Four Ways to Change Coalitions: Agents, Dependencies, Norms and Internal Dynamics

Leendert van der Torre[1] and **Serena Villata**[2]

Abstract. We introduce a formal social network approach to distinguish four ways in which coalitions change. First, the agents in the network change. Second, dependencies among the agents change, for example due to addition or removal of powers and goals of the agents. Third, norms can introduce normative dependencies for obligations and prohibitions. Fourth, coalitions can change due to internal processes. We propose a number of stability measures to identify each one of the four proposed sources of coalitions' dynamics and the consequences they induce on the stability of coalitions.

1 Introduction

Coalitions play a central role in social reasoning, and thus various theories have been used and developed in multiagent systems. For example, coalitional game theory has been adopted from economics and extended for multiagent systems [8, 9], and social networks have been adopted from social sciences and modified to represent dependence networks among agents [10, 6, 7]. These theories differ in various ways. For example, in the former, potential coalitions may be seen as sets of agents while in the latter, dependence networks can be seen as criteria for proposing/accepting to form coalitions [10], or *potential* coalitions are viewed as sets of dependencies (the dependencies represent the contract of the potential coalition) [7]. Moreover, in the former various notions of stability are defined, whereas in the latter they are not. In this paper, we address the question how to distinguish and model the different reasons behind the change of coalitions.

Possible reasons behind these changes are due to operations of addition and removal of the components of our model such as agents, dependencies among agents, normative dependencies concerning normative goals and powers. More precisely, how do we measure the evolution and the changes of a coalition over time in terms of:

changes of the agents and dependencies. We distinguish two kinds of uses for dependence networks: global use in software engineering where the designer models all stakeholders [4], and social simulation where no such assumption is made [10]. In the former, game theory can be used for reasoning about social interaction, in the latter simulation methods are used. We follow the tradition of TROPOS [4], as formalized by Sauro [7] and close to qualitative game theories developed by Wooldridge et al. [1], not the latter [10].

changes of the dependencies related to norms. Norms are used for the dynamics of dependence networks, which explained why they have not been considered thus far in the static dependence networks [11]. A norm analytically implies that agents (intend to) execute them, and therefore leads to dependencies among agents just like the original goal-based dependencies studied by Sichman and Conte [11]. More precisely, norms generate normative goals in the dependence networks, and these normative goals, i.e., obligations, are treated just like goals derived from the agent's desires. The coalitions which may emerge depend on the dependencies among the agents, so since norms change the dependencies among agents, they also change the coalitions which will emerge.

internal dynamics. Changes of the coalition itself in terms of goal-based and norm-based dependencies composing the coalition, e.g., an agent is excluded from a coalition because of a malicious behaviour.

We call the last kind of change *internal dynamics* to distinguish it from the other dynamics related to the addition or deletion of agents or goal-based and norm-based dependencies. They represent the case in which the network remains the same, involving the same agents and dependencies, but the composition of the coalition changes, including new dependencies or excluding the old ones. A simple and intuitive common sense example of the above presented changes can be the next one. Consider a soccer team as a coalition. It can change because new players come in, or players retire. It can change, because agents acquire new abilities or loose abilities, e.g., they loose their form, they break a leg, and so on, or get new goals, e.g., they want to play in the national team. Concerning norms, there can be the obligation set by the trainer for a player to play in the left wing position. Concerning internal dynamics, there may be a malicious behavior of a player, e.g., he gets too many red cards since he is too aggressive and he is no longer allowed to play. In the paper, we explain the changes using a grid-based running example.

From the multiagent systems field, we use the normative multiagent paradigm while from social network theory we take the idea of defining graph theoretic measures. Concerning measures, we define measures associated to the number of agents and the number of goal-based dependencies present in each time instant, counting the number of norm-based dependencies in each time instant and counting the changes in the dependencies composing coalitions. Our measures are unified in an average measure returning coalitions' stability depending on the differences between values associated to consecutive time instants.

