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Chapter 8 – Web Services Foundations

Outline

- Service-oriented computing
  - Motivation & Architecture
  - Implementing SOAs
- Web Services
  - System Architecture
  - Overview of Technologies and Standards
- SOAP for Web Service Invocation
  - Message Format
  - Processing Model
- WSDL for Web Service Description
  - Main Ingredients & Document Structure
  - Web Service Policies
- UDDI for Web Service Discovery
- Application Development

Service-Oriented Computing (SOC)

- Service-oriented architecture (SOA)
  - models an application as a composition of reusable services
    - focus is on functions, not things (in contrast to OO-design)
  - services are characterized by
    - the messages they exchange
    - the interface contracts defined between service requester and provider
- TP system based on SOA may include
  - multiple reusable services offered by a single TA-program, or multiple distributed services
  - both synchronous and asynchronous communication mechanisms
    - service is invoked by sending a message to the service
  - service can implement a TA or a step within a TA (request controller or TA server)
- Increased popularity of SOC
  - service-oriented access to functions of large-scale web sites (search, social networking, e-commerce)
  - advent of standard web service protocols

Types of E-Business

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

B2B Integration - Conventional Middleware

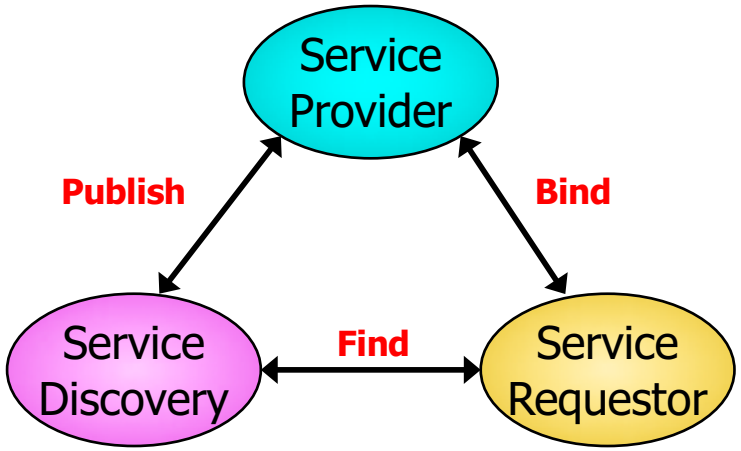
- Middleware itself is (logically) centralized
  - usually controlled by a single company
  - now requires agreement on using, managing specific middleware platform across companies ("third party")
  - need to implement a "global workflow"
  - problems
    - lack of trust
    - autonomy needs to be preserved
    - 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

Service-Oriented Architecture (SOA)

- Service Requestor
  - Finds required services via Service Discovery
  - Binds to services via Service Provider
- Service Provider
  - Provides e-business services
  - Publishes availability of these services
- Service Discovery
  - Service Registry
    - Provides support for publishing and locating services
    - Like telephone yellow pages
  - Service Index
    - Publication is "passive": service descriptions are made available and gathered by index service
  - Peer-to-peer Dicovery
    - Dynamic discovery: requestor send queries to peers in a network

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"



Implementing SOAs

- Implementation based on Web Services
  - application function is mapped to a specific service interface (e.g., *AddCustomer*)
  - standards for SOA: invocation (SOAP), interface description (WSDL), registry (UDDI), all based on XML
  - interoperability: interfaces are available for appl. servers, ORBs, MOM, DBMS, …
    - includes transaction interoperability
  - service assembly & composition: tools and techniques available
- Implementation based on Representational State Transfer (REST)
  - architectural style for building large-scale distributed hypermedia systems
  - application function is mapped to a specific resource providing a generic interface
    - resource identification through URI; uniform interface: HTTP GET, PUT, POST, DELETE
    - example: *HTTP POST* on *www.company-xyz.com/customers* to add customer
  - resources encode session state, function identifiers and parameters
    - *representational state transfer* using self-contained messages
  - self-descriptive messages using HTTP header (*content-type*, *accept* fields)
    - resources are decoupled from their representation
    - content can be accessed in a variety of formats, such as JSON (content negotiation)

