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)*

*McIlraith, S. A., Son, T. C. and Zeng, H. (2002) Semantic Web Services, IEEE Intelligent Systems. Sp. Issue on The Semantic Web, 16(2), p. 46-53

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

Adopted from **Fensel, D., Bussler, C.** (2002) Semantic Web enabled Web Services project presentation

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) 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)

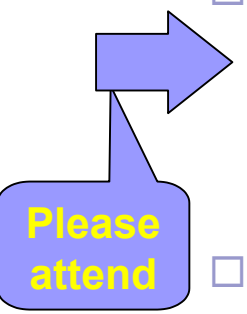
- WS description – **WSDL**:
  - defines services as collections of network endpoints or *ports*. A port is defined by associating a network address with a binding; a collection of ports define a service
- WS publication, registration, discovery – **UDDI**:
  - provides a mechanism for clients to find 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. In 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 (ICWS'03)
  - CAiSE Workshop on Web Services and e-Business Technology
  - Web Services & Multimedia at IEEE MSE'2002
  - International Workshop on Web Services: Modeling, Architecture and Infrastructure (WSMAI 2003) at the Fifth International Conference on Enterprise Information Systems (ICEIS'2003)
  - Invited Session on: Automated Knowledge and Service Sharing in Agent-Enabled Concurrent Engineering 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 Transactions on Systems, Man, and Cybernetics Part A: Systems and Humans. Special issue M-services - Web Services for the Wireless World
  - IEEE Computer. Special Issue on Web Services Computing
  - **!!!NEW!!!** Journal on "Web Semantics: Science, Services and Agents on the World Wide Web" http://www.semanticwebjournal.org/

Current Landscape: R&D

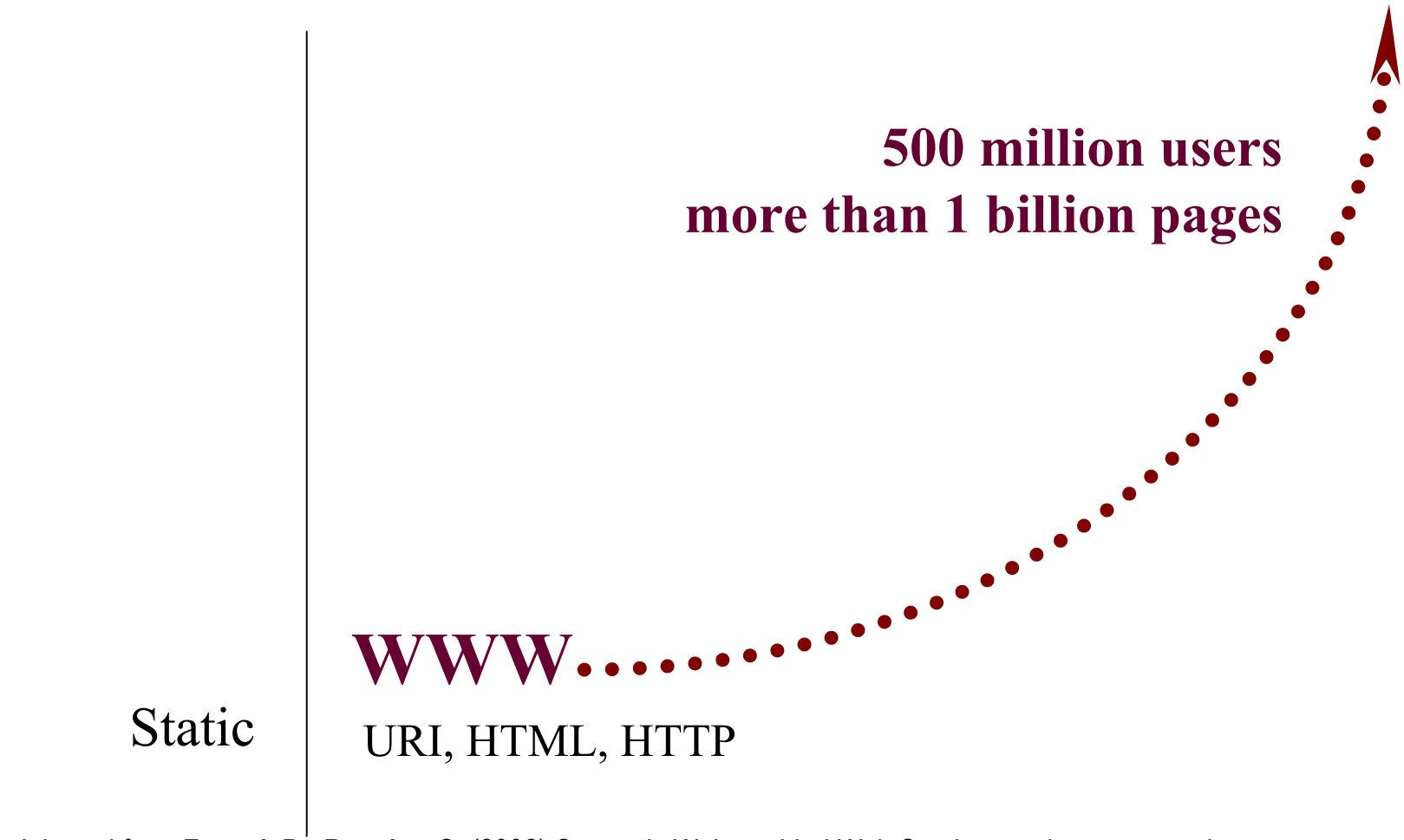
(Not excessive)

