LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Praktikum Mobile und Verteilte Systeme

Web Services

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HiWi-Stelle

Für die Mitarbeit am Projekt School-Wide Information and Feedback Technologies (SWIFT) mit Partnern der Uni Köln und aus der Industrie sucht der Lehrstuhl für Mobile und Verteilte Systeme ab sofort eine wissenschaftliche Hilfskraft.

Es geht um:
- Einsatz moderner Sensorik im Schulunterricht
- Automatische Erkennung von Faktoren für Lernerfolg in der Schule

Du hast Lust auf:
- Recherche zum Thema
- Implementierung einfacher Demonstratoren für aktuelle Technologien

Melde dich!

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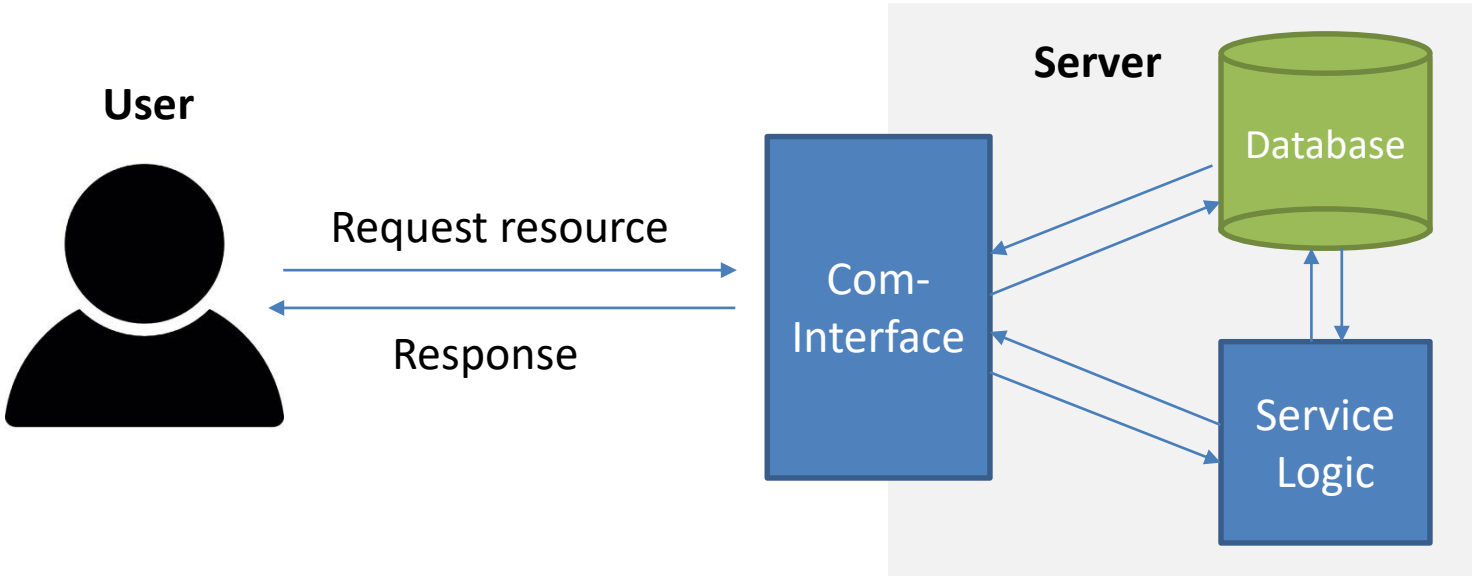
Introduction

- **Exchange** of **resources** by using protocols of the application layer
- Resources or services are encoded in **standardized formats** (XML, JSON)
- Implementations:
  - Remote Procedure Calls (**RPC**), WSDL-based
  - Simple Object Access Protocol (**SOAP**), WSDL-based
  - Representational State Transfer (**REST**)



Representational State Transfer (REST)

- A lightweight alternative to the SOAP/WSDL universe

- Defined by Roy T. Fielding
  - Dissertation: “Architectural Styles and the Design of Network-based Software Architectures“ (2000)
  - main author of HTTP/1.0 and HTTP/1.1
  - co-founder of the Apache HTTP server project (**httpd**)
- REST is an architectural style (and HTTP can be regarded as one incarnation of it)
- REST relies on some important architectural principles:
  - Everything is a **resource**
  - Communicate **statelessly**
  - Use a **common interface** for all resources
  - Resources can have **multiple representations** (content negotiation)