RESTful Web Services

- Web services provided purely based on the above principles
  - alternative to WSDL/SOAP-based "big" web services
- Rationale
  - perceived to be simple
    - leverages existing, well-known standards (HTTP, XML, URI, MIME)
  - light-weight infrastructure that requires only minimal tooling, is inexpensive
    - similar to building dynamic web site
  - REST and Ajax (see later chapter) complement each other nicely
  - suitable for hosting applications on the web
- Drawbacks and limitations
  - (still) needs careful design and enumeration of resources to be exposed, mapped to generic interface, and of data representations used
    - more flexible, but more format variations to account for
  - only RPC-style interactions, HTTP-only
  - requires manual implementation of reliability, transactions

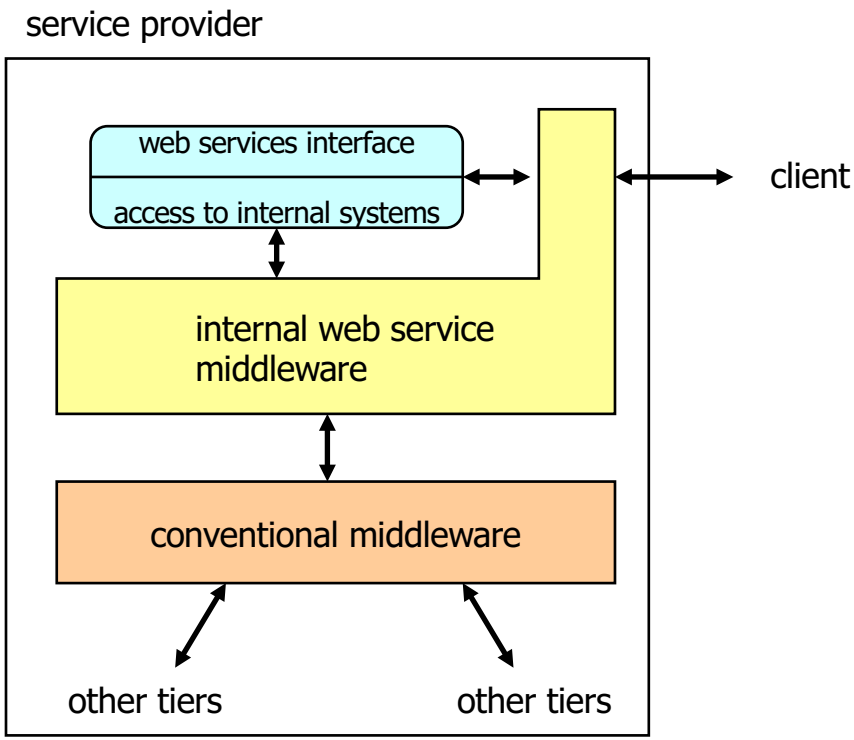
Web Services

- 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

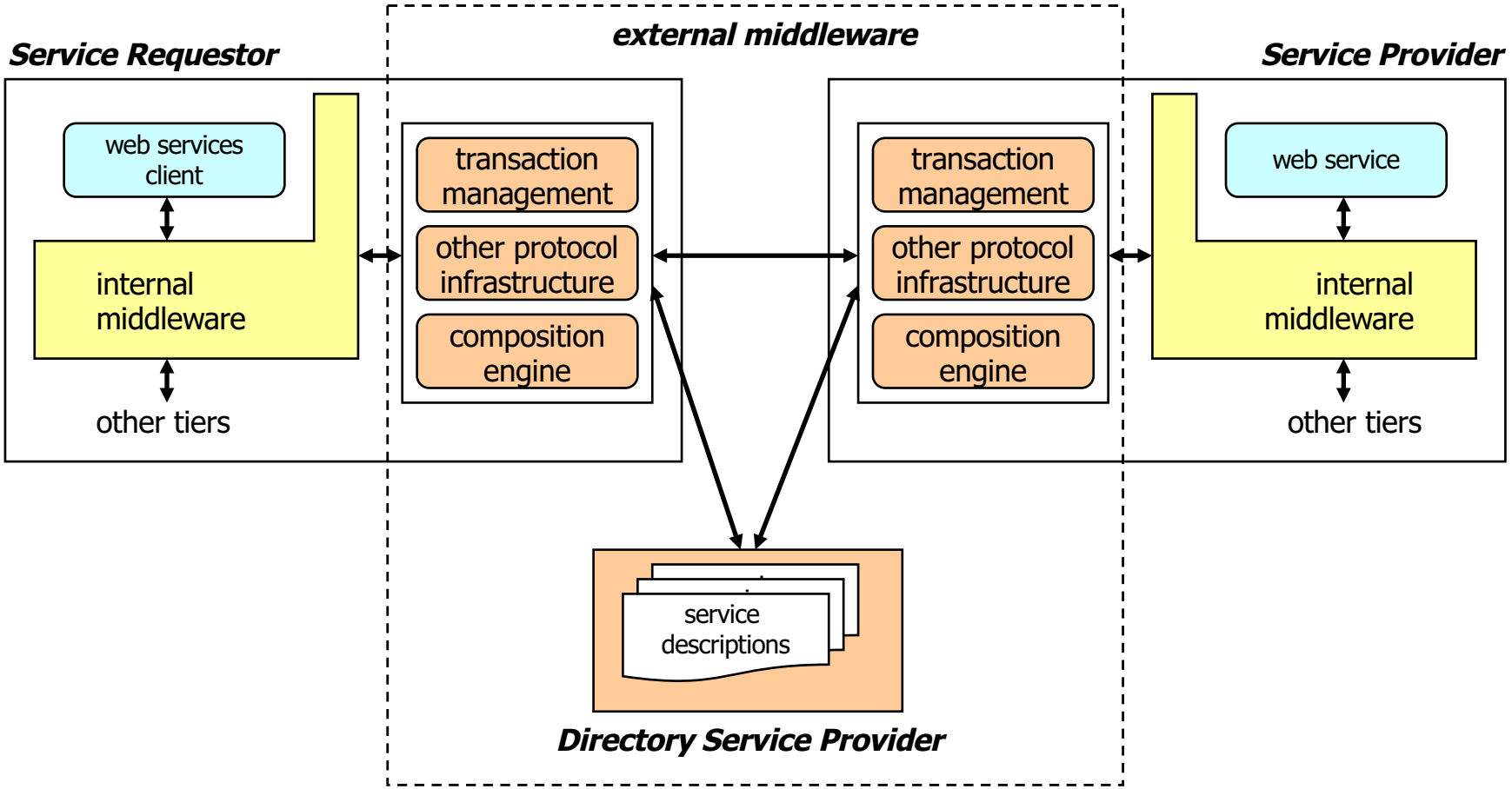
➔ Web services as wrappers for existing IS-functionality

Web Service System Architecture

- Common internal architecture leveraging conventional middleware

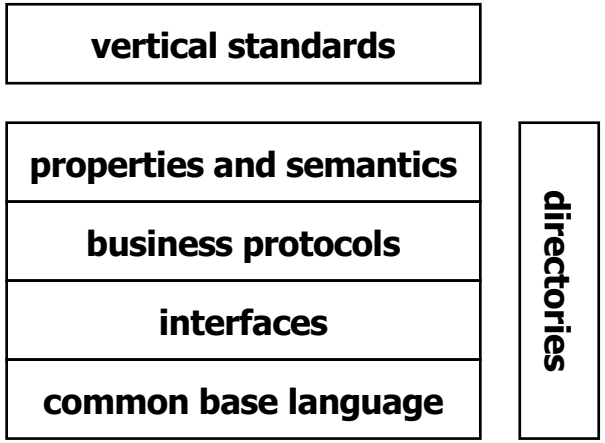


External Web Services Architecture



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)
      - textual descriptions
    - organize this information
  - Vertical Standards
    - interfaces, protocols, etc. specific to application domains

