

Middleware and Web Services

Lecture 7: Service Concepts and Technologies

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Service Oriented Architecture



- SOA supports two core business strategies
 - Growing top-line revenue
 - Enterprise reacts quickly to requirements from the market
 - Business processes can be reconfigured rather than reimplemented
 - Improving bottom-line profit
 - Saving development costs by reusing existing services
- Pre-integrated solutions
 - Out-of-the-box applications and integration solutions among them

Overview

- Integrating Applications
- Web Service Architecture
- Web Service Technologies

Integration and Interoperability

- Integration
 - *A process of connecting applications so that they can exchange and share capabilities, that is — information and functionalities.*
 - *Includes methodological approaches as well as technologies*
- Interoperability
 - *Ability of two or more applications to understand each other*
 - *Interoperability levels*
 - *Data – syntax/structure and semantics*
 - *Functions/Processes – syntax and semantics*
 - *Technical aspects – protocols, network addresses, etc.*

Integration Approaches Overview



Data-oriented Integration



- Third-party database access
 - Application D accesses a database of application B directly by using SQL and a knowledge of database B structure and constraints
 - In the past: monolithic and two-tier client/server architectures
 - Today: ETL (Extract, Transform, Load) technologies
- Problems
 - App D must understand complex structures and constraints
 - Data – very complex, includes structure and integrity constraints
 - Functions/processes – hidden in integrity constraints
 - Technical – access mechanisms can vary

Service-oriented Integration



- Integration at the application layer
 - Application exposes services that other applications consume
 - Services hide implementation details but only define interfaces for integration
- Problems
 - Can become unmanageable if not properly designed
 - Interoperability
 - Data – limited to input and output messages only
 - Functions/processes – limited to semantics of services
 - Technical – access mechanisms can vary

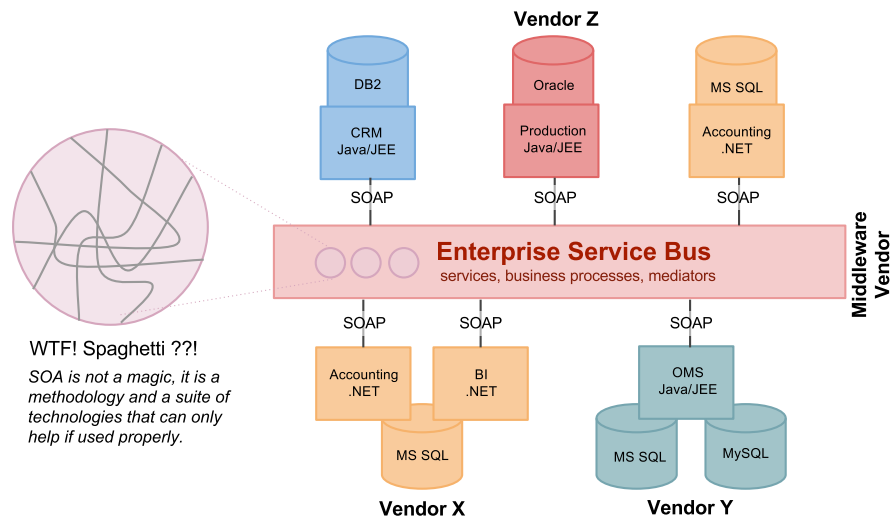
One-to-One Service Integration

- Direct integration of applications
 - Multiple protocols problem, multiple vendor problem
 - Replication of integration functionalities such as interoperability solutions



Many-to-Many Service Integration

- Enterprise Service Bus – central integration technology
 - Realizes so called Service Oriented Architecture (SOA)
 - Contains various integration components such as process server, mediators, messaging middleware, identity management, etc.



