Semantic Web Technologies

Semantic Web Services

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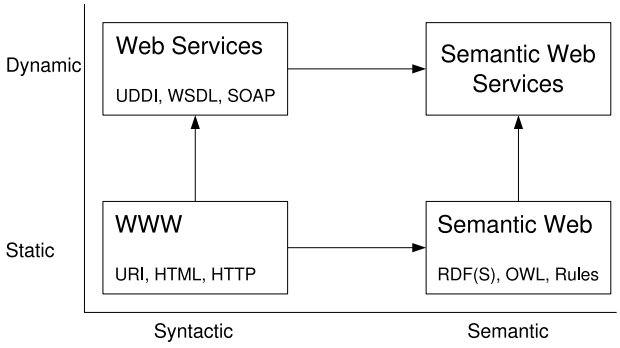
Outline

The Vision of Semantic Web Services



The World Wide Web

What is the WWW?

- Largest document repository ever (> 8 billion Web pages indexed by Google)
- Highly distributed
  - Millions of publishers
  - No control over consistency of published content
- Web Technologies
  - HTTP for transferring documents
  - HTML for marking up documents
  - URI for addressing documents
- Most content on the Web is in natural language (HTML)
  - Natural language not suitable for machine reading
  - Current Web is "syntactic"
  - Problems in automatically:
    - Retrieving documents
    - Extracting relevant information from retrieved documents
    - Combining information from different sources

The Semantic Web

- Making the Web machine-readable
- Publishing data in machine-readable format
- Relating data on the Web to established vocabularies (ontologies)
- Ontologies specified in formal language to allow reasoning
- Ontologies enable automation in:
  - Retrieval of relevant information
  - Extracting relevant information from retrieved document
  - Combination of information from different sources (as long as they are related to the same ontology)

Web Services

- Next step in software engineering:
  - 1960s: Procedural languages
  - 1980s: Object Orientation
  - 1990s: Component Orientation
  - 2000s: Web Services
- Loosely coupled, reusable components
- Add new level of functionality to the Web(?)
- Web Service Technologies
  - SOAP for accessing Web Services
  - WSDL for describing Web Services
  - UDDI for publishing and looking up Web Services

Web Services are not enough

- Like the current Web, Web Services are "syntactic"
- No automation in:
  - Finding services
  - Selecting services
  - Negotiation with service provider
  - Composing services
  - Executing services

Combining Semantic Web and Web Services

Semantic Web Services

- Semantic Web + Web Services = Semantic Web Services
- Using Semantic Web technologies to describe Web Services
- Enable automation in:
  - Publication
  - Discovery
  - Selection
  - Composition
  - Mediation
  - Execution

Business Vision of Web Services

- Business services can be completely decentralized and distributed over the Internet and accessed by a wide variety of communications devices.
- The internet will become a global common platform where organizations and individuals communicate among each other to carry out various commercial activities and to provide value-added services.
- Dynamic enterprise and dynamic value chains become achievable and possibly even mandatory for competitive advantage.

Current Web Service Technologies

- UDDI
  - Registry of services
- WSDL
  - Service description
- SOAP
  - Message format

UDDI

- UDDI provides a mechanism for clients to find web services.
- A UDDI registry is similar to a CORBA trader, or it can be thought of as a DNS service for business applications.
- **UDDI consists of:**
  - **White pages**: Who is the service provider?
  - **Yellow pages**: What is the service providing?
  - **Green pages**: How can I make use of the service?
- Public UDDIs
  - Microsoft, IBM, others
  - Multitude of services is registered
  - Most services no longer available
  - Not used in practice
  - Private UDDIs

WSDL

- **Port type**
  - Collection of **operations**
    - Name
    - Input/output
- **Message formats**
  - Content defined through **XML Schema**
- **Services**
  - **Ports**
    - Endpoint (network addresses)
    - Protocol (e.g. SOAP, RMI)
    - Port type
    - Message format

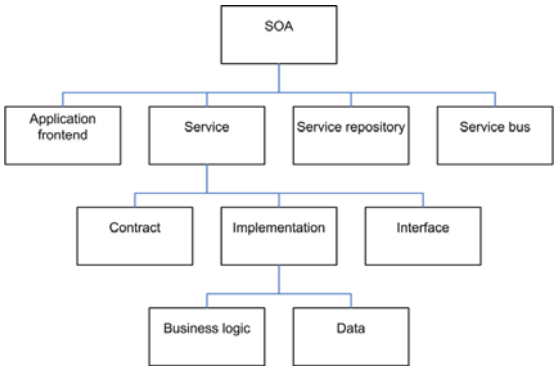
SOAP

- SOAP
  - used to stand for Simple Object Access Protocol
  - is a message layout specification that defines a uniform way of passing XML-encoded data.
- Binding to HTTP as communication protocol.
- SOAP is basically a technology to allow for "RPC over the web".
- **SOAP Message**
  - **Envelope**
    - Sender address
    - Receiver address
    - Intermediate nodes
    - Security information
    - Format of the body
  - **Body**
    - Message content
    - Typically XML