- 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

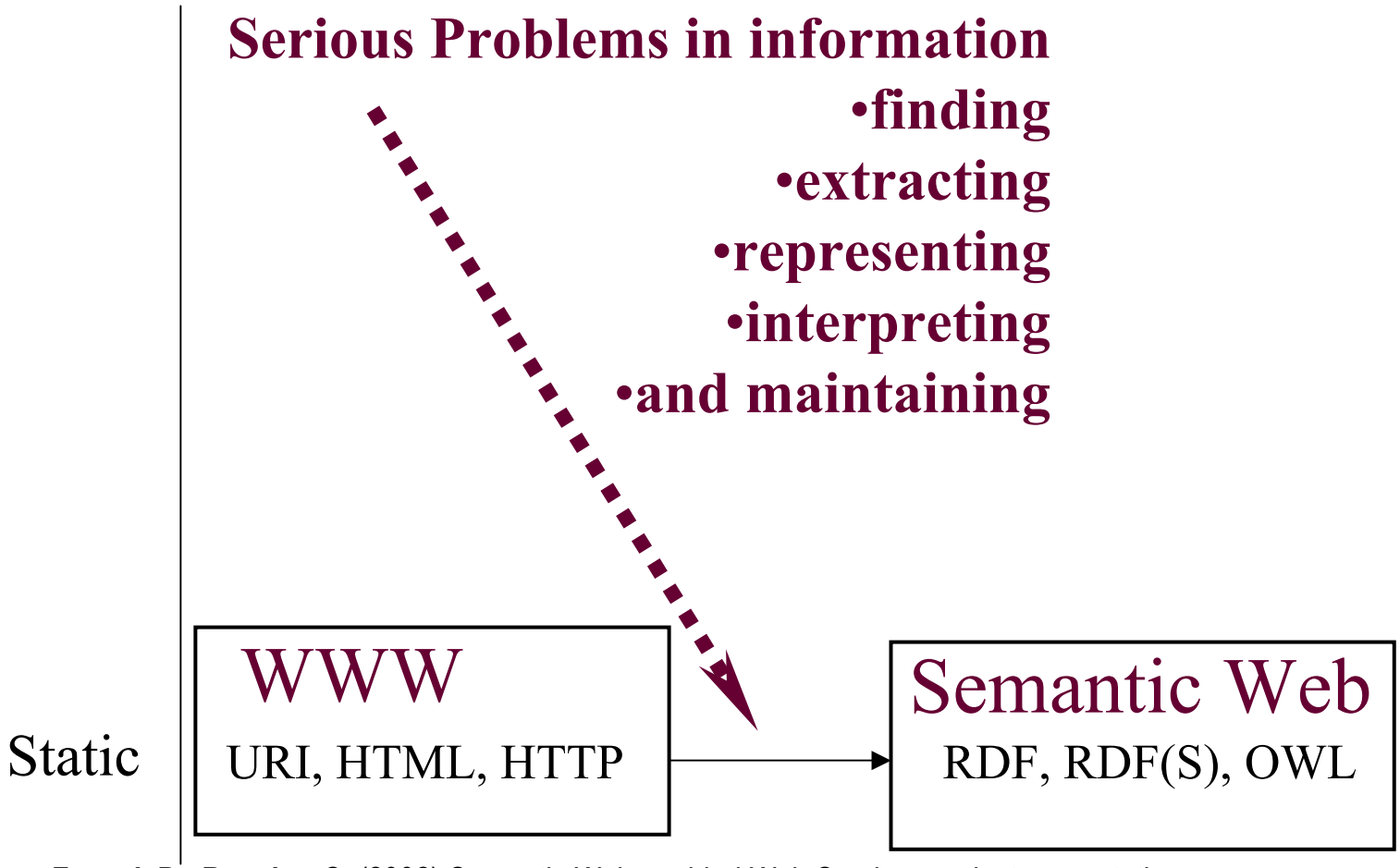
- XML-based languages / ontologies
  - WSFL, ebXML, BPML, RuleML, …
- Frameworks
  - Stanford KSL Semantic Web Services Framework (Mcillraith et al.)
  - WSMF (Bussler, Fensel),
  - …
- Going to present these frameworks (shortly)

Stages of Web (of S) Development



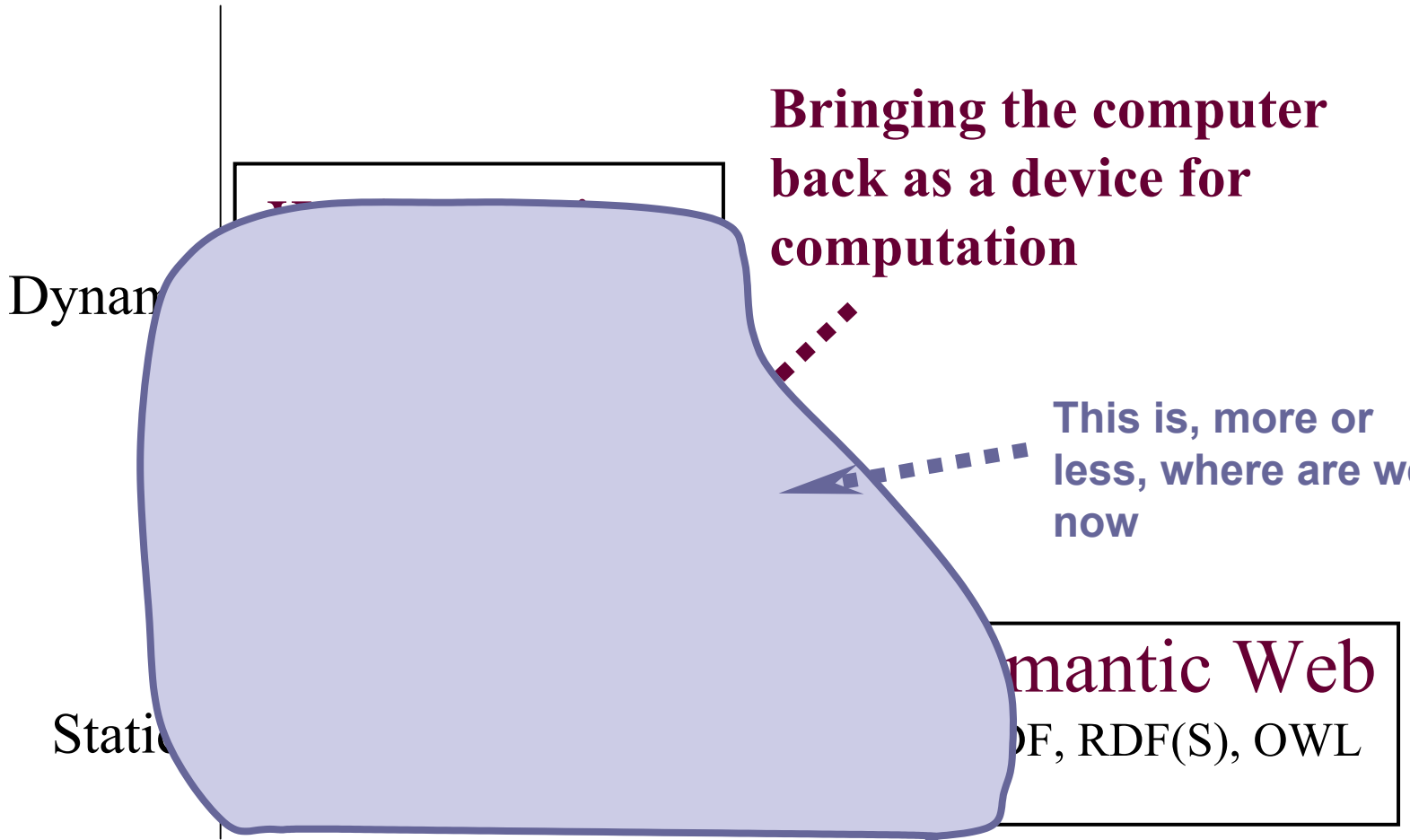
Adopted from **Fensel, D., Bussler, C.** (2002) Semantic Web enabled Web Services project presentation

