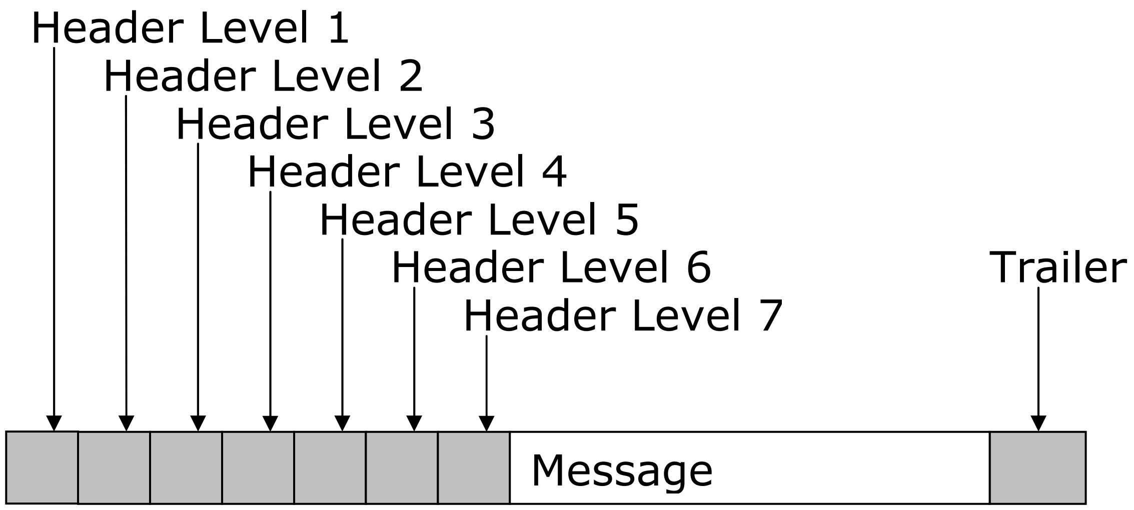
Multithreaded Server

This section demonstrates how java and threads can be used into a network environment to realize multithreaded server. We consider **socket communication** and **XML remote procedure calls**.

Contents

1. Client-Server Modell

Distributed systems could be realized using the **OSI**[1] reference model. Using this technique implies that a message has to be packed from each sender's layer and unpacked by the receiver.



This **management overhead** can be accepted in WAN (wide area network) environments but is unacceptable in LAN (local area network) environments.

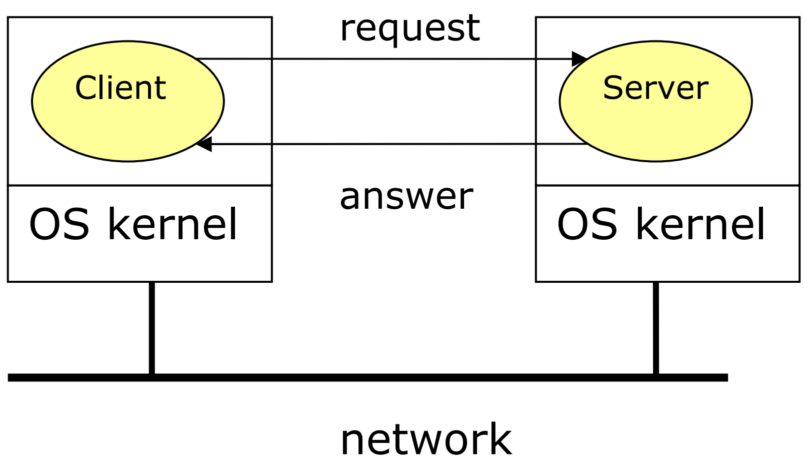
Here, the **client server model** is a better choice.

[1] Open Systems Interconnect model

A distributed system based on the client server model consists of a set of cooperating processes (server) which offer services to clients.

In a client server system a **request/answer protocol** is used between clients and servers:

A client sends a request (message) to a server which is responsible for the required service. The server sends the desired information (answer message) back to the client.



This kind of communication is more effective because only protocol layer 1, 2 and 5 are involved. Therefore client server communication can be represented within the OSI model as follows:

OSI layer	
7 (application)	
6 (representation)	
5 (session)	answer/request
4 (transport)	
3 (network)	
2 (data-link)	connection
1 (physical)	transmission

We will consider **socket communication** and **remote procedure calls** to demonstrate, how Java threads can be used within client server environments.

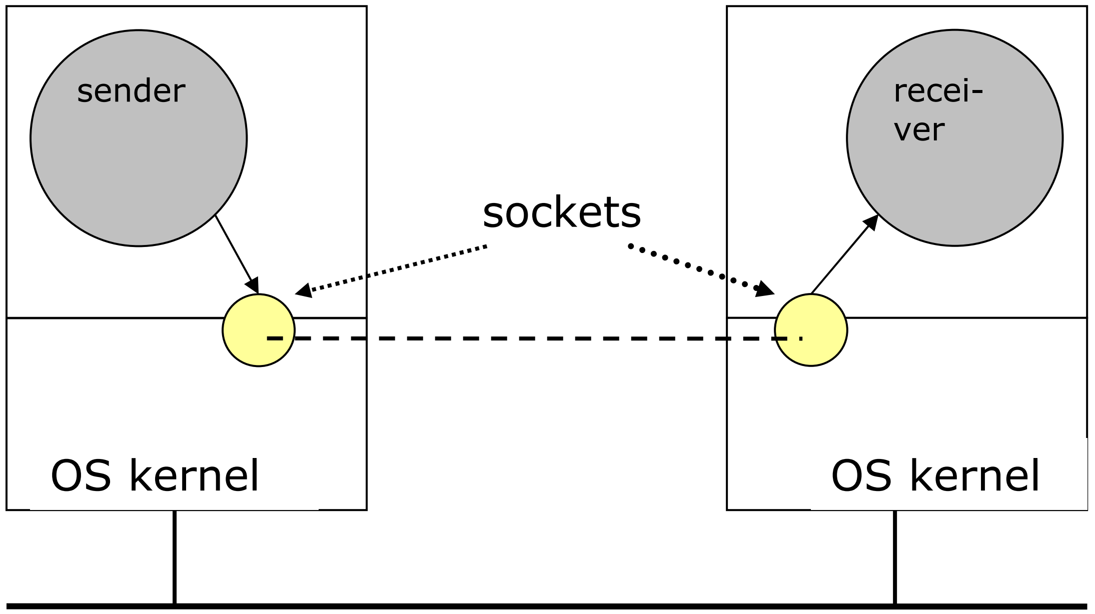
We realize clients and servers communicating over a TCP/IP network using sockets and remote procedure calls as communication primitives.

2. Socket communication

Sockets are communication **endpoints**, which are from a programmer's point of view an interface to a network.

Thus, a programmer can use the interface without worry about transmission details.

Sockets can be considered as abstractions of a physical net.



The socket interface was first provided with the VAX system, circa 1982. It supported the following communication protocols:

- Unix domain,
- **Internet domain** and

  - Xerox NS domain

We will only consider the Internet domain protocol.

2.1. Basics

Sockets can be created and destroyed dynamically. The creation returns a file descriptor which can be used to:

- establish a connection,
- read and write operations and
- disable a connection.

