15-440

Distributed Systems

Recitation 4

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Slides Adopted from:

Previous TAs

Last Time

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

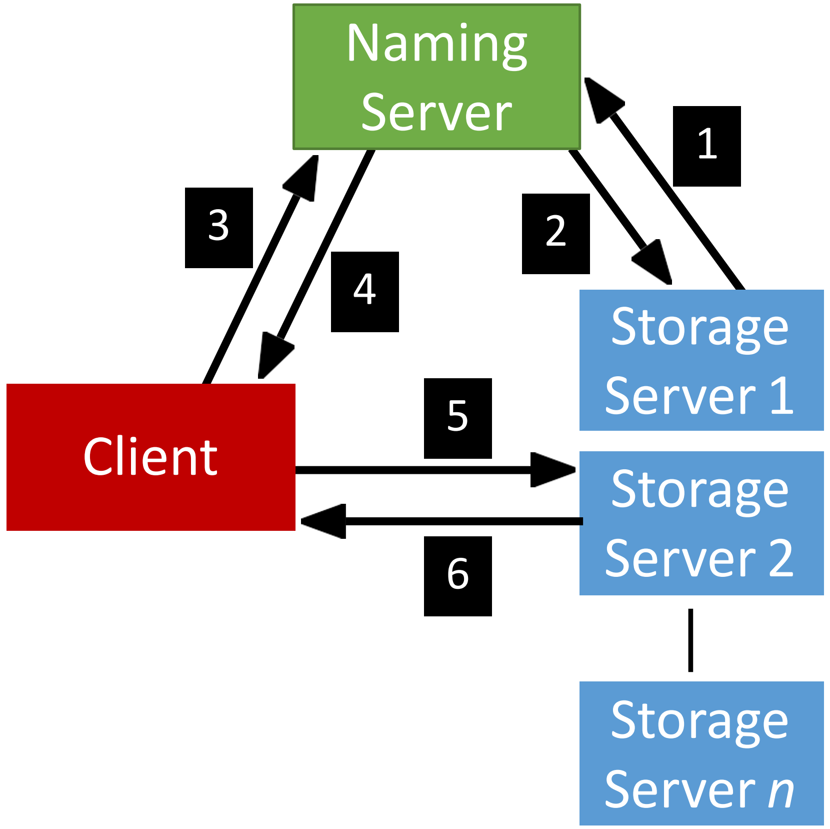
Today

- Packages dive-in:
  - ✓ RMI
  - ✓ Common
  - ✓ Naming
  - ✓ Storage

Quick Recap

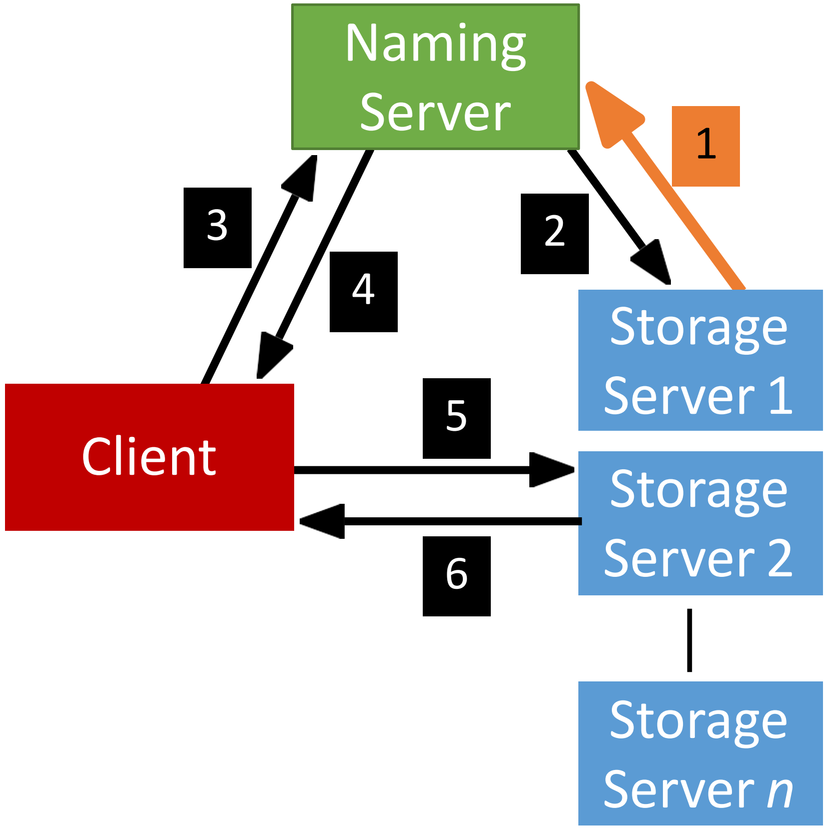
Architecture

- FileStack will boast a Client-Server architecture:



