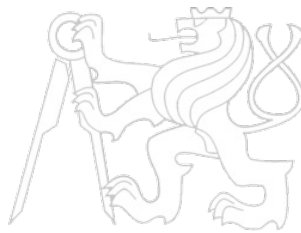


Web 2.0

Lecture 4: HATEOAS, Scalability and Description

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Humla v0.3

REST Core Principles

- REST architectural style defines constraints
 - *if you follow them, they help you to achieve a good design, interoperability and scalability.*
- Constraints
 - *Client/Server*
 - *Statelessness*
 - *Cacheability*
 - *Layered system*
 - *Uniform interface*
- Guiding principles
 - *Identification of resources*
 - *Representations of resources and self-descriptive messages*
 - *Hypermedia as the engine of application state (HATEOAS)*

Overview

- **HATEOAS**
 - *Stateful vs. Stateless*
 - *Links and Preconditions*
- Scalability

HATEOAS

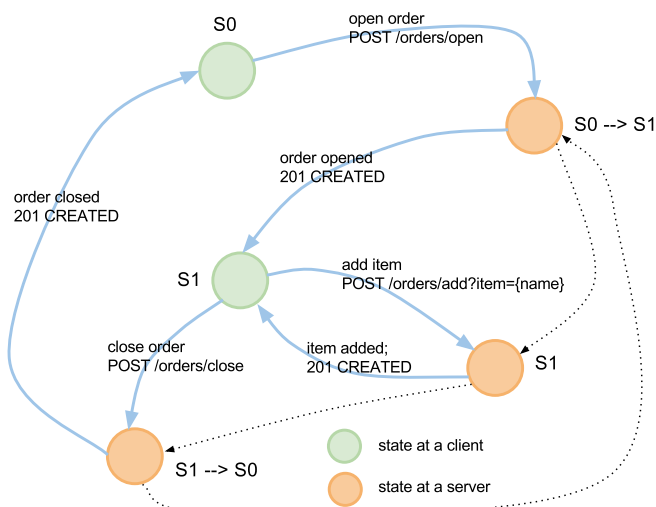
- HATEOAS = Hypertext as the Engine for Application State
 - *The REST core principle*
 - **Hypertext**
 - *Hypertext is a representation of a resource with **links***
 - *A link is an URI of a resource*
 - *Applying an access to a resource via its link = state transition*
- Statelessness
 - *A service does not use a memory to remember a state*
 - *HATEOAS enables stateless implementation of services*

Overview

- HATEOAS
 - *Stateful vs. Stateless*
 - *Links and Preconditions*
- Scalability

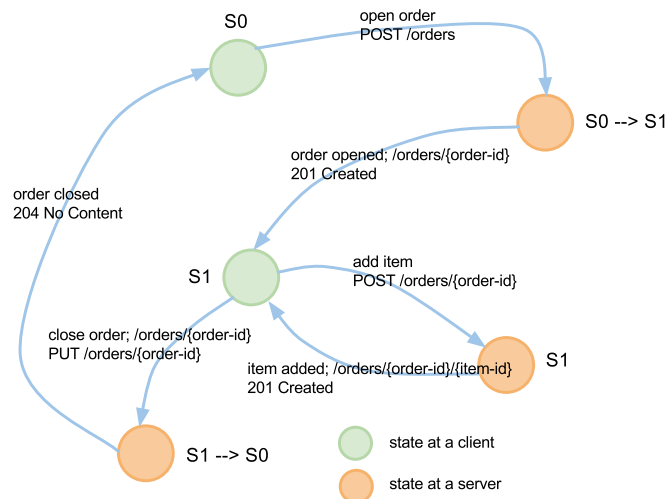
Stateful server

- Sessions to store the application state
 - Recall HTTP state management in MDW
 - The app uses a server memory to remember the app's state
 - when server restarts, the app state is lost



Stateless server

- HTTP and hypermedia to transfer the app state
 - Does not use a server memory to remember the app state
 - State transferred between a client and a service via HTTP metadata and resources' representations



