

# Middleware Architectures 1

## Lecture 4: HATEOAS, Caching and Concurrency

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# Overview

- HATEOAS
- Caching, Revalidation, Concurrency Control
- Richardson Maturity Model

# HATEOAS

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

# Stateful server

- Sessions to store the application state
  - *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*

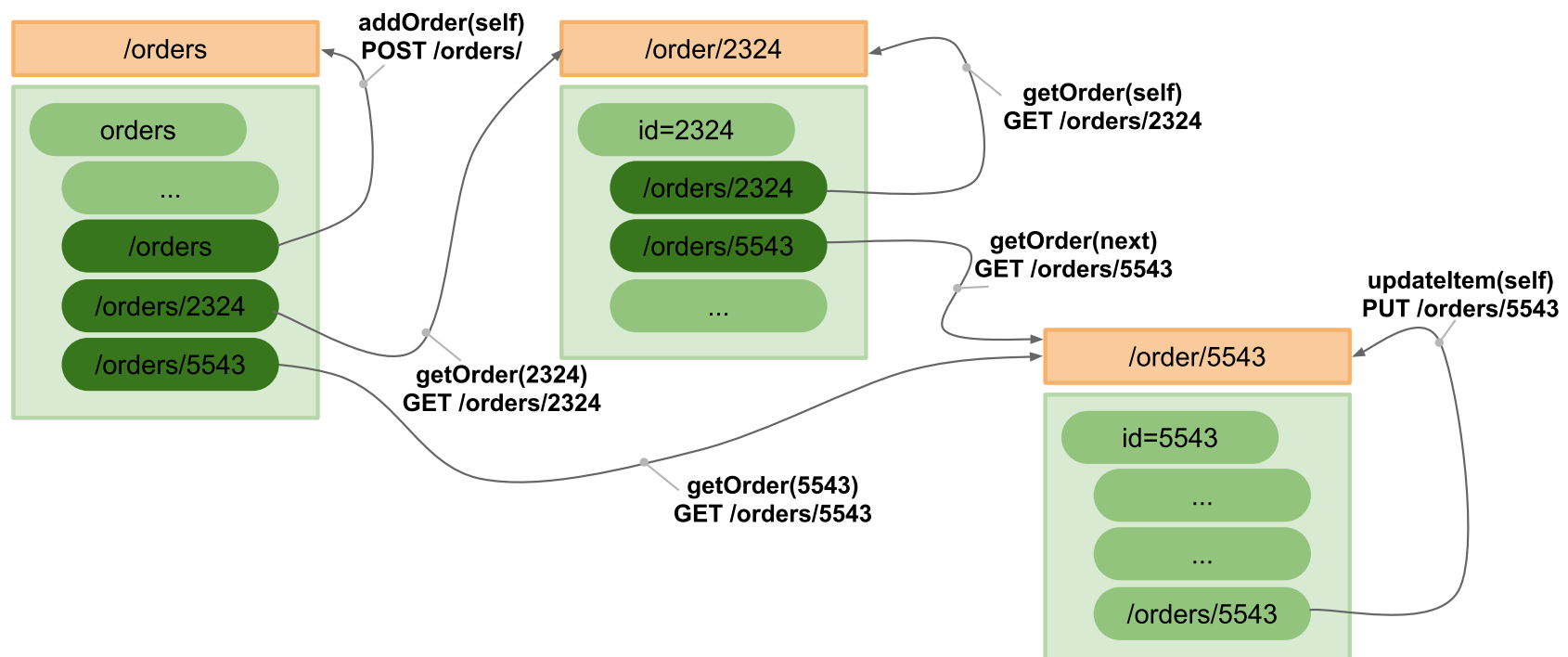


# Persistent Storage and Session Memory

- Persistent Storage
  - *Contains the app data*
  - *Data is serialized into resource representation formats*
  - *All sessions may access the data via resource IDs*
- 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)*