Integration and Types of Data

- Transactional data – Web services
 - Service-oriented integration
 - online, realtime communication between a client and a service
 - Usually small amount of data and small amount of service invocation in a process
- Bulk data – ETL
 - Data-oriented integration
 - processing of large amount of data in batches
- **ESB provides both Web service and ETL capabilities**

Overview

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- Web Service Technologies

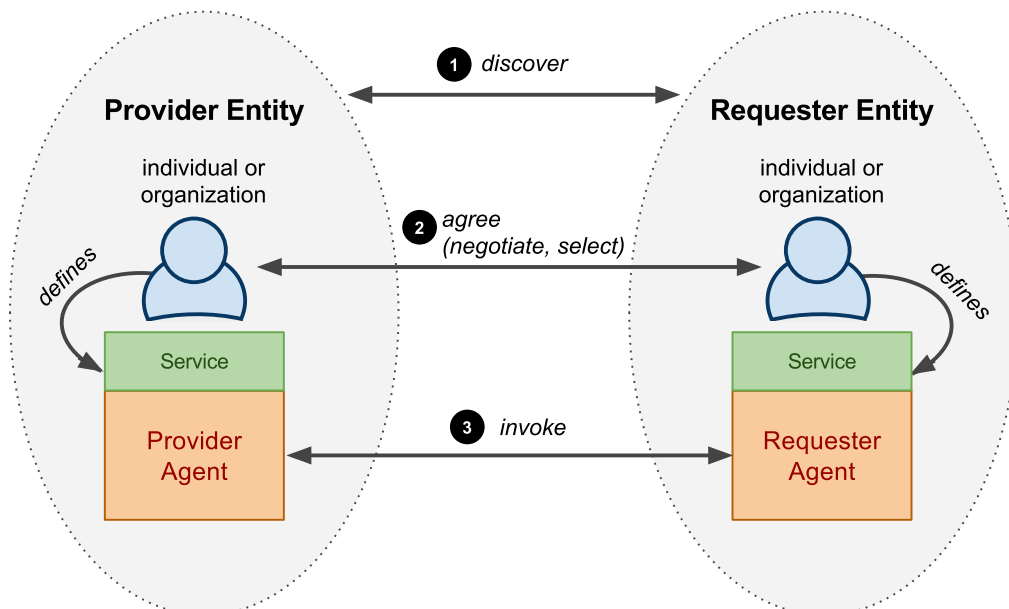
Web Service Architecture

- Web Service Architecture
 - Defined by W3C in *Web Service Architecture Working Group Note* [🔗](#)
 - Defines **views**
 - *message-oriented view (WSDL and SOAP)*
 - *resource-oriented view (REST and HTTP)*
 - Defines **architecture entities** and their **interactions**
 - *Abstraction over underlying technology*
 - *Basis for service usage processes and description languages*
- Service Oriented Architecture
 - *Collection of tools, methods and technologies*
 - *There is some implicit understanding of SOA in the community such as*
 - *SOA provides advances over Enterprise Application Integration*
 - *SOA is realized by using SOAP, WSDL, (and UDDI) technologies*
 - *SOA utilizes Enterprise Service Bus (ESB)*
 - ⇒ *~ a realization of Web Service Architecture message-oriented view*

Basic Entities

- **Agent**
 - *software or hardware that sends/receives messages*
 - *concrete implementation of a service*
- **Service**
 - *abstract set of functionality and behavior*
 - *two different agents may realize the same service*
- **Provider**
 - *owner (person or organization) that provides an agent realizing a service*
 - *also called a service provider*
- **Requester**
 - *a person or organization that wishes to make use of a provider's service*
 - *uses a requester's agent to exchange messages with provider's agent*