Persistent Storage and Session Memory

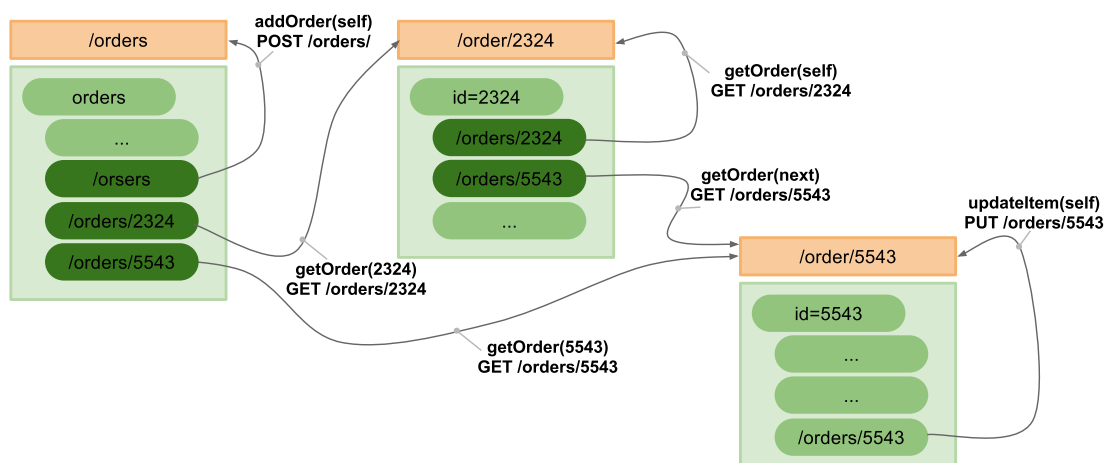
- Persistent Storage
 - Contains app data
 - Data is serialized into resource representation formats
 - All sessions may access the data via resource IDs
 - Note
 - Our simple examples implement a storage in a server memory!
- Session Memory
 - Server memory that contains a state of the app
 - A session may only access its session memory
 - Access through cookies
 - Note
 - A session memory may be implemented via a persistent storage (such as in Google AppEngine)

Overview

- HATEOAS
 - *Stateful vs. Stateless*
 - *Links and Preconditions*
- Scalability

Link

- Service operation
 - *Applying an access to a link (GET, PUT, POST, DELETE)*
 - *Link: HTTP method + resource URI + optional link semantics*
- Example: **getOrder**, **addOrder**, and **updateItem**



Atom Links

- Atom Syndication Format

- XML-based document format; Atom feeds
- Atom links becoming popular for RESTful applications

```
1 <order a:xmlns="http://www.w3.org/2005/Atom" xmlns="...">
2   <a:link
3     rel="next"
4     href="http://company.com/orders/5543"
5     type="application/xml"/>
6   <customer>Tomas</customer>
7   <items>...</items>
8 </order>
```

- Link structure

rel – name of the link

~ semantics of an operation behind the link

href – URI to the resource described by the link

type – media type of the resource the link points to

Link Semantics

- Standard **rel** values

- Navigation: **next**, **previous**, **self**
- Does not reflect a HTTP method you can use

- Extension **rel** values

- You can use **rel** to indicate a semantics of an operation
- Example: add item, delete order, update order, etc.
- A client associates this semantics with an operation it may apply at a particular state
- The semantics should be defined by using an URI

```
1 <order a:xmlns="http://www.w3.org/2005/Atom" xmlns="...">
2   <id>2324</id>
3   <a:link rel="http://company.com/op/addItem"
4     href="http://company.com/orders/2324"/>
5   <a:link rel="http://company.com/op/deleteOrder"
6     href="http://company.com/orders/2324"/>
7 </order>
```

Pagination

- Dividing a resource into a number of pages
 - A client retrieves a resource in pages to optimize interactions
 - Example: `/orders?page={startPage}&size={numberReturned}`
 - A client needs to ask for (or have default values for) a start page and a number of orders to return (must have a pre-defined knowledge)

- Example `/orders` resource:

```
1 <orders a:xmlns="http://www.w3.org/2005/Atom" xmlns="...">
2   <order>...</order>
3   <a:link rel="next" href="http://company.com/orders?page=2&size=10" />
4   <a:link rel="last" href="http://company.com/orders?page=10&size=10" />
5 </orders>
```

- client does not need to remember which page of orders it is viewing

Link Headers

- An alternative to Atom links in resource representations
 - links defined in HTTP Link header, Web Linking IETF spec [🔗](#)
 - They have the same semantics as Atom Links
 - Example:

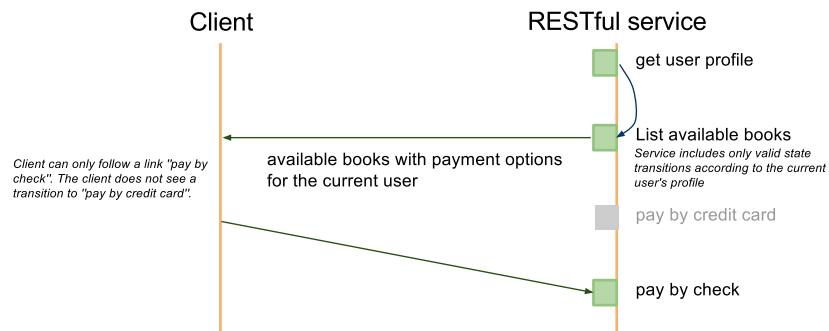
```
> HEAD /orders HTTP/1.1
```

```
< Content-Type: application/xml
< Link: <http://company.com/orders/?page=2&size=10>; rel="next"
< Link: <http://company.com/orders/?page=10&size=10>; rel="last"
```