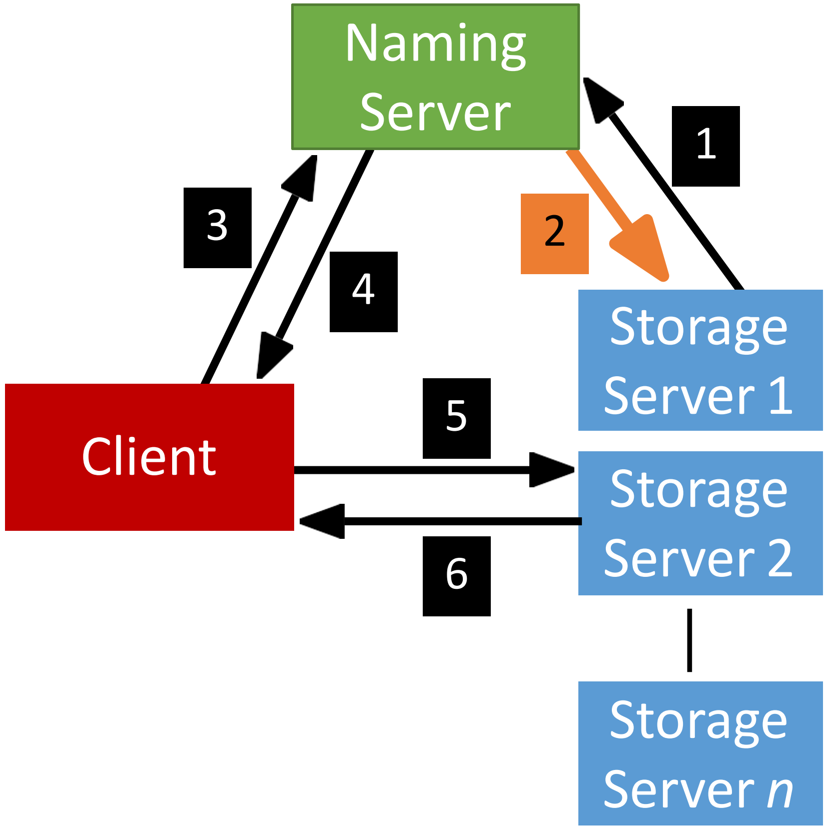
Communication

- Registration phase



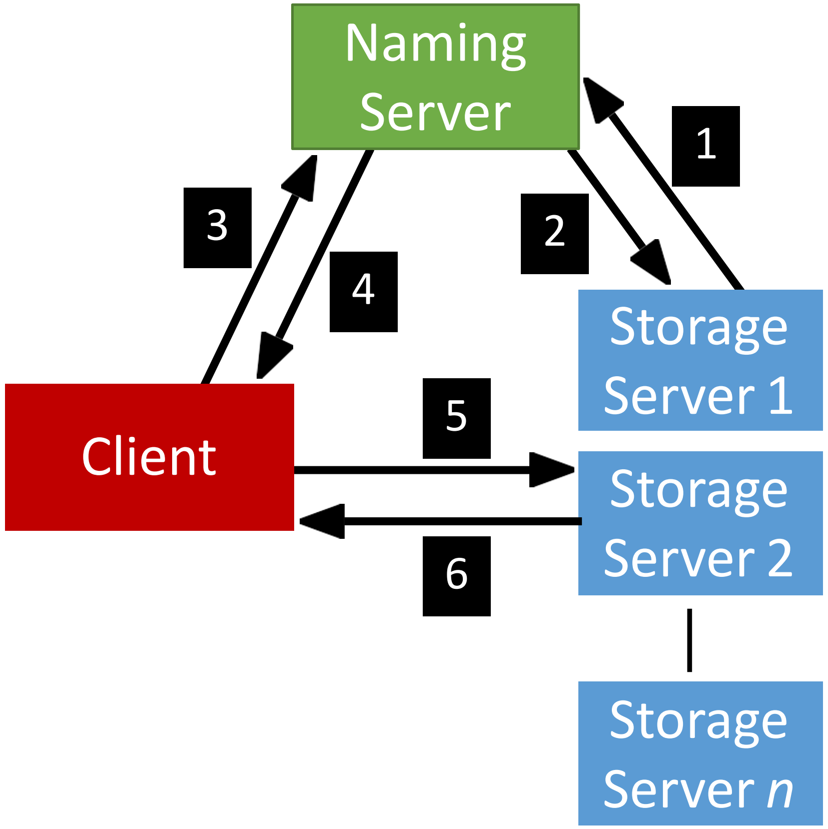
Communication

- Post registration, the Naming