Konzepte objektorientierter Programmierung
– Lecture 9 –

Prof. Dr. Peter Müller

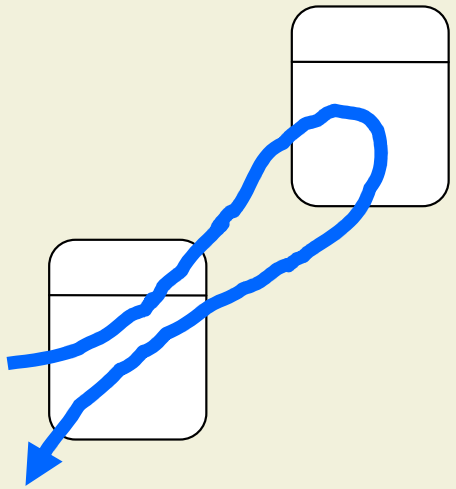
Software Component Technology

Wintersemester 05/06

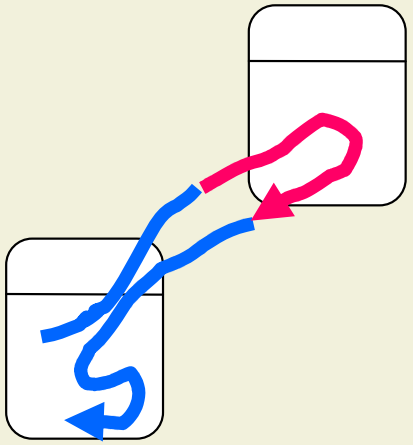
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Concurrency in OO-Programs

- Passive objects
  - Threads **pass through different objects** (by method invocations)
  - **Several threads** executed **on one object** possible

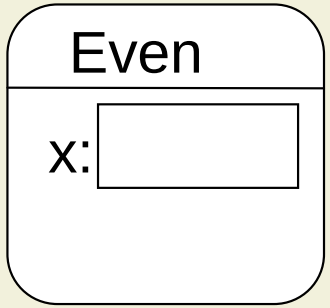


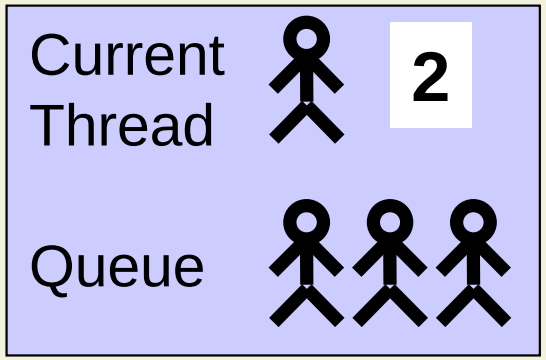
- Active objects
  - **Each object has** its own **thread**
  - Upon method invocation, the thread of the target object serves the request
  - **At most one thread** executed on one object



Object-Oriented Monitors

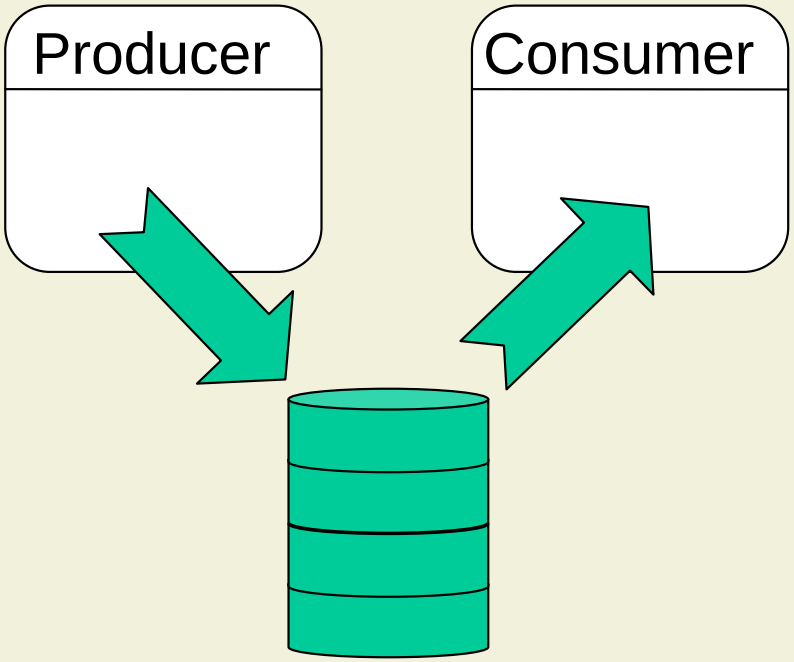
- Each object has a monitor
- Execution of synchronized methods requires lock of monitor
  - Lock is obtained upon invocation
  - Lock is released upon termination
  - Other threads have to wait
- Monitor keeps track of
  - Thread that has locked the monitor
  - Number of locks of this thread
  - Queue of blocked threads

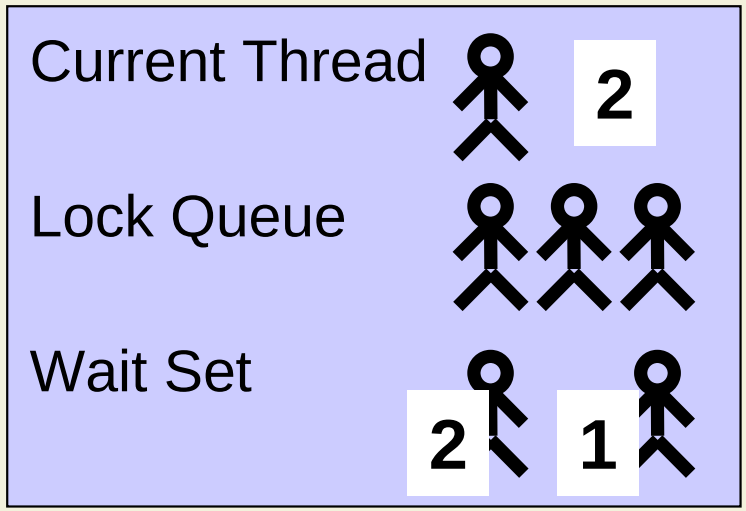




Wait and Notify

- Wait operation
  - Can be applied if a thread has locked a monitor
  - Puts thread into wait state and adds thread to wait set
  - Releases lock
- Notify operation
  - Can be applied if a thread has locked a monitor
  - Chooses one thread from wait set and re-enables it for scheduling





Agenda for Today

9. Distribution

- 9.1 Sockets
- 9.2 Serialization
- 9.3 Remote Objects
- 9.4 Middleware Architectures
- 9.5 Heterogeneous Environments

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

9. Distribution

Producer-Consumer Example

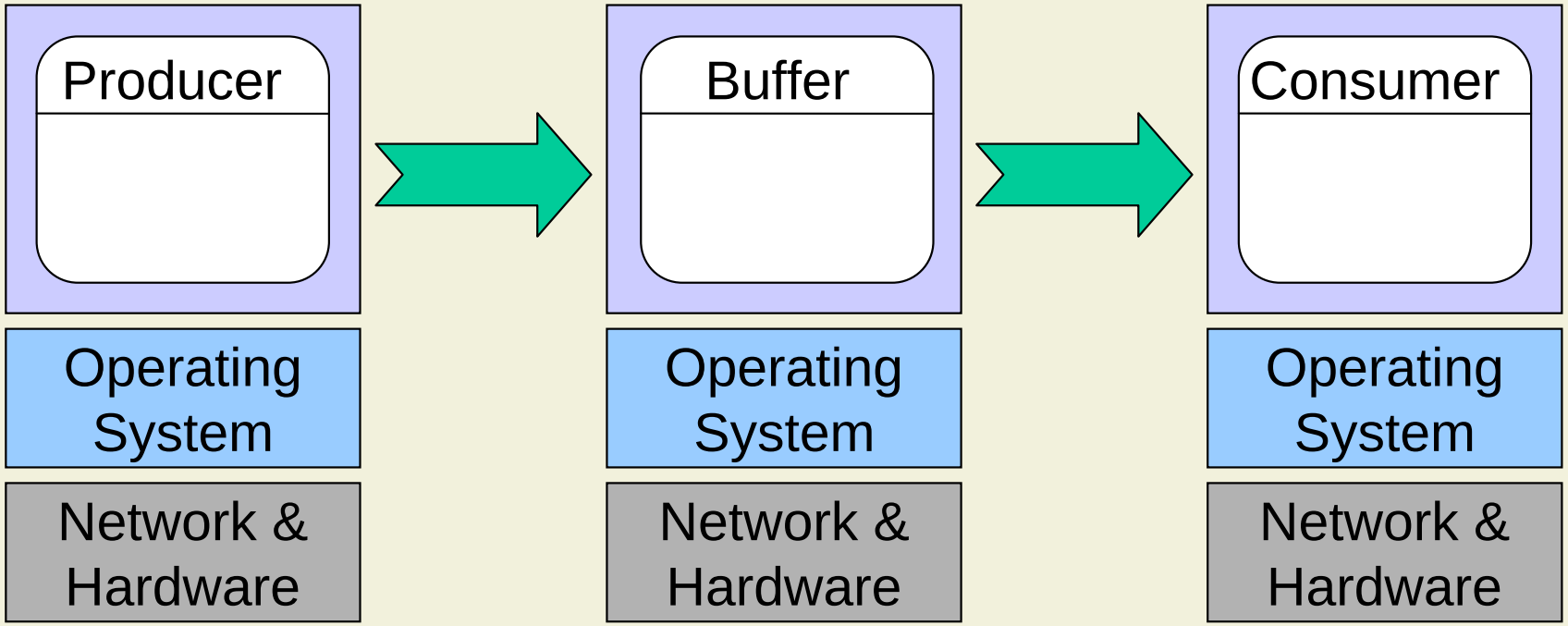
```
class Buffer {
  …
  synchronized void put( Prd p ) {
    if ( isFull( ) )       wait( );
    …
    notify( );
  }

  synchronized Prd get ( ) {
    if ( isEmpty( ) )   wait( );
    …
    notify( );
  }
}
```

```
class Producer extends Thread {
  Buffer buf;
  void run( ) {
    while ( true )
      buf.put( new Prd( ) );
  }
}
```