- Advantages
 - no need to get the entire document
 - no need to parse the document to retrieve links
 - use HTTP HEAD only

Preconditions and HATEOAS

- **Precondition**
 - Recall Preconditions and effects in MDW
 - A conditions that must hold in a state before an operation can be executed.
- **Preconditions in HATEOAS**
 - Service in a current state generates only valid transitions that it includes in the representation of the resource.
 - Transition logic is realized at the server-side



Advantages

- **Location transparency**
 - only "entry-level" links published to the World
 - other links within documents can change without changing client's logic
 - HATEOAS may reflect current user's rights in the app
- **Loose coupling**
 - no need for a logic to construct the links
 - Clients know to which states they can move via links

Overview

- HATEOAS
- **Scalability**
 - *Caching and Revalidation*
 - *Concurrency Control*

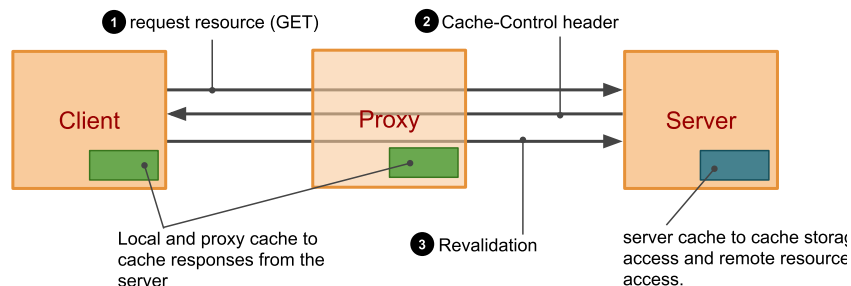
Scalability

- Need for scalability
 - *Huge amount of requests on the Web every day*
 - *Huge amount of data downloaded*
- Some examples
 - *Google, Facebook: 5 billion API calls/day*
 - *Twitter: 3 billions of API calls/day (75% of all the traffic)*
 - *50 million tweets a day*
 - *eBay: 8 billion API calls/month*
 - *Bing: 3 billion API calls/month*
 - *Amazon WS: over 100 billion objects stored in S3*
- Scalability in REST
 - *Caching and revalidation*
 - *Concurrency control*

Overview

- HATEOAS
- Scalability
 - *Caching and Revalidation*
 - *Concurrency Control*

Caching



- Your service should cache:
 - *anytime there is a static resource*
 - *even there is a dynamic resource*
 - *with chances it updates often*
 - *you can force clients to always revalidate*
- three steps:
 - *client GETs the resource representation*
 - *server controls how it should cache through **Cache-Control** header*
 - *client revalidates the content via conditional GET*

Cache Headers

- **Cache-Control** response header
 - controls over local and proxy caches
 - **private** – no proxy should cache, only clients can
 - **public** – any intermediary can cache (proxies and clients)
 - **no-cache** – the response should not be cached. If it is cached, the content should always be revalidated.
 - **no-store** – can cache but should not store persistently. When a client restarts, content is lost
 - **no-transform** – no transformation of cached data; e.g. compressions
 - **max-age**, **s-maxage** a time in seconds how long the cache is valid; **s-maxage** for proxies
- **Last-Modified** and **ETag** response headers
 - Content last modified date and a content entity tag
- **If-Modified-Since** and **If-None-Match** request headers
 - Content revalidation (conditional GET)

Example Date Revalidation

- Cache control example:

```
> GET /orders HTTP/1.1
> ...

< HTTP/1.1 200 OK
< Content-Type: application/xml
< Cache-Control: private, no-store, max-age=200
< Last-Modified: Sun, 7 Nov 2011, 09:40 CET
<
< ...data...
```

 - only client can cache, must not be stored on the disk, the cache is valid for 200 seconds.
- Revalidation (conditional GET) example:
 - A client revalidates the cache after **200** seconds.

```
> GET /orders HTTP/1.1
> If-Modified-Since: Sun, 7 Nov 2011, 09:40 CET

< HTTP/1.1 304 Not Modified
< Cache-Control: private, no-store, max-age=200
< Last-Modified: Sun, 7 Nov 2011, 09:40 CET
```

