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Framework for Semantic Web Process Composition

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Abstract

Web services have been recognized to have the potential to revolutionize e-commerce. The potential for businesses to be able to interact with each other on the fly is very appealing. To date, however, the activity of creating Web processes using Web services has been handled mostly at the syntactic level. Current composition standards focus on building the processes based on the interface description of the participating services. The limitation of such a rigid approach is that it does not allow businesses to dynamically change partners and services. We enhance the current Web process composition techniques by using *Semantic Process Templates* to capture the semantic requirements of the process. The semantic process templates can act as configurable modules for common industry processes maintaining the semantics of the participating activities, control flow, intermediate calculations, conditional branches and exposing it in an industry accepted interface. The templates are instantiated to form executable processes according to the semantics of the activities in the templates. The use of ontologies in template definition allows much richer description of activity requirements and more effective way of locating services to carry out the activities in the executable Web process. During discovery of services, we consider not only functionality, but also the QoS of the corresponding activities. Our unique approach combines the expressive power of the present Web service composition standards and the advantages of the semantic Web techniques for process template definition and Web service discovery. The prototype implementation of the framework for building the templates, carrying out semantic Web service discovery and generating the processes is discussed.

Keywords: Web Services Composition, Semantic Web Process, Semantic Web Service Discovery, Semantic Process Templates

1. Introduction

There has been significant excitement over the promise of Web services. The existence of standardized software components over the Internet that can be accessed, described and registered using XML based standards could lead to powerful applications spanning the Internet. From the perspective of e-commerce, the idea of creating dynamic business processes on the fly (described as "dynamic trading processes" in [1]), would allow corporations to enable full-scale business process integration [2] further leveraging the power of the World Wide Web. There has been a flurry of activity in the area of Web services and in ways to assemble these Web services to create Web processes. Web Processes represent next generation technology for carrying out core business activities, such as e-commerce and e-services, and are created from the composition [3] of Web Services or other software components. Web processes encompass the ideas of both inter and intra organizational workflow. While there has been a significant progress in this area, there are a number of factors that prevent the wide scale deployment of Web services and creation of Web processes. The most inherent problems concern describing and discovering Web services. The current solutions and standards take a structural approach to describing Web services using XML based definitions [4]. The main problem with this approach is that, it is not possible to explicitly define the purpose of the Web services as intended by the Web service provider. "Formally self-described" [5, 6, 7, 8] semantic Web services are a solution to semantically describe and discover Web services. Most of the composition standards build on top of Web service description standards. Hence semantically describing a service could help in composing a process whose individual components are semantically described. When all the tasks involved in a Web process are semantically described, we may call such process as Semantic Web Processes (SWP) [9].

As part of the METEOR-S project at the Large Scale Distributed Information Systems (LSDIS) Lab at the University of Georgia, we are using techniques from the semantic Web [10], semantic Web services [11] and earlier research in workflow management as part of the METEOR project [12, 13] to deal with the problems of semantic Web service description, discovery and composition. In particular, the METEOR-S project associates semantics to Web services, covering input/output, functional/operational descriptions, execution and quality, and exploits them in the entire Web process lifecycle encompassing semantic description/annotation, discovery, composition and enactment (choreography and orchestration) of Web services. The current emphasis of the METEOR-S project has been on semantic annotation of Web services [14], semantic discovery infrastructure for Web services (MWSDI: METEOR-S Web Service Discovery Infrastructure) [15] and semantic composition of Web services (MWSCF: METEOR-S Web Service Composition Framework). This paper focuses on MWSCF.

MWSCF aims at using the power of Web services to allow corporations to create processes that mirror today's dynamic and ever-changing business needs. Corporations can expose their application software as Web services so that other corporations can dynamically find and invoke them. In order to precisely define a business or workflow process, several process specification languages have been created. Some of these standards are specifically designed for process composition using Web services. These standards are based on WSDL descriptions. They focus on creating static processes where in Web services to be used at different stages of processes are known at design time. However there is a need in representing the semantics of process requirements, so that partners and Web services can be dynamically discovered before the executable process is created. We have defined Semantic Process Templates (SPTs), which allow us to semantically define each activity involved in a process. With an SPT, an executable process can be generated with each activity bound to a concrete Web service implementation that conforms to the semantics of the activity. The main focus of this paper is one aspect – that of creating semantically enriched process templates, which can be refined into concrete executable processes based on the activity requirements. The most challenging problem in creating a process template is to capture the semantic capabilities of activities in the process, so that relevant Web services can be bound to activities of the process. We extend our previous efforts on semantic Web service description and discovery to describe the process template and to discover relevant Web services for each activity and to generate the executable process based on the discovered services. Using the approach stated and the framework discussed in this paper, semantic Web processes can be more effectively designed. This is a straightforward approach that is compatible with present industry standards for Web services.

The key features and contributions of this paper are the following:

- A comprehensive framework for composition of SWPs
- Using process templates to store semantics of each activity in an SWP, and
- Dynamic discovery of services based on semantics of each activity in the SWP and executable process generation.

The rest of the paper is organized as follows. Section 2 discusses three of the most popular composition standards. We also present a sample of a typical Web process that will be used for illustrative purposes. Section 3 presents a detailed discussion of the components making up our composition framework. It also briefly summarizes the steps involved in composing a semantic Web process. Key features of MWSCF are highlighted in section 4. Section 5 discusses related work. Conclusions and future work are presented in section 6.

2. Background study

In this section, we first present an overview of the present composition standards. Later, we provide a sample Web process and explain the implementation with respect to each of the presented composition standards.

2.1. Overview of Present Standards for Process Specification

The importance of the languages for Web service composition has increased due to their ability to enable enterprise application integration (EAI) and business process integration within and across organizations. So have the number of proposals for the Web service composition standards proposed by different vendors, organizations and consortia. These XML based standards are proposed for assembling a number of Web services to form a business process. The standards that are currently being considered for building processes using Web service composition include (among others) BPEL4WS [16], BPML [17] and DAML-S [5]. In spite of the fact that all of these standards aim to solve the problems related to process description, they differ in many aspects. Comparing these standards requires an in-depth study of application scenarios of the composed processes and the support of these standards for each of the scenarios. [18] compares these standards using a framework with a set of patterns that are representative of the recurring situations found in different workflow management systems and in the context of enterprise application integration. Comparison based on other criteria is available in [19, 20, 21, 22, 23, 24, 25]. The following sub-sections provide an overview of three major proposed standards; interested readers are referred to the above comparative studies for further information.

2.1.1 BPEL4WS

The Business Process Execution Language for Web Services {BPEL4WS) [16] is a language to specify business processes and business interaction protocols. It superseded XLANG [26] and WSFL [27] as a standard for Web services flow specification. The model and XML-based grammar provided by BPEL define the interactions between a process and its partners using Web services interfaces. BPEL also defines the states and logic of coordination between these interactions and systematic ways of dealing with exceptional conditions. The business interaction protocols are called abstract processes. They are used to specify public and visible message exchange between different parties involved in a business protocol, but they do not reveal the internal behavior or the implementation of the involved parties. The executable processes on the other hand are like workflow descriptions represented using basic and structured activities specifying a pattern of execution of Web services. The process model defined by BPEL is based on the WSDL service description model. The services (described as partners in BPEL) that are invoked by the process and the services that invoke the process are represented using their WSDL description. An executable process can be a Web service by itself and the interface of that process can be represented using WSDL.

2.1.2 BPML

The Business Process Modeling Language (BPML) [17] is based on an abstract model and grammar for expressing *abstract* and *executable* business processes. Using BPML, enterprise processes, complex Web services and multi-party collaborations can be defined. A process in BPML is a composition of activities that perform specific functions. The process directs the execution of these activities. It can also be a part of another composition by defining it as a part of a parent process or by invoking it from another process. Each activity (both simple and complex) in the process has a *context*, which defines common behavior for all activities executing in that context. Hence a process can be defined as a type of complex activity that defines its own context for execution. The BPML specification defines 17 *activity* types, and three *process* types. The different process types are *nested processes* which are defined to execute within a specific context and whose definitions are a part of context definition, *exception processes* to handle exceptional conditions in executing a parent process and *compensation processes* to provide compensation logic for their parent processes. Each process definition may specify any of the three ways of instantiating a process: in response to an input message, in response to a raised *signal*, or invoked from an *activity*. BPML specifications support importing and referencing service definitions given in WSDL. It also suggests standardizing BPML documents by using RDF for semantic meta-data, XHTML and the Dublin Core metadata to improve human readability and application processability.

2.1.3 DAML-S

The DAML-based Web Service Ontology (DAML-S) [5] is an initiative to provide an ontology markup language expressive enough to semantically represent capabilities and properties of Web services. DAML-S is based on DAML+OIL and the aim is to discover, invoke, compose, and monitor Web services. It defines an upper ontology appropriate for declaring and describing services by using a set of basic classes and properties. In DAML-S, each service can be viewed as a *Process* and its *Process Model* is used to control the interactions with the service. Using the *Process Ontology*'s sub-ontologies, *Process Ontology* and *Process Control Ontology*, it aims to capture the details of the Web service operation. The *Process Ontology* describes the inputs, outputs, preconditions, effects, and component sub-processes of the service. *Process Control Ontology* is used to monitor the execution of a service. However, the current version (version 0.7) of DAML-S does not define the *Process Control Ontology*. DAML-S also categorizes three types of processes. The first type is an *atomic process*, which do not have any sub-processes and can be executed in a single step. The second type is a *simple process*, which is not invocable as it is used as an abstraction for representing an atomic or composite process. A c*omposite process* is the third type, which is decomposable into sub-processes. A composite process uses several control constructs to specify how inputs are accepted and how outputs are returned.

There is a need to compare and analyze the features of these languages in detail to frame a single and powerful and interoperable standard for composing processes. Web processes should be dynamic and flexible enough to adapt to the changes in demands from customers or market forces. To meet this requirement, BPEL and BPML, abstract the service references in the process from actual service implementations. This helps in selecting a correct service implementation for each activity during process deployment (deployment-time binding) or execution (execution-time binding). However, the present composition standards like BPEL and BPML are lacking in an important aspect, semantically representing the activity components of a process.

We handle this problem by capturing semantics of the activities in the process template. The activities are not bound to Web service implementations but defined using semantic descriptions. Before deployment or execution of the process, the services that satisfy the semantic requirements are discovered and bound to the activities in the process template. Using the interfaces and message types supported by the services, an executable process is generated. Any process management system in an organization will demand a powerful discovery algorithm integrated into the process management system. This demand becomes critical when the size and the number of services available in the Web are taken into consideration. Our approach supports precise semantics based discovery of Web services. The following section details a sample business process. Composition of this process using our framework is discussed in the subsequent sections.

2.2 Sample Web Process

Let us consider an example for a typical Web process in the e-business domain, an electronic toy manufacturer processing a distributor's order. The manufacturer hosts an application (*getOrderPriceAndDeliveryDate*) where the distributor can query for the price and date of delivery by specifying an order. The manufacturer, upon receiving the order details, processes the order and returns the details that the distributor is querying for. Based on the details returned by the application, the distributor can place the actual order (using an application *placeOrder*) keeping the returned details as the agreement between the manufacturer and the distributor. The applications, *getOrderPriceAndDeliveryDate* and *placeOrder*, have several intermediate steps, which are to be carried out by services within and outside the manufacturer's organization. For brevity, we have considered only the *getOrderPriceAndDeliveryDate* application in our example. In the *getOrderPriceAndDeliveryDate* application, when the distributor places an order, the manufacturer checks the inventory to verify if it has enough goods to satisfy the order. In case there is enough stock then the manufacturer contacts its delivery partner for a date of delivery and its agreement database or accounts department to fix a price for the order. Based on the price returned by the delivery partner and the fix price stages, the price for the order is finalized. Then, the possible delivery date and the finalized price are returned to the distributor. In the other case, when there is not enough stock in the inventory, the manufacturer contacts its supplier partner for the required components. Then the manufacturer contacts its delivery partner to arrange for delivery of components to its manufacturing site and later to deliver the products to the distributor. The price and delivery date are returned to the distributor. The following figure depicts this process in detail.