Server responds with a list of *duplicates* (if any).



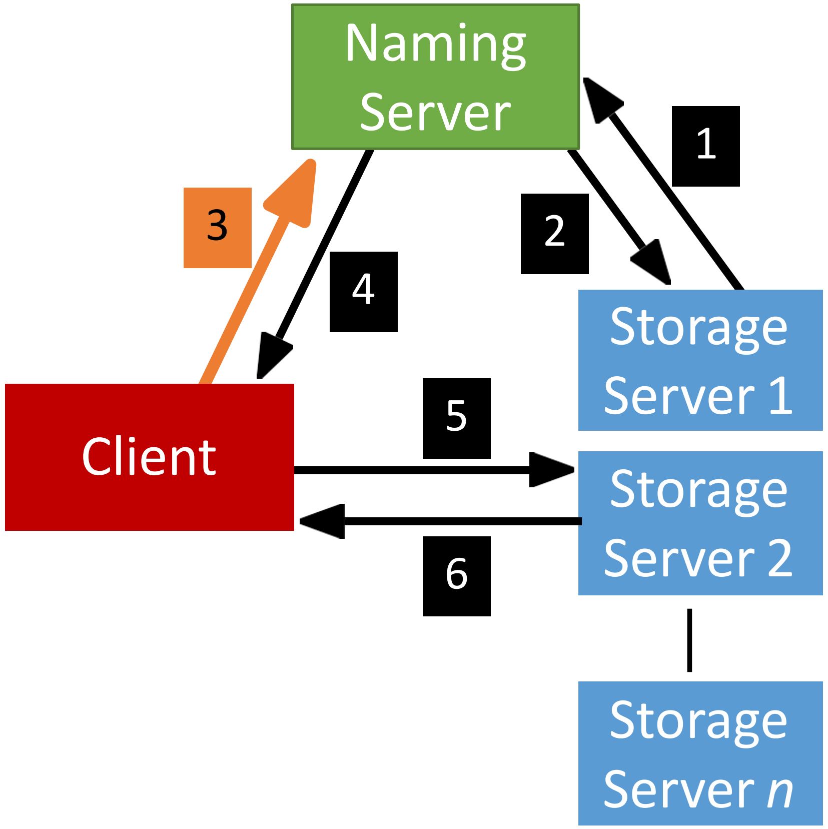
Communication

- System is now ready, the Client can invoke requests.



