

Middleware and Web Services

Lecture 7: Service Concepts and Technologies

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Service Oriented Architecture

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- 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 resuing 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

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Data-oriented Integration

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- 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

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- 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*

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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.*

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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**

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- **Web Service Architecture**
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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

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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

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- 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

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

Web Service Architecture

- WSDL, SOAP and UDDI

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

SOAP Protocol

- SOAP defines a messaging framework

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- *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

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- *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/evaluate"
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_client_
```

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/3.14.0.0 z1
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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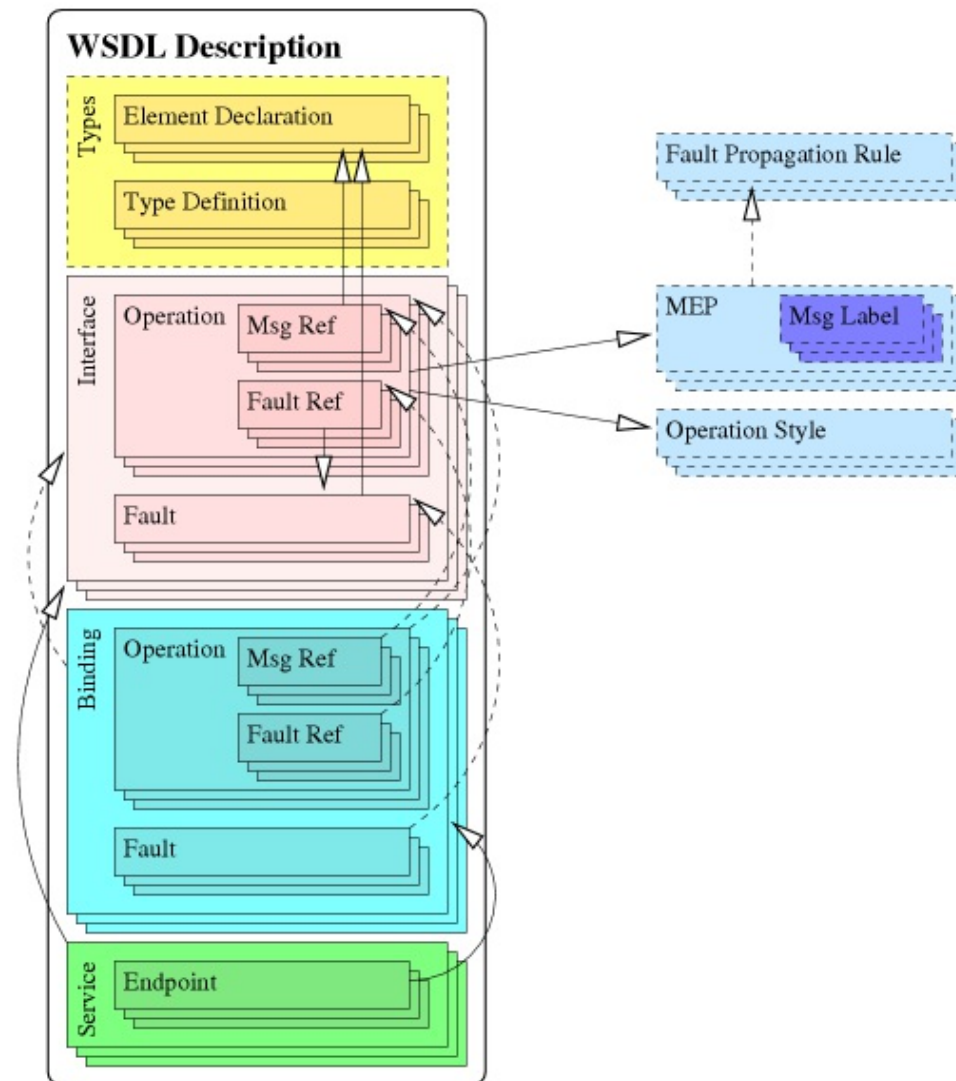
Specifications

- 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/policy"
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*

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Interface Example (1)

- Order process complex conversation
 1. The client invokes **processOrder**.
 2. The service responds back **synchronously** with order status.
 3. The client gets the status of order processing by invoking synchronous **getStatus** operation (this can be invoked several times).
 4. 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"/>
```

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-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: "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/OrderProcess
14     <ns1:process-id>18a9baec2d5ac0a2:64d155de:1425c4185f1:-7ff2</ns1:process-i
15     </ns1:StatusRequest>
16   </soap:Body>
17 </soap:Envelope>
```

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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)*

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Resources over Entities

- Application's data model
 - *Entities and properties that the app uses for its data*

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- 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
 - *Practically, 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