RMISecurityManager( ) );
        try { String name = "//" + args [0] + "/HelloServer";
            HelloInterface obj = (HelloInterface) Naming.lookup (name);
            String message = obj.sayHello( );
            System.out.println(message);

        } catch (Exception e) {
           System.out.println("HelloClient exception: " + e);
        }
    }
}
```

Missing access rights results in the exception:

Developing RMI applications

The steps developing an RMI application differs slightly from the development steps of a traditional RPC application.

1. Defining a remote interface
2. Implementing the remote interface
3. Generating stubs and skeletons
4. Remote object registration
5. Client implementation

At the end the client must be started.

Parameter Passing in RMI

Parameters with primitive data types are passed with their values between JVMs; for object parameters, a distinction is made between local and remote:

1. local object parameter

   RMI passes the object itself, rather than the object reference.

   The transmitted object must implement the interface `java.io.Serializable` or `java.io.Externalizable`.

   Classes requiring special handling must implement

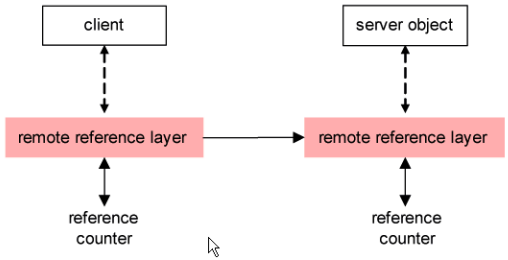
```
private void writeObject(java.io.ObjectOutputStreamout) throws
IOException;

private void readObject(java.io.ObjectInputStreamin) throws
IOException, ClassNotFoundException;
```

2. remote object parameter

   RMI transmits the stub of the remote object; the stub is a reference to the remote object.

Utilization of life references for each JVM; reference counter represents the number of life references.



The first client access creates a referenced message sent to the server.

If there is no valid client reference, then an unreferenced message is sent to the server.

Time limit of references ("lease time", e.g. 10 minutes); the connection to the server must be renewed by the client, otherwise the reference becomes invalid.