Towards Dynamic Assignment of Rights and Responsibilities to Agents

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Abstract

Multi-agent computational systems are systems of multiple, interacting software entities. For many such systems, the concepts of organization and roles provide a useful way to structure the activities of agents and of the system, and thus provide a means to structure the design and engineering of these systems. Accordingly, most architectures and frameworks for multi-agent systems (MASs) have some notion of organization and of roles within organizations, and of rights and responsibilities of agents associated to particular roles.

For many applications, the roles, rights and responsibilities of agents may change during the running of the system. In these cases, roles and/or rights and responsibilities (R&Rs) need to be assigned to agents dynamically – ie, at run-time. In this paper, after describing normative issues of R&Rs, dynamic issues in MAS, the issue of dynamic assignment of R&Rs of roles to agents is discussed. The paper presents the basis for our future work aimed at implementing a middleware tool for such dynamic assignment in multi-agent systems.

Keywords

Agent, Role, Rights and Responsibilities, Dynamic Assignments, Normative Multiagent Systems.

1. Introduction

Using the metaphor of organizational infrastructure is a very fundamental and useful pattern for developing multiagent systems (MAS), because an organization model provides a very high–level abstraction to model and develop complex systems. The concepts of roles, rights and responsibilities of roles, and the interrelations of roles are examples of such abstractions provided by an organization model.

However, the emergence of advanced features such as open, dynamic, unpredictable and distributed environments with high degree of interaction causes an increase in the complexity of MASs. In order to ameliorate the complexity, the investigation of novel approaches and techniques over the organizational model is essential.

For example, consider open MAS characterized by unknown agents in which the population of agents can change over time. Considering the organization structure in such a dynamic environment, agents join to the system dynamically, so their roles must be assigned to them dynamically as well. Dynamic assignment of roles to agents is an instance where the organizational-based approach has been proposed to reduce complexity.

This paper aims to present dynamic assignment of rights and responsibilities of roles to agents, as a new approach to cope with the complexity of normative multiagent systems. Normative multiagent systems are multiagent systems regulated by norms. The agents can decide whether to follow the represented norms from the normative system [1, 2].

In a typical MAS based on organization structure, roles have rights and responsibilities which are implemented using protocols. In normative MAS, rights and responsibilities of roles can be considered as norms, although, in addition to the protocol-based norms, normative MAS contains rule-based norms as well.

The main difference between protocol-based and rule-based norms at runtime is that agents *cannot but follow* the predefined dialogues of protocols while they *decide* whether to *follow the rules*. In fact, agents have full autonomy for acting according to the rules or against the rules.

This approach focused on the rule-based type of rights and responsibilities (R&Rs) of roles. Agents

with full autonomy to follow or violate the rules in a normative MAS make an unpredictable and dynamic environment such that the execution of rules to impose rights and responsibilities of the agent at each instant of time would be a runtime task. This means at runtime specific R&Rs of roles are assigned to agents at each instant of time. Such assignments are based on the represented norms of the normative MAS and dynamic triggers including the actions of the agent or other environmental events.

This paper introduces a proposal for dynamic assignment of rule-based R&Rs of roles to the agents in normative MAS. Section 2 gives an overview of the main concepts of rights and responsibilities in normative MAS. Then dynamic issues in MAS are discussed in Section 3, which talks about the sources of dynamism in multiagent systems and the influence of such dynamic issues in normative MAS. Section 4 describes different types of dynamic assignments in normative MAS and specifically explains our proposal for dynamic assignment of R&Rs in detail with comprehensive examples. Related work is discussed in Section 5. Finally Section 6 gives some concluding remarks.

2. Rights and Responsibilities of Roles

This section begins with an introduction to roles in multiagent systems. Then after introducing rights and responsibilities of roles in general, the normative viewpoint of R&Rs of roles is explained.

2.1. Roles

The concept of roles in multiagent systems originates from real roles in organizations. In a human organization, there are some predefined and specified roles which throughout the organization's lifetime different individuals might fill.

