OpenEHealth - A Unified Negotiation System for Hospital Collaboration

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OpenEHealth - A Unified Negotiation System for Hospital Collaboration

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Abstract. This paper presents the OpenEHealth project that studies fundamental application problems that arise in open ehealth systems, where heterogeneous and self-interested care providers and care consumers dynamically interact with one another, for instance by sharing medical information. The main outcome of the project will be an analysis of current research solutions using intelligent agent technology research, and a proposal for a governing multiagent eHealth infrastructure, where humans and agents are interconnected in a hybrid MAS.

Keywords: agent-based negotiation, hospital platform, multi-agent systems, e-health, drug management

1 Introduction

During the last decade there have been many efforts towards the reduction of health costs [24][27]. The public health care system rapidly is absorbing an ever-increasing share of the gross domestic product [25]. According to the latest available data, hospital costs account for approximately 35% physicians, 25% drugs, 15% medical equipment and supporting IT tools while the rest 25% concerns various secondary health costs [26].

Although there have been numerous research projects trying to reduce the hospital costs without losing the quality of offered services, the cost of drug and medical equipment supplies is continuing to increase. Based on this observation we propose an automatic negotiation mechanism that will enhance the cooperation of medical units as well as the optimal use of their medical supplies, leading to a reduction of medical supplies costs.

The idea of cooperation among hospitals is not new. There have been efforts for the creation of hospital networks in order to deal mainly with organizational issues. Our proposed negotiation system wants to take these organizational cooperations one step further in order to give an answer to the following challenges:

- How do we exploit medicament overplus;
- How do we exploit medicaments whose expiration date is approaching? How is it possible to supply them at another hospital unit;
- How do we enhance the cooperation and the coordination of hospital units during urgent incidents;

- How do we reduce the costs for drug supplies at the hospitals;
- How do we ensure the cost and time efficient accomplishment of inter-hospital requests;
- How do we exploit medical equipment that is not necessary anymore.

A flexible approach to deal with these problems is an electronic negotiation platform based on multi-agent systems. Such an electronic negotiation platform cannot be used in order to replace human decisions, but instead it contributes to the automation of a part of human actions.

Negotiation is an extremely critical process in any enterprise, given that through negotiation important savings can be achieved or profits generated [12]. Despite of its apparent randomness, negotiation has a finite number of variables and laws that it obeys. In our case, the negotiation platform could support the trading of two different categories of products:

- Medicaments
- Medical equipment

The negotiation system between hospitals can be considered as a virtual enterprise . Virtual enterpises are complex organizational structures that for organizations, customers, suppliers and sub-contractors, engaged collectively in the design, development and delivery of services to the end users [31]. The term is often used to describe such collaborations when the participating organizations are distributed over large geographic areas and come from multiple independent companies. A virtual enterprise allows its member organizations to respond collectively to special conditions, in situations where the members individually would be unable to respond efficiently.

The negotiation virtual enterprise will contain organizations (hospital units) and institutions (auctions) [6]. As virtual enterprises may be long term relationships, the chosen suppliers are reliable and frequently strongly contracted. In this situation the negotiations are performed over parameters like delivery dates, quantity or price. In some cases delivery dates and quantities are negotiated while in other cases, price is the negotiable parameter. The application is independent of such parameters as it will obey the rules specified by the customer that are defined over the price or the quantity.

The negotiation process is a game, where the players move alternatively in order to maximize the possible payoff for them [21]. The negotiation process influences radically all the other processes inside the virtual enterprise being the driver of the business schema. It is the process that fires or not all processes. At the same time, the negotiation process has costs (time or money) as any other process in the enterprise. A player's dominant strategy is his strictly best response to any actions made by other players. Most games do not have dominant strategies and the players must try to figure out each others in order to choose their own. However, we must mention that the goal of the OpenEHealth project is not to propose negotiation strategies from the point of view of the different players but to provide an adequate and funcionable mean (platform) for the negotiation to take place.

From the business point of view, an auction/market is a method for determining the value of a commodity that has a variable or perhaps undetermined price. By definition, an auction is the process of buying and selling goods by offering them for bid, taking bids and selling the item to the higher bidder or asking for the item from the lowest bidder. Usually such negotiations or auctions are not automated, except perhaps semi-automated web-based solutions where the system assists in the offering and procuring activities, leaving the decision-making process to the managers [7][12][19].

Generally speaking, electronic exchanges involve three main phases: firstly potential buyers and sellers must find each other or meet in a marketplace, secondly they need to negotiate the terms of the transaction and, finally, they execute the transaction and the goods resources change hands. Agent technology can be used in all three phases, from matchmaking to negotiation and payment systems. As agents encode their users' preferences they can negotiate for goods and services on their behalf.

A negotiation platform among hospitals can be considered as an open interaction system: it will be dynamically entered and left by autonomous agents. Each hospital's request to the system is carried out by a correspondent agent. In order to include all the possible cases of trading as described at the previous section we adopt a hybrid approach. While the system will be totally automated there will be also the possibility of human intervention.

2 Motivating Case Study

2.1 Drug Cost Management

The topic of increasing drug costs has received significant attention over the last decades, and many public programs have tried to tackle it. Many hospitals are trying to develop programs and services to reduce the rising cost of providing prescription drug benefits. Strategic alternatives that are being explored include:

- renegotiating network pharmacy contracts;
- implementing preferred drug lists;
- forming purchasing coalitions.

Being aware of the potential issues and developing in advance a response to those potential issues will be critical if hospitals are to achieve their goals of implementing programs designed to control costs. As hospitals evaluate various approaches to controlling pharmaceutical costs, they usually apply decision-making frameworks to each alternative that might be pursued. The most common framework, adapted from [28], includes five key areas, and is outlined below:

- Evaluate program cost drivers. The hospital estimates the real cost of pharmaceutical products taking into account the consumption at all the units and services of the hospital unit;
- Evaluate alternative strategies to address cost drivers. The hospital calculates the details of each of the alternative strategies referenced above and their implications for the functionality of the hospital itself;
- Evaluate stakeholder impact and political climate. The hospital examines the non-financial concequences of an alternative strategy, e.g. the renegotitation of contract can lead at higher prices for future pharmaceutical products since the provider considers higher risk after the moodification of the old contract terms;

- Determine cost to implement the recommended strategy. Each new strategy can have implementetion costs. The creation of preferred drug list for example is forcing a hospital to upgrade its information systems;
- Evaluate the financial benefit(s) of the selected strategy.