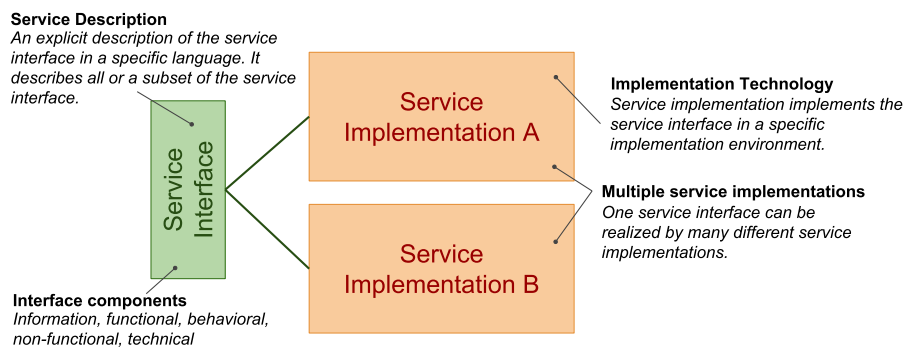
Interaction of Entities



Service

- Difficult to agree on one definition
- Business definition
 - *A service realizes an effect that brings a business value to a service consumer*
→ *for example, to pay for and deliver a book*
- Conceptual definition
 - *service characteristics*
→ *encapsulation, reusability, loose coupling, contracting, abstraction, discoverability, composability*
- Logical definition
 - *service interface, description and implementation*
 - *service usage process*
→ *service use tasks, service types*
- Architectural definition
 - *business service (also application service)*
→ *external, exposed functionality of an application*
 - *infrastructure service*
→ *internal/technical, supports processing of requests*

Interface, Description and Implementation



- Terminology clarification
 - *service ~ service interface + service implementation*
 - *WSDL service ~ service description in WSDL language*
 - *SOAP service ~ a service interface is possible to access through SOAP protocol; there is a WSDL description usually available too.*
 - *REST/RESTful service ~ service interface that conforms to REST architectural style and HTTP protocol*

Service Characteristics

Loose Coupling

The requester agent's implementation is independent from service usage. That is, there is no "hard-wired" knowledge required to use the service.

Reusability

The service can be used in many different scenarios by different requester agents that are unforeseen during the service design.

Contracting

The service interface is a contract between the requester and the provider. They both agree to follow the service description in order to achieve interoperability.

Abstraction

Service interface is abstracted from underlying service implementation as well as all software and hardware technology.

Discoverability

Requester can discover the service interface and decide how to use it.

Encapsulation

The provider agent implementation is hidden to the requester agent accessing the service. The requester agent only knows the service interface to consume its functionality.

Composability

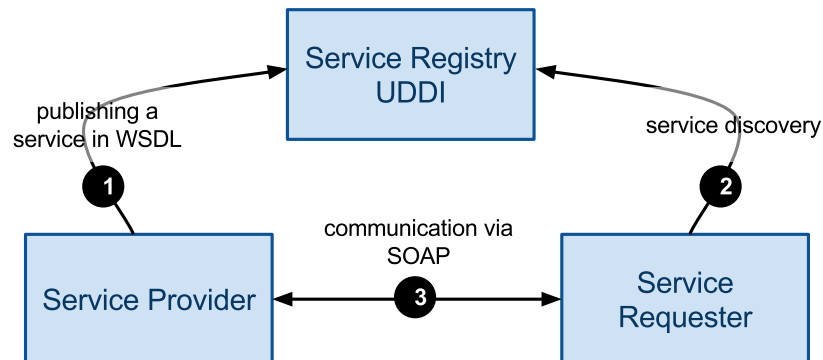
It is possible to compose services into more complex processes. Such processes can again be accessed as services.

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 - *SOAP*
 - *WSDL*
 - *WS-Addressing*
 - *REST*
 - *Comparison*

Web Service Architecture

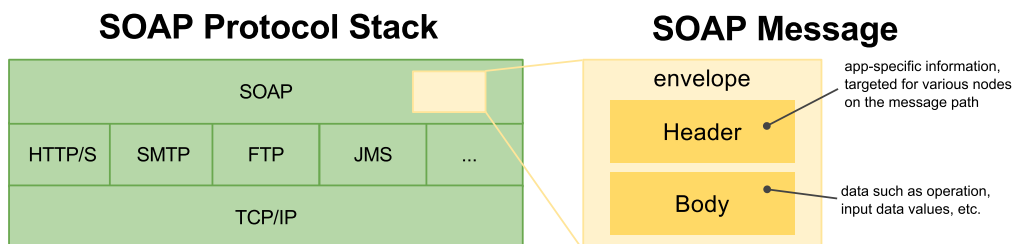
- WSDL, SOAP and UDDI



- *Realization of SOA*
- *Message-Oriented view*
 - *SOAP messaging (header, body)*
 - *types of messages – input, output, fault*

