Dynamic Collaborative Cloud Service Platform: Opportunities and Challenges

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This letter presents a model for a dynamic collaboration (DC) platform among cloud providers (CPs) that prevents adverse business impacts, cloud vendor lock-in and violation of service level agreements with consumers, and also offers collaborative cloud services to consumers. We consider two major challenges. The first challenge is to find an appropriate market model in order to enable the DC platform. The second is to select suitable collaborative partners to provide services. We propose a novel combinatorial auction-based cloud market model that enables a DC platform among CPs. We also propose a new promising multi-objective optimization model to quantitatively evaluate the partners. Simulation experiments were conducted to verify both of the proposed models.

Keywords: Dynamic collaboration, combinatorial auction market, cloud computing, partner selection, multi-objective optimization.

I. Introduction

The proprietary nature of existing cloud providers (CPs) restricts consumers to simultaneously use multiple or collaborative cloud services. That is, interoperability and scalability are two major challenging issues for cloud computing. Forming a dynamic collaboration (DC) [1] platform among CPs can create business opportunities for them to address these issues. In a DC platform, each CP can share its own local resources/services with other partner CPs, and each CP can also maximize its profit by offering existing service capabilities to collaborative partners so they may create a new value-added collaborative service by mashing up existing services. These capabilities can be made available and tradable through a service catalog for easy mash-up to support new innovations and applications.

However, there are two major challenges involved. The first is to create an appropriate cloud market model that can commercialize the DC platform. The second challenge is to minimize the large number of conflicts (or disagreements) that may occur in a market-oriented DC platform when negotiating among providers. One reason for these conflicts is that each provider must agree with the services contributed by other providers against a set of its own policies in a DC [2]. Another reason is due to the inclusion of high collaboration costs by the providers with their bidding prices. Examples of these costs include network establishment, information transmission, and capital flow. The reason for these costs is that providers do not know with whom they will need to collaborate after winning an auction.

In this letter, we discuss these two major challenges to forming a DC platform among CPs and present candidate solutions for them. To the best of our knowledge, this is the first paper that has reported on the formation of a market-oriented DC platform among CPs in providing single or collaborative cloud services to consumers.

II. Proposed Combinatorial Auction-Based Cloud Market Model

The formation of a DC is initiated by a primary CP (pCP) that realizes a good business opportunity by forming a virtual

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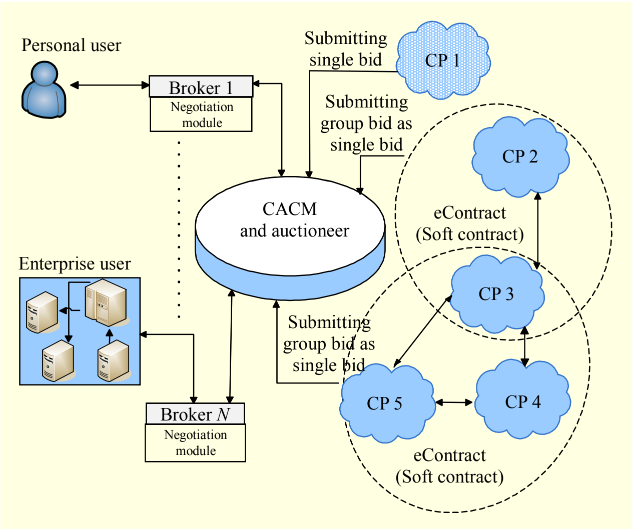

Fig. 1. Proposed CACM model to enable a DC platform among CPs.

organization (VO)-based DC platform with other collaborator CPs for providing a set of services to various consumers. Users interact transparently with the DC platform by requesting services through a service catalog of the pCP. The requested service requirements (single, multiple, or collaborative cloud services) are served either directly by the pCP or by any collaborating CPs within a DC.

The proposed combinatorial auction-based cloud market (CACM) model to enable this DC platform among CPs is shown in Fig. 1. The existing auction policy of the CA is modified in the CACM model to address the issue of conflict minimization among providers in a DC platform. The CACM model allows any CP to dynamically collaborate with appropriate partner CPs to form groups. It also allows for publication of their group bids as a single bid to completely fulfill the consumer service requirements while supporting the other CPs to submit bids separately for a partial set of services. This new approach can create more opportunities to win auctions for the group since collaboration costs, negotiation time, and conflicts among CPs can be minimized. As shown in Fig. 1, the main participants in the CACM model are brokers, users/consumers, cloud service providers, and auctioneers. We use the auction scheme based on [3] to address the CACM model.

