36 ClassLoader

- How are classes loaded into the Java Virtual Machine (JVM)?
  - from the local file system (**`CLASSPATH`**).
  - by an instance of **`ClassLoader`**
- ... and when? - When they are needed the first time.

```
class Test {
    public String toString() {
        Hello hello = new Hello();
    }
}
```

```
ClassLoader cl = new ...;
Class c = cl.loadClass("Test");
Object t=c.newInstance();
t.toString();
```

(1) class Test is loaded by classloader **`cl`**

(2) toString is executed and class **`Hello`** is needed

(3) the classloader of **`Test`** (= **`cl`**) is asked to load **`Hello`**

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36.1 ClassLoader

- A classloader creates a name space.
  - There can exist classes with the same name in one JVM, provided that they are loaded by different classloader instances.
- **`java.lang.ClassLoader`**
  - can create a class from an array of bytes that conforms to the class file format (method **`defineClass()`**)
  - if this class uses other classes your class loader is asked to load them (method **`loadClass(String name)`**)
  - look for previously loaded classes with **`Class findLoadedClass(String name)`**
- multiple **`ClassLoader`**s can be running in one JVM

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36.2 Example ClassLoader

```
import java.io.*;

public class SimpleClassLoader extends ClassLoader {

    public synchronized Class loadClass(String name, boolean resolve) {

        Class c = findLoadedClass(name);
        if (c != null) return c;

        try {
            c = findSystemClass(name);
            if (c != null) return c;
        } catch(ClassNotFoundException e) {}

        try {
            RandomAccessFile file = new RandomAccessFile("test/" +
                                              name + ".class", "r");
            byte data[] = new byte[(int)file.length()];
            file.readFully(data);
            c = defineClass(name, data, 0, data.length);
        } catch(IOException e) {}

        if (resolve)
            resolveClass(c);

        return c;
    }
}
```


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36.3 Example Appletviewer

- **`appletviewer`** uses a special class loader (**`sun.applet.AppletClassLoader`**)
- What happens when the **`appetviewer`** is started?

1. String parameter is converted to **`URL`** object.
2. **`URL`** stream is parsed looking for the **`<applet>`** tag.
3. **`AppletClassLoader`** with URL specified in **`codebase`** is created.
4. Class specified in **`code`** parameter is loaded by the **`AppletClassLoader`**.

- **`AppletClassLoader`** is initialized with URL:

```
    AppletClassLoader(URL baseURL)
```

- the **`loadClass(String name)`** method creates an URL from **`baseURL`** and the class name **`name`** and calls **`loadClass(URL url)`**
- **`loadClass(URL url)`** gets the URL stream, reads the bytes of the class and calls **`defineClass()`**

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37 Java Security

- Sandboxing
- Bytecode Verifier
- Security Manager
- Implementation of the Java libraries

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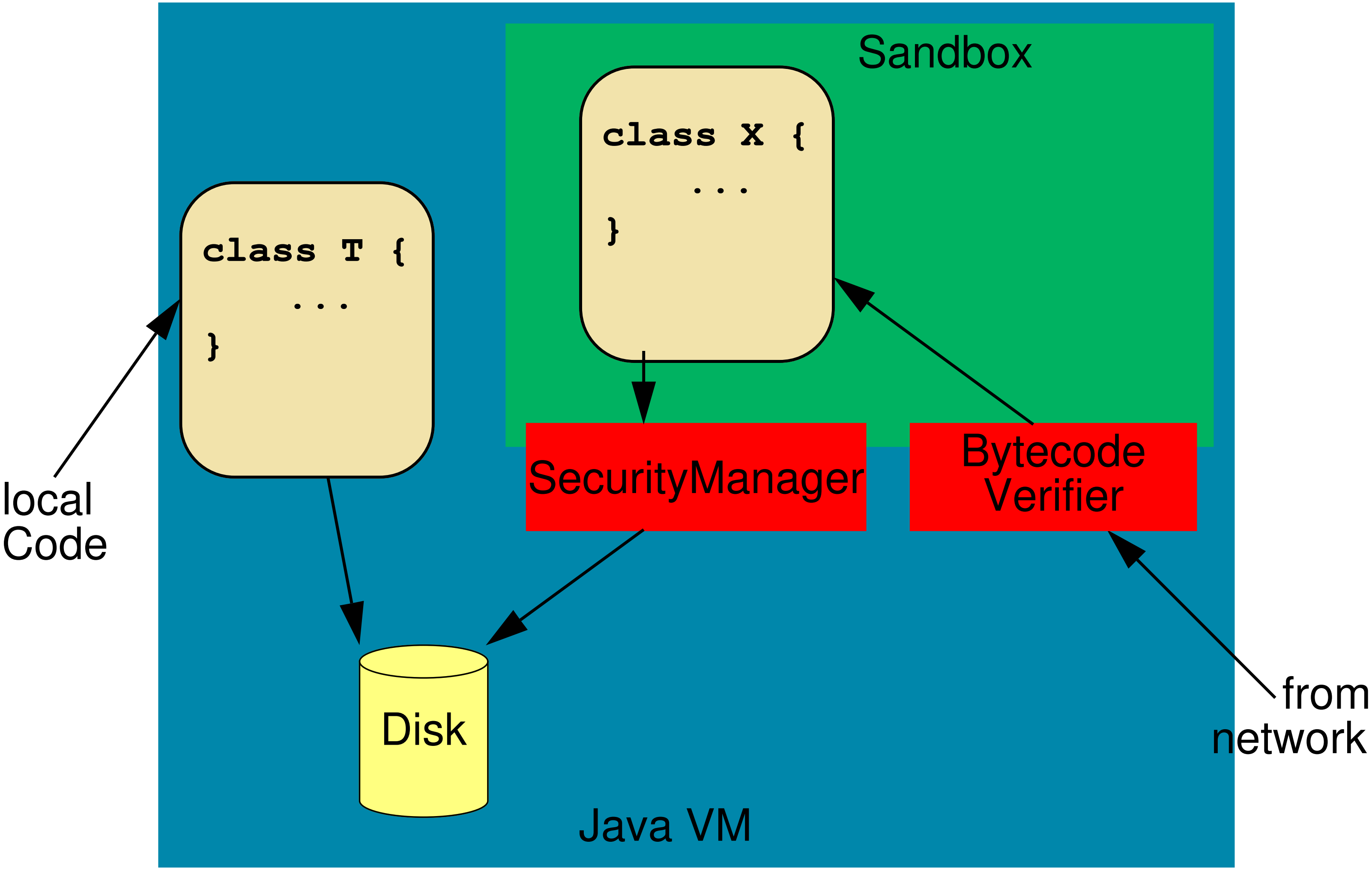
37.1 Sandboxing

