



Web Services Modelling Ontology

John Domingue

Semantic Web Service Broker



Client



Airline	Departure Time	Arrival Time	Total Travel Time	Roundtrip Price (lowest fare and taxes)
British Airways Flight 123	3:45pm London, Great Britain (LHR)	7:25am - Thu, Dec 1 Next day arrival Mauritius, Mauritius (MRU)	11hrs 40min - 1 stop	\$1,236 per person Select
Air France Flight 1071	11:15am London, Great Britain (LHR)	5:55am - Thu, Dec 1 Next day arrival Mauritius, Mauritius (MRU)	14hrs 40min - 1 stop Change planes in Charles de Gaulle, France (CDG)	\$1,297 per person Select
Air France Flight 1071 Air Mauritius Flight 91 operated by AIR FRANCE	11:15am London, Great Britain (LHR)	5:55am - Thu, Dec 1 Next day arrival Mauritius, Mauritius (MRU)	14hrs 40min - 1 stop Change planes in Charles de Gaulle, France (CDG)	\$1,369 per person Select
Air France Flight 902 operated by CITYJET Air Mauritius Flight 91 operated by AIR FRANCE	9:05am London, Great Britain (LCY)	5:55am - Thu, Dec 1 Next day arrival Mauritius, Mauritius (MRU)	16hrs 50min - 1 stop Change planes in Charles de Gaulle, France (CDG)	\$1,380 per person Select

Services

Hotels: Choose a hotel		LOWEST RATES, GUARANTEED!	
Port Louis, Mauritius - and surrounding areas		0871 200 0171	
Sort by: Distance Price Star Rating			
★★★★★ The Oberoi Mauritius POINTE-AUX-ERMITES	Average Nightly Rate €486.74	Nov 17	Nov 18
View hotel information	SELECT	€486.74	€486.74
★ Mauritius Hotel Mauritius MAURITIUS (BALACALVA)	Average Nightly Rate €196.00	Nov 17	Nov 18
View hotel information	SELECT	€196.00	€196.00
★★★ Hotel Tamatin MAURITIUS (FANOU)	Average Nightly Rate €77.00	Nov 17	Nov 18
View hotel information	SELECT	€77.00	€77.00
★★★★ Veranda Hotel MAURITIUS (GRAND RAZ)	Average Nightly Rate €122.00	Nov 17	Nov 18
View hotel information	SELECT	€122.00	€122.00



Web Service Modelling Ontology (WSMO)

WSMO Design Principles



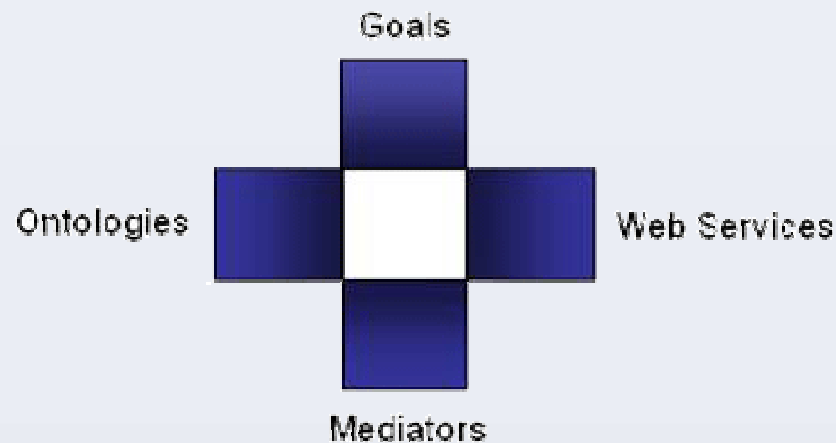
- Web Compliance
- Ontology-Based
- Strict Decoupling
- Centrality of Mediation
- Ontological Role Separation
- Description versus Implementation
Execution Semantics
- Service versus Web service

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

Non-Functional Properties



- Every WSMO element can be described by properties that contain relevant, non-functional aspects.
- Sample information sets are:
 - Dublin Core Metadata Set:
 - For resource management
 - Versioning Information
 - For evolution support
 - Quality of Service Information
 - For availability, stability
 - Other
 - WSMO non functional properties are extensible

Non-Functional Properties List



Dublin Core Metadata

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

Quality of Service

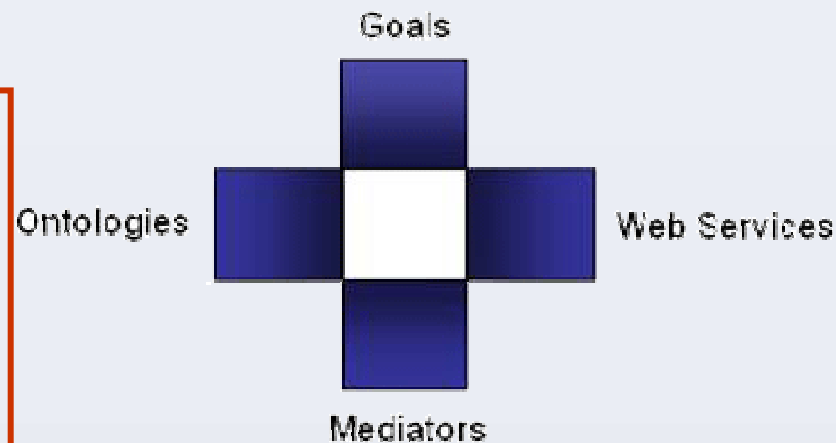
Accuracy
NetworkRelatedQoS
Performance
Reliability
Robustness
Scalability
Security
Transactional
Trust

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Ontology Description and Usage



- Ontologies are used as the ‘data model’ throughout WSMO
 - WSMO is defined in terms of itself
 - All data-types used in Web Service interfaces are ontology concepts
 - Discovery, mediation and composition are based on 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
- 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:**

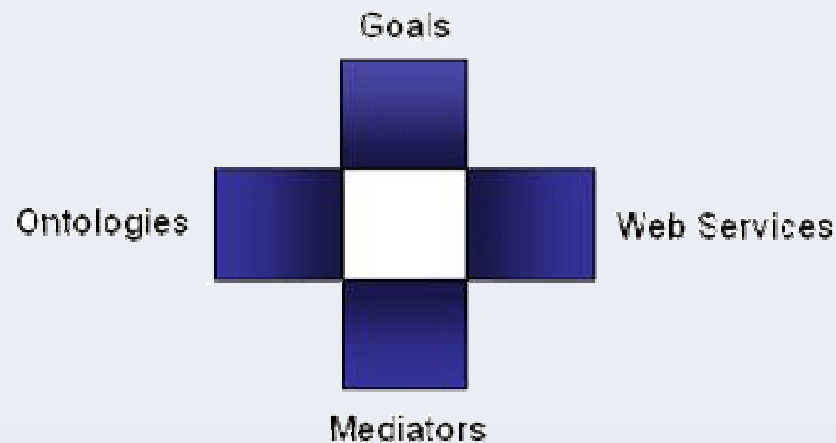
Concepts	set of concepts that belong to the ontology, incl.
Attributes	set of attributes that belong to a concept
Relations	define interrelations between several concepts
Functions	special type of relation (unary range = return value)
Instances	set of instances that belong to the represented ontology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

