A service classification and selection framework for efficient provider discovery in a Cloud based Supply Chain

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Abstract

Due to the extremely high volume of web services available on the web, it is currently very difficult to improve the selection of the best services. Discovering good services is a very important step for building a dynamic supply chain. In this paper, we propose a framework that combines agent and web services technologies. Our proposed framework lies firstly on the classification and selection mechanism that permits to select the best services which can satisfy the customers' goals and reduce the response time cost. The main idea is to use concepts as multi-agent systems and web services to perform the different activities of a supply chain management system. The essential part of the framework is the UDDI cloud level and the agent level. The UDDI cloud level allows web services, which represent enterprises' business functionalities, to be classified, discovered, invoked, and composed by agents that are applied for supply chain management construction and partner's interaction.

Keywords – Supply chain management; multi-agent system; web services discovery; web services classification, web services selection.

1 Introduction

SC[1] systems are composed of interacting components, exhibiting a wide range of dynamic behaviors that interfere with scheduling and controlling an enterprise [Chen et al., 2005]. The human resources, funds, technologies and facilities of the SC members should be integrated. Therefore software vendors have realized the potential for applying cloud-based solutions into their SC strategies and activities to increase proficiency and profitability. However, using SC resources with a cloud-based solution and taking full advantages of manufacturing technology, information technology, network technology and computer become the important content of current SCM[2]. Furthermore, it must be noted that the competition is intense and the financial pressures are unrelenting. Companies are seeking ways to become more flexible and adaptive in response to the competitive international economic environment. SC is, then, a complex system which must manage a large number of services. This complexity is firstly due to the high number of autonomous enterprises and actors, which collaborate to achieve a given process. Secondly, the interactions between the actors change depending on the objectives and geographical location. Finally, as a result of the two previous characteristics, the actors face a lack of visibility in the global SC (provider, manufacturer, distributer, etc…). These sites only have a local visibility but are coordinated with other sites through product flows.

Evaluation and selection of providers in SC manufacturing organizations are very important. Because the price and quality of sold products is directly related to the price and quality of purchased raw materials. Therefore provider selection in a SC is important for multiple sourcing problems. Basing on the evaluation with regard to product quality, service, price, delivery time and emissions of candidates for providers, a pool of providers is chosen in the process of provider selection [Bajec et al., 2017].

With the rapid development of cloud computing, cloud service is becoming one of the research hotspots. Therefore, moving to a could-based solution for SC makes SC services management problems more and more important. As the current UDDI standard and implementation cannot describe the quality and low-level resources information of cloud service well, it is difficult to meet the new requirement of an optimal cloud services query, selection and access. Provisioning resources as a service in a scalable on-demand manner and QoS[3] guarantees are basic features of cloud

[1] **SC :** Supply chain
[2] **SCM :** Supply ChainManagement
[3] **QoS :**Quality of Service

computing notably cloud-based SC. Though cloud services are typically designed and implemented as web services [Ye et al., 2012]. Consequently, new technical challenges arise: how to classify services for cloud providers and select high cost-effective cloud services for service customers to access.

In this paper, we propose a framework that is based on the combination of web services and agent technologies. It contains two levels (UDDI cloud level and Agent level). The UDDI level in our framework collects the different information from the actors of the SC and organizes them into an easy-controlled structure. We estimate that the use of web services in building a dynamic SC and the discovery of the right services is an important step. The framework proposed provides a dynamic environment for different actors in the SC to cooperate. Thus, it is a new way of answering requirements, adapted of advantage to the current reality due to the simplicity of its structure. The agent level represents the society of software agents that manage the different steps of cooperation between actors in the SC. Two types of agents are proposed: the provider and consumer agent; each agent is assigned to model the facility and the interaction protocol to connect the agents that are defined. The intelligent agents interact with each other to accede, to transfer and to evaluate the information of the SC dynamically.

The remaining of this paper is organized as follows. Section 2 discusses some related work and indicates the contemporary drawbacks in SC interoperability progress. Section 3 presents the different levels of the proposed framework and their functionalities. Section 4 shows our experimental study. Finally, some conclusions and open research lines are presented.

