# HTTP, REST Web Services

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Winter Term 2021

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# What is a web service?

> *Definition: A Web service is a software system designed to support interoperable machine-to-machine interaction over a network. It has an interface described in a machine-processable format (specifically WSDL). Other systems interact with the Web service in a manner prescribed by its description using SOAP messages, typically conveyed using HTTP with an XML serialization in conjunction with other Web-related standards.*
>
> — W3C, Web Services Glossary

`https://www.w3.org/TR/ws-arch/#whatis`

# Two Major Classes

*We can identify two major classes of Web services:*

- *REST-compliant Web services, in which the primary purpose of the service is to manipulate XML representations of Web resources using a uniform set of ”stateless” operations; and*
- *arbitrary Web services, in which the service may expose an arbitrary set of operations.*

— W3C, Web Services Architecture (2004)

`https://www.w3.org/TR/ws-arch/#relwwwrest`

# From SOAP to REST

- First technology for interactive web applications used AJAX – Asynchronous Javascript And Xml, but processing of XML is not convenient in Javascript
- Raise of using JavaScript Object Notation – JSON
  - Simple testing
  - Plenty of helping apps: Postman, Insomnia, curl, web browser
  - Javascript is simpler to start with than Java (e.g. there are more JS programmers and they are cheaper)

# Web Service API Distribution

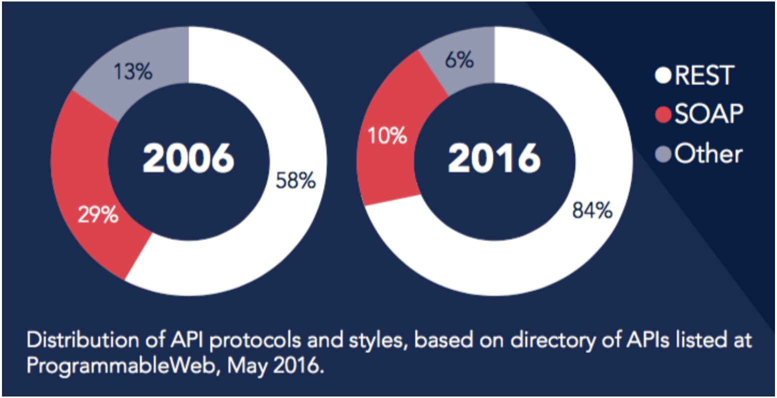


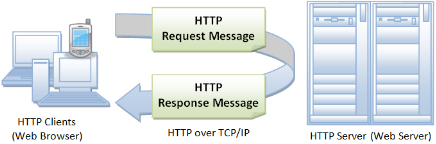
Figure: Interest in web service APIs. Source: `https://blog.wishtack.com/rest-apis-best-practices-and-security/`

## Basic terms

- **Uniform Resource Identifier (URI)** is a string of characters used to identify a resource. (e.g., `http://www.fel.cvut.cz/cz/education/`)
- **The Hypertext Transfer Protocol (HTTP)** is an application *protocol* for distributed, collaborative, hypermedia information systems. It is the foundation of data communication for the World Wide Web.
  - initiated by Tim Berners-Lee at CERN in 1989
- **Representational State Transfer (REST)** is an *architectural style* for distributed hypermedia systems.
  - defined in 2000 by Roy Fielding in his doctoral dissertation

# HTTP

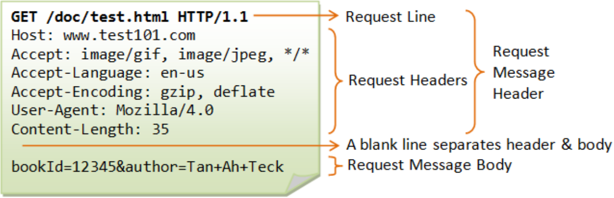
# HTTP protocol basics



- HTTP is a client-server application-level protocol
- Typically runs over a TCP/IP connection
- Extensible – e.g., video, image support
- Stateless
- Cacheable
- Requires *reliable* transport protocol – no UDP

