3 RESTful Service Design

Cesare Pautasso
Faculty of Informatics
University of Lugano, Switzerland

c.pautasso@ieee.org
http://www.pautasso.info
REST Design Constraints

1. Resource Identification
2. Uniform Interface
   GET, PUT, DELETE, POST
   (HEAD, OPTIONS...)
3. Self-Describing Messages
4. Hypermedia Driving Application State
5. Stateless Interactions
REST Design - Outline

• Design Methodology
  • Is URI Design part of REST?
• Simple Doodle Service Example
• REST Architectural Elements
• Design Tips
  • Understanding GET vs. POST vs. PUT
  • Multiple Representations
    • Content-Type Negotiation
  • Exception Handling
    • Idempotent vs. Unsafe
    • Dealing with Concurrency
  • Stateful or Stateless?
• Some REST AntiPatterns
**Design Methodology**

1. Identify resources to be exposed as services (e.g., yearly risk report, book catalog, purchase order, open bugs, polls and votes)
2. Model relationships (e.g., containment, reference, state transitions) between resources with hyperlinks that can be followed to get more details (or perform state transitions)
3. Define “nice” URIs to address the resources
4. Understand what it means to do a GET, POST, PUT, DELETE for each resource (and whether it is allowed or not)
5. Design and document resource representations
6. Implement and deploy on Web server
7. Test with a Web browser

<table>
<thead>
<tr>
<th></th>
<th>GET</th>
<th>PUT</th>
<th>POST</th>
<th>DELETE</th>
</tr>
</thead>
<tbody>
<tr>
<td>/loan</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>/balance</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>/client</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>/book</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>/order</td>
<td>✓</td>
<td>?</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>/soap</td>
<td>×</td>
<td>×</td>
<td>✓</td>
<td>×</td>
</tr>
</tbody>
</table>
Design Space

<table>
<thead>
<tr>
<th>N Resources (Variable)</th>
<th>GET</th>
<th>PUT</th>
<th>POST</th>
<th>DELETE</th>
</tr>
</thead>
<tbody>
<tr>
<td>/loan</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>/balance</td>
<td>✓</td>
<td>✓</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>/client</td>
<td>✓</td>
<td>✓</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>/book</td>
<td>✓</td>
<td>✓</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>/order</td>
<td>✓</td>
<td>✔</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>/soap</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
</tbody>
</table>
URI - Uniform Resource Identifier

- Internet Standard for resource naming and identification (originally from 1994, revised until 2005)
- Examples:
  - `https://www.google.ch/search?q=rest&start=10#1`

- REST does **not** advocate the use of “nice” URIs
- In most HTTP stacks URIs cannot have arbitrary length (4Kb)
What is a “nice” URI?

A RESTful service is much more than just a set of nice URIs

http://map.search.ch/lugano

http://maps.google.com/lugano

http://maps.google.com/maps?f=q&hl=en&q=lugano,+switzerland&layer=&ie=UTF8&z=12&om=1&iwloc=addr
**URI Design Guidelines**

- **Prefer Nouns to Verbs**
- **Keep your URIs short**
- **If possible follow a “positional” parameter-passing scheme for algorithmic resource query strings (instead of the key=value&p=v encoding)**

Some use URI postfixes to specify the content type

- **Do not change URIs**
- **Use redirection if you really need to change them**

**GET /book?isbn=24&action=delete**

**DELETE /book/24**

- **Note:** REST URIs are opaque identifiers that are meant to be discovered by following hyperlinks and not constructed by the client

- **This may break the abstraction**

- **Warning:** URI Templates introduce coupling between client and server
Simple Doodle API Example Design

1. Resources:
   - polls and votes

2. Containment Relationship:

<table>
<thead>
<tr>
<th>URI</th>
<th>GET</th>
<th>PUT</th>
<th>POST</th>
<th>DELETE</th>
</tr>
</thead>
<tbody>
<tr>
<td>/poll</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>/poll/{id}</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>/poll/{id}/vote</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>/poll/{id}/vote/{id}</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>?</td>
</tr>
</tbody>
</table>

