What is REST?

From SOA to REST: Designing and Implementing RESTful Services [./] Tutorial at WWW2009 [http://www2009.org/] (Madrid, Spain)

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Contents

Abstract (2)

Representational State Transfer (REST) is defined as an *architectural style*, which means that it is not a concrete systems architecture, but instead a set of constraints that are applied when designing a systems architecture. We briefly discuss these constraints, but then focus on explaining how the Web is one such systems architecture that implements REST. In particular, the mechanisms of the *Uniform Resource Identifiers (URIs)*, the *Hypertext Transfer Protocol (HTTP)*, media types, and markup languages such as the *Hypertext Markup Language (HTML)* and the *Extensible Markup Language (XML)*. We also introduce *Atom* and the *Atom Publishing Protocol (AtomPub)* as two established ways on how RESTful services are already provided and used on today's Web.

Abstraction Layers

What is REST? (4)

- Defining *Representational State Transfer*: 3 popular definitions

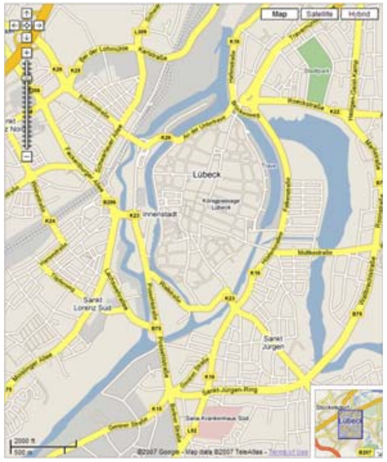
1. An *architectural style* for building loosely coupled systems
   - defined by a set of very general *constraints* (*principles*)
   - the Web (URI/HTTP/HTML/XML) is an *instance* of this style
2. *The Web used correctly* (i.e., not using the Web as transport)
   - HTTP is built according to RESTful principles
   - services are built on top of Web standards without misusing them
   - most importantly, HTTP is an *application protocol* (not a *transport protocol*)
3. Anything that *uses HTTP and XML* (XML without SOAP)
   - XML-RPC was the first approach for this
   - violates REST because there is no uniform interface

What is Architecture? (5)

- Architecture is *constraint-based design*
  - design without constraints probably is *art*
- Constraints can be derived from a wide variety of sources
  - technical infrastructure (current landscape and expected developments)
  - business considerations (current landscape and expected developments)
  - time horizon (short-term vs. long-term requirements)
  - existing architecture
  - scalability
  - performance (based on performance requirements and definitions)
  - cost (development, deployment, maintenance)

Architecture Examples (6)

Traffic
Map
Satellite
Hybrid
New York



Architecture vs. Design (7)

Architectural Styles (8)

- Architectural Style vs. Architecture
  - Architectural Style: General principles informing the creation of an architecture
  - Architecture: Designing a solution to a problem according to given constraints
  - Architectural styles *inform* and *guide* the creation of architectures

- Architecture: Louvre [http://en.wikipedia.org/wiki/Louvre]
- Architectural Style: Baroque [http://en.wikipedia.org /wiki/Baroque_architecture]

- Architecture: Villa Savoye [http://en.wikipedia.org/wiki/Villa_Savoye]
- Architectural Style: International Style [http://en.wikipedia.org /wiki/International_Style_(architecture)]

REST is not an Architecture (9)

- REST is an architectural style
  - distilled from the Web *a posteriori*
  - some of the Web's standards and practices are not perfectly RESTful
- SOA probably also is more a style than it is an architecture
- SOA's biggest problem: What is a *service*?
  - is a service something that is described by RPC-like custom functions?
  - is a service exposed through a uniform interface?
- OASIS [http://www.oasis-open.org/] has a SOA Reference Model TC [http://www.oasis-open.org /committees/tc_home.php?wg_abbrev=soa-rm]
  - the Reference Model [http://docs.oasis-open.org/soa-rm/v1.0/soa-rm.pdf] defines a “service” as “a mechanism to enable access to one or more capabilities, where the access is provided using a prescribed interface and is exercised consistent with constraints and policies as specified by the service description.”
  - the Reference Architecture [http://docs.oasis-open.org/soa-rm/soa-ra/v1.0/soa-ra-pr-01.pdf] describes a WS-* oriented world view
- SOA can be done RESTfully or not
  - whether a RESTful approach makes sense depends on the constraints
  - if the constraints allow REST, there should be a good reason for ignoring REST

REST: The Definition

The REST Architectural Style (11)

