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A new fuzzy negotiation protocol for grid resource allocation

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ABSTRACT

In real-life trading, relaxing decisions in the face of trading pressure is common. Similarly, in market-based grid resource allocation problem designing negotiator agents with the flexibility to relax their decision to (quickly) complete a deal in the face of intense Grid Market Pressure (GMP) is essential. To make this idea possible, we design Enhanced Market- and Behavior-driven Negotiation Agents (EMBDNAs) that adopt new fuzzy negotiation protocol. The protocol focuses on both (1) enhancing *Rubinstein's sequential alternating offer* protocol to handle multiple trading opportunities and market competition and (2) designing two new Fuzzy Grid Market Pressure Determination Systems (FGMPDSs) for both grid resource consumers and grid resource owners to guide negotiator agents in relaxing their bargaining terms under intense GMP to enhance their chance of successfully acquiring/leasing out resources. Implementing the idea in an agent-based testbed, an experiment for evaluating and comparing EMBDNA against EMDA (Enhanced Market-Driven Agent) and our previous work in name MBDNA (Market- and Behavior-driven Negotiation Agent) were carried out through stochastic simulations. While EMDA relaxes its bargaining term in the face of intense GMP by considering just two relaxation factors the MBDNA uses the same negotiation strategy as EMBDNA but does not relax its bargaining term in the face of intense GMP. The results show that adopting the new fuzzy negotiation protocol, EMBDNAs outperform MBDNAs and EMDAs.

1. Introduction

Grid computing is emerging as the foundation upon which virtual organizations can be built. Such organizations are becoming of increasing importance for tackling various projects, both in academic and in business fields (Arafah et al., 2007). As the computational grid focuses on large-scale resource sharing, and because *Grid Resource Owners* (*GROs*) and *Grid Resource Consumers* (*GRCs*) may have different goals, preferences and policies, which are characterized and specified through a *utility model* (or *utility function*), an efficient resource management, is central to its operations. The term resource management refers to the operations used to control how capabilities provided by grid resources and services are made available to other entities, whether users, applications, or services. Utilization of grid resource is not for free (Xing and Lan, 2009), which means that the GROs charge GRCs according to the amount of resource they consume, so adapting some of the successful ideas of economical models to resource allocation in large-scale computing systems is essential for realizing the vision of grid computing environments (Bai et al., 2008). One of the solutions for grid resource management is usage of market based methods (Izakian et al., 2010). A market method which has received much attention in recent years is the overall algorithmic structure within which a market mechanism or principle is embedded (Tucker and Berman, 1996).

Numerous economic models (Buyya et al., 2002), including microeconomic and macroeconomic principles for resource management, are proposed in literature (Buyya, 2002; Huhns and Stephens, 2000; Lai et al., 2005; Chunlin et al., 2009; Rahwan et al., 2007; Aminul et al., 2011). As negotiation-like protocol is found to be suitable when the participants cooperate to create the value of objects (Kersten et al., 2000), adopting negotiation mechanism for successfully reconciling the differences between GROs and GRCs seems to be more

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Table 1
Notation and basic terms used in the negotiation utility subsection of this paper (alphabetic sort).

Symbol	Basic definition	Symbol	Basic definition
A_child_k	k'th instance of negotiator *A*	$no.\ competitor_t^A$	Number of negotiator *A*'s competitors at round t
B_k	k'th trading partner of negotiator *A*	$no.trading\_partner_t^A$	Number of negotiator *A*'s trading partners at round t
GRC	Grid Resource Consumer	$P_t^{A\_child_k}$	A_child_k's proposal at round *t*
GRCA	Grid Resource Consumer Agent	$P_t^{B_k}$	Proposal of B_k at round *t*
GRC_EMBDNA	Grid resource consumer of type EMBDNA	$P_t^{consensus}$	The consensus price
$GRC\_job\_prof_p^i$	GRC_i's p'th job characteristics	RP_A	Reserve Price of *A*
GRNM	Grid Resource Negotiation Market	t	Negotiation round
GRO	Grid Resource Owner	$t_{deadline}^A$	*A*'s deadline (e.g., a time frame by which *A* needs negotiation result)
GROA	Grid Resource Owner Agent	u_{min}	The amount that is considered to distinguish the utilities between deals and no deals
GRO_EMBDNA	Grid resource owner of type EMBDNA	$U_t^{A\_child_k}[P_t^{A\_child_k} \rightarrow B_k]$	Utility of A_child_k's at round t if its proposal is accepted by B_k
$GRO\_resource\_prof_r^j$	GRO_j's r'th resource characteristics	$U_t^{A\_child_k}[P_{t-1}^{B_k} \rightarrow A\_child_k]$	Utility that is generated for A_child_k by accepting the opponent's proposal $P_{t-1}^{B_k}$
IP_A	Initial Price of negotiator *A*		