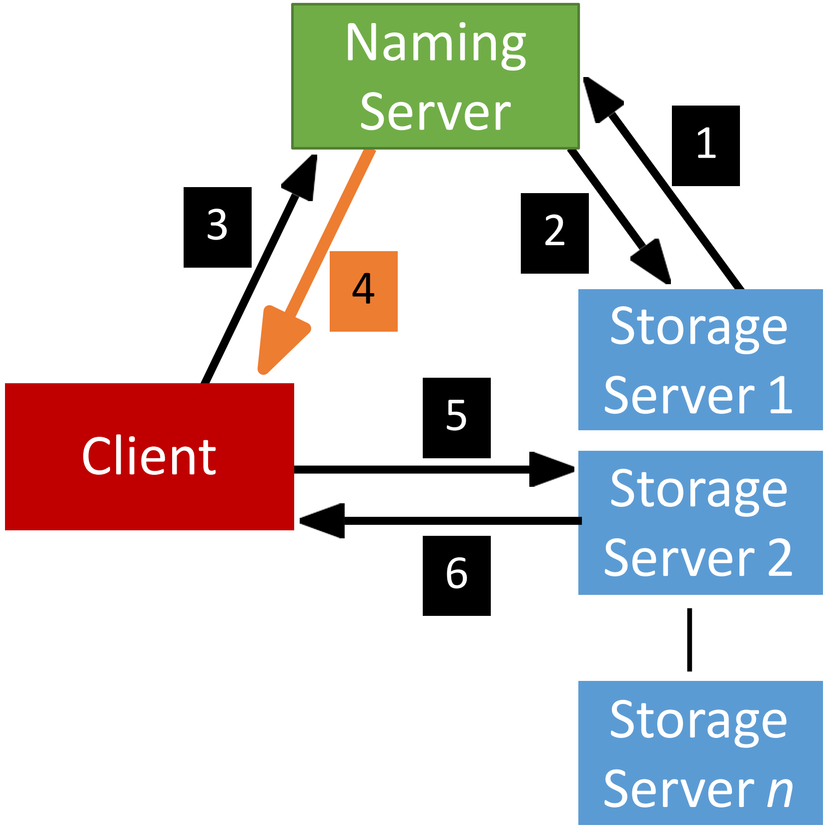
Communication

- Client requests a file (to read, write etc…) from the Naming Server.



