

Organisational Structures in Next-Generation Distributed Systems:

Towards a Technology of Agreement

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Abstract. This paper provides a brief overview of the field of coordination in multiagent systems, and outlines its relation to current efforts working towards a paradigm for smart, next-generation distributed systems, where coordination is based on the concept of agreement between computational entities. Two examples are provided to visualize the types of mechanisms that can be part of a “technology of agreement”. They explain how techniques from the field of organisations can be used to foster coordination and agreement in open multiagent systems.

Keywords: multiagent systems, organisational techniques, coordination, agreement technologies, distributed systems.

1 Introduction

Computers and computer networks nowadays mediate an increasing number of transactions and interactions. An appealing way to model and design such applications is by purposefully combining components to which more and more complex tasks can be delegated. These components need to show an adequate level of intelligence, should be capable of sophisticated ways of interacting, and are usually massively distributed, sometimes embedded in all sort of appliances and sensors. In order to allow for an efficient design and implementation of systems of these characteristics, it is necessary to effectively enable, structure, and regulate their communications in different contexts. These characteristics raise some technological challenges. Firstly, the open distributed nature of such systems adds to the *heterogeneity* of its components. The *dynamicity* of the environment calls for a continuous *adaptation* of the structures that regulate the components' interactions, so as to achieve and sustain desired functional properties. On the other hand, non-functional issues related to *scalability*, *security*, and *usability* need to be taken into account. When designing mechanisms that address these challenges, the notion of *autonomy* becomes central: components may show complex patterns of activity aligned with the different goals of their designers, while it is usually impossible to directly influence their behaviour from the outside.

Coordination in multiagent system (MAS) aims at harmonising the interactions of multiple autonomous components or agents. Therefore, it appears promising

to review different conceptual frameworks for MAS coordination, and to analyse the potential and limitations of the work done in that field with regard to some of the aforementioned challenges.

This paper is organised as follows. Section 2 provides a brief overview of coordination in MAS, identifies the notion of *agreement* as a centrepiece of an integrated approach to coordination in open distributed systems, and outlines some research topics related to the vision of a technology of agreement. In third section two examples explained, with a certain level of detail, how organisational structures could be used to instil coordination and agreement in open multiagent systems, in the realm of matchmaking and trust mechanisms. Conclusions are drawn in Section 4.

2 Coordination and Agreement in Multiagent Systems

Originally, agents were conceived as single actors, which had to reconcile a number of conflicting requirements on their inside. But with the advent of MAS, a different method has become possible, causing the focus to change. Now a separate agent can be devoted to a different goal; and the whole system gets the responsibility of reconciling these views and solving the problem. The trade-off continues, but has transformed into a *coordination* problem.

Maybe one of the most accepted definitions of coordination in the MAS field is taken from Organisational Science. It defines coordination as the *management of dependencies* between organisational activities [21]. This definition allows

deducing the components of coordination: goals, activities, actors and interdependencies. In summary, when using MAS as a software solution the problem of coordination is always present.

2.1 The Problem of Coordination

In an MAS setting the entities to coordinate are the agents while the coordination objects are usually the goals, actions or plans. Depending on the characteristics of the MAS environment, taxonomy of dependencies can be established, and a set of potential coordination actions assigned to each of them (e.g. [37], [24]). Within this model, the *process* of coordination is to accomplish two major tasks: first, a *detection* of dependencies needs to be performed, and second, a *decision* respecting which coordination action to apply must be taken. A coordination *mechanism* shapes the way that agents perform these tasks [22]. From a *macro-level* (MAS-centric) perspective, the outcome of coordination can be conceived as something global (plan, decision, action etc.). This can be a “shared plan” [29] if the agents reach an explicit agreement during the coordination process, or it just can be the summa of individual plans (or decisions, actions etc. – sometimes called “multi-plan” [25]). At this level, results of coordination can be evaluated as a conjunction of agent goals or taking into account the MAS functionality as a whole. If no such notion can be ascribed to the MAS, other, more basic features can be used instead. A good

result of coordination, for instance, often relates to “efficiency”, which frequently comes down to the notion of Pareto-optimality.

