Web 2.0
Lecture 2: Representational State Transfer

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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

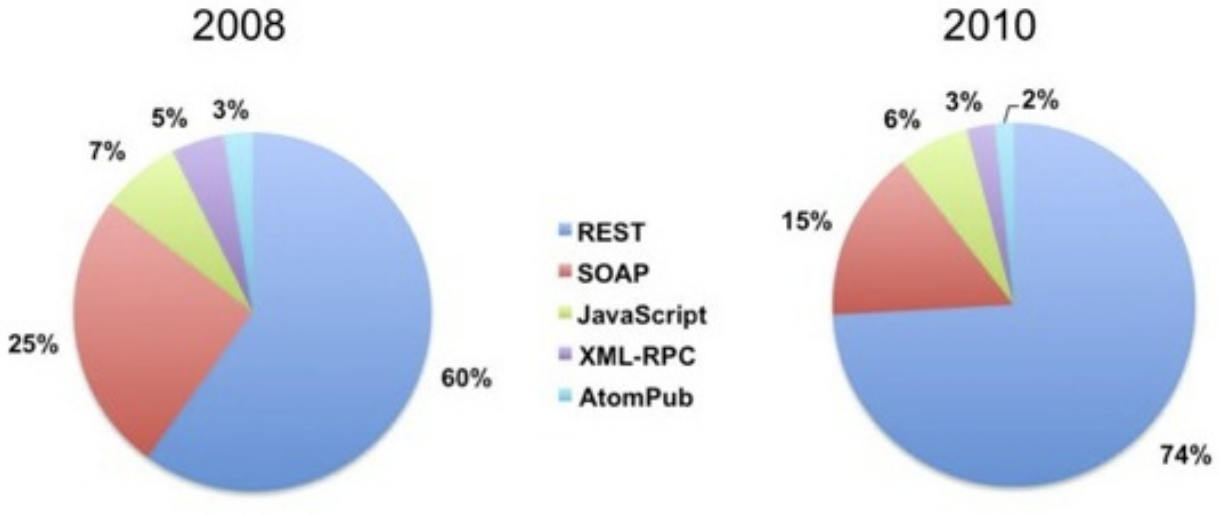
- Tim-Berners Lee
  - *"creator", father of the Web*
- Key Principles
  - *Separation of Concerns*
    → enables independent innovation
  - *Standards-based*
    → common agreement, big spread and adoption
  - *Royalty-free technology*
    → a lot of open source, no fees
- Architectural Basis
  - ***Identification:*** *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*



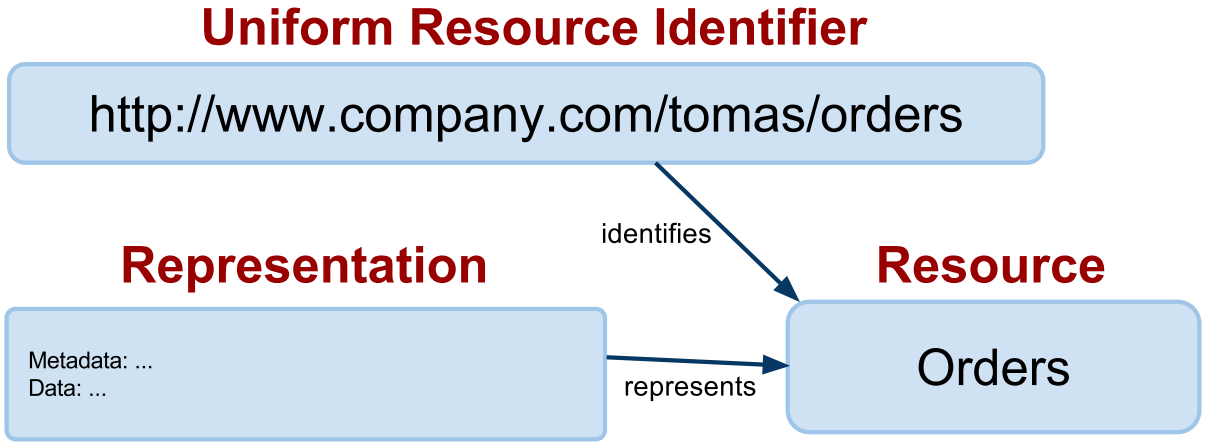
  - *Based on directory of 2,000 Web APIs listed at ProgrammableWeb, May 2010.*
  - *Source Open APIs: a State of the Market*

