

Web 2.0

Lecture 2: Representational State Transfer

doc. Ing. Tomáš Vitvar, Ph.D.

tomas@vitvar.com • @TomasVitvar • <http://vitvar.com>



Czech Technical University in Prague

Faculty of Information Technologies • Software and Web Engineering • <http://vitvar.com/courses/w20>



Evropský sociální fond
Praha & EU: Investujeme do vaší budoucnosti

Modified: Wed Mar 22 2017, 17:38:47
Humla v0.3

Overview

- Introduction to REST
- Uniform Resource Identifier
- Resource Representation

REST

- REST
 - *Representational State Transfer*
- Architecture Style
 - Roy Fielding – co-author of HTTP
 - He coined REST in his PhD thesis [🔗](#).
 - The thesis abstracts from HTTP technical details
 - HTTP is one of the REST implementation → **RESTful**
 - REST is a leading programming model for Web APIs
- REST (RESTful) proper design
 - people break principles often
 - See REST Anti-Patterns [🔗](#) for some details.
- REST and Web Service Architecture
 - REST is a realization of WSA resource-oriented model

REST and Web Architecture

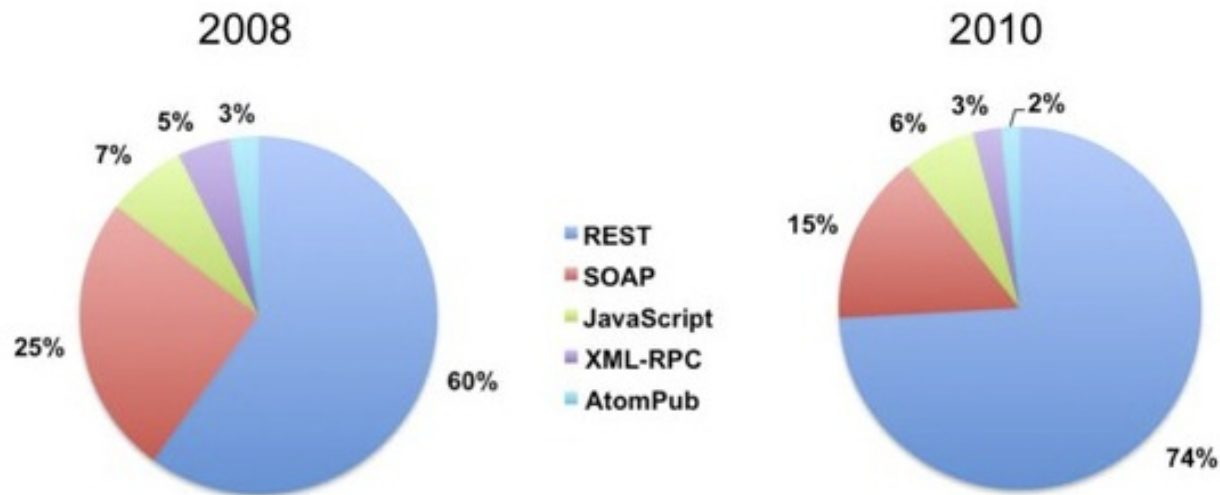
- Tim-Berners Lee
 - *"creator", father of the Web*
- Key Principles
 - *Separation of Concerns*
 - *enables independent innovation*
 - *Standards-based*
 - *common agreement, big spread and adoption*
 - *Royalty-free technology*
 - *a lot of open source, no fees*
- Architectural Basis
 - **Identification:** *universal linking of resources using URI*
 - **Interaction:** *protocols to retrieve resources – HTTP*
 - **Formats:** *resource representation (data and metadata)*

HTTP Advantages

- Familiarity
 - *HTTP protocol is well-known and widely used*
- Interoperability
 - *All environments have HTTP client libraries*
 - *technical interoperability is thus no problem*
 - *no need to deal with vendor-specific interoperability issues*
 - *You can focus on the core of the integration problem*
 - *application (domain, content) interoperability*
- Scalability
 - *you can use highly scalable Web infrastructure*
 - *caching servers, proxy servers, etc.*
 - *HTTP features such as HTTP GET idempotence and safe allow you to use caching*