The dependency model of coordination appears to be particularly adequate for *representing* relevant features of coordination problems in MAS. Frameworks based on this model have been used to capture coordination requirements in a variety of interesting MAS domains (e.g. [8]). Still, dependency detection may become a rather knowledge intensive task. From a design perspective, coordination is probably best conceived as the effort of *governing the space of interaction* [5] of a MAS, as the basic challenge amounts to how to make agents converge on interaction patterns that adequately (i.e. instrumentally with respect to desired MAS features) solve the dependency detection and decision tasks. A variety of approaches that tackle this problem can be found in [31][23], and [[10].

From the point of view of an agent, the problem of coordination is related to find the sequence of actions that best achieves its goals. In practice, this implies a series of non-trivial problems. Models of coalition formation determine when and with whom to form a team for the achievement of some common (sub-) goal, and how to distribute the benefits of synergies that arise from this cooperation [33]. Distributed planning approaches [9] determine how to (re-) distribute tasks among team members and how to integrate results. From an individual agent’s perspective, the level of trustworthiness of others is central to almost every stage of these processes, so as to determine whether other agents are likely to honour the commitments that have been generated [34].

Several quite different approaches and mechanisms coexist in the field of coordination in MAS [26]. Not all of them are relevant to the challenges for the design of open distributed systems outlined in the introduction. For instance, the whole set of *coupled* coordination mechanisms [36] are effectively useless for the purpose of this paper, as they require having a direct influence on the agent programs. On the other hand, the problem of semantic interoperability is usually outside the scope of MAS coordination models and languages.

2.2 Towards the Agreement between Computational Entities

As already noted, the problem of coordination is always present in an MAS setting and there are several approaches to tackle this problem.

The notion of *agreement* among computational agents appears to be a right concept for the proposal outlined in this paper.

Following a recent research effort in the field of “Agreement Technologies” [1], the process of agreement-based coordination can be conceived based on two main elements:

- (1) *a normative context*, that determines the rules of the game, i.e. interaction patterns and additional restrictions on agent behaviour; and
- (2) *a call-by-agreement interaction method*, where an agreement for action between the agents that respects the normative context is established first; then actual enactment of the action is requested.

Methods and mechanisms from the fields of *semantic alignment*, *norms*, *organization*, *argumentation and negotiation*, as well as *trust and reputation* are

envisioned be part of a “sandbox” to build software systems based on a technology of agreement [1].

These can be seen in a “tower” structure, where each level provides functionality and inputs to the one above (see Figure 1).

Semantic technologies should constitute a centrepiece of such an enterprise as semantic problems pervade all the others. Solutions to semantic mismatches and alignment of ontologies [4] are needed to have a common understanding, e.g. of norms or deals. The use of semantics-based approaches to service discovery and composition will allow exploring the space of possible interactions and, consequently, shaping the set of possible agreements [12].

At system-level, *norms* are needed to determine constraints that the agreements, and the processes to reach them, have to satisfy. Reasoning about a system’s norms is necessary at design-time to assure that the system has adequate properties, but it may also be necessary at run-time, as complex systems usually need dynamic regulations [14].

Organisational structures further restrict the way agreements are reached by fixing the social structure of the agents: the capabilities of their roles and the relationships among them (e.g. power, authority) [3].

Moving further towards the agent-level, *negotiation* methods are essential to make agents reach agreements that respect the constraints imposed by norms and organisations. These methods need to be complemented by an *argumentation*-based approach: by exchanging arguments, the agents’ mental states may evolve and, consequently, the status of offers may change [2] [6].

Finally, agents will need to use *trust* mechanisms that summarise the history of agreements and subsequent agreement executions in order to build long-term relationships between the agents [35].

Of course, these methods should not be seen in isolation, as they may well benefit from each other. For instance, in certain situations trust mechanisms may take advantage of the roles structures included in an organisational model, so as to improve their performance when only limited information about previous interactions is available.

3 Organizational structures and agreement

This section explains the types of mechanisms that can be part of the agreement technology “sandbox” mentioned previously. In particular, two examples will be provided to explain, with a certain level of detail, how organisational structures could be used to foster coordination and agreement in open MAS will be provided.

Organisational models underlying approaches such as Agent-Group-Role [11], MOISE [17], or RICA [32] provide a rich set of concepts to specify and structure mechanisms that govern agent interactions through the corresponding infrastructures or middleware.

