

# **Remote Method Invocation (RMI)**

# Introduction to RMI

- **Overall goals**
  - Distribute tasks across the network
  - Greater scalability and availability
  - Transparent programming model
  - Interoperability with existing technologies
- **Java is great fit for distributed computing**
  - Platform neutral
  - Flexible security model
  - Designed with network in mind

# Overview

- **We want to make method calls to an object on a remote system. To do this:**
  - **Create an interface with the needed methods**
  - **Write a class implementing the interface**
  - **Perform a few steps to set up glue**
  - **Make a connection**
  - **Interact with the remote object as if it were local**

# What Do We Need?

- **Objects accessible across the network**
  - Encapsulation - achieved using interfaces
  - Marshaling of parameters across the network
    - Simple types
    - Complex objects
    - Remote interfaces
  - Way to obtain object's interface
  - Ability to advertise object's interfaces
  - Runtime management

# Passing Parameters in RMI

- Simple types are passed as is
- Objects are serialized across the network and reference on client side has nothing to do with server side
- For remote objects stubs are created on client side
- Non-serializable and non-remote objects can't be passed as parameters in RMI

# RMI Basic Elements

- Remote object
  - Implementation of remote methods
  - Dealing with threads (not thread safe)
- Registry
  - Naming
    - Urls are used for remote objects ( `rmi://` )
  - Locating
    - Must dispatch URL to a correct server
  - Registering
    - Server objects advertise their availability

# RMI Server

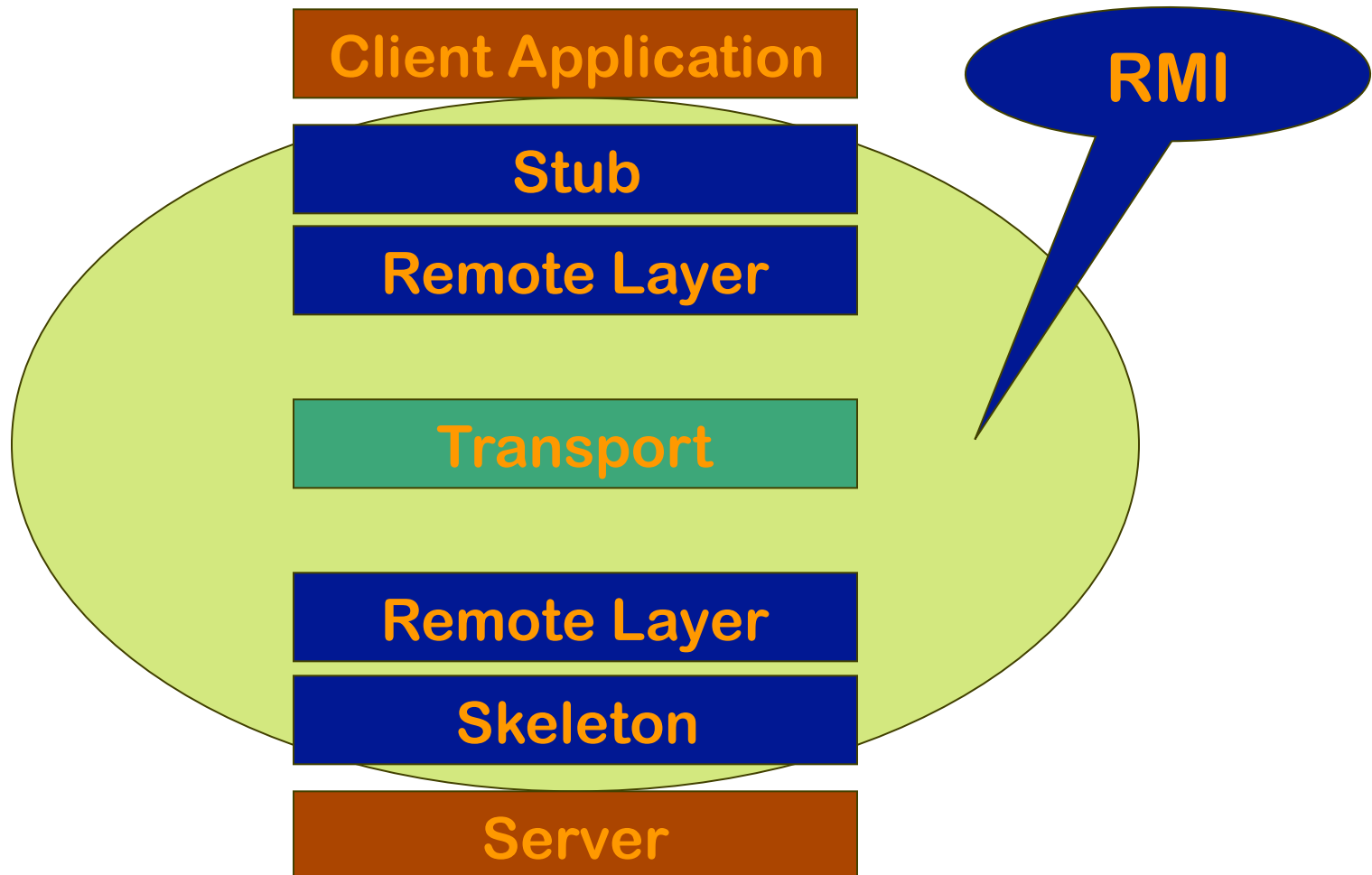
- Lifetime management
- Garbage collection
- Resource pooling
  - Reuse connections
- Thread management
  - All requests are free threaded