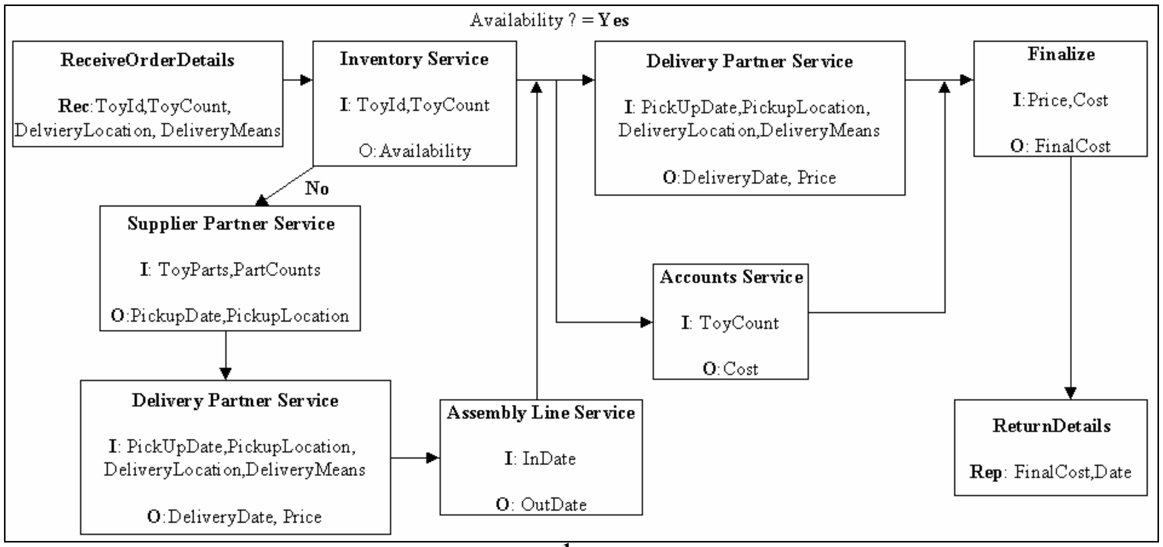


Figure 1: Sample Web Process[1] **(*getOrderPriceAndDeliveryDate*)**

This above-mentioned procedure for order processing can be implemented as an SWP. This process may span across several organizations. In this example, the process

[1] I, O respectively represent inputs and outputs of each acivity. Rec and Rep are the inputs to be received by the process and output produced by the process

design will happen in the manufacturer's organization. When the process is statically composed as a workflow, then the supplier partner and delivery partner services are decided before hand and integrated in the process along with manufacturer's intra organizational services such as fix price, assembly line, inventory, etc. Due to the dynamic nature of the business, hard coding the business logic and participating services may not be efficient. This process should be able to be integrated with any potential delivery partner or supplier partner. The present standards support this kind of design, but they impose a restriction on the interface provided by these potential partners. In BPEL, it is assumed that if a service needs to be a part of a process instance, then it should provide the interface specified by the WSDL's port type[2] construct in the process definition. We attempt to solve this problem by specifying the process as templates during process design. Such templates are independent of the service description and process definition standards. Hence any service that satisfies the semantic requirements of an activity (in the template) can be used to carry out that activity in the process. Before execution, the process templates are used to instantiate an executable process in any of the process definition standards and executed accordingly.

The idea of customizable processes and using process templates has been discussed earlier in [1]. It proposes three architectures/modalities for managing inter-organizational business processes. One of the architectures envisions *Process Portal* hosted by an enterprise or an organization for its customers. It manages a variety of customizable processes in which a subscribing company or a trading partner might do an individual activity. The second architecture is the *Process Vortex* for specialized markets where interactions are controlled by some third party. The business processes in the process vortex are designed to incorporate different trading models and they are available as templates that can be used to customize processes. The *Dynamic Trading Process* architecture defined as the third architecture is a virtual market place for different products spanning across multiple industries. In this architecture, processes can be constructed based on customer's needs. It supports flexible and dynamic trading processes that are composed upon requests from customers and are based on the QoS requirements specified by the customer. The framework discussed in our present work can be used to design processes in any of these modalities. In our system, the processes can be defined using semantic templates and the users of the process or provider of the process can customize and generate executable process.

The next section explains the METEOR-S composition framework and demonstrates how it can be used to design the *getOrderPriceAndDeliveryDate* SWP.

3. METEOR-S Web Service Composition Framework (MWSCF)

This section describes the MWSCF. There are four major components in MWSCF: the Process Builder, the Discovery Infrastructure (MWSDI), XML repositories and the Process Execution Engine. The process builder constitutes a designer and a process generator. It provides a graphical user interface to design/open process templates and passes it to the process generator, which uses MWSDI and data in XML repositories

[2] *PortType* construct in WSDL is used to group operations

to convert the template into an executable process. The METEOR-S Web Service Discovery Infrastructure (MWSDI) is used to access a community of Web service registries and semantically search for Web services. The generated executable process is then executed using a process execution engine. The XML repositories in the architecture are used to store ontologies, activity interfaces and process templates. The details of each of these components are discussed in the following sections. Figure 2 shows the overall architecture of MWSCF.

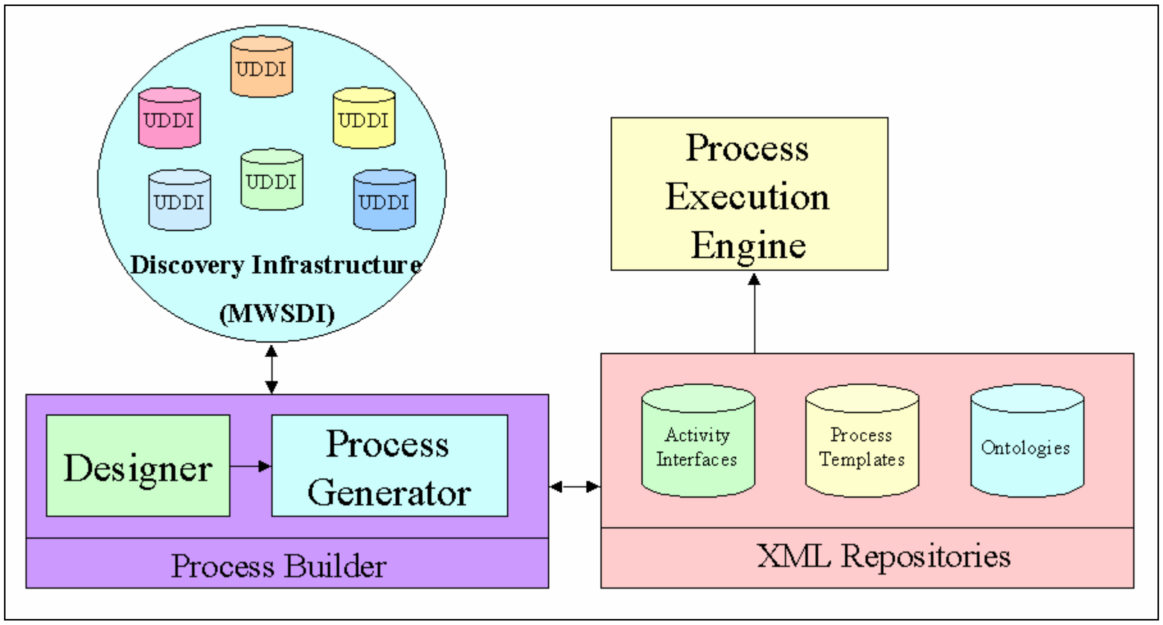


Figure 2: Web Service Composition Framework

3.1 METEOR-S Web Service Discovery Infrastructure (MWSDI)

Web services are advertised in registries. The initial focus of Universal Description, Discovery and Integration [28] specifications was geared towards working with a Universal Business Registry (UBR), which is a master directory for all publicly available Web services. However, the new version of the UDDI specification [29] recognizes the need for existence of multiple registries and the need for interactions among them. A large number of registry/repository implementations for electronic commerce, each focusing on registering services of interest to respective sponsoring groups, are also anticipated. Hence, the challenge of dealing with hundreds of registries (if not thousands) during service publication and discovery becomes critical. Searching for a particular Web service would be very difficult in an environment consisting of hundreds of registries. This search would involve locating the correct registry in the first place and then locating the appropriate service within that registry.

Finding the right services would be easier if the registries were categorized based on domains with each registry maintaining only the Web services pertaining to that domain. If the registries are specialized like this, it would be possible to use domain specific ontologies. As a result all the service definitions pertain to that registry may be forced to conform to that ontology and search for services in that domain can be carried out in a relevant registry. In addition, adding semantics to the domain-registry association will help in efficiently locating the right registries based on query requirements. In MWSDI, we use a specialized ontology called the *Registries Ontology*, which maintains relationships between all domains in MWSDI, and associates registries to them (see [15] for details).

Improving service discovery also involves adding semantics to the Web service descriptions and registering these descriptions in the registries. Adding semantics to Web service descriptions can be achieved by using ontologies that support shared vocabularies and domain models for use in the service description. Using domain specific ontologies, the semantics implied by structures in service descriptions, which are known only to the writer of the description (provider of web service), can be made explicit. Hence, while searching for a Web service, relevant domain specific ontologies can be used to enable semantic matching of services. MWSDI provides support for this kind of matching by relating both Web service descriptions and user requirements to ontologies. It also provides an infrastructure for accessing multiple registries. The registries are provided by different registry operators and they may support their own domain specific ontologies for their registries. The registries may also want to offer their own version of semantic publication and matching algorithms. Along with that, each operator may also provide value added services for the registry users.

We have implemented MWSDI to demonstrate this scalable infrastructure of Web service registries for semantic publication and discovery of services. It is implemented as a P2P network of UDDI registries. The MWSDI prototype system allows different registries to register in a P2P network and categorize registries based on domains. These registries in turn support domain specific ontologies and provide value added services for performing registry operations. MWSDI supports semantic publication of services. The inputs and outputs of the services are semantically annotated and these annotations are captured in UDDI. To perform semantic discovery according to the original implementation, the users can annotate the inputs and outputs of the service requirements and the discovery process in a UDDI will result in the services that match these semantic requirements. This discovery algorithm has been extended later in [14] that also supports annotating each operation in a WSDL file with a concept in functional ontology along with the annotation of preconditions and effects of that operation. Hence during discovery the service requirements are semantically annotated by associating it with concepts in ontologies that represent operation, inputs, outputs, preconditions and effects of the service. The discovery mechanism supported in MWSCF is based on all these kinds of annotations in addition to input and output semantics. Using the MWSDI with the semantic publication and discovery algorithms can significantly improve upon the current standards in Web service registration and discovery. MWSDI provides the flexibility to search for Web services based on ontologies. The present implementation of MWSCF uses MWSDI for semantic discovery. However, the discussion and use of *Registries Ontology* will be a future work. MWSDI architecture has been implemented on a cluster of SUN workstations as peer-to-peer network using the JXTA [30] framework. Xindice [31], a native XML database that comes with JWSDP [32] is used for implementing UDDI registries in MWSDI. UDDI4J [33] is used for accessing UDDI registries during publication and discovery.

