1. Introduction

Choreography and Orchestration are part of the interface definition of a WSMO service description [Roman et al., 2004]. They describe the behavior of the service from two
perspectives: communication (how to communicate with the service such that the service will provide its capability), and respectively collaboration (how the service collaborates with other WSMO services to achieve its capability).

Choreography describes the behavior of the service from a user point of view; this definition is in accordance to the following definition given by W3C Glossary [W3C Glossary, 2004]: Web Services Choreography concerns the interactions of services with their users. Any user of a Web service, automated or otherwise, is a client of that service. These users may, in turn, be other Web Services, applications or human beings.

The orchestration of a WSMO service defines how the overall functionality of the service is achieved by the cooperation of other WSMO service providers. It describes how the service works from the provider’s perspective (i.e. how a service makes use of other WSMO services or goals in order to achieve its capability). This complies with the W3C definition of Web Service Orchestration [W3C Working Group]: An orchestration defines the sequence and conditions in which one Web Service invokes other Web Services in order to realize some useful function. That is, an orchestration is the pattern of interactions that a Web Service agent must follow in order to achieve its goal.

The aim of this document is to provide a core conceptual model for describing choreographies and orchestrations in WSMO. The state-based mechanism for describing WSMO choreographies and orchestrations is based on the Abstract State Machines [Gurevich, 1995] methodology. ASMs have been chosen as underlying model of choreography and orchestration for the following three reasons:

- **Minimality:** ASMs provide a minimal set of modeling primitives, i.e., enforce minimal ontological commitments. Therefore, they do not introduce any ad hoc elements that would be questionable to be included into a standard proposal.
- **Maximality:** ASMs are expressive enough to model any aspect around computation.
- **Formality:** ASMs provide a rigid mathematical framework to express dynamics.

For a detailed explanation on ASMs we refer the reader to [Börger, 1998].

The rest of the document is organized as follows: Section 2 provides a core conceptual model for WSMO choreographies, Section 3 presents the conceptual model for WSMO orchestrations by pointing out the differences to the core conceptual model for WSMO choreographies, Section 4 gives an example for choreography and orchestration, and Section 5 provides conclusions and points to future work with respect to WSMO choreography and orchestration.

### 2. WSMO Choreography

As the WSMO Choreography is based on ASMs, it inherits the core principles of ASMs, which summarized, are: (1) it is **state-based**, (2) it represents a **state by an algebra**, and (3) it models state changes by **guarded transition rules** that change the values of functions and relations defined by the signature of the algebra.

Taking the ASMs methodology as a starting point, a WSMO choreography is state-based and consists of two elements which are defined as follows:
Listing 1. WSMO choreography definition

```
Class wsmoChoreography
  hasState type ontology
  hasGuardedTransitions type guardedTransitions
```

State

A state is described by an ontology as defined in [Roman et. al., 2004] Section 4.

Guarded transitions

Transition rules that express changes of states by changing the set of instances.

The rest of this section is organized as follows: Section 2.1 describes what the state is in more details, and Section 2.2 describes the guarded transitions.

2.1 State

In extension to a "normal" WSMO ontology, an Ontology that is used to describe states in a WSMO choreography introduces a new non-functional property. When a concept, relation or function in a choreography is defined, the attribute mode can be defined as a new non functional property. It can take one of the following values:

- **static** - meaning that the extension of the concept, relation, or function cannot be changed. If not explicitly defined, the attribute mode takes this value by default.
- **controlled** - meaning that the extension of the concept, relation, or function can only be changed by the service.
- **in** - meaning that the extension of the concept, relation, or function can only be changed by the environment. A grounding mechanism for this item must be provided that implements write access for the environment.
- **shared** - meaning that the extension of the concept, relation, or function can be changed by the service and the environment. A grounding mechanism for this item must be provided that implements read/write access for the environment.
- **out** - meaning that the extension of the concept, relation, or function can only be changed by the service. A grounding mechanism for this item must be provided that implements read access for the environment.

For more details on WSMO Grounding we refer the reader to [Kopecky et. al., 2005].

The signature of the states of a WSMO choreography is defined by all legal WSMO identifiers, concepts, relations, functions, and axioms. This signature is the same for all states. The elements that can change and that are used to express different states of a choreography, are the instances (and their attribute values) of concepts, functions, and relations that are not defined as being static. In conclusion, a specific state is described by a set of explicitly defined instances and values of their attributes or through a link to an instance store.

2.2 Guarded transitions

Guarded Transitions are used to express changes of states by means of rules, expressible in the following form:

```
if Cond then Updates.
```

Cond is an arbitrary WSML axiom, formulated in the given signature of the state. The Updates
consist of arbitrary WSMO Ontology instance (see Section 4.7 of WSMO 1.1) statements.