A key notion in most organisational models is the concept of role. The roles can often be organised in a taxonomy, which can be modelled as a pair $\langle R, \leq \rangle$ where R is the set of concepts representing roles and \leq is a partial order among R .

Subsection 3.1 shows how role taxonomies can be used to locate suitable interactions partners, by providing additional information regarding the usability of services in a certain interaction context. Subsection 3.2 outlines how such taxonomies can be used for the bootstrapping of reputation mechanisms, when only limited information about past interactions is available in the system.

3.1 Organisational structures and matchmaking mechanisms

This example refers to service-oriented MAS where the capabilities of agents are modelled in the shape of services which, in turn, are described by some standard service description language. An approach to enriching service descriptions with organisational information will be presented in the following paragraph. For this purpose, simple languages for representing role-based service advertisements and service requests are introduced first.

A service advertisement S is a set of pairs so that

$$S \subseteq \left\{ \langle r, \rho \rangle \mid r \in R, \rho = \bigvee_{i=1}^n \bigwedge_{j=1}^m r_{ij}, r_{ij} \in R \right\}$$

In this definition, r is the role played by the provider in the interaction, and ρ is a set of roles that must be played by the requester agent for the correct accomplishment of the service, given by a formula in disjunctive normal form (DNF).

A service request Q is a set of pairs so that

$$Q = \{ \langle \rho, C \rangle \mid \rho = \bigvee_{i=1}^n \bigwedge_{j=1}^m r_{ij}, r_{ij} \in R, C \subseteq R \}$$

Again, ρ is a DNF role expression (usually atomic) specifying the searched provider roles, and C is a set of roles that define the *capabilities* of the requester (the roles it is able to play).

Although organisational information is not a first-class citizen in service description languages such as OWL-S¹ or WSMO², it is not difficult to incorporate it into them. In OWL-S, for instance, it is possible to include the role description as an additional parameter, called *Service_Roles*, in the case of service descriptions (r and ρ are mapped to *providerRole* and *dependingRoles* tags, respectively), and *Query_Roles* for service requests (ρ and C are mapped to *SearchedProviderRoles* and *CapabilityRoles*) [12].

In many multiagent settings, this kind of organisational information can be used to complement standard I/O based matchmaking in order to improve its performance.

The *semantic match of two roles* r_A (advertisement) and r_Q (query) is made based on the domain ontology R in which they are defined. It is a function that depends on two factors:

- *The Level of match*, which is the (subsumption) relation between the two roles (r_A, r_Q) in the ontology. We differentiate among the four degrees of match proposed by Paolucci et al. [27]: *exact* ($r_A = r_Q$), *plug-in* (r_Q subsumes r_A), *subsumes* (r_A subsumes r_Q) and *fail* (otherwise).
- The *distance* (number of arcs) between r_A and r_Q in the taxonomy (Rada [28]).

We combine both criteria into a final degree of match, which is a real number in the range $[0, 1]$. In this combination, the level of match always has higher priority: the value representing the degree of match is equal to 1 in case of an *exact* match, it varies between 1 and 0.5 in case of a *plug-in* match, rests between 0.5 and 0 in case of a *subsumes* match, and it is equal to 0 in case of a *fail*. These considerations lead to the following equation:

$$dom(r_A, r_Q) = \begin{cases} 1 & \text{if } r_A = r_Q \\ \frac{1}{2} + \frac{1}{2 \cdot e^{\|r_A, r_Q\|}} & \text{if } r_A \text{ is subclass of } r_Q \\ \frac{1}{2} \cdot e^{\|r_A, r_Q\|} & \text{if } r_Q \text{ is subclass of } r_A \\ 0 & \text{otherwise} \end{cases}$$

Where $\|r_A, r_Q\|$ is the distance between r_A and r_Q ($dist(r_A, r_Q)$) in the ontology (if there is a subsumption relation between them). This function guarantees that the value of a *plug-in* match is always greater than the value of a *subsumes* match, and it only considers the distance between the two concepts, rather than the total depth of the ontology tree, which may change depending on the domain. Furthermore, the smaller the distance between concepts (either in the case of *plug-in* or *subsumes* match), the more influence will have a change of distance in the degree of match.

