A Reputation Model for Organisational Supply Chain Formation *

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Abstract. The use of organisational concepts and the design of reputation mechanisms have been proved as successful methods to build multiagent systems where agents' decision-making processes to select partners are seminal for the system functioning. In supply chain domains this latter issue becomes crucial in the phase of *formation* since entities participating need to establish business relationships as soon as possible in order to maximise their profits. In this work we propose: *i)* a novel formalisation of supply chains using organisational concepts and, *ii)* a reputation model based on those organisational concepts and on *personal norms* with which agents define their preferences about potential interactions. To conclude, we present a case study pointing out the stronger points of our work.

1 Introduction

A supply chain comprises multiple enterprises to collaboratively provide customers with products or services [16]. A supply chain life-cycle contemplates two main processes: the supply chain formation and the supply chain management. This paper focuses on the supply chain formation that concerns the selection of the participants to the supply chain and the agreement about terms of the exchange [7]. In particular, the main goal of the paper is to contribute to the selection of the enterprises that will participate in the supply chain in order to establish stronger relationships.

Due to the need to quickly respond to market requirements changes and to rapidly create or reconfigure supply chains, we present an approach that contributes to the dynamic supply chain formation. A supply chain is viewed as an organisation composed of different enterprises, each represented by an agent playing roles in the organisation.

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Agents and organisations to represent enterprises and supply chains, respectively, have been used because, in recent years, multi-agent systems (MAS) have been recognised as a promising technology for the automation of supply chains [16]. In addition, organisational approaches are more and more used since they allow facing complex problems using simple abstractions [10]. Those abstractions can be concepts that structure relationships among organisation members, such as roles that agents can play, and also constraints, such as norms that attempt to regulate agents' behaviour.

The ability to select suitable partners is one of the keys to build successful supply chains [18], so this issue should be adequately supported by our model. As it has been demonstrated by several studies [2, 3, 13], trust and reputation contribute significantly to the formation of suitable partners and of stable supply chains. Therefore, we propose the use of *a reputation mechanism based on norms to give support to the dynamic supply chain formation*. The reputations of the agents are evaluated according to the (organisational and personal) norms that they violate and fulfil. Norms define the actions agents are prohibited, permitted or obligated [17] to perform and the sanctions/reward to be applied in the case of violations/fulfilment [19]. The organisational norms are the ones defined by supply chains (or organisations) while the personal norms are defined by the agents themselves. Note that the reputation mechanism should be used together with other mechanisms to investigate the most appropriated enterprises to participate in the supply chain being formed by analysing, not only the enterprises reputations, but also the products or resources provided, their cost, etc.

The remainder of the paper is organised as follows. Section 2 formalises our organisation model and Section 3 our reputation model. In Section 4 we present an overview of supply chain formation and Section 5 uses the formalisation presented in Section 2 to formalise supply chains. Section 6 illustrates our approach by using a supply chain case-study. Finally, Section 7 states some related work and Section 8 concludes and introduces some future work.

2 Organisational Model

In this section we present the formalisation of our organisational model. This model relies on three basic entities, namely: *roles*, *organisational norms* and *agents* endowed with *personal norms*. We define them in next sections.

2.1 Organisation definition

Following the framework proposed in [1], our work focuses on a particular type of organised multiagent system - from now on *organisation* - which is endowed with two different organisational mechanisms: *organisational norms* and *roles*, both used to influence agents' behaviour. Taking into account these elements, we formally define an organisation as follows:

Definition 1 *An organisation* $\mathcal{O}$ *is a tuple* $\langle \mathcal{A}g, \mathcal{A}, \mathcal{X}, \phi, x_0, \varphi, \{\mathcal{ON}^{om}, \mathcal{R}^{om}\}\rangle$ *where:*

- $\mathcal{A}g$ is a set of agents participating in the organisation, $|\mathcal{A}g|$ denotes the number of agents;
- $\mathcal{A}$ is a possibly infinite action space that includes all possible actions that can be performed in the system. $\mathcal{A}$ includes an action a_{skip}; the action of doing nothing[3];
- $\mathcal{X}$ is the environmental state space;
- $\phi : \mathcal{X} \times \mathcal{A}^{|\mathcal{A}g|} \times \mathcal{X} \rightarrow [0..1]$ is the transition probability distribution, describing how the system evolves as a result of agents' actions;
- $x_0 \in \mathcal{X}$ stands for the initial state of the system;
- $\varphi : \mathcal{A}g \times \mathcal{X} \times \mathcal{A} \rightarrow \{0, 1\}$ is the agents' capability function describing the actions agents are able to perform in a given state of the environment. $\varphi(ag, x, a) = 1$ means that agent ag is able to perform action a in the state x (0 in other case);
- $\mathcal{ON}^{om}$ is an organisational mechanism based on organisational norms that regulates agents' behaviour;
- $\mathcal{R}^{om}$ stands for an organisational mechanism based on roles that defines the positions agents may enact in the organisation.

