

Middleware Architectures 1

Lecture 6: Representational State Transfer

doc. Ing. Tomáš Vitvar, Ph.D.

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



Czech Technical University in Prague

Faculty of Information Technologies • Software and Web Engineering • <https://vitvar.com/lectures>



Modified: Sun Nov 19 2023, 19:53:57
Humla v1.0

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.

Overview

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

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

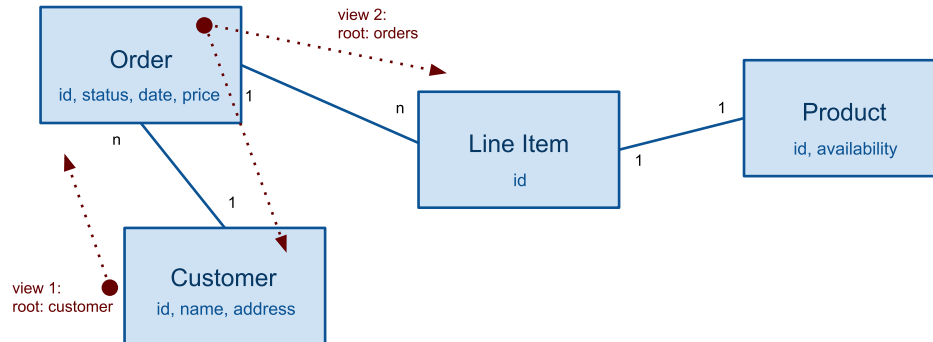
URI

- 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 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

Major characteristics

- Capability URL
 - Short lived URL generated for a specific purpose
 - For example, an user e-mail verification
- URI Alias
 - Two different URIs identifying the same resource
- URI Collision
 - One URI identifying two different resources (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

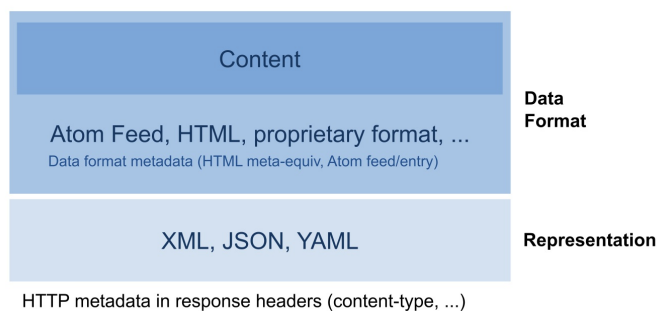
- Introduction to REST
- Uniform Resource Identifier
- **Resource Representation**
- Uniform Interface

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

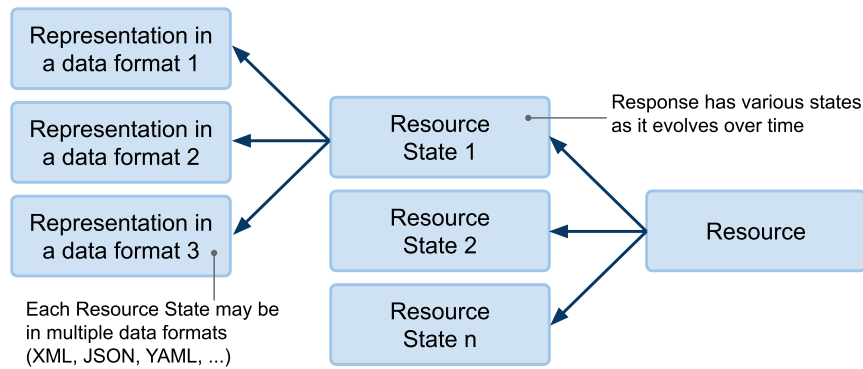
- Access
 - to be retrieved (*GET*)
 - to be inserted or updated (*PUT, POST*)
 - to be deleted (*DELETE*)
- Request
 - HTTP header **Accept**, part of content negotiation protocol
- Response
 - HTTP header **Content-Type: type/subtype; parameters**
 - Specifies an Internet Media Type of the resource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

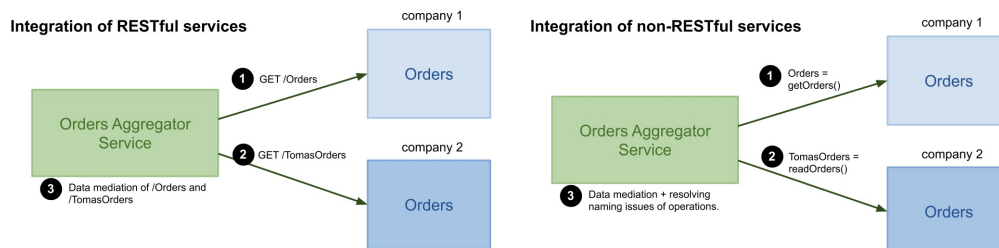
- The resource **/orders** has different states in **t1** and **t3**.

Overview

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

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*
- 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