Other Web Service Standards

- WS-Addressing
  - Defining endpoints of services
- WS-Security
  - Comprehensive security framework for web services
- WS-Policy
  - Specification of policies for access, pricing, etc...
- WS-RF (Web Service Resource Framework)
  - Specification for **Grid computing**
  - Accessing **resources** (e.g. data, processor time, disk space)
- *etc...etc...etc...*
  - Responsible: Microsoft, IBM, BEA, Sun, Netscape, ...

Elements of a Service-Oriented Architecture (SOA)



Current use of Web Services

- On the Web
  - Amazon
    - Finding products
    - Adding, deleting, updating shopping cart
    - Payment still over the Web
  - Google
    - Search Google via Web Service API
    - Accessing other Google services
  - Weather, stock tickers, etc...
  - Most public services use HTTP/GET, not SOAP
- In Enterprises
  - Many companies started implementing SOAs
  - Example: Verizon
    - Before SOA: information about telephone numbers stored in 50 places
    - With SOA: one Web Service to retrieve telephone numbers
    - 1500 Business functions implemented using Web Services
    - Custom registry with services

Advertising Services

- Current repositories (UDDI)
  - "polluted"
- Advertise functionality of the service
- Non-functional aspects
  - Security
  - Accessibility
  - Cost

Discovering Services

- Finding services which provide **required functionality**
- Requester needs to **specify** requirements
- Mechanism for matching **required** with **advertised** functionality
- Currently no way of specifying requirements
- Discovery currently **manual**

Selecting Services

- Given a set of services which meet requirements, select service with
  - **best** availability,
  - **lowest** cost,
  - **best** security measures,
  - etc..
- Select best service wrt. set of preferences
  - Specification of requester's preferences
  - Specification of non-functional properties of service
- Selection currently **manual**

Service Composition

- Required functionality requires **multiple** services to be invoked in **some combination**
  - Sequential execution
  - Parallel execution
  - loops
- Specifying requirements
  - Single requirement specification vs.
  - workflow description with identified tasks
- Single requirement specification
  - **Find** composition which fulfills requirement
- Workflow description
  - Discovery of services for each task
  - Optimizing preferences when selecting services
- Composition currently manual process specification (e.g. BPEL, WSFL)

Service Execution

- How to invoke a service?
- If requester and provider use same format, current technologies suffice.
- What if actual formats differ?
- $\Rightarrow$ Translation of message content

Semantics in Web Services

- Description of
  - Functionality of services
    - e.g. searching, selling books, booking flight
  - User requirements
    - e.g. finding, buying books, booking flight
  - Web Service policies
    - Permissions
    - Cost
    - etc...
  - User preferences
  - Data in messages
- Matching descriptions
  - functionality of service vs. user requirements
  - policies vs. user preferences
- Data translation
- Web Service Composition
  - Finding compositions
  - Matching composition with user requirements

Functional Description of Services

- Describe functionality of Services
- Similar to software specification
- View web service as a function: *input* $\longrightarrow$ *output*
- Coarse-grained approach:
  - Functionality described as single task
    - e.g. "book sales", "flight reservation"
  - Organizing tasks in hierarchy
  - Interpreting task as set $\Rightarrow$ subsumption reasoning
  - No clear relation between input and output
- Fine-grained approach:
  - Specify conditions on the input: **preconditions**
  - Specify relation between input and output: **postconditions**
  - Intuitively: $(\forall)$*preconditions* $\Rightarrow$ *postconditions*

DLs (OWL DL) for functional description

- Model service as DL concept S
- S represents set of possible service executions
- Model required functionality as DL concept R
- R represents set of service executions which fulfill requirements
- Relation between C, D determines match

Notions of matching

- **Exact match**: $S \equiv R$
  - Service provides **exactly** the requested functionality
- **PlugIn**: $R \sqsubseteq S$
  - Service provide **more** than the requested functionality
- **Subsume**: $S \sqsubseteq R$
  - Service provides **some** of the requested functionality, and nothing more
- **Intersection**: $\neg(S \sqcap R \sqsubseteq \bot)$
  - Service provides **some** of the requested functionality, and perhaps more
- **Disjoint**: $S \sqcap R \sqsubseteq \bot$
  - Service provides **none** of the requested functionality

