

On Grievance Protocols for Conflict Resolution in Open Multi-Agent Systems

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Abstract

This paper presents the specification of an agent-based framework for conflict resolution into Open Multi-agent Systems by means of grievance protocols. In this framework, any grievance process primarily involves negotiation (with or without mediation) and arbitration or a combination of both. In this way, the result of a conflict resolution can be an agreement among the conflicting parties by which they voluntarily settle the conflict, or a decision from the arbitrator (a neutral third party) which is final, and binding on both conflicting parties. The framework is designed in such a way that multiple agreement mechanisms may be available at any given time, to be activated and adjusted on demand (on-line) by participating agents. The framework is also generic enough so that new protocols may be easily added. The objective is to have a generic electronic institution that may be tailored to specific needs and grafted into other electronic institutions.

1. Introduction

Open Multi-agent Systems (Open MAS) are systems in which heterogeneous and autonomous agents [22] may need to coexist in a complex social and regulated framework that can evolve to address the different and often conflicting objectives of the many stakeholders involved. Open MAS need to be specified from a high abstraction level (organizations and their structure) to the individual definition of each agent. The individual agent architecture is usually represented by means of its individual objectives, capabilities and internal states of each agent. Social order is mainly represented by means of a defined organizational structure, the social relationships between agents, the played roles and the norms that regiment the society. Moreover, Open MAS should allow heterogeneous agents and organizations to interact between them in order to achieve their social and individual goals. Characteristic features of all these ideas include decision-making based on local information, decentralized control, and heterogeneous – and

therefore unpredictable – network component with potentially conflicting goals. As a result there is a scope for error: either by malice, disobedience, self-interested, accident, or necessity, system operation may occasionally deviate from the ideal.

In this sense, an important requirement for Open MAS is how to regulate agent's action in an efficient way. The most common way to regulate a system is by means of norms. Norms are usually used to define which behavior is allowed in the organization, which is prohibited and which are the obligations of each agent. Moreover, norms should specify the commitments between agents and, in a high level of abstraction, between agents and their organizations. Nowadays there are several languages to define norms in a formal way [11, 1], but controlling that each agent follows the norms is still an open research topic.

There are two main controlling mechanisms for norms: regimentation and enforcement mechanisms. Regimentation mechanisms organize the system in such a way that external actions leading to a violation of those norms are made impossible. This type of mechanisms has some drawbacks: (1) they drastically decrease agent autonomy; (2) difficult the interaction with external agents; (3) decrease the reactive time of the agents due to the control management; (4) it makes the organization and structure rigid. On the other hand, enforcement is based on the idea of responding after and when the violation of the norms has occurred. Such a response, which includes sanctions [3], aims to return the system to an optimal state. This approach is more flexible and respects agents' autonomy. Most of enforcement approaches are based on the fact that the actions that violate norms are observable by the system. But in open regulated systems where internal and external heterogeneous agents interact, it is very difficult to control whether the commitments between agents are fulfilled. Despite if the violation is observable or not, norm-violation can be subject to dispute and/or conflict between otherwise independent partners who are participating in the Open MAS. When a conflicting situation arises within an organization, the parties involved in the conflict tend to seek a method

of resolving the conflict that achieves their own goals. However, the conflicting parties themselves cannot resolve every conflict. If one or both of the parties resist coming to an agreement by holding to their original positions, the resolution of the conflict is impossible. In particular, in an organization with shared goals that need to be achieved within a limited time frame, a conflicting situation cannot be held indefinitely. Therefore, timely action is required to resolve the conflict, and a third-party mediator is often involved to help the parties move to a settlement. Nevertheless, there are some conflicting situations in which the dispute cannot be settle even with the help of the mediator. In those cases other mechanisms must be used.

In this paper it is presented a framework for conflict resolution based on grievance protocols [32] in which alternative dispute resolution (ADR) like mechanisms [4][5] are included in order to settle the conflicts internally in the Open MAS. In this framework, any grievance process primarily involves negotiation (with or without mediation) and arbitration or a combination of both. In this way, the result of a conflict resolution can be an agreement among the conflicting parties by which they voluntary settle the conflict, or a decision from the arbitrator (a neutral third party) which is final, and binding on both conflicting parties. The framework is designed in such a way that multiple agreement mechanisms may be available at any given time, to be activated and adjusted on demand (on-line) by participating agents. The framework is also generic enough so that new protocols may be easily added. The objective is to have a generic electronic institution that may be tailored to specific needs and grafted into other electronic institutions. The implementation is accomplished with the standard current version of the EIDE tools [7].

The framework presented in this paper is being used as a component of a larger institutional framework designed as a demand module for water management modeling [6].