2 Some Research Related Work

Nowadays, the organization systems dedicated to supply chain are increasing in complexity. It is relevant to provide innovative tools and decision support systems that can help them to communicate and share different information. The selection of providers in the supply chain is a very active area of research. There are different works that present approaches for modeling supply chain systems which span multiple organizations and that treat the selection of the efficient provider.

One of the necessary and important steps in managing the companies'corporate legitimacy and reputation is controlling and monitoring the provider evaluation and selection [Bai et al., 2010]. Moreover the papers related to the provider selection, the number of the researches incorporating the environmental and technical factors in provider evaluation and selection is rising. Several research works [Glock et al., 2011; Hu et al., 2014; Patil et al., 2016; Xiangshuo, 2018] determine how many providers should be selected and how much should be allocated to the selected providers. Although, the optimal strategy of single or multiple sourcing is a special case of provider selection and deriving the optimal sourcing strategy has been studied in [Bhattacharya et al., 2012 ; Serel, 2015 ; Wawasan, 2018]. Bouyakoub et al. [Bouyakoub et al., 2014] have presented a framework for web service publication and discovery in UDDI cloud for distributed systems such as supply chain ones. The framework, based on a multi-agent system, gives a new model for services' publishing and searching. The service description includes an enriched representation, composed of contexts and quality of service (QoS) parameters, in order to make more efficient the discovery and selection stages. In this proposition, the search agent uses a new quantitative similarity measure to calculate the correspondence rate between the client and the services profiles in order to provide users with appropriate services according to their contexts and required QoS parameters. In (Zhang et al., 2005), a mediate module ADDI (Agent-based extension to UDDI for SC management) has been proposed to organize the UDDI nodes published by the different corporations on SC and to establish a UDDI dynamic ranking model.

As a matter of fact, a number of researchers [Nfaoui et al., 2009; Gomez-Cruz et al., 2017; Sabs et al., 2018] have attempted to apply the agent technology to manufacturing integration, supply sourcing, supply chain management, negotiation, information transfer and knowledge sharing within a supply chain. These approaches and other research works [Rongfen, 2011, Rouzafzoon et al., 2016] have explored only the multi-agent system paradigm for supply chain management, none of them has integrated web services as the basic foundation to build the supply chain framework.

Until now, the research community debates on how to integrate the agents with service concepts. In [Wobcke et al., 2012], a discussion about the relationship between agent-based computing and service-oriented architectures is detailed. It explains what an agent based computing can offer to service-oriented architectures. Several works tried the combination of the agent paradigm with the web services technology.

The research work presented in [Kamalendu & Bill, 2014] has proposed a multi agent and web service framework for Collaborative Material Procurement System (CMPS) in a supply chain. In this work, the information in CMPS is used in two ways: business service rules and service description cases. It uses this hybrid information in order to form the appropriate provider, by using rule-based reasoning and case-based reasoning.

As we know, none of the above works has talked about the classification and the selection mechanism for the web services provided by the supply chain entities. Our current work is similar to the research works presented in [Bouyakoub et al., 2014] in terms of using the QoS to select the appropriate services but we notice that we have proposed two mechanisms: the classification mechanism and the selection one. The first one is to classify the UDDI nodes published by the different providers of the SC and the second one is to select the best services, it is based on the organization of web services in vectors according to their UF (Utility Function). Our purpose is to save time and efforts with optimizing the search for services. Therefore, the originality of our research work is that, it allows connecting components information systems in the distributed and coordinated activities in the supply chain in order to satisfy organizational purposes. In addition, we combine the advantages of agents and web services based on the common ground between them to design enterprises collaborative modeling in the supply chain in order to have a better interoperability. This interoperation considers the type Provider-Consumer negotiation.

The negotiation protocol presented in this paper has the following features: **1)** Intellective: the agents retrieve the most similar case of negotiation through a referential module which sums up experiences from the operations of agent to improve the negotiation efficiency. **2)** Cooperation: when one of the negotiation agents finds that the negotiation is a logjam, it will send the negotiation offer to the other agents in order to let the actors of the negotiation relation network discuss the offer. **3)** Universal: The presented negotiation protocol is based on the FIPA contract net protocol, which can be used to the negotiation of single issue, multi-issues, one-to-one and one-to-many. This negotiation mechanism fit to all kinds of supply chain.