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Goals



- Ontological De-coupling of Requester and Provider
- Derived from task / problem solving methods/domain model
- Structure and reuse of requests
 - Search
 - Diagnose
 - Classify
 - Personalise
 - Book a holiday
- Requests may in principle not be satisfiable
- Ontological relationships & mediators used to link goals to Web services

Goal Specification (1/2)



- **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**

Goal Specification (2/2)



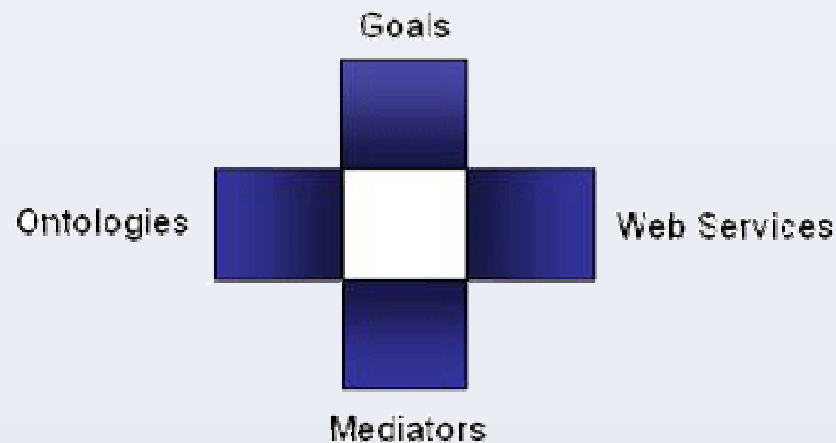
- **Requested Capability**
 - describes service functionality expected to resolve the objective
 - defined as capability description from the requester perspective
- **Requested Interface**
 - describes communication behaviour supported by the requester for consuming a Web Service (Choreography)
 - Restrictions / preferences on orchestrations of acceptable Web Services

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WSMO Web Service Description



- complete item description
- quality aspects
- Web Service Management

Non-functional Properties

DC + QoS + Version + financial

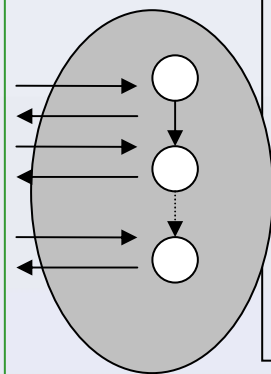
- Advertising of Web Service
- Support for WS Discovery

Capability

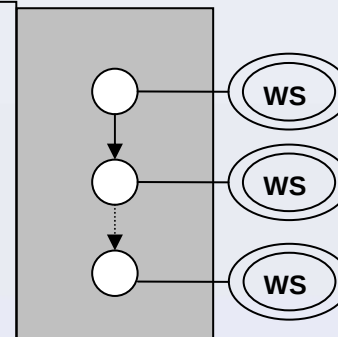
functional description

client-service
interaction interface
for consuming WS

- External Visible Behavior
- Communication Structure
- 'Grounding'



Web Service Implementation
(not of interest in Web Service Description)



realization of
functionality by
aggregating
other Web Services

- functional decomposition
- WS composition

Choreography --- Service Interfaces --- **Orchestration**

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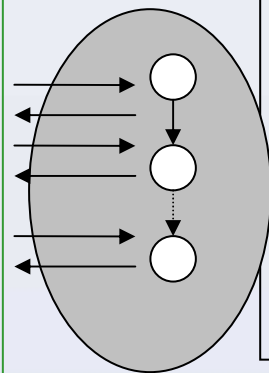
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Capability

functional description

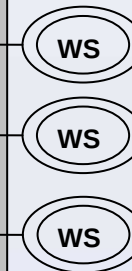
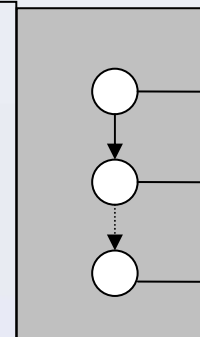
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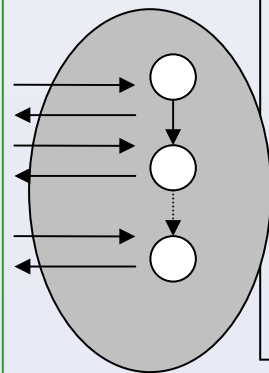
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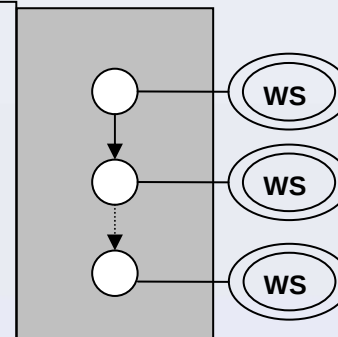
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Capability Specification (1/2)



- **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

Capability Specification (2/2)



- **Pre-conditions**
 - What a web service expects in order to be able to provide its service
 - 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 WS 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)

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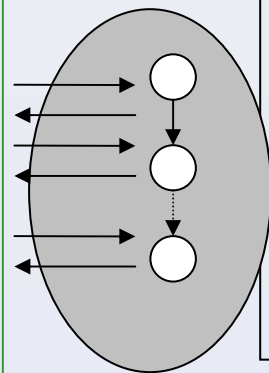
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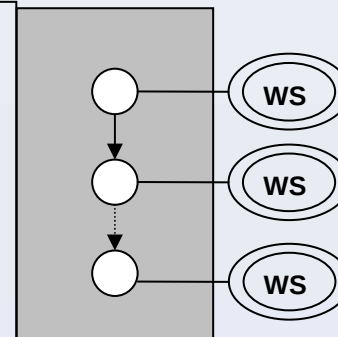
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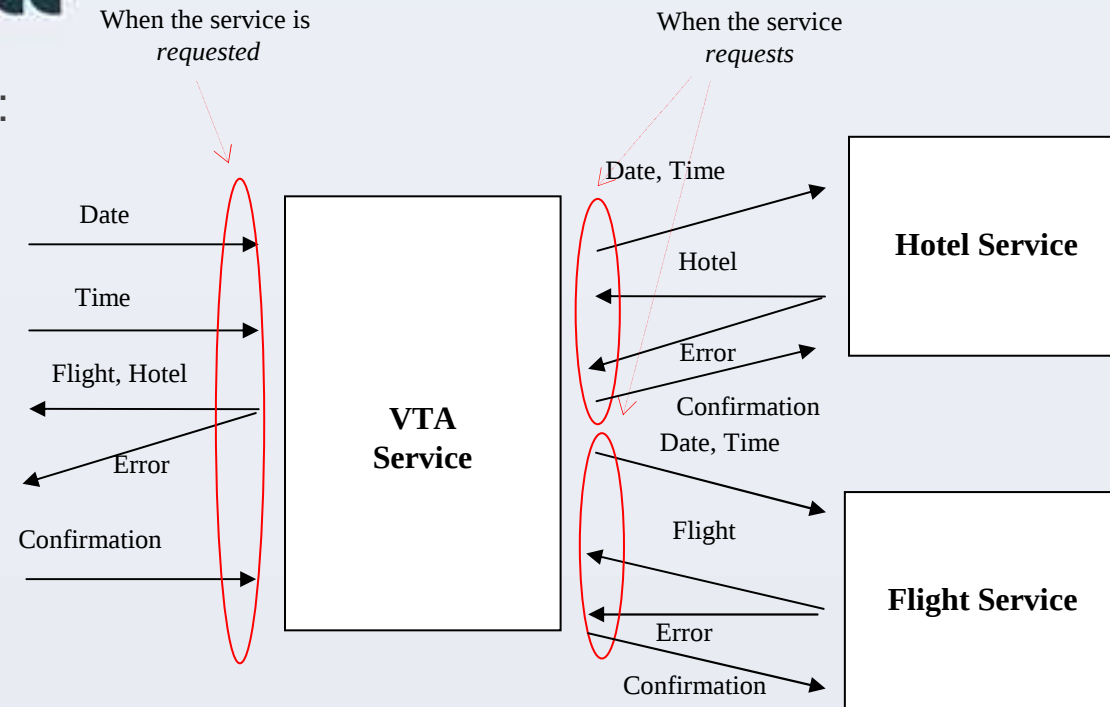
- functional decomposition
- WS composition