# HTTP Request

- Message header
  - Request line – identifies HTTP method, URI and protocol version
  - Request headers
- Message body



```
GET /doc/test.html HTTP/1.1
Host: www.test101.com
Accept: image/gif, image/jpeg, */*
Accept-Language: en-us
Accept-Encoding: gzip, deflate
User-Agent: Mozilla/4.0
Content-Length: 35

bookId=12345&author=Tan+Ah+Teck
```

Request Line

Request Headers

Request Message Header

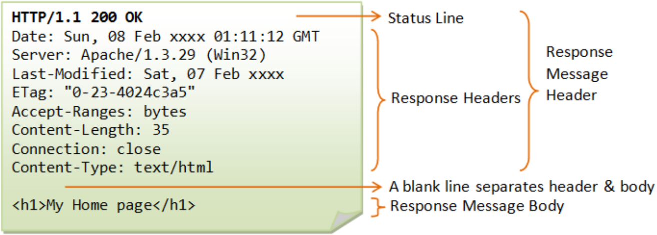
A blank line separates header & body

Request Message Body

Figure: HTTP request example. Source: https://www.ntu.edu.sg/home/ehchua/programming/webprogramming/HTTP_Basics.html

# HTTP Response

- Message header
  - Status line – identifies protocol version and response status code
  - Response headers
- Message body



```
HTTP/1.1 200 OK
Date: Sun, 08 Feb xxxx 01:11:12 GMT
Server: Apache/1.3.29 (Win32)
Last-Modified: Sat, 07 Feb xxxx
ETag: "0-23-4024c3a5"
Accept-Ranges: bytes
Content-Length: 35
Connection: close
Content-Type: text/html

<h1>My Home page</h1>
```

Figure: HTTP request example. Source: https://www.ntu.edu.sg/home/ehchua/programming/webprogramming/HTTP_Basics.html

# HTTP Headers

Typical, often used HTTP headers

| | **Request** | **Response** |
|---|---|---|
| Content | • Content-Type<br>• Content-Length<br>• Content-Encoding<br>• Accept | • Content-Type<br>• Content-Length<br>• Content-Encoding |
| Caching | • If-Modified-Since<br>• If-Match | • Last-Modified<br>• ETag |
| Miscellaneous | • Cookie<br>• Host<br>• Authorization<br>• User-Agent | • Set-Cookie<br>• Location |

# HTTP Methods

## GET

- Used to retrieve resource at request URI
- Safe and idempotent
- Cacheable
- Can have side effects, but not expected
- Can be conditional or partial (If-Modified-Since, Range)

## POST

- Requests server to create new resource from the specified body
- Can be used also to update resources
- Should respond with 201 status and location of newly created resource on success
- Neither safe nor idempotent
- No caching

# HTTP Methods

## PUT

- Requests server to store the specified entity under the request URI
- Server may possibly create a resource if it does not exist
- Usually used to update resources
- Idempotent, unsafe

## DELETE

- Used to ask server to delete resource at the request URI
- Idempotent, unsafe
- Deletion does not have to be immediate

# HTTP Response Status Codes

- **1xx** – rarely used
- **2xx** – success
  - 200 OK – requests succeeded, usually contains data
  - 201 Created – returns a *Location* header for new resource
  - 202 Accepted – server received request and started processing
  - 204 No Content – request succeeded, nothing to return
- **3xx** – redirection
  - 304 Not Modified – resource not modified, cached version can be used

# HTTP Response Status Codes

- **4xx** – client error
  - 400 Bad Request – malformed syntax
  - 401 Unauthorized – authentication required
  - 403 Forbidden – server has understood, but refuses request
  - 404 Not Found – resource not found
  - 405 Method Not Allowed – specified method is not supported
  - 409 Conflict – resource conflicts with client data
  - 415 Unsupported Media Type – server does not support media type
- **5xx** – server error
  - 500 Internal Server Error – server encountered error and failed to process request

# RESTful web services

# Understanding REST

- REST is an architectural style, not standard
- It was designed for distributed systems to address *architectural properties* such as performance, scalability, simplicity, modifiability, visibility, portability, and reliability
- REST architectural style is defined by 6 *principles/architectural constraints* (e.g., client-server, stateless)
- System/API that conforms to the constraints of REST can be called *RESTful*

