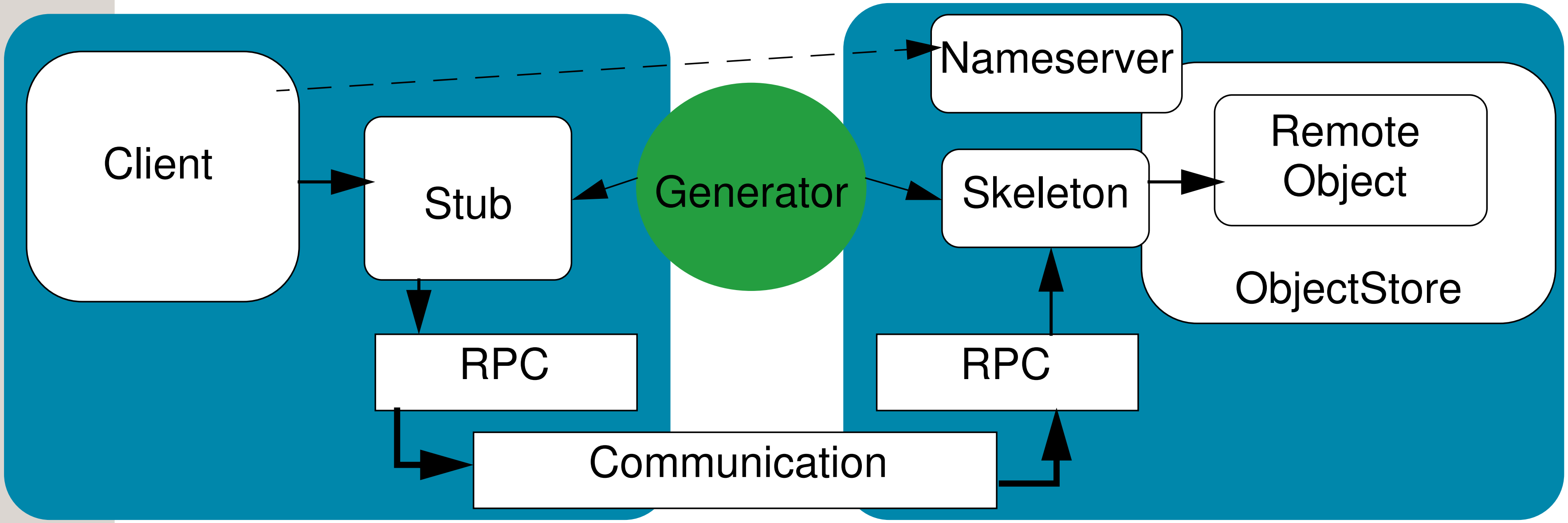
39 Object Request Brokers

- invoke methods at remote objects (objects that run in another JVM)
- example ORBs: RMI, JavaIDL

