Middleware and Web Services

Lecture 4: Advanced Service Concepts and Technologies

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Overview

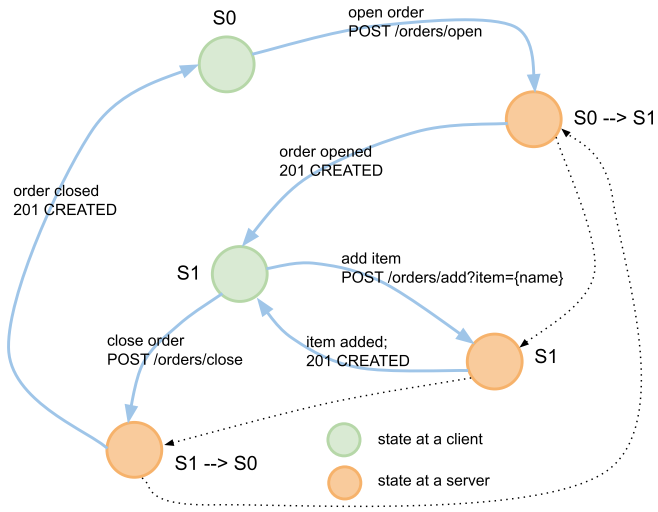
- HATEOAS
- Caching, Revalidation, Concurrency Control
- Richardson Maturiy Model
- SOAP and WSDL

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*

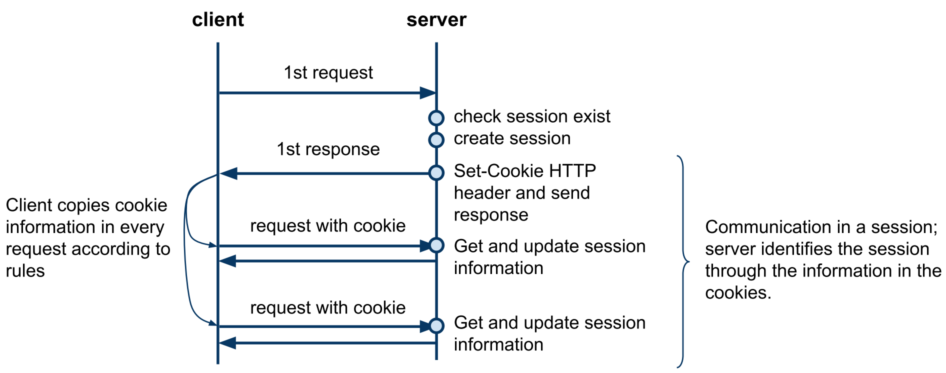


State Management

- HTTP is a stateless protocol – original design
  - *No information to relate multiple interactions at server-side*
    - → *Except* `Authorization` *header is copied in every request*
    - → *IP addresses do not work, one public IP can be shared by multiple clients*
- Solutions to check for a valid state at server-side
  - ***Cookies*** *– obvious and the most common workaround*
    - → *RFC 2109 – HTTP State Management Mechanism*
    - → *Allow clients and servers to talk in a context called* ***sessions***
  - ***Hypertext*** *– original HTTP design principle*
    - → *App states represented by resources (hypermedia), links define transitions between states*
    - → *Adopted by the REST principle* ***statelessness***

Interaction with Cookies

- Request-response interaction with cookies
  - *Session is a logical channel maintained by the server*



- Stateful Server
  - *Server remembers the session information in a server memory*
  - *Server memory is a non-persistent storage, when server restarts the memory content is lost!*

Set-Cookie and Cookie Headers

- `Set-Cookie` response header

```
set-cookie = "Set-Cookie:" cookie ("," cookie)*
  cookie     = NAME "=" VALUE (";" cookie-av)*
  cookie-av = "Comment" "=" value
            | "Domain" "=" value
            | "Max-Age" "=" value
            | "Path" "=" value
```

