

# Towards Agent-Based Rational Service Composition – RACING Approach



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# Semantic Web Services' Orchestration: the field is becoming increasingly hot

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- Several ongoing initiatives define **compositional notations** for web services
- E.g.:
  - **IBM, Microsoft and BEA** have recently released **BPEL4WS** as the **specification for coordinating business processes** over the Web
  - **OASIS** has formed the **Technical Committee** to continue the work on the **Web Services Business Process Execution Language**
- **These notations** express the flow of control and data across a collection of web services **whose choreography performs a workflow**

# ...Having a Recipe doesn't yet Grant Having a Meal...

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- A **pro-active component** capable to understand the “score” is required
- Pro-active understanding of the process specification is:
  - Not only the **ability to ensure the right sequence** and **the proper combination** of the components
  - But also the **capability** to find **the best provider** in the dynamic and open environment
- This is why much attention is paid to the field of **agent-enabled web service composition**

# The Convergence is Mutually Beneficial

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- Agents may acquire new capabilities by assimilating the semantics of web services' orchestration

**"... 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, (Eds.), *Agentcities: Challenges in Open Agent Environments*, pp 25-31, Springer-Verlag.

# What we should like to offer is:

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- A new understanding of a **web service** as:
  - An **agent capability** implemented as a self-contained software component (a **pro-active component**)
  - A kind of **a generalized resource** (described by the **compositional notation** and being the **subject of negotiation and trade**)
- It implies the appearance of the **rational service providing agent**:
  - Demanding the **negotiable incentive** for the **certain service**
  - And thus **aiming to increase its utility**
    - E.g.: if a service requested from a travel agency is `'BookRoundtrip('Kiev', 'Erfurt', 22/09/03, 25/09/03, ...)'`, the price paid by the requestor will comprise:
      - the prices of consumable resources (air fare, hotel room, ...)
      - plus the incentive paid to the contracted service provider for `'BookRoundtrip'` service usage

# What's behind the scenes ...

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- The **agent** performing '**BookRoundtrip**' service should be able to realize that the requested **task is composite** and will **require RATIONAL cooperation** with at least:
  - Air Companies' service providing agents
  - And hotel booking service providing agents
- These **freelance actors** will also intend to increase their own utilities by requesting fees for their service provision

# 'BookRoundtrip' Scenario

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## Agent roles (played by human actors):

- **AUTHOR (A)** – acts on behalf of the one of the paper authors attending ICWS'03-Europe , requests '**BookRoundtrip**' service
- **TRAVEL AGENT (T)** –provides '**BookRoundtrip**' service, generates and conducts corresponding task execution behind the scenes
- **FARE AGENT (F)** – provides air fare information and booking services
- **ICWS INFO (I)** – provides information services on ICWS'03-Europe: local arrangements, infrastructure, accommodation, etc
- **HOTEL AGENT (H)** – provides hotel room reservation services
- **BUSINESS PARTNER (P)** – acts on behalf of **A**'s business partner in Austria with whom **A** intends to meet in Germany in time of the conference to discuss a joint proposal

# 'BookRoundtrip' Exercise Inputs

- Semi-formally (enough for human actors to understand unambiguously):

**Starting\_Point**= "Kiev, Ukraine"

**Destination**="Erfurt, Germany"

**Beg\_Date**=22/09/2003

**End\_Date**=25/09/2003

**Event**="ICWS'03-Europe"

**Preferences**=(“low fare”, “non-stop flights”, “fast connections”, “4-star hotel”, “continental breakfast”, “conference discounts”)

**Constraints**=(**Budget** = €1500, **Payment**=(VISA, USD),

**Hotel** >= 3-star, **Room-per-night** <= €110, **Hotel\_Location**="in Max 20 min walk from the Conference venue")

**Special\_Arrangements**=(**Event**="business dinner",

**Agent**=(“Prof. Heinrich C. Mayr”, <http://www.ifi.uni-klu.ac.at/IWAS/HM/Staff/Heinrich.Mayr/>),

**Date**=(23/09/2003, 24/09/2003),

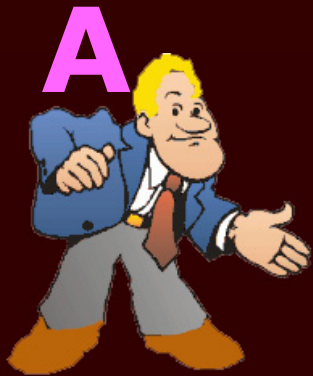
**Location**=(Erfurt, Munich),...)





# What are the parties supposed to do?

- Negotiates with **T**-s about which **A** believes that they are:
  - **Capable** to provide '**BookRoundtrip**'
  - **Reliable** partners
- Collects **proposals** from **T**-s and selects the best of them
- Hires the **T** which has given the best proposal
- Pays and gets the results
- Analyses if **A**'s inputs allow to accept the job
- Prepares the proposal based on its **previous experience**
- IF hired:
  - Conducts the performance of '**BookRoundtrip**' according to:
    - Its **knowledge about the job**
    - Its beliefs about the **other service providers** which **might be involved**
  - Provides the best result possible to prove that it is **reliable**
  - But does it **rationally** for not to loose its income



# And why do they do it?

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## A desires:

- ❑ Not to go behind the scenes
- ❑ To rely on the T-s competencies
- ❑ To pay a reasonable incentive for that

## A believes:

- 'BookRoundtrip' is an atomic activity – just a piece of cake
- 'BookRoundtrip' may be outsourced to T



## T desires:

- ❑ To be hired and paid for the job
- ❑ To spend the money most efficiently (remain competitive)
- ❑ To remain a reliable partner for A

## T believes:

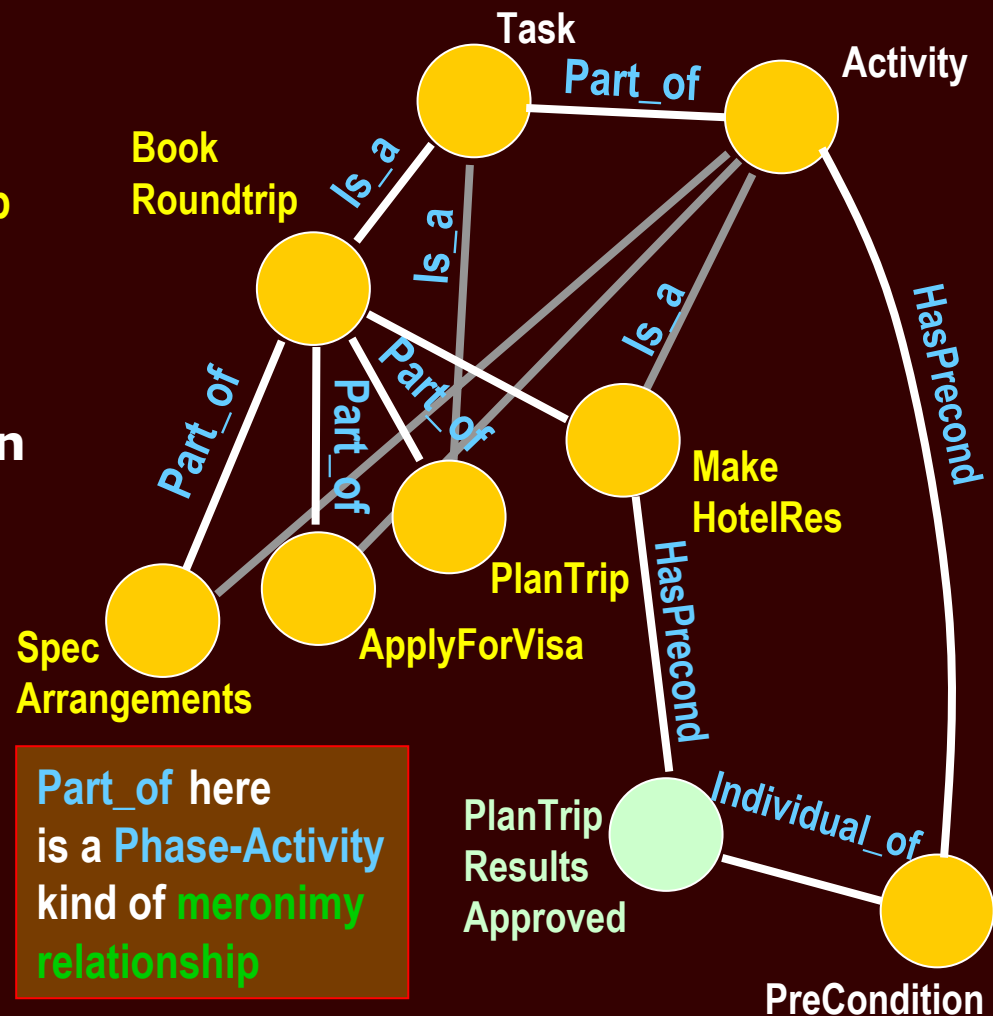
- 'BookRoundtrip' is a complex, dynamic, composite task