- A set of constraints that inform an architecture

1. Resource Identification [Resource Identification (1)]
2. Uniform Interface [Uniform Interface (1)]
3. Self-Describing Messages [Self-Describing Messages (1)]
4. Hypermedia Driving Application State [Hypermedia Driving Application State (1)]
5. Stateless Interactions [Stateless Interactions (1)]

- Claims: scalability, mashup-ability, usability, accessibility

Resource Identification (12)

- Name everything that you want to talk about
- “Thing” in this case should refer to *anything*
  - *products* in an online shop
  - *categories* that are used for grouping products
  - *customers* that are expected to buy products
  - *shopping carts* where customers collect products
- *Application state* also is represented as a resource
  - *next* links on multi-page submission processes
  - *paged results* with URIs identifying following pages

Uniform Interface (13)

- The same small set of operations applies to everything [Resource Identification (1)]
- A small set of *verbs* applied to a large set of *nouns*
- verbs are universal and not invented on a per-application base
- if many applications need new verbs, the uniform interface can be extended
- natural language works in the same way (new verbs rarely enter language)
- Identify operations that are candidates for optimization
  - GET and HEAD are *safe operations*
  - PUT and DELETE are *idempotent operations*
  - POST is the catch-all and can have side-effects
- Build functionality based on useful properties of these operations

Self-Describing Messages (14)

- Resources are abstract entities (they cannot be used *per se*)
  - Resource Identification [Resource Identification (1)] guarantees that they are clearly identified
  - they are accessed through a Uniform Interface [Uniform Interface (1)]
- Resources are accessed using *resource representations*
  - resource representations are sufficient to represent a resource
  - it is communicated which kind of representation is used
  - representation formats can be negotiated between peers
- Resource representations can be based on different constraints
  - XML and JSON can represent the same model for different users
  - whatever the representation is, it must support links [Hypermedia Driving Application State (1)]

Hypermedia Driving Application State (15)

- Resource representations [Self-Describing Messages (1)] contain links to identified resources [Resource Identification (1)]
- Resources and state can be used by navigating links
  - links make interconnected resources navigable
  - without navigation, identifying new resources is service-specific
- RESTful applications *navigate* instead of *calling*
  - representations [Self-Describing Messages (1)] contain information about possible traversals
  - the application navigates to the next resource depending on link semantics
  - navigation can be delegated since all links use identifiers [Resource Identification (1)]

Stateless Interactions (16)

- This constraint does not say “Stateless Applications”!
  - for many RESTful applications, state is an essential part
  - the idea of REST is to avoid long-lasting transactions in applications
- Statelessness means to move state to clients or resources
  - the most important consequence: avoid state in server-side applications
- *Resource state* is managed on the server
  - it is the same for every client working with the service
  - when a client changes resource state other clients see this change as well
- *Client state* is managed on the client
  - it is specific for a client and thus has to maintained by each client
  - it may affect *access* to server resources, but not the resources themselves
- *Security issues* usually are important with client state
  - clients can cheat by lying about their state
  - keeping client state on the server is expensive (but may be worth the price)

Web Architecture

What is the Web? (18)

- Web = URI + HTTP + (HTML | XML)
- RESTful Web uses HTTP methods as the uniform interface
  - non-RESTful Web uses GET/POST and tunneled RPC calls
  - a “different RESTful Web” uses *Web Distributed Authoring and Versioning (WebDAV)*
- Imagine your application being used in “10 browsers”
  - resources to interact with should be identified [Resource Identification (1)] and linked [Hypermedia Driving Application State (1)]
  - a user's preferred font size could be modeled as client state
  - what about an access count associated with an API key?
- Imagine your application being used in “10 browser tabs”
  - no difference as long as client state is representation-based
  - cookies are shared across browser windows (different “client scope”)

Uniform Resource Identifier (URI)

Identifying Resources on the Web (20)

- Essential for implementing a Resource Identification [Resource Identification (1)]
- URIs are human-readable universal identifiers for “stuff”
  - many identification schemes are not human-readable (binary or hex strings)
  - many RPC-based systems do not have universally identified objects
- Making every thing a universally unique identified thing is important
  - it removes the necessity to *scope* non-universal identifiers
  - it allows to talk about all things in exactly the same way

URI Schemes (21)

```
URI = scheme ":" hier-part [ "?" query ] [ "#" fragment ]
```

- URIs in their general case are very simple
  - the scheme identifies how resources are identified
  - the identification may be hierarchical or non-hierarchical
- Many URI schemes are hierarchical
  - it is then possible to use relative URIs such as in a href="../"
  - the slash character is not just a character, in URIs it has semantics

> […] the URI syntax is a federated and extensible naming system wherein each scheme's specification may further restrict the syntax and semantics of identifiers using that scheme.