SOAP Protocol

- SOAP defines a messaging framework



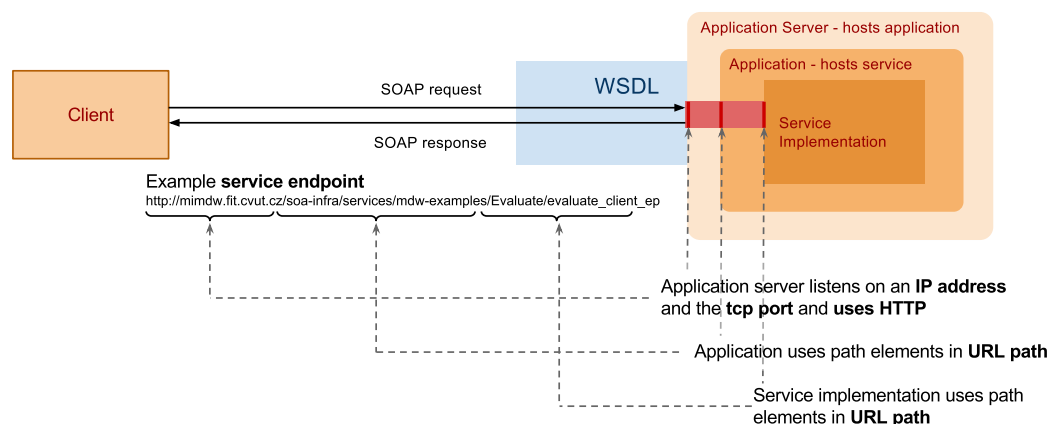
- *XML-based protocol*
- *a layer over transport protocols*
 - *binding to HTTP, SMTP, JMS, ...*
- *involves multiple nodes (message path)*
 - *sender, receiver, intermediary*

SOAP Message

- Envelope
 - *A container of a message*
- Header
 - *Metadata – describe a message, organized in header blocks*
 - *routing information*
 - *security measures implemented in the message*
 - *reliability rules related to delivery of the message*
 - *context and transaction management*
 - *correlation information (request and response message relation)*
 - *WS extensions (WS-*) utilize the message header*
- Body (payload)
 - *Actual contents of the message, XML formatted*
 - *Contains also faults for exception handling*
- Attachment
 - *Data that cannot be serialized into XML such as binary data*

Endpoint

- SOAP service endpoint definition



- *Endpoint – a network address used for communication*
- *Communication – request-response, SOAP messages over a communication (application) protocol*
- *Synchronous communication – only service defines endpoint*
- *Asynchronous communication – service and client define endpoints*

Service Invocation Example (1)

- Example service implementation
 - A service that evaluates an expression
 - Uses SOAP over HTTP
 - We can use standard HTTP tools to invoke the service
- SOAP request message

evaluate-input.xml

```
1 <soap:Envelope xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/">
2   <soap:Body>
3     <ns1:evaluateRequest
4       xmlns:ns1="http://xmlns.oracle.com/mdw_examples/Evaluate/evalu
5         <ns1:x>12</ns1:x>
6         <ns1:y>18</ns1:y>
7       </ns1:evaluateRequest>
8     </soap:Body>
9 </soap:Envelope>
```

- Invoking the service using `curl`

```
1 curl -s -X POST --header "Content-Type: text/xml; charset=UTF-8" \
2 --header "SOAPAction: \"evaluate\"" --data @evaluate-input.xml \
3 http://mimdw.fit.cvut.cz/soa-infra/services/mdw-examples/Evaluate/evaluate_cli
```

Service Invocation Example (2)

- Invocation result

```
1 * About to connect() to mimdw.fit.cvut.cz port 80 (#0)
2 * Trying 147.32.233.55... connected
3 * Connected to sb.vitvar.com (147.32.233.55) port 80 (#0)
4 > POST /soa-infra/services/mdw-examples/Evaluate/evaluate_client_ep HTTP/1.1
5 > User-Agent: curl/7.19.7 (x86_64-redhat-linux-gnu) libcurl/7.19.7 NSS/3.14.0.
6 > Host: mimdw.fit.cvut.cz
7 > Accept: */*
8 > Content-Type: text/xml; charset=UTF-8
9 > SOAPAction: "evaluate"
10 > Content-Length: 302
11 >
12 } [data not shown]
13 < HTTP/1.1 200 OK
14 < Date: Sun, 17 Nov 2013 11:24:59 GMT
15 < Server: Oracle-Application-Server-11g
16 < Content-Length: 569
17 < X-ORACLE-DMS-ECID: 004upqiWhdD0zkWVlybQ8A0005uX0004Y^
18 < SOAPAction: ""
19 < X-Powered-By: Servlet/2.5 JSP/2.1
20 < Content-Type: text/xml; charset=UTF-8
21 < Content-Language: en
```