3. WSMO Orchestration

Identically to a WSMO choreography, a WSMO Orchestration is state-based and consists of the same elements as a WSMO Choreography (see Listing 1). In extention, a guarded transition can also take the following form:

if <condition> then <mediator ID>

The difference with respect to choreography is that of using mediators to link the orchestration to other goals or web services. The mediators used are of type \textit{wwMediator} or \textit{wgMediator}. If the required service is already known, a \textit{wwMediator} is used to link the orchestration to the choreography of the required service. If the required service is still unknown, then a \textit{wgMediator} is used to link to the goal which expresses what is needed by the orchestration at the given state.

4. Choreography and Orchestration description example

Our service makes reservations for trips, for which the starting and ending points are located in Austria or Germany. The information requested by the service from the user is route and credit card information. In case it can provide the requested service it will perform the booking for the client. This scenario is depicted in Figure 1 below.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{route_reservation_service.png}
\caption{Route Reservation Service accepts a route and a credit card and returns a reservation to the client}
\end{figure}

\textbf{Listing 2} describes the Trip Reservation Ontology, containing concepts, relations and functions needed for making a trip reservation. Another ontology used for specifying the choreography of the above mentioned service is the Purchase Ontology. \textbf{Listing 3} describes this ontology.
Listing 2. Trip Reservation Ontology.

namespace {"http://www.wsmo.org/ontologies/tripReservationOntology"},
dc <"http://purl.org/dc/elements/1.1">,
xsd <"http://www.w3.org/2001/XMLSchema">,
tc <"http://www.wsmo.org/ontologies/trainConnection">,
prs <"http://www.wsmo.org/mediators/owlPersonMediator.wsml"/>
on ontology <"http://www.wsmo.org/ontologies/tripReservationOntology"/>
nonFunctionalProperties
dc#title hasValue "Trip Reservation Ontology"
dc#creator hasValue "DERI Innsbruck"
dc#description hasValue "an ontology for describing trip reservation related knowledge"
dc#publisher hasValue "DERI International"
dc#contributor hasValues "Titi"
dc#date hasValue "2004-10-22"
dc#type hasValue <http://www.wsmo.org/2004/d2/#ontology>
dc#format hasValue "text/html"
dc#language hasValue "en-us"
dc#rights hasValue <http://deri.at/privacy.html>
version hasValue "$Revision 1.17 $"
endNonFunctionalProperties
importsOntology <http://www.wsmo.org/ontologies/trainConnection/>
usesMediator <http://www.wsmo.org/mediators/owlPersonMediator.wsml">

concept route
nonFunctionalProperties
dc#description hasValue "concept of a route between two stations"
endNonFunctionalProperties
startLocation impliesType tc#station
dendLocation impliesType tc#station
cost ofType xsd#float
available ofType xsd#boolean

concept reservation
nonFunctionalProperties
dc#description hasValue "concept of reservation, containing a reservation holder"
endNonFunctionalProperties
reservationNumber ofType xsd#integer
reservedRoute impliesType route
reservationHolder impliesType prs#person

relation connectionExists/2
nonFunctionalProperties
dc:description hasValue "connection existance relationship between two stations"
endNonFunctionalProperties
Listing 3. Purchase Ontology.

```
namespace {"http://www.wsmo.org/ontologies/purchaseOntology#"},
dc  "http://purl.org/dc/elements/1.1#",
xsd <http://www.w3.org/2001/XMLSchema#>,
prs <http://www.wsmo.org/mediators/owlPersonMediator.wsml#>
}ontology "http://www.wsmo.org/ontologies/purchaseOntology#"

nonFunctionalProperties
  dc#title hasValue "Purchase Ontology"
  dc#creator hasValue "DERI Innsbruck"
  dc#description hasValue "an ontology for describing purchase related knowledge"
  dc#publisher hasValue "DERI International"
  dc#contributor hasValues "Titi"
  dc#date hasValue "2004-10-22"
  dc#type hasValue "http://www.wsmo.org/2004/d2/#ontology"
  dc#format hasValue "text/html"
  dc#language hasValue "en-us"
  dc#rights hasValue "http://deri.at/privacy.html"
version hasValue "$Revision 1.17 $"
endNonFunctionalProperties

usesMediator
  <http://www.wsmo.org/mediators/owlPersonMediator.wsml>

concept creditCard
  nonFunctionalProperties
    dc#description hasValue "concept of credit card, containing an owner, a balance and an expiry date"
endNonFunctionalProperties
owner impliesType prs#person
balance ofType xsd#integer
expiryDate ofType xsd#dateTime

relation validCreditCard/2
  nonFunctionalProperties
    dc#description hasValue "Function that checks whether a credit card is valid or not"
    dc#relation hasValue {ValidCreditCardDef,
      FunctionalDependenceValidCreditCard}
endNonFunctionalProperties

axiom ValidCreditCardDef
definedBy
  forall ?x, ?y ( validCreditCard(?x, ?y) equivalent
       ?x memberOf creditCard and
       ?y = true impliedBy
       neg(wsml#date-less\-than(?x.expiryDate, wsml#current\-date()))
    or
       ?y = false impliedBy
       wsml#date-less\-than(?x.expiryDate, wsml#current\-date())
  )

axiom FunctionalDependenceValidCreditCard
definedBy
  forall ?x, ?y1, ?y2 ( false impliedBy ValidCreditCard(?x,?y1) and
      (ValidCreditCard(?x,?y2) and ?y1 != ?y2)) .
```
As explained in Section 2.1, the non-functional properties of some of the concepts, relations and functions used in the choreography of a service are extended with the attribute `mode`. For those elements that have the mode `in`, `out` or `shared`, a grounding mechanism must be provided. Such a mechanism is attached to an element by introducing an extra attribute `grounding` of the associated non-functional properties whose value refers to it. For enriching elements defined in external ontologies with these two non-functional properties, the ontology that describes the state of the service imports the relevant ontologies and redefines these elements by inheriting their definition and defining values for the two additional non-functional properties (or just one in the case of entities with the mode `static` or `controlled`). In our example, the relevant ontologies for the choreography are those described above, namely the Trip Reservation Ontology and the Purchase Ontology. They are imported by the ontology that describes the state of this choreography, namely the Trip Reservation Choreography Ontology. The content of this new ontology is provided in Listing 4.