The *semantic match* between a service advertisement S and a query Q (service request) is done by searching the role in S that best matches the one in Q . The degree of match between a role in the request and a service advertisement, given the set of capabilities of the requester, is done by comparing the searched role with every other given role and returns the maximum degree of match. For each

role in the advertisement, the match between the provider roles is made, as well as the match between the depending roles and the capabilities of the requester.

The minimum of both values is considered the degree of match. In case of logical expressions, the minimum is used as combination function for the values in a conjunction and the maximum for disjunctions (which always keep the value resulting of the combination within the range $[0, 1]$).

The following algorithm was developed to determine the degree of match (dom) between a service request (Q) and a service advertisement (S), and constitutes the nucleus of the role-based matchmaker called ROWLS. The implementation relies on the Mindswap Java Library³ for parsing OWL-S service descriptions, and on Jena⁴ for managing OWL ontologies.

Match (Q: service request, S: service advertisement)

dom = 0

FOR ALL CRS_i IN Q.p

dom' = α

FOR ALL r_j IN CRS_i

dom' = min(dom', MatchAtomicRequest(r_j, Q.C, S))

dom = max(dom, dom')

return dom

MatchAtomicRequest(role: Role, Capabilities: SET OF Roles,

S: service advertisement)

dom = 0

```

FOR ALL <r, ρ> IN S {
    dom1 = MatchRole(r,role)
    dom2 = MatchRoleExpr(ρ, Capabilities)
    dom = max(dom, min(dom1,dom2))
return dom
}

MatchRoleExpr(RExpression: SET OF ConjunctiveRoleSet,
              Capabilities: SET OF Roles)
{
    dom = 0
    FOR ALL CRSi IN RExpression {
        dom' = α
        FOR ALL rj IN CRSi {
            dom' = min(dom', MatchRoleInSet(rj, Capabilities))
        }
        dom = max(dom, dom')
    }
    return dom
}

MatchRoleInSet(role: Role, RS: SET OF Roles)
{
    dom = 0
    FOR ALL ri IN RS {
        dom = max(dom, MatchRole(ri,role))
    }
    return dom
}

```

This approach is intended to be complementary to other general-purpose matchmakers. Experiments have been performed combining an implementation of the semantic match between services (ROWLS) with OWLS-MX [20], one

of the leading hybrid matchmakers available to-date. The combination of both matchmakers outperforms a standalone version of the OWLS-MX matchmaker in both efficiency and effectiveness [12].

3.2 Organisational structures and trust mechanisms

In this example an agent shows how can use knowledge about the organisational structure to infer confidence in a situation when no previous experience about a specific interaction is available. Similar to other approaches [18][30], this work sets out from a trust model based on the idea of *confidence* and *reputation*. Both ratings evaluate the trustworthiness of other agents in a particular situation (e.g., playing a particular role in a particular interaction). *Confidence* is a local measure that is only based on an agent's own experiences, while *reputation* is an aggregated value an agent gathers by asking its acquaintances about their opinion regarding the trustworthiness of another agent. Thus *trust* can be defined as a rating resulting from combining *confidence* and *reputation* values.

A typical scenario for the use of a trust model is the following: an agent A wants to evaluate the trustworthiness of some other agent B – playing the role R – in the interaction I . This trustworthiness is denoted as $t_{A \rightarrow \langle B, R, I \rangle} \in [0..1]$, measuring the trust of A in B (playing role R) being a “good” counterpart in the interaction I . When evaluating the trustworthiness on a potential counterpart, an agent can combine its local information (confidence) with the information obtained from other agents regarding the same counterpart (reputation).

Confidence, $c_{A \rightarrow \langle B, R, I \rangle}$, is collected from A 's past interactions with agent B playing role R and performing interactions of type I . The term *Local Interaction Table* (LIT) is used for an agent's data structure storing confidence values for past interactions with any counterpart the agent has interacted with. Each entry corresponds to a *situation*: an *agent* playing a specific *role* in a particular *interaction*. LIT_A denotes agent A 's LIT. An example is shown in Table 1. Each entry in a LIT consists of:

- (i) The Agent/Role/Interaction identifier $\langle X, Y, Z \rangle$,
- (ii) The confidence value for the issue ($c_{A \rightarrow \langle X, Y, Z \rangle}$), and
- (iii) A reliability value ($r_{A \rightarrow \langle X, Y, Z \rangle}$).

