Semantic Web Services Tutorial

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Agenda

Part I: Introduction to Semantic Web Services

- Vision of Next Generation Web Technology
- Semantic Web Service Challenges

Part II: The Web Service Modeling Ontology WSMO

- Aims & Design Principles
- Top Level Element Definitions

BREAK

Part III: A Walkthru Example

- Virtual Travel Agency Example
- Roles, Elements, Semantic Web Service technology usage

Part IV: The Web Service Execution Environment WSMX

- Aims & Design Principles
- Architecture & Components

PART I:
Introduction to Semantic Web Services

- The vision of the Semantic Web
- Ontologies as the basic building block
- Current Web Service Technologies
- Vision and Challenges for Semantic Web Services

The Vision

- 500 million users
- more than 3 billion pages

Static

WWW

URI, HTML, HTTP

The Vision

Serious Problems in

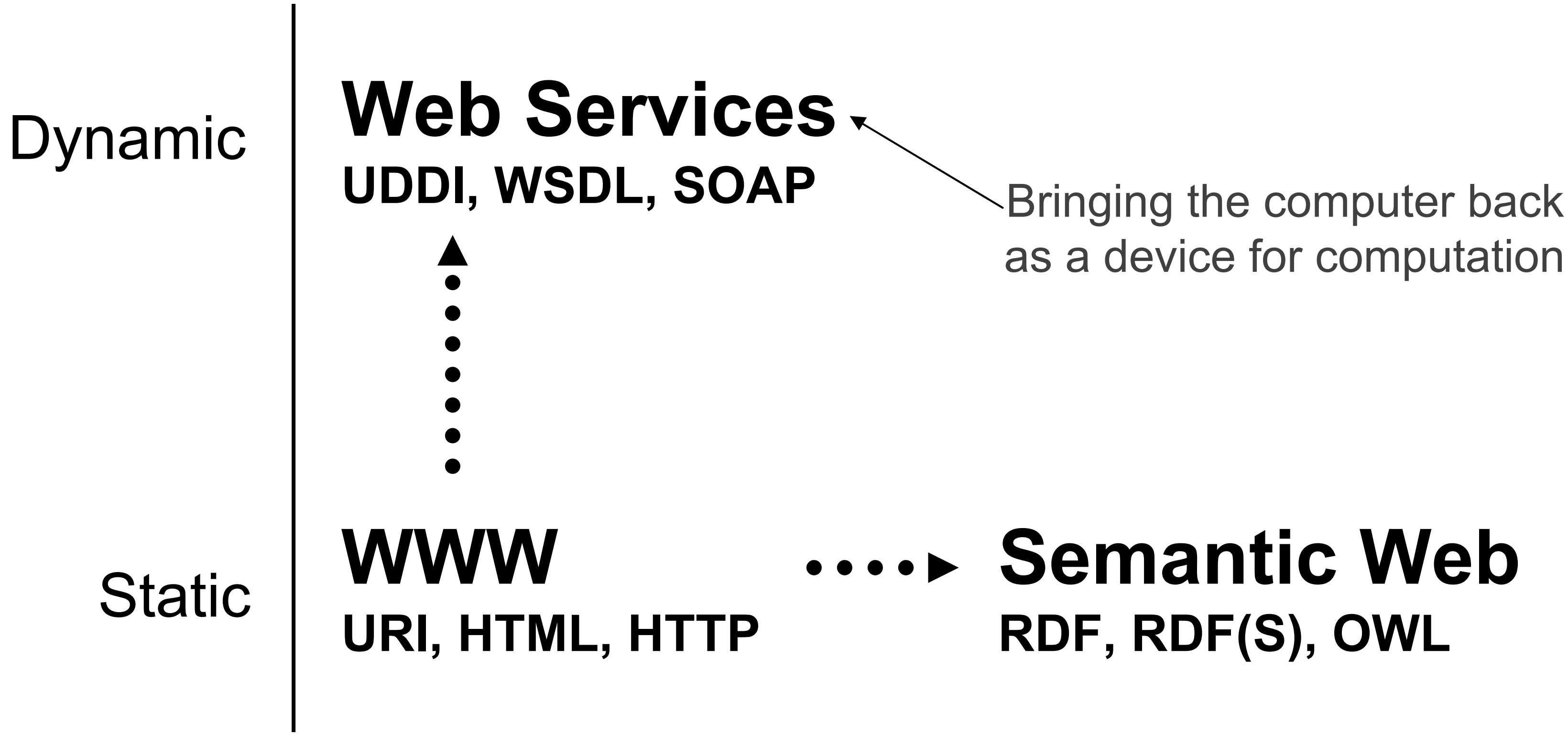
- information finding,
- information extracting,
- information representing,
- information interpreting and
- and information maintaining.

Static

WWW ····▸ **Semantic Web**

URI, HTML, HTTP **RDF, RDF(S), OWL**

The Vision


Dynamic
Static
Web Services
UDDI, WSDL, SOAP
Bringing the computer back
as a device for computation
WWW
URI, HTML, HTTP
Semantic Web
RDF, RDF(S), OWL

The Vision

Bringing the web to its full potential

Dynamic

Web Services
UDDI, WSDL, SOAP

Semantic Web Services

Static

WWW
URI, HTML, HTTP

Semantic Web
RDF, RDF(S), OWL

The Semantic Web

- the next generation of the WWW
- information has machine-processable and machine-understandable semantics
- not a separate Web but an augmentation of the current one
- Ontologies as basic building block

Ontology Definition

unambiguous terminology definitions

conceptual model of a domain (ontological theory)

formal, explicit specification of a shared conzeptualization

machine-readability with computational semantics

commonly accepted understanding

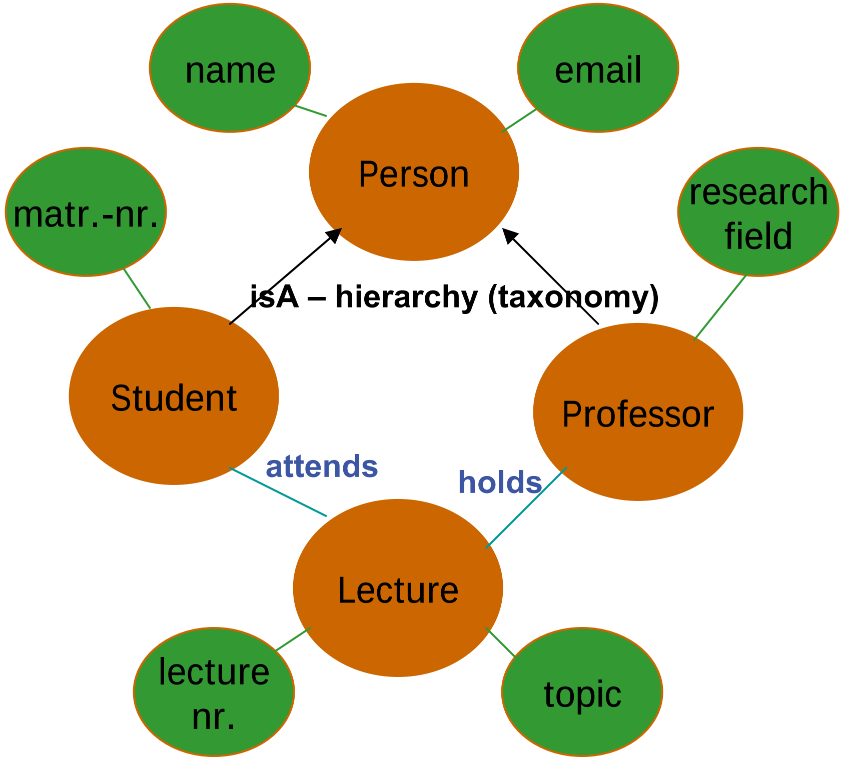
Ontology Example

Concept
conceptual entity of the domain

Property
attribte describing a concept

Relation
relationship between concepts or properties

Axiom
coherency description between Concepts / Properties / Relations via logical expressions



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Lecture.topic = Professor.researchField

Ontology Technology

To make the Semantic Web working we need:

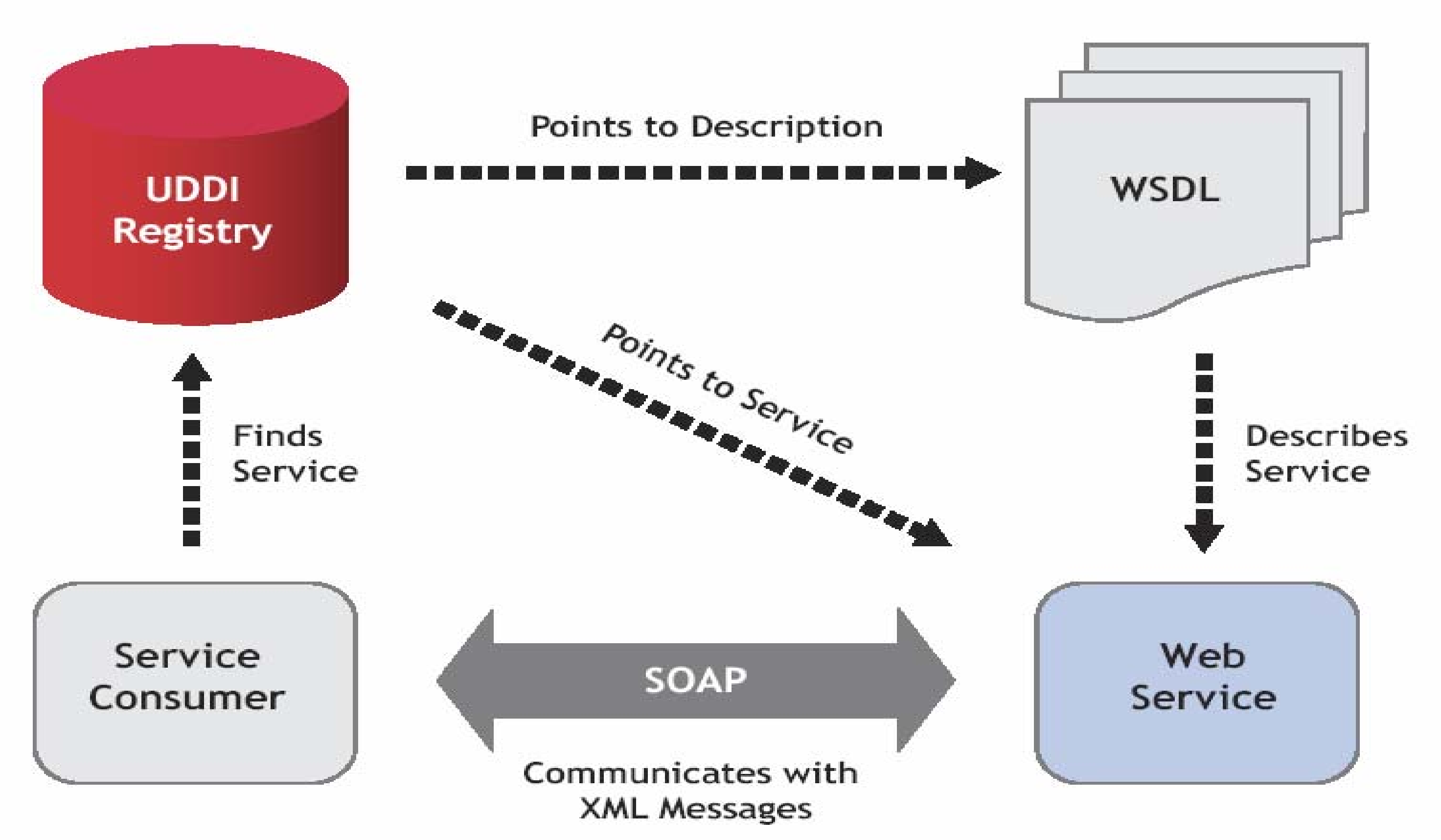
- **Ontology Languages**:
  - expressivity
  - reasoning support
  - web compliance
- **Ontology Reasoning**:
  - large scale knowledge handling
  - fault-tolerant
  - stable & scalable inference machines
- **Ontology Management Techniques**:
  - editing and browsing
  - storage and retrieval
  - versioning and evolution Support
- **Ontology Integration Techniques**:
  - ontology mapping, alignment, merging
  - semantic interoperability determination
- and … **Applications**

Web Services

- loosely coupled, reusable components
- encapsulate discrete functionality
- distributed
- programmatically accessible over standard internet protocols
- add new level of functionality on top of the current web

The Promise of Web Services

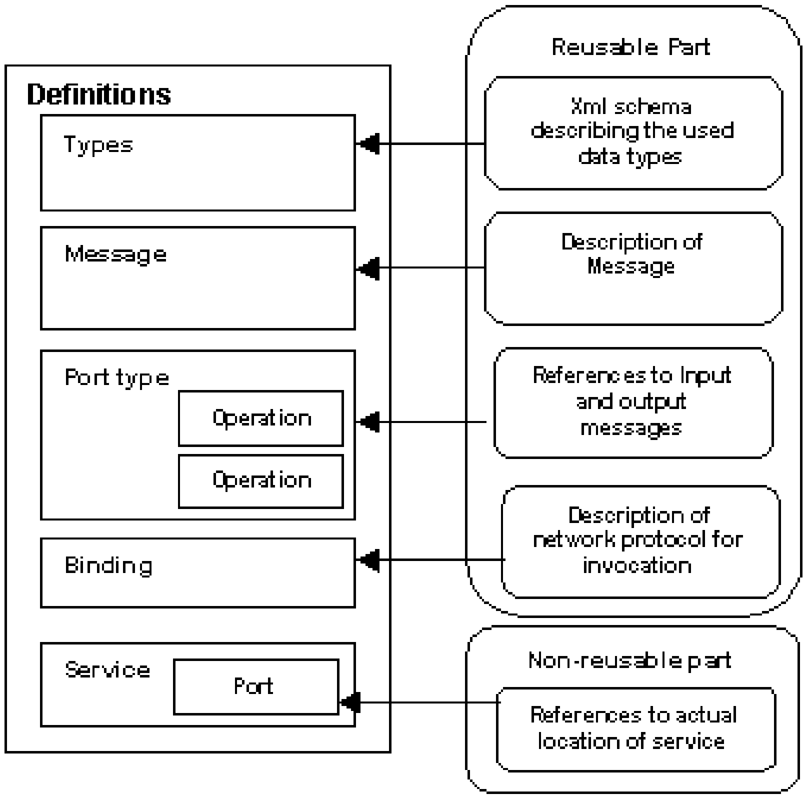
web-based SOA as new system design paradigm



WSDL

- Web Service Description Language
- W3C effort, WSDL 2 final construction phase

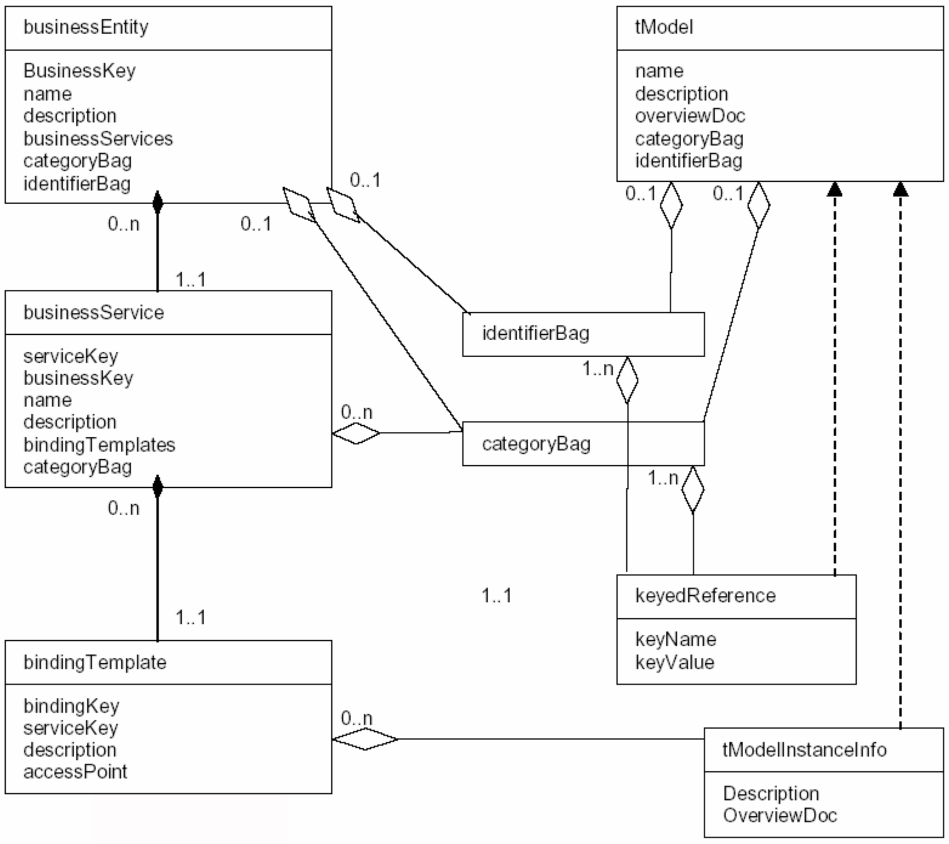
describes interface for consuming a Web Service:
- Interface: operations (in- & output)
- Access (protocol binding)
- Endpoint (location of service)



UDDI

- Universal Description, Discovery, and Integration Protocol
- OASIS driven standardization effort

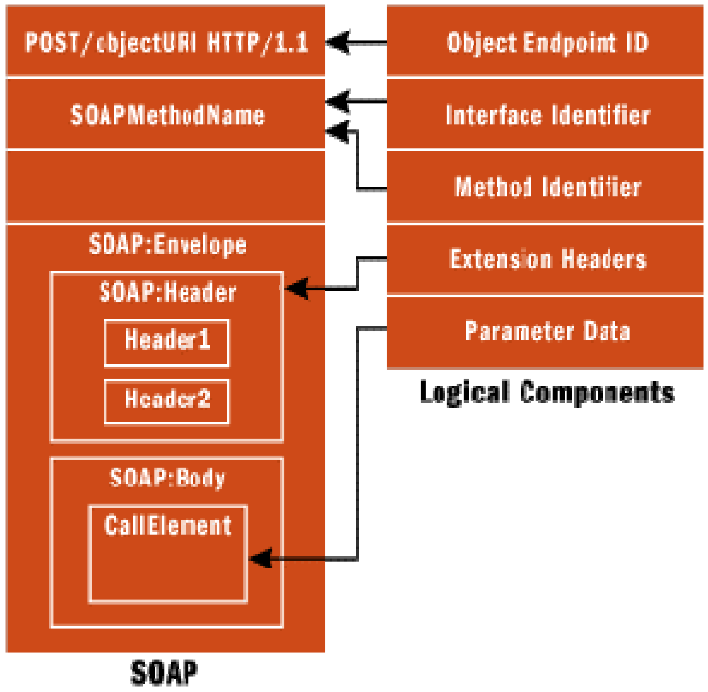
Registry for
Web Services:
- provider
- service information
- technical access



SOAP

- Simple Object Access Protocol
- W3C Recommendation

XML data transport:
- sender / receiver
- protocol binding
- communication aspects
- content



Deficiencies of WS Technology

- current technologies allow usage of Web Services
- but:
  - only syntactical information descriptions
  - syntactic support for discovery, composition and execution

  => ***Web Service usability, usage, and integration needs to be inspected manually***
  - no semantically marked up content / services
  - no support for the Semantic Web

=> current Web Service Technology Stack failed to realize the promise of Web Services

Semantic Web Services

Semantic Web Technology

- allow machine supported data interpretation
- ontologies as data model

+

Web Service Technology

automated discovery, selection, composition,
and web-based execution of services

=> Semantic Web Services as integrated solution for realizing the vision of the next generation of the Web

Semantic Web Services

- define exhaustive description frameworks for describing Web Services and related aspects **(Web Service Description Ontologies)**
- support ontologies as underlying data model to allow machine supported data interpretation **(Semantic Web aspect)**
- define semantically driven technologies for automation of the Web Service usage process **(Web Service aspect)**

Semantic Web Services

Usage Process:

- Publication: Make available the description of the capability of a service
- Discovery: Locate different services suitable for a given task
- Selection: Choose the most appropriate services among the available ones
- Composition: Combine services to achieve a goal
- Mediation: Solve mismatches (data, protocol, process) among the combined
- Execution: Invoke services following programmatic conventions

Semantic Web Services

Execution support:

- Monitoring: Control the execution process
- Compensation: Provide transactional support and undo or mitigate unwanted effects
- Replacement: Facilitate the substitution of services by equivalent ones
- Auditing: Verify that service execution occurred in the expected way

PART II:
The Web Service Modeling Ontology WSMO

- Aims & Working Groups
- Design Principles
- Top Level Notions
  - Ontologies
  - Web Services
  - Goals
  - Mediators
- Comparison to OWL-S

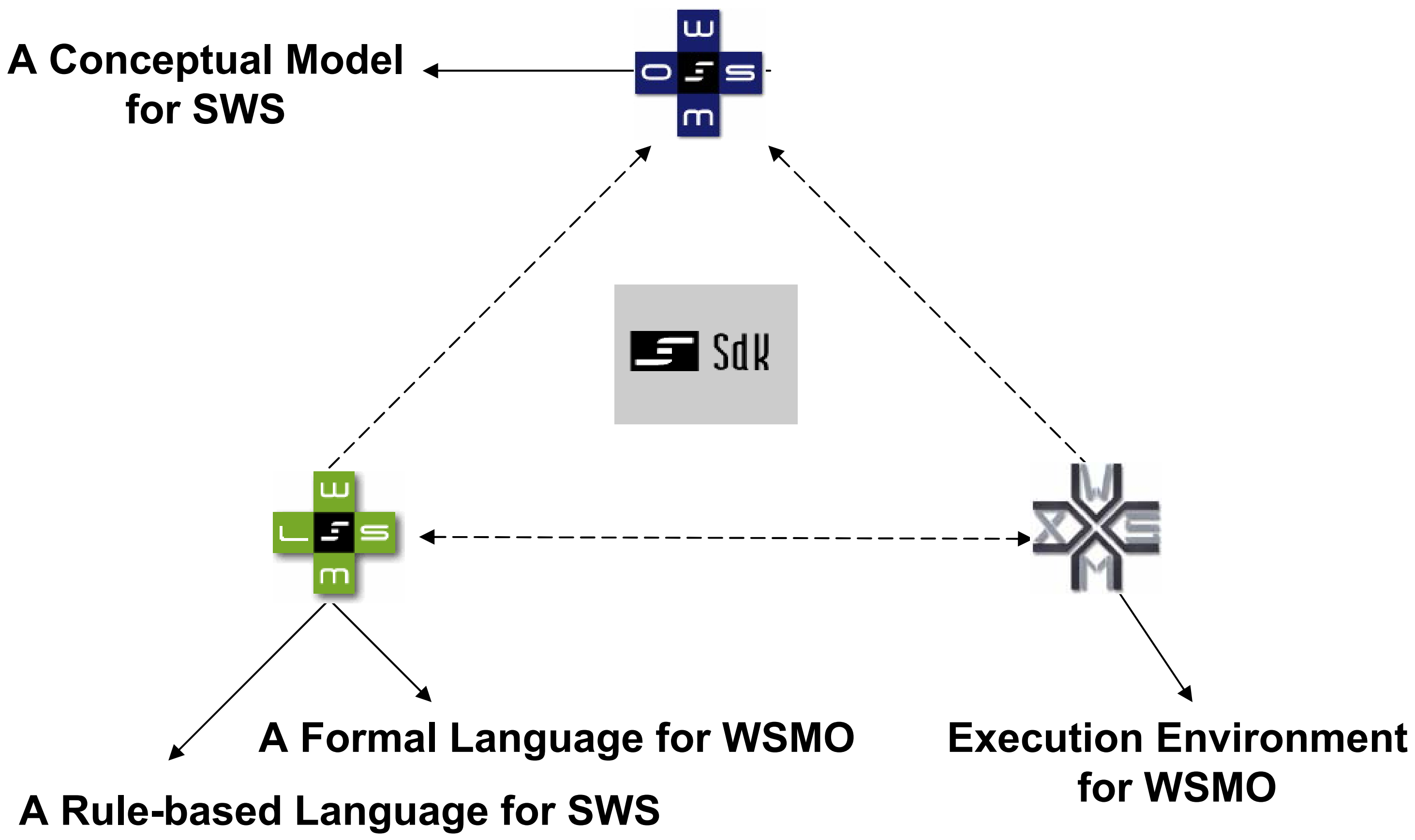
WSMO is ..