3. URIs embed IDs of “child” instance resources

4. POST on the container is used to create child resources

5. PUT/DELETE for updating and removing child resources
Simple Doodle API Example

1. Creating a poll
   (transfer the state of a new poll on the Doodle service)

   POST /poll
   <options>A,B,C</options>

   201 Created
   Location: /poll/090331x
   /poll/090331x/vote

2. Reading a poll
   (transfer the state of the poll from the Doodle service)

   GET /poll/090331x

   200 OK
   <options>A,B,C</options>
   <votes href="/vote"/>
Simple Doodle API Example

- Participating in a poll by creating a new vote sub-resource

```
POST /poll/090331x/vote
<name>C. Pautasso</name>
<choice>B</choice>

201 Created
Location: /poll/090331x/vote/1
```

```
GET /poll/090331x
200 OK
<options>A,B,C</options>
<votes>
<vote id="1">
<name>C. Pautasso</name>
<choice>B</choice>
</vote>
</votes>
```
Simple Doodle API Example

- Existing votes can be updated (access control headers not shown)

```xml
PUT /poll/090331x/vote/1
<name>C. Pautasso</name>
<choice>C</choice>

GET /poll/090331x
200 OK
<options>A,B,C</options>
<votes>
  <vote id="/1">
    <name>C. Pautasso</name>
    <choice>C</choice>
  </vote>
</votes>
```
Simple Doodle API Example

- Polls can be deleted once a decision has been made

```
/poll
/poll/090331x
/poll/090331x/vote
/poll/090331x/vote/1
```

```
GET /poll/090331x
```

```
200 OK
```

```
DELETE /poll/090331x
```

```
GET /poll/090331x
```

```
404 Not Found
```
Real Doodle Demo

• Info on the real Doodle API: http://doodle.com/xsd1/RESTfulDoodle.pdf
• Lightweight demo with Poster Firefox Extension: http://addons.mozilla.org/en-US/firefox/addon/2691
REST Architectural Elements

- Client/Server
- Layered
- Stateless Communication
- Cache

User Agent → Proxy → Gateway → Connector (HTTP) → Origin Server → Cache
Basic Setup

Adding Caching
Proxy or Gateway?

Intermediaries forward (and may translate) requests and responses

A proxy is chosen by the Client (for caching, or access control)

The use of a gateway (or reverse proxy) is imposed by the server
## Uniform Interface Principle

<table>
<thead>
<tr>
<th>CRUD</th>
<th>REST</th>
</tr>
</thead>
<tbody>
<tr>
<td>CREATE</td>
<td>POST</td>
</tr>
<tr>
<td>READ</td>
<td>GET</td>
</tr>
<tr>
<td>UPDATE</td>
<td>PUT</td>
</tr>
<tr>
<td>DELETE</td>
<td>DELETE</td>
</tr>
</tbody>
</table>

**Create**
- **POST**
  - Create a sub resource

**Read**
- **GET**
  - Retrieve the *current state* of the resource

**Update**
- **PUT**
  - Initialize or update the state of a resource at the given URI

**Delete**
- **DELETE**
  - Clear a resource, after the URI is no longer valid
POST vs. GET

- GET is a read-only operation. It can be repeated without affecting the state of the resource (idempotent) and can be cached.
  
  **Note:** this does not mean that the same representation will be returned every time.

- POST is a read-write operation and may change the state of the resource and provoke side effects on the server.

  **Web browsers warn you when refreshing a page generated with POST**
POST vs. PUT

What is the right way of creating resources (initialize their state)?

PUT /resource/{id}

201 Created

Problem: How to ensure resource {id} is unique?
/Resources can be created by multiple clients concurrently/

Solution 1: let the client choose a unique id (e.g., GUID)

POST /resource

301 Moved Permanently

Location: /resource/{id}

Solution 2: let the server compute the unique id

Problem: Duplicate instances may be created if requests are repeated due to unreliable communication
Content Negotiation (Conneg)

Negotiating the message format does not require to send more messages (the added flexibility comes for free)

\[ \text{GET} \ /\text{resource} \]

\[ \text{Accept: text/html, application/xml, application/json} \]

1. The client lists the set of understood formats (MIME types)

\[ \text{200 OK} \]

\[ \text{Content-Type: application/json} \]

2. The server chooses the most appropriate one for the reply (status 406 if none can be found)
Advanced Content Negotiation

Quality factors allow the client to indicate the relative degree of preference for each representation (or media-range).