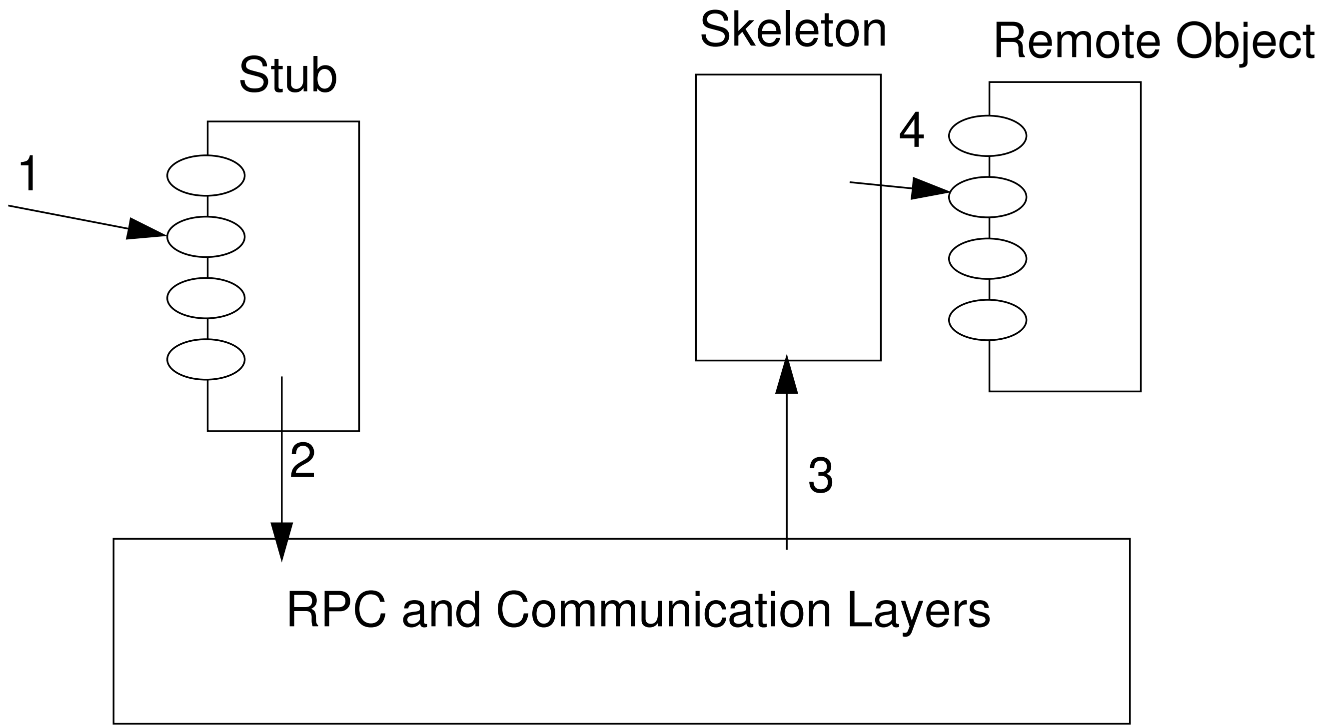
40 Components of an ORB

- *Communication Layer*: transfers data between hosts
- *RPC Layer*: defines method invocation semantics and marshalling
- *Object Store*: lifecycle management of remote objects
- *Stub and Skeleton Generator*: create code for stubs and skeletons
- *Nameserver*: find object by name



40.1 Stubs and Skeletons

- Stub: Proxy for remote object
- Skeleton: Invokes methods at remote object depending on the method ID



40.1.1 Stub

- similar to a proxy for the remote object; implements the remote interface
- pack method call into a request packet:
  - object ID, method ID, method parameters
- uses the RPC layer to send request
- transform returned object into appropriate type and return
- example generated method code (without exception handling)

```
public int deposit(int param0) {
    Object[] parameters = new Object[1];
    parameters[0] = new Integer(param0);
    Request req = new Request(ctx, oid, 9, parameters);
    Object ret = req.send();
    return ((Integer)ret).intValue();
}
```

40.1.1 Stub

- example generated stub class

```
package test;
import orb.*;
public class AccountImpl_Stub implements test.Account {
  int oid;
  ClientContext ctx;
  public AccountImpl_Stub(int oid, ClientContext ctx) {
    this.oid = oid;
    this.ctx = ctx;
  }
  // generated methods
  // ...
}
```