- a conceptual model for Semantic Web Services:
  - ontology of core elements for Semantic Web Services
  - a formal description language (WSML)
  - execution environment (WSMX)

- derived from and based on the Web Service Modeling Framework WSMF

- a SDK-Cluster Working Group
  (joint European research and development initiative)

WSMO Working Groups



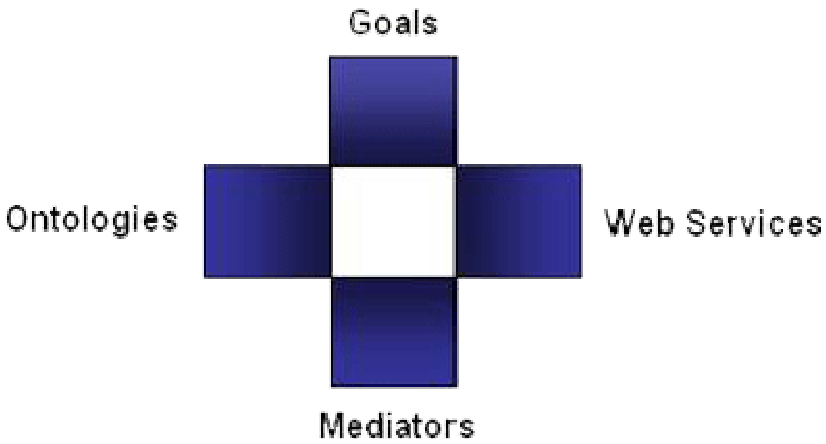
WSMO Design Principles

- Web Compliance
- Ontology-Based
- Goal-driven
- Strict Decoupling
- Centrality of Mediation
- Description versus Implementation
- Execution Semantics

WSMO Top Level Notions

Objectives that a client wants to achieve by using Web Services

Provide the formally specified terminology of the information used by all other components



Semantic description of Web Services:
- **Capability** *(functional)*
- **Interfaces** *(usage)*

Connectors between components with mediation facilities for handling heterogeneities

WSMO D2, version 1.2, 13 April 2005 (W3C submission)

Non-Functional Properties

every WSMO elements is described by properties that contain relevant, non-functional aspects

- Dublin Core Metadata Set:
  - complete item description
  - used for resource management
- Versioning Information
  - evolution support
- Quality of Service Information
  - availability, stability
- Other
  - Owner, financial

Non-Functional Properties List

Dublin Core Metadata

- Contributor
- Coverage
- Creator
- Description
- Format
- Identifier
- Language
- Publisher
- Relation
- Rights
- Source
- Subject
- Title
- Type

Quality of Service

- Accuracy
- NetworkRelatedQoS
- Performance
- Reliability
- Robustness
- Scalability
- Security
- Transactional
- Trust

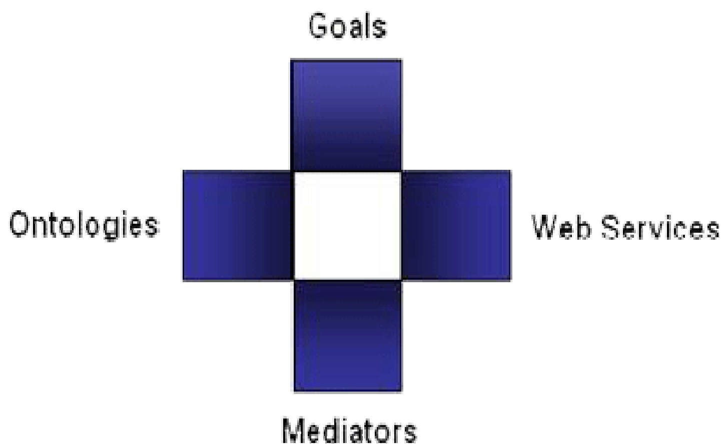
Other

- Financial
- Owner
- TypeOfMatch
- Version

WSMO Ontologies

Objectives that a client wants to achieve by using Web Services

Provide the formally specified terminology of the information used by all other components



Semantic description of Web Services:
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- **Interfaces** *(usage)*

Connectors between components with mediation facilities for handling heterogeneities

Ontology Usage & Principles

- **Ontologies are used as the 'data model' throughout WSMO**
  - all WSMO element descriptions rely on ontologies
  - all data interchanged in Web Service usage are ontologies
  - Semantic information processing & ontology reasoning
- **WSMO Ontology Language WSML**
  - conceptual syntax for describing WSMO elements
  - logical language for axiomatic expressions (WSML Layering)
- **WSMO Ontology Design**
  - Modularization: import / re-using ontologies, modular approach for ontology design
  - De-Coupling: heterogeneity handled by **OO Mediators**

Ontology Specification

• **Non functional properties**	(see before)
• **Imported Ontologies**	importing existing ontologies where no heterogeneities arise
• **Used mediators**	OO Mediators (ontology import with terminology mismatch handling)

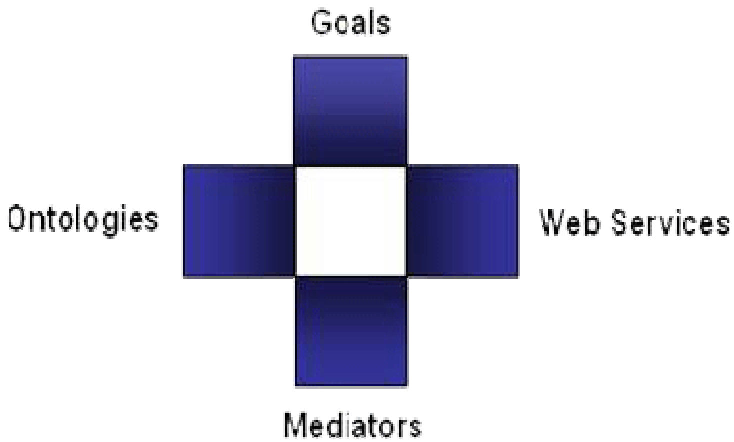
Ontology Elements:

Concepts	set of concepts that belong to the ontology, incl.
Attributes	set of attributes that belong to a concept
Relations	define interrelations between several concepts
Functions	special type of relation (unary range = return value)
Instances	set of instances that belong to the represented ontology
Axioms	axiomatic expressions in ontology (logical statement)

WSMO Web Services

Objectives that a client wants to achieve by using Web Services

Provide the formally specified terminology of the information used by all other components



Semantic description of Web Services:
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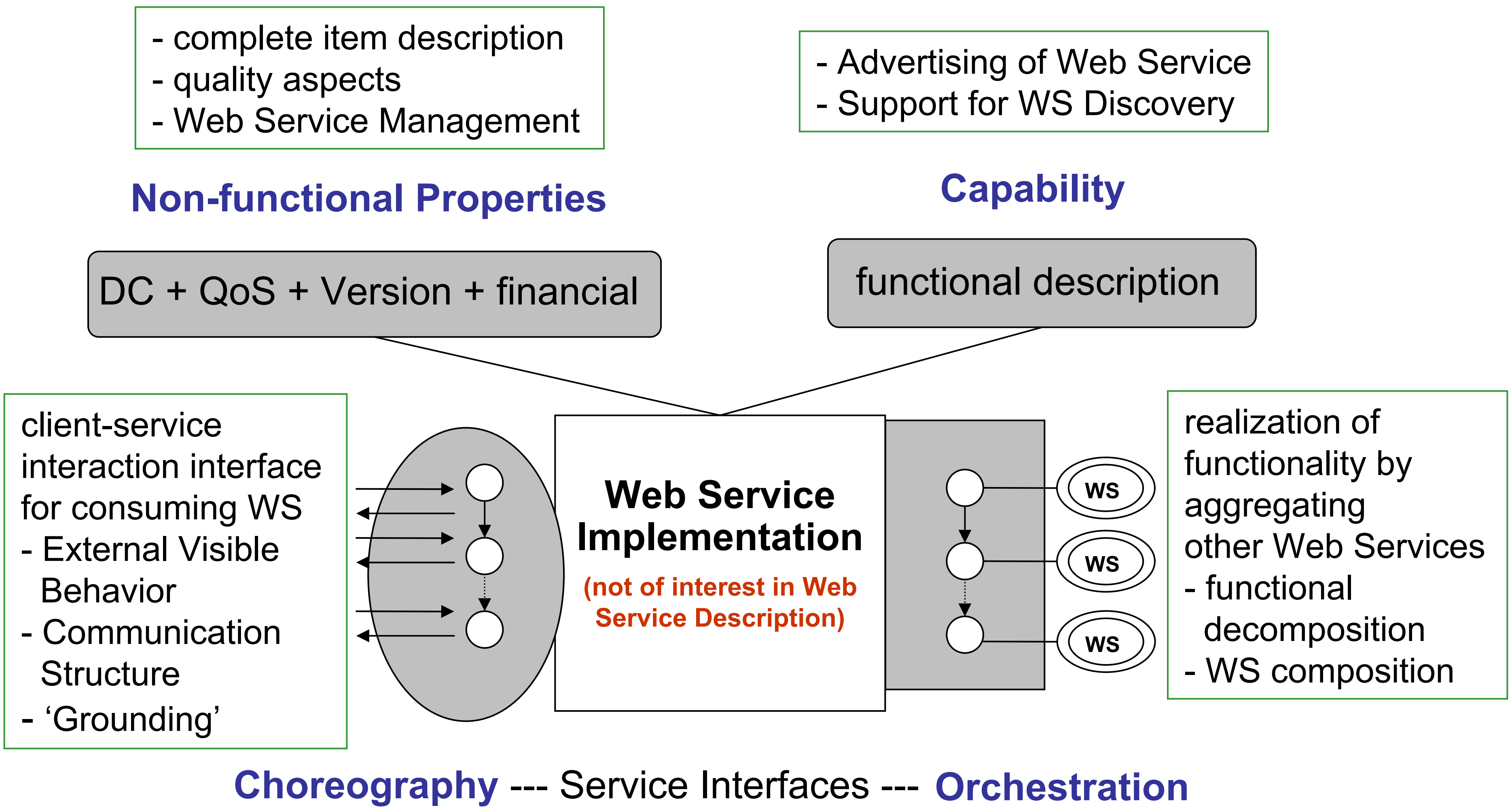
WSMO Web Service Description



Capability Specification

- **Non functional properties**
- **Imported Ontologies**
- **Used mediators**
  - *OO Mediator:* importing ontologies with mismatch resolution
  - *WG Mediator:* link to a Goal wherefore service is not usable a priori
- **Pre-conditions**

  What a web service expects in order to be able to provide its service. They define conditions over the input.
- **Assumptions**

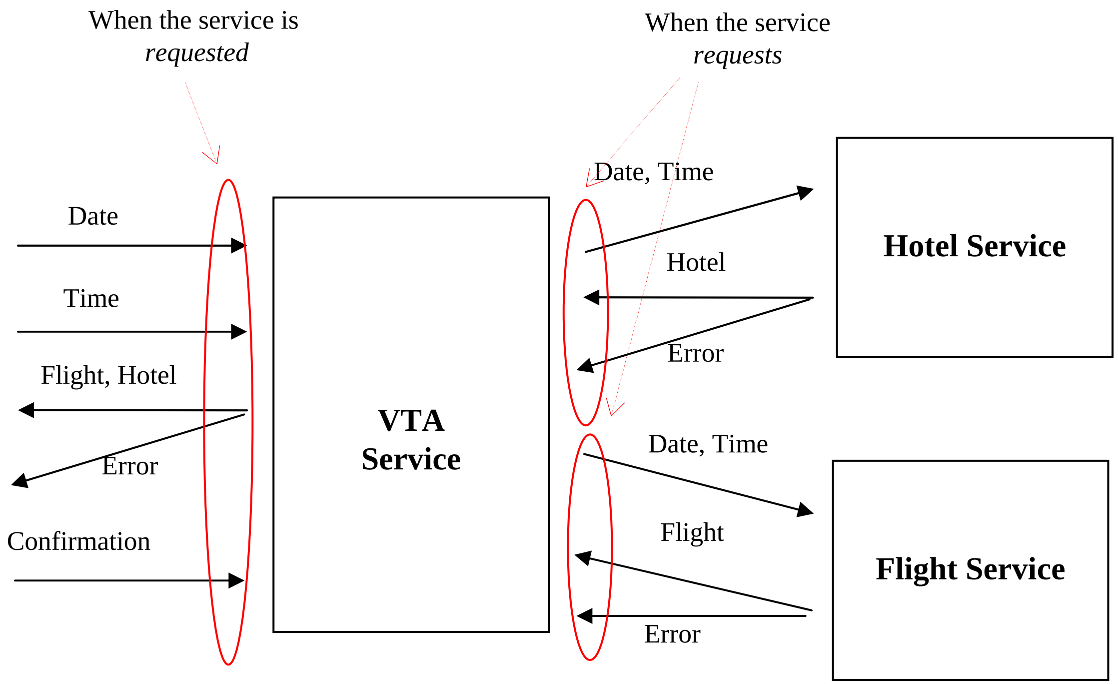
  Conditions on the state of the world that has to hold before the Web Service can be executed
- **Post-conditions**

  describes the result of the Web Service in relation to the input, and conditions on it
- **Effects**

  Conditions on the state of the world that hold after execution of the Web Service (i.e. changes in the state of the world)

Choreography & Orchestration

- VTA example:



- **Choreography =** how to interact with the service to consume its functionality
- **Orchestration =** how service functionality is achieved by aggregating other Web Services

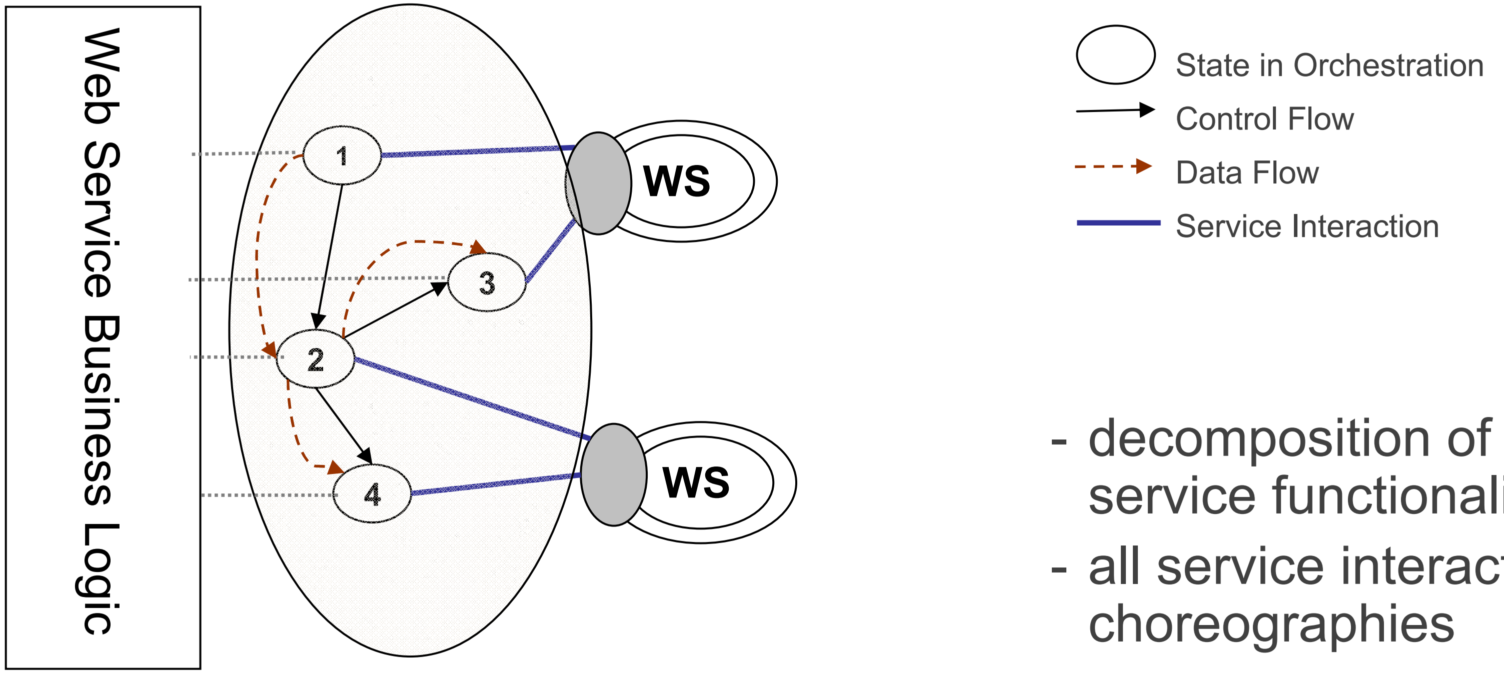
Choreography Aspects

Interface for consuming Web Service

- **External Visible Behavior**
  - those aspects of the workflow of a Web Service where Interaction is required
  - described by workflow constructs: sequence, split, loop, parallel
- **Communication Structure**
  - messages sent and received
  - their order (communicative behavior for service consumption)
- **Grounding**
  - executable communication technology for interaction
  - choreography related errors (e.g. input wrong, message timeout, etc.)
- **Formal Model**
  - reasoning on Web Service interfaces (service interoperability)
  - allow mediation support on Web Service interfaces

Orchestration Aspects

Control Structure for aggregation of other Web Services



- decomposition of service functionality
- all service interaction via choreographies

WSMO Web Service Interfaces

- service interfaces are concerned with service consumption and interaction
- Choreography and Orchestration as sub-concepts of Service Interface
- common requirements for service interface description:
  1. represent the dynamics of information interchange during service consumption and interaction
  2. support ontologies as the underlying data model
  3. appropriate communication technology for information interchange
  4. sound formal model / semantics of service interface specifications in order to allow operations on them.

Service Interface Description

- **Ontologies as data model:**
  - all data elements interchanged are ontology instances
  - service interface = evolving ontology

- **Abstract State Machines (ASM) as formal framework:**
  - dynamics representation: high expressiveness & low ontological commitment
  - core principles: state-based, state definition by formal algebra, guarded transitions for state changes
  - overcome the “Frame Problem”

- **further characteristics:**
  - not restricted to any specific communication technology
  - ontology reasoning for service interoperability determination
  - basis for declarative mediation techniques on service interfaces

Service Interface Description Model

- Vocabulary Ω:
  - ontology schema(s) used in service interface description
  - usage for information interchange: in, out, shared, controlled
- States ω(Ω):
  - a stable status in the information space
  - defined by attribute values of ontology instances
- Guarded Transition GT(ω):
  - state transition
  - general structure: ***if*** (condition) ***then*** (action)
  - different for Choreography and Orchestration
  - additional constructs: *add*, *delete*, *update*

Service Interface Example

Communication Behavior of a Web Service

Ω_{in} **hasValues** {
concept A [
att1 **ofType** X
att2 **ofType** Y]
…}

Ω_{out} **hasValues** {
concept B [
att1 **ofType** W
att2 **ofType** Z]
…}

Vocabulary:
- Concept A in Ω_{in}
- Concept B in Ω_{out}

State ω_1

a **memberOf** A [
att1 **hasValue** x
att2 **hasValue** y]

→

Guarded Transition GT(ω_1)

IF (a **memberOf** A [
att1 **hasValue** x])
THEN
(b **memberOf** B [
att2 **hasValue** m])

→

State ω_2

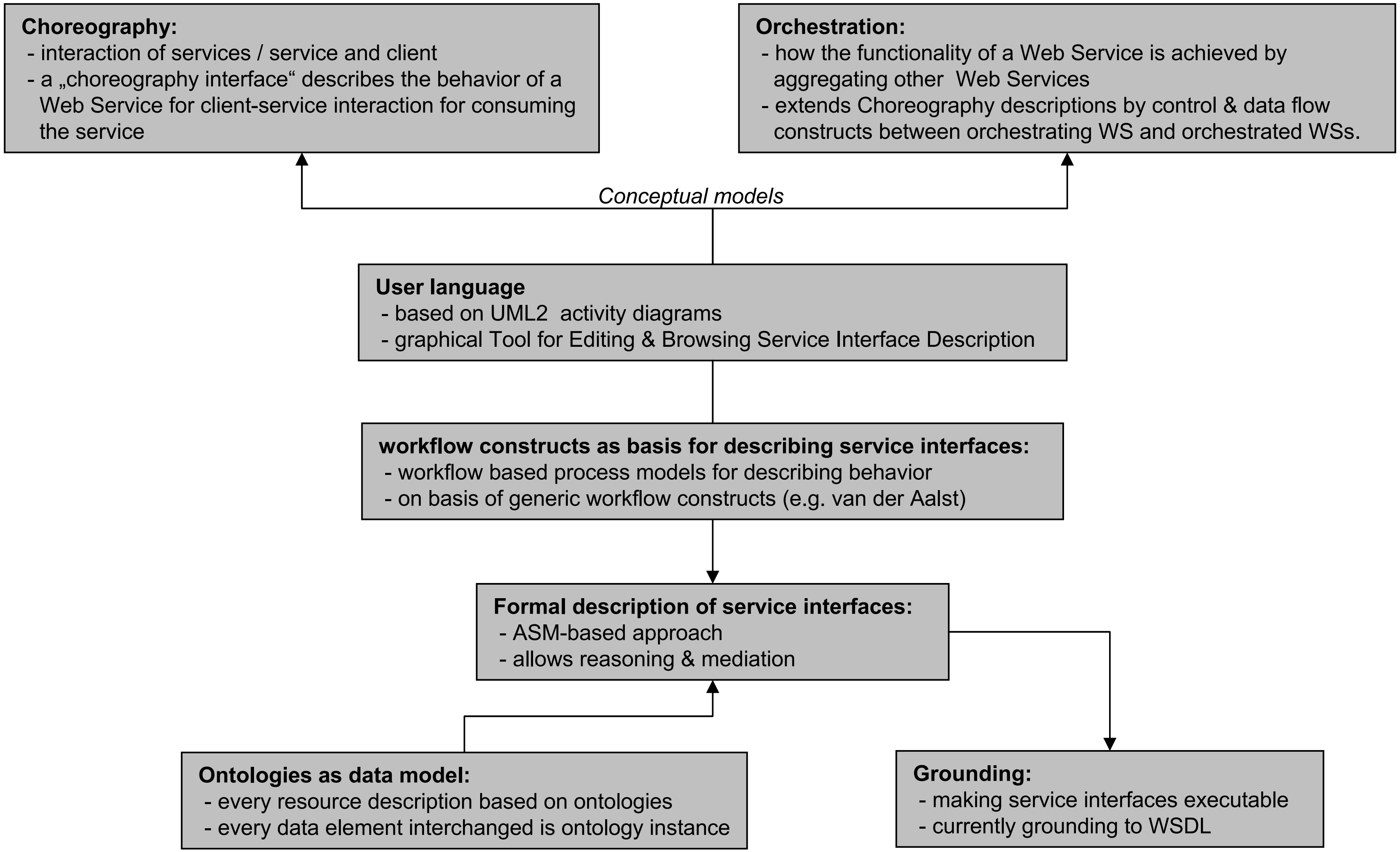
a **memberOf** A [
att1 **hasValue** x,
att2 **hasValue** y]

b **memberOf** B [
att2 **hasValue** m]

received ontology instance ***a***

sent ontology instance ***b***

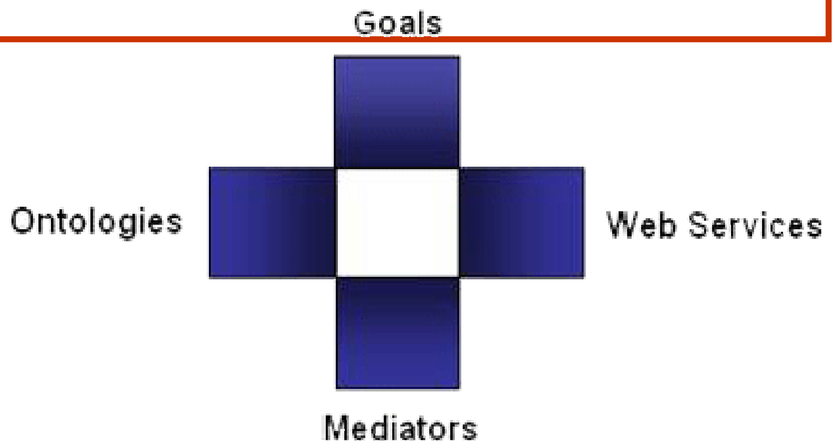
Future Directions



WSMO Goals

Objectives that a client wants to achieve by using Web Services

Provide the formally specified terminology of the information used by all other components



Semantic description of Web Services:
- **Capability** *(functional)*
- **Interfaces** *(usage)*

Connectors between components with mediation facilities for handling heterogeneities

Goals

- **Ontological De-coupling of Requester and Provider**

- **Goal-driven Approach**, derived from AI rational agent approach
  - requester formulates objective independently
  - ‘intelligent’ mechanisms detect suitable services for solving the Goal
  - allows re-use of Services for different purposes

- **Usage of Goals within Semantic Web Services**
  – A requester (human or machine) defines a Goal to be resolved
  – Web Service discovery detects suitable Web Services for solving the Goal automatically
  – Goal resolution management is realized in implementations

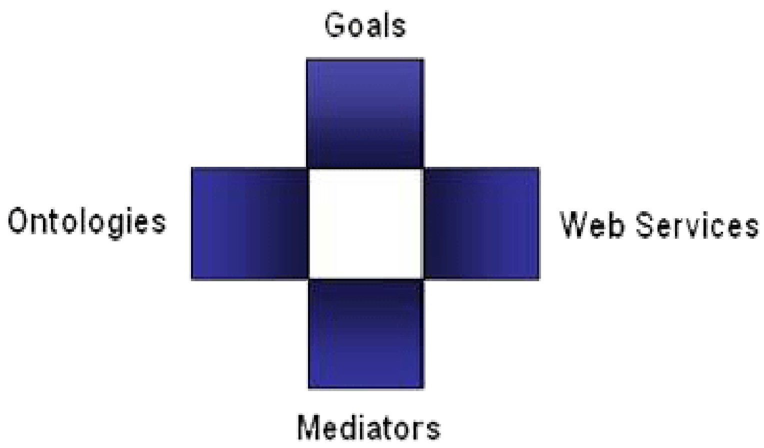
Goal Specification

- **Non functional properties**
- **Imported Ontologies**
- **Used mediators**
  - *OO Mediators:* importing ontologies with heterogeneity resolution
  - *GG Mediator:*
    - Goal definition by reusing an already existing goal
    - allows definition of **Goal Ontologies**
- **Requested Capability**
  - describes service functionality expected to resolve the objective
  - defined as capability description from the requester perspective
- **Requested Interface**
  - describes communication behaviour supported by the requester for consuming a Web Service (Choreography)
  - Restrictions / preferences on orchestrations of acceptable Web Services

WSMO Mediators

Objectives that a client wants to achieve by using Web Services

Provide the formally specified terminology of the information used by all other components



Semantic description of Web Services:

- **Capability** *(functional)*
- **Interfaces** *(usage)*

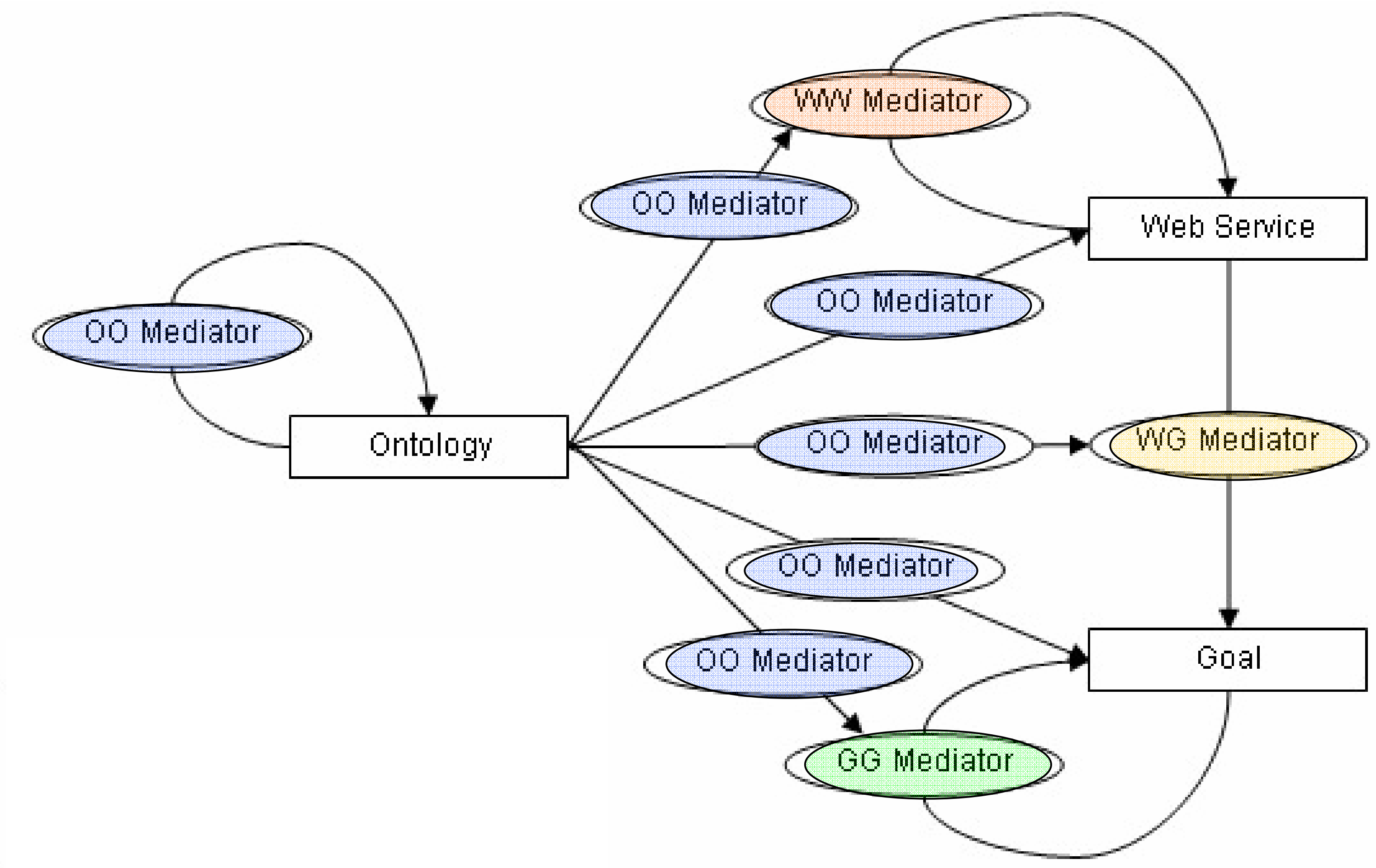
Connectors between components with mediation facilities for handling heterogeneities

Mediation

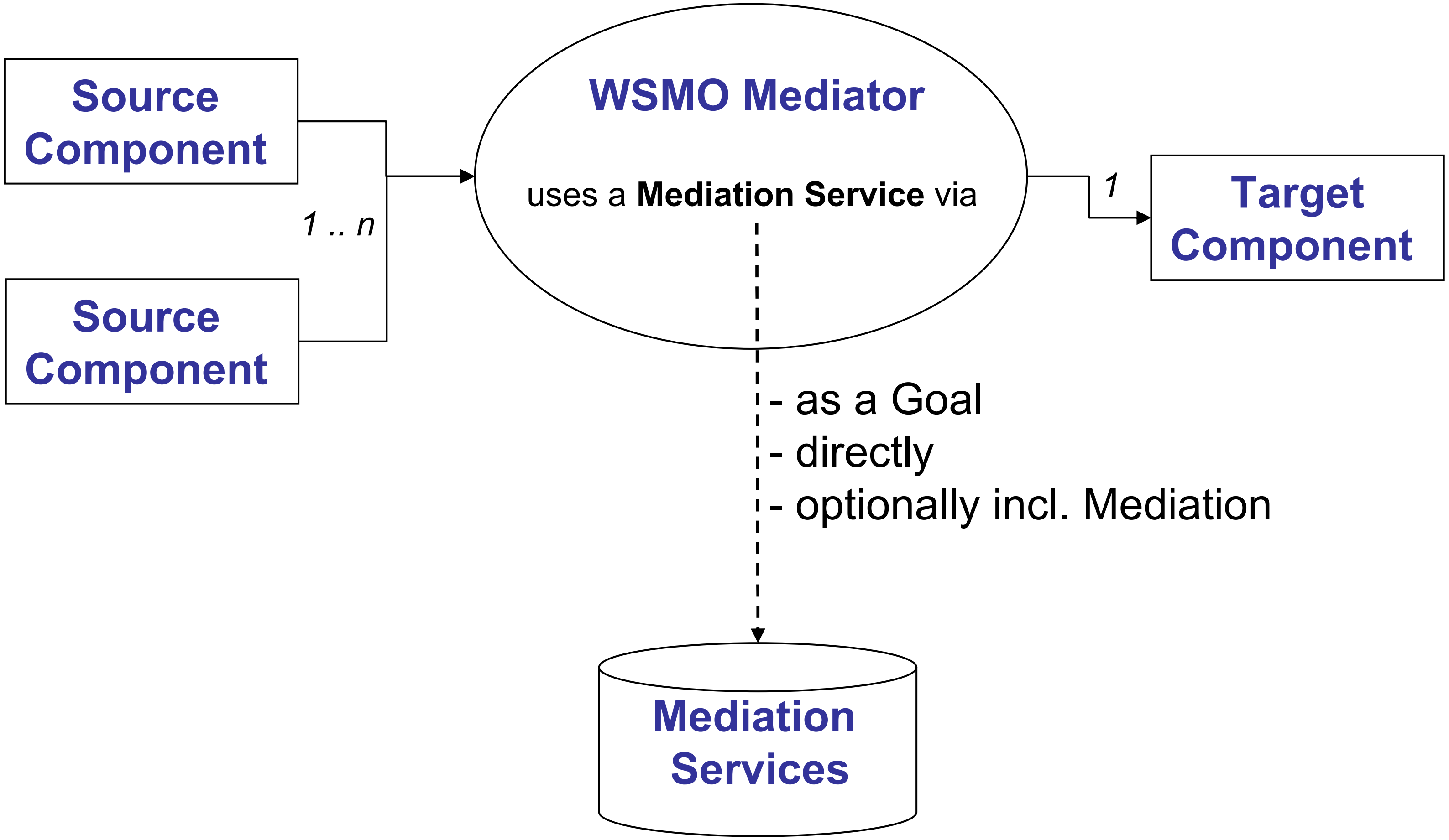
- **Heterogeneity …**
  - Mismatches on structural / semantic / conceptual / level
  - Occur between different components that shall interoperate
  - Especially in distributed & open environments like the Internet
- **Concept of Mediation** (Wiederhold, 94):
  - ***Mediators*** as components that resolve mismatches
  - Declarative Approach:
    - Semantic description of resources
    - 'Intelligent' mechanisms that resolve mismatches independent of content
  - Mediation cannot be fully automated (integration decision)
- **Levels of Mediation within Semantic Web Services** (WSMF):

  (1) Data Level: mediate heterogeneous Data Sources
  (2) Protocol Level: mediate heterogeneous Communication Patterns
  (3) Process Level: mediate heterogeneous Business Processes

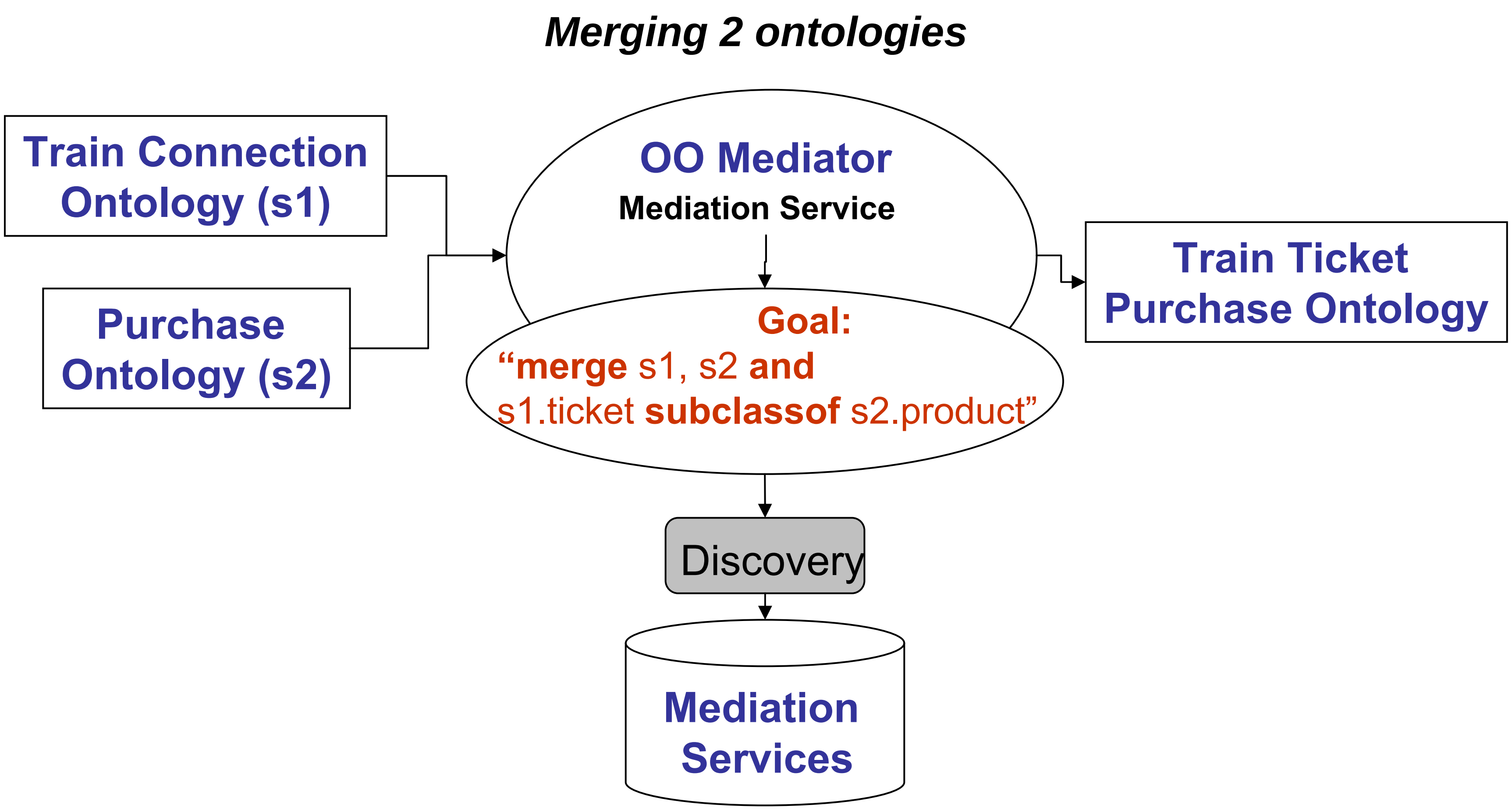
WSMO Mediators Overview



Mediator Structure



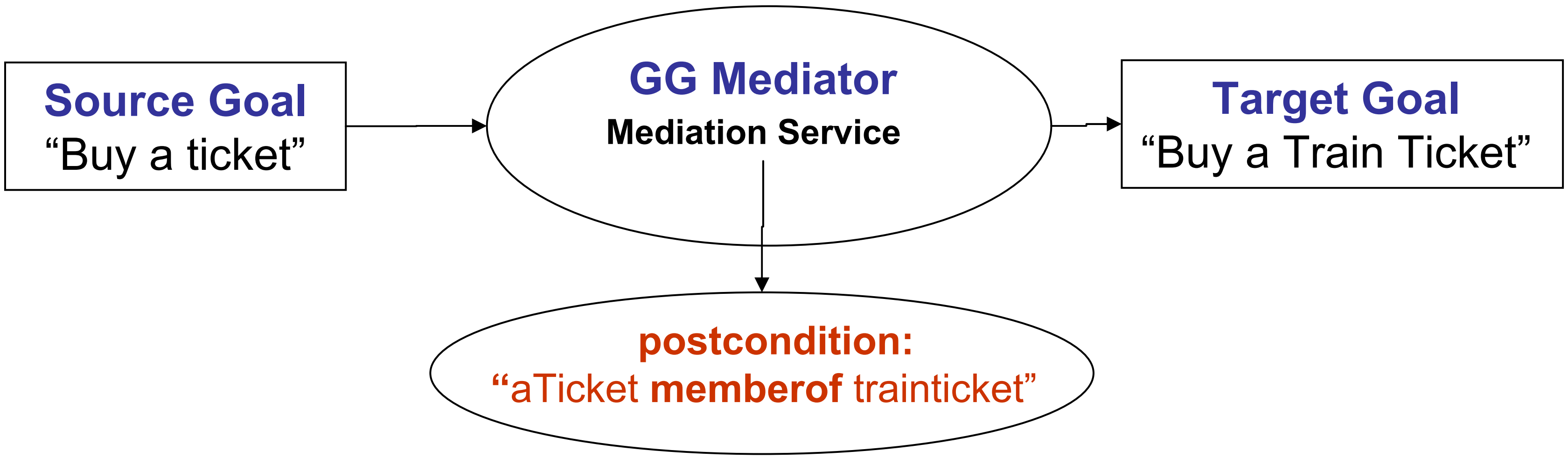
OO Mediator - Example



GG Mediators

- **Aim:**
  - Support specification of Goals by re-using existing Goals
  - Allow definition of **Goal Ontologies** (collection of pre-defined Goals)
  - Terminology mismatches handled by OO Mediators

- **Example: Goal Refinement**



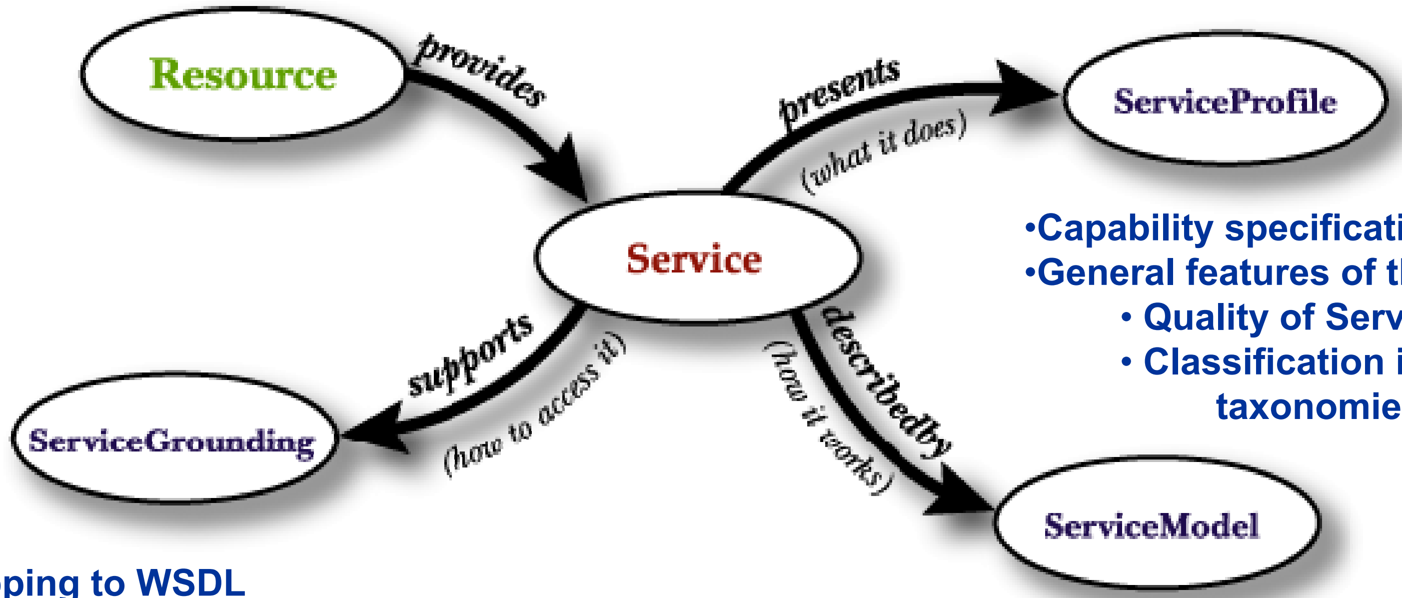
WG & WW Mediators

- **WG Mediators:**
  - link a Web Service to a Goal and resolve occurring mismatches
  - match Web Service and Goals that do not match a priori
  - handle terminology mismatches between Web Services and Goals
  - ⇒ broader range of Goals solvable by a Web Service

- **WW Mediators:**
  - enable interoperability of heterogeneous Web Services
  - ⇒ support automated collaboration between Web Services

  - **OO Mediators** for terminology import with data level mediation
  - Protocol Mediation for establishing valid multi-party collaborations
  - Process Mediation for making Business Processes interoperable

Comparison to OWL-S



- Capability specification
- General features of the Service
  - Quality of Service
  - Classification in Service taxonomies

- Mapping to WSDL
  - communication protocol (RPC, HTTP, …)
  - marshalling/serialization
  - transformation to and from XSD to OWL

- Control flow of the service
  - Black/Grey/Glass Box view
- Protocol Specification
- Abstract Messages

Perspective

- OWL-S is an ontology and a language to describe Web services
  - Strong relation to Web Services standards
    - rather than proposing another WS standard, OWL-S aims at enriching existing standards
    - OWL-S is grounded in WSDL and it has been mapped into UDDI
  - Based on the Semantic Web
    - Ontologies provide conceptual framework to describe the domain of Web services and an inference engine to reason about the domain
    - Ontologies are essential elements of interoperation between Web services
- WSMO is a conceptual model for the core elements of Semantic Web Services
  - core elements: Ontologies, Web Services, Goals, Mediators
    - language for semantic element description (WSML)
    - reference implementation (WSMX)
  - Mediation as a key element
  - Ontologies as data model
    - every resource description is based on ontologies
    - every data element interchanged is an ontology instance

OWL-S and WSMO

OWL-S profile ≈ WSMO capability +
goal +
non-functional properties

- OWL-S uses Profiles to express existing capabilities (advertisements) and desired capabilities (requests)
- WSMO separates provider (capabilities) and requester points of view (goals)

OWL-S and WSMO

OWL-S Process Model ≈ WSMO Service Interfaces

- Perspective:
  - OWL-S Process Model describes operations performed by Web Service, including consumption as well as aggregation
  - WSMO separates Choreography and Orchestration
- Formal Model:
  - OWL-S formal semantics has been developed in very different frameworks such as Situation Calculus, Petri Nets, Pi-calculus
  - WSMO service interface description model with ASM-based formal semantics
  - OWL-S Process Model is extended by SWRL / FLOWS

both approaches are not finalized yet

OWL-S and WSMO

OWL-S Grounding ≈ current WSMO Grounding

- OWL-S provides default mapping to WSDL
  - clear separation between WS description and interface implementation
  - other mappings could be used
- WSMO also defines a mapping to WSDL, but aims at an ontology-based grounding
  - avoid loss of ontological descriptions throughout service usage process
  - 'Triple-Spaced Computing' as innovative communication technology

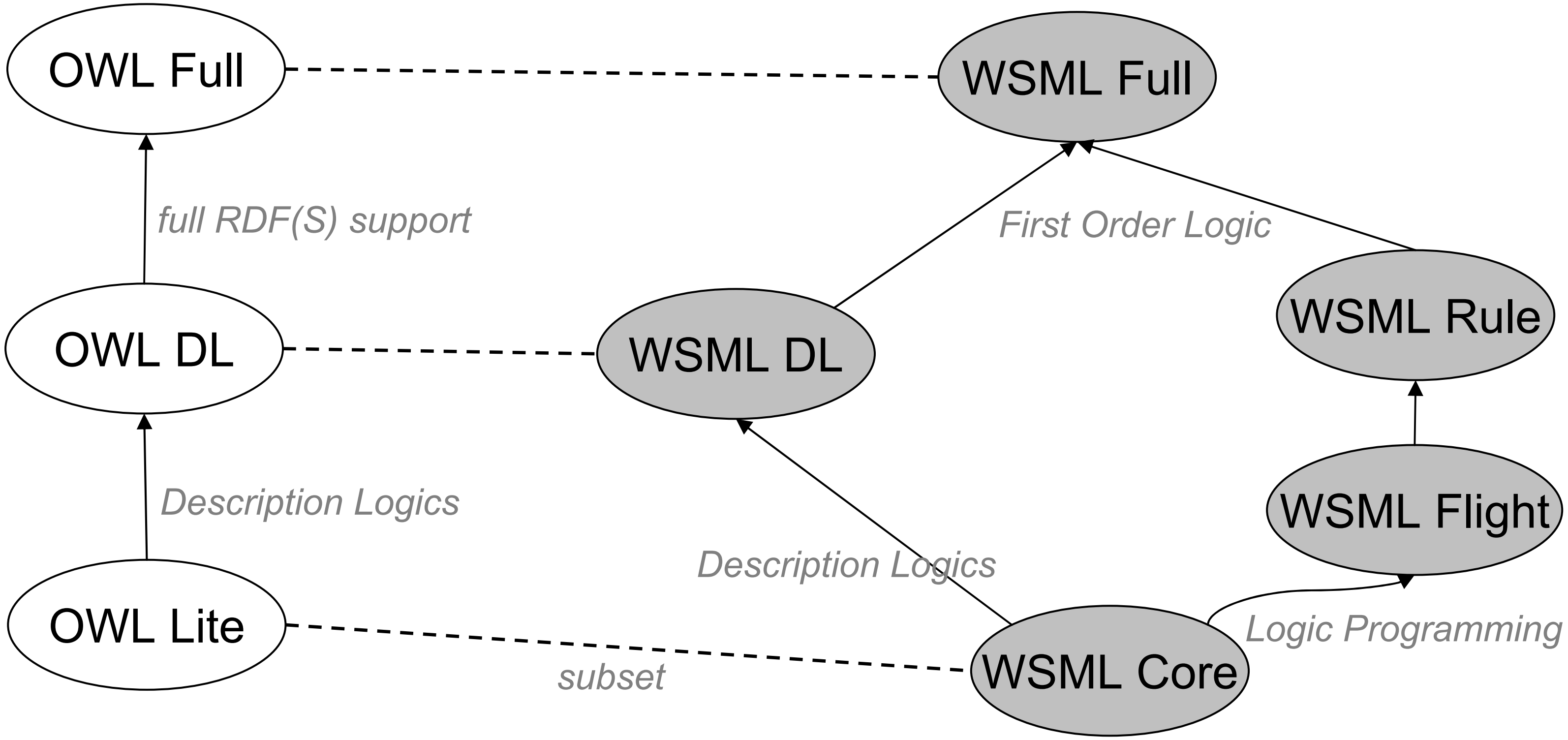
Mediation in OWL-S and WSMO

- OWL-S does not have an explicit notion of mediator
  - Mediation is a by-product of the orchestration process
    - E.g. protocol mismatches are resolved by constructing a plan that coordinates the activity of the Web services
  - …or it results from translation axioms that are available to the Web services
    - It is not the mission of OWL-S to generate these axioms
- WSMO regards mediators as key conceptual elements
  - Different kinds of mediators:
    - OO Mediators for ensuring semantic interoperability
    - GG, WG mediators to link Goals and Web Services
    - WW Mediators to establish service interoperability
  - Reusable mediators
  - Mediation techniques under development

Semantic Representation

- OWL-S and WSMO adopt a similar view on the need of ontologies and explicit semantics but they rely on different logics:
  - OWL-S is based on OWL / SWRL
    - OWL represent taxonomical knowledge
    - SWRL provides inference rules
    - FLOWS as formal model for process model
  - WSMO is based on WSML a family of languages with a common basis for compatibility and extensions in the direction of Description Logics and Logic Programming

OWL and WSML



- WSML aims at overcoming deficiencies of OWL
- Relation between WSML and OWL+SWRL to be completed

Summary

	OWL-S	WSMO	*current Web Service technologies*
Discovery ***detection of suitable WS***	Profile	Goals and Web Services (capability)	*UDDI API*
Consumption & Interaction ***How to consume & aggregate***	Process Model	Service Interfaces (Choreography + Orchestration)	*BPEL4WS / WS-CDL*
Invocation ***How to invoke***	Grounding+ WSDL/SOAP	Grounding (WSDL / SOAP, ontology-based)	*WSDL / SOAP*
Mediation ***Heterogeneity handling***	-	Mediators	-

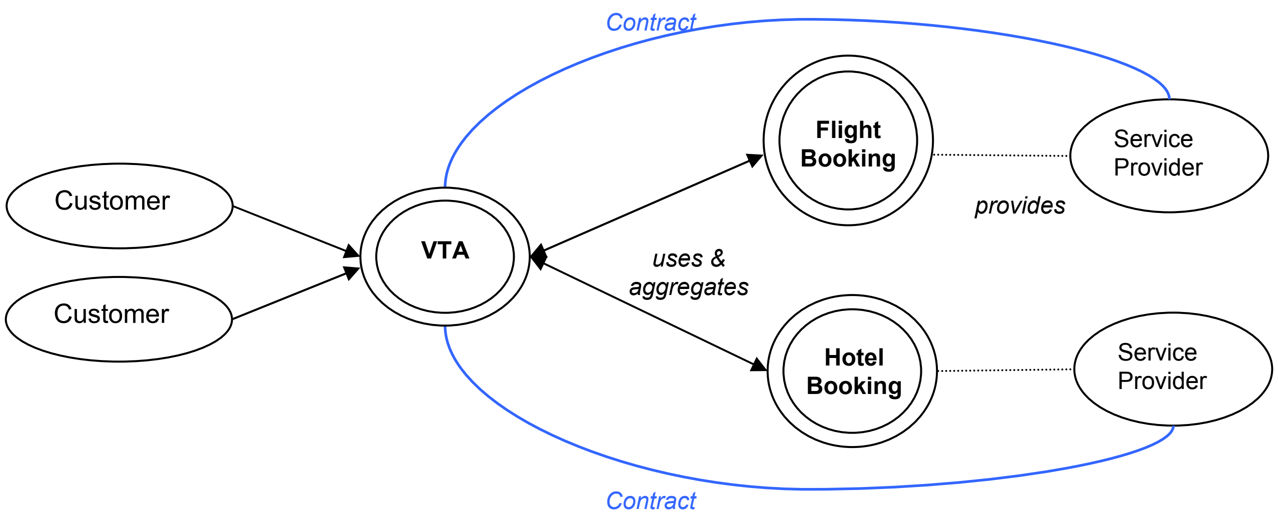
PART III:

A Walkthru Example

Virtual Travel Agency Use Case

- James is employed in DERI Austria and wants to book a flight and a hotel for the ISWC conference
- the start-up company VTA provides tourism and business travel services based on Semantic Web Service technology

=> how does the interplay of James, VTA, and other Web Services look like?



