LECTURE 7: DISTRIBUTED OBJECT- & WEB-BASED SYSTEMS

SECTION 7.1: DISTRIBUTED OBJECT-BASED SYSTEMS
Distributed Objects

• **Introduction**
  - In *distributed object-based* systems, an object plays a key role in getting *distribution transparency*.
  - Everything is treated as an object & clients are offered services/resources as objects that they can invoke.
  - *Distributed objects* form an important paradigm as it’s ‘easy’ to hide distribution aspects behind an object’s interface.
  - As object can be almost anything, also useful paradigm for building systems.
  - Key feature of objects is they encapsulate data (aka *state*), & operations on those data, (aka *methods*)
  - Methods are made available through an *interface*.
  - Process can only access/change object’s state by invoking methods made available via an object’s interface.
  - An object may implement multiple interfaces and for an interface definition, can be several objects offering an implementation of it.
  - Interface separates impln details from user or redirects to different implns.

Distributed Objects (/2)

• **Architecture**
  - The separation between interfaces & objects implementing them is crucial for distributed systems.
  - It allows for placing interface at one machine, with object itself on another machine.
  - This organization is commonly referred to as a *distributed object definition*.

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Organization of a Distributed Object with a Client-Side Proxy
Distributed Objects (/3)

**Architecture**
- Data & operations *encapsulated* in an object,
- Operations implemented as methods grouped into interfaces
- Object offers only its *interface* to clients
- **Object server** is responsible for a collection of objects
- **Client stub** (proxy) implements interface, marshals call
- **Server skeleton** handles (un)marshalling and object invocation (+other stuff)

**Types of objects I**
- **Compile-time objects**: Language-level objects, from which proxy and skeletons are automatically generated.
- **Runtime objects**: Implementable in any language, but need **object adapter** to make implementation appear as an object.

**Types of objects II**
- **Transient objects**: live only due to server: if server exits, so will the object.
- **Persistent objects**: live independently of server: if server exits, object state & code remain (passively) on disk

Distributed Objects (/4)

**Example: Enterprise Java Beans (EJB)**
- Def: Java object hosted by special server that allows for different means of calling the object by remote clients.
- Four Different Types of EJBs
  - **Stateless session bean**: Transient object, called once, does its work and is done.
    E.g.: execute SQL query, return result.
  - **Stateful session bean**: Transient object, but keeps client-related state until session end.
    E.g.: shopping cart.
  - **Entity bean**: Persistent, stateful object, can be invoked over many sessions.
    E.g.: object maintaining client info on last number of sessions.
  - **Message-driven bean**: Reactive objects, often triggered by message types. Used to implement publish/subscribe forms of communication.
Distributed Objects (/5)

- **Processes:** *Object servers*
  - **Servant:** Object implementation, sometimes only implements methods:
    - Collection of C or COBOL functions, that act on structs, records, DB tables, etc.
    - Java or C++ classes
  - **Skeleton:** Server-side stub handles n/w I/O:
    - Unmarshalls incoming requests, calls relevant servant code
    - Marshalls results and sends reply message
    - Generated from interface specifications
  - **Object adapter:** “Manager” of a set of objects:
    - Inspects (as first) incoming requests
    - Ensures referenced object is ‘activated’ (requires identification of servant)
    - Passes request to appropriate skeleton, following specific ‘activation’ policy
    - Responsible for generating object references

Distributed Objects (/6)

- **Client-to-object binding:**
  - **Object reference**
    - Having an object reference allows a client to *bind* to an object:
    - Reference denotes server, object, and communication protocol
    - Client loads associated stub code
    - Stub is instantiated and initialized for specific object
  - **Two ways of binding**
    - *Implicit:* Methods are invoked directly on referenced object
      - Remote-object references allow us to pass references as parameters.
    - *Explicit:* Client must explicitly bind to object first before invoking it
      - This was difficult with ordinary RPCs.
Distributed Objects (/7)

• Remote Method Invocation (RMI)
  – Java Remote Method Invocation (RMI) system allows an object running in one JVM to call methods on objects running in another.
  – RMI gives applications transparent, lightweight access to remote objects.
  – RMI defines a high-level protocol and API.
  – Programming distributed applications in Java RMI is simple:
    • It is a single-language system.
    • Remote object coder must consider behaviour in a concurrent environment.

• Java RMI Applications
  – RMI is supported by two java packages java.rmi & java.rmi.server
  – An application that uses RMI has 3 components:
    • an interface that declares headers for remote methods;
    • a server class that implements the interface; and
    • one or more clients that call the remote methods.

Distributed Objects (/8)

• A Java RMI application needs to do the following:
  – Locate remote objects: An application can use one of two mechanisms to obtain references to remote objects:
    1. An application can register its remote objects with RMI’s simple naming facility the rmiregistry, or
    2. The application can pass and return remote object references as part of its normal operation.
  – Communicate with remote objects:
    • Details of communication between remote objects are handled by RMI;
    • To coder, remote communication looks like standard Java method call.
  – Load class bytecodes for objects that are passed around:
    • RMI provides necessary mechanisms to load object’s code" & send its data.
    • Reason for this is that RMI allows caller to pass objects to remote objects.