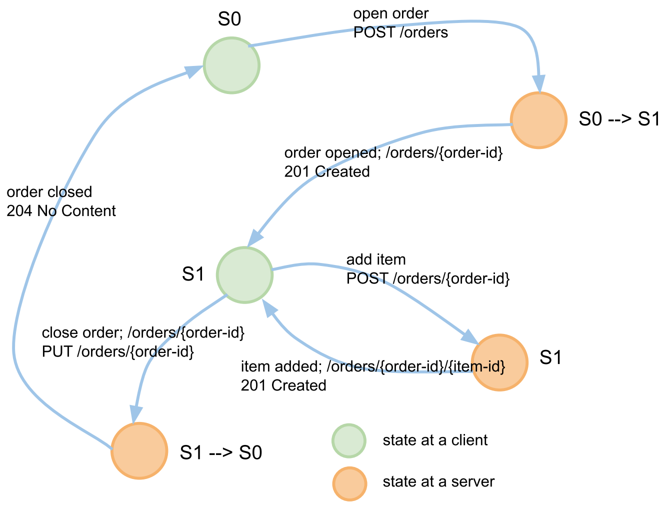
  – `domain` – *a domain for which the cookie is applied*
  – `Max-Age` – *number of seconds the cookie is valid*
  – `Path` – *URL path for which the cookie is applied*
- `Cookie` request header. A client sends the cookie in a request if:
  – `domain` *matches the origin server's fully-qualified host name*
  – `path` *matches a prefix of the request-URI*
  – `Max-Age` *has not expired*

```
cookie  = "Cookie:" cookie-value (";" cookie-value)*
  cookie-value    = NAME "=" VALUE [";" path] [";" domain]
  path            = "$Path" "=" value
  domain          = "$Domain" "=" value
```

  – `domain`, *and* `path` *are values from corresponding attributes of the* `Set-Cookie` *header*

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*

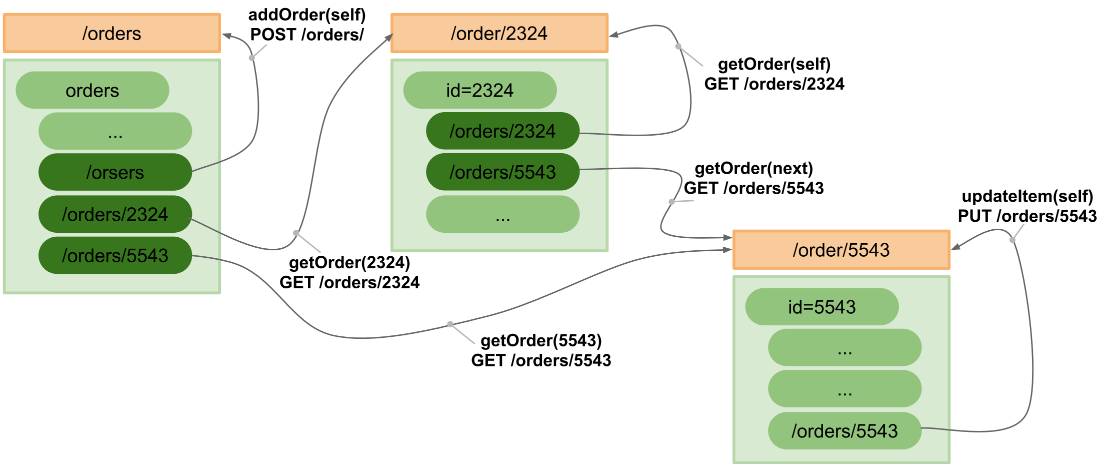


Persistent Storage and Session Memory

- 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*

```
<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>
```

