A Collaborative System Software Solution for Modeling Business Flows Based on Automated Semantic Web Service Composition

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Nowadays, business interoperability is one of the key factors for assuring competitive advantage for the participant business partners. In order to implement business cooperation, scalable, distributed and portable collaborative systems have to be implemented. This article presents some of the mostly used technologies in this field. Furthermore, it presents a software application architecture based on Business Process Modeling Notation standard and automated semantic web service coupling for modeling business flow in a collaborative manner. The main business processes will be represented in a single, hierarchic flow diagram. Each element of the diagram will represent calls to semantic web services. The business logic (the business rules and constraints) will be structured with the help of OWL (Ontology Web Language). Moreover, OWL will also be used to create the semantic web service specifications.

Keywords: *automated service coupling, business ontology, semantic web, BPMN, semantic web.*

1 Introduction

Companies are investing large sums of money in managing business processes. The majority of business processes have been documented so that to create complex management models. Due to the high amount of information and the transformations that occur in the field of IT&C, companies are confronting with problems that became difficult to manage and solve according to the traditional methods. In order to efficiently handle the problem of business flow modeling, ontology, semantic web and intelligent-agent based systems were developed.

By using this technology, data exchange and collaborative process are enabled.

The Semantic Web manipulates machine-processable information and enables communication and collaboration across business flows, between computers without human intervention. Therefore, the process of business flow management and coordination will be automated. Furthermore, the semantic web represents an important tool for the knowledge management process, a key factor in assuring companies' an increased level of performance. Technological progress depends on the access to more and more knowledge and information. The new society proposes to make innovation and to produce knowledge [1].

According to [2], by focusing attention on the importance of the problem-solving strategy designed to transform knowledge into business value, the research work was based on the best understanding of the connections existing between knowledge management practices and the organization's objectives.

Our paper enlarges upon a collaborative software solution for modeling knowledge in business flows. A business flow is formed of a set of business processes. According to [3] a business process is a collection of related, structured activities or tasks that produces a specific service or product (serve a particular goal) for a particular customer or customers.

In order to model business processes there is a series of languages that is used nowadays: UML (Unified Modeling Language) and BPMN (Business Process Modeling Notation). The novelty of the proposed solution resides in the fact that it will include specific features in order to enable automated semantic web service composition for modeling enterprise collaborative processes and tools for modeling and simulating business scenarios.

By proposing this solution we intend to develop a business process model which is able to permit semantic annotation by using ontologies and also designing adaptive business aspects according to the situation and the specific environment.

This type of model can be seen as a diagram which will be able to represent all the steps of a business flow, the involved agents/actors and the course of action. Each element of the diagram is in fact a call to web services which contain specific functionalities. The solution will also have a semantic modeling language based on ontology starting from OWL, a query language which will be an extension of BPMQ, and also simulation and adaptive tools on concrete working situations. The application will integrate the adaptive semantic model based collaboration, with web service composition functionality and cognitive agents. To be more specific, starting from the general ontologies specially designed for a business process combined with adaptive features and the web services that contain methods for implementing business logic intelligent systems will be developed. The obtained systems will be able to simulate real business situations. In order to correctly model a business process, it is necessary to follow certain steps according to BPMN standard.

2. General working scenario for business flow design using BPMN standard

According to [4], BPMN standard, a single process diagram will be implemented. This diagram will be easy to use and understand, even by less IT experienced persons. In addition to this, the diagram will also be intuitive which will enable complex business processes modeling that will lately be mapped into the implementation, simulation and execution languages.

In order to develop the solution for modeling a business process, the following steps should be taken:

- to identify the most important events and processes that compose the business flow
- to model the identified events and processes by using specific graphic elements
- to determine the business logic behind the events and processes
- to analyze the events and processes that occur and to implement the web services' appropriate methods

In addition to this, the solution that we plan to develop will bring new features such as:

- integrating specific tools for converting OWL-ontology language into a specific web service description
- implementing semantic web service composition
- centralizing the results obtained from web service calls and web service cooperation.

These features are necessary in order to assure portability and service interoperability for a collaborative system.