Service Invocation Example (3)

- SOAP response message

```
1  <?xml version="1.0"?>
2  <env:Envelope xmlns:env="http://schemas.xmlsoap.org/soap/envelope/"
3      xmlns:wsa="http://www.w3.org/2005/08/addressing">
4      <env:Header>
5          <wsa:MessageID>urn:E42018C04F7A11E3BFD5D1953058407C</wsa:MessageID>
6      </env:Header>
7      <env:Body>
8          <evaluateResponse
9              xmlns="http://xmlns.oracle.com/mdw_examples/Evaluate/evaluate">
10             <result>30</result>
11          </evaluateResponse>
12      </env:Body>
13  </env:Envelope>
```

Client Implementation

- WSDL – Web Service Description Language
 - definitions for the client to know how to communicate with the service
 - which operations it can use
 - data formats for input (request), output (response) and fault messages
 - how to serialize the data as payloads of a communication protocol (binding)
 - where the service is physically present on the network
- Clients' environments
 - Clients implemented in a language such as Java
 - Tools to generate service API for the client, e.g. WSDL2Java
 - Can be written manually too, e.g. our example in bash
 - Clients reside on the middleware, e.g. on an Enterprise Service Bus
 - They provide added values in end-to-end communication, proxy services, SOAP intermediaries

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 - *SOAP*
 - *WSDL*
 - *WS-Addressing*
 - *REST*
 - *Comparision*

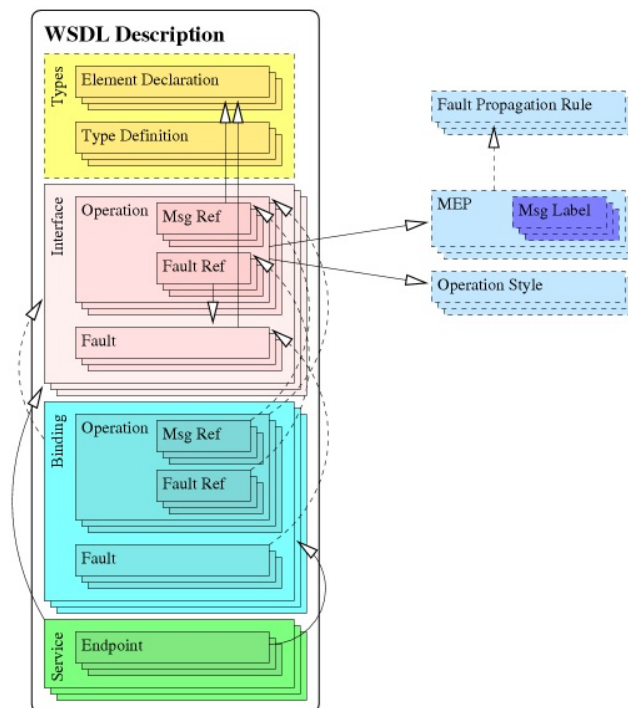
Specifications

- WSDL = Web Service Description Language
 - *A standard that allows to describe Web services explicitly (main aspects)*
 - *A contract between a requester and a provider*
- Specifications
 - *WSDL 1.1 – still widely used*
 - *Web Service Description Language 1.1* [↗](#)
 - *WSDL 2.0 – An attempt to address several issues with WSDL 1.1*
 - *SOAP vs. REST, naming, expressivity*
 - *WSDL 2.0 Primer (part 0)* [↗](#)
 - *WSDL 2.0 Core Language (part 1)* [↗](#)

WSDL Overview and WSDL 1.1 Syntax

- Components of WSDL
 - Information model (**types**)
 - Element types, message declarations (XML Schema)
 - Set of operations (**portType**)
 - A set of operations is "interface" in the WSDL terminology
 - operation name, input, output, fault
 - Binding (**binding**)
 - How messages are transferred over the network using a concrete transport protocol
 - Transport protocols: HTTP, SMTP, FTP, JMS, ...
 - Endpoint (**service**)
 - Where the service is physically present on the network
- Types of WSDL documents
 - **Abstract WSDL** – only information model and a set of operations
 - **Concrete WSDL** – everything, a concrete service available in the environment