The confidence value is obtained from some function that evaluates past experiences on the same situation. It is supposed that $c_{A \rightarrow \langle X, Y, Z \rangle} \in [0..1]$, where higher values represent higher confidence.

Each direct experience of an agent regarding a situation $\langle X, Y, Z \rangle$ changes its confidence value $c_{A \rightarrow \langle X, Y, Z \rangle}$. In this sense, agents have some mechanism to evaluate the behaviour of other agents that they interact with. Let $g_{\langle X, Y, Z \rangle} \in [0..1]$ denote the evaluation value an agent A calculates for a particular experience with the agent X playing role Y in the interaction of type Z .

The following formula is used to update confidence:

$$c_{A \rightarrow \langle X, Y, Z \rangle} = \varepsilon \cdot c'_{A \rightarrow \langle X, Y, Z \rangle} + (1 - \varepsilon) \cdot g_{\langle X, Y, Z \rangle}$$

Where $c'_{A \rightarrow \langle X, Y, Z \rangle}$ is the confidence value in A 's LIT before the interaction is performed and $\varepsilon \in [0..1]$ is a parameter specifying the importance given to A 's past confidence value. In general, the aggregated confidence value from past experiences will be more relevant than the evaluations of the most recent interactions.

Reliability ($r_{A \rightarrow \langle X, Y, Z \rangle} \in [0..1]$) measures how certain an agent is about its own confidence in a situation, being based on the work by Huynh et al. [19], taking into account the number of interactions a confidence value is based on and the variability of the individual values across past experiences. Furthermore, it is assumed that $r_{A \rightarrow \langle X, Y, Z \rangle} = 0$ for any tuple $\langle X, Y, Z \rangle$ not belonging to LIT_A .

An agent may build trust directly from its confidence value or it may combine confidence with reputation. In this work we do not deal the problem of gathering opinions from other acquaintances by using reputation mechanism, but focus on exploiting past experience to infer expected behaviour on others.

Basic trust models as the one outlined before run into problems when no interactions of a specific type have been performed before and, in addition, social reputation is not available or not reliable. In such a situation, information of the organisational structure can be used to determine an approximate degree of trust.

In particular, one approach consists of using the agent/role confidence $c_{A \rightarrow \langle B, R, _ \rangle}$ (or the agent confidence $c_{A \rightarrow \langle B, _, _ \rangle}$) as an estimation for $c_{A \rightarrow \langle B, R, I \rangle}$ if agent A has no reliable experience about situation $\langle B, R, I \rangle$. This approach relies

on the hypothesis that, in general, *agents behave in a similar way in all interactions related to the same role*. As described before, past experiences are accumulated by agents in form of atomic confidence values for agent/role/interaction tuples in their LIT. This information can be now used to calculate confidence (and trust) values for other organisational elements by accumulating the corresponding entries in an agent LIT.

An agent's trust in a specific role within the organisation is evaluated by the agent/role confidence. It measures the confidence an agent A has in agent B playing a role R and can be calculated by compiling past experiences from any type of interaction where A and B (playing role R) have met:

$$c_{A \rightarrow \langle B, R, _ \rangle} = \frac{\sum_{\langle B, R, _ \rangle_i \in LIT_A} c_{A \rightarrow \langle B, R, _ \rangle_i} r_{A \rightarrow \langle B, R, _ \rangle_i}}{\sum_{\langle B, R, _ \rangle_i \in LIT_A} r_{A \rightarrow \langle B, R, _ \rangle_i}}$$

The notation $\langle B, R, _ \rangle$ refers to tuples for a fixed agent B and a fixed role R regardless the interaction. Agent/role confidence may be used as an additional evidence measure when calculating $t_{A \rightarrow \langle B, R, I \rangle}$. However, more importantly it provides a manner to evaluate $c_{A \rightarrow \langle B, R, I \rangle}$ (and $t_{A \rightarrow \langle B, R, I \rangle}$) if agent A has none or not enough experience regarding the issue $\langle B, R, I \rangle$, that is, if $r_{A \rightarrow \langle B, R, I \rangle} < \theta$. The importance increases if none of the agents in the organisation has had any experience regarding the issue $\langle B, R, I \rangle$, and therefore, none of the agents could

give any (reliable) recommendation. In such a scenario, $c_{A \rightarrow \langle B, R, _ \rangle}$ can provide a valuable approximation of $c_{A \rightarrow \langle B, R, I \rangle}$ for any interaction I.

