# Technology Session II

- Serialization, Sockets, **RMI** -

Chair of Programming Methodology

Material based on Prof. Peter Müller's
*Konzepte objektorientierter Programmierung*
course

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# Agenda for Today

## Distributed Programming

- Sockets
- Serialization
- Remote Objects

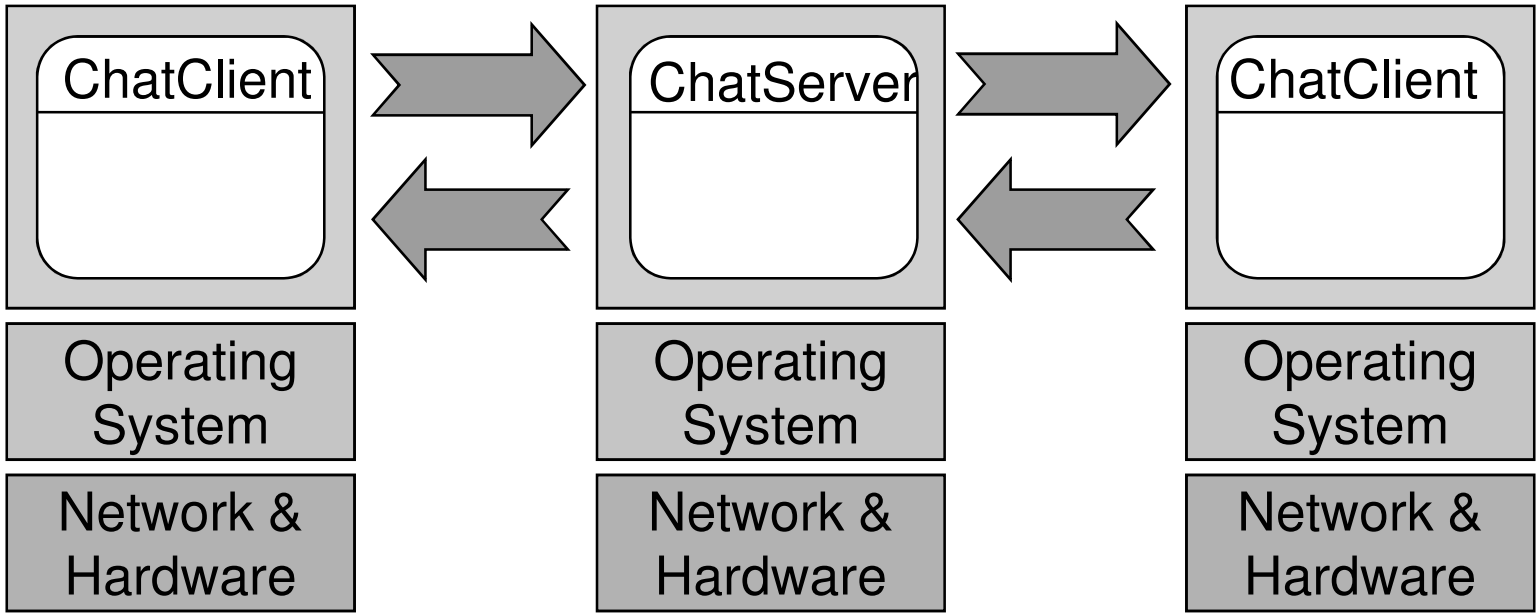
## Objectives

- Remote objects
- Remote method invocation

# Aspects of Distributed Programming

- Programs run in **different processes** or on different computers
  - Usually no shared memory
- **Communication** is crucial
  - Communication is not robust
  - Communication takes time
- Distributed systems are often **heterogeneous**
  - Different hardware
  - Different operating systems
  - Different programming languages

