Middleware and Web Services

Lecture 3: Representational State Transfer

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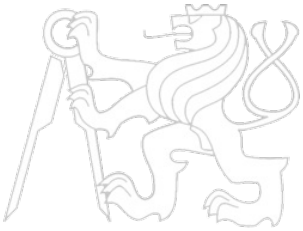

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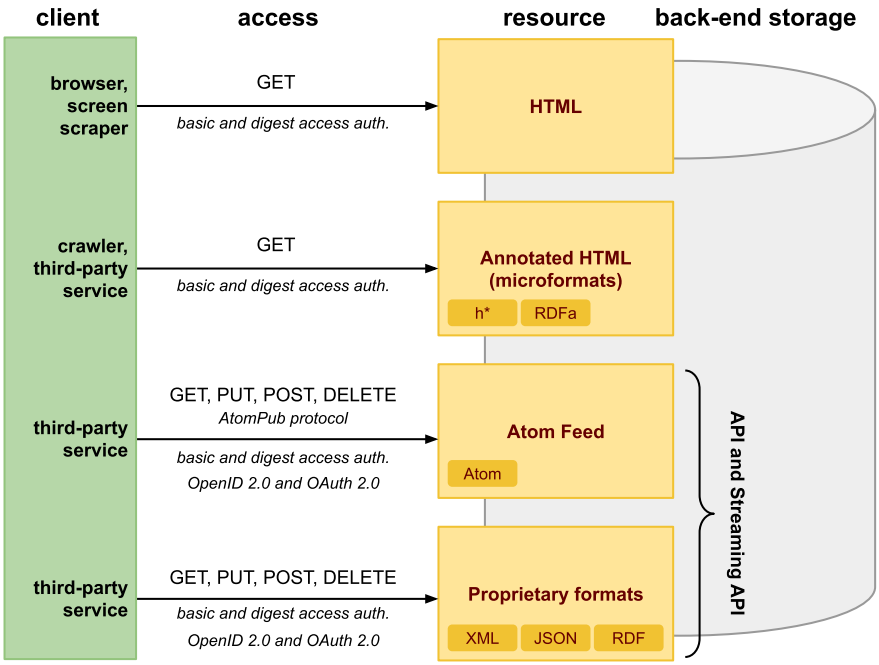
Overview

- Introduction to REST
- Uniform Resource Identifier
- Resource Representation
- Uniform Interface

Data on the Web



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

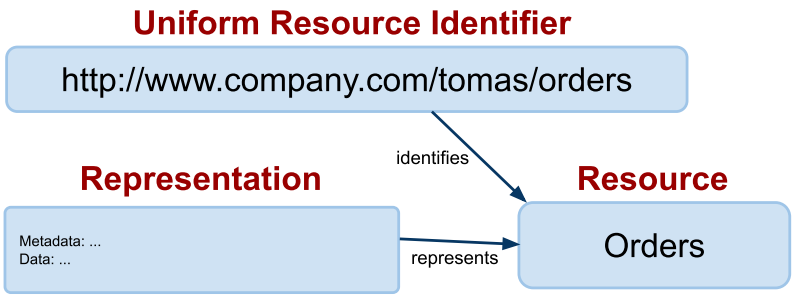
- Familiarity
  - *HTTP protocol is well-known and widely used*
- Interoperability
  - *All environments have HTTP client libraries*
    - *→ technical interoperability is thus no problem*
    - *→ no need to deal with vendor-specific interoperability issues*
  - *You can focus on the core of the integration 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*