  *i.e. object translated/’serialized’/’marshalled’ into bytecode
Distributed Objects (/9)

- **RMI Architecture**
  - **Stub**: lives client-side; pretends to be the remote object
  - **Skeleton**: lives on server; talks with true remote object
  - **Reference Layer**: determines if referenced object is local or remote
  - **Transport Layer**: packages remote invocations; dispatches messages between stub & skeleton

![Diagram](image)

Distributed Objects (/10)

- **Java RMI Basics**: (Assumes client stub, server skeleton in place)
  - Client invokes method at *stub*
  - *Stub* marshals request and sends it to server
  - Server ensures referenced object is active:
    - Create separate process to hold object
    - Load the object into server process
  - Object *skeleton* unmarshalls request & referenced method is invoked
  - If request contains object reference, invocation is applied recursively (i.e., server acts as client)
  - Result is marshalled and passed back to client
  - Client *stub* unmarshalls reply & passes result to client application
Distributed Objects (/10)

- **RMI: Parameter passing**

  - **Object reference**: Much easier than in the case of RPC:
    - Server can simply bind to referenced object, and invoke methods
    - Unbind when referenced object is no longer needed

- **Object-by-value**: Client may also pass a complete object as parameter value:
  - An object has to be marshalled:
    - Marshall its state
    - Marshall its methods, or give ref to where an implementation can be found
  - Server unmarshalls object (n.b. now have copy of original object)
  - Object-by-value passing tends to introduce nasty problems

Distributed Objects (/11)

- **RMI Parameter Passing**
  - **Note**: System-wide object reference usually contains:
    - Server address
    - Port to which adapter listens, and
    - Local object ID.
  - **Extra**: Info on protocol between client & server (TCP, UDP, SOAP, etc.)
Distributed Objects (/12)

• RMI Registry
  – A simple server-side bootstrap naming facility allowing remote clients to get a reference to a remote object
    • Servers name & register their objects to be accessed remotely with the RMI Registry.
    • Clients use the name to find server objects and obtain a remote reference to those objects from the RMI Registry.
  – Registry service is background program with a list of registered server names on a host and invoked by: `rmiregistry port &`
  – Registry service is provided by a Naming object providing two key methods:
    • *Bind:* to register a name and server
    • *Lookup:* to retrieve the server bound to a name

RMI Inheritance

![RMI Inheritance Diagram](image-url)
Security Manager

- RMI programs must install a security manager
  - Otherwise RMI will not download classes

```java
if (System.getSecurityManager() == null) {
    System.setSecurityManager(new SecurityManager());
}
```

- Security policies specify actions that are unsafe
  - For every unsafe action there is a corresponding checkXXX() method
  - Actions not allowed throw a SecurityException

- Only one security manager can be installed
  - By default, an application has no security manager installed

- Policies are specified using *.policy files
  - Server and client application must specify their policy file
    - Default file: java.home/lib/security/java.policy
  - Use -Djava.security.policy property specify a file

RMI Example: Database Interface

```java
import java.rmi.*;
import java.rmi.server.*;
public class Database extends UnicastRemoteObject 
    implements DatabaseInterface {
    private int data = 0; // the database

    public Database(int value) throws RemoteException {
        data = value;
    }

    public int read () throws RemoteException {
        return data;
    }

    public void write (int value) throws RemoteException {
        data = value;
        System.out.println("New value is: " + data);
    }
}
```
RMI Example (/2): Database Server

```java
import java.rmi.*;
import java.rmi.server.*;
public class DatabaseServer {
    public static void main (String[] args) {
        try {
            // create Database Server Object
            Database db = new Database(0);

            // register name and start serving
            String name = "rmi://fuji:9999/DB";
            Naming.bind(name, db);
            System.out.println(name + " is running");
        } catch (Exception ex) {
            System.err.println(ex);
        }
    }
}
```