In MAS, roles afford the ***appropriate level of abstraction*** for the specification of communication between agents. For instance, a supermarket as an organization has roles such as *store manager*, *sales manager* and *sales assistant* and these roles are instantiated with actual individuals such that:

- During the supermarket's lifetime there is always an individual who takes the role of e.g. *store manager*.
- The role of an individual may be changed after a while, such as promoting a *sales assistant* to give them a *sales supervisor* position.
- Different individuals may have the same position (in a supermarket, there are several *sale assistants*).
- Different roles can be assigned to one individual (a person may have both *sale assistant* and *customer service provider*).

2.2. Rights and Responsibilities

Generally in MAS rights and responsibilities of roles have the following main features:

First, in MAS, each role has its own set of rights and responsibilities, ***independent from the other roles***. Roles do, however, have interrelations and contribute towards the collective objectives of the multiagent system. For instance, in the supermarket example, the role of *store manager* has a set of rights and responsibilities which are different from *sale assistant*.

Second, the rights and responsibilities of roles are ***predefined*** in a multiagent system and are ***independent of the agent or individual who plays the role***. For instance, *sale assistant* is a role in the supermarket, which has several rights and responsibilities. These rights and responsibilities are the same if *Mari* is the agent who plays the role of *sale assistant* or *Sarah* is the agent who plays the role. But both have the common objective of keeping the supermarket active.

Specifically in normative MAS, rights and responsibilities of roles have additional features relevant to normative issues. In normative MAS, there are two types of regulation for roles: ***protocol-based norms*** and ***rule-based norms***.

Protocol-based norms provide the necessary conventions for agent interactions. This type of norm establishes the permitted actions of each agent at each instant of time, considering the past actions of agents. These protocols are statically designed at design time. It requires the designer to define all norms or regulations of agents in the format of protocols at design time. So at runtime agents just follow the predefined dialogues of protocols, moving from one state to the other.

Rule-based norms are defined by a certain type of first-order formulae that set up a dependency relation between actions. These norms specify that under certain conditions, new commitments will be produced for agents to carry out some actions. The definition of rule-base norms are *statically* defined in the knowledge base of the MAS, but the execution of rule-based norms for agents is a *dynamic* task which is done at runtime.

As a main difference between protocol-based and rule-based norms, during the runtime, agents *can not decide but follow* the predefined dialogues of protocols while they *decide* whether to *follow the rules*. In fact, agents have full autonomy to act according to the rules or against the rules.

So far we have focused on the rule-based type of rights and responsibilities (R&Rs) of roles, next the normative viewpoint of R&Rs (or norms) is discussed.

2.3. Classifications for norm types

According to [3], there are three types of norms:

- **Regulative norms** are those which help to regulate existing actions of agents. As an example, driving is an action which traffic rules help to regulate. This type of action can be done ignoring the regulations as well, but regulative norms are used to regulate actions which could be performed in any case. Regulative norms describe obligations, permissions and prohibitions.
- **Constitutive norms** are non-regulative norms, which have a classificatory or definitional character. Such types of norm have been called *counts-as conditional* with the formalization of "X counts as Y in context C" [4]. For example, *"Motorcycles count as vehicles in the transportation domain."* defines a classification. The other well-known example is chess in which the rules of the game constitute the activities of the game. Such activities are dependant on these norms, as opposed to the regulative systems where activities are independent from the norms.
- **Distributive norms** define how rewards, costs and punishments are assigned to the social system. The main contribution of this type of norm is in the enforcement of the norms; specifying the rewards for doing a legal action or the punishment after a violation. Later, in relation to norm enforcement, these issues will be discussed further.

In this classification, norms are classified based on how they function in human interactions and these three kinds of norms tend to show different degrees of force. For example, distributive norms tend to present a stronger reaction against violations; otherwise, a distributive norm is just an additional norm.

2.4. Regulative norms

As mentioned earlier, regulative norms point out the norms containing obligations, permissions or prohibitions. Here the main elements of regulative norms are presented.

2.4.1. The key elements of regulative norms

In the following the key elements of the regulative norms are shown by means of examples.