# T: 'BookRoundtrip' is a Complex Task

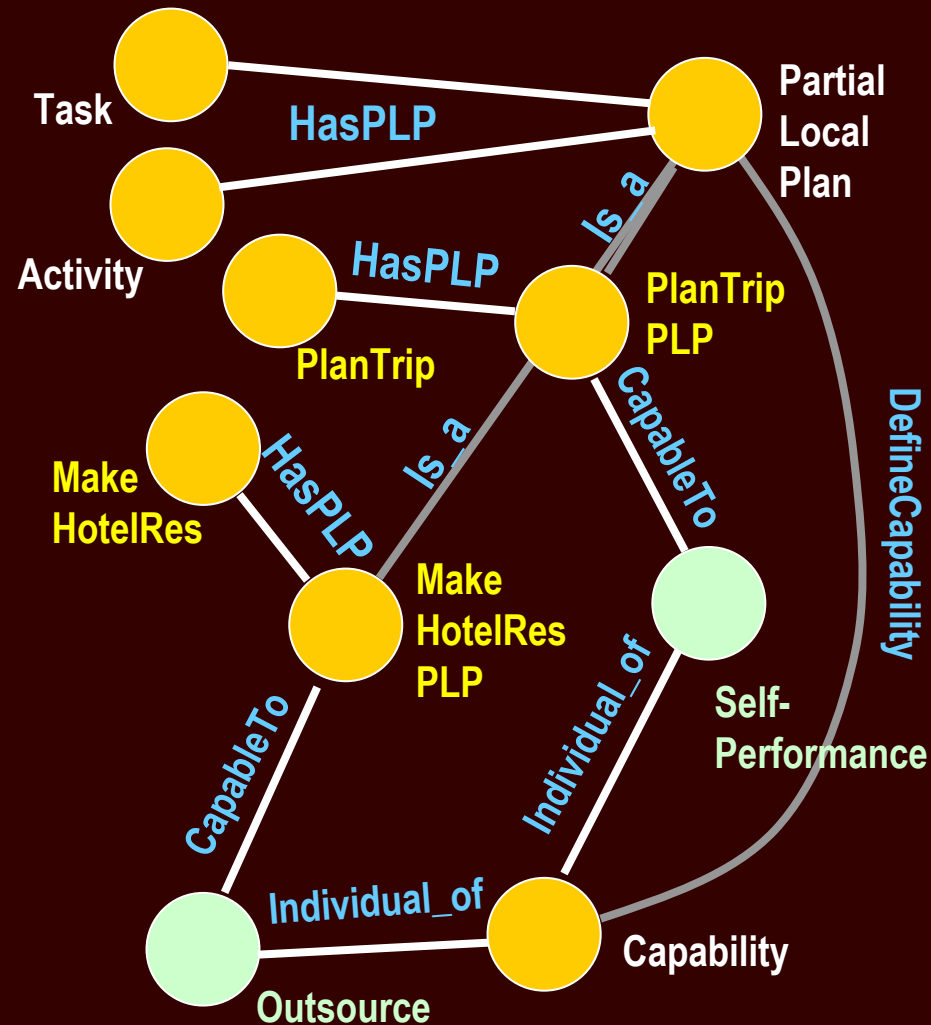
- The knowledgebase of T contains facts:
  - **BookRoundtrip** is a **Task**
  - It **contains at least** **PlanTrip Task** and **MakeHotelRes, ApplyForVisa, SpecArrangements Activities** as its **phases**
  - **MakeHotelRes** requires **PlanTrip** results as the **PreCondition**
  - **SpecArrangements** and **ApplyForVisa** may be performed concurrently with **PlanTrip** and **MakeHotelRes**

- These facts are formulated in the terms of the **Task Ontology** (namespace for the compositional notation)



# T: 'BookRoundtrip' – More Facts

- The knowledgebase of **T** contains facts:
  - **Tasks** and **Activities** have **Partial Local Plans (PLP)**
  - **PLPs** among other facts define the **Capability** to perform an **Activity** either by **itself** or by **outsourcing** it to another agent
  - According to **PlanTripPLP** **T** is capable to perform **PlanTrip** by **itself**
  - According to **MakeHotelResPLP** **T** needs to **outsource** **MakeHotelRes** to another agent (via **Contract Net negotiation**)



!!! Another **T** may have **different Capabilities** and **PLPs** wrt '**BookRoundTrip**' phases

# T: behaves pro-actively

## – Adjusts Inputs

- An intelligent service provider may propose to **pro-actively change** the **Task Inputs** in order to get better overall result

- E.g., for **PlanTrip** the following alternative dates:

- **Beg\_Date=20.09, End\_Date=25.09**

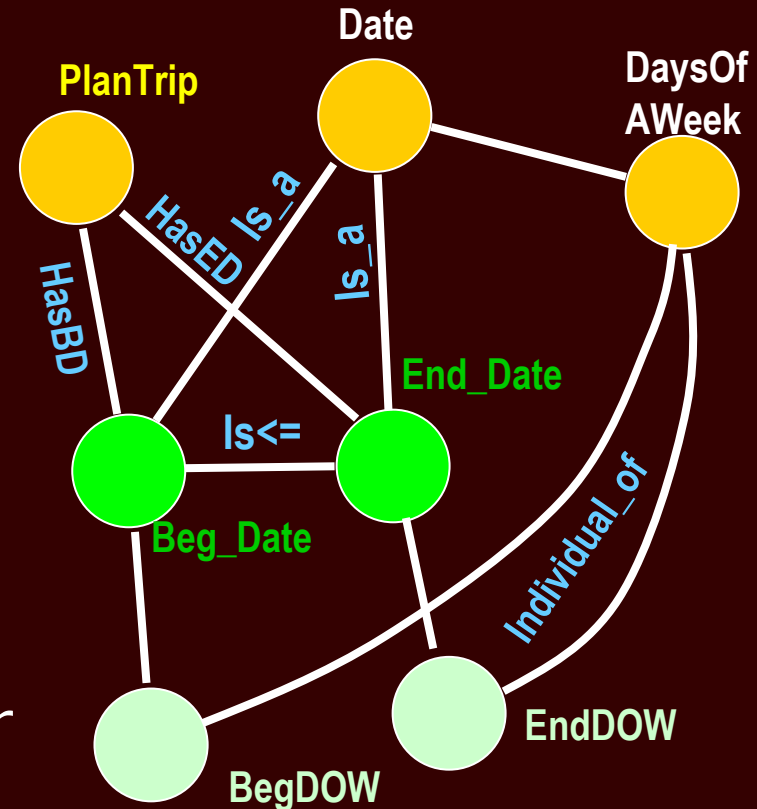
Or

- **Beg\_Date=22.09, End\_Date=28.09**

- May significantly **lower the cost** of the air fare because of the **Sunday Rule** Discounts