2. Background

In this section more details on the background and the motivation for this work are presented. Alternative Dispute Resolution is first analyzed. Then, a brief overview on Electronic Institutions, which is the conceptual model used in designing the proposed framework for Open MAS, is detailed.

Nowadays MAS applications require more and more regulation and regimentation mechanisms in order to assure the correct and secure execution of the interactions and transactions in the open agent societies [22] they are implementing. In this kind of systems it is

necessary to apply norm enforcement mechanisms to control the behavior of agents and the possible evolution of the system, since it is not always possible to guarantee the fulfillment of obligations and prohibitions by the autonomous agents. Moreover, not only can be difficult to regiment all actions, introducing control mechanisms that prevent the agents violate their commitments, but sometimes it is inevitable and even preferable to allow agents to violate their commitments [8], because either it is impossible to take a thorough control of all their actions, or agents could obtain higher personal benefits when violating certain rules. Furthermore, norm-violation can be subject to dispute and/or conflict between partners who are participating in the Open MAS. In this way, it is required a mechanism to deal with such conflicts, and, moreover that this mechanism can settle (when possible) the conflicts internally in the Open MAS.

2.1. Alternative dispute resolution - ADR

Alternative Dispute Resolution, especially on-line, includes dispute resolution processes and techniques that fall outside of the government judicial process, and usually takes the form of negotiation, mediation or arbitration [4][5]. Dispute resolution techniques range from methods where parties have full control of the procedure, to methods where a third party is in control of both, the process and the outcome. When the process is conducted mainly online it is referred to as Online Dispute Resolution (ODR), i.e. to carry out most of the dispute resolution procedure online, including the initial filing, the neutral appointment, evidentiary processes, oral hearings if needed, online discussions, and even the rendering of binding settlements. Thus, ODR is a different medium to resolve disputes, from beginning to end, respecting due process principles

The rise in importance of ADR methods over the past two decades is due to the numerous benefits offered to the parties involved in a dispute, coupled with the well-known shortcomings of litigation. Consequently, investigating and implementing ADR in the context of intelligent legal system is an important focus of attention [9][34].

The followings are the dispute resolution methods and processes most used in ADR.

(i) Consensual Methods: Automated Negotiation or Assisted Negotiation [33].

(ii) Adjudicative Methods: Online Arbitration. Arbitration [27] is a process where a neutral third party (arbitrator) delivers a decision that is final, and binding on both parties. It can be defined as a quasi-judicial procedure because the award replaces a judicial

decision. However, in an arbitration procedure parties usually can choose the arbitrator and the basis on which the arbitrator makes the decision. Furthermore, it is less formal than litigation, though more than any other consensual process.

2.2. Electronic institutions

Electronic Institutions (EI) are computational counterparts of conventional institutions [7][10]. Institutions are, in an abstract way, a set of conventions that articulate agent interactions [12]. In practice they are identified with the group of agents, standard practices, policies and guidelines, language, documents and other resources ---the organization--- that make those conventions work. Electronic Institutions are implementations of those conventions in such a way that autonomous agents may participate, their interactions are supported by the implementation and the conventions are enforced by the system on all participants. Electronic institutions are engineered as regulated open MAS environments. These MAS are open in the sense that the EI does not control the agents' decision-making processes and agents may enter and leave the EI at their own will. An EI is specified through: (1) A *dialogical framework* which fixes the context of interaction by defining roles and their relationships, a domain ontology and a communication language; (2) *scenes* that establish interaction protocols that determine for the agents playing a given role in that scene, which illocutions are admissible and under what conditions; (3) *performative structures* that, like the script of a play, express how scenes are interrelated and how agents playing a given role may move from one scene to another, and (4) *rules of behaviour* that regulate how commitments are established and satisfied [7].

3. An agent-based framework for conflict resolution into Open MAS

In this section, the specification of an agent-based framework for conflict resolution into Open MAS is presented. The framework is developed with the EIDE tool for EI [7]; in this way we define its dialogical components and its performative structure. In the proposed framework three methods for ADR are included: negotiation, mediation (negotiation through a third party mediator), and arbitration.

Picture a MAS application in which there are sets of heterogeneous agents that dynamically enter and exit the system. The open societies in which these agents work are defined and regimented by means of procedural conventions (i.e. structural norms) and social norms. When the participating agents interact

among them norm-violations (for example, a given product was not delivered to the buyer with the required quality) can appear that cannot be solved by the regimentation nor enforcement mechanisms defined in the given agent societies. In those situations, a conflict among the participating agent appears and the proposed method to solve it is to initiate a grievance procedure. In the proposed approach, the grievance procedure gets active whenever any participating agent believes there is an incorrect execution of a given norm and/or policy (for example, the buyer starts a grievance process when he/she believes the quality of the bought product does not satisfy the initial trading agreement).