Choreography --- Service Interfaces --- **Orchestration**

Choreography & Orchestration



VTA example:



Choreography Aspects (1/2)



- *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)
 - choreography related errors (e.g. input wrong, message timeout, etc.)

Choreography Aspects (2/2)



- *Interface for consuming Web Service*
 - Grounding
 - concrete communication technology for interaction
 - Formal Model
 - reasoning on Web Service interfaces (service interoperability)
 - allow mediation support on Web Service interfaces

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- quality aspects
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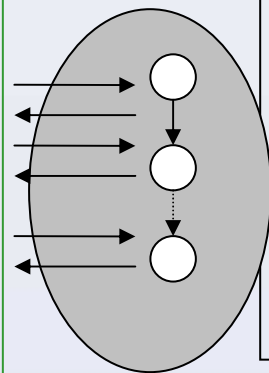
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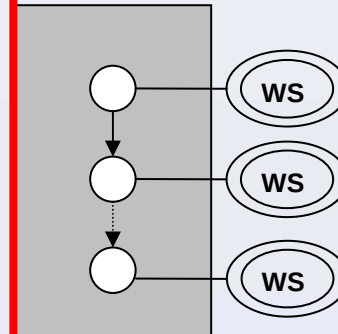
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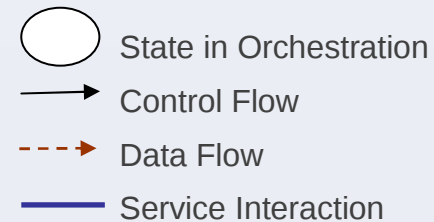
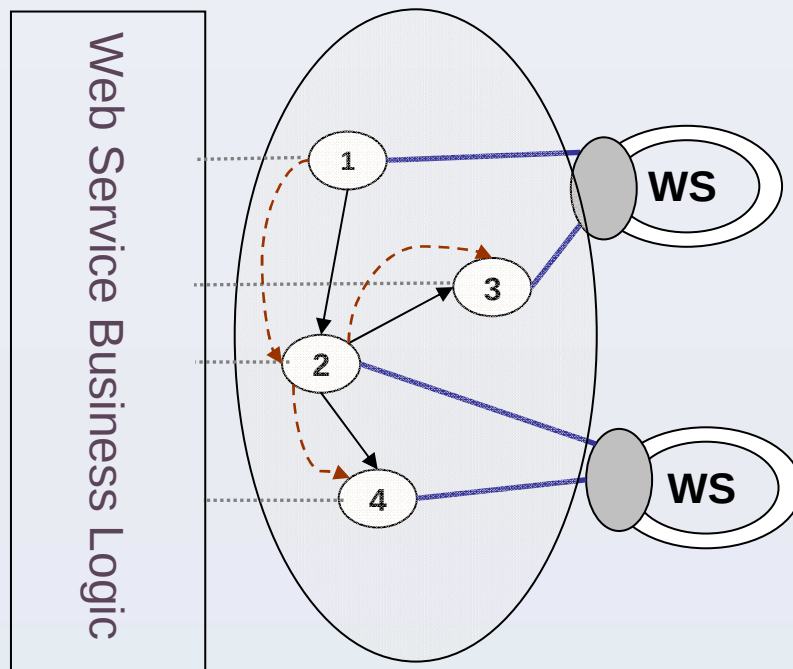
- functional decomposition
- WS composition

Choreography --- Service Interfaces --- **Orchestration**

Orchestration Aspects



Control Structure for aggregation of other Web Services



- decomposition of service functionality
- all service interaction via choreographies