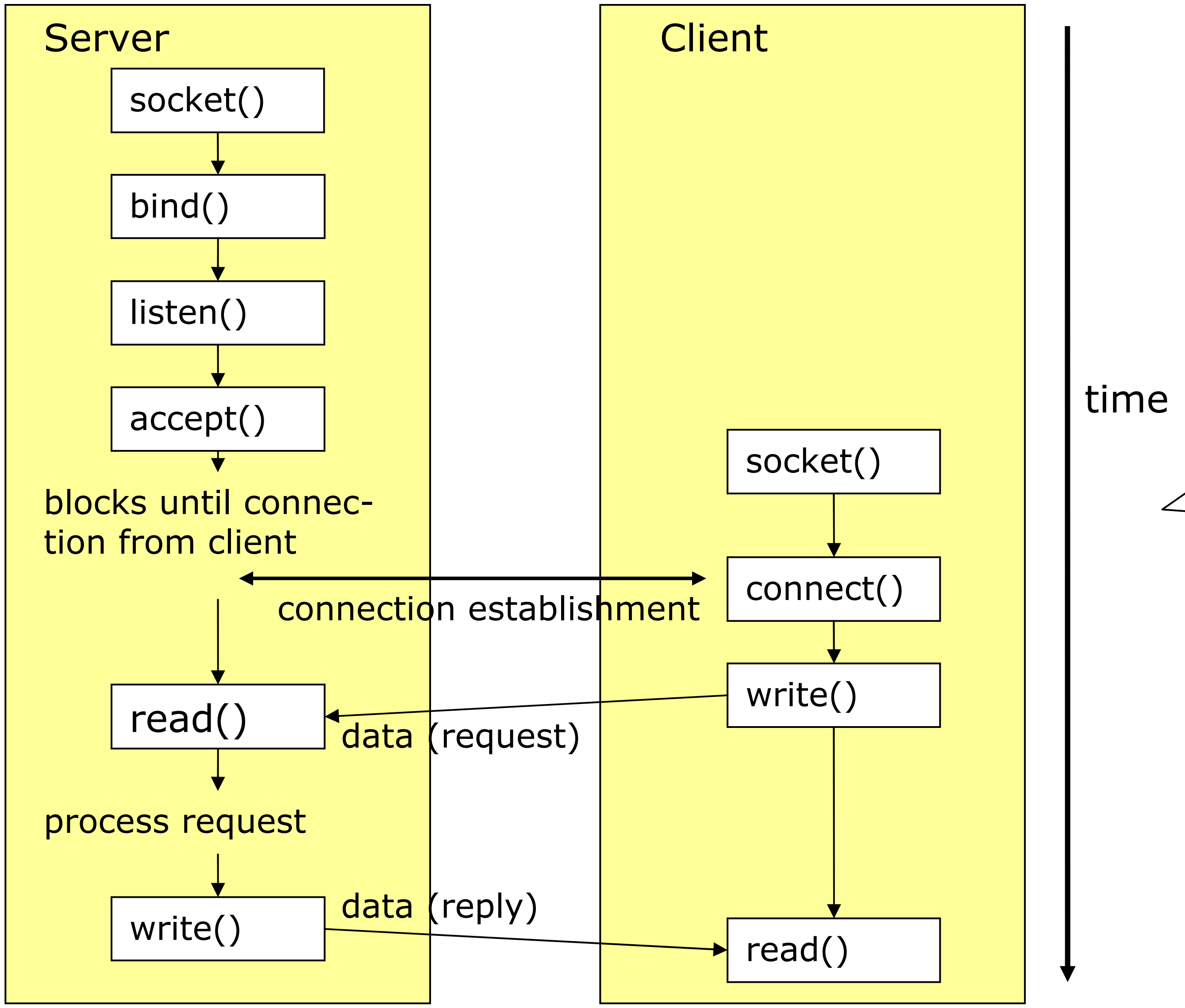
Berkeley sockets supports the following communication protocols:

- Unix domain (on same Unix system)
- Internet domain (TCP/IP)

To use sockets, a set of library calls are available (C, Java):

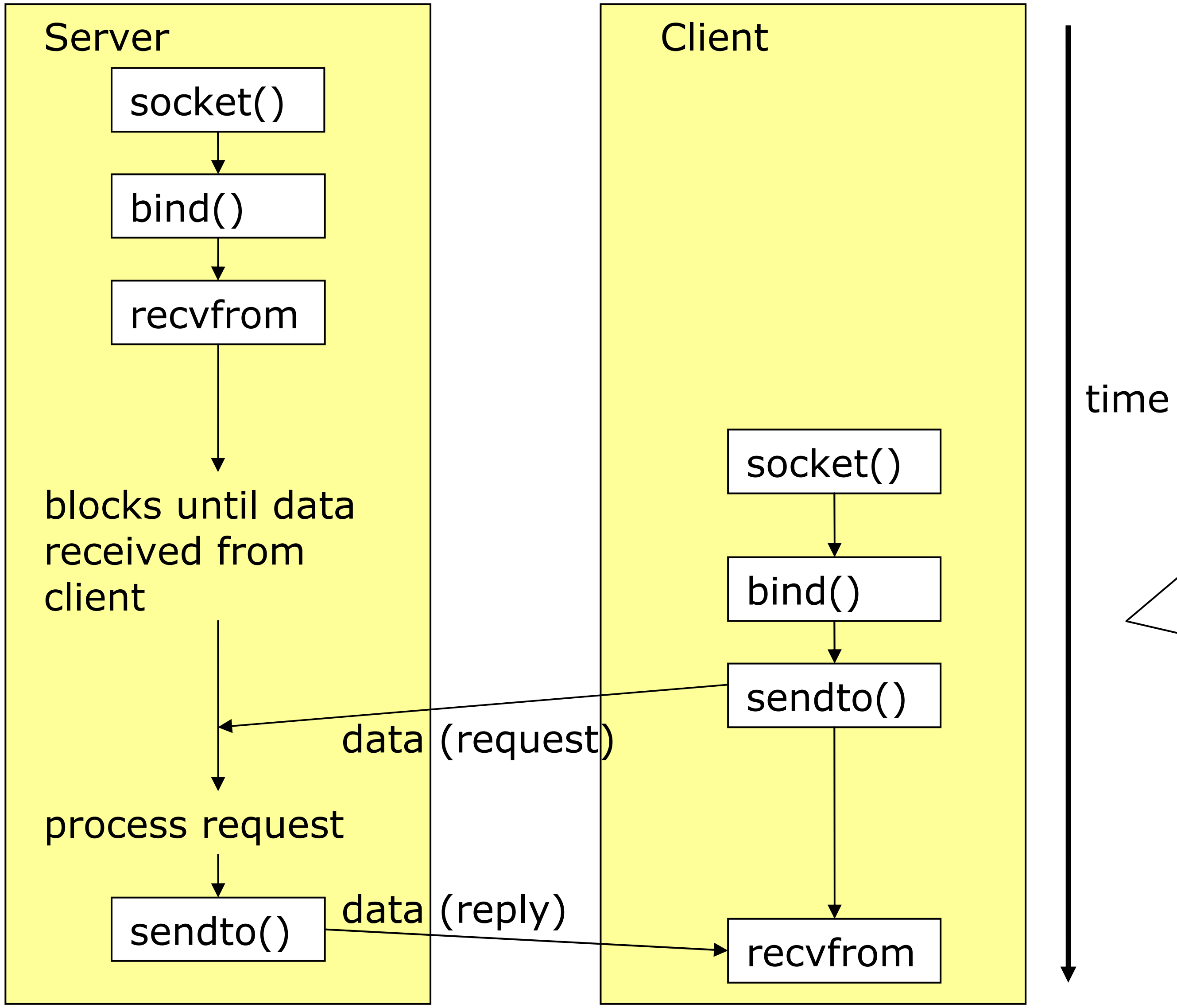
system call	connection-oriented	connectionless
socket()	creating communication endpoints	
bind()	assigning a name to the endpoint	
listen()	server ready for communication	
accept()	server accepts requests	
read(), write()	reading, writing	
connect()	connection establishment	
sendto(), recvfrom()		reading, writing

The following figure shows the timeline of a typical scenario that takes place for a **connection-oriented** transfer:



First, the server is started, and then sometimes later a client is started that connects to the server.

