Web Services for Cooperative Management

Ouahrani Leila, Alimazighi Zaia
Computer Science Department
University of Sciences Saad Dahlab
Blida, Algeria
l.ouahrani@arn.dz, Alimazighi@wissal.dz

ABSTRACT: *A rigorous management of pharmaceuticals is directly related to a country's ability to address public health concerns. The problem of management of pharmaceutical stocks in health systems is of great importance in a context of scarce resources, increasing medicines demand and inciting control costs. Because medicines are resources so important and so limited, ways must be developed to improve their supply and their costs. In this paper, we propose to explore an uncoupled approach: agents and web services for cooperative management of pharmaceutical stocks to minimize costs within the maintaining quality and continuity of care. A cooperative management based on an agent paradigm, is proposed and articulated around Resource Agents and Federator Agents and allows each site to store an optimal quantity and to avoid over-storage or under-storage of medicines. We use, as technological framework, Web Services which make applications possible to expose their functionalities through standardized interfaces using agents.*

Keywords: Health system, Pharmaceutical Stock, Multi-agents systemt, Web services, Cooperative management

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1. Introduction

Public hospitals are confronted in recent years to a mutation imposed by their guardianship and their users. This change should lead them to develop a more efficient organization and force them to go into management of resources much more objective and rigorous. Due to replenishment often empirical, hospitals need tools and methods to ensure a more rigorous and objective management policy. Stocks management applied to an extended enterprise such as the health system where resources are distributed on different interconnected sites requires the design, the modeling and the validation of criteria related to communication, interaction and cooperation. A pharmaceutical stock exceeding a non tolerated threshold affects negatively the hospital system. Indeed, under-storage in an intensive care unit can cause a rupture, which may force the patient to spend several days in hospital waiting for medicines not available in his unit while same medicines might exist in over-stocking in another site. Also, one more day in hospital generates increased costs of hospitalization and negatively influences health (poor state of the patient, risk of nosocomial infections, patient's psychological state ...). Over-storage can cause significant financial loss related to the dormant stock of unused medicines in the unit and risk of expiration. We must therefore seek a stock optimal in terms of cost and availability to not expose the health care system to an abnormal situation.

Hospitals consist of several autonomous, administratively distinct wards and ancillary units. Stocks include safety stocks and rolling stocks[1]. Rolling stock is the one with which the work is done daily. The safety stock is designed to avoid ruptures, but it is too large, it is expensive and may cause some medicines become obsolete. A stocks management policy at each site consists of answering the following questions:

- What medicines replenish?
- When replenish?
- By how much?
- From what site partner replenish?

Research within the cooperation framework draw part from the cooperation, the behavior and the knowledge representation models developed in Distributed Artificial Intelligence and in the Multi-Agents Systems (MAS)[2]. There is however no complete standard/consensus definition of an agent. As a result, agents tend to be characterized in terms of a number of their behavioral attributes like autonomy, reactivity, pro-activity, communication, cooperation and negotiation ([3], [4]). We retain the definitions shared on the whole by the Distributed Artificial Intelligence/MAS community and largely inspired from [5]. Ultimately, all in a MAS is distributed: control, knowledge, competences, activity, planning, ...

Multi-agent systems are considered a suitable technology for the development of healthcare applications where the use of loosely coupled and heterogeneous components, the dynamic and distributed management of data and the remote collaboration among users are often considered the most relevant requirements [6]. The use of agents in Healthcare has been continuously evolving and covering more aspects. Intelligent Agents are normally used to observe the current situation and knowledge base, and then support the expert's decision-making on an action consistent with the domain they are in, and finally perform the execution of that action on the environment. MAS are acting in a diversity of applications to healthcare(Distributed patient scheduling, patient management, elderly care delivery, patient monitoring and diagnosis, Medical agent-based decision support systems…)([7], [8], [9]). The use of agent paradigm to model our problem is well justified:

- The architecture of a health system is extensive, distributed over several sites, each of which may consist of one or more sub-sites that are all affected by medicines use,
- Each site is autonomous for decision making and choice of partners,
- The interaction between the sites of the system is evident in order to achieve a balance,
- The objective of the system is balancing resources(medicines stocks) of distributed system, which therefore requires an approach based on cooperation between sites for the emergence of the solution in one side and the dynamics of the system, ie a continuous balancing over time in an another side.