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:*

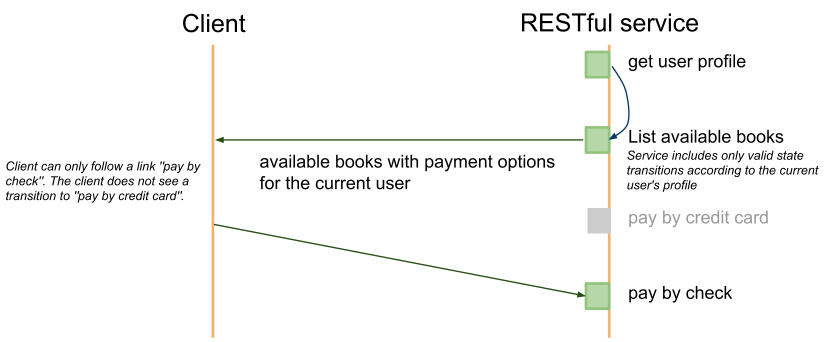
```
> HEAD /orders HTTP/1.1

< 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*

Overview

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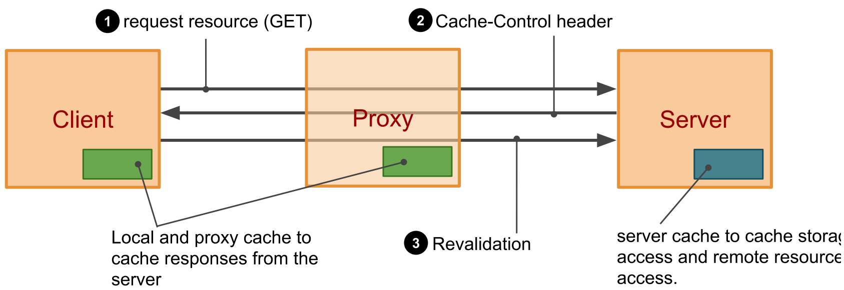
Scalability

- 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

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

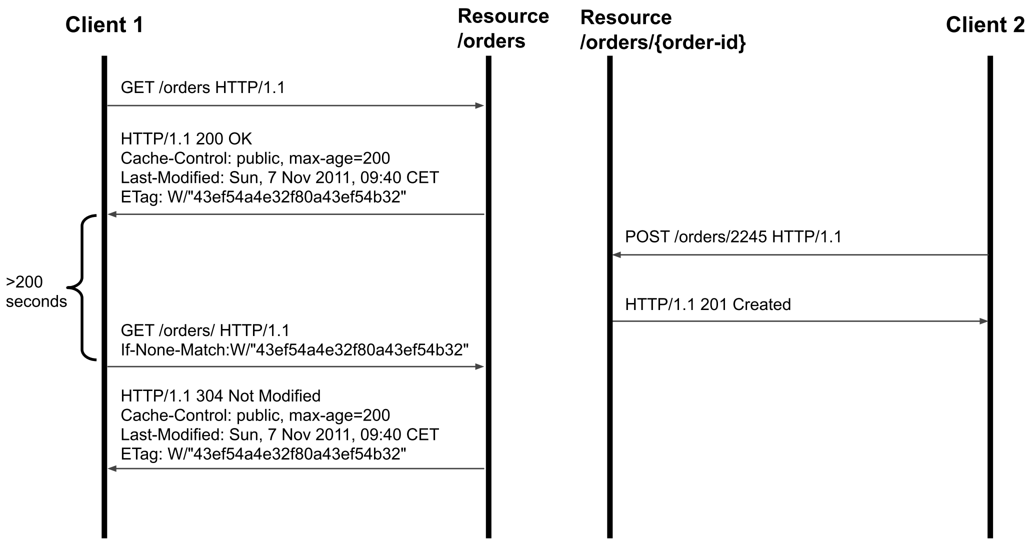
- Weak ETag compute function example
  - *Any modification to an order's items is not significant for* `/orders`*:*

```
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*



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) ?