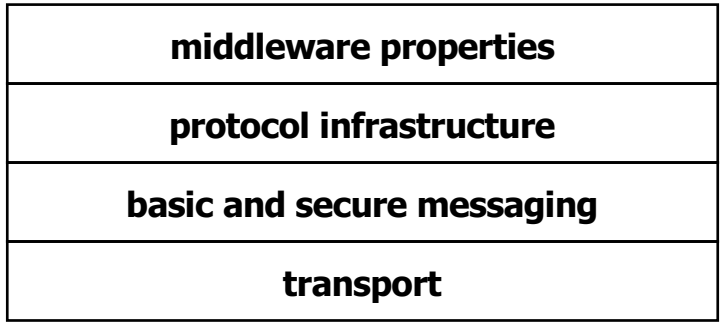


Service Description and Discovery Stack

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

Technologies: Service Interaction & Composition

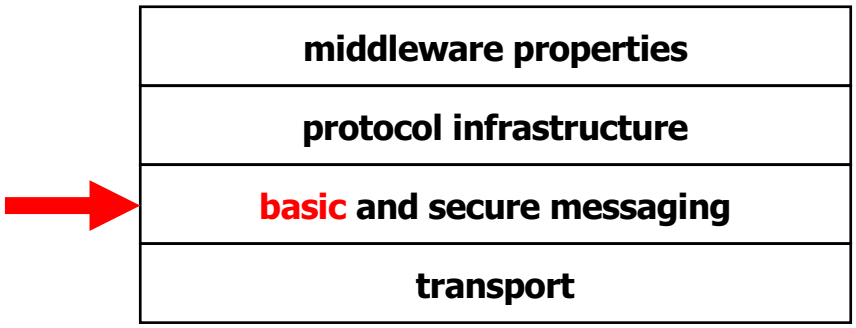
- Service Interaction
  - Transport
    - lots of possibilities
    - HTTP most common
  - Basic and Secure Messaging
    - standardize how to format/package information to be exchanged (→SOAP)
    - define how to extend basic mechanism to achieve additional capabilities (→WS-Security)
  - Protocol Infrastructure (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 Interaction Stack

- Service Composition
  - Implement web service by invoking other web services
  - Similar to workflow management, only for web services

SOAP – Simple Object Access Protocol



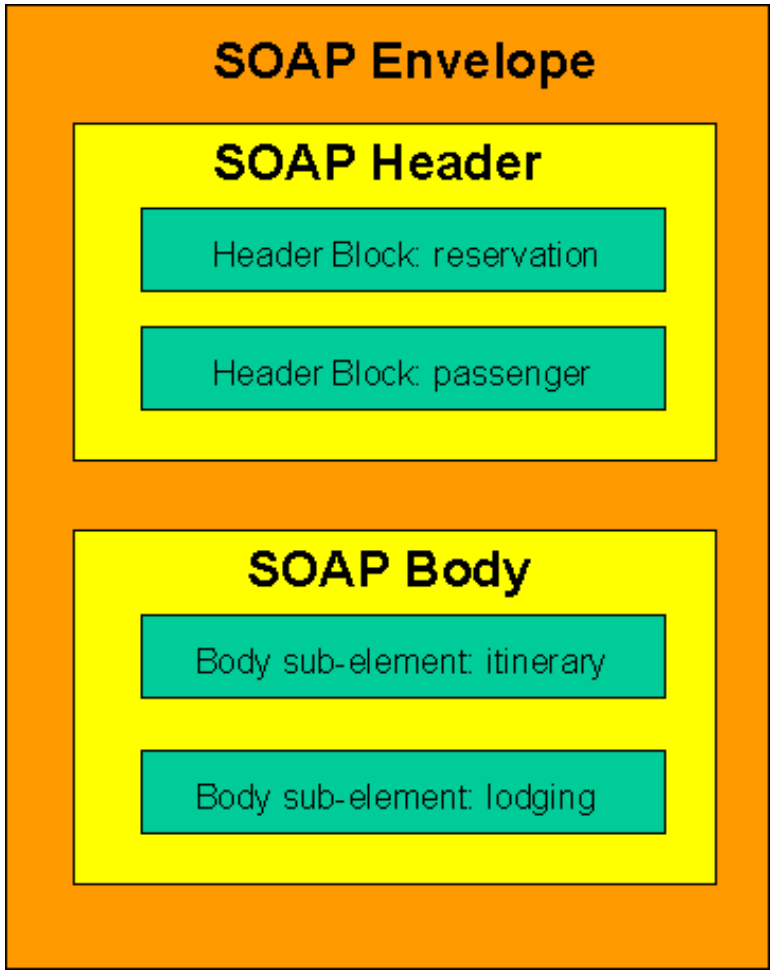
Service Interaction Stack

- 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)