This study aims then to contribute to the modeling, by the agent paradigm, of an optimal management of pharmaceutical distributed stocks. The Web Services technology is used to implement the solution. The proposed preventive policy should ensure:

- Optimization of replenishment parameters (cost and availability)
- A reduction of expenses (avoid dormant stocks)
- A setting of thresholds to be ordered for a stock than just run (neither under-stocking nor over-stocking)
- A forecast of failures, particularly in countries where shortages are chronic and financial resources are limited.

In this paper we regard the MAS as a whole of agents in interaction answering the architecture of the system and obeying to an organizational model, and on the basis of an interaction model between agents, and activating for the emergence of a global solution of balancing of the pharmaceutical resources that ensures "*optimal availability of medicines for all sites in the system*". On this basis, elements: organization, autonomy, interaction and objectives are, in our view, the main characteristics that must have the pair (agent - MAS) and are the result of the dynamics of the system.

Section 2 presents the Multi-Agents System (MAS) organization. In section 3 we detailed the agent typology. Functionalities and scenarios interactions between agents are presented in section 4. In section 5 we present the Web Services solution. Section 6 will enable us to conclude.

2. The Multi-Agent System Organization

The medicines of the various sites of the health system are regarded as resources. To Each resource an agent is associated. Each one of them is presented as a server offering services (in the case of an on-storage) and as a client seeking services (in the case of under-storage). Our approach is articulated around Resource Agents (RA) and Federator Agents (FA) which allow an operational interworking of the various resources. The cooperation concept corresponds to an intelligent interworking, which consists of an active step of servers and customers aiming at an optimal collaboration.

A cooperative management to ensure stock balancing requires the use of three key features:

- Maintain information on the state of charge of each site in order to establish the overall system charge,
- Establish guidelines to control and decision making based on the charge and the proposed distribution policy, and
- To transfer the charge between the network nodes.

We use the role concept [10] which the agent can play in the system. We affect roles to our agents according to the functionalities to ensure during the balancing of resources. We chose the following distribution of roles:

- RA customer(in the case of under-storage),
- RA server(in the case of an over-storage),
- Federator Agent (FA): regroups RA corresponding to a same type of medicines of all sites.
- Stock Agent (SA): ensures classical management of complete stock in a given site.

To each type of medicines an agent is associated which represents it with respect to the distributed system. Each one of them is presented as a server offering services (in the case of over-storage) and as a client seeking services (in the case of under-storage).

The organizational model ("Figure 1") is based on the notion of group. In fact, we plan to consolidate Resources Agents of the same type of products from different sites in a group supervised by a Federator Agent which role is to receive alerts over-stocking and under-storage for a same type of product and performs mediation between a RA server and a RA client based on offers and demands. The agents RA have knowledge on the resources system and agents FA coordinate RA actions by ensuring the cooperation for a cooperative management.

The aim of our MAS, when it runs, is to achieve a balance of stocks of different sites of the system. To do this, Each RA detects abnormal situations of over-stocking and under-storage and informs the federator agent that interacts, with a principle of cooperation, with other RA in the same group. The RA examines the previous consumption of the product type a period to determine future consumption and detects the date when the stock will reach the critical threshold of rupture or over-stock. This is generalized for all types of medicines and for all sites involved in the cooperation. Associating a Federator Agent to a group of Resources Agents has two major advantages:

- Avoid bottlenecks by focusing management based on a balancing within a single Federator,
- Have as much information available on a particular product type at at any time.

For replenishment orders, we use the estimation method needs based on past consumption.

- The Average Monthly Consumption (AMC): the most important parameter for estimating medicines requirements. The average monthly consumption is equal to: (Sum of outputs) / Number of months.

- The Rolling Stock (RS): This is the stock to meet demand between deliveries. It must consider the periodicity and timeliness of delivery is equal to: RS = AMC * (FC + PD) With: FC = Frequency of Commands & PD = Period of Delivery.

- The Safety Stock (SS): It sets the threshold below which the stock available must never fall. It protects against possible shortages, if deliveries are late or if the rolling stock is consumed more quickly than expected It is the consumption between two commands (usually one month). The quantity of safety stock is usually assessed consumption for the period of delivery.

• Estimated Total Needs (ETN): corresponds to the maximum stock which is equal to the rolling stock added to the safety stock. ETN = RS + SS.

