# 15-440: Distributed Systems

## Recitation 4

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# Last lecture

- Entities, Architecture and Communication
- RMI
- Interfaces
- Skeleton & Stub
- Example

# Today

- Packages dive-in:

✓ RMI

✓ Common

✓ Naming

✓ Storage

*** Note: You should implement the packages in the above order.*

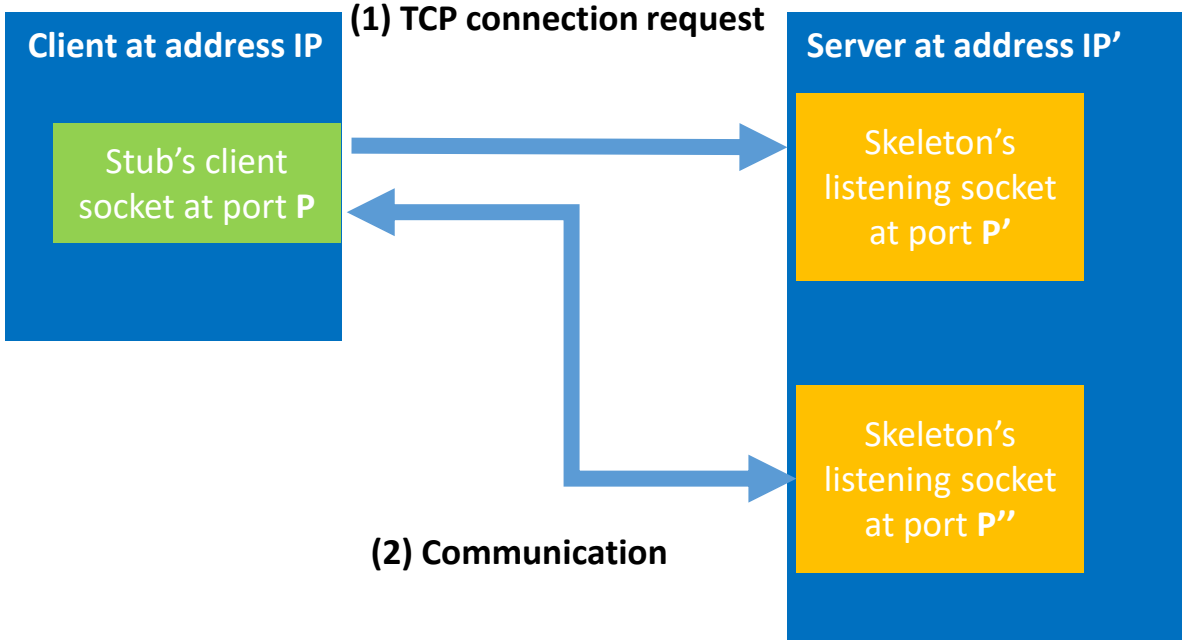
# RMI package (overview)

# RMI package

- It contains two parametrized (generic-type) classes:
  1. Skeleton.java
  2. Stub.java
- RMIException
- Both the Skeleton and the Stub classes take a remote interface as a parameter.

# RMI package

- We implement multi-threaded socket programming
- The skeleton is **multi-threaded**
- When it is started, the main thread creates a listening socket and waits for client requests.
- Once a client's request is received, the skeleton accepts the request, creates a new thread, and instantiates a new service socket to handle the communication



# Skeleton.java

```
public void start() {
        create serverSocket();
        bind(address);
        while (!stopped) {
                clientSocket = accept();
                Thread a = new Thread (new serviceThread(clientSocket));
                a.start() ;
        }
}

serviceThread {
        String methodName = (String) in.readObject();
        Class[] argTypes = (Class[]) in.readObject();
        Object[] args = (Object[]) in.readObject();
        Method m = c*.getMethod(methodName,argTypes);
        Object result = m.invokeMethod(implementation*, args);
        out.writeObject(result);
}
```

