

Middleware and Web Services

Lecture 3: Representational State Transfer

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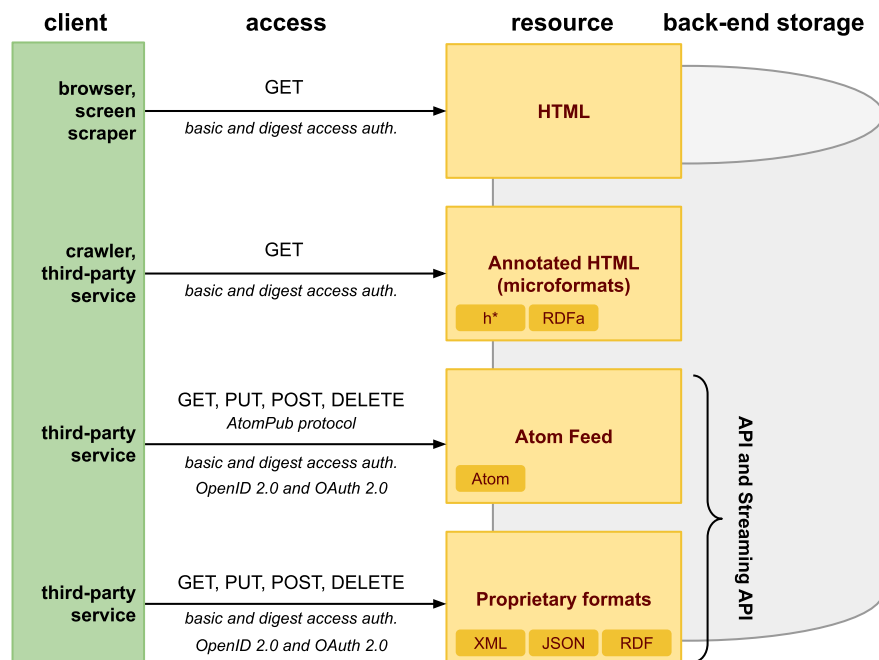


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Overview

- **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 [\[4\]](#).
 - 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* [\[4\]](#) 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

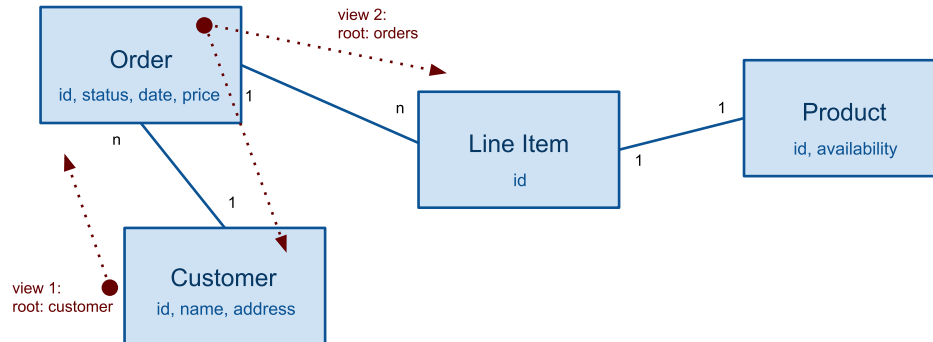
URI

- 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.

```
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-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

Overview

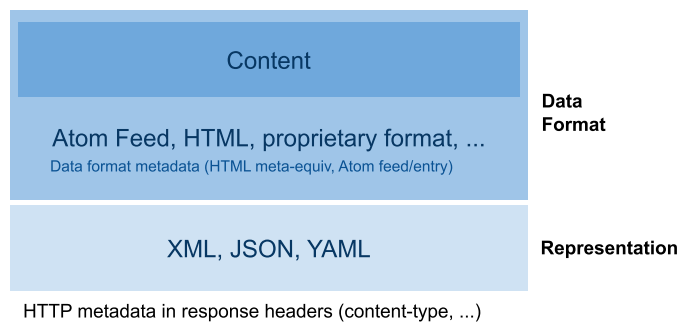
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Representation and Data Format

- 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

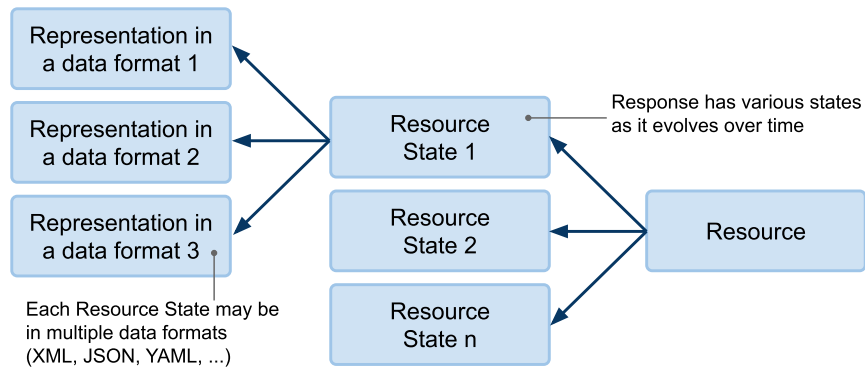
- Access
 - to be retrieved (*GET*)
 - to be inserted or updated (*PUT, POST*)
 - to be deleted (*DELETE*)
- Request
 - HTTP header **Accept**, part of content negotiation protocol
- Response
 - HTTP header **Content-Type: type/subtype; parameters**
 - Specifies an Internet Media Type [☞](#) of the resource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

```
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>
```

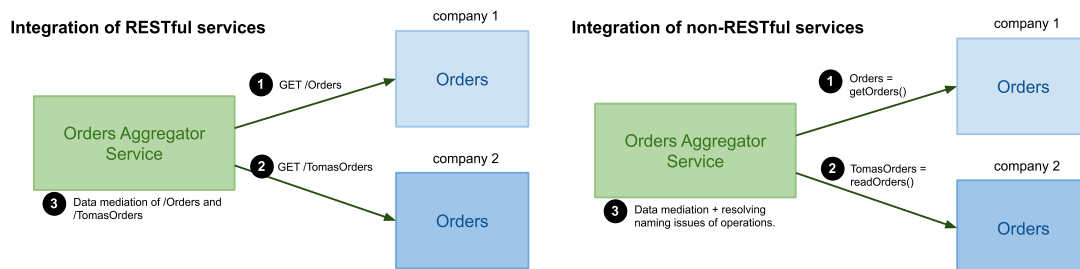
- The resource **/orders** has different states in **t1** and **t3**.

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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

```
1 PATCH /myFeed/1/1/
2 Content-Type: application/xml
3
4 <entry xmlns='http://www.w3.org/2005/Atom'
5       xmlns:gd='http://schemas.google.com/g/2005'
6       gd:fields='description'>
7   <title>New title</title>
8 </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** and 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