Some Statistics

- ProgrammableWeb data
 - *Distribution of API protocols and styles*



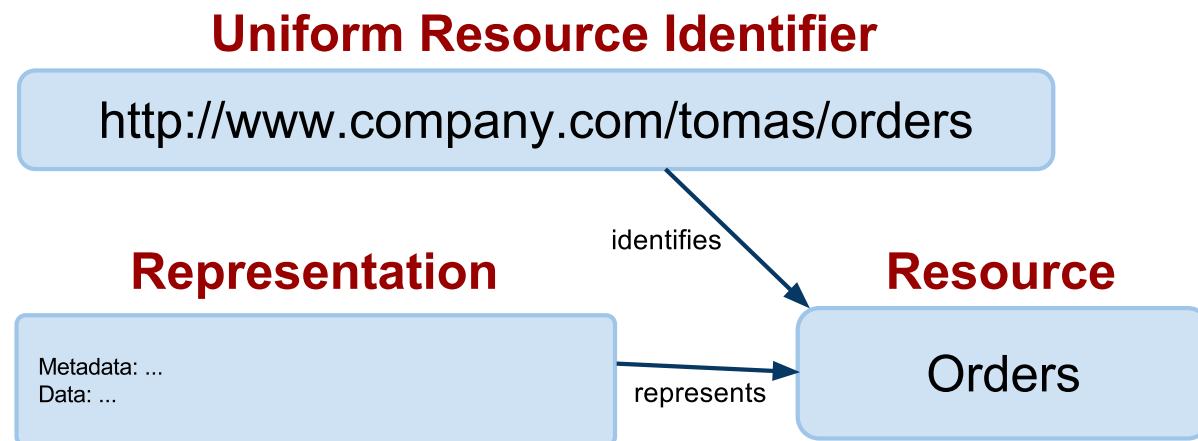
- *Based on directory of 2,000 Web APIs listed at ProgrammableWeb, May 2010.*
- *Source Open APIs: a State of the Market* [🔗](#)

REST Core Principles

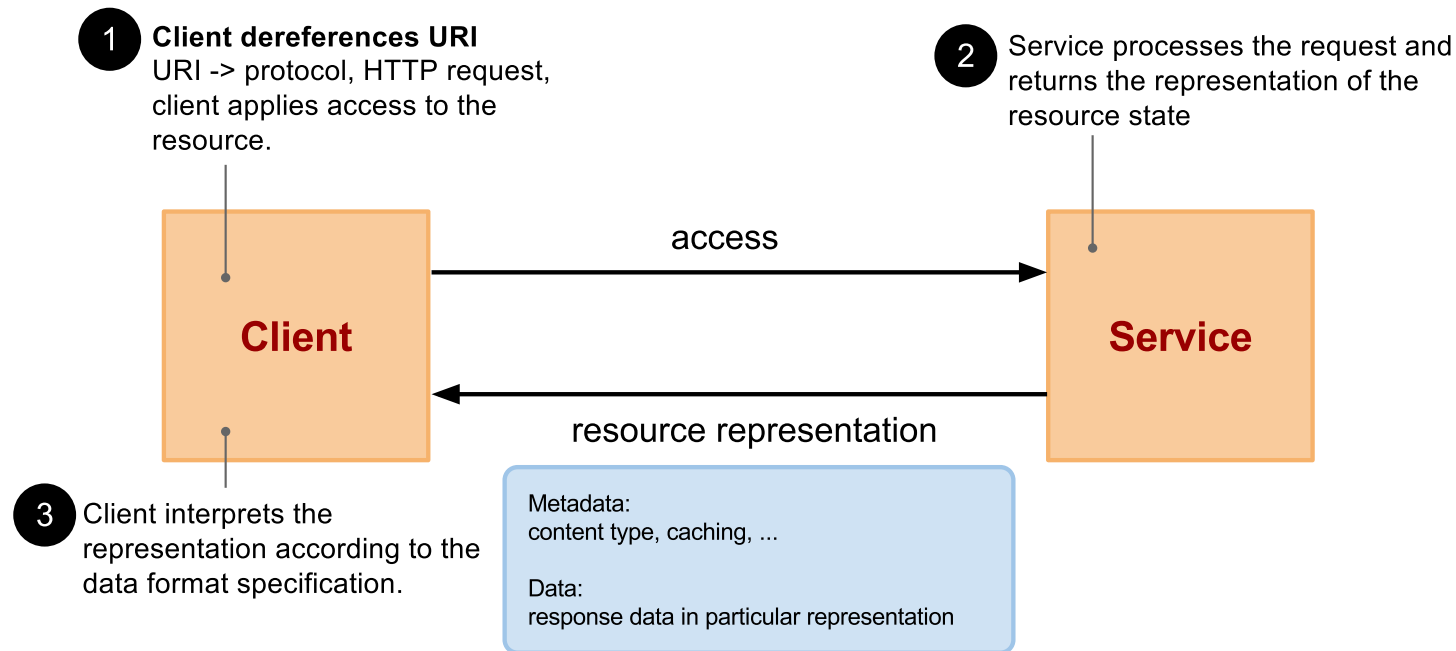
- REST architectural style defines constraints
 - *if you follow them, they help you to achieve a good design, interoperability and scalability.*
- Constraints
 - *Client/Server*
 - *Statelessness*
 - *Cacheability*
 - *Layered system*
 - *Uniform interface*
- Guiding principles
 - *Identification of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