Goal Description

- "book flight and hotel for the ICWS 2005 for James"
- goal capability postcondition: get a trip reservation for this

```
goal _"http://www.wsmo.org/examples/goals/icws2005"
 importsOntology {_"http://www.wsmo.org/ontologies/tripReservationOntology", …}
 capability
  postcondition
   definedBy
    ?tripReservation memberOf tr#reservation[
      customer hasValue fof#james,
      origin hasValue loc#innsbruck,
      destination hasValue loc#orlando,
      travel hasValue ?flight,
      accommodation hasValue ?conferenceHotel
      payment hasValue tr#creditcard
    ] and
    ?flight[airline hasValue tr#staralliance] memberOf tr#flight and
    ?hotel[name hasValue "Sheraton Safari Hotel"] memberOf tr#hotel .
```

VTA Service Description

- book tickets, hotels, amenities, etc.
- capability description (pre-state)

capability VTAcapability
 sharedVariables {?creditCard, ?initialBalance, ?item, ?passenger}
 precondition
  definedBy
   ?reservationRequest[
        reservationItem **hasValue** ?item,
        passenger **hasValue** ?passenger,
        payment **hasValue** ?creditcard,
      ] **memberOf** tr#reservationRequest **and**
     ((?item **memberOf** tr#trip) **or** (?item **memberOf** tr#ticket)) **and**
     ?creditCard[balance **hasValue** ?initialBalance] **memberOf** po#creditCard.

 assumption
  definedBy
   po#validCreditCard(?creditCard) **and**
   (?creditCard[type **hasValue** po#visa] **or** ?creditCard[type **hasValue** po#mastercard]).

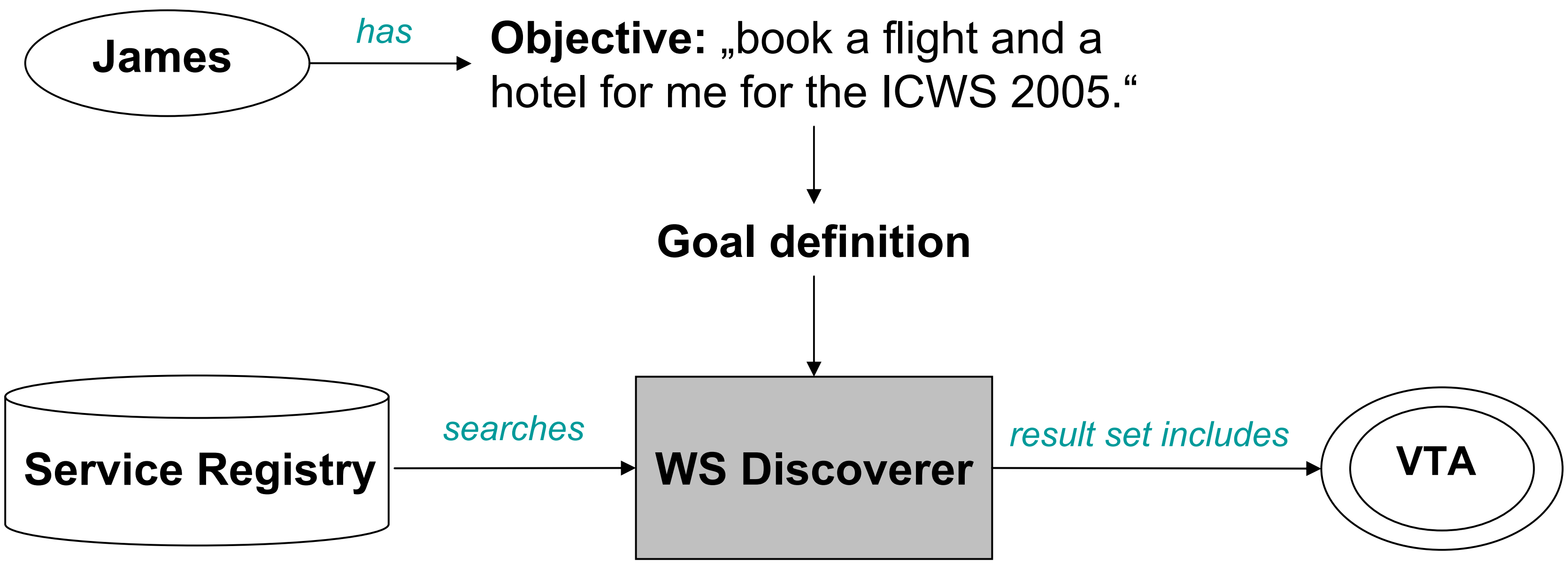
VTA Service Description

- capability description (post-state)

```
postcondition
    definedBy
      ?reservation[
          reservationItem hasValue ?item,
          customer hasValue ?passenger,
          payment hasValue ?creditcard
       ] memberOf tr#reservation .

  assumption
    definedBy
      reservationPrice(?reservation, "euro", ?tripPrice) and
      ?finalBalance= (?initialBalance - ?ticketPrice) and
      ?creditCard[po#balance  hasValue  ?finalBalance] .
```

Web Service Discovery



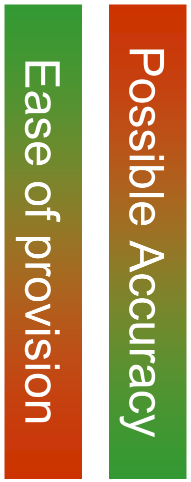
Semantic Web Service Discovery

find appropriate Web Service for automatically resolving a goal as the objective of a requester

- Aims:
  - high precision discovery
  - maximal automation
  - effective discoverer architectures
- Requirements:
  - infrastructure that allows storage and retrieval of information about Web services
  - description of Web services functionality
  - description of requests or goals
  - algorithms for matching requesters for capabilities with the corresponding providers

Discovery Techniques

- different techniques available
  - trade-off: ease-of-provision <-> accuracy
  - resource descriptions & matchmaking algorithms



Key Word Matching

match natural language key words in resource descriptions

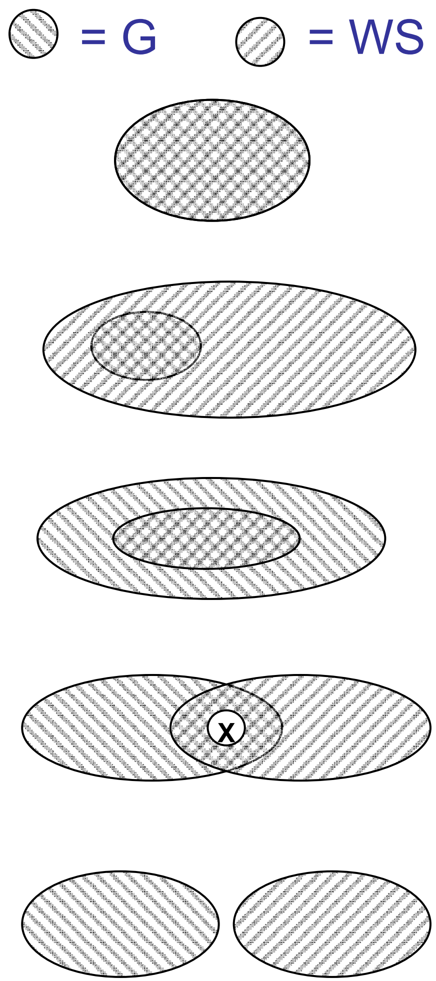
Controlled Vocabulary

ontology-based key word matching

Semantic Matchmaking

… what Semantic Web Services aim at

Matchmaking Notions & Intentions



Exact Match:

$G, WS, O, M \models \forall x. (G(x) \Leftrightarrow WS(x))$

PlugIn Match:

$G, WS, O, M \models \forall x. (G(x) \Rightarrow WS(x))$

Subsumption Match:

$G, WS, O, M \models \forall x. (G(x) \Leftarrow WS(x))$

Intersection Match:

$G, WS, O, M \models \exists x. (G(x) \wedge WS(x))$

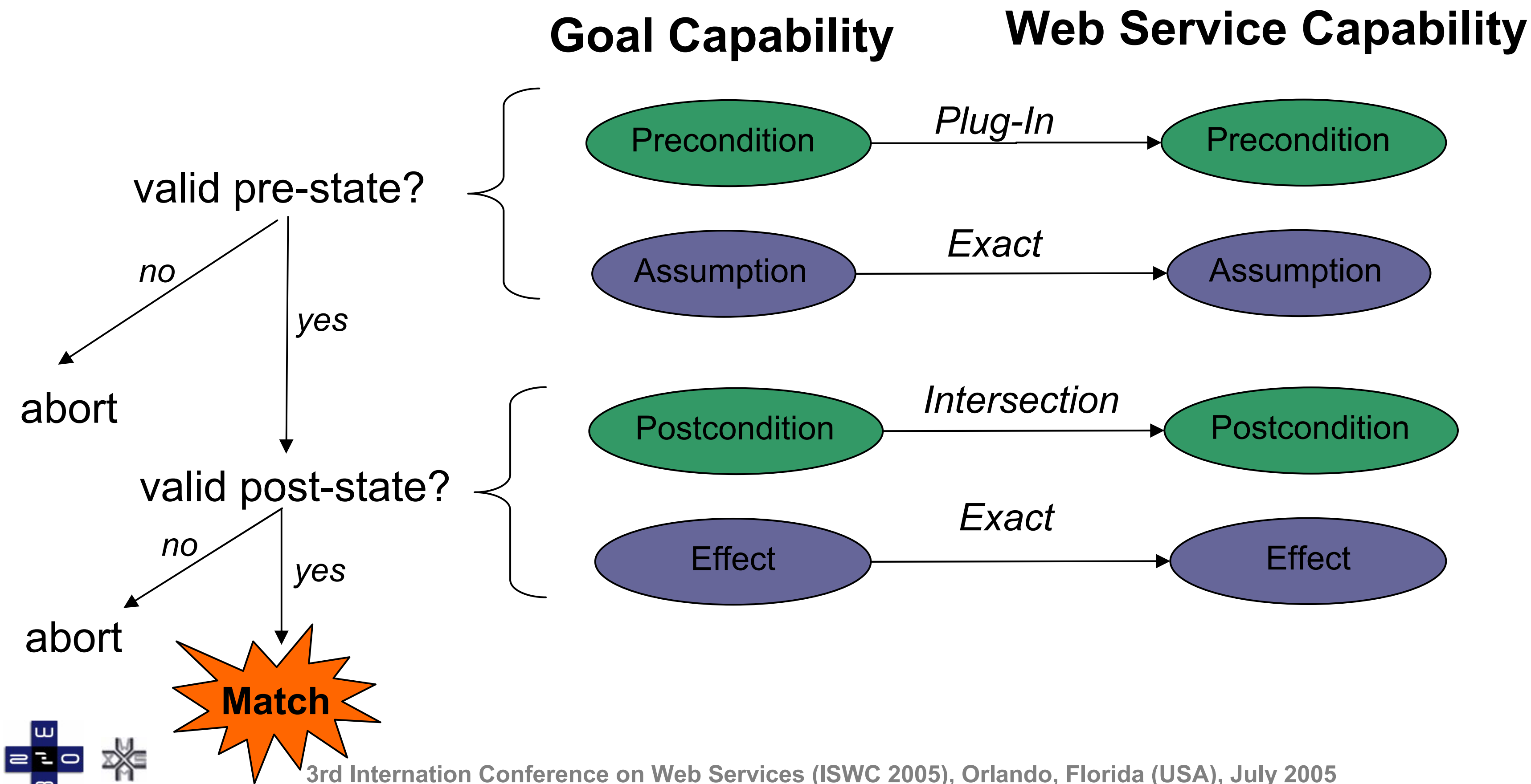
Non Match:

$G, WS, O, M \models \neg\exists x. (G(x) \wedge WS(x))$

Keller, U.; Lara, R.; Polleres, A. (Eds): *WSMO Web Service Discovery*. WSML Working Draft D5.1, 12 Nov 2004.

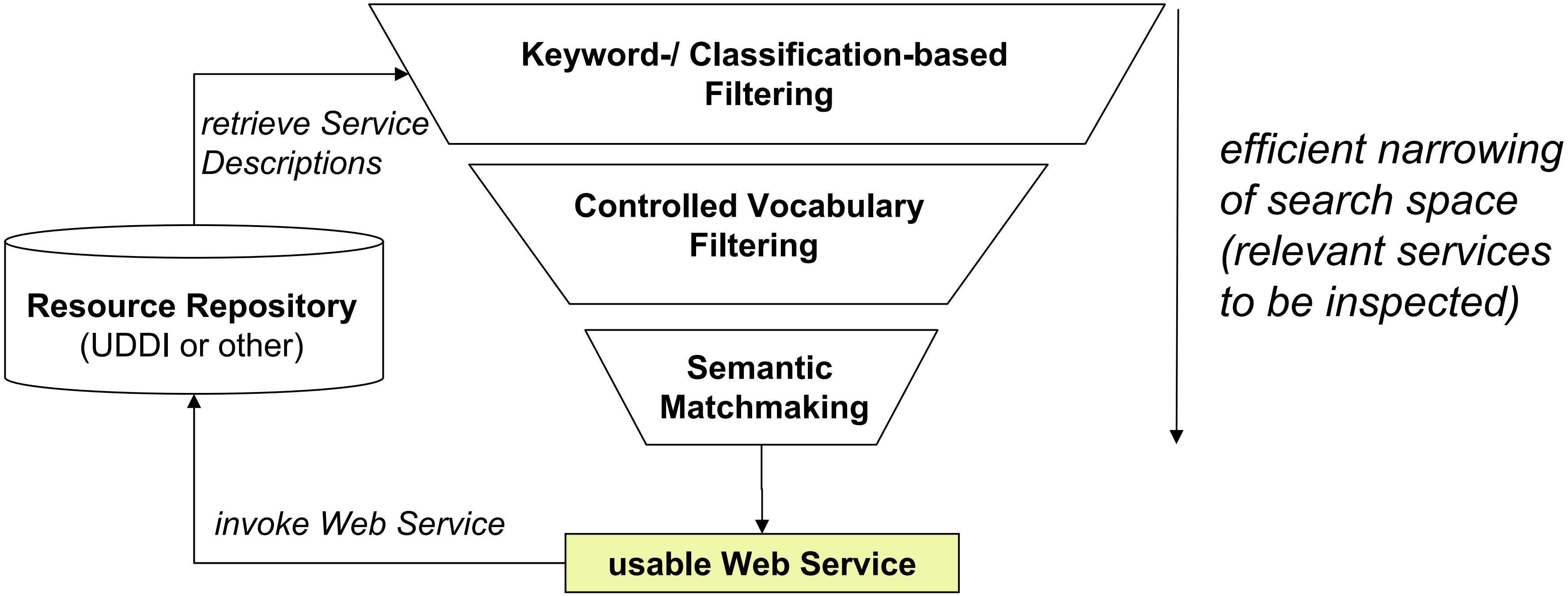
Discovery Approach

- Matchmaking Notion to be used defined for each goal capability element
- **Basic Procedure:**

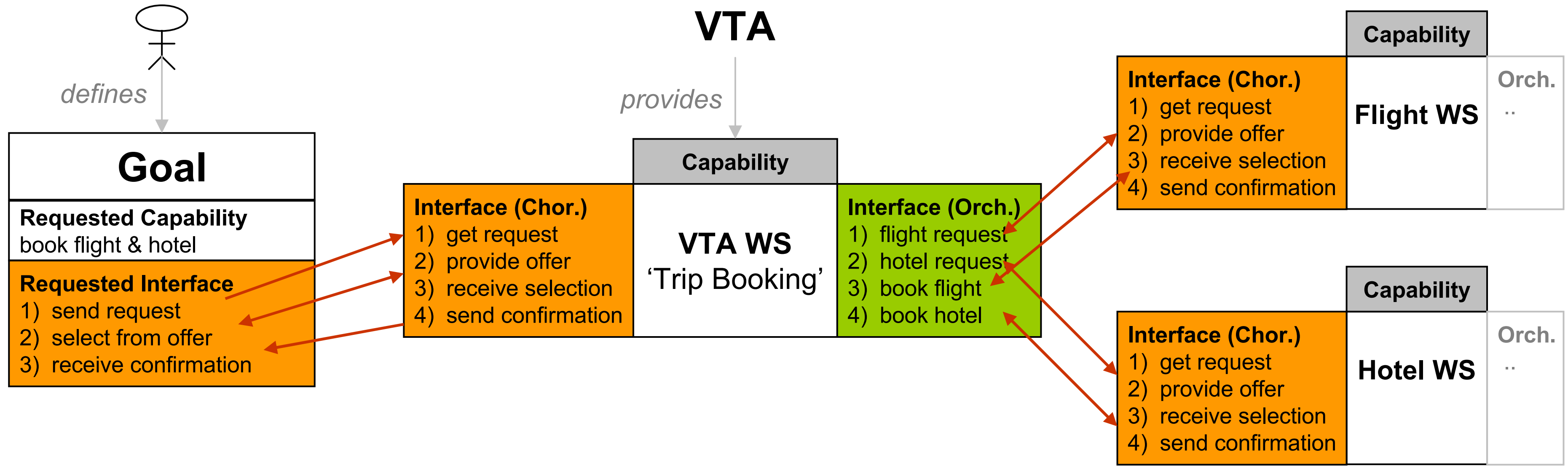


Discoverer Architecture

- Discovery as central Semantic Web Services technology
- Integrated Discoverer Architectures admired:



Service Interfaces



Behavior Interface: how entity can interact

Choreography: interaction between entities

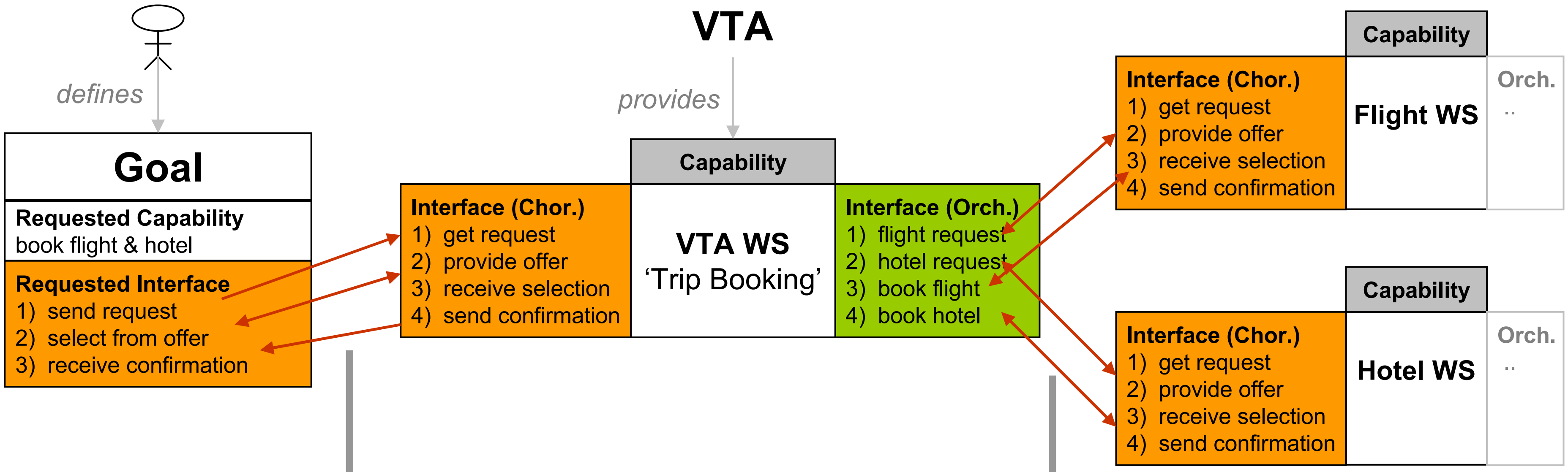
Orchestration: service aggregation for realizing functionality

VTA Service Description

- Behavior Interface
- Transition “get request” to “provide offer”

```
choreography VTABehaviorInterface
 importsOntology {_"http://www.wsmo.org/ontologies/tripReservationOntology“, …}
 vocabularyIn {reservationRequest, …}
 vocabularyOut {reservation, …}
guardedTransitions VTABehaviorInterfaceTransitionRules
if (reservationRequest memberOf tr#reservationRequest[
      reservationItem hasValue tr#trip,
      origin hasValue loc#city,
      destination hasValue loc#city,
      passenger hasValue tr#passenger]
then reservationOffer memberOf tr#reservation[
 reservationItem hasValue tr#trip,
 reservationHolder hasValue ?reservationHolder] .
```

Choreography Discovery



- both behavior interfaces given ("static")
- correct & complete consumption of VTA
=> existence of a valid choreography?

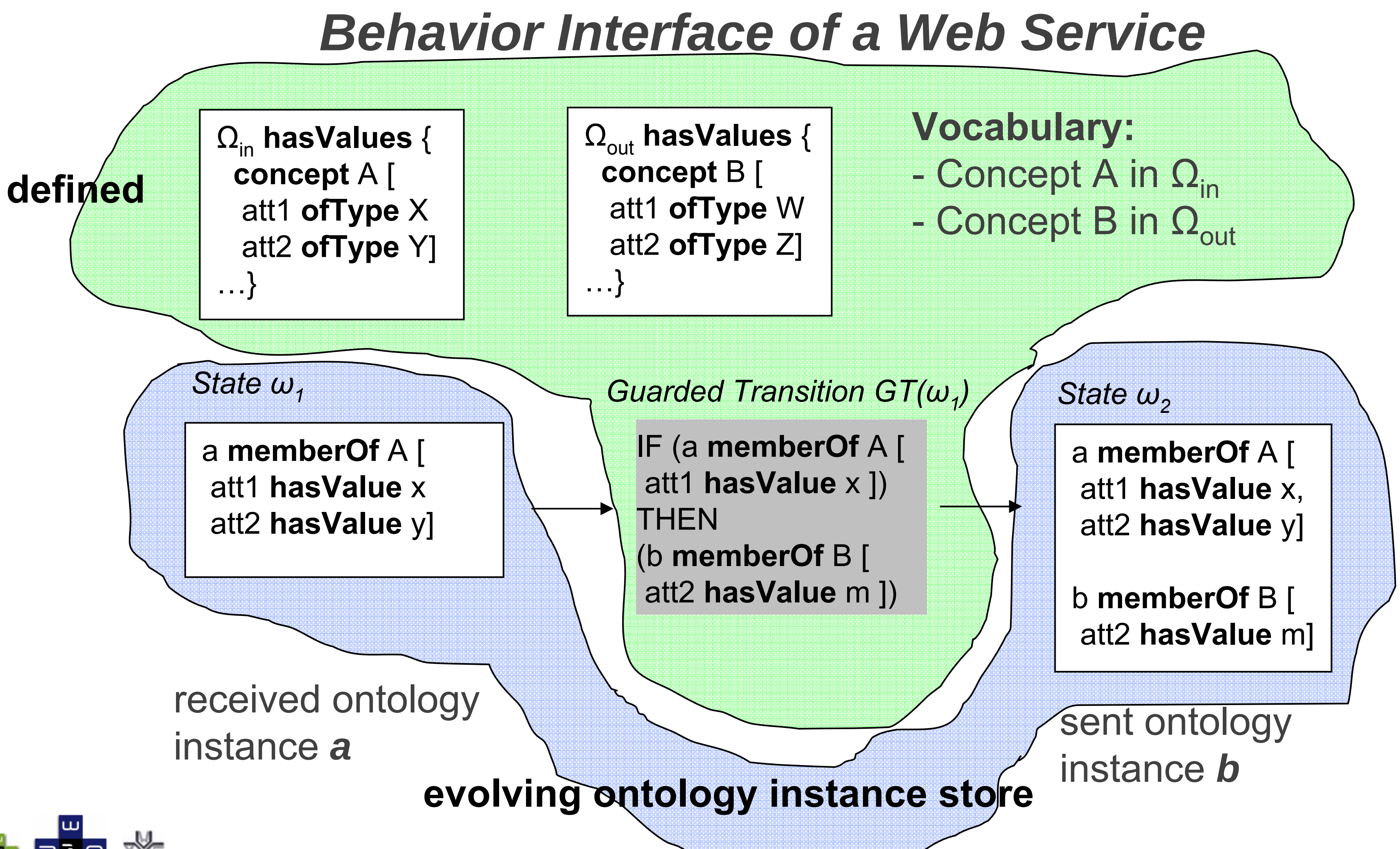
- VTA Orchestration & Behavior Interfaces of aggregated WS given
=> existence of a valid choreography between VTA and each aggregated WS?