- Assertions on **Task Inputs** will form, e.g., the **initial proposal** for AirFare **negotiation**

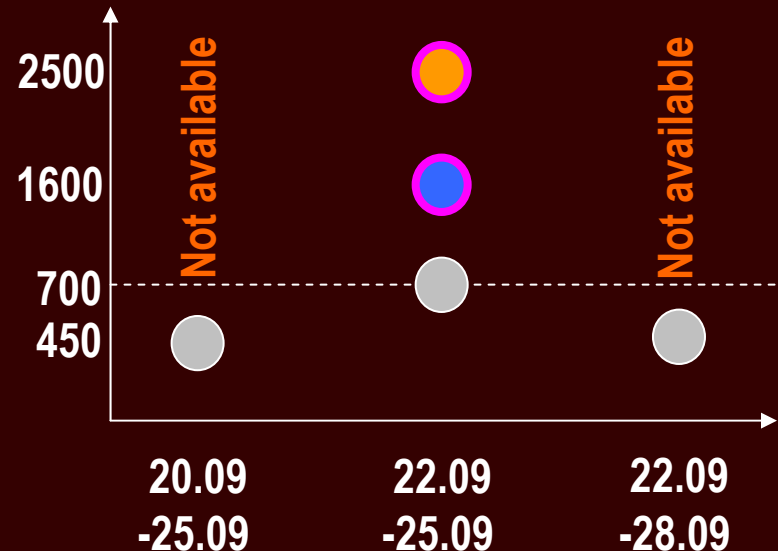
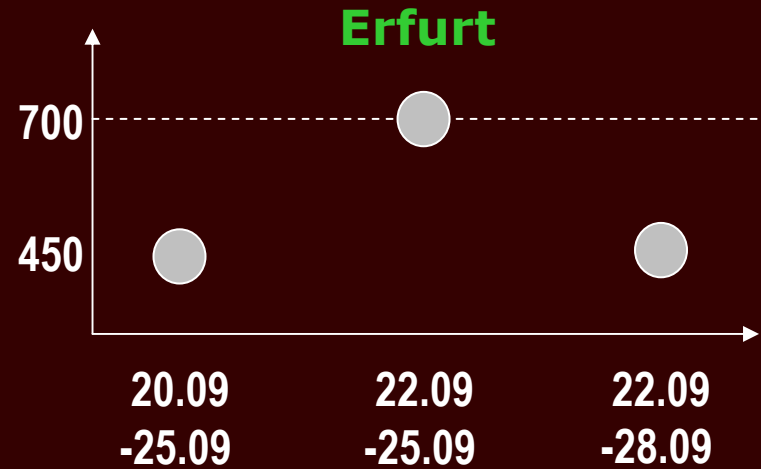
- **T** should undertake it to **outsource** **InquireFares Activity** while performing **PlanTrip Task**



**SundayRuleDates** (**Beg\_Date, End\_Date**):  
(**End\_Date-Beg\_Date**>6) Or (**BegDOW**>**EndDOW**)

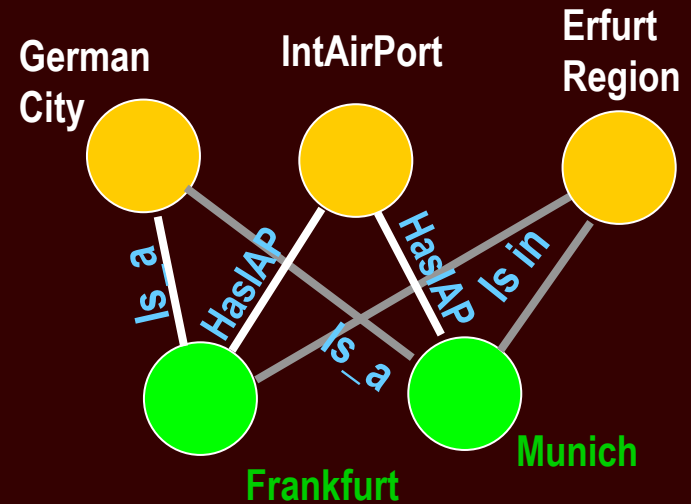
# T-F-s: Negotiation on Air Fares

- **T** knows from his knowledgebase that **InquireFares** should be outsourced
- **T** knows from his previous experience that:
  - Some **F-s** are **capable** to perform **InquireFares**
  - Some of them are **trusted partners**
- **T** starts **Contract Net negotiation** by declaring **Activity Inputs** and the **Intended Price**
- **F-s** invoke **Web Services** they wrap and respond with ...
- These responses are not satisfactory for **T** ...

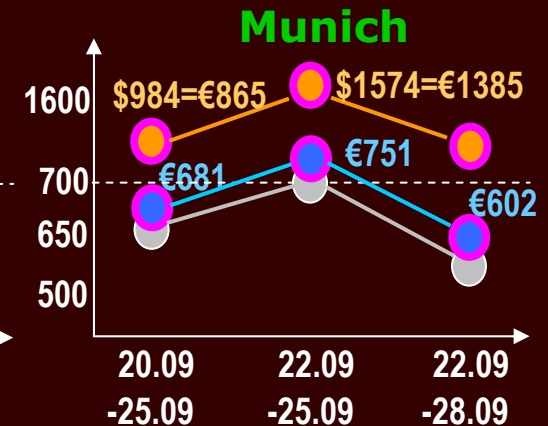
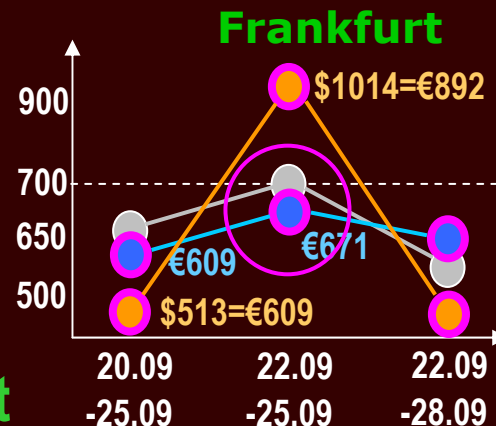


# T: yet one more Adjustment

- T has got unsatisfactory responses from F-s
- T pro-actively tries to alter the **destination point** to the one close to Erfurt ...

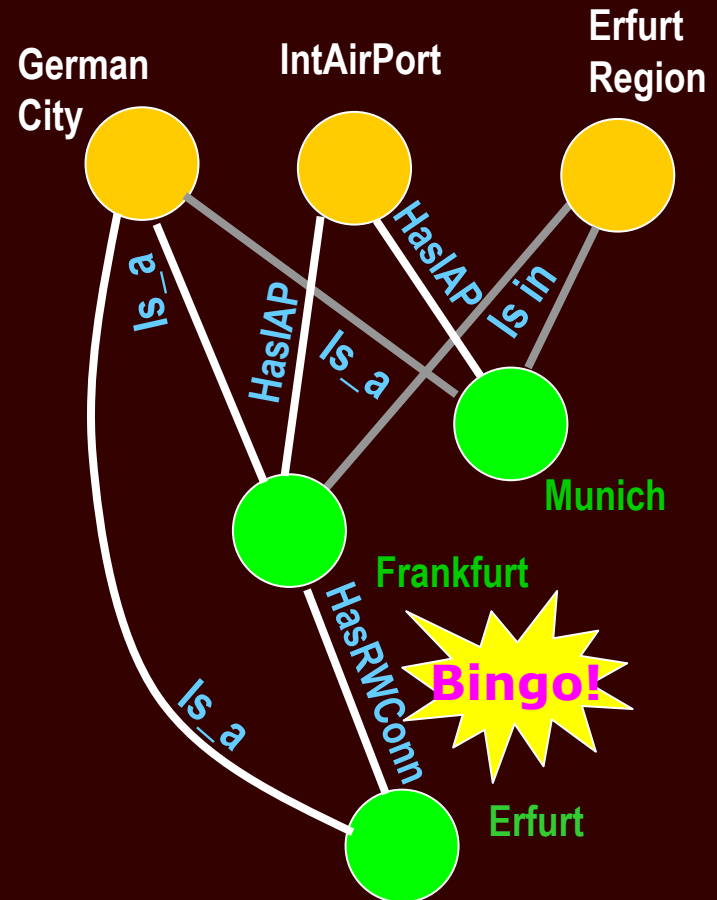


- Negotiations on **Frankfurt** and **Munich** fares result in:
- **Frankfurt** is chosen as the **destination point**