Here, we see the situation using the **connectionless** protocol:

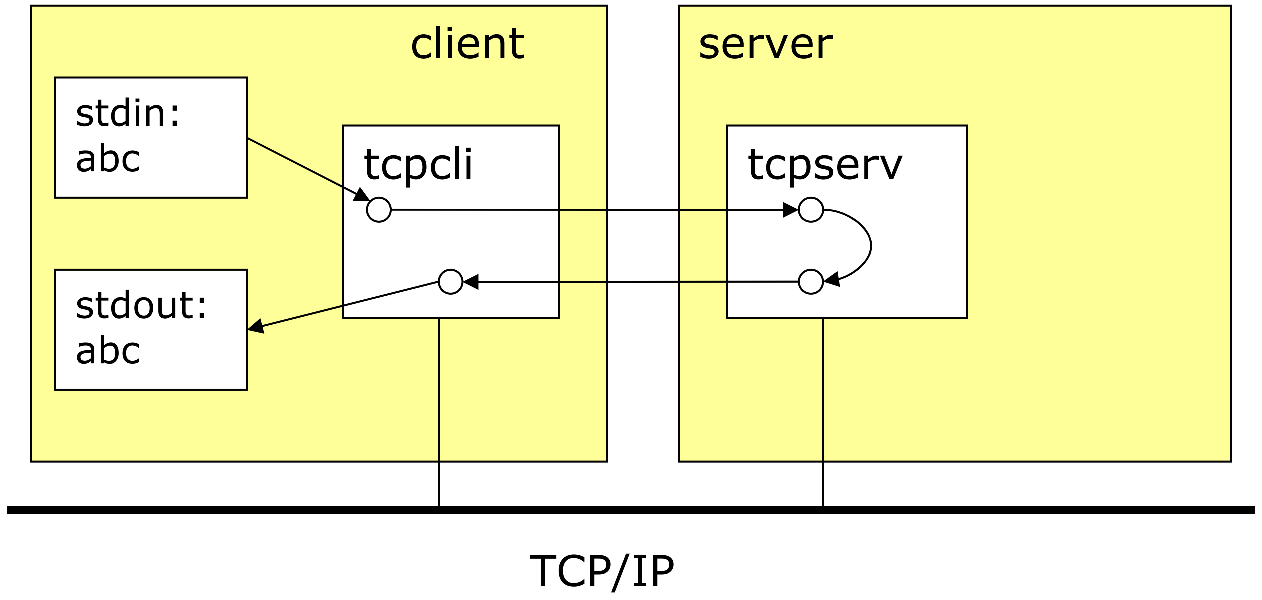


The client just sends a datagram using `sendto` (with the server as parameter) to the server.

The server just issues a `revfrom` system call that waits until data arrives from some client.

2.2. Example – Echoserver

Socket communication is demonstrated using the example of an **echo server**:



1. The **client reads** a line from its **standard input** and **writes** that line to the **server**.
2. The **server reads** a line from its **network input** and **echoes the line back** to the client over the network.
3. The **client reads** the ech-oed line from the **network** and **prints** it on **its stan-dard output**.

While we develop our implementation of an echo server, we have to know that most TCP/IP implementations provide such a server, using TCP and UDP.

The code we demonstrate could be the basis for your own socket programs by adding more functionality to the server.

First, we show a simple version where the server waits for a connection, handling the request and goes on waiting for the next connection.

Next, we illustrate how to make a multithreaded server out of the first approach.

2.2.1. Socket basics in Java

Opening a socket

First, we have to open a socket.

If we are programming a **client**, then we could open a socket like this:

```
Socket MyClient;
MyClient = new Socket("Machine name", PortNumber);
```

Where `Machine` name is the machine we are trying to open a connection to, and `PortNumber` is the port (a number) on which the server we are trying to connect to is running.

When selecting a port number, you should note that **port numbers** between 0 and 1023 are **reserved** for privileged users (that is, super user or root). These port numbers are reserved for standard services, such as **email**, **FTP**, and **HTTP**. When selecting a port number for the server, select one that is greater than 1023!

In the example above, we didn't make use of exception handling, however, it is a good idea to handle exceptions. From now on, all our code will handle exceptions; thus, we write:

```
Socket MyClient;
try {
           MyClient = new Socket("Machine name", PortNumber);
}
catch (IOException e) {
    System.out.println(e);
}
```

If programming a **server**, then this is how to open a socket:

```
ServerSocket MyService;
try {
           MyServerice = new ServerSocket(PortNumber);
}
catch (IOException e) {
   System.out.println(e);
}
```

When implementing a server you also need to create a socket object from the `ServerSocket` in order to listen for and accept connections from clients.

```
Socket clientSocket = null;
try {
       clientSocket = MyService.accept();    // waits until a client
                                             //establishes a connection


}
catch (IOException e) {
   System.out.println(e);
}
```

Creating an input stream

On the **client side**, we can use the `DataInputStream` class to create an **input stream** to **receive response** from the server:

```
DataInputStream input;
try {
   input = new DataInputStream(MyClient.getInputStream());
}
catch (IOException e) {
   System.out.println(e);
}
```

The class `DataInputStream` allows us to read lines of text and Java primitive data types in a portable way. It has methods such as `read`, `readChar`, `readInt`, `readDouble`, and `readLine`.

On the **server side**, we can use `DataInputStream` to **receive input** from the client:

```
DataInputStream input;
try {
      input = new DataInputStream(serviceSocket.getInputStream());
}
catch (IOException e) {
   System.out.println(e);
}
```

Creating an output stream

On the **client side**, we can create an **output stream** to **send** information to the server **socket** using the class `PrintStream` or `DataOutputStream` of java.io:

```
PrintStream output;
try {
   output = new PrintStream(MyClient.getOutputStream());
}
catch (IOException e) {
   System.out.println(e);
}
```

socket

The class `PrintStream` has methods for displaying textual representation of Java primitive data types. Its `write` and `println` methods are important here. Also, you may want to use the `DataOutputStream`:

```
DataOutputStream output;
try {
   output = new DataOutputStream(MyClient.getOutputStream());
}
catch (IOException e) {
   System.out.println(e);
}
```

The class `DataOutputStream` allows us to write Java primitive data types; many of its methods write a single Java primitive type to the output stream. The method `writeBytes` is a useful one.

On the **server side**, we can use the class `PrintStream` to send information to the client.

```
PrintStream output;
try {
   output = new PrintStream(serviceSocket.getOutputStream());
}
catch (IOException e) {
   System.out.println(e);
}
```

socket

Alternatively, you can use other classes, like PrintWriter or BufferedReader.

Close sockets

You should always close the output and input stream before you close the socket.

