

11.10 Web Services (Overview)

- History: RPC (Remote Procedure Call)
 - call a specific procedure at a specific server
(client stub→marshalling→message→unmarshalling→ server stub→ server).
- History: OMG Standard (Object Management Group) CORBA (1989, “Common Object Request Broker Architecture”; cf. Slides 38 ff.):
 - Middleware, usually applied in an Intranet,
 - central ORB bus where services can connect,
 - service registry (predecessor of WSDL and UDDI ideas),
 - description of service interfaces in object-oriented style
(IDL - interface description language, similar to C++ declarations),
 - exchanging objects between services via OIF (Object Interchange Format),

⇒ RPC abstraction (call abstract functionality) by the ORB as a broker.
- XML-RPC and SOAP+WSDL+UDDI are XML-based variants of RPC+Corba.
- SOA (“Service-Oriented Architecture”).

589

HTTP: HYPERTEXT TRANSFER PROTOCOL (OVERVIEW)

- HTTP 0.9 (1991), HTTP 1.0 (1995), HTTP 1.1 (1996).
- Application Layer Protocol [OSI Level 7], based on a (reliable) transport protocol (usually TCP “Transmission Control Protocol” [ISI/OSI Level 4] that belongs to the “Internet Protocol Suite” (IP))
[see Telematics lecture].
- Request-Response Protocol: open connection, send something, receive response (both can be streamed), close connection.
- well-known from Web browsing and HTML:
 - send (HTTP GET) URL, get URL (=resource) contents
 - ⇒ this is already a (very basic) Web Service
 - also: send HTTP POST URL+Data (Web Forms) get answer
 - ⇒ this is also a (still basic) Web Service; “Hidden Web”
- common protocol used for communication with and between Web Services ...

590

INFRASTRUCTURE ARCHITECTURE

Web Server

- hosts different things; amongst them
 - “simple” HTML pages, binaries (pdfs, pictures, movies, ...)
 - Web Services, i.e. software artifacts that implement some functionality.
- Example: Apache Web Server.
- not the topic of this lecture (→ technical infrastructure).

(Java) Servlet

- a piece of software that should be made available as a Web Service,
- implements the methods of the Servlet interface
(Java: `javax.servlet.http.HttpServlet`, subclasses `GenericServlet`, `HttpServlet`)

Web (Service|Servlet) Container

- a piece of software that extends a Web Server with infrastructure to provide the runtime environment to run servlets as Web Services,
- hosts one or more Web Services that extend the container's base URL

591

WEB SERVLET CONTAINER [INCORRECT: WEB SERVICE CONTAINER]

- Servlets are the pieces of software that are used to *provide* services.
- The servlets' code must be accessible to the Web Servlet Container, usually located in a specific directory,
- WSC controls the lifecycle of the servlets: (`init()`, `destroy()`)
- maps the incoming communication from ports via the URLs to the appropriate servlet invocation.
Container: method `service(httpContents)`, mapped to Servlets' `doGet(httpContents)`, `doPost(httpContents)`, (`doPut(httpContents)`), (`doDelete(httpContents)`).
- Example: Apache tomcat.
- standalone tomcat: one port (default 8080), one base URL;
- tomcat might be run in a Web Server (Apache), then, multiple base URLs can be mapped to the same tomcat.
- URL tails do not necessary belong to the same/different Servlets (see next slides)!

⇒ URL tails are just abstract names
(even the internal organization/implementation might change over time)

592

ABSTRACTION LEVELS

Goal: abstract from internal software/programming structure of the projects against the externally visible URLs.

- a Web Service Container contains several “projects” (eclipse terminology) or “applications”:
 - from the programmer’s view, a “project” is an (e.g., eclipse) project, as a package it is a single .war file, at the end, it is a subdirectory in the container.
Each project has an (internal) name (its directory name in the container), e.g. xquery-demo or servletdemo.
- Each project consists of one or more servlets:
 - each servlet has an (internal) name (relative to its directory name in the container), e.g. the servletdemo project contains three different servlets (just due to its programming as a “silly example”, nothing about efficiency) (nobody from the outside will see what are the actual names of these servlets)
 - each servlet’s code is a class that extends `javax.servlet.http.HttpServlet`;

593

Abstraction Levels: URL mapping

HTTP connections received by the servlet container are internally forwarded to the servlets.

