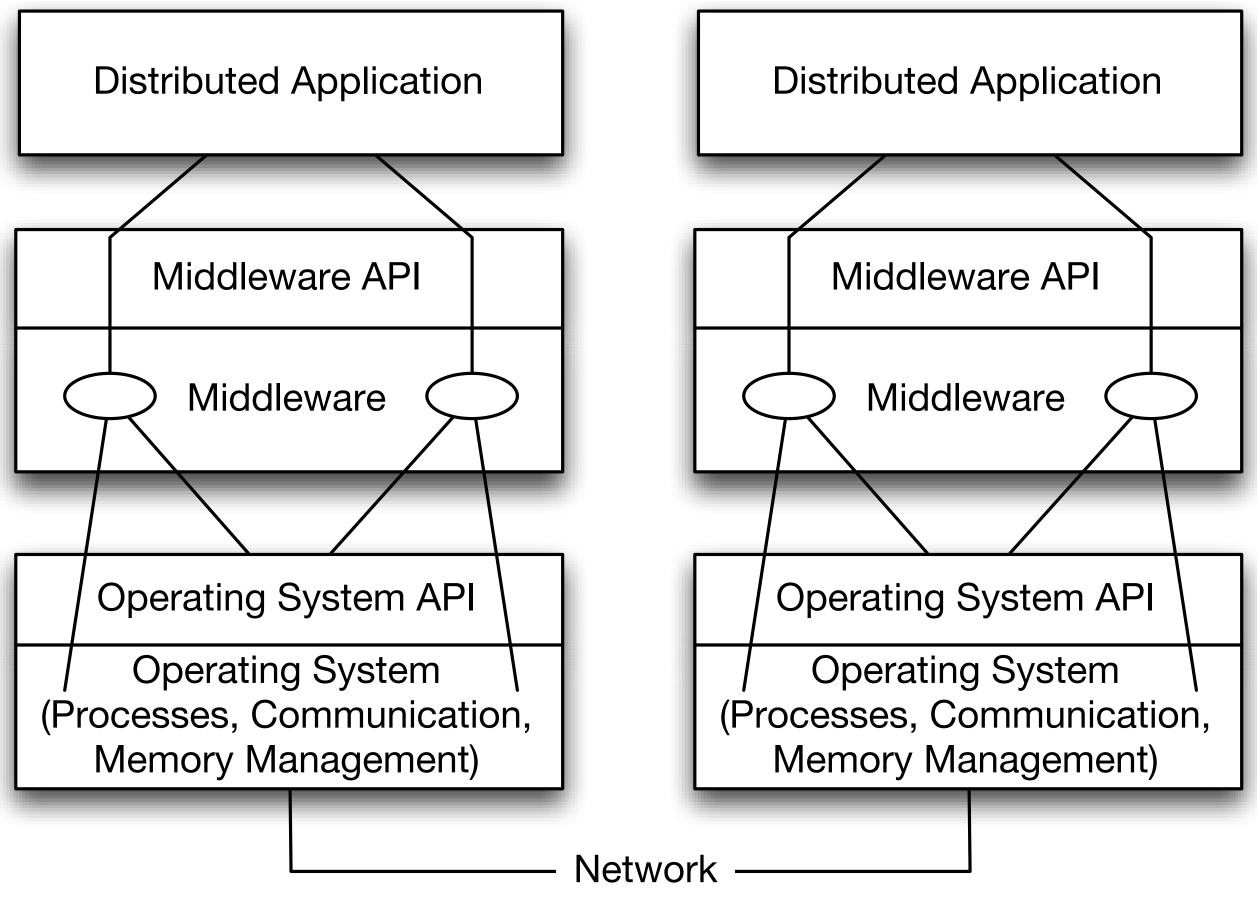
Middleware

What is Middleware?

Middleware is a *class of software technologies* designed to help (I) **manage the complexity** and (II) **heterogeneity inherent in distributed systems.**

Middleware as a Programming Abstraction

- A software layer **above the operating system** and **below the application program** that provides a common programming abstraction across a distributed system
- A higher-level building block than APIs provided by the OS (such as sockets)



Middleware as a Programming Abstraction

heterogeneity =dt.
Heterogenität
Ungleichartigkeit
Verschiedenartigkeit

Programming abstractions offered by **middleware mask some of the heterogeneity and handles some of the complexity programmers of a distributed application must deal with**:

- Middleware always mask heterogeneity of the underlying networks, hardware
- Most middleware mask heterogeneity of operating systems and/or programming languages
- Some middleware even mask heterogeneity among different vendor implementations of the “same” middleware standard

e.g., CORBA-IDL

Middleware as a Programming Abstraction

Raising the Abstraction Level

- An operating system (OS) is the software that makes the hardware useable
  (A bare computer without an OS could be programmed with great difficulty.)

- Middleware is the software that makes a distributed system (DS) programmable
  (Programming a DS is much more difficult without middleware.)

Middleware as Infrastructure

- Behind programming abstractions there is a complex infrastructure that implements those abstractions
  (Middleware platforms are very complex software systems.)
- As programming abstractions reach higher and higher levels, the underlying infrastructure implementing the abstractions must grow accordingly
  - Additional functionality is almost always implemented through additional software layers
  - The additional software layers increase the size and complexity of the infrastructure necessary to use the new abstractions

E.g. to handle errors we can have “transactional RPCs”

Middleware as Infrastructure

The infrastructure is also intended to *support additional functionality* that makes **development**, **maintenance**, and **monitoring** easier and less costly:

- logging,
- recovery,
- advanced transaction models (e.g. transactional RPC),
- language primitives for transactional demarcation,
- transactional file system,
- etc.