Orchestration Aspects



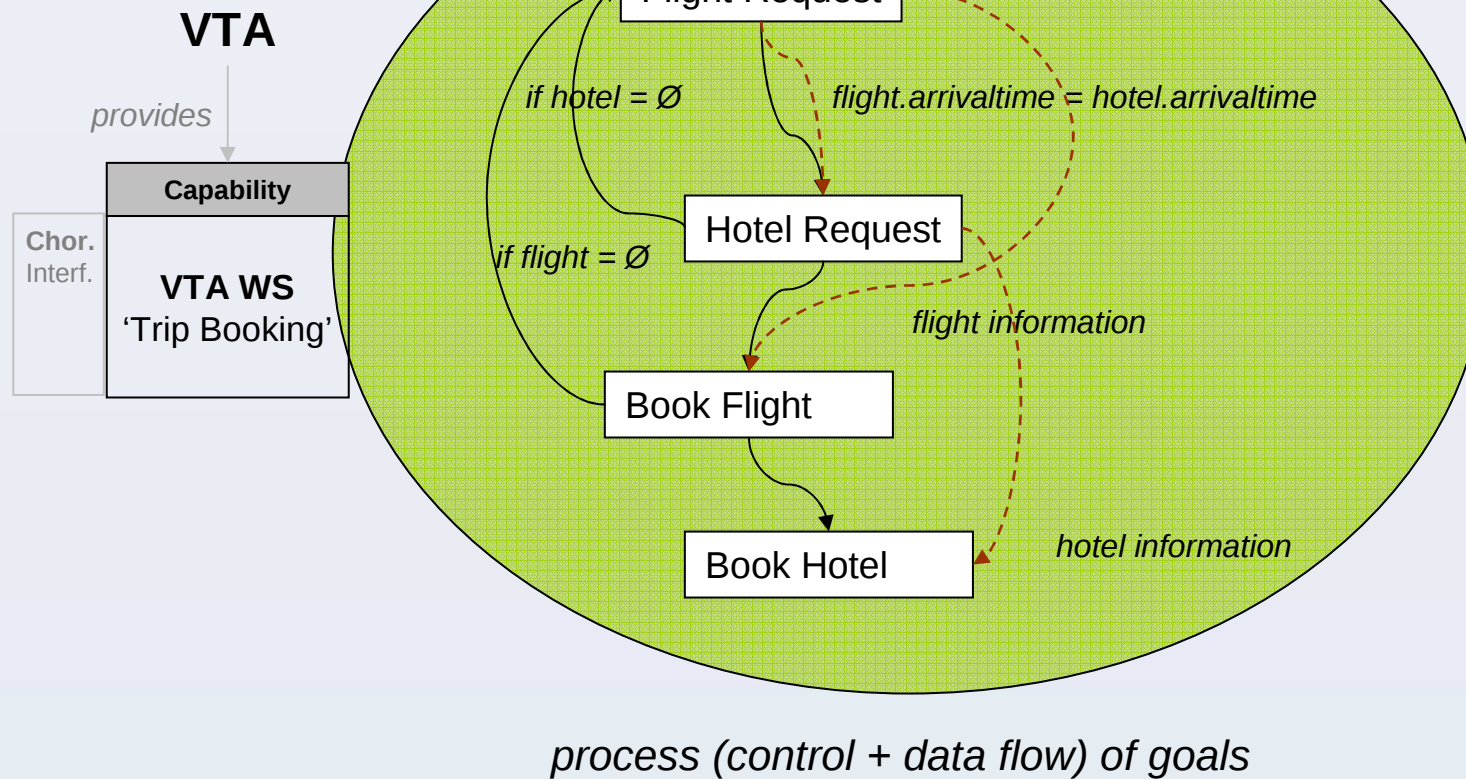
- Service interfaces are concerned with service consumption and interaction
- Choreography and Orchestration as sub-concepts of Service Interface

Common requirements for service interface description

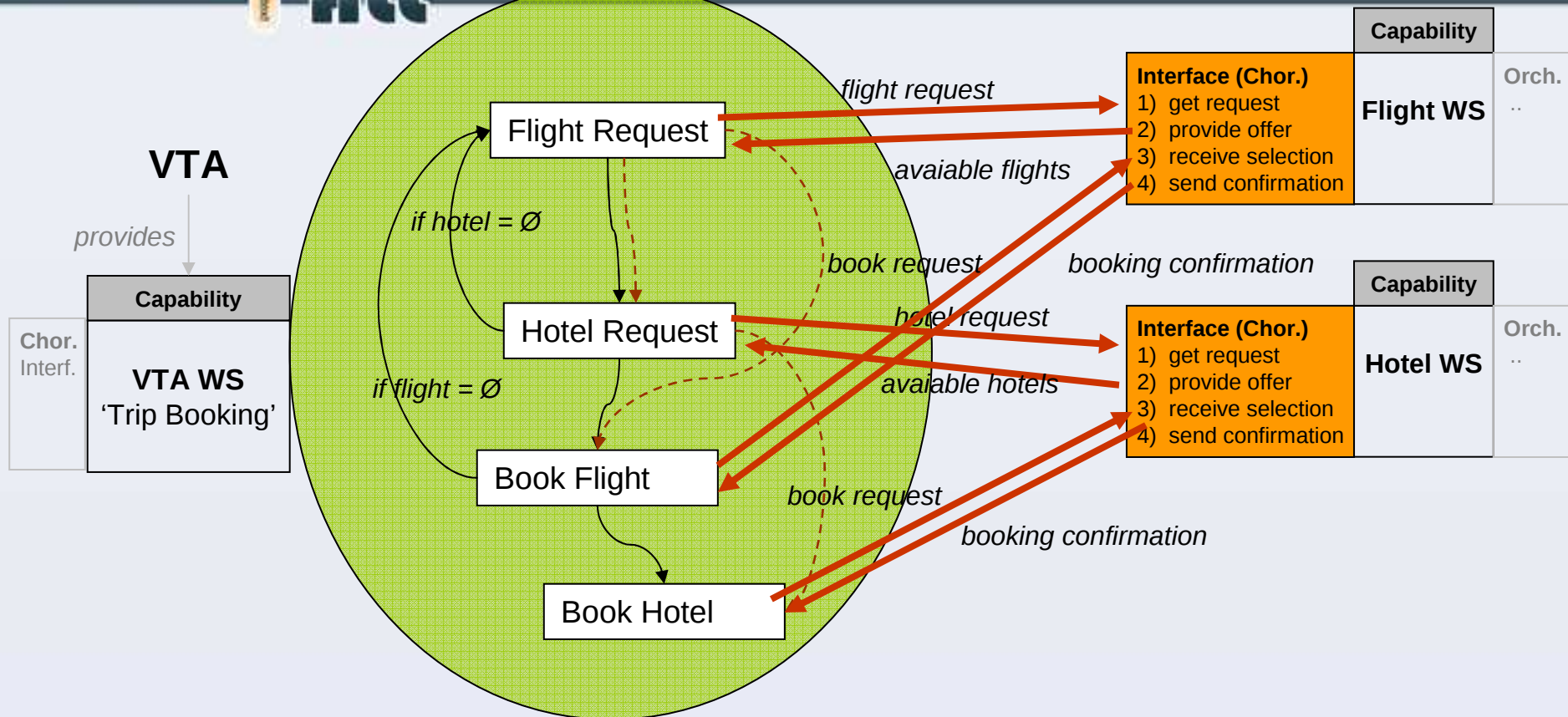


- Represent the dynamics of information interchange during service consumption and interaction
- Support ontologies as the underlying data model
- Appropriate communication technology for information interchange
- Sound formal model / semantics of service interface specifications in order to allow operations on them.

Orchestration Definition



Runtime Orchestration



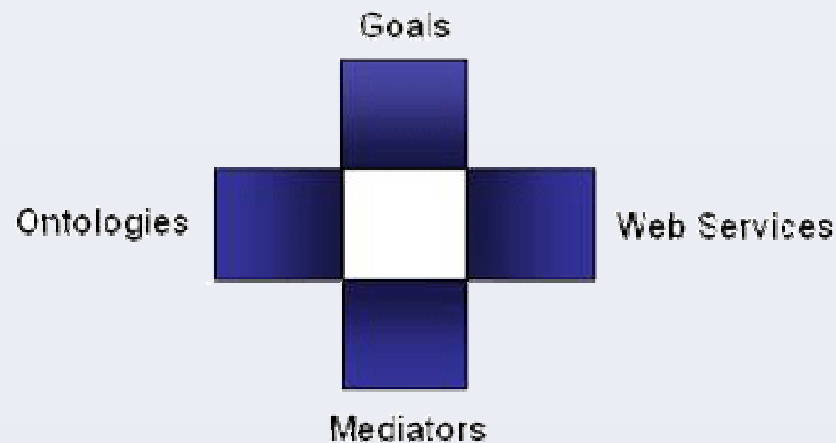
process (control + data flow) between "states"
+ communication behavior of orchestrating Web Service