- **Choreography Discovery** as a central reasoning task in Service Interfaces
- 'choreographies' do not have to be described, only existence determination
=> choreography discovery algorithm & support from WSMO model

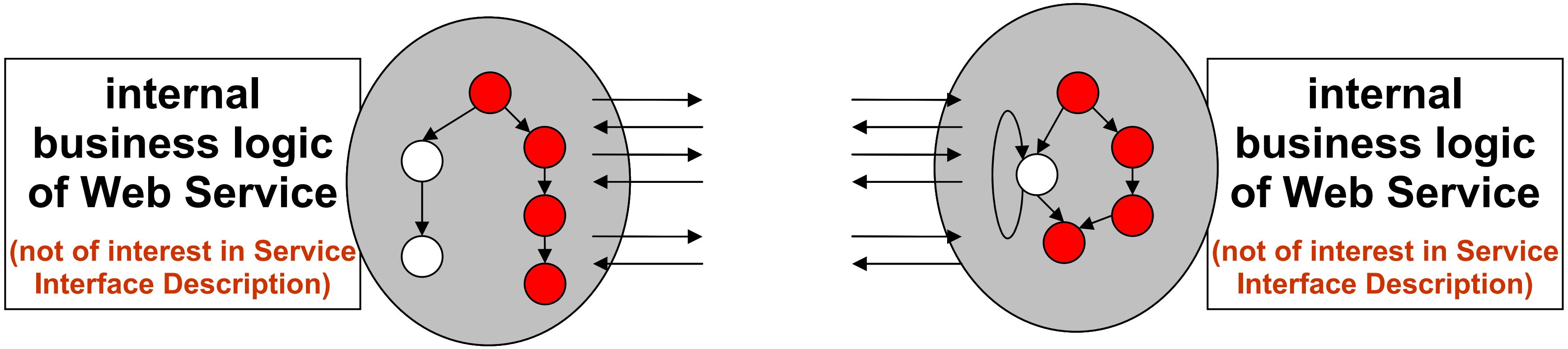
WSMO Service Interface Description Model

- common formal model for Service Interface description
  - ontologies as data model
  - based on ASMs
  - not restricted to any executable communication technology
- general structure:
  - Vocabulary Ω:
    - ontology schema(s) used in service interface description
    - usage for information interchange: in, out, shared, controlled
  - States $\omega(\Omega)$:
    - a stable status in the information space
    - defined by attribute values of ontology instances
  - Guarded Transition $GT(\omega)$:
    - state transition
    - general structure: ***if*** (condition) ***then*** (action)
    - different for Choreography and Orchestration
    - additional constructs: *add, delete, update*

Service Interface Example



Choreography Discovery



- a valid choreography exists if:
  - 1) **Information Compatibility**
    - compatible vocabulary
    - homogeneous ontologies
  - 2) **Communication Compatibility**
    - start state for interaction
    - a termination state can be reached without any additional input

Information Compatibility

If choreography participants have compatible vocabulary definitions:

- $\Omega_{in}(S1)$ and $\Omega_{shared}(S1) = \Omega_{out}(S2)$ and $\Omega_{shared}(S2)$
- determinable by Intersection Match from Discovery

$$\mathbf{SI_{S1}, SI_{S2}, O, M} \models \exists \mathbf{x}. (\Omega_{S1(in\ U\ shared)}(\mathbf{x}) \wedge \Omega_{S2(out\ U\ shared)}(\mathbf{x}))$$

- more complex for multi-party choreographies

Prerequisite: choreography participants use homogeneous ontologies:

- semanticInteroperability(S1, S2, …, Sn)
- same ontologies in Service Interfaces, or usage of respective OO Mediators

Communication Compatibility

- Definitions (for “binary choreography” (only 2 services), more complex for multi-party choreographies)

Valid Choreography State:

$\omega_x(C(S1, S2))$ **if** informationCompatibility $(\Omega S1(\omega_x), \Omega S2(\omega_x))$

– means: action in GT of S1 for reaching state $\omega_x(S1)$ satisfies condition in GT of S2 for reaching state $\omega_x(S2)$, or vice versa

Start State:

$\omega_{\emptyset}(C(S1, S2))$ **if** $\Omega S1(\omega_{\emptyset})=\emptyset$ and $\Omega S2(\omega_{\emptyset})=\emptyset$ and $\exists\ \omega_1(C(S1, S2))$

– means: if initial states for choreography participants given (empty ontology, i.e. no information interchange has happened), and there is a valid choreography state for commencing the interaction

Termination State:

$\omega_T(C(S1, S2))$ **if** $\Omega S1(\omega_T)=noAction$ and $\Omega S2(\omega_T)=noAction$ and $\exists\ \omega_T(C(S1, S2))$

– means: there exist termination states for choreography participants (no action for transition to next state), and this is reachable by a sequence of valid choreography states

- Communication Compatibility given if there exists a start state and a termination state is reachable without additional input by a sequence of valid choreography states

Communication Compatibility Example

James' Goal Behavior Interface

$\Omega_{S1}(\omega\varnothing) = \{\varnothing\}$

if Ø **then** request

$\Omega_{S1}(\omega 1) = \{request(out)\}$

if cnd1(offer) **then** changeReq

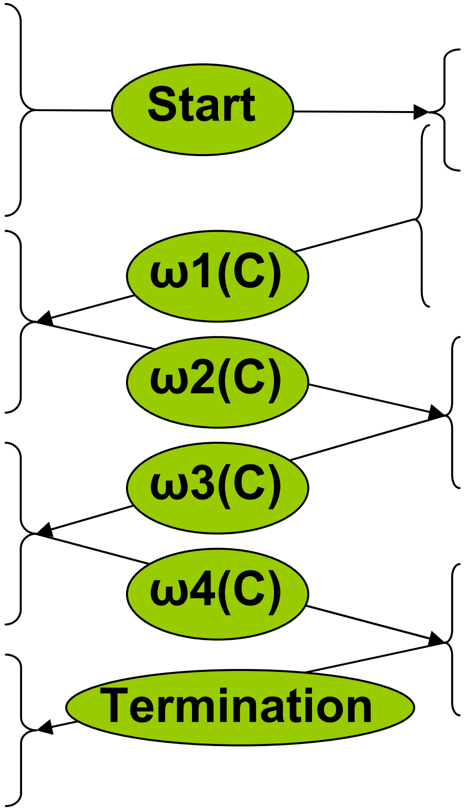
$\Omega_{S1}(\omega 2a) = \{offer(in), changeReq(out)\}$

if cnd2(offer) **then** order

$\Omega_{S1}(\omega 2b) = \{offer(in), order(out)\}$

if conf **then** Ø

$\Omega_{S1}(\omega 3) = \{offer(in), conf(in)\}$



VTA Behavior Interface

$\Omega_{S2}(\omega\varnothing) = \{\varnothing\}$

if request **then** offer

$\Omega_{S2}(\omega 1) = \{request(in), offer(out)\}$

if changeReq **then** offer

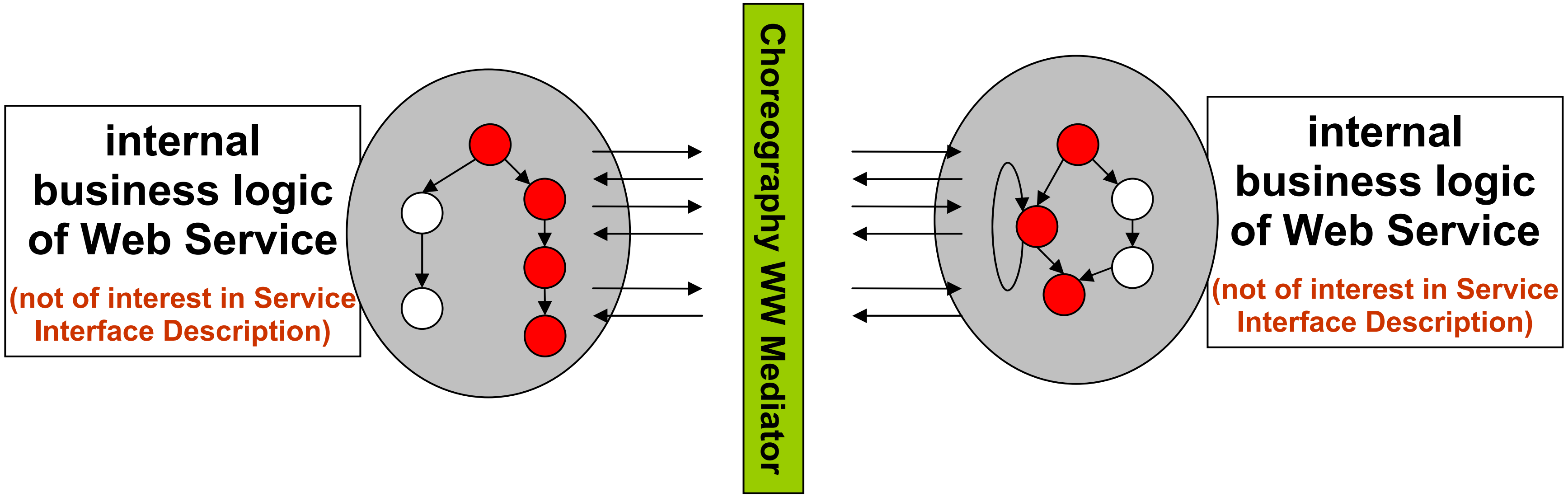
$\Omega_{S2}(\omega 2a) = \{changeReq(in), offer(out)\}$

if order **then** conf

$\Omega_{S2}(\omega 2b) = \{order(in), conf(out)\}$

existence of a valid Choreography

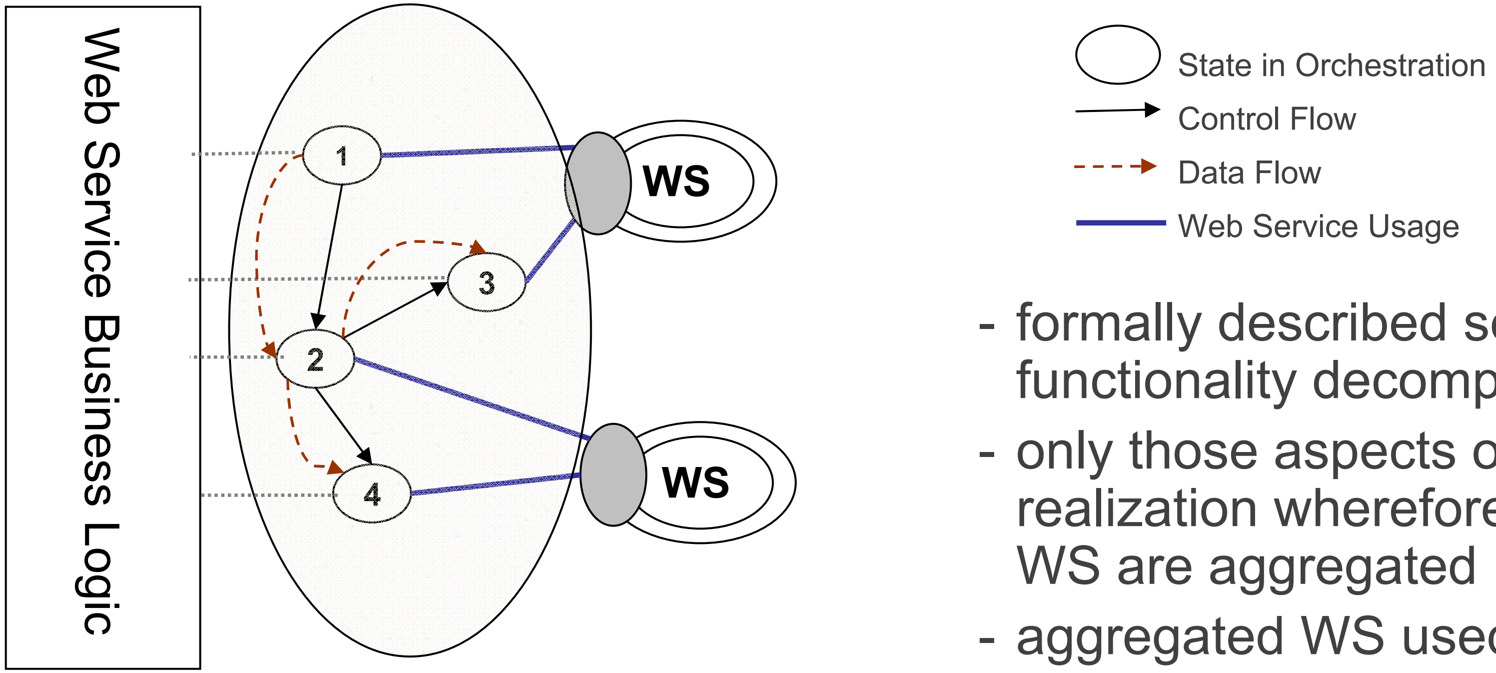
WW Mediators in Choreography



- if a choreography does not exist, then find an appropriate WW Mediator that
  - resolves possible mismatches to establish Information Compatibility (OO Mediator usage)
  - resolves process / protocol level mismatches in to establish Communication Compatibility

Orchestration

Control Structure for aggregation of other Web Services



- formally described service functionality decomposition
- only those aspects of WS realization wherefore other WS are aggregated
- aggregated WS used via their behavior interface

Orchestration Description & Validation

- Orchestration Description:
  - interaction behavior of “Orchestrator” with “orchestrated Web Services”
  - WSMO Service Interface description model, extension of Guarded Transitions general structure:

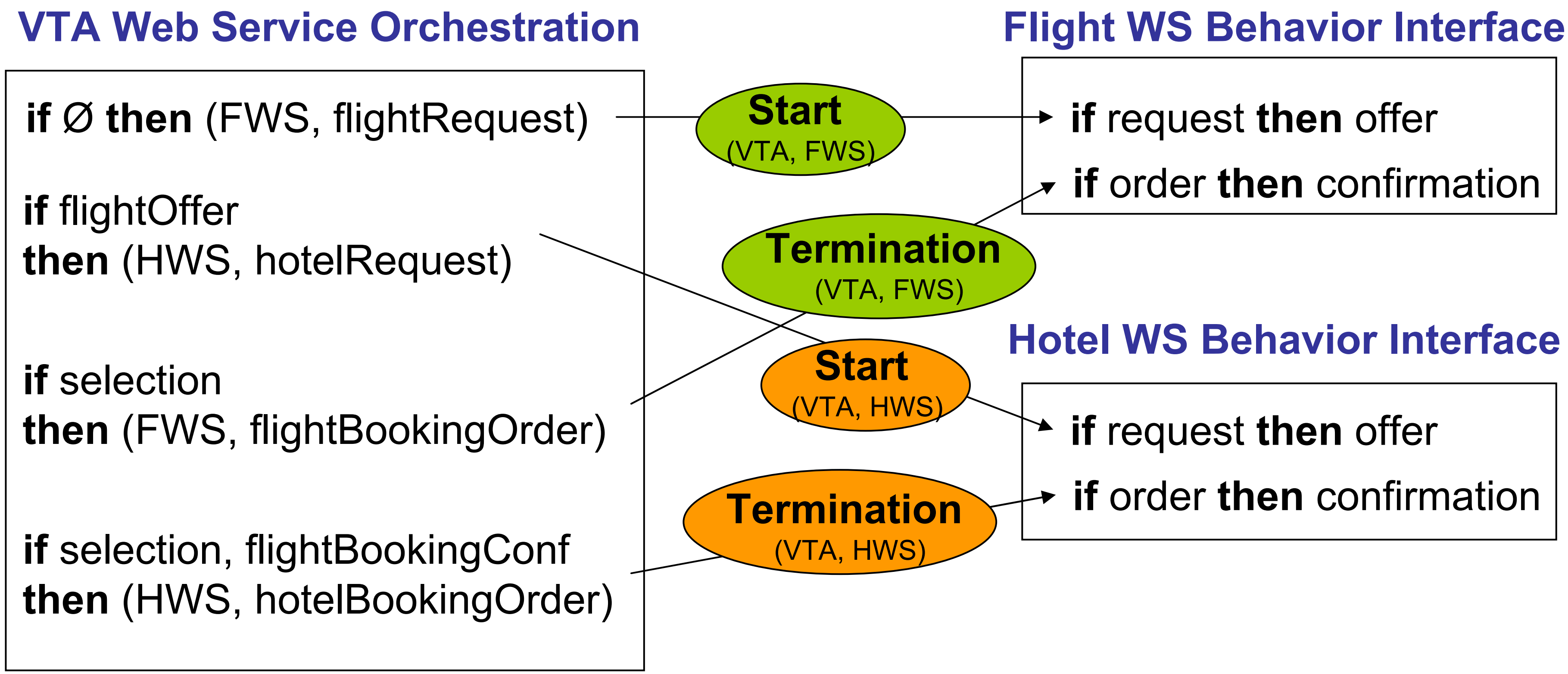
    if condition **then** operation

    Operation = (Orchestrator, Web Service, Action)
  - Orchestrator serves as client for aggregated Web Services

- Orchestration Validation:
  - need to ensure that interactions with aggregated Web Service can be executed successfully

  => Choreography Discovery for all interaction of Orchestrator with each aggregated Web Service

Orchestration Validation Example



Orchestration is valid if valid choreography exists for interactions between Orchestrator and each aggregated Web Service, done by choreography discovery

Service Composition and Orchestration

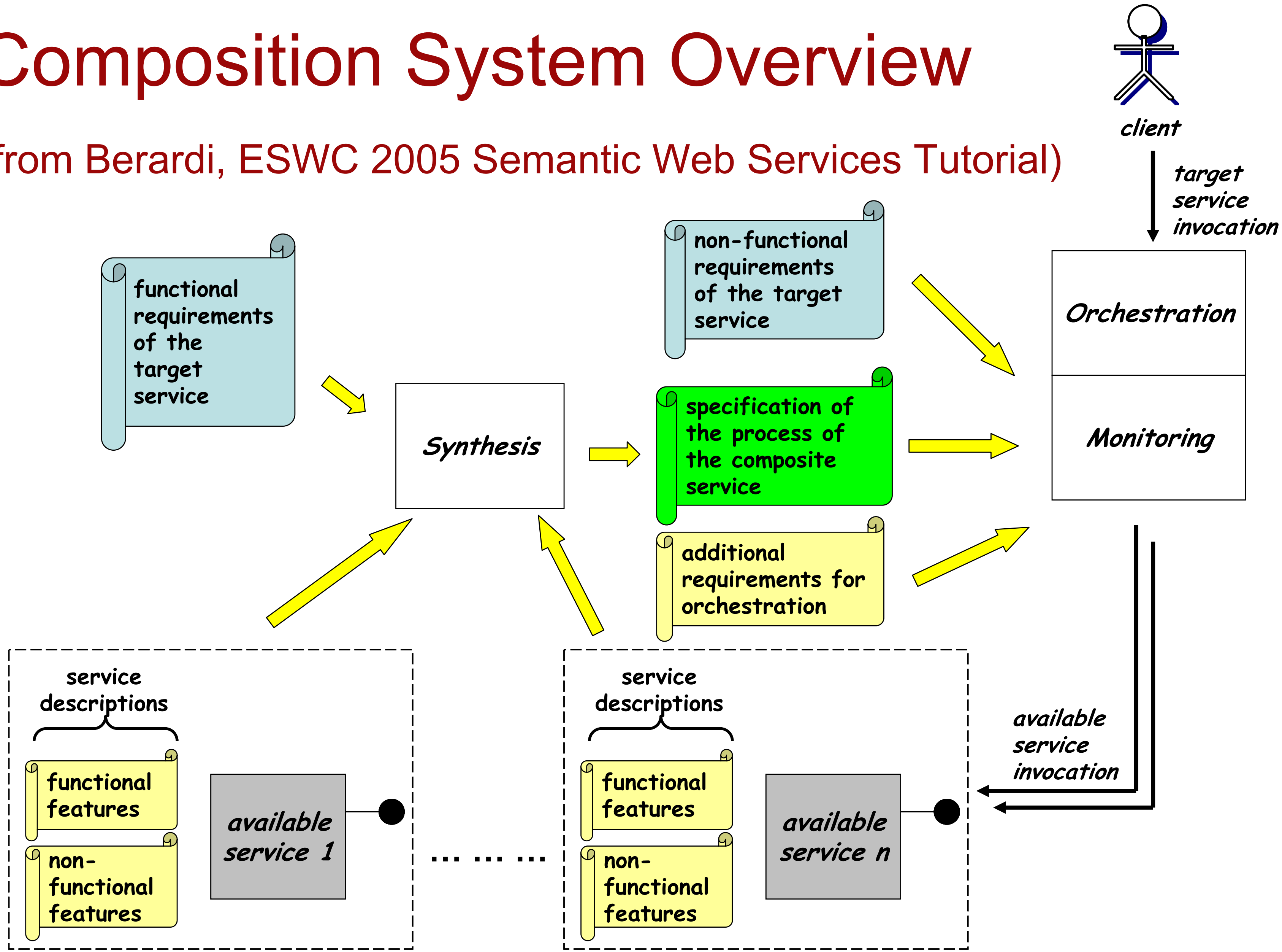
- Web Service Composition:
  - the realization of a Web Service by dynamically composing the functionalities of other Web Services
    - The new service is the *composite* service
    - The invoked services are the *component* services
  - a composite service can provide the skeleton for a Web Service (e.g. the VTA Web Service)

- Current Composition techniques only cover aspects for valid orchestrations partially
  - functional Web Service composition (on capability descriptions)
  - dynamic control and data flow construction for composite Web Service
  - delegation of client / goal behavior to component services

=> Orchestration Validation needed to ensure executable Web Service aggregations

Composition System Overview

(from Berardi, ESWC 2005 Semantic Web Services Tutorial)



Conclusions

- Semantic Web Service descriptions require
  - expertise in ontology & logical modeling

  => tool support for users & developers under development
  - understanding of Semantic Web Service technologies
    - what it does, and how it works
    - which are the related descriptive information

- Semantic Web Service technologies aim at automation of the Web Service usage process
  - users only define goal with tool support
  - 'intelligent' SWS middleware for automated Web Service usage

- state of the art in technology & tool development
  - theoretical approaches are converging; standardization efforts
  - prototypical SWS technologies existent
  - industrial strength SWS technology suites aspired in upcoming efforts

PART IV:
The Web Service Execution Environment WSMX

- Aims & Design Principles
- WSMX Development Process and Releases
- Components and System Architecture
  - Components
  - Event-based Implementation
  - System Entry Points
  - Execution Semantics

WSMX Introduction

- Software framework for runtime binding of service requesters and service providers
- WSMX interprets service requester's goal to
  - discover matching services
  - select (if desired) the service that best fits
  - provide data mediation (if required)
  - make the service invocation
- is based on the conceptual model provided by WSMO
- has formal execution semantics
- SO and event-based architecture based on microkernel design using technologies as J2EE, Hibernate, Spring, JMX, etc.

Design Principles

Strong Decoupling & Strong Mediation

autonomous components with mediators for interoperability

Interface vs. Implementation

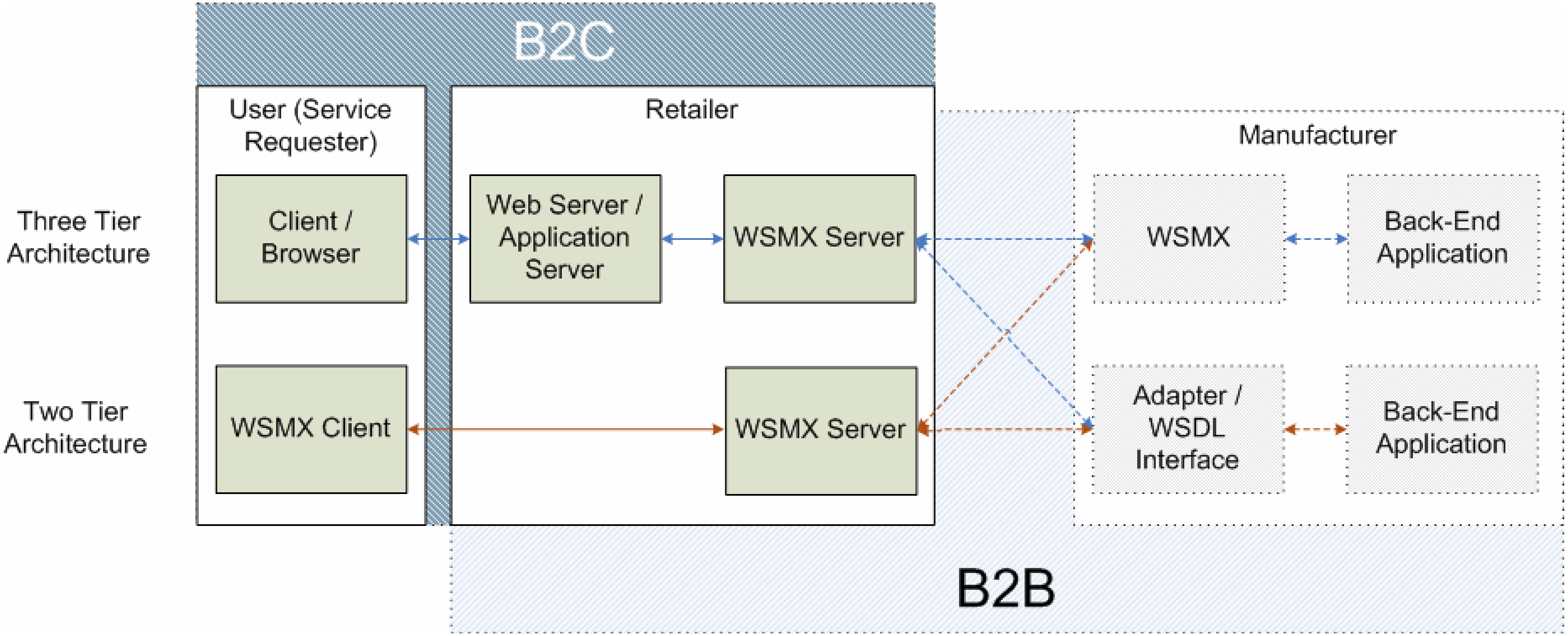
distinguish interface (= description) from implementation (=program)

Peer to Peer

interaction between equal partners (in terms of control)

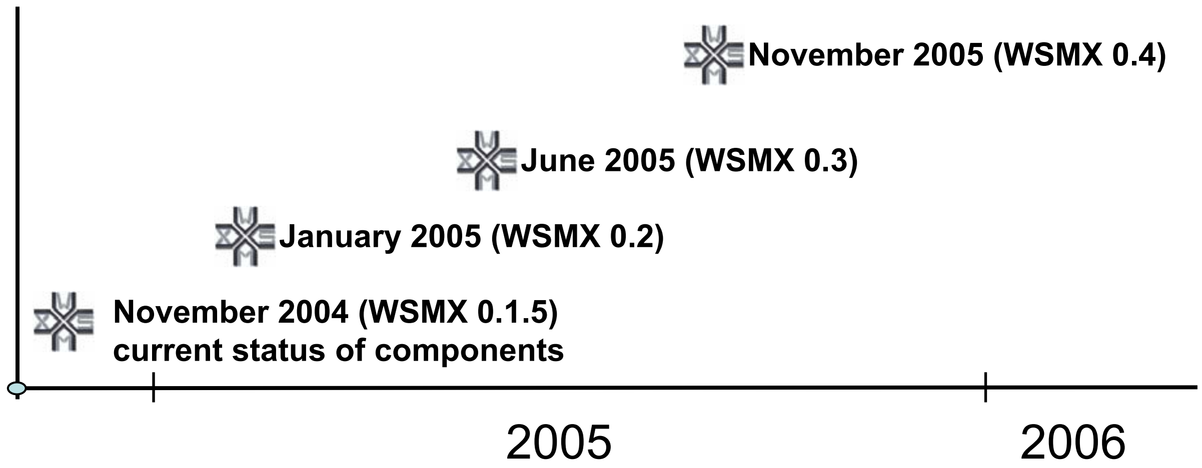
WSMO Design Principles == WSMX Design Principles == SOA Design Principles