• Quantity Commanded (QC): It takes into account the remaining available stock. It is equal to the maximum stock - available stock. If the available stock is equal to the Stock max then the command is launched: QC = SS + (AMC * period between two commands) – available stock.

3. Agent Typology

The agents AR have knowledge on the resources of the system and agents AF coordinate their actions by ensuring the cooperation:

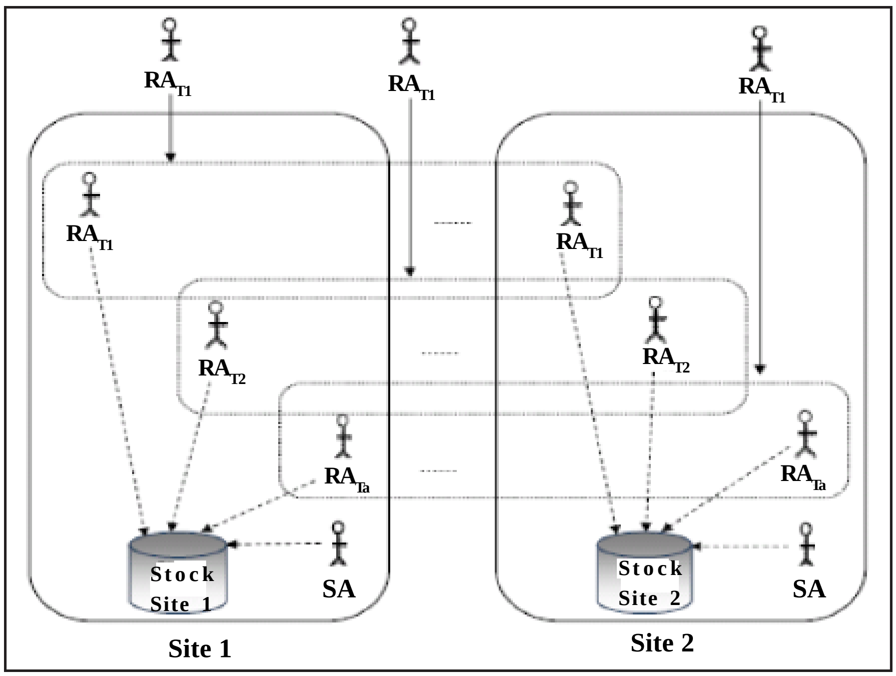

Figure 1. The Organizational Model

3.1 Resource Agent (RA)

It is an informational agent that maintains the charge state for a type of medicines at each site of the system. It regularly examines the stock and anticipates situations of under-and over-stock for a specific type of medication. It is an intelligent agent equipped with capabilities to decide based on its knowledge base. Periodically, it examines quantities available based on past consumption (average consumption, rolling stock, safety stock, maximum stock). It can thus provide cases of under and over-stock and calculate Tc (Estimated number of weeks of stock availability) that compares to Tmax (ETN = RS + SS) relative to the maximum stock. It sends to the FA a request message of supply when Tc < Tmax or sends an offer message otherwise. This ensures optimal management of the distributed stock in a cooperative framework between the different sites of the expanded hospital network as shown in “*Figure 2*”.

The RA has competences, knowledge and intentions:

1) Competences: Services offered to the cooperation and services which the agent can carry, procedures calculation, decisional procedures consisted of rules which express the conditions paired with data resulting from the database of the agent or with the received messages.

2) Knowledge: Services offered, the constraints associated (management rules, rules allowing the agents resources to achieve their goal) and the localization of AF to which it is logically attached.

3) Intentions: Goals to reach to satisfy balancing following an alert of under-stock by a client or an alert of over-stock by a supplier within the framework of the global strategy to reach for the cooperative system.

3.2 Federator Agent (FA)

It is an intelligent agent that controls the allocation of the overall charge on one type of medication. It receives alerts stock (a replenishment request) or over-stock (an offer to the global system) from the RA that it must treat in order to balance inventory. Its role is to receive needs and offers of different sites. It classes the needs, optimizes the costs and responds to clients according to offers which it has already classed. An agent AF intervenes for the realization of collaborator goals associating a group of agents. It has competences, knowledge and intentions related to its mediator role:

1) Competences: necessary to the management of the cooperation according to its mediation role:

• Receive REQUESTS and OFFERS,

• Sort OFFERS,

• Calling for tender to potential suppliers sites classified by lowest cost,

• Establish contract between client sites and supplier sites.