The proposed model adopts the view in which an agent's environment is everything that surrounds it, i.e., any existing entity including other agents. Accordingly, when agents perform actions that are executed in the environment, these actions may influence other agents. The model assumes that the organisation evolves at discrete time steps. In each time step, all agents participating in the organisation perform an action and the new state of the system is produced, with certain probability, through the joint actions of all agents. We also assume that agents can select a "skip" action (a_{skip}), which allows for modelling asynchronous behaviours. The agents' capability function defines what actions the agents are able to perform in a given state. It defines the environmental limitations imposed by the own environment (e.g. if there does not exist a hotel in the environment, agents cannot book a room). This environmental limitations could be considered as hard constraints, in the sense that cannot be avoided, i.e. an agent either has the capability to perform an action or not.

2.2 Agents

Agents are considered independent, autonomous software components that are able to perceive observations about their environment and, based on these observations, take actions. This could be a general definition about agents. However in our work we add the concept of *personal norms*. They are individual norms which agents have and apply to situations in which they are involved. Therefore, we formally define an agent as follows:

Definition 2 *An agent $\mathcal{A}g$ is a tuple $\langle \mathcal{S}, \mathcal{O}, g, t, per, \delta, s_0, \mathcal{PN}^{im} \rangle$ where:*

- $\mathcal{S}$ is the infinite set of internal states of the agents;

[3] This action allows for modelling asynchronous behaviours.

- $\mathcal{O}$ is the set of possible observations an agent is able to perceive from the system;
- $g : \mathcal{O} \times \mathcal{S} \rightarrow \mathcal{S}$ is the agent's state transition function;
- $t : \mathcal{S} \rightarrow \mathcal{A}$ is the agent's decision function describing the next action it will choose given an internal state;
- $per : \mathcal{X} \rightarrow \mathcal{O}$ is a perception function assigning an observation to an environmental state;
- $\delta : \mathcal{A} \rightarrow \{0, 1\}$ stands for the agent's capability function which assigns 1 to an action when the agent has the capability to perform it, or 0 in other case;
- s_0 is the agent's initial internal state;
- $\mathcal{PN}^{im}$ stands for a mechanism based on *personal norms* that internally regulates the agent's behaviour.

At each time step, agents perceive an observation from the current environmental state. Agents transit from that observation to a new internal state, and then they will select their next action by using their own decision function taking into account their new internal state. Furthermore, agents regulate their own behaviour according their personal norms (they are described in Section 2.6).

2.3 Roles as Organisational Mechanisms

In order to better describe how roles act as organisational mechanism we need first to formally define a role:

Definition 3 *Let $\mathcal{RI}$ be a set of role identifiers. A role is a pair $\langle r_{id}, \omega \rangle$ where*

- $r_{id} \in \mathcal{RI}$ is the role name;
- $\omega : \mathcal{A} \rightarrow \{0, 1\}$ is a function that represents if the role is suitable to perform an action. The assignment of 0 means the action cannot be performed with the current role.

This definition embraces some different aspects about the role semantics: *i)* holds the sense of being used as a first-order block to build MAS. It does not lose any semantics regarding this issue; *ii)* represents a group of functionalities, since every role will be qualified for the set of possible actions in the system. If the value associated with an action is 0, it means the role cannot be used for doing the specified action; *iii)* the role entails an expected behaviour that the agent enacting it has to fulfil.

As we have pointed out in Def.1 we propose to endow organisations with roles which are defined as an organisational mechanism [1]. Thus, we formally define roles as organisational mechanisms as follows:

Definition 4 *A role-based organisational mechanism $\mathcal{R}^{om}$ is a tuple $\langle \mathcal{R}, can, isPlaying \rangle$ where:*

- $\mathcal{R}$ stands for a set of roles;

– *can* defines if an agent is able to perform an action and it is defined as follows:

$$can : \mathcal{A}g \times \mathcal{R} \rightarrow \begin{cases} 1 \quad if \quad \delta_{ag_i}(a_j) = 1 \wedge \exists r \in \mathcal{R} \mid \omega_r(a_j) = 1 \wedge \gamma(ag_i, x_k, a_j) = 1 \\ 0 \text{ i.o.c.} \end{cases}$$

where

- $ag_i \in \mathcal{A}g$ represents an agent and $a_j \in \mathcal{A}$ is an action;
- $\delta_{ag_i}(a_j)$ stands for the agent's ag_i capability function performing the action a_j (see Def. 2);
- $\gamma(ag_i, x_k, a_j)$ represents the environmental capabality for the agent ag_i to perform action a_j given an environmental state x_k;
- $\omega_r(a_j)$ defines if the role $r \in \mathcal{R}$ is suitable to perform the action a_j (see Def. 3);

– $isPlaying : \mathcal{A}g \times \mathcal{R} \rightarrow \{0, 1\}$ is a function that returns 1 if an agent *can* play a role and is currently playing it and 0 in any other case. This function is necessary in order to determine which roles agents play at any time.

