A Regression-based Coordination for Concurrent Negotiation

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Abstract

Given that resource providers and consumers may have different requirements and performance goals, concurrent negotiation is considered in this work to successfully obtain commitments with multiple resource providers for consumers in Grid. This work devises a concurrent negotiation mechanism for Grid consumers to acquire multiple resources in which both consumers and providers can renege on contracts. The novel contribution of this work is devising a concurrent mechanism that coordinates multiple one-to-many concurrent negotiations using a regression-based coordination strategy. Empirical results show that the regression-based coordination strategy is stable for different number of required resources and outperformed existing coordination strategies in terms of utility in different kinds of resource market.

1. Introduction

Supporting resource co-allocation (i.e., allocating to an application multiple resources, which may belong to different resource owners) is essential for a Grid resource management system because (i) computationally intensive applications may require more resources than a single computing machine can provide in one administrative domain [1, p.1], and (ii) an application may require several types of computing capabilities from resource providers in other administrative domains. Sim [2] argued that software agents, in particular e-negotiation agents, can play an essential role in realizing the Grid vision. Though applying bargaining to Grid resources allocation has drawn much attentions, very few works (e.g., [1][3]) considered negotiation for Grid resource co-allocation.

This work devises a concurrent negotiation mechanism for consumers to acquire multiple resources in a Grid environment. A leveled commitment contracts [4] (where renegoting from the contract is allowed for both provider and consumer agents during the negotiation) is adopted during the concurrent negotiation for the reasons that (i) if a consumer cannot acquire all its required resources before deadline, it can release those resources acquired, so that providers can assign them to other consumers, and (ii) it allows an agent that has already reached an intermediate deal for a resource to continue to search for a better deal before the termination of the whole concurrent negotiation. Additionally, for Grid resource co-allocation, there may be multiple resource providers providing a specific kind of resource and, a consumer may require multiple resources simultaneously. Resource selection by concurrent negotiation would also involve coordinating multiple one-to-many concurrent negotiations and ensuring that the consumer can successfully obtain all required resources simultaneously. Hence, the challenges of applying concurrent negotiation to Grid resource co-allocation problem in this work include (i) coordinates multiple one-to-many concurrent negotiations between a consumer and multiple resource providers, and (ii) manages (de-)commitment for consumer in each one-to-many negotiation [5] in which both consumers and providers can renegotiate on a contract.

2. A concurrent G-negotiation mechanism

In this work, the Grid resource co-allocation problem for n kinds of resources is transformed into a problem of n concurrent one-to-many negotiations where each one-to-many negotiation is a concurrent multiple one-to-one negotiation for a particular kind of resource $R_i$, $1 \leq i \leq n$. Using this mechanism, a consumer negotiates simultaneously with multiple providers that supply possibly different types of resources. Denote $\{O_i|1 \leq j \leq n\}$ the set of $n_i$ providers that provide resource $R_i$, $1 \leq i \leq n$. Each consumer has $n$ resources to acquire and a hard deadline $\tau$ for acquiring all $n$ resources. Both an agent’s preference for a resource and the strategy that it adopts during the negotiation are private information.
The negotiation mechanism consists of two components: a \textit{coordinator module} and \(n\) commitment managers (CMs, \(1 \leq i \leq n\)). The coordinator is used to determine when to terminate all one-to-many negotiation processes based on the information obtained from each CM so that the consumer’s requirements and/or performance goals could be satisfied (section 3).

Each CM manages a concurrent one-to-many negotiation threads for a particular resource, where each negotiation thread (a bilateral negotiation between the consumer and one of providers) follows Rubinstein’s \textit{sequential alternating protocol}. Since both consumer and provider agents can renegotie on an intermediate contract during negotiation, commitment management strategies are devised for each CM to decide (i) whether or not to accept a resource provider’s proposal and (ii) when to renegotie on a commitment at each negotiation round (details can be found in [6]). In this work, a consumer adopts three classes of commitment management strategies [6] (CMS): \{Linear-CMS, Conciliatory-CMS, and Conservative-CMS\} to manage (de-)commitment.