Prior to designing an overall strategy, a hospital should complete an analysis of the current cost and utilization trends in its pharmacy program. The analysis will provide concrete and analytical data to support the business case for change, and will also provide the basis from which savings estimates can be derived. Most of the hospitals analyze the following areas [17] [28]:

- Current utilization rates/cost trends. The hospitals use statistical tools to study the cost trends for the most used medicaments;
- Current cost-sharing approach. Each hospital analyzes the share of the cost that is forced to pay for each medicament and the share of the cost that the patient needs to contribute with;
- Current utilization management strategies and outcomes. The hospitals produce detailed reports of the medicaments utilization at all the departments and units inside the hospitals;
- Analysis of top therapeutic classes, including drivers of cost. The hospitals evaluate the cost of medicaments for the different patient categories;
- Analysis of generic utilization patterns. The hospitals produce reports and statistical charts for the consumption of medicaments based on the generic patient characteristics(e.g. age, sex etc.).

Once a hospital has evaluated its current program data in detail, it will be in a better position to consider strategic alternatives. The analysis will give an understanding of the drug consumption of different services, and will serve as the basis for establishing program savings estimates.

Strategies that are designed to control drug costs require hospitals to make investments in time and money. The most common initiatives that hospitals pursue require minimal costs like implementing a new drug utilization review, while other efforts require developing a process for negotiating supplemental changes on current contracts.

Once the hospital has evaluated the costs, it can then develop a model that can be used in discussion with policy-makers. The cost development process is always crucial to developing support for the proposed initiatives with policy-makers. In addition, it will form the basis for securing the appropriate level of funding required to implement the proposed initiatives [28].

Based on this context we propose that the establishment of a parallel drug market among hospitals could benefit all the participating members and could offer a succesful alternative strategy to the reduction of drug costs. Starting from the observation that a respectful percentage of the drugs supplied by the hospitals is being wasted annualy, giving the possibility to hospitals to trade about the medicaments they have obtained would optimize their drug management system and also would ensure their independency.

However, legal restrictions can apply at a marketplace between different hospital units. Some of them could be related to the rights of hospitals to resell medical supplies. How we could overcome these legal obstacles is still a point for further study. For the needs of this report, we propose a solution based on the replacement of real monetary units with ”virtual” ones. Each product belonging to one of the three categories mentioned above, will participate at the negotiation procedure accompanied by a starting price expressed in terms of credits. This implies that each hospital unit will have an account balance with the other hospitals on credits. The introduction of the notion of credits instead of real monetary units is crucial in order to avoid legal restrictions on trading of medical supplies.

2.2 Medical Equipment Management

Medical equipment management has also become recently a critical issue for hospitals and medical units. The current tendency for hospitals is to try to sell or rent used equiment to other units. Towards this direction there is an important number of private online marketplaces that allow the exchange of equipment (e.g. MedWOW.com). These online marketplaces are specifically designed for used medical equipment and they connect buyers, sellers and service providers. They offer analytical databases with the specifications of the available equipment as well as an online transaction system for buying and selling equipment.

In our approach we adopt a different view. We propose the establishment of an inter-hospital (and not a private) electronic marketplace; this means a distributed electronic platform where the users will not only be able to discover the equipment throught appropriate queries but also they will negotiate about the price and the delivery time of the goods at a multiple auctioning system. This has the profound advantage to optimize the benefit(s) for both parties (seller and buyer).

3 Negotiation Platform

3.1 Technical Background

In artificial intelligence an intelligent agent is an autonomous entity, which observes and acts upon an environment and directs its activity towards achieving its own goals. Agents may also learn or use knowledge to achieve their goals [22].

A multi-agent system (MAS) is a system composed of multiple interacting intelligent agents. These systems are used in a great variety of applications such as process control, manufacturing and recently electronic commerce and simulations. MASs present very attractive means of more naturally understanding, designing and implementing several classes of complex distributed and concurrent software. The main reason resides in their unique paradigm of combining populations of autonomous active agents within a shared structured entity (environment).

The negotiation system between hospitals and medical units presents a set of properties that can be compared to the one that define an open multi-agent system. These systems are widely recognized for their significance at the development of intrinsically distributed applications (i.e. e-markets, electronic auctions). A MAS can be considered open [20] when it satisfies a set of properties such as:

- Agents are free to join and leave at any time;

– Agents represent different stakeholders with different objectives.

As Barber and Kim specify [2], we can say that as a consequence of these two attributes, to handle an open MAS it is necessary to take into consideration a set of issues. In particular an open MAS is by definition dynamic as the agents may join or leave at any time, it is unsecure as an agent may be programmed to be malicious, it is not deterministic as no agent can have a global knowledge of the system and due to different ownership and there is no central authority in a MAS. The above definition implies that in open interaction systems, it is not always possible to obtain the desired outcome, since the agents act on behalf of competing interests and thus they may choose to ignore or they may fail to comply with the system specifications in order to achieve their goals.

For such agents, e-commerce is considered to be one of the paradigmatic application areas [14]. E-commerce is considered an open system where agents from different shareholders are free to enter or leave on their own will and they have the ability to act according only to their predefined goals. E-commerce utilizes (to various degrees) digital technologies to mediate commercial transactions. As a part of our research we use Traver C.G. Laudon's approach [15] which conceptualizes a commercial transaction as consisting of four phases:

– pre-contractual phase including activities like need identification, product brokering, merchant brokering, and matchmaking;
– negotiation where participants negotiate according to the rules of the market mechanism and using their private negotiation strategies;
– contract execution including activities like order submission, logistics, and payment;
– post-contractual phase that includes activities like collecting managerial information and product or service evaluation.

While there exist many scenarios of applying agents in e-commerce in the health domain, automated trading between hospitals is one of the more promising ones. In particular, we are interested in using agents to support the first three of the phases of a commercial transaction outlined above.

In the field of MASs in general and in the field of agent-based platforms in particilar, major efforts have been devoted to the study, design and experimentation of hybrid open multi-agent systems, in which human and artificial agents interact within a given organizational structure, to carry out complex collective activities [11]. The negotiation platform between the hospitals can be honsidered a hybrid MAS since both human representatives of the hospitals and software agents can participate and negotiate.

As we have already mentioned in previous sections, such complex organizational structures are benefited being designed as virtual enterpises. Modeling of virtual enterprises can be simplified to the modeling of multiple interacting institutions. It is natural to model parts of it by means of distinct institutions, which are then combined to obtain a comprehensive model [8][9]. For instance, a system for performing electronic auctions may be defined using the institution of auctions (to model the auction protocol), the institution of organizations (to describe the auction house running an auction) and the institutions of ownership and of money to formalize the commercial transaction following every session of the auction.