*** **c** is the interface,*
*** **implementation** is the implementation of the interface*

# Stub.java

- A stub is implemented in Java as a dynamic proxy
- A proxy has an associated invocation handler
- The invoke method checks whether the invoked method is or remote
- If the method is remote, the proxy connects to the corresponding skeleton at the server side, marshalls the method name, parameter types and values, and sends the entailed byte stream.
- http://tutorials.jenkov.com/java-reflection/dynamic-proxies.html

# Stub.java (creating proxies)

```
T proxy/stub = java.lang.reflect.Proxy.newProxyInstance(c.getClassLoader(),  new Class[] {c*},  new ProxyHandler());
public class ProxyHandler implements InvocationHandler {
        public Object invoke (String methodname, Class[] argTypes, Object[] args) {
            if method is local // can be toString, equals, hashCode
                call locally implemented method accordingly
            }  else {
                - create socket
                - connect (address)
                - out.writeObject(methodName);
                - out.writeObject(argTypes);
                - out.writeObject(args);
                - Object result = in.readObject();
                - close socket
                - return result
            }
}
```

***** Class loaders: give you a dynamic instance of the class during runtime***

# RMI package
# (Example: File Server)

# Creating a file server:

1. Defining a remote interface
2. Defining a server class
3. Creating the server object and making it remotely-accessible
4. Accessing a server object remotely

# Creating a file server:

1. **Defining a remote interface**
2. Defining a server class
3. Creating the server object and making it remotely-accessible
4. Accessing a server object remotely

```
public interface Server {
        public long size(String path) throws ..;
        public byte[] retrieve(String path)
                                        throws ..;
}
```

# Creating a file server:

1. Defining a remote interface
2. **Defining a server class**
3. Creating the server object and making it remotely-accessible
4. Accessing a server object remotely

```
public class ServerImplementation implements
Server {

        // Fields and methods. ...

        public long size(String path) throws ..{
                //size method impl.

        }

        public byte[] retrieve(String path) throws ..{
                // retrieve method impl.

        } ...

}
```

# Creating a file server:

1. Defining a remote interface
2. Defining a server class
3. **Creating the server object and making it remotely-accessible**
4. Accessing a server object remotely

```
// Create the server object.
ServerImplementation server = new ServerImplementation(...);
// At this point, the server object is a regular local object, and is not accessible remotely.
// Create the skeleton object.
Skeleton skeleton = new Skeleton(Server.class, server);
// Start the skeleton, making the server object remotely-accessible.
skeleton.start();
```

# Creating a file server:

1. Defining a remote interface
2. Defining a server class
3. Creating the server object and making it remotely-accessible
4. **Accessing a server object remotely**

// Create a stub which will forward method calls to the remote object.

InetSocketAddress address = new InetSocketAddress(hostname, port);

Server server = **Stub.create(Server.class, address);**

// Perform some method calls using the stub.

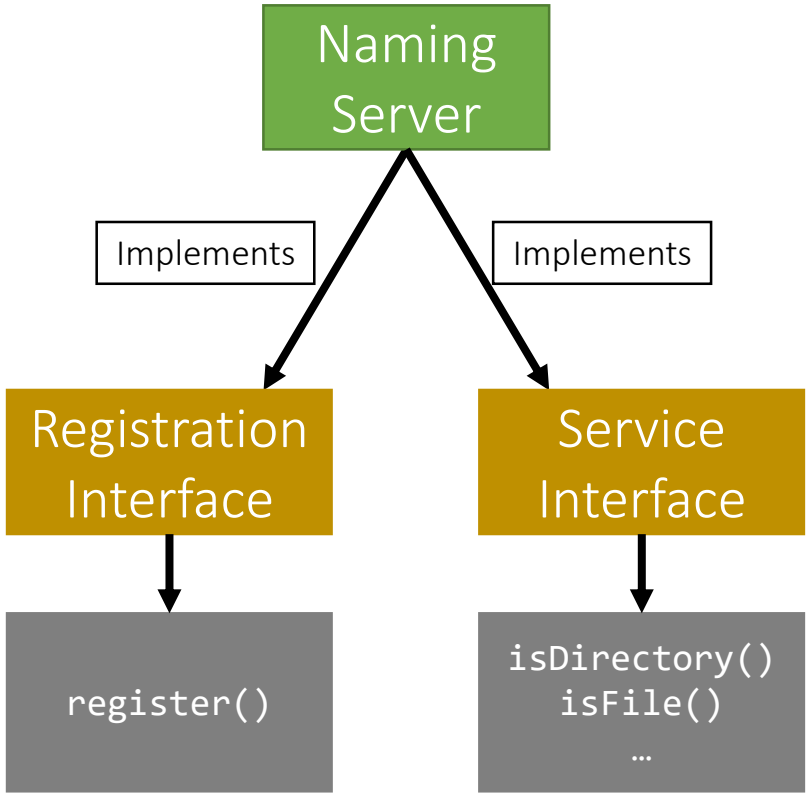
long file_size = server.size("/file"); ... byte[] data = server.retrieve("/file");