- ClientContext should contain information that is common to all stub objects

40.1.2 Skeleton

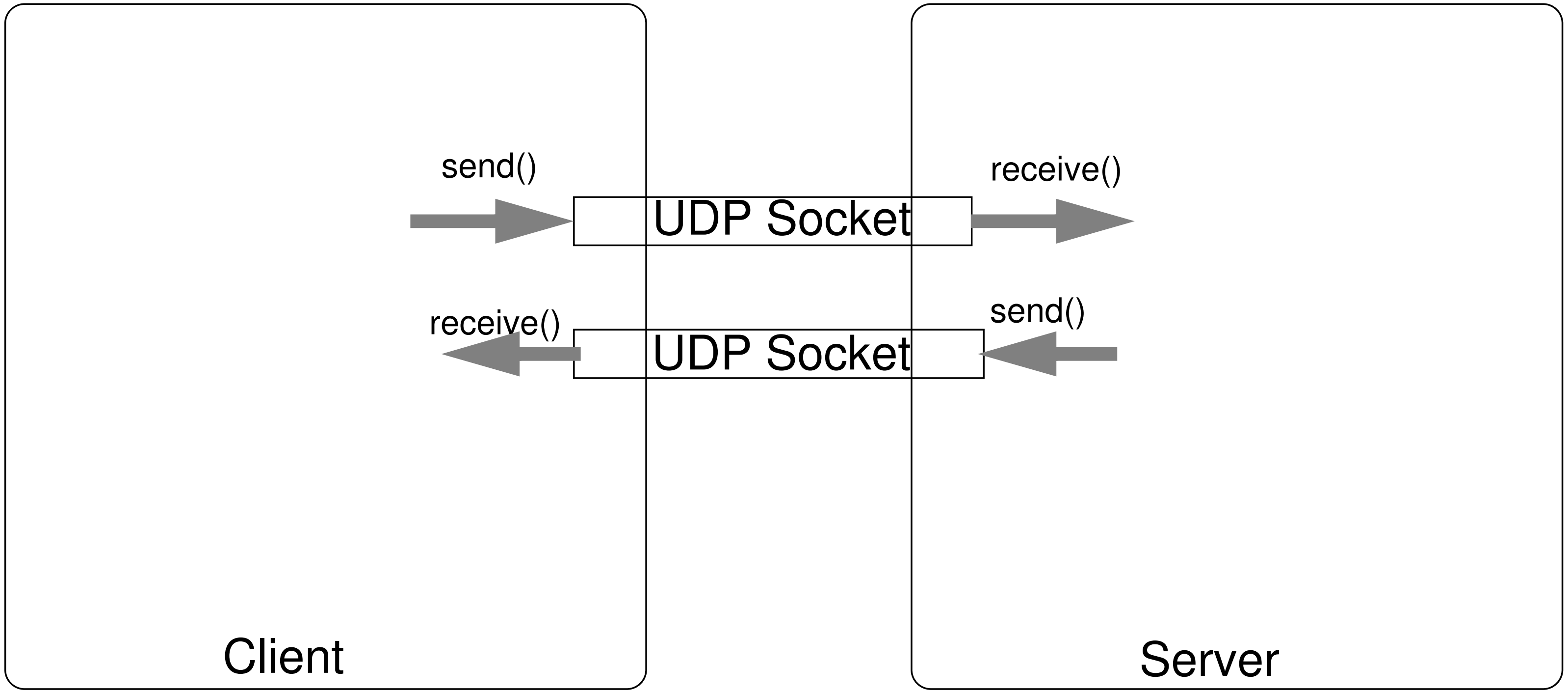
- invoke method at "real" object, given
  - object reference
  - method ID
  - parameters

40.1.3 Skeleton example

```
package test;
import orb.*;
public class AccountImpl_Skel  implements Skeleton {
  AccountImpl  object;
  public AccountImpl_Skel() {}
  public void init(int oid, Object obj) {
    this.oid = oid;
    this.object = (AccountImpl) object;
  }
  public Object invoke(int mid, Object[] parameters) throws
                                                   Exception {
    switch(mid) {
        ...
      case 9: {
          return new Integer(
      object.deposit(((Integer)parameters[0]).intValue()));
      }
    }
  }
}
```

40.2 Communication Layer

- data transfer between hosts
- use **`DatagramSocket`** (UDP)