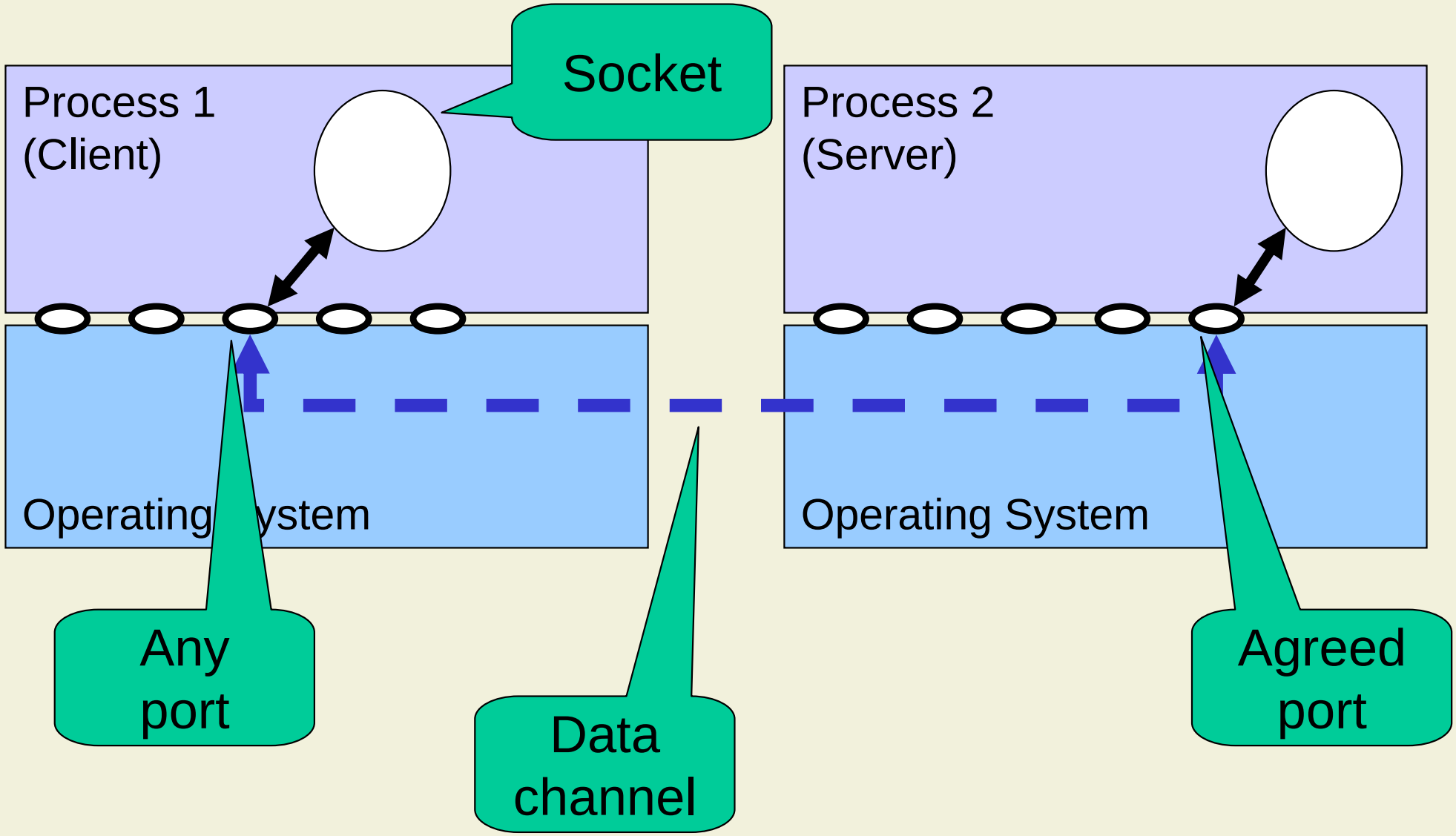
```
class Consumer extends Thread {
  Buffer buf;
  void run( ) {
    while ( true )
    buf.get( );
  }
}
```

Distributed Producer-Consumer Example

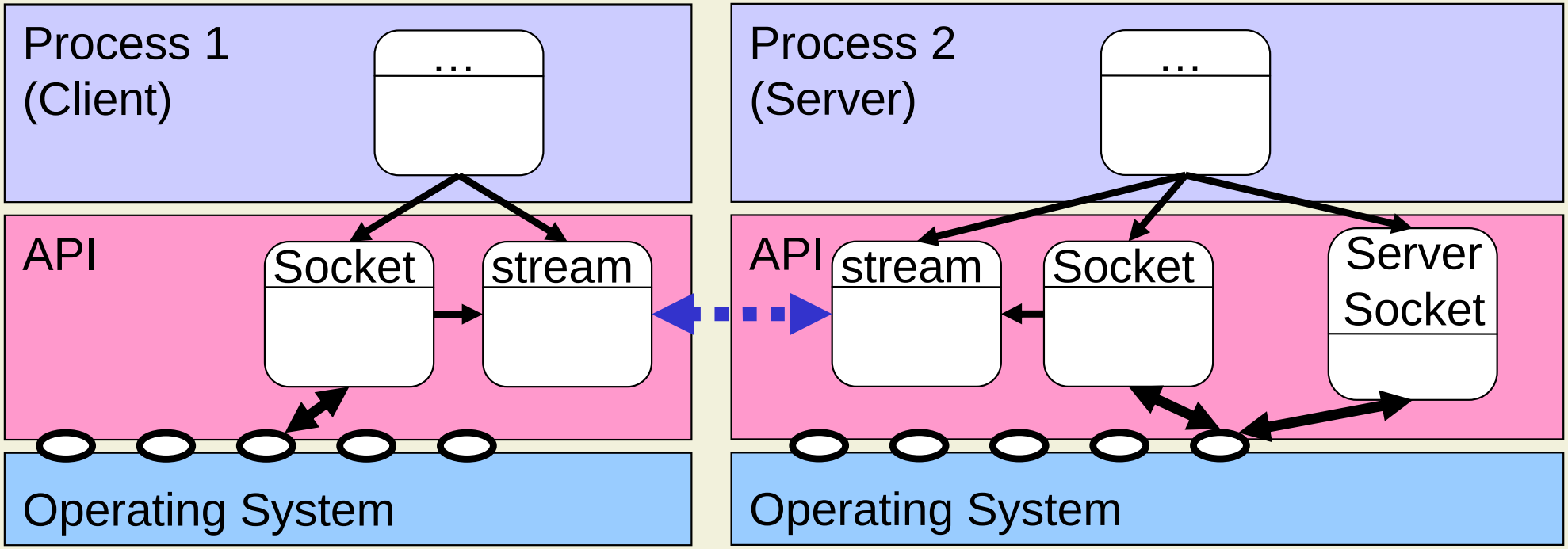


- How to access objects in different address spaces?
- How to communicate across process boundaries?
- How to pass parameters, results, and exceptions?