\section{Coordination strategy}

The coordinator is used to determine when to terminate all one-to-many negotiation processes based on the information obtained from each commitment manager component so that the consumer’s requirements and/or performance goals could be satisfied. In the Grid resource co-allocation problem, two factors are essential for a consumer: (i) successfully obtaining all required resources and, (ii) obtaining the cheapest possible resource options. Since the failure of a one-to-many negotiation for any particular resource will result in the failure of the co-allocation for the consumer, ensuring a high negotiation success rate is the most important. In this section, a regression-based coordination strategy is designed to coordinate concurrent multiple one-to-many negotiations.

At negotiation round \(t\), once a resource provider’s proposal is acceptable for a consumer (the proposal falls into the \textit{agreement zone} of the consumer, i.e., \([IP_{o}, RP_{i}]\)), it will be placed into an acceptable list for that resource by the consumer. If any acceptable list is empty, the coordinator cannot complete the co-allocation; otherwise, the coordinator can terminate all one-to-many negotiations based on its prediction of utility change of the coming rounds. At any round \(t\), if there is no intermediate contract in the sub-negotiation for resource \(R_{i}\), the commitment manager in this sub-negotiation will predict all resource providers’ possible proposals in a specific future negotiation round \(t'\), \((t < t' < \tau)\), and then calculate the predicted change in utility \(\Delta U^i_{t'}\) by taking the difference between the average predicted utility of all providers at the coming round \(t'\) (i.e., \(\text{avg} \left\{ U^i_{\text{exp}}(P^i(t')) \right\} \)) and the average utility of those provider at current round \(t\) (i.e., \(\text{avg} \left\{ U^i(P^i(t)) \right\} \)). Hence, the predicted change in utility will be calculated as follows:

\[
\Delta U^i_{t'} = \text{avg} \left\{ U^i_{\text{exp}}(P^i(t')) \right\}_{1 \leq j \leq n} - \text{avg} \left\{ U^i(P^i(t)) \right\}_{1 \leq j \leq n}
\]

where \(U^i_{\text{exp}}(P^i(t'))\) is the utility of the predicted proposal of negotiation round \(t'\) from resource provider \(O^i_{t}\) (more details are shown in section 3.1). For the concurrent negotiation in this work, the round \(t'\) is dynamically set to be \((\tau - t)/2\), i.e., the middle of the current negotiation round \(t\) and the consumer’s deadline. This is because if the round \(t'\) is long after the current round \(t\), the prediction accuracy can not guaranteed since the current market situation can not accurately reflect situations at round \(t'\) when the market changing over time, however, if \(t'\) is very close to the current round \(t\), many future events may be missed considering by the consumer for the situations of negotiation rounds after \(t'\) are not predicted.

Otherwise, if an intermediate contract has been established between the consumer and the owner \(O^i_{t}\) in the sub-negotiation at round \(t_{ik}\), then at current round \(t\), the commitment manager calculates \(\Delta U^i_{t'}\) by the possible utility loss at the following rounds:

\[
\Delta U^i_{t'} = U^i(\text{Avg}(P(t))) - U^i(P^i(t_{ik})).
\]

This is explained as follows. If the resource owner \(O^i_{t}\) does not renegotie from the intermediate contract then the consumer obtains a utility of \(U^i(P^i(t_{ik}))\). Otherwise, if \(O^i_{t}\) renegoties from the intermediate contract, the consumer will have to choose among the proposal set \(P(t) = \{P^i(t) | 0 < j \leq n\}\) the consumer received at current round \(t\) and obtain a utility of \(U^i(\text{Avg}(P(t)))\). This is because there are potentially many consumers competing for the same resource \(R_{i}\), if \(O^i_{t}\) does renegotie from the intermediate contract, the consumer cannot guarantee to secure another contract with another resource provider of \(R_{i}\) that would guarantee maximum utility. Instead, it is more plausible that the consumer expect to obtain an average utility of \(U^i(\text{Avg}(P^i(t)))\). Hence, the consumer’s possible change in utility resulting from \(O^i_{t}\) renegotie on an intermediate contract is \(U^i(\text{Avg}(P(t))) - U^i(P^i(t_{ik}))\).
Each $CM_i$ submits $\Delta U_i$ to the coordinator. The coordinator then calculates $\Delta U_i = \sum w_i \Delta U_i^j$ where $w_i$ is the weight of resource $R_i$ of the consumer. In the current stage of this work, it is assumed that $w_i$ is the same for all $R_i$. Future enhancements of this work will adopt possibly different values of $w_i$ for different $R_i$ to model the different importance or scarcity of different resources. If $\Delta U_i < 0$, it seems likely that the consumer may possibly lose some utility in the coming round(s).