Resource

- A resource can be anything such as
 - *A real object: car, dog, Web page, printed document*
 - *An abstract thing such as address, name, etc. → RDF*
- A resource in REST
 - *A resource corresponds to one or more entities of a data model*
 - *A representation of a resource can be conveyed in a message electronically (information resource)*
 - *A resource has an identifier and a representation and a client can apply an access to it*



Access to a Resource



- Terminology
 - *Client = User Agent*
 - **Dereferencing URI** – a process of obtaining a protocol from the URI and creating a request.
 - **Access** – a process of sending a request and obtaining a response as a result; access usually realized through HTTP.

Overview

- Introduction to REST
- **Uniform Resource Identifier**
 - *Resources and Application Data*
 - *Good URI/URL Design*
- Resource Representation

URI, URL, URN

- URI – Uniform Resource Identifier
 - *URI only identifies a resource*
 - *it does not imply the resource physically exists*
 - *URI could be URL (locator) or URN (name)*
- URL – Uniform Resource Locator
 - *in addition allows to locate the resource*
 - *that is — its network location*
 - *every URL is URI but an URI does not need to be URL*
- URN – Uniform Resource Name
 - *refers to URI under "urn" scheme (RFC 2141 [🔗](#))*
 - *require to be globally unique and persistent*
 - *even if the resource cease to exist/becomes unavailable*

URI

- Definition

URI = scheme ":" ["//" authority] ["/" path] ["?" query] ["#" frag]

- Hierarchal sequence of components

- **scheme**

- *refers to a spec that assigns IDs within that scheme*

- *examples: http, ftp, mailto, urn*

- **scheme != protocol**

- **authority**

- *registered name (domain name) or server address*

- *optional port and user*

- **path and query**

- *identify resource within the scheme and authority scope*

- *path – hierarchal form*

- *query – non-hierarchal form (parameters key=value)*

- **fragment**

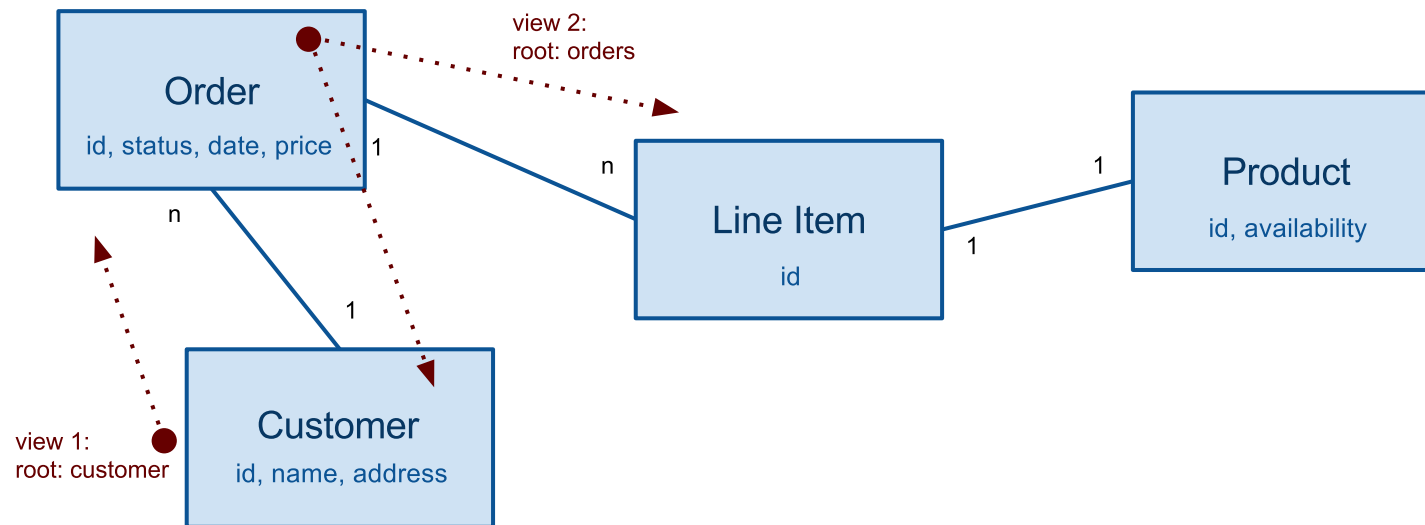
- *reference to a secondary resource within the primary resource*