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

Example: Buffer with Socket

```
class Buffer {
  …
  synchronized void put( String p )  { … }
  synchronized String get ( )        { … }
}
```

```
class BufferServer {
  static Buffer buf = new Buffer( );
  static void main( … ) {
    ServerSocket ss = new ServerSocket( 1199 );
    while ( true ) {
      Socket s = ss.accept( );
      new ServiceThread( s ).start( );
} } }
```

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

Example: Buffer with Socket (cont'd)

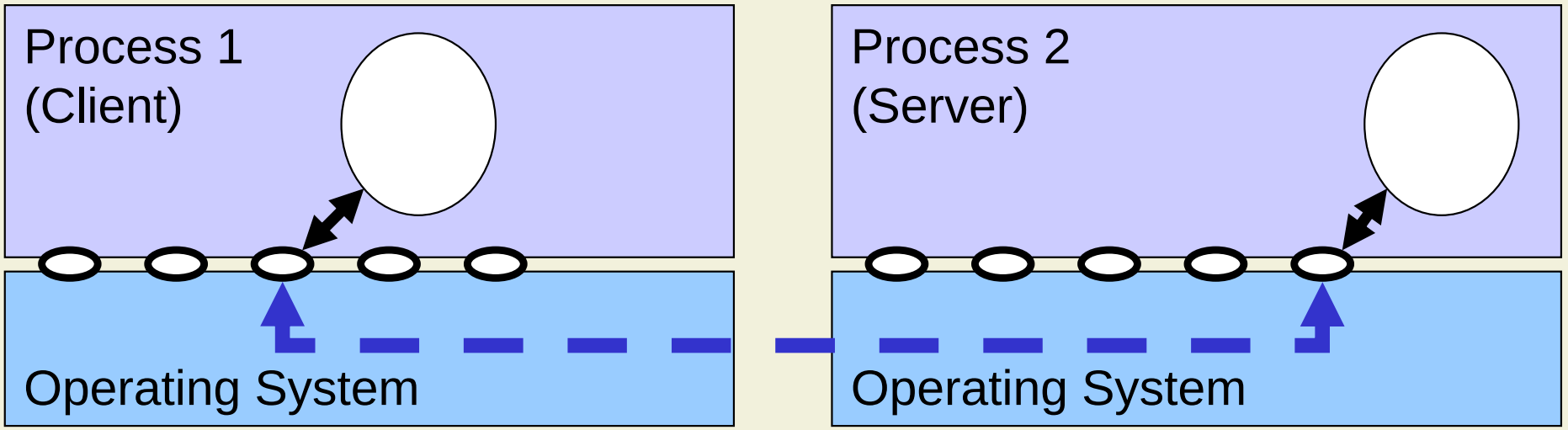
```
class ServiceThread extends Thread {
  Socket s;
  ServiceThread( Socket p ) { s = p; }

  void run( ) {
    BufferedReader br =
        new BufferedReader( new InputStreamReader( s.getInputStream( ) )
      );
    if ( br.readLine( ).equals( "put“ ) )
      BufferServer.buf.put( br.readLine( ) );
    else {
      PrintWriter pw = new PrintWriter( s.getOutputStream( ),true );
      pw.println( BufferServer.buf.get( ) );
} }
```

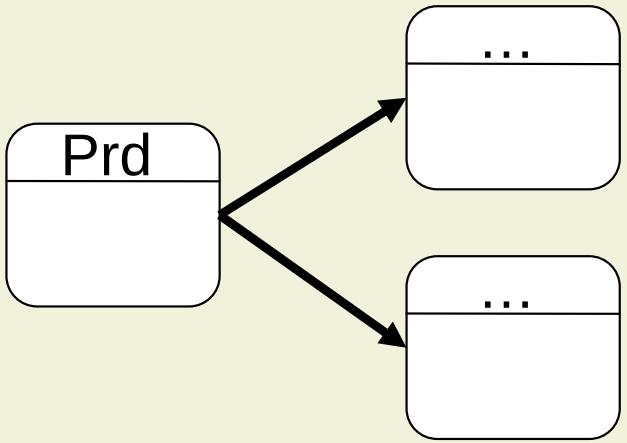
Example: Producer with Socket

```
class Producer extends Thread {
  String computer; int port;
  Producer( String c, int p ) { computer = c; port = p; }
  void run( ) {
    while ( true ) {
      Socket s = new Socket( computer, port );
      PrintWriter pw = new PrintWriter( s.getOutputStream( ),true );
      pw.println( "put“ );
      pw.println( "Product“ );
      sleep( 1000 );
    } }
  static void main( … ) { new Producer( “monkey",1199 ).start( ); }
}
```

Parameter Passing



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



9. Distribution

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

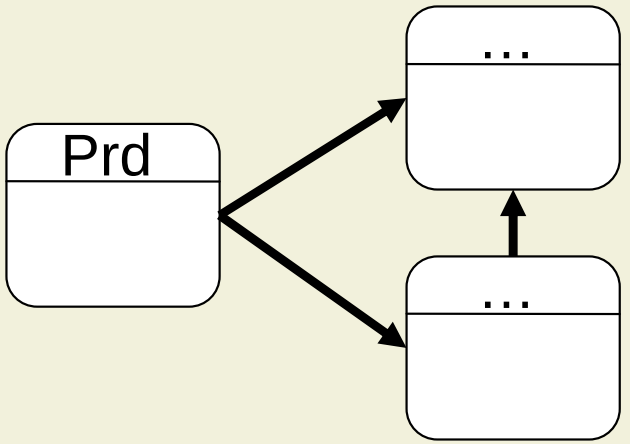
Object Streams in Java

- 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 { … }
 … }
```



Producer with ObjectStream

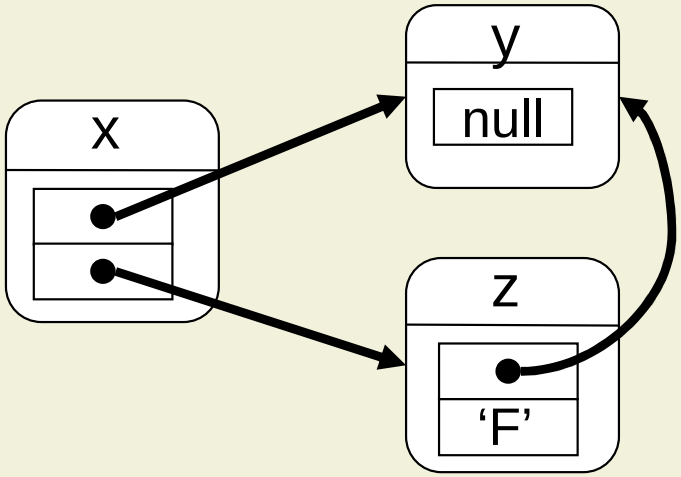
```
class Prd implements Serializable { … }
```

```
class Producer extends Thread {
  …
  void run( ) {
    while ( true ) {
      Socket s = new Socket( computer, port );
      ObjectOutputStream out =
        new ObjectOutputStream( s.getOutputStream( ) );
      out.writeObject( "put“ );
      out.writeObject( new Prd( ) );
      sleep( 1000 );
    }
} }
```

How Object Streams Work (Simplified)

Simplified Algorithm