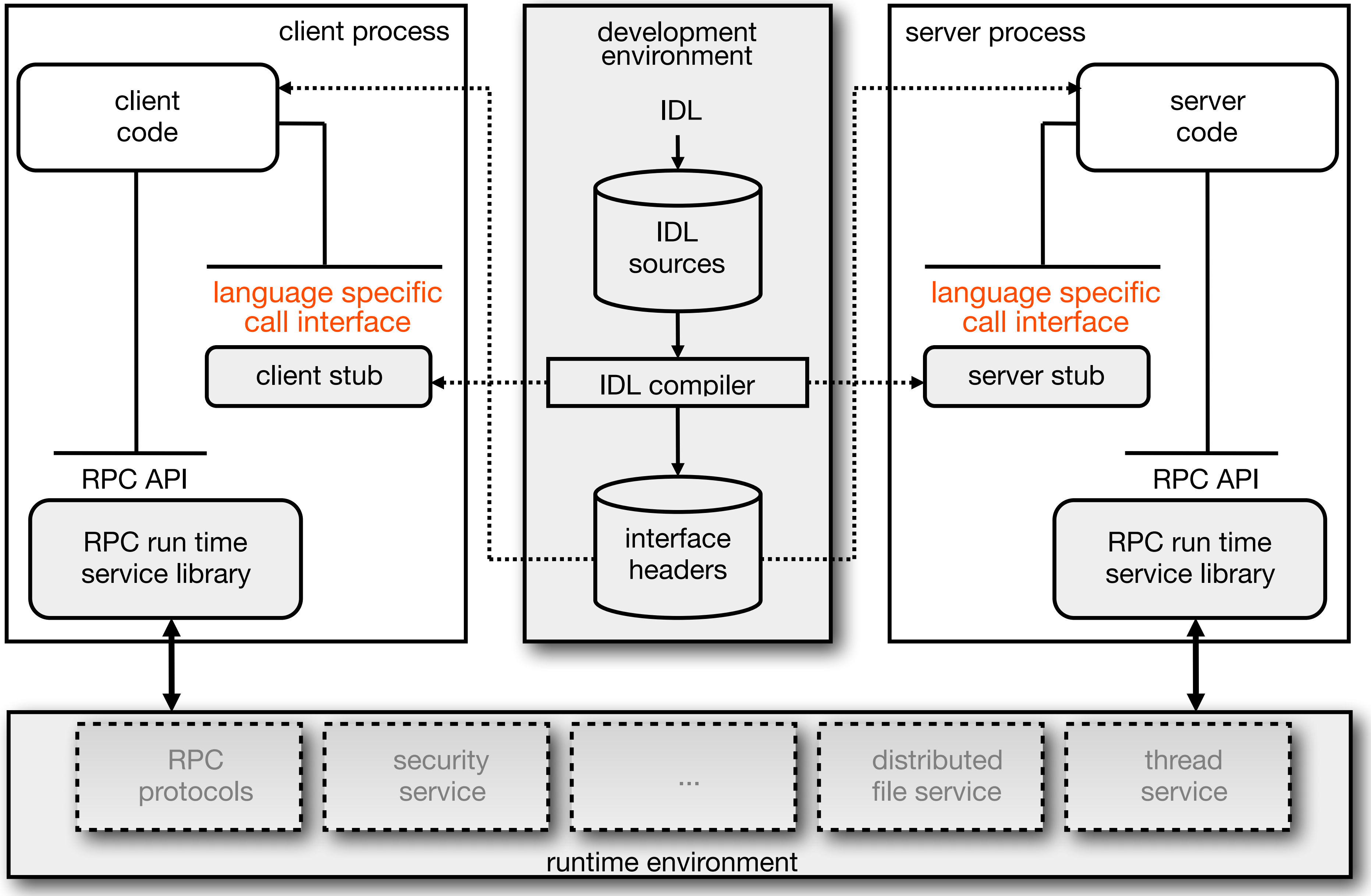
Middleware as Infrastructure

The **infrastructure also takes care of (all) the non-functional properties** typically ignored by data models, programming models, and programming languages:

- performance,
- availability,
- resource management,
- reliability,
- etc.

Middleware as Infrastructure

Conceptual Model



[Alonso; Web services: Concepts, Architectures and Applications; Springer, 2004]

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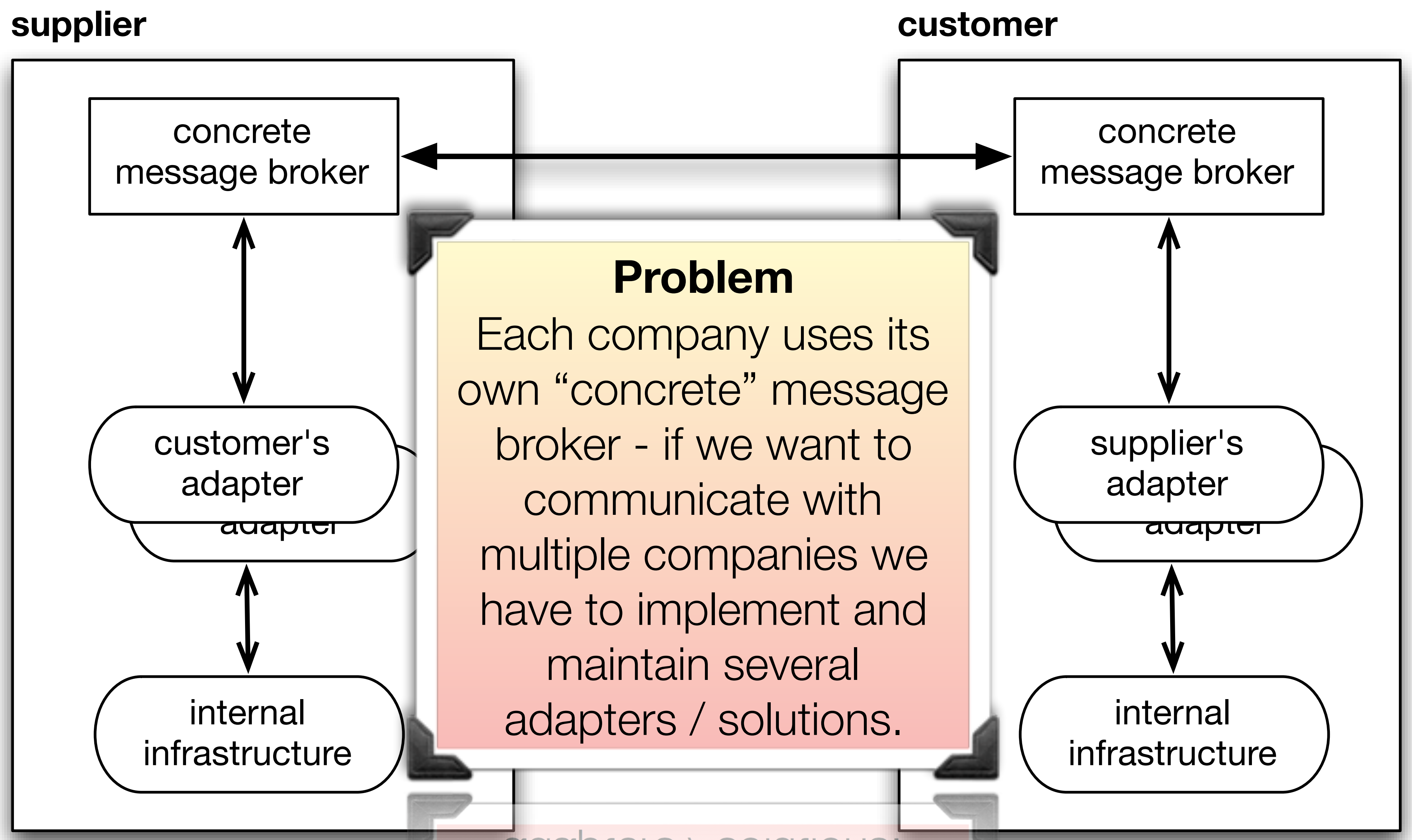
Web Services

Point-to-point integration across companies



Problem
Each company uses its own “concrete” message broker - if we want to communicate with multiple companies we have to implement and maintain several adapters / solutions.