In a similar way, agents can compute agent confidence $c_{A \rightarrow \langle B, _, _ \rangle}$ – the (global) confidence agent A has in agent B. Agent confidence values can provide a second level of approximation when building $t_{A \rightarrow \langle B, R, I \rangle}$. They may be used as an alternative for $c_{A \rightarrow \langle B, R, I \rangle}$ if there is not even enough expertise for a reliable confidence $c_{A \rightarrow \langle B, R, _ \rangle}$. In a more general environment with agents possibly participating in several organisations, agent confidence may also be used as a gauge to authorise agents to join an organisation.

The previous equation can be adapted to calculate role confidence $c_{A \rightarrow \langle _, R, _ \rangle}$ and interaction confidence $c_{A \rightarrow \langle _, _, I \rangle}$. It is also possible to compute agent/interaction confidence values $c_{A \rightarrow \langle B, _, I \rangle}$; although it is unclear in which settings this measure can be useful.

Role confidence measures an agent's confidence in a specific role within an organisation. This value could be used as default confidence one assigned to agents that just entered an organisation playing a specific role and with no confidence values associated. Interaction confidence provides an estimation of the trust in a concrete interaction within an organisation despite the actual agents that have participated in the interaction. Interaction confidence may be

used as a means to choose between several alternative interactions an agent could participate in.

Confidence (and trust) values can also be aggregated for groups of agents – either in general or in relation to one or more interactions or roles. [15]

As an alternative approach to the one presented above lacking confidence values for a situations $\langle B, R, I \rangle$ could be estimated on the basis of considering experiences in similar situations. Based on the assumption that agents behave in a similar way in similar situations, confidence ratings for similar agent/role/interaction tuples can be accumulated to provide evidence for the trustworthiness of the situation $\langle B, R, I \rangle$. Trust can be built by taking into account all the past experiences an agent has, focusing on their degree of similarity between organisational concepts, with the situation of interest $\langle B, R, I \rangle$. In particular, trust can be calculated as a weighted mean over all the confidence values an agent has accumulated in its LIT. This is shown in the following equation:

$$t_{A \rightarrow \langle B, R, I \rangle} = \frac{\sum_{\langle X, Y, Z \rangle \in LIT_A} c_{A \rightarrow \langle X, Y, Z \rangle} \cdot \omega_{A \rightarrow \langle X, Y, Z \rangle}}{\sum_{\langle X, Y, Z \rangle} \omega_{A \rightarrow \langle X, Y, Z \rangle}}$$

$\omega_{A \rightarrow \langle X, Y, Z \rangle}$ is the weight given to agent A 's confidence on situation $\langle X, Y, Z \rangle$.

The weights combine the confidence reliability with the similarity of the situation $\langle X, Y, Z \rangle$ to the target issue $\langle B, R, I \rangle$ in the following way:

$$\omega_{A \rightarrow \langle X, Y, Z \rangle} = r_{A \rightarrow \langle X, Y, Z \rangle} \cdot \text{sim}(\langle X, Y, Z \rangle, \langle B, R, I \rangle)$$

The similarity function $sim(\langle X, Y, Z \rangle, \langle B, R, I \rangle)$ is computed as the weighted sum of the similarities of the individual elements (agent, role and interaction) as it is shown in the following equation:

$$sim(\langle X, Y, Z \rangle, \langle B, R, I \rangle) = \begin{cases} \beta \cdot sim_R(R, Y) + \gamma \cdot sim_I(I, Z) & \text{if } X = B \\ 0 & \text{otherwise} \end{cases}$$

Where $sim_R(R, Y), sim_I(I, Z) \in [0..1]$ measures the similarity between roles and interactions, respectively, and β and γ with $\beta + \gamma = 1$, are parameters specifying the sensibility regarding the individual similarities.