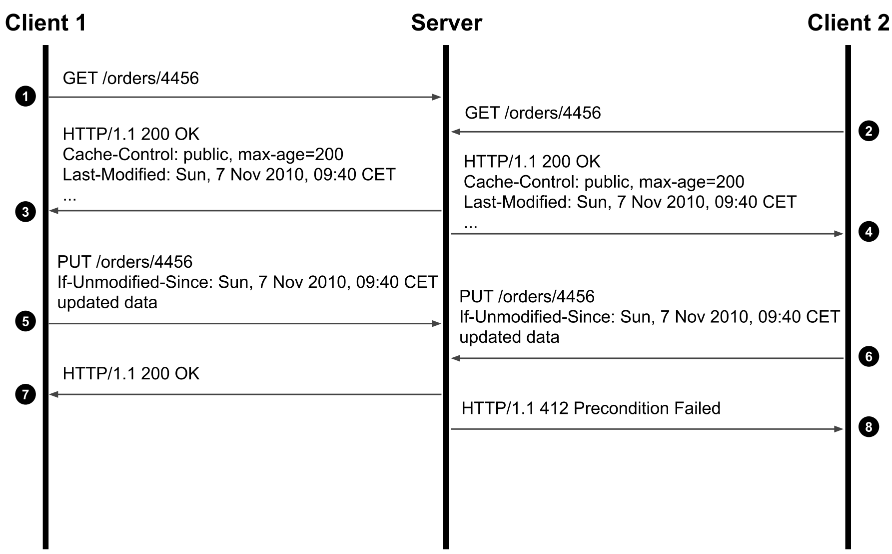
- Concurrency control
  - *Conditional* `PUT`

    → *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

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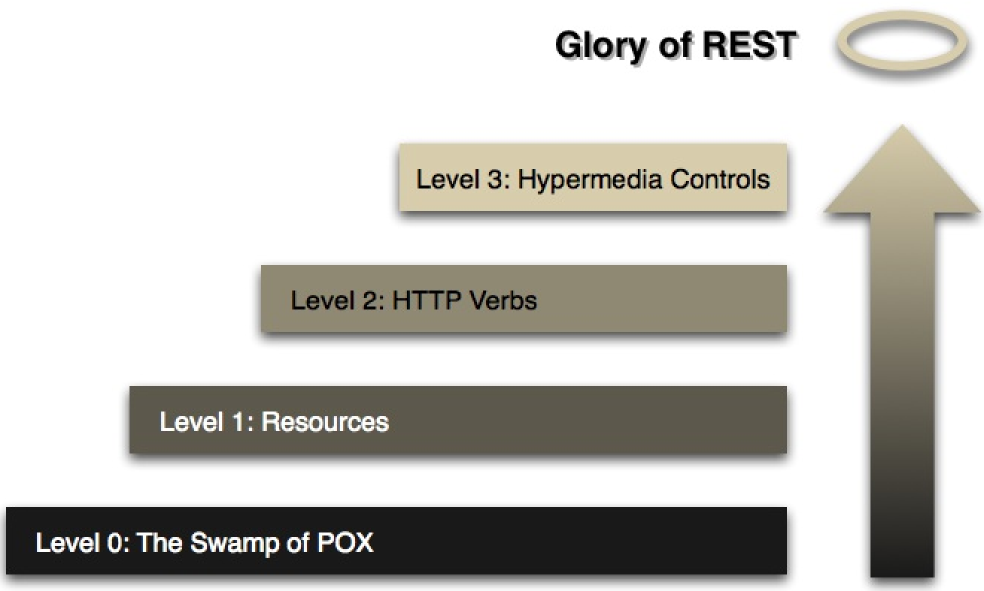
Steps towards REST



See Richardson Maturiy 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*

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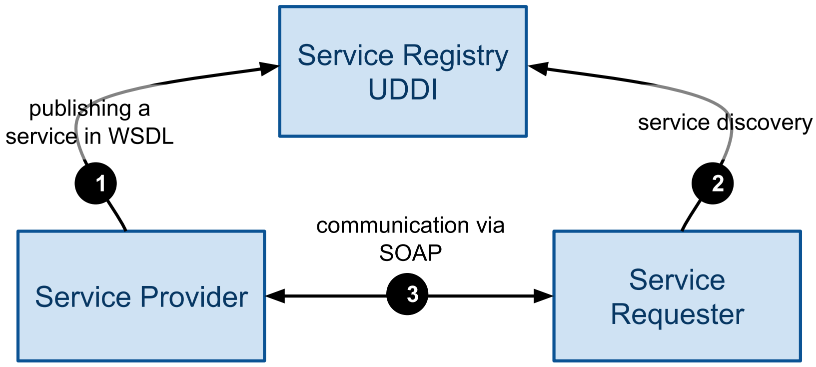
  - *Introduction to SOAP*
  - *WSDL*
  - *WS-Addressing*