- the Web Service Container has a base url;
`http://www.semwebtech.org`.
(actually, this is the base URL of an Apache that maps most things to a tomcat)
- Service URLs: `http://www.semwebtech.org/xquery-demo`,
`http://www.semwebtech.org/servletdemo`,
`http://www.semwebtech.org/services/2016/xml2sql` etc.
- the Web Service Container maps *relative paths* to projects (by tomcat’s `server.xml`):
`/xquery-demo` to `xquery-demo`, and `/servletdemo` to `servletdemo`, and
`/services/2016/xml2sql` to `xmlconverter`.
- each project’s configuration (in its `web.xml`) maps URL path tails to servlet ids, and servlet ids to servlet classes, e.g. for the `servletdemo` project
`/sum` to `sum-servlet` to `org.semwebtech.servletdemo.SumServlet`,
`/format`, `/all` and `/reset` to `format-servlet` to `org.s.s.FormatServlet`,
`/makecalls` to `makecalls-servlet` to `org.s.s.MakeCallsServlet`, and `index.html` is the front page served for “/”.

⇒ internal software organization independent from externally visible URLs

594

TOMCAT BASIC INSTALLATION

- See course Web page for detailed instructions with servlet examples.
- Web Servlet Container with simple Web Server: Download and install Apache Tomcat
 - can *optionally, but not necessarily* be combined with the Apache Webserver,
 - can be installed in the CIP Pool
- set environment variable (catalina is tomcat's Web Service Container)

```
export CATALINA_HOME=~/apache-tomcat-x.x.x
```
- configure server: edit

```
$CATALINA_HOME/conf/server.xml:  
<!-- Define a non-SSL HTTP/1.1 Connector on port 8080 -->  
<Connector port="8080" .../>
```
- start/stop tomcat:

```
$CATALINA_HOME/bin/startup.sh  
$CATALINA_HOME/bin/shutdown.sh
```
- logging goes to

```
$CATALINA_HOME/logs/catalina.out
```

595

Tomcat: Servlet Deployment

- upon startup, tomcat deploys all servlets that are available in

```
$CATALINA_HOME/webapps
```

(considering path mappings etc. in `$CATALINA_HOME/conf/server.xml`)

Two alternatives how to make servlets available there:

- create a `myproject.war` file (web archive, similar to jar) and copy it into `$CATALINA_HOME/webapps`.
(e.g. via `build.xml` targets "dist" and "deploy")
(tomcat will unpack and deploy it upon startup)
When replacing an old war file, delete the old unpacked stuff also.
- create a directory `myproject`, copy everything that is in the `WebRoot` directory there.
(e.g. `build.xml` target "deploy"; cf. Demo-Servlet)

596

Tomcat's conf/server.xml

The URL paths to the projects can be defined to differ from the defaults (path name = webapps-directory name)

This is done in the `<Host>` element:

```
<Host>
  <Context path="/services/2016/xml2sql" reloadable="false" docBase="xmlconverter"/>
  :
</Host>
```

- if the project name is the same as the path (e.g. xquery-demo and servlet-demo), the entry can be omitted
(usually, software projects do not have the same name, but distributed .war archive files can be renamed accordingly).
- reloadable: automatically reloads the servlet if the code is changed (e.g. a new .war archive).
Should be done only during development.
- the path attribute is key. There can be multiple paths that are mapped to the same docBase.

597

GENERAL SERVLET (ECLIPSE) PROJECT DIRECTORY STRUCTURE

MyProject: project directory (anywhere outside tomcat)

MyProject/build.xml: the ant file for compiling and deploying – see later.

MyProject/src: the .java (and other) sources

MyProject/WebRoot: roughly, all this content is copied to the Servlet Container.