\[ \text{Media/Type}; \ q=X \]

If a media type has a quality value \( q=0 \), then content with this parameter is not acceptable for the client.

\[ \text{Accept: text/html, text/*}; \ q=0.1 \]

The client prefers to receive HTML (but any other text format will do with lower priority)

\[ \text{Accept: application/xhtml+xml, text/html}; \ q=0.9, \text{ text/plain}; \ q=0.1 \]

The client prefers to receive XHTML, or HTML if this is not available and will use Plain Text as a fall back
Forced Content Negotiation

The generic URI supports content negotiation

GET /resource
Accept: text/html, application/xml, application/json

The specific URI points to a specific representation format using the postfix (extension)

GET /resource.html
GET /resource.xml
GET /resource.json

Warning: This is a conventional practice, not a standard. What happens if the resource cannot be represented in the requested format?
Content Negotiation is very flexible and can be performed based on different dimensions (each with a specific pair of HTTP headers).

<table>
<thead>
<tr>
<th>Request Header</th>
<th>Example Values</th>
<th>Response Header</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accept:</td>
<td>application/xml, application/json</td>
<td>Content-Type:</td>
</tr>
<tr>
<td>Accept-Language:</td>
<td>en, fr, de, es</td>
<td>Content-Language:</td>
</tr>
<tr>
<td>Accept-Charset:</td>
<td>iso-8859-5, unicode-1-1</td>
<td>CharSet parameter fo the Content-Type header</td>
</tr>
<tr>
<td>Accept-Encoding:</td>
<td>compress, gzip</td>
<td>Content-Encoding:</td>
</tr>
</tbody>
</table>
## Exception Handling

Learn to use HTTP Standard Status Codes

<table>
<thead>
<tr>
<th>Code</th>
<th>Status Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Continue</td>
</tr>
<tr>
<td>200</td>
<td>OK</td>
</tr>
<tr>
<td>201</td>
<td>Created</td>
</tr>
<tr>
<td>202</td>
<td>Accepted</td>
</tr>
<tr>
<td>203</td>
<td>Non-Authoritative</td>
</tr>
<tr>
<td>204</td>
<td>No Content</td>
</tr>
<tr>
<td>205</td>
<td>Reset Content</td>
</tr>
<tr>
<td>206</td>
<td>Partial Content</td>
</tr>
<tr>
<td>300</td>
<td>Multiple Choices</td>
</tr>
<tr>
<td>301</td>
<td>Moved Permanently</td>
</tr>
<tr>
<td>302</td>
<td>Found</td>
</tr>
<tr>
<td>303</td>
<td>See Other</td>
</tr>
<tr>
<td>304</td>
<td>Not Modified</td>
</tr>
<tr>
<td>305</td>
<td>Use Proxy</td>
</tr>
<tr>
<td>307</td>
<td>Temporary Redirect</td>
</tr>
</tbody>
</table>

### 4xx Client’s fault

- 400 Bad Request
- 401 Unauthorized
- 402 Payment Required
- 403 Forbidden
- 404 Not Found
- 405 Method Not Allowed
- 406 Not Acceptable
- 407 Proxy Authentication Required
- 408 Request Timeout
- 409 Conflict
- 410 Gone
- 411 Length Required
- 412 Precondition Failed
- 413 Request Entity Too Large
- 414 Request-URI Too Long
- 415 Unsupported Media Type
- 416 Requested Range Not Satisfiable
- 417 Expectation Failed

### 5xx Server’s fault

- 500 Internal Server Error
- 501 Not Implemented
- 502 Bad Gateway
- 503 Service Unavailable
- 504 Gateway Timeout
- 505 HTTP Version Not Supported
Idempotent vs. Unsafe

- Idempotent requests can be processed multiple times without side-effects
  - GET /book
  - PUT /order/x
  - DELETE /order/y
  - If something goes wrong (server down, server internal error), the request can be simply replayed until the server is back up again
  - Safe requests are idempotent requests which do not modify the state of the server (can be cached)
  - GET /book

- Unsafe requests modify the state of the server and cannot be repeated without additional (unwanted) effects:
  - Withdraw(200$) //unsafe
  - Deposit(200$) //unsafe

- Unsafe requests require special handling in case of exceptional situations (e.g., state reconciliation)
  - POST /order/x/payment

- In some cases the API can be redesigned to use idempotent operations:
  - $B = \text{GetBalance}()$ //safe
  - $B = B + 200$ //local
  - SetBalance(B) //idempotent
Dealing with Concurrency

• Breaking down the API into a set of idempotent requests helps to deal with temporary failures.