In order to provide a generic framework that can implement the conflict resolution process internally in the Open MAS it is proposed the electronic institution depicted in Figure 1. This structure can be easily grafted as a pre-built part into other agent organization in order to provide grievances processes for conflict resolution (a case study is presented in Section 4).

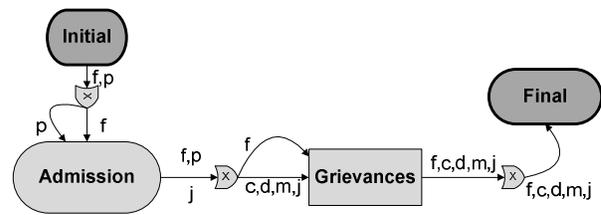


Figure 1: Main structure of the EI framework for conflict resolution. Roles: *p* – Party, *c* – Claimant, *d* – Defendant, *f* – Facilitator, *j* – Jury, *m* – Mediator

Figure 1 shows two scenes. The first one is the *Admission* scene tailored for registering guest parties as users in the grievance process. The second one is a complex performative structure (it is decomposed into other three complex processes, see Sections 3.2 to 3.4). This last performative structure is the core structure for conflict resolution. Figure 2 shows its backbone structure. This complex structure includes a first scene for *Recruiting Conflicting Parties* (see Section 3.2). Moreover, in the *Grievances* structure, any conflict can be solved by means of two alternative processes (these processes are similar to those used in ADR and ODR [4][5]). (i) Conflict resolution by means of negotiation tables (*Conflict Resolution Negotiation Table* performative structure, see Section 3.3). In this mechanism a negotiation table is created on demand whenever any participating agent wants to solve a conflict, by means of negotiation (with or without mediator), with other/s agent/s. Any such negotiation table can use different negotiation protocols, such as face-to-face, standard double auction, etc. (ii)

Arbitration mechanisms for conflict resolution (*Arbitration* performative structure, see Section 3.4). In this last mechanism, a jury solves the conflict sanctioning the offenses.

In order to get a better understanding of the framework let's suppose there are two agents (say *A* and *B*) that previously (at time *t*) committed to a deal (for example, *A* sells product *P* of quality *Q* to *B*, and *B* pays *X* Euros to *A* for *P*). At time *t'* (*t' > t*), agent *B* believes that the product *P* has a quality *Q'*, and *Q'* is poorer than *Q*. At this moment *B* decides to start a grievance process in order to solve the conflict. *B* wants to solve the conflict negotiating with *A*, to this end *B* request to open a *Conflict Resolution Negotiation Table*. When negotiating the conflict resolution *B* and *A* present their evidences and arguments in order to settle the conflict. Let's suppose that after negotiation there is no conflict settlement and *B* wants to continue with the grievance process and requests to start an *Arbitration* process in which the dispute is put to a panel or "jury" that adjudicates and solves the conflict.

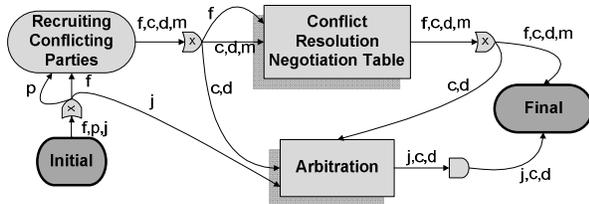


Figure 2: *Grievances* performative structure.

Roles: *p* – Party, *c* – Claimant, *d* – Defendant, *f* – Facilitator, *j* – Jury, *m* – Mediator

In the following sections these two different processes are detailed, together with the dialogical framework that defines the key ontological components of the framework.

3.1. Dialogical framework

The specification of the interaction protocol of a conflict resolution negotiation table, like an automatic face-to-face, a fate-to-face with mediator, or even mediated multi-issue, partially ordered bipartite negotiation, and arbitration protocols is a rather straight-forward task with ISLANDER¹, provided the inherent dialogical framework is properly defined. In practical terms, it is at the level of these protocols and the specific content of the different facts, demands and arguments where one has to commit to a given domain ontology, the roles required by the protocol and the

communication language (with the intended meaning of all those terms that may appear in institutionally valid illocutions). Thus, what in practice constitutes a conflict resolution deal and an arbitration sanction will have to encompass the distinctive features that the domain ontology imposes.

