Chapter 8 – Web Services Foundations

Types of E-Business

<table>
<thead>
<tr>
<th>Business To Consumer (B2C)</th>
<th>Business To Business (B2B)</th>
<th>Intra Business</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Relation between enterprise and customers</td>
<td>• Relation between processes of different enterprises</td>
<td>• Electronic organization of internal business processes, like realization within workflow systems</td>
</tr>
<tr>
<td>• Sales-related aspects are predominant, like product presentation, advertising, service advisory, shopping</td>
<td>• Predominant are relation to suppliers, and customer relations to other enterprises like industrial consumers, retailers, banks</td>
<td></td>
</tr>
</tbody>
</table>

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Middleware for Information Systems
B2B Integration – Conventional Middleware

- Middleware itself is (logically) centralized
  - usually controlled by a single company
  - now requires agreement on using, managing specific middleware platform across companies (“third party”)
  - need to implement a "global workflow"
  - problems
    - lack of trust
    - autonomy needs to be preserved
    - business transactions are confidential
- Point-to-point solutions
  - lack of standardization
  - many partners involved -> heterogeneity of middleware platforms
- Focus on LAN
  - insufficient support for internet protocols
  - problems with firewalls
  - cannot work with multiple trust domains

Web Services

- New distributed computing platform built on existing infrastructure including XML & HTTP
  - Web services are for B2B what browsers are for B2C
- Self-contained, self-describing, modular service that can be published, located and invoked across the web
  - Refer to open standards and specifications:
    - component model (WSDL)
    - inter-component communication (SOAP)
    - discovery (UDDI)
  - Platform- and implementation-independent access
  - Described, searched, and executed based on XML
- Enable component-oriented applications
  - Loose coupling from client to service
  - Enable to integrate legacy systems into the web
  - Useful for other distributed computing frameworks such as CORBA, DCOM, EJBs
  - Web services as wrappers for existing IS-functionality
## Service-Oriented Architecture (SOA)

- **Service Requestor**
  - Finds required services via Service Broker
  - Binds to services via Service Provider

- **Service Provider**
  - Provides e-business services
  - Publishes availability of these services through a registry

- **Service Registry**
  - Provides support for publishing and locating services
  - Like telephone yellow pages

### Definition (given by OASIS SOA Reference Model):
“A paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains”

## Web Services - Definition

- **W3C Web Services Architecture WG**
  - produces WS Architecture Specification (working group note, 02/2004)
    - provide a common definition of a web service
    - define its place within a larger Web services framework to guide the community

### Definition
“A Web service is a software system designed to support interoperable machine-to-machine interaction over a network. It has an interface described in a machine-processable format (specifically WSDL). Other systems interact with the Web service in a manner prescribed by its description using SOAP messages, typically conveyed using HTTP with an XML serialization in conjunction with other Web-related standards.”

Earlier, more general definition:
“A Web service is a software application identified by a URI, whose interfaces and bindings are capable of being defined, described, and discovered as XML artifacts. A Web service supports direct interactions with other software agents using XML based messages exchanged via internet-based protocols.”

(October 2002)
Web Service System Architecture

- Common internal architecture leveraging conventional middleware

![Diagram of Web Service System Architecture]

External Web Services Architecture

![Diagram of External Web Services Architecture]
Technologies: Service Description & Discovery

- **Service Description**
  - Common Base Language (→XML)
  - Interfaces (→WSDL)
    - extend "traditional" IDLs
    - interaction mode
    - address/transport protocol info
  - Business Protocols (→WSCL, BPEL)
    - describe possible conversations
    - order of interactions
  - Properties and Semantics
    - (→UDDI, WS-Policy)
      - descriptions to facilitate binding in a loosely-coupled, autonomous setting
      - e.g., non-functional properties (cost, transactional & security support)
  - Vertical Standards
    - interfaces, protocols, etc. specific to application domains

- **Service Discovery**
  - Directory/Repository for WS descriptions
  - APIs and protocols for directory interaction
    - at design-time or run-time

Technologies: Service Interaction & Composition

- **Service Interaction**
  - Transport
    - lots of possibilities
    - HTTP most common
  - Basic and Secure Messaging
    - standardize how to format/package information to be exchanged (→SOAP)
    - define how to extend basic mechanism to achieve additional capabilities (→WS-Security)
  - Protocol Infrastructure (meta-protocols)
    - general infrastructure for business interactions
    - maintain state of conversation
    - meta-protocols
    - which protocols do we use?
    - who is coordinating?
  - Middleware Properties (horizontal protocols)
    - properties similar to those of conventional middleware
    - reliability, transactions, ...