3.2 Process Builder

The process builder implemented in Java has a designer that assists in composing semantic Web process templates. WSDL4J [34] has been used for processing WSDL files. The Jena tool kit (DAML API) has been used to building and processing ontologies. The designer supports three different approaches to specify an activity in the process template. Each activity in the process can be specified using a

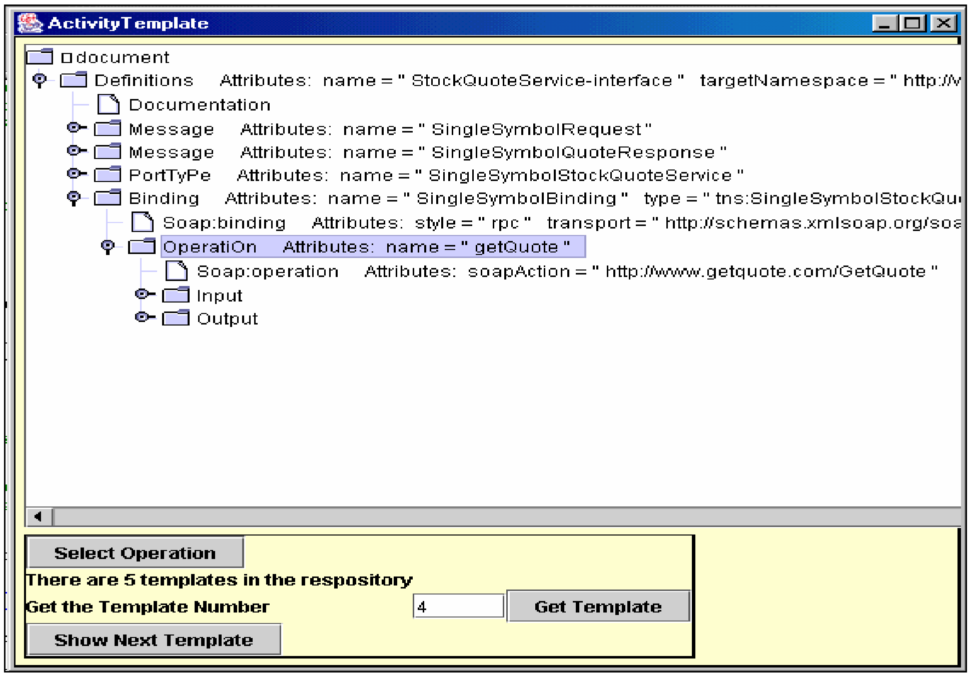
- Web service implementation,
- Web service interface, or
- Semantic activity template.

3.2.1 Specifying an Activity using a Web Service Implementation

Static composition of a process is done by specifying activities using concrete Web service implementations. This type of composition is discussed in one of our previous projects called SCET [35]. MWSCF allows binding an activity to a WSDL file and a relevant operation in it. For example, in the process discussed in section 2.2, the process creator knows the details of the intra organizational activities like *checkInventory*, *fixPrice*, etc. These activities can be carried out using intra-organizational services. Hence, the process creator with the knowledge of intra-organizational services can map intra-organizational activities to a WSDL file and an operation in it. Even if the service interface or implementation changes, as long as the URL of the WSDL and the name of the operation do not change, MWSCF can associate the activity with that operation. During process generation, the *portType* and *message* details are extracted from the WSDL and used in the generated executable process.

3.2.2 Specifying an Activity using a Web Service Interface

An activity can also be specified using a Web service interface. If an activity is linked to a Web service interface, during process generation, a concrete service that implements the interface could be used to carry out the activity. Service discovery for this kind of activity results only in the activities that implement the interface. Discovering services that implement interfaces has been suggested in [36]. UDDI is a registry and not a repository and hence it does not allow publishing the interface definitions. Popular or industry specific interfaces can be published in UDDI using tModels that will have references to the interface definitions. All the services that implement that interface will indicate the conformance to that interface by binding the *tModel* using *binding template* constructs in UDDI. During discovery process, the tModel that represent an interface can be used and all the services that implement this interface can be discovered. In MWSCF, during the creation of process templates, process creator can specify activities using Web service interfaces. During process generation a service can be selected from the list of services that implement the interface. The *portType* and *message* details of the implementing services are retrieved and used during process generation. In MWSCF, Web service interfaces are stored in a XML repository. The interfaces in the interface repository are identified using the same *id* as that of the *tModels* in UDDI that represent each of these interfaces. The user while designing a process can browse (shown in figure 3) through these interfaces and select an interface and an operation in the interface to link to an activity. The identifier (same as *tModel id*) of the interface is used during a UDDI search to retrieve services that implement the interface.



```
document
Definitions   Attributes: name = " StockQuoteService-interface "   targetNamespace = " http://v
    Documentation
    Message   Attributes: name = " SingleSymbolRequest "
    Message   Attributes: name = " SingleSymbolQuoteResponse "
    PortTyPe   Attributes: name = " SingleSymbolStockQuoteService "
    Binding   Attributes: name = " SingleSymbolBinding "   type = " tns:SingleSymbolStockQu
        Soap:binding   Attributes: style = " rpc "   transport = " http://schemas.xmlsoap.org/soa
        OperatiOn   Attributes: name = " getQuote "
            Soap:operation   Attributes: soapAction = " http://www.getquote.com/GetQuote "
            Input
            Output
```

There are 5 templates in the respository

Get the Template Number 4

Figure 3: Browser to Web Service Interfaces

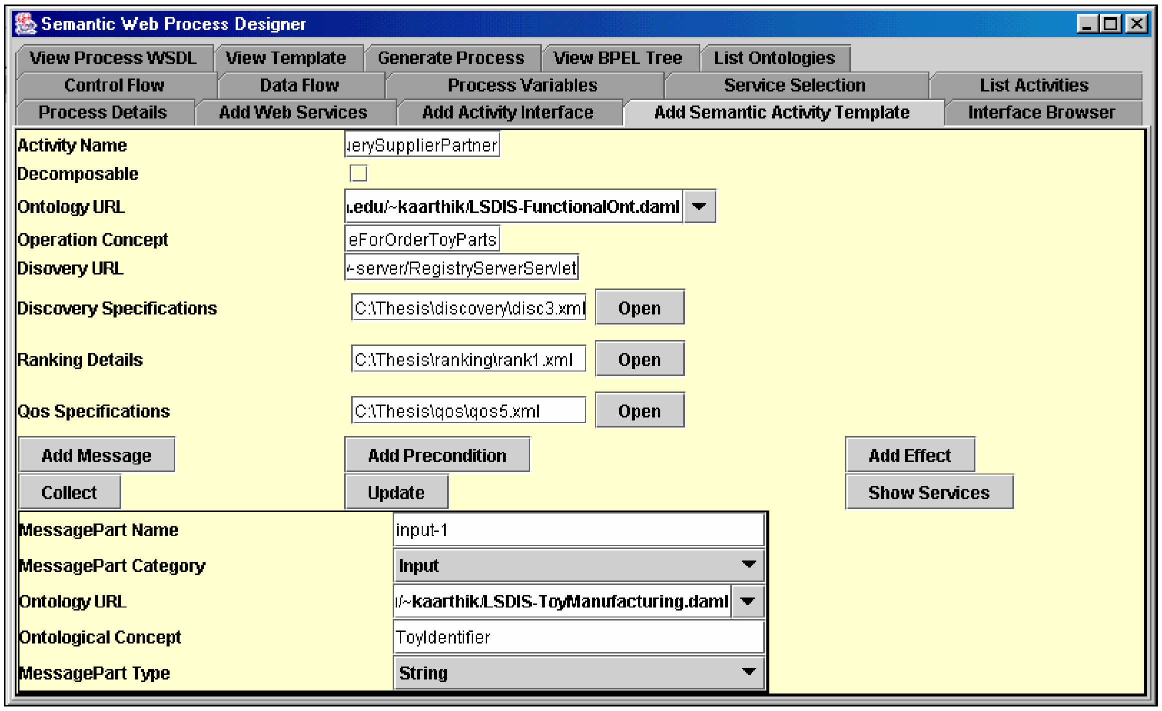
The user in addition to specifying the interface and an operation may also optionally specify the discovery details and QoS requirements for that activity. The discovery details are the details based on which UDDI registries can be queried. The UDDI specification supports searching for services based on name of the business or services (keywords, wildcard character and qualifiers), categorization (in taxonomies), characterization (technical fingerprint), etc. These details in addition to the interface details are used during discovery of Web services for an activity. For example, if a *tModel* representing a technical fingerprint is specified in the discovery details of an activity, then a *tModelBag* is constructed using this *tModel* and the *tModel* that represents the interface. The constructed *tModelBag* is used during service search. Future work involves using *Registries Ontology* [15] in the template. The discovery details are given in an XML representation of the API supported by UDDI specifications.

The QoS requirements may also be specified by using a XML file. The QoS details are used in ranking the discovered services. The process creator can use this ranking to select an appropriate service to carry out an activity. The details are given in section 3.2.7. An example for this kind of activity could be *DeliveryPartnerService* discussed in sample web process in section 2.2. If there is a standard interface for this activity, it can be cached in the XML repository. This will act as a repository of Web service interfaces. Then during the process template design, the activity for *delivery* service can be specified using that interface.

3.2.3 Specifying an Activity using a Semantic Activity Template

In the third approach, the requirements for an activity are given using its semantic characteristics. In the previous approach (section 3.2.2), the activity is specified using an interface, meaning that an operation in the interface to carry out the activity and the data type (complex or simple) for input and output of the activity is stated in the activity requirements. When the activity is specified as a semantic activity template, the activity requirements are given as the semantics of the inputs/outputs (IO) along with the functional semantics of the activity are specified. The functional semantics of an activity, its IO, its preconditions and effects are represented using ontological concepts. The services that conform to these semantic characteristics are discovered and ranked. The process creator can select a service from the list of discovered services. This approach of specifying the activities requires that all services that are considered for discovery are semantically annotated by which each operation in a WSDL file, its inputs, and outputs are mapped to ontological constructs and having additional tags for preconditions and effects of the operations. With this methodology, capabilities of each operation in a WSDL file can be captured. These semantic details in a WSDL file could be published in a UDDI. Hence, given a set of requirements based on these semantic details, the services that match these requirements could be more precisely found. A detailed discussion is presented in [14]. The data types of input and output are optional and could be used as a weighted component by the semantics driven service selection algorithm. As in the previous approach (section 3.2.2), the discovery details and QoS requirements could be specified for the semantic activity template too. These discovery details are combined with the semantic requirements and search is performed within an appropriate registry. The QoS requirements may be used to rank the resulting services. The figure 4 shows the user interface window to specify an activity as a semantic activity template.

In our example discussed in section 2.2, the activity for *DeliveryPartnerService* could be specified as a semantic template. The input and output of the activity can be represented using a standard vocabulary or ontology. A domain ontology for the domain *Cargo Services*, for example, could be used for this requirement annotation. Our work like most other work in semantic Web research is based on rich framework for ontology engineering and re-use. The *Cargo Services* ontology may encompass concepts like *Air Cargo Services*, *Cargo Insurance*, *Maritime Cargo Services*, *Rail Cargo Services and Trucking*. Hence, using such ontology, the semantics of an activity are specified. During service discovery, the service implementations that have used this ontology and annotate their descriptions will be semantically compared with the requirements and ranked. The process creator can select one of the discovered services based on the ranking and the activity under consideration is bound to this Web service.



Activity Name	ierySupplierPartner
Decomposable	☐
Ontology URL	.edu/~kaarthik/LSDIS-FunctionalOnt.daml
Operation Concept	eForOrderToyParts
Disovery URL	-server/RegistryServerServlet
Discovery Specifications	C:\Thesis\discovery\disc3.xml
Ranking Details	C:\Thesis\ranking\rank1.xml
Qos Specifications	C:\Thesis\qos\qos5.xml

MessagePart Name	input-1
MessagePart Category	Input
Ontology URL	l/~kaarthik/LSDIS-ToyManufacturing.daml
Ontological Concept	ToyIdentifier
MessagePart Type	String

Figure 4: Semantic Activity Template Specification Interface

3.2.4 Process Composition

When composing a generic process template, the process creator specifies the list of activities and control flow constructs to link the activities. After finalizing the template, the user can save the template for future use or can find service implementations for each activity in the template. Though the templates could be used during run-time to find services for each activity, at present MWSCF only support deployment time binding. This is because the initial implementation of MWSCF uses an engine that supports deployment time binding. Though the builder supports different approaches to design, the focus of this work is on the approach discussed in section 3.2.3, where an activity is designed using semantic templates. If the process template has activities that are specified using semantic templates then it is called a semantic process template.