3.2 Agent-based negotiations

In the context of this chapter we understand negotiations as a process by which agents come to a mutually acceptable agreement on a price, quantity and delivery price of a specific trading product. [16].

Auctions are one of the most popular and well-understood forms of automated negotiations [30]. An increased interest has been manifested recently in attempts to parameterize the auction design space with the goal of facilitating more flexible automated negotiations in multi-agent systems [30][16]. One of the first attempts for standardizing negotiation protocols was introduced by the Foundation for Intelligent Physical AgentsFIPA. FIPA defined a set of standard specifications of agent negotiation protocols including English and Dutch auctions.

Different authors [4][3] analyzed the existing approaches to formalizing negotiations (including FIPA protocols) and argued that they do not provide enough structure for the development of truly portable systems. Consequently, they outlined a complete framework comprising:

- a negotiation infrastructure;
- a generic negotiation protocol
- a structure of declarative rules.

The negotiation infrastructure defines roles of negotiation participants and of a host. Participants negotiate by exchanging proposals and, depending on the negotiations type, the host can also become a participant.

The generic negotiation protocol defines the three phases of a negotiation: admission, exchange of proposals and formation of an agreement, in terms of how, when and what types of messages should be exchanged between the host and participants. Negotiation rules are used for enforcing the negotiation mechanism. Rules are organized into a specific structure:

- rules for admission of participants to negotiations;
- rules for checking the validity of negotiation proposals;
- rules for protocol enforcement;
- rules for updating the negotiation status and informing participants;
- rules for agreement formation and rules for controlling the negotiation termination.

Finally, they introduce a negotiation template that contains parameters that distinguish one form of negotiations from another, as well as specific values characterizing a given negotiation.

In this context it should be noted that rule-based approaches have been indicated as a very promising technique for introducing intelligent negotiating agents [5][10]. Furthermore, proposals have been put forward to use rules for describing both negotiation mechanisms and strategies [23].

3.3 Negotiation Platform Description

As we have already mentioned a negotiation platform among hospitals can be considered as a virtual enterpise. In a virtual enterprise consisted of hospitals, we distinguish two different cases.

- Participation of hospital units for satisfaction of short term needs. This case usually applies to emergency incidents when the need for medicaments and/or blood is significantly increased. In such situations, the decision support systems cannot accurately estimate the extra needs and thus the software agents will not put a request to the system. Managers can then bypass software agents and put the request based on their own knowledge. This may lead to different types of negotiations. Either between human agents either between human and software agents. Hybrid multi-agent systems can successfully model this type of behavior.
- Participation of hospital units for satisfaction of midterm needs. In this case the decision support systems can successfully evaluate the need for medical supplies and the software agents can substitute human agents at the negotiation procedure. Two different types of agents are of great importance in an electronic negotiation platform: buyer agents and seller agents. Buyer agents can search products, and negotiate and access negotiation records. The seller agents negotiate with the buyer agent and access products and the consumer list of participants.

These software agents share three very important characteristics:

- Intelligence: The agent automatically customizes itself to the preferences of its customer hospital, based on previous experience and imprecise information from interaction with other customers. The agent also automatically adapts to changes in its environment;
- Autonomy: An agent is able to take the initiative and exercise a non-trivial degree of control over its own actions through service agreements;
- Cooperation: An agent does not blindly obey commands, but makes suggestions to modify requests or asks clarification questions. It also cooperates with other agents to query the modules needed.

The deployment of software agents in electronic hospital marketplaces will bring significant advantages: it will eliminate the need for continuous user involvement, reduce the negotiation time and transaction costs and provide more efficient allocation of goods and resources for all parties involved.

The electronic negotiation platform works as an open environment where buyer and seller agents meet in the marketplace, as shown in figure 1. This entity facilitates agent meeting and matching, besides supporting the negotiation process.

This negotiation platform can be considered as a marketplace where multiple dutch auctions can occur simultaneously. Each hospital can start an auction in order to trade a product or it can join an already running auction in order to express interest about buying a product. A Dutch auction is a type of auction where the auctioneer begins with a high asking price which is lowered until some participant is willing to accept the auctioneer's price, or a predetermined reserve price (the seller's minimum acceptable price) is reached. The winning participant pays the last announced price. This is also known as a clock auction or an open-outcry descending-price auction. This type of auction is convenient when it is important to auction goods quickly, since a sale never requires more than one bid.

The life-cycle of a Dutch auction within the auction house agent environment (the marketplace) is presented at the following diagram which will be used for the explanation of the electronic marketplace functionality.

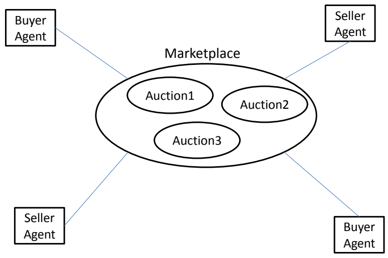

Fig. 1. Marketplace

According to figure 2, inside the system there are tree type of agents:

- Buyer agent: The Buyer agent acts on behalf of a hospital that is interested in buying a quantity of drugs or medical equipment. On the one hand it listens for orders from the client hospital and, to fulfill them:
  - queries the marketplace for possible running auctions that they trade about goods inside his range of interests;
  - decides to participate at an open auction either he is putting a request to the marketplace in order to be automatically included at the next auctions that will take place and concerns the product it is interested about. When the buyer agent has already made purchases on behalf of the hospital client, it is passing at a state where is waiting a message from the client hospital with new goal directions.

  On the other hand it goes through a multi-criteria decision making procedure that can be summarized as following:
  - evaluation of the details of the product of interest (product type, product quantiy, desirable price, desirable delivery time);
  - perception and analysis of the details of the running auctions that concern the desirable product;
  - estimation of the percentage of fulfillment of agent's goals at the auction where it is participating. Each buyer agent has a percentage tolerance to its goal accomplishment depending on its designer demands.

  This procedure has in the end one of the three following possible outcomes:
  - to attempt at completing a selected purchase;
  - to await better opportunity;
  - to declare the purchase impossible and notify the client hospital accordingly.