According to BPMN standard, after identifying the most important events, the decision elements and also flow branching elements will be determined. These elements are implemented by using specific blocks called "gateways" [4]. The gateways are elements similar to decision symbols from logical schemas. The diagram

Each business event (situation) is designed with the help of block elements called processes. A process can be detailed by using other elements called sub processes. The sub processes are designed in a separate diagram which is connected with the main diagram by using parent process blocks. The processes that cannot be decomposed in sub processes are considered tasks. The decomposed processes are represented using the "+" symbol next to the process name. If a process does not have the sign next to its name, that process is considered to be a task. Grouping elements such as "pools" are used in order to specify which is the responsible for executing a certain process or event. The "pools" can as well be portioned so that to offer additional details. The events that are being executed can be of different types and complexities. When complex business flow processes are modeled, more complex events, timers, triggers, business rules and error conditions are to be used.

The decision blocks that model the process interaction logic will have specific implementations for each type of logic operator: "or", "and", "xor". Furthermore, the standard offers the possibility to model complex decisions with the help of logic operations composition.

The BPMN standard [4] also permits reality close business flow modeling and business rules definition elements. The system does not enable blocks connection for elements that are not compliant with the defined business rules. Therefore, the risk for introducing logical errors is diminished.

The set of transformations that occur along the business flow happen with the help of business processes. Furthermore, in order to model data along the business flow diagram, the main data types must be identified, and after that, data object will be used. Data objects are artifacts that represent electronic and physical elements. However, basically they can be seen as entities corresponding to database tables or classes corresponding to Object Oriented Models. Data modeling can be optional because it does not affect the business flow. It is more of a detailed description of the processes composing the flow.

Whilst the above presented working scenario represents a logical description of the business flow, the simulation model refers to "miming" the business operations which will be implemented through step by step events testing. During the simulation process, performance metrics will be recorded offering the possibility for further analysis and evaluation. The advantage of this stage is that it substantially reduces the risk of making mistakes with severe consequences in the real working and business environment.

Another important stage in the business flow management process by using the BPMN standard is the business model mapping over the linguistic modeled. While BPMN uses BPEL4WS, we plan to use OWL-S because our solution will use ontologies in order to develop the semantic business model. Therefore, the OWL-S will be easily integrated and will be used in order to realize the automated service coupling. In our application, the semantic and lexical rules will be created starting from heuristics in conformity with the linguistic rules and economic logic. The linguistic model will be based on the OWL language for modeling and structuring the information.

Nowadays, the majority of linguistic models uses XML and is built over the WSDL (Web Service Description Language) according to W3C standards. The major feature of WSDL is that the language combines static interfaces descriptions for information binding with certain communication protocols.

With the help of linguistic model the following elements are being represented: data flows, messages, events, rules, constraints, exceptions, alternative situations, different types of transactions, group functionalities, In order to implement a business model based on interoperability between agents and collaborative systems, it is very important to pay attention to the web service model. The web services contain specific functionalities for each element of the diagram. Web services represent the basis for the previously described model elements. This stage will also have five sub stages:

- designing the business process
- developing the web services which implement the functionalities for each model component
- simulating the process and realizing certain modifications in order to enhance performance
- web service publishing
- web service modeling related to the business processes by assembling and coordinating their behavior

3. Semantic Web

The Semantic web is a concept firstly introduced by Tim Berners-Lee in 1998 in "The Semantic Web Road Map". The idea was lately developed and became an important project for the World Wide Web Consortium (W3C). The W3C is working to improve, extend and standardize the system, and many languages, publications have already been developed.

The growing trend in software architecture is to build platform-independent software components, called web services that are available in the distributed environment of the Internet. Furthermore, composition of Web services has enormous potential in business-to-business or enterprise application integration. The functionality of a web service needs to be described with additional pieces of information, either by a semantic annotation of what it does and/or by a functional annotation of how it behaves.

The Semantic Web is targeted to easily access documents over the internet by adding machine-processable meaning on the web pages. The Semantic Web has two major components. On one hand there is the component that refers to common formats for integration and combination of data obtained from diverse sources, different from the original web where data is to be found by interchanging and interlacing documents (words and phrases rather than meanings). On the other hand, there is the language component which refers to the language used for recording objects, the semantic relationships that are established between terms according to the real world meanings and connections. [5]. A computer or intelligent agent based system can depict a series of rules and models by analyzing an initial database of terms and concepts and then move on or redirect towards a wide range of other databases connected to the starting point and in between by meaning. Therefore, the process of business flow management and coordination will be automated. Business flow management is typically viewed to reside between fully vertically integrated firms, where the entire material flow is owned by a single firm and those where each channel member operates independently. The Semantic Web is an evolving collection of knowledge, built to encourage collaborative work on the internet. Users are responsible for adding what they know and find answers to their questions. Information on