3.2.5 Semantic Process Template

The semantic process template is a collection of activities, which can be linked using control flow constructs. A sample process template (in XML) format is shown in figures 5 and 6. The process templates in MWSCF have BPEL-like syntax. For representing control flow, the template uses the BPEL constructs. Other constructs in the template like *invoke-activity*, *criteria*, *semantic-spec*, *discovery-spec* etc. are not a part of the BEPL specifications. They are MWSCF specific constructs independent of any process specification standard that are used to generate executable processes. In addition to template creation a WSDL is created that represents the description for the desired process and it is generated using a WSDL editor. This WSDL is then linked to the process template. The template can be explained as follows:

- *Process-template* is the root element that encloses the entire template definition. It has different attributes representing different ontologies or other name spaces.
- The control constructs (<*sequence*>, <*flow*>, <*switch*> etc.) are used to represent control flow in the template. They do not need translation and they are used as is during the process generation phase.
- In the example discussed in section 2.2, the inputs and outputs of the respective activities *Receive Order Details* and *Return Details* are represented as messages in the WSDL file (shown in section 3.4) of the process. The *receive* and *reply* constructs in the process template are linked to an operation in the WSDL representing process description (using the attribute *process-wsdl-operation*) created by the process creator. The messages that are to be received and returned by the process are captured in that WSDL file. They will be translated to containers[3] in the generated executable process.
- The *invoke-activity* elements in the process template are translated into corresponding *invoke* elements in the generated processes. The *invoke-activity* elements in the template are of three *types*:
    1. *ServiceImpl*, if the activity is specified using a concrete Web service implementation,
    2. *WSInterface*, if the activity is specified using a Web service interface, and
    3. *SemanticTemplate*, if the activity is specified using a semantic activity template.

  Based on the discovery[4] criteria (*semantic-spec*, *discovery-URL*, *tModel id*, *discovery-spec*) and QoS criteria (*qos-spec*) specified for each of the activities, the relevant services to carry out each activity are discovered and selected (discussed in section 3.2.6). Service discovery is needed only for activities of types *WSInterface* and *SemanticTemplate*. *ServiceImpl* type does not need discovery as the location of WSDL (*wsdl-URL*) and the name of the operation (*operation-name*) to invoke are given in the template itself The *invoke* elements in the generated executable process will have other details like *portType*, *operation*, *input* and *output containers*, etc. that are extracted from the WSDL description of the service that is selected to carry out the activity.
- Input and output *container* details of the *invoke* elements in the executable processes are generated from the data flow details provided by the user (shown in figure 11). Data flow is not specified in the template. While the process creator manually selects a service for an activity, data flow may be specified between the selected service and other services that had been selected for other activities.

[3] called Variable is BPEL version 1.1

```
<?xml version = "1.0" encoding = "UTF-8"?>
<process-template name = "sample process"
                LSDIS-ToyManufacturing = "uuid:f4a6574b-49f4-a657-f908-45fa62354d84"
                LSDIS-OrderPlacement = "uuid:f4 a9574b-49f4-a957-f956-45fa62355c94"
                LSDIS-FunctionalOnt = "uuid:f4a5904b-49f4-c563-f590-45fa65289d77"
                LSDIS-CargoServices = "uuid:f4a8884b-49f4-b634-f888-45fa62098d43"
                xsd = "http://www.w3.org/2001/XMLSchema">
  <sequence name = "sequence-1">
    <receive name = "receive-1"process-wsdl-operation = "getDetails "/>
    <invoke-activity name = "InventoryCheckActivity" type = "ServiceImpl"
                wsdl-URL = "http://lsdis.cs.uga.edu/proj/meteors/wsdls/all_services.wsdl"
                operation-name = "checkInventory"/>
    <switch name = "switch-1">
      <case condition = "(inventory-availability,' = ','no')">
        <sequence name = "sequence-3">
        <invoke-activity name = "QuerySupplierPartner"  type = "SemanticTemplate"
                semantic-spec = "semantic-1"
                qos-spec = "qos-1"
                ranking-weights = "ranking-1"
                discovery-URL  = "http://lsdis.cs.uga.edu:7001/registry-server/RegistryServerServlet"/>
        <invoke-activity name = "DeliveryPartnerService" type = "WSInterface"
                tModel-id = "uuid:f4a6574b-49f4-a657-f908-45fa62354d84"
                operation-name = "arrangeDelivery"
                qos-spec = "qos-2"
                discovery-details = "discovery-1"
                discovery-URL  = "http://lsdis.cs.uga.edu:7001/registry-server/RegistryServerServlet"/>
        <invoke-activity name = "AskAssemblyLine" type = "ServiceImpl"
                wsdl-URL = " http://lsdis.cs.uga.edu/proj/meteors/wsdls/all_services.wsdl "
                operation-name = "assemblyService"/>
        </sequence>
      </case>
    </switch>
    <sequence name = "sequence-2">
      <flow name = "flow-1">
        <invoke-activity name = "DeliveringToysToDistributor" type = "ServiceImpl"
                 wsdl-URL = " http://lsdis.cs.uga.edu/proj/meteors/wsdls/all_services.wsdl "
                operation-name = "deliveryService"/>
        <invoke-activity name = "FixPrice" type = "ServiceImpl"
                wsdl-URL = "http://lsdis.cs.uga.edu/proj/meteors/wsdls/all_services.wsdl"
                operation-name = "fixPrice"/>
      </flow>
      <invoke-activity name = "FinalizePrice"  type = "ServiceImpl"
                wsdl-URL = "http://lsdis.cs.uga.edu/proj/meteors/wsdls/all_services.wsdl"
                operation-name = "finalizePrice"/>
    </sequence>
    <reply name  = "reply-1" process-wsdl-operation = "getDetails "/>
  </sequence>
```

Figure 5: Sample Process Template Listing 1

```
  <criteria>
    <semantic-spec name = "semantic-1">
          <input name = "input-1"
                onto-concept = "LSDIS-ToyManufacturing:ToyIdentifier"/>
          <input name = "input-2“
                onto-concept = "LSDIS-OrderPlacement:OrderCount"/>
          <operation name = "operation-name"
                operation-concept = "LSDIS-FunctionalOnt:getDetailsForOrderToyParts"/>
          <output name = "output-1"
                onto-concept = "LSDIS-CargoServices:PickupDate“/>
          <output name = "output-2"
                onto-concept = "LSDIS-CargoServices:PickupLocationIdentifier“/>
    </semantic-spec>
    <discovery-spec name = "discovery-1">
          <find_service>
            <categoryBag>
              <keyedReference tModelKey = "uddi:ubr.uddi.org:categorization:geo3166-2"
                      keyName = "GEO:United States"
                      keyValue = "US"/>
            </categoryBag>
          </find_service>
    </discovery-spec>
     <qos-spec name = "qos-1">
          <delaytime unit = "milliseconds" qualifier = "LT"> 90 </delaytime>
    </qos-spec>
     <qos-spec name = "qos-2">
          <delaytime unit = "milliseconds" qualifier = "LT"> 200 </delaytime>
    </qos-spec>
    <ranking-weights name = "ranking-1">
          <semantic-matching-weight> 75 </semantic-matching-weight>
          <qos-weight> 25 </qos-weight>
          <input-semantics-weight>30 </input-semantics-weight>
          <output-semantics-weight> 20 </output-semantics-weight>
          <operational-semantics-weight> 50 </operational-semantics-weight>
          <delay-time-weight> 100 </delay-time-weight>
    </ranking-weights>
    <protocol-variable name = "inventory-availability" type = "xsd:string"/>
  </criteria>
</process-template>
```

Figure 6: Sample Process Template Listing 2

- The business protocol data (like *inventory-availability*) that are used as variables in process control (like conditional statements) need not be explicitly assigned in the process template. Instead, during process generation, the user can map output from any of the participating service to that variable. These details are translated into <*assign*> and <*copy*> tags in the final generated executable process.

- Other details given by the user for discovery (*semantic-spec, discovery-spec* and *qos-spec*) and ranking (*ranking*-details) for activities during process design are present in the process template under the *criteria* element. *semantic-spec* element is used to give the semantics of the activity. *qos-spec* is used to specify the QoS criteria of the activities. The *ranking-weights* element is used to assign weights to rank the discovered services. Detailed discussion on discovery and ranking is given in the following section. The *discovery-spec* element in the template (figure 6) refers to a XML representation of the query supported by UDDI specification to find services. These details are used during discovery process For example in the process template (figure 6), since *discovery-spec* element is given in conjunction with an activity of type *WSInterface*, when finding Web services for the activity *DeliveryPartnerService*, all the services that implement the interface and that are categorized under the category 'US' in the geo3166-2 taxonomy are discovered and ranked.

3.2.6 Service Ranking and Selection

Web service selection is a crucial aspect of process composition. Hence the Web service discovery algorithms in our system are supplemented with a good ranking scheme. The service selection is based on the discovery details for the activity provided by the user. The user could specify the discovery URL for each activity. This discovery URL could point to a market place registry, a private enterprise registry, a domain registry, or a Universal Business Registry. The service discovery will be carried out in that registry. Future work will involve using *Registries Ontology* for registry selection. Registry selection can also be based on the registries ontology as proposed in MWSDI. Since discovery could result in a large number of candidate services, we have implemented a ranking mechanism that will help the process creator to select appropriate services. The ranking of services for each activity can be based on the semantic matching of activity requirements with the service specifications and on the satisfiability of service in terms of QoS requirements of the activity. Our approach requires that each service registered with UDDI is linked to a semantically annotated WSDL description and that the WSDL descriptions are linked to WSEL [27] (Web Service Endpoint Language) files that have the QoS details of all the operations in the service. WSEL is an XML format for the description of non-operational and behavioral characteristics of service endpoints, like quality-of-service or security properties. This specification is under development and at present no specification exists for this language. WSFL [27] specification envisions the need for this language and suggests using it in conjunction with an activity in a process to describe endpoint properties and enable better matchmaking. We have taken this idea and linked each WSDL file to a WSEL file, which has the QoS specifications of the operations defined in the WSDL file.

If an activity is specified as a semantic activity template then the overall ranking of a service for this activity is the weighted arithmetic mean of the ranking values in two dimensions. The first dimension is based on the *Semantic Matching*. The second dimension is the *QoS criteria matching*. Semantic matching is performed while ranking if the activity is specified as a semantic template. However, the QoS based ranking can be done if the activity is specified as a service interface or semantic template. Semantic matching on the semantic template of the activity is done against the *operations*, *inputs*, *outputs*, *preconditions* and *effects* of the services available. The ranking on semantic matching is based on the weights assigned by the process creator to the individual semantic parts of the activity namely operations, inputs, outputs, preconditions and effects. The assigned weights are normalized before calculation (at least one weight must be non-zero). During discovery the semantic criteria of the activity (defined as semantic template) are matched against the semantic details of the services registered in UDDI. The weights corresponding to the matched semantic parts are used to rank the services. The formula used in MWSCF to calculate the ranking value for semantic matching is shown in figure 7. It calculates the weighted arithmetic mean of individual semantic parts (operation, inputs, outputs, preconditions and effects).

$$M_s = \frac{\sum_{i=1}^{5} M_i W_i}{\sum_{i=1}^{5} W_i}$$

M_s : Overall Semantic Matching Value

i : Index of the assigned weights (1-5)

M_i : Semantic Matching value of the ith semantic part

W : Weight of the ith part

Figure 7: Formula for Calculating Overall Semantic Matching Value

Let us consider a sample calculation of overall semantic matching value using the semantic specifications of an activity given in the process template (in figure 6). The template refers to four different ontologies, namely, *LSDIS-ToyManufacturing*, *LSDIS-OrderPlacement*, *LSDIS-FunctionalOnt*, *LSDIS-CargoServices* that are published in UDDI and identified by *a tModel id*. The same *tModel id* is used to index the ontologies in the ontology repository. The semantic specifications of the activity *QuerySupplierPartner* are given in *semantic-spec* element named *semantic-1*. It specifies that the candidate Web services for that activity should have an operation that conforms to the concept *getOrderDetailsForOrderToyParts* in the ontology represented by namespace *LSDIS-FunctionalOnt* and takes two inputs and produces two outputs. It also specifies the semantics of the inputs and outputs using ontological constructs. The semantic specifications of this activity states that one of the inputs of the *QuerySupplierPartner* should conform to the *OrderCount* concept (class) in the *LSDIS-OrderPlacement* ontology. The other input should conform to *ToyIdentifier* concept in *LSDIS-ToyManufacturing* ontology. Outputs of this activity should conform to *PickupDate* and *PickupLocationIdentifier* in *LSDIS-CargoServices* ontology.