```
proc serialize( o )
  if o is already serialized then
    lookup and write id of o
  else
    assign unique id to o
    enter o and id to table
    write id of o
    write fields of o
```

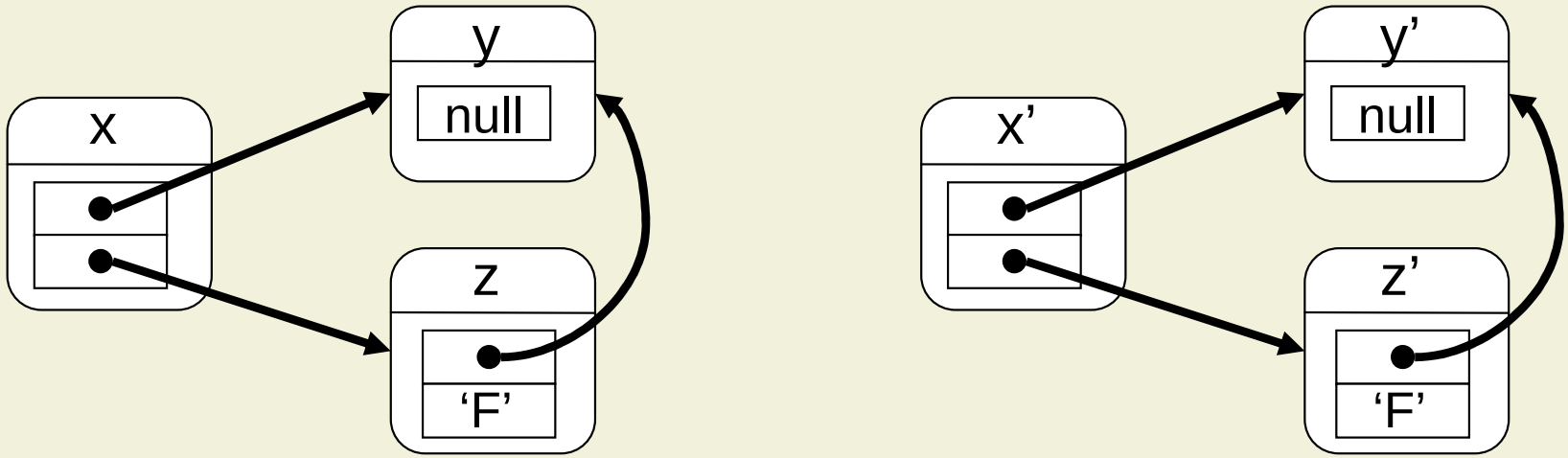


Object	Id
x	1
y	2
z	3

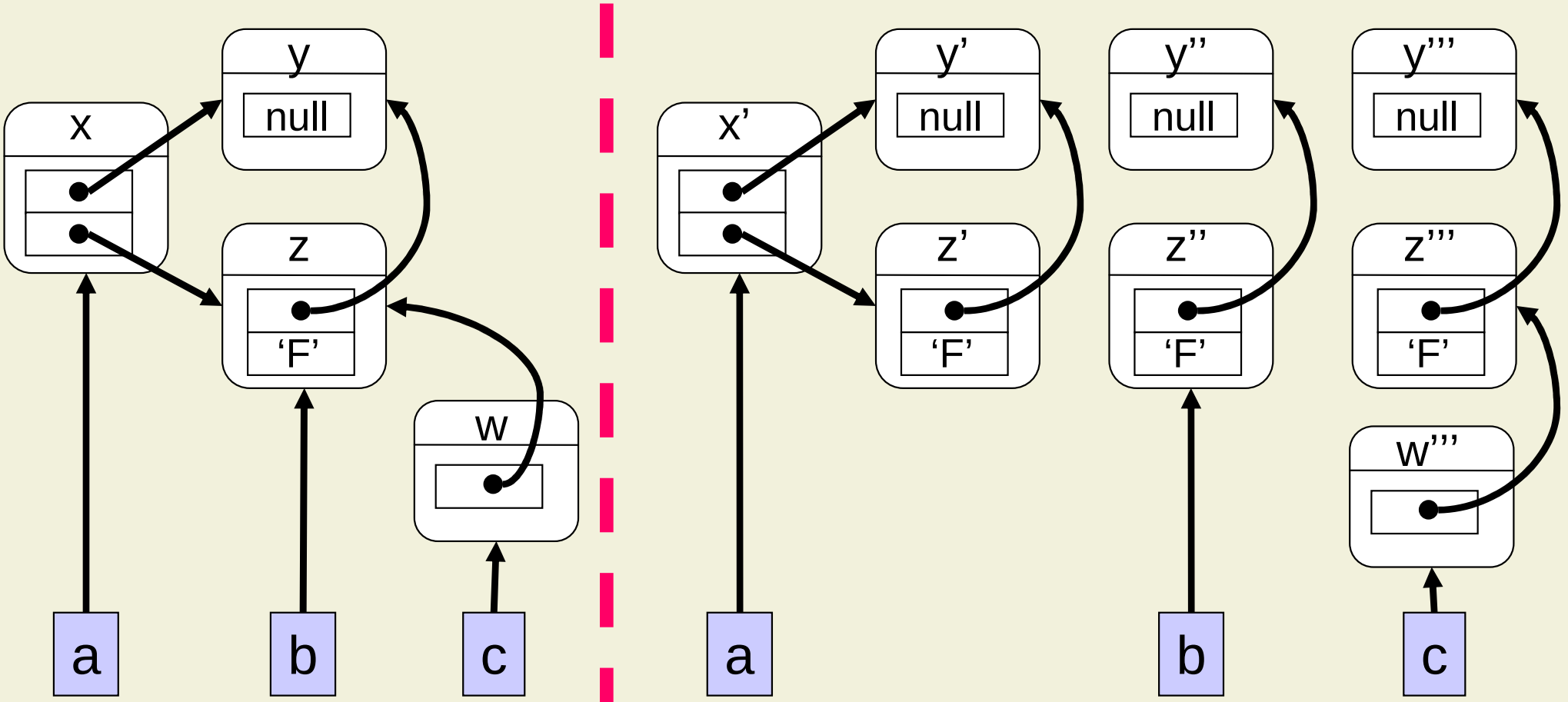
Stream: 1 – 2 – null – 3 – 2 – F

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

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

```
while ( true )
  buf.put( new Prd( ) );
```

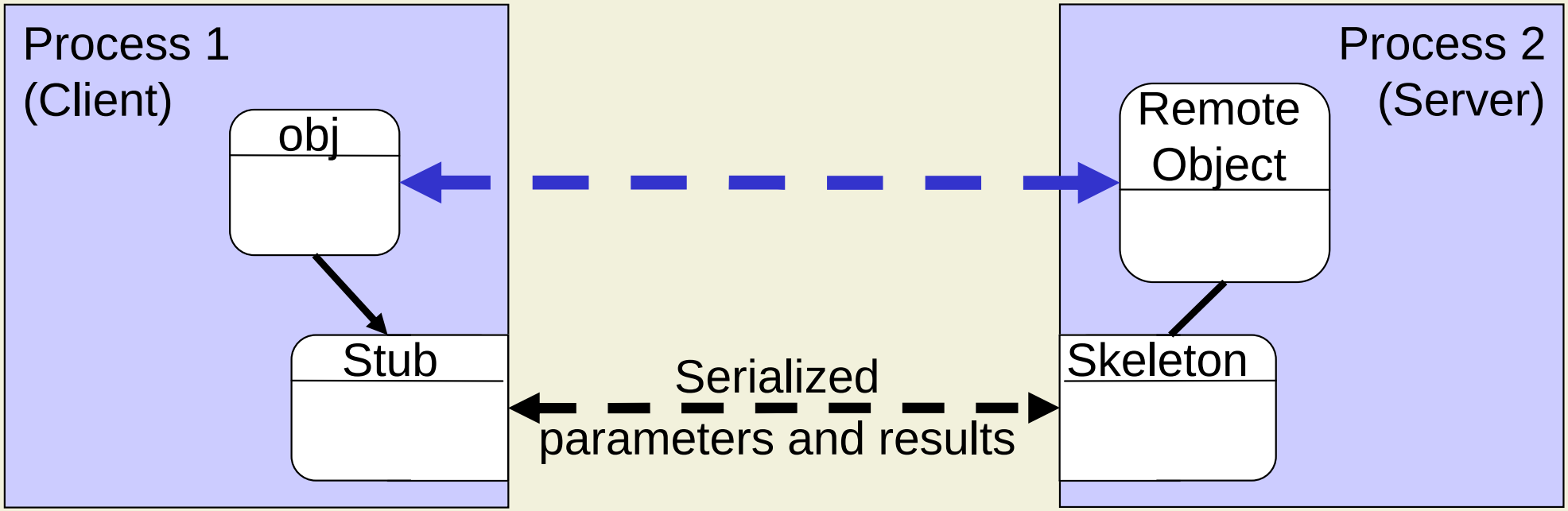
```
while ( true ) {
  Socket s = new Socket( computer, port );
  ObjectOutputStream out = new
   ObjectOutputStream( s.getOutputStream( ) );
  out.writeObject( "put“ );
  out.writeObject( new Prd( ) );
}
```

9. Distribution

The Holy Grail Of Remote Computing

[From Charlie Sawyer's course "*Java For Distributed Programming*", Harvard University, 2003]

Stubs and Skeletons



- Remote objects are represented locally by stubs
- Stubs and skeletons provide communication
- Code for stubs and skeletons can be generated automatically (RMI compiler rmic)

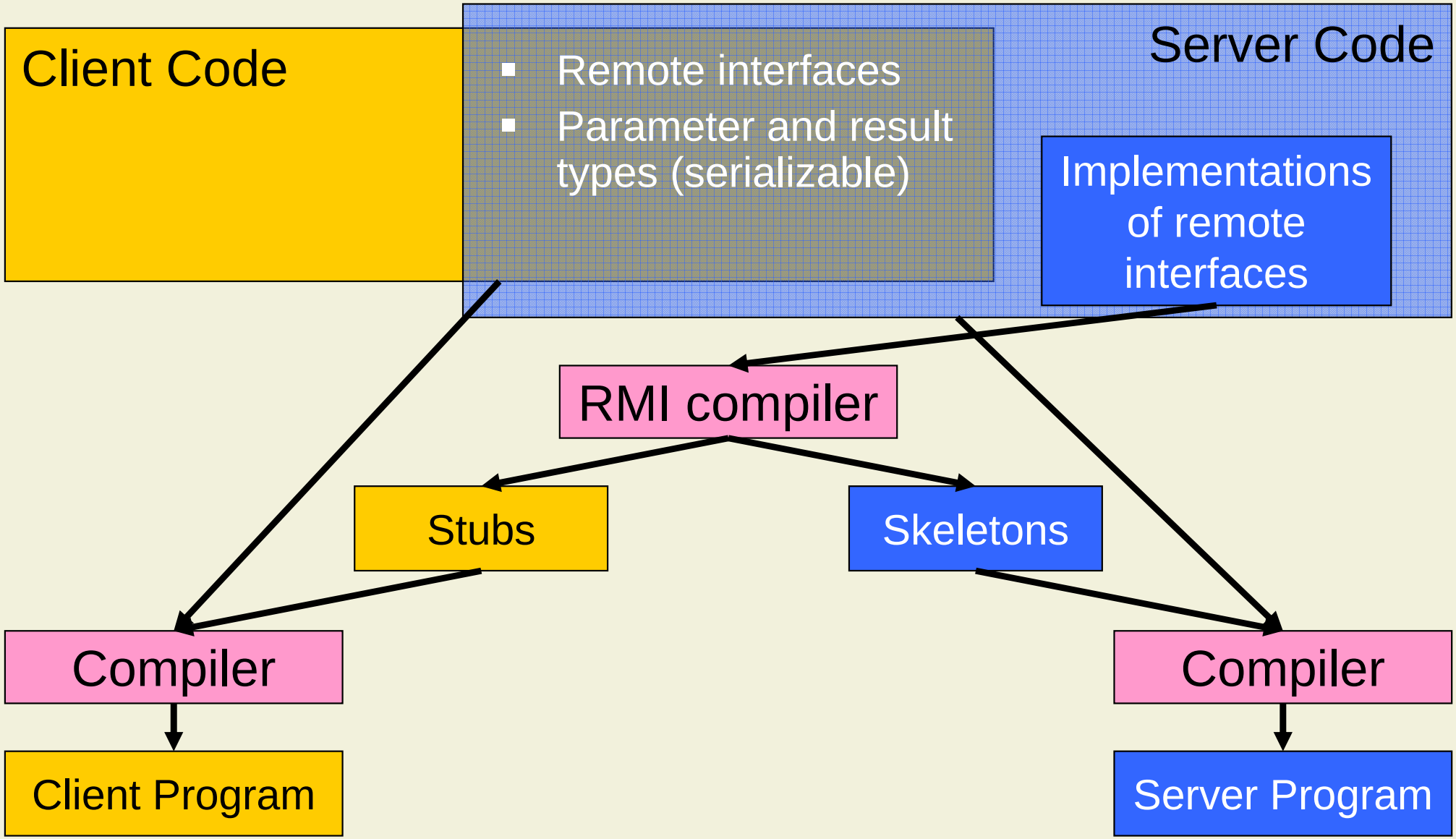
Remote Interfaces

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