- Classes loaded by ClassLoader execute within a *Sandbox*



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37.2 SecurityManager

- Checks if a class is allowed to perform an operation
- **`System.getSecurityManager()`** returns the global security manager
- checks must e done by the protected class itself

```
SecurityManager security = System.getSecurityManager();
if (security != null) {
    security.checkConnect(address.getHostAddress(), port);
}
```

- **`System.setSecurityManager()`** installs a global security manager
  - ◆ this method can be called *only once*!

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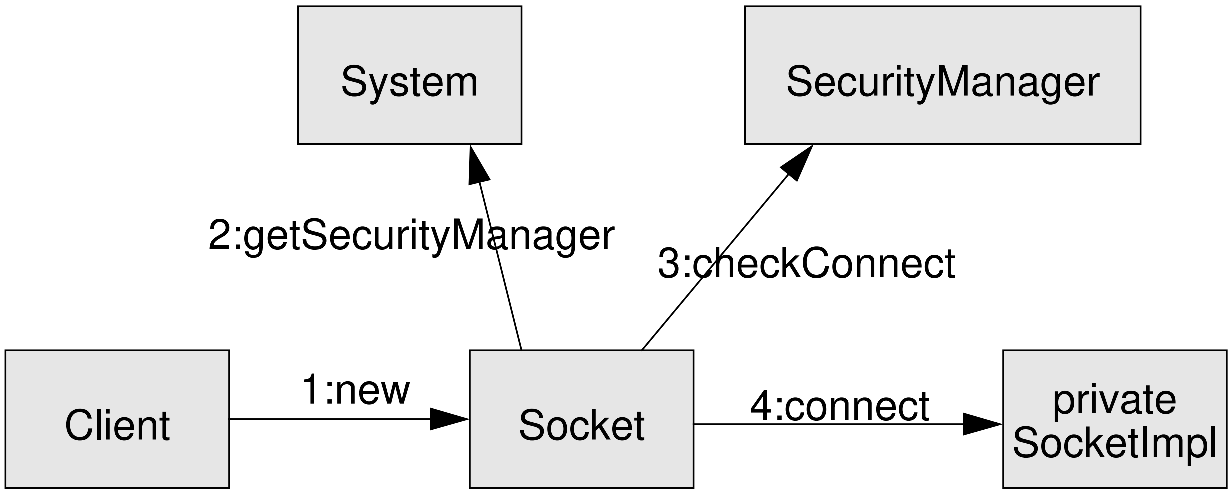
37.3 SecurityManager und Sockets

- Example network communication: creating a new Socket



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37.4 Example SecurityManager

```
public class SimpleSecurityManager extends SecurityManager
{
    public void checkRead(String s) {
        if (...) {
            throw new SecurityException("checkread");
        }
    }
}
```


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37.4 What is Protected by a Security Manager?

- Access to the local file system
- Access to operating system
  - executing programs
  - reading system information
- Access to the network
- Thread manipulation
- Creation of factory objects (socket implementation)
- JVM: Linking native code, Exiting the interpreter, creating classloaders,
- Creating windows
- ...