REST Core Principles

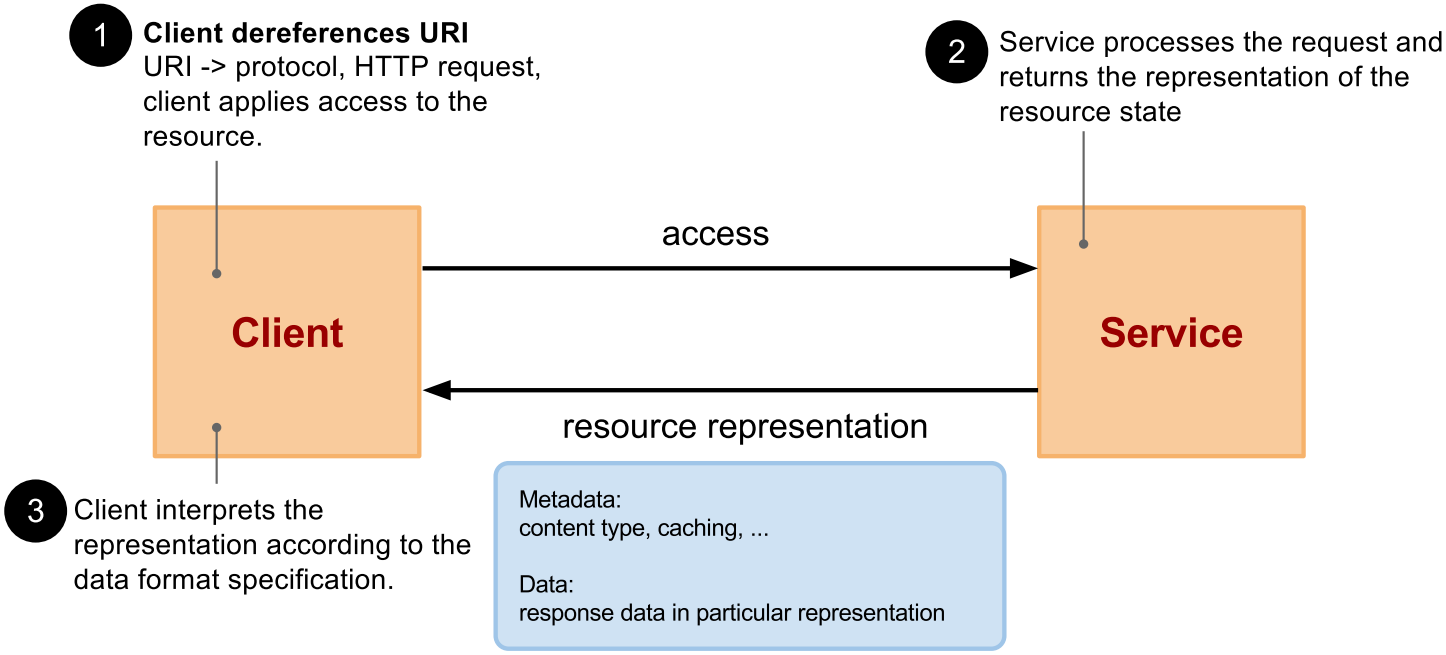
- REST architectural style defines constraints
  - *if you follow them, they help you to achieve a good design, interoperability and scalability.*
- Constraints
  - *Client/Server*
  - *Statelessness*
  - *Cacheability*
  - *Layered system*
  - *Uniform interface*
- Guiding principles
  - *Identification 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.*

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  - *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*

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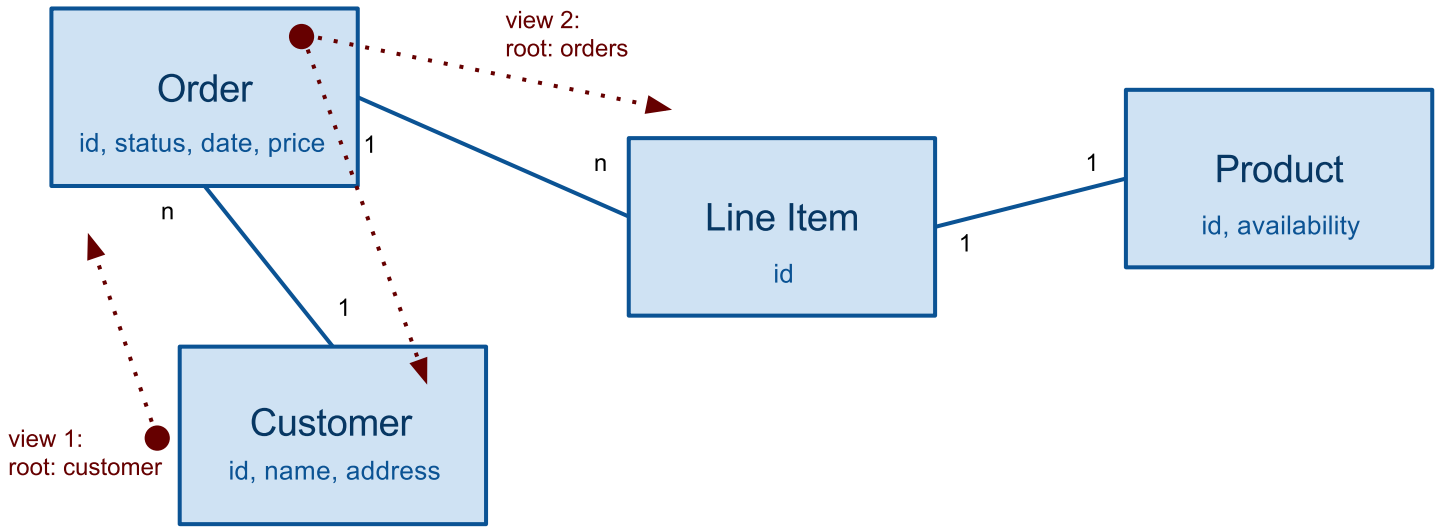
Resources over Entities