WSDL Components and Dependencies



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Overview

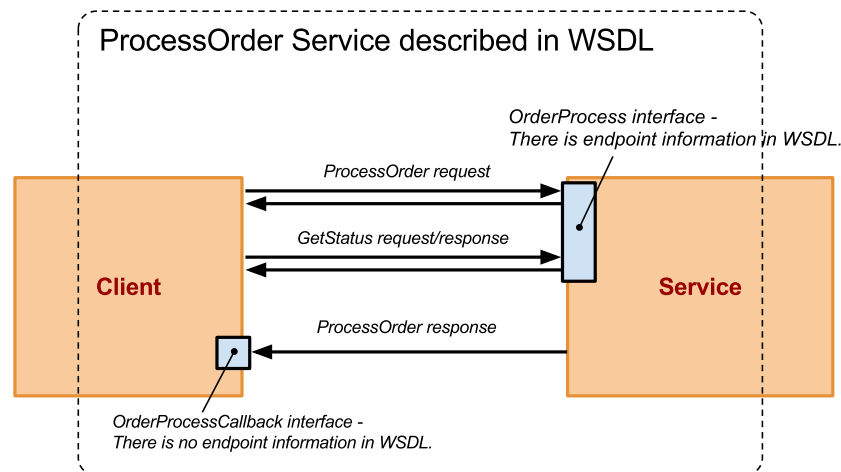
- WS-Addressing
 - W3C Recommendation, May 2006 [🔗](#)
 - A transport-independent mechanisms for web services to communicate addressing information
 - WSDL describes WS-Addressing as a policy attached to a WSDL binding

```
1 <binding name="OrderProcessBinding" type="op:OrderProcess">
2   <soap:binding transport="http://schemas.xmlsoap.org/soap/http"/>
3   <PolicyReference xmlns:wsp="http://schemas.xmlsoap.org/ws/2004/09/polic
4     URI="#wsaddr_policy" wsdl:required="false"/>
```

- Two main purposes
 1. Asynchronous communication
 - Client sends an endpoint where the server should send a response asynchronously
 2. Relating interactions to a conversation
 - Client and service communicate conversation ID

Order Processing Example

- Asynchronous communication via callback, steps:
 - Client submits an order request
 - Service starts processing of the order (CRM, OMS, back-office)
 - Client can retrieve the order status
 - Service responds asynchronously with an order response message



Interface Example (1)

- Order process complex conversation
 - The client invokes **processOrder**.
 - The service responds back **synchronously** with order status.
 - The client gets the status of order processing by invoking synchronous **getStatus** operation (this can be invoked several times).
 - The service responds back **asynchronously** by invoking **processOrderResponse** – callback on client's interface
- Interface implemented by the order process service
 - getStatus** operation must be executed in the same **conversation** as **processOrder** operation

```
1 <portType name="OrderProcess">
2   <operation name="processOrder">
3     <input message="op:OrderProcessRequestMessage"/>
4     <output message="op:OrderStatusResponseMessage"/>
5   </operation>
6   <operation name="getStatus">
7     <input message="op:OrderStatusRequestMessage"/>
8     <output message="op:OrderStatusResponseMessage"/>
9   </operation>
10 </portType>
```

Interface Example (2)

- Interface implemented by the client

```
1 <portType name="OrderProcessCallback">
2   <operation name="processOrderResponse">
3     <input message="op:OrderProcessResponseMessage"/>
4     <fault message="op:OrderProcessFaultMessage"/>
5   </operation>
6 </portType>
```