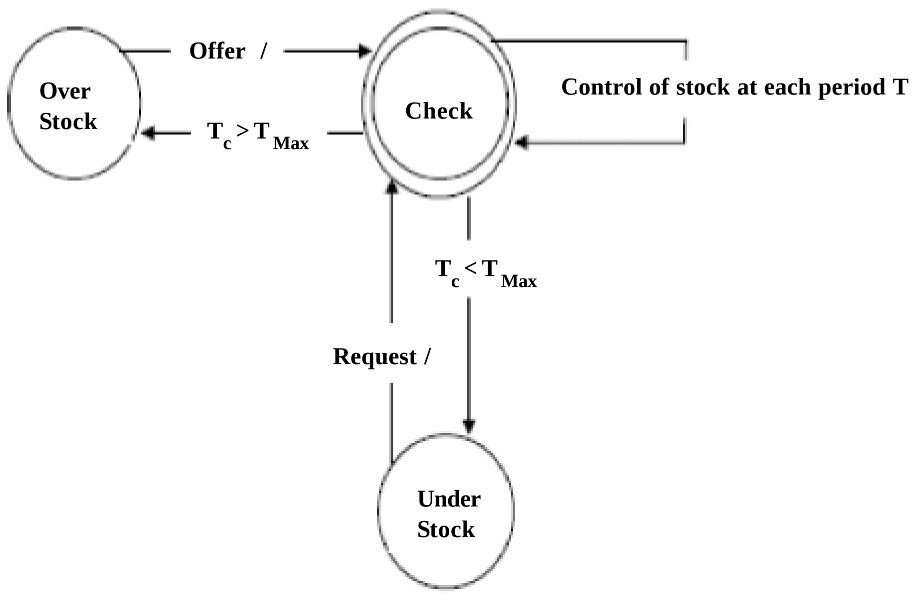

Figure 2. State transitions of an AR

2) Knowledge: on the agents RA of the group (localization, requests and offers), decisions rules allowing it to elect adequate servers during the balancing process, and procedures calculations corresponding to the various actions carried out by the FA during a request development.

3) Intentions: goals related to the global strategy of preventive management of distributed pharmaceutical stocks.

3.3 Stock Agent (SA)

It is a reactive agent without any form of intelligence. Its role is to ensure a classical management for the complete stock on a site and for all types of medicines (consultation, update...). It communicates the quantities input and output to the various resources agents so they can maintain knowledge of the state of charge at each site and for each type of medication. In a preceding work [11], we detailed the typology and the structure of the agents.

4. Interactions Modeling

The System functionalities are given by examining the functional needs for each actor expressed in the form of a class of interactions. An actor starts scenarios which can use other scenarios. They are descriptions of a sequence of events which define the desired system behavior. The cooperation between agents is based on service messages. We use the Contract-Net protocol which allows the development and the fulfillment of a contract between an agent manager and a contracting agent [12]. The interactions, with the aim of balancing stock, highlight the following scenarios:

4.1 Replenishment Demand scenario following an alert of under-storage

An agent RA customer calls upon a group of agents RA through their FA. The invocation of a particular service implies the negotiation of the required service:

1) Definition of the potential servers: The FA confronts the request with the received offers and filters servers (RA) of the group then sends the request to the list of the potential servers.

2) Development of the offer: Each agent RA develops an offer and sends an answer, corresponding to its capacity to solve the request.

3) Establishment of the contracts: After offers evaluation, The FA establishes contracts with the agents RA which answer contains determining elements in the resolution of the request.

4.2 Offer scenario following an alert of over-stock

Each RA within a group sends an offer to the FA to indicate an alert of an over-stock. The agent FA classes the offer among all the offers already received. These offers can respond to future under-stock alerts. This will spread to all sites and for all articles listed in the pharmaceutical stock. This way of cooperation between sites from the same extended enterprise, constitutes what might be called a balancing of resources between these sites.