# Naming package

# Naming package

- The naming package contains:

1. Registration interface
2. Service interface
3. NamingServer class: creates the necessary skeletons and stubs and implements the logic of all the operations handled by the Naming Server



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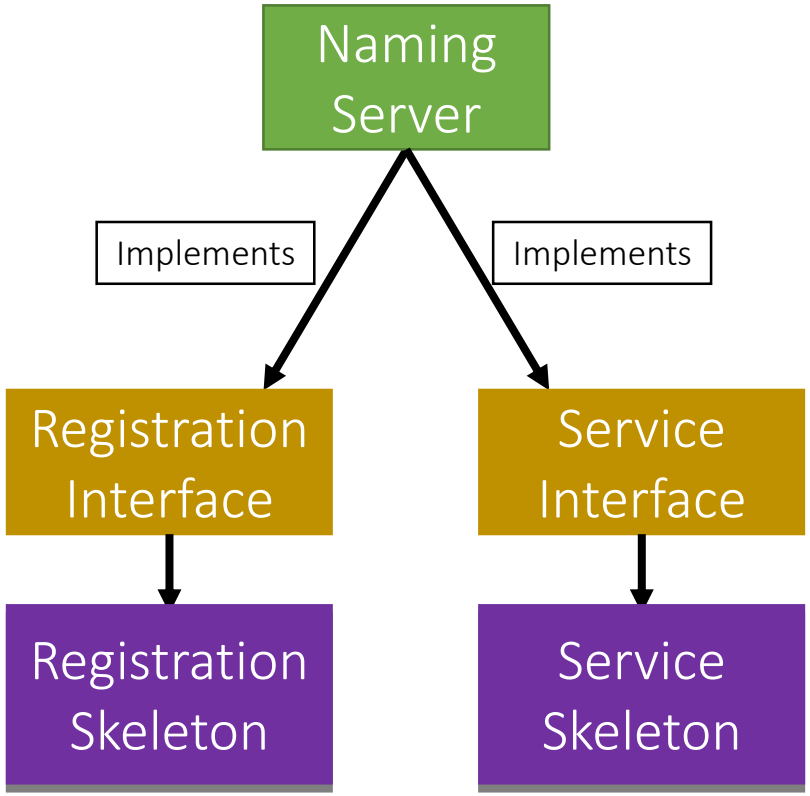

# Naming package (NamingServer.java)

- The Naming Server creates and maintains the FileStack directory tree:
  - ✓ Top-level directory being the root represented by the path "/".
  - ✓ Inner tree nodes represent directories,
  - ✓ the leaves represent files
- The Naming Server builds its tree during registration.
- After registration, the Naming Server uses its tree to handle operations.
- It is important to design the directory tree in a way that allows the Naming Server to easily look-up, traverse and alter the tree, as well as detect invalid paths.