REST principles I: Everything is a resource

- from a REST point of view, **every data element** of an application a designer deems worthy of having its own URI **is a resource**
  - entities, attributes, collections, etc.
- each resource has a **unique ID**
  - REST makes use of a resource's URI
    - global standard namespace, globally unique
- a resource is not an actual object or service itself, but rather **an abstract interface** for using it
- using **human-readable URIs** is common (yet not obligatory)

```
http://example.com/customers/1234
http://example.com/orders/2013/1/12345
http://example.com/orders/2013/1
http://example.com/products/4554
http://example.com/products?color=green
http://example.com/processes/salary-increase
```

REST principles II: Communicate statelessly

- REST includes the concept of **statelessness** on behalf of the server
  - but, of course, there is some state…
- All application state should either
  - be **turned into resource state**
  - or be **managed at the client**
- All **requests should be independent** from earlier requests
  - messages are **self-contained**, including all necessary information
- Advantages:
  - **scalability**
  - **isolation of the client** against changes on the server

REST principles III: Use standard methods

- REST demands the usage of **simple, uniform interfaces** for all resources

- When making a HTTP request on a resource, we expect the application to actually **do something meaningful**
  - this is achieved with every resource **providing a standardized interface**
    (i.e., the same set of methods)
- REST is making usage of the **HTTP verbs** (as in the HTTP specification)
- With REST, these verbs are mapped to resource-specific semantics

```
class Resource {                        // analogy to oo-programming
  Resource(URI u);                      // URI
  Response get();                       // HTTP GET
  Response post(Request r);             // HTTP POST
  Response put(Request r);              // HTTP PUT
  Response delete();                    // HTTP DELETE
}
```

REST principles IV: Different representations

- Resources can (and actually should) have **multiple representations**
  - provide multiple representations of resources for different needs (at the same interface)
  - ideally, at least one standard format should be provided

- Selection of data formats is done **using HTTP content negotiation**
  - clients can ask for a representation in a particular format

```
GET /customers/1234 HTTP/1.1
Host: example.com
Accept: application/xml
```

```
GET /customers/1234 HTTP/1.1
Host: example.com
Accept: text/x-vcard
```

- Advantages:
  - By having several representations of a resource (e.g., text, XML, HTML, JSON…), they are **consumable by standard applications** (web browsers, etc.)
  - An application's Web UI can actually be regarded as its Web API, providing a better Web interface for both humans and applications

REST-conformant usage of HTTP methods

- **HTTP GET**
  - Used for accessing the requested resource without any side-effects. A resource must never be changed via a GET request (read-only)!
- **HTTP PUT**
  - Used for creating or updating a resource at a known URI.
- **HTTP DELETE**
  - Used for removing a resource.
- **GET**, **PUT** and **DELETE** must be implemented as idempotent methods
  - can be called repeatedly without leading to different results
- **HTTP POST**
  - Update an existing resource or create a new one (not idempotent – depending on its implementation)

A simple example of a RESTful web service

- Mapping of **“normal” method names** to RESTful resource interfaces
  - combination of resource URIs and the standard HTTP methods

Normal method name	URI (RESTful resource)	HTTP method
listOrders	/orders	GET
addNewOrder	/orders	POST
addNewOrder	/orders/12344	PUT
getOrder	/orders/12344	GET
deleteOrder	/orders/12344	DELETE
listCustomers	/customers	GET
getCustomer	/customers/beck	GET
addCustomer	/customers	POST
addCustomer	/customers/beck	PUT
updateCustomer	/customers/ebert	PUT
…		

