Towards Cooperative Distributed Service Composition on the Semantic Web

Vadim Ermolayev
eva@zsu.zp.ua  http://eva.zsu.zp.ua/

Dept of Math Modeling & IT
Zaporozhye State Univ.
Ukraine
Emerging Web of Services

Emerging Semantic Web - the result of the evolution of the conventional Web into a provider of services both

- For humans
- For artificial intelligent actors

“The Web, once solely a repository for text and images, is evolving into a provider of services — information-providing services, such as flight information providers, temperature sensors, and cameras, and world-altering services, such as flight-booking programs, sensor controllers, and a variety of e-Commerce and business-to-business applications. Web-accessible programs, databases, sensors, and a variety of other physical devices realize these services. ...”

Sheila McIlraith et al. (2001)*

The Web of Business Services

If to go closer to the rational world of Business:

- 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.
- The dynamic enterprise and dynamic value chains become achievable and may be even mandatory for competitive advantage.

WS for EB/EC

- E-business infrastructure companies are beginning to announce platforms to support some level of Web-service automation

- Some of the Examples:
  - Hewlett-Packard’s e-Speak, a description, registration, and dynamic discovery platform for e-services
  - Microsoft’s .NET and BizTalk frameworks
  - Oracle’s Dynamic Services Framework
  - IBM’s Application Framework for E-Business
  - Sun’s Open Network Environment
Web Services – the Features

- Self-contained
- Self-described
- Modular
- Active

components for assembling intelligent infrastructures on the Web
(at run time, dynamically)
W3C: Web Services
– the Features

“A Web Service is a software application identified by a URI, whose interfaces and binding are capable of being defined, described and discovered by XML artifacts and supports direct interactions with other software applications using XML based messages via Internet-based protocols”

W3C Web Services Architecture Working Group
Advanced WS Features (e.g., NGE)

- **Means for:**
  - Service *negotiation*
  - Service *outsourcing*
  - Service *trade*

- **What we’ll need to cope with:**
  - Reputation and trust
  - Privacy and legal issues
  - Security
  - *Dynamic Service Composition for optimal Cooperative Distributed Business Process Management and Performance (CDBPMP)* — the topic of the talk
Compositional Notations for WS

- Several ongoing initiatives define compositional notations for Web Services.
- These notations express the flow of control and data across a collection of Web Services whose choreography performs a workflow.
- Recently IBM, Microsoft and BEA released BPEL4WS (Business Process Execution Language for Web Services) [link](http://dev2dev.bea.com/techtrack/BPEL4WS.jsp#bpel4ws__toc16502638)
- BPEL4WS is a specification for coordinating business process over the web.
- May be viewed as a *watershed event for industry* as it:
  - represents the first step toward market consolidation,
  - replaces IBM’s WSFL and Microsoft’s XLANG specifications…
Current Landscape: Industry
(Standards… Not excessive)

- **WS description – WSDL:**
  - defines services as collections of network endpoints or *ports*. A port is defined by associating a network address with a binding; a collection of ports define a service

- **WS publication, registration, discovery – 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

- **WS binding, invocation, communication – SOAP:**
  - is a message layout specification that defines a uniform way of passing XML-encoded data. It also defines a way to bind to HTTP as the underlying communication protocol. SOAP is basically a technology to allow for “RPC over the web”

- **Drawbacks:**
  - Merely *syntactical* capabilities
  - Mainly for **HUMAN** users
Yet Unsolved:

- **Service semantic interoperability challenge – passive, static**
  - Means for providing service semantic interoperability infrastructure for intrinsically open systems (like the Web)

- **Cooperative Distributed Service Provision (CDSP) – active, dynamic**
  - Means for cooperative service provision by intelligent distributed open systems (of agents)
WS Domain is Becoming Hot (ter)!

**Events** (upcoming, just some of them to mention):
- eCOMO workshop series at ER – CfP has just been released
- The First [International Conference on Web Services](http://example.com) (ICWS'03)
- CAiSE Workshop on Web Services and e-Business Technology
- Web Services & Multimedia at IEEE MSE'2002
- Invited Session on: [Automated Knowledge and Service Sharing in Agent-Enabled Concurrent Engineering](http://example.com) at 10th ISPE International Conference on Concurrent Engineering: Research and Applications (CE'2003), Madeira Island, Portugal
- … + lots of more (definitely, not less important)
WS Domain is Becoming Hot(ter)!