REST Core Principles

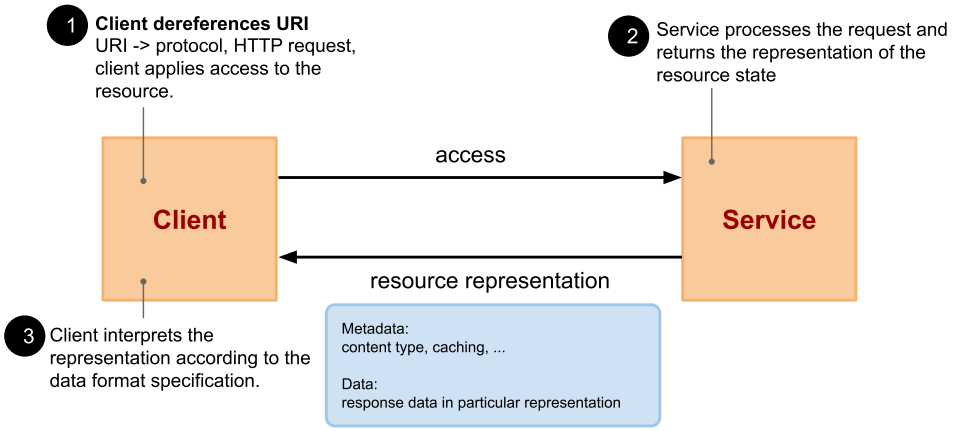
- REST architectural style defines constraints
  - *if you follow them, they help you to achieve a good design, interoperability and scalability.*
- Constraints
  - *Client/Server*
  - *Statelessness*
  - *Cacheability*
  - *Layered system*
  - *Uniform interface*
- Guiding principles
  - *Identification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

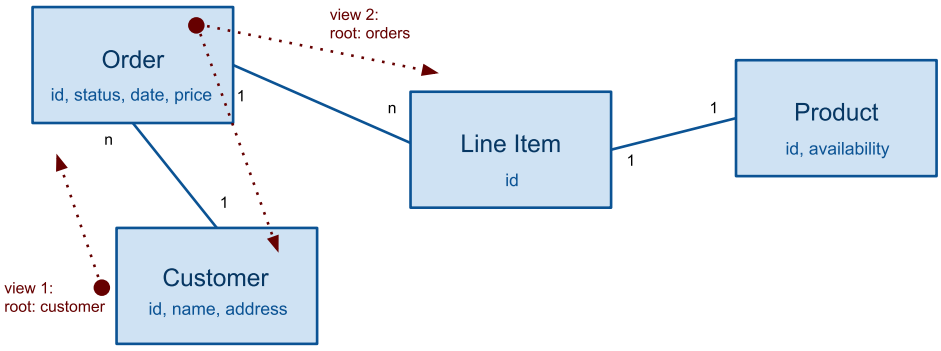
- Definition

```
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*

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.*

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

  ⇒ *there is a HTML element with* `id=3456`

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

```
<orders>
    <order id="3456">...</order>
    ...
</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-level resources' IDs*
  - *Example:* `/customers/{customer-id}/orders/{order-id}/`
  - *There can be more URIs identifying the same resource*

Major characteristics

- Capability URL
  - *Short lived URL generated for a specific purpose*
  - *For example, an user e-mail verification*
- URI Alias
  - *Two URIs identifying the same resource*
- URI Collision
  - *Two URIs identifying the same resource (misuse of an URI authority)*
- URI Opacity
  - *Content type encoded as part of an URI*
  - `http://www.example.org/customers.xml`
- Resource versions encoded in an URI
  - *Two URIs identifying the same resource of different versions*
  - `http://www.example.org/v1/customers.xml`
- Persistent URL
  - *URL is valid even when the resource is obsolete*
  - *For example, a redirection should be in place*

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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*
     - → *Atom Syndication Format such as* `author`, `updated`, *...*
     - → *HTML* `http-equiv` *meta tags*
- Resource anatomy

Content-Type Metadata

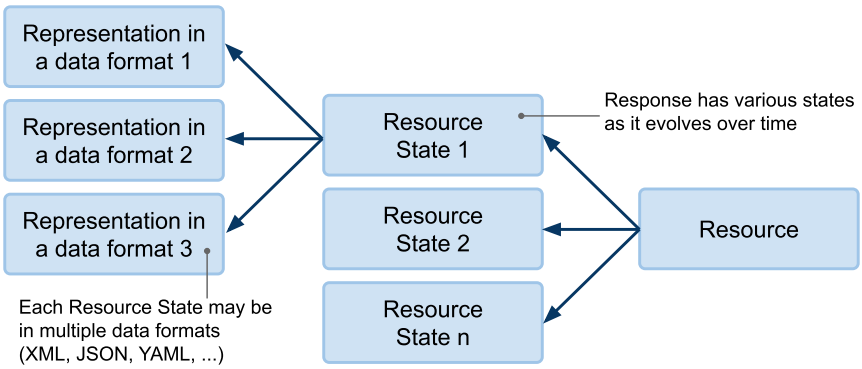
- Access
  - *to be retrieved (GET)*
  - *to be inserted or updated (PUT, POST)*
  - *to be deleted (DELETE)*
- Request
  - *HTTP header* `Accept`*, part of content negotiation protocol*
- Response
  - *HTTP header* `Content-Type: type/subtype; parameters`
  - *Specifies an Internet Media Type of the 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`