```
interface Remote { }
```

```
interface Buffer extends Remote {
  void put( Prd p )
        throws RemoteException;
  Prd get( )
        throws RemoteException;
}
```

Programming with Remote Objects



Example: Remote Buffer Implementation

```
class BufferImpl
        extends UnicastRemoteObject
        implements Buffer {

  // fields identical to local solution;

  BufferImpl() throws RemoteException { }

  synchronized void put( Prd p )
    { // identical to local solution }
  synchronized Prd get( )
    { // identical to local solution }
}
```

- Implementations of remote objects extend UnicastRemoteObject (or similar classes)
- Constructors may throw exception
- Almost identical to class Buffer of local solutions

Remote Method Invocation

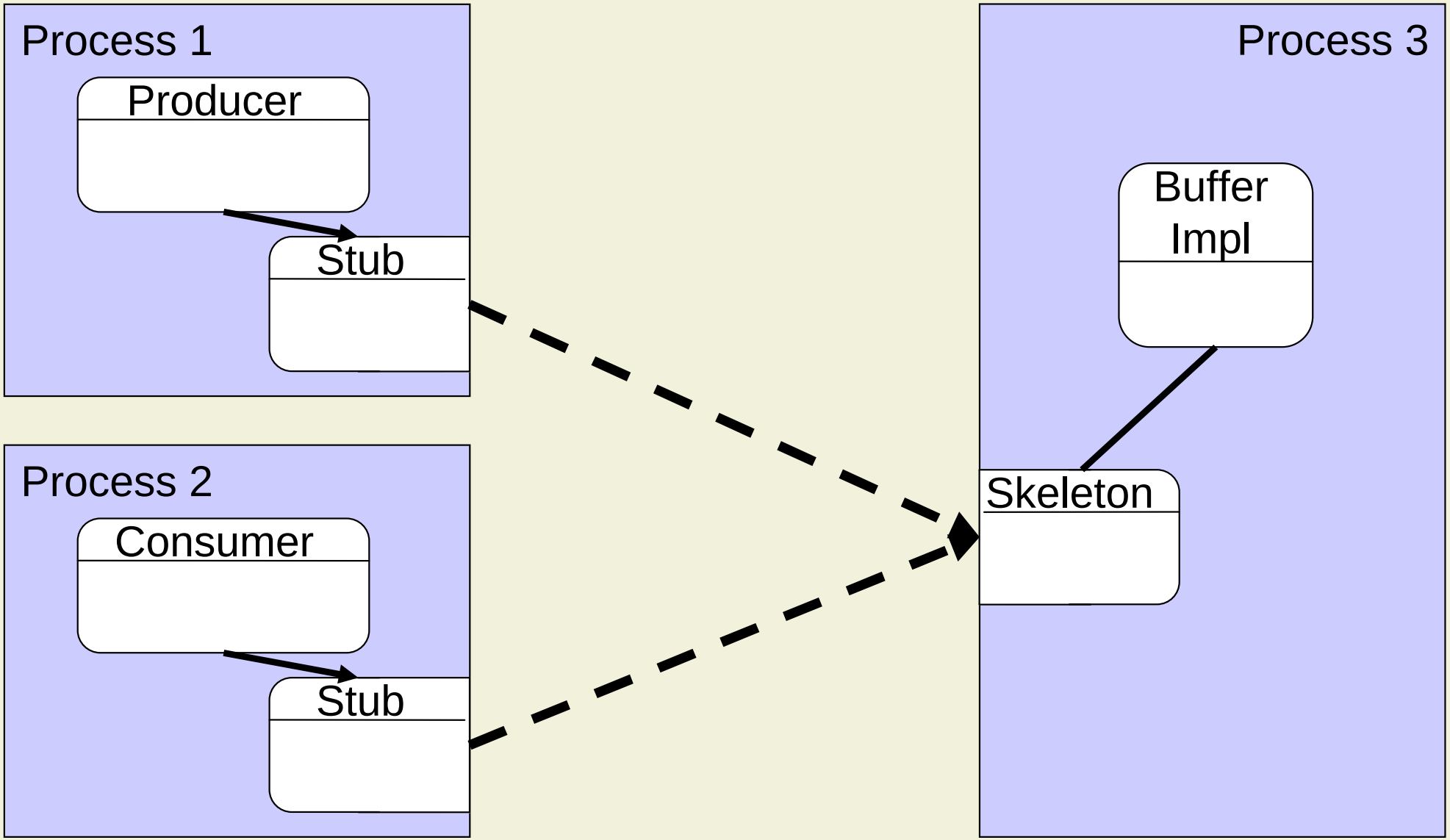
- Remote interfaces can be used to invoke methods of remote objects
- Communication is transparent except for
  - Error handling
  - Problems of serialization
- Coding is almost identical to local solutions

```
class Producer extends Thread {
  Buffer buf;

  Producer( Buffer b ) { buf = b; }

  void run( ) {
    while ( true )
      try {
        buf.put( new Prd( ) );
      } catch( Exception e ) { … }
  }
}
```

Process Interaction



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 …   { … }
  …
}
```

Example: BufferServer

```
class BufferServer {
  static void main( … ) throws Exception {
        Naming.rebind( "buffer", new BufferImpl( ) );
  }
}
```

```
class Producer extends Thread {
  …
  static void main( … ) throws Exception {
    String url = "rmi://monkey/buffer";
    Buffer b = ( Buffer ) Naming.lookup( url );
    new Producer( b ).start( );
  }
}
```