Overview

- Introduction to REST
- Uniform Resource Identifier
 - *Resources and Application Data*
 - *Good URI/URL Design*
- Resource Representation

Resources over Entities

- Application's data model
 - *Entities and properties that the app uses for its data*



- URI identifies a resource within the app's data model
 - **path** – a "view" on the data model
 - data model is a graph
 - URI identifies a resource using a path in a tree with some root

Examples of Views

- View 1
 - *all customers*: `/customers`
 - *a particular customer*: `/customers/{customer-id}`
 - *All orders of a customer*: `/customers/{customer-id}/orders`
 - *A particular order*: `/customers/{customer-id}/orders/{order-id}`
 - View 2
 - *all orders*: `/orders`
 - *All orders of a customer*: `/orders/{customer-id}`
 - *A particular order*: `/orders/{customer-id}/{order-id}`
- ⇒ Design issues
- Good design practices
 - *No need for 1:1 relationship between resources and data entities*
 - *A resource may aggregate data from two or more entities*
 - *Thus only expose resources if it makes sense for the service*
 - *Try to limit URI aliases, make it simple and clear*

Path vs. Query

- Path
 - *Hierarchical component, a view on the data*
 - *The main identification of the resource*
- Query
 - *Can define selection, projection or other processing instructions*
 - *Selection*
 - *filters entries of a resource by values of properties*
`/customers/?status=valid`
 - *Projection*
 - *filters properties of resource entries*
`/customers/?properties=id,name`
 - *Processing instructions examples*
 - *data format of the resource* → *cf. URI opacity*
`/customers/?format=JSON`
 - *Access keys such as API keys*
`/customers/?key=3ae56-56ef76-34540aeb`

Fragment

- Primary resource
 - *Defined by URI path and query*
 - *could be complex, composed resources*
- Sub-resource/secondary resource
 - *Can be defined by a fragment*
 - *No explicit relationship between primary and sub-resource*
 - *For example, we cannot infer that the two resources are in **part-of**, or **sub-class-of** relationships.*
 - *Fragment semantics defined by a data format*
- Usage of fragment
 - *identification of elements in HTML*
 - *URI references in RDF*
 - *State of an application in a browser*

Fragment Semantics

- Fragment semantics for HTML

- *assume that `orders.html` are in HTML format.*

- 1 | `http://company.com/tomas/orders.html#3456`

- \Rightarrow *there is a HTML element with `id=3456`*

- But:

- *Consider `orders` resource in `application/xml`*

- 1 | `<orders>`
 - 2 | `<order id="3456">...</order>`
 - 3 | `...`
 - 4 | `</orders>`

- *Can't say that `http://company.com/tomas/orders.xml#3456` identifies an order element within the `orders` resource.*

- *`application/xml` content type does not define fragment semantics*

Resource ID vs. Resource URI

- Resource ID
 - *Local ID, part of an entity in a data model*
 - *Unique within an application where the resource belongs*
 - *Usually generated on a server (cf. **PUT** to update and insert)*
 - *Exposed to the resource URI as a path element*
/orders/{order-id}
- Resource URI
 - *Global identifier, valid on the whole Web*
 - *Corresponds to the view on the data model of the app*
 - *Include multiple "higher" resources' IDs*
 - *Example:*
/customers/{customer-id}/orders/{order-id}/
 - *There can be more URIs identifying the same resource*

Overview

- Introduction to REST
- Uniform Resource Identifier
 - *Resources and Application Data*
 - *Good URI/URL Design*
- Resource Representation