Stages of Web (of S) Development



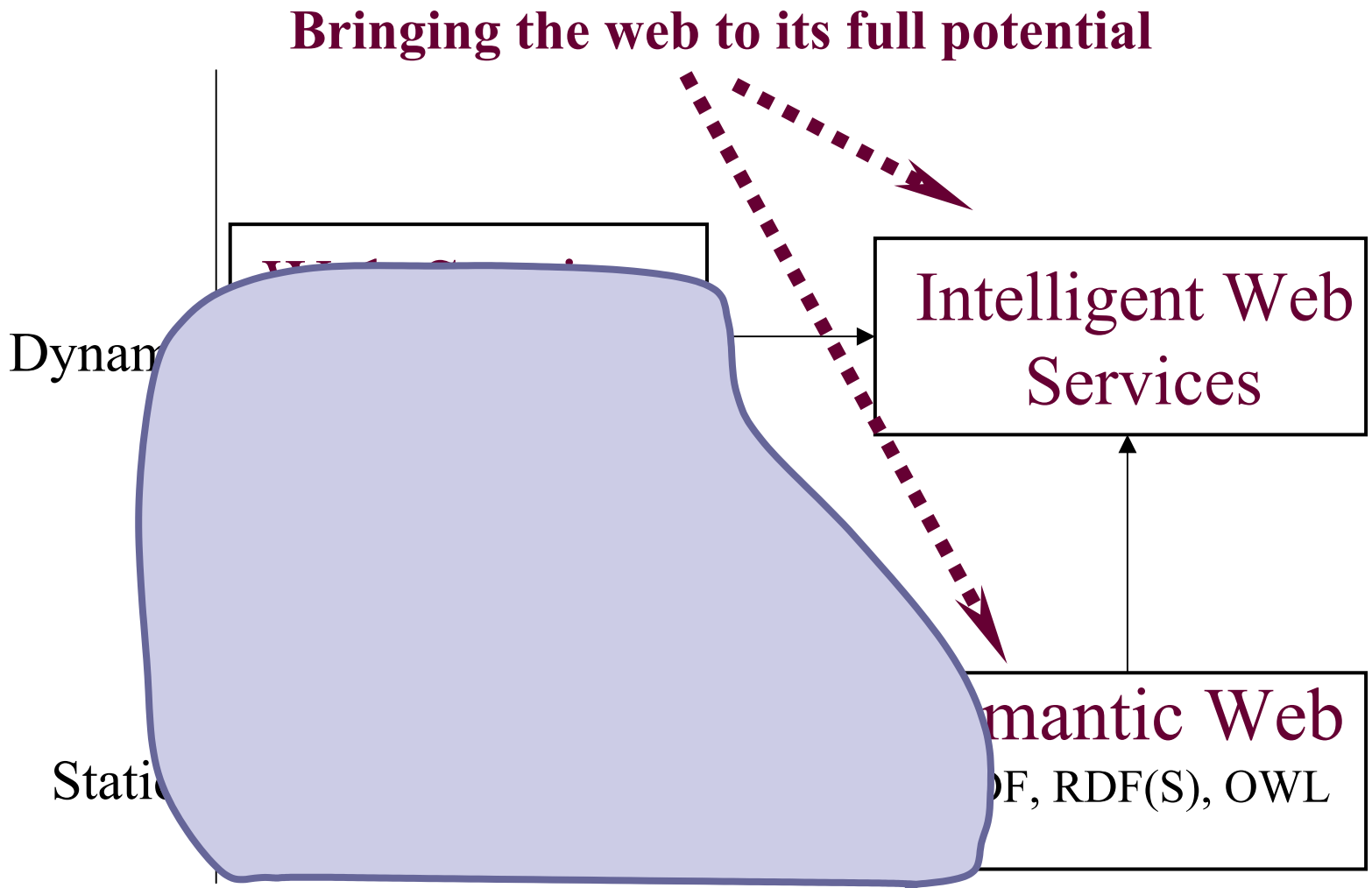
Adopted from **Fensel, D., Bussler, C.** (2002) Semantic Web enabled Web Services project presentation

Stages of Web (of S) Development



Adopted from **Fensel, D., Bussler, C.** (2002) Semantic Web enabled Web Services project presentation

Stages of Web (of S) Development



Adopted from **Fensel, D., Bussler, C.** (2002) Semantic Web enabled Web Services project presentation

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

passive

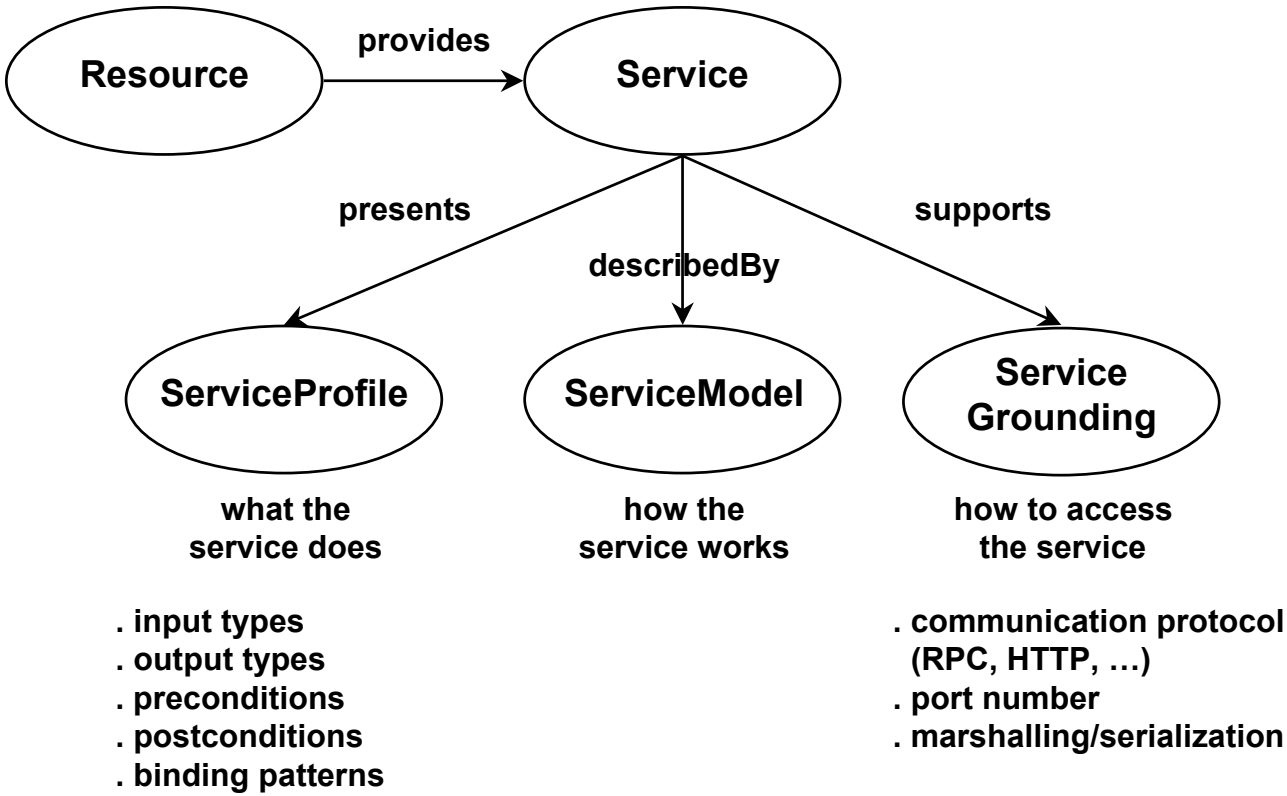
- DAML-S – an extended DAML ontology language specification for providing **semantic markup for Web Services**
- DAML-S is being designed to support the following Web Service related tasks:
  - discovery
  - invocation
  - composition and interoperation
  - execution monitoring

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

*McIlraith, S.A., Son, T.C. and Zeng, H. (2001) Mobilizing the Semantic Web with DAML-Enabled Web Services. In Proc. of the Semantic Web Workshop.