Hence, the coordinator informs the commitment manager of each sub-negotiation that has not yet received proposals from provider of resource. At each negotiation round, the consumer agent will receive proposals from providers of resource $R_i$. Let $\{P_j(0), \ldots, P_j(t)\}$ be the proposal set the consumer received from $O_j$ at current round. To predict next proposal of provider $O_j$ at round $t$, a model consisting of a constant and a linear trend about negotiation rounds is assumed for the proposal set of $O_j$, i.e.,

$$P_j(t) = \alpha + \beta t + \epsilon_j$$

where $\alpha$ and $\beta$ are the unknown parameters to be estimated from the historical proposals the consumer received from corresponding provider $O_j$, while $\epsilon_j$ is the error term. Hence, the prediction function about $O_j$’s proposal at round $t$ can be estimated as

$$\hat{P}_j(t) = \hat{\alpha} + \hat{\beta} \cdot t$$

Since the negotiation environment may change over time, the provider’s recent proposals will reflect current negotiation situation more accurately than its previous proposals. Thus, the parameters of $\alpha$ and $\beta$ at round $t$ are computed by the proposal at round $t$ and its previous $m-1$ proposals, i.e., $\{P_j(t-m+1), \ldots, P_j(t)\}$. Using these $m$ proposals, the linear equation that minimizes the sum of squared error estimates for the given received proposal set, i.e.,

$$\min \sum_{k=t-m+1}^{t} \left[ P_j(k) - (\hat{\alpha} + \hat{\beta} \cdot k) \right]^2$$

Let $S_i = \sum_{k=t-m+1}^{t} k \cdot P_j(k) \cdot S_D = \sum_{k=t-m+1}^{t} k^2$ and $S_{ID} = \sum_{k=t-m+1}^{t} k \cdot P_j(k)$, then, $\hat{\alpha}$ and $\hat{\beta}$ can be estimated as follows,

$$\hat{\alpha} = \frac{S_{ID} - S_{D} \cdot S_U}{m S_U - (S_U)^2}$$
$$\hat{\beta} = \frac{m S_{ID} - S_{D} \cdot S_U}{m S_U - (S_U)^2}$$

After predicting the proposal $\hat{P}_j(t') = \hat{\alpha} + \hat{\beta} \cdot t'$ of negotiation round $t'$ from provider $O_j$, the predicted utility of next proposal can be computed by

$$U_j^i(P_j(t')) = U_j^i(\hat{P}_j(t'))$$

### 4. Simulations and experimental results

To evaluate the effectiveness of the regression-based prediction approach for coordinating the concurrent negotiations in section 3, a series of experiments were carried out.

1) **Objectives and Motivations:** The objective of these experiments is to compare the performances of regression-based coordination strategy with the utility oriented coordination (UOC) strategy in [9] and patient coordination strategy (PCS) in [8] to coordinate concurrent negotiations under three kinds of Grid resource markets (i.e., favorable market, balanced market and unfavorable market). For each kind of market, appropriate CMS is used to manage (de-)commitments, for instance, in favorable (respectively, balanced and unfavorable) market, the Conservative-CMS (respectively, Linear-CMS and Conciliatory-CMS) is tested for reaching highest final utility in previous version of this work.