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)

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

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

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

- Time `t3`: 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 `t1` and `t3`.

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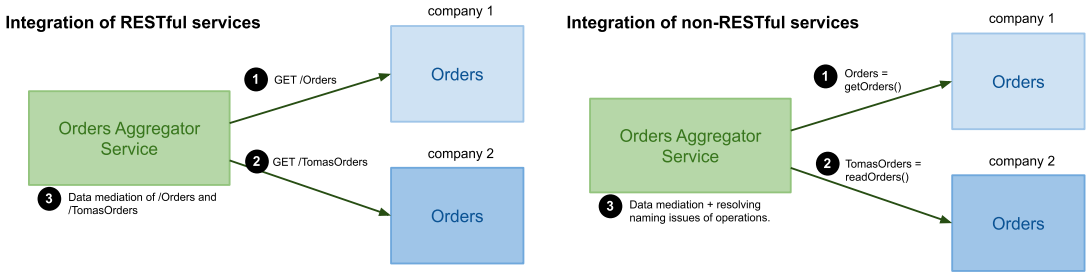
Uniform Interface

- Uniform interface = finite set of operations
  - *Resource manipulation*
    - → *CRUD – Create (POST/PUT), Read (GET), Update (PUT/PATCH), Delete (DELETE)*
  - *operations are not domain-specific*
    - → *For example,* `GET /orders` *and not* `getOrders()`
    - → *This reduces complexity when solving interoperability*
- Integration issues examples



Safe and Unsafe Operations

- Safe operations
  - *Do not change the resource state*
  - *Usually "read-only" or "lookup" operation*
  - *Clients can cache the results and refresh the cache freely*
- Unsafe operations
  - *May change the state of the resource*
  - *Transactions such as buy a ticket, post a message*
  - *Unsafe does not mean dangerous!*
- Unsafe interactions and transaction results
  - `POST` *response may include transaction results*
    - → *you buy a ticket and submit a purchase data*
    - → *you get transaction results*
    - → *and you cannot bookmark this..., why?*
  - *Should be referable with a persistent URI*

Idempotence

- Idempotent operation
  - *Invoking a method on the same resource always has the same effect*
  - *Operations* `GET`, `PUT`, `DELETE`
- Non-idempotent operation
  - *Invoking a method on the same resource may have different effects*
  - *Operation* `POST`
- Effect = a state change
  - *recall the effect definition in MDW*

GET

- Reading
  - `GET` *retrieves a representation of a state of a resource*

```
> GET /orders HTTP/1.1
> Accept: application/xml

< HTTP/1.1 200 OK
< Content-Type: application/xml
<
< ...resource representation in xml...
```

  - *It is read-only operation*
  - *It is **safe***
  - *It is **idempotent***
  - `GET` *retrieves different states over time but the effect is always the same, cf. resource state hence it is idempotent.*
  - *Invocation of* `GET` *involves content negotiation*

PUT

- Updating or Inserting
  - `PUT` *updates or inserts a representation of a state of a resource*
  - *Updating the resource is a **complete replacement of the resource***

```
> PUT /orders/4456 HTTP/1.1
> Content-Type: application/xml
>
> <order>...</order>

< HTTP/1.1 CODE
```

  - *where CODE is:*
    - → `200 OK` *or* `204 No Content` *for updating: A resource with id* `4456` ***exists**, the client sends an updated resource*
    - → `201 Created` *for inserting: A resource **does not exist**, the client generates the id* `4456` *and sends a representation of it.*
  - *It is **not safe** and it is **idempotent***