On the client side:

```
try {
   output.close();
   input.close();
   MyClient.close();  // socket
}
catch (IOException e) {
   System.out.println(e);
}
```

On the server side:

```
try {
   output.close();
   input.close();
   serviceSocket.close();  // socket
   MyService.close();      // socket
}
catch (IOException e) {
   System.out.println(e);
}
```

2.2.2. Client program

When programming a client, you can follow these four steps:

1. **Open** a **socket**.
2. **Open** an input and output **stream** to that **socket**.
3. **Read from** and **write to the socket** according to the server's protocol.
4. **Clean up**.

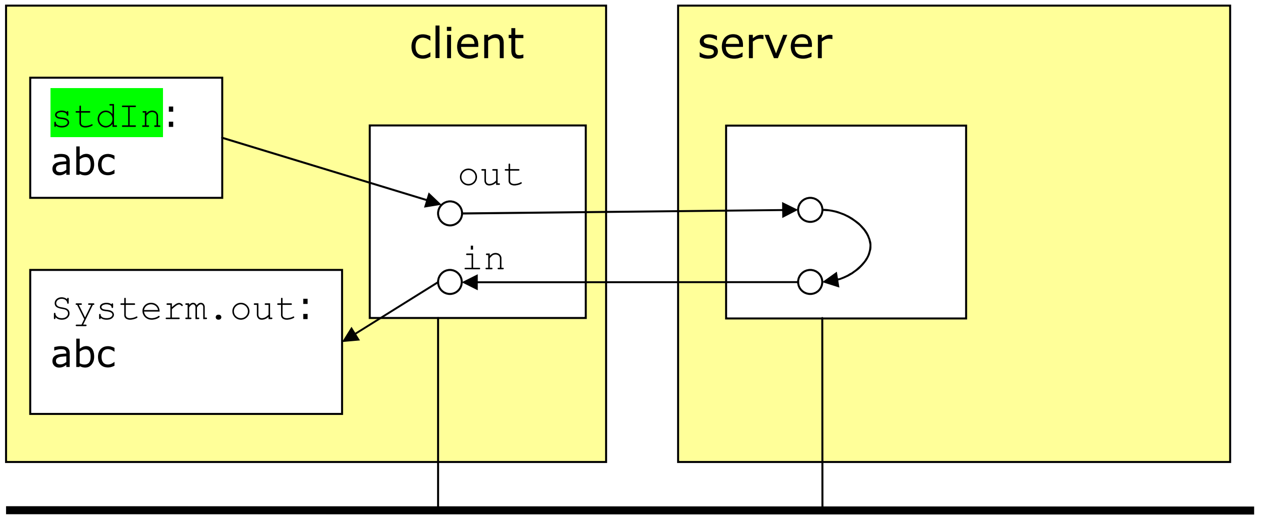
These steps are pretty much the same for all clients. The only step that varies is step three, since it depends on the server you are talking to.

The Client program for our example can be realized as:

```
$ cat EchoClient.java
import java.io.*;
import java.net.*;

public class EchoClient {
    public static void main(String[] args) throws IOException {

        Socket echoSocket = null;
        PrintWriter out = null;
        BufferedReader in = null;
        String host = new String();
        int port = 9999;

        if (args.length != 2) {                          // usage check
               System.err.println(
                      "usage: java EchoClient <server host> <port>");
               System.exit(1);
        } else {
               host = args[0];
               try   {
                      port = Integer.parseInt(args[1]);
               } catch (Exception e) {
                      System.err.println("<port> has to be a number");
                      System.exit(2);
               }
        } // usage check
```

APIs for networking

```
        try {
                // open socket
                echoSocket = new Socket(host, port);

                // creating output stream
                out = new PrintWriter(echoSocket.getOutputStream(), true);

                // creating input stream (using BufferedReader)
                in = new BufferedReader(new InputStreamReader(
                                                    echoSocket.getInputStream()));
        } catch (UnknownHostException e) {
                System.err.println("Don't know about host: "+ host);
                System.exit(1);
        } catch (IOException e) {
                System.err.println("Couldn't get IO for " +
                                   "the connection to: " + host);
                System.exit(1);
        } // open resources

        BufferedReader stdIn = new BufferedReader(
                                        new InputStreamReader(System.in));
        String userInput;
        System.out.println("EchoClient started");
        while ((userInput = stdIn.readLine()) != null) {   // reading from stdin
                out.println(userInput);                    // writing to socket
                System.out.println(in.readLine());         // reading from socket
                                                           // writing to  stdout
        }

        // closing resources
        out.close();
        in.close();
        stdIn.close();
        echoSocket.close();

    } // main
}
$
```



2.2.3. Simple server program

Now let's write a server. This server is very similar to the echo server running on port 7 in Unix.

Basically, the echo server receives text from the client and then sends that exact text back to the client. This is just about the simplest server you can write. Note that this server handles only one client. Next we modify it to handle multiple clients using threads.

```
$ cat EchoServer.java
import java.io.*;
import java.net.*;

public class EchoServer {
    public static void main(String args[]) {
            // declaration section:
            // declare a server socket and a client socket for the server
            // declare an input and an output stream
            ServerSocket echoServer = null;
            String line;
            DataInputStream is;
            PrintStream os;
            Socket clientSocket = null;

            // Try to open a server socket on port 9999
            // Note that we can't choose a port less than 1023 if we are not
            // privileged users (root)
            try {
                    echoServer = new ServerSocket(9999);
            } catch (IOException e) {
                    System.out.println(e);
            } // ServerSocket
            while (true) {
                // Create a socket object from the ServerSocket to listen and accept
                // connections.
                // Open input and output streams
                try {
                     clientSocket = echoServer.accept();
                     is = new DataInputStream(
                                     clientSocket.getInputStream());
                     os = new PrintStream(clientSocket.getOutputStream());

                     // As long as we receive data, echo that data back to the client.
                     while ((line = is.readLine()) != null) { // read from socket
                             os.println(line);                // write to socket
                     } // while
                } catch (IOException e) {
                     System.out.println(e);
                } // connection
            }
    } // main
}
$
```

When more than one client connects to the server, the second client has to wait until the first client has terminated. This situation is not acceptable. Think about a Web server which only accepts one request at a time.

The idea is to change the server, so that it creates a new thread, when a client sends a request. This thread is responsible to satisfy the client request. The server can than wait for new client requests while the previously created thread handles the request.

2.2.4. Multithreaded server

To make a multithreaded server out of our echo server, we have to create a thread after accepting a client request:

```
while (true) {
        // listen to server socket
        Socket clientSocket = serverSocket.accept();

        // start thread when client connects
        new MultiServerThread(clientSocket, clientId++).start();
}
```

The new thread than performs the task of reading from the socket and echoing the request.

```
public void run() { // handle connection
        try {
            …
            while ((socketInput = is.readLine()) != null) {
                os.println(socketInput);
                System.out.println(getName() + ": " + socketInput);
            } // while
        }
        …
}
```

Now we are able to finalize the multithreaded server:

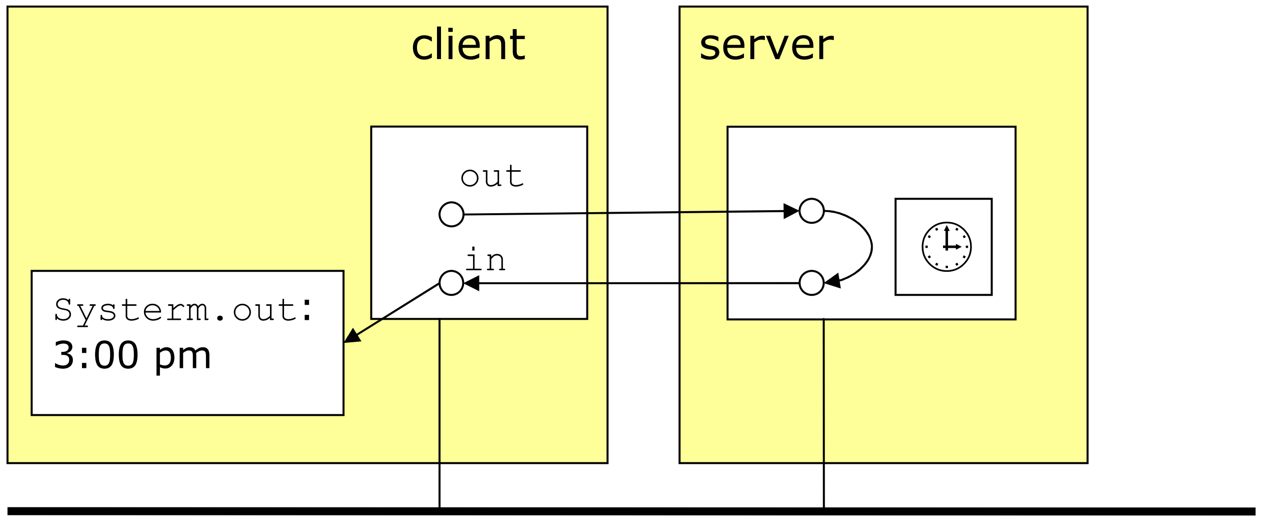
```
$ cat MultiThreadedEchoServer.java
// a multi threaded echo server
import java.net.*;
import java.io.*;

public class MultiThreadedEchoServer {
    private static int clientId = 0;          // clientId to identify clients
    public static void main(String[] args) throws IOException {
        ServerSocket serverSocket = null;
        boolean listening = true;
        int port = 8777;
        System.out.println("EchoServer started");

        if (args.length != 1) {               // check usage
                System.err.println("usage: java EchoServer <port>");
                System.exit(1);
        } else
        port = Integer.parseInt(args[0]);

        // Create a socket from the Server Socket
        try {
            serverSocket = new ServerSocket(port);
        } catch (IOException e) {
            System.err.println("Could not listen on port: "+port);
            System.exit(1);
        }

        while (listening) {
                // listen to server socket
                Socket clientSocket = serverSocket.accept();

                // start thread when client connects
                new MultiServerThread(clientSocket, clientId++).start();
        }

        serverSocket.close();
    } // main
} // MultiThreadedEchoServer

class MultiServerThread extends Thread {
        private Socket socket = null;

        public MultiServerThread(Socket socket,int clientId) {
                super("Client " + clientId);
                this.socket = socket;
        }
        public void run() {
            System.out.println("Handle new connection");
            try {
                DataInputStream is;
                PrintStream os;

                is = new DataInputStream(socket.getInputStream());
                os = new PrintStream(socket.getOutputStream());

                String socketInput;
                // As long as we receive data,
                // echo that data back to the client.
                while ((socketInput = is.readLine()) != null) {
                        os.println(socketInput);
                        System.out.println(getName() + ": " + socketInput);
                } // while

                os.close();
                is.close();
            } catch (IOException e) {e.printStackTrace();
            }
            System.out.println("close connection");
        } // run
} // MultiServerThread
$
```

Classroom exercise 1:

Download the client code, compile it and execute it to connect to my server.

Classroom exercise 2:

Use our example `MultiThreadedEchoServer.java` and modify it to realize a **time** server:



The client sends a request to the server to get the actual server time. The server answers that request by taking its own actual time and sends it over the socket to the client.

Most Unix systems have a time server running, listening on port 13. The following Java program just opens a socket on that port and read whatever the server sends.

```
$ cat Inettime.java
import java.io.*;
import java.net.*;
class Inettime {
    public static void main(String[] args) {
        String host;
        int port;
        if (args.length > 0)          // check usage
            host = args[0];
        else
            host = "localhost";       // deafult host
        if (args.length > 1)
            port = Integer.parseInt(args[1]);
        else
            port = 13;                // date port
        new Inettime(host, port);
    }
    Inettime(String host, int port) {
        try {
            Socket s = new Socket(host, port);   //create socket
            InputStreamReader in = new InputStreamReader(s.getInputStream());

            int c;
            do {
                c = in.read();
                if (c>0)
                    System.out.print((char) c);
            } while (c>0);
            System.out.print('\n');
        }
        catch(IOException e) {
            System.out.println("Error" + e);
        }
    }
}
$
```

```
$ java Inettime rh
17 JUL 2002 22:30:26 CEST

$
```

3. Remote Procedure Call

Inside every computer, every time you click a key or the mouse, thousands of "**procedure calls**" are spawned, analyzing, computing and then acting on your gestures.

A procedure call is the **name of a procedure**, its **parameters**, and the **result** it returns.

A **remote procedure call** (RPC for short) is a very simple extension to the procedure call idea, it says let's create connections between procedures that are running in different applications, or on different machines.

3.1. Basics

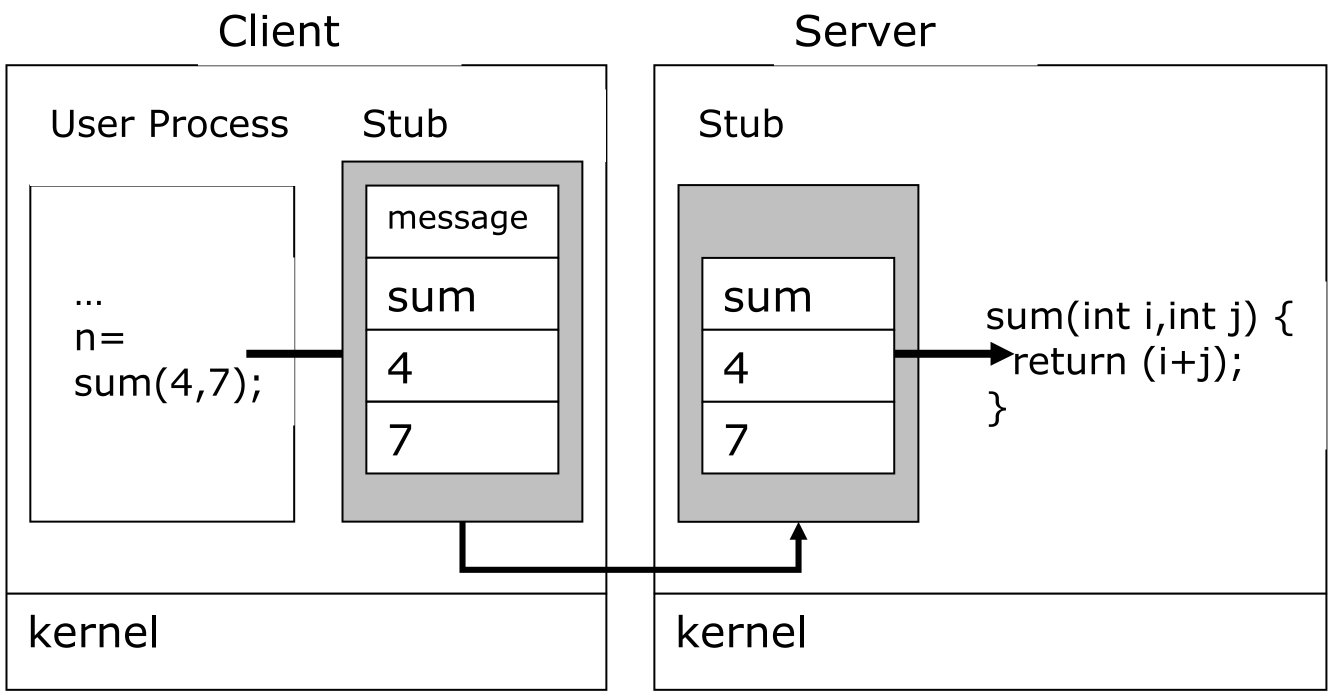
Conceptually, there's no difference between a local procedure call and a remote one, but they are implemented differently, perform differently (RPC is much slower) and therefore are used for different things.