# REST principles

1. Client-server
2. Uniform interface
    - Resource-based
    - Manipulation of resource through representation
    - Self-descriptive messages
    - Hypermedia as the engine of application state
3. Stateless interactions
4. Cacheable
5. Layered system
6. Code on demand (optional)

# Building RESTful API

- Can be built on top of existing web technologies
- Reusing semantics of HTTP 1.1 methods
  - Safe and idempotent methods
  - Typically called HTTP verbs in context of services
  - Resource oriented, correspond to CRUD operations
  - Satisfies **uniform interface** constraint
- HTTP Headers to describe requests & responses
- Content negotiation

# HTTP GET

```
GET /eshop/rest/categories HTTP/1.1
Host: localhost:8080
Accept: application/json
Cache-Control: no-cache
```

```
HTTP/1.1 200
Cache-Control: no-cache, no-store, max-age=0, must-revalidate
Content-Type: application/json;charset=UTF-8

[{
  "id": 2,
  "name": "CPU"
}, {
  "id": 7,
  "name": "Graphic card"
}, {
  "id": 11,
  "name": "RAM"
}]
```

# HTTP verbs – POST

```
POST /eshop/rest/categories HTTP/1.1
Host: localhost:8080
Content-Type: application/json
Cookie: EAR_JSESSIONID=18162708908C126C0BA5A3D3081CCAC9
Cache-Control: no-cache

{
  "name": "Motherboard"
}
```

```
HTTP/1.1 201
Cache-Control: no-cache, no-store, max-age=0, must-revalidate
Location: http://localhost:8080/eshop/rest/categories/151
```

# HTTP verbs – PUT

```
PUT /eshop/rest/products/8 HTTP/1.1
Host: localhost:8080
Content-Type: application/json
Cookie: EAR_JSESSIONID=18162708908C126C0BA5A3D3081CCAC9

{
  "id":8,
  "name":"MSI GeForce GTX 1050 Ti 4GT OC",
  "amount":50,
  "price":4490.0,
  "categories":[{
    "id":7,
    "name":"Graphic card"
  }],
  "removed":false
}
```

```
HTTP/1.1 204
Cache-Control: no-cache, no-store, max-age=0, must-revalidate
```

# HTTP verbs – DELETE

```
DELETE /eshop/rest/products/8 HTTP/1.1
Host: localhost:8080
Cookie: EAR_JSESSIONID=18162708908C126C0BA5A3D3081CCAC9
Cache-Control: no-cache
```

```
HTTP/1.1 204
Cache-Control: no-cache, no-store, max-age=0, must-revalidate
```

# Recommended Interaction of HTTP Methods w.r.t. URIs

| **HTTP Verb** | **CRUD** | **Collection (e.g. /categories)** | **Specific Item (e.g. /categories/{id})** |
|---|---|---|---|
| POST | Create | 201 Created[1] | 405 Method Not Allowed /409 Conflict[3] |
| GET | Read | 200 OK, list of categories | 200 OK, single category/404 Not Found[4] |
| PUT | Update/Replace | 405 Method Not Allowed[2] | 200 OK/**204 No Content**/404 Not Found[4] |
| PATCH | Update/Modify | 405 Method Not Allowed[2] | 200 OK/**204 No Content**/404 Not Found[4] |
| DELETE | Delete | 405 Method Not Allowed[2] | 200 OK/**204 No Content**/404 Not Found[4] |

Table: Recommended return values of HTTP methods in combination with the resource URIs.