RMI Example (/3): Database Client

```java
import java.rmi.*;
public class DatabaseClient {
    public static void main (String[] args) {
        try {
            // set RMI Security Manager
            System.setSecurityManager(new RMISecurityManager() {
                public void checkConnect(String host, int port) {}
                public void checkConnect(String host, int port, Object Context) {}
            });

            // get database object
            String name = "rmi://fuji:9999/DB";
            DatabaseInterface db = (DatabaseInterface)Naming.lookup(name);
            int value, rounds = Integer.parseInt(args[0]);
            for (int i = 0; i < rounds; i++) {
                value = db.read();
                System.out.println("read: " + value);
                db.write(value+1);
            }
        } catch (Exception ex) {
            System.err.println(ex);
        }
    }
}
RMI Example (/4): Building the Application

Steps involved in Building the Application:

1. Compile the code:
   ```
   javac Database.java DatabaseClient.java
   DatabaseInterface.java DatabaseServer.java
   ```

2. Generate stub and skeleton class files:
   ```
   rmic Database (note: not needed for Java 5 or later)
   ```

3. Start the RMI registry (if don’t specify port, 1099 is the default):
   ```
   rmiregistry 9999 &
   ```

4. Start the Server:
   ```
   java -Djava.security.policy=java.policy DatabaseServer
   ```

5. Start the Client:
   ```
   java -Djava.security.policy=java.policy DatabaseClient 10
   ```

SECTION 7.2: DISTRIBUTED WEB-BASED SYSTEMS
Introduction to Web Services

- WS offered by one electronic device to another, communicating via web
- Here, web technology (e.g. HTTP), originally to be used for human-to-machine comms, is used for M2M chatter, e.g. in XML and JSON.
- HTTP defines message format, how sent and what Web servers & browsers do in turn
- WS typically provides OO web-based interface to a DB server, used by another web server, or mobile apps showing UI to end users
- In 2002, W3C defined a WS Architecture,
  - Req’d standardized “Web service” impln with interface described in WSDL.
- Other systems interact with the WS using SOAP* messages, typically using HTTP with XML serialization with other Web-related standards.
- Later extended to include
  - REST-compliant WS, where service changes forms of Web resources (URIs) using a uniform set of stateless operations (aka ‘CRUD’)
  - Arbitrary WS where service exposes arbitrary operations (little used)

Background to Web Services

- Apache Web servers
  - Observation: More than 45% of 1.8 billion* Websites are Apache.
  - Server is internally organised roughly according to steps needed to process an HTTP request.
  - The anatomy of an Apache Web Server is shown below:

Background to Web Services (/2)

- **Server Clusters**
  - **Essence:** To improve performance & availability, WWW servers are often clustered in a way that is transparent to clients.
  - Below a server cluster is used with a front end to implement a WS.

![Diagram of server clusters with front end handling incoming requests and responses.]

Background to Web Services (/3)

- **Problem with Server Clusters:**
  - Front end gets easily overloaded, thus need for special measures.
    1. **Transport-layer switching:**
      - Front end simply passes TCP request to a server, according to some performance metric (e.g. load balancing).
    2. **Content-aware distribution:**
      - Front end reads the content of HTTP request and selects best server.

![Diagram of TCP handoff in server clusters.]

Role of a TCP Handoff in Server Clusters:

1. Switch gets a TCP connection request.
2. Finds best server & sends request to that.
3. Server sends 'ACK' to client with switch's IP address as source.
4. Must do this as Client was expecting to hear from switch.
Background to Web Services (/4)

- **Naming: The Naming Service**
  - Names play a very important role in all computer systems.
  - For sharing resources, uniquely identifying entities, referring to locations...
  - Important issue for naming:
    - a name must be resolvable to its entity it refers to,
    - for *Name resolution* need to implement a *Naming System*.
  - Naming in distributed systems & non-distributed systems differs in the implementation.
  - In Chord, DS naming system implementation is itself often distributed.
  - How this distribution is done dictates efficiency & scalability of the naming system.

Background to Web Services (/5)

- **Naming: Names in General**
  - *Name in DS*: string of bits/characters used to refer to it.
  - **Entities**
    - In DS can be anything (e.g. resources such as hosts, printers, disks & files).
    - Other examples of explicitly named entities are processes, users, mailboxes, Web pages, messages, network connections.
  - Entities can be operated on
    - e.g., a printer offers an interface with operations for printing docs & others
    - e.g. network connection offers data send/ receive, set QoS parameters etc.
  - Operating on entities need an *Access Point*, another DS entity:
    - The name of an access point is called an *address*.
    - Address of entity’s access point entity is called an *address of that entity*.
  - Note: A *location-independent name* for an entity $E$, is independent from the addresses of the access points offered by $E$. 
Background to Web Services (/6)

• Naming: Names in General (cont’d)
  – Entities can offer more than one access point
    • e.g. phone is person’s access point, with phone number as address
    • people have many phone numbers, for their many addresses.
  – In DS, a typical access point is a host running a specific server.
    • address is e.g. IP address+port (i.e. server’s transport-level address).
  – Entities may change access points over course time.
    • laptop moves location, it’s often assigned a different IP address
    • similarly, changing jobs or ISPs, means changing e-mail addresses.

Background to Web Services (/7)

• Naming: Identifiers
  – Pure name
    • A name that has no meaning at all; it is just a random string.
    • Pure names can be used for comparison only.
  – Identifier: A name having the following properties:
    • P1: Each identifier refers to at most one entity
    • P2: Each entity is referred to by at most one identifier
    • P3: An identifier always refers to the same entity (prohibits reusing an identifier)
  – Observation
    • Identifier needn’t necessarily be a pure name i.e. can have content
Background to Web Services (/8)

- **Naming: Uniform Resource Locator (URL)**
- Often contain information on how/where to access a document.
- **Some URLs**
  - **Using only a DNS Name**
  - **Combining a DNS name with a port number**
  - **Combining a DNS name with a port number**

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Host name</th>
<th>Pathname</th>
</tr>
</thead>
<tbody>
<tr>
<td>http</td>
<td><a href="http://www.cs.vu.nl">www.cs.vu.nl</a></td>
<td>inbox/steen/mbox</td>
</tr>
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<th>Scheme</th>
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<tr>
<td>http</td>
<td><a href="http://www.cs.vu.nl">www.cs.vu.nl</a></td>
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<td>http</td>
<td>192.37.24.11</td>
<td>80</td>
<td>inbox/steen/mbox</td>
</tr>
</tbody>
</table>

**SECTION 7.2.1: SOAP-BASED WEB SERVICES**
Web Services: SOAP-Based

• The Principle of a Web Service
  – Standardization dictates how those services are described such that they can be looked up by a client application.
  – Also, need to ensure that service call proceeds according to server application rules.
  – This is no different from what is needed to realize a remote procedure call.

   ![Diagram of SOAP-based Web Services]

Web Services: SOAP-Based (/2)

• Standardization needed so client can look up/access services.
  – Three Components:
    – **Directory Service**: Stores service descriptions.
      • Adheres to Universal Description, Discovery & Integration standard (UDDI).
      • As its name suggests, this prescribes DB layout with service descriptions.
      • Allows Web service clients to browse for relevant services.
    – **Interface**: Services described in Web Services Definition Lang (WSDL).
      • Formal language akin to IDLs used to support RPC-based communication.
      • Description contains precise definitions of interfaces provided by a service.
        – e.g. procedure specification, data types, (logical) location of services, etc.
      • A WSDL description is one that can be automatically translated to client-side and server-side stubs, akin to in ordinary RPC-based systems.
    – **Communication**: Simple Object Access Protocol (SOAP) is used
      • Specification of how communication takes place.
      • SOAP is used, which is essentially a framework for standardizing communication between two processes.
Web Services: SOAP-Based (/3)

• Service-Oriented Architectures
  • So far, a Web service is offered in terms of a single invocation.
    • In practice, more complex invocation structures needed before a service can be considered as completed.
      e.g. book order requires selecting a book, paying, and ensuring its delivery.
    • So must model actual service as a transaction with multiple ordered steps.
    • Means dealing with a complex service built from number of basic services.
  • SOA principles for organising s/w not restricted to Web services use
    • Loose Coupling (independent & self-contained)
    • Discoverability
    • Abstract service description (independent of implementation)
    • Encapsulation (autonomy and abstraction)
    • Compositionality (can be composed of other services)
    • Additional for web services: based on open standards & vendor neutral

Web Services: SOAP-Based (/4)

• Java Web Services: Java supports web services thro JAX-WS
  – Java Web Services can be deployed in the following ways:
    • Core Java only
    • Core Java with the current Metro release (helps when building a client)
    • Stand-alone web container (e.g. Tomcat)
    • Java application server (e.g. Glassfish – useful for implementing EJB)
  – Can implement SOAP-based web service as a single Java class
  – But usually consists of the following:
    • SEI (Service Endpoint Interface): Declares methods (web service operations)
    • SIB (Service Implementation Bean)
      – Defines the methods declared in the interface
      – Can be either POJO (Plain Old Java Object) or EJB (Enterprise Java Bean)
Web Services: SOAP-Based (/4)

• Writing a Web Service Client
  – Web service client is a program using Web service, e.g. Java application
  – How to access the Web services:
    • Send a HTTP POST request with request as SOAP message to server
    • Better: use wsimport to generate Java stubs to do this for you
  – However, wsimport needs a description of Web services offered by the Web server:
    • Use WSDL document generated by the Web server
    • URL of this document can be obtained by looking at Web services section at http://localhost:4848