WSMX Usage Scenario

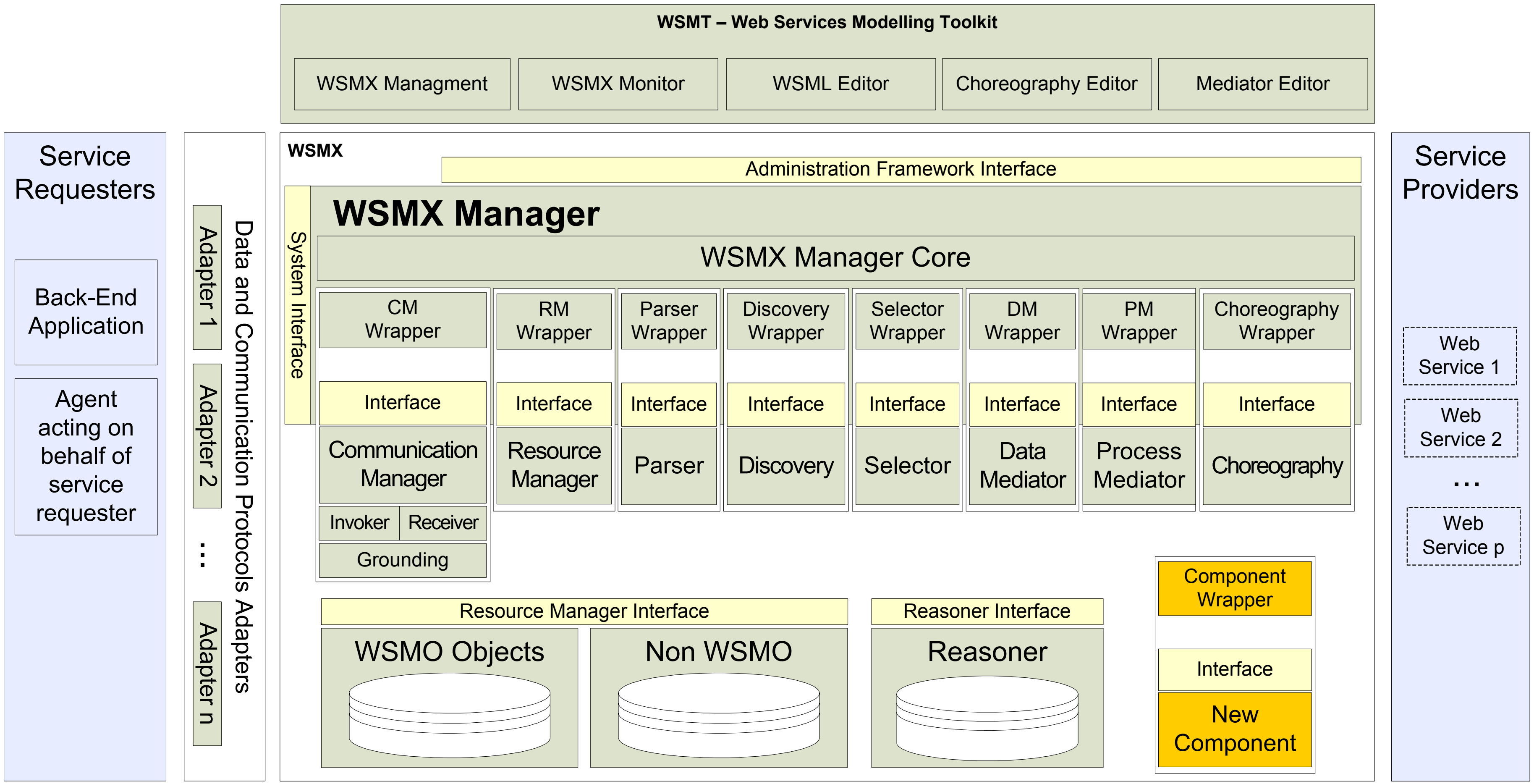


Development Process & Releases

- The development process for WSMX includes:
  - Establishing its conceptual model
  - Defining its execution semantics
  - Develop the architecture
  - Design the software
  - Building a working implementation
- Planned releases:



Components & System Architecture



Selected Components

- Adapters
- Parser
- Invoker
- Choreography & Process Mediator
- Matchmaker
- Data Mediator
- Resource Manager

Adapters

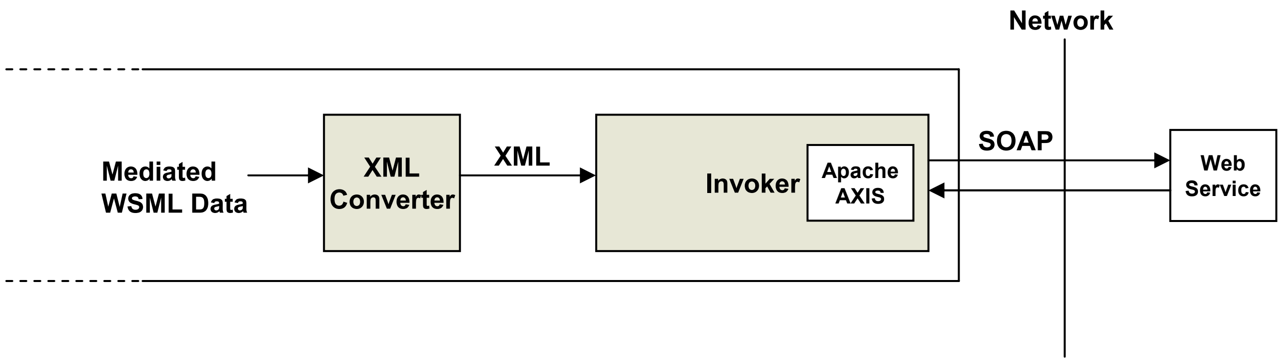
- to overcome data representation mismatches on the communication layer
- transforms the format of a received message into WSML compliant format
- based on mapping rules

Parser

- WSML 1.0 compliant parser
  - Code handed over to wsmo4j initiative
- Validates WSML description files
- Compiles WSML description into internal memory model
- Stores WSML description persistently (using Resource Manager)

Invoker

- WSMX V0.1 used the SOAP implementation from Apache AXIS
- Web Service interfaces were provided to WSMX as WSDL
- Both RPC and Document style invocations possible
- Input parameters for the Web Services were translated from WSML to XML using an additional XML Converter component.



Choreography & Process Mediator

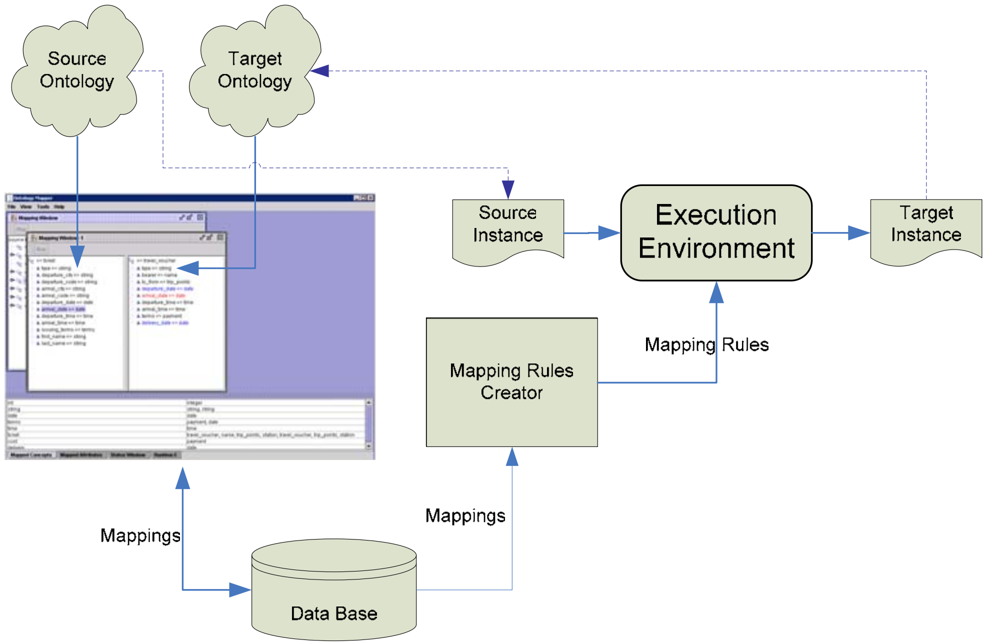
- requester and provider have their own communication patterns
- only if the two match precisely, a direct communication may take place
- at design time equivalences between the choreographies' conceptual descriptions is determined and stored as set of rules
- Choreography Engine & Process Mediator provides the means for runtime analyses of two choreography instances and uses mediators to compensate possible mismatches

Matchmaker

- responsible for finding appropriate Web Services to achieve a goal (discovery)
- currently the built-in matchmaking is performed by simple string-based matching; advanced semantic discoverers in prototypical stage

OOMediator

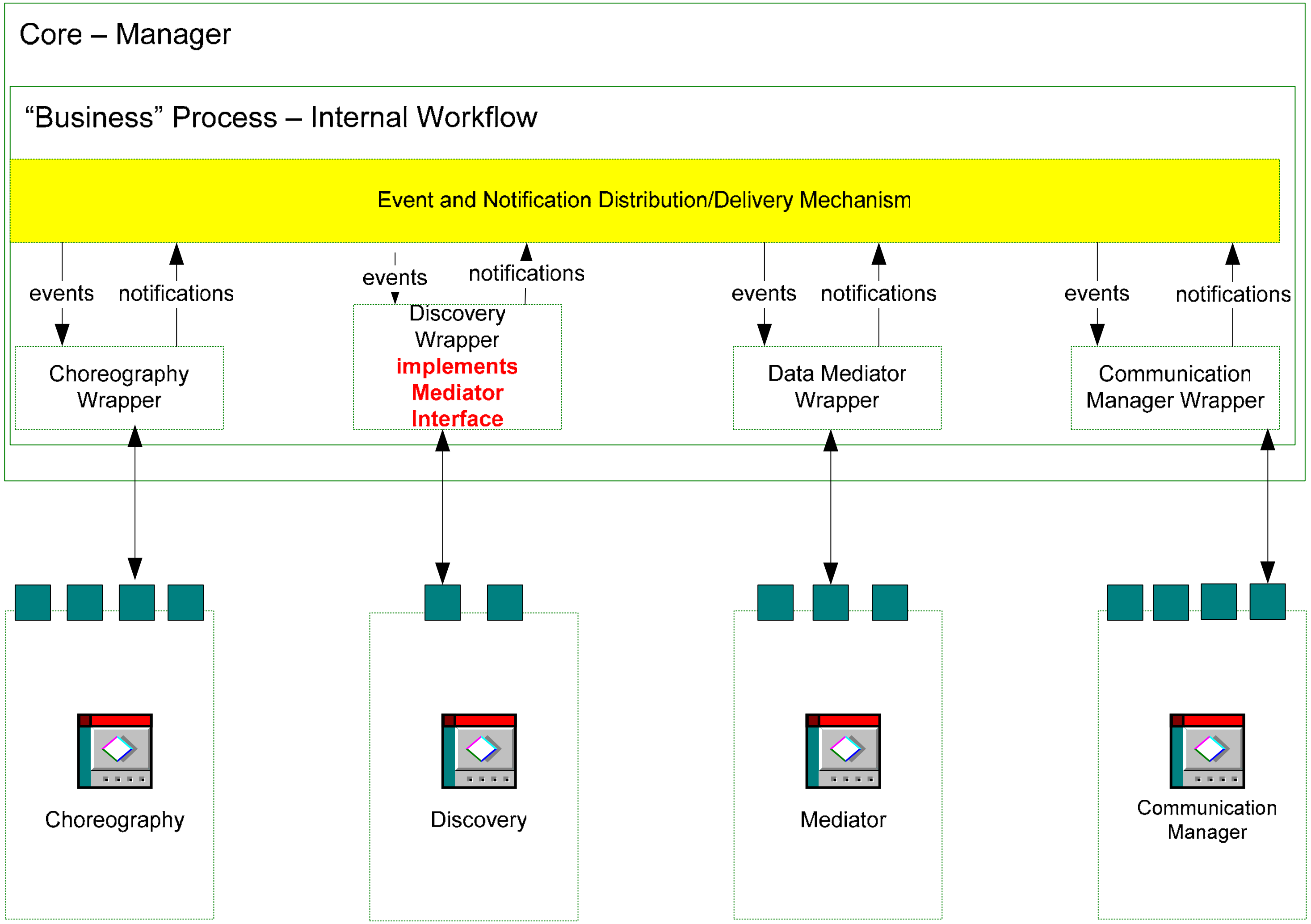
- Ontology-to-ontology mediation
- A set of mapping rules are defined and then executed
- Initially rules are defined semi-automatic
- Create for each source instance the target instance(s)



Resource Manager

- Stores internal memory model to a data store
- Decouples storage mechanism from the rest of WSMX
- Data model is compliant to WSMO API
- Independent of any specific data store implementation i.e. database and storage mechanism

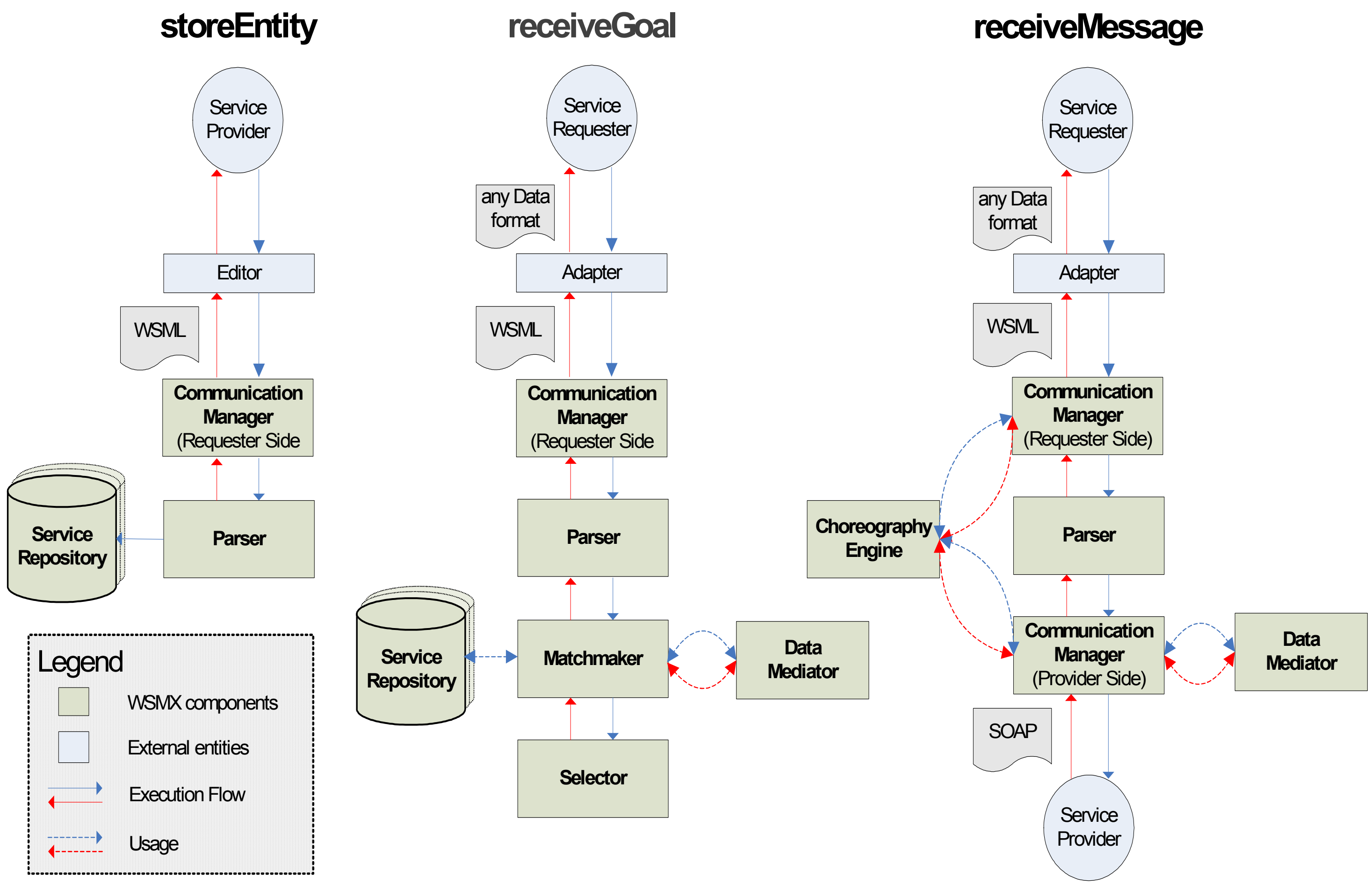
Event-based Implementation



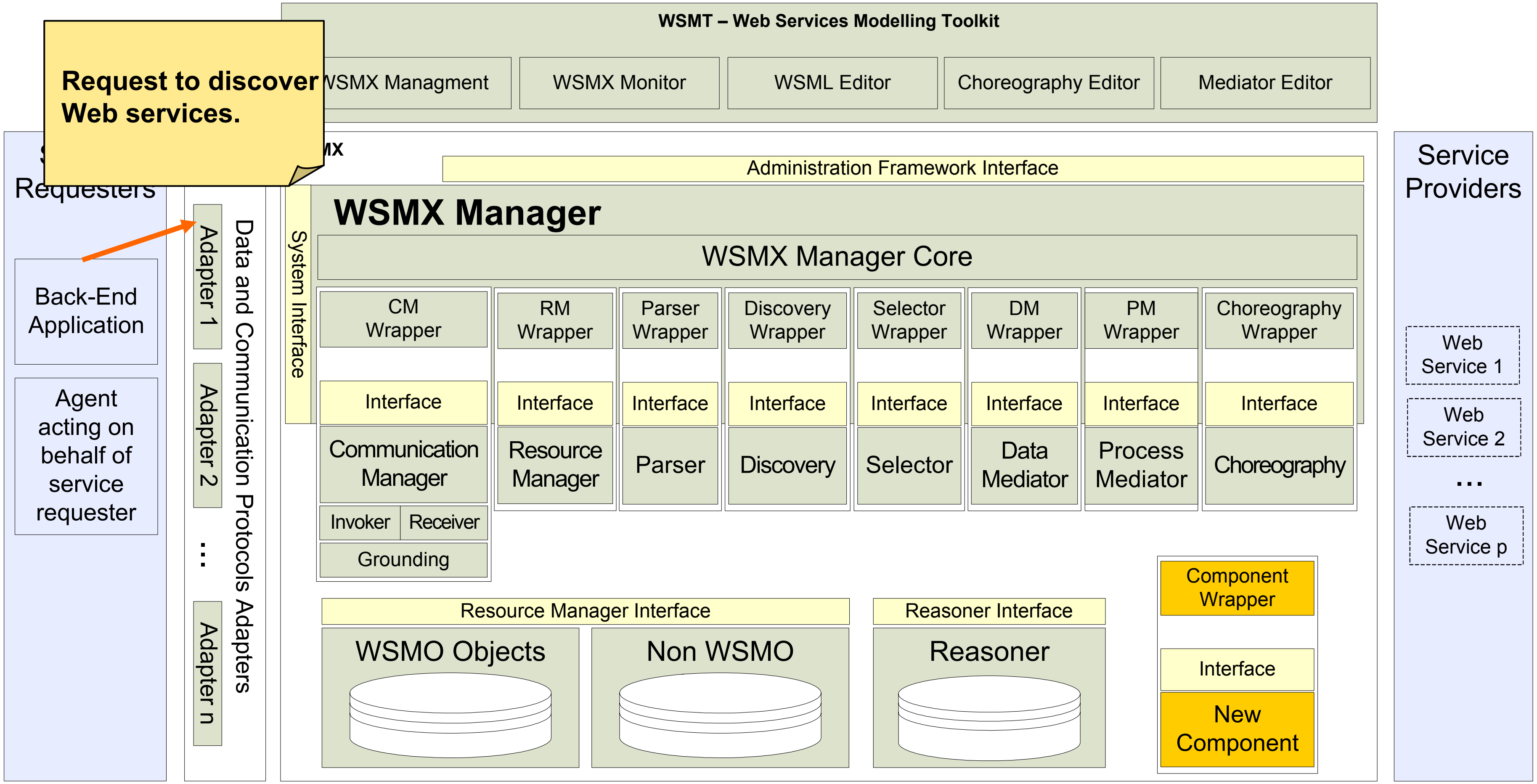
System entry points

- storeEntity(WSMOEntity):Confirmation
  - provides an administration interface for storing any WSMO-related entities (Web Services, Goals, Ontologies)
- realizeGoal(Goal, OntologyInstance):Confirmation
  - service requester expects WSMX to discover and invoke Web Service without exchanging additional messages
- receiveGoal(Goal, OntologyInstance, Preferences):WebService[]
  - list of Web Services is created for given Goal
  - requester can specify the number of Web Services to be returned
- receiveMessage(OntologyInstance,WebServiceID, ChoreographyID):ChoreographyID
  - back-and-forth conversation to provide all necessary data for invocation
  - involves execution of choreographies and process mediation between service interfaces

System Entry Points



Execution Semantics



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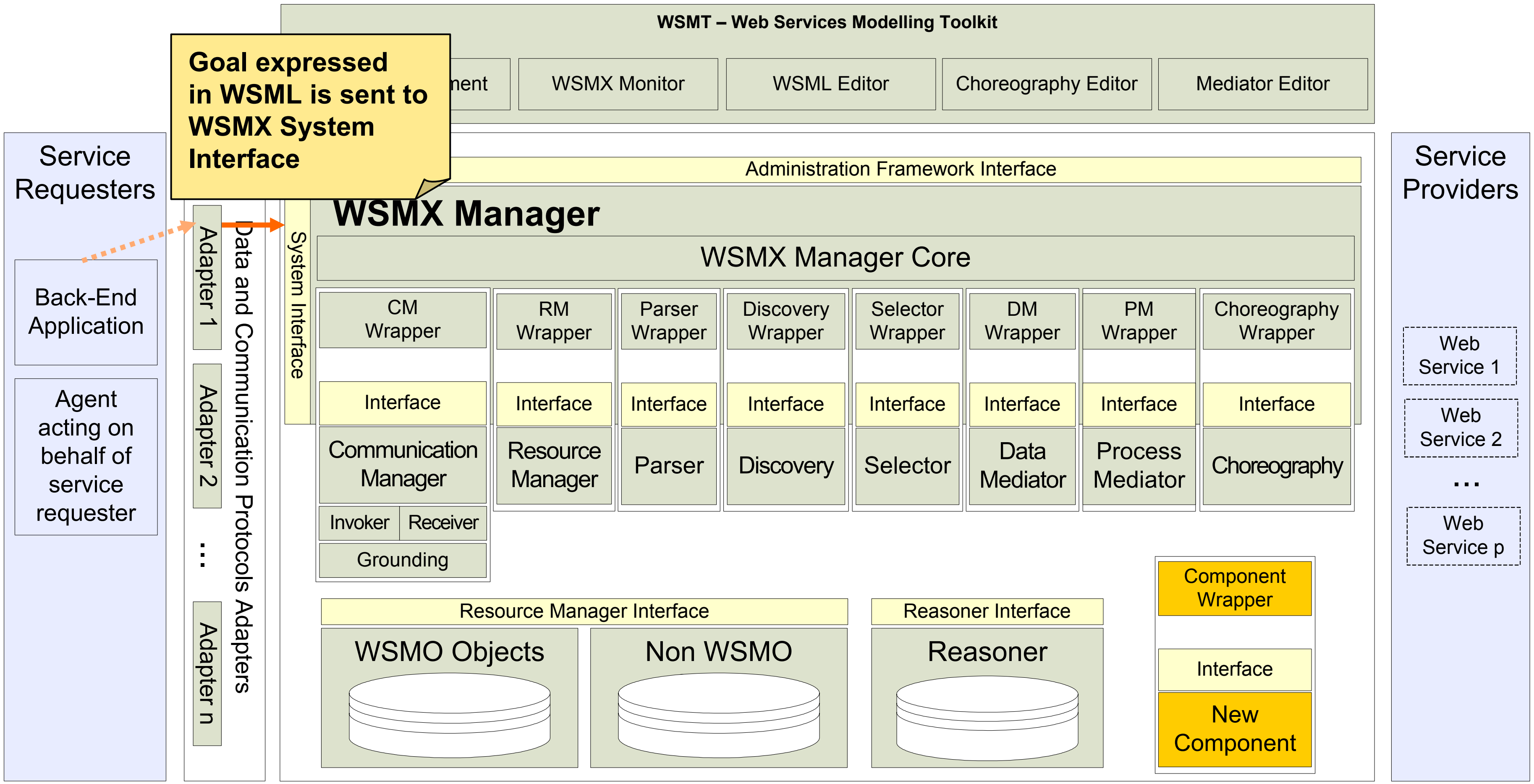