# T: Additional Activity is Required

- ...But Frankfurt is not Erfurt
- So, T needs to explore Frankfurt's Properties for Connections
- Luckily, there is an appropriate fact in T-s knowledgebase:
  - Frankfurt HasRWConn to Erfurt
- This leads T to incorporate one more Activity to PlanTrip Task: BookRWFare ...
- Further on, Die Bahn Web Service provides the result
- The mechanism seems to be the same as for InquireFares

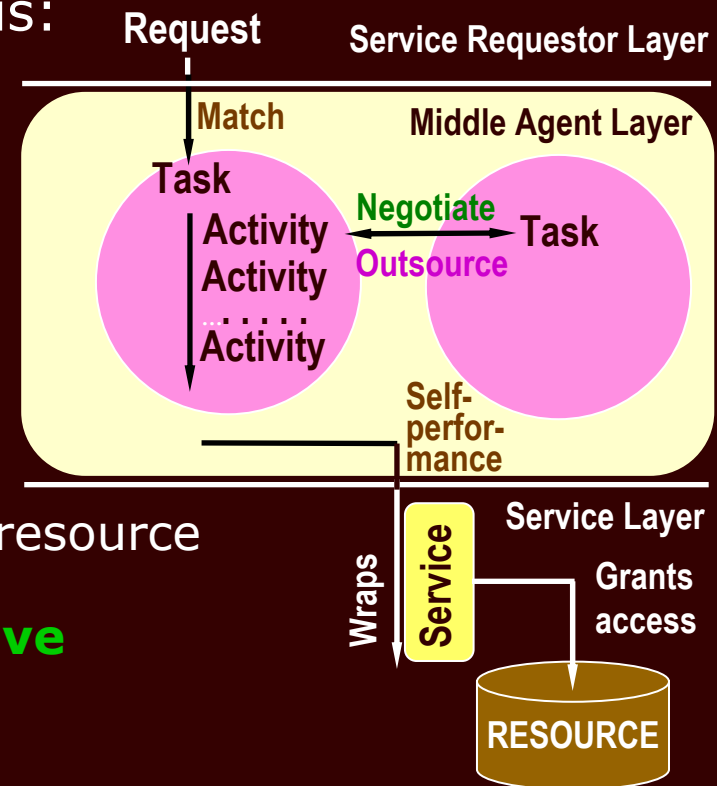






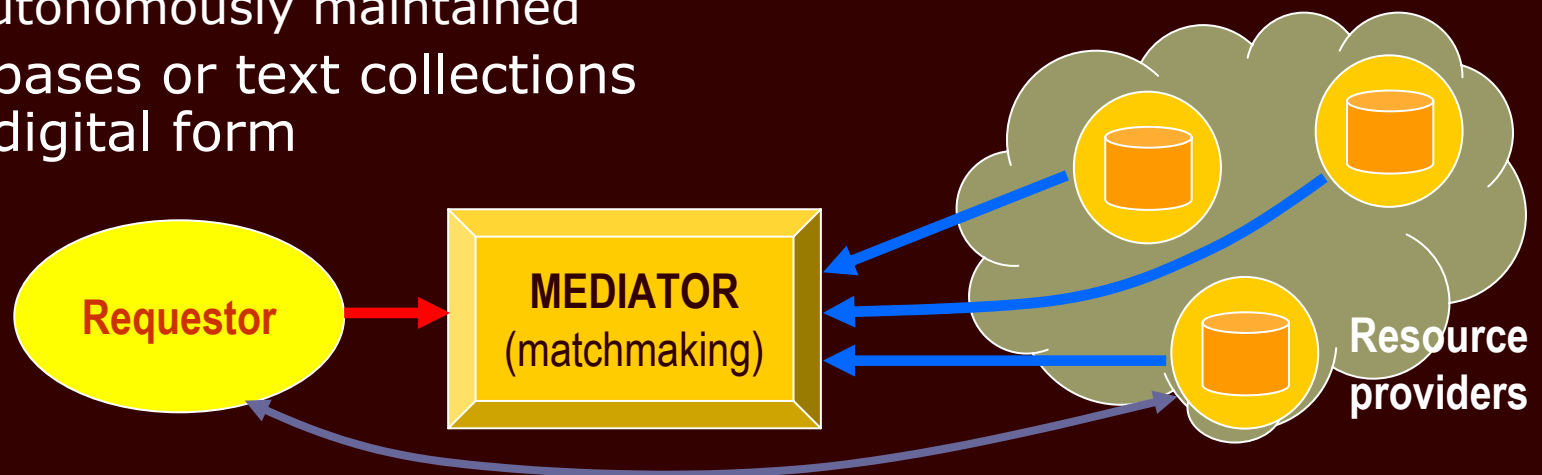
# RACING: the Very High Idea

- ❑ **RACING: Rational Agent Coalitions for INTELLiGent Mediation of Information Retrieval on the Net**
- ❑ In a Nutshell – **RACING approach** is:
  - In exploiting **Agent-Service-Resource** wrapping hierarchy
  - For getting possibilities to apply **CDPS technique** to Intelligent Rational **Information Retrieval** and **Information Fusion**
- ❑ **Overall high-level goal** of 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**



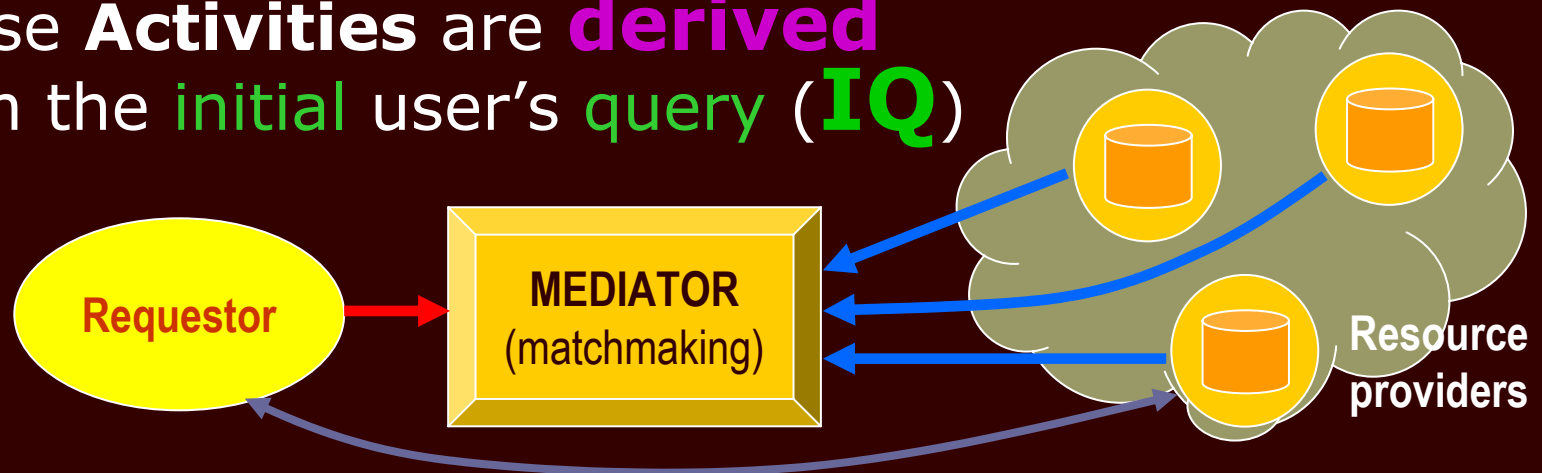
# RACING: the Very High Idea

- In the field of document retrieval a service request is traditionally presented in the form of a query: a first order logic expression over the list of keywords or phrases
  - E.g., **<paper> AND <ICWS'03-Europe> AND <pdf>**
- Documents or resources (web pages, scientific papers, magazines, books) are stored at:
  - disparately structured,
  - distributed,
  - autonomously maintained
- databases or text collections in a digital form