3 Proposed Services Classification and Selection Framework

The proposed framework is based on web services and multi-agent technologies. It is based on two levels: the UDDI cloud level and the agent one. The UDDI cloud level has been proposed to classify and select the best services which must be consistent among the nodes of a UDDI cloud. The agent level consists of a set of agents that seek to coordinate and synchronize different activities.

As known, UDDI provides only the data structure to store web services in separated groups. However, in the SC field, this syntactic registry is often insufficient. Therefore, our contribution consists of proposing a UDDI cloud level that represents an important element in cloud-based SC. It includes a set of UDDI web service registries. Its role allows providing web services' data published by the SC actors. This level increases productivity, competitiveness and streamline communication between different parts of SC. However, to manage interactions between UDDI cloud level and SC level, we need a strategy for providing, selecting and using resources (services). The principal idea consists of focusing on the way how services are structured in UDDI element, and how get the best service which responds to the requester's desires. We must establish, at the first step, the web service classification mechanism. At the second step, we propose to use the Utility Function calculation which consists in using the attribute values of QoS to select the best services from a discovered services list which can satisfy the user's goal.

3.1 Ranking of Web Services in the SC

The availability of a correct classification that is used to organize providers based on their capability descriptions is the key to build an efficient registry for the suppliers. The ISO (International Organization for Standardization) provides a Metadata Registry (MDR) standard which consists of a hierarchy of concepts, where each concept is associated with properties. These standard classifications cannot describe exactly the diverse industries, products, and services; therefore the discovery of providers (in the SC) is inaccurate and inefficient. Providers advertise their capabilities using product catalogue either via the internet or by hard copies. They expect consumers to investigate their catalogues manually and to place orders. However the catalogue may not include the detailed manufacturing capabilities necessary to provide products and/or services.

On the basis of the professional analyzed knowledge about SC and through the service-oriented analysis, we have defined the following SC product types and divided them into four classes (figure 1):

- Material product: Producer stocks materials.
- Final product: Producer imports products from manufacturer.
- Distributed product: Provider finds out an appropriate distribution center for consignment.
- Consuming product: Consumer purchases goods from market or retailer.

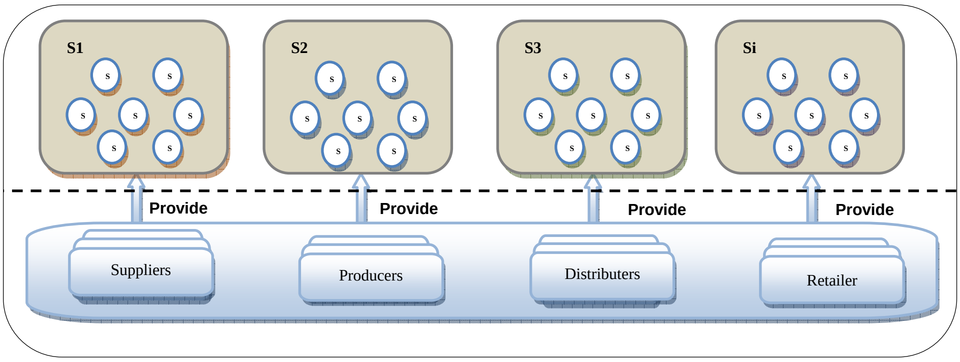

Figure 1: Web services classification for the SC.

We propose to use a provider registry for the SC entities through which providers publish their capabilities and consumers discover providers. What we focus on is the classification and selection mechanism, that is to say, how we divide a mass of web services into several types that defined as compatible to the SC entities. The provider registry classifies the SC entities according to different classes. Each class represents a type of provider for the SC which can manage the same product types and the information of these types is provided by their providers when the web services are published to UDDI. A provider registry play a central role in configuring a global SC for service-oriented enterprise integration by providing an open platform for publishing and discovering suppliers distributed over the Internet.

