CS5220 Advanced Topics in Web Programming

Web Services

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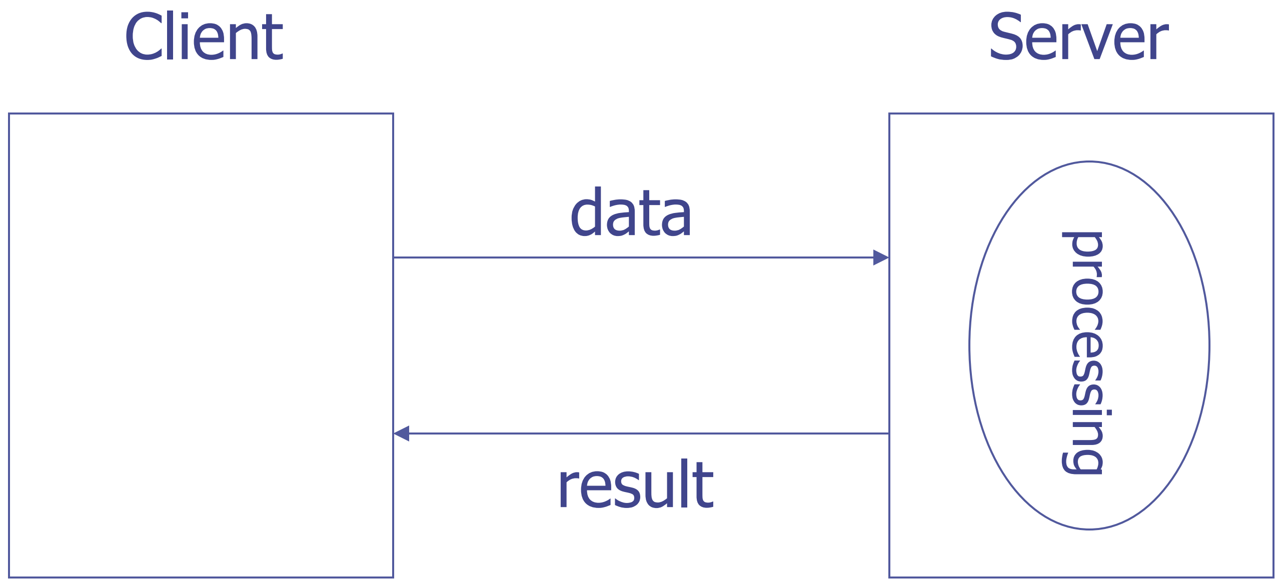
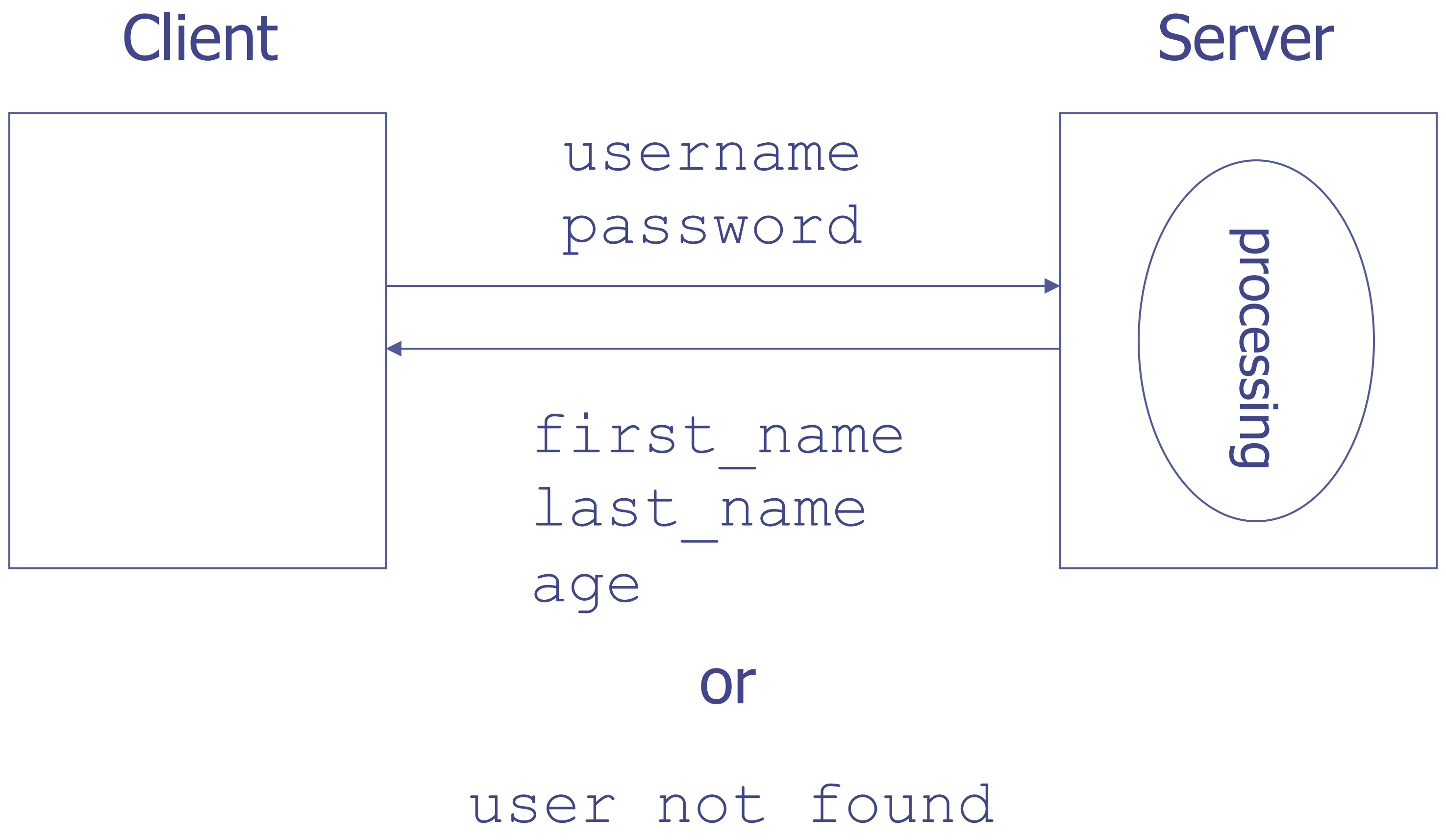
Client-Server Architecture in Network Programming