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37.5 AppletSecurityManager

Security Checks	AppletSecurityManager
checkCreateClassLoader	not allowed
checkConnect	allowed, if URL of the classes ClassLoader contains the target host
checkExit	not allowed
checkExec	not allowed

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38 Remote Method Invocation (RMI)

- Abstraction in a distributed system

Socket Communication	no abstraction
↓	
Remote Procedure Call	procedural abstraction
↓	
Remote Method Invocation	object abstraction

- Remote Method Invocation: calling methods at objects on other hosts
- Transparent object references to remote objects

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38.1 RMI Introduction

- *Remote Object*: object that can be used from a different JVM
- *Remote Interface*: Declares Methods of the remote object.
- Remote Interface must inherit **`java.rmi.Remote`** (marker interface)
- Accessing remote objects only via remote interfaces
- remote class must implement remote interface
- remote objects can implement multiple remote interfaces
- remote objects can use other remote objects
- Parameter passing:
  - by value: default (non-remote objects) -- Copy to remote host
  - by reference: if parameter implements **`java.rmi.Remote`**

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38.2 Local vs. Remote Method Call

- every invocation can throw a **`RemoteException`**,
  - client does not know if mehod was executed completely, partly, or not at all
- remote objects can only be used via interfaces
- local objects are passed by value

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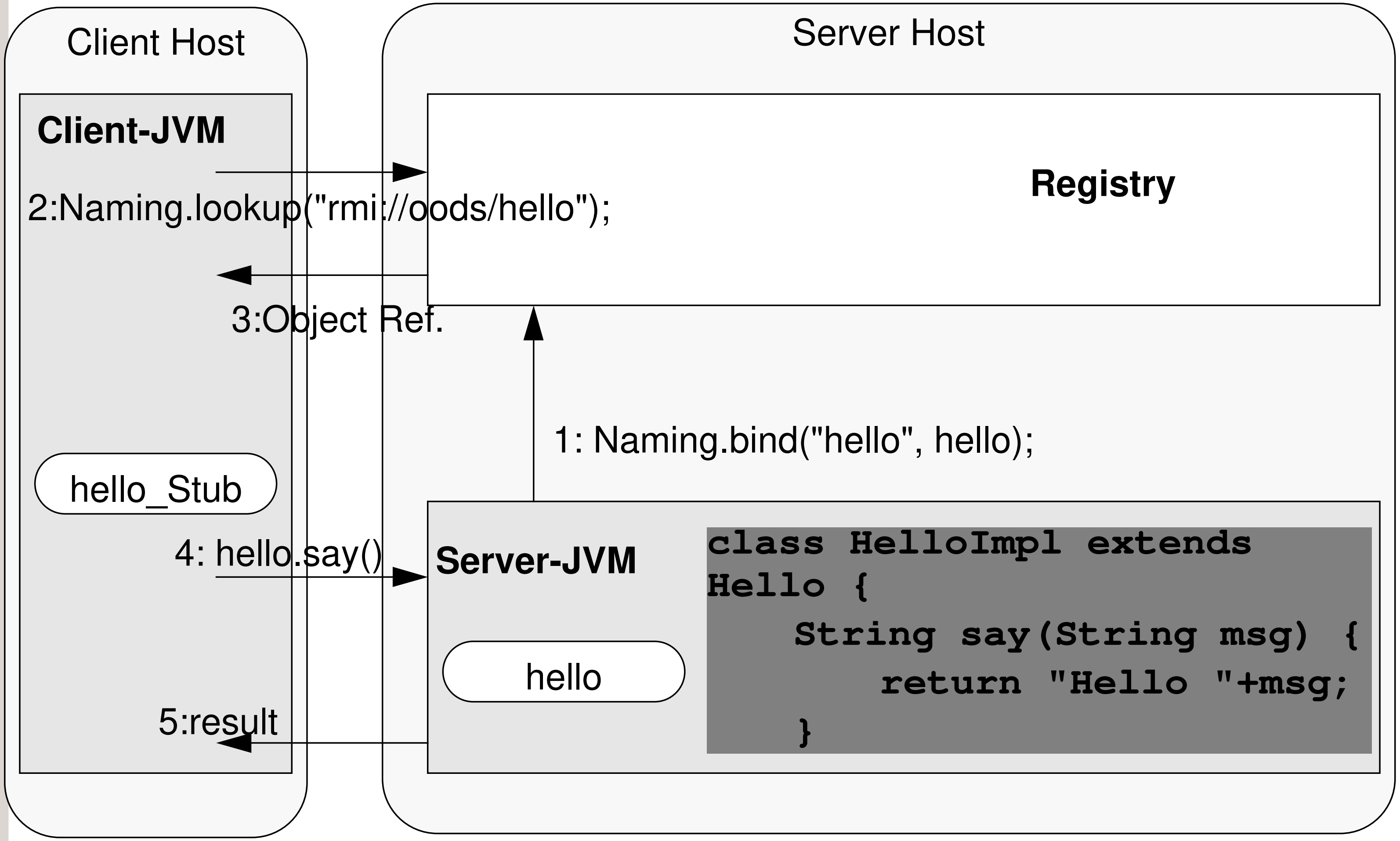
38.3 RMI Operation



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38.4 Registry (1)

- The registry maintains the mapping between object names and references.
- Accessed using the class **`java.rmi.Naming`**
  - ◆ **`void Naming.bind(String name, Remote obj)`**
    registers object with a specific name,
    exception is thrown if object already registered
  - ◆ **`void Naming.rebind(String name, Remote obj)`**
    registers object under name,
    if object already registered, old binding is destroyed
  - ◆ **`Remote Naming.lookup(String name)`**
    finds reference for a given object name
  - ◆ **`void Naming.unbind(String name)`**
    destroys binding between object and its name
- Binding only possible on registry at same host!