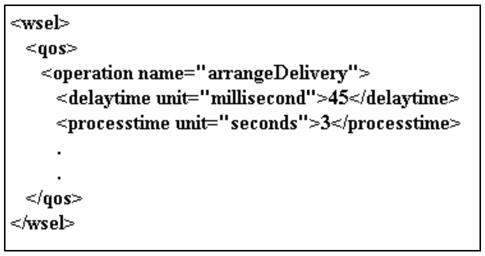
In the process template, the operation, inputs, outputs of the activity *QuerySupplierPartner* are annotated. Hence the process creator can assign weights to these semantic parts (in *ranking-weights* element). The semantics of preconditions and effects are not specified in the semantic requirement specification of *QuerySupplierPartner* and hence weights are also not assigned for the precondition and effects. In this example, the weights are assigned only to three parts (i=3) inputs, outputs and operation. The weights assigned in the template are 30, 20 and 50 respectively. The semantic specifications are matched against WSDL descriptions of the services in UDDI registry identified by the URL given in *discovery-URL* attribute. Let is consider how to calculate the semantic matching value between the semantic requirements of this activity and an operation in a candidate WSDL file that takes two inputs and produces two outputs with the following semantics:

1. The functionality of the operation in the candidate WSDL is mapped to *LSDIS-FunctionalOnt:getDetailsForOrderToyParts*. The functional semantics of the service (operation in WSDL) exactly matches with the functional semantics of the activity. Hence the semantic matching value of the service, M_1 is 1.
2. One of the inputs of the operation in candidate WSDL is annotated using *LSDIS-ToyManufacturing:ToyIdentifier* and the other input is annotated using *LSDIS-OrderPlacement:OrderCount*. In this case the input semantics of the service (represented by the WSDL) exactly match to the inputs semantics of the activity *QuerySupplierPartner* in the process template. The semantic matching value M_2 is 1.
3. One of the outputs of the operation of interest is annotated with *LSDIS-CargoServices:PickupDate* and the other output is annotated with *LSDIS-CargoServices:PickupLocationDetails* which is a concept in the ontology that is 2 levels up in the hierarchy of subClassOf relationships. One of the outputs of the service represented by the operation in WSDL match exactly one of the outputs of the activity *QuerySupplierPartner* and the other output does not match exactly. For exact semantic matching the semantic matching value is 1 and for non-exact matches the semantic matching value is calculated using a linear function that decides the semantic matching value based on the subClassOf hierarchy. The final semantic matching value M_3 is the average of semantic matching values of the two outputs. In the example the value of M_3 is (1+0.8)/2 = 0.9. The subClassOf hierarchy and linear function used in this implementation can be extended with a better function that can be used to characterize two concepts separated in an ontology by a number of named relationship properties.
4. The overall semantic matching value between the activity *QuerySupplierPartner* in the process template and the operation of interest in candidate WSDL, M_S is the weighted arithmetic mean of the individual semantic parts, (1 * 50 + 1 * 30 + 0.9 * 20) / (50+30+20) = 0.98.

The next dimension in overall ranking is based on the QoS requirements of each activity. Each activity of types *WSInterface* and *SemanticTemplate* may be linked to requirements specification that defines the QoS parameters of that activity. For simplicity, our present work considers four different QoS parameters, which are the subset of QoS details that we have identified in one of our previous work [37]. The different QoS specification parts used in ranking are:

- Task Delay Time
- Task Process Time
- Task Realization Cost
- Task Reliability Measure

In addition to QoS, the WSEL file can also support representing boundary values[5] and possible values for the input and output parameters of each operation. However, our present discovery method does not take boundary values into consideration. In our present implementation, each WSDL is lined to a WSEL file representing QoS of different operations defined in WSDL. The following figure shows a sample WSEL file.



```
<wsel>
  <qos>
    <operation name="arrangeDelivery">
      <delaytime unit="millisecond">45</delaytime>
      <processtime unit="seconds">3</processtime>
      .
      .
  </qos>
</wsel>
```

Figure 8: Sample WSEL Details of a Service

When specifying the requirements of an activity in a process the process creator can specify QoS criteria of the activity. The QoS requirements are specified with qualifiers. In our implementation, all services in UDDI may be linked to WSDL files and each of the WSDL files may be linked to WSEL files with QoS details of the service. A sample QoS requirements specification is shown in the template in figure 6 under *qos-spec* element. Each of the QoS parameter in the requirements description of an activity is given a weight. For every service that is discovered for an activity, the QoS compatibility is checked and using the weight for each QoS parameter the ranking value of the service is calculated for the activity. The formula for calculating QoS matching of an activity is shown in figure 9. It calculates the weighted arithmetic mean of individual QoS criteria.

Considering the sample template (figure 6) and the activity named *QuerySupplierPartner* in it, the *qos-spec* indicates that there is only one QoS requirement and it states that the *delay-time* for the activity should be less than 90 milliseconds. The QoS matching value of the candidate services are calculated using a matching function. If for a candidate service the QoS matching value is 0.9 (calculated using a function considering the compatibility between QoS specification of the services and QoS criteria

[5] For example if a service 'TakeOrder' has an operation that takes order for some product X and if the maximum order that it can handle as input is 1000, it can specify that the value for the input parameter for this service should be less than 1000. Also if the input takes any enumerated value set it could be specified in the WSEL file. These details help users in properly discovering and selecting appropriate services.

of the activity) then the value of M_Q is calculated as (0.9 * 100) / 100 = 0.9, where 100 is the weight given to QoS specification *delay-time*.

$$M_Q = \frac{\sum_{i=1}^{4} M_i W_i}{\sum_{i=1}^{4} W_i}$$

M_Q : Overall QoS Matching Value

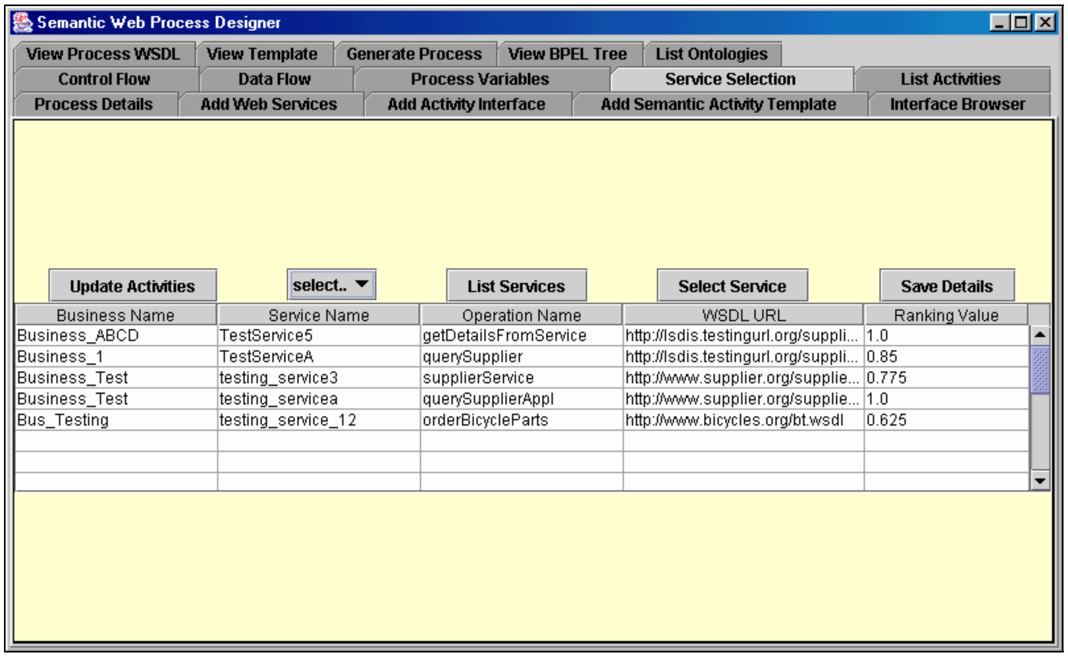
i : Index of the assigned weights (1-4)

M_i : Semantic Matching value of the i^{th} QoS criterion

W : Weight of the i^{th} QoS criterion

Figure 9: Formula for Calculating Overall QoS Matching Value

After calculating the ranking values (M_S and M_Q) for the Semantic Matching and QoS dimensions, weights assigned by the user for each of these dimensions are used to calculate the overall ranking. The overall ranking value is the weighted arithmetic mean of the ranking values in each dimension. In the example discussed above, for the activity *QuerySupplierPartner*, the weights for Semantic matching and QoS matching are respectively 75 and 25. The overall ranking value is hence calculated as (0.98 * 75 + 0.9 * 25) / (75 + 25) = 0.96. The services are ranked based on the calculated overall ranking values of the services and the process creator can select one from the list of services (see figure 10):



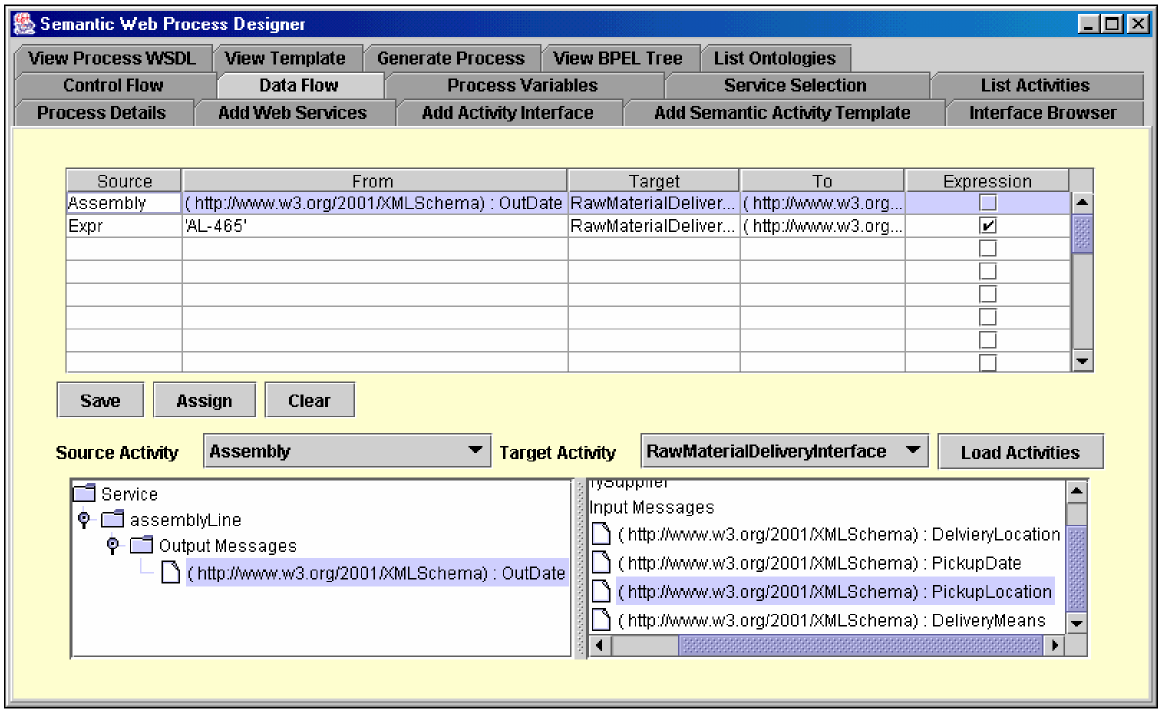
Business Name	Service Name	Operation Name	WSDL URL	Ranking Value
Business_ABCD	TestService5	getDetailsFromService	http://lsdis.testingurl.org/suppli...	1.0
Business_1	TestServiceA	querySupplier	http://lsdis.testingurl.org/suppli...	0.85
Business_Test	testing_service3	supplierService	http://www.supplier.org/supplie...	0.775
Business_Test	testing_servicea	querySupplierAppl	http://www.supplier.org/supplie...	1.0
Bus_Testing	testing_service_12	orderBicycleParts	http://www.bicycles.org/bt.wsdl	0.625

Figure 10: Service Ranking Display Window for an Activity

3.2.7 Process Generation

After designing the template, the process creator can generate an executable process. This involves finding services pertinent to each activity in the process, retrieving their WSDL file, and extracting relevant information, establishing data flow and generating the process. The discovery of services is done for each activity independent of other activities. The process designer helps in finding Web services for each activity in the process. The creator can then link services to incorporate data flow in the process. For this purpose, after obtaining control flow requirements between two services, the process generator assists the user in establishing explicit data flow link between output parameters of one service to the input parameters of the other.