Client-Server Example



Socket Programming – Client

```
create socket
write string to socket
write string to socket
read string s from socket
    if( s == “user not found” ) return null;
    else
        return new User( s,
            read string from socket
            read integer from socket
        )
close socket
```

- Tedious networking code
- Application specific data exchange protocols

Client-Server Interaction as Function Calls

Client

```
User user = auth(username, password);
```

- Automatically translate function calls to network operations
  - Encode and decode parameters and return values
  - Send and receive data between the client and the server

Server

```
User auth(String u, String p)
{ … return user; }
```

RPC and RMI

- Remote Procedure Call (RPC)
  - C
- Remote Method Invocation (RMI)
  - Java

RMI – Server

- Create a service interface
  - Remote interface
  - Declares the methods to be remotely invoked
- Create a service implementation
  - Remote object
  - Implements the methods to be remotely invoked
- Register the service with a RMI registry so a client can find and use this service

RMI – Client

- Include the remote interface
- Get an implementation of the remote interface by
  - Connecting to the RMI registry
  - Looking up the service by name
- Invoke the method

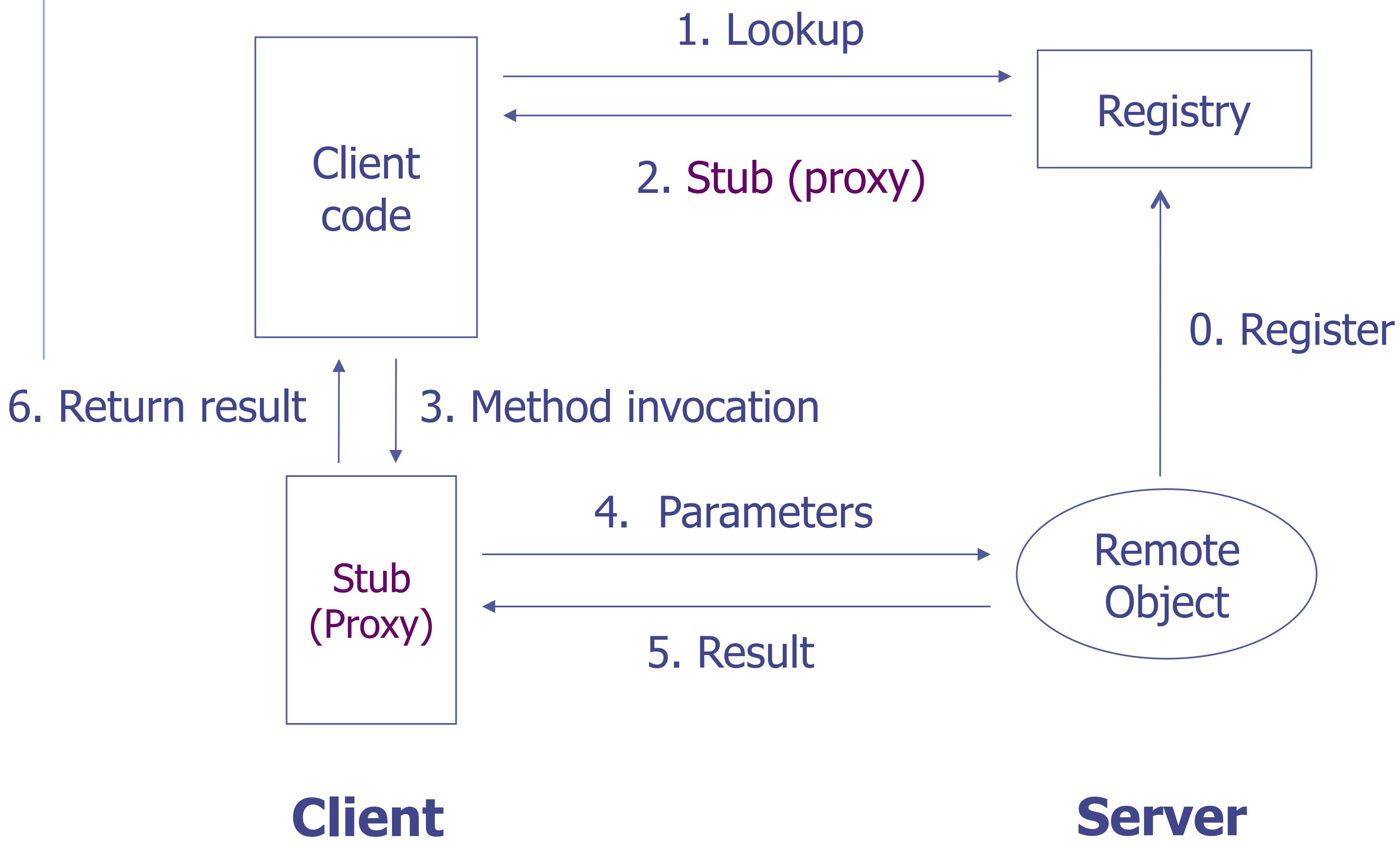
RMI Example: AuthService

- Shared by both server and client
  - `AuthService`
  - `User`
- Server
  - `AuthServiceImpl`
  - `AuthServiceStartup`
- Client
  - `AuthServiceClient`

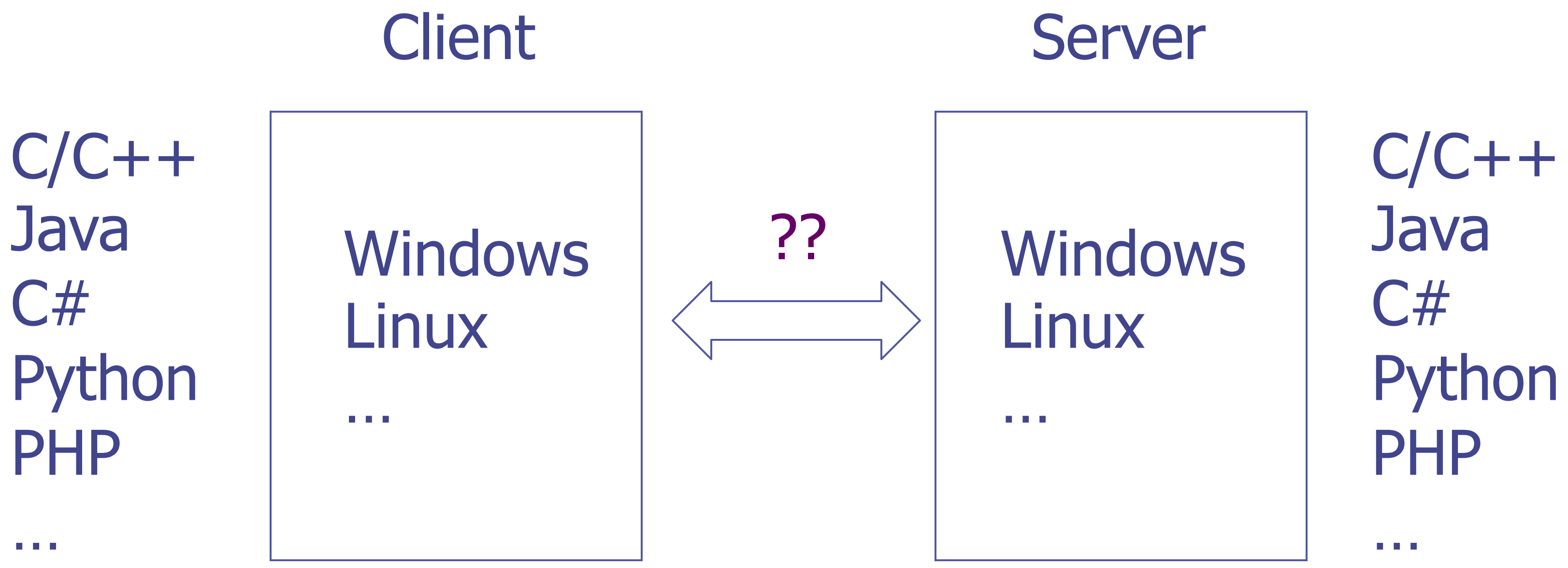
Why does `User` have to implement the `Serializable` interface?