- **Journals** (upcoming, just some of them to mention):
  - IEEE Computer. Special Issue on Web Services Computing
Current Landscape: R&D
(Not excessive)

- Some of the Key Players:
  - Semantic Web Community
    http://www.semanticweb.org/
  - DAML Services arm of the DAML program
    http://www.daml.org/services/
  - OntoWeb – European Network of Excellence
    http://www.ontoweb.org/

- Some projects:
  - Semantic Web enabled Web Services (IST) -
    http://swws.semanticweb.org/
  - Esperonto Services (IST) -
    http://www.esperonto.net/
Current Landscape:

R&D mainstream

- XML-based languages / ontologies
  - WSFL, ebXML, BPML, RuleML, …

- Frameworks
  - Stanford KSL Semantic Web Services Framework (Mcillraith et al.)
  - WSMF (Bussler, Fensel),
  - …

- Going to present these frameworks (shortly)
Stages of Web (of S) Development

Static
- WWW
- URI, HTML, HTTP

500 million users
more than 1 billion pages

Stages of Web (of S) Development

Serious Problems in information
  • finding
  • extracting
  • representing
  • interpreting
  • and maintaining

Static
WWW
URI, HTML, HTTP

Semantic Web
RDF, RDF(S), OWL

Stages of Web (of S) Development

- **Static**
  - HTML, HTTP, URI
  - **Semantic Web**
    - RDF, RDF(S), OWL

- **Dynamic**
  - UDDI, WSDL, SOAP

This is, more or less, where we are now.

Bringing the computer back as a device for computation.

Stages of Web (of S) Development

- Bringing the web to its full potential

- Web Services
  - UDDI, WSDL, SOAP
  - URI, HTML, HTTP
  - RDF, RDF(S), OWL

- Semantic Web

- Intelligent Web Services

Recall: Yet Unsolved …

- Service semantic interoperability challenge - passive
  - Means for providing service semantic interoperability infrastructure for intrinsically open systems (like the Web)

- Cooperative Distributed Service Provision (CDSP) - active
  - Means for cooperative service provision by intelligent distributed open systems (of agents)
Ontology-Based WS MarkUp

- DAML-S – an extended DAML ontology language specification for providing **semantic markup for Web Services**
- DAML-S is being designed to support the following Web Service related tasks:
  - discovery
  - invocation
  - composition and interoperation
  - execution monitoring
DAML-S: WS MarkUp

- DAML-S – a declarative semantic extension to WS standards
- DAML-S provides a machine interpretable, ontology-backed semantic description (markup) of both atomic and composite Web-Services*:
  - **Declarative** advertisements for service properties and capabilities which can be used for automatic service discovery
  - **Declarative** APIs for individual Web Services that are necessary for automatic Web Service execution
  - **Declarative** specifications of the prerequisites and consequences of individual service use that are necessary for automatic service composition and interoperation

DAML-S: Upper Ontology of WS

Frameworks Based on DAML-S MarkUp

KSL, Stanford Univ.

Semantic Web Services framework composition:

- Semantic markup of Web services
- User constraints
- Web agent generic procedures
- In addition to the markup, the framework includes a variety of agent technologies - specialized services that use an agent broker to send requests for service to appropriate Web services and to dispatch service responses back to the agent.

WSMF: the Philosophy

- The Conceptual Framework ...
- WSMF is to provide a rich conceptual model for the development and the description of web services
- The philosophy of WSMF is based on the following principles:
  - maximal de-coupling complemented by
  - scalable mediation service

- These are pre-requisites for applying semantic web technology for web service discovery, configuration, comparison, and combination
WSMF for e-Business: the Principles

- Fully enabled e-Business based on workable web services requires a modeling framework that is centered around two complementary principles:

  - **Strong de-coupling** of the various components that realize an e-Commerce application. This de-coupling includes information hiding based on the difference of internal business intelligence and public message exchange protocol interface descriptions.

  - **Strong mediation** service enabling anybody to speak with everybody in a scalable manner. This mediation service includes the mediation of different terminologies as well as the mediation of different interaction styles.