5. Implementation of The Solution

Web Services constitute a robust framework to ensure interworking between heterogeneous, accessible on line applications. They offer homogeneous representation of observable behavior of the service. Web Services model rests on a Services Oriented Architecture [13]. It utilizes three categories of actors: services suppliers (entities in charge for the WS), the customers (clients) which are used as intermediaries to services users and directories which offer to the suppliers the capacity to publish their services and to the customers the means of locating their requirements in terms of services. The dynamics of architecture regroups three stages: the publication of the service by the supplier in a directory, the localization of the service by the customer and the interaction between the customer and an execution occurrence of the service. The Web Services offered to a client are based on XML standards containing:

- SOAP (Simple Object Access Protocol)[14]. It is a protocol managing the exchange of information. It uses XML to format its messages and HTTP to convey them.
- WSDL (Web Service Language Description)[15]. Gives the XML WS description by specifying the methods being able to be called upon, their signature and the access point (URL, port…).
- UDDI (Universal Description and Discovery Integration)[16] It is a directory indexing the WS accessible to a unit from partners according to the exchanges level.

For a few years already, we attend a bringing together between MAS and WS according to different directions [17]:

- MAS play a mediator role in the WS operational model. They facilitate the localization, the planning and the composition of WS ([18], [19]).
- WS are used as conceptual and technological framework to make the MAS accessible through the Web. The design can integrate WS developed according to an agent model in order to carry out complex management tasks of commercial transactions ([20], [21]). It can be uncoupled while associating a given MAS, a layer containing WS which make capacities agents accessible through the Web [22].

We use an uncoupled approach using WS as technological framework to make our MAS accessible through the Web ("*Figure* 3"). RA publish their offers as WS which can be used independently of the conceptual and technical characteristics of these agents. The interaction protocol is integrated into the FA which implements the directory of the group and constitutes the interface between the MAS and the WS environment. The objective is then to allow an interworking most simply possible, by

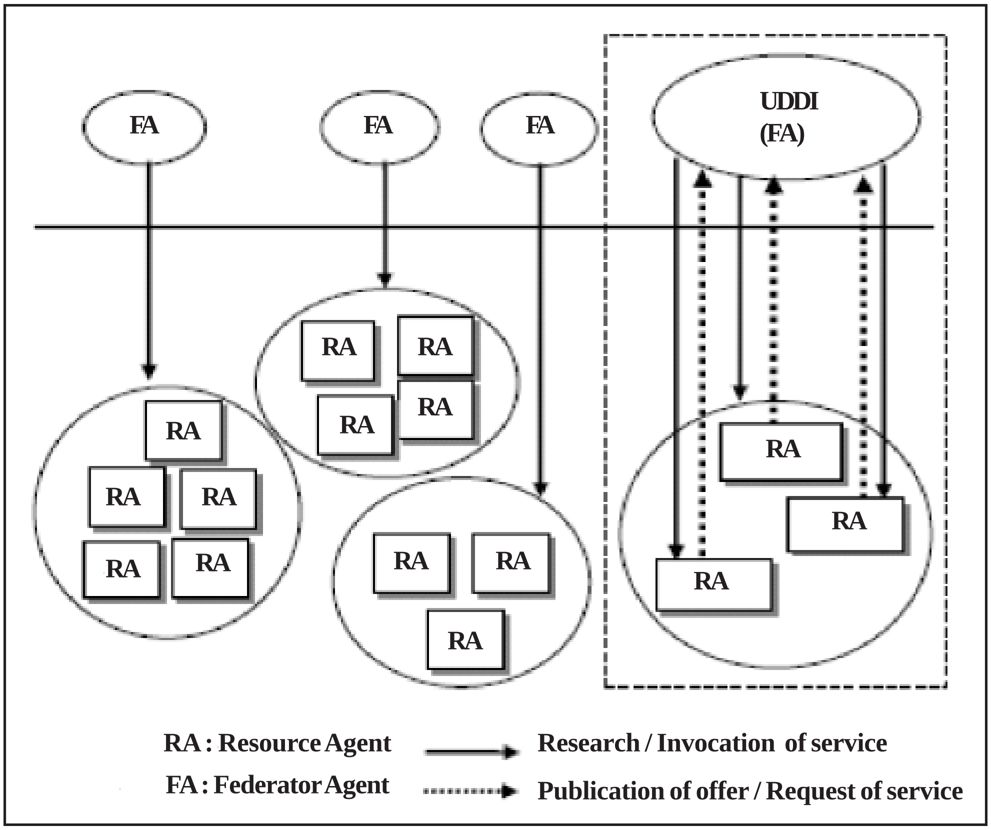

Figure 3. The Web Services Solution

making transparent; the diversity of the environments of the various sites in cooperation.