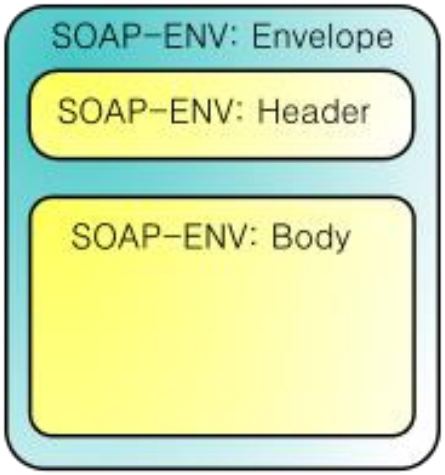
Advantages of the RESTful approach

- **Simplicity**
  - well known interfaces (URIs, HTTP methods), no new encoding specifications
- **Lightweightness**
  - short messages, little overhead
- **Multiple representations**
- **Security**
  - authentication and authorization can be done by the web server
- **Scalability (e.g., multi-device usage / multiple servers)**
- **Reliability (e.g., on restoring state / recovering)**
- **Caching**
- **Easy service orchestration** (via hyperlinks)
  - URIs define global namespace, no application boundaries

Simple Object Access Protocol (SOAP)

- **Protocol specification** for the exchange of **structured data**
- **XML-encoding** for realizing the message format
- Relies on **application layer** protocols (HTTP / SMTP)
- Three major characteristics:
  - **Extensibility**
  - **Neutrality**
  - **Independence**
- SOAP message consists of different SOAP building-blocks:
  - **Envelope** (**required**)
  - **Header** (**not** required)
  - **Body** (**required**)
  - **Fault Parameters** (**not** required)

https://en.wikipedia.org/wiki/SOAP



REST vs. SOAP (1)

- requesting a user's details **using SOAP** (via a POST request)

```
<?xml version="1.0"?>
<soap:Envelope
xmlns:soap="http://www.w3.org/2001/12/soap-envelope"
soap:encodingStyle="http://www.w3.org/2001/12/soap-encoding">
  <soap:body pb="http://www.example.com/phonebook">
    <pb:GetUserDetails>
      <pb:UserID>12345</pb:UserID>
    </pb:GetUserDetails>
  </soap:Body>
</soap:Envelope>
```

- requesting a user's details **using REST** (via a GET request)

```
http://www.example.com/phonebook/UserDetails/12345
```

- REST resources are usually **defined as nouns**, not as verbs
  - GetUserDetails (SOAP) vs. UserDetails (REST)

REST vs. SOAP (2)

- In contrast to Service oriented architectures (such as SOAP), REST can be considered a Resource Oriented Architecture (ROA)

	RESTful Web services	SOAP Web services
Architectural style	REST/ROA	SOA
Server state	Stateless	Stateless or stateful
Data format	Text, HTML, XML, JSON, binary, …	XML
Application Protocol	REST	SOAP
Level of formality of interface definitions	Rather low (XSD, WADL) - not specified -	High (WSDL)
Typing	None	Strong
Support for asynchronous communication	No	Yes (WebService-Notification)
Caching of results	yes	no
Scalability	high	medium
Performance	high	lower
ACID transactions	no	Yes (WS-AtomicTransaction)
Access control	Webserver (easy)	WS-Security (more complex, yet more powerful)
Fields of application	Data-oriented, short term services	Both data-oriented and long-term process-oriented services

REST vs. SOAP (3)

- **REST**
  - **Light-weight** and **easy to understand**
  - offers maximum **performance and scalability**
  - makes use of **existing standards** only (i.e., URI and HTTP)
  - is perfectly fit for handling **CRUD operations** on data using a single common interface

- **SOAP**
  - brings its **own protocol** (for service exchange)
  - focuses on **exposing application logic** (not resources) as a service using different interfaces
  - is supported by a plethora of existing **software tools**
  - allows for **ACID transactions** (WS-AtomicTransactions), mature **security mechanisms** (WS-Security) and **guaranteed message delivery** (WS-ReliableMessaging) → enterprise security features

How to implement a RESTful Service

- Various frameworks for all kind of programming languages and implementation models:
  - Firebase
  - Python Eve
  - NodeJS
  - Java Spring
  - Jersey (JAX-RS)
  - **Others…**

Python Eve

- Open source REST API framework for Python
- Pretty simple implementation

```
from eve import Eve

app = Eve()
app.run()

@app.route('/hello')
def hello_world():
        return 'hello world!'
```