```java
package ch01.ts; // time server

import javax.jws.WebService;
import javax.jws.WebMethod;
import javax.jws.soap.SOAPBinding;
import javax.jws.soap.SOAPBinding.Style;

/**
 * The annotation @WebService signals that this is the
 * SEI (Service Endpoint Interface). @WebMethod signals
 * that each method is a service operation.
 * 
 * The @SOAPBinding annotation impacts the under-the-hood
 * construction of the service contract, the WSDL
 * (Web Services Definition Language) document. Style.RPC
 * simplifies the contract and makes deployment easier.
 */
@WebService
@SOAPBinding(style = Style.RPC) // more on this later
public interface TimeServer {
    @WebMethod String getTimeAsString();
    @WebMethod long getTimeAsElapsed();
    // These methods can be call akin to an RMI interface
    // But no remote exceptions thrown.
}
```

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package ch01.ts;

import java.util.Date;
import javax.jws.WebService;

/**
 * The @WebService property endpointInterface links the
 * SIB (this class) to the SEI (ch01.ts.TimeServer).
 * Note that the method implementations are not annotated
 * as @WebMethods.
 */

@WebService(endpointInterface = "ch01.ts.TimeServer")
// Links the service to the interface
public class TimeServerImpl implements TimeServer {
    public String getTimeAsString() { return new Date().toString(); }
    public long getTimeAsElapsed() { return new Date().getTime(); }
}

package ch01.ts;

import javax.xml.ws.Endpoint;

/**
 * This application publishes the Web service whose SIB is ch01.ts.TimeServerImpl.
 * For now, the service is published at network address 127.0.0.1., which is localhost,
 * and at port number 9876, as this port is likely available on any desktop machine.
 * The publication path is /ts, an arbitrary name.
 * The Endpoint class has an overloaded publish method. In this two-argument version,
 * the first argument is the publication URL as a string and the second argument is
 * an instance of the service SIB, in this case ch01.ts.TimeServerImpl.
 * The application runs indefinitely, awaiting service requests. It needs to be
 * terminated at the command prompt with control-C or the equivalent.
 * Once the application is started, open a browser to the URL
 * http://127.0.0.1:9876/ts?wsdl
 * to view the service contract, the WSDL document. This is an easy test to
 * determine whether the service has deployed successfully. If the test succeeds,
 * a client then can be executed against the service.
 */

public class TimeServerPublisher {
    public static void main(String[] args) {
        // 1st argument is the publication URL
        // 2nd argument is an SIB instance, implementor obj to create interface implementations dynamically
        Endpoint.publish("http://127.0.0.1:9876/ts", new TimeServerImpl());
        // After publish has been called, endpoints starts accepting incoming requests
    }
}
TimeServer (/4)

- TimeServer: Compiling and Running
  - Compiling the SEI, SIB and publisher `javac ch01/ts/*.java`
  - Running the publisher `java ch01.ts.TimeServerPublisher`
  - Testing the web service with the browser:
    - Access the URL: `http://127.0.0.1:9876/ts?wsdl`
    - Accessing WSDL using `curl`:
      ```
      curl http://127.0.0.1:9876/ts?wsdl
      ```
  - TimeServer will Return the current time:
    - Either as a string or
    - Elapsed milliseconds from Unix epoch, midnight January 1, 1970 GMT.

TimeServer (/5): Ruby Client

```ruby
#!/usr/bin/ruby
# one Ruby package for SOAP-based services
require 'soap/wsdlDriver'

wsdl_url = 'http://127.0.0.1:9876/ts?wsdl'

# Get a service object from the WSDL_url
service = SOAP::WSDLDriverFactory.new(wsdl_url).create_rpc_driver

# Save request/response messages in files named '...soapmsgs...'  
# since want to inspect them
service.wiredump_file_base = 'soapmsgs'