In this paper, we do not give a formal ontology but we define indications of the possible changes of coalitions. Moreover, we do not perform any simulation as in Carley's dynamic networks analysis [5]. This paper is organized as follows. Section 2 presents a grid-based scenario. Section 3 and 4 present the key concepts of our metamodel and the three coalitions' changes in detail. Related work and conclusions end the paper.

[1] University of Luxembourg, Luxembourg
[2] University of Turin, Italy, email:villata@di.unito.it

2 Changing coalitions in a GRID scenario

We use the following example of a coalition in a grid environment. Inside a virtual organization (VO), local coalitions may be formed in order to cooperate to achieve shared goals such as, i.e., computations and storage of satellites' data. We depict a section of the VO composed by five nodes, as in Figure 1.a, following the legend of Figure 3. The VO is composed by four nodes connected to each other by dependencies based both on goals and on norms and nodes a, b and c form a local coalition. Considering goal-based dependencies, node b depends on node a to save the file *satellite.jpg*, node c depends on node b to save the file *satellite.mpeg* and node c depends on node d to run the file *results.mat*, since they are not able to perform their goals alone. Considering norm-based dependencies, instead, node a depends on node c to have the permission to open the file *data-June.mat* while node c is obliged to give to node b the results of the running of file *mining.mat*.

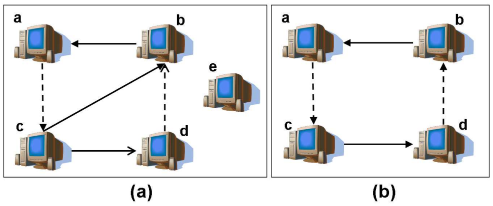

Figure 1. Grid network:a-Coalition $\{a, b, c\}$;b-Coalition $\{a, b, c, d\}$.

The first kind of change of coalitions in the grid scenario follows directly from the grid metaphor. Computers can be connected to the grid like electrical machines can be connected to the power net. So the computers connected to the grid changes frequently, e.g., node e. If they do so, then also the coalition changes. How frequently they change is our first measure.

The second kind of change concerns goal-based dependencies. Node b fulfilled the goal of node c to save the file *satellite.mpeg*. This dependency does not hold anymore and it is deleted, as shown in Figure 1.b. This deletion of dependencies changes the structure of the local coalition because of now the reciprocity involves also node d inside the system. The deletion, as the addition, of a goal-based dependency may cause a change in the coalitions composed by these dependencies.

The third kind of change is related with security. A node has a number of private information, e.g., a unique access to its pc. If another node has the necessity to access to it, it has to ask the first node the permission, e.g., a login and a password, as in the norm-based dependency among nodes a and c. Obligations, instead, are due to particular services provided by the nodes. The obligation is represented as a dependency, as in the case of the norm-based dependency among nodes d and b, and it is removed if the obligation is no more active in the system. Figure 2.a shows the introduction of a norm-based dependency representing the obligation for node b to give the access to file *finalres.txt* to node a.

The fourth kind of change, internal changes of coalitions, represents changes in the composition of the coalition because of internal reasons. In Grid networks, malicious behaviours can be recognized, e.g., in case of attacks or for not properly following the protocol, and malicious nodes can be excluded from further interactions with the other nodes, as shown in Figure 2.b.

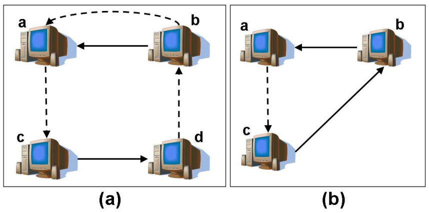

Figure 2. Grid network:a-Coalition $\{a, b, c, d\}$;b-Coalition $\{a, b, c\}$.