- Resource `/hello` is now available via HTTP:
  - `http://<your-server-ip>:<port>/<subpath>/hello`
- Server responds with *„hello world!“*
- Subpath is a term that you make up

Google Firebase

- **Mobile and web application platform** for building „high quality apps“
- Founded in 2011, acquired by **Google** in 2014
- Originally: **realtime database** for **synchronizing and storing** data across multiple devices.
- Now: **full suite** for app development:
  - FB Analytics
  - FB Cloud Messaging (successor of Google Cloud Messaging (GCM))
  - FB Auth
  - FB Database
  - **Others…**
- Integration of Android, iOS, Javascript, Java, Objective-C, swift, etc.
- REST API: **Server-Sent Events** protocol (HTTP connections are created for receiving push notifications from a server)

Using REST with Java: Jersey (JAX-RS)

- Jersey is “the open source, production quality, JAX-RS (JSR 311) Reference Implementation for building RESTful Web services”
- can be downloaded from **jersey.java.net** 
- works with any Servlet Container (e.g., Apache Tomcat, Grizzly, Glassfish, etc.)
- contains both server and client APIs
- Jersey supports the automatic creation (marshalling) of XML and JSON representations of resources (based on JAXB)
- as a key feature, JRS 311 makes use of **Java annotations** to define the REST relevance of Java classes (Media-Type, HTTP-Method, URI, …)

Getting started with Jersey

- Create a new **Dynamic Web Project** (e.g., with Eclipse and JavaEE), then download and copy the Jersey JAR-files to `WEB-INF/lib` (or set dependencies)

- After installing and configuring your **Server**, applications can be deployed…
  - by copying the application's `WEB-INF/` and `META-INF/` folders to a subfolder of Tomcat's `webapps` directory
  - by creating a WAR (**W**eb **AR**chive)-file of the application and storing it in the `webapps` folder

- Every web application should include a deployment descriptor (according to the Servlet 2.4 specification)
  - this file (`web.xml`) must always be placed in the `WEB-INF/` folder
  - can be generated using Eclipse (but has to be modified)

- Deployed Webapps can be managed (start, stop, reload, etc.) using your servers application manager, e.g., for Tomcat accessible at **http://host:port/manager**

Example web.xml file

- In order to correctly dispatch incoming requests to the Jersey servlet, the RESTful application's `web.xml` should look similar to this:

```
<?xml version="1.0" encoding="UTF-8"?>
<web-app xmlns:xsi= … >
 <display-name>DISPLAY_NAME</display-name>
 <servlet>
  <servlet-name>SERVLET_NAME</servlet-name>
  <servlet-class>
     <servlet-class><used-servlet-servlet-description></servlet-class>
  </servlet-class>
  <init-param>
   <param-name>com.sun.jersey.config.property.packages</param-name>
   <param-value>your.package.name</param-value>
  </init-param>
 </servlet>
 <servlet-mapping>
  <servlet-name>SERVLET_NAME</servlet-name>
  <url-pattern>/whatever/you/want/*</url-pattern>
 </servlet-mapping>
</web-app>
```

- For this example accessable via
  - `http://<your-ip>:<port>/whatever/you/want/<resource-name>`

Using POJOs for building RESTful Web services

- with Jersey, RESTful web services can be realized by simply annotating POJOs in order to define allowed HTTP-methods, content-types, parameters, etc.
- such classes are known as **root resource classes**

```
@Path("/hello") //the resource's URI
public class Hello {

 @GET //HTTP method
 @Produces(MediaType.TEXT_PLAIN) //requested content-type
 public String sayHello() {
   return "Hello Jersey";
 }

 @GET //HTTP method
 @Produces(MediaType.TEXT_XML) //requested content-type
 public String sayXMLHello() {
   return "<?xml version=\"1.0\"?>" + "<hi>Hello Jersey" + "</hi>";
 }
}
```

Annotation basics in JAX-RS (1)

- the **@Path** annotation's value is a relative URI path. The base URI is the application path as set in the `web.xml` (display-name + url-pattern).