Three distributed software actors; the supplier, the directory and the customer must communicate by using a communication protocol HTTP or HTTPS. In our case, the service provider and service requester are the RA for different types of medicines sites clients or suppliers to tender. FA represents the UDDI, because it has the best offers and controls the interaction between clients and the potential suppliers maintaining maximum autonomy. The RA are equipped with a publication module which enables them to publish their offers as WS. A module implementing the Contract Net protocol is integrated into the FA which implements the directory of the group and constitutes the interface between the MAS and the environment of WS. The RA agents represent suppliers and customers of services. The FA offers for each group of RA a library in order to publish, locate and call upon WS. Each site requesting for a type of medicines is regarded as a client for a service from another supplier of site after consultation the FA agent which maintains a group directory with the best offers as showed in "Figure 4".

The dynamics of the system highlights two principal scenarios: publication of a service and the resolution of a balance global request:

5.1 Publication

• An RA publishes offers corresponding to its state of charge. Each offer is associated with a description specifying the aspects related to the invocation and the execution,

• Publication module creates a WS corresponding to the description of the offer and deploys it on the local web server,

• The description of the WS is published in the UDDI corresponding to the FA with which the RA is attached.

5.2 Resolution of a global request (under-storage)

Each FA is equipped with an interaction module allowing selecting the adequate service to satisfy the request according to the