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38.5 Registry (2)

- Using a specific port:
  - Registry waits for TCP/IP connections at port 1099
  - other port can be specified as parameter, e.g. 10412:

    `rmiregistry 10412`
  - if a registry at a specific port should be used, the URL passed to **`bind/rebind/unbind`** must contain this port:

    `Naming.rebind("//oobp.informatik:10412/hello", hello)`
  - ... and **`lookup`**

    `Naming.lookup("rmi://oobp.informatik:10412/hello")`

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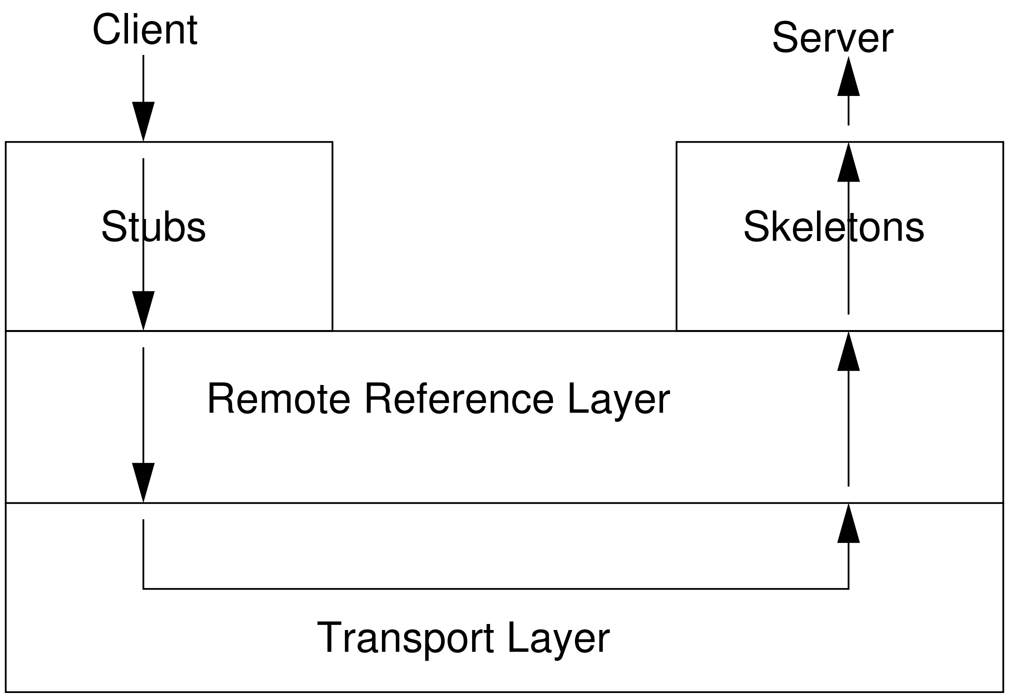
38.6 System Architecture



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38.7 Stubs and Skeletons

- Stub (Client Side) - implements the remote interface

1. gets `ObjectOutputStream` from RemoteReference Layer
2. writes the parameters to this stream
3. message to remote reference layer to invoke method
4. gets `ObjectInputStream` from RemoteReference Layer
5. reads the return object from this stream
6. returns the return object to the caller

- Skeleton (Server Side)

1. gets `ObjectInputStream` from RemoteReference Layer
2. reads parameters from this stream
3. invokes the method at the implementation object
4. gets `ObjectOutputStream` from RemoteReference Layer
5. writes the return object to this stream

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38.8 Remote Reference Layer / Transport Layer

- Remote Reference Layer
  - ◆ responsible for garbage collection of remote objects
  - ◆ implements invocation semantics, e.g.
    - unicast point-to-point
    - invocation at replicated object
    - persistent reference to remote object
    - strategies to reconnect after connection termination
- Transport Layer
  - ◆ responsible for data transport between hosts
  - ◆ current implementation uses TCP/IP sockets
  - ◆ different transport mechanisms possible