Web Service Architecture

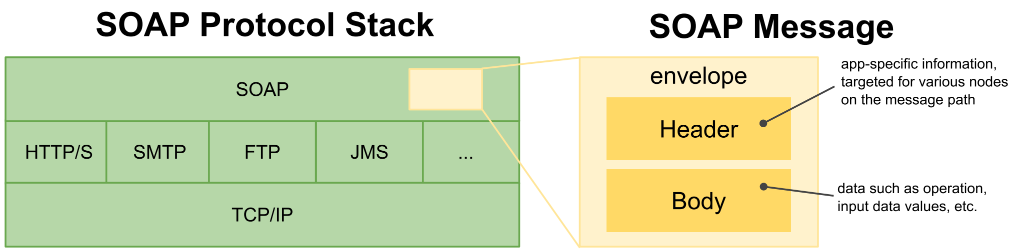
- WSDL, SOAP and UDDI



– *Realization of SOA*
– *Message-Oriented view*
  → *SOAP messaging (header, body)*
  → *types of messages – input, output, fault*

SOAP Protocol

- SOAP defines a messaging framework



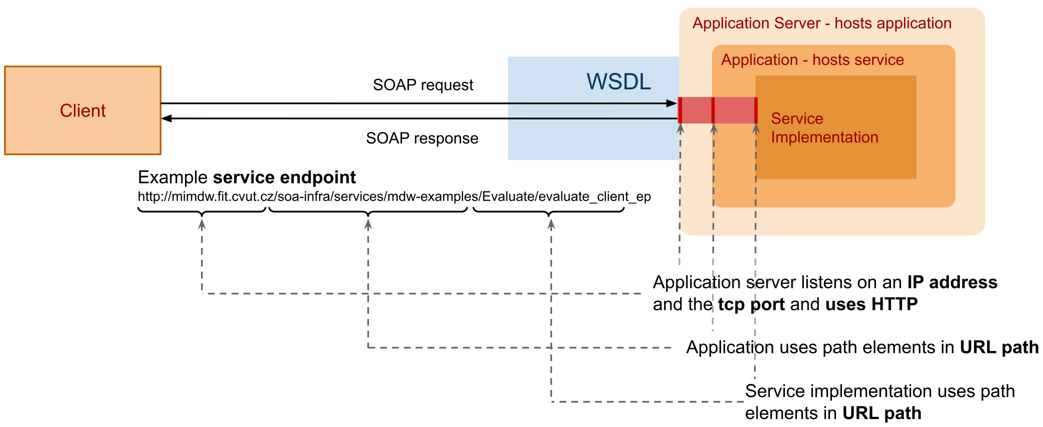
– *XML-based protocol*
– *a layer over transport protocols*
  → *binding to HTTP, SMTP, JMS, ...*
– *involves multiple nodes (message path)*
  → *sender, receiver, intermediary*

SOAP Message

- Envelope
  – *A container of a message*
- Header
  – *Metadata – describe a message, organized in header blocks*
    → *routing information*
    → *security measures implemented in the message*
    → *reliability rules related to delivery of the message*
    → *context and transaction management*
    → *correlation information (request and response message relation)*
  – *WS extensions (WS-*) utilize the message header*
- Body (payload)
  – *Actual contents of the message, XML formatted*
  – *Contains also faults for exception handling*
- Attachment
  – *Data that cannot be serialized into XML such as binary data*

Endpoint

- SOAP service endpoint definition



  – *Endpoint – a network address used for communication*
  – *Communication – request-response, SOAP messages over a communication (application) protocol*
  – *Synchronous communication – only service defines endpoint*
  – *Asynchronous communication – service and client define endpoints*

Service Invocation Example (1)