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Connectors between components with mediation facilities for handling heterogeneities

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)

Mediation



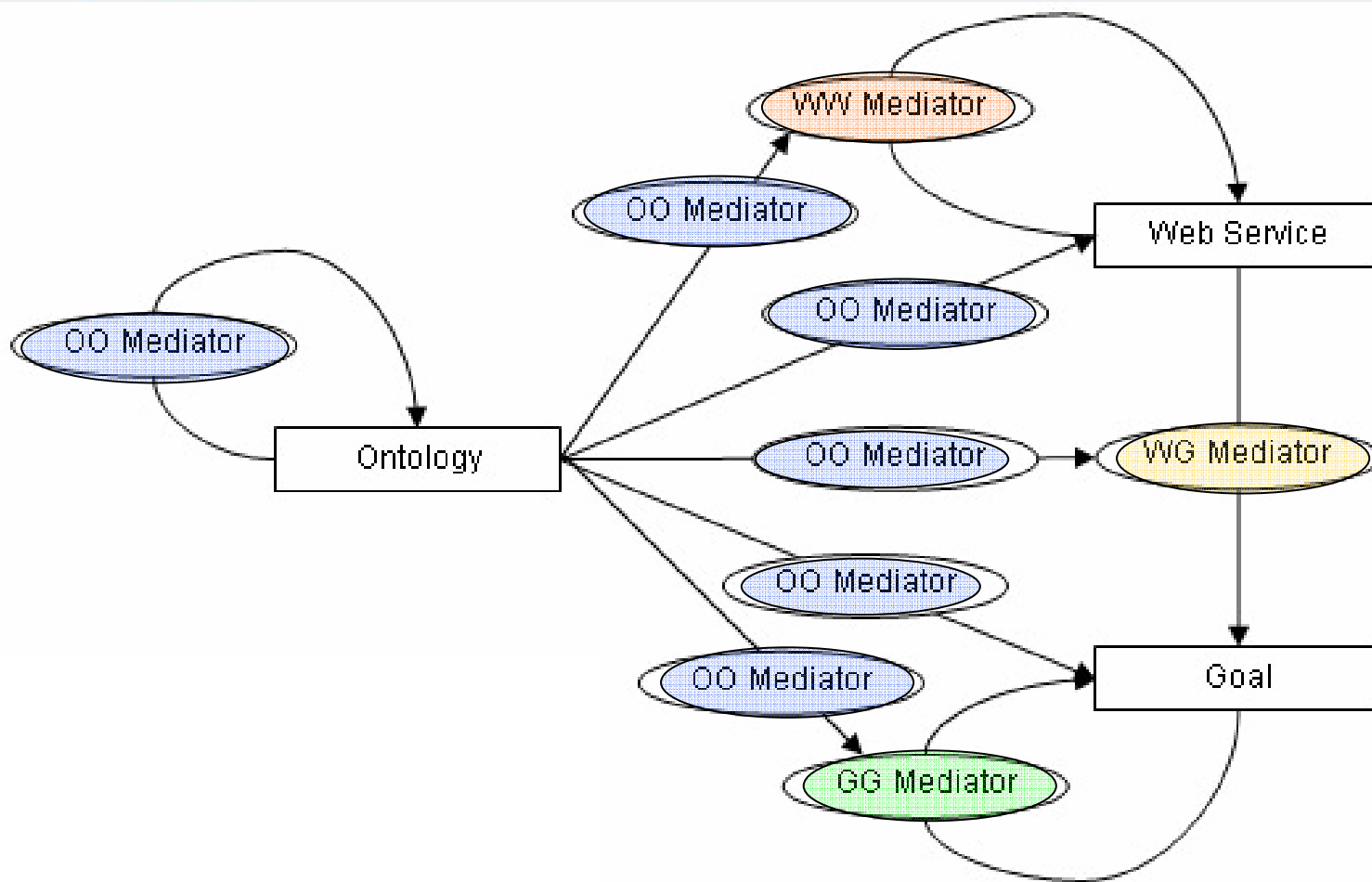
- For 1\$ on programming, \$5 - \$9 on integration © IBM, Nelson Mattos
- Mismatches on structural / semantic / conceptual / level
- Assume (nearly) always necessary
- Description of role

