CS 580 Client-Server Programming
Spring Semester, 2007
Doc 17 Distributed Computing Intro
April 17, 2007

References

Distributed Computing, http://en.wikipedia.org/wiki/Distributed_computing

JSON - JavaScript Object Notation,

Main JSON web site, http://www.json.org/

JSON in Java, http://www.json.org/java/index.html

Java's Object Streams

Java 6 API documentation, http://java.sun.com/javase/6/docs/api/

Object Stream Spec, http://java.sun.com/javase/6/docs/platform/serialization/spec/protocol.html

XML-RPC

Apache's Java XML-RPC implementation, http://ws.apache.org/xmlrpc/xmlrpc2/index.html

XML-RPC main page, http://www.xmlrpc.com/

XML-RPC spec, http://www.xmlrpc.com/spec

JSON-RPC

Main web site, http://json-rpc.org/

Related Terms

Concurrent Computing

- Simultaneous execution of multiple interacting computational tasks

Networking

- Multiple computers interacting via network
- Do not share single program

Distributed Computing

- Different parts of a program run on multiple computers
- Parts communicate via network

Parallel computing

- Different parts of a program run on multiple processors in same computer

Some Motivation

Basic Communication Steps

Design protocol

Create domain objects

Extract protocol string from select domain objects

Convert protocol string to domain object

Vote Example

```
public class Vote {
    static String CR = "\r";
    int id;
    String option;

    public Vote(int pollId, String optionVote) {
        id = pollId;
        option = optionVote;
    }

    public int id() {return id;}

    public String option() {return option;}

    public String toString() {
        StringBuffer protocol = new StringBuffer();
        protocol.append("command:VOTE");
        protocol.append(CR);
        protocol.append("poll-id:");
        protocol.append(id);
        protocol.append(CR);
        protocol.append("option:");
        protocol.append(option);
        protocol.append(CR);
        protocol.append(CR);
        return protocol.toString();
    }
```

Vote Example - Converting

```
public static Vote fromString(String voteString) {
        String[] lines = voteString.split(CR);
        HashMap<String, String> data = new HashMap<String, String>();
        for (int k = 0; k < lines.length;k++) {
            String[] keyValue = lines[k].split(":");
            data.put(keyValue[0].toLowerCase(), keyValue[1]);
        }
        return fromMap(data);
    }

    public static Vote fromMap(Map<String,String> voteData ){
        String option = voteData.get("option");
        Integer id = Integer.valueOf(voteData.get("poll-id"));
        return new Vote(id.intValue(), option);
     }
}
```