- **Service Composition**
  - Implement web service by invoking other web services
  - Similar to workflow management, only for web services
SOAP – Simple Object Access Protocol

- Defines how to format information in XML so that it can be exchanged between peers
  - message format for stateless, one-way communication
  - support loosely-coupled applications
  - conventions for interaction patterns (RPC)
    - implement "on top of" one-way messaging
    - first message encodes the call, second (reply) message the result
  - processing rules for SOAP messages
  - how to transport SOAP messages on top of HTTP, SMTP

SOAP Envelope Framework

- Defines mechanism for identifying
  - What information is in the message
  - Who should deal with the information
  - Whether this is optional or mandatory
- **Envelope** element is the root element of the SOAP message, contains
  - Optional header element
  - Mandatory body element
- Body element
  - Contains arbitrary XML
    - application-specific
  - Child elements are called body entries (or bodies)
- Some consequences
  - Message body cannot contain general XML **document**, only elements
  - Validation of application data (i.e., the body) requires separation from the surrounding SOAP-specific XML
    - Many web service engines support that
Sample SOAP Message

```xml
<?xml version='1.0' ?>
<env:Envelope xmlns:env="http://www.w3.org/2003/05/soap-envelope">
  <env:Header>
    <m:reservation xmlns:m="http://travelcompany.example.org/reservation" env:role="http://www.w3.org/2003/05/soap-envelope/role/next" env:mustUnderstand="true">
      <m:reference>uuid:093a2da1-q345-739r-ba5d-pqff98fe8j7d</m:reference>
      <m:dateAndTime>2001-11-29T13:20:00.000-05:00</m:dateAndTime>
    </m:reservation>
    <n:passenger xmlns:n="http://mycompany.example.com/employees" env:role="http://www.w3.org/2003/05/soap-envelope/role/next" env:mustUnderstand="true">
      <n:name>Åke Jógvan Øyvind</n:name>
    </n:passenger>
  </env:Header>
  <env:Body>
    <p:itinerary xmlns:p="http://travelcompany.example.org/reservation/travel">
      <p:departure>
        <p:departing>New York</p:departing>
        <p:arriving>Los Angeles</p:arriving>
        <p:departureDate>2001-12-14</p:departureDate>
      </p:departure>
      <p:return>
        <p:departing>Los Angeles</p:departing>
        <p:arriving>New York</p:arriving>
        <p:departureDate>2001-12-20</p:departureDate>
      </p:return>
    </p:itinerary>
    <q:lodging xmlns:q="http://travelcompany.example.org/reservation/hotels">
      <q:preference>none</q:preference>
    </q:lodging>
  </env:Body>
</env:Envelope>
```

SOAP Headers

- **Primary extensibility mechanism in SOAP**
  - Additional facets can be added to SOAP-based protocols
  - Mechanism to
    - provide additional “control” information (e.g., directives, context information)
    - pass information that is orthogonal to the specific information to execute the request
  - Any number of headers can appear in a SOAP envelope

- **Usage areas**
  - Application-specific extensions (see previous example)
    - e.g., reservation identification, customer identification and information, ...
  - Generic service extensions
    - authentication, authorization, transaction management, payment processing, tracing, auditing

- **Header content**
  - Arbitrary XML
  - Determined by the schema of the header element
SOAP Intermediaries

- SOAP intermediaries provide "value-added services"
  - SOAP message can travel through multiple SOAP nodes
    - Sender [-> Intermediary ...] -> ultimate Receiver
  - Intermediaries process one or more SOAP headers
    - Header is removed from the message after processing (default behavior)
      - can be reinserted by the intermediary, possibly with modified values
    - Intermediary does not need to understand message body