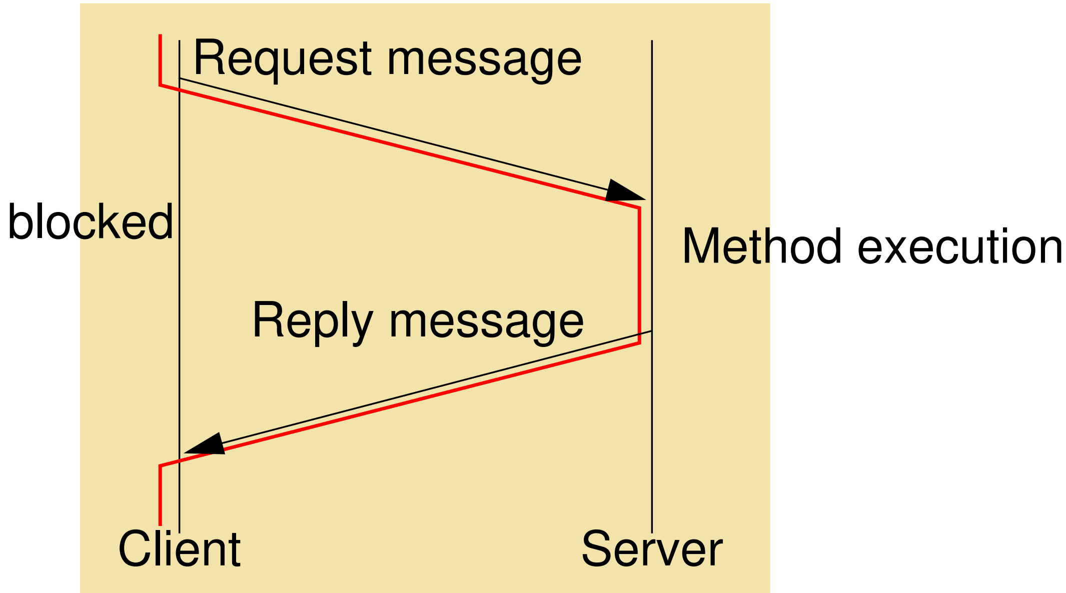


40.3 RPC Layer

- handles forwarding of method invocations
- is used by the stubs/skeletons
- uses the communication layer to ship bytes