- Example service implementation
  - *A service that evaluates an expression*
  - *Uses SOAP over HTTP*
    - → *We can use standard HTTP tools to invoke the service*
- SOAP request message

evaluate-input.xml

```
<soap:Envelope xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/">
        <soap:Body>
                <ns1:evaluateRequest
                xmlns:ns1="http://xmlns.oracle.com/mdw_examples/Evaluate/evalu
                        <ns1:x>12</ns1:x>
                        <ns1:y>18</ns1:y>
                </ns1:evaluateRequest>
        </soap:Body>
</soap:Envelope>
```

- Invoking the service using curl

```
curl -s -X POST --header "Content-Type: text/xml;charset=UTF-8" \
--header "SOAPAction: \"evaluate\"" --data @evaluate-input.xml \
http://mimdw.fit.cvut.cz/soa-infra/services/mdw-examples/Evaluate/evaluate_cli
```


Service Invocation Example (2)

- Invocation result

```
* About to connect() to mimdw.fit.cvut.cz port 80 (#0)
*   Trying 147.32.233.55... connected
* Connected to sb.vitvar.com (147.32.233.55) port 80 (#0)
> POST /soa-infra/services/mdw-examples/Evaluate/evaluate_client_ep HTTP/1.1
> User-Agent: curl/7.19.7 (x86_64-redhat-linux-gnu) libcurl/7.19.7 NSS/3.14.0.
> Host: mimdw.fit.cvut.cz
> Accept: */*
> Content-Type: text/xml;charset=UTF-8
> SOAPAction: "evaluate"
> Content-Length: 302
>
} [data not shown]
< HTTP/1.1 200 OK
< Date: Sun, 17 Nov 2013 11:24:59 GMT
< Server: Oracle-Application-Server-11g
< Content-Length: 569
< X-ORACLE-DMS-ECID: 004upqiWhdD0zkWVLybQ8A0005uX0004Y^
< SOAPAction: ""
< X-Powered-By: Servlet/2.5 JSP/2.1
< Content-Type: text/xml; charset=UTF-8
< Content-Language: en
```

Service Invocation Example (3)

- SOAP response message

```
<?xml version="1.0"?>
<env:Envelope xmlns:env="http://schemas.xmlsoap.org/soap/envelope/"
    xmlns:wsa="http://www.w3.org/2005/08/addressing">
  <env:Header>
    <wsa:MessageID>urn:E42018C04F7A11E3BFD5D1953058407C</wsa:MessageID>
  </env:Header>
  <env:Body>
    <evaluateResponse
        xmlns="http://xmlns.oracle.com/mdw_examples/Evaluate/evaluate">
      <result>30</result>
    </evaluateResponse>
  </env:Body>
</env:Envelope>
```


Client Implementation

- WSDL – Web Service Description Language
  - *definitions for the client to know how to communicate with the service*
    - → *which operations it can use*
    - → *data formats for input (request), output (response) and fault messages*
    - → *how to serialize the data as payloads of a communication protocol (binding)*
    - → *where the service is physically present on the network*
- Clients' environments
  - *Clients implemented in a language such as Java*
    - → *Tools to generate service API for the client, e.g. WSDL2Java*
    - → *Can be written manually too, e.g. our example in bash*
  - *Clients reside on the middleware, e.g. on an Enterprise Service Bus*
    - → *They provide added values in end-to-end communication, proxy services, SOAP intermediaries*

