

What is REST?

RESTful Web Services: Principles, Patterns, Emerging Technologies

[./]

Tutorial at ICWE 2010

[<http://icwe2010.webengineering.org/>] (Vienna,
Austria)

[Erik Wilde](#) ([UC Berkeley School of Information](#))

July 6, 2010



[<http://creativecommons.org/licenses/by/3.0/>]

[This work is licensed under a CC
Attribution 3.0 Unported License](#) [<http://creativecommons.org/licenses/by/3.0/>]

[Erik Wilde: What is REST?](#)

[Contents](#)

Contents

• Abstract	2
• 1 Abstraction Layers	
◦ What is REST?	4
◦ What is Architecture?	5
◦ Architecture Examples	6
◦ Architecture vs. Design	7
◦ Architectural Styles	8
◦ REST is not an Architecture	9
◦ SOA is not an Architecture	10
• 2 REST: The Definition	
◦ The REST Architectural Style	12
◦ Resource Identification	13
◦ Uniform Interface	14
◦ Self-Describing Messages	15
◦ Hypermedia Driving Application State	16
◦ Stateless Interactions	17
• 3 Web Architecture	
◦ What is the Web?	19
◦ 3.1 Uniform Resource Identifier (URI)	
▪ Identifying Resources on the Web	21
▪ URI Schemes	22
▪ Query Information	23
▪ Processing URIs	24

○ 3.2 Hypertext Transfer Protocol (HTTP)	
■ How RESTful Applications Talk	26
■ HTTP Methods	27
■ Cookies	28
• 4 Representations	
○ 4.1 Structured Documents	
■ What is identified by a URI?	31
■ Extensible Markup Language (XML)	32
■ JavaScript Object Notation (JSON)	33
■ JSON Example	34
■ Resource Description Framework (RDF)	35
■ Atom	36
○ 4.2 Linked Documents	
■ Making Resources Navigable	38
■ URI Templates	39
• 5 State	
○ State Management on the Web	41
○ State in HTML or HTTP	42
○ State in the Server Application	43
○ State as a Resource	44
○ Stateless Shopping	45
○ Reusing Resources	46
• Conclusions	47

[Erik Wilde: What is REST?](#)

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 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

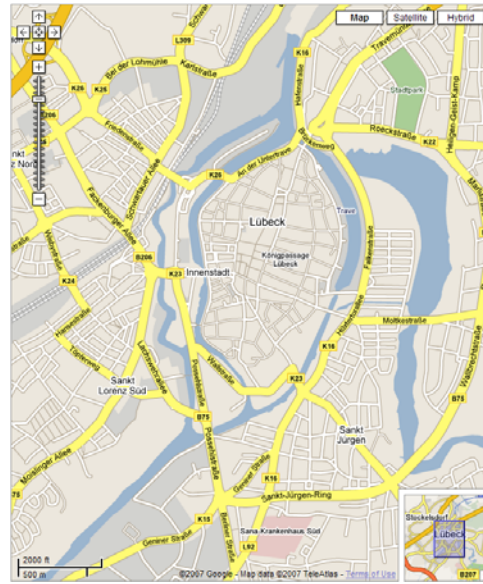
What is Architecture?

(5)

- What is the "A" in SOA?
- Architecture is *constraint-based design*
 - *constraints* are derived from *requirements* ("contextualized requirements")
 - 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)



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



- Architecture: [Villa Savoye](http://en.wikipedia.org/wiki/Villa_Savoye) [http://en.wikipedia.org/wiki/Villa_Savoye]
- Architectural Style: [International Style](http://en.wikipedia.org/wiki/International_Style_(architecture)) [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
- The Web is an information system following REST
- It is possible to design other RESTful information systems
 - different uniform interfaces (not using HTTP's methods)
 - different representations (not using HTML or XML)
 - different identification (not using URIs)

SOA is not an Architecture

(10)

- SOA is more a style than 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/) [http://www.oasis-open.org/] has a [SOA Reference Model TC](http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=soa-rm) [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) [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) [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

(12)

- 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

(13)

- 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

(14)

- 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 (15)

- 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 (16)

- [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

(17)

- 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 be 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 (try to) 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?