The main idea consists in dividing the web services into different aggregations (classes Si) according to the different providers operating on the different products' types. The provider registry plays a central role in SC configuration because it can manage the capability descriptions of providers, and link consumers and providers. Therefore, the web services, in the SC entities, are classified and when a request comes it is sent to the corresponding set Sj. As a Consequence, we do not need to discover all the web services. In this way the real-time response cost is evidently reduced.

3.2 Selection of Web Services in the SC

In the specific selection step, web service requesters often have many different technical requirements aspects when many services provide similar functions. Therefore, in order to distinguish services with similar functions, the non-functional properties must be taken into account.

Let us consider a set Sj classes of services. Each service class Sj contains all the services that provide the same functionality, but differ in terms of QoS non-functional potential properties. Service providers of each class provide the same web service with different quality levels: acceptable quality grade (Q), price (P), volume (V), delivery time (T) and delivery cost (FC) (considering the distance from the vendor to the vendee). With these dimensions, we propose that every web service quality is concluded through the formula presented in [Pantakar, 2008]. The computation of Utility function consists in using the attribute values of QoS to enable a uniform measure of QoS regardless of their units and their ranks. In this technique, the comparison between the minimum and the maximum value is based on available information about QoS of alternative web services (the other web services that provide the same functionality). Each value of QoS is translated into a value between 0 and 1. Qmin (j, k) and Qmax (j, k) are respectively the minimum and the maximum values of the k-th attribute (qk) of QoS of the class Sj of web services.

$$Qmin(j,k) = \min\ q_k(s) \qquad \forall s \in Sj$$
$$Qmax(j,k) = \max\ q_k(s) \qquad \forall s \in Sj$$

The utility of a web service “s” belonging to “Sj” is computed as follows.

$$U(s) = \sum_{k=1}^{r} \frac{Qmax(j,k) - q_k(s)}{Qmax(j,k) - Qmin(j,k)} * w_k$$

W_k is the weight of the QoS ($wk \in R^{+}_{0}$), qk is a coefficient which represents the user priority. If a user prefers the execution time to the price of a web service, in this case the time weight will be greater than the price weight.

The web services are organized in sorted vectors (Figure 2) according to their Utility function. These vectors will remain in the main memory for a quick access. When a consumer request arrives, only these vectors are used to make a limited number of combinations to find the best composition. In this case, the required time is very limited. Therefore, the classification and selection aim to reduce data space and the computation time.