- The **Addressee of the norm** [5]is the norm subject that can be specified by the norm for an individual, an agent, public or the system. In the other words, addressee is the agent which does the act.
- The **Beneficiary of the Norm** is someone who benefits from the norm. The beneficiary of the norm is as important as the addressee of the norm. For example, in the following norm:
  "In an Auction, the Winner of an item is obliged to pay the Seller the price of the item."
  Winner is the addressee and Seller is the beneficiary.
- **The legal modality** (deontic modality) [5] determines if the norm is either an obligation (ought), a prohibition (ought not) or a permission (may). For example:
  "*In an auction, seller is forbidden to place a bid."* shows a prohibition on placing a bid by the seller.
  Rights can be considered as a kind of permission which needs to be made explicit in the context.
- **The act** [5] is what the addressee is commanded, prohibited or permitted to perform. In the above example, *placing a bid* is the act.
- **Time** [5, 6]. Most norms are affected by time in different ways and the norm should specify *"When must something done or forborne?*".
  The notion of time in norms can be divided into start-time, deadlines (if passed, these give rise to violations) and time limits. Time parameters can be attached to a norm with functions of after(t), before(t) and between(t1,t2).
  Some norms will be activated from a moment of time for ever, such as: *"Smoking will be banned in restaurants after April 2007."* Some norms are active for a period of time and after that they will be deactivated. However, some norms are timeless which means this type of norms expresses an obligation, permission or prohibition all the time. For instance, *"Drivers are obliged to follow the traffic regulations."* is an example of a timeless norm.
- **Conditions** [6] for norms specifies that activation or deactivation of a norm is subject to some circumstances. In other words, if some conditions hold, the conditional norm will be activated or deactivated. For example, the condition may be occurrence of an action, such as *"If Winner pays the price of item, Buyer is obliged to send the item."*

2.4.2. The Key Issues on Legal Modality

Since the legal modality is the major element of the norm, the key issues of legal modalities are explained with more details.

An **obligation** is an action which should be performed by the addressee. If doing the action is not performed, the addressee may be subject to some punishment or forfeit some right. (e.g. *"Everybody is obliged to pay tax."*)

A **prohibition** is an action which according to the law, should not be done by the addressee. Like an obligation, the addressee may be subject to some punishment or sanction if the norm is violated. (e.g. "*In an auction, seller is forbidden to place a bid."*).

A **permission** is an action that addressee is allowed to do. (e.g. *"Students is permitted to access to the university library."), and allowed not to do*.

Right [7] is a kind of permission, but permission is more general than right. With a right, if the action does not happen, the beneficiary will lose something and s/he can complain to some agent in authority for compensation. The following example shows the difference of permission and right:

Norm1:"A member is permitted to login to the auction."

Norm 2:"Seller has the right to receive the money from the Winner of the auction."

Norm1 indicates a permission, but if the member does not do the log in action, s/he will not lose anything. But based on Norm 2 if winner does not pay, seller will lose the money and s/he can complain to the auction manager for compensation.

2.5. Norm Enforcement

The enforcement of norms is the other important aspect in norm discussions. In a normative system, norm enforcement is necessary, because of the possibility of violations. Violations are illegal actions or states that may occur. With respect to the legal modalities, violation can occur in the following cases:

- An obligation is not fulfilled by the end of the period of obligation.
- A prohibition (forbidden) activity occurs in the duration of prohibition.

Note that permissions are never violated by the addressee of the norm.

In order to control operation in accordance with the norms, and detect and handle violations, normative systems have enforcement mechanisms which define extra regulations called distributive norms over the normative system which such mechanism will be explained next.

2.5.1. Norm Enforcement Mechanism

In order to enforce norms, a plan of action to respond to the actions of agents relevant to norms should be defined. Such a plan would be a *punishment* when a violation occurs or a *reward* when a norm is retracted. Punishment and reward can be defined as follows:

- **Punishment:** Punishments are actions to punish the violator when a violation occurs: for example, additional obligations or loss of permissions may be a kind of punishment.
- **Reward:** Rewards are supplied when the norms retracted and no violation of such norms occurred. For example, additional permissions or entitlements may be a kind of reward.