Remote calls are "**marshalled**" by “stub procedures” into a format that can be understood on the other side of the connection; here “stub procedures” have to “unmarshall” the format.

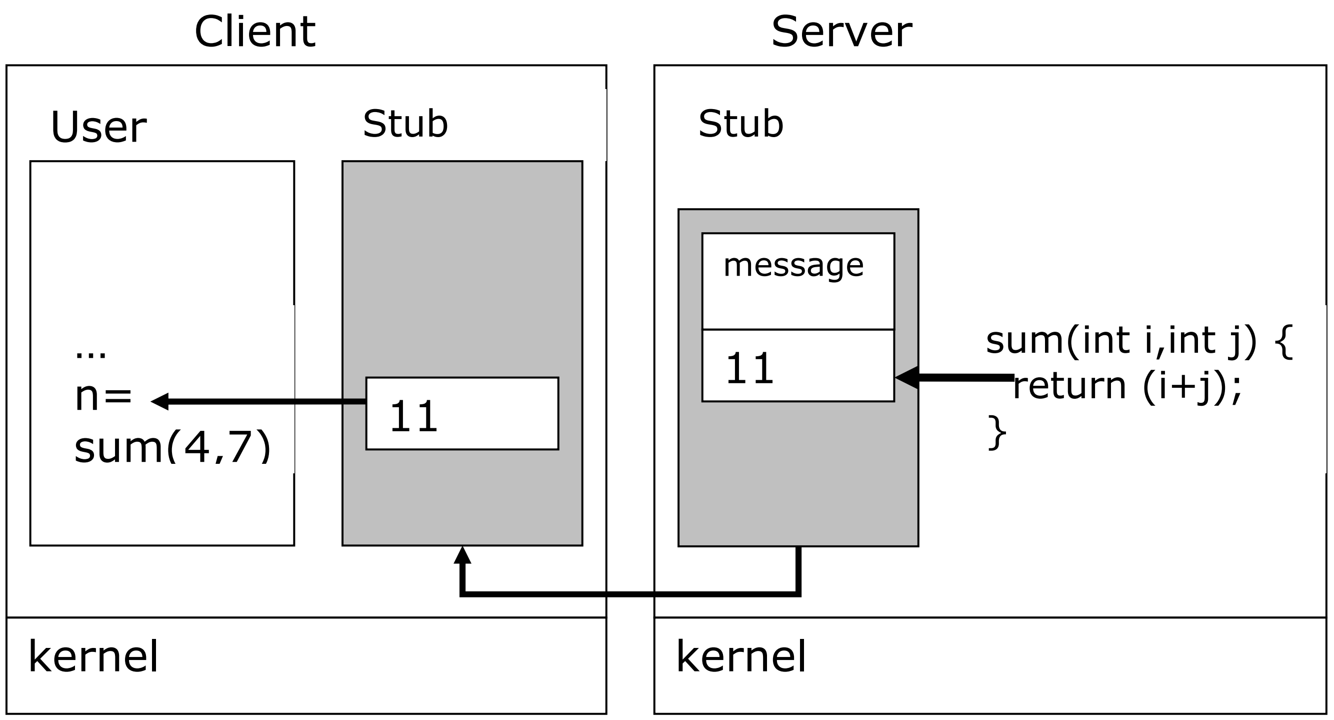
After the remote procedure has terminated its execution, the remote stub procedure marshals the result and transfers it to the caller, where it is made available to the caller of the remote procedure.

This idea is shown in the following picture:

1. remote procedure call



2. return result



There are an almost infinite number of **formats** possible.

To specify such a format, languages (**i**nterface **d**efinition **l**anguages) have been developed, i.e.:

- Suns ONC-RPC: XDR (eXternal Data Representation)
- OSF-RPC (DCE): IDL (Interface Definition Language)
- CORBA: IDL (Interface Definition Language)

One other possible format is **XML**, a new language that both humans and computers can read. **XML-RPC** uses **XML** as the **marshalling format**. It allows Macs to easily make procedure calls to software running on Windows machines and BeOS machines, as well as all flavours of Unix and Java, and IBM mainframes, and PDAs and mobile phones.

With XML it's easy to see what it's doing, and it's also relatively easy to marshal the internal procedure call format into a remote format.

3.2.XML-RPC Specification[2]

XML-RPC is a Remote **Procedure** calling protocol that works over the **Internet**.

An **XML-RPC message** is an HTTP-POST request. The **body** of the request is in **XML**. A procedure executes on the server and the **value** it **returns** is also formatted in **XML**.

Procedure parameters can be scalars, numbers, strings, dates, etc.; and can also be complex record and list structures.

[2] © Copyright 1998-2002 UserLand Software, Inc.. (www.userland.com)
XML-RPC is a trademark of UserLand Software, Inc.

3.2.1. Requests

Here's an **example** of an **XML-RPC request**:

```
POST /RPC2 HTTP/1.0
User-Agent: Frontier/5.1.2 (WinNT)
Host: betty.userland.com
Content-Type: text/xml
Content-length: 181

<?xml version="1.0"?>
<methodCall>
   <methodName>
      examples.getStateName
   </methodName>
   <params>
      <param>
         <value>
            <i4>
               41
            </i4>
         </value>
      </param>
   </params>
</methodCall>
```

header

request as XML string

Header requirements

The format of the URI in the first line of the header is not specified. For example, it could be empty, a single slash, if the server is only handling XML-RPC calls. However, if the server is handling a mix of incoming HTTP requests, we allow the URI to help route the request to the code that handles XML-RPC requests. (In the example, the URI is /RPC2, telling the server to route the request to the "RPC2" responder.)

A **User-Agent** and **Host** must be specified.

The **Content-Type** is text/xml.

The **Content-Length** must be specified and must be correct.

Payload format

The payload is in XML, a single <methodCall> structure.

The <**methodCall**> must contain a <**methodName**> sub-item, a string, containing the name of the method to be called. The string may only contain identifier characters, upper and lower-case A-Z, the numeric characters, 0-9, underscore, dot, colon and slash. It's entirely up to the server to decide how to interpret the characters in a methodName.

For example, the methodName could be the name of a file containing a script that executes on an incoming request. It could be the name of a cell in a database table. Or it could be a path to a file contained within a hierarchy of folders and files.

If the procedure call has parameters, the <**methodCall**> must contain a <**params**> sub-item. The <**params**> sub-item can contain any number of <**param**>s, each of which has a <**value**>.