Plain HTML pages like index.html can be placed here.

MyProject/WebRoot/WEB-INF: the whole content of MyProject/WebRoot except WEB-INF is visible later (e.g., HTML pages can be placed here); the contents of WEB-INF is *used* by the Servlet Container.

MyProject/WebRoot/WEB-INF/web.xml: web application configuration,

MyProject/WebRoot/WEB-INF/classes: compiled binary stuff,

MyProject/WebRoot/WEB-INF/lib: used jars (except javax.servlet.jar – tomcat has own classes for servlets, this would create conflicts),

MyProject/lib: jars that are needed for building, but should not be copied to the Servlet Container (put javax.servlet.jar here),

build path: all jars in MyProject/lib + MyProject/WebRoot/WEB-INF/lib

598

SERVLET-DEMO EXAMPLE

Basic demonstration of servlet programming [servletdemo.zip on course Web page]

- The basic functionality is simple:
a form where the user enters two numbers, and the servlet computes the sum (SumServlet),
[HTML form with simple HTTP GET from servlet, simple answer]
- The same (added to the same form): the result is presented in an HTML table (FormatServlet),
[HTML page as an answer]
- The same again (added to the same form): the numbers are taken, submitted to the SumServlet, and all three are submitted to the FormatServlet and a HTML page is created as answer (MakeCallsServlet).
[HTML form with simple HTTP POST to servlet, inter-Servlet HTTP POST]
- The Demo collects all formatted tables and can output them.
[persistent information, multiple GETs in the same servlet]
- it can be reset.

599

THE PROJECT'S WEB.XML (EXCERPT)

```
<web-app>
  <!-- Define servlet names and associate them with classfiles -->
  <servlet>
    <servlet-name>makecalls-servlet</servlet-name>
    <servlet-class>org.semwebtech.servletdemo.MakeCallsServlet</servlet-class>
    <init-param>
      <param-name>myURL</param-name>
      <param-value>http://localhost:8080/servletdemo</param-value>
    </init-param>
  </servlet>
  <servlet> ... </servlet>
  <!-- define mapping of path tails to servlets -->
  <servlet-mapping>
    <servlet-name>makecalls-servlet</servlet-name>
    <url-pattern>/makecalls</url-pattern>
  </servlet-mapping>
  <servlet-mapping> ... </servlet-mapping>
  <!-- optionally: define default html page -->
  <welcome-file-list>
    <welcome-file>index.html</welcome-file>
  </welcome-file-list>
</web-app>
```

600

Comments: web.xml

- `<servlet>`:
 - a short, abstract name (unique)
 - which java class
 - optional: init parameters that can be read in the `init(ServletConfig cfg)` method with `cfg.getInitParameter(param-name)`;
 - * allows some adaptation of “foreign” servlets by only editing the web.xml, without recompiling Java code (e.g. if a .war contains only binaries).
 - * if servlets (like MakeCallsServlet) need to call other servlets or use files, they can be told about their actual URLs.
 - * directories where files can be found locally can be specified:

```
<init-param>
  <param-name>examplesDir</param-name>
  <param-value>/home/may/teaching/ssd/XQuery/</param-value>
</init-param>
```
- `<servlet-mapping>`:
 - url-pattern: key, things like `/*` allowed,
 - multiple patterns can be mapped to the same servlet.

601

A Minimal Configuration (tomcat)

- A java class `Abc.java` which extends `HttpServlet`,
- implement a simple GET method for testing (HTML, Hello World)
- for compiling ist locally, put `.../tomcat/lib/servlet-api.jar` into the CLASSPATH,
- Directory structure:

```
tomcat/webapps/XYZ/WEB-INF/classes/Abc.class
tomcat/webapps/XYZ/WEB-INF/web.xml
```
- web.xml:

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE web-app PUBLIC "-//Sun Microsystems, Inc.//DTD Web Application 2.3//EN"
  "http://java.sun.com/dtd/web-app_2_3.dtd">
<web-app>
  <servlet> <servlet-name>foobla</servlet-name>
            <servlet-class>Abc</servlet-class> </servlet>
  <servlet-mapping> <servlet-name>foobla</servlet-name>
                   <url-pattern>/</url-pattern> </servlet-mapping>
</web-app>
```
- reachable via URL `localhost:8080/XYZ/`

602

COMMUNICATION WITH SERVLETS: HTTP METHODS GET AND POST

The servlets (virtually) run continuously in the Servlet Container and wait for incoming calls ...

HTTP GET and POST: request-response paradigm

HTTP GET should be used only if invocation does *not* change

- Request consists only of URL+parameters:

`http://www.example.org/mondial?type=city&code=D&name=Berlin&province=Berlin`

HTTP POST should be used if it has side effects or changes the state of the Web Service

- Request URL consists only of the plain URL,
- parameters (e.g. queries using forms) or any other information is sent via a stream

⇒ often also queries use POST

Response: always as a stream.

- other HTTP methods PUT (resource), DELETE (resource) are used in REST (Representational State Transfer) “architectures” (e.g. the eXist XML database and document management system uses REST)

603

Content of the Response

- if the service is invoked via the browser (forms; e.g. the XQuery-Demo), the response contents is the HTML code that is shown as “Web page” to the user.
- The “page” that is shown initially:
 - static index.html in the WebRoot directory (servletdemo), or
 - *answer* dynamically generated by the servlet on the first GET request (HTTP GET `http://www.semwebtech.org/xquery-demo`).
- if the service is invoked by another Web Service, the answer contains data (this course: in XML form).

Simple GET: “Content” of the Request

- A simple GET (from filling a Web form) carries the parameters as extension to the URL:
`http://www.semwebtech.org/xquery-demo?query-text=//country[name='Germany']`
`https://univz.uni-goettingen.de/qisserver/?search=3&raum.dtxt=2.101`
(simplified)

604

HTML Forms: invoking Web Services via Browser

The following elements (and several others) can be used in HTML pages:

```
<form action="./sum" method="get">    will call thisURL/sum, HTTP GET
  <input type="text" name="a"/>        form field to type in parameter "a"
  <input type="text" name="b"/>        form field to type in parameter "b"
  <input type="submit"/>              click here to submit HTTP GET ...
</form>                               with the parameters a and b
```

- the call URL is e.g. `http://localhost:8080/servletdemo/sum?a=4&b=5`
- an HTML page can contain multiple separate forms, to the same or different URLs/"actions",
- cf. `servletdemo/WebRoot/index.html`

605

SERVLET PROGRAMMING

- event-driven (cf. SAX): on incoming HTTP connections, the servlet container calls the servlets' `doGet()` (=react-on-get) and `doPost()` (=react-on-post) methods.

```
public class MyServlet extends HttpServlet
{ public void init(ServletConfig cfg) throws ServletException
    { // initialization ...
      // read web.xml init params by  cfg.getInitParameter(...);
    }
    protected void doGet(HttpServletRequest request,
                          HttpServletResponse response) throws ServletException { ... }
    protected void doPost(HttpServletRequest request,
                          HttpServletResponse response) throws ServletException { ... }
}
```

- `doGet()` and `doPost()` both read the `HttpServletRequest` and write the `HttpServletResponse` object,
- the `HttpServletRequest` differs for GET (simpler) and POST (including a **stream**),
- the `HttpServletRequest` always provides a **stream**.

606

Recall:

- the distribution of connection URLs to projects is done according to tomcat's server.xml,
- the distribution inside of the project to servlets is done according to the project's web.xml,
- **multiple URLs can be mapped to the same method (doGet/doPost) of the same servlet** (Demo: FormatServlet)

⇒ must be analyzed in doGet() and doPost().

- Request.getPathInfo(): contains the tail of the URL path *after* the mapping by web.xml (non-null if <url-pattern>*/</url-pattern>)
- Request.getServletPath(): contains the tail of the URL path that is exploited for mapping according to the web.xml.

doGet/doPost(HttpServletRequest req, HttpServletResponse resp) throws ...