What exactly does `registry.lookup()` return?

How RMI Works



Cross Platform RPC

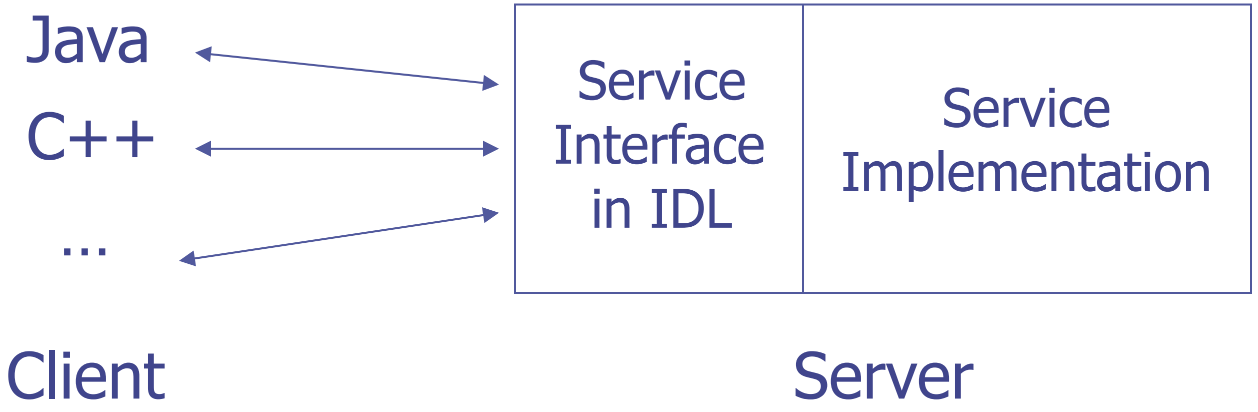


- The client and the server use different languages and/or platforms

How do we define service interface??

CORBA

- Common Object Request Broker Architecture
- Use Interface Definition Language (IDL) to describe service interface
- Provide mappings from IDL to other languages such as Java, C++, and so on.



IDL Example

```
module bank {

  interface BankAccount {

    exception ACCOUNT_ERROR { long errcode; string message;};

    long querybalance(in long acnum) raises (ACCOUNT_ERROR);
    string queryname(in long acnum) raises (ACCOUNT_ERROR);
    string queryaddress(in long acnum) raises (ACCOUNT_ERROR);

    void setbalance(in long acnum, in long balance) raises (ACCOUNT_ERROR);
    void setaddress(in long acnum, in string address) raises (ACCOUNT_ERROR);
  };

};
```

(Traditional) Web Services

- RPC over HTTP
  - Client and server communicate using HTTP requests and responses
- Many different web service protocols
  - Language support: single language vs. language independent
  - Message encoding: binary vs. text
- Most widely used: SOAP

Metro

- https://javaee.github.io/metro/
- A Java web service library backed by SUN/ Oracle
- Implementation of the latest Java web service specifications
- Guaranteed interoperability with .NET Windows Communication Foundation (WCF) web services
- Easy to use