DAML-S: Upper Ontology of WS



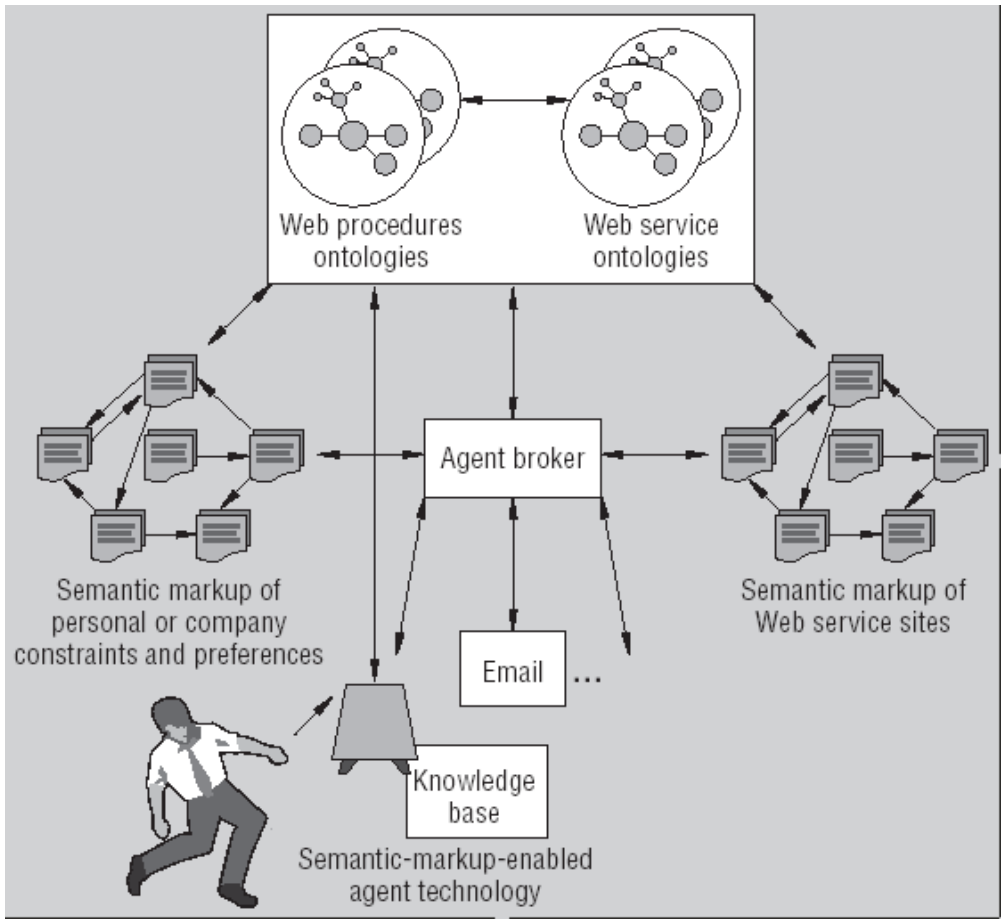
Adopted from: **Jorge Cardoso, Christoph Bussler, Amit Sheth and Dieter Fensel** (2002) Semantic Web Services and Processes: Semantic Composition and Quality of Service. Tutorial at Federated Conferences On the Move to Meaningful Internet Computing and Ubiquitous Computer 2002, Irvine CA, October 2002.

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



Source: **McIlraith, S. A., Son, T. C. and Zeng, H.** (2002) Semantic Web Services, IEEE Intelligent Systems. Sp. Issue on The Semantic Web, 16(2)

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

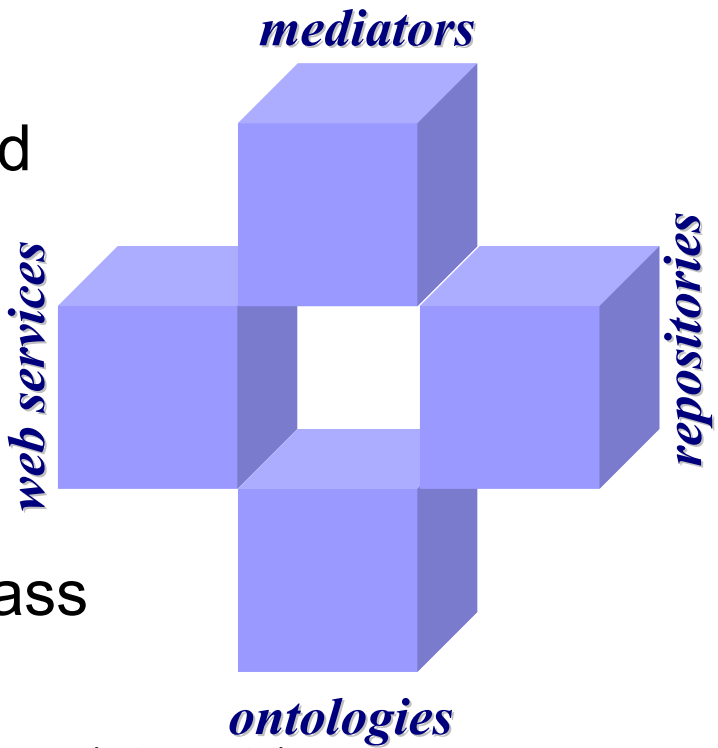
WSMF for e-Business: the Principles

- 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

Adopted from **Fensel, D., Bussler, C.** (2002) Semantic Web enabled Web Services project presentation

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



Adopted from **Fensel, D., Bussler, C.** (2002) Semantic Web enabled Web Services project presentation

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**."*

*__Paul Buhler and José M. Vidal.__ (2003) Semantic web services as agent behaviors. In B. Burg, J. Dale, T. Finin, H. Nakashima, L. Padgham, C. Sierra, and S. Willmott, editors, *Agentcities: Challenges in Open Agent Environments*, pages 25-31. Springer-Verlag.

A sad story: "BookRoundTrip" Scenario

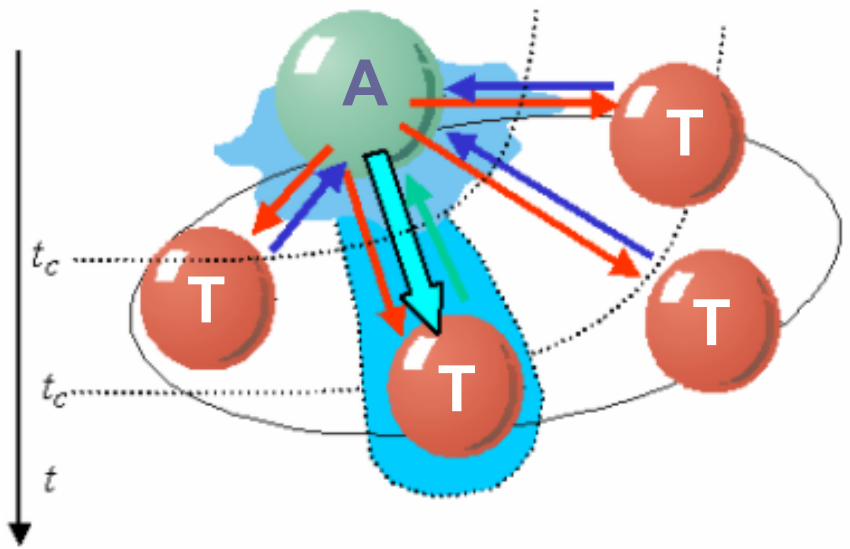
- Service composition by an example…
- Travel planning scenario…
- Suppose, the dreams came true…:
  - Web Services are available at the desired level of semantic interoperation
  - Web Services are wrapped by intelligent (software) agents
- The overall high-level (customer's) goal is to:
  `BookRoundTrip(Kiev, 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