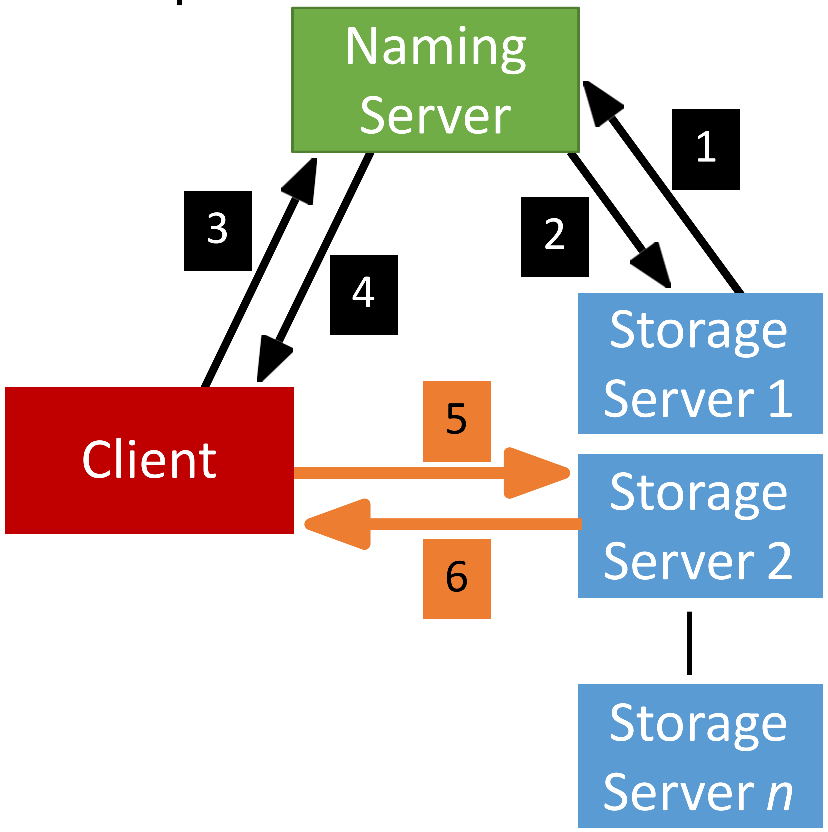
Communication

- Depending on the operation, the Naming Server could either perform it, or, respond back to the Client with the Storage Server that hosts the file.