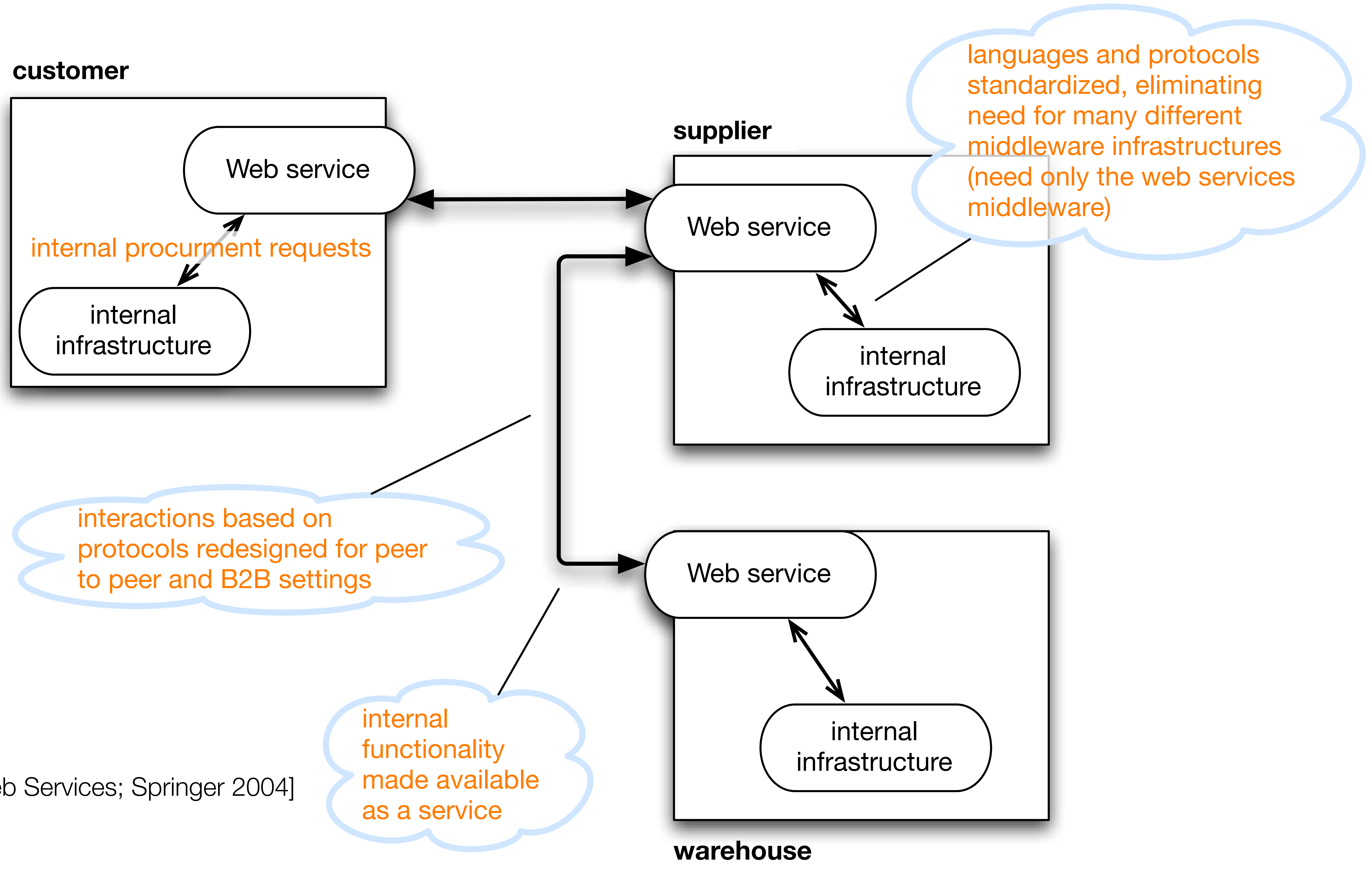
[Web Services - Concepts, Architectures and Applications; Alonso et al.; Springer 2004]

What is a Web Service?

[…] self-contained, modular business applications that have open, internet-oriented, standards-based interfaces.

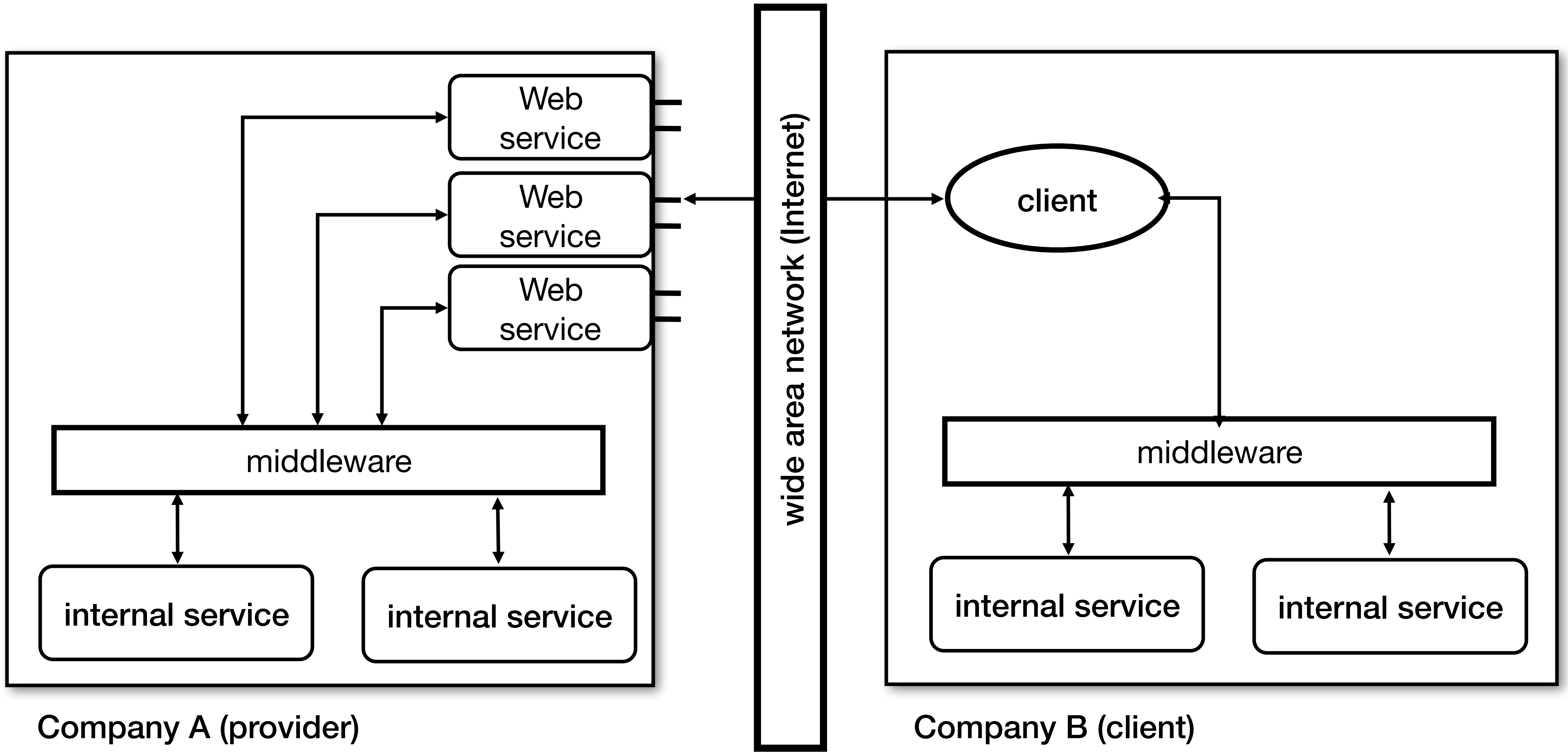
Definition by the UDDI consortium

What is a Web Service?


customer
Web service
internal procurment requests
internal infrastructure
supplier
Web service
internal infrastructure
languages and protocols standardized, eliminating need for many different middleware infrastructures (need only the web services middleware)
interactions based on protocols redesigned for peer to peer and B2B settings
Web service
internal infrastructure
warehouse
internal functionality made available as a service

[Web Services; Springer 2004]

What is a Web Service?