"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)),…)

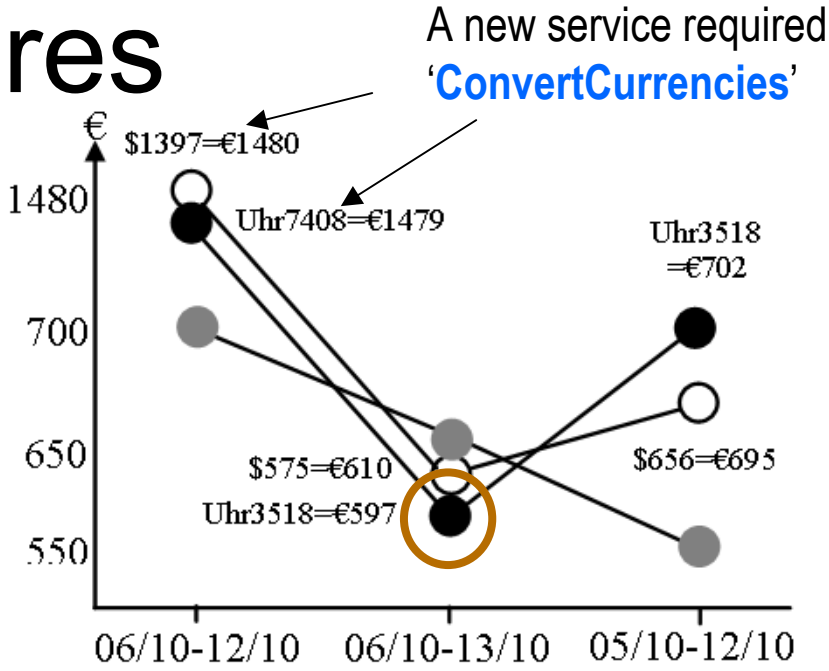
*Ermolayev, V. Keberle, N., Tolok, V. (2002) OIL Ontologies for Collaborative Task Performance in Coalitions of Self-Interested Actors. In: H. Arisawa, Y. Kambayashi, V. Kumar, H.C. Mayr, I. Hunt (Eds.):Conceptual Modeling for New Information Systems Technologies ER 2001 Workshops, HUMACS, DASWIS, ECOMO, and DAMA, Yokohama Japan, November 27-30, 2001. Revised Papers - **LNCS** vol. **2465**, p. 390-402

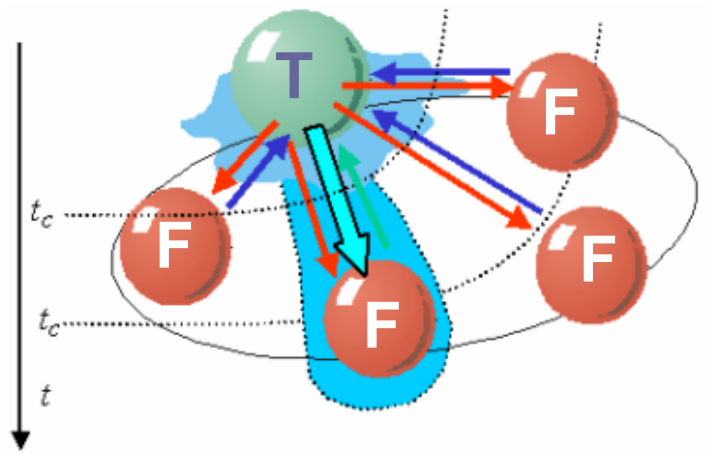
Task Decomposition and Contracting

- The chosen T (the contractor) **decomposes** "**BookRoundTrip**" according to his local knowledge (the instance of the **Task Ontology**):
  - '**PlanTrip**', '**ApplyForVisa**', '**MakeHotelRes**', '**SpecArrangements**', '**ApproveSolution**'
- '**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**