- [1] – returns *Location* header with link to /categories/{id} containing new ID
- [2] – unless you want to update/replace/modify/delete whole collection
- [3] – if resource already exists
- [4] – if ID is not found or invalid

## Naming conventions

- resources should have name as nouns, not as verbs or actions
- plural if possible to apply
- URI should follow a predictable (i.e., consistent usage) and hierarchical structure (based on structure-relationships of data)

### Correct usages

**POST** /customers/12345/orders/121/items
**GET** /customers/12345/orders/121/items/3
**GET**|**PUT**|**DELETE** /customers/12345/configuration

### Anti-patterns

**GET** /services?op=update_customer&id=12345&format=json
**PUT** /customers/12345/update

# Demo

Let's examine SpaceX REST API.

https://documenter.getpostman.com/view/2025350/RWaEzAiG#intro

## The Richardson Maturity Model

- provides a way to evaluate compliance of API to REST constraints

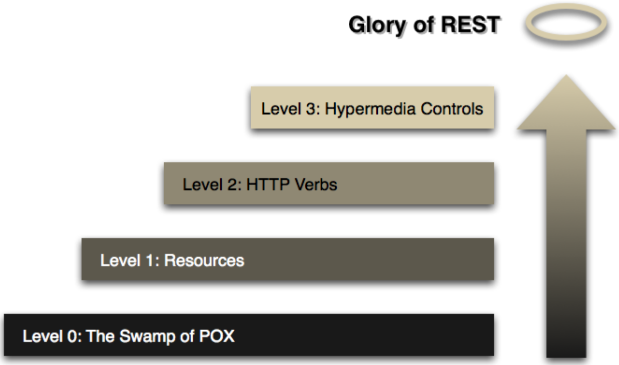


Figure: A model (developed by Leonard Richardson) that breaks down the principal elements of a REST approach into three steps about *resources*, *http verbs*, and *hypermedia controls*. Source: `http://martinfowler.com/articles/richardsonMaturityModel.html`

# HATEOAS

- *Hypermedia as the Engine of Application State*
- Final level of the Richardson Maturity Model
- Client needs zero or little prior knowledge of an API
- Client just needs to understand hypermedia
- Server provides links to further endpoints
- Often difficult to implement
  - Not many usable libraries

# HATEOAS Example

**EAR e-shop does not support HATEOAS.*

```
{
  "id": 2,
  "name": "CPU",
  "links": [{
    "rel": "self",
    "href": "http://localhost:8080/eshop/rest/categories/2"
  }, {
    "rel": "edit",
    "href": "http://localhost:8080/eshop/rest/categories/2"
  }, {
    "rel": "products",
    "href": "http://localhost:8080/eshop/rest/categories/2/products"
  }]
}
```

We are using the *Atom* link format.

# REST Documentation

- Documentation of REST is done in two (similar) formats: Swagger or OpenApi

```
openapi: 3.0.0
info:
  title: Deployed Resources
  version: 1.0.0
servers:
- url: http://pidibook:8080/DemoRest1
  description: Default Server.
paths:
  /resources/demo:
    get:
      operationId: ping
      responses:
        default:...
  /resources/demo/objects:
    get:
      operationId: objects
      responses:
        default:
          content:
            '*/*':
              schema:
```

# Linked Data

# Linked Data

- Method of publishing structured data allowing to interlink them with other data
- Builds upon the original ideas of the Web
  - Interconnected resources, but this time, machine-readable
- Knowledge-based systems, context-aware applications, precise domain description, knowledge inference
- Still possible to build REST APIs, but resources have global identifiers now
- Attributes and relationships also globally identifiable and may have well-defined meaning

# Linked Data Example

```
{
 "@context": {
  "name": "http://www.w3.org/2000/01/rdf-schema#label",
  "description": "http://purl.org/dc/terms/description",
  "products": "http://onto.fel.cvut.cz/ontologies/eshop/has-product"
 },
 "@id": "http://onto.fel.cvut.cz/eshop/categories/cpu",
 "products": {
  "@id": "https://ark.intel.com/products/97455/Intel-Core-i3-7100-
      Processor-3M-Cache-3-90-GHz",
  "name": "Intel Core i3-7100"
 },
 "description": "Category of Central Processing Units for computers.",
 "name": "CPU"
}
```

# REST in Spring

```
@RestController
public class CarController {
   @Inject private CarService carService;

      @GetMapping("/cars")
      public Cars allCars(@RequestParam(value = "name", defaultValue =
          "World") String name) {
            return carService.listAllCars();
      }
}
```