# RMI Server

- **Transport**
  - Good abstraction - socket factory
- **Marshaling**
  - Serialization



# RMI Layers



# Remote Method Invocation

- Remote Object
  - Implements `java.rmi.Remote` interface
  - Only remote methods can be accessed by a client
  - Can implement more than one remote interface
  - Never accessed directly by a client, stub is used instead
  - Made available (exported) by server
  - Advertised using registry

# Basic Algorithm

- **Server**
  - Create `RMISecurityManager` (optional)
  - Initialize remote object
  - Advertise this object
    - Prepare to accept connections
    - Associate URL with this object
- **Client**
  - Locate the object
  - Get a reference for this object's stub
  - Call remote method

# Extending Remote Interface

- **Interface and implementation object**

```
public interface Basket extends Remote
{
    int add(String sFruit, int c)
        throws RemoteException;

    void remove(String sFruit, int c)
        throws RemoteException;

    void hangOnTree(String sTree);
}
```

**Each remote method must be declared to throw RemoteException**

# Implementing the Remote Object

```
public interface Basket extends Remote
{
    int add(String fruit, int c)
    throws RemoteException, BasketException;

    void remove(String fruit, int c)
    throws RemoteException;
}
```

- **add() and remove() are remote methods**

# Implementing Remote Object

```
public class BasketImpl extends UnicastRemoteObject
                           implements Basket {
    public BasketImpl()
        throws RemoteException
    { ... }

    public int add( String fruit, int c )
        throws RemoteException, BasketException
    { ... }

    public int remove( String fruit, int c )
        throws RemoteException
    { ... }

    public void hangOnTree(String tree) {
        // local methods are legal
    }
}
```

# Obtaining a Registry

- **Server locates an existing registry, or creates one in process**
  - Default registry port is 1099

- **Locating a registry**

```
Registry reg = LocateRegistry.getRegistry(host,1099);
```

- **Creating a registry**

```
Registry reg = LocateRegistry.createRegistry(1099);
```

# Binding the Remote Object

```
public static void main( String args[] ) {  
    String SERVER_NAME = "BasketServer";  
    System.setSecurityManager(new RMISecurityManager());  
    try {  
        BasketImpl server = new BasketImpl();  
        Registry reg = LocateRegistry.createRegistry(1099);  
        reg.rebind(SERVER_NAME, server );  
    }  
    catch( Exception ex ) {  
        System.out.println( ex.getMessage() );  
        ex.printStackTrace();  
    }  
}
```



# RemoteException

- Extends from IOException
- Wraps other exceptions that happen inside your method (even your subclass)
- Base class for all remote exceptions

# Getting a Remote Object

- **Client looks up remote object**

```
String host = "localhost";  
String url = "://" + host + "/" + SERVER_NAME;  
Basket server = (Basket)Naming.lookup(url);
```

- **Once connected other Remote objects can be passed as arguments**

# exportObject

- `UnicastRemoteObject.exportObject(...)`
  - **When a remote object cannot subclass `UnicastRemoteObject`**
  - **Implement a `Remote` interface**
  - **Call `UnicastRemoteObject.exportObject(...)`**
  - **Allows passing as a remote object**

**Let's take a break!**

# RMI Cookbook

- **Write a Remote interface**
  - Derive from `java.rmi.Remote`
  - All methods throw `java.rmi.RemoteException`
- **Write a remote server**
  - Derive from `UnicastRemoteObject`
  - Implement Remote interface

# **RMI Cookbook II**

- **Write Code to Register the Server**
- **Write the client**
  - **Lookup server**
  - **Cast as remote interface**
- **Start the server**
- **Start the client**

# RMI Security

- Client may load classes from server
- Server may load classes from client
- Start command.

```
java -Djava.rmi.server.codebase=http://host/classes/  
-Djava.security.policy=net.policy ClassToRun
```

- codebase - where this client/server loads its code from
- policy - specifies the policy file containing the permissions granted to code bases

# Policy Files

- Allow socket connections
- Allow access to codebase

```
grant {  
    permission java.net.SocketPermission  
        "*:1025-65535", "connect,accept";  
    permission java.net.SocketPermission  
        "*:80", "connect";  
    permission java.io.FilePermission  
        "d:\\classes\\", "read";  
};
```



# RMI Callback

- Remote objects can be passed as parameters
- Allows the server to make calls on the client
- Objects which are passed do not have to bind to a name server

# RMI Magic

- RMI server creates an instance object
- `UnicastRemoteObject`'s constructor exports the object
  - Makes object available to service incoming RMI calls
  - Binds to an arbitrary TCP socket
  - Creates thread which listens for incoming requests