Example:

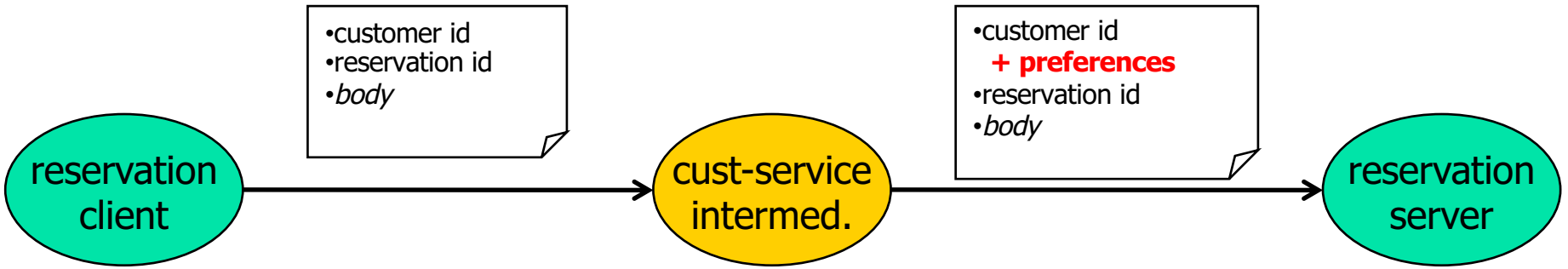


SOAP Headers

- 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



SOAP-based RPCs

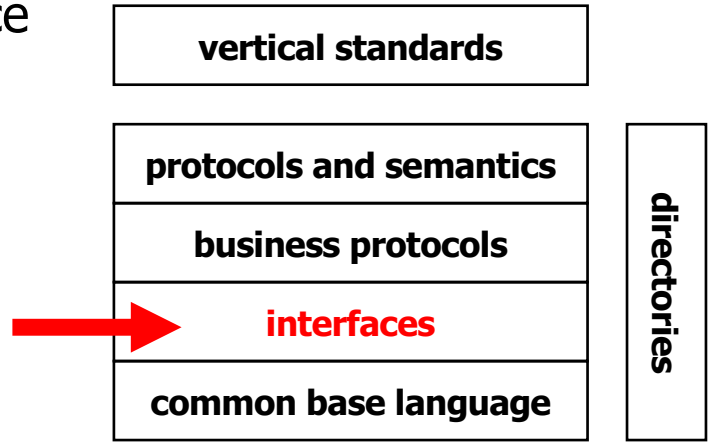
- SOAP is fundamentally a stateless, one-way message exchange paradigm
  - …but applications can create more complex interaction patterns
    - Request/response, request/multiple responses
- SOAP-based RPC
  - Employs request/response message exchange pattern (MEP)
    - MEPs define "templates" for more complex message eschanges
  - 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

More SOAP

- SOAP protocol bindings
  - SOAP is transport-independent, can be bound to any protocol type
    - E.g., SMTP, JMS, UDP, …
    - SOAP standard defines a binding to HTTP
  - Binding to HTTP (synchronous protocol) makes RPC-style "natural"
    - One-way exchange will use simple acknowledgement as HTTP response
- 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, …
- 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

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
    - SOAP, …
  - 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