# Distributed Chat Example

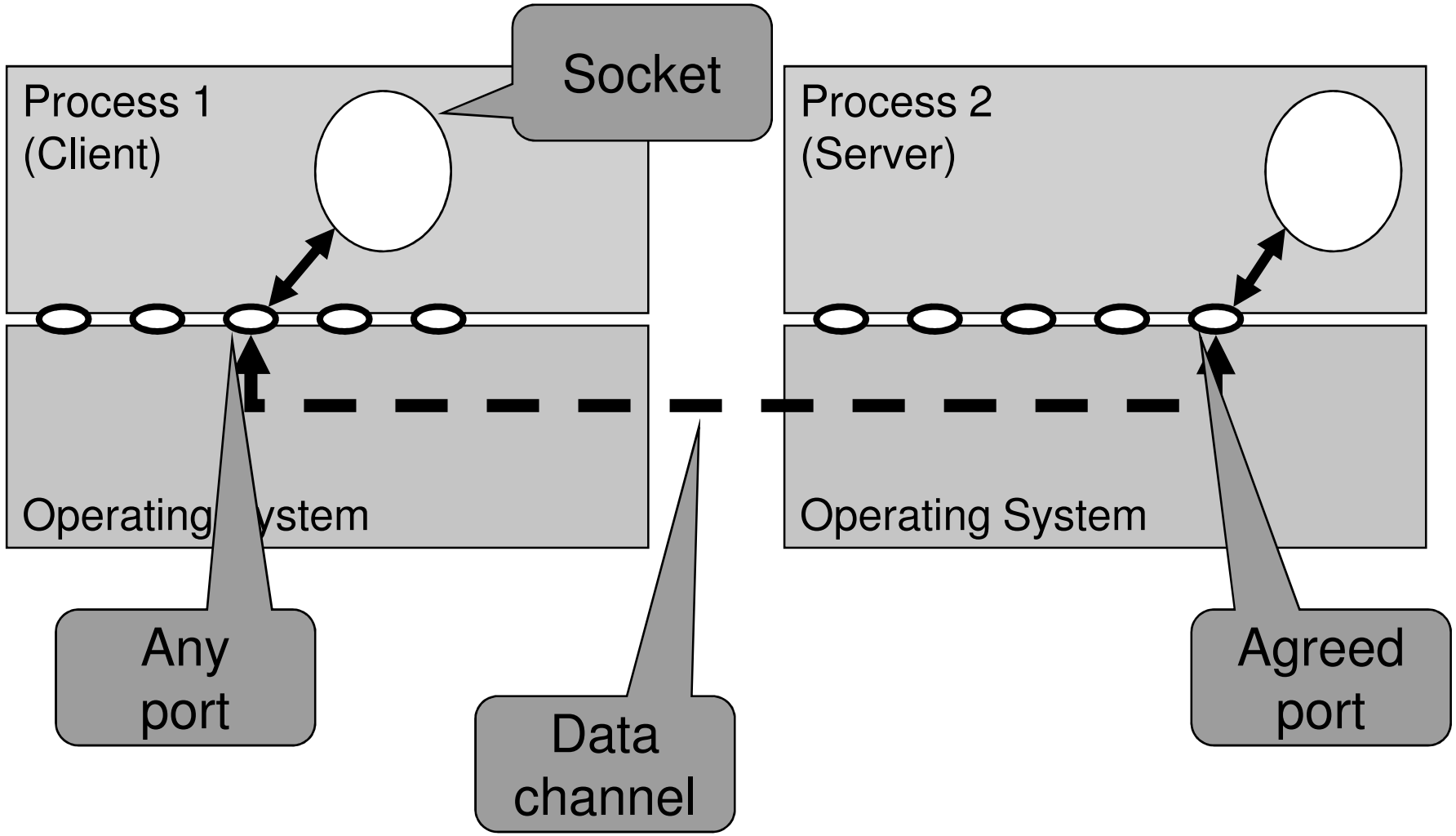



- How to access objects in different address spaces?
- How to communicate across process boundaries?
- How to pass parameters, results, and exceptions?

