An Adaptive Configuration for Agent-based Supply Network

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Abstract

A supply network is comprised of multiple heterogeneous subsystems gathered in a dynamic coalition to collaboratively provide an outcome. For a supply network to be effective in an open and competitive environment, it has to be scalable. An adaptive reconfiguration strategy is needed in order to respond effectively to the market changes, by dynamically creating and maintaining supply network's organization. This paper presents a new taxonomy of configuration methods based on the agents' social interaction, a brief critique of each method, and finally suggests an adaptive configuration strategy. The proposed strategy uses a combination of these methods by selecting the right interaction method that is suitable for each market situation.

1. Introduction

The *Reconfigurable Virtual Supply Network* (RVSN) is a "rapidly configured multi-disciplinary network of small, process-specific firms configured to meet a window of opportunity to design and produce a specific product" [18]. For a RVSN to be re-configurable, business entities need an interaction method to harmonize their goals with RVSN's goal. Several earlier literature reviews have been conducted on the aspects of Supply Network (SN) configuration [12, 22, 23].However no survey has been introduced classifying agent SN configuration on the basis of their social interaction. The paper is organized as follows: Section 2 provides some detailed statements on SN configuration, and motivation for modelling with Multi Agent System (MAS). In Section 3 we present our taxonomy of multi agent configuration methods based on social interactions (auction bidding, contracting, and negotiation), and we provide a critical discussion about each form based on the attributes of agents' interactions. In Section 4 we present our adaptive configuration strategy for supply network based on MAS. This strategy uses a combination of interaction methods based on characteristics of each method provided in the critical discussion. Finally, concluding remarks and a discussion about the future work are given in Section 5.

2. Overview

2.1. Supply Network Configuration Issues

From a structural point of view, The RVSN life cycle has three phases: Initial configuration, Operational reconfiguration, and Dissolution. During initial configuration, the virtual entrepreneur finds a business opportunity through the virtual consumers' market represented by the consumers' vector (see 1), and wants to outsource "out-of-core" needs via the internet.

$$[Customers]_{1xk}[BusinessUnits]_{mxn} \quad (1)$$

RVSN is represented by a constellation matrix in 1, where the row's elements represent vertical integration and the column's elements represent horizontal integration. As a result of outsourcing,the SN Business-process-plan starts to decompose and the candidate SN becomes highly complex. SN's capacity utilization changes as its role changes from agility to leanness during the Product Life Cycle (PLC) phases (Introduction, Growth, Maturity, and Decline) [17]. Moreover, RVSN has a lifespan that is limited by PLC. Due to SN's re-configuration needs, the constellation matrix's size is always changing as a result of its varying organizational structure. In order to solve configuration problems, a higher level of harmonization among its partners is needed.Harmonization is concerned with the creation of a harmonious distributed decision making network across the entire SN. Therefore, the fundamental challenge for RVSN is to achieve behavioral Harmonization between members through their interactions, in spite of multiple ownerships, in order to achieve a common global goal.

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2.2. Adaptive configuration for agent-based Supply Network

the MASs include a number of heterogeneous agents working independently and in a cooperative and interactive manner to solve problems in a decentralized environment. Therefore the distributed problem-solving paradigm in an SN's resources allocation is consistent with the principle of the MASs. The RVSN has a global goal which is to be achieved by a set of activities, which are performed by a set of roles. The agents that fill these roles are the members of the RVSN and are selected on the basis of how well they will meet the requirement for those roles. MASs are able to capture an SN hierarchical organization, as each subsystem can be represented by an autonomous agent. Also it has the advantage of being able to be easily re-configured when the SN structure is needed to be re-organized. the MASs facilitate the integration of the entire SN as a networked system of independent echelons, each of which utilizes its own decision-making procedure. The question here is which interaction method to utilize for harmonization of agents' behavior along the SN life cycle. Our taxonomy suggests that the harmonization between the nodes of an SN can be leveraged through three main interaction methods: (auction bidding, contracting, and negotiation).