The interaction protocols (for the conflict resolution negotiation or the arbitration) also determine those parameters that may be fixed for an instantiation of the given protocol or for online tuning while an interaction process is underway. For example, in an automatic face-to-face protocol, those parameters could be the speed of the clock, time-out between rounds, penalty for invalid bids, tie-breaking convention, etc. The interaction protocol determines the roles that participants may play —e.g. claimant, defendant, mediator— and determines potential conditions for participation in the table as well as for the settlement of conflict resolution agreements.

The actual dialogical framework for the conflict resolution institution will, in fact, result from the aggregation of these interactions dialogical frameworks plus a few additional elements. Hence, we recognize six main roles (depicted in Figures 1 and 2).

For illustration purposes we introduce a crude dialogical framework that involves parties which bring up demands that are backed by arguments whose structure involves evidential facts that support requests. The framework may be assimilated to standard argumentation frameworks [23][24] and would be made precise when dealing with specific grievance domain and practices. The dialogical framework we present here attempts only to give an indication of the type of formal elements that may be involved in a grievance and is inspired by the case study of Sec 4 where we are concerned with grievances that stem from the trade and use of water rights. Thus grievance requests involve agreements on issues that are specific to water rights --like volume and quality of water and duration of the right of use--- and potential agreements are presented as "deals" about those issues. The case study also allows for illustrating the type of judgment aggregation involved in arbitration that involves panels of judges, thus our dialogical framework captures notions like opinions on topics and degrees of confidence that are relevant for the decision-making processes [25][28].

Figures 1 and 2 show a Party role (*p*) that represents a user that wants to enter the conflict resolution environment. The Party may be specialized as Claimant (*c*) and Defendant (*d*), to differentiate the parties that are acting as initiators or invitees in a given conflict resolution negotiation table and/or arbitration. Moreover the Party can be also specialized as third party Mediator (*m*), any user that can mediate in the

¹ ISLANDER is the graphical tool of EIDE for EI.

negotiation process. The third party can be determined by those involved, and can come from within the system. The Jury role (j) is in charge of the arbitration process and can issue an award, which is final and not open to negotiation or appeal. Finally, there is an internal role. The Facilitator (f) runs institutional activities like managing the public exchange of information, managing the opening of negotiation tables and the concomitant recruitment of participants.

The dialogical structure of the conflict resolution institution is defined by the following key entities in the ontology, which constitute the core concepts that the institution recognizes. These key concepts are derived from [13] and [9]:

A fact or evidence is defined as $evidence(I, O, S)$. Where I denotes the party who asserts the evidence, O is the party at whom the evidence affects, and S is the statement that defines the evidence. For example, $evidence(A, B, \text{"product was not delivered on time"})$, means that agent A asserts that agent B has not delivered the product on time.

A demand is defined as $demand(I, O, S)$. Where I is the claimant, O is the defendant, and S is the statement that defines the demand. For example, $demand(A, B, \text{"pay 100 Euros"})$, means that A demands from B an economic compensation of 100 Euros.

An argument [33] is defined as $argument(I, premise, conclusion)$. Where I is the agent who issues the argument; $premise$ is the statement that I puts forward as a truth, but which is not proven (the premise can be an evidence); $conclusion$ is the statement with which I wants the other agent to agree (a conclusion can be a demand).

A *deal* is a list of demands that can be negotiated in the conflict resolution tables.

An agreement is a full instantiated deal among two or more conflicting parties. It is defined as $agreement(P, deal, date, status)$. Where P is the set of parties that enact the deal; $deal$ is the agreed deal from a previous conflict resolution negotiation process; $date$ is the agreement date; $status$ represents the stage where the agreement currently holds—it can take a value from a domain dependent enumeration, e.g. pending, executed, cancelled, etc. A sample agreement is, $agreement(\{A, B\}, \{demand(A, B, \text{"pay 95 Euros"}), demand(A, B, \text{"payment deadline September 2010"})\}, 15/06/2010, pending)$.

A *topic* is an article about which the arbitrators (judges) hold opinions. The topics are the specific cases – which, in turn, are the evidences of a case. In the arbitration process the evidences are called topics.

An $opinion(J, topic)$ is a function mapping to a number in the real number range $[0,1]$, (0 representing total disagreement and 1 total agreement). For example $opinion(J, topic(A, B, \text{"product was not delivered on$

$time\})) = 1$, means that judge J totally agrees that B has not delivered on time the product to A .

Every judge or arbiter (J) has a $confidence(J, J')$ value, which is a number in the range $[0,1]$, with each arbitrator (J') of its acquaintance. The higher the confidence number value for a particular associate, the more likely that arbitrator is to be influenced by the opinions of that associate (see Section 3.4).

When instantiating the framework to a given domain the specific contents to describe evidence and demand statement, premises and conclusions of the arguments are to be defined with an appropriate ontology. It is assumed that a full ontology to represent these contents in the given domain exists and that the information presented by the parties is represented using the same ontology.