# Invoke service operations.
result1 = service.getTimeAsString
result2 = service.getTimeAsElapsed

# Output results.
puts "Current time is: #{result1}"  
puts "Elapsed milliseconds from the epoch: #{result2}"  
```
#!/usr/bin/perl -w

use SOAP::Lite;

# provides under-the-hood functionality allowing client to issue
# appropriate SOAP request & process the ensuing SOAP response

my $url = 'http://127.0.0.1:9876/ts?wsdl';
# request url ends with a query string asking for WSDL doc

my $service = SOAP::Lite->service($url);

# PERL client gets WSDL and SOAP::Lite library then generates
# appropriate service object. In consuming WSDL doc, SOAP::Lite gets
# info needed (e.g. WS operations & their data types)

print "\verb+\n+Current time is: ",
$service->getTimeAsString();

print "\verb+\n+Elapsed milliseconds from the epoch: ",
$service->getTimeAsElapsed(), "\verb+\n+";

---

POST http://127.0.0.1:9876/ts HTTP/ 1.1
Accept: text/html
Accept: multipart/*
Accept: application/soap
User-Agent: SOAP::Lite/Perl/0.69
Content-Length: 434
Content-Type: text/xml; charset=utf-8
SOAPAction: ""

<?xml version="1.0" encoding="UTF-8"?>
<soap:Envelope

---

- HTTP Startline specifies it's a POST method
- <soap:Body> contains a single method whose localname is getTimeAsString
HTTP/1.1 200 OK
Content-Length: 323
Content-Type: text/html; charset=utf-8
Client-Date: Mon, 28 Apr 2008 02:12:54 GMT
Client-Peer: 127.0.0.1:9876
Client-Response-Num: 1

<?xml version="1.0"?>
<soapenv:Envelope
    xmlns:soapenv="http://schemas.xmlsoap.org/soap/envelope/"
    xmlns:xsd=http://www.w3.org/2001/XMLSchema
    <soapenv:Body>
        <ans:getTimeAsStringResponse xmlns:ans="http://ts.ch01/">
            <return>Thu Mar 21 14:45:17 GMT 2013</return>
        </ans:getTimeAsStringResponse>
    </soapenv:Body>
</soapenv:Envelope>

• HTTP/1.1 200 OK signals all processed normally

TimeServer (/9): WSDL Document Structure

• A WSDL document has two parts:
  - Interface (abstract)
    • Available services: operations grouped in portTypes
    • Which messages are needed by operations: A message can have parts
    • Used data types and XML-elements
  - Implementation (concrete)
    • binding to message layer (e.g. SOAP):
      How message parts mapped to body/header elements of SOAP messages
    • bindings to transport layer (e.g. HTTP):
      Where do I find the service?
    • A service may offer several ports,
      i.e. ways to call it
TimeServer (/10): WSDL Document Structure

```xml
<message name="getTimeAsString"></message>
<message name="getTimeAsStringResponse">
  <part name="return" type="xsd:string"></part>
</message>
<message name="getTimeAsElapsed"></message>
<message name="getTimeAsElapsedResponse">
  <part name="return" type="xsd:long"></part>
</message>
```

- For the TimeServer service, four messages

```xml
<portType name="TimeServer">
  <operation name="getTimeAsString" parameterOrder="">
    <input message="tns:getTimeAsString"></input>
    <output message="tns:getTimeAsStringResponse"></output>
  </operation>
  <operation name="getTimeAsElapsed" parameterOrder="">
    <input message="tns:getTimeAsElapsed"></input>
    <output message="tns:getTimeAsElapsedResponse"></output>
  </operation>
</portType>
```

- portType for TimeService has two operations, each with one input message & one output message

Lecture 7: Distributed Obj & Web-based Systems

TimeServer (/11): Generating Client Support Code From WSDL

- After TimeServerPublisher generated WSDL, execute:
  ```bash
  ```
  - The -keep option specifies that the source files should be kept
  - The -p client option specifies Java package in which generated files are to be placed
  - Above command generates two source & two compiled files in the subdirectory client

- Approaches to Web Services 1: The Contract-First Approach
  - Above approach, where WSDL contract is used to generate all required artifacts for WS development, deployment, & invocation is known as the Contract-First Approach.
TimeServer (/12): Generating WS Artifacts From Java Code

• Approaches to Web Services 2: The Code-First Approach
  – A second approach, where Java classes are available and used to generate all required artifacts for WS development, deployment, & invocation is known as Code-First Approach.
  – Command \texttt{wsgen -cp . [Compiled Java Code]} achieves this.
  – Run the publisher to deploy the web service.
• This contrasts with the Contract-First seen earlier which was a top-down approach to generate JAX-WS Artifacts
• In general, for a number of reasons Contract-First approach is preferred to Code-First

TimeServer (/12): How to pick a tool?

• Following lists process to create a WS starting from Java sources, classes, or a WSDL file (server side):
• Starting from Java classes use Code-First:
  – Use \texttt{wsgen} to generate portable artifacts (e.g. SE Interface & Implementation classes etc).
  – Deploy the Web Service
• Starting from a WSDL file use Contract-First:
  – Use \texttt{wsimport} to generate portable artifacts.
  – Implement the service endpoint.
  – Deploy the Web Service
• Following lists the process to invoke a web service (client side):
  – Starting from deployed web service's WSDL
  – Use \texttt{wsimport} to generate the client-side artifacts.
  – Implement the client to invoke the web service.
A Compromise Approach

A third Approach: *Code First, Contract Aware*

- Updating Code-First service, might find that WSDL changes too.
- To get around this, there is a style called *Code First, Contract Aware*.
- Write code first but annotate to tightly constrain generated WSDL.

Some annotations:

- @WebMethod, indicates a method exposed as Web Service operation,
- @SOAPBinding specifies WS mapping onto SOAP message protocol
- @WebParam maps a parameter to a WS msg part & XML element,
- @WebResult specifies that operation result in generated WSDL is something other than default return e.g. IntegerOutput.

```java
package ch01.team;
import java.util.List;
import javax.jws.WebService;
import javax.jws.WebMethod;
package ch01.team;
import java.util.List;
import javax.jws.WebService;
import javax.jws.WebMethod;

@WebService
public class Teams {
    private TeamsUtility utils;

    public Teams() {
        utils = new TeamsUtility();
        utils.makeTestTeams();
    }

    @WebMethod
    public Team getTeam(String name) {
        return utils.getTeam(name);
    }