2.4 Agents, Roles and Action Dynamics

As we have introduced before, during the execution of the organisation, agents must select and perform an action at each time step[4] while playing a role. We define this fact as a situation, so then agents will be involved in several situations during a finite time period. Formally, we define a situation as follows:

Definition 5 *A situation $\mathcal{S}$ is a tuple $\langle \mathcal{A}g, \mathcal{R}, \mathcal{A}, T \rangle$ where:*

– $\mathcal{A}g$ is the agent involved in the situation;
– $\mathcal{R}$ is the role which is being playing by the agent $\mathcal{A}g$ in that situation;
– $\mathcal{A}$ stands for the action which is being performed by the agent $\mathcal{A}g$ playing the role $\mathcal{R}$;
– T is the time period in which the situation takes place.

Different types of situations can be defined following the definition above. Situations in which do not exist either a role or an action or even an agent are valid; for instance, a situation in which an agent is performing an action, regardless of the role it is playing at the current time; or an agent playing a role without performing any action; or even a situation can describe the fact that all agents are playing a particular role and are performing a particular action during a time period. Therefore, the components agent, role or action could be empty in a situation as well. In this work, situations are a key concept to deal with norms.

[4] Including the action of doing nothing (a_{skip})

2.5 Organisational Norms as Organisational Mechanisms

Organisational norms regulate agents' behaviour by defining the actions agents are prohibited, permitted or obligated [17] to perform, and the sanctions/rewards to be applied in the case of violations/fulfilments [19]. Hence, organisational norms can be classified as organisational mechanisms, particularly as incentive mechanisms [1], since they can introduce rewards and/or penalties trying to influence agents' behaviour. In this sense, we define organisational norms as an organisational mechanism as follows:

Definition 6 *An organisational mechanism based on organisational norms* $\mathcal{ON}^{om}$ *is a tuple* $\langle \mathcal{ON}, monitor, act \rangle$ *where:*

- $\mathcal{ON}$ stands for a set of organisational norms defined in the organisation;
- $monitor : \mathcal{X} \times \mathcal{ON} \rightarrow \{0, 1\}$ represents a function which is able to monitor the state of an organisation, determining when an organisational norm has been violated (assigning 1) or fulfilled (assigning 0);
- $act : \mathcal{X} \rightarrow \mathcal{A}$ is a function that applies the consequences of the violation or fulfilment of a norm - perceived by the *monitor* function -, so imposing a punishment and/or a reward or nothing (a_{skip}).

On the other hand, we define organisational norms as norms which regulate situations, that is, they regulate when a situation is prohibited, permitted or obligated to perform. Formally we define organisational norms as follows:

Definition 7 *An organisational norm* $\mathcal{ON}_i(Org, \mathcal{S})$ *regulates a situation in an organisation where:*

- Org stands for an organisation and $\mathcal{S}$ is a situation.

Organisational norms entail institutional constraints in the system. They can be seen as a second regulation layer imposed by the organisation. Even if an agent *can* perform an action, it does not mean that the agent should do it. Of course the agent can do the action, but organisational norms should also influence the agent somehow if the selected action is violating one of them. Thus, the agents are firstly constrained by its capability to do actions from a physical perspective (what can I do?) and, secondly, by the organisational norms in the organisation (what should I do?).

2.6 Personal Norms as Individual Mechanisms

These norms regulate the situation in which an agent is involved from an individual point of view. The difference to organisational norms is that the former have a private scope, since organisational norms must be known by all participants in the organisation, whilst personal norms could only be known by the owner. Another important difference between personal and organisational norms is how their violation/fulfilment are dealt. In the case of organisational norms the violation/fulfilment of them may be checked by a third independent party (an *authority*) not involved in the situation which is being violated/fulfiled. Meanwhile, the only entity able to apply a penalty or a reward when a personal norm is violated/fulfiled is the agent that is the owner of the norm. Hence, following Def. 6, the functions *monitor* and *act* should be defined in the agent owner of the personal norm; that is, this agent will be in charge of monitoring and acting when a personal norm is violated or fulfilled. Formally, personal norms are defined as follows:

Definition 8 *A personal norm-based individual mechanism* $\mathcal{PN}^{im}$ *is a tuple* $\langle \mathcal{PN}, monitor, act \rangle$ *where:*

- $\mathcal{PN}$ stands for a set of personal norms defined by an agent;
- $monitor : \mathcal{S} \times \mathcal{PN} \rightarrow \{0, 1\}$ represents a function which is able to monitor the agent's internal state, determining when a personal norm has been violated (assigning 1) or fulfilled (assigning 0);
- $act : \mathcal{S} \rightarrow \mathcal{A}$ is a function that selects an action in order to impose a reward and/or a punishment, when the *monitor* function determines if a personal norm has been violated/fulfilled in an agent's internal state.