- 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
```

  ⇒ *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*

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Capability URL

- What's capabiliy 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 persisent

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  - *Representation, Data Format and Metadata*
  - *Resource State*
  - *Content Negotiation*

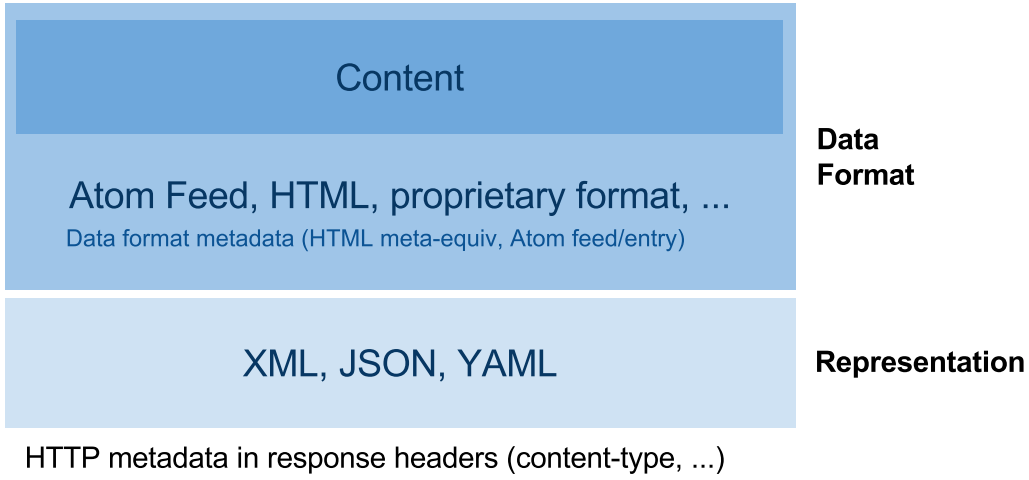
Representation and Data Format

- 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`

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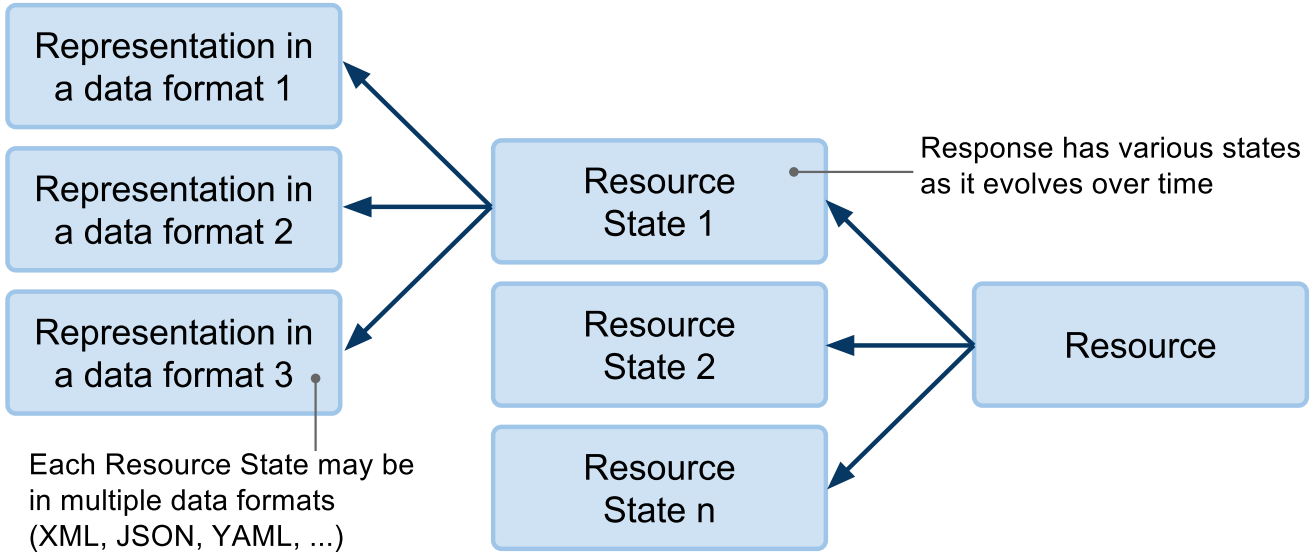
Resource State

- 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 t_1: client A retrieves a resource `/orders` (GET)

```
<orders>
    <order id="54467"/>
    <order id="65432"/>
</orders>
```

- Time t_2: client B adds a new order (POST)

```
<order>
    ...
</order>
```

- Time t_3: client A retrieves a resource `/orders` (GET)

```
<orders>
    <order id="54467"/>
    <order id="65432"/>
    <order id="74567"/>
</orders>
```

- The resource `/orders` has different states in t_1 and t_3.

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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 choses 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!*