Listing 4. Trip Reservation Choreography Ontology.

```xml
namespace
  {"http://www.wsmo.org/ontologies/tripReservationChoreographyOntology#"},
  dc    "http://purl.org/dc/elements/1.1#",
  xsd  "http://www.w3.org/2001/XMLSchema#",
  tr     "http://www.wsmo.org/ontologies/tripReservationOntology#",
  po   "http://www.wsmo.org/ontologies/purchaseOntology#"
}ontology "http://www.wsmo.org/ontologies/tripReservationChoreographyOntology#"
nonFunctionalProperties
  dc#title hasValue "Trip Reservation Choreography Ontology"
  dc#creator hasValue "DERI Innsbruck"
  dc#description hasValue "an ontology for that redefines concepts from other ontologies in order to use them in the choreography by defining for those two additional non-functional properties: mode and grounding"
  dc#publisher hasValue "DERI International"
endNonFunctionalProperties

importsOntology
  {"http://www.wsmo.org/ontologies/tripReservationOntology#"},
  "http://www.wsmo.org/ontologies/purchaseOntology#"
}

concept route subConceptOf tr#route
  nonFunctionalProperties
    mode hasValue in
    grounding hasValue reservationWSDL#reserveRoute
endNonFunctionalProperties

concept reservation subConceptOf tr#reservation
  nonFunctionalProperties
    mode hasValue out
    grounding hasValue reservationWSDL#reserveRoute
endNonFunctionalProperties

concept creditCard subConceptOf po#creditCard
  nonFunctionalProperties
    mode hasValue in
    grounding hasValue reservationWSDL#reserveRoute
endNonFunctionalProperties
```

Listing 5 contains the definition of the Trip Reservation Service. The capability offered by it, Reservation Service Capability, is presented in Listing 6, and its choreography, Trip Reservation Service Choreography, is described in Listing 7. Note that Listing 6 and Listing 7
are assumed to be in the same namespace (i.e. the Trip Reservation Service namespace).

Listing 5. Trip Reservation Service definition.

```
namespace {"http://www.wsmo.org/ontologies/tripReservationService#",
dc    <"http://purl.org/dc/elements/1.1#">,
xsd   <"http://www.w3.org/2001/XMLSchema#">,
tr    <"http://www.wsmo.org/ontologies/tripReservationOntology#">,
tc    <"http://www.wsmo.org/ontologies/trainConnection#">,
po    <"http://www.wsmo.org/ontologies/purchaseOntology#">,
loc   <"http://www.wsmo.org/ontologies/location#">,
trc   <"http://www.wsmo.org/ontologies/tripReservationChoreographyOntology#"}

webService <"http://www.wsmo.org/ontologies/tripReservationService.wsml">
nonFunctionalProperties
  dc#title hasValue "Trip Reservation Service"
  dc#creator hasValue "DERI Innsbruck"
  dc#description hasValue "service for online trip reservations for Austria and Germany"
  dc#publisher hasValue "DERI International"
  dc#contributor hasValues "Titi"
  dc#date hasValue "2004-10-22"
  dc#type hasValue <"http://www.wsmo.org/2004/d2/#service">
  dc#format hasValue "text/html"
  dc#language hasValue "en-us"
  dc#coverage hasValues {tc#austria, tc#germany}
  dc#rights hasValue <"http://deri.at/privacy.html">
  version hasValue "$Revision 1.17 $"
endNonFunctionalProperties

importsOntology {
  <"http://www.wsmo.org/ontologies/location#">
}

usesMediator
  <"http://www.wsmo.org/mediators/owlPersonMediator.wsml">

capability reservationServiceCapability

interface reservationServiceInterface
  choreography reservationServiceChoreography
```