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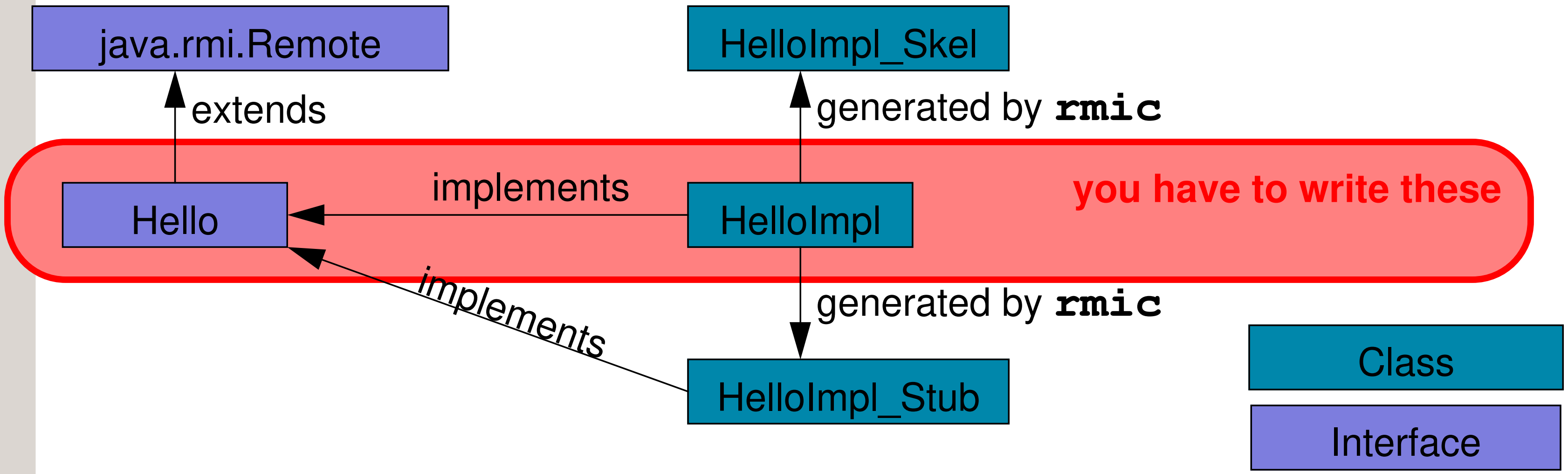
38.9 Interface and Implementation



- Programmer writes the remote interface **`Hello`** and the implementation **`HelloImpl`**.
- The stub **`HelloImpl_Stub`** and the skeleton **`HelloImpl_Skel`** are generated by **`rmic`** from the implementation class **`HelloImpl`**.
- **`RMIClassLoader`** loads classes of parameters and return values.

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38.10 Example

0

1. write the remote interface
2. write the server
3. register the remote object
4. write the client
5. start the system

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38.10.1 Remote Interface

- every remote object must implement an interface that contains all remotely callable methods
- interface must inherit from **java.rmi.Remote**
- all methods must throw a **java.rmi.RemoteException**
- all parameters and return values must be serializable (implement **java.io.Serializable**) or remote objects
- Exampe:

```
import java.rmi.*; import java.io.*;
public interface Bank extends Remote {
    void deposit(Money amount, Account account) throws RemoteException;
}

public class Money implements Serializable {
    private float value;
    public Money(float value) { this.value = value; }
}

public interface Account extends Remote { ... }
```


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38.10.2 Server

- The server must implement the remote interface.
- Methods has not to throw **RemoteException**.
- Two ways to create a remote object:
  - ◆ Server subclasses **rmi.server.UnicastRemoteObject**

```
public class BankImpl extends UnicastRemoteObject
                                        implements Bank {
    public void deposit(Money amount, Account account){
        account.deposit(amount);
    }
}
BankImpl bank = new BankImpl();
```

  - ◆ using **exportObject**

```
public class BankImpl implements Bank {... }

Remote bank = UnicastRemoteObject.exportObject(new BankImpl())
```


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Initialize the Server

- Register the remote object (**`bind`** or **`rebind`**).

```
Naming.bind("rmi://oods/bank", bank);
```

protocol hostname object name

- Install a security manager.
  - RMI refuses to load classes from the network without a security manager.
  - Server JVM sets a security manager with

```
System.setSecurityManager(new RMISecurityManager());
```

  - **`RMISecurityManager`** similar to **`AppletSecurityManager`**

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38.10.4 Client

- Get a remote reference using **`lookup`**.
- Example:

```
Bank bank = (Bank)Naming.lookup("rmi://oods/bank");
Account account = new AccountImpl();
bank.deposit(new Money(10), account));
```