# 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*

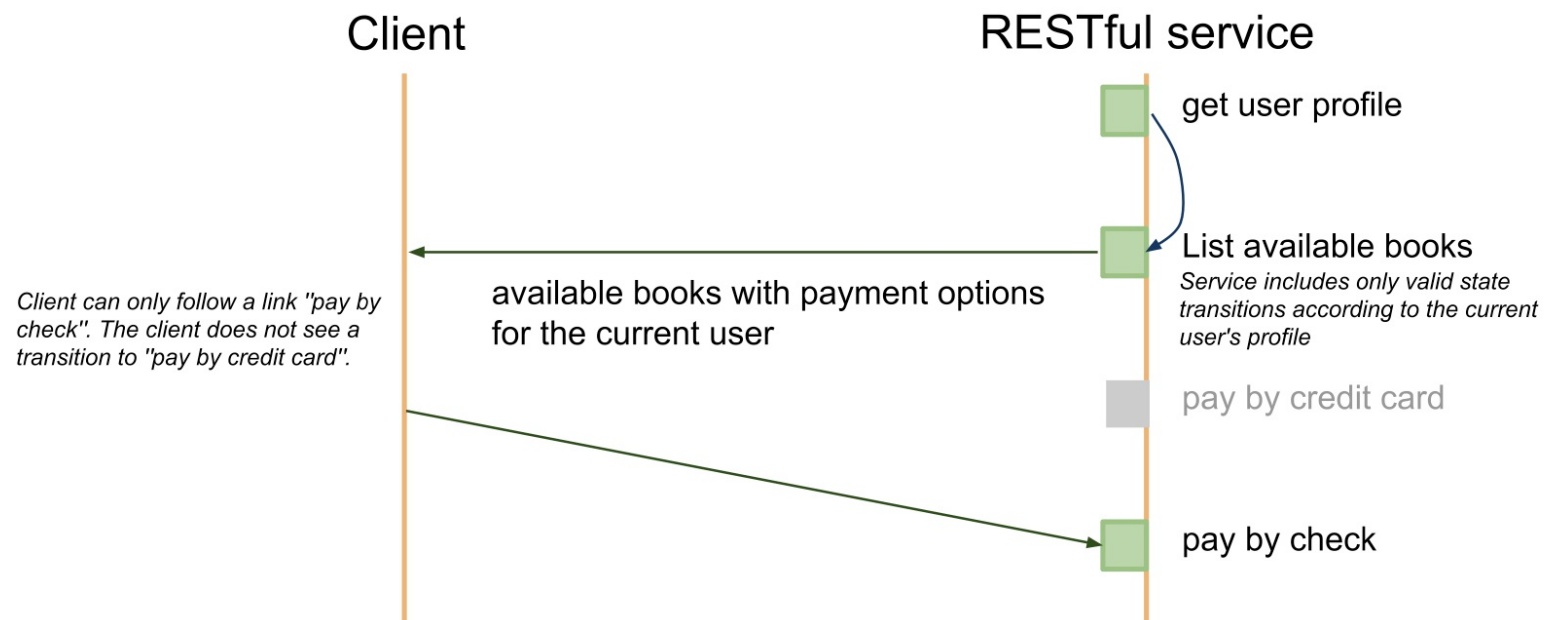
```
1 <order a:xmlns="http://www.w3.org/2005/Atom" xmlns="...">
2   <id>2324</id>
3   <a:link rel="http://company.com/op/addItem"
4     href="http://company.com/orders/2324"/>
5   <a:link rel="http://company.com/op/deleteOrder"
6     href="http://company.com/orders/2324"/>
7 </order>
```

# 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

- 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*
  - *Hypertext represents the current user's view, i.e. rights or other context*
- Loose coupling
  - *no need for a logic to construct the links*
  - *Clients know to which states they can move via links*
- Statelessness and Cloud
  - *Better implementation of scalability*

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# 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*