3.2. Starting a grievance process

The first step in any conflict resolution process is to present a grievance statement [32]. The grievance statement is defined instantiating the messages of the dialogical framework (Section 3.1) and following the protocol stated in this section. In the proposed framework any participating agent can issue a grievance whenever he/she believes there is a norm-violation or an incorrect execution of a service in the agent society he/she inhabits. In order to start the grievance process the claimant agent goes to the *Recruiting Conflicting Parties* scene (Figure 2), and sends the following message:

$startGrievance(p_c, f, demand(p_c, p_d, S), mechanism)$ where p_c represents the claimant agent, f is the facilitator who will manage the grievance process, p_d is the defendant agent, S is the statement that defines the grievance and/or demand. Finally, $mechanism$ defines what ADR mechanism is preferred by the claimant agent for the conflict resolution process –negotiation, or arbitration.

If the selected ADR mechanism is negotiation [28], the claimant agent sends the following message right after the previous one:

$request(p_c, f, open, protocol(params), demand(p_c, p_d, S), type)$,

with this message p_c requests to the framework facilitator f to open a conflict resolution negotiation table with the negotiation protocol $protocol$. The negotiation protocol is instantiated with the set of values for the parameters $params$. The table is created to negotiate about the $demand(p_c, p_d, S)$. $type$ is one of the following values: automated or assisted.

When the facilitator, f , receives a request to open a conflict resolution negotiation table, it instantiates a new negotiation table scenario with the requested negotiation protocol and the given parameters. Next, f

issues an information illocution to the p_c agent who requested the table.

$inform(f, p_c, table_{ID}, error)$,

where $table_{ID}$ is the ID of the new conflict resolution negotiation table if it was successfully created, or a *null* value when the table cannot be created due to *error* conditions.

In order to complete the conflict resolution negotiation table creation the facilitator needs to recruit the defendant party to the new conflict resolution negotiation table. To do so, f sends a recruiting message to p_d

$invite(f, p_d, table_{ID}, protocol(params), demand(p_c, p_d, S), type)$.

On the other hand, if the selected ADR mechanism is arbitration [26], when f receives the request to start a new arbitration process, it instantiates a new arbitration scenario with the grievance defined by the claimant agent. Informs to p_c that the arbitration scenario is started with the following message

$inform(f, p_c, arbitration_{ID}, error)$,

and, sends the corresponding summon message to the defendant agent as follows

$summon(f, p_d, arbitration_{ID}, demand(p_c, p_d, S))$.

3.3. Negotiation tables for conflict resolution

In the proposed framework (recall Figure 2), a facilitator, f , can open a new *Conflict Resolution Negotiation Table* whenever a party requests to negotiate a conflict after stating the grievance. In such a case, a party chooses a negotiation protocol from a set of available ones (e.g., automated face-to-face, mediated or assisted face-to-face, mediated multi-issue or any other). Consequently, in order to accommodate different negotiation mechanisms (different approaches for negotiation models and protocols can be found in specialized literature, for a reference reading please consult [32]), we assemble the *Conflict Resolution Negotiation Table* performative structure, Figure 3, as a list of different scenes, each corresponding to a valid negotiation protocol. Each instance of a *Conflict Resolution Negotiation Table* scene is managed by a facilitator, f , who knows the structure, specific data and management protocol of the given negotiation protocol. Among other negotiation mechanisms, we have included automated face-to-face, assisted face-to-face, mediated multi-issue and partially ordered bipartite negotiation, etc. Nevertheless, new negotiation protocols may be easily added providing that the new protocol definition complies with the generic structure.

Every generic *Conflict Resolution Negotiation Table* is defined as a three scene performative structure (see Figure 3). The first scene is *Registration*, in which

f applies a filtering process to assure that only valid parties can enter a given negotiation table. The second scene is the negotiation protocol itself, in which the set of steps of the given protocol are specified. Finally, in the last scene, *Validation*, a set of closing activities are executed, for example registering the final deals, stating the following steps for settling the conflict, verifying that the leaving party satisfies the leaving norms of the negotiation table, etc.

Let's suppose a negotiation table for conflict resolution was created due to the messages:

$startGrievance(A, f, demand(A, B, "pay 95 Euros"), Negotiation)$;

$request(A, f, open, AssistedFace2Face(C, 5min), demand(A, B, "pay 95 Euros"), AssistedNegotiation)$

In order to manage this messages the facilitator, f , creates a new table and recruits the participating entities, which are B and C as defendant and mediator respectively (issuing the recruiting messages explained in Section 3.2).