PATCH

- `PATCH` to partial update a resource
  - *IETF specification, see PATCH Method for HTTP*
- Use in GData Protocol
  - *To add, modify or delete selected elements of an Atom feed entry*
  - *Example to delete a description element and add a new title element* `gd:fields` *uses the partial response syntax*

```
PATCH /myFeed/1/1/
Content-Type: application/xml

<entry xmlns='http://www.w3.org/2005/Atom'
    xmlns:gd='http://schemas.google.com/g/2005'
    gd:fields='description'>
  <title>New title</title>
</entry>
```

  - *Rules*
    - → *Fields not already present are added*
    - → *Non-repeating fields already present are updated*
    - → *Repeating fields already present are appended*

POST

- Inserting
  - `POST` *inserts a new resource*
  - *A server generates a new resource ID, client only supplies a content and a resource URI where the new resource will be inserted.*

```
> POST /orders HTTP/1.1
> Content-Type: application/xml
>
> <order>...</order>

< HTTP/1.1 201 Created
< Location: /orders/4456
```

  - *It is **not safe** an it is **not idempotent***
  - *A client may "suggest" a resource's id using the* `Slug` *header*
    - → *Defined in AtomPub protocol*

DELETE

- Deleting
  - `DELETE` *deletes a resource with specified URI*

```
> DELETE /orders/4456 HTTP/1.1
< HTTP/1.1 CODE
```

  - *where CODE is:*
    - → `200 OK`*: the response body contains an entity describing a result of the operation.*
    - → `204 No Content`*: there is no response body.*
  - *It is* ***not safe*** *and it is* ***idempotent***
    - → *Multiple invocation of* `DELETE /orders/4456` *has always the same effect – the resource* `/orders/4456` *does not exist.*

Other

- HEAD
  - *same as* `GET` *but only retrieves HTTP headers*
  - *It is* ***safe*** *and* ***idempotent***
- OPTIONS
  - *queries the resource for resource configuration*
  - *It is* ***safe*** *and* ***idempotent***

Types of Errors

- Client-side – status code `4xx`
  - `400 Bad Request`
    - → *generic client-side error*
    - → *invalid format, such as syntax or validation error*
  - `404 Not Found`
    - → *server can't map URI to a resource*
  - `401 Unauthorized`
    - → *wrong credentials (such as user/pass, or API key)*
    - → *the response contains* `WWW-Authenticate` *indicating what kind of authentication the service accepts*
  - `405 Method Not Allowed`
    - → *the resource does not support the HTTP method the client used*
    - → *the response contains* `Allow` *header to indicate methods it supports*
  - `406 Not Acceptable`
    - → *so many restrictions on acceptable content types (using* `Accept-*`*)*
    - → *server cannot serialize the resource to requested content types*

Types of Errors (Cont.)

- Server-side – status code `5xx`
  - `500 Internal Server Error`
    - → *generic server-side error*
    - → *usually not expressive, logs a message for system admins*
  - `503 Service Not Available`
    - → *server is overloaded or is under maintenance*
    - → *the response contains* `Retry-After` *header*

Use of Status Codes

- Service should respect semantics of status codes!

```
> GET /orders HTTP/1.1
> Accept: application/json

< HTTP/1.1 200 OK
< Content-Type: application/json
<
< { "error" :
<    { "error_text" :
<        "you do not have rights to access this resource " }
< }
```

  - *Client must understand the semantics of the response.*
  - *This breaks loose coupling and reusability service principles*
  - *The response should be:*

```
< HTTP/1.1 401 Unauthorized
< ...

< ...optional text describing the error...
```


Respect HTTP Semantics

- Do not overload semantics of HTTP methods
  - *For example,* `GET` *is read-only method and idempotent*
  - *REST Anti-pattern:*

    `GET /orders/?add=new_order`

    → *This is not REST!*

    → *This breaks both safe and idempotent principles*
- Consequences
  - *Result of* `GET` *can be cached by proxy servers*
  - *They can revalidate their caches freely*
  - *You can end up with new entries in your storage without you knowing!*
- The same is true for other methods