

Figure 1: Interest in web service APIs. Source: <https://blog.wishtack.com/rest-apis-best-practices-and-security/>

What is a web service?

A Web service is a software system designed to support interoperable machine-to-machine interaction over a network.

— W3C, Web Services Glossary

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)

Web Service API Distribution

REST vs SOAP Interest

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

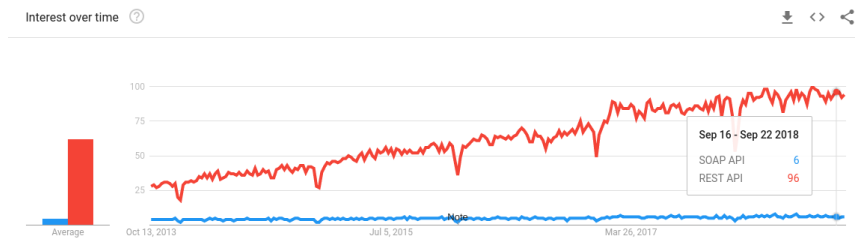
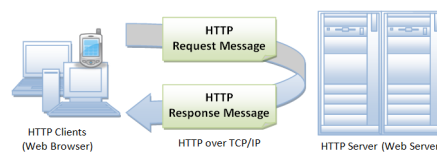


Figure 2: Interest over time for REST API versus SOAP API based on Google Insights for Search. Source: <https://www.google.com/trends>



- **Representational State Transfer (REST)** is an *architectural style* for distributed hypermedia systems.
 - defined in 2000 by Roy Fielding in his doctoral dissertation

1 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

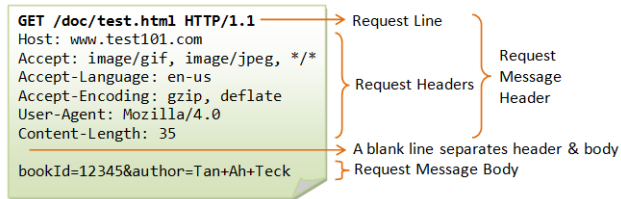


Figure 3: HTTP request example. Source: https://www.ntu.edu.sg/home/ehchua/programming/webprogramming/HTTP_Basics.html

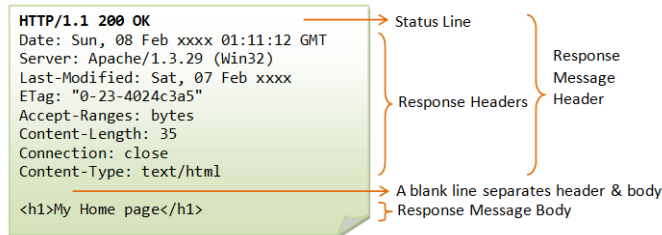


Figure 4: HTTP request example. Source: https://www.ntu.edu.sg/home/ehchua/programming/webprogramming/HTTP_Basics.html

HTTP Response

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

HTTP Headers

Typical, often used HTTP headers

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)

	Request	Response
Content	<ul style="list-style-type: none"> • Content-Type • Content-Length • Content-Encoding • Accept 	<ul style="list-style-type: none"> • Content-Type • Content-Length • Content-Encoding
Caching	<ul style="list-style-type: none"> • If-Modified-Since • If-Match 	<ul style="list-style-type: none"> • Last-Modified • ETag
Miscellaneous	<ul style="list-style-type: none"> • Cookie • Host • Authorization • User-Agent 	<ul style="list-style-type: none"> • Set-Cookie • Location

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

2 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 build 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
```

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

Recommended Interaction of HTTP Methods w.r.t. 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

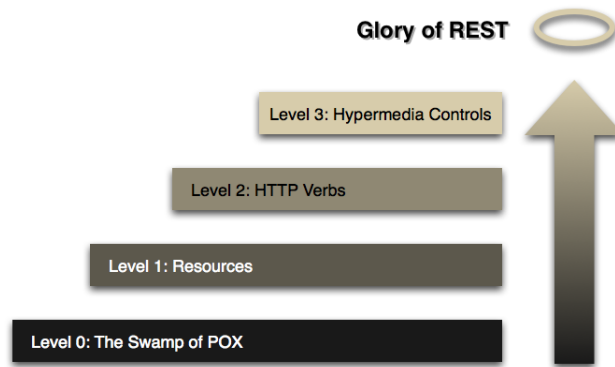


Figure 5: A model (developed by Leonard Richardson) that breaks down the principal elements of a REST approach into three steps about *resources*, *http verbs*, and *hypermedia controls*. Source: <http://martinfowler.com/articles/richardsonMaturityModel.html>

2.1 HATEOAS

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.

3 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"
}
```

4 Conclusions

REST

Pros

- Easy to build
- Easy to use
- Standard technologies – HTTP, JSON, XML
- Platform-independent

- Stateless, cacheable

Cons

- No standard for REST itself – APIs build in various ways
- No standard for documentation and publishing REST API description
- 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/>