WSMF Constituents

- **Ontologies** that provide the terminology used by other elements and glue up formal semantics and real world semantics
- **Goal Repositories** that define the problems that should be solved by web services (pre- and post-conditions)
- **Web Services’ descriptions** that define various aspects of a web service
- **Mediators** which (attempt to) bypass interoperability problems

Agent-Based WS Composition

**active**

**RACING** philosophy:
- Approach based on **Cooperative Distributed Problem Solving (CDPS)**
- Agents “wrap” Web Services
- **Web Services** are considered **Agents’ Capabilities**
- The **collection of Web Services** (which are wrapped by a certain agent) forms its **expertise, its role**
- Agents **negotiate to compose** their services into more complex ones resulting in **dynamic business processes**, performed **cooperatively**
Workflow Enactment – a Social and an Intelligent Activity

- To mention that we are not alone…
- “Workflow enactment by a multi-agent system is an example of cooperative problem solving. … For cooperative problem solving to occur, an agent in the multi-agent society must recognize that the best path to achieving a goal is to enlist the help of other agents. Social commitments arise when one agent makes a commitment to another. Typically a social commitment comes about due to a social dependency.”

A sad story:

“BookRoundTrip” Scenario

- Service composition by an example...
- Travel planning scenario...
- Suppose, the dreams came true...:
  - Web Services are available at the desired level of semantic interoperation
  - Web Services are wrapped by intelligent (software) agents
- The overall high-level (customer’s) goal is to:
  \[ \text{BookRoundTrip}(Kiev, \ UA, \ Tampere, \ FI, 07/10/2002, \ 12/10/2002, \ ER'2002) \]
“BookRoundTrip” Scenario

Agent roles:

- AUTHOR (A) – someone intending to attend ER conference workshop and requesting ‘BookRoundtrip’ service (to be composed)
- TRAVEL AGENT (T) – the ones providing ‘BookRoundtrip’ service by generating and conducting corresponding task execution
- FARE AGENT (F) – the ones providing various air fare information and booking services
- ER INFO (I) – an agent providing information services on ER local arrangements, infrastructure, accommodation, etc in Tampere
- HOTEL AGENT (H) – agents providing hotel room reservation services
- BUSINESS PARTNER (P) – an agent representing A’s business partner in Sweden with whom A intends to meet in Finland in time of the workshop to discuss a joint proposal
“BookRoundTrip” – High Level

- A negotiates (Contract NET IP) with several T-s about whom A believes that they are:
  - Capable to provide ‘BookRoundTrip’ service
  - Credible enough for A to trust them in the context of ‘BookRoundTrip’ service provision
Towards Cooperative Distributed Service Composition on the Semantic Web

"BookRoundTrip" – High Level Negotiation

- A formulates the task proposition for T-s according to the Task Ontology*
- The Task Ontology is shared by A and T-s
- BookRoundTrip task (service) inputs are:

  - Starting_Point= “Kiev, Ukraine”
  - Destination=“Tampere, Finland”
  - Beg_Date =07/10/2002
  - End_Date=12/10/2002
  - Event=“ER’2002”
  - Preferences=(“Non-stop flight”, “4-star hotel, continental breakfast”, “Search for ER Conference Discounts”)
  - Constraints=(Budget = €1500, Payment=(VISA, USD), Hotel >= 3-star, Room-per-night <= €110, Hotel_Location=”in Max 30 min walk from Workshop venue”)
  - Special_Arrangements=((Event=“business dinner”, Agent = (Mr. Lars Dahlqvist”, http://www.strandhotel.o-vik.se/~Lars/…), Date=(10/10/2002,11/10/2002), Location=(Tampere, Vaasa)),…)

Task Decomposition and Contracting

- The chosen T (the contractor) decomposes “BookRoundTrip” according to his local knowledge (the instance of the Task Ontology):
- ‘PlanTrip’ appears to be a complex thing as well:
  - ‘InquireFares’, ‘ApplyConstraints’, ‘BookFare’, ‘ApproveSolution’

- T notices: Savings are possible due to Sunday Rule discounts
- T decides to discuss alternative dates:
  - Sat.,05-Thu.,10.10, Mon.,07-Sat.,12.10, Sun.,06-Sun.,13.10
Negotiation on Fares

- **T** asks **A** about his Fare desirability function in terms of dates, max price
- **T** advertises Fare desirability to **F-s**
- **T** gets feedbacks from **F-s**, converts currencies, chooses the best offer
- **F** who provided the best offer becomes the Contractor for ‘BookFare’ service
Towards Cooperative Distributed Service Composition on the Semantic Web