- Relay attribute (optional)
  - relays headers that were targeted at the intermediary but were not processed have to be forwarded
  - non-relayable headers that were targeted at the intermediary but were not processed have to be removed

SOAP Processing Model

- Describes logical actions taken by a node when receiving a SOAP message
- Every node has to
  - check message for syntactical correctness
  - analyze SOAP-specific parts
    - envelope, header, body elements
- Role attribute (optional)
  - governs further processing of header blocks
  - node assumes one or more roles, selects headers targeted at these roles
    - every node must assume the role "next"
  - predefined roles ("next", "ultimate_receiver", ...) vs. user-defined roles
- MustUnderstand attribute (optional)
  - if set to "true" for a selected header, a node assuming the target role MUST understand and be able to process it
  - generate fault if header cannot be processed, before any processing is started
SOAP-based RPCs

- SOAP is fundamentally a stateless, one-way message exchange paradigm
  - ...but applications can create more complex interaction patterns
    - Request/response, request/multiple responses
- SOAP-based RPC
  - Employs request/response message exchange pattern (MEP)
  - MEPs define "templates" for more complex message exchanges
  - Invocation is modeled as a struct of in/inout parameters
    - <doCheck>
      - <product> ... </product>
      - <quantity> ... </quantity>
    - </doCheck>
  - Response is modeled as a struct as well
    - <doCheckResponse> ... </doCheckResponse>
  - All data is passed by-value
  - Endpoint (address of target node) to be provided in a protocol binding-specific manner
- Protocol Bindings and RPC
  - RPC not predicated to any protocol binding
  - Binding to HTTP (synchronous protocol) makes RPC-style "natural"
    - One-way exchange will use simple acknowledgement as HTTP response