# Naming package (Tree)

- How can we build the *Directory Tree*?
  - One way is to use **Leaf**/**Branch** approach:
    - **Leaf** will represent:
      - A file (name) and stub
    - **Branch** will represent:
      - A list of **Leafs**/**Branches**

# Naming package (Classes)

```
public class Node {
	String name;
}

public class Branch extends Node {
	ArrayList<Node> list;
}

public class Leaf extends Node {
	Command c;
	Storage s;
}
```

# Naming package

NamingStubs.java (`public class`)

- Creates:
  - Registration ***Stub***
  - Service ***Stub***

# Storage package

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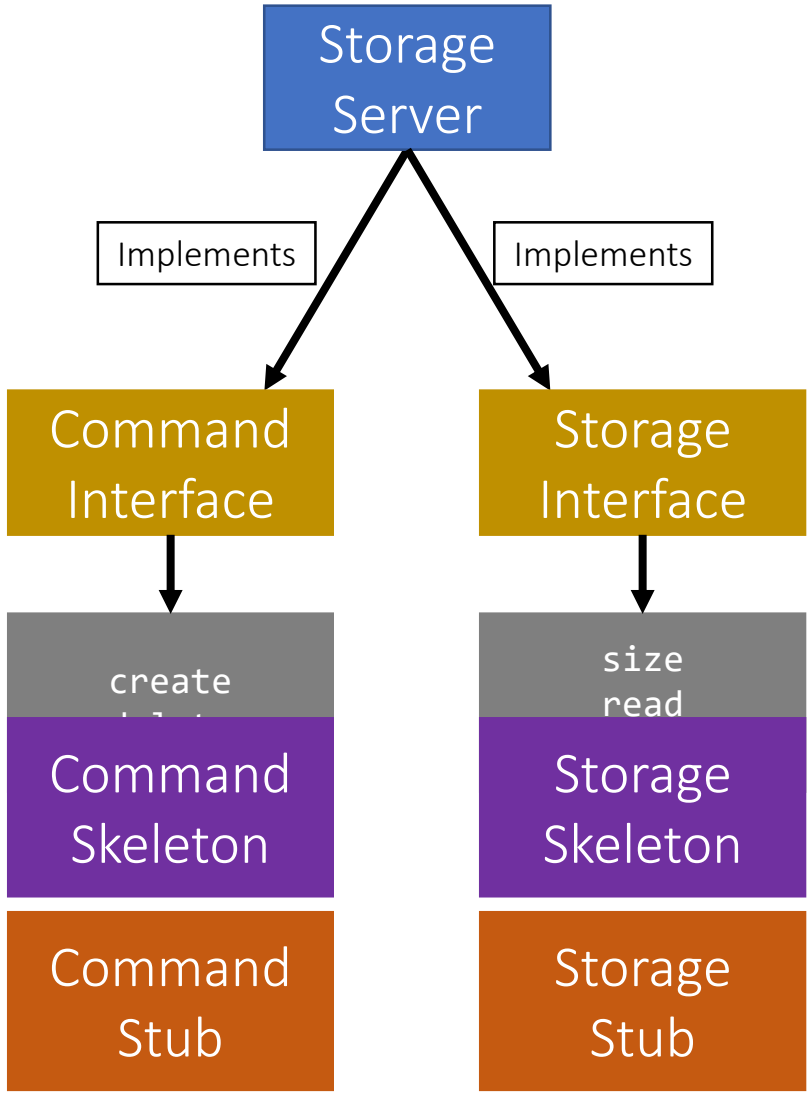


These stubs are sent to the Naming server during registration

# Storage package

- The **Storage** Package:
  - Command.java (interface)
  - Storage.java (interface)
  - StorageServer.java (public class)
    - Implements:
      - Command ***Interface***
        - **methods(s):** create, delete
      - Storage ***Interface***
        - **methods(s):** size, read, write
    - Has functions:
      - ***start()***
      - ***stop()***

# Storage package

- The StorageServer start() function will:
  - **Start** the Skeletons:
    - *Command* Skeleton
    - *Storage* Skeleton
  - **Create the stubs**
    - *Command* Stub
    - *Storage* Stub

# Storage package

- The StorageServer start() function will:
  - **Registers** itself with the **Naming Server** **using**:
    - Its **files**
    - The created **stubs**
  - Post registration, we receive a list of **duplicates** (*if any*):
    - **Delete** the duplicates
    - ***Prune*** **directories** if needed

# Storage package

- The StorageServer stop() function will:
  - **Stop** the skeletons:
    - *Command* Skeleton
    - *Storage* Skeleton