the Semantic Web is maintained and processed in a structured message form, different from the natural language. As a consequence, information search, exchange and update are easily realized and can also be automatically managed.
The Semantic Web uses metadata in order to add extra meaning to data and also to apply knowledge representation techniques by using distributed and collaborative environments. The metadata provide a detailed description of data referring to the collecting methods that were used, the user responsible for that specific information and the standard used to structure the data. By adding metadata to the existing Web (the technique called semantic annotation of web pages), the Semantic Web will allow both humans and machines to find and use data in different manners than before (searching after the semantic meaning rather than the word or phrase).
Berners-Lee and the W3C present Semantic Web as a common framework that allows data to be shared and reused across applications, enterprises and communities. According to [6] the knowledge is expressed as descriptive statements, relationships that exist between one concept and another. The Semantic web main components, technologies and standards are the following: URI, XML, XML Schema, RDF, RDF Schema and OWL.
The basic meta-language used by the Semantic Web is the XML. This meta-language was chosen because it can facilitate document information structuring and it is easily interpreted by browsers. It also provides the possibility for defining hierarchic and structural relationships between tags. The XML has no predefined semantics, therefore the document semantics will be defined by the applications that generate that specific document.
Another important element designed by the W3C for developing the Semantic Web is the Resource Description Framework (RDF). RDF is a group of specifications that play the role of metadata and it is based on the XML meta-language.
The main use of the RDF is to model knowledge that is to determine the connection between concepts and meanings and also the semantic and lexical relationships that exist between terms. The metadata of the RDF are used in order to describe "the semantic resources" that are integrated by using the triple groups: subject-predicate-object expression. RDF combines URIs and text strings into triples which express basic concepts or statements. The Semantic Web adds a type to this link, making it easily accessed by automated smart agents.
In order to define ontologies, the W3C developed an extension of the RDF, called RDFS (RDF Schema). Its main use is to structure RDF resources.
The main RDFS components are included in the ontology language known as OWL. The most important RDFS elements are: classes and subclasses, plus property domain and range.
But, according to [7] the major advantage of the Semantic Web is that people can collaboratively create ontologies and build common vocabulary without centralized control. Ontologies are the most important component of the Semantic web. They consist of logical, lexical and semantic relationships that are established between terms. The ontology for the World Wide Web has classifications, some inference rules and also semantic and lexical constraints. Ontologies generally describe: individual objects, classes, attributes, relations**.** The relations can be both semantic and lexical (meronym, holonym, hypernym, hyponym, coordinate terms, etc) specific for each part of speech.
The most common languages used for modeling ontologies are: OWL Lite and OWL Full.

4. Semantic Web Services

According to [8] the term "Web Services" can be confusing because it is often used in different ways. Compounding this confusion is term "services" that has a different meaning than the term "Web Services." *Web Services* refer to the technologies that allow for making connections. *Services* represent the elements that are being connected with the help of Web Services. A service is the endpoint of a connection. Also, a service has some type of underlying computer system that supports the connection offered. The combination of services - internal and external to an organization - makes up a *service-oriented architecture*.
Services are platform-independent entities that can be described, published, discovered, and coupled in different ways. They can perform different and complex functionalities from answering simple requests to executing sophisticated business processes requiring peer-to-peer relationships among multiple layers of service consumers and providers. Furthermore, they have features that permit software reengineering and also software reusability and transformation into network-available service. [9]
The specification of a web service is expressed in WSDL (Web Services Description Language),

which presents only the syntax of messages that enter or leave a computer program. The order in which messages have to be exchanged between services must be described separately in a flow specification.

Nowadays, technologies for web services only provide descriptions at the syntactic level, making it difficult for requesters and providers to interpret or represent statements such as the meaning of inputs and outputs, applicable constraints or the business rules they are implementing.

The semantic web services are developed so that to facilitate web service cooperation and interoperability. In order to achieve this objective, they provide functionalities for creating, managing and transforming semantic mark up.

According to [10] the web services flow specification languages are BPEL4WS and WSCI. The semantic annotations are considered to be conditions and effects of web services and are explicitly declared in the Resource Description Format (RDF) using terms from pre-agreed ontologies. Consequently, it enhances the ability of smart agents to understand, transform and deliver messages over the web.

5. Semantic Web Service Composition

The main goal for using semantic web services is that to increase the possibility of automated service discovery, composition invocation and monitoring over the web and in this manner to assure interoperability and collaboration between different business flow modeling applications.

The semantic web community is conducting complex studies in order to determine the most efficient methods for synthesizing web services' complex behaviors and determining an universal semantic representation for the transformation that occur.

