# Middleware Architectures 1

## Lecture 6: Representational State Transfer

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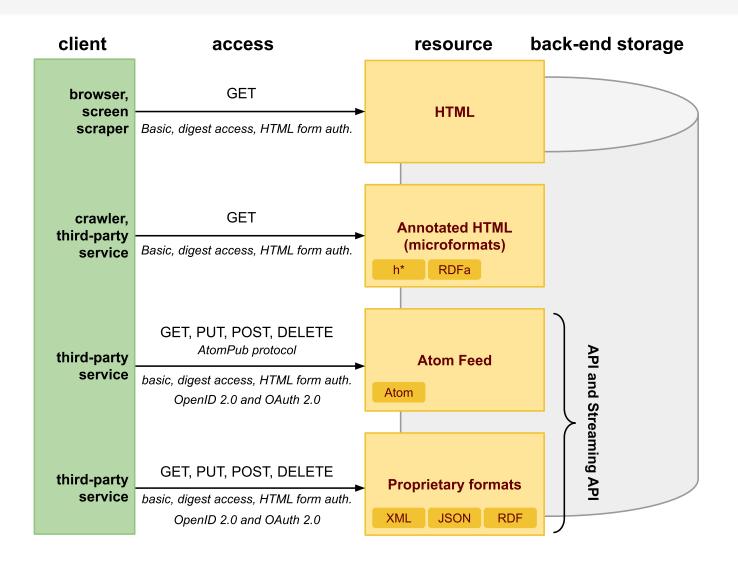




## **Overview**

- 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
    - $\rightarrow$  HTTP is one of the REST implementation  $\rightarrow$  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
    - $\rightarrow$  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
  - $\rightarrow$  caching servers, proxy servers, etc.
- HTTP features such as HTTP GET idempotence and safe allow you to use caching

# **REST Core Principles**

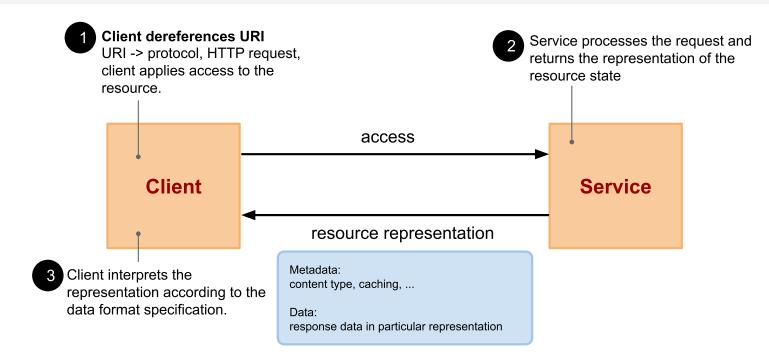
- REST architectural style defines constraints
  - if you follow them, they help you to achieve a good design, interoperability and scalability.
- Constraints
  - Client/Server
  - Statelessness
  - Cacheability
  - Layered system
  - Uniform interface
- Guiding principles
  - Identification of resources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

# Uniform Resource Identifier http://www.company.com/tomas/orders Representation Resource Metadata: ... Data: ... Orders

## 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
    - $\rightarrow$  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
    - $\rightarrow$  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
    - $\rightarrow$  even if the resource cease to exist/becomes unavailable

#### URI

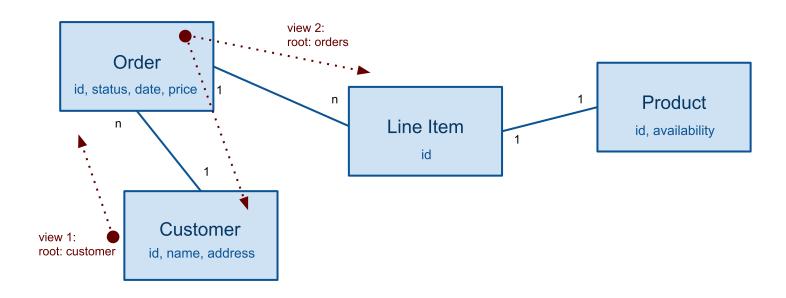
Definition

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

- Hierarchal sequence of components
  - scheme
    - $\rightarrow$  refers to a spec that assigns IDs within that scheme
    - $\rightarrow$  examples: http, ftp, mailto, urn
    - → scheme != protocol
  - authority
    - → registered name (domain name) or server address
    - $\rightarrow$  optional port and user
  - path and query
    - → identify resource within the scheme and authority scope
    - $\rightarrow$  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
    - $\rightarrow$  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
    - $\rightarrow$  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
    - $\rightarrow$  data format of the resource  $\rightarrow$  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
  - $\Rightarrow$  there is a HTML element with id=3456
- But:
  - Consider orders resource in application/xml