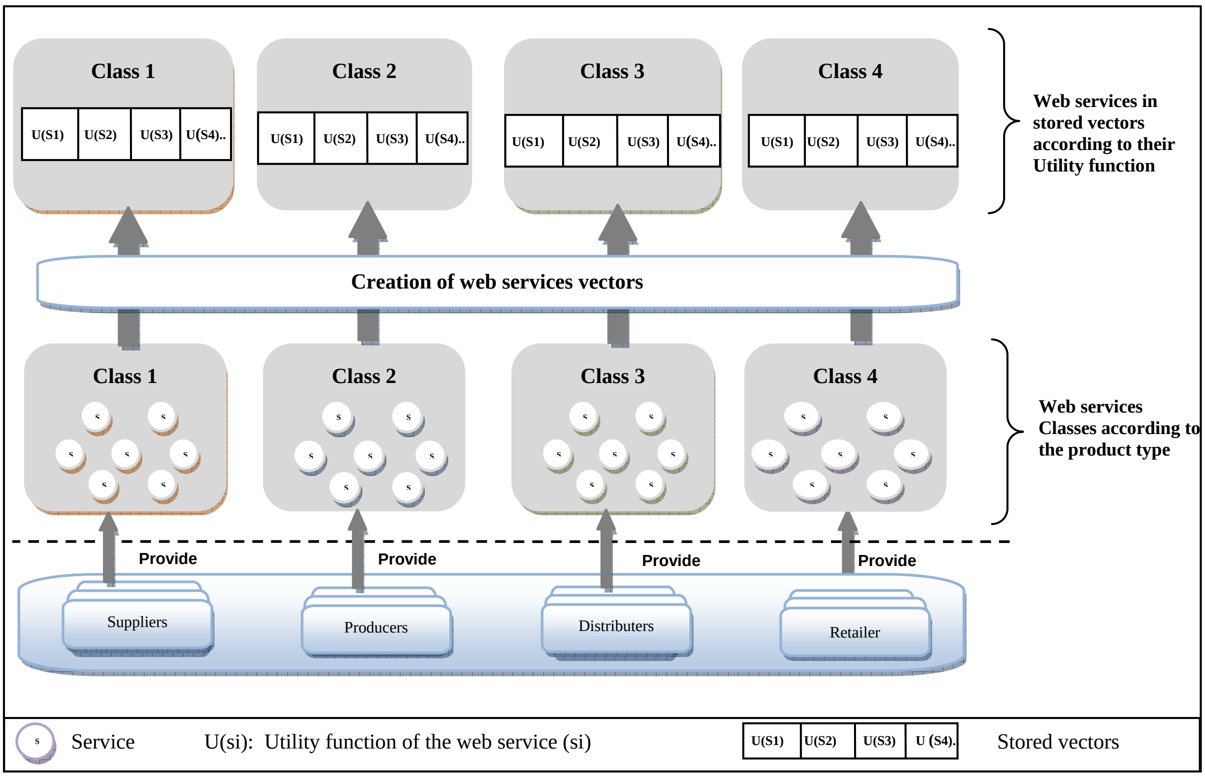

Figure 2: Web services selection for the SC.

3.3 Agent Level

This level consists of a set of agents (provider or consumer), each one of them being an actor in the SC. They manage the different steps of cooperation and negotiation between the SC actors.

The different agents of our framework must be intelligent. They must have the capacities of reasoning and could evaluate the proposed offers in order to decide whether they are interesting or not. Considering the past experiences, we assume that every single agent has a “referential” that keeps the trace of its negotiation rounds with the other agents.

Every single agent represents one actor of the SC: consumer or provider. This later provides the enterprise business functionalities as web services and their quality. Therefore, the agent level includes two types of agents: the consumer agent and the provider one.

3.3.1 Structure of Agents

Each agent in our framework represents an actor in the SC. It communicates, negotiates and cooperates with other agents of the system in order to reach its purposes. The components of each agent are represented in Figure 3:

- Communication module: it manages the interaction between an agent and an outside world (the other agents). It contains all the processes of taking charge of the resulting messages of another agent. This module is responsible for all the features of expedition and for the reception of messages;
- Coordination module: it considers the whole global process of the coordination (negotiation, panning). It takes as input parameters of a set of purposes (the interpretation results of messages) and produces a plan which satisfies these purposes. It considers the negotiation process as the functionalities of services, the conflicts resolution and the convergence towards agreements with partners;
- Knowledge base: it includes facts and rules. It belongs to an agent (what allows having an organizational interoperability between various partner agents involved in the SC system). Consequently, this knowledge base allows to achieve the process of cooperation and the management of interactions with the other agents;
- Reasoning module: according to the agent objectives, knowledge, ability and the latest information, it makes reasoning and decision-making. It is used for information and business processes;
- Referential module: it sums up experiences from the agent actions, and increases new knowledge and it improves their ability to adapt. Therefore, it regards the past experiences and keeps the trace of its negotiations with the other agents.