- Seller agent: The seller agent acts on behalf of a hospital that is interested in selling a quantity of drugs or medical equipment. Its responsibility is to ask a marketplace agent to start an auction about a specific product. The seller agent is asking from the marketplace agent to start an auction at a specific time, for a specific product and with a specific starting price. If this type of negotiation is succesful it is called agreement/commitment between the seller and the marketplace agent and it

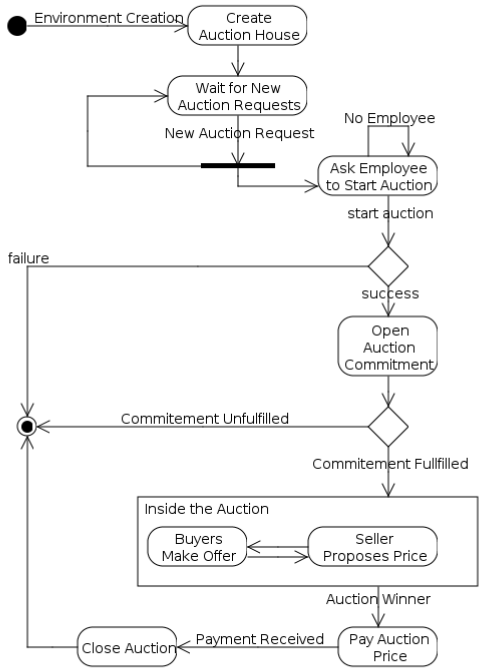

Fig. 2. Auction House Environment State Chart

is considered an informal contract. When the auction is succesful, the seller agent is transfering the result to the client hospital and is listening for new messages for future selling products.

– Marketplace agent: The marketplace agents are responsible for the organization of the dutch auctions inside the marketplace. The accept the request for new auctions from the seller agents and at the appropriate time the start and direct the auction. If there is no offer at the predefined price from a buyer agent, the marketplace agent is responsible for lowering the price of the product. If there is no interest, these agents close the auction as unsuccesful. When the auction is succesful these agents are performing the transaction of changing the credit account balance between the corresponding hospital by sending a message to the buyer and the seller agent.

Inside the marketplace there is a number of rules that apply and restrict the behaviour of the agents:

– A seller agent cannot ask for a new auction unless there is at least one available marketplace agent;
– A buyer agent cannot join an auction when a sanction has already applied to him by a marketplace agent;

- A marketplace agent cannot agree with a seller agent to start an auction for a product that has not been registered to the system database;
- A marketplace agent must start an agreed auction at the predefined time and the predefined starting product price;
- A marketplace agent must during a auction lower the price of a product when there are no buyers;
- A marketplace agent must announce as winner the first agent that gives an offer for a product;
- When a marketplace agent has an offer must send a notification to both the buyer and the seller agent in order to modify their account balance;
- A buyer agent cannot be declared the winner of the auction until he has modified his account balance with the seller agent;
- The seller and the buyer agent must notify the marketplace agent that have changed their account balance;
- A marketplace agent cannot close an auction until he has a confirmation that the account balance between the seller and the buyer has been modified;
- When the buyer has not changed his account balance the marketplace agent must cancel the auction and send a notification to the seller agent;
- When the buyer has not changed his account balance the marketplace agent must apply a sanction restricting its behaviour.

3.4 Negotiation Platform Requirements

Based on the technical information described in the the previous sections, we summarize here the full list of requirements for the Hospital Negotiation Platform.

User and Functional Requirements

- The hospitals must be capable of programming offline their trading software agents according to their own goals;
- The hospitals must be able to register their agents inside the platform;
- The hospital administrator must be able to monitor the actions of its trading agent;
- The hospital administrator must be able to take control online over its software agent;
- The platform has to provide the possibility for negotiation between software agents and between sotware and human agents;
- The platform must support multiple dutch auctions simultaneously;
- The platform must provide infrastructure agents (marketplace agents) which can negotiate with the trading agents towards the opening of auctions;
- The trading agents must be able to perceive the current state of the platform; that is to perceive the negotiation environment of open auctions;
- The trading agents must have the possibility to make a request to the platform in order to get notifications for open auctions about specific products;
- The trading agent can enter an auction at any time, providing that the marketplace agent has not declared it as closed;
- The platform must provide an appropriate negotiation protocol for the communication between the trading and the merketplace agents;

- The platform must provide safe payment services to the trading agents;
- The negotiation platform must check the validity of the selling medical goods against the database of registered medical products;
- The platform must provide a number of rules for the admission of agents to negotiations, for the checking the validity of selling or buying proposals and for controlling the agreements formations and the negotiation termination;
- The platform must provide explicit rules for the function of a dutch auction which must be perceivable by all the registered agents;
- The platform must provide appropriate roles to the agents according to the context of their actions;
- The platform must allow trading agents to cancel their requests for opening auctions;
- The platform must allow hospital units to develop their own applications inside the system (e.g. applications that apprise of the other participants for their available trading medical products).

Security Requirements

- The platform must allow participating hospital to register providing username and password credentials;
- The platform must be able to authenticate buyer and seller hospital agents when they log into the system;
- The platform must provide encrypted communication channels between the participant agents in order to guarantee the safety of the exchanging messages;
- The platform must allow both the offline and online reprogramming of the agent targets by the corresponding hospital units;
- The platform must provide confidentiality of payment transaction data;
- The platform must preserve the integrity of payment data;
- The platform must explicitly define algorithms and protocols necessary for all the security services;
- The platform must produce log files describing all the past activities inside the system.

Interoperability Requirements

- The platform must provide all required details to ensure that applications developed by the various vendors will interoperate;
- The platform must create and support an open payment card standard (based on virtual credits);
- The platform must ensure compatibility with and acceptance by appropriate standard bodies;
- The platform must support implementation on any combination of hardware and software platforms such as Intel, UNIX, Mac OS, Windows;

3.5 Negotiation Platform Technology

As we have already mentioned in the previous sections, we use a rule-based approach to formalize the negotiation procedure inside the platform and we also use multi-agent systems technology to deal with the automatic negotiations. This observation is leading us to adopt the concepts of normative systems.

Normative systems, or as Agotnes et al. specify [1], systems were social rules apply; try to tackle the issues presented by open MAS by defining rules to coordinate the heterogeneous agents. Social agents are assumed to belong to a group and follow the norms that are obliged to be followed by members of that group. Following norms is taken as to behave according to expectations. The objective reality is extended by a social reality of obliging norms (acknowledged as such by the group). The conformity between the norms of the group and the behavior of the agents and the relation between the norms and the generalized interests of the agents (and thus if it is useful for the agents to confirm to those norms) are part of this social rationality. Agents act with respect to an objective world and a social world, namely the normative context that defines the possible interactions and legitimate interagent relationships.