- 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

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# Representation and Data Format

## Representation

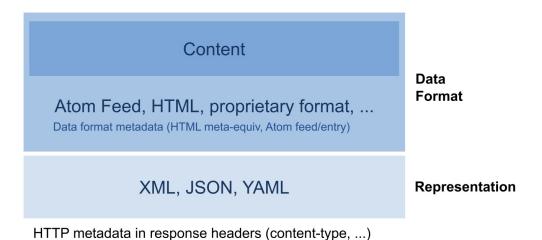
- Various languages, one resource can have multiple representations
  - $\rightarrow$  XML, HTML, JSON, YAML, RDF, ...
  - → should conform to Internet Media Types

#### • Data format

- Format of resource data
- Binary format
  - → specific data structures
  - $\rightarrow$  pointers, numeric values, compressed, etc.
- Textual format
  - $\rightarrow$  in a defined encoding as a sequence of characters
  - $\rightarrow$  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, ...
    - $\rightarrow HTML$  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

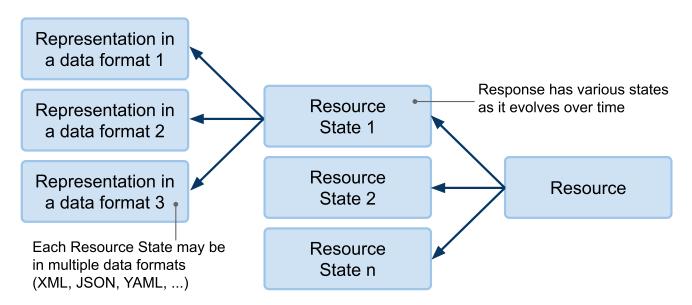
- HTTP header Content-Type: type/subtype; parameters
- Specifies an Internet Media Type of the resource representation.
  - → IANA (Internet Assigned Numbers Authority) manages a registry of media types and character encodings
  - → subtypes of text type have an optional charset parameter text/html; 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
    - $\rightarrow$  +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)

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

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

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

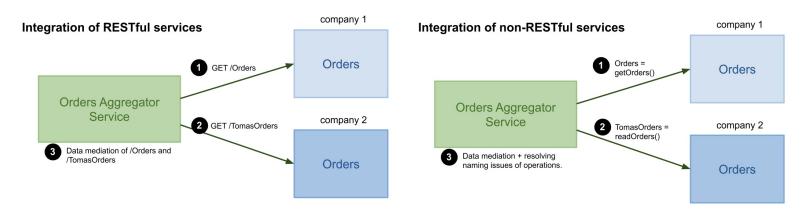
• The resource /orders has different states in t1 and t3.

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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
    - $\rightarrow$  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...</pre>
```

- 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</pre>
```

- where CODE is:
  - → 200 OK or 204 No Content for updating: A resource with id 4456 *exists*, the client sends an updated resource
  - $\rightarrow$  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

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

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

citle>New title</fields</pre>
```

- 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</pre>
```

- 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

#### DELEGIE

- Deleting
  - DELETE deletes a resource with specified URI
    - > DELETE /orders/4456 HTTP/1.1
    - < HTTP/1.1 CODE
  - where CODE is:
    - $\rightarrow$  200 OK: the response body contains an entity describing a result of the operation.
    - $\rightarrow$  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)
    - $\rightarrow$  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
    - $\rightarrow$  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
    - $\rightarrow$  the response contains Retry-After header

## **Use of Status Codes**

• Service should respect semantics of status codes!

- 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...</pre>
```

# **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
```

- $\rightarrow$  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