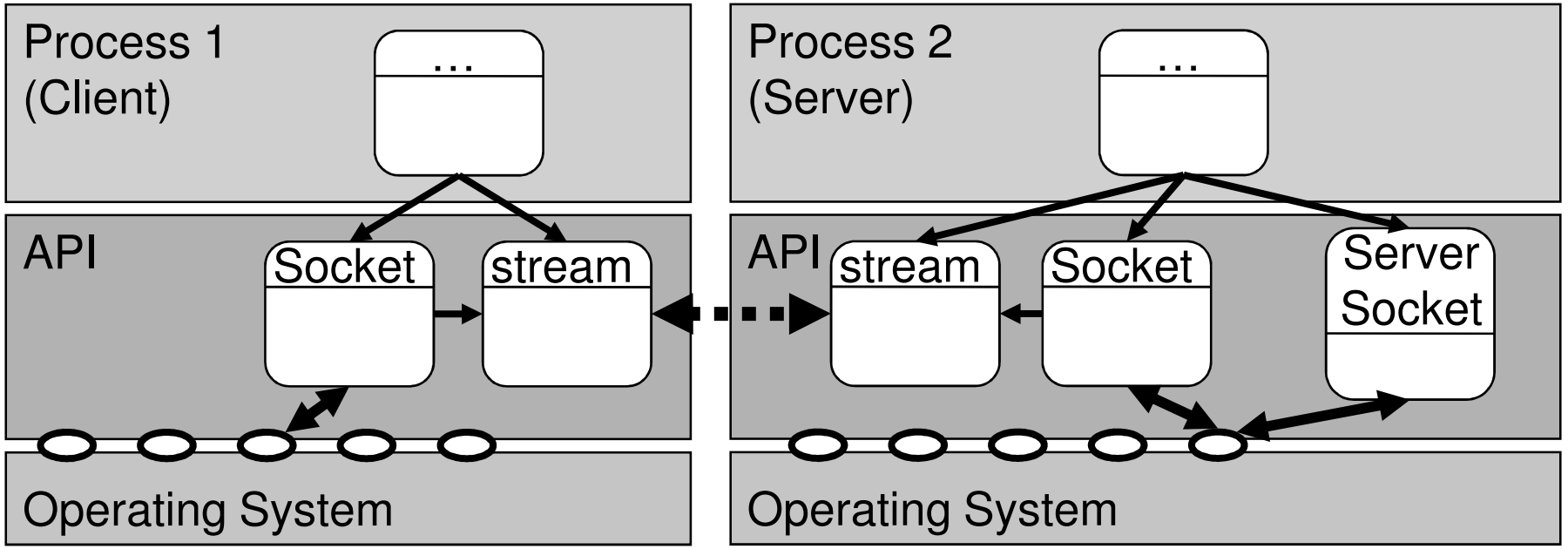
# Distributed Programming

- **Sockets**
- Serialization
- Remote Objects

# Sockets and Ports

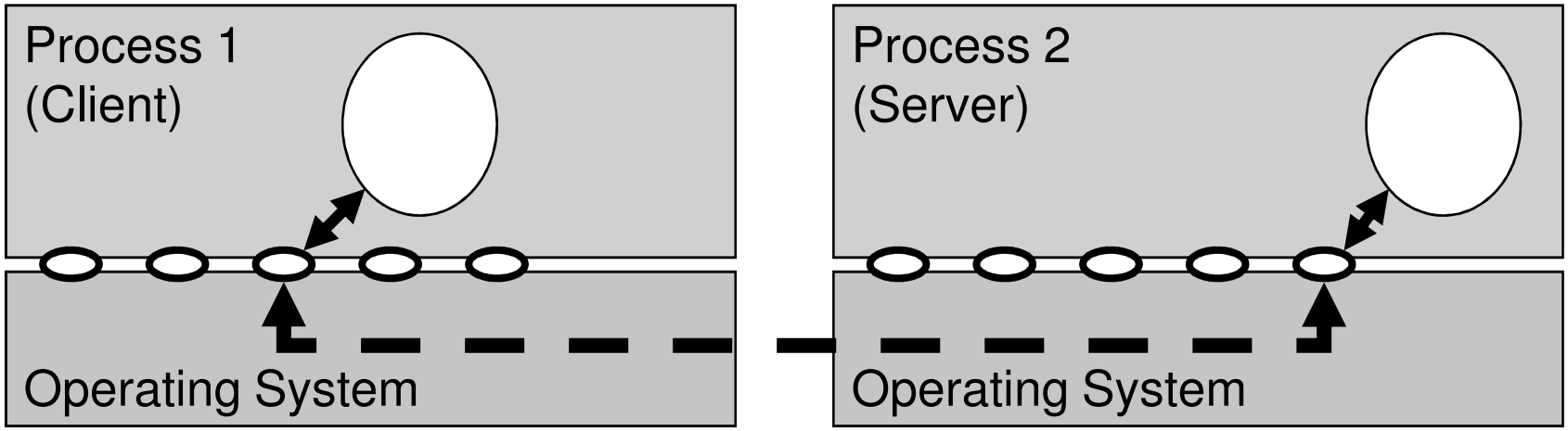


# Communication via Sockets

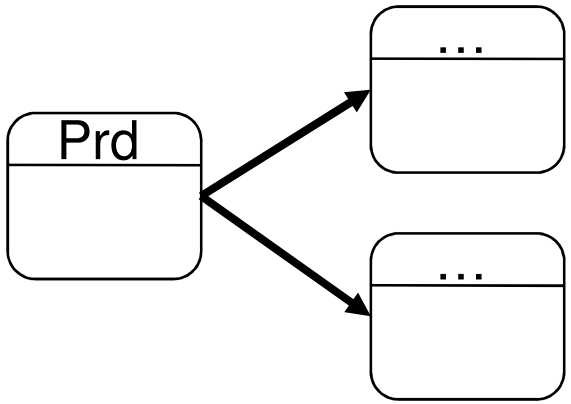



- Server sockets wait for communication partners on an agreed port
- Sockets provide communication facilities
- Input and output streams to transmit data

# Parameter Passing




- Commands, parameters, results, and exceptions are transmitted as **sequential byte streams**



# Example: Chat server with Socket

```
public class SocketChatServer {


   public static void main( String[] args ) {
      SocketChatServer srv = new SocketChatServer();
      ServerSocket ss = new ServerSocket( 6666 );
       while ( true ) {
          Socket s = ss.accept( );
          new ServiceThread( s ).start();
       }
   }
}
```

- Main loop accepts clients and starts new threads
- Code does not show exception handling

# Example: Chat server with Socket (cont'd)

```
class ServiceThread extends Thread {
  Socket s;
   public ServiceThread( Socket p ) { s = p; }

    public void run( ) {
       ObjectInputStream ois = new ObjectInputStream( s.getInputStream());
       String cmd = (String) ois.readObject();
        if ( cmd.equals("register") )            { … }
       else if ( cmd.equals("deregister") )  { … }
        else if ( cmd.equals("bcast") )         { … }
        else { System.err.println("Unknown command!"); }
        ois.close();
        s.close();
     } }
```

# Example: Chat client Socket

## Registers to Chat server at known server port

(sends “register” + client IP addr + client port number)

## Waits for messages on client port

(checks if starts with “msg” + displays message)

## Sends messages to server

(sends message with “broadcast” prefix to server)

# Example: Chat client with Socket

```
public class SocketChatClient extends Thread {
   …
   public static void main( String[] args ) {
      SocketChatClient scc = new SocketChatClient(IP_ADDR, PORT);
      scc.start();
      while ( true ) {
         Socket s = client_socket.accept( );
         new ClientServiceThread( s ).start( );
      }
   }
}
```

# Example: Chat client with Socket (cont'd)

```
class ClientServiceThread extends Thread {
   Socket s;
   public ClientServiceThread( Socket p ) { s = p; }

   public void run( ) {
     ObjectInputStream ois = new ObjectInputStream( s.getInputStream() );
     String cmd = (String) ois.readObject();
     if ( cmd.equals("msg") )
          SocketChatClient.this.receive((Message) ois.readObject());
     else
          System.err.println("Unknown command!");
       ois.close(); s.close();
     }
}
```

# Discussion of Socket Solution

- Communication has to be coded explicitly
  - Commands, parameters, results, exceptions
- No static type safety
- Loss of object identities
- Significantly different from local solution

| | |
|---|---|
| server.broadcast(“Hello”); | Socket s = **new** Socket(host, port);<br>ObjectOutputStream oos = **new** ObjectOutputStream( s.getOutputStream( ) );<br>oos.writeObject( "broadcast" );<br>oos.writeObject( “Hello”);<br>oos.close();<br>s.close(); |

# Distributed Programming

- Sockets
- **Serialization**
- Remote Objects

# Serialization and Deserialization

- Serialization transforms object structures into a **sequential format**
- Sequential format is **independent of memory addresses**
- Serialization is used
  - To save object structures persistently
  - To exchange object structures between address spaces
- Often called marshalling and unmarshalling