In particular, there are two approaches to define normative systems [18]:

- regimentation based normative systems, in which a set of rules and protocols are defined to coordinate the behaviour of the agent;
- enforcement based normative systems, in which some of the agents in the open MAS have the role of regulator agents enforcing the rules when they discover they have been violated.

On one hand, Modgil et al. [18] argue that the enforcement based normative systems are more flexible than regimentation based normative systems as for the latter it is necessary to specify the rules at design time and the agents are not free to perform actions outside the rules defined by the normative system. On the other hand, the enforcement based approach allows agents to take actions outside the rules of the normative system, but it has the drawback that sometimes the agents can behave maliciously and not being caught by the enforcer of the law.

In our platform we utilize the enforcement based normative systems where we try to apply a flexible approach to the definition of rules for the normative systems.

We primarily use Electronic institutions (EI) [13], which are considered an approach to normative systems, which contain a constitutive and regulative part and have many properties common to agent environments. We can regard an EI as a mean for imposing a well-defined structure to the social reality within which agents interact. Actually, institutions define a set of rules that mediate the interaction taking place between the agents representing the different hospitals. This type of mediation in EIs is realized by using three main concepts for mediation:

- power;
- obligation;
- permission.

Power specifies that an agent can perform a designated action in a context, which creates or changes an institutional fact (propose a price for a pharmaceutical product inside an auction). Obligation expresses the idea that at a given time the hospital agents should produce an action as specified by the rules of the normative system (marketplace). Obligations imply also the concept of prohibition or negative obligation as an action that is forbidden by the rules of the system at a certain time. The concept of permission is both related to the state of the institution and to the concept of power. When a hospital agent tries to perform an action for which it has the power, this action will have success only if the action is also permitted in the institution (e.g. auction) at that point in time. In other words, an agent can exercise its power, if and only if the institutional conditions permit it.

The space that provides the surrounding conditions for agents and the electronic institutions to exist and that mediates both the interaction among agents and the access to resources in our system is called agent environment [29]. The environment in an independent block inside the MAS structure of the OpenEHealth platform that has its own responsibilities irrelevant to the goals of the hospital agents. The agent environment in our case of the hospital negotiation platform offers four level of support:

- Virtualization. The environment is offering an abstract view of the resources of the MAS, hiding the low level details from the hospital agents. This abstract view is always synchronized in order to reflect the real state of the resources;
- Virtual resources. These virtual resources are in fact functionalities/services of the negotiation system that can be used by the hospital agents when they register inside the platform;
- Mediated Interaction. The environment mediates the interaction of the agents with both the environment and the resources applying also the corresponding laws and norms.
- Reflection. The environment supports the modification of its composition and function during runtime. The hospital agents can perceive the properties of the environment and interact in order to modify its state e.g. the hospital agents can interact with each other inside the negotiation platform and ask for a rule of the dutch auctions to change. When this happens they environment representing the platform corresponds appropriately.

The environment in our hospital platform is a software infrastructure that regulates all the actions inside the MAS. We describe the environment as a programmable coordination medium because of the fact that it is possible for the developer of the platform to specify the laws and the norms of the MAS as reaction to events, where events are data that are released inside the environment and can result to specific reaction. This approach has the strong advantage that allows the regulation not only of the agents interaction but almost all the activities inside the system.

3.6 General Architecture

The negotiation platform should allow users, through a web user interface, to create buyer and seller agents that negotiate under the model we just described. The system should be designed in layers, in order to separate the infrastructure components that provide the communication and negotiation protocols from those associated with the agents negotiation strategies. This provides both openness and easy expandability.

For this type of platform we propose the following layers for the general architecture schema:

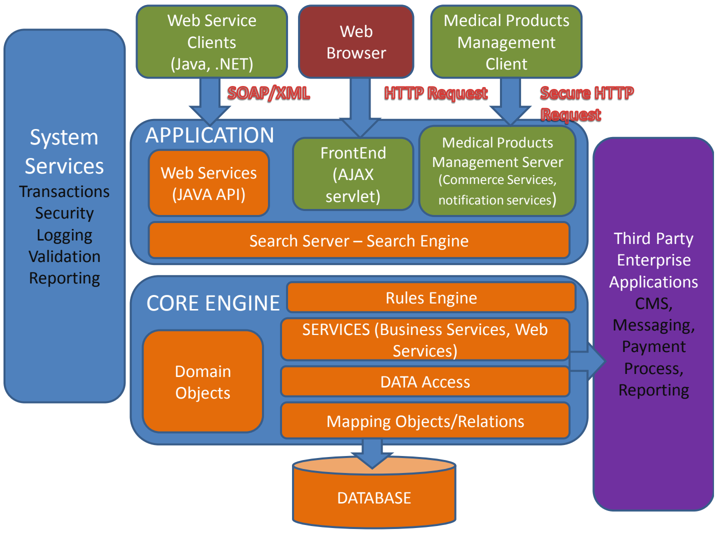

Fig. 3. General Architecture Overview

Service Layer

The service layer provides services to various consumers in the web layer as well as web service consumers. There are several types of services that serve different roles in the application:

- Persistence services provide the capability to save and retrieve domain objects;
- Domain services implement the logic for a use case that is inappropriate for encapsulation by any one domain object;
- Integration services implement functionality that is considered outside the domain of the hospital negotiation application and typically integrate with other systems or technologies (e.g. EmailService);
- System services handle various concerns that cut across many parts of the application;
- Web services expose service layer functionality to web services clients. These services are delvered via SOAP.

Domain Layer

The Domain layer contains an object model of the negotiation platform domain. This object model consists of classes that model real-world entities such as hospitals (including hospital software agents), products and auction institutes. This layer includes the predefined market agents, that were built using the MarketAgent template. The behavior and relationships of these classes is a reflection of the real-world entities.

Data Access Architecture

The data access layer is responsible for saving and retrieving data from persistent storage. The majority of persistent data at the clients site is stored in the database using the Java Persistence API (JPA). A small number of configuration files can be persisted directly to the file system using XML and properties files.