Entity Tags

- Signature of the response body
 - A hash such as MD5
 - A sequence number that changes with any modification of the content
- Types of tag
 - Strong ETag: reflects the content bit by bit
 - Weak ETag: reflects the content "semantically"
 - The app defines the meaning of its weak tags

- Example content revalidation with ETag

```
< HTTP/1.1 200 OK
< Cache-Control: private, no-store, max-age=200
< Last-Modified: Sun, 7 Nov 2011, 09:40 CET
< ETag: "4354a5f6423b43a54d"

> GET /orders HTTP/1.1
> If-None-Match: "4354a5f6423b43a54d"

< HTTP/1.1 304 Not Modified
< Cache-Control: private, no-store, max-age=200
< Last-Modified: Sun, 7 Nov 2011, 09:40 CET
< ETag: "4354a5f6423b43a54d"
```

Design Suggestions

- Composed resources use weak ETags
 - For example `/orders`
 - a composed resource that contains a summary information
 - changes to an order's items will not change semantics of `/orders`
 - It is usually not possible to perform updates on these resources
- Non-composed resources use strong ETags
 - For example `/orders/{order-id}`
 - They can be updated
- Further notes
 - Server should send both `Last-Modified` and `ETag` headers
 - If client sends both `If-Modified-Since` and `If-None-Match`, `ETag` validation takes preference

Weak ETag Example

- App specific, `/orders` resource example

```
1  {
2    "orders" :
3      [
4        { "id"       : 2245,
5          "customer" : "Tomas",
6          "descr"    : "Stuff to build a house.",
7          "items"    : [...] },
8        { "id"       : 5546,
9          "customer" : "Peter",
10         "descr"    : "Things to build a pipeline.",
11         "items"    : [...] }
12      ]
13 }
```

- Weak ETag compute function example

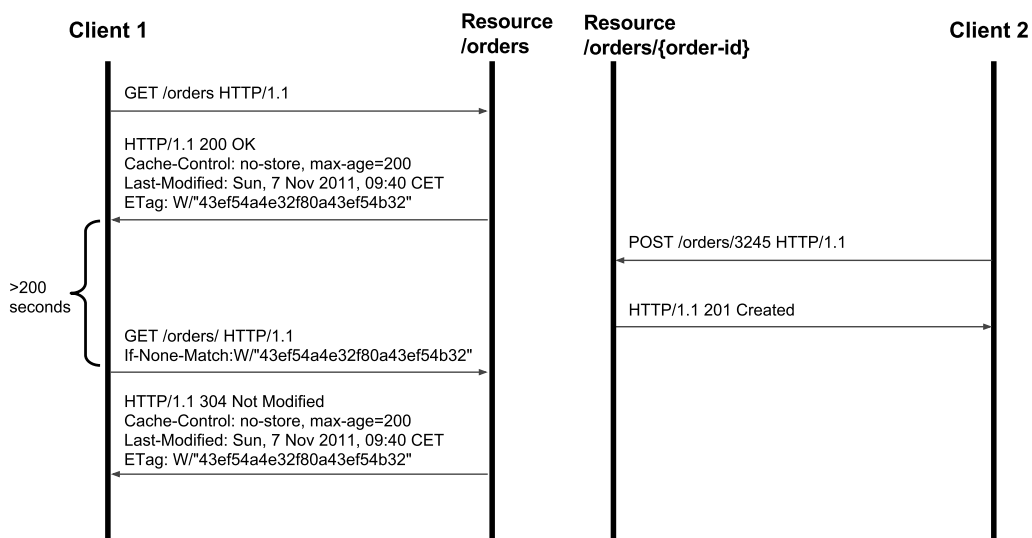
– Any modification to an order's items is not significant for `/orders`:

```
1  var crypto = require("crypto");
2
3  function computeWeakETag(orders) {
4    var content = "";
5    for (var i = 0; i < orders.length; i++)
6      content += orders[i].id + orders[i].customer + orders[i].descr;
7    return crypto.createHash('md5').update(content).digest("hex");
8  }
```

Weak ETag Revalidation

- Updating `/orders` resource

– `POST /orders/{order-id}` inserts a new item to an order
– Any changes to orders' items will not change the Weak ETag