ProcessOrder Request Message

- Client sends process order request – **processOrder**
 - it sends addressing information where the client listens for the callback
 - it sends conversation ID (message ID) to start the conversation on the server

```
1 > POST /soa-intra/services/mdw-examples/ProcessOrder/orderprocess_client_ep HTTP/1.1
2 > Host: mimdw.fit.cvut.cz
3 > Content-Type: text/xml; charset=UTF-8
4 > SOAPAction: "processOrder"
5 > Content-Length: 810
6
7 <soap:Envelope xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/"
8   xmlns:ord="http://mimdw.fit.cvut.cz/mdw-examples/cdm/order">
9   <soap:Header xmlns:wsa="http://www.w3.org/2005/08/addressing">
10     <wsa:ReplyTo>
11       <wsa:Address>http://192.168.94.110:2233/path/to/service</wsa:Address>
12     </wsa:ReplyTo>
13     <wsa:MessageID>urn:AXYYBA00531111E3BFACA780A7E5AF64</wsa:MessageID>
14   </soap:Header>
15   <soap:Body>
16     <ord:Order>
17       <ord:CustomerId>1</ord:CustomerId>
18       <ord:LineItems>
19         <ord:item>
20           <ord:label>Apple MacBook Pro</ord:label>
21           <ord:action>ADD</ord:action>
22         </ord:item>
23       </ord:LineItems>
24     </ord:Order>
25   </soap:Body>
26 </soap:Envelope>
```

GetStatus Request Message

- Client sends get status request – **getStatus**
 - after it invokes **processOrder** with conversation ID (message ID)
 - it uses the same conversation ID for get status request too
 - the request will be processed by the running service instance

```
1 > POST /soa-infra/services/mdw-examples/ProcessOrder/orderprocess_client_ep HTTP/1.1
2 > Host: mimdw.fit.cvut.cz
3 > Content-Type: text/xml; charset=UTF-8
4 > SOAPAction: "getStatus"
5 > Content-Length: 472
6
7 <soap:Envelope xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/">
8   <soap:Header xmlns:wsa="http://www.w3.org/2005/08/addressing">
9     <wsa:RelatesTo>urn:AXYYBA00531111E3BFACA780A7E5AF64</wsa:RelatesTo>
10   </soap:Header>
11   <soap:Body>
12     <ns1:StatusRequest
13       xmlns:ns1="http://mimdw.fit.cvut.cz/mdw_examples/ProcessOrder/OrderProces
14     <ns1:process-id>18a9baec2d5ac0a2:64d155de:1425c4185f1:-7ff2</ns1:process-
15     </ns1:StatusRequest>
16   </soap:Body>
17 </soap:Envelope>
```

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 - **REST**
 - Comparison

REST

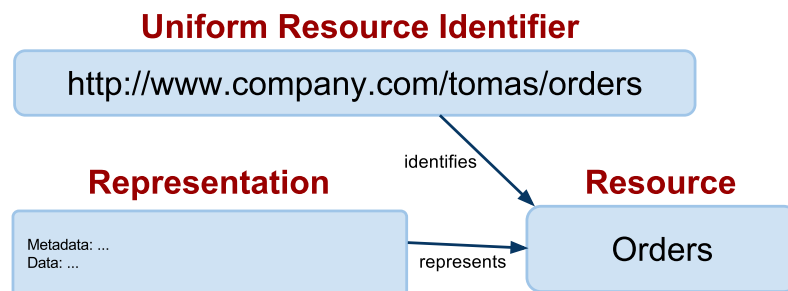
- REST
 - *Representational State Transfer*
- Architecture Style
 - Roy Fielding – co-author of HTTP
 - He coined REST in his PhD thesis [🔗](#).
 - The thesis abstracts from HTTP technical details
 - HTTP is one of the REST implementation → **RESTful**
 - REST is a leading programming model for Web APIs
- 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 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)