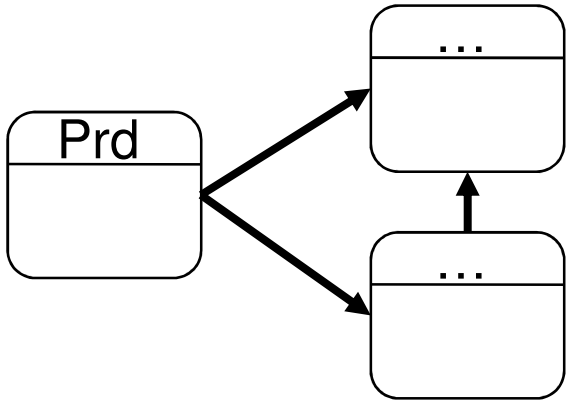
# Object Streams in Java

- Serialization needs access to private fields
  - Interface Serializable is used as tag
- Object streams serialize
  - Values of primitive types
  - Serializable objects
- All objects except strings are written only once

```
interface Serializable { }
```

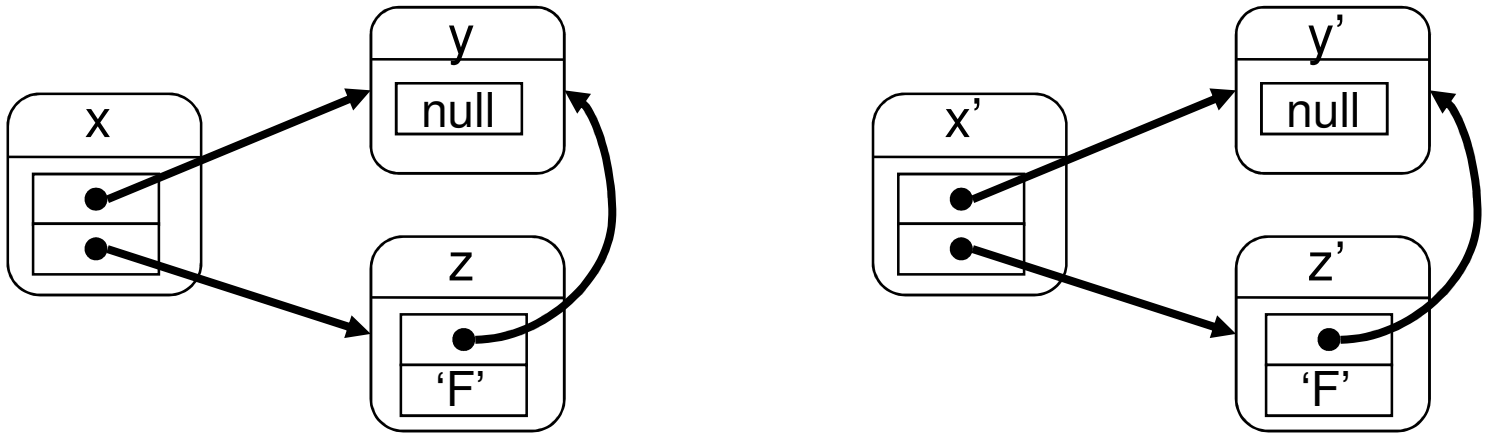
```
class ObjectOutputStream
        extends OutputStream
        implements … {

  void writeObject( Object obj )
      throws IOException { … }
  … }
```