3 The model

Our modeling approach aims to provide a design methodology both for multiagent systems and social systems, based on the normative multiagent paradigm. The main concepts and relationships composing our models are agents, institution, roles, dependency, norm, power, goals. For more details on the conceptual metamodel, see [2, 3]. We divide our conceptual metamodel in three submodels: the agent model, the institutional model, and the role assignment model. Such a decomposition is common in organizational theory, because the organization can be designed without having to take into account the agents that will play a role in it. Likewise, agents can be developed without knowing in advance in which institution they will play a role. The notion of agent and all its features as goals, capabilities, facts are used in the conceptual modeling. Moreover, we add to these notions those related to the institution [3] such as the notion of role and all its institutional goals, capabilities and facts. Both these notions, combined in the combined view, are used in the conceptual modeling and to each agents it is possible to assign different roles depending on the organization in which the agent is inserted.

A coalition can be defined using the modeling technique of dependence networks, based on the idea that to be part of a coalition, every agent has to contribute something, and has to get something out of it. Roughly, a coalition can be formed when there is a cycle of dependencies (the definition of coalitions is more complicated due to the fact that an agent can depend on a set of agents, as we will see below). Since the processes involving coalitions dynamics are complex and costly social behaviors, agents have to maintain the stability of their own coalition, paying attention to the possible actions that can be performed by the other agents to strategically increase their profit, mining the position of the agents inside the coalition or, even worse, destroying the coalition itself.

3.1 The model definition

In this section, we present our model as a tuple composed by the concepts of agents, goals, norms, time. These components are linked by the relationship of dependency, which characterizes our dependency modeling activity. Our model can be represented as follows:

Definition 1 $\langle A, G, N, T, D, D \subseteq A \times A \times G, T \rightarrow 2^A, T \rightarrow 2^D, N \rightarrow 2^D, C \subseteq 2^D, N \subseteq C \rangle$ *consists in a set of agents* A*, a set of goals* G*, a set of norms* N*, a set of time instants* T *and a set of dependencies* D*. Every time instant is related to the set of agents and to the set of dependencies* D *present in the system in that instant. Norms are represented as a subset of dependencies. A coalition is represented as a set of dependencies and a subset of the dependencies composing a coalition can be represented by norms.*

In this model, a coalition can be represented by a set of dependencies, represented by $C(a, B, G)$ where a is an agent, B is a set of agents and G is a set of goals. Intuitively, the coalition agrees that for each $C(a, B, G)$ part of the coalition, the set of agents B will see to the goal G of agent a. Otherwise, the set of agents B may be removed from the coalition or be sanctioned.

Example 1 *Given a set of agents* $A = \{n_1, n_2, n_3, n_4, n_5\}$, *a set of goals* $G = \{g_1, g_2, g_3, g_4, g_5\}$, *a set of norms* $N = \{nr_1, nr_2\}$, *a set of time instants* $T = \{t_1, t_2, t_3\}$ *(these instants are associated to instants* t_1, t_3 *and* t_5 *of Figure 5), we have the following assignments showing what agents are present in each time instant* $(t_1, \{n_1, n_2, n_3, n_4, n_5\})$, $(t_2, \{n_1, n_2, n_3, n_4\})$, $(t_3, \{n_1, n_2, n_3, n_4\})$, *what dependencies are present in each time instant* $(t_1, \{(n_1, n_3, g_1), (n_3, n_4, g_2), (n_4, n_2, g_3), (n_2, n_1, g_4), (n_3, n_2, g_5)\})$, $(t_2, \{(n_1, n_3, g_1), (n_3, n_4, g_2), (n_4, n_2, g_3), (n_2, n_1, g_4)\})$, $(t_3, \{(n_1, n_3, g_1), (n_2, n_1, g_4), (n_3, n_2, g_5)\})$, *what dependencies are norm-based ones* $(n_1, \{(n_1, n_3, g_1)\})$, $(n_2, \{(n_4, n_2, g_3)\})$ *and how are coalitions composed* $C_1 = \{(n_1, n_3, g_1), (n_3, n_4, g_2), (n_4, n_2, g_3), (n_2, n_1, g_4)\}$, $C_2 = \{(n_1, n_3, g_1), (n_2, n_1, g_4), (n_3, n_2, g_5)\}$.