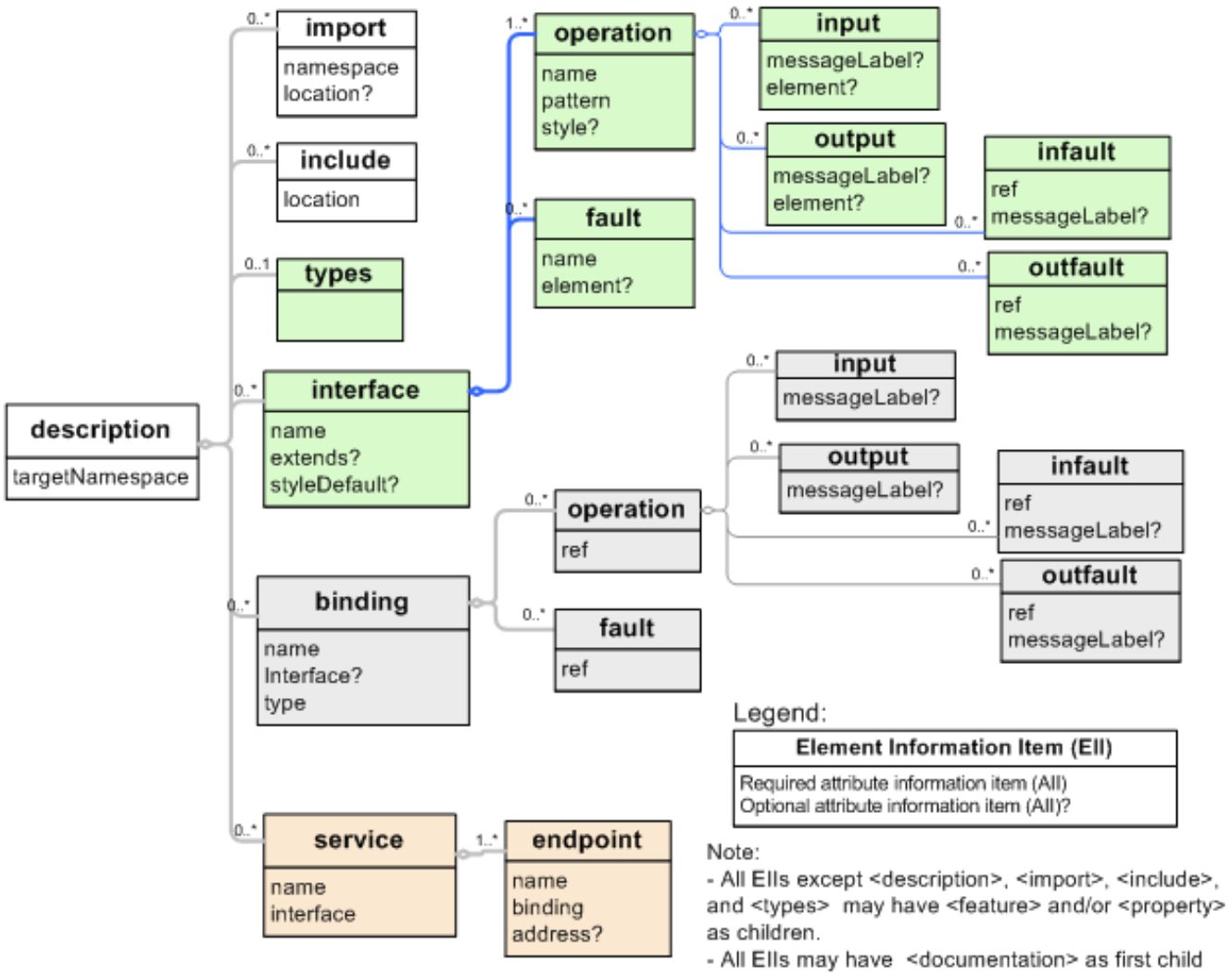


Service Description and Discovery Stack

Ingredients of WSDL

- Abstract part (typical scope of an interface definition language)
  - Types: Definitions of data types needed (e.g., message types)
    - uses XMLSchema as a default language
  - Message Exchange Pattern: Abstract definition of data exchange
    - defines sequence of input and output messages, independent of a specific service
  - 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
    - E.g., SOAP/HTTP, HTTP GET/POST
    - the same service can be supported by multiple protocols/bindings simultaneously
  - Endpoint: Single individual "end point" identified by a network address supporting a particular binding
  - Service: Collection of related "end points"
    - Group endpoints related to the same service interface but expressed by different protocols (bindings)