A Simple SOAP/HTTP RPC

```
POST /StockQuote HTTP/1.1
Host: www.stockquoteserver.com
Content-Type: application/soap+xml ; charset="utf-8"
Content-Length: nnnn

<SOAP-ENV:Envelope
  xmlns:SOAP-ENV=http://schemas.xmlsoap.org/soap/envelope/
  SOAP-ENV:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/">
  <SOAP-ENV:Body>
    <m:GetLastTradePrice xmlns:m="Some-URI">
      <symbol>DIS</symbol>
    </m:GetLastTradePrice>
  </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```
A Simple SOAP Response

HTTP/1.1 200 OK
Content-Type: application/soap+xml;
            charset="utf-8",
Content-Length: nnnn

<SOAP-ENV:Envelope
    xmlns:SOAP-ENV=http://schemas.xmlsoap.org/soap/envelope/
    SOAP-ENV:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"/>
    <SOAP-ENV:Body>
        <m:GetLastTradePriceResponse xmlns:m="Some-URI">
            <Price>34.5</Price>
        </m:GetLastTradePriceResponse>
    </SOAP-ENV:Body>
</SOAP-ENV:Envelope>

More SOAP

- SOAP protocol bindings
  - SOAP standard defines a binding to HTTP
  - SOAP is transport-independent, can be bound to any protocol type
    - E.g., SMTP, message queuing systems, ...
- SOAP with Attachments
  - XML isn’t good at carrying non-XML things within it
  - Introduces an outer multipart MIME envelope
  - Root part is SOAP envelope
  - Other parts can be anything: XML, images, ...
Beyond SOAP – WS-Addressing

- Source and Destination information
  - SOAP does not define them as part of the message itself
    - relies on protocol-specific bindings
  - Example: SOAP/HTTP
    - endpoint reference is a URL encoded in the HTTP transport header
    - destination of the response is determined by the return transport address
  - Information might be lost
    - transport connection terminates (timeout)
    - message forwarded by an intermediary (e.g., a firewall)
  - Response always goes to sender
    - not possible to have response go somewhere else

- WS-Addressing
  - provides a mechanism to place the target, source and other important address information directly within the Web service message
  - decouples address information from any specific transport model
  - w3c recommendation

WS-Addressing Constructs

- Endpoint reference
  - uniquely identifies WS endpoint
- Message information headers
  - describe end-to-end message characteristics such as
    - source and destination endpoints
    - message identity
- Example:
  ```xml
  <S:Envelope xmlns:S="http://www.w3.org/2002/12/soap-envelope"
              xmlns:wsa="http://schemas.xmlsoap.org/ws/2003/03/addressing">
    <S:Header>
      <wsa:MessageID>http://example.com/6B29FC40-CA47-1067-B31D-00DD010662DA</wsa:MessageID>
      <wsa:ReplyTo>
        <wsa:Address>http://business456.com/client1</wsa:Address>
      </wsa:ReplyTo>
      <wsa:To>http://fabrikam123.com/Purchasing</wsa:To>
    </S:Header>
    <S:Body>
      ...
    </S:Body>
  </S:Envelope>
  ```
Web Services Description Language (WSDL)

- Provides all information necessary to programmatically access a service
  - documentation for distributed systems
  - recipe for automating the details involved in applications communication
- Description of the logical web service interface
  - operations, parameters, ...
  - similar to IDL in conventional middleware
- Describes mechanism to access the web service
  - which protocol is used
  - service location
- WSDL standardization pursued by w3c
  - V1.1 specification is a w3c note
    - not an official standard, but most widely used
  - WSDL 2.0 is a w3c recommendation

Ingredients of WSDL

- Abstract part
  - Types: Definitions of data types needed
  - Message Exchange Pattern: Abstract definition of data exchanged
  - Operation: Abstract actions supported by the service
  - Interface: Interface defined as set of operations
- Concrete part
  - Binding: Concrete protocol and data format used to implement an interface
  - Endpoint: Single individual "end point" identified by a network address supporting a particular binding
  - Service: Collection of related "end points"
WSDL 2.0 Document Structure

- WSDL document defines a target namespace
  - similar to XML Schema target namespace
- Import/Include
  - `<description>
    [ <import namespace="uri" location="uri"/> | <include location="uri"/> ]
  </description>`
  - Can be used to factor out any kind of definitions
    - Types, Interface, Bindings,... or any combination of these
    - Example:
      - Import Interface and specify Binding
      - Import Binding and specify Service
- Import, include differ regarding namespaces
  - include: referenced WSDL document needs to have same target namespace
  - import: referenced WSDL can have different target namespace
  - components are referenced in importing document using qualified names
Message Exchange Patterns

- Defines interaction paradigms
  - exchange of several asynchronous messages
  - sequence and cardinality of messages in an operation
    - abstract: no message types, no binding-specific information is specified
    - minimal contract
- Standard MEPs defined by WSDL specification
  - in-bound MEPs
    - In-Only, Robust In-Only, In-Out, In-Optional-Out
  - out-bound MEPs
    - Out-Only, Robust Out-Only, Out-In, Out-Optional-In
  - Where to send to? Outside scope of WSDL
    - Information could be provided through another (subscribe) operation or defined at deployment time
- Extensibility – possible to define new MEPs

Types

<description...>
  <types>
    <xsd:schema.../>
  </types>
</description>

- Type clause used to define types used in message exchange
  - all message types (normal, fault) are single, top-level elements
- Default type system is XML Schema
  - Special extensibility element foreseen to refer to other type system
- Example