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38.10.5 Start the System

1. Set CLASSPATH (for **`rmic`** and **`java`** (server))

```
setenv CLASSPATH /proj/i4oods/www/pub/rmi
```

2. Create stubs and skeletons

```
rmic -d ${CLASSPATH} bank.BankImp
```

3. Start the registry on the server host

```
rmiregistry 10412&
```

4. Start the server object

```
java -Djava.rmi.server.codebase=http://oods/pub/rmi/ bank.BankImpl
```

5. Use the applet:

```
appletviewer http://oods/pub/rmi/bank.html
```


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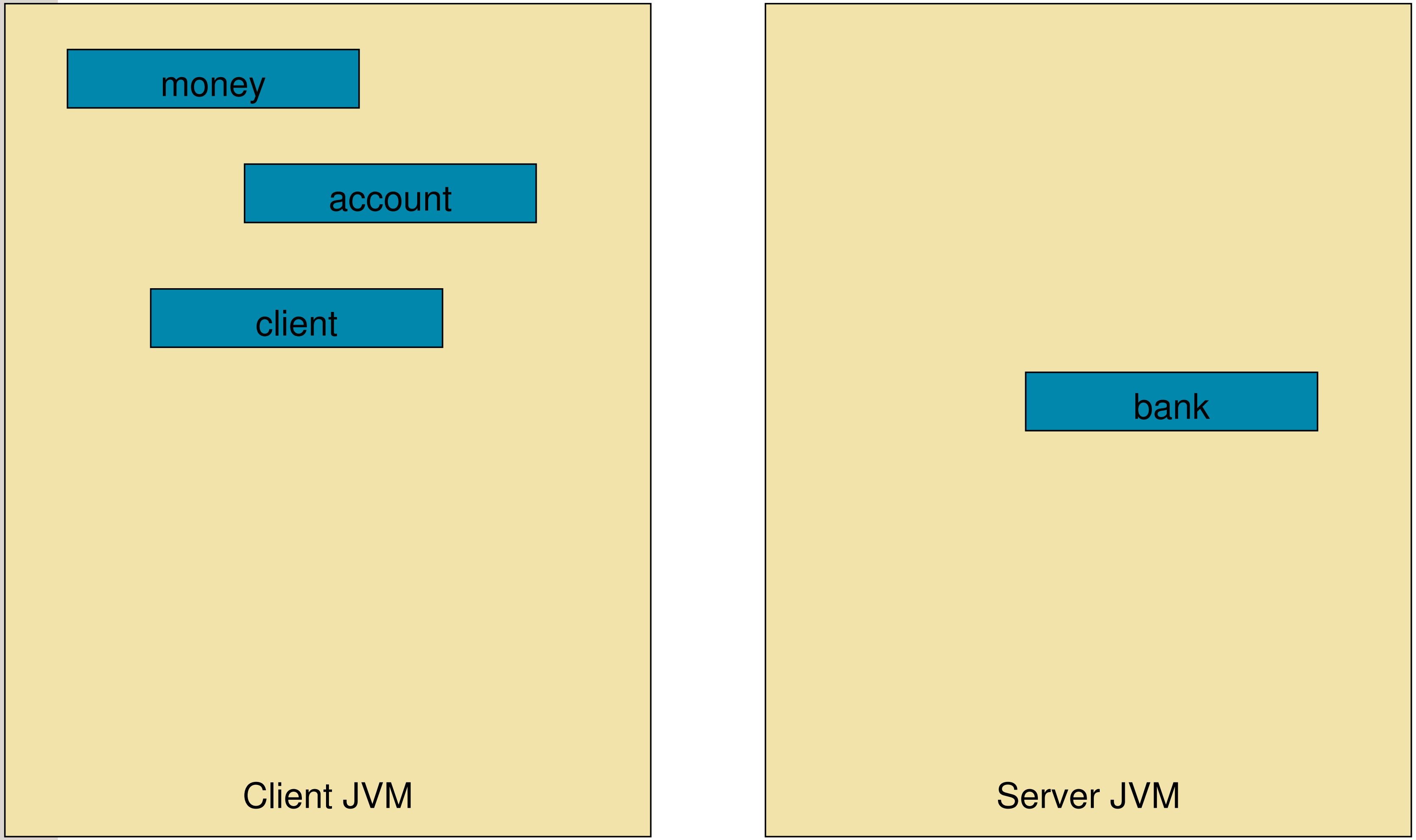
38.10.6 Interaction during the remote call