```
{ String path = req.getPathInfo();
  if (path == null) path = req.getServletPath();
  if (path.startsWith("/reset")) { ... }
  else if (path.startsWith("/format")) { ... }
  else if (path.startsWith("/all")) { ... }
}
```

607

Servlet Programming: Read Parameters and Contents

- GET and POST Requests can have parameters; POST can also have contents
- in doGet() and doPost() for accessing parameters:

```
java.util.Map<java.lang.String, java.lang.String[]> mymap =
    req.getParameterMap();
String strA = req.getParameter("a"); (always Strings!)
```

- in doPost() for reading contents:

ServletInputStream in = req.getInputStream();
retrieves the body of the (POST) request (as binary data) using a ServletInputStream,
where any Reader (e.g. a StAX XMLStreamReader) can be put on
(usually, set reader's encoding to UTF-8).

java.io.BufferedReader r = req.getReader(); retrieves the body of the (POST)
request as character data (according to character encoding decl of the body) using a
BufferedReader.

For instance, one can create a JDOM from the contents:

```
BufferedReader in = req.getReader();
SAXBuilder builder = new SAXBuilder();
Document doc = builder.build(in);
Element root = doc.getRootElement();
```

608

Servlet Programming: Write into a Response

- `doGet()` and `doPost()` provide the `HttpServletResponse` object of the HTTP connection,
- it consists mainly of a stream,
- The requesting service (Browser, Web Service) has a Reader waiting on the stream (see next slide).
- `PrintWriter out = resp.getWriter();`
yields a Writer to the response – send character text (or XML events).
- `ServletOutputStream os = resp.getOutputStream();`
yields an output stream that can directly fed with `write()`, `print()`, `println()` or can be connected to another stream. Don't forget `os.flush()` and `os.close()`.

609

Invoking a new HTTP Connection (to a Web Service)

(servletdemo: MakeCallsServlet)

- (Http)URLConnection object is created by invoking the `openConnection` method on a URL;
- below: `urlstr` is a string, in the GET case already with parameters.

```
URLConnection.setFollowRedirects(true);    // static
URLConnection con = (URLConnection) new URL(urlstr).openConnection();
con.setRequestMethod("GET or POST");
    con.setDoInput(true);        // can be omitted - default is true
    con.setDoOutput(true);       // default is false(!), for "get" it's OK
    con.setRequestProperty("Connection", "keep-alive"); // is answer takes longer
    con.setRequestProperty("Content-type", ...);
    con.setRequestProperty("Accept", "text/xml");
con.connect();
-- use con.getOutputStream() to write contents of the request
con.getOutputStream().close();
-- use con.getInputStream() to read contents of the response
-- BufferedReader in =
    new BufferedReader(new InputStreamReader(con.getInputStream(), "UTF-8"));
con.getInputStream().close();
```

610

Code: HTTP GET

- Parameters given with the URL:

```
import java.io.BufferedReader;
import java.io.InputStreamReader;
import java.net.HttpURLConnection;
import java.net.URL;
public class HttpGetSimple {
    public static void main(String[] args) { try {
        BufferedReader br = null;
        URL inputURL = new URL("http://www.semwebtech.org/xquery-demo/" +
            "?action=query&query-text=//country[1]");
        HttpURLConnection con = (HttpURLConnection) inputURL.openConnection();
        con.setRequestMethod("GET");
        con.connect();
        String s = "";    StringBuffer res= new StringBuffer();
        br = new BufferedReader(new InputStreamReader(con.getInputStream(), "UTF-8"));
        while ((s = br.readLine()) != null) { res.append(s+ "\n"); }
        br.close();
        System.out.println(res);
    } catch (Exception e) { e.printStackTrace(); } }}
```

 [Filename: java/HttpGetSimple.java]

611

Code: HTTP POST – Parameters in the Request

- <https://docs.oracle.com/javase/tutorial/networking/urls/readingWriting.html>