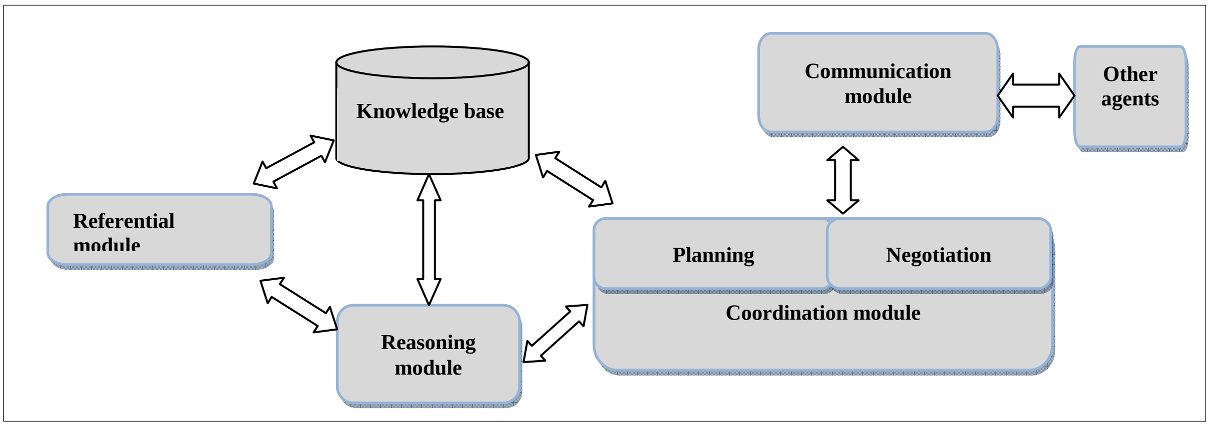

Figure 3: Global structure of agent

3.3.2 Interaction Protocol Between Agents

In order to model the negotiation between agents, we are interested by the interaction between the agents belonging to the different actors of the SC (relation of consumer/provider). This interaction generates decisions about the different types of flows. Thus, the agents representing the consumer actor (purchaser agent) and the provider one (delivery agent) negotiate by exchanging different messages.

The recursive negotiation protocol that is proposed takes place at least between two agents, the initiative of the negotiation and the receiver. The number of counter-proposals is limited. Once this limit is reached, the agent arrives to a rejection.

The protocol rules can be described as:

- Agent C sends the request to agent P.
- Agent P that receives the request sends back a message in order to show his willing. If agent C does not receive the feedback message in a limited time or the feedback message is unwilling, the negotiation ends.
- Agent C sends an offer to agent P that has the willing to negotiate and the offer/counter-offer being interactive between them.

If the feedback message is accepted or rejected, the negotiation will end up. If one of the negotiation agents finds that the negotiation is a logjam, it will send the negotiation offer to sharing-area (other agents) and begin a new round of negotiation. The algorithm below resumes these rules.

```
Algorithm: Agents negotiation
Inputs: Negotiation-apply
Outputs: Agreement or disagreement
Begin
    t= 0;
    Send (C,P,Negociation-apply);
    If receive (P,C,unwilling) or t>Endtime
        End negociation;
   Else
        Create (C, request);
        Send (C,P,request);
   End if
   Do while (t<temp)
    If receive (P,C,accept) or receive
              (P,C,unwilling)
          End negotiation;
     Else
          Evaluation (C,counter-offer);
          Send (C,P, response);
      Endif
      if find (C,logjam)
          Send(C,talk-area, shared-offer);
          Send(talk-area,C,talked-offer);
          Exit;
      Endif
      End do
End.
```

4 Some Implementation Aspects

In order to evaluate the work presented in this paper, we applied the approach proposed on a prototype of a supply chain. We consider three levels in the SC: distributer level, wholesaler level and Retailer one (Figure 4). This case is proposed to justify and explain the interest of specifying our model using multi agent system.