Note that it depends on the legislator of the normative system to define punishments or rewards; in some cases, systems have not foreseen any punishments or rewards to provide a sanction mechanism.

Enforcing punishments or rewards in normative system needs some extra norms which are the distributive norms. Such extra norms include:

- **Check norm**: specifies the policy of the normative system for detecting the violation. Violation may occur at any time by any violator. Different systems have different mechanism to check the violation. Some of them have random checks to detect violation or some of them check the system based on a schedule. Therefore, check norms determine who and when the system will check to detect violations.
- **Reaction norm:** after detecting the violation, reaction norm defines what the reaction against the violation is.

To clarify, we refer to the following example of norm, check norm and reaction norm:

*"**Norm**: Winner is obliged to pay the item's price in three days.*

***Check norm:** The auction manager should perform random checks of the payments status every day.*

***Reaction norm:** If a winner has not paid by the deadline, then winner will be fined accordingly."*

3. Dynamic Issues in MAS

Traditionally agent based systems dealt with well-behaved entities in reliable infrastructures and simple domains; however, currently one of the main characteristics of open multiagent systems is that it is a dynamic environment and the management of dynamic environment is more complex. Therefore, the first step for handling such complexity would be

recognizing the sources of these dynamics in open MAS. In this section, the sources of dynamism and change are explained. Then, the next section will show the influence of these sources in the process of dynamic assignment of rights and responsibilities to agents.

3.1. The Source of Dynamism

The number of agents connected to the open system is unpredictable and may change. Therefore, the population of agents is not fixed at design time, but may emerge at run time. Consequently the variation in the population of agents is a dynamic factor in the environment of open multiagent systems.

For example, in a session of an auction system, there may be six buyers at the beginning. After a few minutes perhaps four of them remain, two of them have left the session and one new buyer has joined the session.

3.2. The Source of Changes

Runtime changes may also influence MAS. In a normative multiagent system, this change may cause a rule from represented normative system to be applied. So for dynamic assignment of rights and responsibilities it is necessary to recognize sources of changes.

The major sources of changes which affect on MAS are actions and environmental events. As the primary focus of this paper is on normative multiagent systems, environmental events have been divided in three parts as well.

Here, along with description of the sources of changes, using an example we explain that how a normative MAS may be influenced by occurrence of a change. So the sources of changes in normative multiagent system can be categorized as follows:

- **Agent action:** The action of an agent is what an agent does, which is the ability of the agent to affect its environment. Therefore if an agent does an action, a change has occurred. For example, *"Mari advertised a gold watch in Auction5 at 10:00."* shows that an agent (Mari) did an action (advertising). Following this action, some norm will be activated for agent (Mari) such as prohibition for placing a bid in Auction5.
- **Environmental events** are significant occurrences or changes (in agent's environment or internally from the agent) that the agent should respond to it by some means. Here we divide events in three parts:
    - **Action of other agents:** For example, *"David placed a bid of £30 for watch in Auction5 at 10:15."* Suppose Ali is the auctioneer of this auction, then David's action (placing a bid) is an event that gives rise to an obligation for Ali to validate the bid.
    - **Parameter Changes:** The system may have some environmental variables which may change at runtime. For example, *"increasing the number of negative feedbacks."* Suppose that after the last negative feedback increment, the number of negative feedback for an agent reaches to 3, and then given a particular auction rule, the agent account will be suspended.
    - **Passing time**: For example, suppose that *"Auction5 ends at 11:00"*. This time then imposes a new obligation on the auctioneer to close the auction session and declare the winner.

Note that here we do not consider network problems such as disconnections.

4. Dynamic Assignments

Management of the dynamic environment in open MAS is a complicated task. In order to cope with this complexity, the solution of dynamic assignment of roles to agents has already been proposed. For example, in [8], the authors have described dynamic assignment of roles to agents and supporting methodologies. In Section 5, a summary of that work is provided.

In this paper, the aim is to provide a similar dynamic assignment that improves the management of *normative multiagent systems* that is a certain class of open multiagent systems which are normative as well. Therefore, providing dynamic assignment of rights and responsibilities to agents of a normative multiagent system is the main objective of this work.