Levels of Mediation within Semantic Web Services

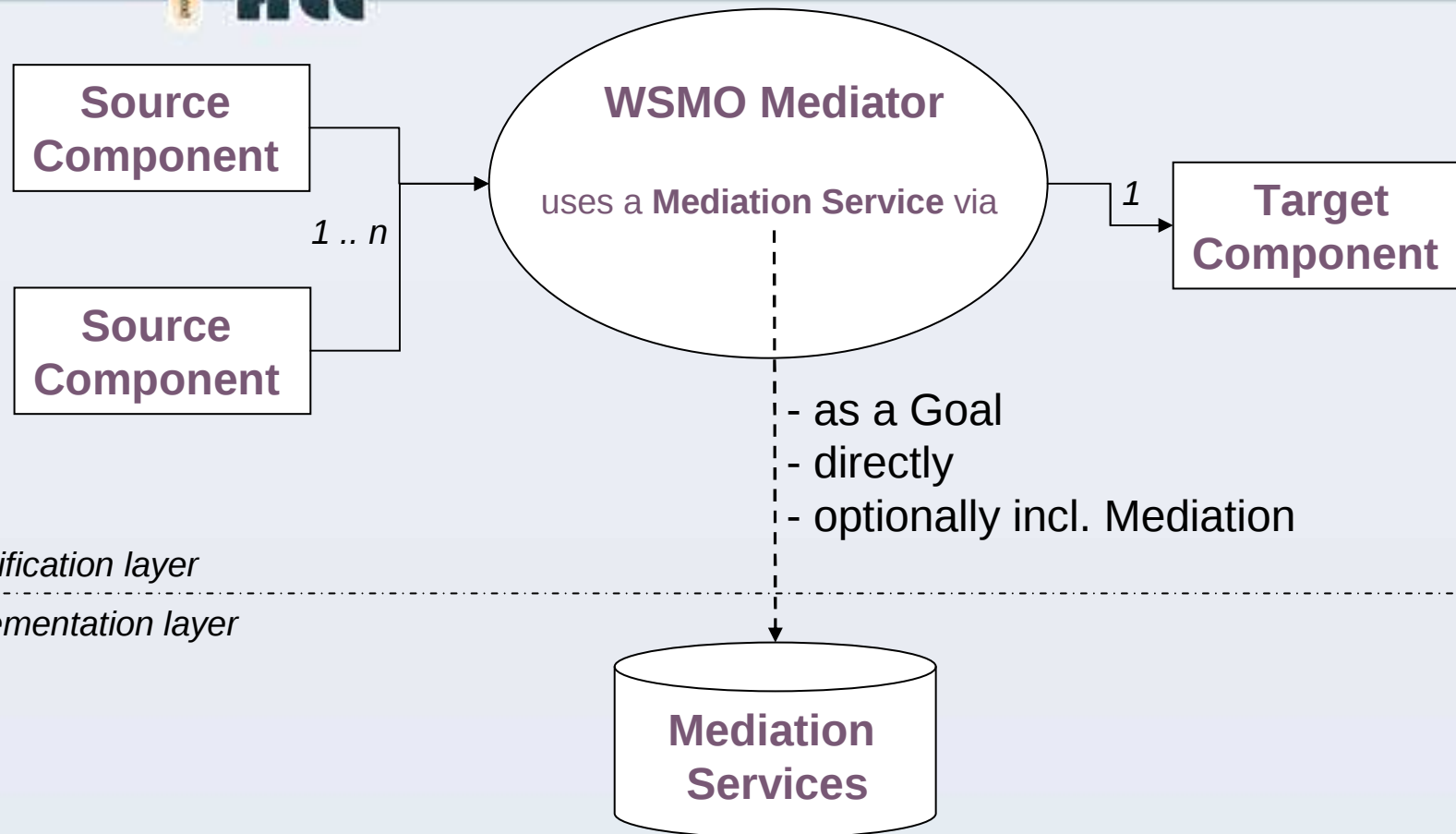


- **Data Level**
 - mediate heterogeneous Data Sources
- **Functional Level**
 - mediate mismatches between Web Service/Goal and Web Service/Goals functionalities
- **Process/Protocol Level**
 - mediate heterogeneous Business Processes/Communication Patterns
- **Layers of Mediators**
 - **Specification Layer** – WSMO Mediators
 - **Implementation Layer** – Levels of Mediation