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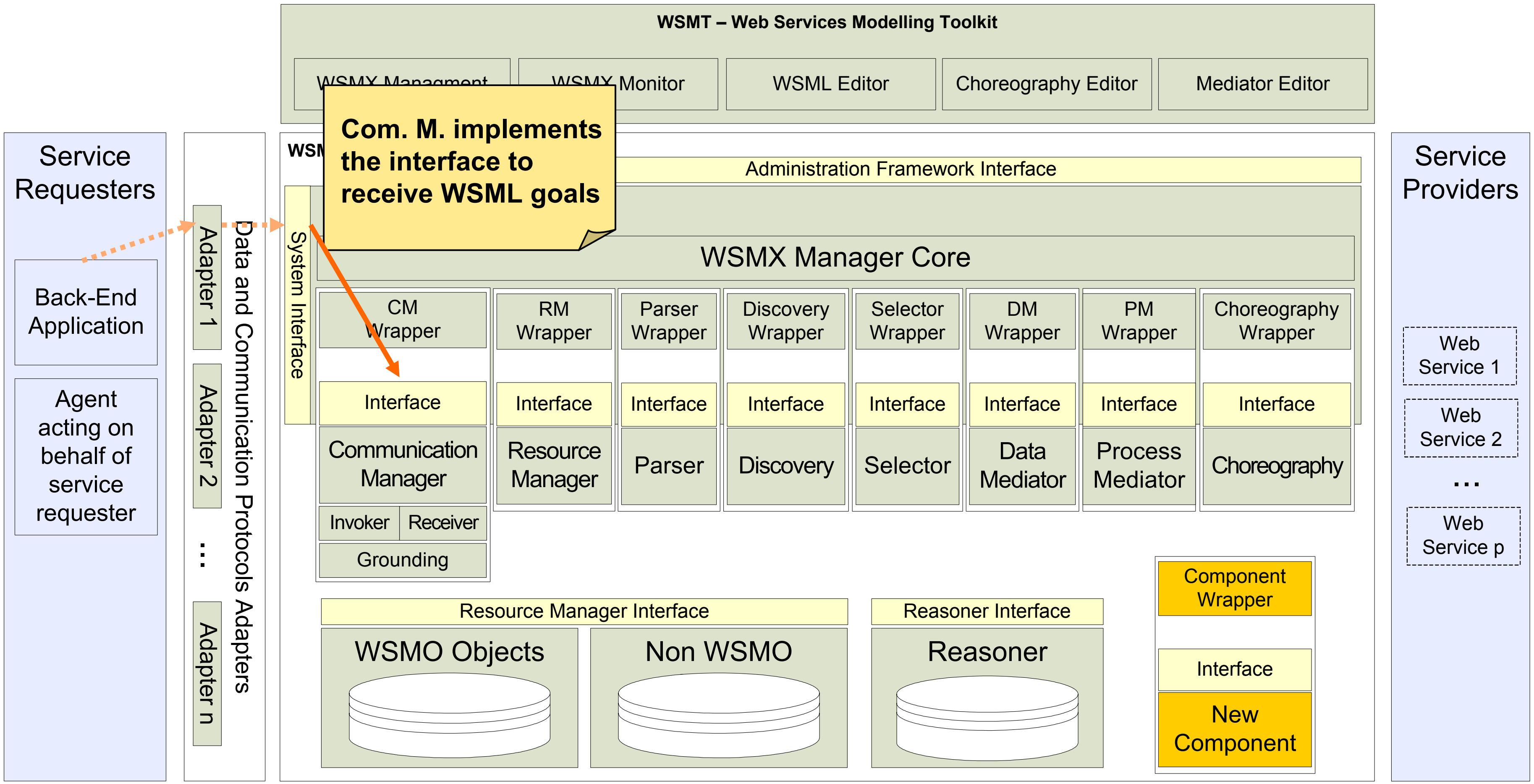

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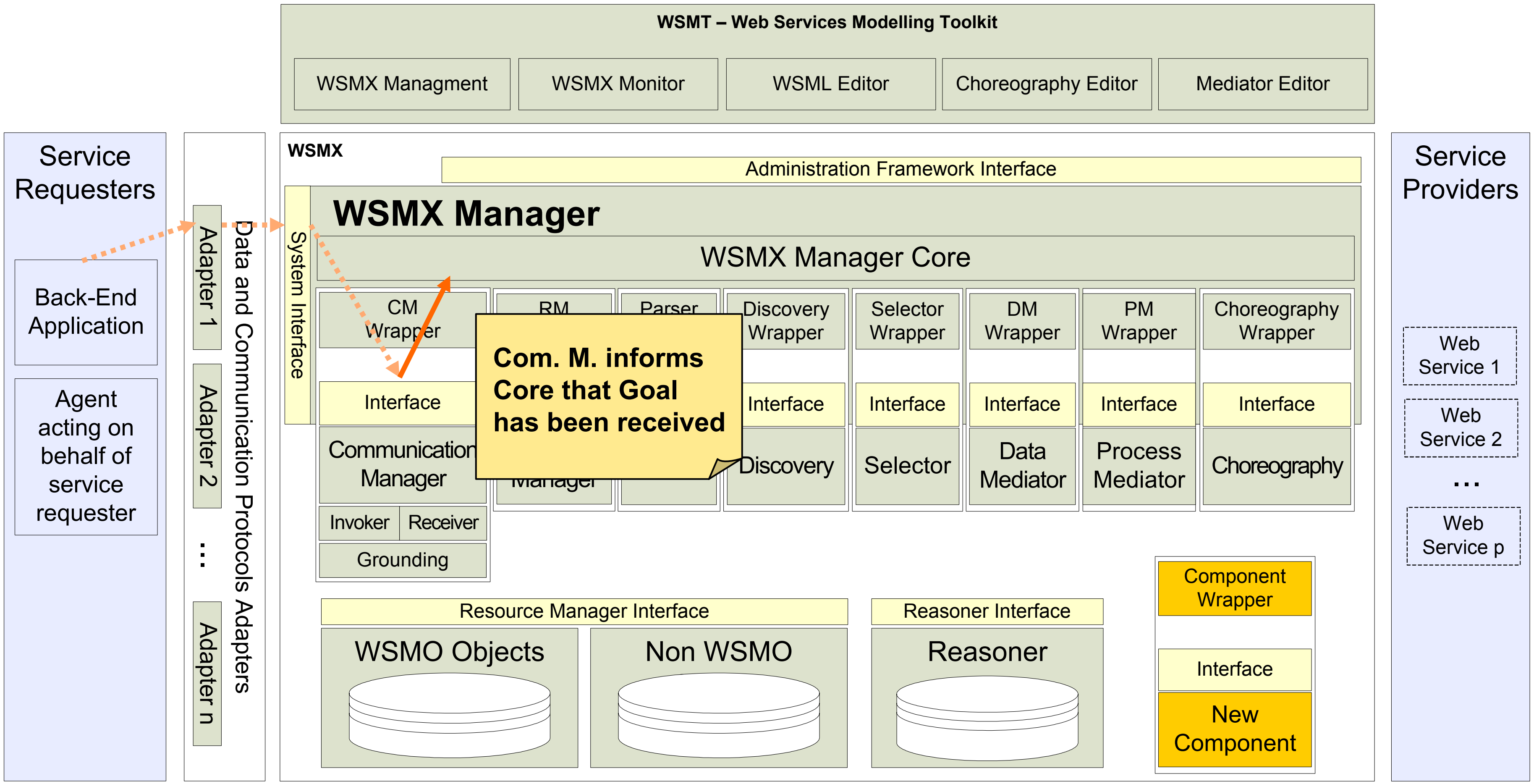

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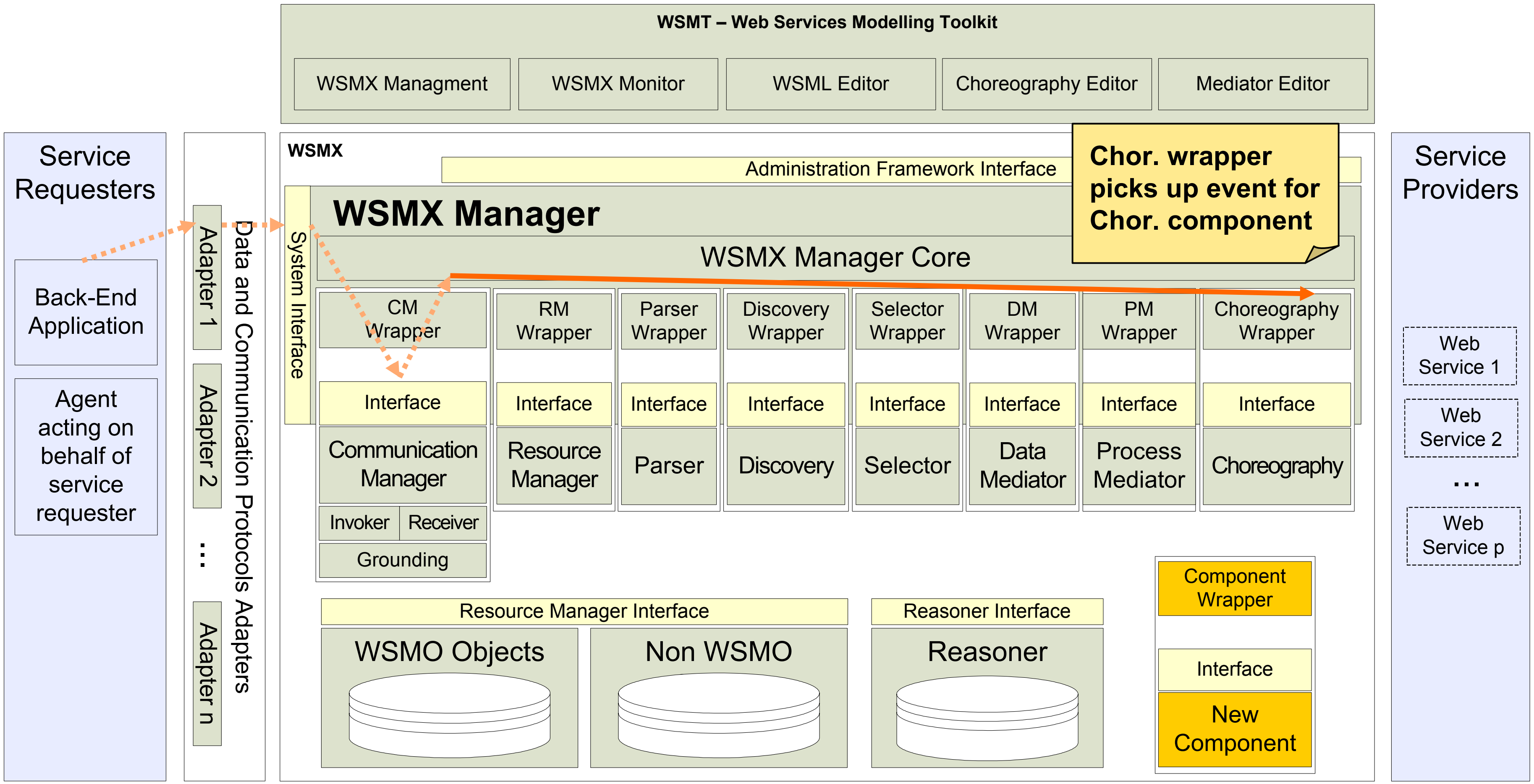

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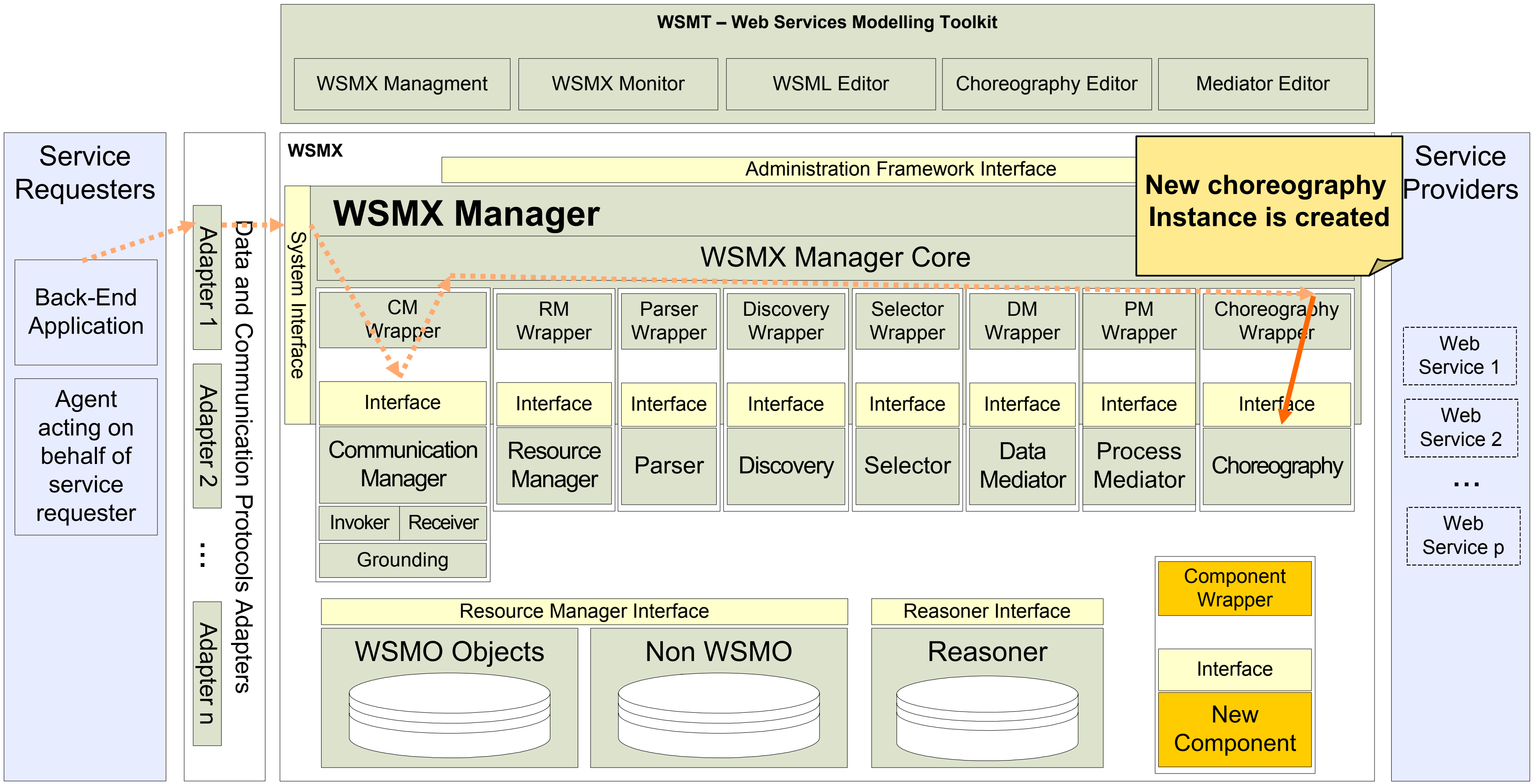

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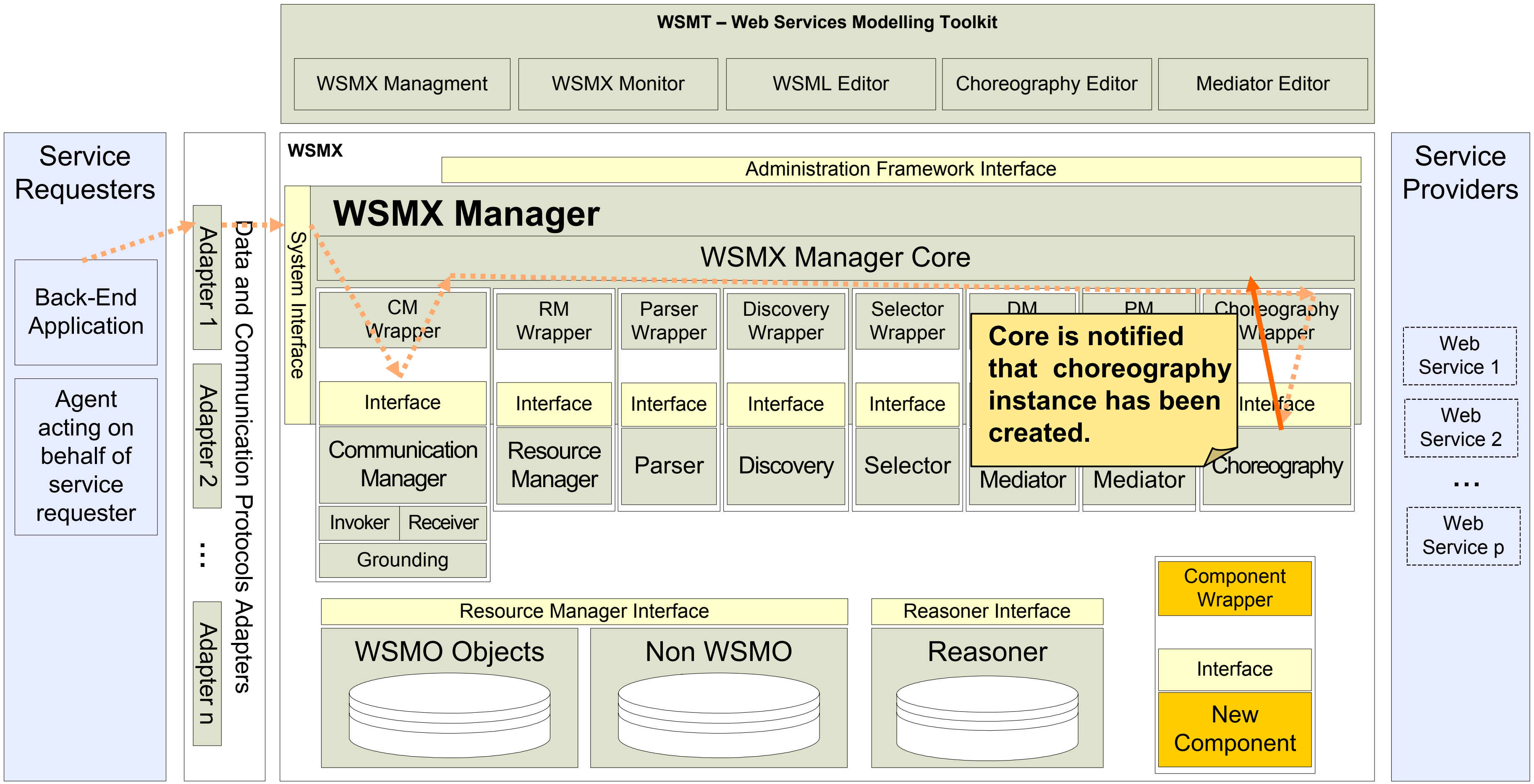

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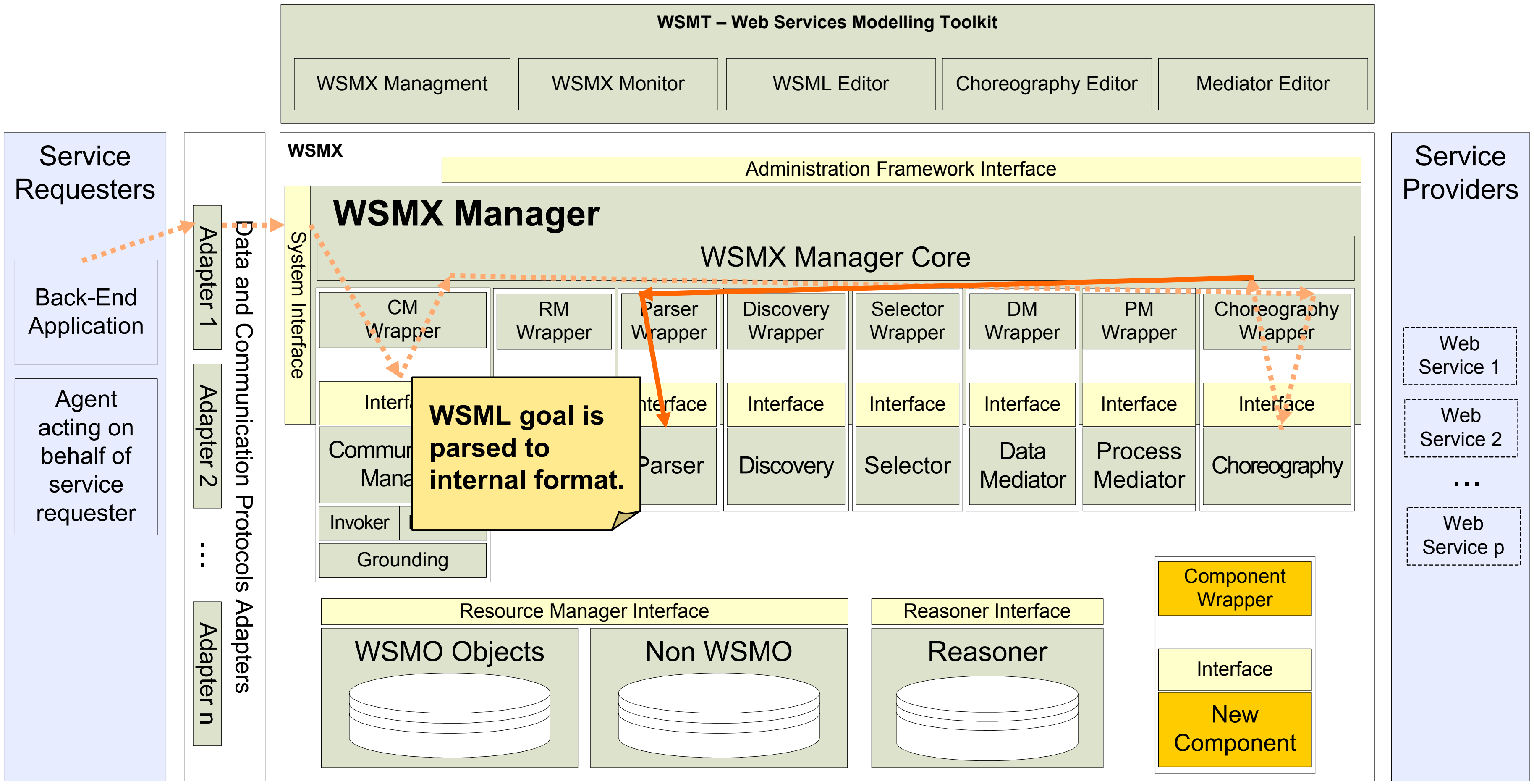
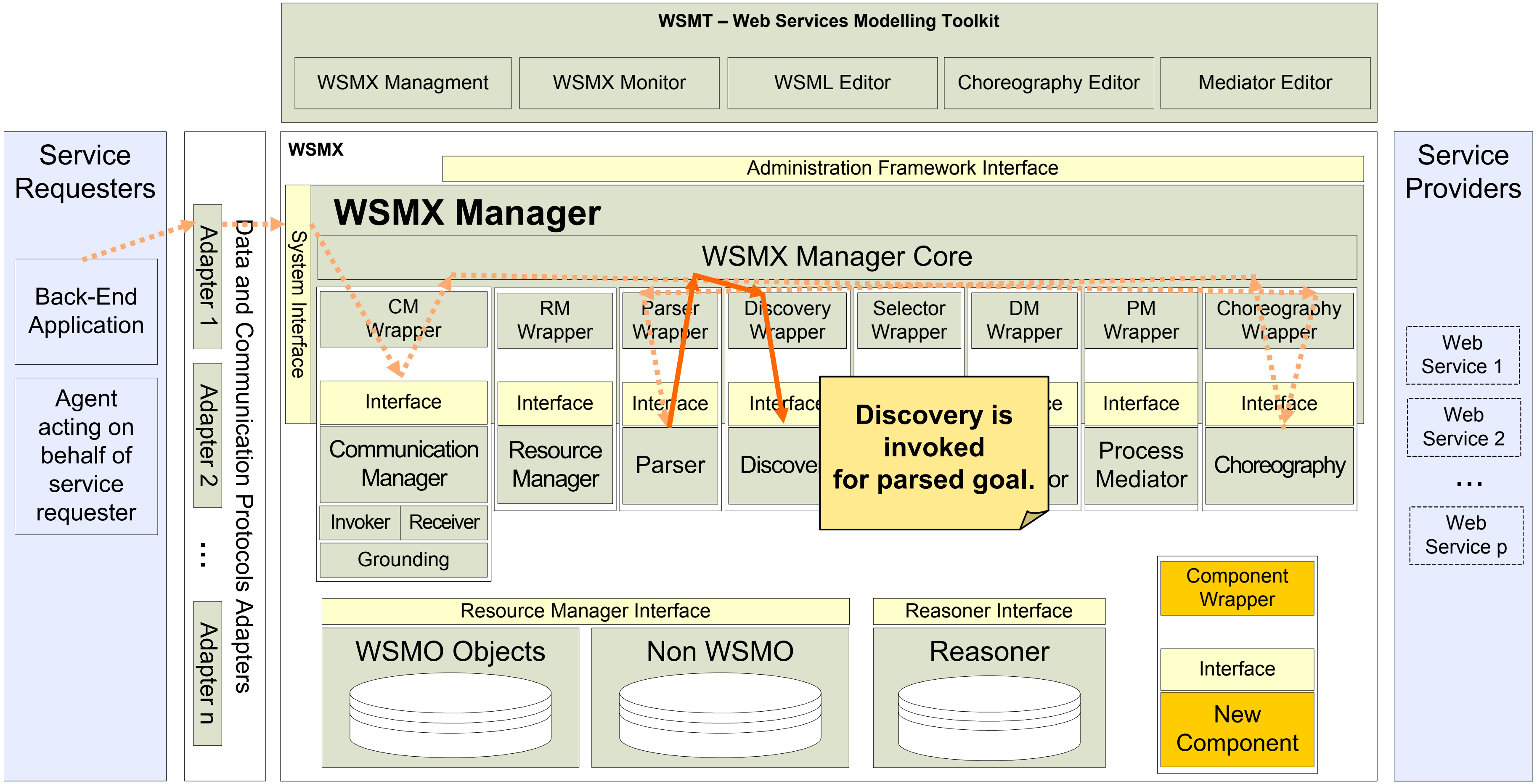


Execution Semantics



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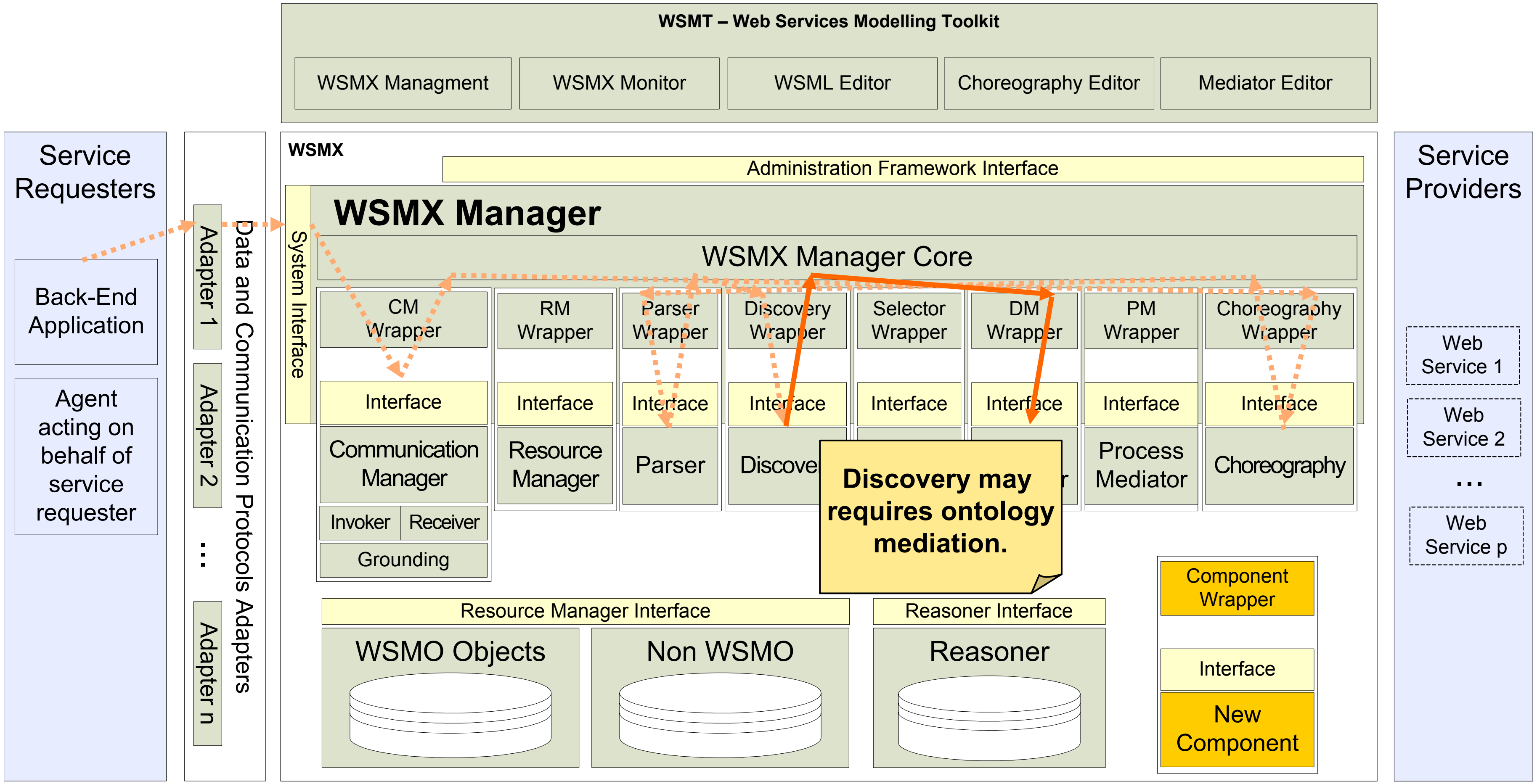