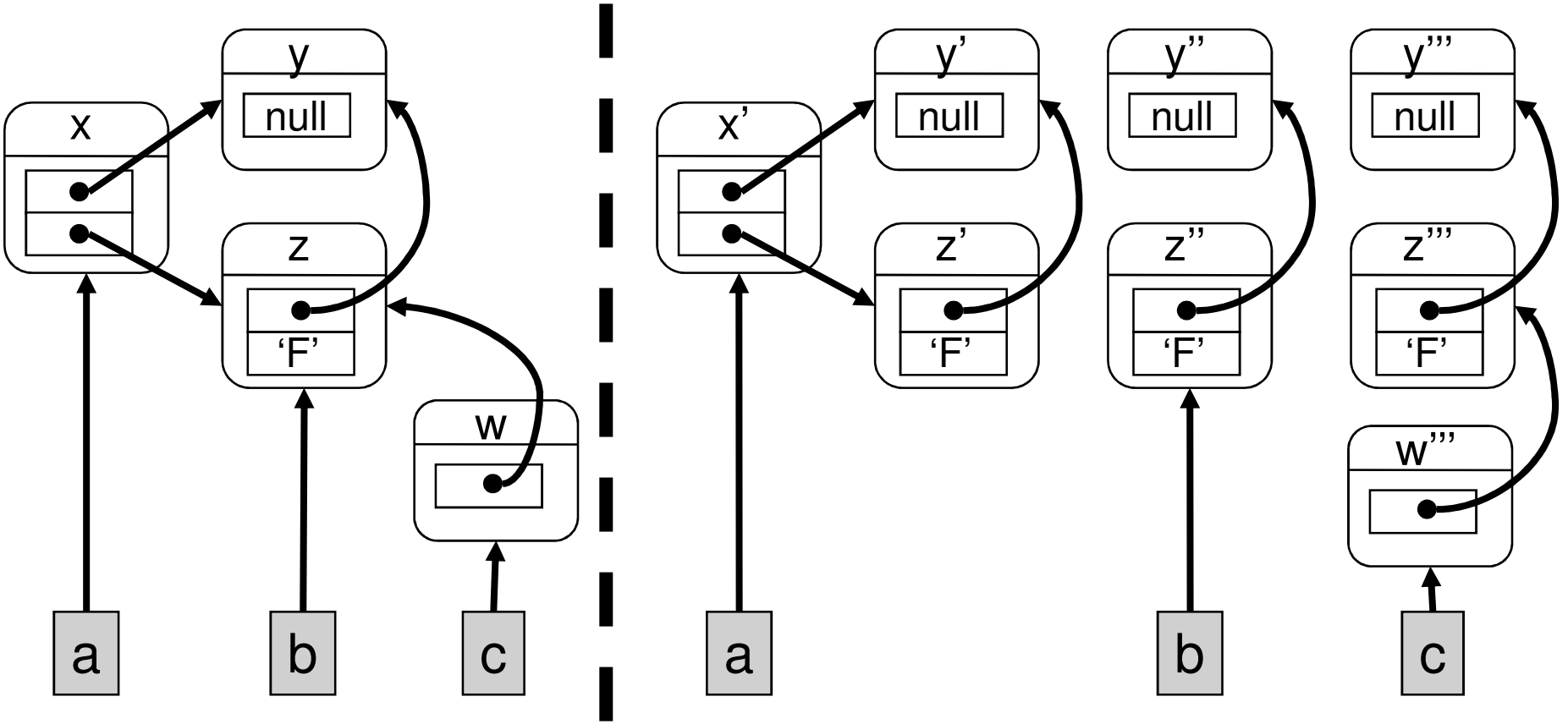


# Object Identity

- Serialization and deserialization
  - **Preserve "relative" object identities** within object structures (except strings)
  - **Do** (of course) **not preserve absolute object identities**
- Consequences for **side-effects** and comparison



# Aliasing

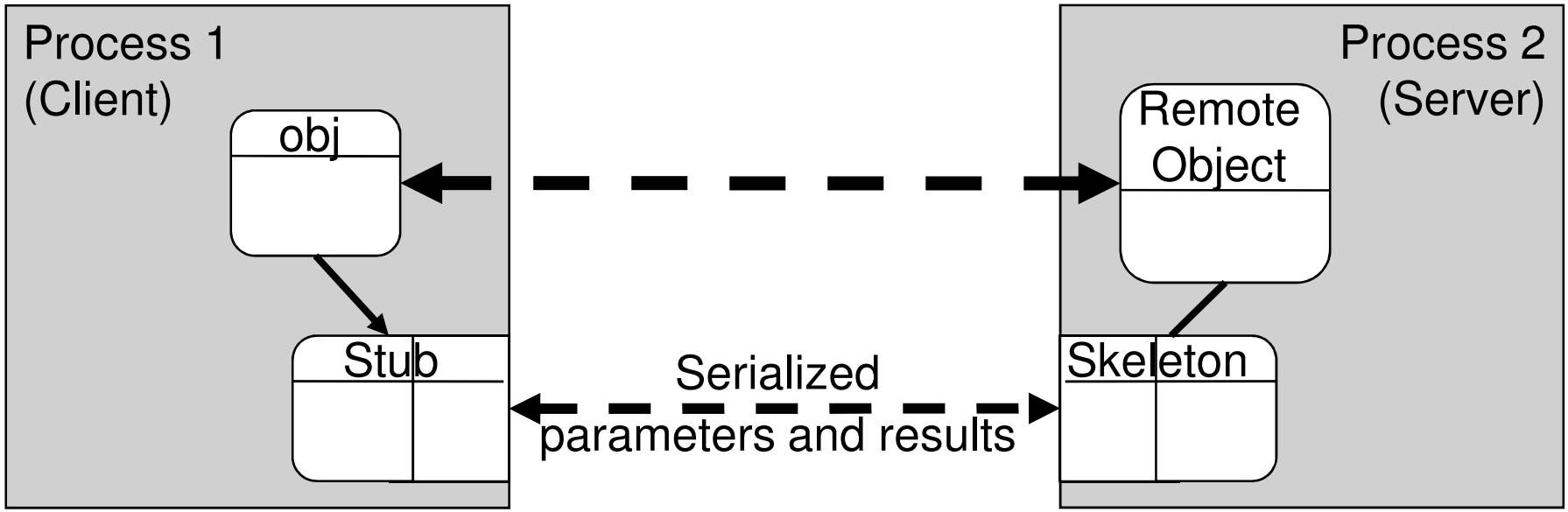



- Only reachable objects are serialized
- Serialization can destroy aliasing properties

# Distributed Programming

- Sockets
- Serialization
- **Remote Objects**

# Stubs and Skeletons




- Remote objects are represented locally by stubs
- Stubs and skeletons provide communication
- Code for stubs and skeletons are generated automatically