The interface in MWSCF that assists in establishing data flow is shown in the figure 11. If the process creator wants to specify the data flow link between two activities, the respective Web service descriptions can be fed to the graphical user interface that can be used to establish the data flow between the activities in the process. Then the process creator has to manually specify the mapping between output parameters of one service to the input parameters of the other.



Source	From	Target	To	Expression
Assembly	(http://www.w3.org/2001/XMLSchema) : OutDate	RawMaterialDeliver...	(http://www.w3.org...	☐
Expr	'AL-465'	RawMaterialDeliver...	(http://www.w3.org...	✓
				☐
				☐
				☐
				☐
				☐
				☐

Source Activity: Assembly
Target Activity: RawMaterialDeliveryInterface

Service
assemblyLine
Output Messages
(http://www.w3.org/2001/XMLSchema) : OutDate

rySupplier
Input Messages
(http://www.w3.org/2001/XMLSchema) : DelvieryLocation
(http://www.w3.org/2001/XMLSchema) : PickupDate
(http://www.w3.org/2001/XMLSchema) : PickupLocation
(http://www.w3.org/2001/XMLSchema) : DeliveryMeans

Figure 11: Interface to Establish Data Flow

The porttype data extracted from the WSDL of the process (created by process creator), the data flow requirements obtained from the user and the control flow constructs in the templates are used to generate an executable process. The WSDL descriptions of the participating Web services are also retrieved. These WSDL files will be used during deployment time binding. During the process generation phase the process

WSDL file[6] is updated with the service link details. A sample executable BPEL process that is generated from the template shown in section 3.2.5 can be found in the appendix.

3.3 XML Repositories

In MWSCF, we have a pool of XML repositories that are used for managing (storing, searching and reusing/sharing) the following

- Ontologies which are used during annotation of services and annotation of semantic activity templates,
- Semantic process templates which can be opened, edited and saved back for later use, and
- Activity/service interfaces in WSDL syntax.

All data (ontologies, interface definitions and process templates) are based on XML and since they are meant for sharing and re-use, using XML repositories will be of much use in this regard. The ontologies in the repositories are identified using the *tModelId*s. *tModels* are published in UDDI to represent and refer to ontologies. In another XML repository, the process templates are categorized and stored. The categorization (taxonomy or ontology) is stored in the same XML repository as that of the process templates. Each category in the categorization has an identifier. The XML repository for storing process templates has different collections based on these identifiers and each process template is categorized by storing the template under a particular collection that represents a category. There is also an interface repository that stores the WSDL interface definitions which can be browsed and selected to link to an activity during the process design. Using these repositories during process design, service discovery or process generation gives the user a powerful environment to compose a process. Xindice is used for implementing these XML repositories.

3.4 Execution Engine

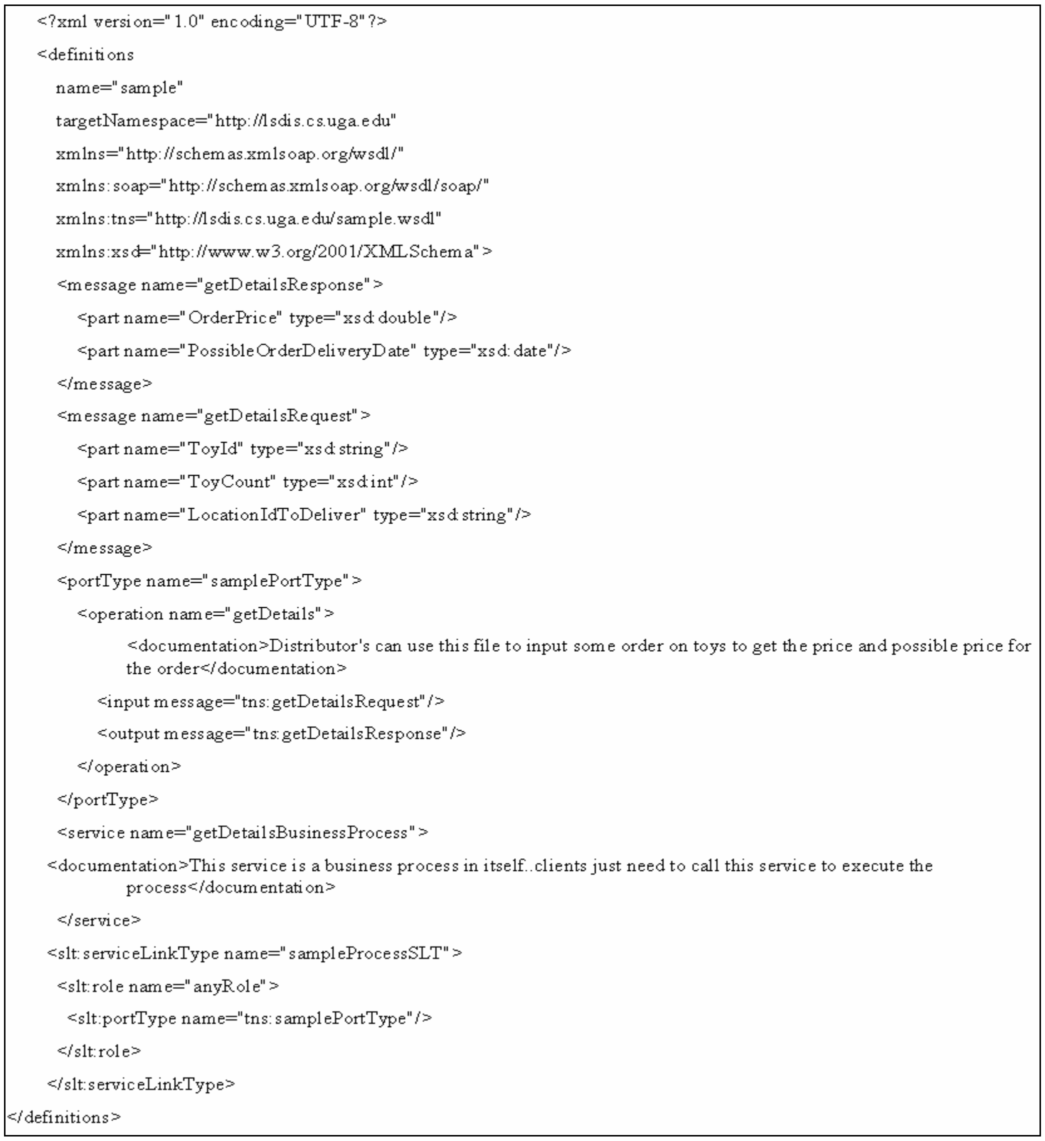
The generated executable BPEL4WS process can be executed in any BPEL execution engine. As the work to develop our own execution engine is underway, at present MWSCF has been implemented and tested using BPWS4J orchestration server. Deploying a process in BPWS4J [38] engine requires a BPEL file containing the process definition, a WSDL description[7] for the process and the other WSDL descriptions of the web services that a part of the process. The WSDL descriptions of the participating services are needed for deployment time binding. Using the WSDL files of the participating services and other details, an in-memory model [39] of the process is generated. Since the present release of BPWS4J does not allow deploying a process without a BPEL file, we have used the BPWS4J printer class to write the in-memory model of the process into a BPEL file. This file is then validated using the tool validator

[6] WSDL file describing the process. It is designed by the process creator. It has the details of the inputs, outputs and operations of the process
[7] created by the process composer (shown in Figure 14)

that comes with BPWS4J. Once it is validated, it is deployed in the BPWS4J engine and it can be invoked like any other Web service.

3.4. Summary of Steps in Semantic Process Composition

This section summarizes how Semantic Web Processes are designed (using process templates), composed and executed.



```
<?xml version="1.0" encoding="UTF-8"?>
<definitions
  name="sample"
  targetNamespace="http://lsdis.cs.uga.edu"
  xmlns="http://schemas.xmlsoap.org/wsdl/"
  xmlns:soap="http://schemas.xmlsoap.org/wsdl/soap/"
  xmlns:tns="http://lsdis.cs.uga.edu/sample.wsdl"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema">
  <message name="getDetailsResponse">
    <part name="OrderPrice" type="xsd:double"/>
    <part name="PossibleOrderDeliveryDate" type="xsd:date"/>
  </message>
  <message name="getDetailsRequest">
    <part name="ToyId" type="xsd:string"/>
    <part name="ToyCount" type="xsd:int"/>
    <part name="LocationIdToDeliver" type="xsd:string"/>
  </message>
  <portType name="samplePortType">
    <operation name="getDetails">
          <documentation>Distributor's can use this file to input some order on toys to get the price and possible price for
          the order</documentation>
      <input message="tns:getDetailsRequest"/>
      <output message="tns:getDetailsResponse"/>
    </operation>
  </portType>
  <service name="getDetailsBusinessProcess">
 <documentation>This service is a business process in itself..clients just need to call this service to execute the
          process</documentation>
  </service>
 <slt:serviceLinkType name="sampleProcessSLT">
  <slt:role name="anyRole">
   <slt:portType name="tns:samplePortType"/>
  </slt:role>
 </slt:serviceLinkType>
</definitions>
```

Figure 12: Process WSDL

1. The WSDL description for the desired process is generated using a WSDL editor. In the example discussed in section 2.2, the activities *Receive Order Details* and *Return Details* will be represented in the WSDL file of the process. The process template will be linked to this file. The process template shown in section 3.2.5 is linked to the operation

getOrderPriceAndDeliveryDate in this WSDL file. This WSDL file can be annotated and published as a Web service.
2. A process template is opened or created in the process designer.
3. Activities are added to the template and control flow constructs are added to the templates (if needed).
4. Activities may be semantically annotated using two XML files representing discovery details and QoS specifications are linked to them.
5. Services are discovered (using discovery criteria), ranked (using semantic matching and QoS criteria) and selected for each activity.
6. Data flow between services is established (based on the selected service).
7. The executable process is generated by the process generator using the WSDL of the process, the process template and the WSDL files of the participating services.
8. The process is validated, deployed and it is ready for invocation.