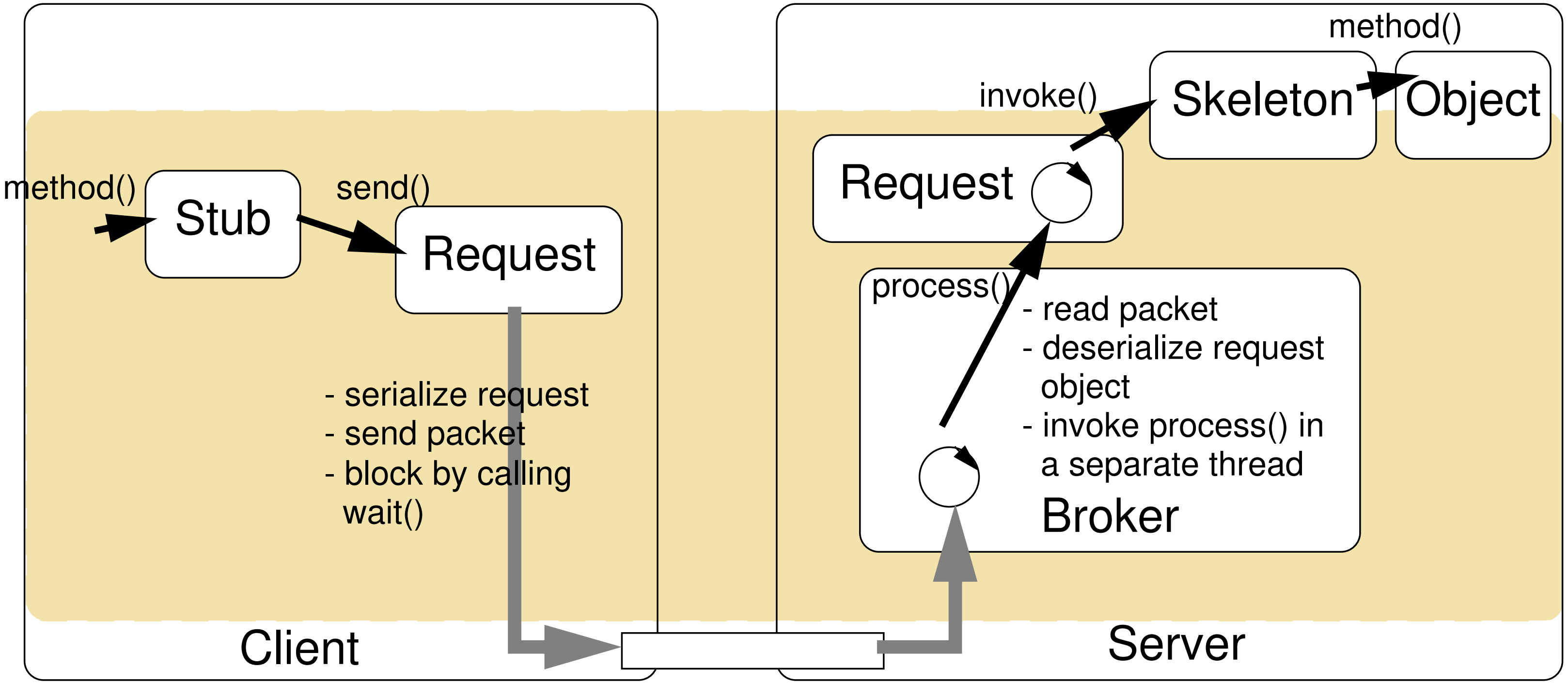
40.3.1 RPC

- simplest RPC is a primitive request/reply protocol



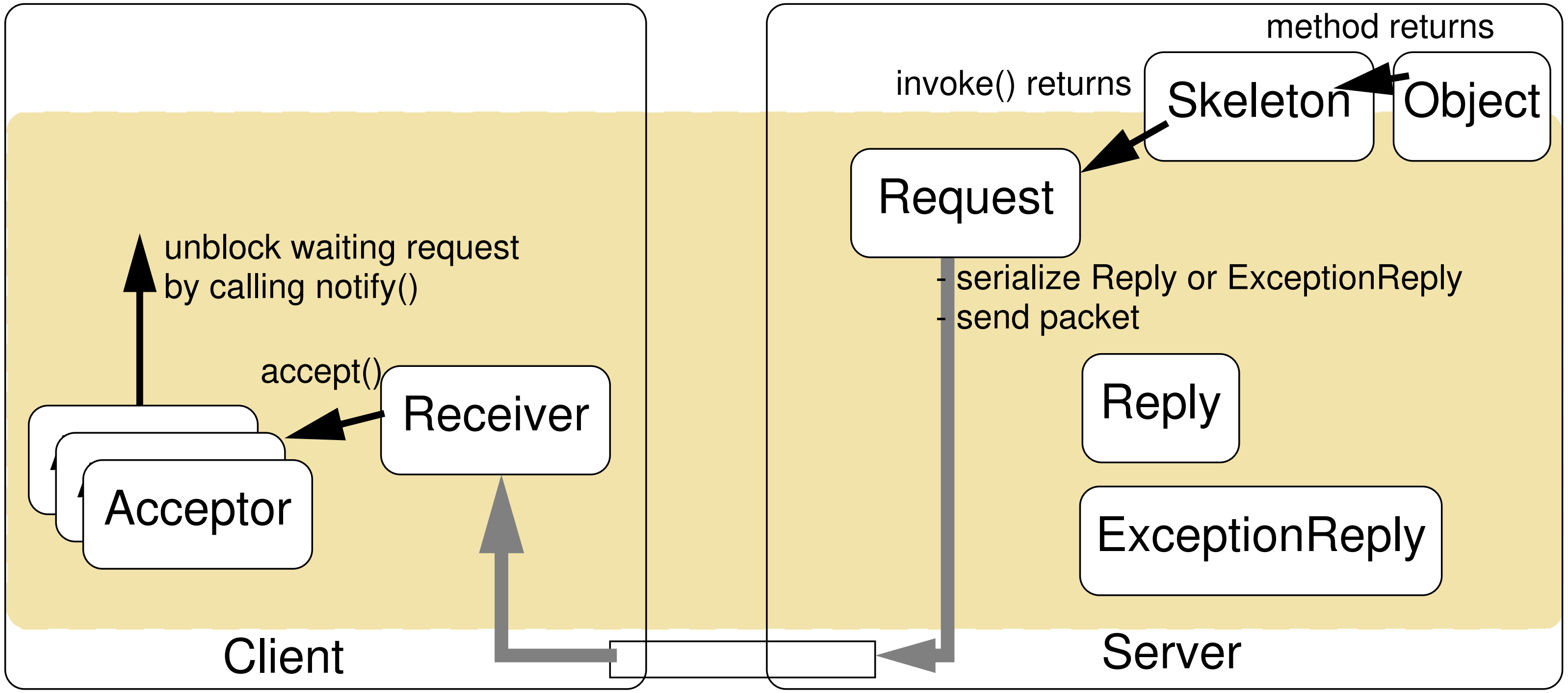
40.3.2 Request

- handles forwarding of method invocations
- is used by the stubs/skeletons
- uses the communication layer to ship bytes
- structure of the RPC layer:



40.3.3 Reply

- handles forwarding of method invocations
- is used by the stubs/skeletons
- uses the communication layer to ship bytes
- structure of the RPC layer



40.3.4 Marshalling

- RPC layer transfers parameters in request packet and return value in reply packet == marshalling
- copy all parameters to the server (better would be: send reference if parameter implements a remote interface)