Below, Listing 6 presents the capability of the service by defining its precondition and postcondition. The precondition expresses the fact that in order to be executed, the service requires a route, for which the start and the end locations have to be in Austria or in Germany, and the existence of a connection between the given start and end locations. The assumption is that a valid credit card is provided by the client. The postcondition expresses the fact that, in case of a successful execution of a service, a reservation is created. Finally, the effect specifies that the credit card is charged with the cost of the reserved route.
Listing 6. Trip Reservation Service Capability definition.

capability reservationServiceCapability

nonFunctionalProperties
dc#title hasValue "Trip Reservation Service Capability"
dc#creator hasValue "DERI Innsbruck"
dc#description hasValue "description of the capability of the reservation service of providing trip reservations for Austria and Germany"
dc#publisher hasValue "DERI International"
dc#contributor hasValues "Titi"
dc#date hasValue "2004-10-22"
dc#format hasValue "text/html"
dc#language hasValue "en-us"
dc#rights hasValue "<http://deri.at/privacy.html>"
version hasValue "$Revision 1.17 $"
endNonFunctionalProperties

sharedVariables ?route, ?creditCard, ?cardOwner

assumption
nonFunctionalProperties
dc#description hasValue "the given credit card must be valid"
endNonFunctionalProperties
definedBy
(?creditCard memberOf po#creditCard[
owner hasValue ?cardOwner
]) and
(po#validCreditCard(?creditCard, true))

precondition
nonFunctionalProperties
dc: description hasValue "a connection must exist for the given route"
endNonFunctionalProperties
definedBy
?route memberOf tr#route[
startLocation hasValue ?start,
endLocation hasValue ?end
] and
(?start[
tc#locatedIn hasValue loc#austria]
or
?start[
tc#locatedIn hasValue loc#germany])
and
(?end[
tc#locatedIn hasValue loc#austria]
or
?end[
tc#locatedIn hasValue loc#germany
]) and
(tr#connectionExists(?start,?end))

postcondition
nonFunctionalProperties
dc: description hasValue "a reservation for the given route is created"
endNonFunctionalProperties
definedBy
?reservation memberOf tr#reservation[
reservationHolder hasValue ?cardOwner
route hasValue ?route
]
For defining the choreography of the service, we also need to define the guarded transitions (Listing 7). Notice that the current state is described in the condition part of the rules and the state changes are modelled in the then part. As stated, these changes are modelled by changes in the attribute values of the instances.

Listing 7. Guarded Transitions in the Choreography of the Trip Reservation Service.

Table 1 provides a trace of the choreography states for the choreography defined above in the case of a particular interaction with a client. This interaction is such that the client provides a route as expected by the service in order to be able to provide a reservation (the origin is InnsbruckHbf, in Austria, and the destination is MünichOstHbf, in Germany) and a valid credit card (its expiration date is in the future). As said before each state is characterized by an ontology, but a set of instances and their attribute values makes the distinction between states. Thus, the table refers to a state as being the set of dynamic instances and leaves apart the state signature:

```java
if (routeInstance memberOf trc#route[
    startLocation hasValue ?start,
    endLocation hasValue ?end
] and
    (tr#connectionExists (?start,?end))
then
    (reservationInstance memberOf trc#reservation[
        reservedRoute hasValue routeInstance
    ])
/*rule 2: if a partial reservation exists and if a credit card information is received that points to a valid credit card, the partial reservation is completed with the name of the credit card owner*/

if ((reservationInstance memberOf trc#reservation) and
    (creditCardInstance memberOf trc#creditCard[
        owner hasValue ?cardOwner
    ])
) and
    po#validCreditCard(creditCardInstance, true))
then
    reservationInstance[
        reservationHolder hasValue ?cardOwner
    ]
```
Table 1. Choreography states trace for a particular interaction with the client.