prudent rather than using other commonly referenced works (e.g., see (Wolski et al., 2001; Wolski et al., 2003; Buyya and Vazhkudai, 2001)). Also Sim Sim (2010) pointed out the principal motivations for considering negotiation mechanisms among GROs and GRCs. Like most of the commonly previous works in providing grid resource management solutions (e.g., see (Rahwan et al., 2007; Srinivas and Varadhan, 2011; Pastore, 2008; Foster et al., 2005)), this approach provides negotiation mechanism for optimizing GROs' and GRCs' profit through providing software components (*Agent*).

Although there are many agent-based approaches for grid resource allocation via negotiation mechanism, the strategies of some of these agents are mostly static and may not necessarily be the most appropriate for changing in *Grid Resource Negotiation Market* (*GRNM*) situations. It means that this type of agents (i.e., fixed strategy negotiation agents) relax their bids (offers) at constant rate and do not properly address trading pressure in GRNM. From now we name the trading pressure of GRNM as *Grid Market Pressure* (*GMP*). The *GMP* is inspired from the concept of stock market pressure (Bhojraj and Libby, 2005) and is defined as a variable that captures the acceptability of the current grid resource negotiation market conditions. Obviously, the GMP arises from trade imbalances and local condition of each market participant. Previous empirical results in Sim and Wong (2001) show that in general, more flexible negotiation agents (e.g., Sim and Wong, 2001; Faratin et al., 1998; Sim, 2002; Sim and Choi, 2003)) that relax their bids in face of GMP outperform fixed strategy negotiation agents in many situations. Most of the existing flexible negotiation agents (of which there are very few) are not sufficiently flexible (as they do not take into consideration all (or most number of) suitable relaxation criteria in the face of intense GMP). For instance, the only two relaxed-criteria of both GRCs and GROs in Sim and Wang (2004) are eagerness and degree of competition, while the only two relaxed-criteria of GRCs and two relaxed-criteria of GROs in Sim and Ng (2007) are recent statistics in GRC's failing/succeeding in acquiring resources and GRC's demand for computing resources, and the amount of the GRO's resource(s) that is currently being used and recent requests from GRCs for resources respectively. Also even though agents in Kowalczyk and Bui (2000) are designed with the flexibility to relax trading conditions such as preferences, priorities and objectives, they were not designed to react to changing market situations such as competition and opportunities. It can be understood that considering more suitable relaxation criteria in determining the GMP's value can increase the chance of negotiation agents in making agreement with their opponents. This motivating consideration provides the impetus for designing flexible negotiation agents that not only focus put on applying near-optimal negotiation strategies but also devising a *new* negotiation protocol in name *EAlternating offer protocol* that model more new relaxation criteria from new perspective to optimize the negotiators' utilities, enhance the success rate and speed of negotiation (measured in number of rounds needed to reach an agreement) in the face of intense GMP. The proposed negotiation protocol focuses on augmenting the alternating offers protocol by designing two new fuzzy decision controllers (i.e., one modeling GRC's criteria, and one modeling GRO's criteria) for determining the amount of relaxation in a negotiation situation.

In summary, the distinguishing features of this work are that:

1) Present an extended approach for determining GMP value (by consulting sets of fuzzy rules) to provide negotiation agents with more accurate GMP value (i.e., degree of relaxation).
2) Devise *EAlternating offer* protocol (i.e., enhancement of *Rubinstein's sequential alternating offer* protocol which is proposed in Rubinstein (1982), Sim and Ng (2007) to handle multiple trading opportunities and market competition, overcome non-reasonable behavior of negotiation agents and relax bargaining criteria of negotiation agents (based on the value of GMP) and
3) Design new *Enhanced Market- and Behavior-driven Negotiation Agents* (*EMBDNAs*) by augmenting the MBDNAs (Market- and Behavior-driven Negotiation Agents that do not adopt the proposed fuzzy negotiation model) (Adabi et al., 2013) with the proposed negotiation protocol.

The remainder of the paper is structured as follows: Section 2 describes the proposed negotiation model of EMBDNAs that includes utility function of negotiator agents, near-optimal negotiation strategies and *EAlternating offer* protocol. The experimental results to study the performance of EMBDNAs are given in Section 3. Finally, the state-of-the-art flexible negotiation agents for grid resource management and conclusions are given in Section 4 and Section 5 respectively.