- use ObjectStreams/ByteArrayStreams/Datagrams to transfer objects

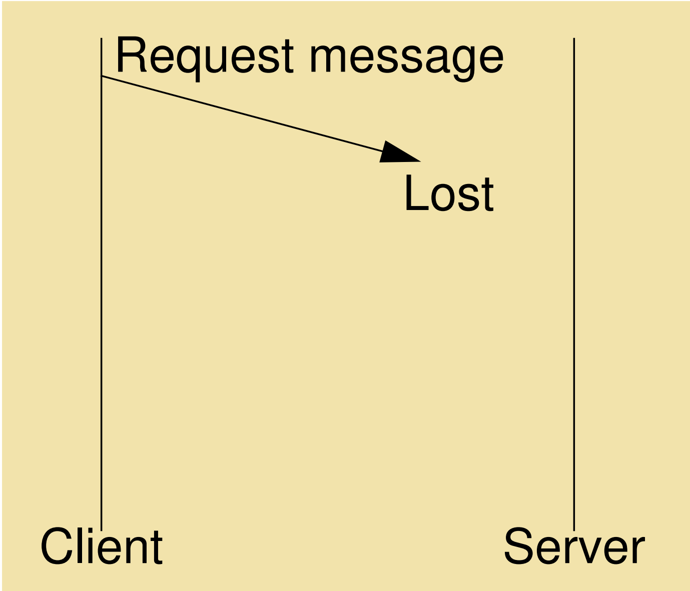
```
ByteArrayOutputStream stream = new ByteArrayOutputStream();
ObjectOutputStream out = new ObjectOutputStream(stream);
out.writeObject(...);
byte[] buf = stream.toByteArray();
DatagramPacket packet = new DatagramPacket(buf, ... );
```

40.3.5 Failure Handling

- implements a certain invocation semantics
  - exactly once
  - at least once
  - at most once
  - last of many
  - ...
- depends on the service quality of the communication layer
- cope with communication failures:
  - lost packet
  - non-FIFO packet order
  - duplicated packet
  - modified packet