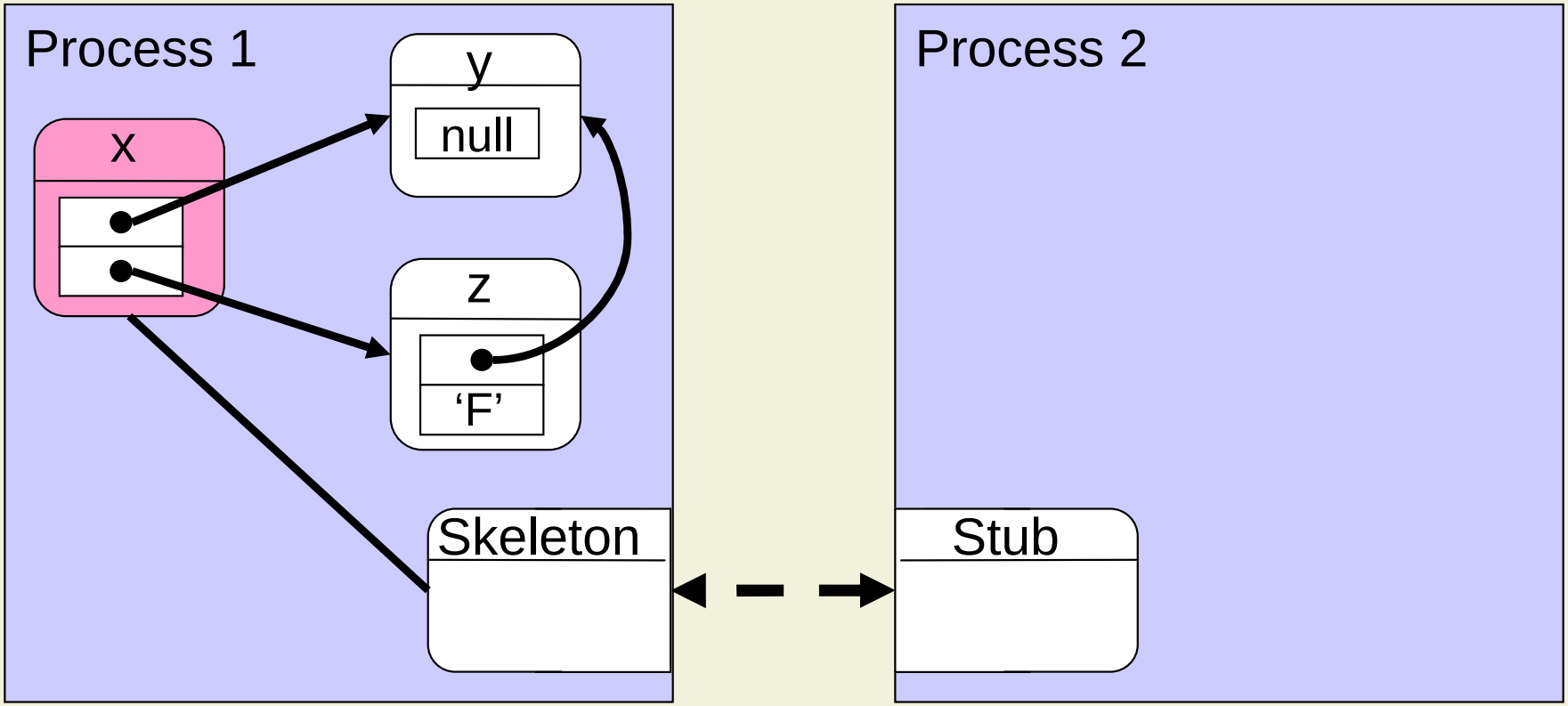
- Remote objects are **registered** at name server
- **URLs** are used to retrieve remote references