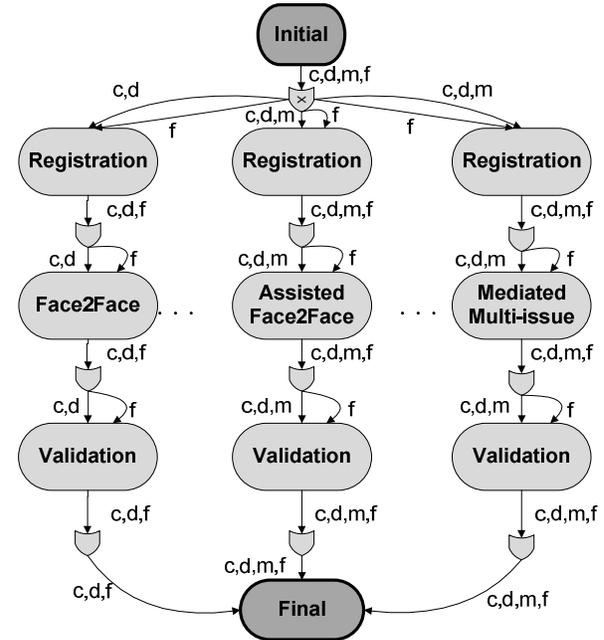


Figure 3: *Conflict Resolution Negotiation Table* performative structure. Roles: c – Claimant, d – Defendant, f – Facilitator, m – Mediator

When the negotiation protocol itself starts, (for example the *AssistedFace2Face*), the different conflicting parties (A and B) presents their demands and evidences in order to solve the dispute (different argumentation techniques [28] can be used by the participating entities to reach an agreement on the conflict resolution). On the other hand the mediator (C) uses information management skills encouraging

parties to reach an amicable agreement by enabling them to communicate more effectively through the rephrasing of their arguments. During the process of negotiation, the third-party mediator clarifies the conflicting situations by identifying the source of the conflict and understanding the respective positions of the conflicting parties [14][15]. Then, considering the impact of the outcomes of possible resolutions, the mediator assists the disputants in reaching an agreement [16]. In this process argumentation frameworks are used. We have adapted Dung's classical argumentation system [33] in order to test the proposed EI in a water-right market case study [6]. Nevertheless, using other argumentation systems is an easy task due to the generic structure of the proposed grievance framework.

3.4. Arbitration

If the conflicting parties cannot settle their dispute by negotiation they can continue with an arbitration process in order to solve the conflict. On the other hand, an arbitration process is also started if the claimant decided to follow it when starting the grievance process (see Section 3.2). The internal function for the arbitration reasoning of the facilitator agent may be implemented following the model presented in [29] or adapting the model of [30].

The performative structure of Figure 4 shows the different steps in the arbitration process [9]. The first step is the arbitration panel composition. Following is the hearing dispute and decision-making process, and finally the resolution of the jury is given in the form of an award. The award is final and not open to negotiation or appeal. In this way the arbitration provides an impartial resolution to a dispute based on the expert legal opinion of a panel of arbitrators.

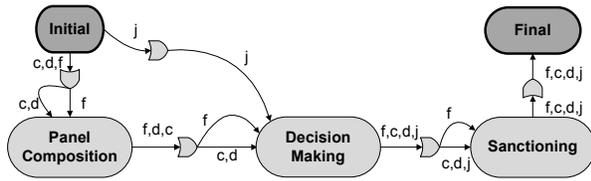


Figure 4: Arbitration performative structure. Roles: c – Claimant, d – Defendant, f – Facilitator, j – Jury

In the arbitration *Panel Composition* (Figure 4), the disputants can choose which neutral third parties arbitrate the dispute. Thus, a panel of arbitrators is chosen from a potential pool of arbitrators. The complex structure of the *Panel Composition* is depicted in Figure 5. During the *Nomination* step the agents

nominate a list of arbitrators in order of preferences with the following message

$nominate(p, f, arbitration_{ID}, arbiterList)$,

where p is the conflicting party that sends the message, f is the facilitator that manage the process, $arbitration_{ID}$ is the arbitration process identifier, $arbiterList$ is the list of arbitrators the party is nominating. $arbiterList$ is a list of pairs $\langle arbiter, preference \rangle$, where $arbiter$ is the arbitrator and $preferences$ is a number, in the real number range $[0,1]$, that defines the preference order for the given arbiter.

When f receives all the nomination messages from the conflicting parties, it activates the *Vetoing* process. In this step both parties may veto some arbitrators from their counterpart's list. In order to decide which arbiter to veto the parties can use different reasoning mechanisms depending on their strategies (who are each likely to choose arbitrators that are sympathetic to their respective case, trust values on similar cases [20] etc). The message for vetoing an arbiter is

$veto(p, f, arbitration_{ID}, arbiter)$.