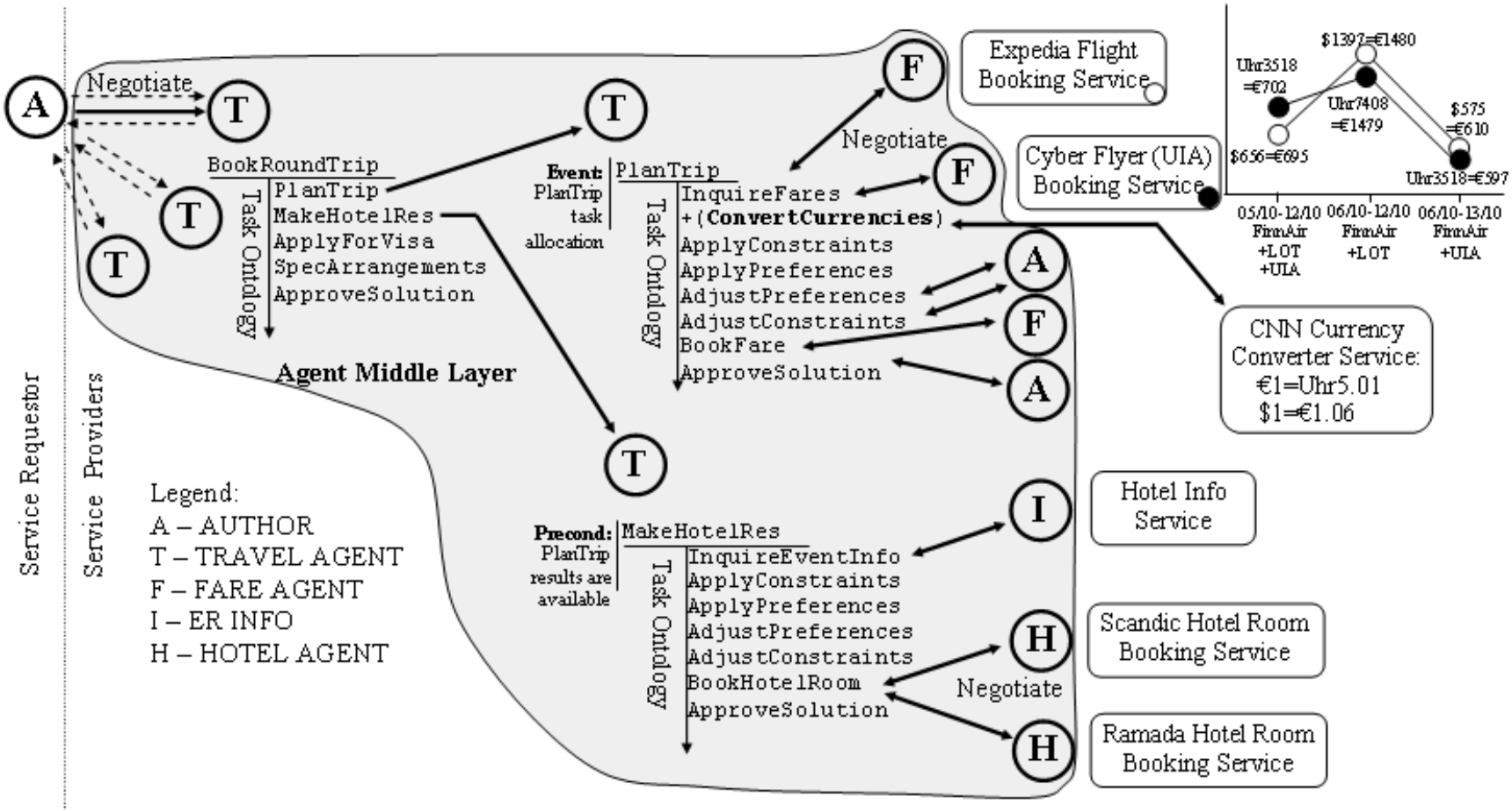
Negotiation on Fares

- 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





'BookRoundTrip' Service Flow



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** (**SPA**s) participating in task execution
- **SPA**s join task coalition only for the time their service is required for the task
- **SPA**s are **economically rational**, **autonomous**, **ready for cooperation**

Agent-Based WS Mediation – the Principles (2)

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

Agent-Based WS Mediation – the Principles (3)

- **Services** are self-contained modular loosely coupled program components **wrapped by SPA**s
- 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**

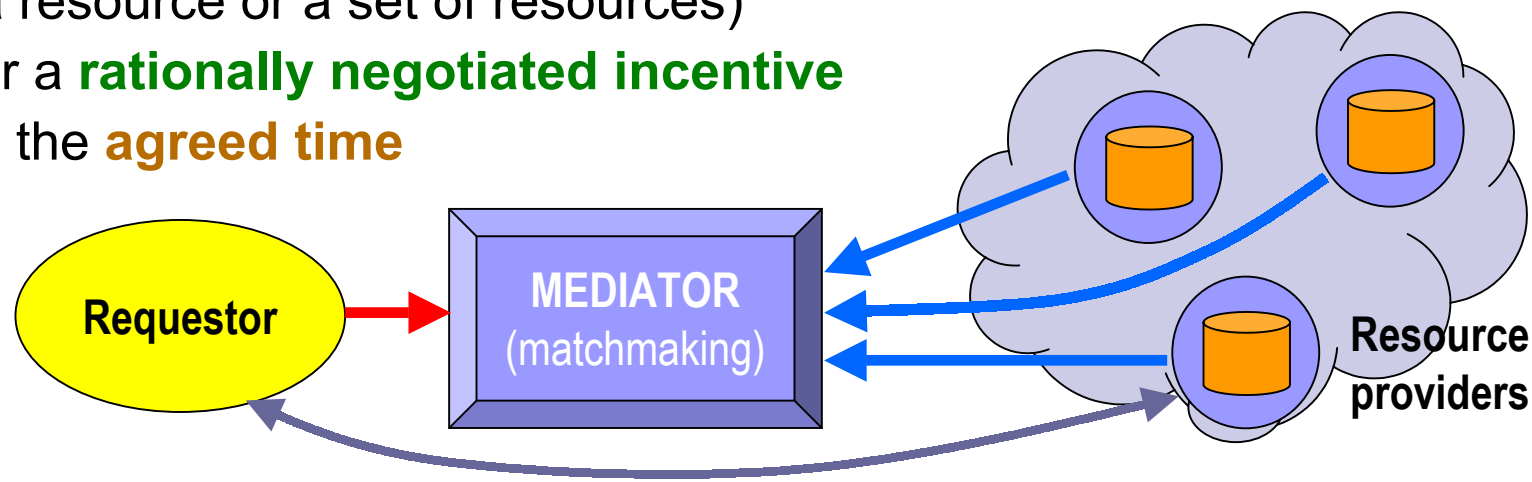
Colleges' Shoulders again:

- "… 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**."*

*__Paul Buhler and José M. Vidal.__ (2003) Semantic web services as agent behaviors. In B. Burg, J. Dale, T. Finin, H. Nakashima, L. Padgham, C. Sierra, and S. Willmott, editors, *Agentcities: Challenges in Open Agent Environments*, pages 25-31. Springer-Verlag.

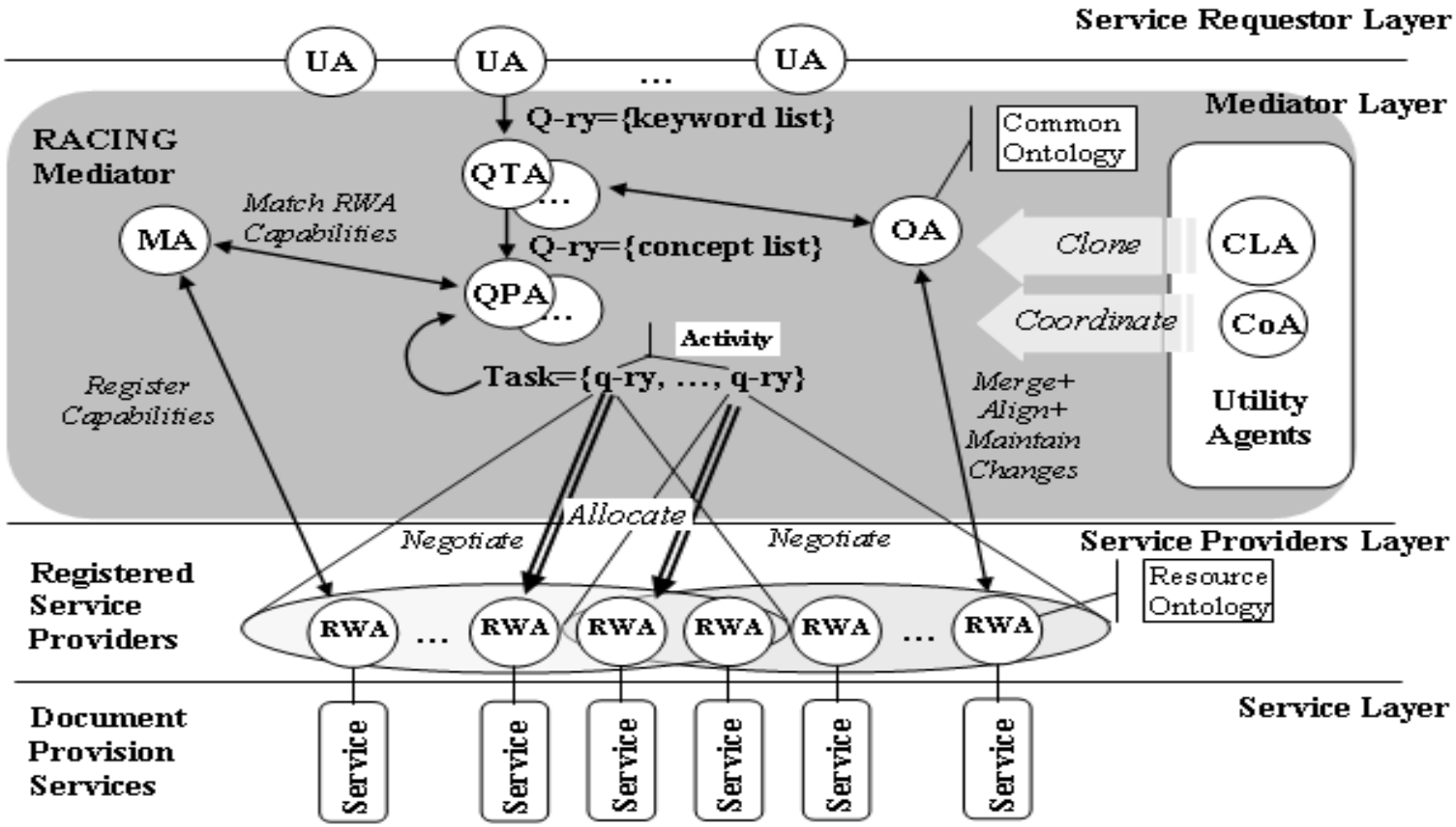
RACING: Agent-Mediated Services for Intelligent IR and Fusion