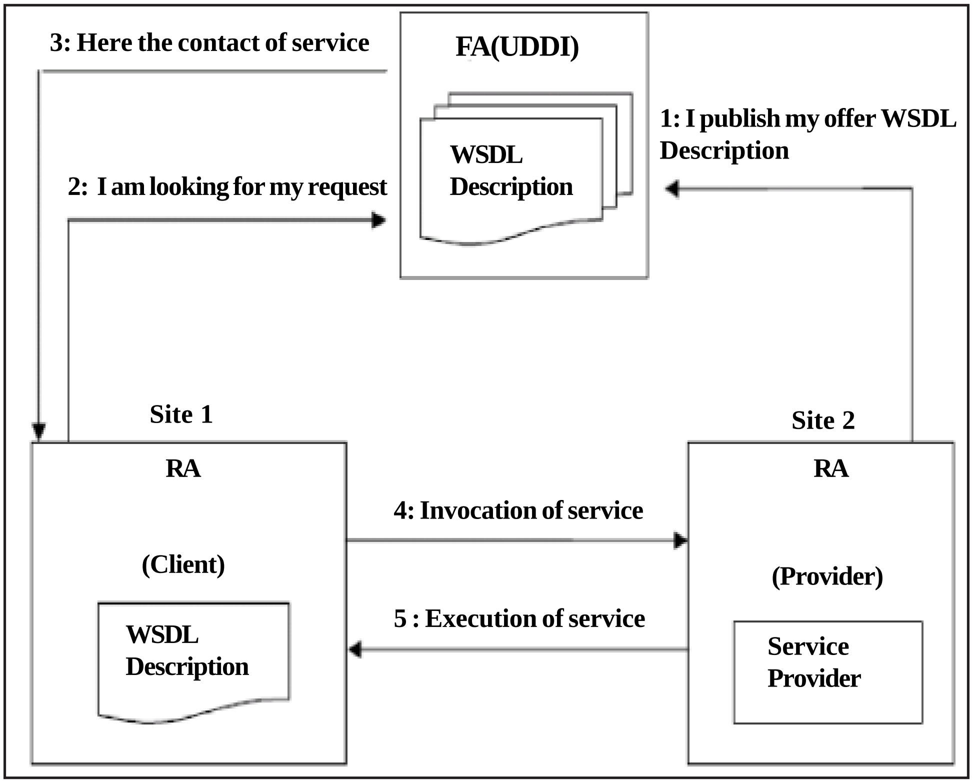

Figure 4. Uncoupling Agents-Web Services

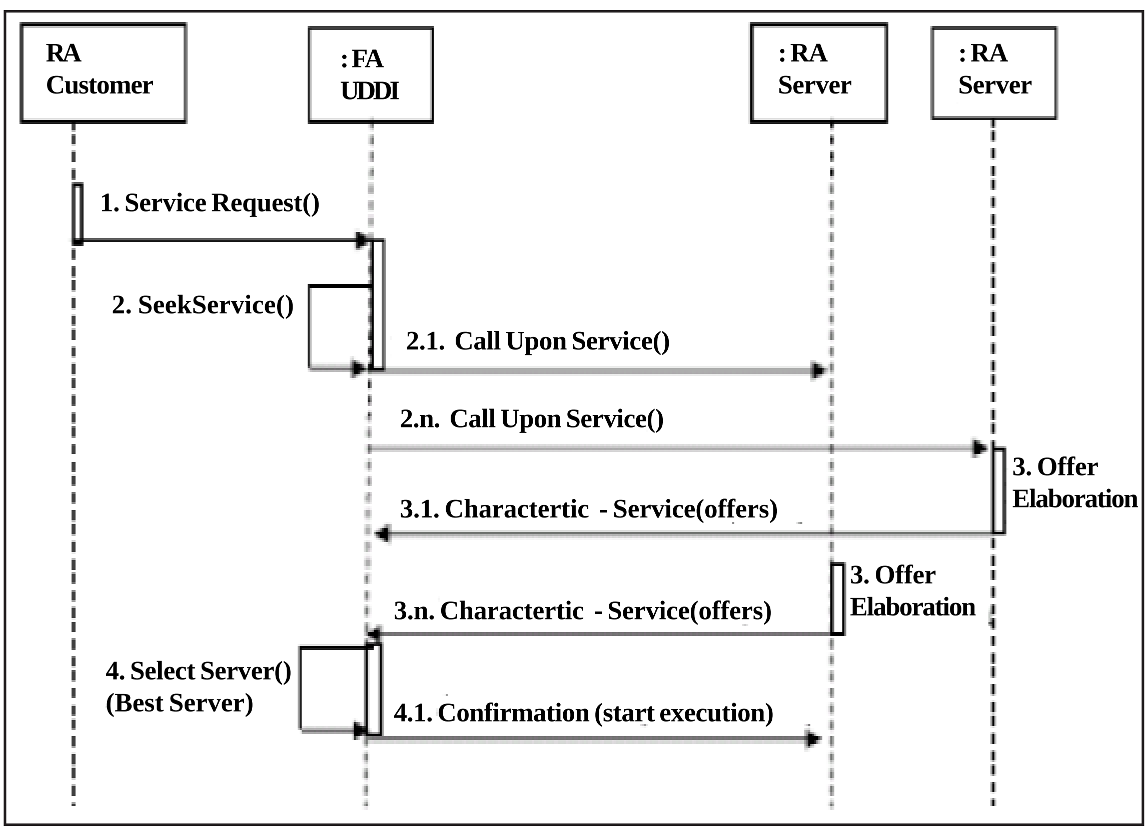

Figure 5. Request Resolution

Contract-Net protocol. The scenario is illustrated in the sequences diagram “*Figure* 5”. The interaction module is carried out as follows:

1) An agent customer emits a request which questions the UDDI (FA).

2) UDDI Agent seeks the list of descriptions of WS corresponding to previous offers and calls upon the corresponding services while launching an invitation to tender from RA.

3) Each RA calls upon the services discovered in order to obtain their various attributes which it sends to the FA UDDI.

4) The UDDI, by its interaction module, selects the most adequate services and sends to the corresponding agent confirmation message. The service transmits the translation of the message in the format execution of the RA supplier which starts the execution of the service.

For a first version, we used Agent Builder Pro version 1.4 to develop the simulation tool, which implements the agents. To extend the tool to implement the WS layer, we used the Java EE platform which simplified us the development of the Web Services by the use of the distant objects technique.

6. Conclusion

We presented in this paper an infrastructure for a cooperative multi-agent system for the management of resources distributed on remote sites connected by the Internet in a healthcare system. This approach is particularly illustrated in the case of pharmaceutical stock, given its vital importance in ensuring continuity of care. Indeed, the proposed solution can manage and in a preventive way, this resource by performing a balancing of all sites supposed interconnected via the Internet, because we have proposed a solution implementation based on Web Services technology. This solution, once implemented on the Web can avoid each partner sites exceeded levels tolerated in terms of availability (in overstocking and under-stocking) and can therefore add value to the quality and continuity of care on one side and cost optimization of another side. In view of this work, we intend to extend our study to other resources in the health system and to consider criteria other than cost of availability. We think particularly at the distributed cooperative management of the personal and shared patient record.

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