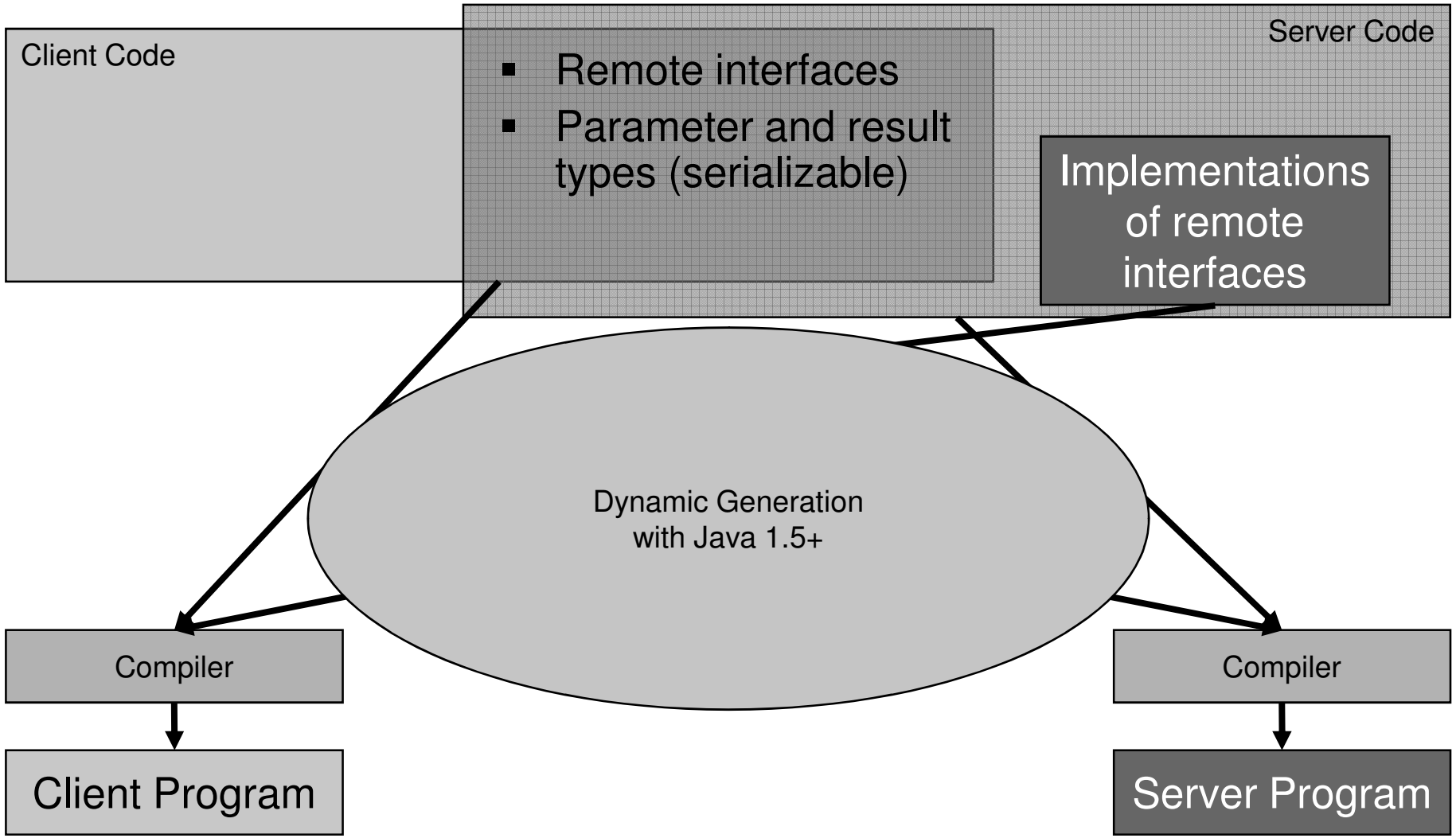
# Remote Interfaces

- Methods that are available remotely must be specified in an interface that extends Remote

```
interface Remote { }
```

```
interface ServerInterface extends Remote {
  void register(ClientInterface c)
       throws RemoteException;
  void sendMessage(String msg)
         throws RemoteException;
}
```