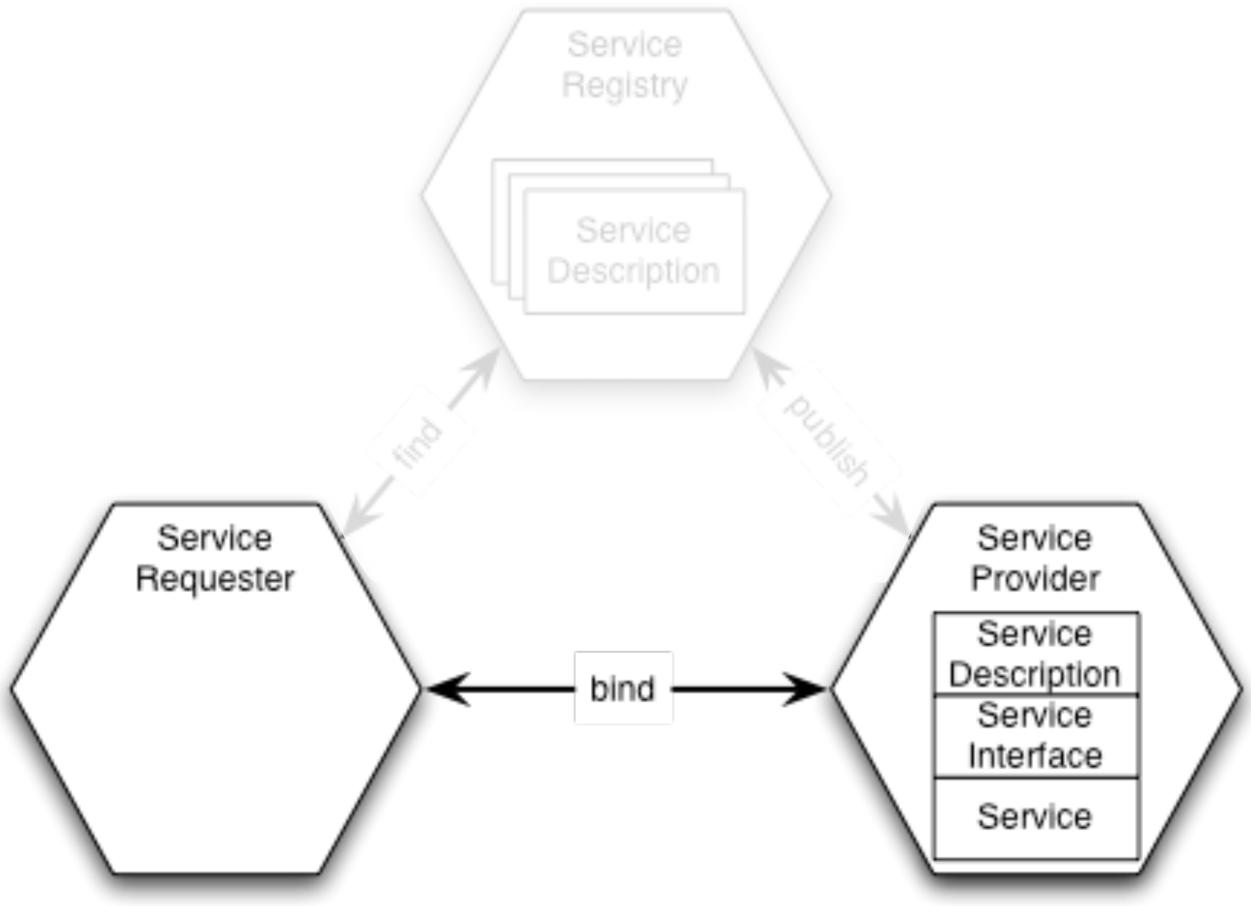


[Web Services; Springer 2004]

What is a Web Service?

Core Elements

- The components:
  - Service requester: The potential user of a service
  - Service provider: The entity that implements the service and offers to carry it out on behalf of the requester
  - Service registry: A place where available services are listed



Dr.-Ing. Michael Eichberg

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“Classical” Web Services

(using SOAP and WSDL)

What is a Web Service?

A Web service is a ***software system identified by a URI****, whose public* ***interfaces and bindings are defined and described using XML****.*

Its definition can be discovered by other software systems.

These systems may then interact with the Web service in a manner prescribed by its definition, using XML based messages conveyed by Internet protocols.

Definition by the W3C

What is a Web Service?

just one type of web services

Web Services are:

- *A standardized way of integrating web-based applications using the XML, SOAP, WSDL and UDDI open standards over an Internet protocol backbone.*
- *XML is used to tag the data, SOAP is used to transfer the data, WSDL is used for describing the services available and UDDI is used for listing what services are available.*