‘BookRoundTrip’ Service Flow

Legend:
A – AUTHOR
T – TRAVEL AGENT
F – FARE AGENT
I – ER INFO
H – HOTEL AGENT

Precond:
PlanTrip results are available

Task Ontology

MakeHotelRes
InquireEventInfo
ApplyConstraints
ApplyPreferences
AdjustPreferences
AdjustConstraints
BookHotelRoom
ApproveSolution

Service Requestor
Service Providers

Agent Middle Layer

BookRoundTrip
MakeHotelRes
ApplyForVisa
SpecArrangements
ApproveSolution

Event
PlanTrip

PlanTrip

Negotiate

Expedia Flight Booking Service

$1.397 = €1.480
$656 = €695

Cyber Flyer (UIA) Booking Service

CNN Currency Converter Service:
€1 = USD5.01
$1 = €1.06
Enumerating the Features

Intelligent Service Provider needs to:

- Have appropriate **formal representation** of the **semantics of the services** it is capable to perform.
- Be capable to pro-actively **adjust service parameters**, assess requestor’s preferences and constraints.
- Be capable to **negotiate** in a rational way on **optimal service provision** and sub-service outsourcing.
- Be capable of **monitoring and assessing the capabilities** and the **credibility** of other service providers.
- Be capable to dynamically **plan and synchronize the service execution flow**.
Agent-Based WS Mediation  
– the Principles (1)

- **Composite services** are interpreted as **tasks** comprising activities of varying granularity by **Agent Middle Layer**
- **Service Mediator** is formed **dynamically** as a coalition of Service Providing Agents (SPAs) participating in task execution
- **SPAs** join task coalition only for the time their service is required for the task
- **SPAs** are **economically rational, autonomous, ready for cooperation**
Agent-Based WS Mediation – the Principles (2)

- **SPAs** are capable of:
  - **Incoming task decomposition** according to its local knowledge (Task Ontology)
  - **Making arrangements** for service (activity) outsourcing to another **SPAs** based on **Contract Net negotiation**
  - **Service (activity) outsourcing** to the chosen contractor **SPA**
  - **Adjusting their beliefs** on other **SPAs’ capabilities and evaluating SPAs’ credibility** through monitoring cooperative activities
Agent-Based WS Mediation
– the Principles (3)

- **Services** are self-contained modular loosely coupled program components wrapped by SPAs
- An **SPA** may allow another SPA (negotiation) to use its service by providing service context relocation
- **Capabilities** of an **SPA** are defined by the set of services it wraps
Colleges’ Shoulders again:

“… the semantic web and the emergence of a Web Services component model can facilitate agent-based workflow management in open environments. If agents are used to wrap semantically described Web Services, then the semantic service descriptions become the basis for determining the agent’s first-order abilities. Likewise, a common semantic markup for Web Services will facilitate effective communication between agents.”

**RACING**: Agent-Mediated Services for Intelligent IR and Fusion

- **In a Nutshell** – **RACING** approach is:
  - In exploiting **Agent-Service-Resource** wrapping hierarchy
  - For getting possibilities to apply **CDPS technique** in Intelligent Rational **Information Retrieval** and **Information Fusion**

- **Overall high-level goal** for the RACING mediator is to:
  - deliver **semantically matching** (to the requestor’s query) **result** (a resource or a set of resources)
  - for a **rationally negotiated incentive**
  - In the **agreed time**

---

**Matchmaking**: 1. Resource semantics; 2. The Price
**RACING**: Mediator Architecture

Legend:
- **UA** – User Agent, **QTA** – Query Translation Agent, **QPA** – Query Planning Agent,
- **RWA** – Resource Wrapper Agent, **OA** – Ontology Agent, **MA** – Matchmaking Agent,
- **CLA** – Cloning Agent, **CoA** – Coordination Agent
**RACING**: Mediator Functionalities

- User **Request Processing**
- Resource Provider (**wrapper**) **Registration**
- Common **Ontology Maintenance**

**Performed as tasks** (distributedly orchestrated dynamic business processes) and exploit various types of **negotiation**
**RACING: User Request Processing**

- **UA**: formulates (assists in) the query in terms of the key phrases familiar to the given user
- **UA**: generates and manages the execution of the query processing task: ‘CloneQTA’, ‘TranslateQry’, ‘CloneQPA’, ‘ExecuteQry’
- Cloning activities are outsourced to CLA (utility agent), which clones QTA and QPA for query processing
- **QTA** performs the translation of the query predicate in terms of keywords to semantically equivalent query predicate in terms of the concepts of mediator’s common ontology
- **QPA** generates the following set of activities for ‘ExecuteQry’ task: ‘DecomposeQry’, ‘PerformQryset’
**RACING**: User Request Processing