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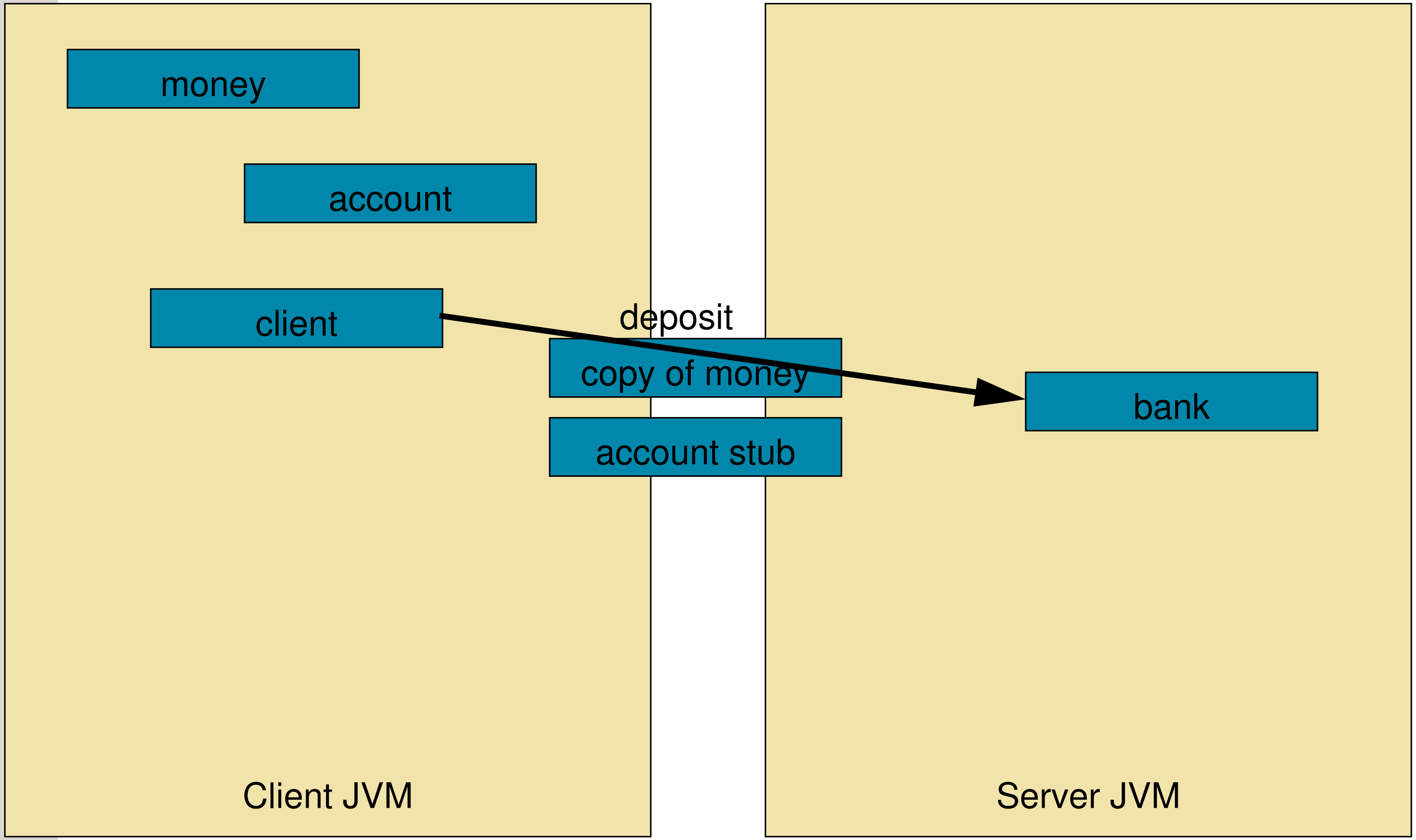
38.10.7 Interaction during the remote call



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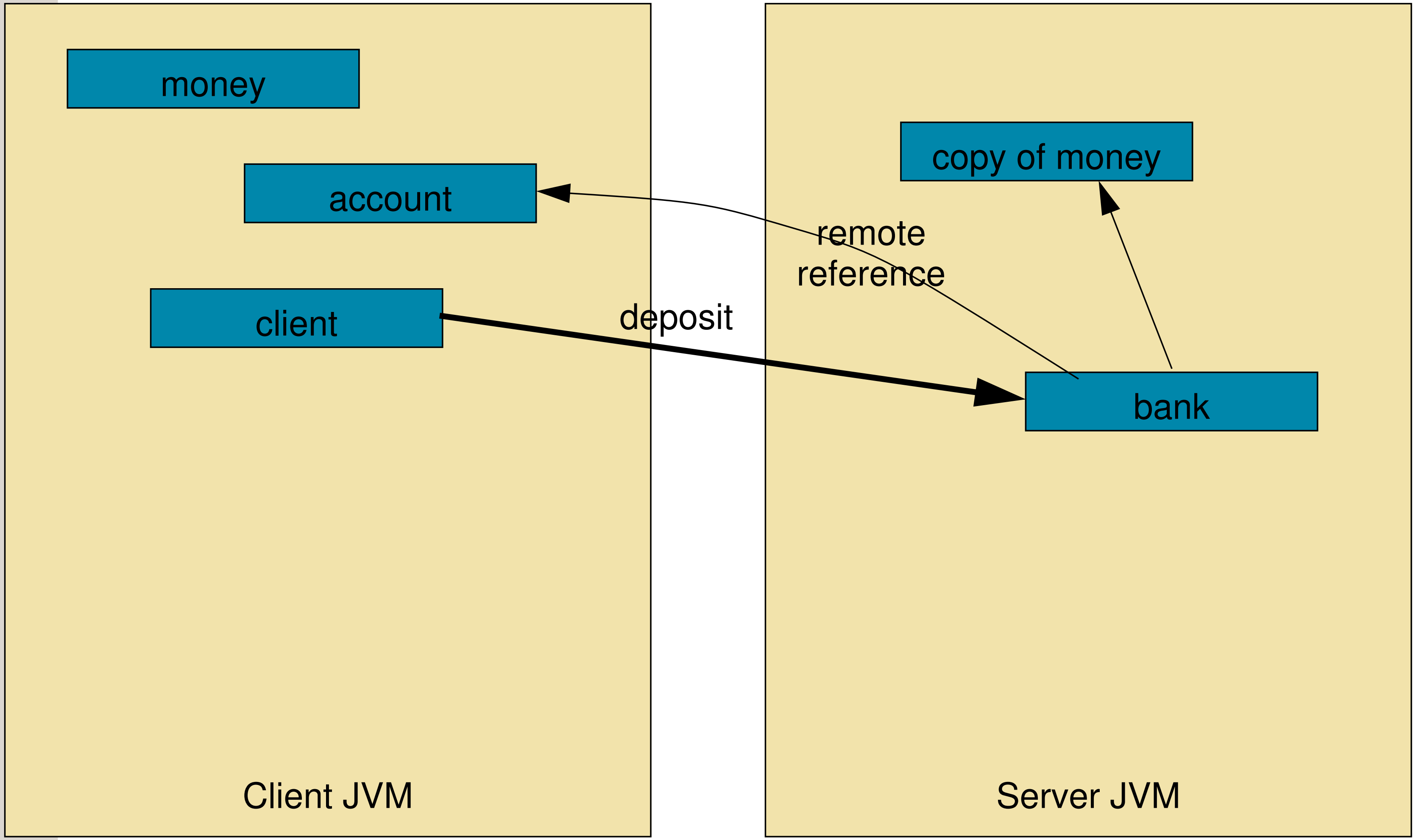
38.10.8 Interaction during the remote call