FrontEnd

The architecture of the FrontEnd component of the hospital negotiation platform is comprised of the following technologies:

- Javascript: Javascript is used to create rich user interfaces in the browser;
- CSS: Cascading Style Sheets provide formatting and positioning for elements across all HTML;

Medical Products Management System

The Medical Products Management System is comprised of the following functionalities:

- Provides centralized file storage for digital assets such as medical product images that are manipulated by Medical Products Management Client users;
- Hosts web services for integration with external systems;
- Executes scheduled batch jobs for both the FrontEnd and Medical Products Management clients.
- Provides the following centralized services the hospital clients:
  - Payment processing;
  - Notification sending;
  - User authentication.
- Database

Rules Engine

The rule system if the negotiation platform is based on the JBoss Rules (formerly Drools Rules) library. JBoss Rules is a third-party rules engine that uses a fast algorithm to evaluate rule conditions and execute their actions. The input to the JBoss Rules engine is a set of objects used in the condition evaluation and action execution as well as the set of rules, which are expressed as text in the Drools language.

Web Sevices

Web Services is one of the methods that remote hospital clients can use to access the clients core application. The Web Services API is a SOAP-based layer that is intended to provide integration functionality for the clients customers.

3.7 IHE Architecture

IHE is an initiative by healthcare professionals and industry to improve the way computer systems in healthcare share information. IHE promotes the coordinated use of established standards such to address specific clinical need in support of optimal patient care. Systems developed in accordance with IHE communicate with one another better, are easier to implement, and enable care providers to use information more effectively. In the OpenEHealth project different standards of the IHE initiative can be used in the system architecture:

ATNA - Audit Trail and Node Authentication
Audit Trail and Node Authentication provides a specification for the characteristics of a basic Secure Node by:

- Describing its security environment (identification, authorization, authentication, access control);
- Defining its basic auditing requirements;
- Defining the basic security requirements for communications (TLS or equivalent);
- Establishing the communication protocol between a Secure Node and an Audit Repository node collecting audit information;
- Defining a Secure Application actor, which basically designates a product configuration that is not able to fulfill the specific requirements of a Secure Node.

Specific implementations of the ATNA profile may choose diverse additional options described in the Technical Framework.

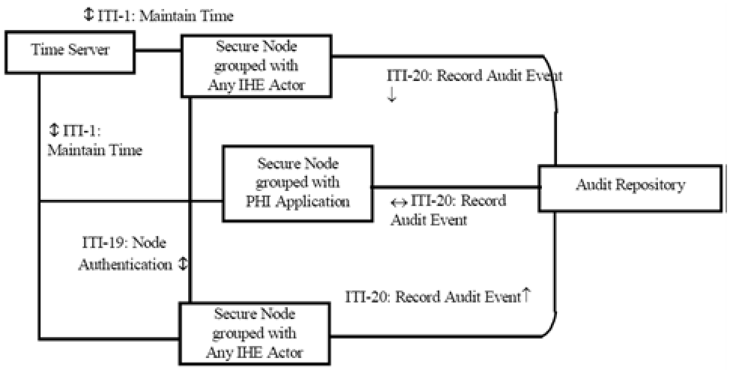

Fig. 4. ATNA Profile Actor Diagram

The actors of this profile include:

- Audit Record Repository. Handles the reception and storage or audit records;
- Secure Node. Node which can establish a trust relationship to other nodes by using a mutual authentication mechanism, which is protocol specific (TLS for example);
- Secure Application. A secure application uses the same authentication mechanisms as a secure node, but to a lesser extent. It only handles authentication and authorization at the application level, without taking care of the security level of the machine it is running on (operating system, network, etc.).

XUA - Cross-Enterprise User Assertion
The Cross-Enterprise User Assertion specifies a way of communicating claims about the identity of an authentication principal (user, application, system, etc.) in transactions, which may cross enterprise boundaries. The objective of the XUA profile is to provide accountability in transactions that cross enterprise boundary, but identifying the requesting principal in a way that enables the receiver to make access decisions and generate the proper audit entries.

The actors of this profile include:

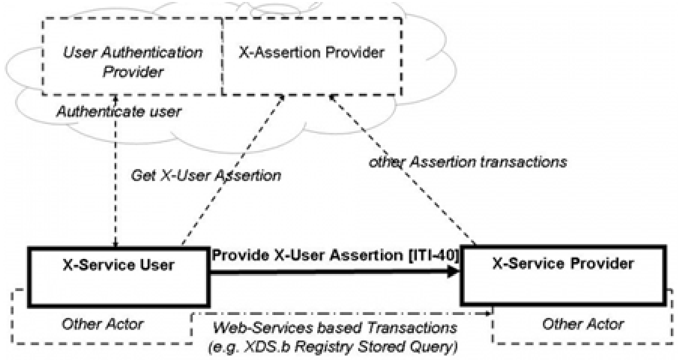

Fig. 5. XUA Profile Actor Diagram

- X-Service User. User requiring a security assertion to connect to a service;
- X-Service Provider. Service providing a security assertion for a transaction, which requires it.

The XUA profile ensures that only authenticated principals are allowed to access services offered by the MAS and the XDS infrastructure in OpenEHealth. Furthermore, assertions are also important for accountability. They convey information about the authenticated principal, included basic demographics, which is enough to provide accurate record events and non-repudiation.

EUA - Enterprise User Authentication

The Enterprise User Authentication Profile helps establishing one name per participant, which can then be used in all the provided services of the domain infrastructure. The EUA profile leverages Kerberos for authentication and HL7 CCOW for user subjects.

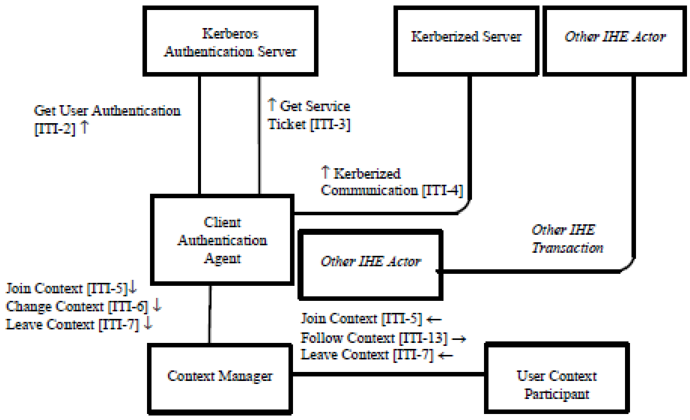

Fig. 6. EUA Profile Actor Diagram

The actors of this profile include:

- Kerberos Authentication Server.Performs the authentication tasks. This server is called the Key Distribution Center (KDC) in Kerberos terminology;

- Client Authentication Agent. Handles the authentication information exchange with the Kerberos Authentication Server. Requests the TGT and performs some internal management;
- Kerberized Server. Accepts and verifies the ticket and use it for related services;
- User Context Participant. Established a secure context session connection with the Context Manager in order to be able to follow User Subject changes in the context;
- Context Manager. Manages the context sessions and responds to all requests to join or leave the context.