Other Java Web Service Libraries

- Apache Axis2
  - http://axis.apache.org/axis2/java/core/
- Apache CXF
  - http://cxf.apache.org/

Web Service Example: HashService

- Dependency:
  - `org.glasshfish.metro:webservices-rt`
  - `com.sun.activation:javax.activation` (for JDK 10+)
- HashService
  - `@WebService` and `@WebMethod`
- web.xml
- sun-jaxws.xml
  - `<endpoint>`

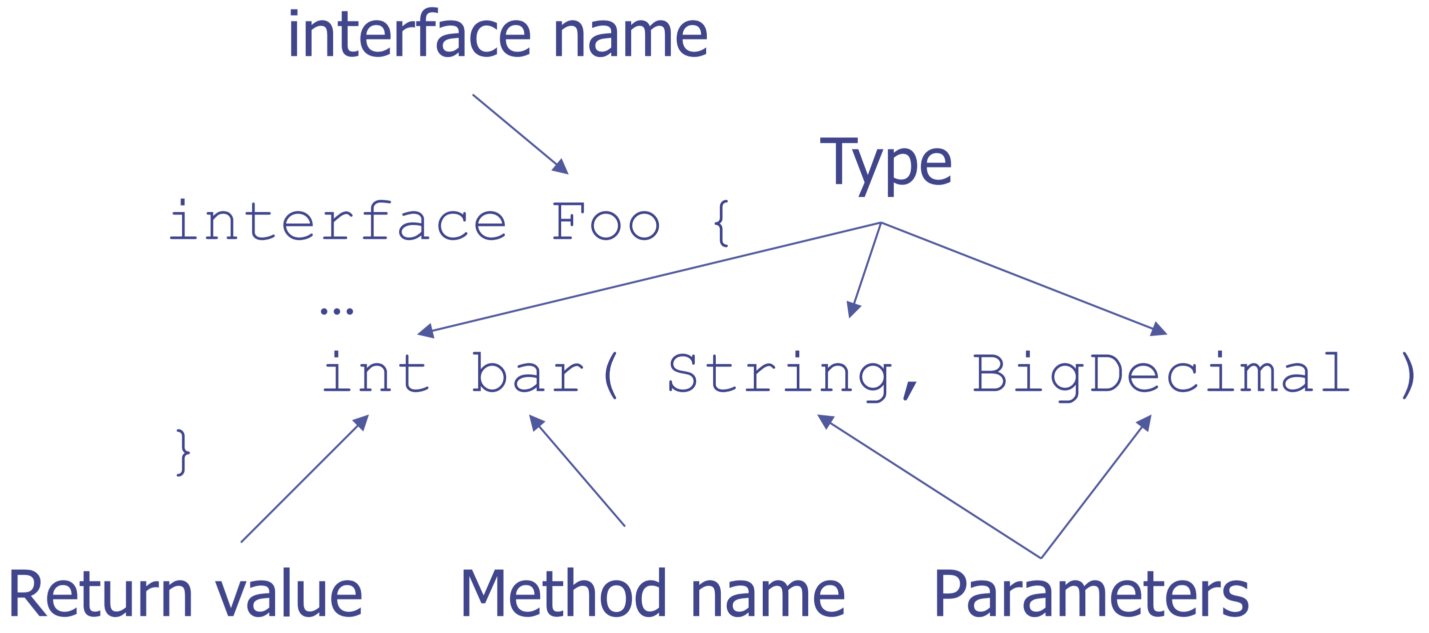
WSDL

- A language for describing web services
  - Where the service is
  - What the service does
  - How to invoke the operations of the service
- Plays a role similar to IDF in CORBA

Sample WSDL Documents

- HashService - http://localhost:8080/ws/hash?wsdl
- Amazon ECS - http://webservices.amazon.com/AWSECommerceService/AWSECommerceService.wsdl

How Do We Describe an API



```
interface Foo {
    …
    int bar( String, BigDecimal )
}
```