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  – *WS-Addressing*

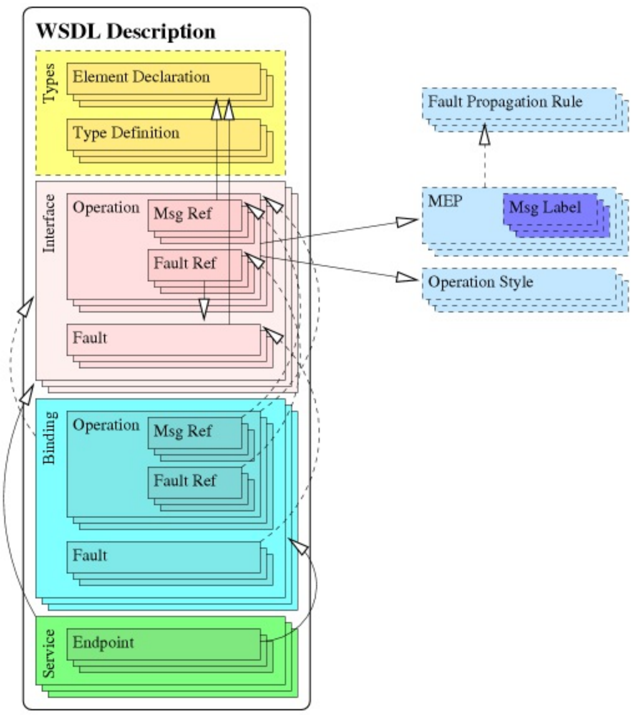
Specifications

- WSDL = Web Service Description Language
  – *A standard that allows to describe Web services explicitly (main aspects)*
  – *A contract between a requester and a provider*
- Specifications
  – *WSDL 1.1 – still widely used*
    → *Web Service Description Language 1.1*
  – *WSDL 2.0 – An attempt to address several issues with WSDL 1.1*
    → *SOAP vs. REST, naming, exrpessivity*
    → *WSDL 2.0 Primer (part 0)*
    → *WSDL 2.0 Core Language (part 1)*

WSDL Overview and WSDL 1.1 Syntax

- Components of WSDL
  - *Information model (*`types`*)*
    - → *Element types, message declarations (XML Schema)*
  - *Set of operations (*`portType`*)*
    - → *A set of operations is "interface" in the WSDL terminology*
    - → *operation name, input, output, fault*
  - *Binding (*`binding`*)*
    - → *How messages are transfered over the network using a concrete transport protocol*
    - → *Transport protocols: HTTP, SMTP, FTP, JMS, ...*
  - *Endpoint (*`service`*)*
    - → *Where the service is physically present on the network*
- Types of WSDL documents
  - ***Abstract WSDL*** *– only information model and a set of operations*
  - ***Concrete WSDL*** *– everything, a concrete service available in the environment*

WSDL Components and Dependencies



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Overview

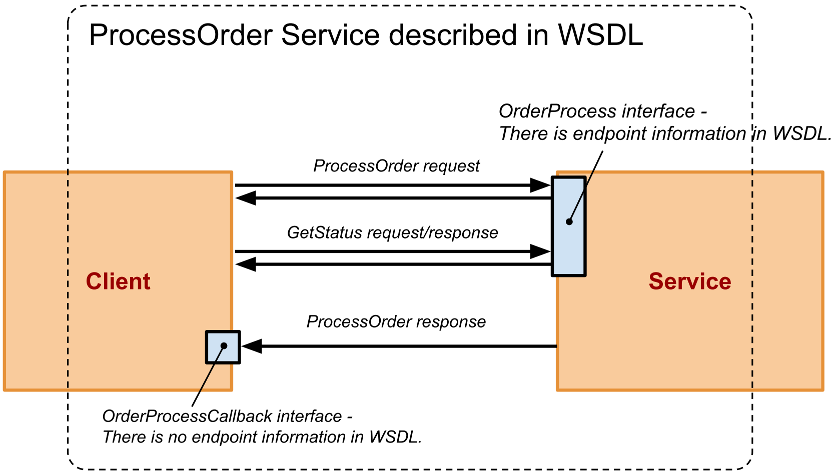
- WS-Addressing
  - *W3C Recommendation, May 2006*
  - *A transport-independent mechanisms for web services to communicate addressing information*
  - *WSDL describes WS-Addressing as a policy attached to a WSDL binding*

```
<binding name="OrderProcessBinding" type="op:OrderProcess">
    <soap:binding transport="http://schemas.xmlsoap.org/soap/http"/>
    <PolicyReference xmlns:wsp="http://schemas.xmlsoap.org/ws/2004/09/polic
        URI="#wsaddr_policy" wsdl:required="false"/>
```

- Two main purposes
  1. *Asynchronous communication*
     - *Client sends an endpoint where the server should send a response asynchronously*
  2. *Relating interactions to a conversation*
     - *Client and service communicate conversation ID*