The EUA profile usually applies in a single enterprise context. Using it in the interaction of multiple organizations may seem like a bad idea first. However, since the agent management platform in OpenEHealth can be seen as a single virtual enterprise, EUA still can be applied for the authentication of principals.

EUA is to be used alongside with HPD and XUA. Implementing EUA may seem like a daunting task at first. Fortunately, there exist security services like OpenAM (formerly OpenSSO) that can be used to ease its implemention.

HPD - Health Care Provider Directory

The IHE Health Care Provider trial implementation intends to specify a profile for the management (persistence and access) of healthcare provider information in a directory structure. The HPD profile distinguishes between two categories of healthcare providers: individual and organizational providers. An individual provider is a person providing health services (nurse, physician, etc.). An organizational provider supports healthcare services. Hospitals and HIE networks fall in this category.

This profile is a significant impact on the management of identities in the OpenEHealth project. The HPD manages demographic and specialty information. Not only does it provide the necessary attributes for construction the XUA assertions, but it also provides the input for the enterprise authentication step (EUA).

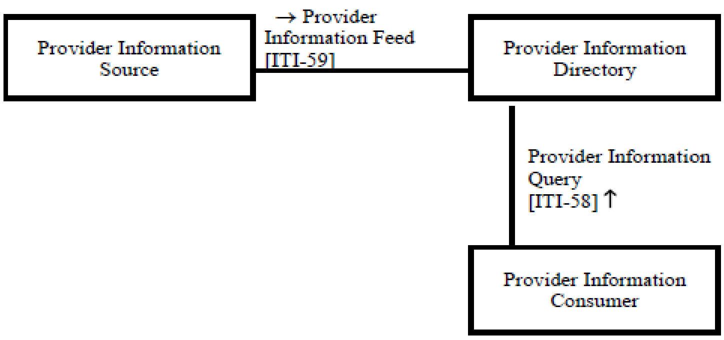

Fig. 7. HPD Profile Actor Diagram

The actors of this profile include:

- Provider Information Source. Feeds provider demographics to the directory. Each feed consists of Add, Update, or Delete requests;

- Provider Information Directory. Manages demographics and replies to queries;
- Provider Information Consumer. Initiates query requests to the Provider Information Directory. Queries include the set of information, which needs to be returned.

HPD relies on sourcing and consuming actors. The Provider Information Source actor provisions the directory persistent information and the Provider Information Consumer consumes it.

XDS - Cross-Enterprise Document Sharing

The Cross-Enterprise Document Sharing profile organizes care units under a single domain (e.g., a community of care), enabling the cooperation in the care of the patient, by sharing clinical records. An XDS domain, also called XDS Affinity Domain is organized into federated document repositories revolving around a single document registry. XDS assesses the ebXML Registry and SOAP standards, allowing effectively the creation of longitudinal records and information sharing inside the same domain, or across enterprise boundaries.

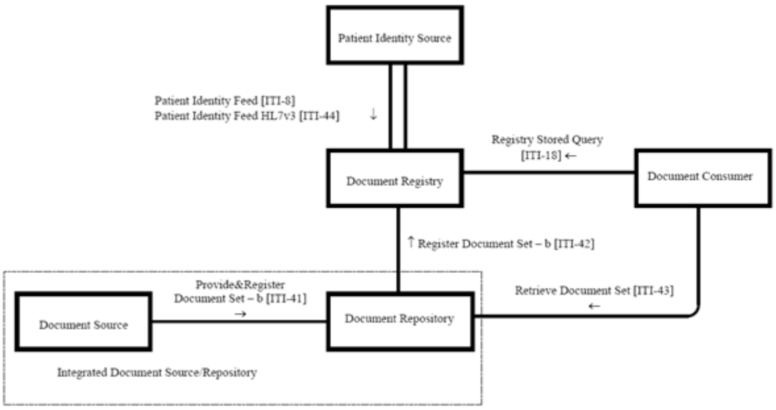

Fig. 8. XDS Profile Actor Diagram

The actors of this profile include:

- Document Registry. Secure Node maintaining metadata about each registered document in the XDS Affinity Domain. It can respond to queries issued by the Document Consumer actor to get metadata matching a certain criteria. It also can respond to a Document Repository in order to register metadata about a document;
- Document Repository. Secure Node maintaining a persistant storage of the registered documents. It is furthermore responsible for forwarding registration requests to the Document Registry of the XDS Affinity Domain;
- Document Source. Actor which produces documents for submission and registration;
- Document Consumer. Actor which consumes documents and metadata from both actors: Document Registry and Document Repository.

In OpenEHealth, it is possible to leverage the distributed capabilities of XDS to isolate individual agents, while making them still able to communicate with the central MAS platform. The figure below shows an example platform, which could be achieved with one central registry and several participating organizations:

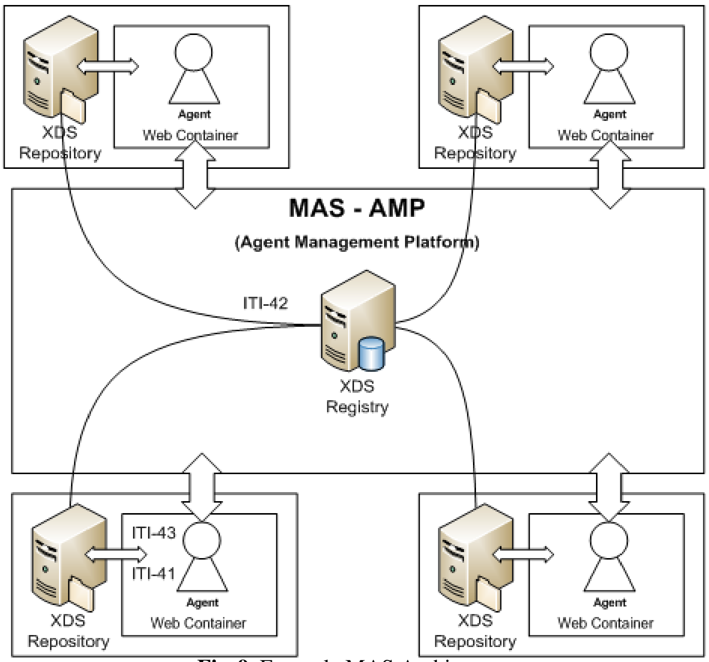

Fig. 9. Example MAS Architecture

The architecture above uses a central management platform and individual agents sitting inside participating hospital infrastructures. While agents store individual data inside their respective XDS repositories, the central MAS-AMP platform manages their interaction with the others. This architecture allows to efficiently isolate agents from external influence while facilitating the supervision of the security infrastructure implementation (well defined input and output channels).