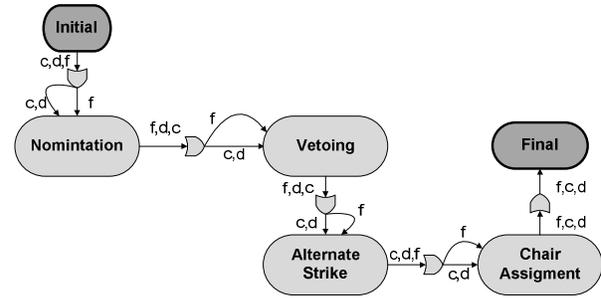


Figure 5: Panel Composition process. Roles: c – Claimant, d – Defendant, f – Facilitator.

Depending on the norms of the multi-agent system in which the grievance process is executing the arbitrator panel will have a number of judges. If after the vetoing step, the resulting arbiter list has fewer elements than the required number for the panel the *Nomination* step is repeated. Otherwise, if the list has more elements than the panel size, the *Alternate Strike* step is activated. In this process both parties successively remove one name from the list until the required panel size is met. In order to remove an arbiter from the list the agent has to issue the following message

$remove(p, f, arbitration_{ID}, arbiter)$

The last step in the *Panel Composition* is the chair appointment. The chair is one arbiter selected from the list by the facilitator f .

After the panel composition the arbitration process continues with the *Decision Making* (Figure 4). In order to start the process the conflicting parties

presents their demands, evidences and arguments in order the panel hears the dispute and defines the topics (see Section 3.1) of the case. One of the main characteristics of a jury is that arbitrators are distinct from one another and consequently, each arbitrator has a different mind-set, i.e. normative models on the regulations of the MAS. In accordance with this characteristic, every arbiter makes an individual decision first [21] based on its “mind-set”. Afterwards, every such individual opinion is informed to the other arbitrators in the panel. The message

informOpinion(j, chair, arbitration_{ID}, opinion(j, topic)),

where *j* is the arbitrator that is issuing the *opinion* on the *topic*.

According to individual opinion aggregation mechanisms [17][18] and the confidence associated with the originator of each received opinion (see Section 3.1) the arbitrators evaluate the given new opinions and update theirs. If after this process a demonstrable consensus is reached then the chair proposes an award.

informAward(chair, arbitration_{ID}, opinion(j, topic))

On the other hand, the arbitrators iteratively exchange their opinions until consensus is reached.

The specific mechanisms for appointing a chair, initial opinion creation and opinion aggregation are configurable aspects of the problem domain. The proposed framework omits details on these aspects because they may only be known to its designer. Nevertheless, every such mechanism can be easily wrapped into the agents’ behavior implementation by means of services and/or functions.

Once the chosen arbitrators have individually considered the details of the case, they go through a formal voting process [19] to establish the dispute outcome. The voting process is executed in the *Sanctioning* step of the arbitration process (see Figure 4). The dispute outcome is informed to the conflicting parties with the following message

informSanction(chair, p_c, p_d, arbitration_{ID}, sanction)

4. A case study application

In this section a case study application of the framework for dispute resolution in Open MAS is described. The case study is *mWater* [6], which is an agent-based application for water-right markets. In order to get a better understanding of the case study the overall functioning of *mWater* and its motivation is first described. Afterwards, the application of the conflict resolution framework in *mWater* is detailed.

mWater is an agent-based electronic market of water rights. The focus is on demand and, in particular,

on the type of regulatory and market mechanisms that foster an efficient use of water while preventing conflicts. The framework is a somewhat idealized version of current water-use regulations² that articulate the interactions of those individual and collective entities that are involved in the use of water in Spain’s basins. For the construction of *mWater* the EI conceptual model [10] is used. The actual specification and implementation of *mWater* is developed with EIDE platform [7].

Procedural conventions in the *mWater* institution are specified through a nested performative structure (Figure 6) with multiple processes. The top structure, *mWaterPS*, describes the overall market environment and includes other performative structures, *TradingHall* provides updated information about the market and at the same time water users and trading staff can initiate most trading and ancillary operations here; finally, *TradingTables* establishes the trading procedures. Once an agreement on transferring a water right has been reached it is “managed” according to the market conventions captured in *AgreementValidation* and *ContractEnactment* structures.

mWater provides a scenario for water-right markets and its outputs are water-right transfer agreement among water users. The execution of these contracts (the real interchange of water from one farm to another) is outside the institution boundaries of the market and cannot be directly controlled by the staff of the market. Nevertheless, *mWater* needs to provide a mechanism to deal with the possible violations or incorrect execution of the contracts that are signed in the institution.