Therefore, we formally define personal norms as follows:

Definition 9 *A personal norm* $\mathcal{PN}(\mathcal{A}g, \mathcal{S})$ *is defined by an agent and regulates a situation in which the agent is involved:*

- $\mathcal{A}g$ stands for the agent, which is the owner of the personal norm;
- $\mathcal{S}$ is the situation regulated by the personal norm.

These norms represent the preferences of an agent related to a situation. Thus, a personal norm describes what should happen in the situation that is regulated by the norm, from the point of view of the agent that defines the norm. Since personal norms are related to agent's preferences they are related to the agent's utility function as well. Then we could say that personal norms somehow tune agent's utility assessment. Organisational and personal norms are related; on the one hand, they may regulate the same situation and; on the other hand, they are defined using the same ontology, shared by all agents participating in the organisation.

3 Reputation Model

In this section we propose a reputation mechanism based on organisations, using the concepts put forward before. Reputation mechanisms are well-known techniques to keep agents from unexpected behaviour (i.e. norm violations) since they provide agents with relevant information about the trustworthiness of others. Most of the reputation systems use quantitative values (opinions) to indicate the reputation of agents [12]. However, such information is not sufficient to understand the behaviour of the agents since such values are subjective, i.e. the same norm violation or fulfilment can be differently evaluated by two different agents. The subjective opinion of each agent about the same third party behaviour could entail the problem of interpreting the meaning of the agent reputation. In order to tackle this issue, we propose a reputation model that not only takes into account a numerical value as the opinion an agent provides about a third party behaviour, but also the set of norms that the latter has violated or fulfilled and the facts associated with them as a justification of the former's evaluation. This could be viewed as a single-step argumentation about how an agent evaluates the opinion about others.

Thus, agents may perform a reputation request to other agents at any time. A *reputation request* is related to a situation, i.e., an agent may request the reputation of another agent playing a role and performing a particular action along a time period. Hence, we formalise a *reputation request* as follows:

Definition 10 *A reputation request $\mathcal{R}^{req}_{\mathcal{A}g_1 \rightarrow \mathcal{A}g_2}$ is a request performed by an agent $\mathcal{A}g_1$ to another agent $\mathcal{A}g_2$ about the reputation of agent $\mathcal{A}g$ in a particular situation, $\mathcal{R}^{req}_{\mathcal{A}g_1 \rightarrow \mathcal{A}g_2}(\langle \mathcal{A}g, \mathcal{R}, \mathcal{A}, T \rangle)$ where:*

- $\mathcal{A}g_1$ is the agent which is requesting the reputation request;
- $\mathcal{A}g_2$ stands for the agent which receives the reputation request;
- $\mathcal{A}g$ represents the third party which agent $\mathcal{A}g_1$ wants to know about;
- $\mathcal{R}$ is the role which has been played by the agent $\mathcal{A}g$;
- $\mathcal{A}$ stands for the action which is performed by the agent $\mathcal{A}g$;
- T represents the time period in which the situation has taken place.

When an agent receives a *reputation request* it may reply with the reputation value it has assigned to the agent participating in that situation. So far, this is the common way to use a reputation mechanisms. However, we propose reply with a subjective value which indicates the reputation of a third party, as well as the organisational norms which were violated by the agent, the facts which produced the violation of those norms and how many times the agent violated them. Hence, we define a reply to a *reputation request* as follows:

Definition 11 *A reply to a reputation request $\mathcal{R}^{reply}_{\mathcal{A}g_2 \rightarrow \mathcal{A}g_1}$ is a tuple $\langle \mathcal{S}, RepVal, \mathcal{ON}, \mathcal{F}, r \rangle$ which represents the message sent by agent $\mathcal{A}g_2$ to agent $\mathcal{A}g_1$ as a reply to a reputation request, where:*

- $\mathcal{S}$ stands for the situation related to the reputation request;
- $RepVal \in [0..1]$ is the reputation value that agent $\mathcal{A}g_2$ sent to agent $\mathcal{A}g_1$ about the agent which is involved in the situation;
- $\mathcal{ON}$ is the set of organisational norms which were violated by the agent involved in the situation;
- $\mathcal{F}$ stands for the set of facts that violated the organisational norms;
- r represents the number of repetitions that the agent involved in the situation violated the organisational norms.