How Do We Describe an Web Service API

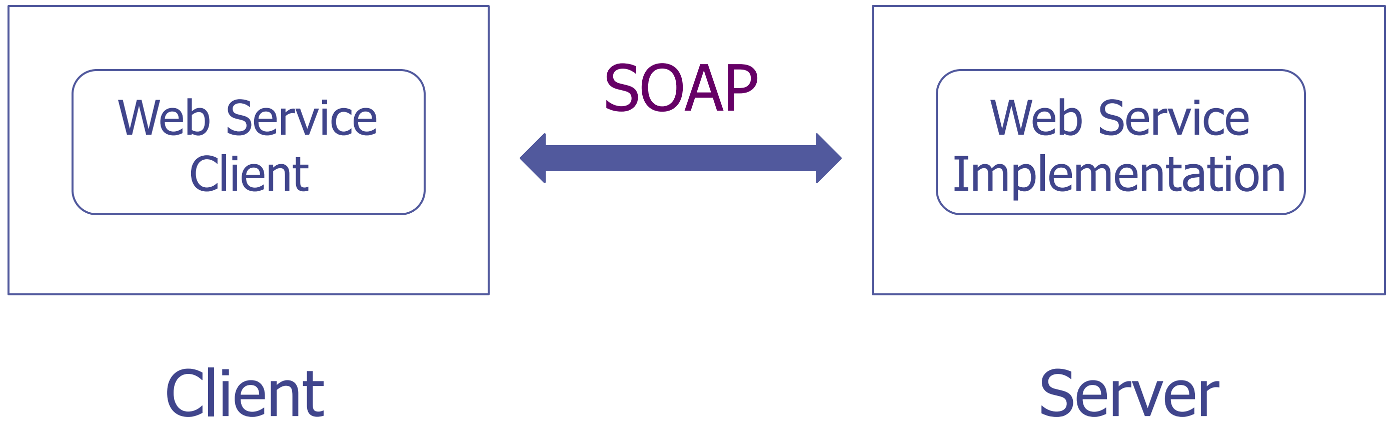
		WSDL
Type	→	<message>
Parameters	→	<input>
Return value	→	<output>
Method name	→	<operation>
Interface name	→	<portType>

Web Service Example: Consume HashService

- Generate client side interface and stub from WSDL using `wsimport` in JDK (before 11)
  - `-s` source code directory
  - `-p` package for generated code
  - URL of the WSDL document
- Write client code

SOAP

- http://www.w3.org/TR/soap/
- Simple Object Access Protocol



A Sample SOAP Message

```
<?xml version='1.0' encoding='UTF-8'?>

<SOAP-ENV:Envelope
        xmlns:SOAP-ENV=http://schemas.xmlsoap.org/soap/envelope/
        xmlns:xsi=http://www.w3.org/1999/XMLSchema-instance
        xmlns:xsd="http://www.w3.org/1999/XMLSchema">
  <SOAP-ENV:Body>
    <ns1:doSpellingSuggestion xmlns:ns1="urn:GoogleSearch"
        SOAP-ENV:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/">
      <key xsi:type="xsd:string">00000000000000000000000000000000</key>
      <phrase xsi:type="xsd:string">britney speers</phrase>
    </ns1:doSpellingSuggestion>
  </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```

A Sample SOAP RPC Response

```
<?xml version='1.0' encoding='UTF-8'?>

<SOAP-ENV:Envelope
  xmlns:SOAP-ENV=http://schemas.xmlsoap.org/soap/envelope/
  xmlns:xsi=http://www.w3.org/1999/XMLSchema-instance
  xmlns:xsd="http://www.w3.org/1999/XMLSchema">
  <SOAP-ENV:Body>
    <ns1:doSpellingSuggestionResponse xmlns:ns1="urn:GoogleSearch“
      SOAP-ENV:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/">
      <return xsi:type="xsd:string">britney spears</return>
    </ns1:doSpellingSuggestionResponse>
  </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```