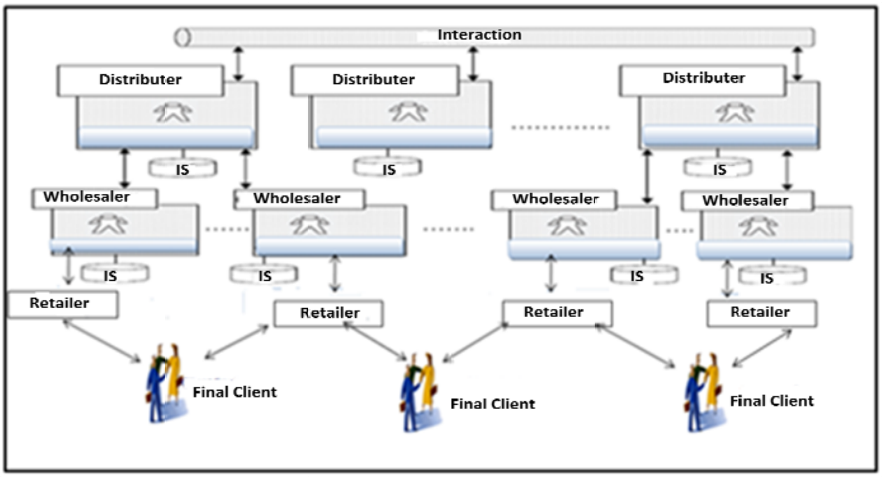

Figure 4: Use case study

Let us assume that the delivery agent from the sub-system of level-1 receives order from the purchaser agent from the sub-system of level-2, for a certain product (P) of quantity (Q) which cannot be delivered partially or completely from the distributor's available inventory, and which is characterized by delivery date (D). We assume that the distributer does not have any part of the ordered quantity or he has a part of the ordered quantity and must complete the rest.This kind of problems is related to the situations when the customer's demand cannot be fulfilled, because there is not enough merchandise in stock. If the situation is frequent it may cause the decrease in customers' loyalty level and retailer's financial losses. In practice, to implement this process in the industrial cases, and in order to satisfy the distributors' needs, three conditions must be checked:

- automatic and Quick solution;
- Transportation costs must be minimized.
- The autonomy and privacy of each participant must be guaranteed;

At this time, taking advantage of the characteristics of agents, they can search on the quantity ordered to solve the problem.

A use case has been implemented using standards. XML technology has been used to represent the information exchanged between agents via the standard communication language ACL (for Agent Communication Language). For the development of the different component, we use Java language which has been chosen for its portability and its considerable contribution in the application development. [JADE, 2004], an open source software framework, is currently the state-of-the-art tool used for developing multi-agent systems and it is the platform chosen as the deployment of our simulation because of its well- known facilities.

For more simplicity, we can implement the discovered web services as tasks that will be executed by the discovered provider agents. The agents of our framework are implemented by the following two classes:

- Consumer class: it describes the behavior of the consumer agent.
- Provider class: it describes the behavior of the provider agent.

These classes are extensions of the basic "Agent" class defined in JADE and include the method "action" of the class "Behaviours" which allows the description of the agent actions.

The consumer agent and the provider agents are respectively instances of Consumer or Provider classes. They are executed in different hosts that are interconnected in an intranet-internet infrastructure. Every host includes a container which can include one or more agents (Figure 5).

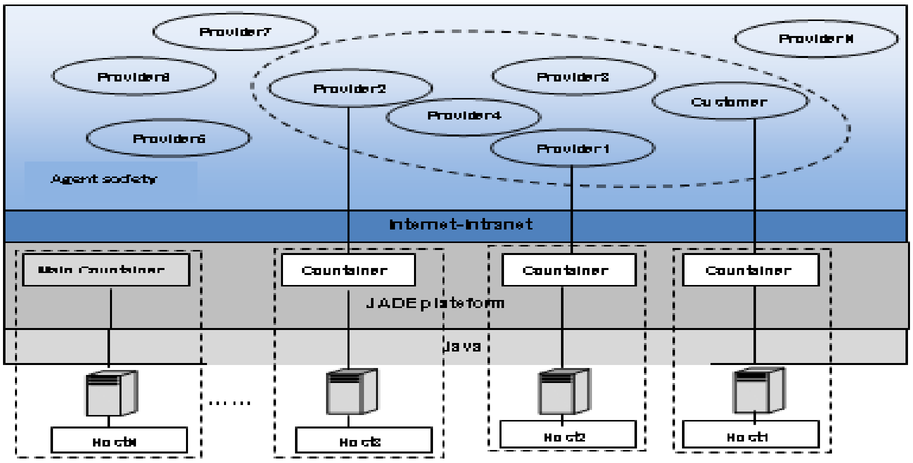

Figure 5: Representation of the implementation mechanism using JADE.

Therefore, once a consumer submits a request, the dynamic ranking mechanism is triggered. At runtime, when a request for a web service is treated, the system starts with the first element (the first element contains the service with the highest value of the Utility function). At this time, there should be a step or process for negotiation between the selected providers and consumer agent, they can therefore enter into communication and negotiations for the outgoing quantities or parameters of different items (for example: an order, a quantity or a delivery).