- *Resource method designator* annotations
  - **@GET** can be used to read a resource without any side effects(!)
  - **@POST** creates a new resource (not idempotent)
  - **@PUT** creates or modifies an existing resource (idempotent)
  - **@DELETE** removes an existing resource (idempotent)
  - **@HEAD** returns the same as @GET, just without the body

- **@Consumes** specifies the MIME types of representations a resource can consume from a client

- **@Produces** specifies the MIME types of representations a resource can produce and send back to a client

Annotations in JAX-RS (2)

- **@Path** annotations might (or might not) have a leading or ending '/' , it doesn't make a difference:
  - a leading '/' in a path is ignored
  - base URIs are treated as if they ended in '/'

- A resource with relative **@Path** annotation can be found at `http://host:port/<display-name>/<url-pattern>/<@Path>`

- **@Consumes** and **@Produces** can be applied at class and method levels

- More than one media type may be declared in the same **@Produces** or **@Consumes** declaration

- Method level annotations can be used to **override** class level annotations

Useful features of JAX-RS (1)

- One thing that makes Jersey extremely useful is that you can embed variables in the URIs (so-called *URI path templates)*:

```
@Path("/login/{user}") //{user} will be substituted
public class UserResource {

 @GET //HTTP method
 @Produces("text/plain") //output format
 public String loginUser(@PathParam("user") String userName){
   return "hi, „ + userName;
 }
}
```

- and also as query parameters:

```
@Path(„/foo") //simply another path…
@GET //HTTP method
public Response bar(@DefaultValue("1") @QueryParam("a") int a,
      @DefaultValue("true") @QueryParam("b") boolean b) {
  …
}
```

Useful features of JAX-RS (2)

- If the HTTP request **contains a body** (PUT, POST requests), this data can easily be accessed as a **method parameter**:

```
@POST //HTTP method
@Consumes("text/plain") //input format of request body
 public String handlePlaintext(String message){
    //store the plaintext message somewhere
    …
 }
}
```

- If several methods exist for the same resource, Jersey will select the (most) appropriate one for handling a request (method, MIME types…)

```
@POST //HTTP method
@Consumes(MediaType.TEXT_XML) //input format of request body
 public String handleXML(String message){
    //store the xml string somewhere
    …
 }
}
```

Jersey and JAXB

- Jersey allows for the automatic mapping (marshalling) from POJOs to representations in XML (and also JSON!)
- Realized with the support of JAXB (*Java Architecture for XML Binding):*
  - Java standard defining how to convert Java objects from/to XML
  - provides a standard set of mappings
  - defines an API for reading and writing Java objects to and from XML
  - JAXB is making usage of Java annotations, too

```
//Define the root element for a XML tree
@XmlRootElement(namespace = "namespace")
//Set the order of the fields in the XML representation
@XmlType(propOrder = { "field2", "field1",.. })
//generate a XML wrapper element
@XmlElementWrapper(name = “wrapper_element")
//set the name of the entities
@XmlElement(name = “element_one")
```

Example of Jersey using JAXB (1)

```
package com.example;

import javax.ws.rs.GET;
import javax.ws.rs.Path;
import javax.ws.rs.Produces;

@Path("")
public class TicketServer {

        /**
         * Returns the server status.
         *
         * @return the server status
         */
        @GET
        @Path("ping")
        @Produces(MediaType.APPLICATION_JSON)
        public ServerStatus getPing() {
                return ServerStatus.getServerStatusInstance();
        }
}
```

Example of Jersey using JAXB (2)

```
import javax.xml.bind.annotation.XmlElement;
import javax.xml.bind.annotation.XmlRootElement;
import java.util.Date;

@XmlRootElement
public class ServerStatus {
  private final static ServerStatus instance = new ServerStatus();

  public static ServerStatus getServerStatusInstance() {
    return instance;
  }

  private boolean running; //Laufzeitstatus

  @XmlElement(name = "running")
  public boolean isRunning() { return running; }

  @XmlElement(name = "server_now")
  public Date getServerNow() { //Aktuelle Zeit
    return new Date();
  }
  …
}
```

Example of Jersey using JAXB (3)

- Testing the web service in your browser
  - Request:

```
GET /ping HTTP/1.1
Host: example.com
Accept: application/json
```

  - Response:

```
{ "running": "true",
  "server_now": "2013-01-10T16:31:56.843+01:00“,
  … }
```