A Sample Fault Response

```
<SOAP-ENV:Envelope
   xmlns:SOAP-ENV="http://schemas.xmlsoap.org/soap/envelope/"
   SOAP-ENV:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/">
   <SOAP-ENV:Body>
      <SOAP-ENV:Fault>
         <faultcode>SOAP-ENV:Client</faultcode>
         <faultstring>Client Error</faultstring>
         <detail>
            <m:dowJonesfaultdetails xmlns:m="DowJones">
               <message>Invalid Currency</message>
               <errorcode>1234</errorcode>
            </m:dowJonesfaultdetails>
         </detail>
      </SOAP-ENV:Fault>
   </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```

SOAP Encoding

- http://schemas.xmlsoap.org/soap/encoding/
- Include all built-in data types of *XML Schema Part 2: Datatypes*
  - `xsi` and `xsd` name spaces

SOAP Encoding Examples

int a = 10;	<a xsi:type="xsd:int">10</a>
float x = 3.14159;	<x xsi:type="xsd:float">3.14159</x>
String s = “SOAP”;	<s xsi:type="xsd:string">SOAP</s>

Compound Values and Other Rules

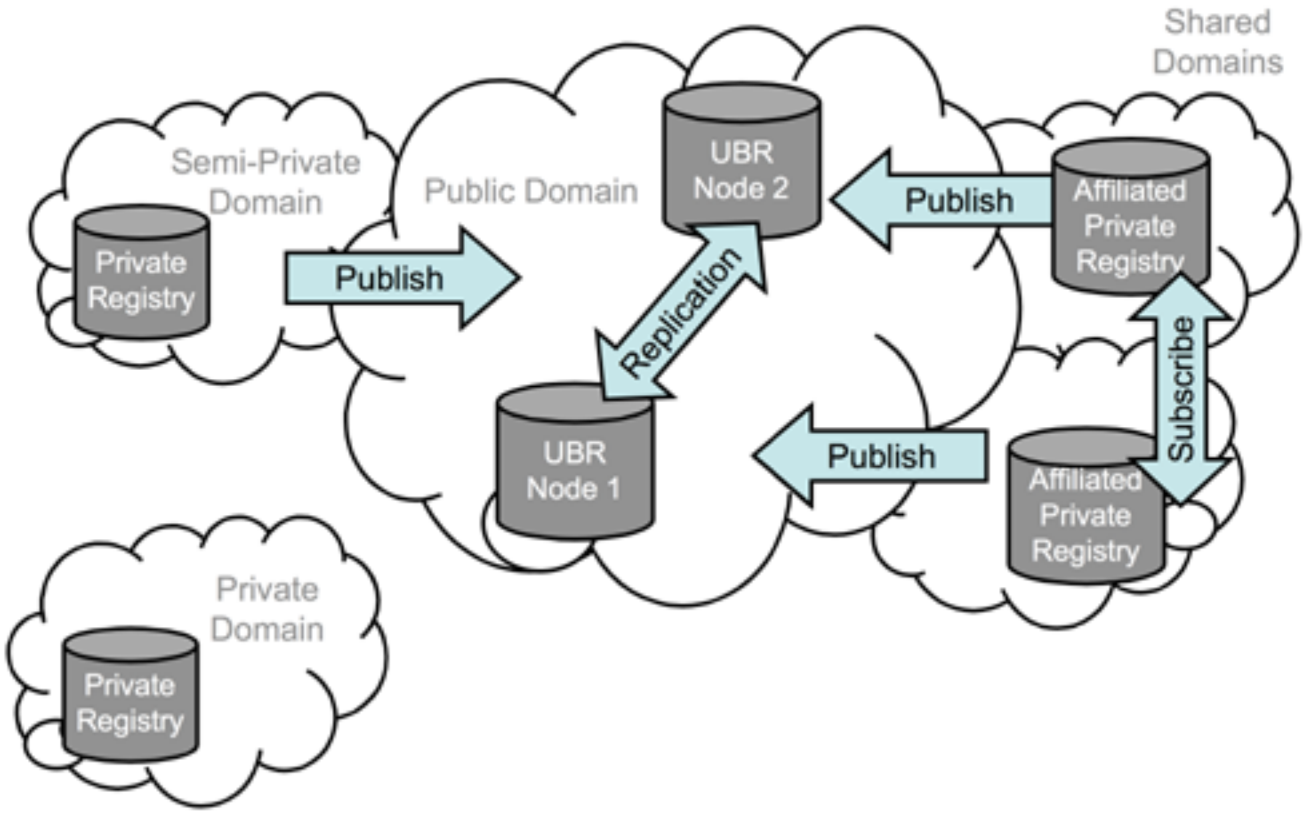
```
<iArray xsi:type=SOAP-ENC:Array SOAP-ENC:arrayType="xsd:int[3]">
    <val>10</val>
    <val>20</val>
    <val>30</val>
</iArray>

<Sample>
    <iVal xsi:type="xsd:int">10</iVal>
    <sVal xsi:type="xsd:string">Ten</sVal>
</Sample>
```

- References, default values, custom types, complex types, custom serialization …

UDDI

- Universal Description Discovery and Integration
- A registry for web services
- A web API for publishing, retrieving, and managing information in the registry

UDDI Registries



Problems with SOAP Web Service

- Very complex
  - Based on some very complex specifications
  - Very difficult to create supporting libraries
  - Virtually impossible to use without supporting libraries
- Not very efficient

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RESTful Web Services

A RESTful Web Service

Request

Get user with id=1: `/service/user/1`

⬇

XML Response or JSON Response