Using RMI in Java

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

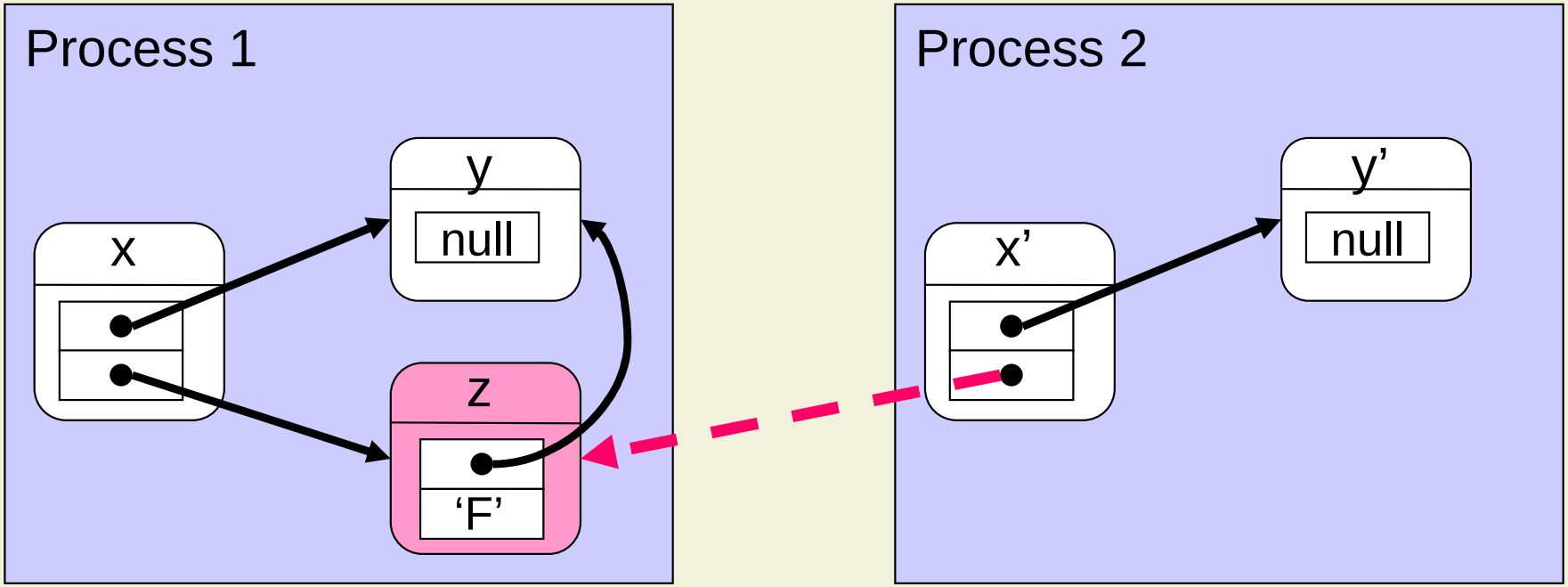
Serialization of Remote Objects

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



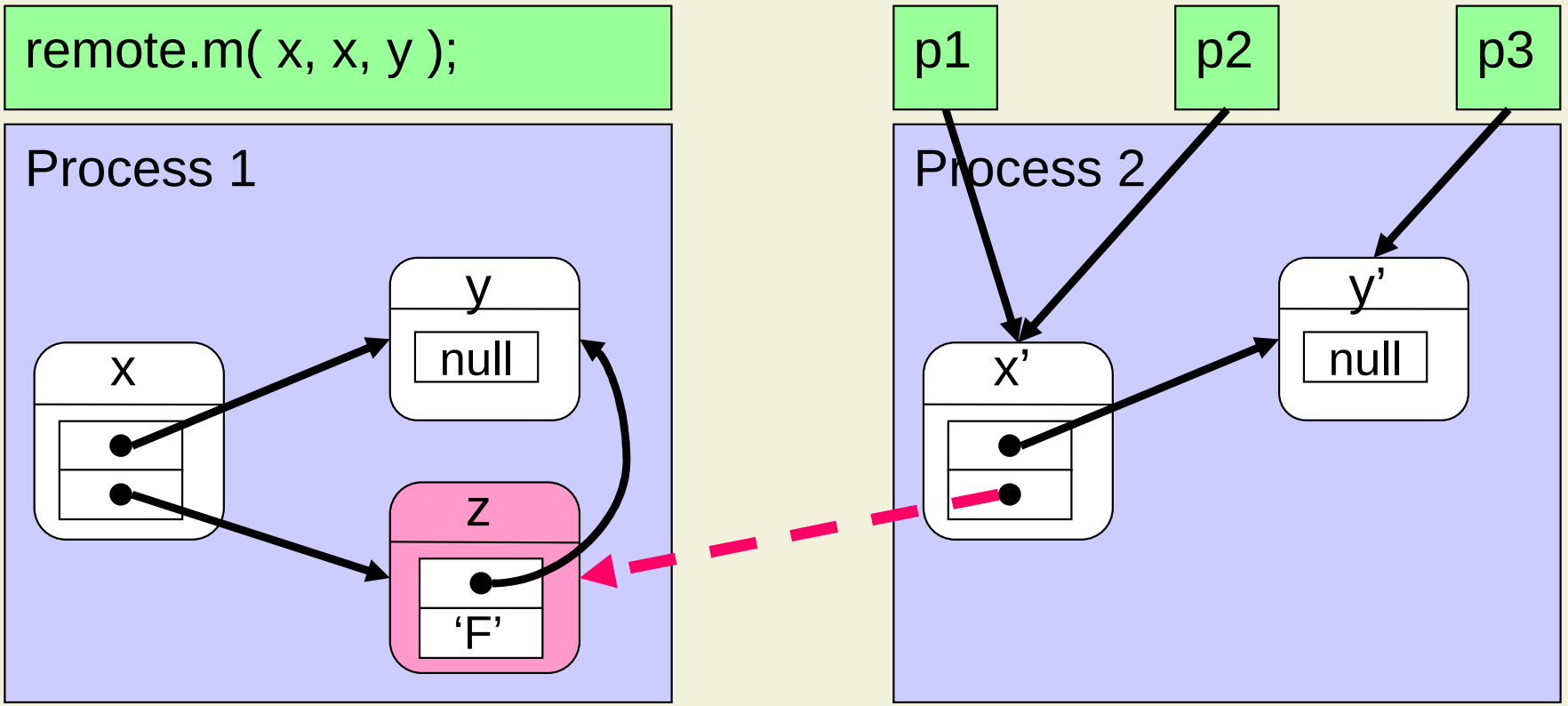
Details of Serialization

- 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

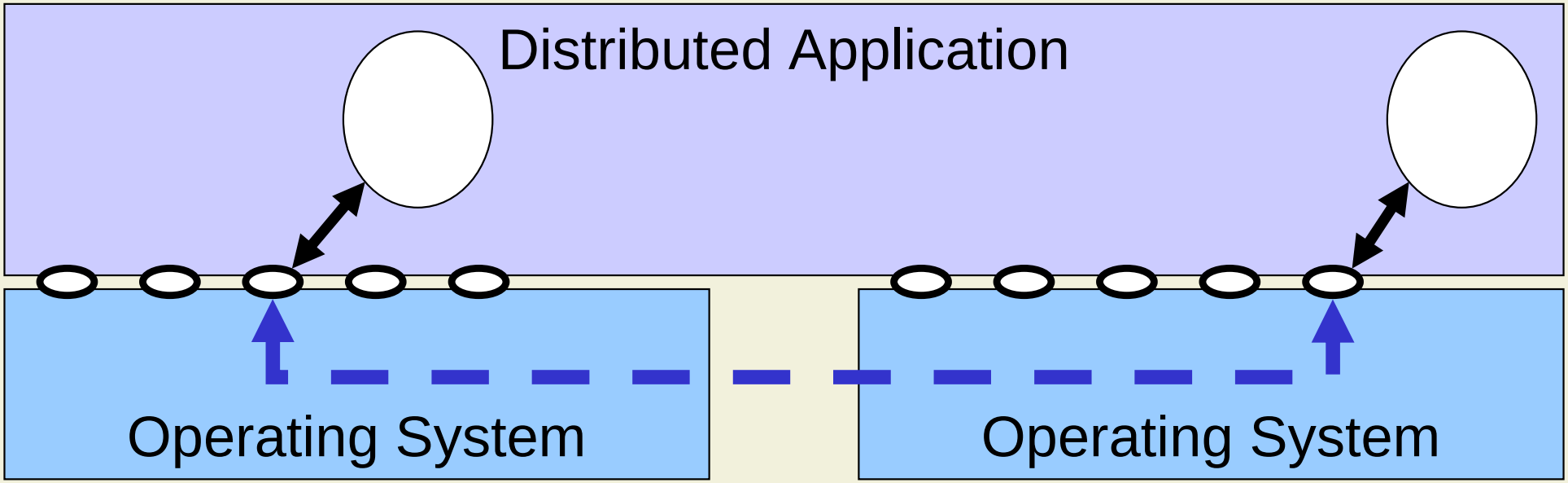


Remote Objects: Summary

- 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

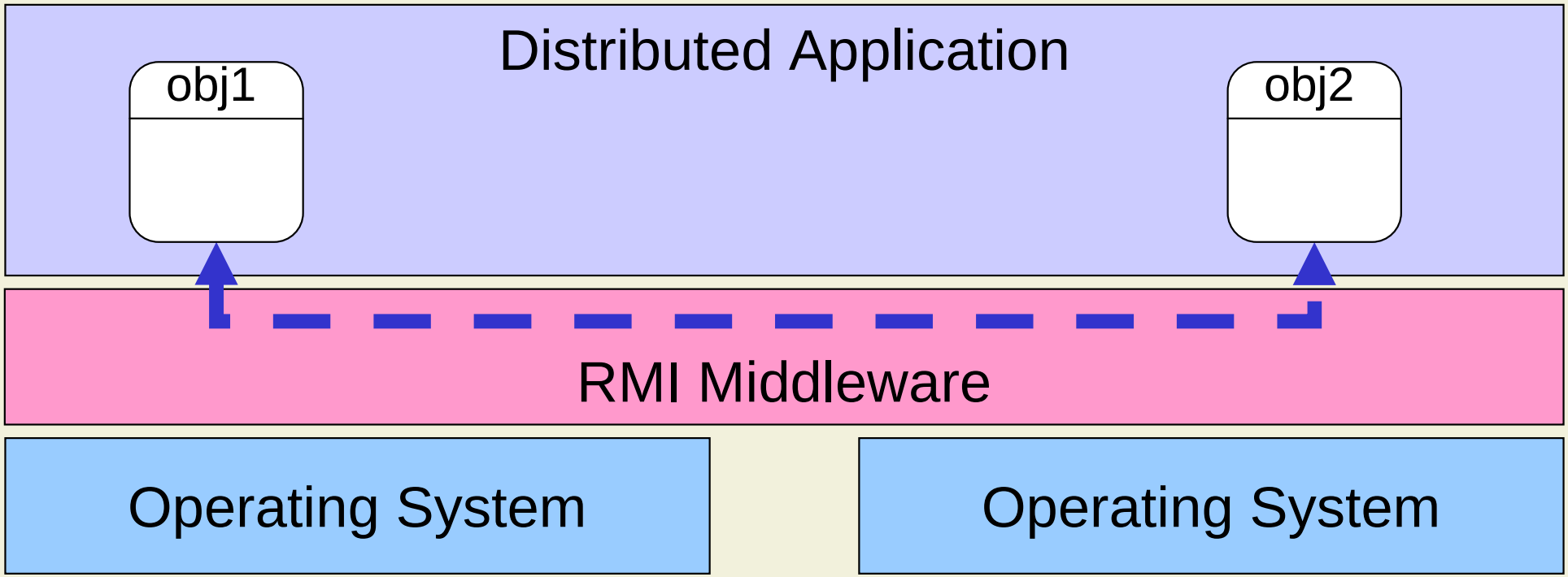
9. Distribution

Socket Communication



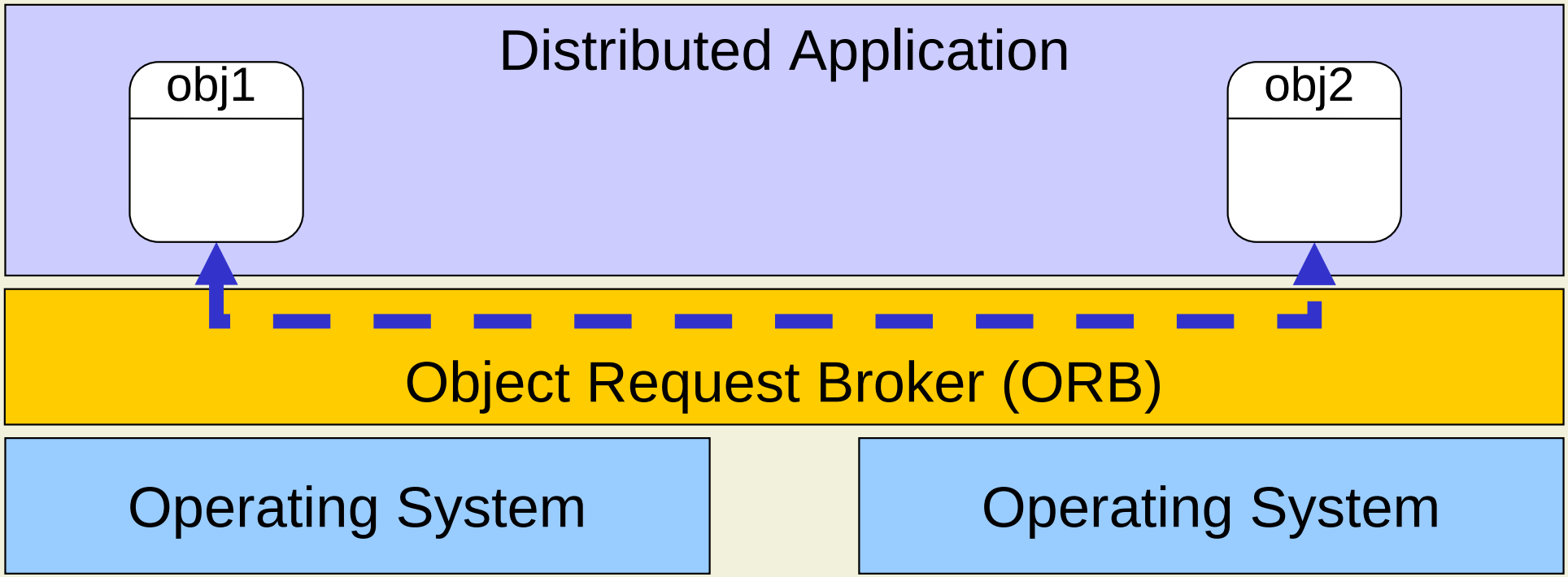
- Application has to deal with communication explicitly
  - Locations of objects
  - Communication protocol