Overview

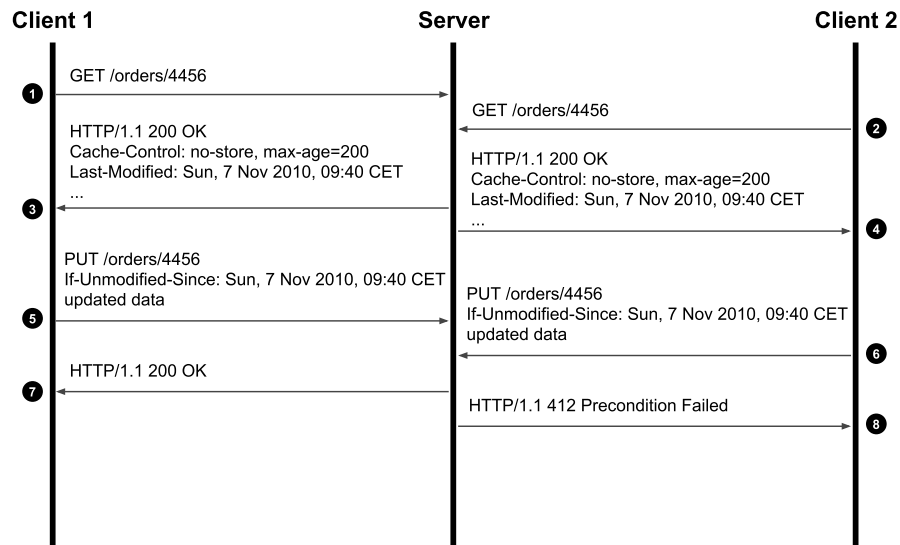
- HATEOAS
- Scalability
 - *Caching and Revalidation*
 - *Concurrency Control*

Concurrency

- Two clients may update the same resource
 - 1) a client GETs a resource **GET /orders/5545**
 - 2) the client modifies the resource
 - 3) the client updates the resource via **PUT /orders/5545 HTTP/1.1**

What happens if another client updates the resource between 1) and 3) ?
- Concurrency control
 - **Conditional PUT**
 - *Update the resource only if it has not changed since a specified date or a specified ETag matches the resource content*
 - **If-Unmodified-Since** and **If-Match** headers
 - Response to conditional **PUT**:
 - **200 OK** if the **PUT** was successful
 - **412 Precondition Failed** if the resource was updated in the meantime.

Concurrency Control Protocol



- Conditional PUT and ETags
 - *Conditional PUT must always use strong entity tags or date validation*

Overview

- HATEOAS
- Scalability
 - *Documentation*

Documentation

- RESTful API Documentation
 - *Until recently, not a standard way, only good practices*
 - *and only textual, not in a formal language*
 - *there were attempts such as WADL, hREST*
 - *it is even possible to use WSDL 2.0*
 - *Today, Swagger and Open API Specification*
- Client libraries in major languages
 - *JavaScript, Java, ...*
 - *these could be documented*
 - *they hide protocol details*
- Best practices in RESTful API documentation
 - *learn from Google, Twitter, and others*

Best Practices

- Include resource diagram
 - *in UML, with links*
- For each resource, describe
 - *URI with parameters, such as*
`http://company.com/orders/{order-id}`
 - *definition of the parameters*
 - *list of properties (attributes), with values, link to XML Schema*
 - *representations you support (XML, JSON)*
 - *sample request*
 - *sample response in representations you support*
 - *error codes*
- Make sure
 - *people can copy sample code and run it in a browser or by using*
`curl`

Swagger Overview

- Emerging standard
 - Started as a private company effort (SmartBear)
 - Recently became so popular and evolved to a community effort
 - Open API Specification under Apache Foundation
 - Google, IBM, 3Scale, ...
- Guiding Principles
 - A minimal effort to describe an API
 - API description should be generated, e.g. via code annotations
 - It can always be written manually too
 - A minimal effort to write clients
 - Sanbox comes out-of-the-box

Swagger API Description

- Server
 - Server provides a **Resource Listing** at **/api-docs**
 - For each resource, there is an **API Declaration**
- Resource Listing
 - JSON Representation

```
1  {
2    "swaggerVersion": "1.2",
3    "apis": [
4      {
5        "path": "http://localhost:8000/listings/greetings",
6        "description": "Generating greetings in our application."
7      }
8    ]
9  }
```

Swagger API Description

- API Declaration

– *JSON Representation*

```
1  {
2    "swaggerVersion": "1.2",
3    "basePath": "http://localhost:8000/greetings",
4    "apis": [
5      {
6        "path": "/hello/{subject}",
7        "operations": [
8          {
9            "method": "GET",
10           "summary": "Greet our subject with hello!",
11           "type": "string",
12           "nickname": "helloSubject",
13           "parameters": [
14             {
15               "name": "subject",
16               "description": "The subject to be greeted.",
17               "required": true,
18               "type": "string",
19               "paramType": "path"
20             }
21           ]
22         }
23       ]
24     ],
25     "models": {}
26   }
27 }
```