In a multiagent system, since an agent is put into a system that involves also other agents, he can be supported by the others to achieve his own goals if he is not able to do them alone. This leads to the concept of power representing the capability of a group of agents (possibly composed only by one agent) to achieve some goals (theirs or of other agents) performing some actions without the possibility to be obstructed. The power of a group of agents is defined as follows:

Definition 2 (Agents' power) $\langle A, G, power : 2^A \rightarrow 2^{2^G} \rangle$ *where* A *is a set of agents,* G *is a set of goals. The function* $power$ *relates with each set* $S \subseteq A$ *of agents the sets of goals* $G_S^1, \ldots, G_S^m$ *they can achieve.*

Example 2 *Given a set of agents* $A = \{n_1, n_2, n_3, n_4, n_5, n_6\}$ *and a set of goals* $G = \{g_1, g_2, g_3, g_4, g_5, g_6\}$, *the function power relates each agent with the set of goals it can achieve:* $power(n_1) = \{\{g_5\}\}$, $power(n_2) = \{\{g_1\}\}$, $power(n_3) = \{\{g_2\}, \{g_6\}\}$, $power(n_4) = \{\emptyset\}$, $power(n_5) = \{\{g_4\}\}$, $power(n_6) = \{\{g_3\}\}$.

Definitions 1 and 2 have the aim to explain how social dependence networks can be seen as multiagent systems. The notion of power is relevant for our methodology since it represents the social basis for the development of our model based on the methodology of dependence networks as developed by Conte and Sichman [11]. In this model, an agent is described by a set of prioritized goals, and there is a global dependence relation that explicates how an agent depends on other agents for fulfilling its goals. For example, *dep*$(\{a, b\}, \{c, d\}) = \{\{g_1, g_2\}, \{g_3\}\}$ expresses that the set of agents $\{a, b\}$ depends on the set of agents $\{c, d\}$ to see to their goals $\{g_1, g_2\}$ or $\{g_3\}$. A dependence network is defined as follows:

Definition 3 (Dependence Networks (DN)) *A dependence network is a tuple* $\langle A, G, dep, \geq \rangle$ *where:*

- A *is a set of agents and* G *is a set of goals;*
- *dep* : $2^A \times 2^A \rightarrow 2^{2^G}$ *is a function that relates with each pair of sets of agents all the sets of goals on which the first depends on the second.*
- $\geq$: $A \rightarrow 2^G \times 2^G$ *is for each agent a total pre-order on goals which occur in his dependencies:* $G_1 \geq (a) G_2$ *implies that* $\exists B, C \subseteq A$ *such that* $a \in B$ *and* $G_1, G_2 \in depend(B, C)$.

The *dependency modeling* represents our modeling activity consisting in the identification of the dependencies among the agents. Our *dependency modeling* is represented as a directed labeled graph whose nodes are instances of the metaclasses of the metamodel, e.g., agents, goals, and whose arcs are instances of the metaclasses representing relationships between them such as goal-based dependency and norm-based dependency. A graphical representation of the model obtained following this modeling activity is depicted in the legend of Figure 3. The *dependency modeling* describes the agents (white circles), the dependency among agents (one arrowed line connecting two agents with the eventual addition of a label representing the goal on which there is the dependency), the norm-based dependency among agents (one arrowed striped line connecting two agents with the eventual addition of a label representing the goal on which there is the dependency), the goal-based or norm-based dependency composing a coalition (one arrowed [striped] line with plain arrow) and the goal-based or norm-based dependency not composing a coalition (one arrowed [striped] line with open arrow). Open and closed arrows are used to provide an immediate graphical representation of coalitions.

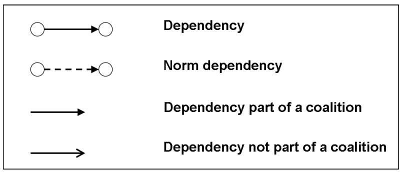

Figure 3. Legend of the graphical representation.

Example 3 presents the dependence network arising from the power relations of Example 2 with all dependencies belonging to a single coalition.