    @WebMethod
    public List<Team> getTeams() {
        return utils.getTeams();
    }
}
```
public class TeamsUtility {
    private Map<String, Team> team_map;

    public TeamsUtility() {
        team_map = new HashMap<String, Team>();
        make_test_teams();
    }

    public Team getTeam(String name) {
        return team_map.get(name);
    }

    public List<Team> getTeams() {
        List<Team> list = new ArrayList<Team>();
        for (String key : team_map.keySet()) {
            list.add(team_map.get(key));
        }
        return list;
    }

    private void make_test_teams() {
        List<Player> players = new ArrayList<Player>;
        players.add(new Player("Harpo", "Marx");
        players.add(new Player("Bud", "Burns");
        players.add(new Player("Abbe and Allen", "Costello");
        for (Player player : players) {
            team_map.put(player.getName(), player);
        }
    }
}

public class Player {
    private String name;
    private String nickname;

    public Player() {
    }

    public Player(String name, String nickname) {
        this.name = name;
        this.nickname = nickname;
    }

    public void setName(String name) {
        this.name = name;
    }

    public String getName() {
        return name;
    }

    public void setNickname(String nickname) {
        this.nickname = nickname;
    }

    public String getNickname() {
        return nickname;
    }
}
SECTION 7.2.2: REST-BASED WEB SERVICES

Introduction to REST

- REST, or REpresentational State Transfer, is a distributed communication architecture
  - Overall SOAP WS architecture has many layers with protocols & standards for security & reliability=>tedious for WS developers.
  - REST is fast becoming the lingua franca for Cloud Computing
  - Central REST abstraction is the Resource i.e. anything with a URI.
  - In practice, resource is an info item that has hyperlinks to it.
### Contrast Between SOAP & REST

- REST & SOAP are quite different

#### SOAP & REST: Protocol Layering

<table>
<thead>
<tr>
<th>SOAP</th>
<th>REST</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTTP</td>
<td>HTTP</td>
</tr>
<tr>
<td>POST</td>
<td>POST</td>
</tr>
<tr>
<td>GET</td>
<td>GET</td>
</tr>
<tr>
<td>DELETE</td>
<td>DELETE</td>
</tr>
</tbody>
</table>

#### SOAP Technology Stack

---

### Contrast Between SOAP & REST (/2)

- REST & SOAP are quite different

<table>
<thead>
<tr>
<th>No.</th>
<th>SOAP</th>
<th>REST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td>SOAP is a protocol.</td>
<td>REST is an architectural style.</td>
</tr>
<tr>
<td>2)</td>
<td>SOAP stands for Simple Object Access Protocol.</td>
<td>REST stands for Representational State Transfer.</td>
</tr>
<tr>
<td>3)</td>
<td>SOAP can’t use REST because it is a protocol.</td>
<td>REST can use SOAP web services because it is a concept and can use any protocol like HTTP, SOAP.</td>
</tr>
<tr>
<td>4)</td>
<td>SOAP uses services interfaces to expose the business logic.</td>
<td>REST uses URI to expose business logic.</td>
</tr>
<tr>
<td>5)</td>
<td>JAX-WS is the java API for SOAP web services.</td>
<td>JAX-RS is the java API for RESTful web services.</td>
</tr>
<tr>
<td>6)</td>
<td>SOAP defines standards to be strictly followed.</td>
<td>REST does not define too much standards like SOAP.</td>
</tr>
<tr>
<td>7)</td>
<td>SOAP requires more bandwidth and resource than REST.</td>
<td>REST requires less bandwidth and resource than REST.</td>
</tr>
<tr>
<td>8)</td>
<td>SOAP defines its own security.</td>
<td>RESTful web services inherits security measures from the underlying transport.</td>
</tr>
<tr>
<td>9)</td>
<td>SOAP permits XML data format only.</td>
<td>REST permits different data format such as Plain text, HTML, XML, JSON etc.</td>
</tr>
<tr>
<td>10)</td>
<td>SOAP is less preferred than REST.</td>
<td>REST more preferred than SOAP.</td>
</tr>
</tbody>
</table>
### Contrast Between SOAP & REST (/3)

<table>
<thead>
<tr>
<th>SOAP Web Services</th>
<th>RESTful Web Services</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WS Security:</strong></td>
<td><strong>WS Security:</strong></td>
</tr>
<tr>
<td>• Defines own security (WS Security)</td>
<td>• Supports just standard security to set up encrypted link between server &amp; client SSL</td>
</tr>
<tr>
<td>• Has standard impln of data integrity &amp; data privacy</td>
<td></td>
</tr>
<tr>
<td><strong>Atomic Transaction:</strong></td>
<td><strong>ACID Transactions:</strong></td>
</tr>
<tr>
<td>• Supports ACID transactions.</td>
<td>• Supports transactions, but not ACID compliant.</td>
</tr>
<tr>
<td>• Internet apps mostly don’t need transactional reliability, enterprise apps sometimes do.</td>
<td>• Limited by HTTP (can’t provide 2-phase commit across distributed transactional resources)</td>
</tr>
<tr>
<td><strong>Messaging:</strong></td>
<td><strong>Reliable Messaging:</strong></td>
</tr>
<tr>
<td>• Has successful/retry logic built in</td>
<td>• Has no standard messaging system</td>
</tr>
<tr>
<td>• End-to-end reliable even thru SOAP intermediaries.</td>
<td>• Expects clients to retry if comms failures</td>
</tr>
<tr>
<td><strong>Slow:</strong></td>
<td><strong>Fast:</strong></td>
</tr>
<tr>
<td>• Uses XML format that must be parsed to be read.</td>
<td>• No strict specification like SOAP.</td>
</tr>
<tr>
<td>• Defines many standards to be followed while developing the SOAP applications.</td>
<td>• Consumes less bandwidth and resource.</td>
</tr>
<tr>
<td>• =&gt; slow &amp; consumes more b/w &amp; resource.</td>
<td></td>
</tr>
<tr>
<td><strong>WSDL dependent:</strong></td>
<td><strong>Permits different data format:</strong></td>
</tr>
<tr>
<td>• Uses WSDL and doesn’t have any other mechanism to discover the service.</td>
<td>• Different data format possible</td>
</tr>
<tr>
<td></td>
<td>• E.g. Plain Text, HTML, XML and JSON.</td>
</tr>
</tbody>
</table>

### Contrast Between SOAP & REST (/4)

- REST tries to isolate complexity at endpoints (Clients & Service):
  - **Service**:
    - Could need logic/computation to process **XML** to maintain Resources & generate their representation.
  - **Client**:
    - May have to process XML to extract info from **WSDL** representation.
- But this complexity is kept from the transport level.
- SOAP complicates the transport level as a SOAP message is encapsulated as transport message body.
More on Resources in REST

• Resources have certain properties:
  – **Representation**: usually MIME (commonly \text{text/html}, \text{text/xml}).
  – **State**: i.e. they are mutable.

• Note:
  – In a RESTful request on it, resource itself stays service-side.
  – If request succeeds, requester gets resource’s **representation** (this transfers from server to requester machine).
  – For successful request to read resource, it’s typed **representation** (e.g. \text{text/xml}) transfers from resource’s server to the requester.

Roy Fielding’s Principles of REST

1. The web has **addressable resources** each with a URI.
2. The web has a **uniform and constrained interface**.
   – HTTP is synchronous request/response network protocol
   – Has a small number of methods.
   – Use these to manipulate resources.
3. Web is **representation oriented** – providing diverse formats.
4. The web may be used to **communicate statelessly** – providing scalability
5. **HATEOAS**: Hypermedia is used as the engine of application state.
Principles of REST 1: Addressability

scheme://host:port/path?queryString#fragment

- The scheme need not be HTTP. May be FTP or HTTPS.
- The host field may be a DNS name or a IP address.
- The port may be derived from the scheme. Using HTTP implies port 80.
- The path is a set of text segments delimited by the “/”.
- The queryString is a list of parameters represented as name=value pairs with each delimited by an “&”.
- The fragment is used to point to a particular place in a document.

REST Principles 2: Uniform Constrained Interface

- Small number of HTTP Operations:
  - No need for IDL
  - Interoperability

| HTTP GET  | /publications/publicationId | Get a publication under <id> ... Get a publication under <id> ... 0de9f3899f1d538f96821e5e3b5029f0f8cc5f62df7152c8f66cf4f30177d50f | Read-only method
|           |                            |                           | is often repeatable since does not make any changes | 1040c1b7f2a9f1dd1f8e70b85369f657c372b3b94f28f34f9bab532f43b2a68e |
| HTTP PUT  | /publications/publicationId | Update/change a publication under <id> ... Update/change a publication under <id> ... 64a23c1b5a58f99f693f37f2f6e48e9fe3f66d52c8f66cf4f30177d50f | Write method
|           | with new content in the message |                           | is repeatable since updates the same resource | 1040c1b7f2a9f1dd1f8e70b85369f657c372b3b94f28f34f9bab532f43b2a68e |
| HTTP DELETE | /publications/publicationId | Delete a publication under <id> ... Delete a publication under <id> ... 0de9f3899f1d538f96821e5e3b5029f0f8cc5f62df7152c8f66cf4f30177d50f | Write method
|           | with corresponding publication in the message |                           | is repeatable since one deleted there is nothing to delete anymore | 1040c1b7f2a9f1dd1f8e70b85369f657c372b3b94f28f34f9bab532f43b2a68e |
| HTTP POST | /publications/ | Create a new publication ... Create a new publication ... 64a23c1b5a58f99f693f37f2f6e48e9fe3f66d52c8f66cf4f30177d50f | Write method
|           | with corresponding publication in the message |                           | Non-idempotent – Is not repeatable since it will create every time some new resource | 1040c1b7f2a9f1dd1f8e70b85369f657c372b3b94f28f34f9bab532f43b2a68e |
REST Principles 2: Uniform Constrained Interface (2)

REST Response...

... is a representation of a resource. It could have several representations (e.g. XML, JSON, text, etc.)

contains metadata in the Header:
- Status Code
- Message length
- Date
- Content Type
- Etc.

Representations of resources are exchanged.
- GET returns a representation.
- PUT & POST sends representations to server so underlying resources may change.

Representations may be in many formats: XML, JSON, etc.

HTTP uses CONTENT-TYPE header to specify message format the server is sending.

The value of the CONTENT-TYPE is a MIME typed string.

Examples:
- text/plain
- text/html
Principles of REST 4: Communicate Statelessly

- The application may have state but there is no client session data stored on the server.
- Server only records & manages state of resources it exposes.
- Any session-specific data is held & maintained by the client for sending to server with each request as needed.
- Server is easier to scale. No replication of session data concerns.
  - Client sessions only kept server-side due to browser limitations
  - Around 2008 browsers got powerful enough to maintain their own session state=>fat clients possible

Principles of REST 5: HATEAOS

- Final REST principle is idea of using Hypermedia As The Engine Of Application State (HATEOAS).
- Hypermedia is document-centric approach with added support to insert links to other services & info in that document format.
- REST client doesn’t need any prior info on interacting with any application or server except understanding of hypermedia.
- REST client enters REST application thro simple fixed URL.
- All future actions client takes discoverable in resource representations returned from the server.
- Provide further guidance in the response!!!
A Subtlety: Opacity of URIs

• A URI is meant to be opaque
  – Means that URI: http://bedrock/citizens/fred has no inherent connection to the URI: http://bedrock/citizens/
  – Although Fred happens to be a citizen of Bedrock.
  – Of course, good designers devise URIs akin to what they identify, but URIs have no intrinsic hierarchical structure.

• A Note of caution
  – URI syntax resembles that for file system navigation, but this can mislead:
  – URIs are opaque identifiers, each naming exactly one resource.
A User Interface Client on a Web Service

• Example
  – Note: password is user hash from registration with Bibsonomy.com.

A User Interface Client on a Web Service (2)

• Example
  – The bookmark results of the previous `Get` operation.
A User Interface Client on a Web Service (/3)

• Example
  – RestClient uses **Post** to add a Bookmark to Bibsonomy.com.
  – Nb: Change content-type to application/xml & charset to **UTF-8**.

---

A User Interface Client on a Web Service (/4)

• Example: The bookmark results of the previous **Post** operation.
A User Interface Client on a Web Service (/5)

- Example: RestClient uses `Put` to change a Bookmark thus
  
  \[ \text{http://www.bibsonomy.org/api/users/martycrane/posts/hash} \]

  *Use of hash to alter/delete*

A User Interface Client on a Web Service (/6)

- Example: The bookmark results of the previous `Put` operation.

  *New Tag: “HypochondriaStuff”*
A User Interface Client on a Web Service (/7)

- Example: RestClient uses `Delete` to remove a Bookmark thus http://www.bibsonomy.org/api/users/martycrane/posts/hash

A User Interface Client on a Web Service (/8)

- Example: The bookmark results of the previous `Delete` operation.
A JAX-RS REST Example: Customer Class