WSMO Mediators Overview



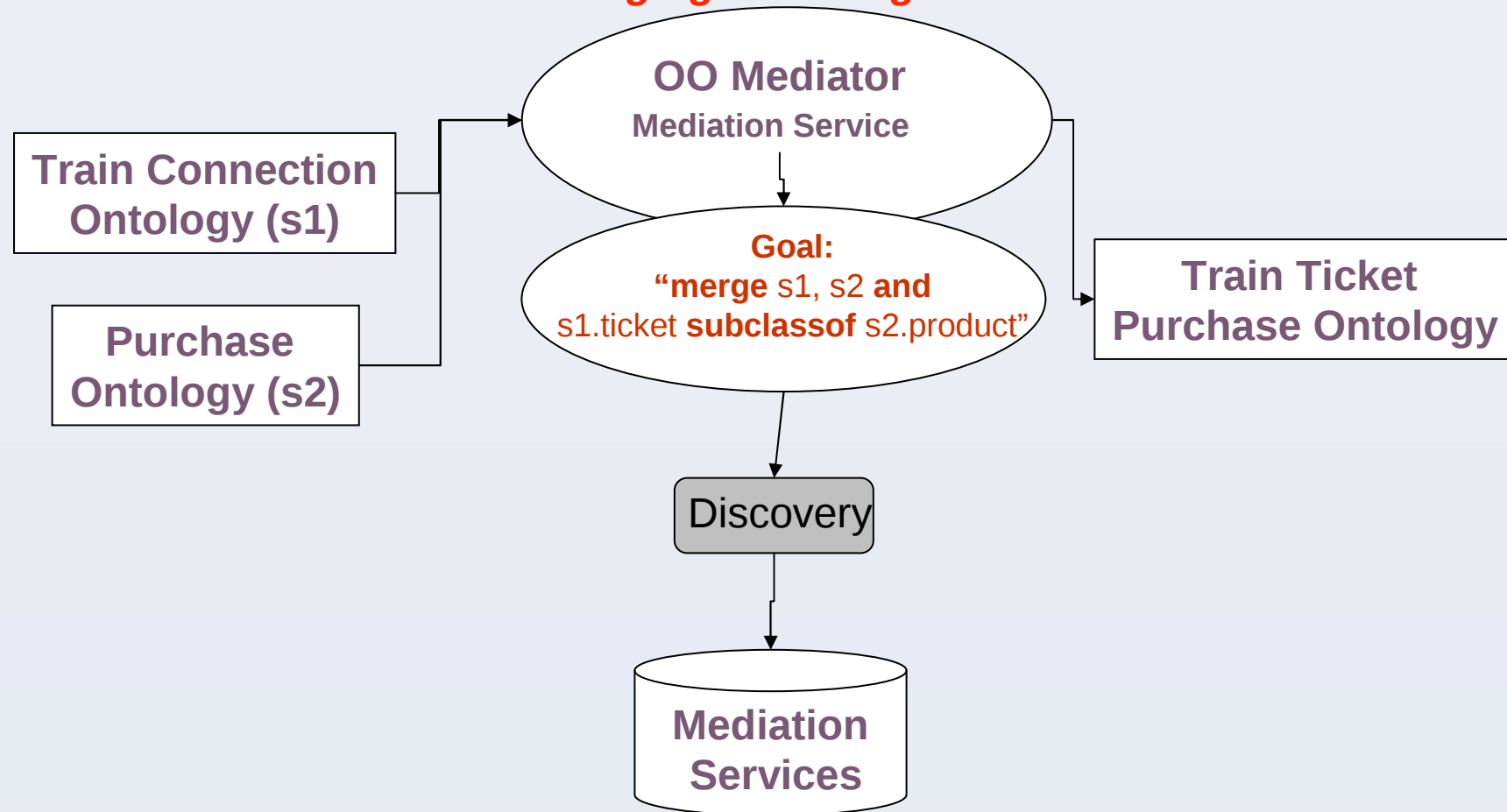
Mediator Structure



OO Mediator - Example



Merging 2 ontologies

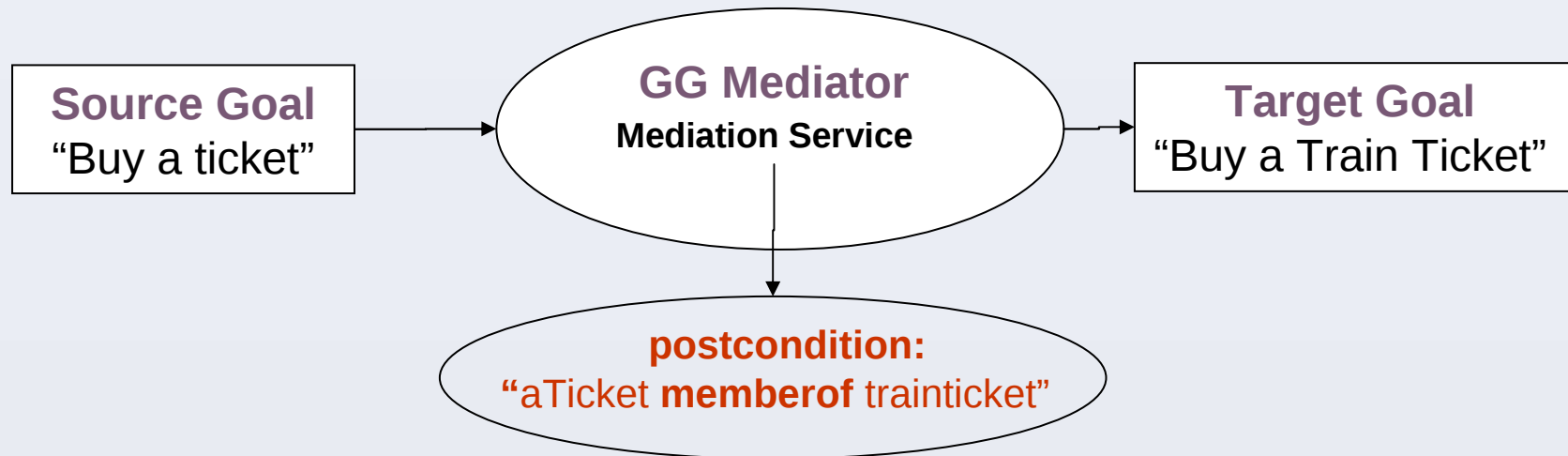


GG Mediators



- 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

GG Mediator Example



WG Mediators



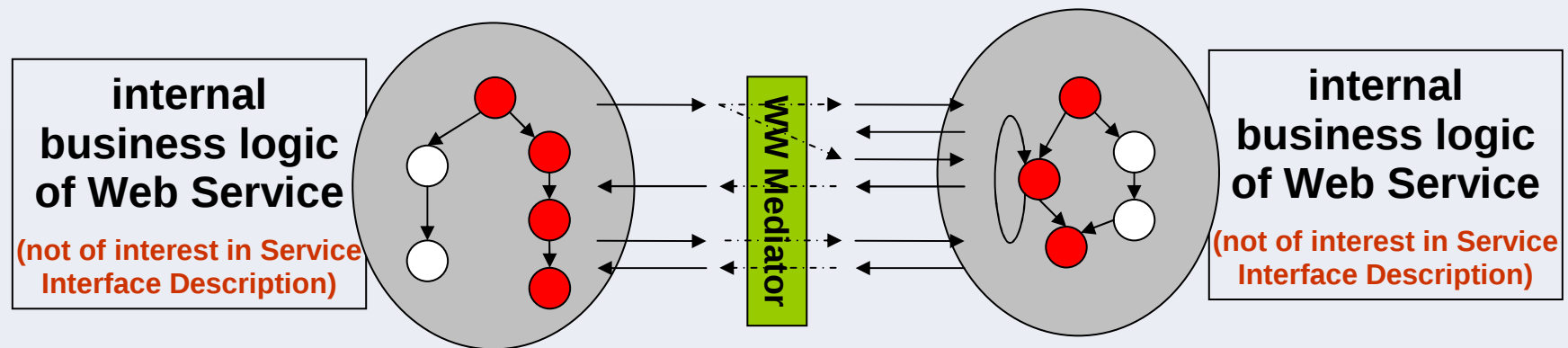
- Link a Web Service to a Goal and resolve occurring mismatches
- Match Web Service and Goals that do not match a priori
- Handle terminology mismatches between Web Services and Goals
 - broader range of Goals solvable by a Web Service

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

WW Mediator Example



Data Level Mediation (1/2)



- Scope
 - Solving terminological mismatches
- Related Aspects / Techniques:
 - Ontology Integration (Mapping, Merging, Alignment)
 - Data Lifting & Lowering
 - Transformation between Languages / Formalisms

Data Level Mediation (2/2)



- Terminology Mismatches Classification
 - Conceptualization Mismatches
 - same domain concepts, but different conceptualization
 - different levels of abstraction
 - different ontological structure
 - => resolution only includes human intervention
 - Explication Mismatches
 - mismatches between:
 - T (Term used), D (definition of concepts), C (real world concept)
 - => automated resolution partially possible

Functional Level Mediation (1/2)

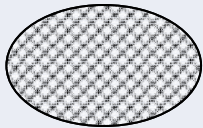


- Scope
 - Solving functional mismatches between goals and/or ws
- Related Aspects/Techniques
 - Discovery
 - Semantic Matchmaking
- Matchmaking Mismatches

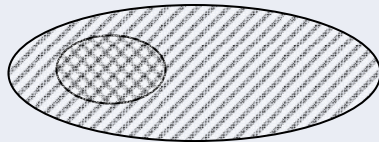
Functional Level Mediation (2/2)