Repeat

Repeat for each Command

Repeat for each client-server project

Some Ways to Automate the Work

JSON

ObjectStreams

JSON

http://www.json.org/

JavaScript Object Notation

data-interchange format

rfc 4627

Maps to/from strings

null

true, false

number

string

array

objects

Implementations in

C, C++, C#, D, E, Java, Objective C

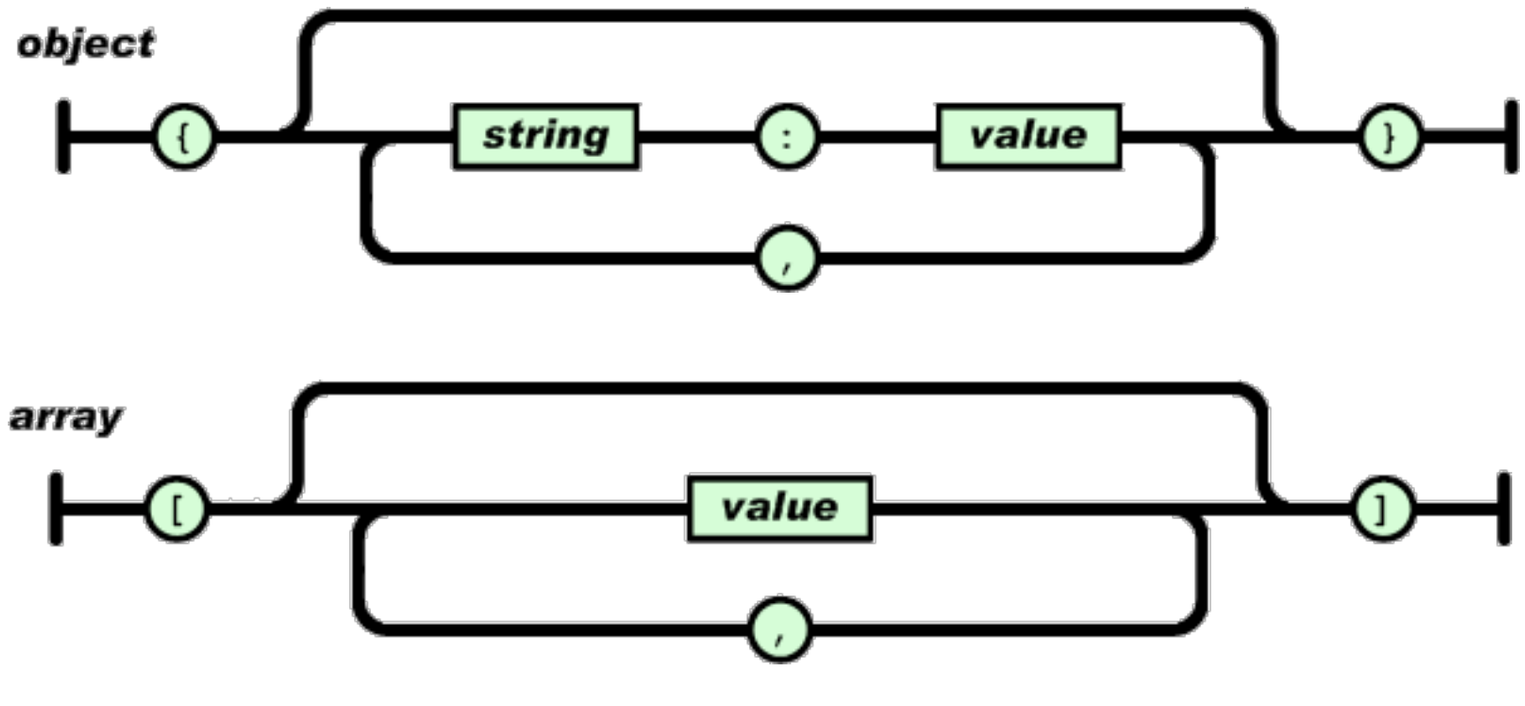
Cold Fusion, Delphi, Erlang, Haskell

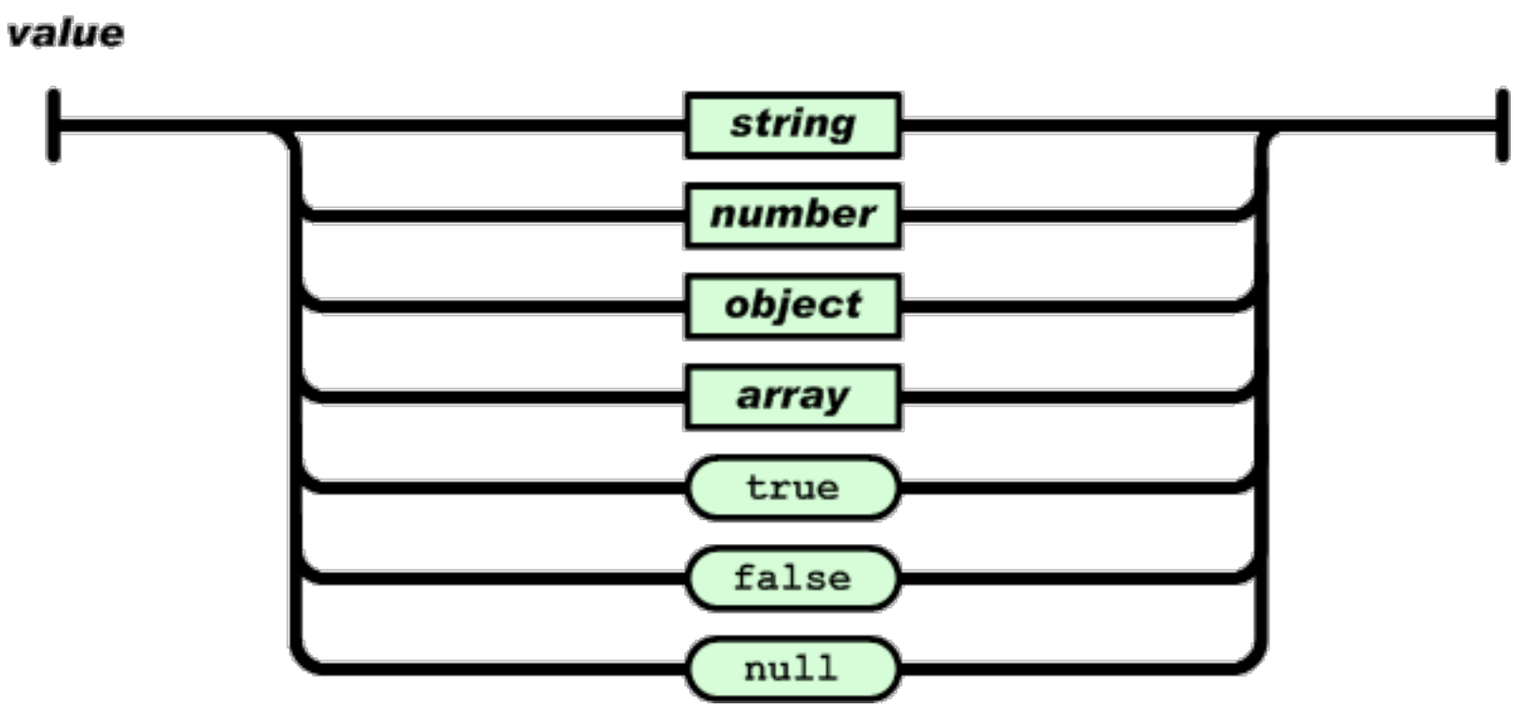
JavaScript, Lisp, LotusScript, Perl,

PHP, Pike, Prolog, Python, Ruby, Smalltalk

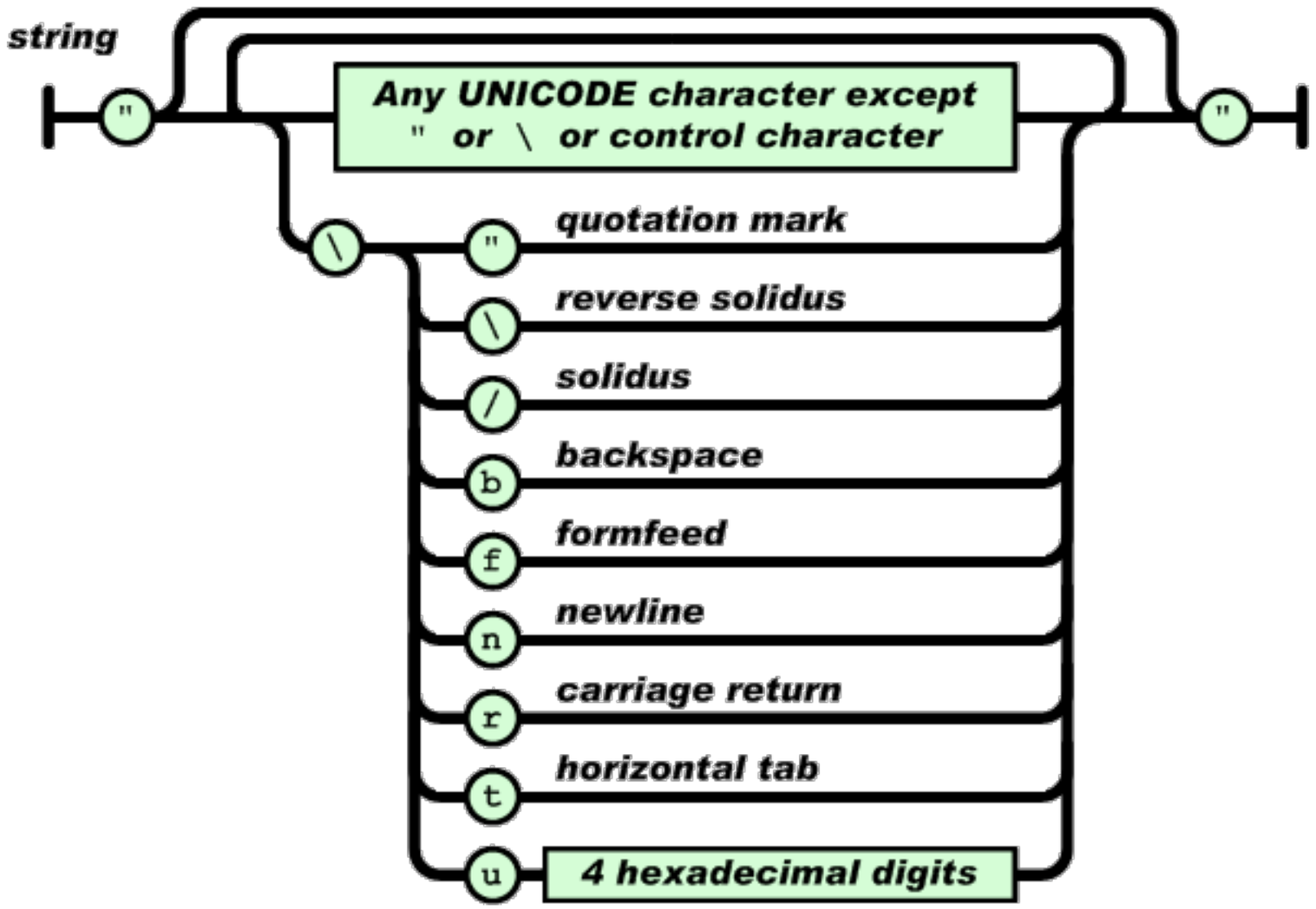
JSON Definition

Source: http://www.json.org/

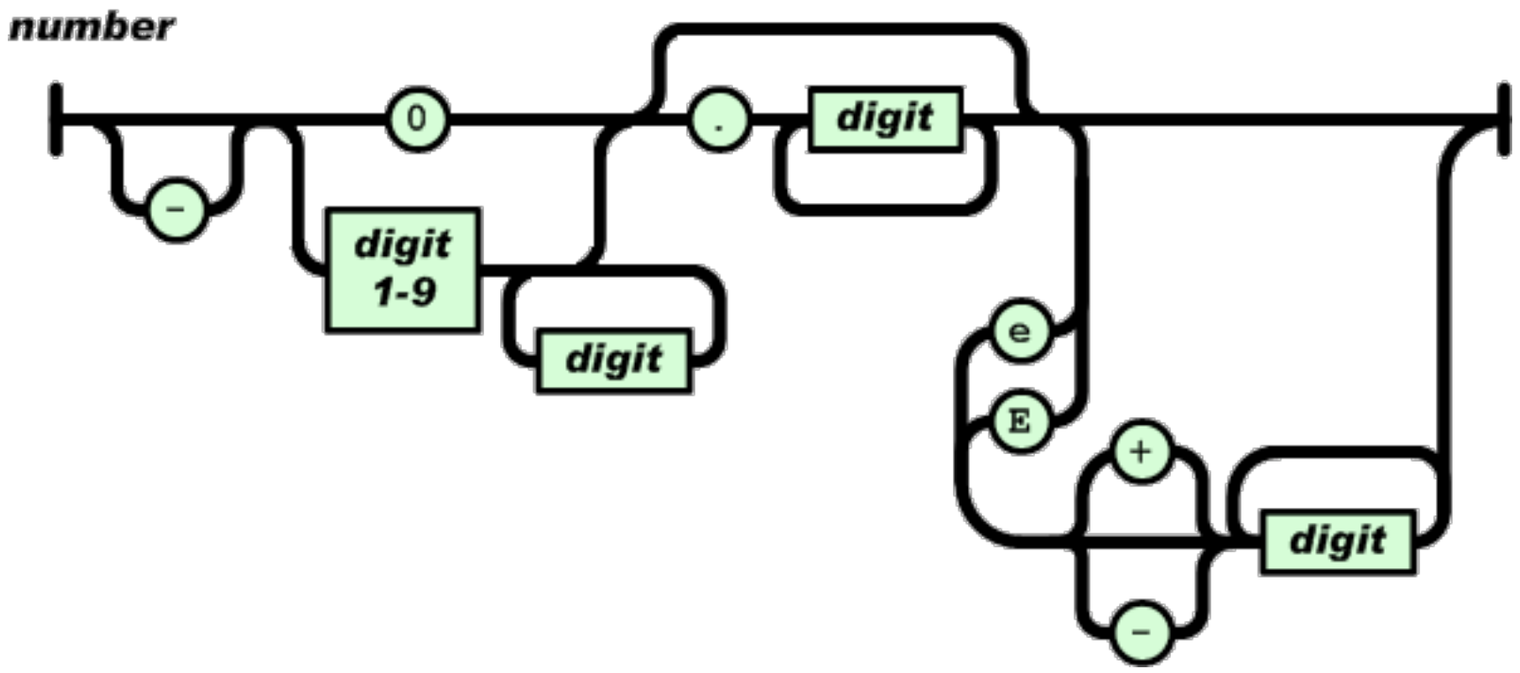




String


string
"
Any UNICODE character except
" or \ or control character
"
\
"
quotation mark
\
reverse solidus
/
solidus
b
backspace
f
formfeed
n
newline
r
carriage return
t
horizontal tab
u
4 hexadecimal digits

Number



Examples

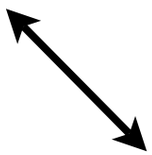
Java Structure

```
Vector array = new Vector();
array.append(new Integer(12));
array.append("Egypt");
array.append(new Boolean(false));
array.append(new Integer(-31));