# Programming with Remote Objects



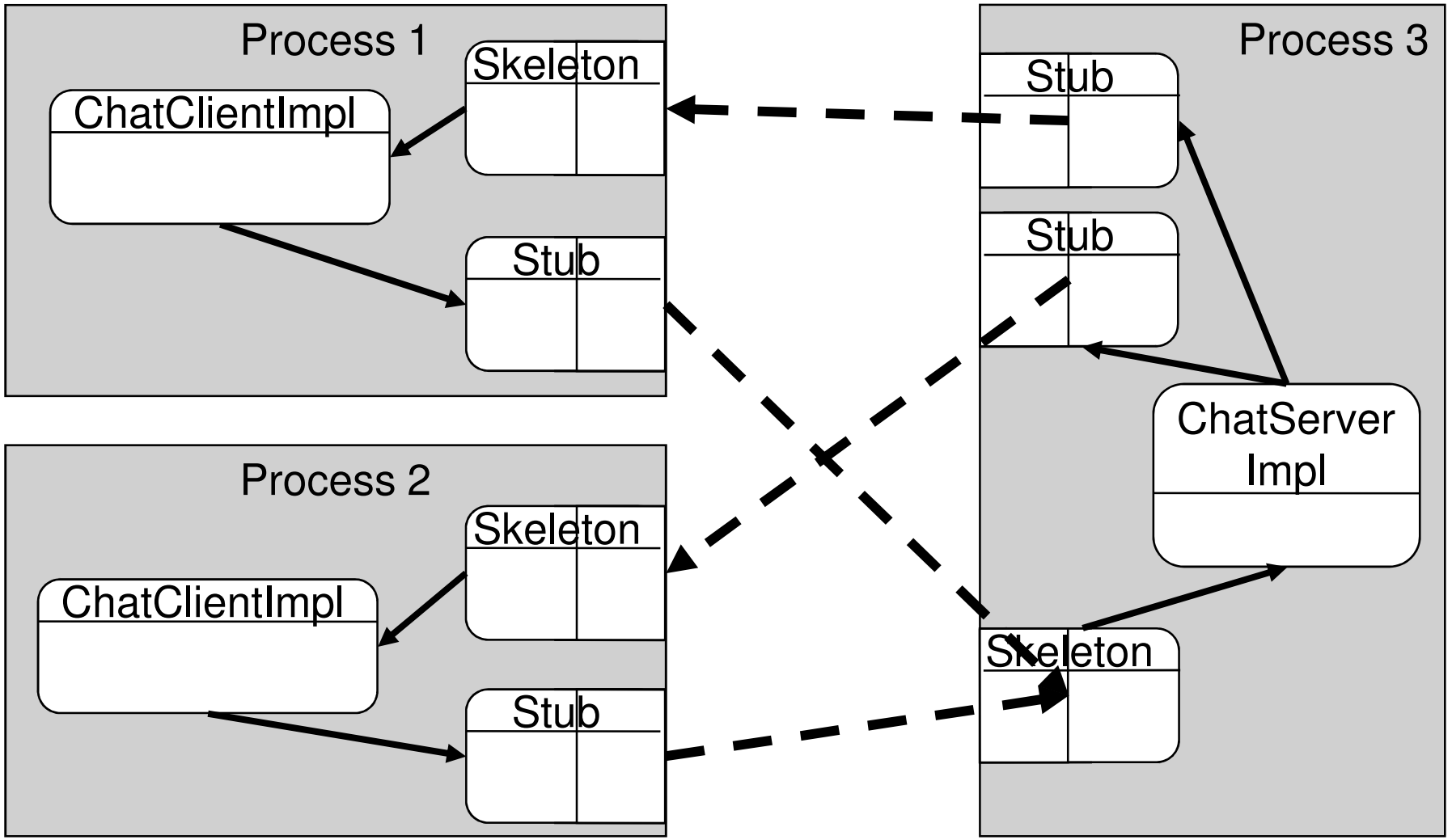
# Remote Method Invocation

- Implementations of remote objects extend UnicastRemoteObject (or similar classes)
- Constructors may throw exception

- Remote interfaces can be used to invoke methods of remote objects
- Communication is transparent except for
  - Error handling
  - Problems of serialization

- Coding is almost identical to local solutions

# Process Interaction of Chat application



# Finding Objects

- References to remote objects are obtained through a **name service**
- **Name server** (rmiregistry) must run on server site
  - Offers service at a certain port
  - Communication with name server is handled by API

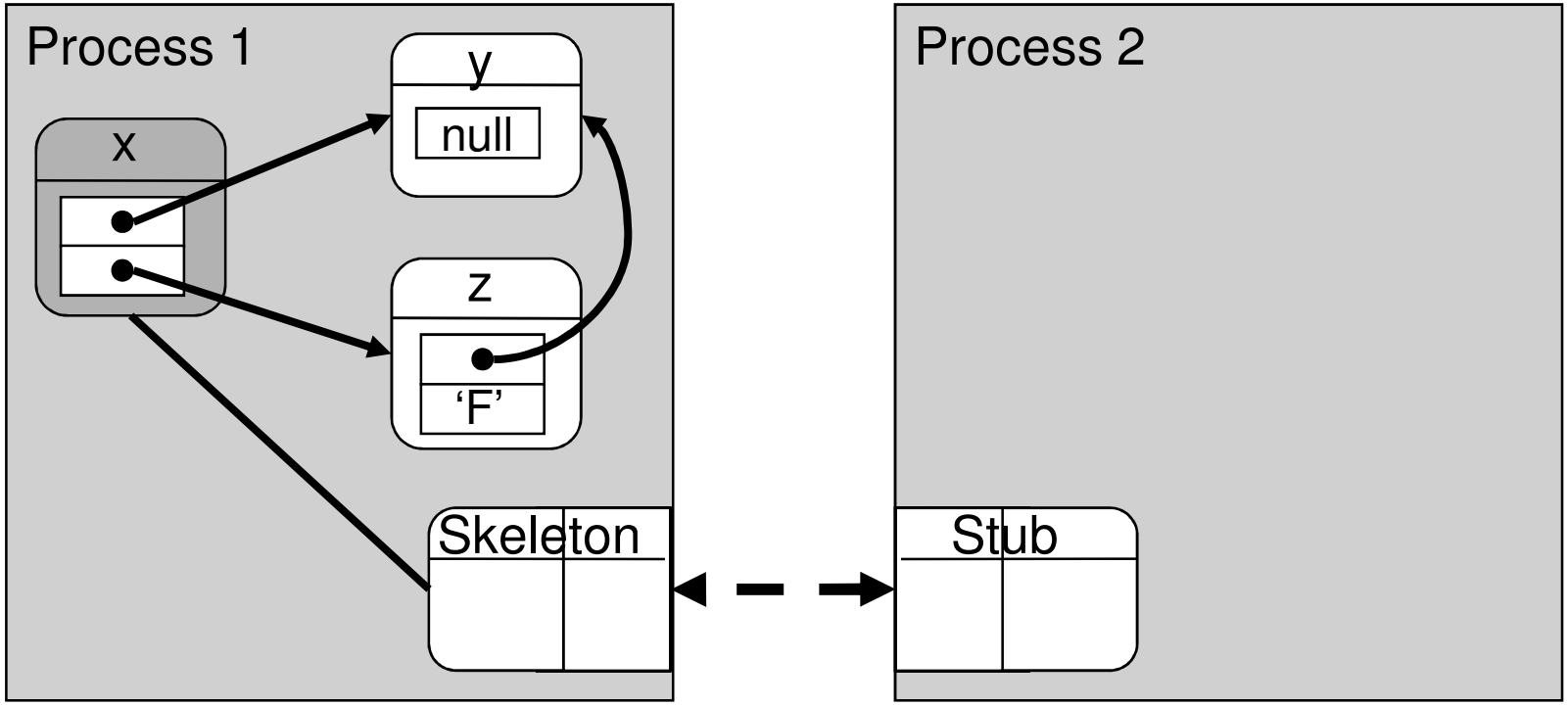
```
class Naming {
  static Remote lookup( String name )      throws …   { … }
  static void rebind( String name, Remote obj )   throws …   { … }
  …
}
```