In this way, web services will be easier to discover on the internet by specific subscribers and also it will be easier to assure web service composition and interaction in Service Oriented Architecture based solutions.

According to [10] a business process or application is associated with some explicit business goal definition that can guide a planning-based composition tool to select the right service. A business process model describes the processing of persistent data objects in discrete process steps. The applications that implement web service composition have a SOC (Service Oriented Computing) architecture that is based on SOA. This type of architecture uses services to support the development of rapid, low-cost, interoperable, evolvable and distributed applications.

As it is stated in [9], "according to SOC research road map, SOC provides a logical separation of functionality into three planes: service foundations at the bottom, service composition, service management and monitoring.

This logical stratification is based on the need to separate:

- basic service capabilities provided by a middleware infrastructure and conventional SOA from more advanced service functionality needed for dynamically composing services,
- business services from systems-centered services, and
- service composition from service management

The service characteristics cut across all three planes including semantics, nonfunctional service properties, and quality of service. QoS encompasses important functional and nonfunctional attributes such as performance metrics (for example, response time), security attributes, transactional integrity, reliability, scalability, and availability. Traditionally, QoS quantifies the degree to which applications, systems, networks, and other IT infrastructure elements support availability of services at a required performance level under all access and load conditions. Web services environments also demand greater availability of applications and introduce increased complexity in terms of accessing and managing services".

6. A proposed collaborative business flow modeling solution

According to the "Enterprise Interoperability Research Roadmap" [11], defined in 2006 by a European consortium and supported by the European Commission as a guideline for business innovation, "To meet their business objectives, enterprises need to collaborate with other enterprises. For some enterprises, doing business globally has become critical to their survival, while others discover new opportunities by focusing their business in a local setting. Enterprises, both big and small, need to establish cooperation agreements with other enterprises. Small and medium sized enterprises (SMEs), who need to specialize in niche activities in order to raise their own added value, particularly have to combine forces to compete jointly in the market.".

Starting from this our objective is to develop an integrated, open-source collaborative software solution. A collaborative system represents, from the implementation viewpoint, software entities

that are developed during a life cycle process that starts with the problem analysis and ends with the implementation of a fully functional software system. [12]
Having all the above mentioned facts in mind, the solution that we present will able to permit:
- semantic enterprise web services interoperability
- the possibility of modeling adaptive business processes as new web services are being discovered and composed
- a collaborative, flexible and scalable model for business processes

Our solution develops a business process model that includes components semantic annotation, business process adaptive features according to the specific business environment, and also collaborative processes that will be saved and evaluated so that to become future working flows.
The architecture (figure 1) will be composed of the following elements:
- a business flow design component
- a business rules developing component
- a semantic web service design component
- an implementation platform, having a SOC architecture, which will enable automatic semantic web service coupling
- a web service browser responsible for web service discovering
- the application platform, used to develop business application for specific business types

This solution will permit automated semantic web service coupling and discovery according to the business context.