<table>
<thead>
<tr>
<th>State Informal Description</th>
<th>State Formal Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The initial state</td>
<td>Ø</td>
</tr>
<tr>
<td>State in which a route instance has been received</td>
<td>{routeInstance memberOf trc#route[ startLocation hasValue tc#InnsbruckHbf, endLocation hasValue tc#MünichOstHbf ] }</td>
</tr>
<tr>
<td>The state after the execution of the first transition rule: a partial reservation has been created</td>
<td>{routeInstance memberOf trc#route[ startLocation hasValue tc#InnsbruckHbf, endLocation hasValue tc#MünichOstHbf ]}, reservationInstance memberOf trc#reservation[ reservedRoute hasValue routeInstance ] }</td>
</tr>
<tr>
<td>The state where a partial reservation exists and a credit card information is received</td>
<td>{routeInstance memberOf trc#route[ startLocation hasValue tc#InnsbruckHbf, endLocation hasValue tc#MünichOstHbf ]}, reservationInstance memberOf trc#reservation[ reservedRoute hasValue routeInstance ], creditCardInstance memberOf trc#creditCard[ owner hasValue prs#John, expiryDate hasValue &quot;2006-10-10&quot; ] }</td>
</tr>
<tr>
<td>The state after the execution of the second transition rule: the reservation is completed with the reservation holder being instantiated as the credit card owner</td>
<td>{routeInstance memberOf trc#route[ start hasValue loc#InnsbruckHbf, end hasValue loc#MünichOstHbf ]}, reservationInstance memberOf trc#reservation[ reservedRoute hasValue routeInstance, reservationHolder hasValue prs#John ], creditCardInstance memberOf trc#CreditCard[ owner hasValue prs#John, expiryDate hasValue &quot;2006-10-10&quot; ] }</td>
</tr>
</tbody>
</table>
Listing 8 defines the guarded transitions for the Route Reservation Orchestration. The first rule fires when a route instance is available and uses the `findRouteMediator` to find the required route. This mediator links to a Goal (Listing 9) for which a Web Service is to be discovered. The second rule fires when both the route and credit card instances are available and passes the latter to the `performPaymentMediator` to perform the purchase transaction.

### Listing 8. Guarded Transitions in the Orchestration of the Trip Reservation Service.

```plaintext
orchestration reservationServiceOrchestration
  guardedTransitions reservationServiceTransitionRules
  /*rule 1: when a routeInstance is received, the service must make use of another service which provides the route*/
  if (routeInstance memberOf tr#route[
    startLocation hasValue ?start,
    endLocation hasValue ?end
  ] and
  (tr#connectionExists (?start,?end))
  then
  findRouteMediator

  /*rule 2: if a route is available, then the credit card is charged via another service*/
  if ((creditCardInstance memberOf po#creditCard[
    owner hasValue ?cardOwner
  ]) and
  (routeInstance memberOf tr#route[
    available hasValue true,
    startLocation hasValue ?start,
    endLocation hasValue ?end
  ] and
  (tr#connectionExists (?start,?end)) and
  po#validCreditCard(creditCardInstance, true))
  then
  performPaymentMediator
```

Table 2 below provides a trace of the orchestration states for the orchestration defined in Listing 8.

### Table 2. Orchestration states trace.

<table>
<thead>
<tr>
<th>State Informal Description</th>
<th>State Formal Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The initial state</td>
<td>Ø</td>
</tr>
</tbody>
</table>
| The state in which a route instance is to be sent as a request to another service to find the required route. | { routeInstance memberOf trc#route[
                                                                                     startLocation hasValue tc#InnsbruckHbf,
                                                                                     endLocation hasValue tc#MünichOstHbf
                                                                                           ] } |

| The state after which the findRouteMediator is "called" and the required web service has been discovered and invoked thus setting the "available" flag of the route instance to true | \{ routeInstance memberOf trc#route[  
startLocation hasValue tc#InnsbruckHbf,  
endLocation hasValue tc#MünichOstHbf,  
available hasValue true,  
price hasValue 150,  
]  
} |
|---|---|
| The state in which the credit card information has been received and the route is already available | \{ creditCardInstance memberOf po#creditCard[  
owner hasValue prs#John  
balance hasValue 26200  
],  
routeInstance memberOf tr#route[  
available hasValue true,  
startLocation hasValue tc#InnsbruckHbf,  
endLocation hasValue tc#MünichOstHbf,  
price hasValue 150  
]  
} |
| The final state in which the credit card has been charged with the route price | \{ creditCardInstance memberOf po#creditCard[  
owner hasValue ?cardOwner  
balance hasValue 26050  
],  
routeInstance memberOf tr#route[  
available hasValue true,  
startLocation hasValue tc#InnsbruckHbf,  
endLocation hasValue tc#MünichOstHbf  
]  
} |