Rules for Policy Description / Contracts

- Policies are often in the form of rules
  - e.g. "if user is recognized business partner, then give discount"
  - "if used encryption method is at least DES-256, then creditcard detail may be transferred"
- Use Semantic Web rules language for specifying policies
- Initiatives for using rules to specify web service policies (e.g. policy RuleML)

Semantic Web languages for data description

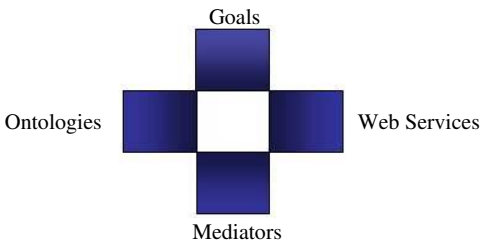
- Transfer data in RDF format
  - Advantage: More flexible than XML
  - Advantage: using ontology for describing structure of data
- Use ontologies for describing structure of data
  - OWL DL does not allow integrity constraints
  - Problem: which data to send over the wire
- If both parties use same ontology, no translation necessary
- Data transformation based on ontology mapping (rules)

The Web Service Modeling Ontology WSMO

Introduction

- An ontology for Semantic Web Services
- Provides conceptual model for SWS
- Based on the Web Service Modeling Framework WSMF
- Principles of WSMO:
  - Ontology-based descriptions
  - Strict decoupling of components
  - Strong mediation between components
  - Interface vs. Implementation

The Web Service Modeling Ontology WSMO



Ontologies

- Provide terminology for:
  - Data exchanged between service requesters and providers
  - Description of other WSMO elements
- Ontologies consist of:
  - Concepts
    - Attributes
  - Relations
  - Functions
  - Instances
  - Axioms

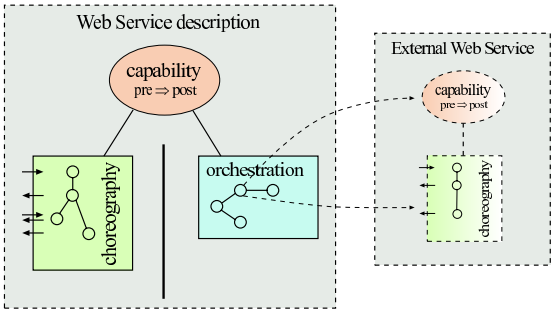
Web Service descriptions

- Functionality offered by the Web Service
- Functional description, in the form of a **capability**:
  - Assumptions
    - Cannot be checked
    - Usually indicate dependency on real world
  - Preconditions
    - Conditions over the input
  - Effects
    - Changes in the real world as a result of execution of the Web Service
  - Postconditions
    - Relation between the input and the output

Web Service descriptions (cont'd)

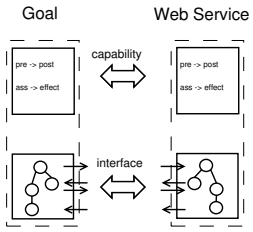
- Behavioral description, in the form of an **interface**:
  - Choreography
    - How to interact with the service
  - Orchestration
    - Use of external Web Service to realize the functionality
  - Both choreography and orchestration are decompositions of the capability

Web Service descriptions (cont'd)



Goals

- Functionality requested from the Web Service
- Description symmetric to Web Service description:
  - Capability
  - Interface



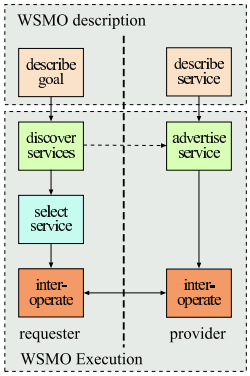
Mediators

- Connect heterogeneous components
- Resolve heterogeneity in different levels
  - Data - differences in data representation
  - Protocol - differences in interaction styles
  - Process - differences in business processes

Types of Mediators

- OO Mediators
  - Connect ontologies to any other component (including mediators)
  - Resolve mismatches conflicts between ontologies
- WW Mediators
  - Link Web Services to services they depend on
  - Resolve representation differences through OO Mediators
- WG Mediators
  - Link Goals and Web Services
  - Resolve differences in data, protocol and process between requester and provider
- GG Mediators
  - Connect generic and refined Goals

WSMO Process



Summary

Semantic Web Services Basics
- The Vision
- Web Services
- Service Oriented Architecture

Challenges in Web Services

Semantics in Web Services

Web Service Modeling Ontology