3. Configuration and Interaction Taxonomy

3.1. Auction bidding

The problems of the SN system, referred to as tasks, are decomposed into sub-problems, or subtasks, for candidate agents to make a bid to complete the tasks or subtasks. Auctions provide some advantages for Agent-based RVSN resources allocation. Auction specifies a correlation between the prices and the quantities of the resources that the agent offers to demand or supply, and agents make their own decision about how to bid based on the prices and their own utilities of the goods. Auction restricts the interaction variables to the price and the quantity, and have minimal communication overheads. Since auction is limited by the exchange of bids to auctions, agents need not interact directly with other agents. An open auction allows the agent to review his offers, and if the auction is public, to refine them by analyzing the offers of other participants and by considering the auction's evolution. A bidding strategy may thus be adapted according to the market's rules. The auction results in a mutually acceptable solution for both the supplier and the buyer while the market's forces alone decide on the auction's termination. Interaction is distributive since markets are naturally distributed, and the market's price systems constitute an effective decentralization of decision making. The main drawbacks of the auction bidding are: outsourcing decision is based solely on pricing where other criteria are not traded off with price, and only one bidder is selected in the outcome.For more details on how auctions are used in forming an SN see [1, 24, 10, 28].

3.2. Contracting

The SN's contract is a set of clauses that offer suitable information and incentive mechanism to guarantee that all the agents in the SN act in harmony with the global objective. the SN's optimal performance can be achieved by specifying a contractual mechanism that consists of parameterized rewards relating to the agent's action (e.g. quantity, price, quality, and time), and the consequences of risk they face with respect to demand, supply or internal process. A contract is said to coordinate the SN, if the set of SN optimal actions is Nash equilibrium (i.e. no agent has profitable unilateral deviation from the set of SN optimal actions). Ideally the optimal actions should also be a unique Nash equilibrium, otherwise the agents may coordinate on a sub-optimal set of actions [6]. Decentralized plan execution by contracting is designed to extend the applicability of the agent's interaction, where quality and lead time affect the cost and feasibility of the products, and where monitoring the performance of task execution is an essential part of the process. Contracts are most effective when complete information is available and all future contingencies can be accounted for. Interaction is simple since agent negotiation space is limited to specific items in the contract. Interaction is stable since agent has no incentive to deviate from agreed upon strategy. The main drawback of contracting is the impossibility of designing a contract that includes all contingencies. For more details on how contracts are used in forming an SN see [9, 7, 5, 25, 16].

3.3. Negotiation and Argumentation

Negotiation is the process of exchanging contradictory demands between participant agents in order to search for new alternatives, reconcile their differences, produce a settlement, and move toward agreement as much as possible. Negotiation is likely to result in a positive outcome only if the value the buyer places on outsourcing the task to his supplier is at least as large as the value the supplier places on performing the task for the buyer. The difference between the values of the buyer and the seller is referred to as the bargaining's surplus. The goal of each negotiation party is to capture as much of barraging's surplus as possible. The key to a successful negotiation mechanism is to have a well defined utility function about the "out of-core-competence" task to be outsourced, to have a good estimate on the suppliers' utility function, bargain's surplus, and to fairly dis-