Example 3 *Considering a Grid composed by six nodes, we can imagine to view each node as an agent and we can form the following dependence network:*

1. *Agents* $A = \{n_1, n_2, n_3, n_4, n_5, n_6\}$ *and Goals* $G = \{g_1, g_2, g_3, g_4, g_5, g_6\}$;
2. *dep*$(\{n_1\}, \{n_2\}) = \{\{g_1\}\}$*: agent* n_1 *depends on agent* n_2 *to achieve the goal* $\{g_1\}$*: to save the file comp.log;*
   dep$(\{n_2\}, \{n_3\}) = \{\{g_2\}\}$*: agent* n_2 *depends on agent* n_3 *to achieve the goal* $\{g_2\}$*: to run the file mining.mat;*
   dep$(\{n_3\}, \{n_1\}) = \{\{g_5\}\}$*: agent* n_3 *depends on agent* n_1 *to achieve the goal* $\{g_5\}$*: to save the file satellite.jpg;*
   dep$(\{n_4\}, \{n_6\}) = \{\{g_3\}\}$*: agent* n_4 *depends on agent* n_6 *to achieve the goal* $\{g_3\}$*: to run the file results.mat;*
   dep$(\{n_6\}, \{n_5\}) = \{\{g_4\}\}$*: agent* n_6 *depends on agent* n_5 *to achieve the goal* $\{g_4\}$*: to save the file satellite.mpeg;*
   dep$(\{n_5\}, \{n_3\}) = \{\{g_6\}\}$*: agent* n_5 *depends on agent* n_3 *to achieve the goal* $\{g_6\}$*: to have the authorization to open the file dataJune.mat;*

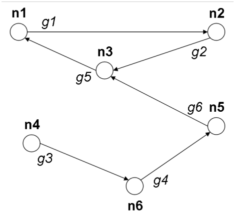

Figure 4. Dependence Network of Example 3.

4 Coalitions' Dynamics

In this section, we present a definition of coalition based on the structure of dependence network and how to use these different kinds of dependencies to model and measure coalitions' dynamics. In our model, a coalition is defined as follows:

Definition 4 (Coalition) *Let A be a set of agents and G be a set of goals. A coalition function is a partial function $C : A \times 2^A \times 2^G$ such that $\{a \mid C(a, B, G)\} = \{b \mid b \in B, C(a, B, G)\}$, the set of agents profiting from the coalition is the set of agents contributing to it. Let $\langle A, G, dep, \geq\rangle$ be a social dependence network, a coalition function C is a coalition if $\exists a \in A, B \subseteq A, G' \subseteq G$ such that $C(a, B, G')$ implies $G' \in dep(a, B)$.*

As introduced before, we can model and measure coalitions' dynamics over time in terms of: changes of the agents and goal-based dependencies, changes of the dependencies related to norms and changes inside the coalition itself.

4.1 Agent and dependencies' changes

The first kind of change is due to agents entering or leaving the multiagent system we model or to the dependencies added or deleted depending on the fulfillment of the related goal or the presence of the power to fulfill this goal. In our model, we distinguish two different kinds of goals, achievement goals and maintenance goals. In contracts goals are typically achievement ones while, in game theoretical approaches, coalitions are typically concerned with maintenance goals. In this paper, we assume that goals are maintenance goals rather than achievement ones, which give us automatically a longer term and a more dynamic perspective to define the evolution of coalitions and thus their stability. Moreover, our model aims to distinguish and represent not only short term situations such as, for example, a virtual meeting on Second Life but also long term situations as, for example, the work of a particular department or office or, in the Grid scenario, the work of a virtual organization for e-Research.

We can define two measures associated to the number of agents and the number of goal-based dependencies present in each time instant. The first measure calculates the ratio between the number of agents added and removed in a particular time instant depending and the number of agents present at the previous time instant. The second measure calculates the ratio between the number of goal-based dependencies added and deleted in a particular time instant depending and the number of goal-based dependencies present at the previous time instant. The measures are defined as follows:

Definition 5 (Agents and Dependencies Measures) *Let t_i be a time instant, N_i^{Agent} is given by the number of agents entering the system A_i^+ and leaving the system A_i^-, depending on the total number of agents A_{i-1} present at time instant t_{i-1}:*

$$N_i^{Agent} = \frac{\sum A_i^+}{\sum A_{i-1}} + \frac{\sum A_i^-}{\sum A_{i-1}}$$