Capability URL

- What's capability URL
 - *They are usually valid for a short period of time*
 - *They are not public, they are private to one person or a group of people*
 - *Ephemeral resources*
- Examples
 - *Password resets, Polls, Google calendar's private URLs, ...*
 - *Access control – key, session*
- Design considerations
 - *They should be https resources!*
 - *limits exposure, in logs or on the network*
 - *They should be revokable by the user/owner*
 - *They should not be persistent, they should expire*
- Normal URLs
 - *No URL collision, URI opacity, human readable, independence on a context, persistent URI*

URI Aliases and URI Collision

- URI Alias
 - *More than one URI identifies a single resource*
 - *This happens, for example*
 - *Different views on the same data entity*
 - view 1: /customers/{customer-id}/orders*
 - view 2: /orders/{customer-id}*
 - *DNS load balancing:*
 - domain name 1: http://api.company.com/orders*
 - domain name 2: http://api2.company.com/orders*
- URI Collision
 - *Two resources have one URI*
 - *This should not happen, for example*
 - *A company uses an authority it does not own*
 - company Amazon: http://amazon.com/orders*
 - company Knihy.cz: http://amazon.com/orders*
 - *Exception: domain example.org*

Representation Reuse

- Compare this:
 - <http://company.com/tomas/orders/?date=111001>
→ *all orders of Tomas till 1st October 2011*
 - <http://company.com/tomas/orders>
→ *all orders of Tomas till today*
→ *when retrieved on 1st October 2011,*
will be the same as the first resource
 - *These are different resources*
→ *We say the two resources reused their representations*
→ *Representation reuse only happens under certain conditions*

URI Opacity

- URI does not describe a resource data format
 - *In general it does not describe any resource metadata*
 - *Thus we cannot determine a format through URIs*
 - *There is no relation between URI and HTTP*
 - *HTTP media types does not affect URI path component*
- Example
 - `http://company.com/orders.html`
 - *there is no guarantee that the resource is in `text/html` format*
- However, it sometimes comes handy
 - *Easy to retrieve a data format by tweaking URL (browser)*
 - *For example, Google API uses query parameter `alt`*
 - *No need to fiddle with headers and using tools such as `curl`*

Human Readable URI

- URIs are both for machines and users
 - *Users should be able to memorize them*
 - *URIs should contain pronounceable words, good number of path components, clear query parameters, etc.*
- Example
 - *A human readable:*
<http://company.com/tomas/orders/>
 - *Not really human readable:*
<http://company.com/?c=gjddjsj224&a=58584&jbd=5553a>
- URIs generated by a machine – capability URLs
 - *URLs that are not meant to be "remembered"*

Independence on a Context

- URIs are independent on a user context
 - *It should be possible to share URIs among users*
 - *For example, you send an URI over an IM system*
 - *Others should be able to retrieve the same resource as you (if they have rights)*
- BUT:
 - *URL may include an access or a session information – capability URL*
- Example
 - *Capability URL: <http://company.com/orders/?session=5582&user=bob>*
 - *This cannot be reused by other user than Bob*
 - *No context: <http://company.com/orders/>*
 - *a user needs to be logged in to access the resource*
 - *HTTP authorization header identifies the user*

Resource Versions

- Resources evolve over time
- Need to deal with various versions
 - *need to support old clients on old versions*
 - *allow new clients to use new versions*
- Versioning at URI level
 - *one path element to identify a version*
`http://company.com/v1/tomas/orders`
 - *should be part of the path component not a query*
 - *API version*
→ *version applies to a set of resources*
- Versioning at resource meta-data level
 - *cf. Version control via content negotiation*

Persistent URI

- Good URLs should not change
 - *They should be indefinitely assigned to a resource*
 - *even if the resource does not exist anymore*
- HTTP and URI persistence
 - *new URI associated with the resource*
 - *HTTP redirection through 3xx response codes*
 - *See response codes*
- Capability URLs are not usually persistent

Overview

- Introduction to REST
- Uniform Resource Identifier
- Resource Representation
 - *Representation, Data Format and Metadata*
 - *Resource State*
 - *Content Negotiation*