```

JSON Representation

```
[12,"Egypt",false,-31]
```

```
HashMap<String,Integer> object = new HashMap<String,Integer>();
object.put("lowerBound", 18);
object.put("upperBound", 139);
```



```
{"lowerBound":18,"upperBound":139}
```

Possible Client-Server Usage

Use JSON as protocol syntax

Use JSON libraries to

- Generate client-server messages
- Parse messages from network

JSON in Java

http://www.json.org/java/index.html

A Java JSON library

JSONObject

- Constructs JSON strings
- Parses JSON strings

```
JSONObject json = new JSONObject();
json.put("lowerBound", 18);
json.put("upperBound", 139);

String objectString = json.toString();        //"{"lowerBound":18,"upperBound":139}"

JSONObject newJson = new JSONObject(objectString);
int bound = newJson.getInt("lowerBound");        // 18
```

Vote Example

```
import org.json.JSONObject;
import org.json.JSONException;

public class Vote implements Serializable {
    int id;
    String option;

    public Vote(int pollId, String optionVote) {
        id = pollId;
        option = optionVote;
    }

    public int id() {return id;}
    public String option() {return option;}

    public String toJson() throws JSONException {
        JSONObject json = new JSONObject();
        json.put("command", "VOTE");
        json.put("poll-id", id);
        json.put("option", option);
        return json.toString();
    }
```

```
    public static Vote fromJson(String jsonString)
                                throws JSONException {
        JSONObject json = new JSONObject(jsonString);
        int id = json.getInt("poll-id");
        String option = json.getString("option");
        return new Vote(id, option);
    }
}
```

Using Java JSON library from
http://www.json.org/java/index.html

Using JSON Strings

```
Vote cat = new Vote(1,"cat{:}dog");
String json = cat.toJson();
System.out.println(json);  //{"command":"VOTE","option":"cat{:}dog","poll-id":1}

Vote jsonVote = Vote.fromJson(json);
assertEquals(jsonVote.id(), 1);
```

Consequences

Benefits

Parsing and generation of protocol simplified

- No need to escape special characters

Define protocol in terms of

- maps (key-value pairs)
- arrays
- basic types (string, number, boolean)

Cross language support

Drawbacks

Nested { } and [] complicate parsing

No general end of message sequence

Limited support for primitive types

Object Streams

ObjectOutputStream

- Serializes objects
- Converts objects to bytes

ObjectInputStream

- Deserializes objects
- Converts DataOutputStream byte back into objects

"Requires" writer and reader to be Java programs

Possible Client-Server Usage

Create Message and Response classes

Send message objects to server

Message object

- Contains needed data
- Possibility executes methods on server

Vote Example

```
import java.io.Serializable;

public class Vote implements Serializable, Message {
    int id;
    String option;

    public Vote(int pollId, String optionVote) {
        id = pollId;
        option = optionVote;
    }

    public int id() {return id;}

    public String option() {return option;}

        public Response execute(VoteServer aServer ) {
                boolean succeeded  = aServer.addVote(id, option);
                if (succeeded)
                        return new SuccessResponse();
                return new FailedResponse();
}
```