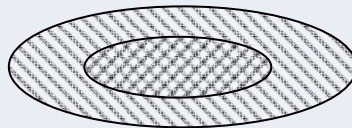
⊙ = G/WS ⊙ = G/WS



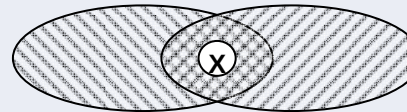
Exact Match



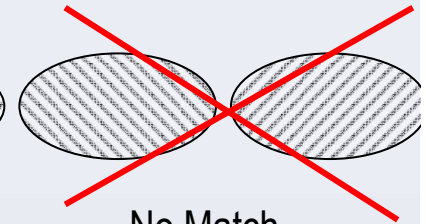
PlugIn Match



Subsumption Match



Intersection Match



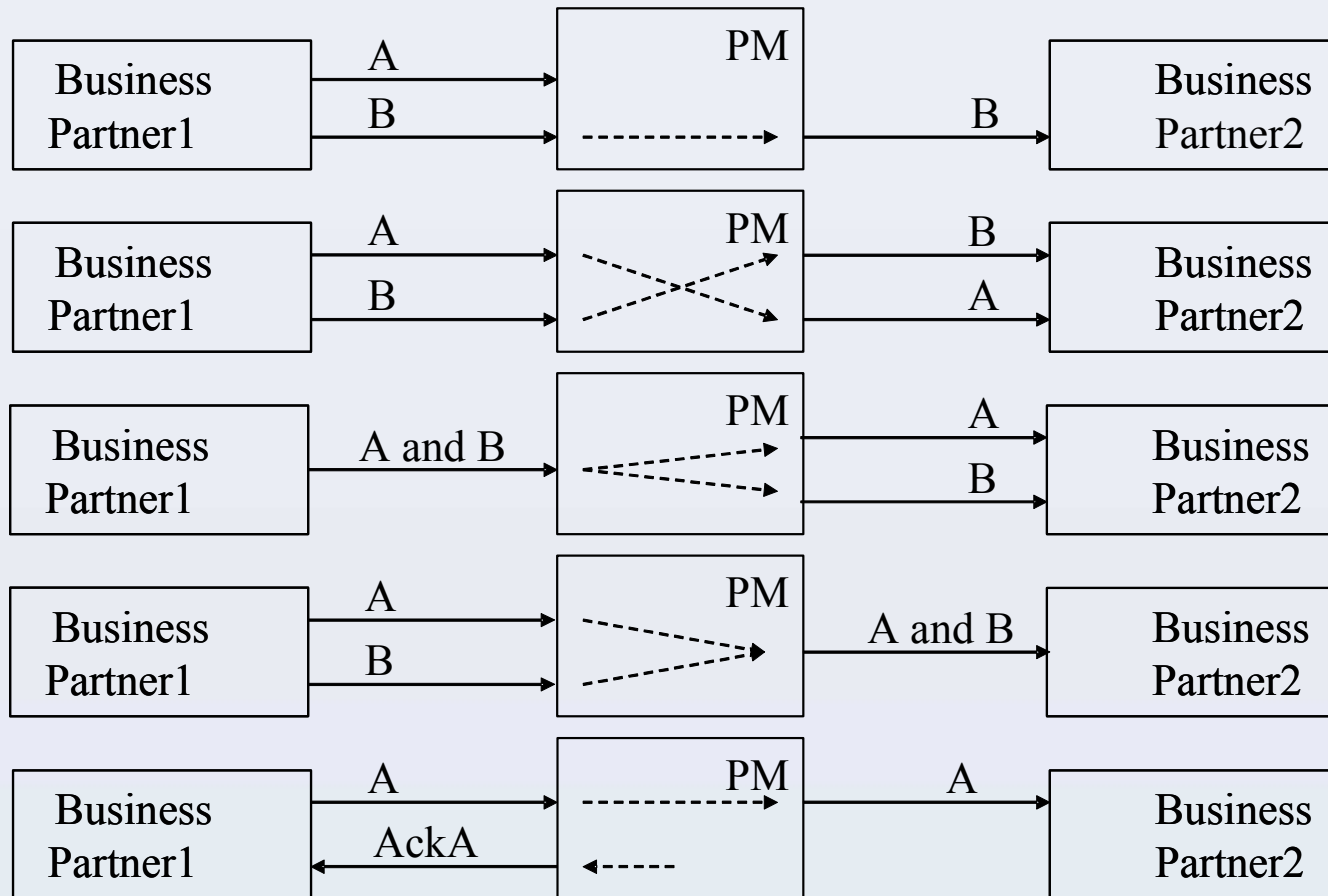
No Match

Process Level Mediation (1/2)



- Scope
 - Resolves communication mismatches and establish behavior compatibility
- Related Aspects/Techniques
 - Data and control flow composition
- Process Mismatches
 - Signature terminology mismatches (need for data level mediation)
 - Communication/behavior mismatches

Process Level Mediation (2/2)

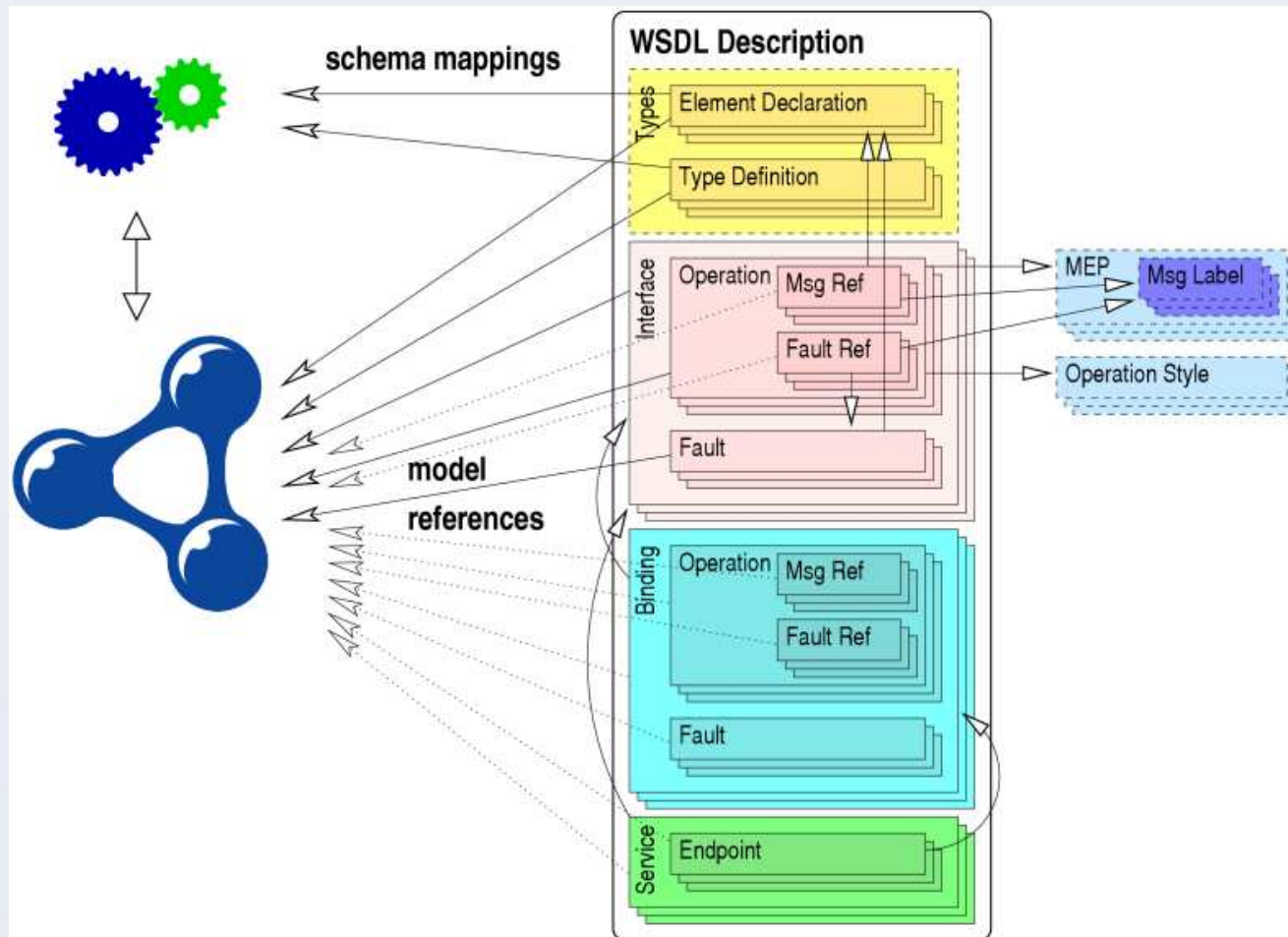


WSMO Work in SOA4All



- WSMO-Lite
 - a lightweight ontology which uses RDFS as the description language and defines mechanisms to annotate WSDL descriptions using SAWSDL.
- MicroWSMO
 - an annotation mechanism for RESTful services.

SAWSDL in a picture



Summary



- Semantic Web Services
 - Potential to cope with Web scale
 - Applies SW to automate application development through reuse of Web services
- WSMO
 - Ontology describing Web services
 - Goals, Mediators, Web Services
 - Choreography and Orchestration

Relevant URLs



- WSMO
 - <http://www.wsmo.org/>
- Conceptual Models of Services
 - <http://cms-wg.sti2.org/>



Thanks