Representation and Data Format

- Representation
 - *Various languages, one resource can have multiple representations*
 - *XML, HTML, JSON, YAML, RDF, ...*
 - *should conform to Internet Media Types*
- Data format
 - *Format of resource data*
 - *Binary format*
 - *specific data structures*
 - *pointers, numeric values, compressed, etc.*
 - *Textual format*
 - *in a defined encoding as a sequence of characters*
 - *HTML, XML-based formats are textual*

Metadata

- Metadata ~ self-description
 - *Data about the resource*
 - *e.g., data format, representation, date the resource was created, ...*
 1. *Defined by HTTP response headers*
 2. *Can be part of the data format*
 - AtomPub protocol such as **author**, **updated**, ...
 - HTML **http-equiv** meta tags
- Resource anatomy



Content-Type Metadata

- Access
 - *to be retrieved (GET)*
 - *to be inserted or updated (PUT, POST)*
 - *to be deleted (DELETE)*
- Request
 - HTTP header **Accept**, part of content negotiation protocol
- Response
 - HTTP header **Content-Type: type/subtype; parameters**
 - Specifies an Internet Media Type [☞](#) of the resource representation.
 - IANA (Internet Assigned Numbers Authority) manages a registry of media types [☞](#) and character encodings
 - subtypes of **text** type have an optional charset parameter
text/html; charset=iso-8859-1
 - A resource may provide more than one representations
 - promotes services' loose coupling

Major Media Types

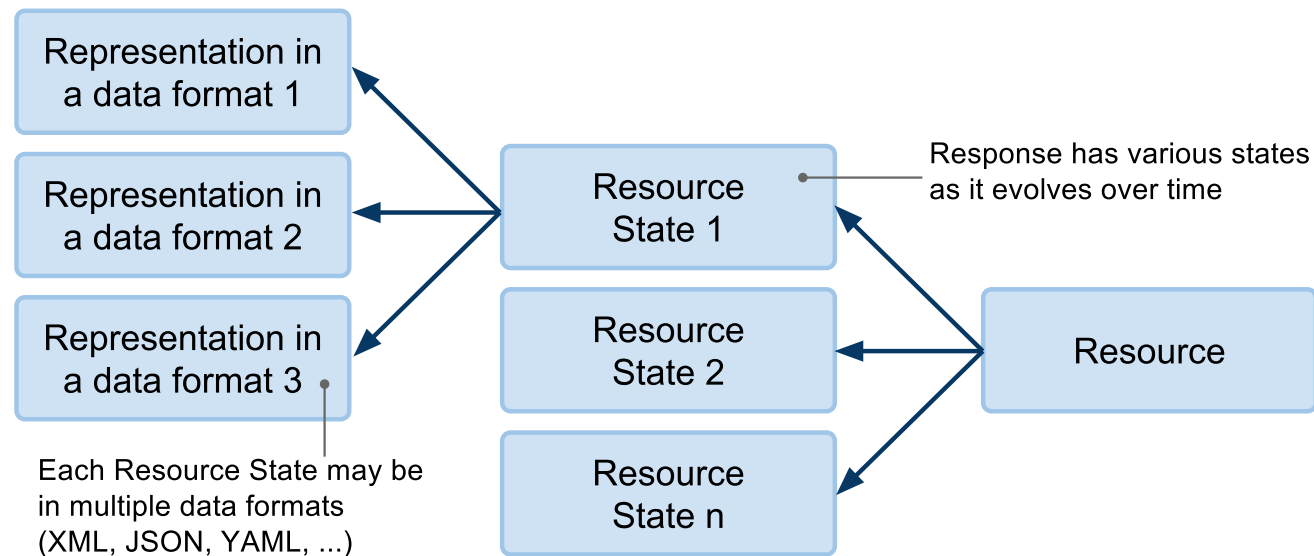
- Common Standard Media Types
 - `text/plain`
→ *natural text in no formal structures*
 - `text/html`
→ *natural text embedded in HTML format*
 - `application/xml`, `application/json`
→ *XML-based/JSON-based, application specific format*
 - `application/wsdl+xml`
→ *+xml suffix to indicate a specific format*
- Non-standard media types
 - *Types or subtypes that begin with `x-` are not in IANA*
`application/x-latex`
 - *subtypes that begin with `vnd.` are vendor-specific*
`application/vnd.ms-excel`

Overview

- Introduction to REST
- Uniform Resource Identifier
- Resource Representation
 - *Representation, Data Format and Metadata*
 - *Resource State*
 - *Content Negotiation*