  <description targetNamespace=...>
    <types>
      <xsd:schema...>
        <xsd:complexType name="registration">
          ...
        </xsd:complexType>
        <xsd:element name="registrationRequest" type="registration"/>
      </xsd:schema>
    </types>
  </description>
Interface

- Interface is a set of abstract operations
  - may extend other interfaces (i.e., multiple interface inheritance)
    - faults, operations, etc. are inherited
    - overloading of operations is not supported
    - inheritance conflicts must not occur
  - default style for operations can be specified
- Operation groups a set of abstract messages involved
  - references a MEP that defines sequence of messages
  - defines the structure of input, output, infault, outfault messages by referencing the appropriate (schema) types
  - optionally declares a style
    - rules used for generating messages, e.g., RPC style
  - may optionally be declared "safe"
    - no further obligations result from an invocation
- Interface Fault
  - definition of faults that can occur in the scope of this interface

Binding

- Interface, type elements define the abstract, reusable portion of the WSDL definition
- The binding element tells the service requestor **how to format the message in a protocol-specific manner**
  - interface can have one or more bindings
- Protocol-specific aspects are provided using binding extensions
  - `<binding name="..." interface="...">
    <operation ref="...">*
      <input messageLabel="...">*
      <output messageLabel="...">*
      <infault ref="..." messageLabel="...">*
      <outfault ref="..." messageLabel="...">*
    </operation>
  </binding>`
  - Standard binding extensions for SOAP/HTTP, HTTP GET/POST, SOAP w/MIME attachments
SOAP Binding - Details

- `<soap:binding>`
  - protocol: HTTP, SMTP, FTP, ...
  - mep: default SOAP message exchange pattern for operations
- `<soap:operation>`
  - action: value of SOAPAction HTTP header (SOAP over HTTP only!)
  - mep: actual mep for the operation
    - e.g., soap-response for implementing an in-out WSDL MEP

Endpoint and Service

- Endpoint
  - Specifies the network address of the endpoint hosting the web service
- Service
  - Contains a set of related endpoint elements
    - Group endpoints related to the same service interface but expressed by different protocols (bindings)
- Example
  ```xml
  <service name="StockQuoteService" interface="StockQuoteInterface">
    <endpoint name="StockQuoteEndpoint" binding="tns:StockQuoteSoapBinding">
      <address="http://myservice.com/stockquote"/>
    </endpoint>
  </service>
  ```
  - address of the endpoint
  - implemented binding
Web Service Policies

- Web service capabilities and requirements need to be described as (machine-readable) metadata
  - examples: addressing, security, transactions, reliability
  - allows tools to check for service compatibility, generate code
- WS-Policy
  - express capabilities, characteristics of entities in a WS-based system
    - policy assertions, expressions, statements
    - example:
      - `<wsam:Addressing>...<wsam:Addressing>
        <ExactlyOne>
          <sp:TransportBinding>...</sp:TransportBinding>
        </sp:AsymmetricBinding>...</sp:AsymmetricBinding>
      </ExactlyOne>
    </All>
  - allows senders, receivers to specify their security requirements and capabilities
- WS-PolicyAttachment
  - associate policy expressions with subjects
    - reference policies from WSDL definitions or inline them in bindings
    - associate policies with UDDI entities

Universal Description
Discovery and Integration (UDDI)

- Goal: enable service discovery
  - catalogue services based on published information of service providers
  - maintain taxonomy(ies) to support searching for appropriate services in business terms
  - specify technical binding information to actually communicate with the selected service
- UDDI registry serves as a directory of web services
  - Allows searching “by what” and “by how” instead of just “by name”
- UDDI defines
  - Set of schemas for describing businesses and their services
    - UDDI data model
  - SOAP API for accessing a UDDI registry
- UDDI initiative
  - Involves more than 300 companies
  - http://www.uddi.org
UDDI Core Data Structures

- **businessEntity**: information about the party publishing service information
- **businessService**: descriptive information about a family of technical services
- **bindingTemplate**: technical information about service entry point and implementation specs
- **tModel**: descriptions of specifications for services or value sets; basis for technical fingerprints

- **UDDI key**
  - uniquely identifies each instance of core data structures within a registry
  - basis for realizing the containment/referencing relationships (using foreign keys)
- **XML Schema definition for UDDI Data Model**

Entities, Services, Binding Templates

- **Business entity** offering services
  - (multiple) name(s) and textual description(s), possibly in multiple languages
  - contact info, discovery URLs referring to other documents
  - known identifiers
    - list of identifiers that a business may be known by (tax number, D-U-N-S, ...)
  - business categories describing specific business aspects
    - categorization by industry, product, geographic region, ...
- **Business Service**: logical service
  - (multiple) name(s), textual description(s), business categories
- **Binding Template**: instance of a web service
  - (multiple) textual description(s), possibly in multiple languages
  - access point representing the network address (e.g., URL) for invoking the service
  - categories describing specific aspects of the service
- **tModelInstanceDetails**
  - points to one or more tModel information elements