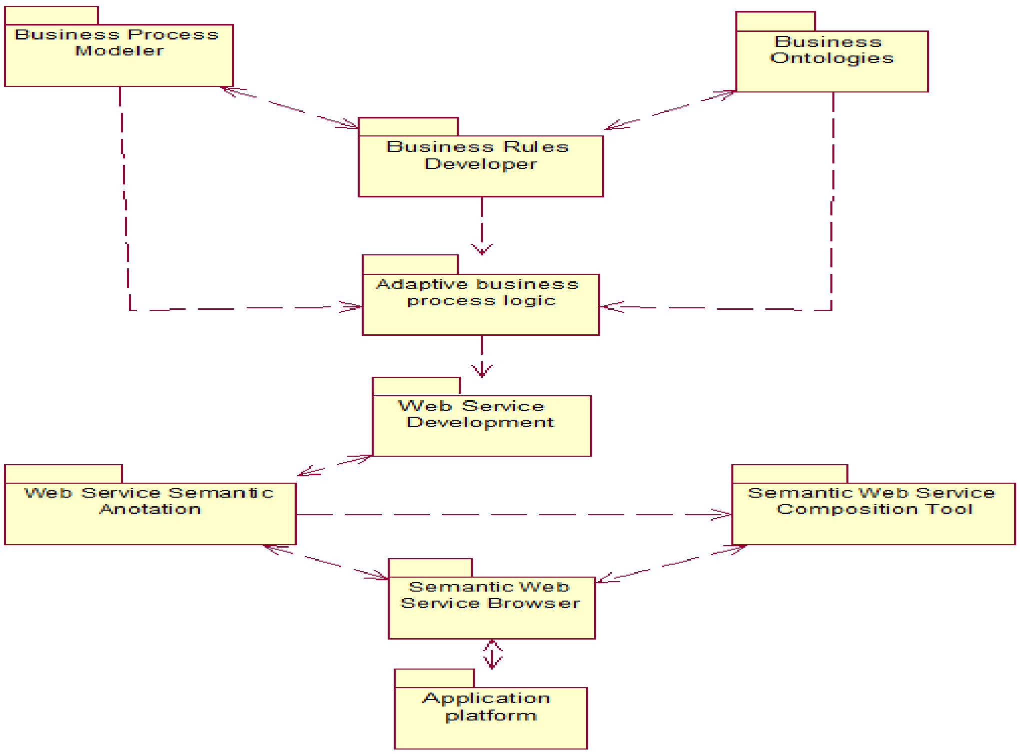

Fig. 1. Collaborative software solution architecture

Furthermore, it will also offer high semantic web service interoperability based on business ontologies. The business flow design component will be implemented according to the BPMN standard. The BPMN offered technologies, will be modified and adapted so that to easily permit service coupling by using an automated tool. Our solution will provide additional facilities to BPMN standard so that to permit the possibility of integrating automated generated OWL Lite code as we plan to use OWLS for web service coupling.
In order to automatically develop business rules as the result of the business rules developing component, we will use SWRL. SWRL is a Semantic Web rules-language, combining sublanguages of the OWL Web Ontology Language (OWL DL and Lite) with those of the Rule Markup Language (Unary/Binary Datalog).The semantic web service design component will im-

plement the OWL-S and WSDL. The service composition module will have two basic components:

- one element in charge with realizing the "composition"
- an inference engine

The inference engine will be provided with a knowledge database in which there will be information stored regarding other existing and known semantic web services. Furthermore, we will implement appropriate data mining algorithms and algorithms that are able to determine the semantic web similarities so that to realize the semantic web services matching.
The element that is doing semantic web service composition is the user interface that handles the communication between the human operator and the engine.
The inference engine is in essence an OWL agent that will be developed by integrating and "collaborating" with specialized OWL generators such as Protege or Semantic Works. Ontological information written in OWL can afterwards be converted into RDF triples and loaded in the knowledge database.
The engine will also provide rules for OWL development. These rules are applied to the information that is stored in the knowledge base of the inference engine. Furthermore, the rules can be applied to all elements, even to the class inheritance relationships that occur between classes and also to subclass relationships.
The tool that is responsible for semantic web service composition, will offer user interaction so that to increase the efficiency and the quality of the semantic web service composition. By implementing this feature, the user will have the possibility to choose from the available choices when needed. Furthermore, the user will be informed about the structure of the web services that will be coupled (details such as: functionality, results, parameters, history, etc will be available for the users). After the user designs the business model by using the business model designer, for each element in the diagram a call to the web service composition module is realized. A specific query will be generated and sent to the knowledge database. The engine will display the web services discovered into the web service browser. The user will choose a certain web service (this is the case when more web services responded to the users query), its choice will be recorded and a query will automatically be generated and sent to the knowledge database.