```
import java.io.BufferedReader;          import java.io.InputStreamReader;
import java.io.OutputStreamWriter;
import java.net.HttpURLConnection;    import java.net.URL;
public class HttpPostSimple {
    public static void main(String[] args) { try {
        BufferedReader br = null;
        URL inputURL = new URL("http://www.semwebtech.org/xquery-demo/");
        String params = "action=query&query-text=//country[1]";
        HttpURLConnection con = (HttpURLConnection) inputURL.openConnection();
        con.setRequestMethod("POST");
        con.setDoOutput(true);    // default is false(!)
        con.connect();
        OutputStreamWriter wr = new OutputStreamWriter(con.getOutputStream());
        wr.write(params);
        wr.flush(); wr.close();
        String s = "";    StringBuffer res= new StringBuffer();
        br = new BufferedReader(new InputStreamReader(con.getInputStream(), "UTF-8"));
        while ((s = br.readLine()) != null) { res.append(s+ "\n"); }
        br.close(); System.out.println(res);    [Filename: java/HttpPostSimple.java]
    } catch (Exception e) { e.printStackTrace(); } }}
```

612

HTTP Access in the Data Management Area

- HTTP GET and POST are important means to access “Deep Web” data via queries against forms, and “Linked Open Data” (LOD) (RDF data, [Semantic Web lecture]).

Alternative: [not tested]

- Connection getContent() method:
returns an Object whose type is determined by the the content-type header field of the response. Uses a ContentHandler to convert data based on its MIME type to the appropriate class of Java Object.
- maybe useful for binary types?
- or even URL.getContent() as a shortcut for openConnection().getContent();
String foo = (String) url.getContent();
seems to be useful for plain GET on HTML pages;
- for XML content, using the stream seems to be more useful
(→ SAXBuilder→ JDOM, or → StAX)

613

Notes on Handling Character Encodings

- default for WebServices is ISO-8859-1 (covers german umlauts, swedish etc.)
- then, for HTML forms, set also
`<form method="get/post" accept-charset="ISO-8859-1">`
- UTF-8 also covers chinese, persian, etc. (localnames in Mondial)
- Web Service side:
 - if HTTP GET is used, request character encoding can only be set *globally* (Apache tomcat: URIEncoding attribute of the <Connector port="..."> element in server.xml to UTF-8).
 - HTTP POST: request.setCharacterEncoding("UTF-8") before reading parameters or contents (e.g. DBIS XQuery and SQL Web Interfaces);
 - use also response.setCharacterEncoding("UTF-8")

614

DATA EXCHANGE: AN INTEGRATED XML PERSPECTIVE

- HTTP connections are Unicode.
- exchanging XML via HTTP basically works on its serialization
 - explicitly working with Reader→String/StringBuffer and String/StringBuffer→Writer is possible, but often not necessary;
 - in:
 - * let a SAXBuilder build a JDOM,
 - * put SAX or an StAX XMLEventReader on the InputStream,
 - * put a JAXB Unmarshaller on the InputStream,
 - * put the Digester on the InputStream,
 - * cf. Examples where these were put on the FileInputStream for mondial.xml.
 - out:
 - * serialize XML by putting an XMLEventWriter on the OutputStream,
 - * let JAXB write into it, ...

615

A Note on Multithreading

- servlets can be instantiated by the container permanently or on-demand.
- if multiple requests for the same servlet come in, the servlet container can run multiple threads on the same instance of a servlet.
 - be careful with instance variables,
 - implement mutual exclusion if necessary
- the servlet container can also create (and remove) additional instances of a servlet.

616

PHP IN TOMCAT

- Tomcat is Java-based,
- Embedded PHP in HTML files or pure PHP is not executed by default.
- Name HTML files that include embedded PHP (cf. Slide 186) *filename.php*,
- there are several implementations of PHP in Java,
- e.g. see <https://stackoverflow.com/questions/779246/run-a-php-app-using-tomcat/779319> and <http://www.studytrails.com/blog/php-on-a-java-app-server-apache-tomcat-using-quercus/>