Listing 9 below presents the WG Mediator which links the Trip Reservation Service to the goal that, if fulfilled, would provide the required route.
Listing 9. WG Mediator linking the Orchestration of the Trip Reservation Service to the Find Route Goal

```xml
namespace {"http://www.wsmo.org/mediators/findRouteMediator#"},
  dc <"http://purl.org/dc/elements/1.1#">,
  xsd <"http://www.w3.org/2001/XMLSchema#">,
  sourceOrch <"http://www.wsmo.org/ontologies/tripReservationService">,
  targetGoal <"http://www.wsmo.org/ontologies/findRouteGoal">
}

wgMediator _"http://www.wsmo.org/mediators/findRouteMediator"

nonFunctionalProperties
  dc#title hasValue "Trip Reservation Service to Find Route Goal linker"
  dc#creator hasValue _"http://www.deri.org/foaf#deri"
  dc#description hasValue "WG Mediator linking Trip Reservation Service to a goal to Find a Train Route"
  dc#publisher hasValue _"http://www.deri.org/foaf#deri"
  dc#contributor hasValue _"http://www.deri.org/foaf#james"
  dc#date hasValue "2005-02-28"
  dc#type hasValue _"http://www.wsmo.org/2004/d2/#wgMediator"
  dc#language hasValue "en-us"
  dc#relation hasValue _{"http://www.wsmo.org/ontologies/tripReservationService",
    _"http://www.wsmo.org/ontologies/findRouteGoal"}
  dc#rights hasValue _"http://www.deri.org/privacy.html"
version hasValue "$Revision: 1.39 $"

endNonFunctionalProperties

source _"http://www.wsmo.org/ontologies/tripReservationService"

target _"http://www.wsmo.org/ontologies/findRouteGoal"

binding(<routeBinding>
  variableBinding(<sourceOrch#routeInstance> <targetGoal#?route>)
)

Listing 10 below defines the findRouteGoal which is linked by the findRouteMediator in Listing 9.

Listing 10. Goal description which is invoked in order to find the required route from another service.

```xml
namespace <http://www.wsmo.org/ontologies/findRouteGoal#>,
dc <http://purl.org/dc/elements/1.1#>,
po <http://www.wsmo.org/ontologies/purchaseOntology#>,
prs <http://www.wsmo.org/2004/d3/d3.3/v0.1/20041008/resources/owlPersonMediator.wsml>,
targetnamespace: <http://www.wsmo.org/ontologies/findRouteGoal#>

goal findRoute

nonFunctionalProperties
dc:title hasValue "Find Route"
dc:creator hasValue "DERI Innsbruck"
dc:description hasValue "A goal that requires a train route between Germany and Austria"
dc:publisher hasValue "DERI International"
dc:contributor hasValue "http://www.deri.org/foaf#james"
dc:date hasValue "2004-10-22"
dc:format hasValue "text/html"
dc:language hasValue "en-us"
dc:rights hasValue <http://deri.at/privacy.html>

version hasValue "$Revision 1.17 $"
endNonFunctionalProperties

usedMediators
<http://www.wsmo.org/mediators/findRouteMediator>

capability

sharedVariables ?route

postcondition
nonFunctionalProperties
dc:description hasValue "the service needs a route, for which the start and end location have to be in Austria or in Germany"
endNonFunctionalProperties

definedBy
?route memberOf ts#route[
    startLocation hasValue ?start
    endLocation hasValue ?end
] and
(?start = Germany or ?start = Austria) and
(?end = Germany or ?end = Austria).

effect
nonFunctionalProperties
dc:description hasValue "A trade is done if a route is available"
endNonFunctionalProperties

definedBy
?trade memberOf po#trade[
    item hasValue ?route
]}
```

Listing 11 defines the ontology that is used by the Perform Payment Service which is based on a different terminology than that of the Trip Reservation Service.
Listing 11. Ontology used by the Perform Payment Service

```xml
namespace {"http://www.wsmo.org/ontologies/creditCard"},
dc <"http://purl.org/dc/elements/1.1">,
xsd <"http://www.w3.org/2001/XMLSchema">,
prs <"http://www.wsmo.org/mediators/owlPersonMediator.wsml"}
} ontology <"http://www.wsmo.org/ontologies/creditCard#">

nonFunctionalProperties
dc#title hasValue "Credit Card Ontology"
dc#creator hasValue "DERI Innsbruck"
dc#description hasValue "An ontology for describing information relative to a credit card"
dc#publisher hasValue "DERI International"
dc#contributor hasValues "http://www.deri.org/foaf#james"
dc#date hasValue "2005-03-01"
dc#type hasValue <"http://www.wsmo.org/2004/d2/#ontology">
dc#format hasValue "text/html"
dc#language hasValue "en-us"
dc#rights hasValue <"http://deri.at/privacy.html">
version hasValue "$Revision 1.0 $"
endNonFunctionalProperties

usesMediator
<"http://www.wsmo.org/mediators/owlPersonMediator.wsml">

concept creditCard
nonFunctionalProperties
dc#description hasValue "credit card ontology"
endNonFunctionalProperties
creditCardType ofType xsd#string
holder impliesType prs#person
maxCredit ofType xsd#integer
ccBalance ofType xsd#float
validUntil ofType xsd#dateTime