  - goal: provide a technical "fingerprint" for identifying compatible services
What Are tModels?

- A tModel (technology model) represents a concept, an idea, a well accepted technical specification (taxonomy, interface)...
  - Its semantics should be clearly described
  - UDDI comes with a set of predefined tModels
- Examples
  - Taxonomies
    - NAICS (industry codes), UNSPC (product & service codes), ISO3166 (geographic locations)...
  - Technical specifications
    - RosettaNet, ebXML, EDI, standard ERP system interface,...
  - Identifiers
    - D&B numbers, US tax codes,...
- When registering a tModel it gets a globally unique identifier: tModelKey
- tModel data structure
  - tModelKey, name, overviewDoc, descriptions, categories, identifiers, ...
  - overviewDoc may contain a URL child element that points to a WSDL file describing the interface ...

Using tModelKeys

- tModelKey is used to give references a semantics
  
  <element name = "keyedReference">
  <type content = "empty">
    <attribute name = "tModelKey" type = "string"/>
    <attribute name = "keyName" minOccurs = "1" type = "string"/>
    <attribute name = "keyValue" minOccurs = "1" type = "string"/>
  </type>
  </element>

  This allows to specify the semantics of a name-value pair, e.g.: Is the identifier a US Tax Number, is it D&B number, is the name of an interface of the system of a particular ERP vendor,...?
- Example: identify SAP AG by its Dun & Bradstreet D-U-N-S® Number, using the corresponding tModelKey within the UDDI Business Registry
  
  <keyedReference
    tModelKey="uddi:ubr.uddi.org:identifier:dnb.com:D-U-N-S"
    keyName="SAP AG"
    keyValue="31-626-8655"/>

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Middleware for Information Systems
Important Registry APIs

- Inquiry API
  - Find things
    - find_business
    - find_service
    - find_binding
    - find_tModel
  - Get Details about things
    - get_businessDetail
    - get_serviceDetail
    - get_bindingDetail
    - get_tModelDetail
- Publishers API
  - Save things
    - save_business
    - save_service
    - save_binding
    - save_tModel
  - Delete things
    - delete_business
    - delete_service
    - delete_binding
    - delete_tModel
  - security...
    - get_authToken
    - discard_authToken

Provided as SOAP-based web services

Inquiry API

- FIND APIs
  - Basic browsing/searching
    - Can return a set of results
  - Limited search capabilities
    - Query is specified in an XML element with subelements for
      - Values of properties to match (e.g., business name starts with "S")
      - Qualifiers that modify the search behavior (e.g., exactNameMatch, sortByNameDesc, …)
    - Example: Find the latest two businesses that registered, and whose name starts with an "S"
      
        `<find_business generic="1.0" maxRows="2" xmlns="urn:uddi-org:api">`
        `<findQualifiers>`
          `<findQualifier>sortByDateDesc</findQualifier>`
        `</findQualifiers>`
        `<name>S</name>`
        `</find_business>`
  - Return unique reference keys identifying the result "elements"
- GET APIs
  - Based on unique reference keys, retrieve detailed information
Registry Types

- Different types of registries
  - corporate/private (e.g., enterprise web service registry)
    - operates within the boundaries of a single company (or for a restricted number of partners)
    - data is not shared with other registries
  - affiliated (e.g., trading partner network)
    - registry is deployed in a controlled environment
    - limited access by authorized clients
    - data may be shared with other registries in a controlled manner
  - public (e.g., UDDI Business Registry)
    - open, public access to registry data
    - secured administrative access, content may be moderated
    - data may shared, transferred among registries

- UDDI Business Registry
  - public, global registry of businesses and their services
  - master directory of publicly available e-commerce services
  - was initial focus of UDDI effort

Registry Architecture

- UDDI registry may consist of multiple UDDI nodes
- UDDI node
  - supports interaction with UDDI data through (subset of) UDDI APIs
  - belongs to exactly one UDDI registry
  - interacts with other nodes in the same registry (through replication) to maintain a single, complete logical copy of the registry data

- Affiliation of registries
  - consists of multiple registries
  - registries define policies for controlled copying of subsets of registry data among each other
  - registries share a common namespace for UDDI keys, have compatible policies for assigning key values

- Enhanced set of APIs to support registry architecture, types of registries
  - security, custody transfer, subscription, replication
Registry Affiliation – Example

Tooling Principles
Java API for XML Web Services (JAX-WS)

- API for building web services and clients based on remote procedure calls and XML
  - Goal: hide all the complexities of SOAP message processing
  - APIs for supporting XML based RPC for the Java platform
    - Define web service
    - Use web service
  - Defines
    - WSDL/XML to Java mapping
    - Java to XML/WSDL mapping
    - Core APIs
    - SOAP support (including attachments)
  - Client and Server Programming models involving generated stub classes

- Client side invocation (standard programming model)
  - Application invokes web service through generated stub class
  - JAX-WS runtime maps the invocation to SOAP, builds the SOAP message, processes the HTTP request

- Server side processing
  - JAX-WS runtime processes HTTP, SOAP message, maps to RPC and dispatches to target (class implementing the web service)

Mapping WSDL <-> Java – Example

**WSDL 1.1 interface definition:**