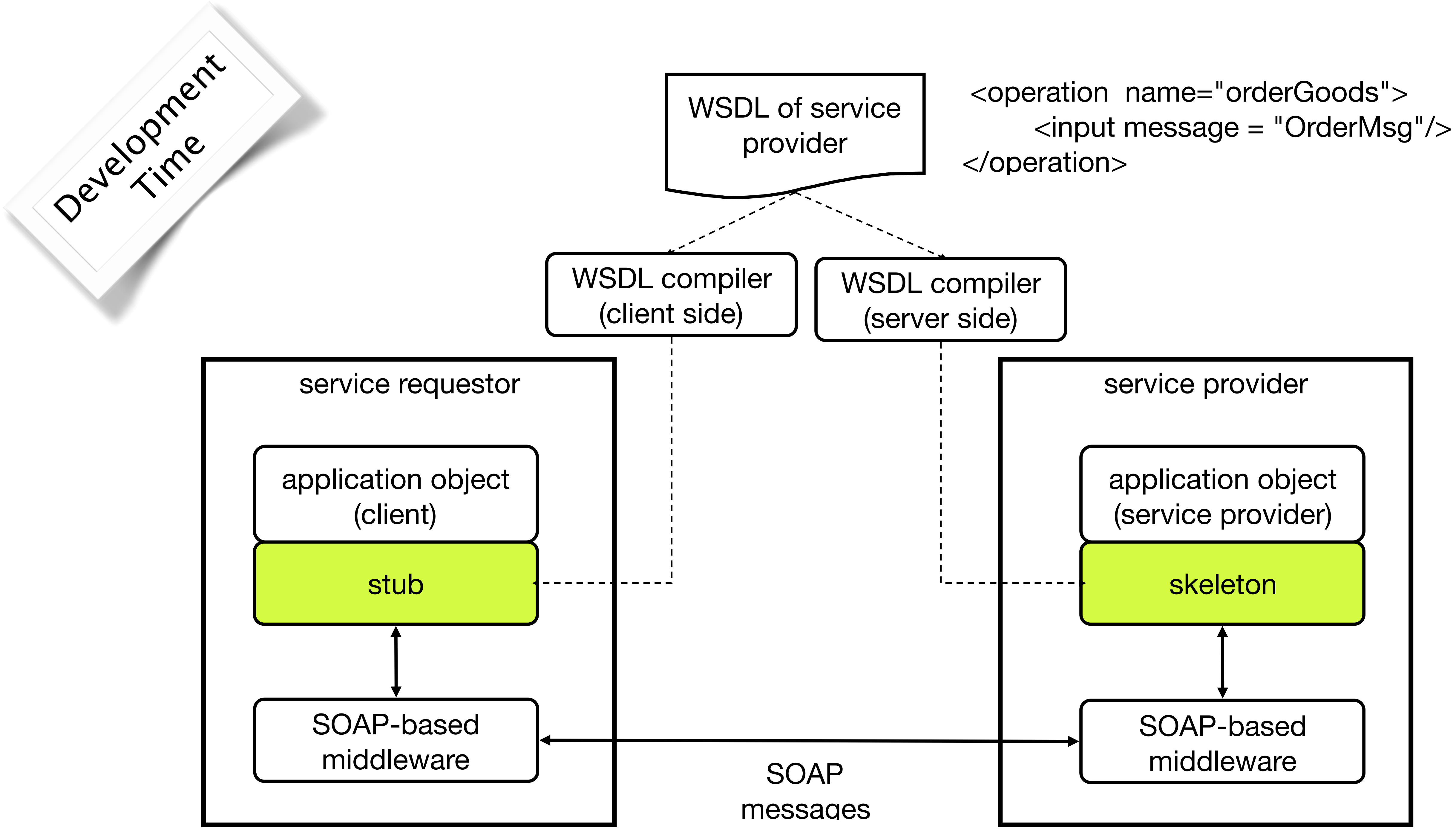
Definition by Webopedia

What is a Web Service?

Core Standards

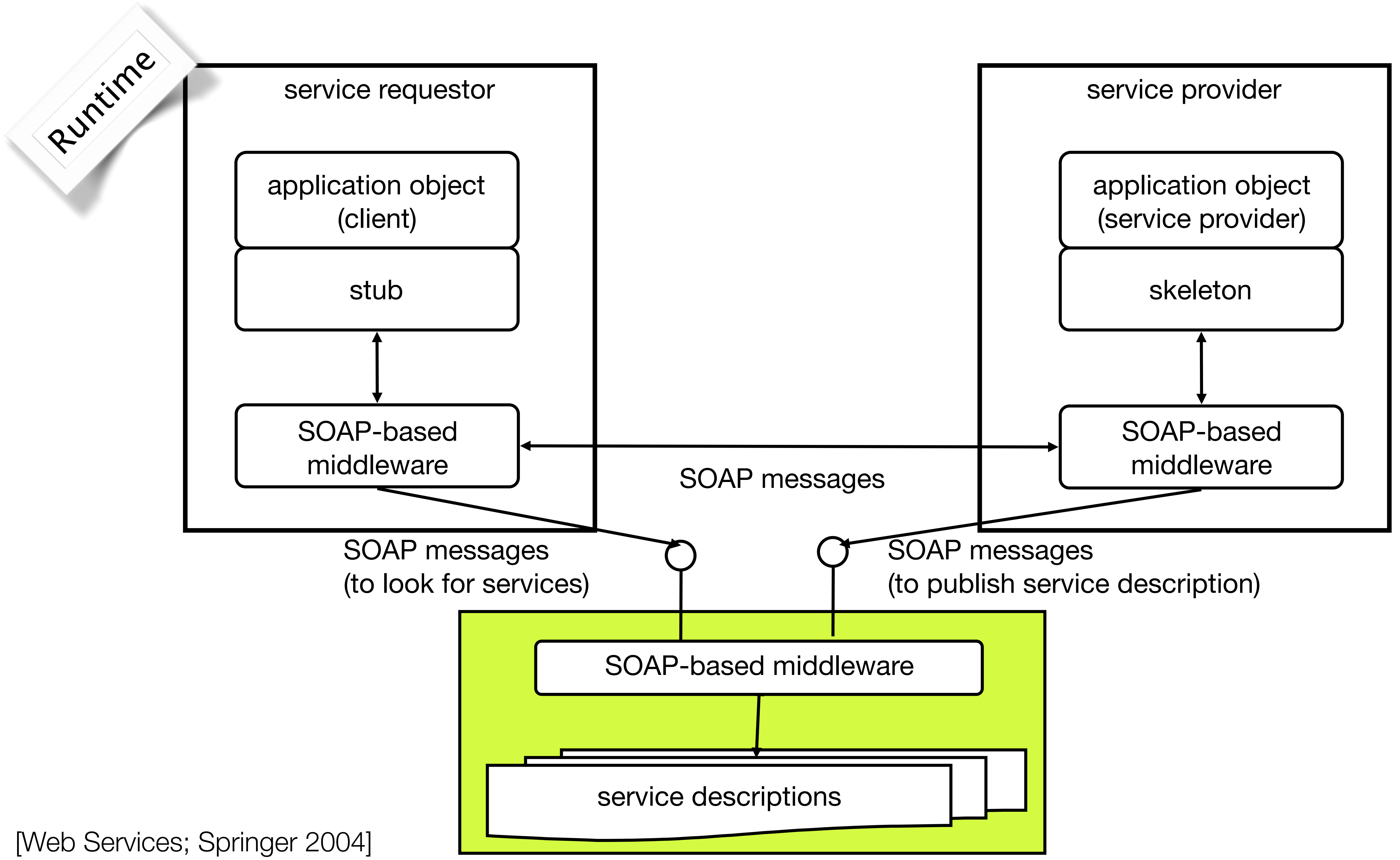
- Simple Object Access Protocol (**SOAP**)
  Web service message format
- Web Services Description Language (**WSDL**)
  Web service interface description
- Universal Description, Discovery, and Integration (UDDI)
  Web service discovery

Minimalist Infrastructure for Web Services


Development Time
WSDL of service provider
<operation name="orderGoods">
<input message = "OrderMsg"/>
</operation>
WSDL compiler (client side)
WSDL compiler (server side)
service requestor
application object (client)
stub
SOAP-based middleware
service provider
application object (service provider)
skeleton
SOAP-based middleware
SOAP messages