- 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



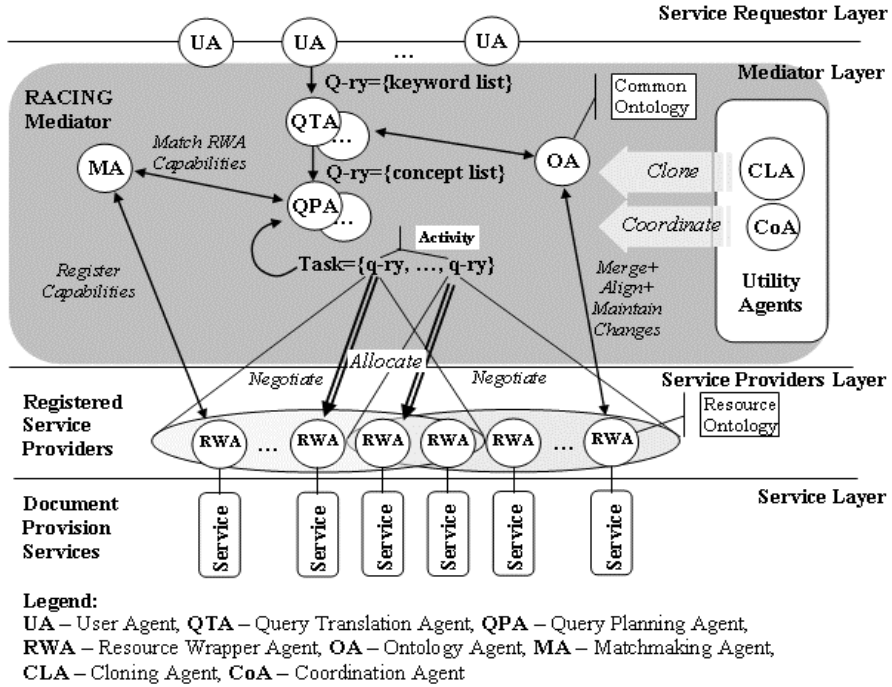
Legend:
UA – User Agent, **QTA** – Query Translation Agent, **QPA** – Query Planning Agent,
RWA – Resource Wrapper Agent, **OA** – Ontology Agent, **MA** – Matchmaking Agent,
CLA – Cloning Agent, **CoA** – Coordination Agent

RACING: Mediator Functionalities

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

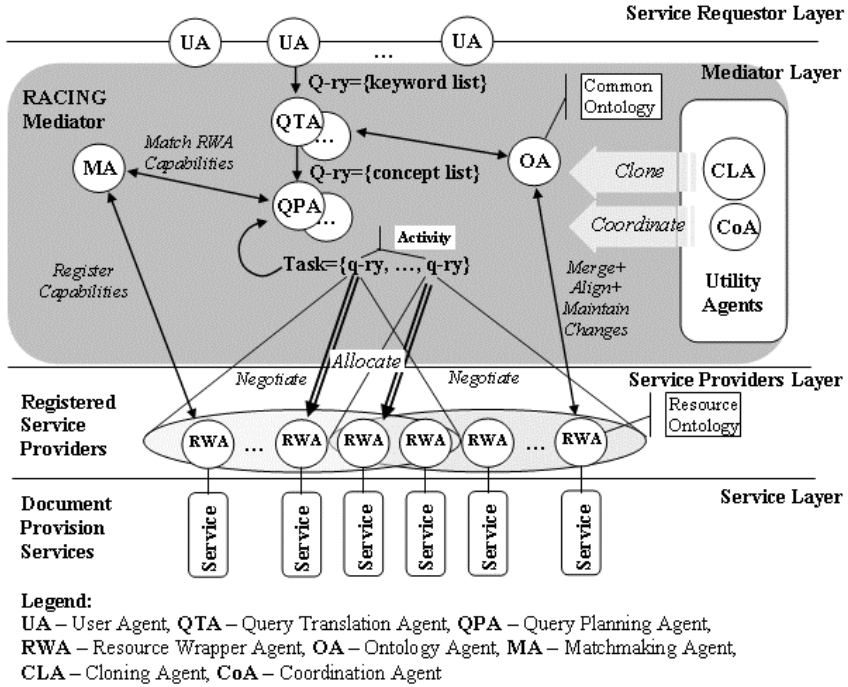
- **Performed as tasks** (distributedly orchestrated dynamic business processes) and **exploit** various types of **negotiation**

RACING: User Request Processing



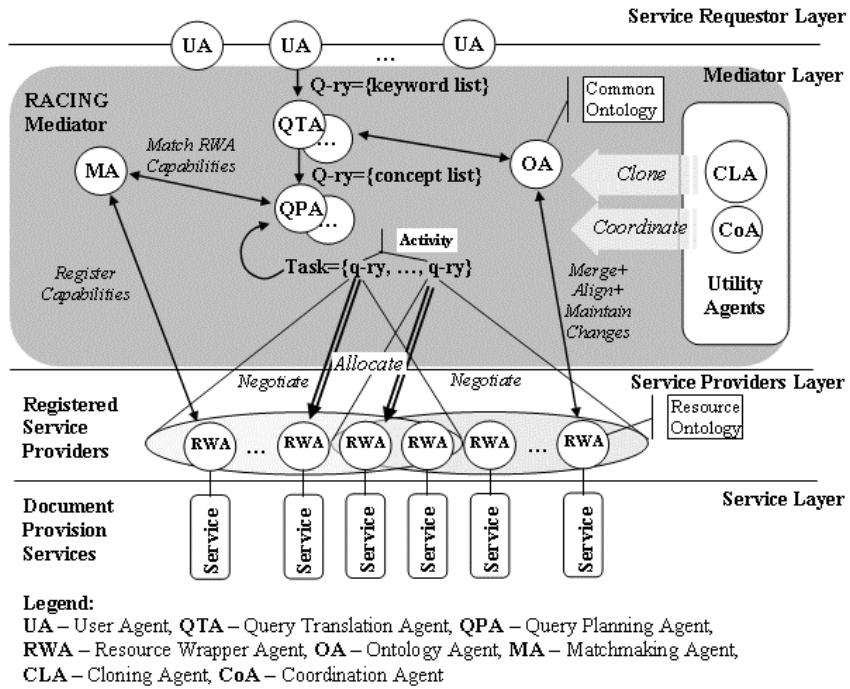
- **UA**: formulates (assists in) the query in terms of the key phrases familiar to the given user
- **UA**: generates and manages the execution of the query processing task: '**CloneQTA**', '**TranslateQry**', '**CloneQPA**', '**ExecuteQry**'
- Cloning activities are outsourced to **CLA** (utility agent), 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