Using ObjectStreams

Writing the Object

```
Vote cat = new Vote(1,"cat");
FileOutputStream catBytes = new FileOutputStream("cat");
ObjectOutputStream out = new ObjectOutputStream(catBytes);
out.writeObject(cat);
out.close();
```

Reading the Object

```
ObjectInputStream in = new ObjectInputStream(new FileInputStream("cat"));
Vote result = (Vote)in.readObject();
```

Output File

```
¨ìsrVoteªl\€ä…álidLoptiontLjava/lang/String;xptcat
```

Sample Client Usage

```
Socket connection = new Socket(server, port);
OutputStream rawOut = connection.getOutputStream();
ObjectOutputStream out = new ObjectOutputStream(rawOut);
InputStream rawIn = connection.getInputStream();
ObjectInputStream in = new ObjectInputStream(rawIn);

Vote forCat = new Vote(1,"cat");
out.writeObject(forCat);
out.flush();
Response answer =(Response) in.readObject();

out.close();
in.close();
```

Sample Server

```
ServerSocket input = new ServerSocket( port );
while (true) {
   Socket client = input.accept();

      OutputStream rawOut = client.getOutputStream();
      ObjectOutputStream out = new ObjectOutputStream(rawOut);
      InputStream rawIn = client.getInputStream();
      ObjectInputStream in = new ObjectInputStream(rawIn);

      Message request = (Message) in.readObject();
      Response answer = request.execute(this);
      out.writeObject(answer);
      out.flush();
 client.close();
}
```

Consequences

Benefits

No need for a text protocol - just send objects

Protocol is just objects one can send

No need for parsing - just read objects

Drawbacks

Client and server need to be in Java

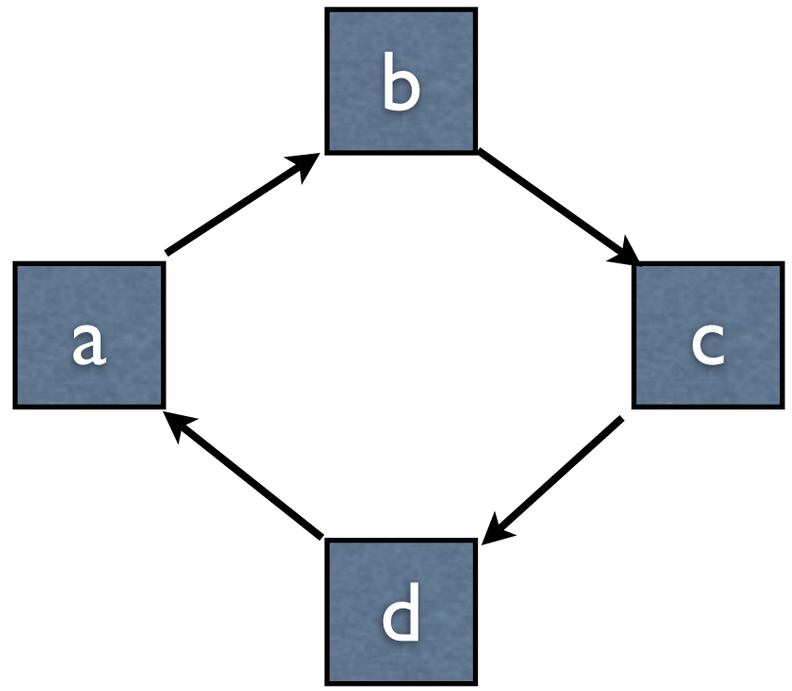
Client & server must have same classes

Modifications of a class can cause problems

Circular References

Care is needed when serializing/deserializing objects with circular references

ObjectStream does it correctly



Object Stream Protocol

The protocol used by Object Stream is documented at:

http://java.sun.com/javase/6/docs/platform/serialization/spec/protocol.html

At least one Lisp implementation of this protocol exists

RPC - Remote Procedure Call

Client "directly" calls a function on the server

Issues

Cross platform

Marshalling/unmarshalling of parameters and results

How can one handle pointers as parameters?