3.8 Working Scenarios

We can better explain what is happening inside the market place with three basic scenarios.

- Scenario1 - Emergency case: In an emergency case, a hospital unit is joining the negotiation system and is quering the marketplace for an open auction concerning the product of interest. In this case the hospital making the request is not interested in the price of product but in the estimated delivery times. The following protocol can be applied:
  - Step1: The hospital is joining the negotiation system;

  - Step2: If currently there is not an open auction the hospital is sending a notification announcing to the system (product type, delivery time, quantity); When there will be an auction about this product the markeplace agent will automatically include the buyer agent to the auction and will send to it a notification.
  - Step3: If there is already an open auction, the buyer agent wil start a negotiation procedure with the marketplace agent in order to participate.
  - Step4: The buyer will check the estimated delivery time of the product if is fulfilling its demands. In case it does not, the buyer will not make an offer. In any other case, the buyer will send a message to the marketplace agent transfering its request to buy the product on the specified price;
  - Step5: The marketplace is closing the auction sending an appropriate message to the participants while at the same time is sending a request to the buyer and the seller to modify their credit account balance in order for the transaction to be fullfiled.

- Scenario2- Selling medicaments: In this scenario, a client hospital following the suggestions from its decision support mechanisms is deciding to send a message to its seller agent to try to sell a quantity of a specific medicament type that is not planning to use until its expiration date. The hospital is offering the product at an initial minimum price and is waiting for counter offers from the other participant units. The following protocol can be applied:
  - Step1: The seller agent is joining the negotiation system;
  - Step2: The agent is starting a negotiation with an available marketplace agent for a new auction. The seller is sending a notifications which includes the desired auction starting time, the product type that want to trade, the initial product price and the estimated dispatch time. When everything is valid the marketplace representative is sending back a positive acknowlegment;
  - Step4: The seller agent is inspecting the progress of the auction. When there is an offer from a buyer, the marketplace agent is sending a notification to the seller which then decides whether it will accept or reject the offer. Each time the marketplace agent is listening for new messages from the buyers concernings new offers
  - Step5: The marketplace is closing the auction sending an appropriate message to the participants while at the same time is sending a request to the buyer and the seller to modify their credit account balance in order for the transaction to be fullfiled.

- Scenario3 - Buying medical equipment: The regular buying scenario differs from the emergency one on the sense that the time of the delivery is not the most important aspect. In addition the hospital is now interested in comparing many offers in order to choose the better price. The following protocol can be applied:
  - Step1: The buyer is joining the negotiation system and is quering the system for open auctions;
  - Step2: If currently there is not an open auction the hospital is sending a notification announcing to the system (product type, delivery time, quantity); When there will be an auction about this product the markeplace agent will automatically include the buyer agent to the auction and will send to it a notification.

- Step3: If there is already an open auction, the buyer agent wil start a negotiation procedure with the marketplace agent in order to participate. It is important to stress out that a buyer agent can participate to more than one auctions simultaneously.
- Step4: The buyer will check the price and the estimated delivery time of the product for whether is fulfilling its demands, at all the auction he participates. In case it does not, the buyer will not make an offer. In any other case, the buyer, according to its strategy, will send a message to the marketplace agent transfering of the auction that best fits its interests. This THis offer will include the price for the product;
- Step5: The marketplace agent is closing the auction sending an appropriate message to the participants while at the same time is sending a request to the buyer and the seller to modify their credit account balance in order for the transaction to be fullfiled. When the transaction is complete, the buyer will send a notifications to all the other auction his is paticipating that it withdraws from the auction

Observing the above scenarios, we can easily notice that while in emergent demands the negotiation procedure needs to be handled by humans, there are other actions that could be efficiently automated. The request for a quantity of medicaments for example, can be made by a software entity in the general case that this request wants to cover midterm needs. A software entity can also substitute humans at the sale of medical equipments that are not necessary any more. These are just some of the cases where software agents could be used in order to significantly facilitate the negotiation procedure.

4 Evaluation Method

In order to evaluate the negotiation platform for hospitals, we need to perform a number of experimental tests using software and human agents. The key question is what criteria we should adopt in order to validate our work. Based on the ISO/IEC 9126 standard, we propose four points of great importance:

- *Functionality*: The functionality dimension is meant to evaluate the essential purpose of a product or service. The main purpose of our work from a technological point of view is to fill in the gap between agents, social rules, services and resources, in such a way that integrating normative systems into automatic open negotiation platforms will be easy. The basic question we need to consider when we evaluate the functionality of our system are related to security and interoperability:
  - How do we ensure the security of the protocols that allow the transactions inside the platform?
  - How do we ensure the optimal use of services and resources by the agents?
  - Since a negotiation system is by definition open, does our model allow the interaction between heterogeneous systems? (different agents that represent each hospital)

– *Reliability*: The reliability characteristic refers to the capability of the system to maintain a stable service under defined conditions for defined periods of time, exactly as it has prescribed at the system specifications. This characteristic of the model is related to the fault-tolerance of the system. We need to answer to a number of issues:
  • How does the system react when the agents do not respect the norms?
  • How does the system react when there is a fault at the application of norms?
  • How do we ensure the safe use of services and resources by the agents?
– *Usability*: The usability dimension refers to how easy is for users and administrators to utilize our system. The questions that are of main concern can be summarized as:
  • Which mechanisms our platform provides to human agents in order to enter the negotiation system?
  • How complicated is for human agents to create an auction inside the system?
  • Does the system provide any functionality for the monitoring of the activities to the end users?
  • How the administrator will supervise the function of the system?
– *Scalability/efficiency*: Scalability of a system indicates its ability to handle growing amounts of work in a graceful manner. In order to achieve optimal scalability of our system we need to consider:
  • How many agents can our system support?
  • How many institutions can be present simultaneously inside the system?
  • What is the throughput of the system in terms of time and fault tolerance when its complexity is growing?
  • How does the system ensure the appropriate resources allocation when the amount of agents is at its upper limit?

Finally, since we want the model we will use in order to develop the negotiation platform, to embed the properties of agent environment into normative systems, we should compare it with other approaches that exist in the literature and try to define its advantages and disadvantages

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