Role similarities can be inferred from role taxonomies contained in an organisational model. In particular, $sim_R(R, R')$ can rely on a *distance function*, similar to the one presented in the previous subsection that estimates the similarity between two roles on the basis of their proximity in the taxonomy. The same holds for $sim_I(I, I')$ when interaction taxonomy is available in an organisational model [16].

Especially if an agent has no reliable experience about a particular agent/role/interaction situation, the organisation-based approach explained can be used to estimate trust without the necessity to rely on the opinions of other agents. So, role and interaction taxonomies can help making agents that use trust mechanisms less vulnerable to dishonest counterparts, as there is less need to rely on third-party information.

4 Discussion

An overview of different approaches to coordination in the MAS field has been presented in this paper. It has been argued that the *notion of agreement is essential to instil coordination in open distributed systems*. Some existing technologies from the field of MAS coordination can be applied to this respect, and others – semantic technologies; in particular – need to be added. To explain the types of mechanisms that can be part of a “technology of agreement”, two examples with a certain level of detail have been provided to show how techniques from the field of organisations can be used to foster coordination and agreement in open MAS.

It was shown how organisational structures could be used to complement traditional matchmaking mechanisms in order to enhance their performance. A role-based matchmaking component has been implemented and evaluated in combination with the well-known OWLS-MX matchmaker. Furthermore, it has been argued that organisational structures can be used to improve reputation mechanisms in situations where only a limited amount of information regarding previous interactions is available. Current work focuses on how, in turn, the history of interactions can be used to evolve organisational structures [15], [16]. The concept of *agreement* is still evolving and the process of defining its limits still continues, but even at this stage, the approach have already proven its utility and expressive power.

Several currently research efforts, which are being carried out as European projects, may contribute to the development of a “technology of agreement” [7]. These efforts promote the emergence of a new paradigm for next-generation distributed systems based on *the agreement* in a society of computational agents.

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Tables

Table 1: LIT (Local Interaction Table)

It is an agent's data structure storing confidence values for past interactions with any counterpart the agent has interacted with.

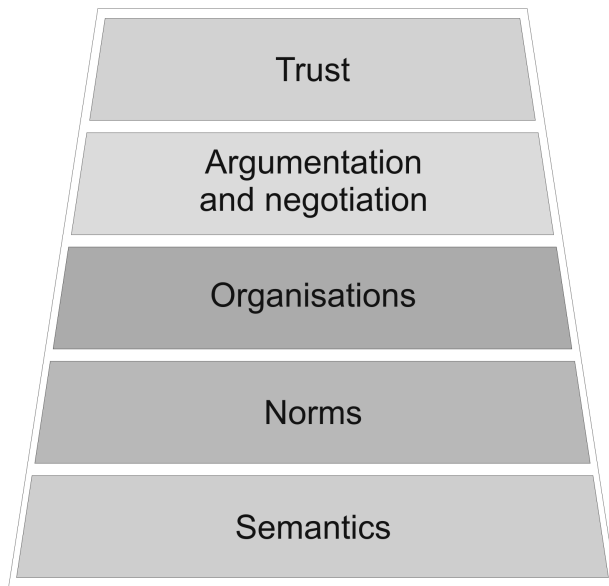
$\langle X, Y, Z \rangle$	$c_{A \rightarrow \langle X, Y, Z \rangle}$	$r_{A \rightarrow \langle X, Y, Z \rangle}$
$\langle a_9, r_2, i_3 \rangle$	0.2	0.75
$\langle a_2, r_7, i_1 \rangle$	0.7	0.3
\vdots	\vdots	\vdots
$\langle a_9, r_2, i_5 \rangle$	0.3	0.5

Each entry corresponds to a situation: an agent playing a specific role in a particular interaction.

LIT_A denotes agent A's LIT.

Figure 1: Agreement Technologies' original tower (layered) structure [1].

Figure 1:



Footnotes

- 1 - <http://www.daml.org/services/owl-s>
- 2 - <http://www.wsmo.org>
- 3 - <http://www.mindswap.org/mhgrove/kowari>
- 4 - <http://jena.sourceforge.net>