"Uniform Resource Identifier (URI): Generic Syntax", RFC 3986, January 2005 [http://dret.net/rfc-index/reference/RFC3986]

Query Information (22)

- Query components specify additional information
  - it is non-hierarchical information further identifying the resource
  - in most cases, it can be regarded as "input" to the resource
- Query components often influence caching
  - successful GET/HEAD requests may be cached
  - only cache query string URIs when explicitly requested (Expires/Cache-Control)

> The query component contains non-hierarchical data that, along with data in the path component […], serves to identify a resource within the scope of the URI's scheme and naming authority […].

"Uniform Resource Identifier (URI): Generic Syntax", RFC 3986, January 2005 [http://dret.net/rfc-index/reference/RFC3986]

Processing URIs (23)

- Processing URIs is not as trivial as it may seem
  - escaping and normalization rules are non-trivial
  - many implementations are broken
  - complain about broken implementations
  - even more complicated when processing an *Internationalized Resource Identifier (IRI)*
- URIs are not just strings
  - URIs are strings with a considerable set of rules attached to them
  - implementing all these rules is non-trivial
  - implementing all these rules is crucial
  - application development environments provide functions for URI handling

Hypertext Transfer Protocol (HTTP)

How RESTful Applications Talk (25)

- Essential for implementing a Uniform Interface [Uniform Interface (1)]
  - HTTP defines a small set of methods for acting on URI-identified resources
- Misusing HTTP turns application into non-RESTful applications
  - they lose the capability to be used just by adhering to REST principles
  - it's a bad sign when you think you need an interface description language
- Extending HTTP turns applications into more specialized RESTful applications
  - may be appropriate when more operations are required
  - seriously reduces the number of potential clients

HTTP Methods (26)

- *Safe methods* can be ignored or repeated without side-effects
  - arithmetically safe: 41 × 1 × 1 × 1 × 1 …
  - in practice, “without side-effects” means “without relevant side-effects”
- *Idempotent methods* can be repeated without side-effects
  - arithmetically safe: 41 × 0 × 0 × 0 × 0 …
  - in practice, “without side-effects” means “without relevant side-effects”
- Unsafe and non-idempotent methods should be treated with care
- HTTP has two main *safe methods*: GET HEAD
- HTTP has two main *idempotent methods*: PUT DELETE
- HTTP has one main *overload method*: POST

Cookies (27)

- Cookies are *client site state bound to a domain*
  - they are convenient because they work *without having to use a representation*
  - they are inconvenient because they are *not embedded representations*
- Cookies are managed by the client
  - they are shared across browser tabs
  - they are not shared across browsers used by the same user
  - essentially, the *client* model of cookies is a bit outdated
- Two major things to look out for when using cookies:
  1. *session IDs* are *application state* (i.e., non-resource state)
  2. cookies break the back button (requests contain a “URI/cookie” combo)
- The ideal RESTful cookie is never sent to the server
  - cookies as *persistent data storage on the client*
  - interactions with the server are only using URIs and representations

Representations

Structured Documents

What is a URI? (30)

- Essential for implementing Self-Describing Messages [Self-Describing Messages (1)]
  - also should provide support for Hypermedia Driving Application State [Hypermedia Driving Application State (1)]
- Resource Identification [Resource Identification (1)] only talks about an *abstract resource*
  - resources are never exchanged or otherwise processed directly
  - all interactions use *resource representations*
- Representations depend on various factors
  - the nature of the resource
  - the capabilities of the server
  - the capabilities or the communications medium
  - the capabilities of the client
  - requirements and constraints from the application scenario
  - negotiations to figure out the “best” representation

Extensible Markup Language (XML) (31)

- The language that started it all
  - created as a streamlined version of SGML
  - took over as the first universal language for structured data
- XML is a metalanguage (a language for representing languages)
  - many domain-specific languages are defined as XML vocabularies
  - some metalanguages use XML syntax (RDF [Resource Description Framework (RDF) (1)] is a popular example)
- XML is only syntax and has almost zero semantics
  - very minimal built-in semantics (language identification, IDs, relative URIs)
  - semantics are entirely left to the XML vocabularies
- XML is built around a tree model
  - each XML document is a tree and thus limited in structure
  - RESTful XML introduces hypermedia to turn XML data into a graph

JavaScript Object Notation (JSON) (32)