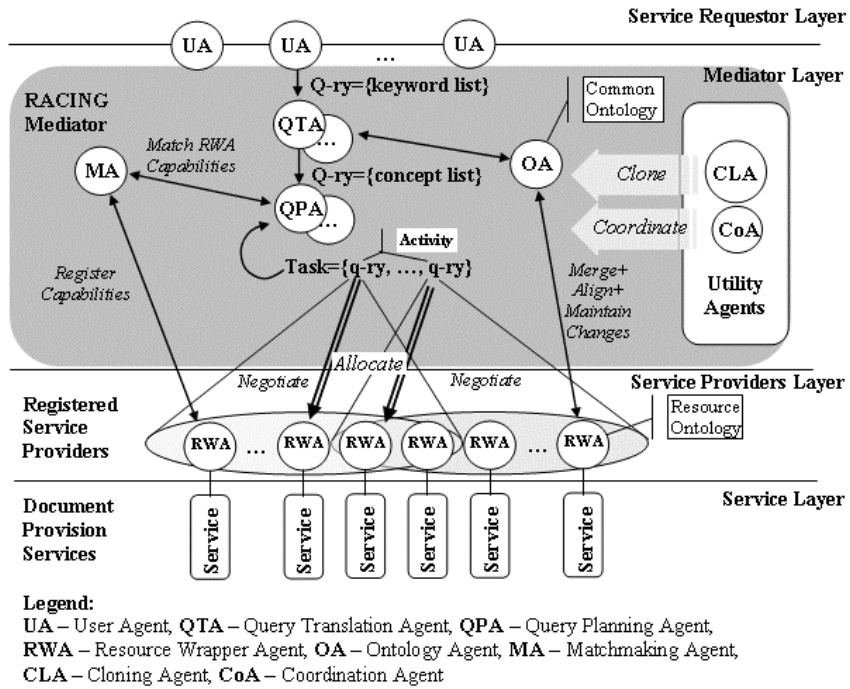
- **QPA** performs **query decomposition** in order to **extract the parts** of the incoming query, which may **require different capabilities** from document service providers
- The extraction is **guided by topic classification of the common mediator ontology**
- Resulting **set of partial queries** 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 **RWA**s 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/

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

* **Tim Berners-Lee, James Hendler and Ora Lassila** (2001) The Semantic Web, Feature article In Scientific American, May, 2001 issue

Feature Sample*: Appointments Planning

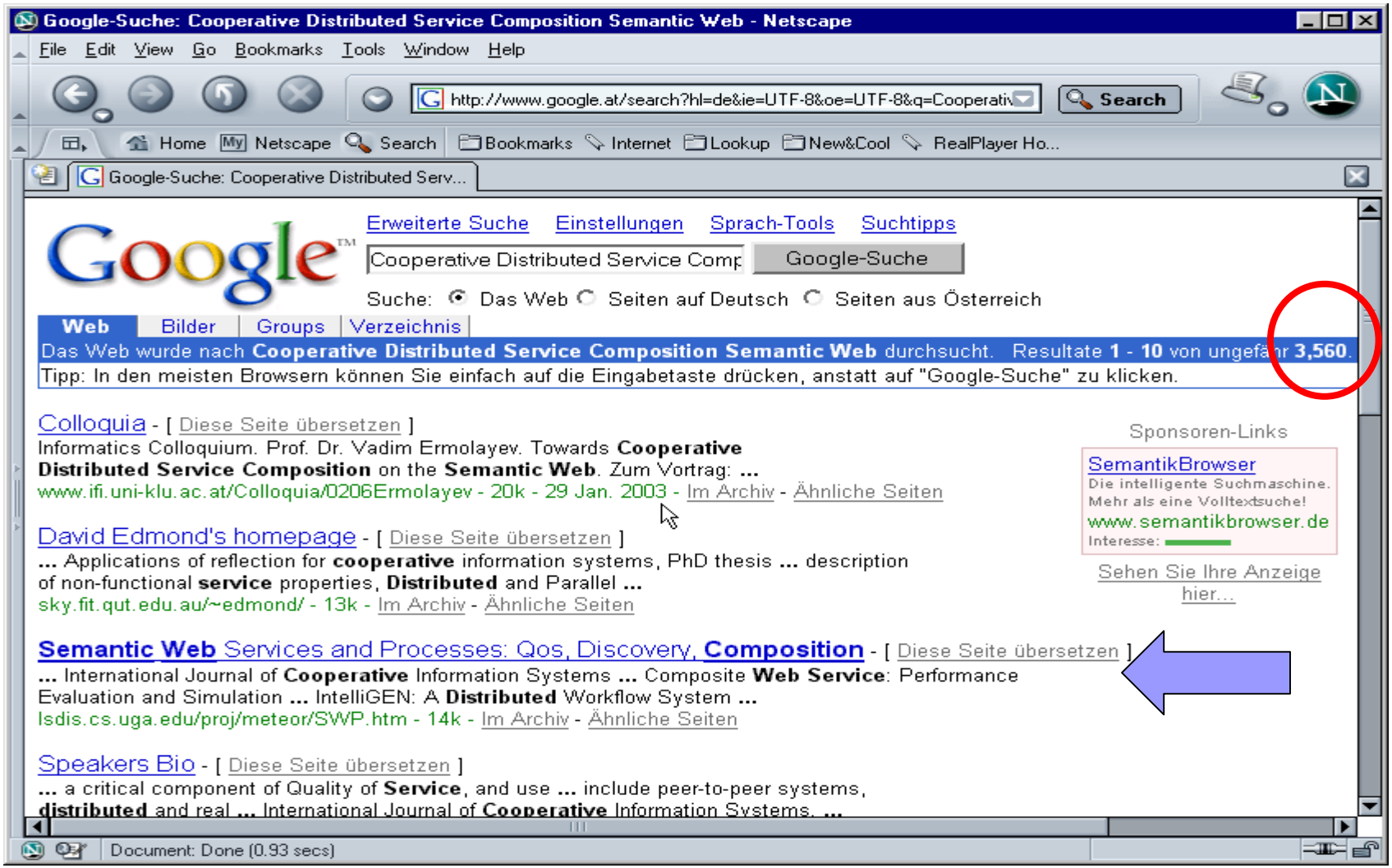
- At the doctor's office, Lucy instructed her **Semantic Web agent** through her handheld Web browser
- The agent:
  - promptly retrieved information about Mom's **prescribed treatment** from the doctor's agent,
  - looked up several lists of **providers**,
  - checked for the ones **in-plan** for Mom's 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 …

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 Cardoso[1], Christoph Bussler[2], Amit Sheth[1, 4], Dieter Fensel[3]
[1]LSDIS Lab, Computer Science, University of Georgia
[2]Oracle Corporation
[3] Universität Innsbruck
[4] Semagix, Inc

Tutorial at Federated Conferences
On the Move to Meaningful Internet Computing and Ubiquitous Computer 2002, Irvine CA, October 2002.

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

Shall be happy …

…To answer your questions