# 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** – *must not store persistently (this turns off caching)*
  - **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, max-age=200
< Last-Modified: Sun, 7 Nov 2011, 09:40 CET
<
< ...data...
```

— *only client can cache, 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, 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, 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, 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

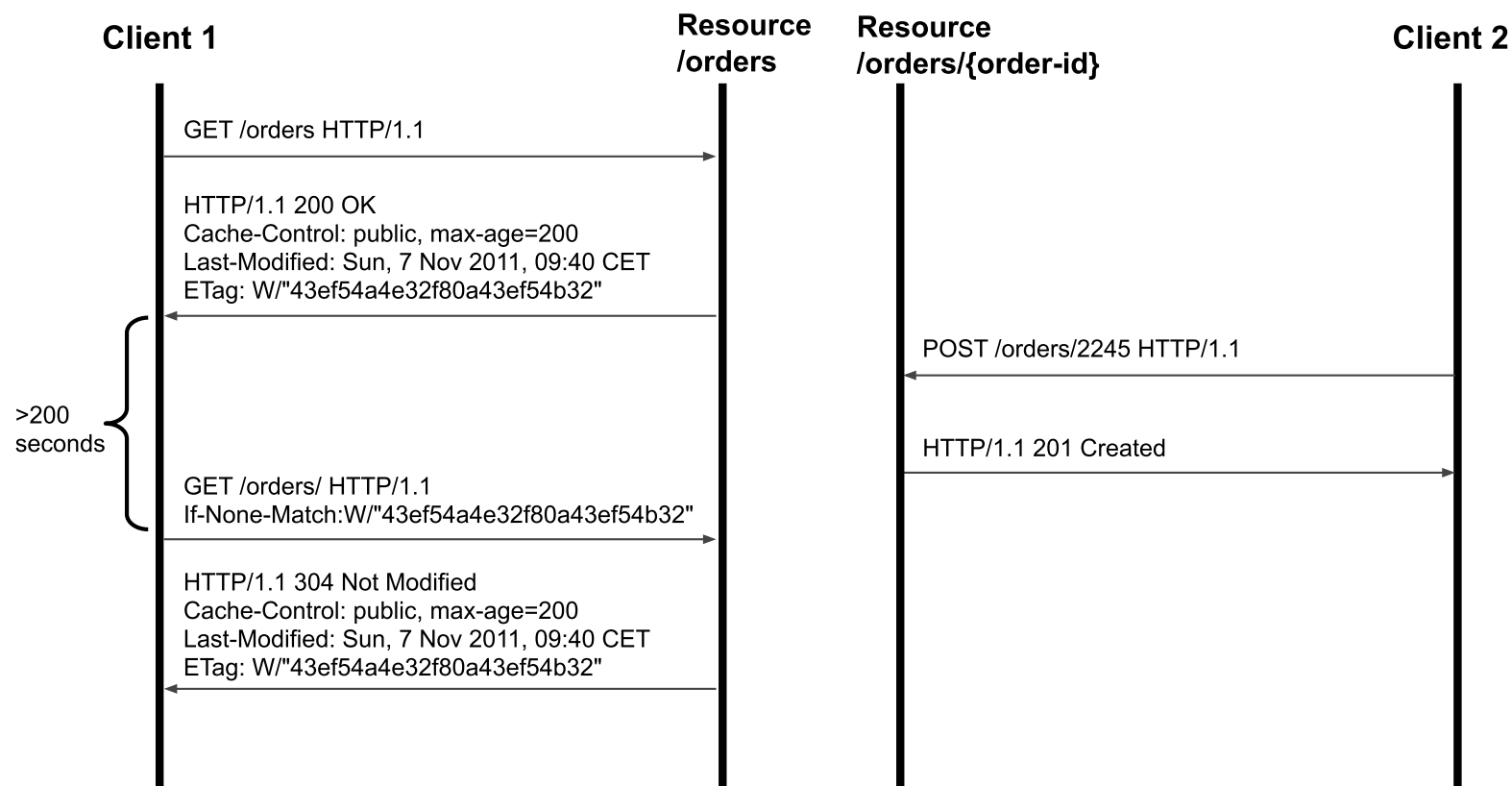
```
1  {  
2    "orders" :  
3      [  
4        { "id"      : 2245,  
5          "customer" : "Tomas",  
6          "descr"    : "Stuff to build a house.",  
7          "items"    : [...] },  
8        { "id"      : 5546,  
9          "customer" : "Peter",  
10         "descr"    : "Things to build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