# RACING: the Very High Idea

- Documents (web pages, scientific papers, magazines, books):
  - are marked-up, annotated and indexed according to **different standards**
  - belong to **different legal entities**
  - and **often cost money**
- A **Task** for document retrieval may be presented as the composition of interrelated **Activities**
- These **Activities** are **derived** from the **initial** user's **query (IQ)**



# RACING: Reference Architecture

## Legend:

**U** – User

## Agents:

**QTA** –Query Transformation

**QPA** –Query Planning

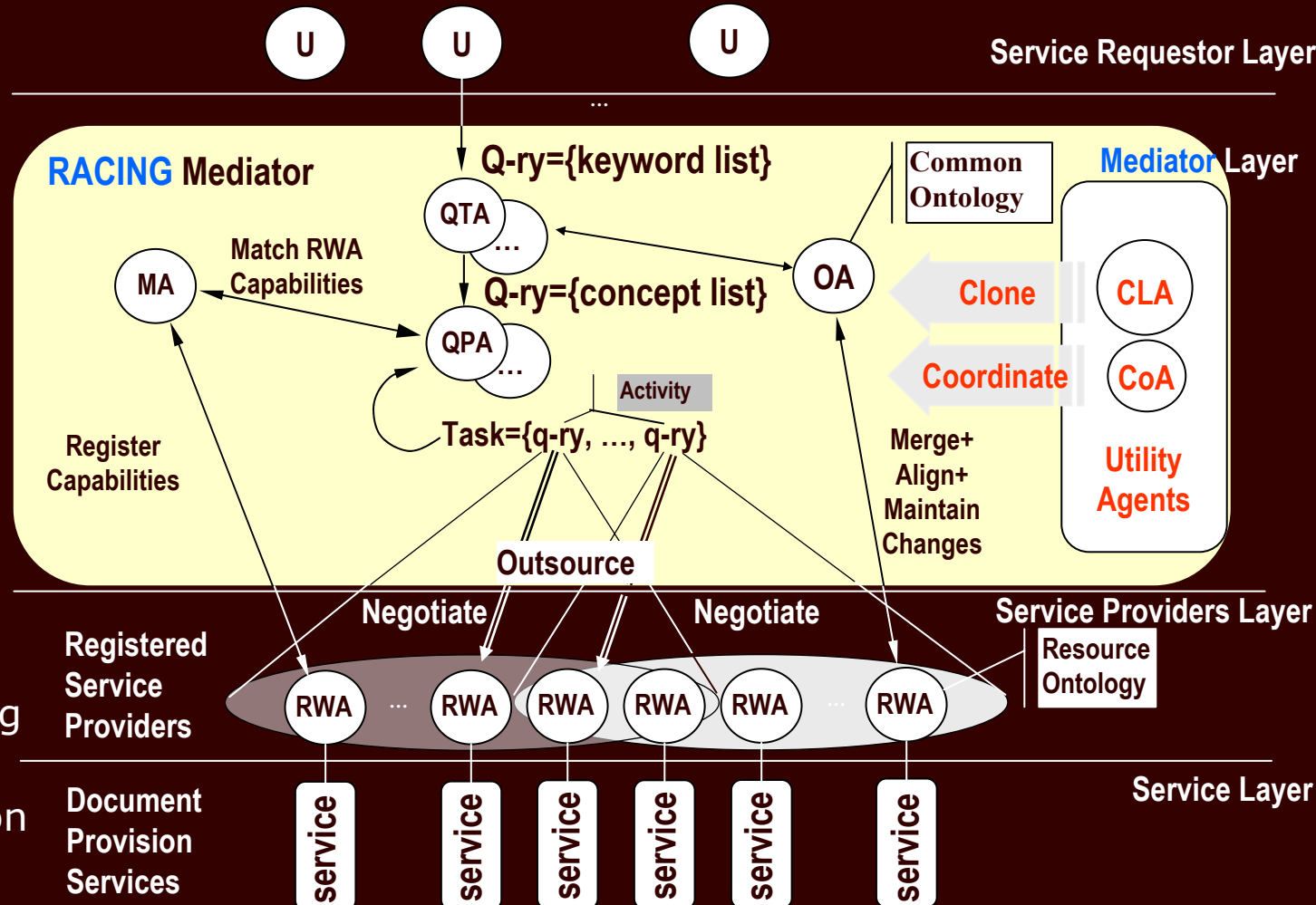
**RWA** –Resource Wrapper

**OA** –Ontology

**MA** –Matchmaking

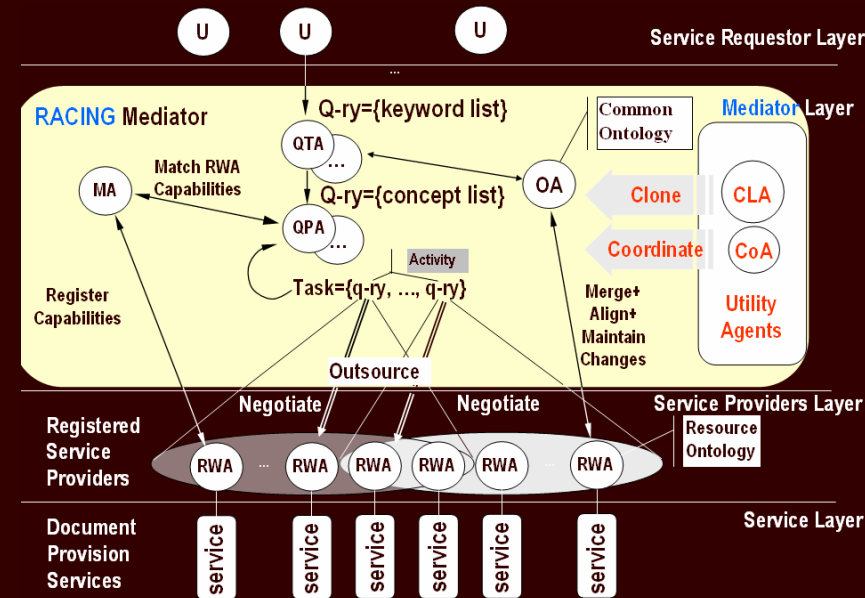
**CLA** –Cloning

**CoA** –Coordination



# RACING: Web Service Composition

- The **agents** of the **RACING** mediator
  - and the **agents** that wrap their **services**
    - That, in turn wrap respective information **resources**
- **Collaboratively perform** the **Tasks** of information retrieval and information fusion
- By orchestrating their web services in a proper composition
- From a **user point of view**, who doesn't see the cooking:
  - These **Composite Tasks**
  - Are simply the **Web Services** provided by the mediator