- The `XMLHttpRequest` API has been built for requesting XML via HTTP
  - this is useful because XML is the most popular data format
  - all requested data has to be processed by using XML access methods in JavaScript
- JavaScript does not have XML as its internal data model
  - the XML received via `XMLHttpRequest` has to be parsed into a DOM tree
  - DOM access in JavaScript is inconvenient for complex operations
  - alternatively, the XML can be mapped to JavaScript objects (also requires parsing)
- *JavaScript Object Notation (JSON)* encodes data as JavaScript objects
  - because the consumer is written in JavaScript, this is more efficient for the consumer
  - this turn the generally usable XML service into a JavaScript-oriented service
  - for large-scale applications, it might make sense to provide XML and JSON
  - this can be negotiated with *HTTP content negotiation*

JSON Example (33)

```
<?xml version="1.0"?>
<menu id="file" value="File">
 <popup>
  <menuitem value="New" onclick="CreateNewDoc()"/>
  <menuitem value="Open" onclick="OpenDoc()"/>
  <menuitem value="Close" onclick="CloseDoc()"/>
 </popup>
</menu>
```

```
{ "menu" : {
 "id" : "file",
 "value" : "File",
 "popup" : {
  "menuitem" : [
   { "value" : "New", "onclick" : "CreateNewDoc()" },
   { "value" : "Open", "onclick" : "OpenDoc()" },
   { "value" : "Close", "onclick" : "CloseDoc()" }
  ]
 }
}}
```

Resource Description Framework (RDF) (34)

- Developed around the same time as XML was developed
  - based on the idea of machine-readable/understandable semantics
  - builds the *Semantic Web* as a parallel universe on top of the Web
- RDF uses URIs for *naming things*
  - RDF's data model is based on (URI, property, value) triples
  - triples are combined and inference is used to produce a graph
- RDF is a metalanguage built on the triple-based data model
  - RDF has a number of syntaxes (one of them is XML [Extensible Markup Language (XML) (1)]-based)
  - RDF introduces a number of schema languages (often referred to as *ontology languages*)

Atom (35)

- A language for representing *syndication feeds*
- Much more modest in its goal than XML [Extensible Markup Language (XML) (1)] or RDF [Resource Description Framework (RDF) (1)]
  - models feeds as a sets of entries with associated metadata
  - uses an XML vocabulary for representing the data model
  - uses *links* for expressing relationships in the data model
- Will be discussed in detail as a good foundation for REST [REST in Practice]

Linked Documents

Making Resources Navigable (37)

- Essential for using Hypermedia Driving Application State [Hypermedia Driving Application State (1)]
- RPC-oriented systems need to expose the available functions
  - functions are essential for interacting with a service
  - introspection or interface descriptions make functions discoverable
- RESTful systems use a Uniform Interface [Uniform Interface (1)]
  - no need to learn about functions
  - but how to find resources?
  1. find them by following links from other resources
  2. learn about them by using URI Templates [URI Templates (1)]
  3. understand them by recognizing representations

URI Templates (38)

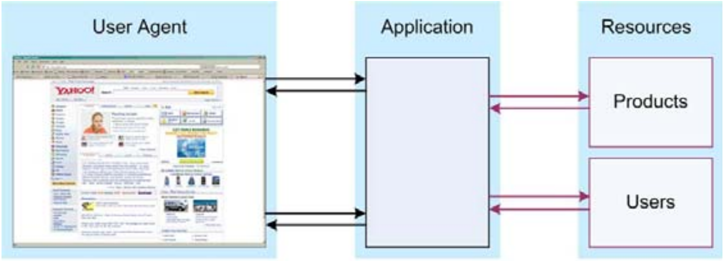
- REST does not care about URI details
- Apart from the scheme, URIs should be semantically opaque
  - media types should not guessed by URI (breaks content negotiation)
  - semantics should not be inferred from inspecting URIs
  - URIs should not be guessed based on previously encountered URIs
- “URI hacking” on the Web works and can be useful
  - Firefox Go Up [http://dret.typepad.com/dretblog/2008/07/go-up.html] allows easy navigation up one level
  - good URIs and bad UIs sometimes turn the address bar into a useful UI
- Technically speaking, URI templates are not required by REST
  - practically speaking, URI templates are a useful best practice
  - all URI navigable resources should also be navigable using representations

State

State Management on the Web (40)