# RMI Magic

- Server registers object with the registry
  - Gives registry the stub for that object
  - Contains information needed to locate object on server
    - *Hostname*
    - *Port*
- A client obtains stub with a registry lookup
- Registry finds stubs using codebase

# RemoteRef.invoke()

- Client issues a remote method invocation
- Stub class provides a RemoteRef
- Marshals the arguments over the connection
- Uses a subclass of ObjectOutputStream
  - Knows how to deal with objects implementing `java.rmi.Remote`
  - Other objects serialized normally

# RMI Magic

- Client connects to the server socket
- Server creates a new thread to deal with the request
- Original thread continues listening
- Server reads the header information and unmarshals the RMI argument

# RMI Magic

- Server calls skeleton class' s "*dispatch*" method
- Skeleton calls appropriate method on the object
- Sends result back across the wire using the same RemoteRef
- Any exceptions are caught and sent instead of the return value

# RMI Magic

- On client side return value is un-marshaled
- Returned from the stub back to client code
- Exception are un-marshaled and re-thrown from the stub

# Synchronization

- No synchronization provided by the server side components
- Responsible for your own thread-safety

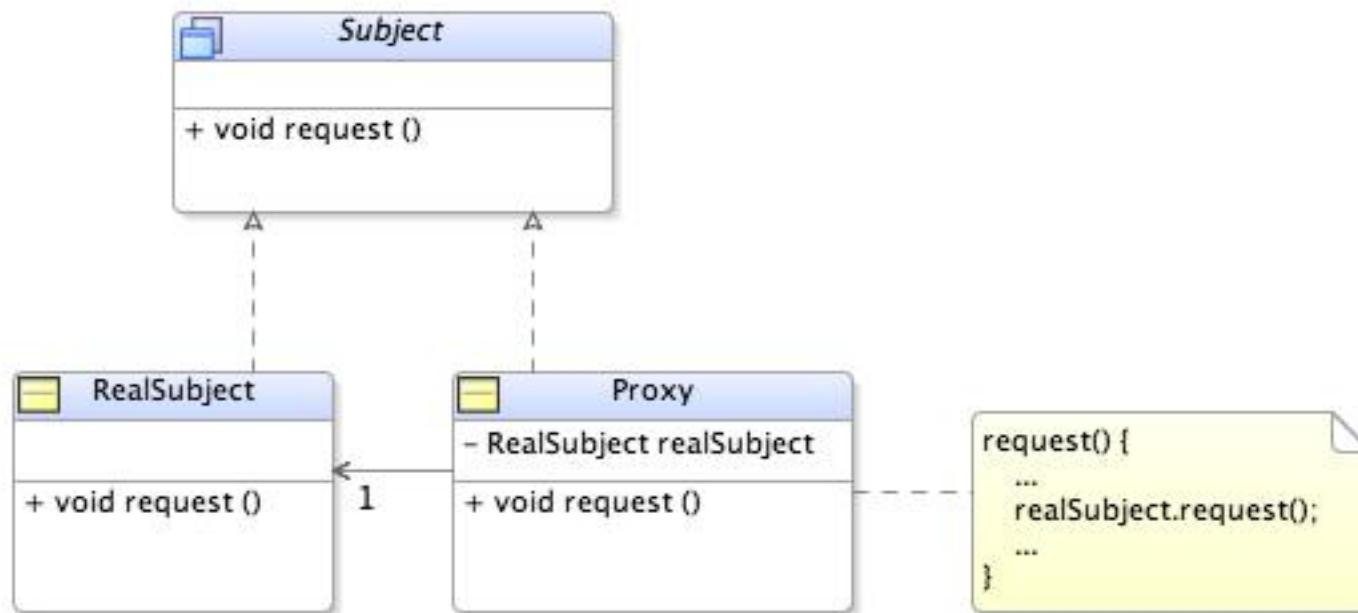


# Socket Connections

- **Server**
  - Single `UnicastRemoteObject`
  - One thread listening for connections
  - Multiple threads dealing with method calls
- **Client**
  - One socket to the server per client (minimum)
  - Multiple stubs pointing to the same server object may multiplex multiple virtual connections over a single concrete connection

# Proxy Pattern

- Use a proxy wherever a “smart” reference is required



# Using IIOP

- **Internet Inter-Orb Protocol (IIOP)**
  - Protocol used by CORBA objects
  - Allows some level of interoperability between CORBA and RMI

# `javax.rmi.PortableRemoteObject`

- **Use as base class for server rather than `java.rmi.RemoteObject`**
- **Use `narrow()` rather than simple cast**  
`Object narrow( Object, Class )`
- **Use `rmic` compiler to compile stubs/skeletons using `-iio` option**

# Using JNDI

- **Java Naming and Directory Service**
  - Part of and used extensively by J2EE
  - `javax.naming`
- **Standard interface**
- **RMI Registry service provider available from Sun**
  - <http://java.sun.com/products/jndi>