Order Processing Example

- Asynchronous communication via callback, steps:
  – *Client submits an order request*
  – *Service starts processing of the order (CRM, OMS, back-office)*
  – *Client can retrieve the order status*
  – *Service responds asynchronously with an order response message*



Interface Example (1)

- Order process complex conversation
  1. *The client invokes* `processOrder`.
  2. *The service responses back* ***synchronously*** *with order status.*
  3. *The client gets the status of order processing by invoking synchronous* `getStatus` *operation (this can be invoked serveral times).*
  4. *The service responses back* ***asynchronously*** *by invoking* `processOrderResponse` *– callback on client's interface*
- Interface implemented by the order process service
  – `getStatus` *operation must be executed in the same* ***conversation*** *as* `processOrder` *operation*

```
<portType name="OrderProcess">
    <operation name="processOrder">
        <input message="op:OrderProcessRequestMessage"/>
        <output message="op:OrderStatusResponseMessage"/>
    </operation>
    <operation name="getStatus">
        <input message="op:OrderStatusRequestMessage"/>
        <output message="op:OrderStatusResponseMessage"/>
    <operation>
<portType>
```

Interface Example (2)

- Interface implemented by the client

```
<portType name="OrderProcessCallback">
    <operation name="processOrderResponse">
        <input message="op:OrderProcessResponseMessage"/>
        <fault message="op:OrderProcessFaultMessage"/>
    <operation>
</portType>
```


ProcessOrder Request Message

- Client sends process order request – `processOrder`
  - *it sends addressing information where the client listens for the callback*
  - *it sends conversation ID (message ID) to start the conversation on the server*

```
> POST /soa-infra/services/mdw-examples/ProcessOrder/orderprocess_client_ep HTTP/1.1
> Host: mimdw.fit.cvut.cz
> Content-Type: text/xml;charset=UTF-8
> SOAPAction: "processOrder"
> Content-Length: 810

<soap:Envelope xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/"
    xmlns:ord="http://mimdw.fit.cvut.cz/mdw-examples/cdm/order">
     <soap:Header xmlns:wsa='http://www.w3.org/2005/08/addressing'>
        <wsa:ReplyTo>
            <wsa:Address>http://192.168.94.110:2233/path/to/service</wsa:Address>
        </wsa:ReplyTo>
        <wsa:MessageID>urn:AXYYBA00531111E3BFACA780A7E5AF64</wsa:MessageID>
     </soap:Header>
     <soap:Body>
        <ord:Order>
            <ord:CustomerId>1</ord:CustomerId>
            <ord:LineItems>
                <ord:item>
                    <ord:label>Apple MacBook Pro</ord:label>
                    <ord:action>ADD</ord:action>
                </ord:item>
            </ord:LineItems>
        </ord:Order>
    </soap:Body>
</soap:Envelope>
```

GetStatus Request Message

- Client sends get status request – `getStatus`
  – *after it invokes* `processOrder` *with conversation ID (message ID)*
  – *it uses the same conversation ID for get status request too*
    → *the request will be procesessed by the running service instance*

```
> POST /soa-infra/services/mdw-examples/ProcessOrder/orderprocess_client_ep HTTP/1.1
> Host: mimdw.fit.cvut.cz
> Content-Type: text/xml;charset=UTF-8
> SOAPAction: "getStatus"
> Content-Length: 472

<soap:Envelope xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/">
    <soap:Header xmlns:wsa="http://www.w3.org/2005/08/addressing">
        <wsa:RelatesTo>urn:AXYYBA00531111E3BFACA780A7E5AF64</wsa:RelatesTo>
    </soap:Header>
    <soap:Body>
        <ns1:StatusRequest
            xmlns:ns1="http://mimdw.fit.cvut.cz/mdw_examples/ProcessOrder/OrderProces
            <ns1:process-id>18a9baec2d5ac0a2:64d155de:1425c4185f1:-7ff2</ns1:process-
        </ns1:StatusRequest>
    </soap:Body>
</soap:Envelope>
```