Web 2.0

Lecture 4: Hypertext and Application State

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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

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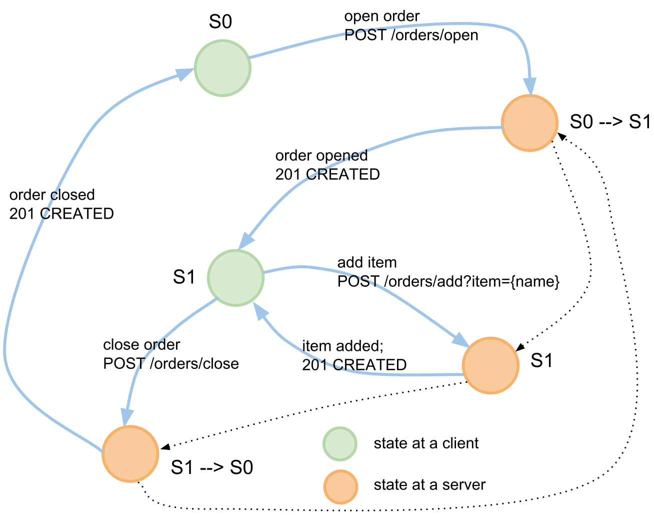
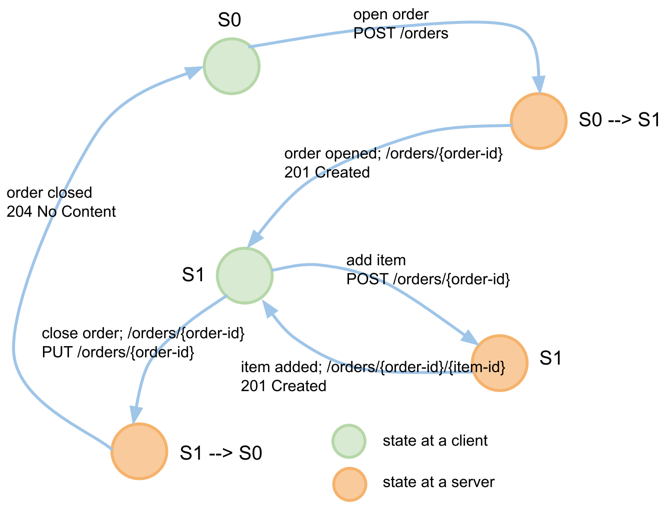
Stateful server

- Sessions to store the application state
  - *Recall HTTP state management in MDW*
  - *The app uses a server memory to remember the state*
  - *When the 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 the 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

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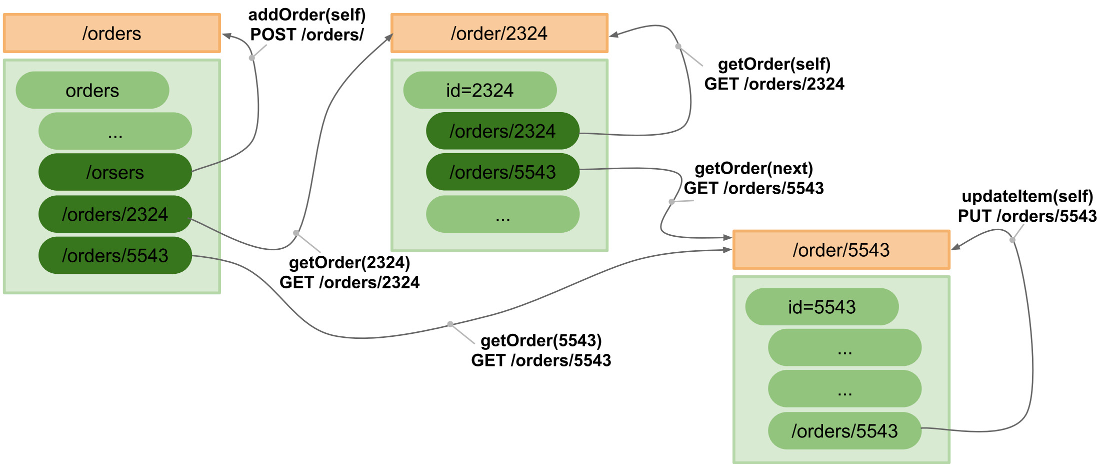
Link