(19)

- 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

(21)

- 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

19 of 40

7/4/2010 19:53

[Erik Wilde: What is REST?](#)

Uniform Resource Identifier (URI)

URI Schemes

(22)

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]

20 of 40

7/4/2010 19:53

Query Information

(23)

- 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

(24)

- 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

(26)

- 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

23 of 40

7/4/2010 19:53

[Erik Wilde: What is REST?](#)[Hypertext Transfer Protocol \(HTTP\)](#)

HTTP Methods

(27)

- *Safe methods* can be ignored or repeated without side-effects
 - arithmetically safe: $41 \times 1 \times 1 \times 1 \times 1 \dots$
 - in practice, "without side-effects" means "without relevant side-effects"
- *Idempotent methods* can be repeated without side-effects
 - arithmetically idempotent: $41 \times 0 \times 0 \times 0 \times 0 \dots$
 - 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

24 of 40

7/4/2010 19:53

Cookies

(28)

- 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 in 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 identified by a URI?

(31)

- 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
- Representations are identified by [media type \(sometimes called MIME type\)](#) [http://dret.net/lectures/web-fall08/mediatypes]

Extensible Markup Language (XML) (32)

- 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) (33)

- 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
 - more efficient for the consumer if the consumer is written in JavaScript
 - this turns 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

(34)

```
<?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)

(35)

- 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

(36)

- 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

(38)

- 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

(39)

- REST does not care about URI details
- Apart from the scheme, URIs should be semantically opaque
 - media types should not be 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) [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

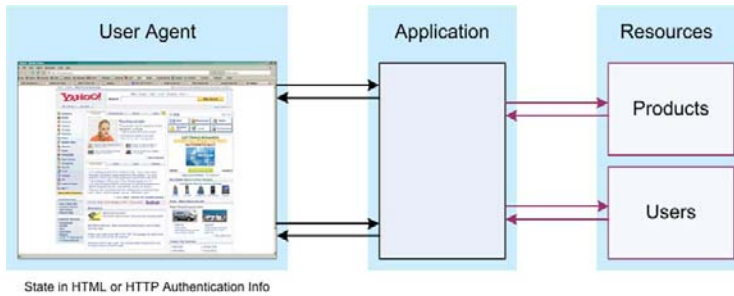
State Management on the Web

(41)

- 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

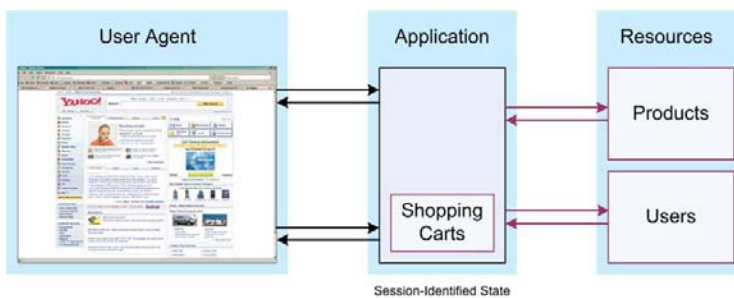
State in HTML or HTTP

(42)



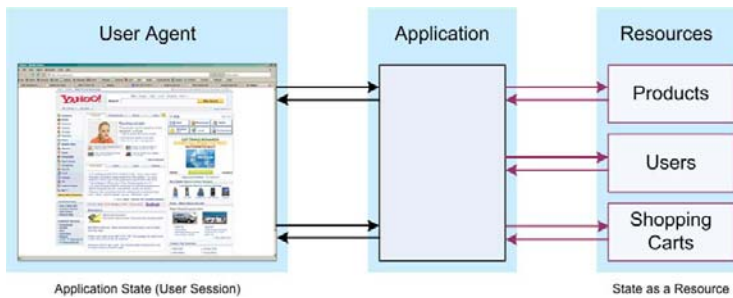
State in the Server Application

(43)



State as a Resource

(44)



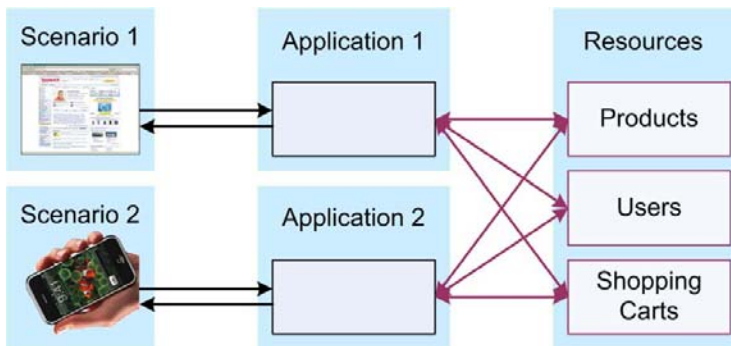
Stateless Shopping

(45)

- Typical “session scenarios” can be [mapped to resources](http://www.peej.co.uk/articles/no-sessions.html) [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

(46)



Conclusions

(47)

- 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