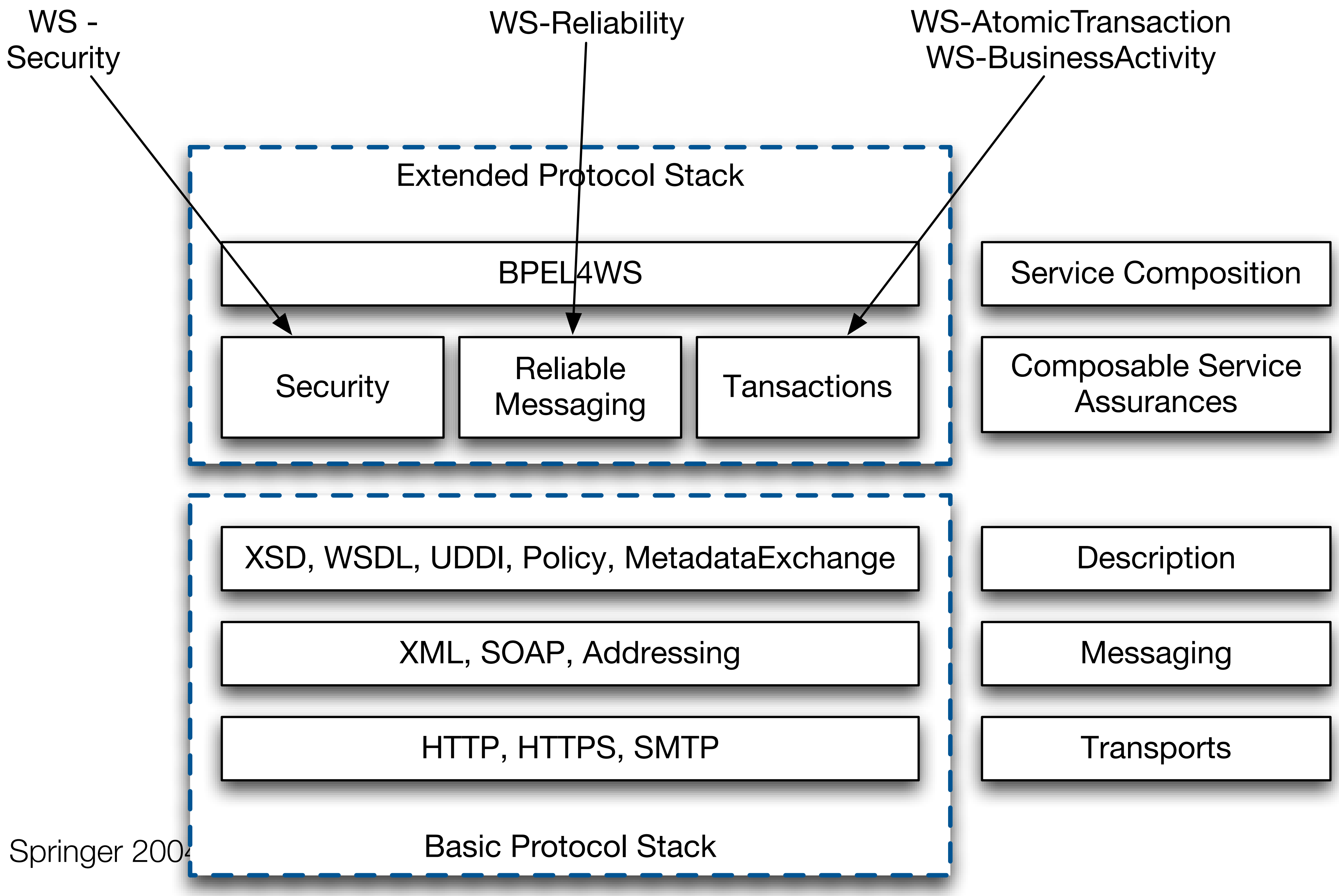
[Web Services; Springer 2004]

Minimalist Infrastructure for Web Services



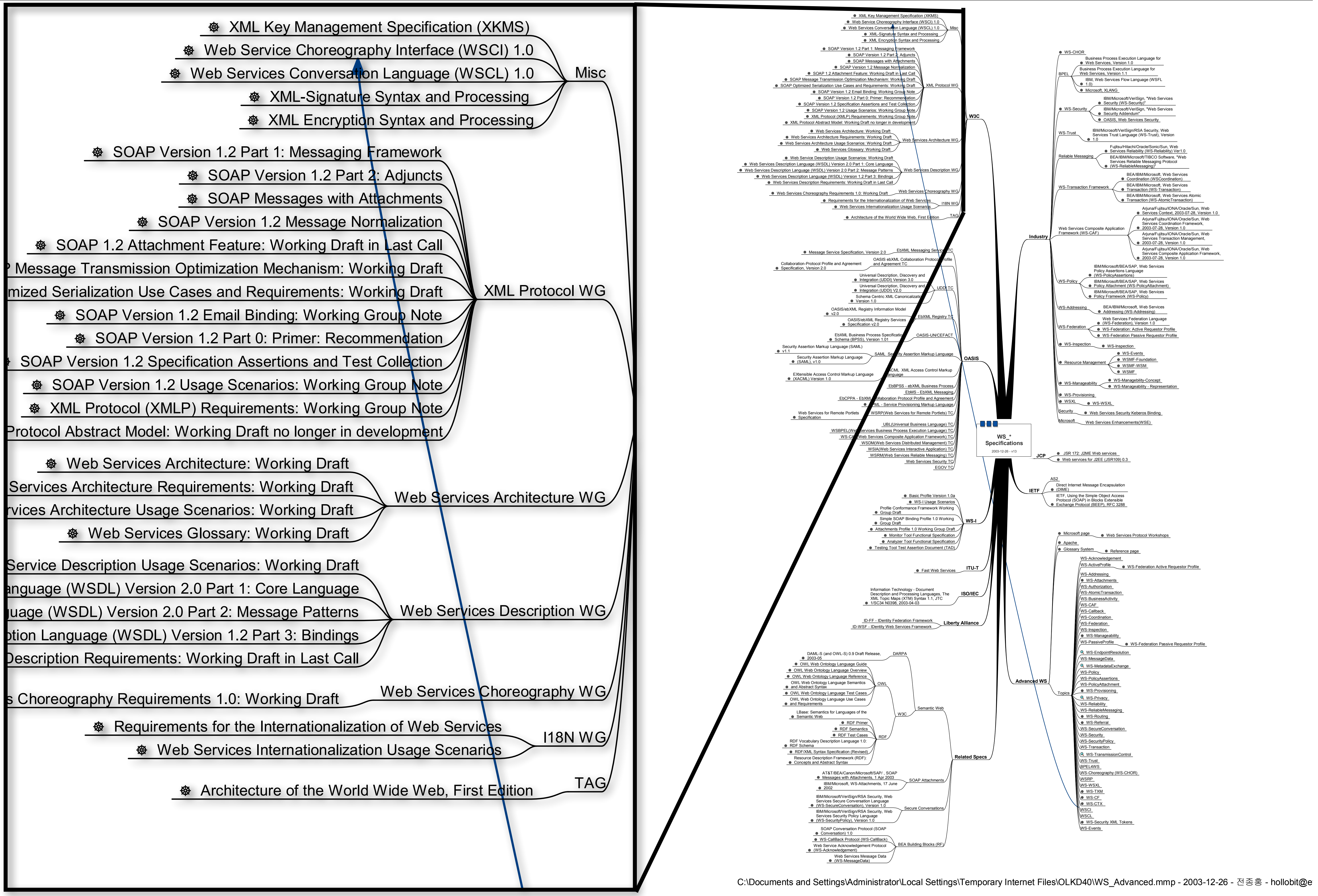
[Web Services; Springer 2004]