```java
package com.restfully.shop.domain;

public class Customer {
    private int id;
    private String firstName;
    private String lastName;
    private String street;
    private String city;
    private String state;
    private String zip;
    private String country;

    public Customer() {
        this.firstName = firstName;
        this.lastName = lastName;
    }

    public int getId() { return id; }
    public void setId(int id) { this.id = id; }

    public String getFirstName() { return firstName; }
    public void setFirstName(String firstName) { this.firstName = firstName; }

    public String getLastName() { return lastName; }
    public void setLastName(String lastName) { this.lastName = lastName; }

    public String getStreet() { return street; }
    public void setStreet(String street) { this.street = street; }

    public String getCity() { return city; }
    public void setCity(String city) { this.city = city; }

    public String getState() { return state; }
    public void setState(String state) { this.state = state; }

    public String getZip() { return zip; }
    public void setZip(String zip) { this.zip = zip; }

    public String getCountry() { return country; }
    public void setCountry(String country) { this.country = country; }
}
```

CustomerResource Class

```java
package com.restfully.shop.domain;

import com.fasterxml.jackson.annotation.JsonProperty;
import javax.ws.rs).*
import java.io.IOException;
import java.net.URI;
import java.net.URISyntaxException;
import java.net.http.HttpHeaders;
import java.net.http.HttpRequest;
import java.net.http.HttpResponse;
import java.net.http.HttpWebSockets;
import java.util.Date;
import java.util.Map;
import java.util.concurrent.ConcurrentHashMap;

import javax.ws.rs.core.MediaType;
import javax.ws.rs.core.MultivaluedMap;
import javax.ws.rs.core.Response;
import javax.ws.rs.core.StreamingOutput;
import javax.xml.parsers.DocumentBuilderFactory;
import javax.xml.xpath.XPathFactory;
import javax.xml.xpath.XPathConstants;
import javax.xml.xpath.XPathExpressionException;
import javax.xml.xpath.XPathFactory;...
```

Lecture 7: Distributed Obj & Web-based Systems  CA4006 Lecture Notes (Martin Crane 2018)
CustomerResource Class (/2)

/* lots of utility methods provided here * /

protected void outputCustomer(PrintStream out, Customer cust) throws IOException {
    writeStream(out, cust);
    writer.print("<customer>");
    writer.print("<first-name>" + cust.getFirstName() + ";");
    writer.print("<last-name>" + cust.getLastName() + ");
    writer.print("<street>" + cust.getStreet() + ");
    writer.print("<city>" + cust.getCity() + ");
    writer.print("<state>" + cust.getState() + ");
    writer.print("<zip>" + cust.getZip() + ");
    writer.print("<country>" + cust.getCountry() + ");
    writer.print("</customer>");
}

Writing a Client MyClient Class

package org.restfully.shop.test;
import org.junit.Test;
import javax.ws.rs.client.Client;
import javax.ws.rs.core.ClientBuilder; /* interface to build/execute
 * Request to consume resps returned */
import javax.ws.rs.core.Controller;
import javax.ws.rs.core.MediaType;
import javax.ws.rs.core.Response;
import javax.xml.parsers.DocumentBuilder;
import javax.xml.parsers.DocumentBuilderFactory;
import javax.xml.stream.XMLStreamWriter;
import org.w3c.dom.Element;
import org.w3c.dom.NodeList;
import org.w3c.dom.Node;
import org.w3c.dom.Element;
import org.w3c.dom.Document;
import org.w3c.dom.Node;
import org.w3c.dom.Text;
import org.w3c.dom.Element;
import org.w3c.dom.Node;
import org.w3c.dom.Text;
import org.w3c.dom.Element;
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import org.w3c.dom.Node;
import org.w3c.dom.Text;
import org.w3c.dom.Element;
import org.w3c.dom.Node;
import org.w3c.dom.Text;
import org.w3c.dom.Element;
import org.w3c.dom.Node;
package com.restfully.shop.services;
import javax.ws.rs.ApplicationPath;
import javax.ws.rs.core.Application;
import java.util.HashSet;
import java.util.Set;

/* services can be either singletons or on a per-request model: former is where one and only one
Java object services HTTP requests; latter is Java object is created to process each incoming
request and is thrown away at the end of that request. We use the former */

@ApplicationPath("/services") /* specs relative base URL path for all JAX-RS services */
public class ShoppingApplication extends Application {
  private Set<Object> singletons = new HashSet<Object>();
  public ShoppingApplication() {singletons.add(new CustomerResource());}
  /* ShopApp.getSingletons() returns Set initialized in constructor & CustomerResource instance. */
  @Override
  public Set<Object> getSingletons() {return singletons;
}
  /* WAR file distributes JavaServer Pages, Java classes, other resources of web application. */
  <any static content>
  WEB-INF/ /* WEB-INF dir contains a file named Web.xml defining web application structure */
  Web.xml
  classes/ com/restfully/shop/domain/
  Customer.class
  com/restfully/shop/services/
  CustomerResource.class
  ShoppingApplication.class

Distributed Objects

• Useful References for REST
  2. RESTful Java with JAX-RS 2.0 by Bill Burke, O’Reilly Press

• But realistically, in real-life, use a framework!