concept acknowledgement
nonFunctionalProperties
dc#description hasValue "Acknowledgement over a card transaction"
endNonFunctionalProperties
acknowledged ofType xsd#boolean
card impliesType creditcard

concept charge
nonFunctionalProperties
dc#description hasValue "amount to be charged"
endNonFunctionalProperties
currency ofType xsd#string
amount ofType xsd#float
```

The ontology in Listing 11 is extended to support the attribute mode to be used by the service's choreography as shown in Listing 12.
namespace {"http://www.wsmo.org/ontologies/performPaymentChoreographyOntology"},
    dc  "http://purl.org/dc/elements/1.1",
    xsd  "http://www.w3.org/2001/XMLSchema#",
    prs  "http://www.wsmo.org/mediators/owlPersonMediator.wsml",
    serviceGrounding  "http://www.wsmo.org/services/performPayment.wsdl"
}ontology  "http://www.wsmo.org/ontologies/creditCard#"

nonFunctionalProperties
    dc#title hasValue  "Credit Card Ontology for Choreography"
    dc#creator hasValue  "DERI Innsbruck"
    dc#description hasValue  "Credit Card ontology as used by the Perform Payment Service choreography"
    dc#publisher hasValue  "DERI International"
    dc#contributor hasValues  "http://www.deri.org/foaf#james"
    dc#date hasValue  "2005-03-01"
    dc#type hasValue  "http://www.wsmo.org/2004/d2/#ontology"
    dc#format hasValue  "text/html"
    dc#language hasValue  "en-us"
    dc#rights hasValue  "http://deri.at/privacy.html"
    version hasValue  "$Revision 1.0 $"
endNonFunctionalProperties

importsOntology {  
    "http://www.wsmo.org/ontologies/creditCard#"
}

usesMediator  
    "http://www.wsmo.org/mediators/owlPersonMediator.wsml"

concept creditCard
    nonFunctionalProperties
        dc#description hasValue  "credit card is an input"
        mode hasValue  in
        grounding hasValue  serviceGrounding#executeTransaction
endNonFunctionalProperties

concept acknowledgement
    nonFunctionalProperties
        dc#description hasValue  "Acknowledgement is an output"
        mode hasValue  out
        serviceGrounding hasValue  serviceGrounding#executeTransaction
endNonFunctionalProperties

concept charge
    nonFunctionalProperties
        dc#description hasValue  "amount to be charged is an input"
        mode hasValue  in
        grounding hasValue  serviceGrounding#executeTransaction
endNonFunctionalProperties

Listing 13 below presents the WG Mediator which links the Trip Reservation Service to the Perform Payment Service.
Listing 13. WW Mediator linking the Orchestration of the Trip Reservation Service to the Perform Payment Service

namespace {"http://www.wsmo.org/mediators/performPaymentMediator#"},
  dc  "http://purl.org/dc/elements/1.1#",
  xsd  "http://www.w3.org/2001/XMLSchema#",
  po <http://www.wsmo.org/ontologies/purchaseOntology#>,
  sourceOrch <http://www.wsmo.org/ontologies/tripReservationService>,
  targetChor <http://www.wsmo.org/ontologies/performPaymentService>
}

wwMediator _"http://www.wsmo.org/mediators/performPaymentMediator"
nonFunctionalProperties
  dc#title hasValue "Trip Reservation Service to Perform Payment Service linker"
  dc#creator hasValue _"http://www.deri.org/foaf#deri"
  dc#description hasValue "WW Mediator linking Trip Reservation Service to a service performing a payment transaction"
  dc#publisher hasValue _"http://www.deri.org/foaf#deri"
  dc#contributor hasValue _"http://www.deri.org/foaf#james"
  dc#date hasValue "2005-02-28"
  dc#type hasValue _"http://www.wsmo.org/2004/d2/#wwMediator"
  dc#language hasValue "en-us"
  dc#relation hasValue (_"http://www.wsmo.org/ontologies/tripReservationService",
    _"http://www.wsmo.org/ontologies/performPaymentService")
  dc#rights hasValue _"http://www.deri.org/privacy.html"
version hasValue "$Revision: 1.39 $"
endNonFunctionalProperties

source _"http://www.wsmo.org/ontologies/tripReservationService"

target _"http://www.wsmo.org/ontologies/performPaymentService"

mapping(<creditCardMapping>
  instanceMapping(<sourceOrch#creditCardInstance> <targetChor#cardInstance>)
)

mapping(<chargedAmountMapping>
  attributeMapping(<sourceOrch#routeInstance:cost> <targetChor#chargeInstance:amount>)
)

Listing 14 finally defines the service which accepts a credit card and the amount to be charged and returns an acknowledgement.
Listing 14. Perform Payment Service