Web Services Protocol Stack



[Web Services; Springer 200

“Classical” Web Services


XML Key Management Specification (XKMS)
Web Service Choreography Interface (WSCI) 1.0
Web Services Conversation Language (WSCL) 1.0
XML-Signature Syntax and Processing
XML Encryption Syntax and Processing
Misc
SOAP Version 1.2 Part 1: Messaging Framework
SOAP Version 1.2 Part 2: Adjuncts
SOAP Messages with Attachments
SOAP Version 1.2 Message Normalization
SOAP 1.2 Attachment Feature: Working Draft in Last Call
P Message Transmission Optimization Mechanism: Working Draft
mized Serialization Use Cases and Requirements: Working Draft
SOAP Version 1.2 Email Binding: Working Group Note
SOAP Version 1.2 Part 0: Primer: Recommendation
SOAP Version 1.2 Specification Assertions and Test Collection
SOAP Version 1.2 Usage Scenarios: Working Group Note
XML Protocol (XMLP) Requirements: Working Group Note
Protocol Abstract Model: Working Draft no longer in development
XML Protocol WG
Web Services Architecture: Working Draft
Services Architecture Requirements: Working Draft
rvices Architecture Usage Scenarios: Working Draft
Web Services Glossary: Working Draft
Web Services Architecture WG
Service Description Usage Scenarios: Working Draft
anguage (WSDL) Version 2.0 Part 1: Core Language
uage (WSDL) Version 2.0 Part 2: Message Patterns
ption Language (WSDL) Version 1.2 Part 3: Bindings
Description Requirements: Working Draft in Last Call
Web Services Description WG
s Choreography Requirements 1.0: Working Draft
Web Services Choreography WG
Requirements for the Internationalization of Web Services
Web Services Internationalization Usage Scenarios
I18N WG
Architecture of the World Wide Web, First Edition
TAG
W3C
OASIS
Industry
WS_* Specifications
2003-12-26 - v13
JCP
IETF
WS-I
ITU-T
ISO/IEC
Liberty Alliance
Advanced WS
Related Specs
C:\Documents and Settings\Administrator\Local Settings\Temporary Internet Files\OLKD40\WS_Advanced.mmp - 2003-12-26 - 전종홍 - hollobit@e

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RESTful Web Services

Some of the following slides are based upon the presentation:
RESTful Web Services; John Cowan; cowan@ccil.org
http://www.ccil.org/~cowan

What’s a Web Service?

(In the context of restful web services.)

- A web service is just a web page meant for a computer to request and process
- More precisely, a Web Service is a *“web page”* that’s meant to be consumed by an autonomous program as opposed to a web browser or similar UI tool

What’s a Web Service?

(In the context of restful web services.)

- Web Services require an **architectural style** to make sense of them, because there’s no smart human being on the client end to keep track
- The pre-web techniques of computer interaction don't scale on the Internet
  They were designed for small scales and single trust domains.

Architectural Style

- “...a set of design rules that identify the kinds of components and connectors that may be used to compose a system or subsystem."
- Some common examples of architectural styles include:
  - Pipes and Filter
  - Layered Architecture
  - ...

REST Style

Basically, a set of design principles to judge architectures.

- Client-server
- Stateless
- Cached
- Uniform interface
- Layered system
- (Code on demand)

RESTful?

- REST = Representational State Transfer
  (Basically, a set of design principles to judge architectures)
  - Resources are identified by uniform resource identifiers
  - Resources are manipulated through their representations
  - Messages are self-descriptive and stateless
  - Multiple representations are accepted or sent
  - Hypertext is the engine of application state

Here, hypertext basically means that a message/representations contains the necessary links to other resources.

- One possible architecture is “the” resource-oriented architecture (ROA)
  The ROA qualifies as being RESTful.
  - **Method information goes into the HTTP method**
  - **Scoping information goes into the URI/IRI**

RESTful Web Services

Foundations

- **HTTP**
  … as the underlying transport protocol; *important property: stateless*
- **URI** (or IRIs if you wish)
  ... to locate resources
- **XML or JSON (not necessarily, but in most cases) (Alternative XHTML)**
  … to get a representation
  (The Web already supports machine-to-machine integration. What's not machine-processable about the current Web (i.e. HTML) isn't the protocol, it's the content.)

Surfing the Web

Surfing the web:

- To fetch a web page, the browser does a `GET` on some URI and retrieves a representation (HTML, plain text, JPEG, or whatever) of the resource identified by that URI
- `GET` is fundamental to browsers because mostly they just browse
- **REST requires a few more verbs to allow taking actions**
  (However, in REST we use universal verbs only.)

“Universal Verbs”

- `GET`
  … to retrieve information
- `POST`
  … to add new information, showing its relation to old information
- `PUT`
  … to update information
- `DELETE`
  … to discard information

Web Pages as Resources

Nouns...

- A web page is a representation of a resource
- **Resources are just concepts**
- URIs tell a client that there's a concept somewhere
- **Clients** can then **request a specific representation** of the concept from the representations the server makes available

Two Types of State

First: Application(/Session) State

- “State” means **application/session state**
  Application state is the information necessary to understand the context of an interaction
  (Authorization and authentication information are examples of application state.)
- Maintained as part of the content transferred from client to server and back to client
- Thus <u>any server can potentially continue a transaction from the point where the transaction was left off</u>

Two Types of State

Second: Resource State

- **Resource state** is the kind of state that the S in REST refers to
- The "stateless" constraint means that all messages must include all application state
  (Basically, that we don’t have sessions.)

(Multiple) Representations

- Most resources have only a single representation
  REST can support any media type, but XML/JSON is expected to be the most popular transport for structured information.
  (HTTP supports content negotiation.)
- XML makes it possible to have as many representations as you need
  - You can even view them in a clever way, thanks to the magic of XSLT and CSS
  - Links can be embedded
    Links mirror the structure of how a user makes progress through an application. The user is in control, thanks to the back button and other non-local actions. In a web service, the client should be in control in the same sense.

Test of RESTfulness

These tests are not anything like complete!

- Can I do a **`GET`** on the URLs that I **`POST`** to?
- If so, do I get something that in some way represents the state of what I've been building up with the **`POST`**s?
  (HTML forms almost always fail miserably.)
- Would the client notice if the server were to be...
  - restarted at any point between requests,
  - re-initialized by the time the client made the next request.

Is REST Enough?

Is a “uniform” interface enough?

- What happens when you think you need application semantics that don't fit into the GET / PUT / POST / DELETE generic interfaces and representational state model?
  - People tend to assume that the REST answer is:
    - If the problem doesn't fit HTTP, build another protocol
    - Extend HTTP by adding new HTTP methods (e.g. WEBDav, WEBCal,..).
- However, the four standard verbs are considered sufficiently general!

RESTful Web Services
a first Example

http://www.peej.co.uk/articles/restfully-delicious.html

Example (Based Upon del.icio.us)

- Lets start with describing what it is the Web Service does
- It allows us to:
  - Get a list of all our bookmarks and to filter that list by tag or date or limit by number
  - Get the number of bookmarks created on different dates
  - Get the last time we updated our bookmarks
  - Get a list of all our tags
  - Add a bookmark
  - Edit a bookmark
  - Delete a bookmark
  - Rename a tag

Resources

Example (based upon del.icio.us)

- Bookmarks
  `http://del.icio.us/api/[username]/bookmarks`
- Tags
  `http://del.icio.us/api/[username]/tags`
- [username] is the username of the user's bookmarks we're interested in

Beware - URI design is important,
but not the most important aspect!