WSDL 2.0 Document Structure



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

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 or Document 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

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:

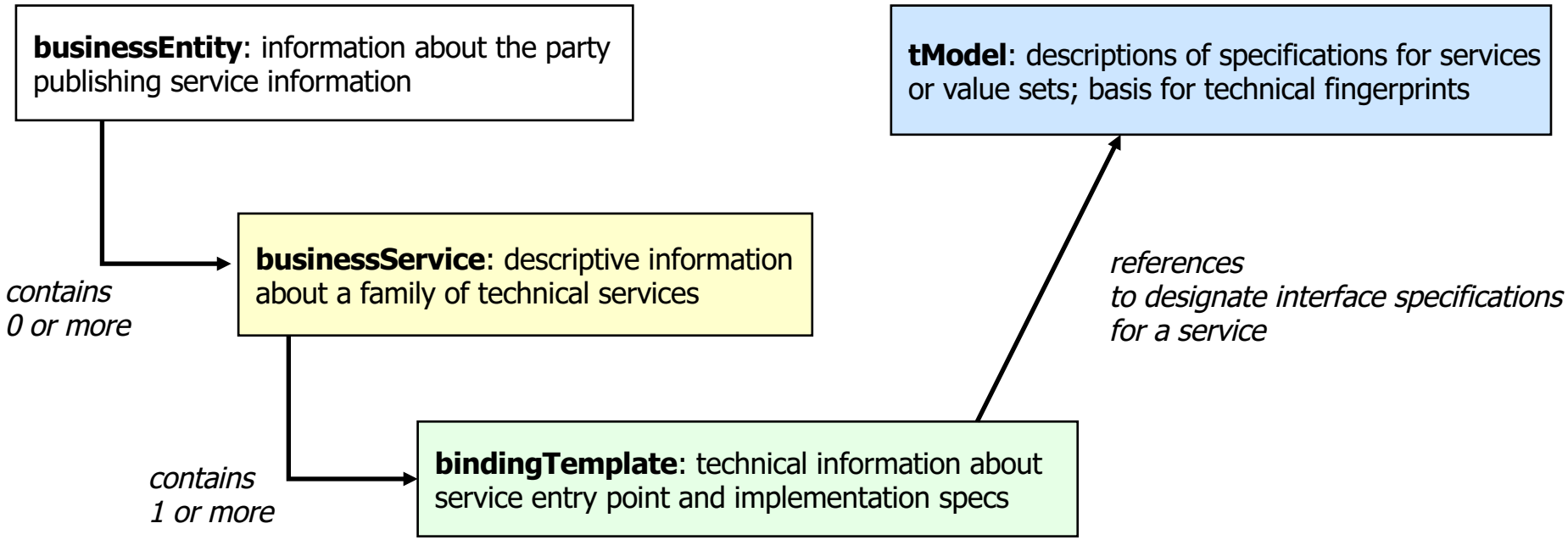
```
<All>
        <wsam:Addressing>…</wsam:Addressing>
        <ExactlyOne>
                <sp:TransportBinding>…</sp:TransportBinding>
                <sp:AsymmetricBinding>…</sp:AsymmetricBinding>
        </ExactlyOne>
</All>
```