# Going back to the kitchen ...

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- **Intelligent Web Service Provider** - Essential features:
  - Have appropriate **formal representation** of the **semantics of the services** it is capable to perform (**Task Ontology** in **RACING**)
  - Be capable to **pro-actively adjust service inputs**, assess requestor's **preferences** and **constraints** (**incremental user profiling** and **ontology-driven query transformation** in **RACING**)
  - Be capable to **negotiate** in a rational way **on optimal service provision** and **sub-service outsourcing** (**Extended FIPA Iterated Contract Net Protocol** and **Negotiation Ontology** in **RACING**)
  - Be capable to **monitor and assess** the **capabilities** and the **credibility factors** of another service providers (**reinforcement learning** technique in **RACING**)
  - Be capable to dynamically **plan and coordinate** the **service execution flow** (**Partial Local Plans** and **Coordination Agent** in **RACING** mediator MAS)

# Essential Components / Capabilities

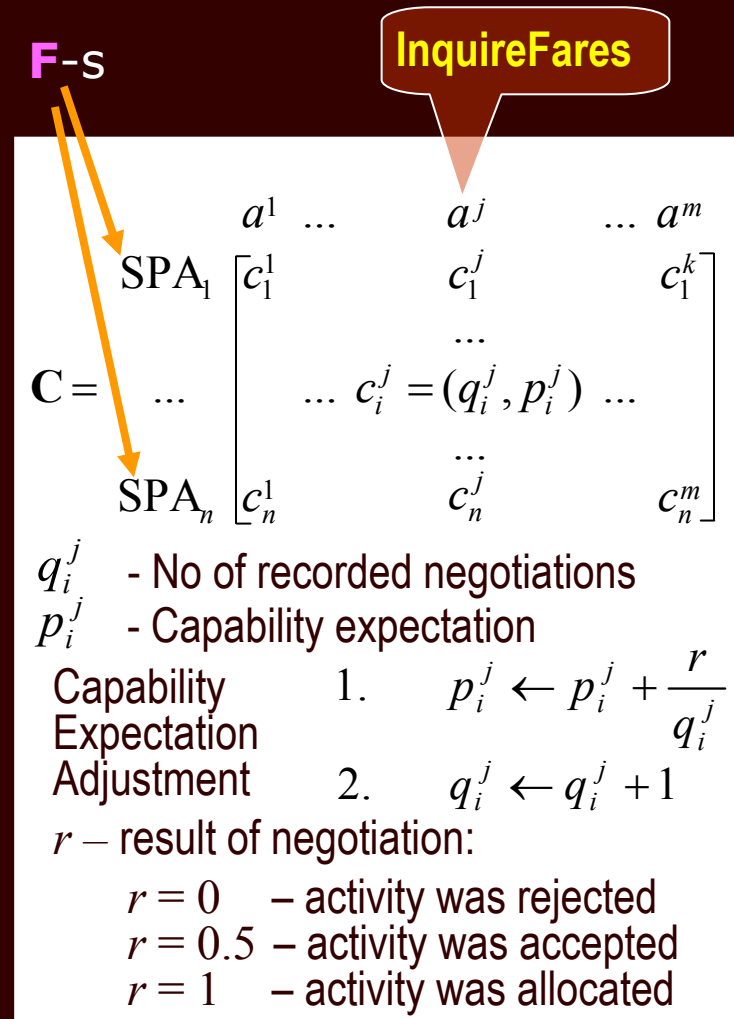
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- **Task Ontology** and **Negotiation Ontology**
  - Ermolayev, V. Keberle, N., Tolok, V. : OIL Ontologies for Collaborative Task Performance in Coalitions of Self-Interested Actors. ER 2001 Workshops, ECOMO, LNCS Vol. 2465, 390-402  
[http://eva.zsu.zp.ua/eva\\_personal/evapubs.htm](http://eva.zsu.zp.ua/eva_personal/evapubs.htm)
- **Partial local Plans** (part of the **Task Ontology**)
- **Incremental User Profiling** and **Ontology-Driven Query Transformation**
  - Ermolayev, V., Keberle, N., Plaksin, S., Vladimirov, V.: Capturing Semantics from Search Phrases: Incremental User Personification and Ontology-Driven Query Transformation ISTA'2003, LNI Vol. P-30, GI-Edition, 9-20  
[http://eva.zsu.zp.ua/eva\\_personal/evapubs.htm](http://eva.zsu.zp.ua/eva_personal/evapubs.htm)
- Partners' **Capability** and **Credibility Assessment** 
- **Rational Negotiation** 



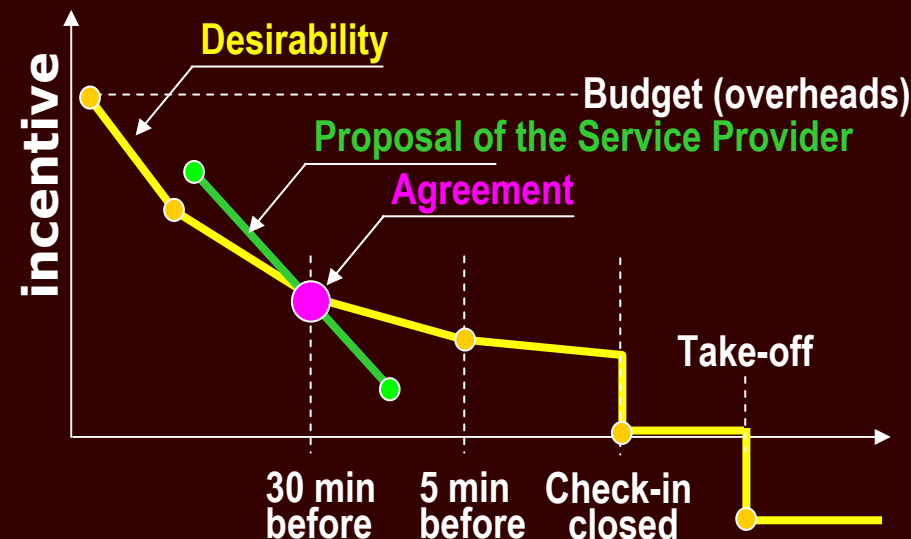
# Service Providers' Capability Assessment

- Recall: agent **T** believes from its previous experience that:
  - Some **F-s** are **capable** to perform **InquireFares**
- These beliefs are maintained by **T** in the form of the **Fellows' Capabilities Estimation Matrix C**
- **Capability Estimations**  $c_i^j$  are adjusted by the results of the previous negotiations on the activity provision
- **IF** ( $p_i > \text{threshold}^j$ ) **SPA<sub>i</sub>** is **capable** to perform  $a^j$



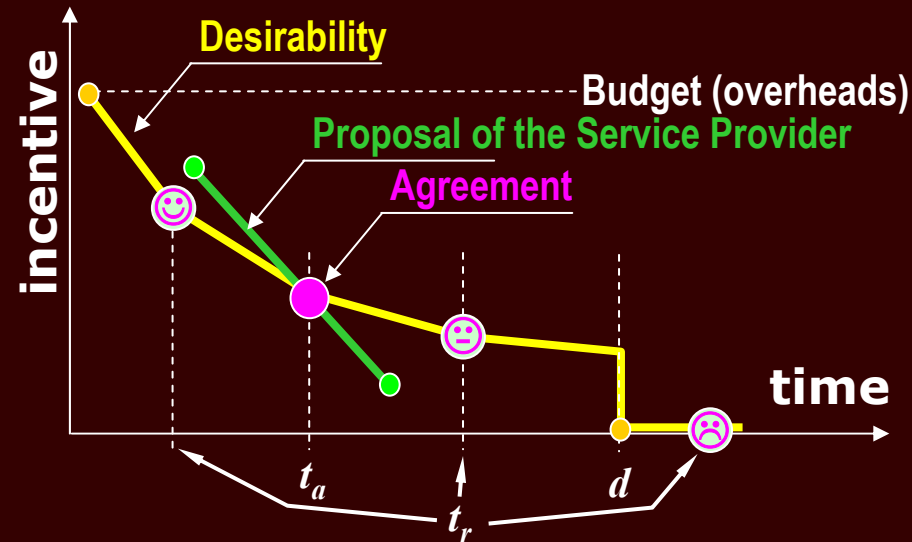
# Service Providers' Credibility Assessment