In the next section we will precisely explain both the idea of *dynamic assignment of roles to agents* and the idea of *dynamic assignment of rights and responsibilities to agents.*

4.1. Dynamic Assignment of Roles to Agents

As a definition, the method of dynamic assignment of roles to agents is a systematic way in which, taking account of conditions of roles, the capabilities of agents and the overall context of actions, roles are dynamically assigned to agents, by a group organizer or management system.

For example, in a supermarket, suppose *Ali* (as an agent) is a sale assistant and he has achieved some new capabilities and experiences which are

matched with the conditions of *department supervisor* (as a role). In the real time of the system, when the *manager* detects this match and assigns the role to *Ali*, a corresponding dynamic assignment of roles to the agents to reflect this change of status must occur.

In the auction example, when *"Mari logs into the system initially as a member"* she chooses to be a buyer in the auction session of Gold Watch. So the central management system gets her request, checks the auction session's conditions (e.g. *"There is an age limit of 18 for joining to this auction, because of the high price."*) and provides a history check for Mari as well. After passing the checks successfully, the role of buyer, and its accompanying rights and responsibilities, will be assigned to Mari by the management system.

Note that, here we use the word of *assignment* to state that dynamic assignment is a *management* task to assign roles to agents as required by events and actions. There is another dynamic way in which agents can themselves decide which roles should be employed for achieving specific goals. In the context of this paper, however, the roles are assigned to agents by the management system, and agents do not choose their roles by themselves.

The idea of *dynamic assignment of roles to agents* has been previously presented and supported by some methodologies. In [8], the authors described dynamic assignment of roles to agents and the supporting methodologies, followed by an evaluation and a comparison table.

4.2. Dynamic Assignment of R&Rs to Agents

Recall that dynamic assignment of rights and responsibilities to agents is proposed to improve the management of normative multiagent systems. Normative multiagent systems are multiagent systems together with normative systems in which agents can make decision whether to follow the represented norms in normative system [1, 2].

The normative part of the normative MAS represents all norms that agents have to follow them. Such norms indicate the obligations, permissions, prohibitions, rights and norms related to sanctions including check norms and reaction norms, as described in Section 2.

As in other multiagent systems, the concepts of ***role*** and ***rights& responsibilities*** can be used in the structure of normative MAS, so norms in normative MAS (which agents have to follow) can be considered as rights and responsibilities of roles which are assigned to agents at runtime.

Therefore, when at runtime a role is assigned to an agent, all the norms related to that role can be assigned to that agent. For example, in an auction system, there is a set of rights and responsibilities for the role of *Auctioneer*. So as long as "*Ali plays the role of auctioneer."* he should follow the whole set of norms related to the role of *Auctioneer*.

Although once the role of the agent has been allocated, all the rights and responsibilities of the agent are identified, our approach attempts to specify and assign the specific right or responsibility of an agent at each instant of runtime. There are two main factors in such an assignment: first, the represented norms of the normative MAS and second, the dynamic triggers including the actions of the agent or other environmental events.

From the normative viewpoint, as the rules of the normative system are conditional and time-related, a norm will be fired when the condition of the norm holds or an important time is reached. From the MAS viewpoint, the sources of dynamism and change influence the environment.

As a result, the knowledge base of the normative system also contains all conditional rules (R&Rs of roles). When a change occurs in a normative MAS, a condition of a norm may become satisfied, and the corresponding norm will be fired. We have already defined the sources of dynamism and changes as changing the population of agents, occurrence of an action or environmental events. Therefore, occurrence of any of the above sources may cause the condition of a right or a responsibility to be satisfied, so that a dynamic assignment of R&R takes place. For example:

> ***Norm1:*** *"The Auctioneer is obliged to reject lower bids, during the auction session."*
>
> ***Norm2:*** *"During the auction session, if a lower bid is placed and Auctioneer did not reject it, punishment_ 2 will be applied for Auctioneer."*

According to Norm1, the obligation is activated and assigned to Auctioneer agent only during the auction session. Norm2 shows that if auctioneer agent violates during the auction session, s/he will be punished. So if the condition of this norm is satisfied it will be activated and assigned to Auctioneer.