Resource State

- State
 - *Resource representation is in fact a **representation of a resource state***
 - *Resource may be in different states over time*



- In REST resource states represent application states

Resource State Example

- Time **t1**: client A retrieves a resource **/orders** (GET)

```
1 <orders>
2   <order id="54467"/>
3   <order id="65432"/>
4 </orders>
```

- Time **t2**: client B adds a new order (POST)

```
1 <order>
2   ...
3 </order>
```

- Time **t3**: client A retrieves a resource **/orders** (GET)

```
1 <orders>
2   <order id="54467"/>
3   <order id="65432"/>
4   <order id="74567"/>
5 </orders>
```

- The resource **/orders** has different states in **t1** and **t3**.

Overview

- Introduction to REST
- Uniform Resource Identifier
- Resource Representation
 - *Representation, Data Format and Metadata*
 - *Resource State*
 - *Content Negotiation*

Content Negotiation

- Advantages
 - *Different clients may want to use different formats*
 - *Web browser: JSON*
 - *Java client: XML*
 - *Ruby client: YAML*
 - *Clients want internationalized data*
 - *translated information in various languages*
 - *applications evolve*
 - *need for version support*
- HTTP Content Negotiation
 - *a protocol, also called conneg*
 - *format, encoding, language*

Representation Negotiation

- Client requests specific media types it supports
 - client sets **Accept** header in the request
 - the value is a comma delimited set of content types
- Specific requests
 - to ask for xml or json representations:
 - > GET /orders HTTP/1.1
 - > Accept: application/xml, application/json
 - server chooses one of the types (by applying preference ordering) and serializes the resource in that type
 - when the server cannot find any type, it sends **406 Not Acceptable** response code
- Generic requests
 - client may specify wildcards to ask for any type or subtype
 - > GET /orders HTTP/1.1
 - > Accept: text/*, text/html; level=1

Preference Ordering – Implicit Rule

- Implicit rule

- *More specific media type takes preference over less specific ones.*

- Example:*

- > GET /orders HTTP/1.1

- > Accept: text/*, text/html;level=1, */*, application/xml

- *server interprets the client preference as:*

- 1. **text/html;level=1** – *most specific*

- 2. **application/xml** – *no parameters*

- 3. **text/*** – *more concrete than match-all*

- 4. ***/*** – *less specific*

Preference Ordering – Explicit Rules

- Explicit rules

- using **q** parameter (qualifier), numeric value from 0.0 to 1.0 (1.0 indicates the most preferred type)

- > GET /orders HTTP/1.1

- > Accept: text/*;q=0.9, */*;q=0.1, application/json, application/xml;q=0.5

- server interprets the client preference as:

- 1. **application/json** – implicit qualifier 1.0, most specific

- 2. **text/*** – the second next highest qualifier 0.9

- 3. **application/xml** – more specific but lower pref. value 0.5

- 4. ***/*** – anything otherwise

Language and Encoding Negotiation

- Language negotiation
 - Client uses **Accept-Language** header; the value is a comma separated list of language (ISO 639) and country codes (ISO 3166)
 - > GET /orders HTTP/1.1
 - > Accept-Language: en-us, cs, fr
 - < Content-Language: en-us
 - Supports preference qualifiers too
- Encoding negotiation
 - Client uses **Accept-Encoding** for message compression the value is a comma separated list of acceptable compressions
 - > GET /orders HTTP/1.1
 - > Accept-Encoding: gzip, deflate
 - < Content-Encoding: gzip
 - Supports preference qualifiers too
 - When a client or a server compress a message body the **Content-Encoding** must always be specified!

Resource Version Negotiation

- Applications and their resources evolve
 - *A service need to support old clients*
 - *The service's URI and methods do not need to change – the content it provides may be in different versions*
 - *cf. resource versions in Lecture 2.*
- Encode the version information
 - > GET /orders HTTP/1.1
 - > Accept: application/xml; version=2.0

 - < HTTP/1.1 200 OK
 - < Content-Type: application/xml; version=2.0

Respecting Standards?

- Negotiation by URI patterns
 - *quite common, for example:*
`http://company.com/orders/?alt=json` (*Google APIs*)
 - *or in the URI path component:*
`http://company.com/orders.xml`
`http://company.com/orders.xml.en-us`
`http://company.com/orders.json`
 - *But be aware of the **URI Opacity!***