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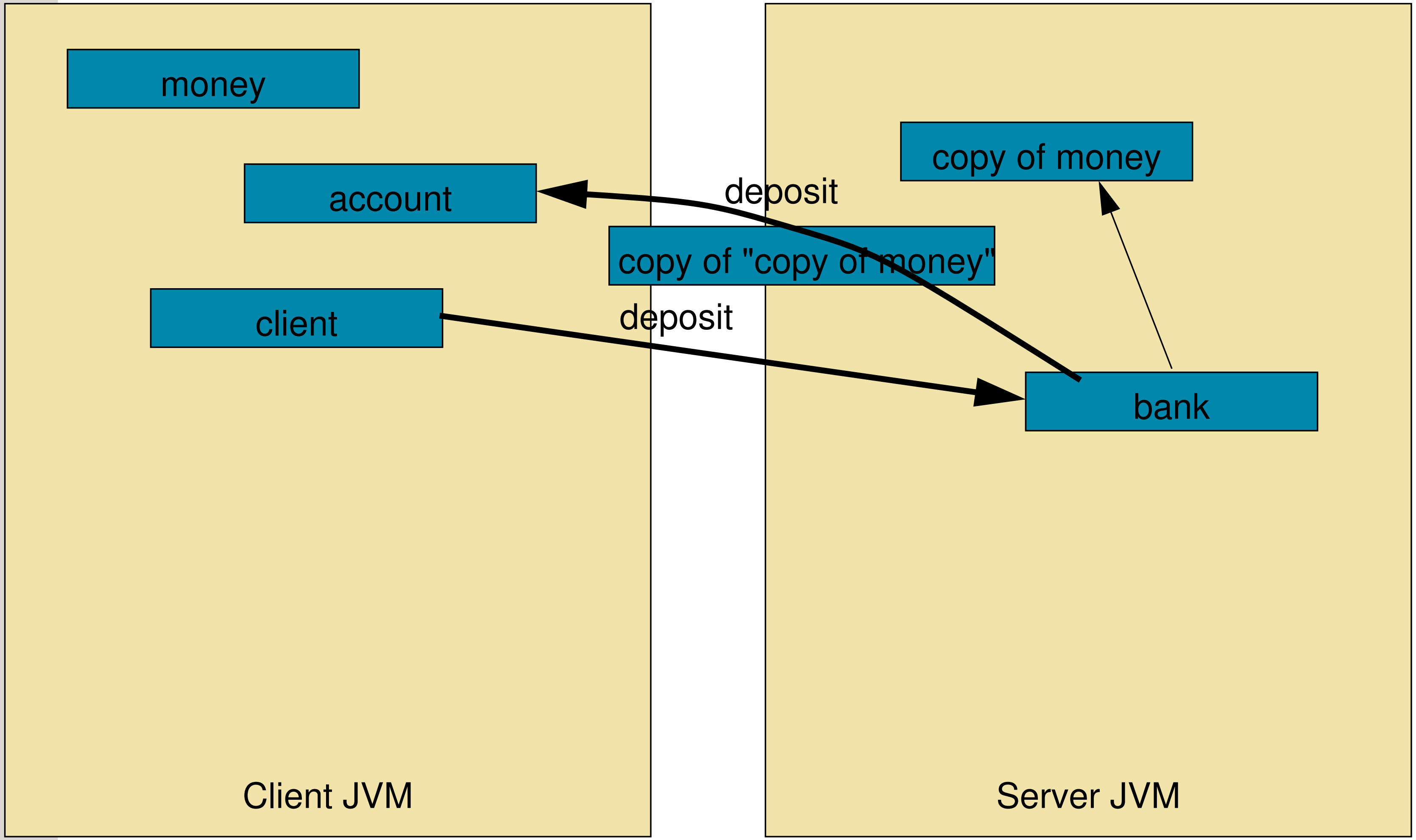
38.10.9 Interaction during the remote call



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38.11 Summary

- A remote object must implement a remote interface.
- All methods of the remote interface must throw RemoteException.
- Use/extend UnicastRemoteObject to create remote objects.
- Use Naming to bind / lookup the remote object at a registry.
- Clients only use the remote interface.

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