- 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*

```
<order a:xmlns="http://www.w3.org/2005/Atom" xmlns="...">
    <a:link
        rel="next"
        href="http://company.com/orders/5543"
        type="application/xml"/>
    <customer>Tomas</customer>
    <items>...</items>
</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*

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

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

  – *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:*

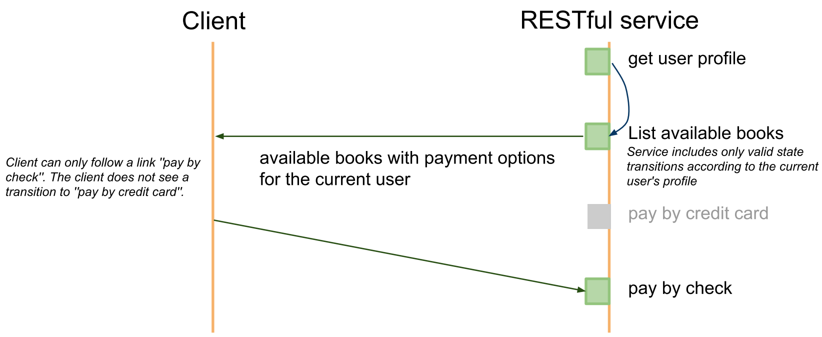
```
> HEAD /orders HTTP/1.1

< 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

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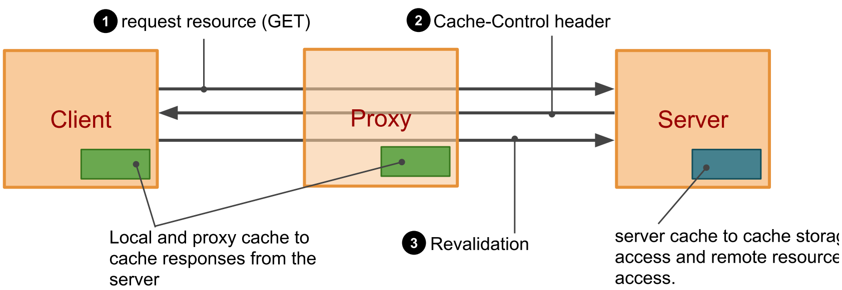
Caching



- 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

```
{
    "orders" :
        [
            { "id"         : 2245,
              "customer"   : "Tomas",
              "descr"      : "Stuff to build a house.",
              "items"      : [...] },
            { "id"         : 5546,
              "customer"   : "Peter",
              "descr"      : "Things to build a pipeline.",
              "items"      : [...] }
        ]
}
```