- **QPA** performs **query decomposition** in order to **extract the parts** of the incoming query, which may **require different capabilities** from document service providers.
- The extraction is **guided by topic classification of the common mediator ontology**.
- Resulting **set of partial queries** is performed by **QPA** as the following activity sequence: ‘**MatchRWA**’, ‘**PerformQry**’.
- ‘**MatchRWA**’ activity is negotiated with and outsourced to **MA**.
- **MA** returns the list of **RWAs** capable to perform document providing services relevant to the partial query.
RACING: User Request Processing

- **QPA** negotiates ‘**PerformQry**’ activity with matching (results from **MA**) RWAs in terms of:
  - service ‘overheads’ over time
  - and document price
- **QPA** chooses the contractor **RWA** for ‘**PerformQry**’ execution
- Contractor **RWA** receives the **partial query** in terms of **Common Mediator Ontology**
- **RWA** needs to **translate** the query into the terms of its **Resource Ontology**
- **RWA** outsources the translation activity to **OA**
- **RWA** than **invokes wrapped document service** with the **translated query** and returns documents relevant to the query to **QPA**
**RACING:** Wrapper Registration

- It is assumed that **RWA directory** is maintained by a dedicated **Matchmaker Agent (MA)**
- **Registration task** is initiated by an **RWA**
- **RWA** provides the **list of topics** in terms of its **Resource Ontology** to which it is capable to deliver documents
- **MA** outsources **ontology alignment** activity to **OA**
- **OA** performs incoming resource ontology **alignment and merging** to **Common Ontology** and returns the list of translated topics to **MA**
- **MA** stores the list of translated topics to the directory entry of the new **RWA**
Concluding Remarks

- Approach to how diverse web services may be composed and mediated by means of middle agents and their coalitions performing tasks for service requestors.
- Such a mediation may substantially enhance today’s solutions for web service provision.
- The approach is grounded on CDPS technique and on the results obtained in agent-enabled business process modeling and management.
- ... Still there is the long road to go. Some statements may therefore seem to be provocative.
- ... Still there are no fully implemented solutions, yet. Ongoing activities are targeted to such kind of implementation:
  - E.g.: RACING project [http://www.zsu.zp.ua/racing/](http://www.zsu.zp.ua/racing/)
Feature Sample*: Appointments Planning

- The entertainment system was **belting out the Beatles' "We Can Work It Out"** when the phone rang. When Pete answered, his phone turned the sound down by sending a message to all the other local devices that had a volume control.

- His sister, Lucy, was on the line from the doctor's office: "Mom needs to see a specialist and then has to have a series of physical therapy sessions. Biweekly or something. I'm going to have my agent set up the appointments."

- Pete immediately agreed to share the chauffeuring.

Feature Sample*: Appointments Planning

- At the doctor's office, Lucy instructed her Semantic Web agent through her handheld Web browser.
- The agent:
  - promptly retrieved information about Mom's prescribed treatment from the doctor's agent,
  - looked up several lists of providers,
  - checked for the ones in-plan for Mom's insurance:
    - within a 20-mile radius of her home
    - and with a rating of excellent or very good on trusted rating services
  - It then began trying to find a match between available appointment times (supplied by the agents of individual providers through their Web sites) and Pete's and Lucy's busy schedules.
The greatest thing we may learn from this feature…

- … Is that The Beatles will last forever!!!

- It is also topical that the Semantic Web is supposed to ensure this through Agents and Web Services (composed by agents in an intelligent and social way) …

- Just one more thing to justify that we are likely not wasted time …
Towards Cooperative Distributed Service Composition on the Semantic Web

A funny fact is … (31.01.2003, 15:42)

Search criterion: **cooperative+distributed+service+composition+semantic+web**

... announced just 2 days before
More Coverage of the Topic:

Semantic Web Services and Processes: Semantic Composition and Quality of Service

Jorge Cardoso¹, Christoph Bussler², Amit Sheth¹, ⁴, Dieter Fensel³

¹LSDIS Lab, Computer Science, University of Georgia
²Oracle Corporation
³Universität Innsbruck
⁴Semagix, Inc


Web Resource for this tutorial:
http://lsdis.cs.uga.edu/lib/presentations/SWSP-tutorial-resource.htm
Shall be happy …

…To answer your questions