Let t_i be a time instant, N_i^{Dep} is given by the number of goal-based dependencies added to the network D_i^+ and deleted form the network D_i^-, depending on the total number of goal-based dependencies D_{i-1} present at time instant t_{i-1}:

$$N_i^{Dep} = \frac{\sum D_i^+}{\sum D_{i-1}} + \frac{\sum D_i^-}{\sum D_{i-1}}$$

Example 4 *In Figure 5, we present the case of six time instants depicting the evolution of a system. In the first time instant, we have five agents and a coalition composed by agents a, b, c. Always in this first instant, there are two norm-based dependencies and three goal-based dependencies. The passage from the first instant t_1 to the second one shows the deletion of agent e but all the dependencies remain the same. From instant t_2 to instant t_3, we can observe the deletion of the goal-based dependency connecting agents c and b. This deletion can depend on a removal of the goal or of the power associated to the dependency or on the fulfillment of the goal. In the first case, if an agent has no more the power to fulfill the goal, the dependency has no reason to be maintained and the same thing happens if the agent has no more a particular goal. The coalition changes and it is formed by all the four agents. From instant t_3 to instant t_4, the situation changes back to the original configuration but the coalition is fixed. From instant t_4 to instant t_5, agent d disappears and the coalition changes its actors and is composed by agents a, b and c. From instant t_5 to instant t_6, the situation cames back to the situation of instant t_4. All these time instants can be represented as in Example 1. The measures vary as follows: [Agents] $t_1 : 0/5$, $t_2 : 1/4$, $t_3 : 0/4$, $t_4 : 0/4$, $t_5 : 1/3$, $t_6 : 1/4$; [Dependencies] $t_1 : 0/3$, $t_2 : 0/3$, $t_3 : 1/2$, $t_4 : 1/3$, $t_5 : 1/2$, $t_6 : 1/3$.*

4.2 Norms' changes

The second kind of change is due to norms and, in particular, to obligations. An obligation is a requirement which must be fulfilled to take some course of action, whether legal or moral. Normative reasoning is strictly related to norms' changes and the definition of a representation and a measure for them allows to do it. The norm sets a particular kind of dependency among two agents. This dependency can be deleted if the obligation is fulfilled or a new obligation can be inserted into the system to regulate its behaviour. In our model, we distinguish, represent and measure both short term contracts, e.g., a transaction on e-Bay such as an agreement carried out between separate entities involving the exchange of items of value as goods and money, and long term contracts, e.g., the marriage contract which hopefully lasts forever.

We can define a measure associated to the number of norm-based dependencies present in each time instant. This measure calculates the ratio between the number of norm-based dependencies added and deleted to each time instant depending and the total number of norm-based dependencies present in that time instant. The measure is defined as follows:

Definition 6 (Norms Measure) *Let t_i be a time instant, N_i^{Norm} is given by the number of norm-based dependencies added to the network N_i^+ and deleted form the network N_i^-, depending on the total*

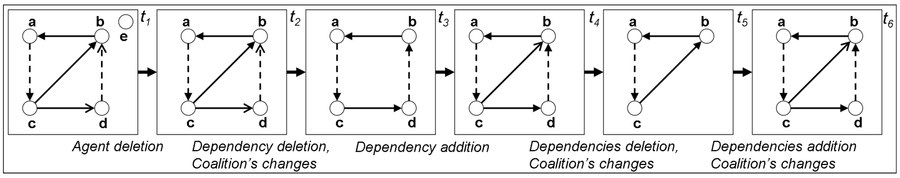

Figure 5. Agents and dependencies' change.

number of norm-based dependencies N_{i-1} present at time instant t_{i-1}:

$$N_i^{Norm} = \frac{\sum N_i^+}{\sum N_{i-1}} + \frac{\sum N_i^-}{\sum N_{i-1}}$$

.