# 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

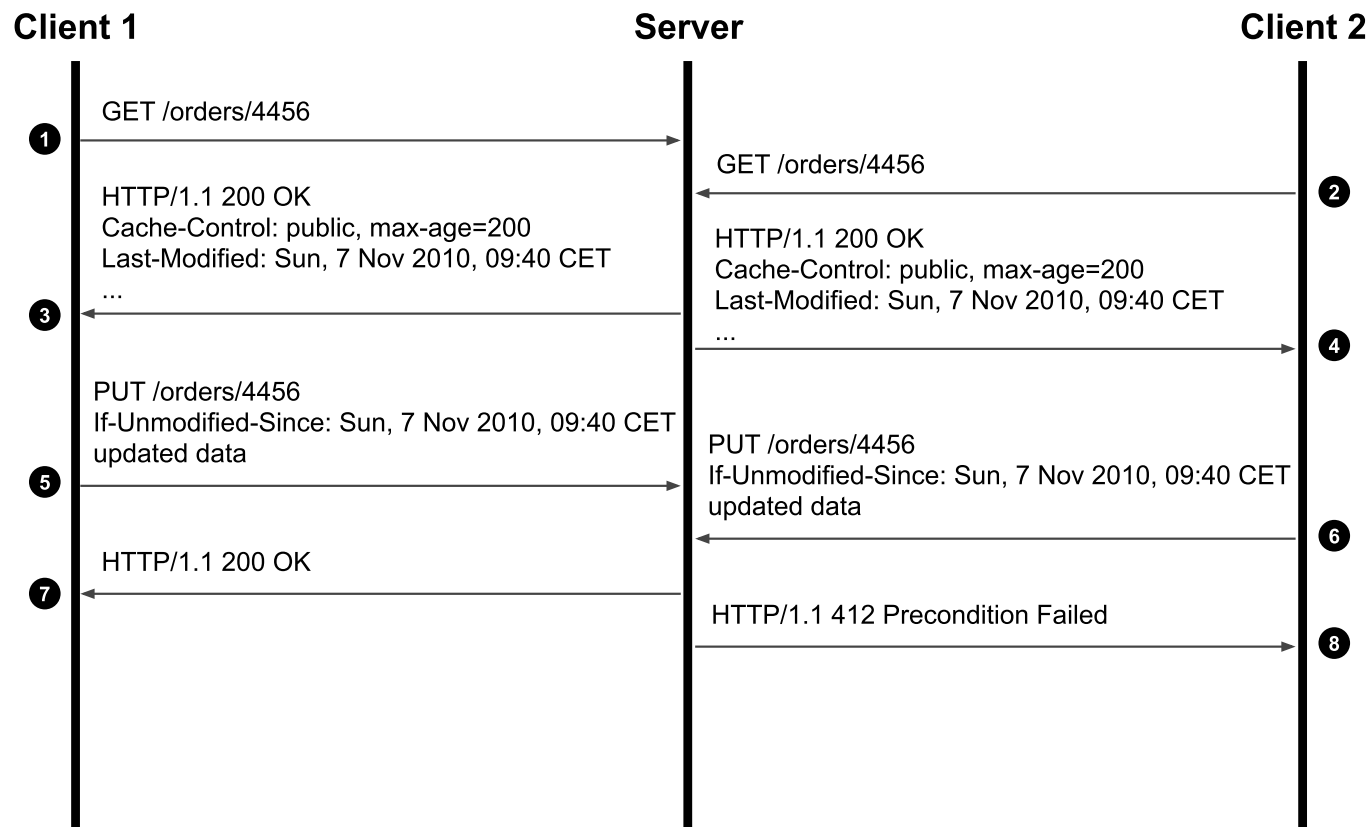
- If-Unmodified-Since and If-Match headers

- 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*

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# Steps towards REST



See Richardson Maturity Model details.

# Levels

- LEVEL 0 – POX (Plain Old XML)
  - *HTTP as a tunneling mechanism*
  - *URL defines a service endpoint*
  - *No Web principles*
- LEVEL 1 – Resources
  - *Take advantages of resources and URIs*
- LEVEL 2 – HTTP Verbs
  - *Use HTTP methods and respect their semantics*
- LEVEL 3 – Hypermedia Controls
  - *HATEOAS*