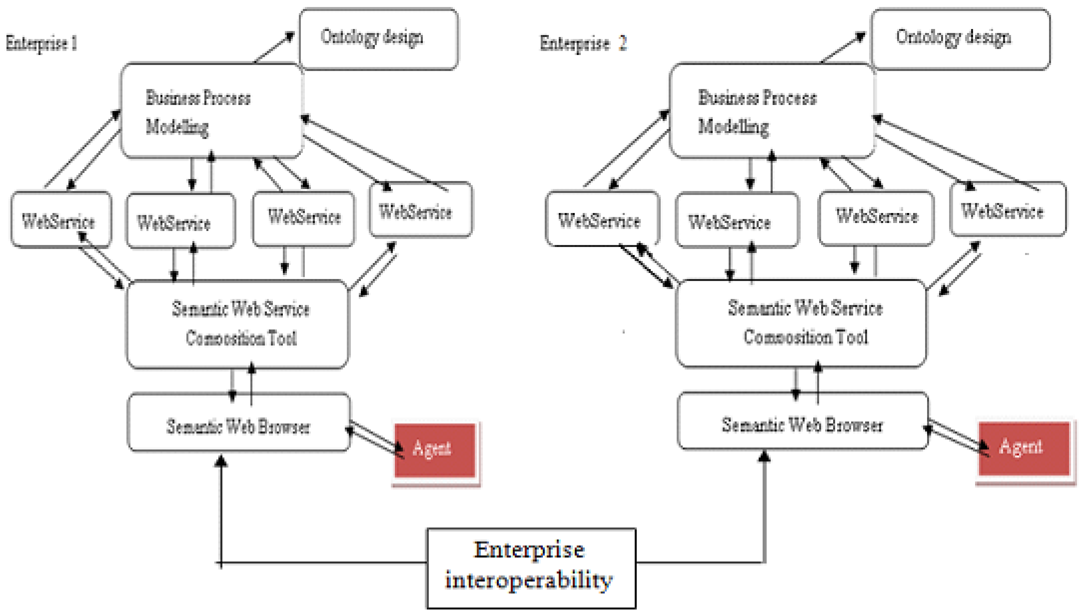

Fig. 2. The collaboration working scenario

The necessary data will be retrieved and the selected information will be displayed. The user will afterwards introduce the parameters.
The module that deals with semantic web service will also offer the user the possibility to display through the semantic web service browser different web service classes and to modify the discovered. Afterwards, there will be a web service filtering stage, feature available through the semantic web browser. During this stage, the web services that were discovered will be filtered according to the business rules design with the business rule developing component.
The manner in which the semantic web service

element that has to implement semantic web service composition works is the following: the web services that respond to the user's request are displayed; afterwards, the outputs of these web services will represent the inputs for the web services that follow the business rules and constraints.
The matching of two services is realized according to the description that is stored in the knowledge database. The description offers information like functionalities, parameters' type, parameters' number, results, etc.
If the service that is to be coupled does not perfectly match access will be restricted. On the other hand, if there is less difference between the two services the user will be informed and will be asked for permission of whether to couple or not the respective services. The results of the web service search are displayed in the semantic web browser in a list form organized in a descending order from the web services offering the exact match to those that offer generic match (those that slightly differ). The inference engine also orders the generic matches such that the priority of the matches are lowered when the distance between the two types in the ontology tree increases and also according to the level of the priority the user gave when choosing the web services that provide generic match.
The number of services displayed in the list as possible matches can be extremely high in many cases. Further, even if the number of services is low, the service names themselves may not be significant enough inform a user about their functionalities, or the short text descriptions from UDDI or other services descriptions would not be sufficient to fully describe the services.
When the name of the service and the other details from the knowledge database do offer sufficient information so that to distinguish the services, other non-functional attributes of the service such as location will be useful to determine the most relevant service for the current task. Therefore, location algorithms can be used, or non-functional attributes might be added to the database in the semantic web service module.
The resulted composed services will have a particular description a specific table in the knowledge database will indicate the web service hierarchy. This table will be queried and the semantic web service description module will generate a specific OWL code for the newly formed semantic web service. The semantic web service composition module will then publish the new web service and will make it available for further semantic web service composition.
The semantic web service composition is essentially based on the message exchange, therefore specific communication protocols have to be implemented and also enhanced security settings and functionalities have to be developed. Consequently, the user application will also serve as a control authority. In order to assure message exchange, the application has to implement the RPC protocol.
The semantic web service browser component will display the list of semantic web serviced discovered, that match the query and the business constraints. The semantic web service search occurs in the order specified in the business model diagram designed by the user. Each element makes a call to the web services. Then, the discovered web services that correspond to the functionalities that is represented by each element symbolizing a business process or task, will be associated to it and will be passed for further composition into the diagram.
The discovered semantic web service for each diagram element will also make calls if necessary so that to determine additional web services that can be coupled.
The latter component refers to the platform on which each business model created with the designer tool will be transformed into platform specific model and adapted to the specific business environment and situations.

7. Conclusions and Future Work

Nowadays, it is very important for the companies to cooperate in order to enhance performance and to reduce the duration of the time consuming activities. In order to attain these goals large scale, interoperable, scalable and platform independent collaborative systems have to be implemented.
The collaborative process is related to the partners' performance and economic activity. The economic results of one partner influence the performance of the others. In order to model the economic behavior of each partner, we use semantic models and business ontologies. With the help of the semantic interaction we can highlight the points in which they intersect. The structure for the negotiation process is somehow like tree structure.
In the future, we plan to implement the proposed solution and also to test it by developing a software application for supply chain business flow. We thought of this type of implementation because nowadays digital economy is gaining more and more field and the supply chain activity is

one of the most important types of business and it implies interoperability and high security requirements.

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