Example 5 *In Figure 6, we model three time instants. In the first time instant t_1, we have a coalition formed by all the four agents, three goal-based dependencies and two norm-based dependencies. From time instant t_1 to time instant t_2, the norm-based dependency involving agents d and b is removed due to the removal of the normative goal or the removal of the associated power. From time instant t_2 to time instant t_3, a new norm-based dependency is set due to the insertion of a new normative goal or the associated normative power. The measure varies as follows: [Norms] $t_1 : 0/2$, $t_2 : 1/1$, $t_3 : 1/2$;*

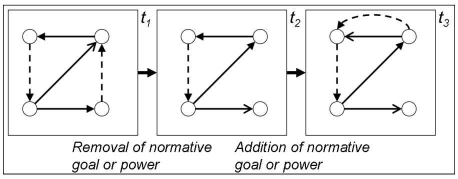

Figure 6. Norms' change.

4.3 Coalitions' changes

The third kind of change is related to changes inside the coalition itself, e.g., an agent is excluded from a coalition because of a malicious behaviour. This third kind of change is the only one related to the coalition itself and it has to represent and measure the changes in the composition of each coalition of the system. We define a measure which calculates the ratio between the number of the goal-based and norm-based dependencies composing the coalition in each time instant and the dependencies composing the coalition in the previous time instant, as follows:

Definition 7 (Coalitions Measure) *Let t_i be a time instant, N_i^{Coal} is given by the number of new norm-based and goal-based dependencies $D_i^+ \cup N_i^+$ belonging to a coalition C_i added to the network and deleted form the network $(D_i^- \cup N_i^- \subseteq C_i)$ depending on the total number of norm-based and goal-based dependencies composing the coalition $(D_{i-1} \cup N_{i-1} \subseteq C_{i-1})$ at time instant t_{i-1}:*

$$N_i^{Coal} = \frac{\sum(D_i^+ \cup N_i^+ \subseteq C_i)}{\sum(D_{i-1} \cup N_{i-1} \subseteq C_{i-1})} + \frac{\sum(D_i^- \cup N_i^- \subseteq C_i)}{\sum(D_{i-1} \cup N_{i-1} \subseteq C_{i-1})}$$

.

Example 6 *Consider the coalition depicted in time instant t_1 of Figure 7. The coalition is composed by agents a, b and c. The passage from time instant t_1 to time instant t_2 sees the addition inside the coalition of agent d due to the reciprocity-based principle of coalition formation. From time instant t_2 to time instant t_3, agent d is excluded from the coalition, without any change in the number or type of the dependencies composing the coalition itself. This can depend, as said, on a malicious behaviour of the excluded agent. The measure varies as follows: [Coalitions] $t_1 : 0/3$, $t_2 : 1/4$, $t_3 : 3/3$;*

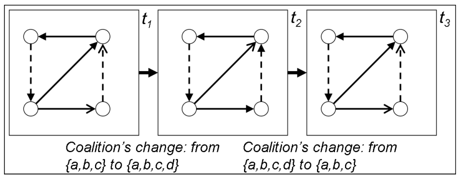

Figure 7. Coalitions' change.

The above measures are defined for one time moment only. We can unify these measures for a sequence of dependence networks associating to each time instant the average number of changes. We can define this measure as follows:

Definition 8 (Changes Measures) *Let t_i be a time instant of a sequence of social dependence networks, the changes measure is given by the following formula:*

$$\frac{N_i^{Agent} + N_i^{Dep} + N_i^{Norm} + N_i^{Coal}}{4}$$

.

For example, considering instants t_2, t_3, t_4 and t_5 depicted in Figure 5, the average number of changes at each moment in time is: $t_2 : 1$; $t_3 : 3$, $t_4 : 1,3$; $t_5 : 11,3$. Thanks to this measure, we underline that the two time instants with the main changes in comparison with their previous time instant are t_3 and t_5, as can be supposed observing the relative figures. Always considering the measures of Figure 5 for time instants t_4, t_5 and t_6, it can be noted that in our measures the deletion of agents, norm-based and goal-based dependencies and dependencies composing coalitions increases the difference of the changes measure associated to two time instants in a row while the addition of these components causes a minor difference relatively to two consecutive time instants. This behaviour is due to the relation of our measure with the game theoretical approaches for defining stability: the stability is maintained in order to avoid the breaking off of the agents from the grand coalition and form their own group. Thus, the removal of agents and dependencies from coalitions is more relevant that their addition and this is represented in the changes measure.