As a result, the activation and deactivation of the above norm is subject to the conditions of time (during the auction), event (place a lower bid) and action (rejection of bid).

Thus the activation and deactivation of ***each specific norm*** happens dynamically at runtime. So assigning ***each activated norm*** to ***the relevant agent*** will be a dynamic task as well. In this work we aim to provide such assignment.

4.2.1. Tri-level structure for MAS

Here, a Tri-level structure for MAS consisting of Agents, Roles and R&Rs is presented. In this structure, the first level includes all the agents who can join the MAS, the middle consists of all predefined roles in the MAS, and the third level includes all R&Rs of roles. The aim of using such a structure is to show firstly how roles can dynamically be allocated to agents, and secondly how a right/ responsibility of a role can dynamically be assigned to an agent.

The following figures, shows dynamic assignments of ***roles to agents*** and ***R&Rs to agents***, in a MAS based on this tri-level structure. Figure 1 shows the initial status of an auction system, when members join the system. At this stage, none of them play a specific role.

Figure2 shows the status of the system just after selecting the roles of the agents (based on agent's actions). This assignment is a dynamic task, because the roles of agents are assigned at runtime: at design time, it is not specified which agent will play which role(s).

Figure 3 shows the status of the system at the start time of the auction. The related norm of the Start Time (says "*Auctioneer is obliged to declare the start of the auction at the Start_Time."*) will be activated and assigned to *Mari* who is the *Auctioneer* of this auction session. Therefore, at the start time, there is an obligation assigned to *Mari* (as an external agent) which says:

"Mari is obliged to declare the start of the auction at the Start_Time."

Suppose that Mari declared the start of the auction. Figure 4 shows the status of the rest of the system just after declaring the start of the auction. There are two related norms for this stage, as follows:

"Buyer is permitted to place a bid after starting the auction."

"Seller is forbidden to place a bid during the auction."

The above norms will be dynamically activated and assigned to the external agents who play the roles of *Buyer* and *Seller*. As the figure shows two buyers (*Ali* and *David*) and one seller (*Sarah*) exist for this auction, and so the result of dynamic assignment would be as:

"Ali is permitted to place a bid after starting the auction."

"David is permitted to place a bid after starting the auction."

"Sarah is forbidden to place a bid during the auction."