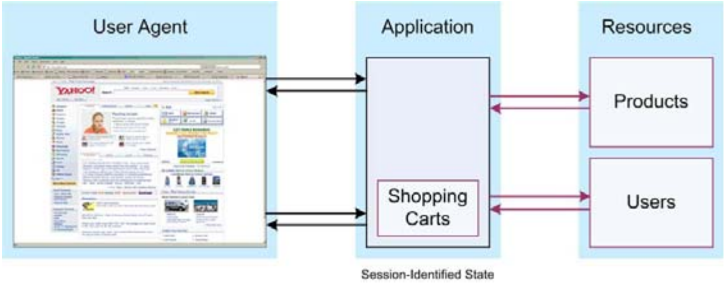
- Essential for supporting Stateless Interactions [Stateless Interactions (1)]
- Cookies [Cookies (1)] are a frequently used mechanism for managing state
  - in many cases used for maintaining session state (login/logout)
  - more convenient than having to embed the state in every representation
  - some Web frameworks switch automatically between cookies and URI rewriting
- Cookies have two interesting client-side side-effects
  - they are stored persistently independent from any representation
  - they are "shared state" within the context of one browser
- Session ID cookies require expensive server-side tracking
  - not associated with any resource and thus potentially global
  - load-balancing must be cookie-sensitive or cookies must be global
- *Resource-based state* allows RESTful service extensions

State in HTML or HTTP (41)

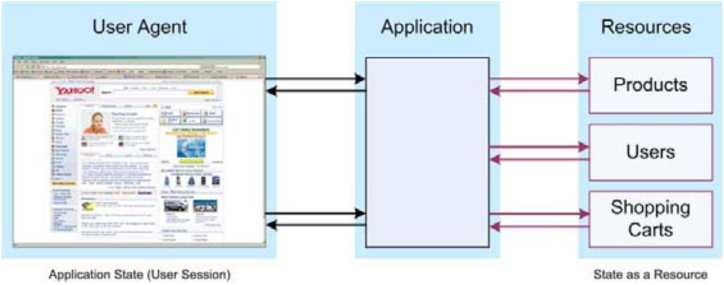


State in HTML or HTTP Authentication Info

State in the Server Application (42)



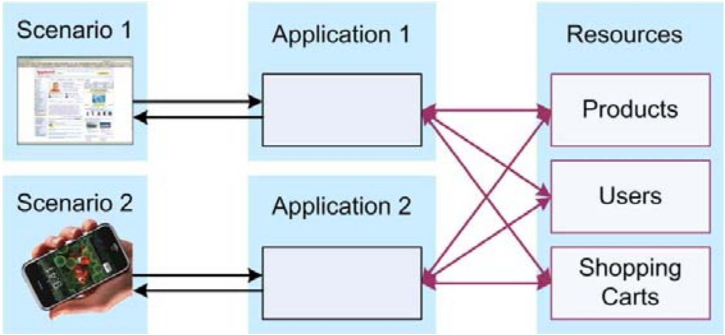
State as a Resource (43)



Stateless Shopping (44)

- Typical “session scenarios” can be mapped to resources [http://www.peej.co.uk/articles/no-sessions.html]
  - Client: Show me your products
  - Server: Here's a list of all the products
  - Client: I'd like to buy 1 of http://ex.org/product/X, I am "John"/"Password"
  - Server: I've added 1 of http://ex.org/product/X to http://ex.org/users/john/basket
  - Client: I'd like to buy 1 of http://ex.org/product/Y, I am "John"/"Password"
  - Server: I've added 1 of http://ex.org/product/Y to http://ex.org/users/john/basket
  - Client: I don't want http://ex.org/product/X, remove it, I am "John"/"Password"
  - Server: I've removed http://ex.org/product/X to http://ex.org/users/john/basket
  - Client: Okay I'm done, username/password is "John"/"Password"
  - Server: Here is the total cost of the items in http://ex.org/users/john/basket
- This is more than just renaming “session” to “resource”
  - all relevant data is stored persistently on the server
  - the shopping cart's URI can be used by other services for working with its contents
  - instead of *hiding the cart in the session*, it is *exposed as a resource*

Reusing Resources (45)



Conclusions (46)

- REST is simple to learn and use
- Unlearning RPC in most cases is the hardest part
  - OO is all about identifying classes and methods
  - distributed systems very often are built around RPC models
  - many classical IT architectures are RPC-centric by design
- REST and RPC do not mix
  - resource orientation ↔ function orientation
  - cooperation ↔ integration
  - openly distributed ↔ hiding distribution
  - coarse-grained ↔ fine-grained
  - complexity in resources formats ↔ complexity in function set