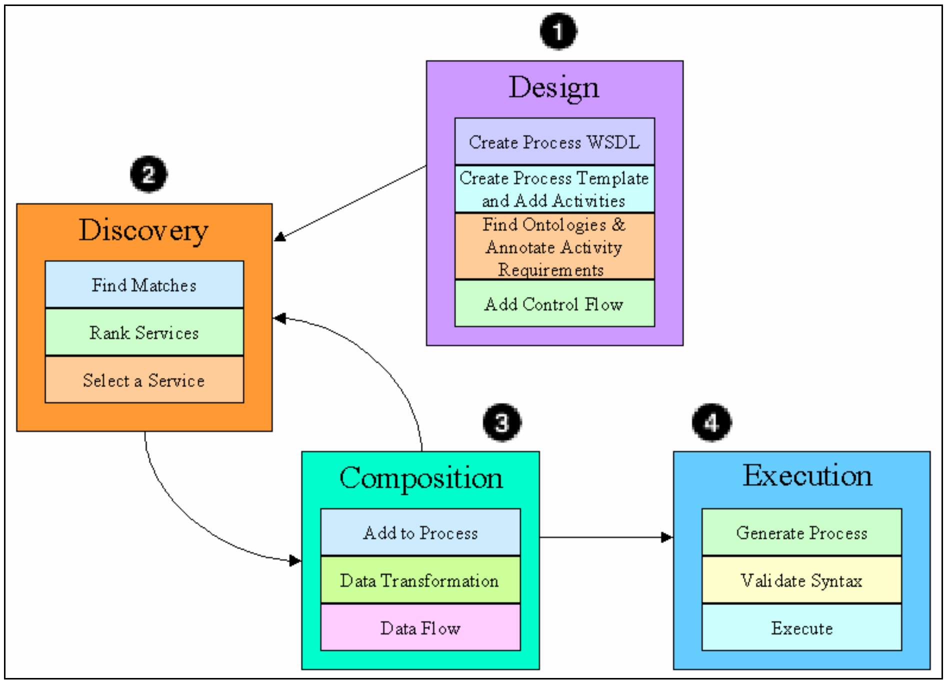


Figure 13: Steps in Semantic Web Process Composition

Figure 13 shows different phases in the semantic Web process composition. In step 1 (design phase), the figure specifically shows designing a process using semantic activity templates. Steps 2 and 3 depict that for each activity a service is to be selected and the data flow is established if needed. These steps are done repeatedly until all the activities are bound to a Web service implementation and data flow is established. After this, the actual executable process is generated.

4. Features of MWSCF

The increasing pressure from the market and competitors force the companies to always strive for efficiency and improvement in their processes. This creates the need for an environment that helps building, analyzing and executing processes that is integrated deeply into the business itself. This environment has to provide interactive features for building processes based on business requirements and application semantics. As a step towards this aim, we have completed an initial prototype implementation of the framework as described in section 3 that has the following features:

Semantically Enriched Service and Process Descriptions

This framework supports building process templates in which activities may be semantically described. This helps in building the executable process, preserving the semantics of each activity. Each activity will be achieved using a Web service. Binding a service to an activity at the design time may not be easy (and appropriate) considering the number of similar Web services that will be available in the future and their heterogeneity. Present standards like BPEL and BPML provide limited forms of dynamic binding. These standards include *portType* descriptions in the process definitions. Hence, to carry out an activity, only the services that implement that *portType* can be used. This type of hard coded binding is not always suitable for ever-changing e-business applications. Using semantic descriptions not only helps in efficiently finding relevant Web services to execute each activity, it also helps in reasoning about them and use it for dynamic binding in a process. Using semantic templates optimized flow or process execution could be calculated and QoS trade-off analysis could be done.

Configurable Processes

MWSCF provides an architecture where the processes are represented using templates, which are not bound to concrete service implementations. This feature is present in almost all process modeling languages. Our designer tool, in addition, allows users to build a process template and configure each activity in the process template using its semantic requirements to build an executable process according to the requirements. Using the builder, users can open an existing process template and configure activities in that process. This improves the usability of generic processes for different situations and, in addition, it also enables personalization of the processes based on the configuration parameters. This will help in the success of new business models like outsourcing of Web processes. Off-the-shelf ready made template can be bought and used (with or without modifications) instead of building it from the scratch. Common processes can be made available for rent/lease using value added service features like easy configuration, friendly interface for configuration, etc. For example, let us consider a typical composite Web service example "Conference Booking". This is a Web process by itself as it involves several activities like booking travel tickets, booking hotel, registering for the conference, etc. An organization that specializes in this type of business can create an abstract Web process template. The clients of the organization can use this template to feed in parameters like QoS of each activity, ranking and discovery details, etc. to build the actual process. The organization can then execute this configured process in its own service execution engine and return the results back to user. Let us consider another example, in intra-enterprise process that takes an order and delivers some product to the customer. Depending on the price that the customer is willing to pay for the delivery service, QoS parameters of the task that is involved in product delivery, can be configured so that the execution engine selects a relevant service that handles the product delivery order satisfying the required QoS criteria.

Comprehensive Framework for Web Service Composition

The MWSCF provides a comprehensive framework for Web Service composition. The MWSCA extends full life-cycle support for achieving semantic Web processes by providing an infrastructure to assist a user starting from service publication and discovery (MWSDI) to designing a process (Process Designer) and executing it (Execution Engine). The designer interface that we have developed as a part of MWSCF provides to easy-to-use interface. Using the built-in powerful discovery technique in the process designer, users can effectively compose a process. The framework provides graphical user interfaces where users can view the ranking of services and select the services for the activity that are appropriate for their requirements. A unique aspect of the framework is that it automatically retrieves the WSDL files for deployment and extracts information from them to generate the process. The generated executable process will preserve the semantics specified in the process template. All these user interfaces and features implemented, as a part of MWSCF will help in rapid and efficient development of Web processes.

Adaptability to any Process Specification Standard

The present implementation of MWSCF allows constructing process template with BPEL-like syntax and the actual process is generated in BPEL syntax based on BPEL schema. However, the generated executable process can be made independent of BPEL syntax. The process generator is implemented as a separate module independent of other modules in the MWSCF. Hence a pluggable process generator module can replace the existing module that generates BPEL process. If the new process generator module is able to generate executable processes in other specifications based on a different schema, then it can be used in the framework to generate a process following a different standard.

5. Related Work

There have been few research efforts and commercial tools to automate business processes to dynamically compose Web services and to use semantic Web techniques in Web service composition. In this section, we will discuss the related work that deals with Web service composition and other research efforts that are related to our work.

The main focus of our paper is creating semantic process templates and using it for executable process generation. There are a few papers that discuss process templates. For example, [40] discusses reusable process skeletons that implement some conversational logic. It argues that the notion of process templates and service libraries would help to speed up and ease the development of processes that incorporate B2B capability. In our work, we have discussed creating templates and storing them in a repository. To ease the discovery and usage of these templates we have categorized them.

Taxonomies of processes have been discussed in [41]. It discusses classifying process instances depending on their characteristics, such as outcome of the process instance, duration of execution, etc. Our work discusses classifying the process templates based on their semantic capabilities.

There are several systems that help in Web service composition. [42] discusses a platform where Web services are declaratively composed and executed in a peer-to-peer environment. It does not perform dynamic discovery. The user has to discover services and then define composition using state-chart diagrams. Then the composition can be executed in a P2P fashion with the help of peer software components coordinators for each constituent Web service. [43] discusses a case based reasoning mechanism for discovery of services to form a composite Web service. The participating services are selected based on the relationships between the services and the constraints involved. eFlow [44] is another system that allows composing, customizing and deploying e-services. The process is modeled as a graph that defines the control and data flow. The nodes represent services in the process. A node could be either an ordinary node which is statically bound to a service or it could be a generic node which is specified with a configuration parameter and a list of services out of which one is bound to the node during run time. They have the notion of process templates and categorizing them in a hierarchy. eFlow also supports dynamic discovery technique using a mediator and the associated rules. Unlike our system neither the discovery mechanism nor the process templates in these systems is semantic.

The fundamental assumption in our work of annotating process definition with ontologies is that the candidate services are semantically described and discovered. The need for semantics in service description has been discussed in quite a few of previous publications [5, 14, 45, 46]. DAML-S is a popular initiative in this direction to describe service capabilities using ontologies. A DAML-S based prototype for semi-automatic composition of services has been discussed in [47]. It provides a composer that will aid the user to select services for each activity in the composition and to create flow specifications to link them. Upon selecting a service, the services that can produce output that could be fed as the input of the selected service are listed after filtering based on profile descriptions. The user can manually select the service that he wants to fit in at a particular activity. After selecting all the services, the system generates a composite process in DAML-S. The execution is done by calling each service separately and passing the results between services according the flow specifications. This kind of step-by-step composition of Web services using DAML-S descriptions has also been discussed in one of our previous papers [48]. It discusses using ontologies to solve the problems in discovery of Web services and to resolve the structural and semantic heterogeneity among these services. The discovery methodology and the set of algorithms discussed in this related work supports discovery of services based on functional requirements and operational metrics. Though all of these related work attempt to solve the same problem (semantic Web service discovery and composition) as that our work, the approach is different. Our work, instead of DAML-S, is based on the industry standards for Web services namely WSDL, UDDI and BPEL4WS. Our work does not discuss sequential composition where the service for an activity in the process is decided before deciding for the next activity. In our work, the entire composition can be defined as a template of semantically annotated activities, and the discovery of services for the activities need not be sequential.

We believe that our composition methodology is better than other present frameworks, because the richness needed in representing services and data in the e-business domain is captured well using ontologies. The use of ontologies to aggregate the products, services, processes and practices within the industry to realize successful net markets has been discussed in [49]. It argues that elements of commerce and relationships between them are used to model market places and identifies ontologies as the means to do that. It states that ontological engineering is the prime requisite for information and services aggregation. It encourages developing and using domain/industry specific ontologies. Representing the products and services using ontologies will help to understand them from the different viewpoints and roles with in that domain/industry. Another related work [50] discusses developing a Universal Business Language (UBL). UBL aims to define Business Information Entities at a semantic level. It is something similar to an ontology with a few restrictions [51]. Like ontologies, UBL is aimed to model the real world focusing on a domain (business) to enable semantic interoperability. Our paper discusses using standard vocabularies/ontologies to markup process templates for better interoperability and process generation. [52] identifies semantics as one of the important aspect that B2B protocol standards should aim to standardize. It also lists *business content* or *vocabulary* as one of the facets of semantics in B2B standards. Another related work [53] states that interoperating services need to agree upon vocabularies, document formats and conversation definitions. They add that, in addition to this, agreement has to be there between various horizontal and vertical industry segments to use the standard vocabularies and conversations. [8] proposes Web Services Modeling Framework (WSMF) to enable flexible and scalable e-commerce using Web Services. It discusses a conceptual model for developing, describing and composing Web services. It advocates using semantic Web techniques to deal with the problems of heterogeneity and scalability in e-commerce. It also discusses different types and approaches for scalable mediation between trading partners in e-commerce. We realize the importance of the mediation mechanism to deal with inherent heterogeneity in an open and flexible environment. This is a separate research direction. Hence we have deferred that for future work. However, our work reiterates the need for using semantics both in service description and abstract process definition to help make the vision of universal interoperability in e-business a reality.

6. Conclusions and Future Work

Web services have created a major wave in the IT industry. Several standards are being proposed, consortia have been created and academic research has increased rapidly. The obvious reasons are the immense power of Web services with regards to e-business and the commercial value behind them. The Web services are indeed useful for easier, faster integration, good in terms of return of investment (ROI), establishing friction free markets, rapid value added assembly of services, etc. However, some of the inherent problems of e-business like scalability and semantic interoperability are not solved by the service-oriented architecture provided by Web services. The convergence of ideas, findings, and results from various initiatives like ebXML, Semantic Web and Web services can bring about better solutions.