In this point, agents could evaluate a third party only with the reputation gathered by all the *reputation requests* asked to different agents. In addition, our model proposes the possibility of asking about the personal norms that the requested agent has in relation to the same situation. Allowing agents to ask about personal norms that other agents have is important to find affinity with other participants or even to build different profiles which allow agents "better" partner selections. Hence, an agent may ask for personal norms about a particular situation to another agent. It is formalised as follows:

Definition 12 *A personal norms request* $\mathcal{PN}^{req}_{\mathcal{A}g_1 \rightarrow \mathcal{A}g_2}$ *is a request performed by an agent* $\mathcal{A}g_1$ *to another agent* $\mathcal{A}g_2$ *about the personal norms that agent* $\mathcal{A}g_2$ *has related to a particular situation,* $\mathcal{PN}^{req}_{\mathcal{A}g_1 \rightarrow \mathcal{A}g_2}(\langle \mathcal{A}g, \mathcal{R}, \mathcal{A}, T \rangle)$ *where:*

- $\mathcal{A}g_1$ is the agent which is requesting the personal norms request;
- $\mathcal{A}g_2$ stands for the agent which receives the personal norms request - the owner of the personal norm;
- $\mathcal{A}g, \mathcal{R}, \mathcal{A}, T$ are already defined.

Agents, as autonomous entities, may or may not reply with their personal norms. If they decide to reply to a personal norms request, they will send a set of personal norms they have related to the situation asked. They can send all the personal norms related to the situation or only a subset of them, this is a decision they have to make. Thus, we can formalise a reply to a personal norms request as follows:

Definition 13 *A reply to a personal norms request* $\mathcal{PN}^{reply}_{\mathcal{A}g_2 \rightarrow \mathcal{A}g_1}$ *is a tuple* $\langle \mathcal{S}, \mathcal{PN}, \mathcal{F}, r \rangle$ *sent by the agent* $\mathcal{A}g_2$ *to agent* $\mathcal{A}g_1$ *informing about its personal norms related to a situation where:*

- $\mathcal{S}$ is the situation about the personal norms request was asked;
- $\mathcal{PN}$ stands for a set of personal norms;
- $\mathcal{F}$ stands for the set of facts which violated the personal norms;
- r represents the number of repetitions that the agents involved in the situation violated the personal norms.

4 Supply Chains Overview

A supply chain is the link among a company, its suppliers and its customers [2]. Most of the companies involved in a supply chain are both customers (that select supplies to buy goods) and suppliers (that sell their finished goods to customers) [4]. The two main processes of a supply chain are: the supply chain formation and the supply chain management. On one hand, the supply chain formation is the problem of deciding who will supply what, who will do what and who will buy what. On the other hand, the supply chain management concerns the coordination among the different operations across the supply chain [6].

In this paper we focus on a bottom-up scenario of the supply chain formation. In the bottom-up scenario, there is not a principal enterprise in charge of the formation (what is the case of the top-down scenario) but every supply chain partner is able to contribute to the formation of the supply chain by using its knowledge about the partners [20]. In this scenario, the selection of participants is made on the fly and not defined a-priori.

With the aim to contribute to the formation of stable supply chains and to the establishment of strong relationships, the use of trust and reputation have been encouraged [2, 3, 13]. Reputation reflects an aggregation value incorporating multiple factor: quality of the product, quality of the service provided, reliability of financial transaction, etc. [8].

5 Supply Chains as Organisations

As we pointed out in sections 1 we claim that supply chains can be modelled as organisational multiagent systems, where agents represents stake-holders in the supply chain and organisational abstractions, such as roles or norms may significantly help agents to easily form a stable supply chain in terms of reliability and profitability. On the other hand, market rules will be represented by organisational norms, those norms shared and accepted for any actor - any agent - in the supply chain, whilst roles represent different functionalities and capacities that different agents have in order to perform different actions. Using both concepts (norms and roles), an organisational flavour endows supply chains with a larger capacity for their participants to reason about others and then better decide what to do next.

In this section we formally define a supply chain using the concepts and properties presented in section 2. We consider the following as the common model that any type of supply chain should fulfil.

Definition 14 *A supply chain* $\mathcal{SC}$ *is a tuple* $\langle \mathcal{A}g, \mathcal{A}, \mathcal{X}, \phi, x_0, \varphi, \{\mathcal{ON}^{om}, \mathcal{R}^{om}\}\rangle$ *where:*

– In the literature we can find different minimum sets of roles involved in a supply chain flow. We adhere the definition of roles participating in any supply chain presented in [6]:

$$\mathcal{RI} = \{Provider, Manufacturer, Purchaser, Carrier, Customer\}^5.$$

– Similarly to roles, we can also distinguish a common set of possible actions $\mathcal{A}$ available in any supply chain. We propose the following:

$$\mathcal{A} = \{Sell, Buy, Transform, Store, Transport\}$$

Other actions could be considered, such as: *PlaceOrder*, *AcceptOrder* or *Manufacture_Good*. Nevertheless, the first two actions could be deemed as part of the process of selling and buying, so they are decompositions of the actions contained in the former set, while the third one is an specialisation of *Transform* action.