- A **Service Requestor** expects the results of the service to be delivered at the **agreed** time:
  - **E.g.**, air ticket at the gate counter in 30 min before the check-in
    - What if the ticket appears to arrive in 5 min before the check-in?
    - What if there is still no ticket and the plane is taking off?
- We may associate a kind of a **service results' desirability value** (*des*) with each of these outcomes
  - Indicating, e.g., the **part of the agreed incentive** for the service provision we are ready to pay



# Service Providers' Credibility Assessment

- The **Credibility Value** ( $Cr$ ) associated with a **Service Provider** may be reduced according to the **lost desirability** in case the agreement is not fulfilled



- A **Service Requestor** maintains its **Fellows' Credibility Matrix** (similarly to **Capability Estimations**)

$t_a$  – agreed results delivery time  
 $t_r$  – factual time of results' delivery  
 $d$  – the deadline

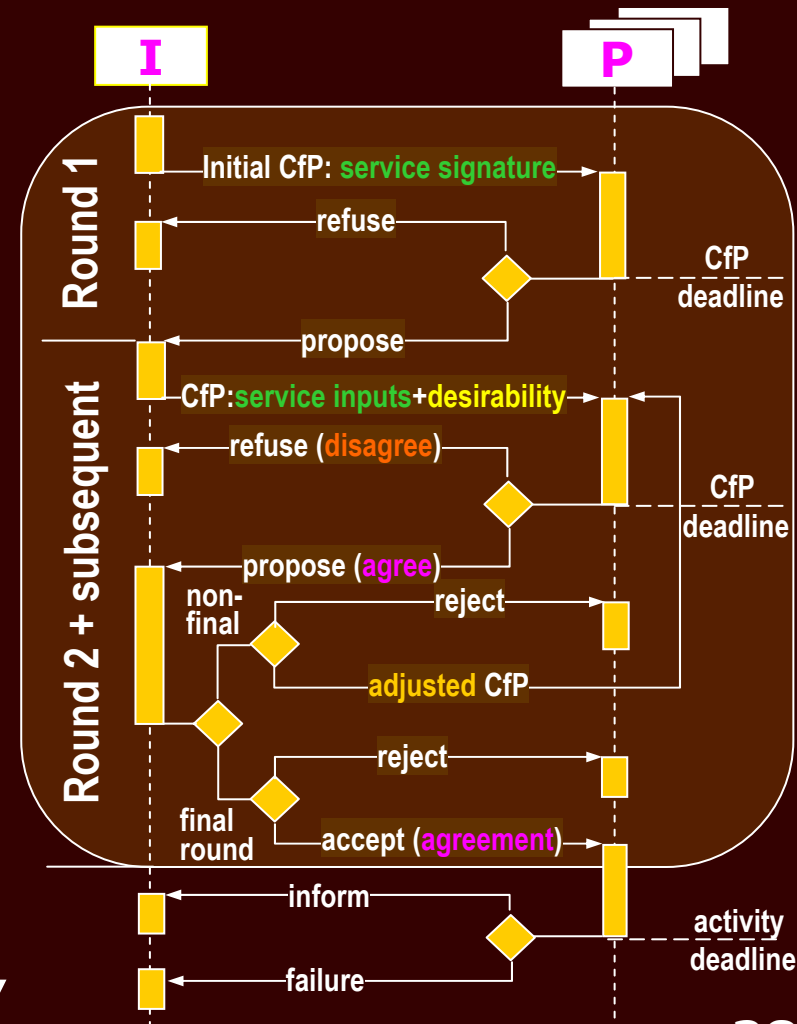
**The rule for Credibility adjustment**  
 ( $Cr$  of SPA $_i$  wrt activity  $j$ ):

$$Cr_{i,j} \leftarrow Cr_{i,j} \times \begin{cases} 1, t_r \leq t_a \\ p(t_a, t_r), t_a < t_r \leq d \\ 0, t_r > d \end{cases}$$

$0 < p(t_a, t_r) < 1$  – the weight factor reflecting desirability losses

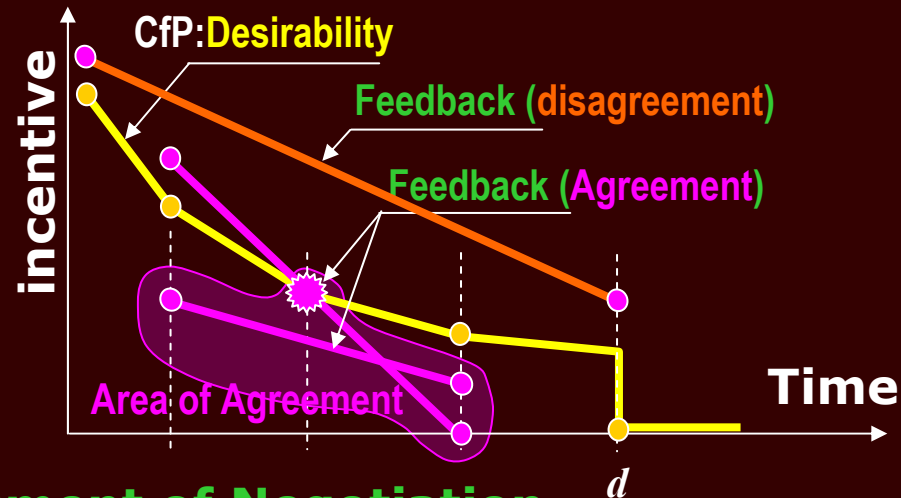
# Negotiation on Service Provision

- Extended **FIPA Iterated Contract Net protocol**:
- Initiator (I)** – Service Requestor
- Participants (P)** – Service Providers (**Capable**)
  - 1-st round** – get initial proposals from **P**-s
  - 2-nd round** – **negotiate**: CFP – **service inputs + desirability**;
    - If several proposals result in **agreement** – choose the best weighted by **Credibility**
  - Subsequent rounds** – **adjust** service inputs in CFP if the proposals on the previous round **do not agree** with CFP
    - E.g.: dates, destination point, ...