Resource Representations

Example (based upon del.icio.us)

- We define some XML document formats and mimetypes to identify them:

Mimetype	Description
delicious/bookmarks+xml	A list of bookmarks
delicious/bookmark+xml	A bookmark
delicious/bookmarkcount+xml	Count of bookmarks per date
delicious/update+xml	When the bookmarks were last updated
delicious/tags+xml	A list of tags
delicious/tag+xml	A tag

Getting Bookmarks

URL	http://del.icio.us/api/*[username]*/**bookmarks**/	
Method	GET	
Querystring	tag=	Filter by tag
	dt=	Filter by date
	start=	The number of the first bookmark to return
	end=	The number of the last bookmark to return
Returns	200 OK & XML (delicious/bookmarks+xml)	
	401 Unauthorized	
	404 Not Found	

Getting Bookmarks

Example delicious/bookmarks+xml document

```
GET http://del.icio.us/api/peej/bookmarks/?start=1&end=2

<?xml version="1.0"?>
<bookmarks start="1" end="2"
    next="http://del.icio.us/api/peej/bookmarks?start=3&amp;end=4">
    <bookmark url="http://www.example.org/one" tags="example,test"
        href="http://del.icio.us/api/peej/bookmarks/a211528fb5108cddaa4b0d3aeccdbdcf"
        time="2005-10-21T19:07:30Z">
        Example of a Delicious bookmark
    </bookmark>
    <bookmark url="http://www.example.org/two" tags="example,test"
        href="http://del.icio.us/api/peej/bookmarks/e47d06a59309774edab56813438bd3ce"
        time="2005-10-21T19:34:16Z">
        Another example of a Delicious bookmark
    </bookmark>
</bookmarks>
```

Get Information on a Specific Bookmark

URL	http://del.icio.us/api/[username]/bookmarks/**[hash]**
Method	GET
Returns	200 OK & XML (delicious/bookmark+xml)
	401 Unauthorized
	404 Not Found

Get Information on a Specific Bookmark

Example delicious/bookmarks+xml document

```
GET http://del.icio.us/api/peej/bookmarks/a211528fb5108cddaa4b0d3aeccdbdcf

<?xml version="1.0"?>
<bookmark url="http://www.example.org/one" time="2005-10-21T19:07:30Z">
    <description>
        Example of a Delicious bookmark
    </description>
    <tags count="2">
        <tag name="example" href="http://del.icio.us/api/peej/tags/example"/>
        <tag name="test" href="http://del.icio.us/api/peej/tags/test"/>
    </tags>
</bookmark>
```

Get Count of Posts per Date

URL	http://del.icio.us/api/[username]/bookmarks/**count**	
Method	GET	
Querystring	tag=	filter by tag
Returns	200 OK & XML (delicious/bookmark+xml)	
	401 Unauthorized	
	404 Not Found	

Get Last Update Time for the User

URL	http://del.icio.us/api/[username]/bookmarks/**update**
Method	GET
Returns	200 OK & XML (delicious/bookmark+xml)
	401 Unauthorized
	404 Not Found

Add a Bookmark

URL	http://del.icio.us/api/[username]/bookmarks/
Method	**POST**
Request Body	XML (delicious/bookmark+xml)
Returns	201 Created & Location
	401 Unauthorized
	415 Unsupported Media Type (if the send document is not valid)

Add a Bookmark

Example delicious/bookmarks+xml document

```
POST http://del.icio.us/api/peej/bookmarks/

<?xml version="1.0"?>
<bookmark url="http://www.example.org/one"
    time="2005-10-21T19:07:30Z">
    <description>Example of a Delicious bookmark</description>
    <tags>
        <tag name="example" />
        <tag name="test" />
    </tags>
</bookmark>
```

Modify a Bookmark

URL	http://del.icio.us/api/[username]/bookmarks/[hash]
Method	**PUT**
Request Body	XML (delicious/bookmark+xml)
Returns	201 Created & Location
	401 Unauthorized
	404 Not Found (new bookmarks cannot be created using put!)
	415 Unsupported Media Type (if the send document is not valid)

Delete a Bookmark

URL	http://del.icio.us/api/[username]/bookmarks/[hash]
Method	DELETE
Returns	204 No Content
	401 Unauthorized
	404 Not Found

Using the Service

Example scenario - navigating and deleting entries

- **GET http://del.icio.us/api/**
  Fetching the API's homepage. We parse the response XML and find the tags URL of the user with the name "Peej"…
- **GET http://del.icio.us/api/peej/tags/**
  We parse the XML and see if the tag "test" is mentioned. If it isn't, then we GET the URL in the "next" attribute and try again. Eventually we'll get the URL http://del.icio.us/api/peej/tags/test...
- **GET http://del.icio.us/api/peej/tags/test**
  We've got the details for the tag "test", i.e. all bookmarks with the tag. Eventually we'll have a list of all bookmarks tagged with "test".
- **DELETE http://del.icio.us/api/peej/bookmarks/[hash]**
  Finally we can walk through our list of bookmarks and call the DELETE HTTP method on each of their URLs.

RESTful Web Services
a second Example using Jersey

(Developing RESTful Web Services using JAX-RS 1.0 (JSR 311))

https://jersey.dev.java.net/

A First Example

Implementation

```
package samples.helloworld.resources;
import javax.ws.rs.*;

// The Java class will be hosted at the URI path "/helloworld"
@Path("/helloworld")
public class HelloWorldResource {

  // The Java method will process HTTP GET requests
  @GET
  // The Java method will produce content identified by
  // the MIME Media type "text/plain"
  @Produces("text/plain")
  public String getClichedMessage() {
    return "Hello World";
  }

  @POST
  @Consumes("text/plain")
  public void postClichedMessage(String message) {
    // Store the message
  }
}
```

The annotation's value is a relative URI path.

The @GET annotation is a request method designator, along with@POST, @PUT, @DELETE, and @HEAD, that is defined by JAX-RS, and which correspond to the similarly named HTTP methods.

The @Produces annotation is used to specify the MIME media types of representations a resource can produce and send back to the client.

The @Consumes annotation is used to specify the MIME media types of representations a resource can consume that were sent by the client.

The `@Path` Annotation and URI Path Templates

JAX RS 1.0 Mini-Tutorial

- The **`@Path`** annotation identifies the URI path template to which the resource responds, and is specified at the class level of a resource
- The **`@Path`** annotation's value is a partial URI path template relative to the base URI of the server on which the resource is deployed
- URI path templates are URIs with variables embedded within the URI syntax. These variables are substituted at runtime in order for a resource to respond to a request based on the substituted URI

```
GIVEN:
@Path("/users/{username}")
public class UserResource {
    @GET @Produces("application/xml")
    public String getUser(@PathParam("username") String userName) { ... }
}

THEN THE URL: http://example.com/users/Galileo
WILL RESULT IN A CALL OF THE “getUser” METHOD WHERE THE “userName” is set to “Galileo”.
```

Using `@Consumes` and `@Produces`

Customize Requests and Responses - JAX RS 1.0 Mini-Tutorial

- The information sent to a resource and then passed back to the client is specified as a MIME media type in the headers of an HTTP request or response
- The **`@Produces`** annotation is used to specify the MIME media types or representations a resource can produce and send back to the client

  -
    ```
    @GET
    @Produces("text/html")
    public String getHtml() {
        return "<html><body><h1>Hello World!</body></h1></html>";
    }
    ```

Using `@Consumes` and `@Produces`

Customize Requests and Responses - JAX RS 1.0 Mini-Tutorial

- The `@Consumes` annotation is used to specify which MIME media types of representations a resource can accept, or consume, from the client. E.g. Consuming form data:

  -
    ```
    @POST @Consumes("application/x-www-form-urlencoded")
    public void post(@FormParam("name") String name) {
        // Store the message
    }
    e.g. to make a HTTP "POST" call use curl:
    curl -d "description=LSP%20-%20Liskov-substitution-principle" http://localhost:8080/
    glossary/LSP
    ```

  -
    ```
    @POST @Consumes("text/plain")
    public void postClichedMessage(String message) {
        // Store the message
    }
    ```