[5] For the sake of simplicity this represents only the set of role names described in Section 2.3

– In our definition of organisation there is an organisational mechanism based on organisational norms which is composed of a set of organisational norms. We claim that some of these norms are not case dependent, but they are common for any type of supply chain - they all are applicable for the same domain. Thus we could consider the set $\mathcal{ON} = \mathcal{ON}^d \cup \mathcal{ON}^c$ as an union of the norms present in an organisational domain, such as, in this case, supply chain domain ($\mathcal{ON}^d$), and those norms that are case-dependent ($\mathcal{ON}^c$), such as specific cases of supply chains (i.e. car manufacturing supply chains).
  An example of norms in $\mathcal{ON}^d$ are:
  - $\mathcal{ON}_1$: *A Provider cannot deliver an order after the delivery deadline.*
  - $\mathcal{ON}_2$: *A Provider cannot deliver less quantity of a good than the one that was ordered.*
  - $\mathcal{ON}_3$: *A Customer cannot pay less to a Provider than the price fixed in the order.*

  Examples of case-dependent norms - those in the set $\mathcal{ON}^c$- can be examined in section 6.

6 Case Study: A Computer Assembly Supply Chain

In this work we have focused on a particular type of supply chain, which represents the computer industry, as illustrated in figure 1. It is usually called *computer assembly supply chain* [14] – from now on *CASC*. Following the approach presented in section 5, we formalise this kind of supply chain as a particular organisation of multiagent system, as follows:

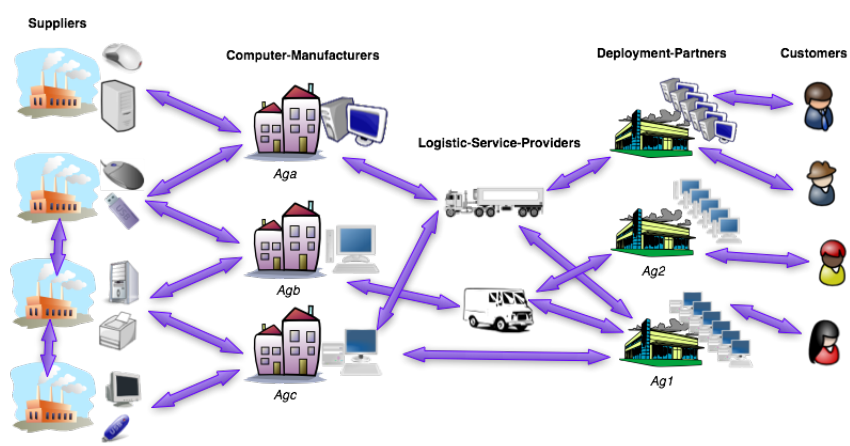

Fig. 1. An example of computer assembly supply chain

Definition 15 *A* CASC *is an organisation defined by the tuple* $\langle \mathcal{A}g, \mathcal{A}, \mathcal{X}, \phi, x_0, \varphi, \{\mathcal{ON}^{om}, \mathcal{R}^{om}\}\rangle$*, where:*

– the set of roles in $\mathcal{R}^{om}$ is the following:

$$\mathcal{RI} = \{ \textit{ supplier}, \textit{ computer-manufacturer}, \textit{ logistic-service-provider}, \textit{ deployment-partner}, \textit{ customer } \}$$

Agents playing role *supplier* are able to supply the products needed to assembly a computer while *computer-manufacturers* are able to perform the assembly of the computers. The *logistic-service-providers* transport the product from different centres and the *deployment-partners* are able to prepare the orders made by the customers. *Customers* can be corporate customers, market stores, small customers, etc. By computer we mean consumer PCs, professional PCs, servers and notebooks.

– the set of *actions* is composed of:

$$\mathcal{A} = \{\textit{Supply-Components}, \textit{ Assembly-Computer}, \textit{ Transport-Products}, \textit{ Prepare-Order}, \textit{ Buy-Computer } \}^6$$

– the set of *organisational norms* in $\mathcal{ON}^{om}$ is composed of the norms shared by all agents, representing the rules of the CASC. Examples of those norms are:
  - $\mathcal{ON}_1$: *"the number of controller cards may not exceed the number of extension slots of the system board"*
  - $\mathcal{ON}_2$: *"the processor type must be compliant with the system board"*
  - $\mathcal{ON}_3$: *"if the computer has not got a PS2 port and the mouse is USB, it will have an adaptor USB to PS2"*