Our work is on applying Semantic Web techniques to design e-business processes. Applying [54] Semantic Web findings to Web services technologies and use them for e-business could revolutionize the existing business models and the way they are carried out. This idea has received much attention and support both from academia and industry. For example, [55] addresses these problems with a framework that aims to align concepts known from the Semantic Web and the ebXML initiative and [56] discusses using Web services for implementing business processes and the need for Business Process Management to use Web services for dynamic e-businesses.

Using Semantic Process Templates in MWSCF provides following advantages:

- It helps in rapid process composition. The discovery of services need not be performed during template construction and can be delegated to the system.
- It is not necessary to build a process from scratch. Templates can be configured and reused.
- Process design is flexible as it is independent of web service *portTypes*. The change in partner interface without change in the semantics of the interface does not affect the process template or the discovery of services.
- Process re-design is greatly facilitated.
- Ready made templates can act as business/reference models and could be re-used by different organizations that want to implement same process with different services.

Our work does not take into consideration the B2B protocol standards that are crucial for inter-enterprise collaboration and achieving public processes. Our work focuses on the private processes of the enterprises that need to incorporate few external services. It is also applicable for process composition that does not involve complex B2B protocol. We understand that typically business transactions occur using some B2B protocol standard [52] that defines the message formats exchanged, sequencing, security, etc. There are several domain specific (Rosetta Net [57]) and domain independent standards (ebXML BPSS [58]]) that focus on different aspects of the B2B protocol. In addition, there are Web services standards (WSCI[8] [59], WS-CS [60]) to define message exchange in a business collaboration and choreograph the activities in the collaboration. These standards aim to improve the stateless synchronous/uncorrelated asynchronous model of interaction supported by WSDL. A multi-party collaboration is carried out either by using a global controller that coordinates various activities on behalf of the involved parties, or using a mechanism [61] that links a data and messages from visible public processes to the private organizational processes. In any case this is outside the

[8] The convergence of complementary standards happened in the case of WSCI and BPML aims to provide comprehensive view of role of businesses in a collaboration and the flow of activities that characterize each business

scope of a process specification language like BPML or BPEL[9] and as well as outside the scope of our work too. We foresee the convergence of standards like BPEL, WSCI, ebXML to realize a powerful e-commerce model. This convergence in conjunction with Semantic Web techniques will revolutionize the way businesses are done over the Internet.

Future research directions that we are beginning to explore include the following:

- Specifying collaboration in the process template and using an algorithm like the one discussed in [62] to check the compatibility of services to engage in a conversation.
- Building own engine for better control over the process execution and performing sub-conversation within a process.
- Extending process templates to capture the behavior of the intended process at high level and providing direct mapping to the formalisms like state charts or Petri nets etc. to enable process verification [63] and simulation [64, 65].
- Using a template in conjunction with other template [66] and a related analysis.
- Incorporating important e-business aspects like negotiation [67], Service Level Agreements [68] and contracts [69] in template design, service discovery and process generation.
- Specifying goal definition as a part of process template. Goal definitions will represent a business goal in high-level representation in some standard format like UML, and
- Investigating possibilities to represent preconditions and effects in a more expressive way and using it effectively during service discovery and process generation.

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Appendix A:Generated Process follows

The following listing shows an executable process generated from the template shown in figures 5 and 6. During process generation 2 files are created. The first file has the executable BPEL process and the second file is a WSDL file (sample-utils.wsdl in this example) that has definition for all the service link types that are given in *partner* elements.

A sample executable process that is generated is as follows:

```
<process name = "sample"
      xmlns:NS1 = "http://lsdis.cs.uga.edu"
       xmlns:tns-utils = "http://lsdis.cs.uga.edu//sample-utils.wsdl"
        xmlns:NS2="http://lsdis.cs.uga.edu:7001/axis/services/sample/axis/services/sample"
          xmlns:NS3="http://decatur.cs.uga.edu:8080/axis/services/sampleSupplierService7
          /axis/services/ sampleSupplierService7"
          xmlns:NS4="http://decatur.cs.uga.edu:8080/axis/services/sampleDelvieryService
          23/axis/services/sampleDelvieryService23"
      xmlns = "http://schemas.xmlsoap.org/ws/2002/07/business-process/">
  <partners>
   <partner name = "caller" serviceLinkType = "NS1:sampleProcessSLT"/>
   <partner name = "service-provider-1" serviceLinkType = "tns-utils:provider-1-SLT"/>
   <partner name = "service-provider-2" serviceLinkType = "tns-utils:provider-2-SLT"/>
   <partner name = "service-provider-3" serviceLinkType = "tns-utils:provider-3-SLT"/>
   </partners>
  <containers>
    <container name = "request" messageType = "NS1:getDetailsRequest"/>
    <container name = "response" messageType = "NS1:getDetailsResponse"/>
    <container name = " InventoryCheckActivity -request"
                 messageType = "NS2:checkInventoryRequest"/>
    <container name = " InventoryCheckActivity -response"
                 messageType = " NS2:checkInventoryResponse"/>
    <container name = "DeliveringToysToDistributor-request"
                          messageType = " NS2:arrangeDeliveryRequest"/>
    <container name = "DeliveringToysToDistributor -response"
                          messageType = " NS2:arrangeDeliveryResponse"/>
    <container name = "FixProce-request" messageType = " NS2:fixPriceRequest"/>
    <container name = "FixPrice-response" messageType = " NS2:fixPriceResponse"/>
    <container name = "FinalizePrice-request" messageType = " NS2:finalizePriceRequest"/>
    <container name = "FinalizePrice-response" messageType = " NS2:finalizePriceResponse"/>
    <container name = "QuerySupplierPartner-request"
                    messageType = " NS3:orderToyPartsRequest"/>
    <container name = "QuerySupplierPartner-response"
                    messageType = " NS3:orderToyPartsResponse"/>
    <container name = "DeliveryPartnerService-request"
                    messageType = " NS4:arrangeDeliveryRequest"/>
    <container name = "DeliveryPartnerService-response"
                    messageType = " NS4:arrangeDeliveryResponse"/>
    <container name = "AskAssemblyLine -request"
                    messageType = " NS2:assemblyServiceRequest"/>
    <container name = "AskAssemblyLine -response"
                    messageType = " NS2:assemblyServiceResponse"/>
</containers>
<sequence name = "sequence-1">
  <receive name = "receive" partner = "caller" portType = "NS1:samplePortType"
        operation = "getDetails" container = "request"
        createInstance = "yes"/>
  <assign>
    <copy>
      <from container = "request" part = "ToyId"/>
      <to container = "InventoryCheckActivity -request" part = "ToyIdentifier"/>
    </copy>
    <copy>
      <from container = "request" part = "ToyCount"/>
      <to container = “InventoryCheckActivity -request" part = "NoOfToys"/>
    </copy>
  </assign>
  <invoke name = "InventoryCheckActivity" partner = "service-provider-1"
        portType = "NS2:IntraOrgServicesPortType"
        operation = "checkInventory" inputContainer = " InventoryCheckActivity -request"
```

```
         outputContainer = "InventoryCheckActivity -response">

     <assign>
       <copy>
          <from container = " InventoryCheckActivity -response" part = "ToysCountToOrder"/>
          <to container = "QuerySupplierPartner-request" part = "OrderCount"/>
       </copy>
       <copy>
          <from container = "request" part = "ToyId"/>
          <to container = "QuerySupplierPartner -request" part = "IdentifierForToy"/>
       </copy>
     </assign>
     <switch name  =  "switch-1">
       <case  condition  =  "bpws:getContainerData('InventoryCheckActivity-response',  'return')  =
'no'">
          <sequence name  =  "sequence-3">
               <invoke name = "QuerySupplierPartner" partner = "service-provider-2"
                         portType = "NS3:SupplierPartnerPT"
                         operation = "orderToyParts"
                         inputContainer = "QuerySupplierPartner -request"
                         outputContainer = "QuerySupplierPartner -response">

               <assign>
                 <copy>
                       <from container = "QuerySupplierPartner-response" part = "PickUpDate"/>
                       <to container = "DeliveryPartnerService-request" part = "CollectDate"/>
                 </copy>
                 <copy>
                       <from container = "QuerySupplierPartner-response"
                              part = "PickUpLocationIdentifier"/>
                       <to container = "DeliveryPartnerService-request" part = "CollectLocationId"/>
                 </copy>
                 <copy>
                       <from expression = "'AA-465'"/>
```

```
                    <to container = "DeliveryPartnerService-request" part =
"DeliveryLocationId"/>
              </copy>
              <copy>
                    <from expression = "'AIR-CARGO'"/>
                    <to container = "DeliveryPartnerService -request" part = "DeliveryMeans"/>
              </copy>
            </assign>
         <invoke name = "DeliveryPartnerService" partner = "service-provider-3"
                     portType = "NS4:DeliveryPartnerPortType"
                     operation = "arrangeDelivery"
                     inputContainer = "DeliveryPartnerService-request"
                     outputContainer = "DeliveryPartnerService-response">
            <assign>
              <copy>
                    <from container = "DeliveryPartnerService -response" part = "DeliveryDate"/>
                    <to container = "AskAssemblyLine -request" part = "InDate"/>
              </copy>
            </assign>
         <invoke name = "AskAssemblyLine" partner = "service-provider-1"
                    portType = "NS2: IntraOrgServicesPortType"
                     operation = "assemblyService"
                     inputContainer = "AskAssemblyLine-request"
                     outputContainer = "AskAssemblyLine-response">
        </sequence>
      </case>
    </switch>
    <assign>
      <copy>
           <from container = "request" part = "DeliveryLocation"/>
           <to container = "DeliveringToysToDistributor -request" part = "DeliveryLocationId"/>
      </copy>
      <copy>
           <from container = "request" part = "DeliveryMeans"/>
```

```
          <to container = "DeliveringToysToDistributor -request" part = "DeliveryMeans"/>
    </copy>
    <copy>
          <from expression = "'AL-465'"/>
          <to container = "DeliveringToysToDistributor -request" part = "PickUpLocationId"/>
    </copy>
    <copy>
          <from container = "AskAssemblyLine-response" part = "OutDate"/>
          <to container = "DeliveringToysToDistributor -request" part = "CollectDate"/>
    </copy>
    <copy>
          <from container = "request" part = "ToyCount"/>
          <to container = "FixPrice-request" part = "ToyCount"/>
    </copy>
  </assign>
<sequence name = "sequence-2">
  <flow name = "flow-1">
    <invoke name = "DeliveringToysToDistributor" partner = "service-provider-1"
           portType = "NS2:IntraOrgServicesPortType "
           operation = "deliveryService"
           inputContainer = "DeliveringToysToDistributor -request"
           outputContainer = "DeliveringToysToDistributor-response">
    <invoke name = "FixPrice" partner = "service-provider-1"
           portType = "NS2: IntraOrgServicesPortType"
           operation = "fixPrice" inputContainer = "FixPrice-request"
           outputContainer = "FixPrice-response">
  </flow>
  <assign>
    <copy>
          <from container = "FixPrice-response" part = "Price"/>
          <to container = "FinalizePrice-request" part = "DeliveryCost"/>
    </copy>
    <copy>
          <from container = "DeliveringToysToDistributor-response" part = "Cost"/>
          <to container = "FinalizePrice-request" part = "ToysCost"/>
    </copy>
  </assign>
  <invoke name = "FinalizePrice" partner = "service-provider-1"
        portType = "NS2:IntraOrgServicesPortType "
        operation = "finalizePrice" inputContainer = "FinalizePrice-request"
        outputContainer = "FinalizePrice-response">
 </sequence>
  <assign>
    <copy>
          <from container = "DeliveringToysToDistributor-response" part = "DeliveryDate"/>
          <to container = "response" part = "PossibleOrderDeliveryDate"/>
    </copy>
    <copy>
          <from container = "FinalizePrice-response" part = "FinalCost"/>
          <to container = "response" part = "FinalCost"/>
    </copy>
  </assign>
 <reply name = "reply-1" partner = "caller" portType = "NS1:samplePortType"
       operation = "getDetails" container = "response"/>
 </sequence>
</process>
```