tribute the bargain's surplus based on the need and the contribution of each party. A multi-dimensional negotiation is required in order to create a win-win situation. However, real-life negotiations between human participants are richer and more complex than the mere exchange of quantitative offers and counter-offers. Participants request information from each other, collectively seek common information, try to persuade each other of contested propositions, and advance arguments for their own benefits and against those of others. This richness has been recognized by the use of argumentation in MAS [20, 21], not only may agents present offers in a negotiation, but also the reasons for the offers, any qualifications of/and conditions on their offers, and reactions to them [4, 3]. Negotiation processes between autonomous agents are costly in terms of communication and computation overheads [2]. If there is no efficient way to negotiate, the negotiating overhead will become a bottleneck which will reduce the efficiency of the agent especially when the environment is dynamic. Therefore in order to achieve efficiency in this domain, agents must have an efficient way to select the right negotiation models, related negotiation strategies, and negotiating partners. A multi-linked negotiation problem occurs when an agent needs to negotiate multiple, related negotiation issues with other agents about different subjects,and the negotiation over one subject has influence on negotiations over other subjects. An agent's lack of complete knowledge about another agent's state makes the result of negotiation uncertain. Consequently, the difficulty in evaluating a commitment, makes it harder to find a local solution that contributes effectively to a good global solution. In Addition, dealing with this negotiation independently and concurrently while ignoring their interactions will not lead to finding a combined feasible solution that satisfies all constraints without re-negotiation over already "settled" issues. Dealing sequentially with negotiation one at a time and basing later negotiation on the result of earlier negotiation will take up valuable time and therefore reduce time available for solving the problem. This leads to reducing potential solution space, especially when the negotiation deadlines are taken into consideration. For more details on how negotiation is used in forming an SN see [14, 8, 27, 11, 13, 15, 19, 26].

3.4. Adaptive Configuration Strategy

The main goal of RVSN adaptive configuration is to respond to changes in the market's environment by changing its organization structure in order to harmonize its structural phases with PLC Figure 1.

According to our taxonomy and the critical discussion, there is no preferred interaction method suitable for all market situations. Agents should achieve adaptive configuration by selecting the right interaction method that is suitable for each economic situation. In order to demonstrate the adaptive strategy the following scenario presented: an agent that needs outsourcing pre-qualifies suppliers' agents on the basis of their past experience with those agents, or on the basis of a trust mechanism between agents. A series of double auction bidding with the predetermined contract's criteria is propagated through pre-qualified supplier agents in order to form the primary SN. If the product or service is feasible to generate, a series of bilateral contracts is then instantiated to get concession on the contracts' criteria. Otherwise, some Contracts' constraints are relaxed and the bidding is repeated. Once the series of contract reaches a concession the main process plan and performance measures are synthesized and the RVSN is ready to satisfy the customers' orders. During the product growth, maturing and saturation stages the above mechanism is repeated in order to outsource new agents. Negotiation is performed only when bidding and contracting mechanisms fail to form an SN, and when reconfiguration of an SN is needed to meet a market's uncertainty.

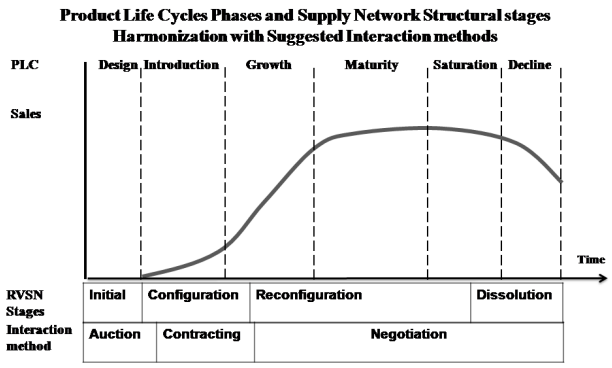

Figure 1. Harmonizing PLC with RVSN stages

4. Conclusion

This paper gives an overview of SN definition,then explains how an SN is configured and outlines the necessity of harmonization for configuration. We introduced a new taxonomy of interaction for agent based SN's configuration on the basis of social interactions, which comprised of auction's bidding, contracting, and negotiation. We provided a critical discussion for each method. We recommend an adaptive strategy approach for an SN dynamic configuration based on agents. This strategy is based on a combination of approaches furnished in the taxonomy on the basis of its at-

tributes. Further work is needed by simulation in order to provide a clear indication of the benefits of such a strategy in terms of effectiveness and efficiency.

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