In order to illustrates how the reputation model proposed in section 3 works in an example of a CASC, consider the CASC exemplified in the table below. Let us put ourselves in the place of the agent $\mathcal{A}g_1$ that is playing the role *deployment-partner (d-p)*. In order to form the supply chain $\mathcal{A}g_1$ has to select at least one *computer-manufacturer (c-m)* to be able to perform the action *prepare-order*[7]. Imagine that the agent has not interact with any *computer-manufacturers* in the system yet. Therefore, the agent decides to use the reputation mechanism to select one of them:

[6] The action *supply-components* includes external units (printers, monitors, ..), accessories (keyboard, mouse, ..), software, etc. The action *assembly-computer* can be divided in *assembly-system-board* and *assembly-system-unit*. The action *transport-products* means transporting any kind of products.

[7] This action includes to place an order to a *computer-manufacturer*. The computer being ordered will be then transported by a *logistic-service-provider*

Org. CASC-1		
Organisational Norms		
$\mathcal{ON}_1$, $\mathcal{ON}_2$ and $\mathcal{ON}_3$		
Participants		
Agents	Role	Personal Norms
$\mathcal{A}g_1$	*deployment-partner (d-p)*	$\mathcal{PN}_{1-1}$: *"the number of empty extension slots must not be greater than one"* $\mathcal{PN}_{1-2}$: *"if the computer has not got a PS2 port and the mouse is USB, it will have an adaptor USB to PS2 and PS2 to USB"*
$\mathcal{A}g_2$	*deployment-partner (d-p)*	$\mathcal{PN}_{2-1}$: *"the number of empty extension slots must be zero"*
$\mathcal{A}g_a$	*computer-manufacturer (c-m)*	$\mathcal{PN}_{a-1}$: ...
$\mathcal{A}g_b$	*computer-manufacturer (c-m)*	$\mathcal{PN}_{b-1}$: ...

1. $\mathcal{R}^{req}_{\mathcal{A}g_1 \rightarrow \mathcal{A}g_2}(\langle \mathcal{A}g_a, \textit{c-m}, \textit{prepare-order}, [0 - now] \rangle)$: agent $\mathcal{A}g_1$ performs a reputation request to agent $\mathcal{A}g_2$ asking about the situation in which the agent $\mathcal{A}g_a$ has been involved playing the role *c-m* (computer-manufacturer) and performing the action *prepare-order* along the time period $[0 - now]$.
2. $\mathcal{R}^{reply}_{\mathcal{A}g_2 \rightarrow \mathcal{A}g_1} = (\langle \mathcal{A}g_a, \textit{c-m}, \textit{prepare-order}, [0 - now] \rangle, 0.2, \mathcal{ON}_2, \mathcal{F}_1, 2)$: agent $\mathcal{A}g_2$ replies to agent $\mathcal{A}g_1$ informing that the agent $\mathcal{A}g_a$, in the situation explained before, has a reputation of 0.2 from his point of view. It also informs that such reputation is due to two violations of the organisational norm $\mathcal{ON}_2$ by the fact $\mathcal{F}_1$. Agent $\mathcal{A}g_1$ knows that such fact describes that agent $\mathcal{A}g_a$ prepared a computer with the wrong processor.
3. Due to the low reputation value, agent $\mathcal{A}g_1$ decides to ask to $\mathcal{A}g_2$ the reputation of agent $\mathcal{A}g_b$, another *computer-manufacture*.
4. $\mathcal{R}^{req}_{\mathcal{A}g_1 \rightarrow \mathcal{A}g_2}(\langle \mathcal{A}g_b, \textit{c-m}, \textit{prepare-order}, [0 - now] \rangle)$: the agent $\mathcal{A}g_1$ performs a new reputation request to agent $\mathcal{A}g_2$ looking for the reputation of agent $\mathcal{A}g_b$.
5. $\mathcal{R}^{reply}_{\mathcal{A}g_2 \rightarrow \mathcal{A}g_1} = (\langle \mathcal{A}g_b, \textit{c-m}, \textit{prepare-order}, [0 - now] \rangle, 0.3, \_, \_, 0)$: agent $\mathcal{A}g_2$ replies to agent $\mathcal{A}g_1$ about the reputation of the agent $\mathcal{A}g_b$ in the specified situation. Although, the agent has not violated any organisational norm, the reputation of agent $\mathcal{A}g_b$ is low, 0.3.
6. Agent $\mathcal{A}g_1$ knows that such a low reputation must be due to the violation of at least one *personal norm* defined by agent $\mathcal{A}g_2$. Thus, $\mathcal{A}g_1$ decides to perform a *personal norms request* to agent $\mathcal{A}g_2$ in order to try to understand the reasons for such a low reputation.
7. $\mathcal{PN}^{req}_{\mathcal{A}g_1 \rightarrow \mathcal{A}g_2}(\langle \mathcal{A}g_b, \textit{c-m}, \textit{prepare-order}, [0 - now] \rangle)$: agent $\mathcal{A}g_1$ sends a personal norms request to agent $\mathcal{A}g_2$ asking about its personal norms which regulates the situation in which the agent $\mathcal{A}g_b$ has been involved playing the role *computer-manufacturer* and performing the action *prepare-order*.
8. Once agent $\mathcal{A}g_2$ receives the request, it may decide whether it answers or not. Suppose that the agent decides to answer with a *reply to a personal norms request*.