```xml
namespace {"http://www.wsmo.org/ontologies/tripReservationService#",
    dc "http://purl.org/dc/elements/1.1#",
    xsd "http://www.w3.org/2001/XMLSchema#",
    cc "http://www.wsmo.org/ontologies/creditCard#",
    ccChor "http://www.wsmo.org/ontologies/performPaymentChoreographyOntology#"} 

webService "http://www.wsmo.org/ontologies/performPaymentService.wsml"

nonFunctionalProperties
dc#title hasValue "Perform Payment Service"
dc#creator hasValue "DERI Innsbruck"
dc#description hasValue "Service for performing a credit card transaction"
dc#publisher hasValue "DERI International"
dc#contributor hasValues "http://www.deri.org/foaf#james"
dc#date hasValue "2005-02-28"
dc#type hasValue "http://www.wsmo.org/2004/d2/#service"
dc#format hasValue "text/html"
dc#language hasValue "en-us"
dc#coverage hasValues {tc#austria, tc#germany}
dc#rights hasValue "http://deri.at/privacy.html"
version hasValue "$Revision 1.0 $"
endNonFunctionalProperties

importsOntology {
    "http://www.wsmo.org/ontologies/performPaymentChoreographyOntology#"
}

usesMediator
    "http://www.wsmo.org/mediators/performPaymentMediator"

capability performPaymentService

nonFunctionalProperties
dc#title hasValue "Perform Payment Service"
dc#creator hasValue "DERI Innsbruck"
dc#description hasValue "description of the capability of the reservation
    service of providing trip reservations for Austria and Germany"
dc#publisher hasValue "DERI International"
dc#contributor hasValues "http://www.deri.org/foaf#james"
dc#date hasValue "2005-02-28"
dc#format hasValue "text/html"
dc#language hasValue "en-us"
dc#coverage hasValues {tc#austria, tc#germany}
dc#rights hasValue "http://deri.at/privacy.html"
version hasValue "$Revision 1.17 $"
endNonFunctionalProperties

sharedVariables ?card, ?cardOwner, ?chargeAmount

assumption
    nonFunctionalProperties
dc#description hasValue "the given credit card must be valid"
endNonFunctionalProperties

definedBy
    (?card memberOf cc#creditCard{
        owner hasValue ?cardOwner
    }) and
    (po#validCreditCard(?card, true))

precondition
    nonFunctionalProperties
```
dc:description hasValue "The client is in fact the owner of the credit card"
endNonFunctionalProperties
definedBy
?creditCard memberOf cc#creditCard and
?chargeAmount memberOf cc#charge and
?cardOwner memberOf prs#person
?creditCard[
  owner hasValue ?cardOwner
]

postcondition
nonFunctionalProperties
  dc:description hasValue "acknowledge the transaction"
endNonFunctionalProperties
definedBy
?ack memberOf cc#acknowledgement[
  card hasValue ?card
]

effect
nonFunctionalProperties
  dc:description hasValue "charge the credit card"
endNonFunctionalProperties
definedBy
?chargeAmount memberOf cc#charge and
?card memberOf cc#creditCard[
  ccBalance hasValue@pre ?initialBalance
] and
?card[
  ccBalance hasValue (?initialBalance-?chargeAmount)
].

choreography reservationServiceChoreography

state <"http://www.wsmo.org/ontologies/performPaymentChoreographyOntology#">

guardedTransitions performPaymentTransitions

if (cardInstance memberOf ccChor#creditCard and
  chargeInstance memberOf ccChor#charge) and
  po#validCreditCard(cardInstance, true))
then
  (acknowledgementInstance memberOf ccChor#acknowledgement[
    success hasValue true
    card hasValue cardInstance
  ])

5. Conclusions and further work

This document presented a core conceptual model for modeling WSMO Choreographies and Orchestrations based on the ASMs methodology. Sequential and parallel workflows can be smoothly expressed in this core model. We did not fix the mathematical model defining parallelism since this is beyond a standardization proposal. We also did not define any tooling (like modeling the flow by UML activity diagrams and automatically mapping them on our ASM-based representation) since this is beyond the scope of this standardization proposal. However, it is also evident that we do not expect the user to directly work with such representation.
References


Acknowledgement

The work is funded by the European Commission under the projects DIP, Knowledge Web, InfraWebs, SEKT, SWWS, ASG and Esperonto; by Science Foundation Ireland under the DERI-Lion project and by the FIT-IT (Forschung, Innovation, Technologie - Informationstechnologie) under the projects RW² and TSC. The editors would like to thank to all the members of the WSMO working group for their advice and input into this document.