We choose the simplest possible measures that capture the stability of the networks, because they represent all possible changes can be performed in the composition of coalitions and of the networks. When the average of the measures for a sequence of dependence networks presents a great difference in the values of two connected time instants, it underlines a lack of stability while when the average presents a small or inexistent difference between two connected time instants, the stability of the coalition and of the network in general is maintained. Moreover, the measures now only give a global indication of the stability of agents, dependencies, norms and coalitions. We could also measure whether changes in agents and dependencies coincides with changes in the coalition thanks to our four measures.

5 Related Work

In a multiagent perspective, a coalition can be viewed under two different representational frameworks. The first one regards cooperative game theory. Cooperative game theory studies those games in which players are able to make binding agreements with the aim to achieve a collective benefit. This approach is strictly related to the field of economics and various approaches of this kind have been presented in literature as, for example, the work of Shehory and Kraus [8]. The second perspective is based on the theory of the social power and dependence pioneered by Castelfranchi [6] as starting point and then developed in the context of coalition formation by Sichman [10] and Sauro [7]. This involves the development of a social reasoning mechanism that analyzes the possibility to profit from mutual-dependencies, e.g., two agents depend on each other for the satisfaction of a shared goal, or reciprocal-dependencies, e.g., two agents depend on each other for the satisfaction of two different goals. Both these two approaches present the following problems: they do not provide a modeling technique to represent coalitions' dynamics and to distinguish them. The comparison among these two approaches is summarized in Table 1.

	GAME THEORY	**SOCIAL NETWORKS**
Coalitions	sets of agents	sets of dependencies
Formation based on	core	reciprocity
Stability	nucleous, Shapley value	none

Table 1. Two models to represent coalitions.

6 Conclusions

We present a model to represent, at each time instant, the state of the system in terms of agents, goals, norms and the dependencies relating all these concepts. This model allows the distinction and measure of the possible coalitions' dynamics. In particular, we distinguish among three different kinds of coalitions' changes: changes based on addition or deletion of agents or goal-based dependencies, changes based on the addition or deletion of norm-based dependencies and changes on the internal structure of the coalition itself. It can be observed that with a more detailed model we could make more detailed and precise distinctions between the four kinds of changes. However, often we only have the given information, for example in systems' design, and we already would like to do kind of analysis on these models. This is precisely where graph-theoretical social network techniques are useful. We combine these techniques with the normative multiagent paradigm introducing in the networks norm-based dependencies. The strength of this combination consists in building a modeling technique able to represent in an intuitive way not only the inter-relationships among the actors of the system but also external constraints such as norms and, particularly, obligations, e.g., in our Grid scenario. The main difficulty of this approach consists in the creation of a common model without simplifying too much the two original frameworks.

Moreover, we introduce four measures aiming to measure these changes inside the networks to each time instant and an average measure to compute the stability of a sequence of dependence networks. Our model allows to measure coalitions' dynamics in terms of changing dependencies, agents and coalitions, distinguishing also among goal-based dependencies and norm-based ones. Using dependence networks as methodology to model a system advantages us from different points of view. First, they are abstract, thus they can be used for conceptual modeling, simulation, design and formal analysis. Second, they are used in high level design languages, like TROPOS [4], thus they can be used also in software implementation.

Concerning future work, we are working on a definition of coalitions' stability in our model, based on the presented measures, because of a lack of a definition of this notion in the field of social network theory. The notion of stability in our model can be identified intuitively in the absence of coalitions' changes we described but it is necessary to provide a formal definition of this notion and to associate it a measure able to represent it. Moreover, we start to simulate the use of our model and its associated measures in order to provide quantitative results based on our approach, similarly to social network theory approaches.

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