```
<user>
    <id>1</id>
    <firstName>John</firstName>
    <lastName>Doe</lastName>
    <email>jdoe1@localhost</email>
</user>
```

```
{
  "id": 1,
  "firstName": "John",
  "lastName": "Doe",
  "email": "jdoe1@localhost"
}
```

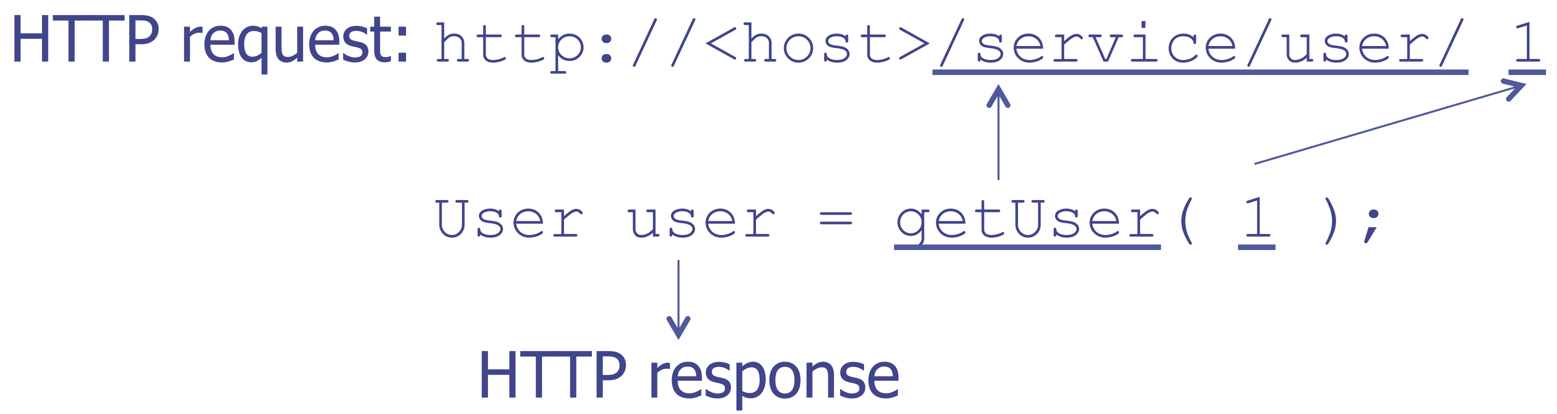
A real-world example: https://dev.twitter.com/rest/public/search

Is That Really A Web Service?

- Where is the method call?
- Why does it look like a web *application*?
- Why is it called *RESTful*?

Where Is The Method Call?

- Answer: it's kind of a method call …



HTTP request: `http://<host>/service/user/ 1`

```
User user = getUser( 1 );
```

HTTP response

The downside is that now it's the client's responsibility to turn an HTTP response into a "return value", which is why the response is usually in XML or JSON format.

Why Does It Look Like A Web Application?

- Answer: it does, and it’s a good thing.

  Now all web technologies/languages/ platforms can be used to create web services (and you don’t have to implement complex specifications like SOAP).

Why Is It Called RESTful?

- REpresentational State Transfer
- Introduced by Roy Fielding in his Ph.D. dissertation on network-base software architecture
- Describes the common characteristics of *scalable*, *maintainable*, and *efficient* distributed software systems

The REST Constraints

- Client and server
- Stateless
- Support caching
- Uniformly accessible
- Layered
- (Optional) support code-on-demand

RESTful Web Services

- Web applications for *programs*
  - Generate responses in formats to be read by machines (i.e. XML and JSON) rather than by humans (i.e. HTML)
- Simulate how the static web (the largest REST system) works
  - Use URLs that look like URLs for static web pages
  - Utilize HTTP request methods and headers
  - *Stateless*, i.e. no session

Summary

- RPC and RMI
- CORBA
  - IDL
- SOAP, WSDL, UDDI
  - Create and consume SOAP web services using Metro
- RESTful web services

Readings

- *The Rise and Fall of CORBA* by Michi Henning
- *Java Web Services Up and Running* by Martin Kalin
- Security Fundamentals for Web Services
- *RESTful Java Web Services* by Jose Sandoval