• But what about if another client concurrently modifies the state of the resource we are about to update?

• Do we need to create an explicit /balance/lock resource? (Pessimistic Locking)

• Or is there an optimistic solution?
Dealing with Concurrency

GET /balance

200 OK
ETag: 26

PUT /balance
ETag: 26

409 Conflict

The 409 status code can be used to inform a client that his request would render the state of the resource inconsistent.
HTTP is a synchronous interaction protocol. However, it does not need to be blocking.

- A Long running request may time out.
- The server may answer it with 202 Accepted providing a URI from which the response can be retrieved later.
- Problem: how often should the client do the polling? /slow/x could include an estimate of the finishing time if not yet completed.
Antipatterns - REST vs. HTTP

REST

HTTP

RESTful HTTP

“RPC”
Antipatterns – HTTP as a tunnel

- Tunnel through one HTTP Method

GET /api?method=addCustomer&name=Wilde
GET /api?method=deleteCustomer&id=42
GET /api?method=getCustomerName&id=42
GET /api?method=findCustomers&name=Wilde*

- Everything through GET
  - Advantage: Easy to test from a Browser address bar (the “action” is represented in the resource URI)
  - Problem: GET should only be used for read-only (= idempotent and safe) requests.
    What happens if you bookmark one of those links?
  - Limitation: Requests can only send up to approx. 4KB of data (414 Request-URI Too Long)
Antipatterns – HTTP as a tunnel

- Tunnel through one HTTP Method
  - Everything through POST
    - Advantage: Can upload/download an arbitrary amount of data (this is what SOAP or XML-RPC do)
    - Problem: POST is not idempotent and is unsafe (cannot cache and should only be used for “dangerous” requests)

```
POST /service/endpoint

<soap:Envelope>
  <soap:Body>
    <findCustomers>
      <name>Wilde*</name>
    </findCustomers>
  </soap:Body>
</soap:Envelope>
```

Is this a resource?
Antipatterns – Cookies

- Are Cookies RESTful or not?
  - It depends. REST is about stateless communication (without establishing any session between the client and the server)

1. Cookies can also be self-contained
   - carry all the information required to interpret them with every request/response

2. Cookies contain references to the application state (not maintained as a resource)
   - they only carry the so-called “session-key”
   - Advantage: less data to transfer
   - Disadvantage: the request messages are no longer self-contained as they refer to some context that the server needs to maintain. Also, some garbage collection mechanism for cleaning up inactive sessions is required. More expensive to scale-up the server.
Stateless or Stateful?

- RESTful Web services are not stateless. The very name of “Representational State Transfer” is centered around how to deal with state in a distributed system.

Client State
- The client interacts with resources by “navigating hyperlinks” and its state captures the current position in the hypertext.
- The server may influence the state transitions of the client by sending different representations (containing hyperlinks to be followed) in response to GET requests.

Resource State
- The state of resources captures the persistent state of the service.
- This state can be accessed by clients under different representations.
- The client manipulates the state of resources using the uniform interface CRUD-like semantics (PUT, DELETE, POST)
RESTful Web services are not stateless. The very name of "Representational State Transfer" is centered around how to deal with state in a distributed system.
Leonard Richardson, Sam Ruby, RESTful Web Services, O’Reilly, May 2007

Raj Balasubramanians, Benjamin Carlyle, Thomas Erl, Cesare Pautasso, SOA with REST, Prentice Hall, End of 2009
Mashups09 @ OOPSLA

http://mashup.inf.unisi.ch/mashups09

3rd International Workshop on
Web APIs and Services Mashups
From SOA to REST

http://dret.net/netdret/docs/soa-rest-icwe2009/

Cesare Pautasso
Faculty of Informatics
University of Lugano, Switzerland
c.pautasso@ieee.org
http://www.pautasso.info

Erik Wilde
School of Information
UC Berkeley
dret@berkeley.edu
http://dret.net/netdret/