2) **Experimental Settings:** The variables of these experiments are set as follows.

a) **Initial price and reserve price:** Without loss of generality, the initial price and reserve price are set to guarantee the existence of intersections between agreement zones (domain between initial and reserve price) of consumers and that of each resource provider.
b) **Deadline**: The deadlines for each resource provider and consumer are uniformly generated from the time region [30, 80].

c) **Negotiation strategy**: All provider agents in this experiment make their proposals using time-dependent strategies [7]. Different providers have different time preference $\lambda$ which is chosen from [0.1, 10].

d) **Market type**: To simulate the complex real Grid environment, for each resource $R_i$, the number of resource provider ($N_{R_i}^n$) is first generated from a region [5, 15] (this is restricted by the computational capacity of the computer used for the experiments). Then, the number of consumer is generated from the region $[2N_{Ri}^n/3, 3N_{Ri}^n/2]$ such that the ratio between the number of consumers and the number of resource providers is in the region $[2/3, 3/2]$. A market is said to be balanced market if each resource $R_i$, $(1 \leq i \leq n)$ is set in this way. Otherwise, if the ratio of number of consumers and the number of resource providers is less than 2/3 or greater than 2, the corresponding market is called favorable market or unfavorable market.

3) **Performance Measure**: In the experiments, (i) the utility of the final co-allocation results and (ii) success rate of acquiring all required resources are used as performance measures, defined as follows:

a) The utility of the consumer ($U_c$) is calculated by the following formula in the experiment:

$$U_c = \begin{cases} \frac{1}{N} \sum_{i=1}^{N} (U'_i - \Gamma') , & \text{if getting all resources} \\ 0, & \text{otherwise} \end{cases}$$

where $U'_i = \frac{RP_i - P}{RP_i - MIN_{i}}$ is the utility of the consumer from a contract, (in which $MIN_{i}$ is the minimum reserve price of all resource providers of resource $R_i$, $P$ is the price of the contract), and $\Gamma'$ is the total penalty that the consumer should pay. Each experiment consists of 1000 runs, and the final utility is averaged.

b) The **success rate** is defined as the ratio of the successful negotiations over the total 1000 runs.

4) **Results and observations**: Empirical results are shown in Figs. 1-3. Fig. 2 shows the performances (final utility and success rate respectively) of the entire concurrent negotiation mechanism by three kinds of coordination strategies in the balanced market, where different number of resources the consumer required is evaluated. The performances results of favorable and unfavorable markets are shown in Fig. 1 and Fig. 3.

It can be observed that, using the regression-based coordination approach and the UOC strategy in [9], the consumer achieves very high success rate (close to 1) in all three kinds of resource markets (Figs. 1-3). Moreover, these two kinds of coordination strategies are more stable, i.e., the consumer obtained (almost) similar utility and success rate for different number of required resources. However, using the patient coordination strategy, the performance deteriorated with the number of resources. This is because the regression-based approach and the UOC strategy in [9] appropriately estimate the negotiation situation for each kind of resource during the negotiation. Then, based on these estimations, the coordinator decides when to terminate the whole negotiation.

It can also be observed that, for each kind of markets, the coordination approach in this work obtains higher final utility than the other two kinds of coordination strategies (i.e., UOC strategy and PCS). This is because, by the regression-based coordination strategy, the consumer could use arbitrary $\lambda$ ($\lambda<5$ in this work) historical proposals of each provider to predict the future negotiation situations for each required resource (the UOC strategy only uses two historical proposals of each provider). Moreover, to support the decision of the coordinator, this work predicts the negotiation situation of future negotiation round $t'$ ($=\tau/t/2$) at round $t$. However, the UOC strategy only predicted the situation of next negotiation round of $t$, which may cause the consumer to ignore considering many future events (i.e., the proposals after the negotiation round $t$).

5. **Conclusions**

The contribution of this work is devising a concurrent negotiation mechanism (section 2) and a regression-based coordination strategy (section 3) for managing multiple concurrent negotiations. The novelty and significance of this work is that it is among one of the earliest works (to the best of the authors’ knowledge) that consider a concurrent negotiation mechanism for Grid resource co-allocation. Empirical results show that the regression-based coordination strategy is stable for different number of required resources and outperformed existing coordination strategies in terms of utility in different kinds of resource market.

**References**