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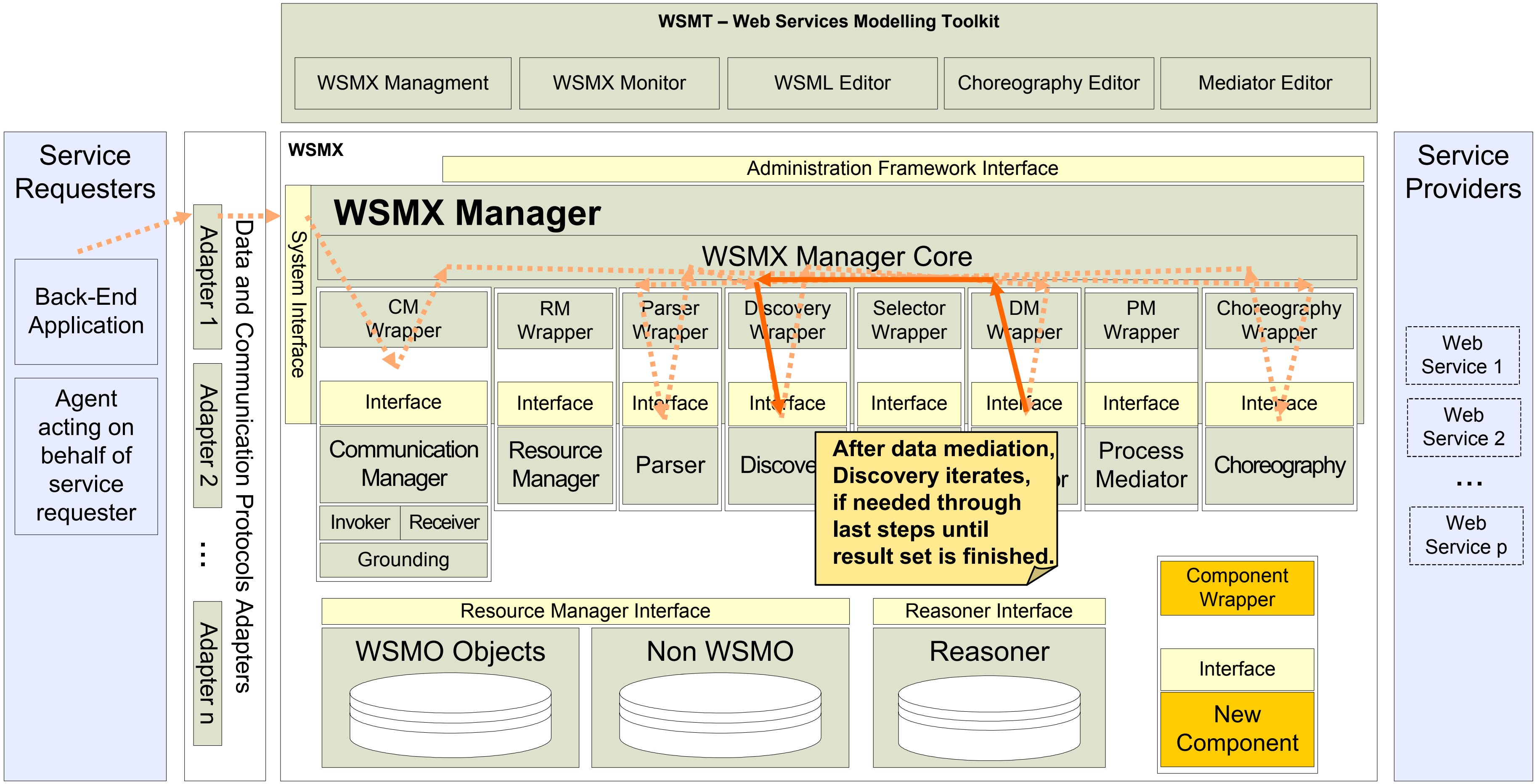
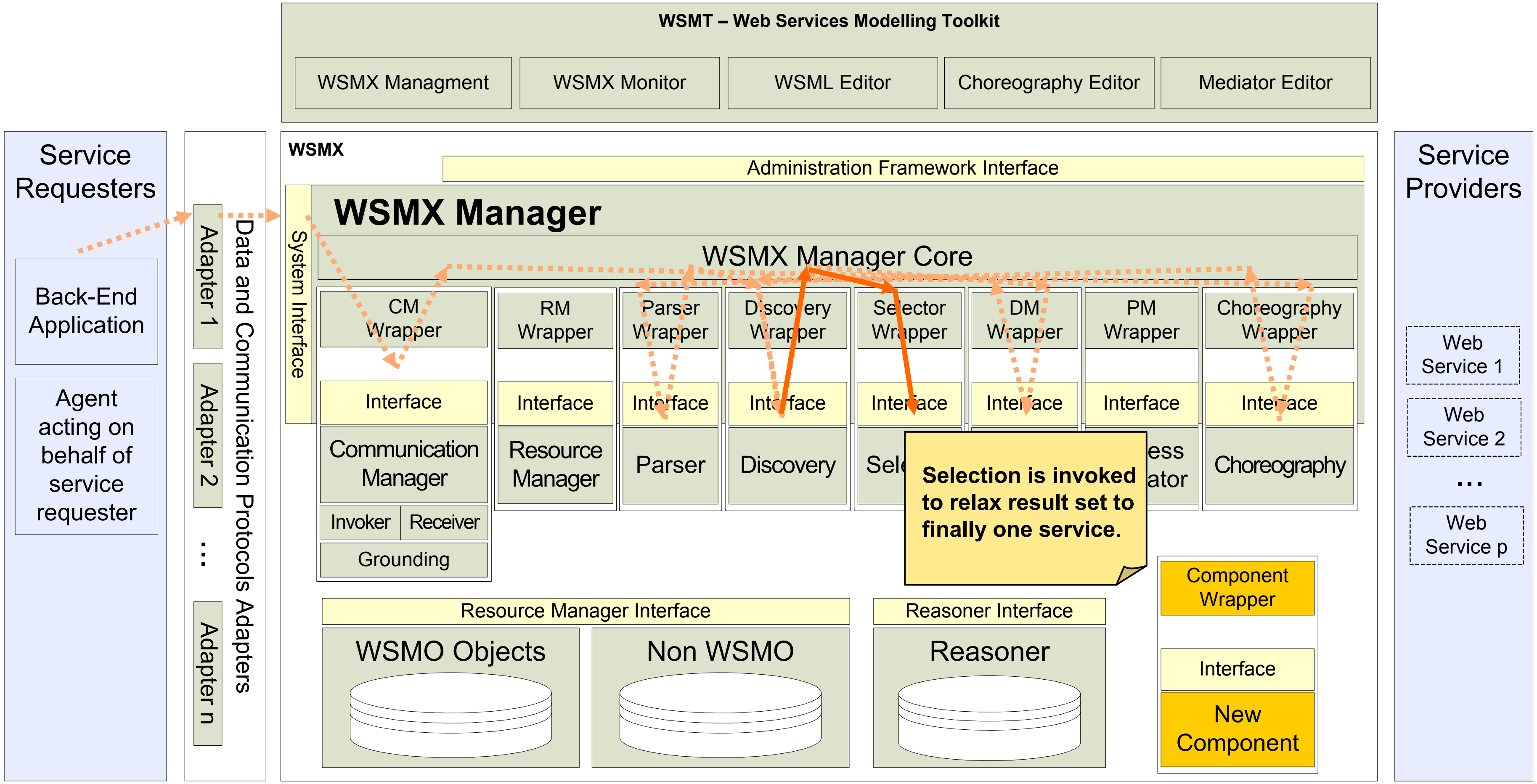
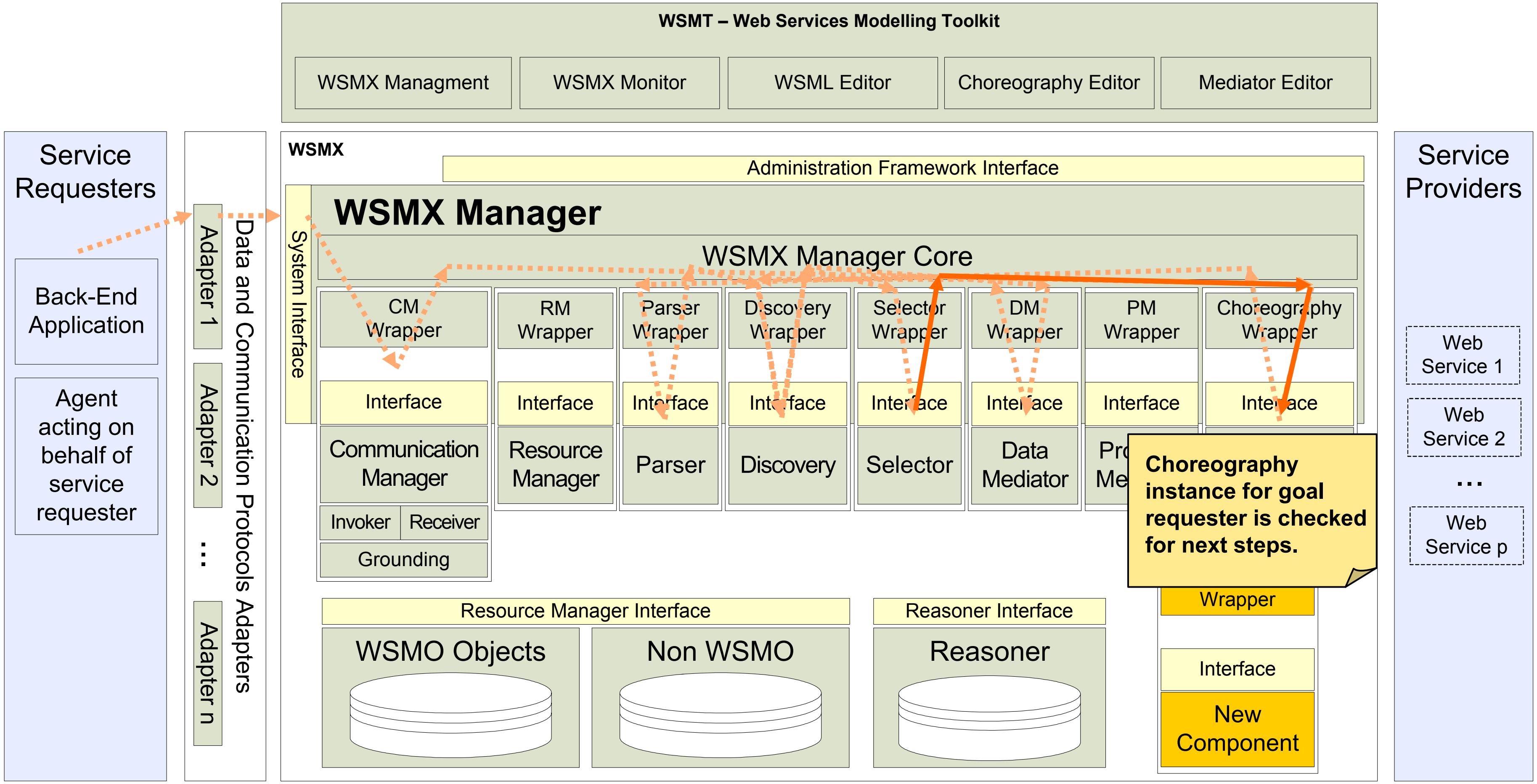


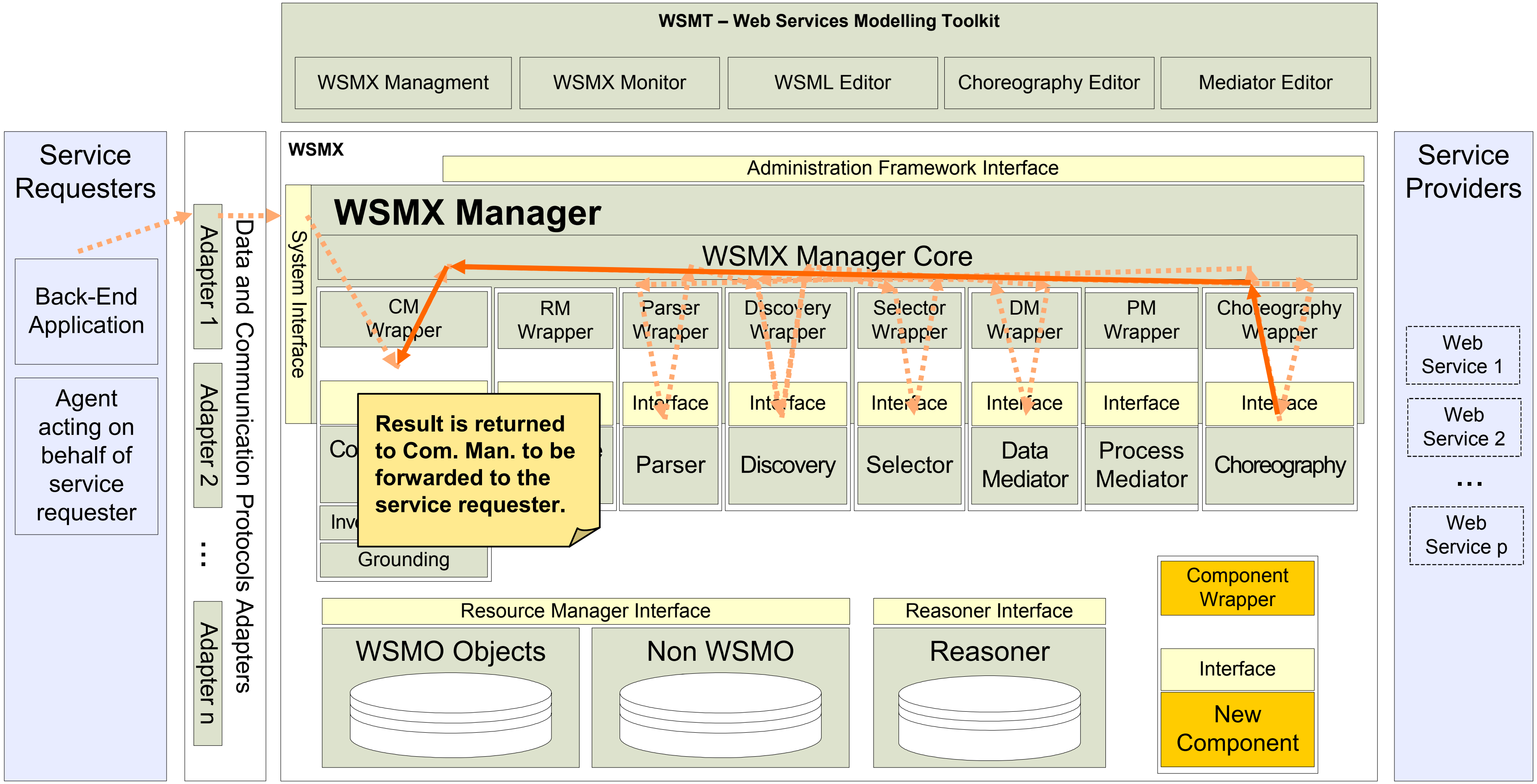
Execution Semantics



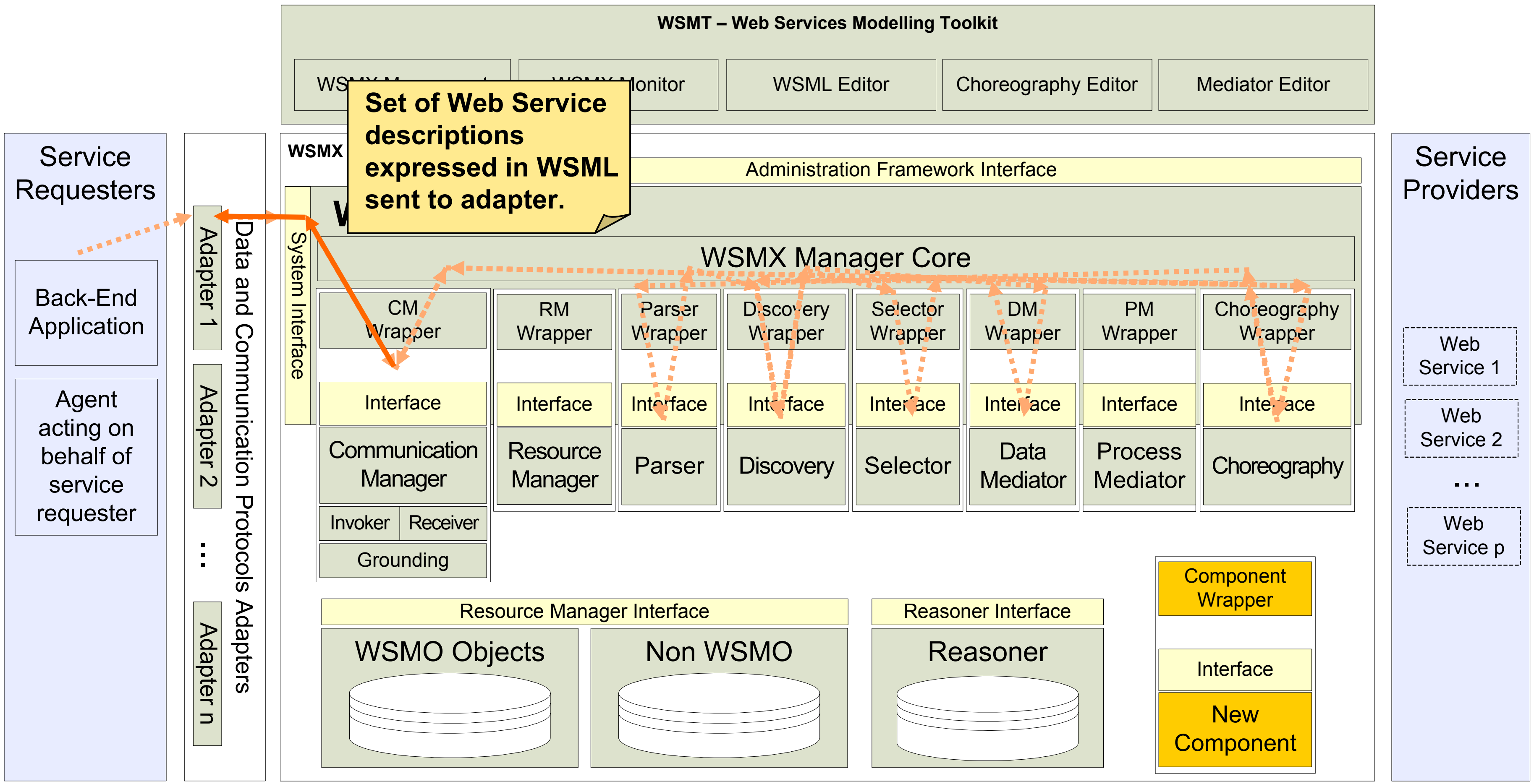
Execution Semantics



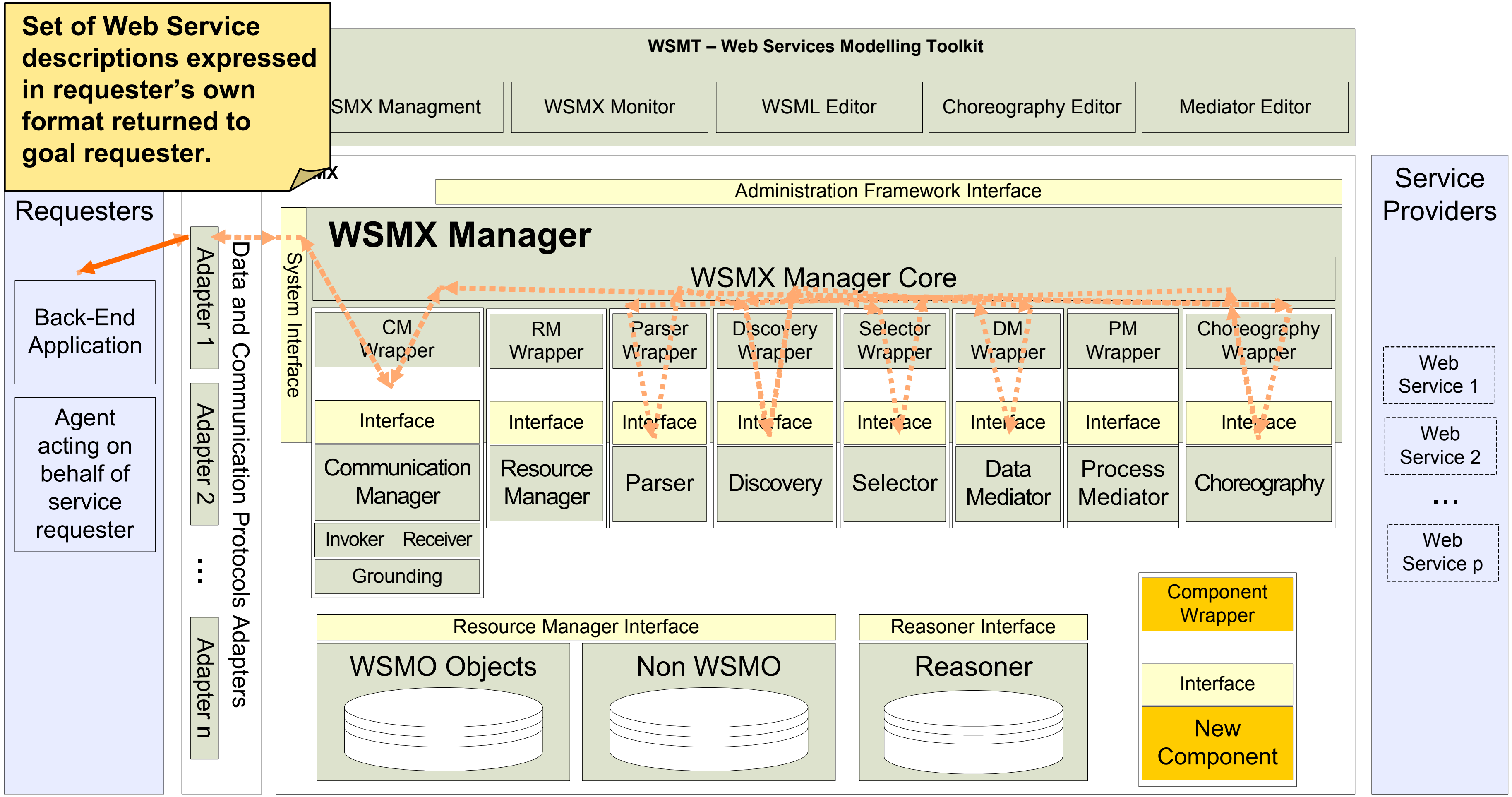
Execution Semantics



Execution Semantics



Execution Semantics



Conclusions

- Conceptual model is WSMO (with some add-ons)
- End to end functionality for executing SWS
- Has a formal execution semantics
- Real implementation
- Open source code base at SourceForge
- Event-driven component architecture
- Developers welcome

WSMX @ Sourceforge.net

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Project: Web Services Execution Environment: Summary

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The Web Services Execution Environment (WSMX) is an execution environment for dynamic matchmaking, selection, mediation, invocation and interoperation of Semantic Web Services.

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- Development Status: 3 - Alpha
- Intended Audience: Developers, Science/Research
- License: MIT License
- Programming Language: Java
- Topic: Distributed Computing

Project UNIX name: wsmx
Registered: 2004-06-29 13:45

Activity Percentile (last week): 37.66%
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Developer Info

Project Admins:
mzaremba

Developers: 20
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wsmx-components	WSMX Components 0.1.6	January 31, 2005	-	Download
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morcen - 2005-03-16 12:17
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Closing, Outlook, Acknowledgements

Tutorial Wrap-up

- The targets of the presented tutorial were to:
  - understand aims & challenges within Semantic Web Services
  - understand Semantic Web Service Frameworks:
    - aims, design principles, and paradigms
    - ontology elements & description
- an overview of Semantic Web Service techniques:
  - element description
  - discovery
  - choreography and service interoperability determination
  - orchestration and composition
- present WSMX a future Web Service based IT middleware
  - design and architecture
  - components design

=> you should now be able to correctly assess emerging technologies & products for Semantic Web Services and utilize these for your future work

Beyond WSMO

- Although WSMO (and OWL-S) are the main initiatives on Semantic Web services, they are not the only ones:
- Semantic Web Services Interest Group
  - Interest group founded at W3C to discuss issues related to Semantic Web Services (http://www.w3.org/2002/ws/swsig/)
  - Standardization Working Group in starting phase
- SWSI: International initiative to push toward a standardization of SWS (http://www.swsi.org)
- Semantic Web services are entering the main stream
  - UDDI is adopting OWL for semantic search
  - WSDL 2 will contain a mapping to RDF
  - The use of semantics is also discussed in the context of standards for WS Policies

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