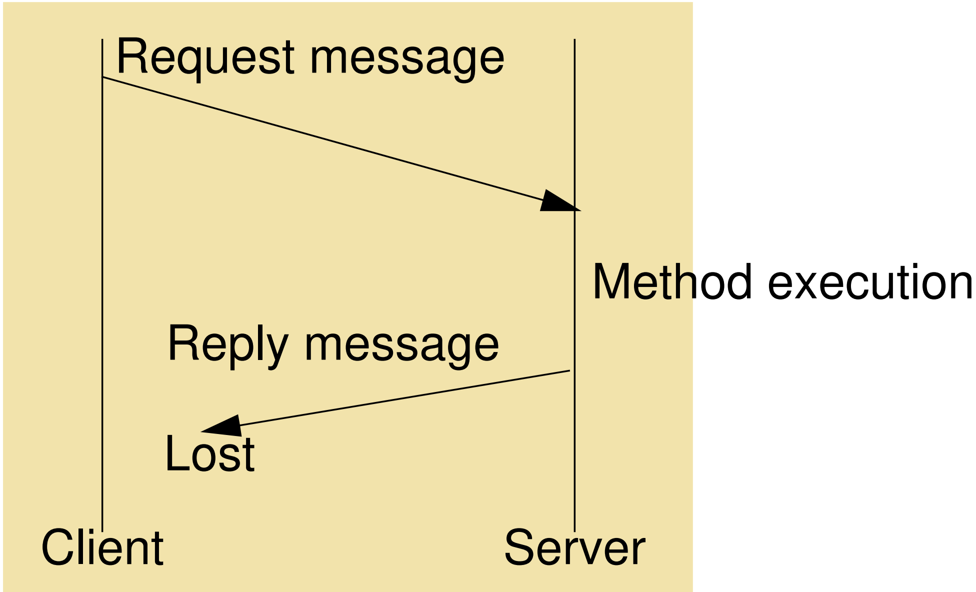
Failure Handling

- Communication failures may lead to the following problems
  - loss of request message



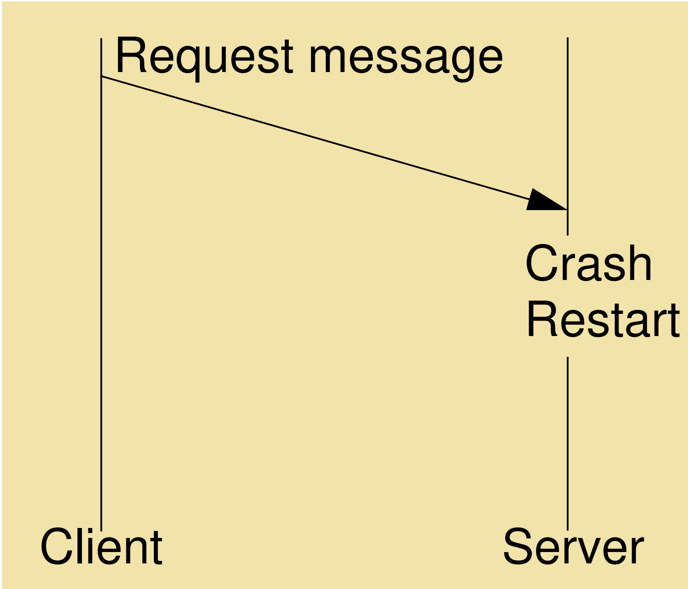
40.3.7 Failure Handling

- Communication failures may lead to the following problems
  - loss of reply message



40.3.8 Failure Handling

- unsucessful execution of the request



40.3.9 Failure Handling

- approximation of exactly once:
  - ◆ to cope with lost request messages resend packet after timeout
  - ◆ to avoid duplicated invocations when resending use request ID that is the same for the original request and all retransmissions
  - ◆ the server uses a reply buffer in case replies get lost (to avoid an additional execution of the request); the reply buffer can be implemented using a Hashtable that maps from request IDs to Reply objects
  - ◆ buffered replies can be deleted when the server receives the next request from this client thread
  - ◆ coping with server crashes is a bit more complicated ... so we ignore it

40.4 Object Store

- Interface:
  - **`int registerObject(Object obj)`**: returns unique object ID
  - **`Object lookupByID(int oid)`**: find object given an object ID
- Implementation technique:
  - use **`java.util.Hashtable`** to remember mapping between ID and object reference (hint: first create an **`Integer`** wrapper for the oid)

40.5 Nameserver

- split into an ID finder and a proxy creator
- ID finder: map names to OIDs
  - ◆ **`void bind(String name, int oid)`**
  - ◆ **`int lookupID(String name)`**
- use **`Hashtable`**
- implement as remote object with OID 1
- a realistic nameserver would return references to stub objects instead of OIDs
- this requires that the class name of the stub is returned together with the OID
- proxy creator: find ID and class name; create proxy object
  - ◆ **`Object lookup(String name)`**
- the Nameserver loads the class and creates an instance of the class

That's it!

Now have fun with CORBA!