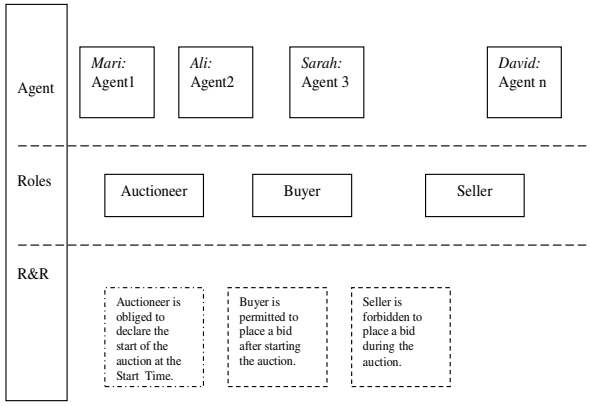

Figure 1-Agents log into the system

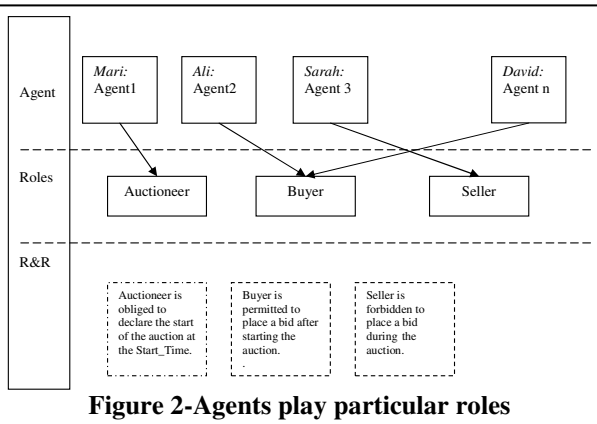

Figure 2-Agents play particular roles

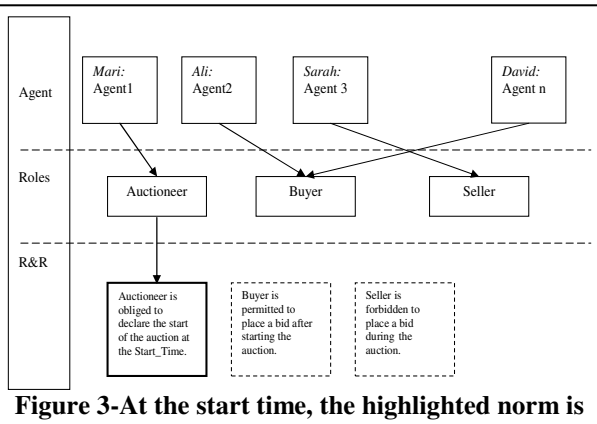

Figure 3-At the start time, the highlighted norm is assigned to auctioneer, here Mari

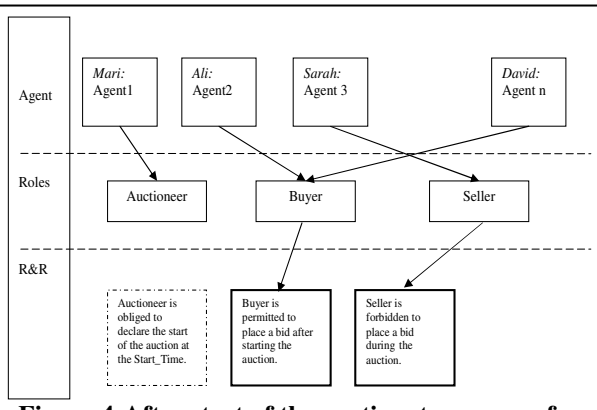

Figure 4-After start of the auction, two norms for Buyer and Seller will be activated.

5. Related Work

This paper has introduced an approach for dynamic assignment of rights and responsibilities of roles to agents which to our knowledge, is novel. However, other dynamic issues in MAS agents have been considered in some agent-based works. Here we refer to the work by Partsakoulakis and Vouros [8, 9] which provided an evaluation of such systems.
The authors of [8, 9] have explained the importance of roles for the reduction of complexity especially in dynamic and unpredictable environments with high degrees of interaction and distribution. It also described *Dynamic Assignment of roles to Agents* as a main characteristic of roles.

There the role-related works on agent-based systems have been evaluated based on role properties. The evaluation shows that most agent-based methodologies are at early stage with respect to the analysis and specification of systems that act in dynamic and unpredictable environments. Such methodologies do not address issues of dynamic assignment of tasks to agents and the runtime selection of roles. However, concerns relating to dynamic notions are more noticeable in formal models. In this evaluation, the instances of implemented multi-agent systems in complex domains is compared as well as those in which more advanced role properties and dynamic issues have been considered. However, none of the current role-related works develop the full range of facilities provided by roles in an integrated approach.

6. Conclusion and Future Work

The design and engineering of multi-agent systems is an important area of current research in computer science. To date, methodologies for agent-oriented software design have assumed that roles, rights and responsibilities are assigned to agents at design-time (by the software engineer), rather than at run-time (by the system or by other agents). The ability to assign roles, rights and responsibilities dynamically is important for several reasons:

- This ability increases the operational autonomy of the system (relative to the software design team).
- Thus, systems with this capability may have greater robustness, being able to operate effectively in a wider variety of circumstances.
- The ability of agents to identify and punish undesirable behaviors at run-time reduces the need for system designers to identify and exclude all such behaviors at design-time.
- Identification and punishment of undesirable behaviors may be undertaken immediately the behaviors happen.

In our future work we intend to define a normative language based on the mentioned normative issues for creating the knowledge base of rights and responsibilities of agents. Such a knowledge base is the normative resource for the middleware tool which in the next step we will design for normative multiagent systems. This tool will enable the practical dynamic assignment of rights and responsibilities to agents in actual multiagent systems.

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