9. $\mathcal{R}^{reply}_{\mathcal{A}g_2 \rightarrow \mathcal{A}g_1} = (\langle \mathcal{A}g_b, \textit{c-m}, \textit{prepare-order}, [0-now] \rangle, \mathcal{PN}_{2-1}, \mathcal{F}_{2-1}, 3)$: the agent $\mathcal{A}g_2$ sends the reply to agent $\mathcal{A}g_1$ informing about the personal norms which regulates the situation requested ($\mathcal{PN}_{2-1}$) and the number of times they have been violated (3 times) by agent $\mathcal{A}g_b$.
10. When agent $\mathcal{A}g_1$ receives the reply it realises that: *i)* the low reputation is due to a violation of a personal norm ($\mathcal{PN}_{2-1}$); *ii)* $\mathcal{PN}_{2-1}$ is a more restricted norm than ($\mathcal{PN}_{1-1}$), its own personal norm; and *iii)* there exists some kind of affinity between them; thus, agent $\mathcal{A}g_2$ might be a potential "good" reputation source for agent $\mathcal{A}g_1$ for future partner selections.

7 Related Work

Although there are several studies [2, 3, 13] that demonstrate that trust and reputation contribute significantly to the formation of stable supply chains, there are several authors that have not considered trust/reputation while proposing their supply chain formation models, mechanism and protocols, such as [9, 5, 7].

In [4] the authors investigate the impact of reputation on supply chains. They demonstrate that a weighting of the agent's decision to choose a supplier in favour of the reputation component at the expense of the price component leads to the formation of stable supply chains that increase the tendency of monopoly formation. An important drawback of their analysis is that they focus on the individual dimension of reputation occurring in direct interactions between two agents. They have not considered that individuals can change information about the reputation of others.

A prototype for an agent-based electronic marketplace using reputations was proposed in [11]. In this prototype agents are able to evaluate the behaviour of others, store the reputations and distribute them to others. The two main disadvantages of this approach are: *i)* it is not clear how the agents evaluate the reputations of others, i.e., it is not clear what influence the reputation of an agent; and *ii)* the information that is distributed among agents is only a reputation value, no other information is communicated about agents' past behaviour.

The paper presented in [15] proposes a decentralised negotiation protocol based on trust for a supply chain environment. One important advantage of such an approach is the use of an incentive compatible mechanisms to avoid exploitation by competitors, i.e., it is able to deal, for instance, with the unwillingness of actors to reveal sensitive but (in terms of system optimisation) valuable information. The main drawback of this approach is that the trust accounting mechanism used in this model does not employ a composed reputation index using, for example, indirect reputation like most MAS reputation applications do. The authors claim that this is not necessary due to the equilibrium property of the system introduced by the negotiation process. On the other hand, the use of indirect trust would help identify regularly cheating agents earlier at the risk of further increasing information flow and negotiation effort.

8 Conclusions

In this paper we propose *i)* an organisational model based on roles and (organisational and personal) norms to define supply chains; and *ii)* a reputation mechanism to help on the supply chain formation. We stimulate the use of reputations to support on the selection of the supply chain participants. In order to do so, supply chains are viewed as organisations and the enterprises as agents playing roles in the organisations. We assume that the enterprises are able to evaluate the behaviour of others by considering the organisational and personal norms that they fulfil and violate, to store such evaluation as reputations and to provide the reputations when requested. Thus, while forming a new supply chain, we stimulate the use of the available reputations to help on the selection of the new partners. It is important to state that there are several works [2, 3, 13] that affirm that trust and reputation contribute significantly to the formation of suitable partners and of stable supply chains.

We are in the process of implementing a simulator to validate our approach. By using the simulator we will be able to evaluate the real benefits that come from the availability of enterprises reputations in the supply chain formation. As future work we also intend to apply our approach in other supply chain domains to demonstrate that our approach is domain-independent. In addition, we plan to extend the reputation mechanism to contemplate an hybrid model. The approach presented in this paper uses a decentralised model. There is not any centralised entity able to store and provide reputations but are the agents themselves that evaluate the behaviour of others, store and provide the reputations. As stated in [12], a hybrid reputation model seems to be the most adequate approach.

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