3.2.2. Types

The following types are supported in XML-RPC:

Scalar <value>s

<value>s can be scalars, type is indicated by nesting the value inside one of the tags listed in this table:

Tag	Type	Example
`<i4> or <int>`	four-byte signed integer	-12
`<boolean>`	0 (false) or 1 (true)	1
`<string>`	ASCII string	hello world
`<double>`	double-precision signed floating point number	-12.214
`<dateTime.iso8601>`	date/time	19980717T14:08:55
`<base64>`	base64-encoded binary	eW91IGNhbid0IHJlYWQgdGhpcyE=

If no type is indicated, the type is string.

<struct>s

A value can also be of type <struct>.

A <struct> contains <member>s and each <member> contains a <name> and a <value>.

Here's an example of a two-element <struct>:

```
<struct>
   <member>
      <name>lowerBound</name>
      <value>
         <i4>18</i4>
      </value>
   </member>
   <member>
      <name>upperBound</name>
      <value>
         <i4>139</i4>
      </value>
   </member>
</struct>
```

<struct>s can be recursive, any <value> may contain a <struct> or any other type, including an <array>, described below.

<array>s

A value can also be of type <array>.

An <array> contains a single <data> element, which can contain any number of <value>s.

Here's an example of **a four-element array**:

```
<array>
   <data>
      <value><i4>12</i4></value>
      <value><string>Egypt</string></value>
      <value><boolean>0</boolean></value>
      <value><i4>-31</i4></value>
  </data>
</array>
```

<array> elements do not have names.

You can mix types as the example above illustrates.

<arrays>s can be recursive, any value may contain an <array> or any other type, including a <struct>, described above.

3.2.3. Response

Here's an example of a response to an XML-RPC request:

```
HTTP/1.1 200 OK
Connection: close
Content-Length: 158
Content-Type: text/xml
Date: Fri, 17 Jul 1998 19:55:08 GMT
Server: UserLand Frontier/5.1.2-WinNT

<?xml version="1.0"?>
<methodResponse>
   <params>
      <param>
         <value><string>South Dakota</string></value>
      </param>
   </params>
</methodResponse>
```

Response format

Unless there's a lower-level error, always return 200 OK.

The **Content-Type** is text/xml.

Content-Length must be present and correct.

The body of the response is a single XML structure, a <**methodResponse**>, which can contain a single <**params**> which contains a single <**param**> which contains a single <**value**>.

The <**methodResponse**> could also contain a <**fault**> which contains a <**value**> which is a <**struct**> containing two elements, one named <**faultCode**>, an <**int**> and one named <**faultString**>, a <**string**>.

A <**methodResponse**> can **not** contain both a <**fault**> and a <**params**>.

Fault example:

```
HTTP/1.1 200 OK
Connection: close
Content-Length: 426
Content-Type: text/xml
Date: Fri, 17 Jul 1998 19:55:02 GMT
Server: UserLand Frontier/5.1.2-WinNT

<?xml version="1.0"?>
<methodResponse>
   <fault>
      <value>
         <struct>
            <member>
               <name>faultCode</name>
               <value><int>4</int></value>
            </member>
            <member>
               <name>faultString</name>
               <value><string>Too many parameters.</string></value>
            </member>
         </struct>
      </value>
   </fault>
</methodResponse>
```

3.2.4. Strategies/Goals

The following items influenced the design of XML-PRC:

- ***Firewalls****.* The goal of this protocol is to lay a compatible foundation across different environments, no new power is provided beyond the capabilities of the CGI interface. Firewall software can watch for POSTs whose Content-Type is text/xml.
- ***Discoverability****.* A clean, extensible format that's very simple is wanted. It should be possible for an HTML coder to be able to look at a file containing an XML-RPC procedure call, understand what it's doing, and be able to modify it and have it work on the first or second try.
- ***Easy to implement****.* An easy to implement protocol that could quickly be adapted to run in other environments or on other operating systems has been desired.

3.2.5. FAQ

The following questions came up on the UserLand discussion group as XML-RPC was being implemented in Python.

- The Response Format section says "The body of the response is a single XML structure, a <methodResponse>, which *can* contain a single <params>..." This is confusing. Can we leave out the <params>?

  No you cannot leave it out if the procedure executed successfully. There are only two options, either a response contains a <params> structure or it contains a <fault> structure.

That's why we used the word "can" in that sentence.

- Is "boolean" a distinct data type, or can boolean values be interchanged with integers (e.g. zero=false, non-zero=true)?

  Yes, boolean is a distinct data type. Some languages/environments allow for an easy coercion from zero to false and one to true, but if you mean true, send a boolean type with the value true, so your intent can't possibly be misunderstood.

- What is the legal syntax (and range) for integers? How to deal with leading zeros? Is a leading plus sign allowed? How to deal with whitespace?

  An integer is a 32-bit signed number. You can include a plus or minus at the beginning of a string of numeric characters. Leading zeros are collapsed. Whitespace is not permitted. Just numeric characters preceeded by a plus or minus.

- What is the legal syntax (and range) for floating point values (doubles)? How is the exponent represented? How to deal with whitespace? Can infinity and "not a number" be represented?

  There is no representation for infinity or negative infinity or "not a number". At this time, only decimal point notation is allowed, a plus or a minus, followed by any number of numeric characters, followed by a period and any number of numeric characters. Whitespace is not allowed. The range of allowable values is implementation-dependent, is not specified.

- What characters are allowed in strings? Non-printable characters? Null characters? Can a "string" be used to hold an arbitrary chunk of binary data?

  Any characters are allowed in a string except < and &, which are encoded as &lt; and &amp;. A string can be used to encode binary data.

- Does the "struct" element keep the order of keys. Or in other words, is the struct "foo=1, bar=2" equivalent to "bar=2, foo=1" or not?

  The struct element does not preserve the order of the keys. The two structs are equivalent.

- Can the <fault> struct contain other members than <faultCode> and <faultString>? Is there a global list of faultCodes? (so they can be mapped to distinct exceptions for languages like Python and Java)?

  A <fault> struct **may not** contain members other than those specified. This is true for all other structures. We believe the specification is flexible enough so that all reasonable data-transfer needs can be accomodated within the specified structures. If you believe strongly that this is not true, please post a message on the discussion group. There is no global list of fault codes. It is up to the server implementer, or higher-level standards to specify fault codes.

- What timezone should be assumed for the dateTime.iso8601 type? UTC? localtime?

  Don't assume a timezone. It should be specified by the server in its documentation what assumptions it makes about timezones.

3.3. Apache XML-RPC

To be able to concentrate to the application development, we use a **Java implementation** of the XML-RPC protocol. It is part of the Apache project.

Apache XML-RPC is a Java implementation of XML-RPC, a popular protocol that uses XML over HTTP to implement remote procedure calls.

3.3.1. Client classes

Apache XML-RPC provides two client classes.

- org.apache.xmlrpc.XmlRpcClient uses java.net.URLConnection, the HTTP client that comes with the standard Java API
- org.apache.xmlrpc.XmlRpcClientLite provides its own lightweight HTTP client implementation.

`XmlRpcClientLite` is usually faster, but if you need full HTTP support (e.g. Proxies, Redirect etc), you should use `XmlRpcClient`.

Both client classes provide the same interface, which includes methods for synchronous and asynchronous calls. We will use the **synchronous** method.

Using the XML-RPC library on the client side is quite straightforward. Here is some sample code:

```
   // create new client, parametrer is the url of the server
   XmlRpcClient xmlrpc = new XmlRpcClient ("http://localhost:8080/RPC2");

   // build parameter for the request
   Vector params = new Vector ();
   params.addElement ("some parameter");

  // call the remote procedure
  String result = (String) xmlrpc.execute ("method.name", params);
```

Note that `execute` can throw `XmlRpcException` and `IOException`, which must be caught or declared by your code.