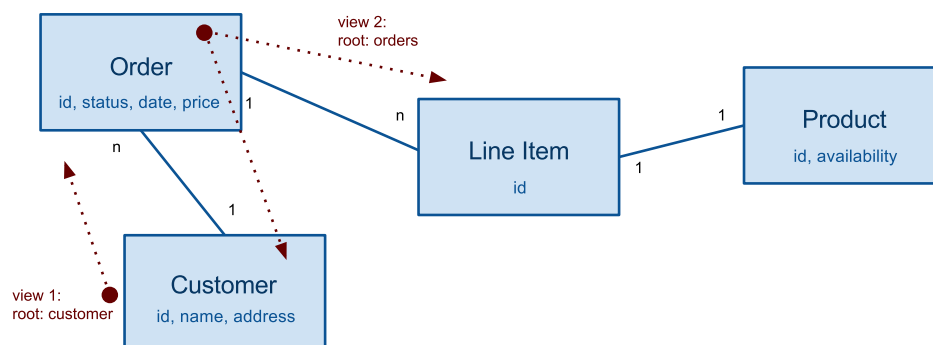
Resource

- A resource can be anything such as
 - A real object: car, dog, Web page, printed document
 - An abstract thing such as address, name, etc. → 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 (URI) and a representation (XML, JSON, ...) and a client can apply an access to it (use HTTP methods)



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
 - 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}`
- Various views represented by **URL path**

Uniform Interface

- Finite set of operations
 - *They are not dependent on the domain semantics*
 - *They only define how to manipulate with resources*
- RESTful service – HTTP methods
 - *GET* – reads a resource (+ *HEAD*, *OPTIONS*)
 - *PUT* – updates or creates a resource (+ *PATCH*)
 - *POST* – creates a new resource
 - *DELETE* – deletes a resource
- HTTP methods' properties
 - *a method is **safe***
 - *It does not change the application state (it does not modify the data)*
 - *GET, OPTIONS, HEAD*
 - *Results can be cached by intermediaries (e.g. proxy servers)*
 - *a method is **idempotent***
 - *Every method invocation will always have the same effect*
 - *GET, PUT, DELETE*

Examples

- Operation **getCustomerOrder(customerId, orderId)**
 - *Retrieves a representation of the order resource that belongs to a particular customer*
 - 1 | > GET /customers/{customerId}/orders/{orderId}
- Operation **openOrder(customerId)**
 - *Creates a new order for a customer*
 - 1 | > POST /customers/{customerId}/orders
 - 2 | < Location: /customers/{customerId}/orders/{orderId}
 - 3 |
 - 4 | > GET /customers/{customerId}/orders/{orderId}
- Operation **addLineItem(customerId, orderId)**
 - *Adds a new item to the order*
 - 1 | > POST /customers/{customerId}/orders/{orderId}
 - 2 | < Location: /customers/{customerId}/orders/{orderId}/items/{itemId}
 - 3 |
 - 4 | > GET /customers/{customerId}/orders/{orderId}/items/{itemId}
- Operation **closeOrder(customerId, orderId)**
 - *Closes the order (i.e., changes a state of the order resource)*
 - 1 | > PUT /customers/{customerId}/orders/{orderId}
 - 2 | > <status>CLOSED</status>

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Service Description

- Standards-driven
 - *Standards that define service description*
 - *They give a space for variability*
 - *too much – big flexibility but increases complexity (~WSDL)*
 - *limited – enforce agreement and interoperability (~REST)*
(as long as parties correctly implement the standard)
- Languages to describe service interfaces
 - *formal – machine processable*
 - *textual – natural text description*
- Comparison of WSDL and REST models for service interfaces

Model	Standards-driven	Languages
WSDL	XML-based WSDL, XML Schema for input/output/fault messages; big space for variations (operations, exchange patterns, protocols)	WSDL+XML, textual description for rules of public processes
REST	Web Architecture, HTTP, XML Schema, JSON; little space for variations (uniform interface, statelessness, etc.)	HTML – mostly textual description, AtomPub, WADL

SOAP vs. REST

- SOAP uses input and output messages in operations
- REST uses resources and defines access on them
- SOAP can use more protocols
- REST uses HTTP
 - *Pratically, most of the SOAP implementations use SOAP over HTTP*
- Operations in SOAP are domain-specific
- HTTP operations are independent on domain semantics
 - *REST operations' semantics is defined by HTTP method + resource semantics*
- SOAP uses XML and XML Schema
- REST can use many representation formats
 - *For example, XML, JSON, YAML, etc.*
- SOAP is defined by WSDL
- REST is described in text or HTML
- Client libraries can be generated from WSDL
- REST vendor provides client libraries

SOAP vs. REST

- SOAP clients must hard-code service's public process
- REST clients can follow links in hypertext for application states
- SOAP services are used for inter/intra-enterprise integration
- REST services are used for Web APIs for integration on the Web