  - 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

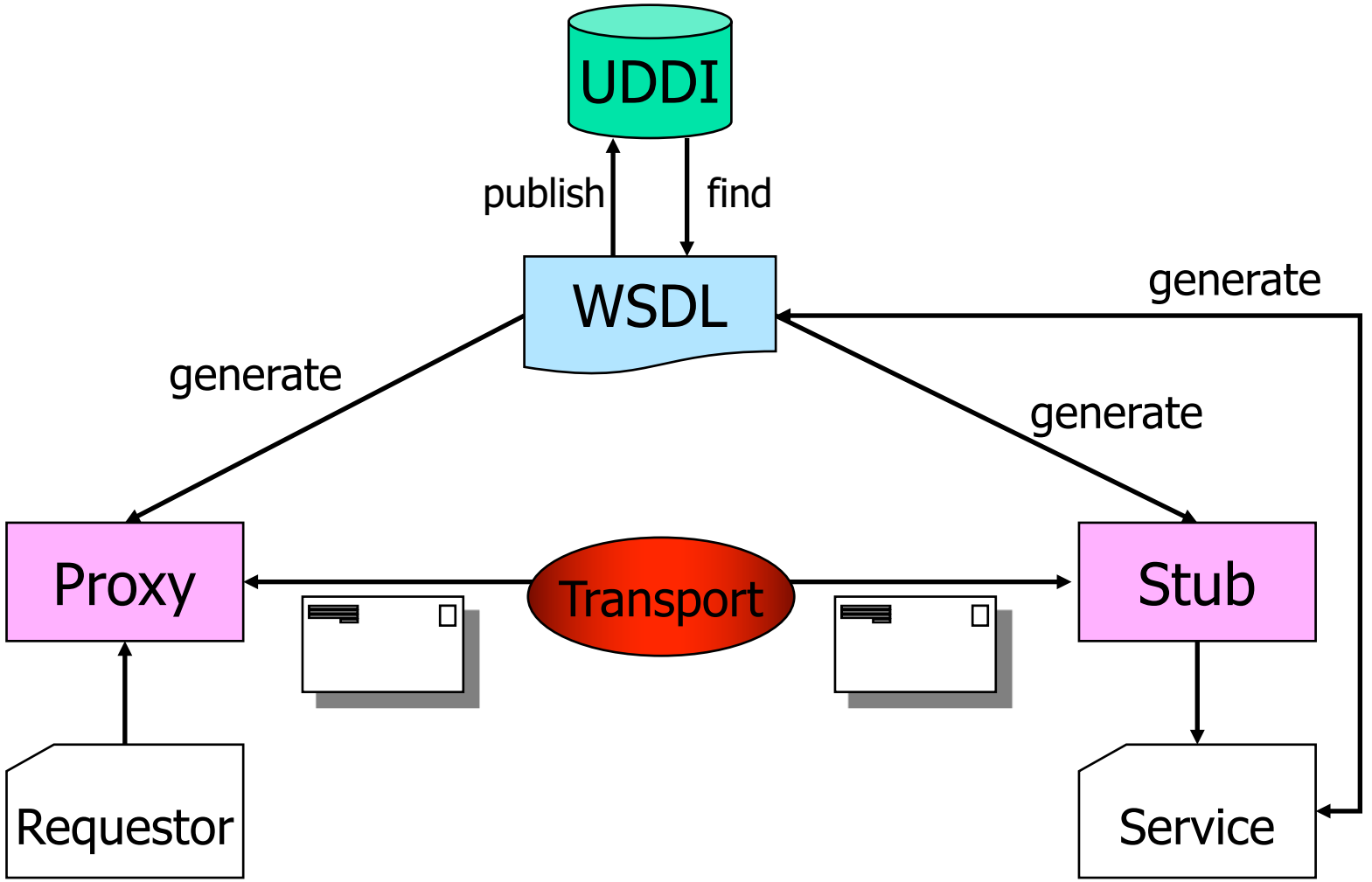


- UDDI key
  - uniquely identifies each instance of core data structures within a registry
  - basis for realizing the containment/referencing relationships (using foreign keys)
- XML Schema definition for UDDI Data Model

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

Application Development



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:

```
<!-- WSDL Extract -->
<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
public interface StockQuoteProvider
    extends java.rmi.Remote {
    float getLastTradePrice(
      String tickerSymbol)
      throws java.rmi.RemoteException;
}
```

Summary

- Service-oriented architectures
  - definition, access, discovery of (web) services
  - web services vs. REST 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
- Web services support based on conventional middleware
  - define standards for reusing/extending existing programming models and middleware infrastructure to support web service
  - Java EE: use/publish servlets, stateless session beans to implement WSs (JAX-WS)
- REST (Representational State Transfer)
  - idea: model a set of services as resources with generic interface (get, put, post, delete)
  - "lightweight", stateless web services
  - Java EE: integration similar to web services, is based on JAX-RS API