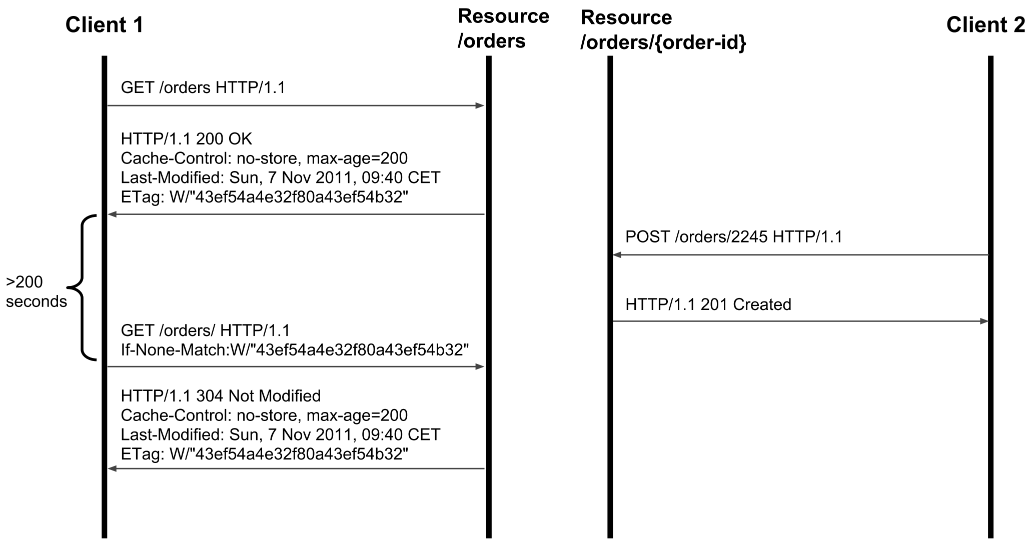
- Weak ETag compute function example
  – *Any modification to an order's items is not significant for* `/orders`*:*

```
var crypto = require("crypto");

function computeWeakETag(orders) {
    var content = "";
    for (var i = 0; i < orders.length; i++)
        content += orders[i].id + orders[i].customer + orders[i].descr;
    return crypto.createHash('md5').update(content).digest("hex");
}
```


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
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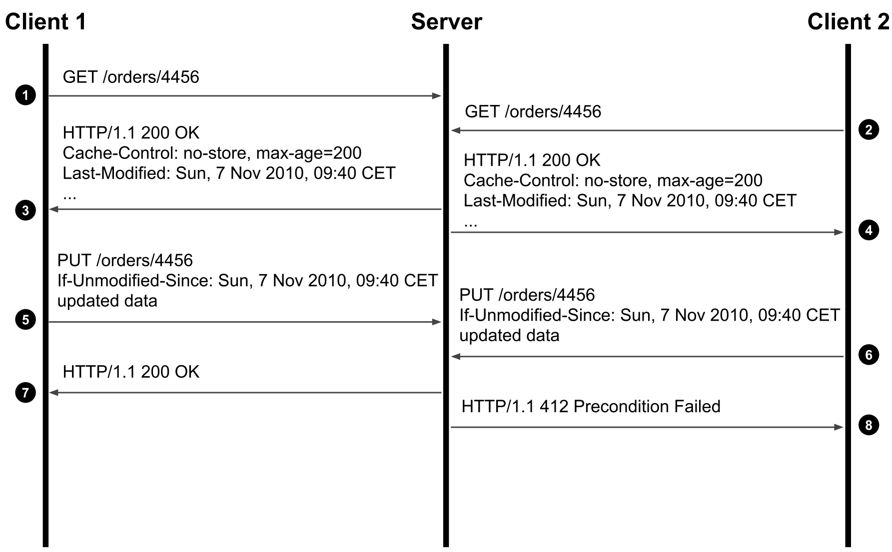
  – *Caching and Revalidation*
  – *Concurrency Control*

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***
- Resouce Listing
  - *JSON Representation*

```
{
  "swaggerVersion": "1.2",
  "apis": [
    {
      "path": "http://localhost:8000/listings/greetings",
      "description": "Generating greetings in our application."
    }
  ]
}
```

Swagger API Description

- API Declaration
  - *JSON Representation*

```
{
  "swaggerVersion": "1.2",
  "basePath": "http://localhost:8000/greetings",
  "apis": [
    {
      "path": "/hello/{subject}",
      "operations": [
        {
          "method": "GET",
          "summary": "Greet our subject with hello!",
          "type": "string",
          "nickname": "helloSubject",
          "parameters": [
            {
              "name": "subject",
              "description": "The subject to be greeted.",
              "required": true,
              "type": "string",
              "paramType": "path"
            }
          ]
        }
      ]
    }
  ],
  "models": {}
}
```