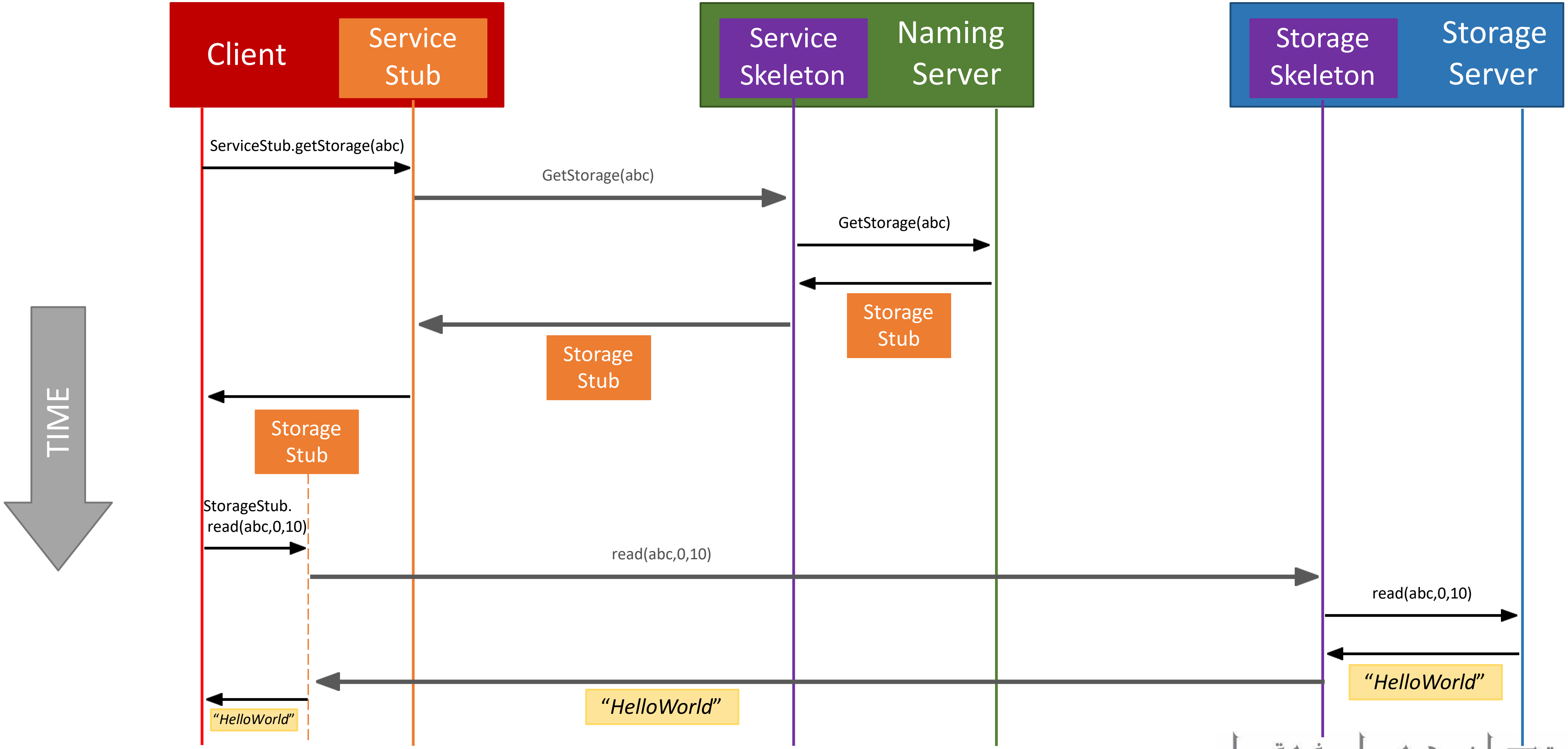


Communication

- After the Client receives which Storage Server hosts the file, it contacts that Server to perform the file operation.



Full Example: Client Read



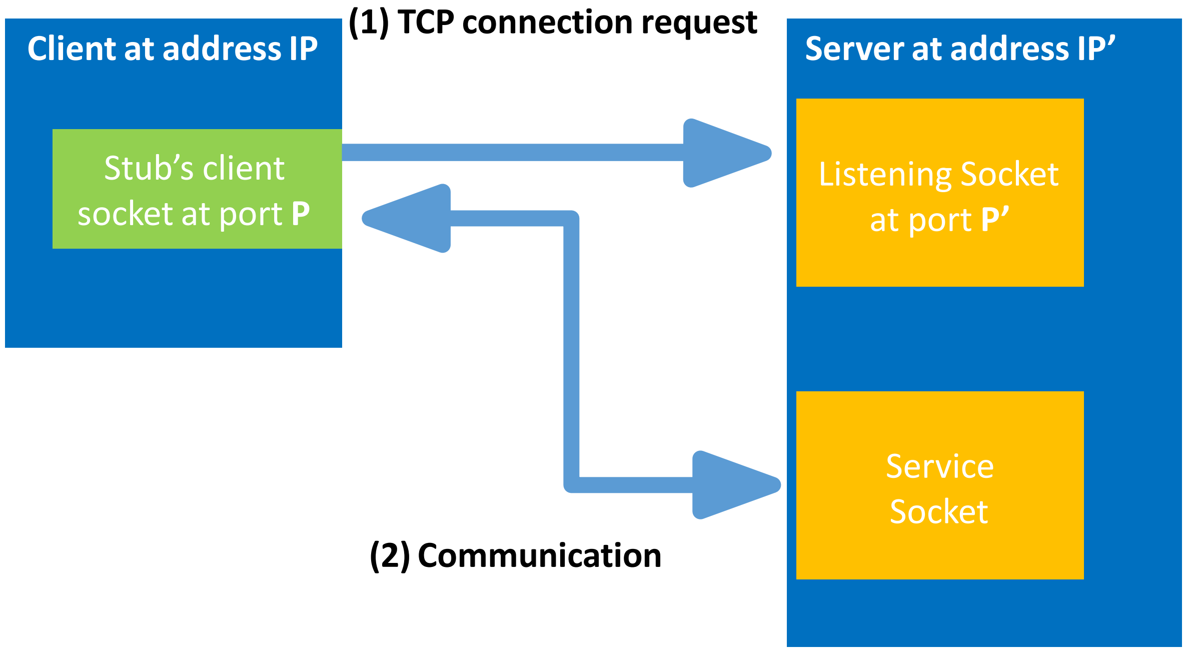
RMI package
(overview)

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


(1) TCP connection request
Client at address IP
Stub's client socket at port P
Server at address IP'
Listening Socket at port P'
Service Socket
(2) Communication

Skeleton.java

*c is the interface,

*implementation is the implementation of the interface

```
 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);
}
```