# JAX-RS

```
@Path("v1/cars")
@Produces(MediaType.APPLICATION_JSON)
public class CarsResource {
   @GET
   public Cars allCars() {
      return service.allCars();
   }

   @Path("{id}")
   @GET
   public Car oneCar(@PathParam("id") Integer id) {
      return service.findById(id);
   }

   @Path("{id}")
   @DELETE
   public Response deleteOneCar(@PathParam("id") Integer id) {
      service.remove(id);
      return Response.noContent().build();
   }
```

# JAX-RS Client

```
Client client = javax.ws.rs.client.ClientBuilder.newClient();
WebTarget webTarget = client.target(BASE_URI).path("v1/cars");
webTarget.request(javax.ws.rs.core.MediaType.APPLICATION_JSON)
   .get(Cars.class)
```

# MicroProfile – REST Support

```
@RegisterRestClient(baseUri = "https://api.spacexdata.com/")
@Path("v3")
public interface SpaceXRestClient {
   @GET
   @Path("rockets/")
   @Produces(MediaType.APPLICATION_JSON)
   public List<RestRocket> all();

   @GET
   @Path("rockets/{rocket_id}")
   @Produces(MediaType.APPLICATION_JSON)
   public RestRocket rocket(@PathParam("rocket_id") String rocketId);
}
use:
   @Inject
   @RestClient
   SpaceXRestClient spaceXRestClient;

{ spaceXRestClient.all(); }
```

# REST – Security

- Same as HTML – HTTPS, passwords
- Usage of JWT (JSON Web Token), mainly makes sense for $\mu$Services (holds signed roles, other information so some services don't need user database)
- Necessary to use either reverse (https) proxy or CORS headers
- Security is a huge problem
  - No way, how to protect access, easy to play with
  - Double security – on client, on server
  - Every single data must have REST, every dropdown list, every table, every form
  - Very difficult to check EVERYTHING – objects are returned and only parts of them are allowed to change (e.g. mail, username, password, but not id, roles). In some other cases it is allowed (e.g. by superadmin).

# REST – Battlefield Experience

- Good support in Spring, JAX-RS, great in MicroProfile
- Good idea to add API version to url, e.g. /rest/v1/cars
- Use DTO frequently, always for list/array
- ID returned in URL – needs to be parsed
- Messages returned in HTTP header are in ASCII, e.g. no Czech messages
- Various errors return messages in various parts of the JS response object
- Usaging JavaScript Object Notation (JSON) even between languages having nothing with JS in $\mu$Services
- No autogeneration of client from service description (at least useful).

# Demo

## JAX-RS, MicroProfile

- http://localhost:4848/openapi
- http://localhost:8080/JAXRSServer/rest/v1/cars
- http://localhost:8080/JAXRSServer/rest/v1/cars/0
- http://localhost:8080/JAXRSServer/rest/v1/cars/5
- http://aubiwork:8080/JAXRSClient/rest/v1/rockets/
- http://aubiwork:8080/JAXRSClient/rest/v1/rockets/by-id?id=falcon1

# Conclusions

# REST

## Pros

- API first (agree on API, then code on both sides)
- Easy to build
- Easy to use
- Standard technologies – HTTP, JSON, XML
- Platform-independent (JS-based web pages, mobiles)
- Stateless, cacheable

## Cons

- No standard for REST itself – APIs build in various ways
- No full generator for all the possibilities (lack in documentation)
- No “registry” of REST services

# The End

Thank You

## Resources

- Fielding, R.T., 2000. Architectural styles and the design of network-based software architectures (Doctoral dissertation, University of California, Irvine),
- Fowler, M., 2010. Richardson Maturity Model: steps toward the glory of REST. Online at `http://martinfowler.com/articles/richardsonMaturityModel.html`.
- Lanthaler, M. and Gütl, C., 2012, April. On using JSON-LD to create evolvable RESTful services. In Proceedings of the Third International Workshop on RESTful Design (pp. 25-32). ACM.
- `https://spring.io/understanding/REST`
- `https://developer.mozilla.org/en-US/docs/Web/HTTP/Overview`
- `http://linkeddata.org/`