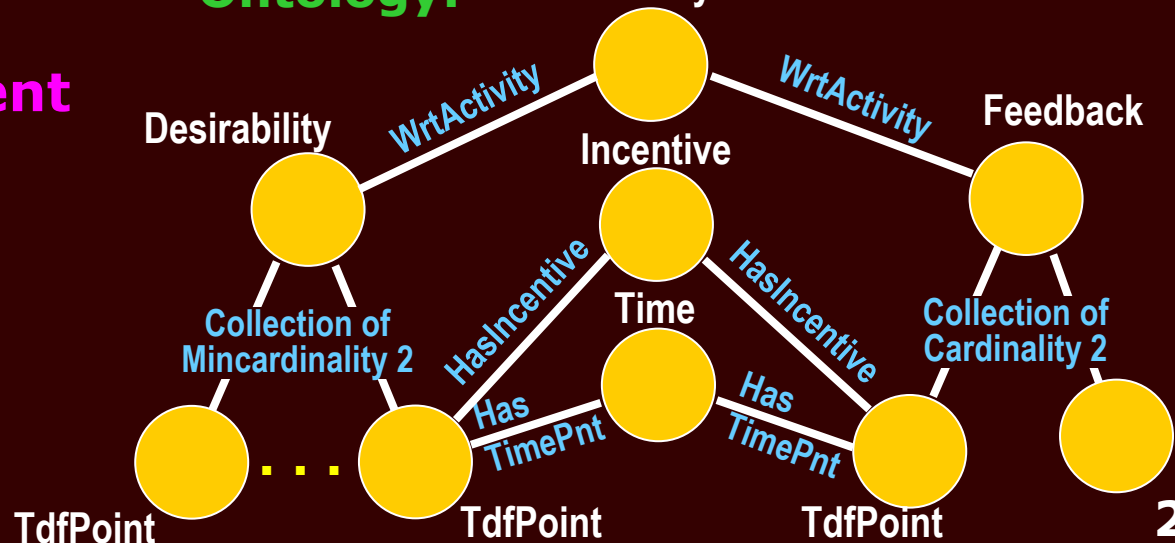


# Negotiation: Agreement and Disagreement

- **I's Desirability** and the **Feedbacks** of **P-s** are formulated in terms of **Negotiation Ontology** as discrete functions of **Incentive per Time**
- The **Feedbacks** which lie **above** the **Desirability** function area indicate **Disagreement**
- Possible **Agreement points** belong to the intersection of the **Desirability** function area and the **Feedback** functions



## Fragment of Negotiation Ontology:



# Conclusions:

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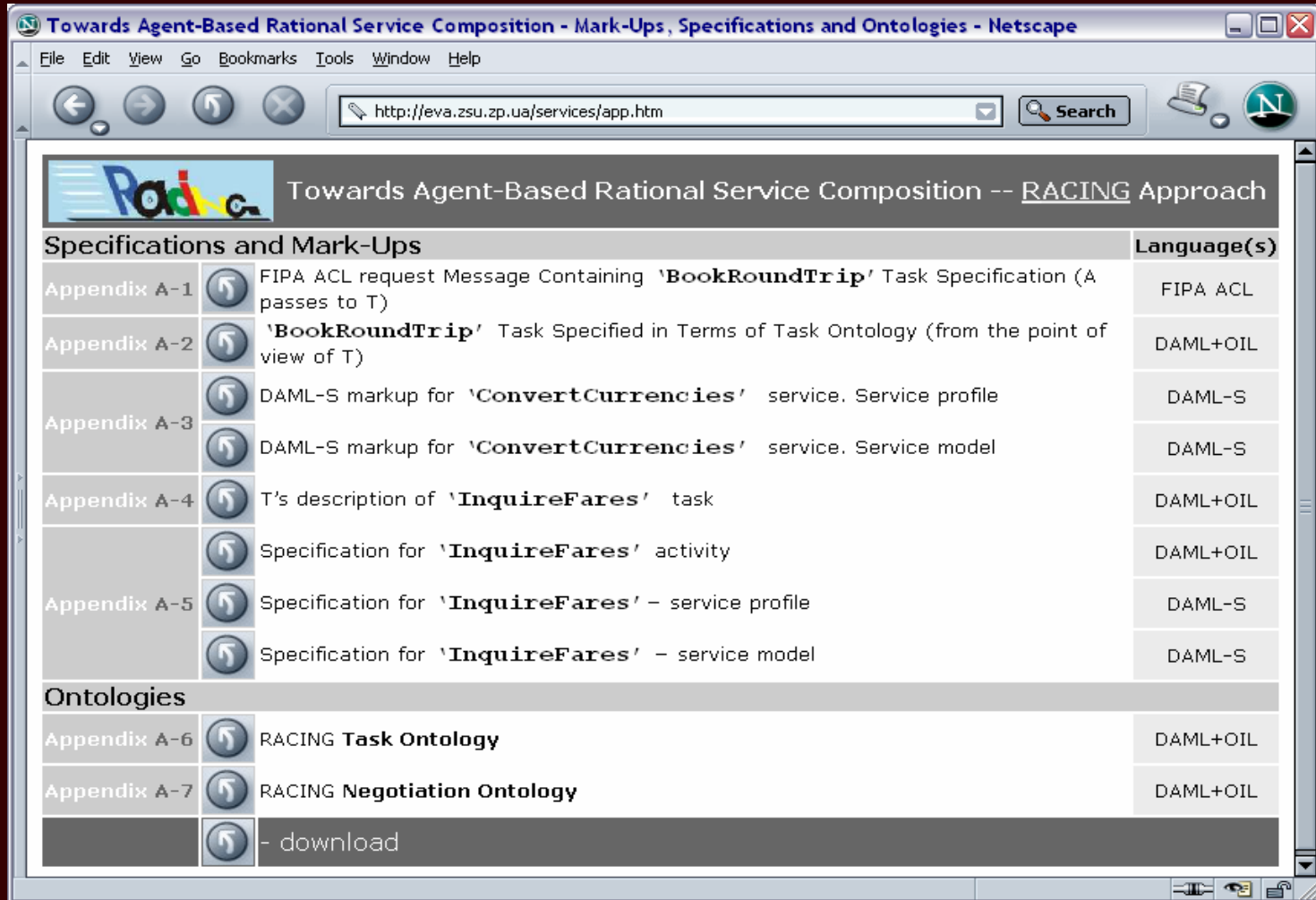
- **Agent Middle Layer** is required for scalable, intelligent, dynamic **service composition**
- **Composite services** are interpreted as **Tasks** comprising **Activities** of **varying granularity**
- **Service Mediator** is formed **dynamically** as the **coalition of service providing agents (SPAs)** participating in the **Task** execution
- **SPAs** are **economically rational** and **autonomous** (independent in taking their decisions)
- **Specialization** of an SPA is defined by **the set of services** it wraps
- **Services** are self-contained modular loosely coupled program components **wrapped by SPAs**

# Conclusions:

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- **SPAs** need to be **capable** to:
  - **Analyze** and **decompose** an incoming **Task** according to its local knowledge (**Task Ontology, Partial Local Plan**)
  - **Make arrangements** for **outsourcing** an **Activity** to another **SPAs** through **Contract Net Negotiation**
  - Pro-actively **adjust service inputs** in the course of **negotiation**
  - **Adjust** their **beliefs** on other **SPAs'** **Capabilities** and evaluating **SPAs' Credibility** through **monitoring** cooperative activities

# To download some Specs:



The screenshot shows a Netscape browser window with the title "Towards Agent-Based Rational Service Composition - Mark-Ups, Specifications and Ontologies - Netscape". The address bar contains the URL "http://eva.zsu.zp.ua/services/app.htm". The page content is titled "Towards Agent-Based Rational Service Composition -- RACING Approach" and features a table with the following data:

Specifications and Mark-Ups		Language(s)
Appendix A-1	FIPA ACL request Message Containing ' <b>BookRoundTrip</b> ' Task Specification (A passes to T)	FIPA ACL
Appendix A-2	' <b>BookRoundTrip</b> ' Task Specified in Terms of Task Ontology (from the point of view of T)	DAML+OIL
Appendix A-3	DAML-S markup for ' <b>ConvertCurrencies</b> ' service. Service profile	DAML-S
	DAML-S markup for ' <b>ConvertCurrencies</b> ' service. Service model	DAML-S
Appendix A-4	T's description of ' <b>InquireFares</b> ' task	DAML+OIL
Appendix A-5	Specification for ' <b>InquireFares</b> ' activity	DAML+OIL
	Specification for ' <b>InquireFares</b> ' - service profile	DAML-S
	Specification for ' <b>InquireFares</b> ' - service model	DAML-S
Ontologies		
Appendix A-6	RACING <b>Task Ontology</b>	DAML+OIL
Appendix A-7	RACING <b>Negotiation Ontology</b>	DAML+OIL
	- download	

<http://eva.zsu.zp.ua/services/app.htm>



# That's it - thanks...

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**Hope there is  
still some time  
for questions**