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 local or remote
- If the 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

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");
```

Common package

Path package

- This package contains the class Path which contains helper methods that are used by Naming Server and the Storage Servers.

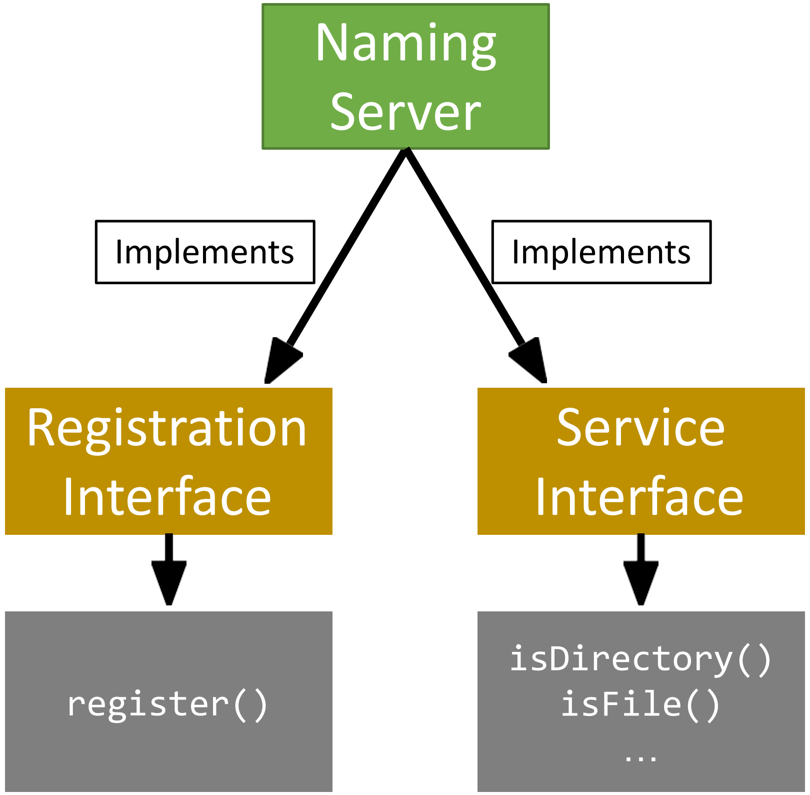
- Path creation
- Listing
- toString
- Equals
- Hashcode
- isRoot
- …

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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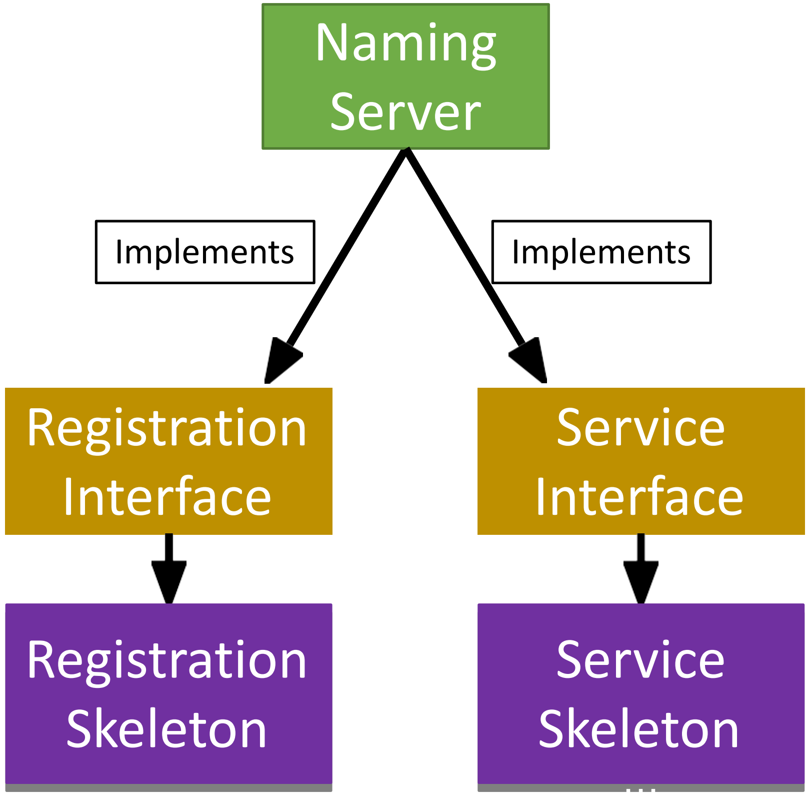


Naming package (NamingServer.java)

- 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