For this purpose, the agents representing the different enterprises in the SC will negotiate the discovered services by exchanging different messages. We assume that the exchanged messages are formulated by the language ACL. This later defines a set of message types (called "performatives") that help us to define the suggested agent' behaviors which receive these messages (Figure 6).

The negotiation between agents is necessary, that is why, the agents which are proposed provide useful reactions to the proposals that they receive. These reactions take the form of a counter-proposal (refused or modified proposal). A counter-proposal is an alternative proposal generated in the response. From such reactions, the agent must be able to generate a proposal which is probably ready to lead to an agreement. Therefore the communication between agents allows the negotiation between providers and consumer agents.

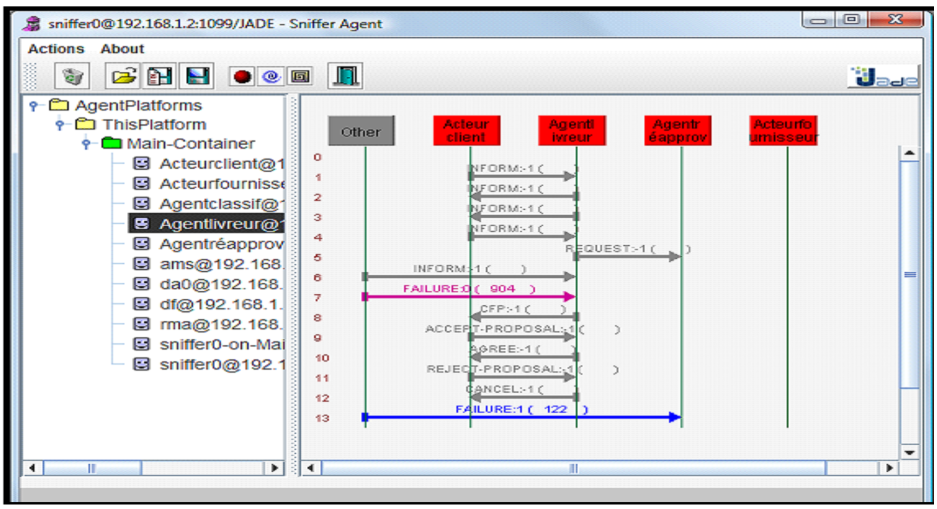

Figure 6: Part of the Negotiation performed between agents.

We have presented an experimental to evaluate the creation of classes's vectors taking into account the measurement of the effectiveness in terms of execution time. We started our experience by creating databases with different dimensions according to QoS attributes with a measure of their values (Utility function), also by giving a different number of services for each class in order to test our proposed selection operation with a larger number of services and different distributions. Firstly, we worked on a database having as a dimension an execution time whose value is between [0,1ms]. We filled the database with a large number of web services, with different values for attributes discussed before. Let us notice that the computation time almost equals to zero (some milliseconds). The results of this experimental study show a significant gain in terms of performance in order to select the most important web services that have been classified.

6 Conclusion

In this paper, we have proposed a framework which is based on the combination of web services and agent technologies. This framework aims to have a better interoperability of enterprises and tackle the complexity and heterogeneity of the networks that integrate SC. The importance of our research work lies firstly on the classification and selection mechanism proposed in the UDDI cloud level that permits to select the best services, satisfy the customers' goals and reduce the response time cost. Second, it lies on the uses of the agent negotiation as a mechanism of interoperation between actors in the SC. We have presented a negotiation protocol related to the SC characteristics and mechanisms. The simulative results indicate that the negotiation protocol of the SC based on provider and customer agents increase the negotiation efficiency and the successful cooperation ratio.

However, prospects for improving our research work remain possible. First, we plan to do semantic enrichment of service descriptions web by annotation, taking ontology as reference and using the SAWSDL (Semantic Annotation of Web Service Description Language) which is a recent standard and which is part of the recommendations of the W3C consortium. Then we want to deal with other aspects like composition of the web services, while taking into account their quality levels since we believe that the major problem posed by the field of composition of web services is the large number of its entities as well as the choice of services to compose.

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