```xml
<message name="getLastTradePrice">
  <part name="tickerSymbol" type="xsd:string"/>
</message>

<message name="getLastTradePriceResponse">
  <part name="result" type="xsd:float"/>
</message>

<portType name="StockQuoteProvider">
  <operation name="getLastTradePrice" parameterOrder="tickerSymbol">
    <input message="tns:getLastTradePrice"/>
    <output message="tns:getLastTradePriceResponse"/>
  </operation>
</portType>
```

**Java service endpoint interface:**

```java
//Java
class StockQuoteProvider extends java.rmi.Remote {
  float getLastTradePrice(String tickerSymbol) throws java.rmi.RemoteException;
}
```
Summary

- Service-oriented architectures
  - definition, access, discovery of (web) services

- SOAP
  - defines SOAP message structure and messaging framework
    - stateless, one-way
    - more complex patterns “on top” (e.g., request/response)
  - provides convention for doing RPCs using SOAP
  - support for extensibility, error-handling, flexible data representation
  - independent of transport protocols
    - binding framework for defining protocol-specific bindings
    - SOAP/HTTP
  - extensions beyond SOAP for addressing, reliable messaging (see next chapter)

Summary (cont.)

- WSDL
  - supports description of all information needed to access a web service
    - interface, operation, message types
    - binding to specific protocol (e.g., SOAP)
      - protocol extensions
    - endpoint, service

- UDDI
  - registry
    - publish information about business, services provided, and the way to use them
      - white, yellow, green pages
    - tModels provide infrastructure for business and service “name space”
      - identification, classification of business, services, protocols, ...
    - can “point to” detailed service descriptions such as WSDL files
  - APIs for manipulating and inquiring about registry content
    - provided as web services
Summary (cont.)

- Application development
  - Integration with programming languages, existing middleware
  - Tooling support

- Programming language binding
  - WSDL as the "IDL for web services"
  - Mapping WSDL to PL (e.g., Java)
    - Enables generation of client proxies, server stubs for web services invocation
  - Mapping PL to WSDL
    - "Publish" existing functionality as a web service
    - Example: JAX-RPC

- Web services support based on conventional middleware
  - Define standards for reusing/extending existing programming models and middleware infrastructure to support web service
  - J2EE: use/publish servlets, stateless session beans to implement web services
    - JAX-WS and SAAJ APIs
      - Basic web services interoperability support
    - Web Services for J2EE specification
    - Describes the packaging and deployment requirements for J2EE applications that provide and use web services
    - EJB specification
      - Extended to support implementing web services using stateless session beans.
    - JAXR API
      - Access to registries and repositories.
    - JAXP API
      - Processing XML documents
        - Java interfaces to XSLT, SAX, DOM-parsers