- Builds its tree during registration.
- After registration, uses its tree to handle operations.
- It is important to design the directory tree in a way that allows the NamingServer 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 (inner node) will represent:
      - A list of Leafs/Branches

Naming package (Classes)

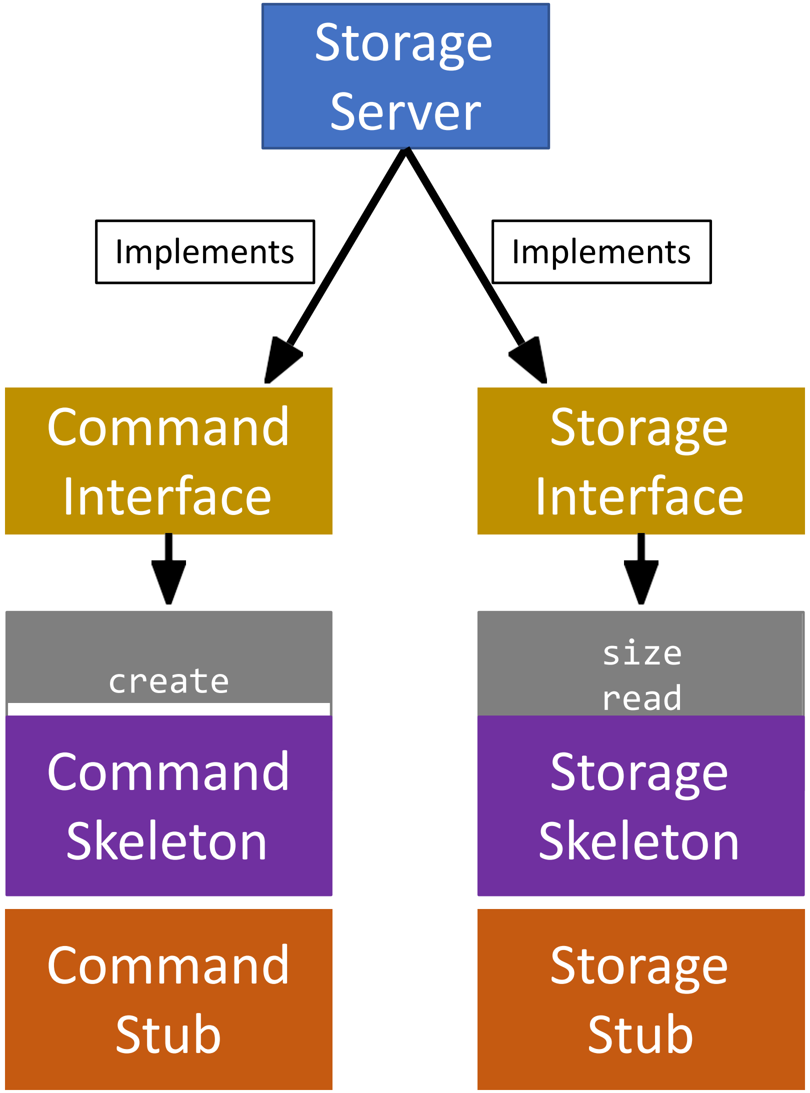
```
public class Node {
    String name;
}

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

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

Storage package

Storage package



These stubs are sent to the Naming server during <u>registration</u>

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