Different contexts of client and server

Registering and finding servers

Sample Uses

Unix NFS (Network File System)
Unix license managers

RPC implementations

SUN RPC
Distributed Computing Environment (DCE)
XML-RPC

XML-RPC

RPC using

HTTP as transport layer and

XML to encode request/response

Language and platform independent

Started by Userland (http://frontier.userland.com/) in 1998

Languages/Systems with XML-RPC implementations

Java, Perl, Python, Tcl, C, C++, Smalltalk

ASP, PHP, AppleScript, COM

Zope, WebCrossing

Led to the development of SOAP

Java Implementation

Apache maintains a Java version of XML-RPC

http://ws.apache.org/xmlrpc/xmlrpc2/index.html

Examples to follow use version 2.0.1

Handles for you

- Network connections
- Sending request to server
- Reading requests
- Responding to requests

XML-RPC Supported Datatypes

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

http://www.xmlrpc.com/spec

Complex Datatype Examples

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

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

JSON Equivalents

```
{"lowerBound":18,"upperBound":139}
```

```
[12,"Egypt",false,-31]
```

Example - Add Server

```
import org.apache.xmlrpc.*;

public class AddServer {
        public Integer addtwo(int x, int y)  {
        return new Integer( x + y);
     }

    public static void main( String[] args)  {
        try {
            System.out.println("Starting server on port 8080");
            WebServer addTwoServer = new WebServer(8080);
            addTwoServer.addHandler("examples", new AddServer());
            addTwoServer.start();
            System.out.println("server running");
        }
         catch (Exception webServerStartError) {
            System.err.println( "JavaServer " + webServerStartError.toString());
         }
    }
}
```

Client can access all public instance methods in AddServer

Example - Client

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

public class XmlRpcExample {
        public static void main (String args[])  {
        try {
            XmlRpcClient xmlrpc =  new XmlRpcClientLite("http://127.0.0.1:8080/");
                    Vector parameters = new Vector ();
            parameters.addElement (new Integer(5) );
            parameters.addElement (new Integer(3) );

            Integer sum = (Integer) xmlrpc.execute("examples.addtwo", parameters);

            System.out.println( sum.intValue() );
        } catch (java.net.MalformedURLException badAddress) {
            badAddress.printStackTrace( System.out);
        } catch (java.io.IOException connectionProblem) {
            connectionProblem.printStackTrace( System.out);
        } catch (Exception serverProblem) {
            serverProblem.printStackTrace( System.out);
        }
    }
}
```

Client Request

```
POST / HTTP/1.1
Host: 127.0.0.1:8080
Content-type: text/xml
Content-length: 190
User-Agent: Smalltalk XMLRPC version 0.5 (VisualWorks® NonCommercial, 7.4.1 of May 30, 2006)
Connection: Keep-Alive

<?xml version="1.0"?>
<methodCall>
        <methodName>examples.addtwo</methodName>
        <params>
                <param><value><int>5</int></value></param>
                <param><value><int>3</int></value></param>
        </params>
</methodCall>
```

Server Response

```
HTTP/1.1 200 OK
Server: Apache XML-RPC 1.0
Connection: close
Content-type: text/xml

<?xml version="1.0"?>
<methodResponse>
        <params>
                <param>
                        <value><int>8</int></value>
                </param>
        </params>
</methodResponse>
```

Note

No explicit sockets
No parsing
Worker pool done for us

Protocol design - just public methods of Server object

Client program has to know

Server machine name or IP
Path to server program
Name of remote method
Number, Type and Order of arguments

Consequences

Benefits

Protocol = public methods
Handles the network communications
Handles generation/parsing of messages
Multiple language support
Platform independent
Simple

Drawbacks

Long messages
Limited support for objects

Apache XML-RPC 3 Extensions

Adds more datatypes

Java Type	Description
None	null value
Byte	8-bit value
Float	32 bit
Long	64-bit integer
org.w3c.dom.Node	DOM Node
Short	16-bit integer
java.io.Serializable	any serializable object
BigDecimal	java.math.BigDecimal
BigInteger	Arbitrary sized integers
java.util.Calendar	

Other XML-RPC systems have similar extensions

Compatibility with these is unknown

JSON-RPC

http://json-rpc.org/

Uses JSON instead of XML for data transfer

Adds convention to support arbitrary objects

JavaScript implementation allows it to be used in Web pages