# Using RMI in Java

1. Define **interface of remote object** (extends Remote)
2. Define **implementation of remote object** (extends UnicastRemoteObject)
3. Start **name server** (rmiregistry)
4. Server program **registers remote objects** at registry
5. Client programs **retrieve remote references** through URL (name of computer and name of remote object)

# Serialization of Remote Objects

- Remote objects are not serialized when passed as parameters or results
- Passing remote objects lead to remote references



# Remote Objects: Summary

- Remote objects can be accessed similarly to local objects
- Remote objects are accessed through Remote interfaces
  - No field access
  - Only public methods
- Communication is transparent except for
  - Error handling
  - Problems of serialization

# Further references

- Slides of *Konzepte objektorientierter Programmierung*
  http://pm.ethz.ch/teaching/as2008/KOOP

- Sun's RMI Tutorial
  http://java.sun.com/docs/books/tutorial/rmi/index.html

- URLClassLoader: load classes from given URLs
  http://java.sun.com/javase/6/docs/api/java/net/URLClassLoader.html

- Reflection: examine and manipulate running program
  http://java.sun.com/docs/books/tutorial/reflect/index.html

# Task: Implement Distributed Chat application

- Create Remote interfaces for server and client side
- Server side:
  - Register server on a given port (and localhost)

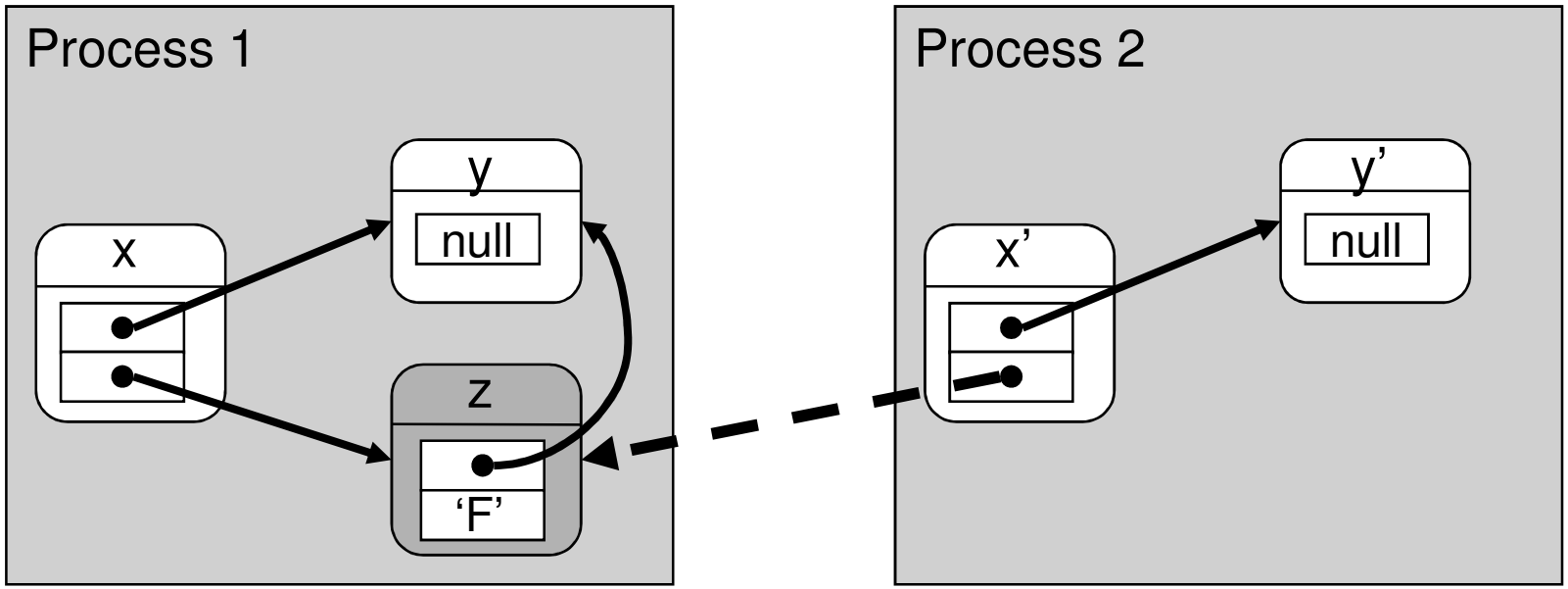
    LocateRegistry.createRegistry(PORT). bind(SERVICE, server)
  - Implement method for registering new clients
  - Implement method for broadcasting messages to registered clients
- Client side:
  - Register application to server

    LocateRegistry.getRegistry(PORT).lookup(SERVICE)
  - Implement method for receiving broadcast messages
  - Implement method for sending messages to server

# BACKUP

# Details of Serialization

- Remote objects are not serialized when passed as parameters or results
- Rule also applies to remote objects that are referenced indirectly



# Details of Serialization: Aliasing

- Parameters of *one* remote method invocation are serialized together
- Aliases do not lead to duplicate objects