3.3.2. Server Side XML-PRC

On the server side, you can either embed the XML-RPC library into an existing server frame-work, or use the **built-in special purpose HTTP server**. Let's first look at how to register handler objects to tell an XML-RPC server how to map incoming requests to actual methods.

XML-RPC Handler Objects

The `org.apache.xmlrpc.XmlRpcServer` and `org.apache.xmlrpc.WebServer` classes provide methods that let your register and unregister Java objects as XML-RPC handlers:

```
    addHandler (String name, Object handler);

    removeHandler (String name);
```

Depending on what kind of handler object you give to the server, it will do one of the following things:

1. If you pass the `XmlRpcServer` any Java object, the **server** will try to **resolve incoming calls** via object introspection, i.e. by **looking for public methods** in the handler object **corresponding** to the **method name** and the parameter types of incoming requests. The input parameters of incoming XML-RPC requests must match the argument types of the Java method (see conversion table), or otherwise the method won't be found. The return value of the Java method must be supported by XML-RPC.
   (We will use that kind of handler object.)
2. If you pass the `XmlRpcServer` an object that implements interface org.apache.xmlrpc.XmlRpcHandler or org.apache.xmlrpc.AuthenticatedXmlRpcHandler the `execute()` method will be called for every incoming request. You are then in full control of how to process the XML-RPC request, enabling you to perform input and output parameter checks and conversion, special error handling etc.

In both cases, incoming requests will be interpreted as **`handlerName.methodName`** with `handlerName` being the String that the handler has been registered with, and `methodName` being the name of the method to be invoked. You can work around this scheme by registering a handler with the name "$default". In this case you can drop the `handlerName.` part from the method name.

Using the build-in HTTP-Server

The **XML-RPC** library comes with its own **built-in HTTP server**. This is **not** a general purpose web server, its only purpose is to handle XML-RPC requests. The HTTP server can be embedded in any Java application with a few simple lines:

```
// create Web-Server
WebServer webserver = new WebServer (port);
// add handler for a request
webserver.addHandler ("examples", someHandler);
```

A special bonus when using the built in Web server is that you can set the IP addresses of clients from which to accept or deny requests. This is done via the following methods:

```
webserver.setParanoid (true);             // deny all clients
webserver.acceptClient ("192.168.0.*");   // allow local access
webserver.denyClient ("192.168.0.3");     // except for this one
...
webserver.setParanoid (false);            // disable client filter
```

If the client filter is activated, entries to the deny list always override those in the accept list. Thus, `webserver.denyClient ("*.*.*.*")` would completely disable the web server.

Using XML-RPC within a Servlet environment (we do not use it in our example)

The XML-RPC library can be embedded into any Web server framework that supports reading HTTP POSTs from an InputStream. The typical code for processing an incoming XML-RPC request looks like this:

```
    XmlRpcServer xmlrpc = new XmlRpcServer ();
    xmlrpc.addHandler ("examples", new ExampleHandler ());
    ...
    byte[] result = xmlrpc.execute (request.getInputStream ());
    response.setContentType ("text/xml");
    response.setContentLength (result.length);
    OutputStream out = response.getOutputStream();
    out.write (result);
    out.flush ();
```

Note that the `execute` method does not throw any exception, since all errors are encoded into the XML result that will be sent back to the client.

A full example servlet is included in the package. There is a sample XML-RPC Servlet included in the library. You can use it as a starting point for your own needs.

3.3.3. Data types

The following table explains how data types are converted between their XML-RPC representation and Java.

Note that the automatic invocation mechanism expects your classes to take the primitive data types as input parameters. If your class defines any other types as input parameters (including `java.lang.Integer, long, float`), that method **won't** be usable from XML-RPC unless you write your own handler.

For return values, both the primitive types and their wrapper classes work fine.

XML-RPC data type	Java date type
`<i4> or <int>`	`int`
`<boolean>`	`boolean`
`<string>`	`java.lang.String`
`<double>`	`double`
`<dateTime.iso8601>`	`java.util.Date`
`<struct>`	`java.util.Hashtable`
`<array>`	`java.util.Vector`
`<base64>`	`byte[]`

3.4.XML-RPC Example

As an example of XML-PRC, we discuss a calculator with the basic operation “add”, “multiply”, “substract” and “divide”.

First, we implement a XML-RPC server.

```
    import java.util.Hashtable;
    import org.apache.xmlrpc.*;

    public class JavaServer {
        …

        public Hashtable add (int x, int y) {
            …
        }

        public static void main (String [] args) {
            try {
                // start XML-RPC server; Invoke me as <http://localhost:8080/RPC2>.
                System.out.println("Starting XML-RPC server ....");
                WebServer server = new WebServer(8080);

                // register our handler
                server.addHandler("calc", new JavaServer());

            } catch (Exception exception) {
                System.err.println("JavaServer: " + exception.toString());
            }
        } // main
    }
```

A simple client could have the form:

```
import java.util.Vector;
import java.util.Hashtable;
import org.apache.xmlrpc.*;

public class JavaClient {
    // The location of our server.
    private final static String server_url =
                                       "http://localhost:8080/RPC2";
    public static void main (String [] args) {
        try {
            // Create an object to represent our server.
            XmlRpcClient server = new XmlRpcClient(server_url);

            // Build our parameter list.
            Vector params = new Vector();
            params.addElement(new Integer(5));
            params.addElement(new Integer(0));

            // Call the server, and get our result.
            Hashtable result = (Hashtable) server.execute("calc.add", params);
            int sum = ((Integer) result.get("add")).intValue();

            // Print out our result.
            System.out.println("Sum: " + Integer.toString(sum));

        } catch (XmlRpcException exception) {
           System.err.println("JavaClient: XML-RPC Fault #" +
              Integer.toString(exception.code) + ": " + exception.toString());
        } catch (Exception exception) {
            System.err.println("JavaClient: " + exception.toString());
        }
    }
}
```

The full server code is:

```
$ cat JavaServer.java
    import java.util.Hashtable;
    import org.apache.xmlrpc.*;

    public class JavaServer {

        public JavaServer () {
                // Our handler is a regular Java object. It can have a
                // constructor and member variables in the ordinary fashion.
                // Public methods will be exposed to XML-RPC clients.
                System.out.println("Handler registered as 'calc''");
        }

        public Hashtable add (int x, int y) {
                Hashtable result = new Hashtable();
                result.put("add", new Integer(x + y));
                return result;
        }
        public Hashtable sub (int x, int y) {
                Hashtable result = new Hashtable();
                result.put("sub", new Integer(x - y));
                return result;
        }

        public Hashtable mul (int x, int y) {
                Hashtable result = new Hashtable();
                result.put("mul", new Integer(x * y));
                return result;
        }

        public Hashtable div (int x, int y) {
                Hashtable result = new Hashtable();
                if ( y == 0 )
                        result.put("div error", new Integer(0));
                else
                        result.put("div", new Integer(x / y));
            return result;
        }
        public static void main (String [] args) {
            try {

                // start XML-RPC server; Invoke me as <http://localhost:8080/RPC2>.
                System.out.println("Starting XML-RPC server ....");
                WebServer server = new WebServer(8080);

                // register our handler
                server.addHandler("calc", new JavaServer());

            } catch (Exception exception) {
                System.err.println("JavaServer: " + exception.toString());
            }
        }
    }
$
```

How can we test our server to be multithreaded?