In order to deal with the situations described above the grievance protocols for conflict resolution environment of Section 3 are included as part of the *mWater* EI (see Figure 6). In this way when a contract is active, other right-holders and external stakeholders may initiate a *Grievance* procedure that impacts the transfer agreement. This procedure is activated whenever any market participant believes there is an incorrect execution of a given norm and/or policy.

The Grievance structure of *mWater* has some simplifications compared to the generic framework of Section 3. These simplifications are due to the specific features of the problem specification and are mainly related with the Arbitration process. Figure 7 shows the *mWater* arbitration process, in which there is no *Panel Configuration* scene because the National Hydrological Plan of Spain’s basin states that the jurypanel is

² The regulated environment of *mWater* is based on the 2001 Water Law of the National Hydrological Plan (NHP) of the Spanish Ministry of Environment, and its amendment in 2005 (see www.boe.es/boe/dias/2001/07/24/pdfs/A26791-26817.pdf).

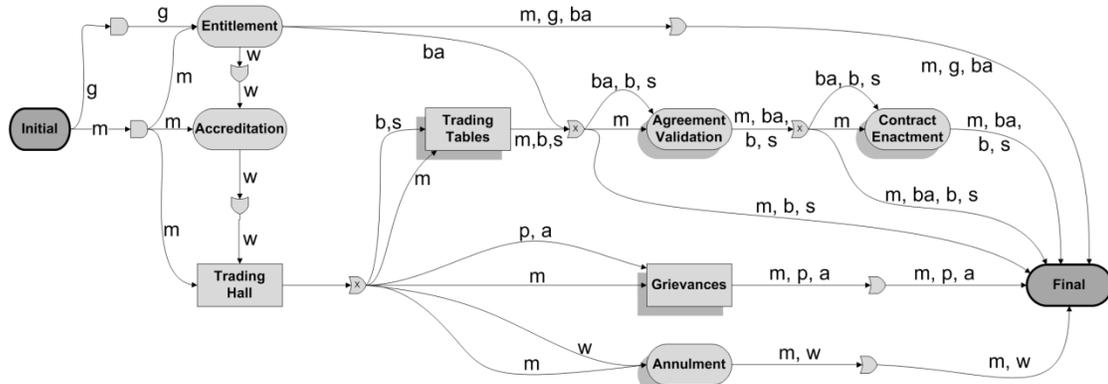


Figure 6: *mWater* overall structure

defined by the basin authority and cannot be nominated by the conflicting parties.

The inclusion of the *Grievance* EI in *mWater* was an easy task in which the main work was devoted to parameterize some message passing, and to adapt the arbitration process to the requirement specification of the domain problem. The backbone of the *Grievance* EI not only helped to develop faster the conflicting scenario of *mWater* but to has a better understanding of the critical requirements when interviewing with the domain problem stakeholders.

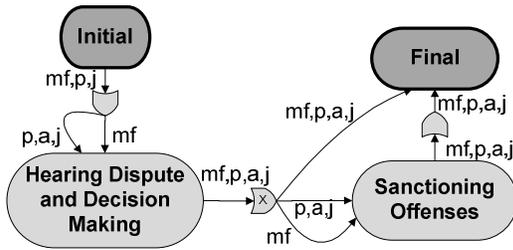


Figure 7: *mWater* Arbitration. Roles: *mf* - Market Facilitator, *p* - Plaintive, *a* - Defendant, *j* - Jury

5. Final remarks

In this work it was presented an Electronic Institution for conflict resolution in Open MAS. The framework includes two mechanisms for Alternative Dispute Resolution, which are negotiation (automated or assisted) and arbitration [26][29][30]. In this way any conflict resolution process can be solved by a voluntary conflict agreement among the parties, or by an award issued by an impartial third party or arbiter. The framework defines the backbone structure of the entire grievance process, the dialogical framework, and the different performative structures and protocols for implementing consensual and adjudicative methods for dispute resolution in Open MAS. In this way a generic electronic institution that may be tailored to specific

needs and grafted into other electronic institutions when required was proposed. The Grievance EI can be used in Open MAS as an enforcement module for those norms which cannot be controlled by traditional regimentation techniques. The generic framework was applied and included as part of another multi-agent system, the *mWater*, a water-right market. In this application the types of conflict that may appear are incorrect execution of contracts, norm-violation, payment delays, etc.

Currently the authors are working on defining parameterized mechanisms for argumentation, initial opinion creation and opinion aggregation. These mechanisms will be included in the Grievance EI as built in services in order to complete the environment.

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