RMI Middleware



- RMI middleware provides
  - Higher-level abstractions (RMI)
  - Location transparency (almost)
  - Independence of communication protocols

Request Broker Architectures

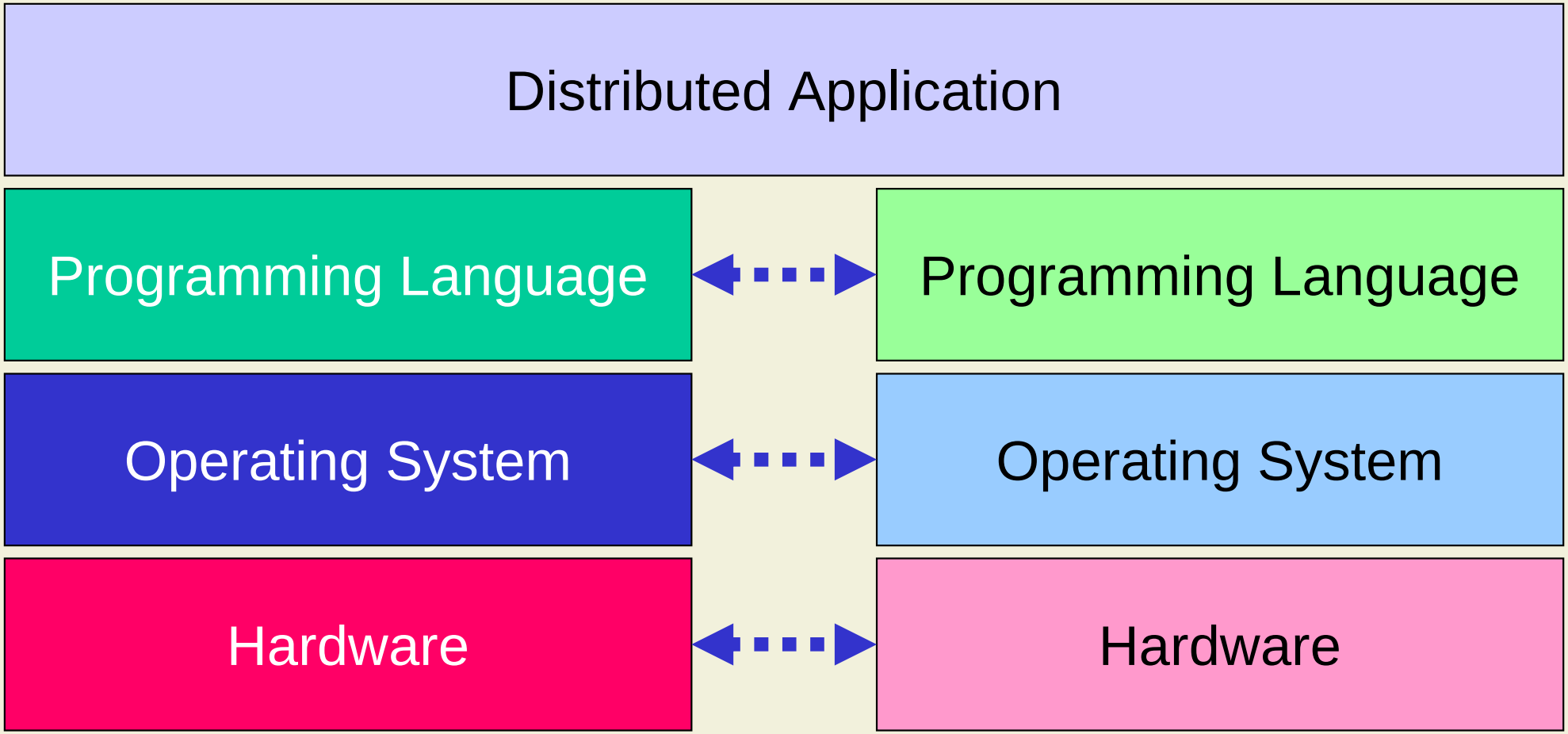


- Object request brokers provide
  - Object brokerage
  - Additional higher-level abstractions (multicast, asynchronous communication)

9. Distribution

Heterogeneous Environments

- Distributed systems usually run in heterogeneous environments

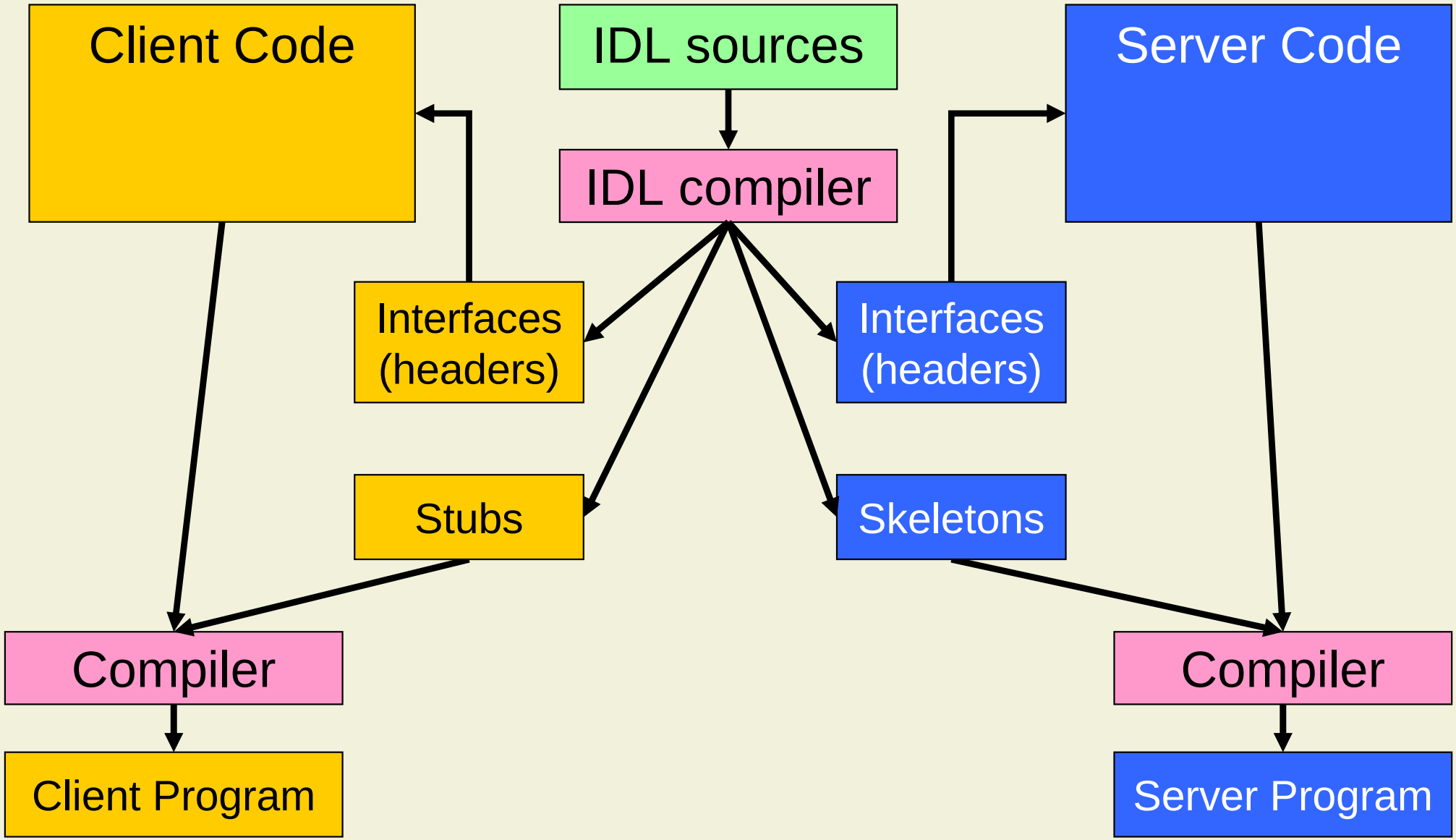


Interface Description Languages (IDLs)

- Remote objects can be implemented in different languages
- Interfaces have to be described independently from language
- IDL descriptions can be mapped to different programming languages

```
module examples
{
  interface Tribble
  {
    void pet (in long times);
    string make_noise ();
    Tribble reproduce ();
  };
};
```

Programming with Interface Descriptions



Serialization of Remote Objects

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