III. Model of CP Partner Selection for pCP

Finding a good combination of CP partners required for making groups and reducing conflicts is a complex problem that has been considered to be NP-hard. Also, the partner selection problem (PSP) for CPs in the CACM model is different from other PSP problems in areas like manufacturing, supply chains, or virtual enterprise due to the inherent multiparty nature of the negotiation in DC. Since every CP has to review the contract and agree with the resources/services contributed by every other CP, there can be a large number of conflicts (or disagreements) among participating CPs. Existing methods of using individual information (INI) to select partners cannot be applied directly to solve the PSP problem of CPs. We propose that past collaborative relationship information (PRI) between partners needs to be considered. In fact, the success of past relationships between participating CPs may reduce uncertainty and conflicts, shorten the adaptation duration/negotiation time, and help with performance promotion. We propose a multi-objective (MO) optimization model of quantitatively evaluating partners using their INI and PRI. All of this information can be obtained from each CP's website, from the market, and also from consumer feedback about their services. The parameters for MO partner selection are defined as follows:

- ϕ_{rj} is the price of CP r for providing service j independently.
- Q_{rj} is the quality value for service j of CP r. Qualitative information can be expressed by the assessment values from 1 to 10 (1= very bad, 10 = very good).
- $W_{rj,xi}$ is the value of past collaboration experience, that is, the number of times collaboratively winning an auction, between provider r for service j and provider x for service i, where $r, x = 1, \cdots, m$ and $i, j = 1, \cdots, n,\ i \neq j$.
- $U = \{U_{rj} \mid r = 1, \cdots, m,\ j = 1, \cdots, n\}$ is a decision vector of the partner selection.

To solve the partner selection problem of a pCP using the INI and PRI, an MO optimization model can be expressed mathematically as

$$\text{minimize Obj\_1 (Price)} = \sum_{j=1}^{n}\sum_{r=1}^{m}\phi_{rj}U_{rj}, \tag{1}$$

$$\text{maximize Obj\_2 (Quality)} = \sum_{j=1}^{n}\sum_{r=1}^{m}Q_{rj}U_{rj}, \text{ and} \tag{2}$$

$$\text{maximize Obj\_3 (PR Performance)} = \sum_{\substack{i,j=1 \\ i\neq j}}^{n}\sum_{r,x=1}^{m}W_{rj,xi}U_{rj}U_{xi}, \tag{3}$$

subject to

$$U_{rj} = \begin{cases} 1 & \text{if choose } P_{rj}, \\ 0 & \text{otherwise,} \end{cases} \quad \& \quad U_{rj}U_{xi} = \begin{cases} 1 & \text{if choose } P_{rj} \text{ and } P_{xi}, \\ 0 & \text{otherwise.} \end{cases}$$

To solve the above model, an MO genetic algorithm (MOGA) that uses INI and PRI, called MOGA-IC, is developed. In order to find an appropriate diversity-preservation mechanism in selection operators to enhance the yield of Pareto optimal solutions during optimization, we utilize two popular MOGAs to develop MOGA-IC, the non-dominated sorting genetic algorithm (NSGA-II) and the strength Pareto evolutionary genetic algorithm (SPEA2) [4], [5]. Natural number encoding is adopted to represent the chromosome of an individual. A chromosome of an individual is an ordered list of CPs. Let $y=[y_1, y_2,\cdots,y_j,\cdots,y_n]$, $j=1, 2,\cdots, n$, and y_j be a gene of the chromosome, with its value between 1 and m (for service j, there are m CPs for a response). If m=50 and n=5, there may be 10 CPs that can provide each service j. Thus, a total of 10^5 possible solutions are available. In this way, the initial populations are generated. A two-point crossover is employed, and in the case of a mutation, one provider is randomly changed for any service.

IV. Simulation Results

Table 1 shows simulation runtimes of both MOGA-IC with NSGA-II and MOGA-IC with SPEA2 for three simulation examples where R is collaborative service requirements, m is providers, G is genetic generations, N is population size, Pc is crossover probability, and Pm is mutation probability. We can see from Table 1 that MOGA-IC with NSGA-II runs much faster than does MOGA-IC with SPEA2. The reason for this behavior is the time consumption in the truncation approach. The time consumption of NSGA-II truncation approach (crowding distance) is much lower than that of SPEA2 (nearest neighbor).

It can be seen from Fig. 2 that SPEA2 initially finds better solutions more quickly than NSGA-II, but in the end cannot provide the best solutions. SPEA2 yields Pareto fronts with wider spans, while NSGA-II distributes solutions in a more focused manner. Thus, we find that NSGA-II is the appropriate algorithm to develop MOGA-IC. Figure 3 shows a performance comparison of MOGA-IC with the existing MOGA-I algorithm, which only considers INI for partner selection. MOGA-I was also implemented with NSGA-II. The pCP uses both MOGA-IC and MOGA-I algorithms to make groups and joins various auctions in the CACM model. In our simulation, 1000 auctions were generated for different R. We can see from Fig. 3 that using the MOGA-IC approach, pCP

Table 1. Simulation runtimes of three examples with MOGA-IC parameters.

Simulation examples	m	R	N	G	Pc	Pm	Runtime (ms)	
							NSGA-II	SPEA2
1	35	5	50	20	0.9	0.1	16.823	25.036
2	100	5	100	50	0.9	0.1	123.60	261.80
3	100	5	100	100	0.9	0.1	298.83	450.01

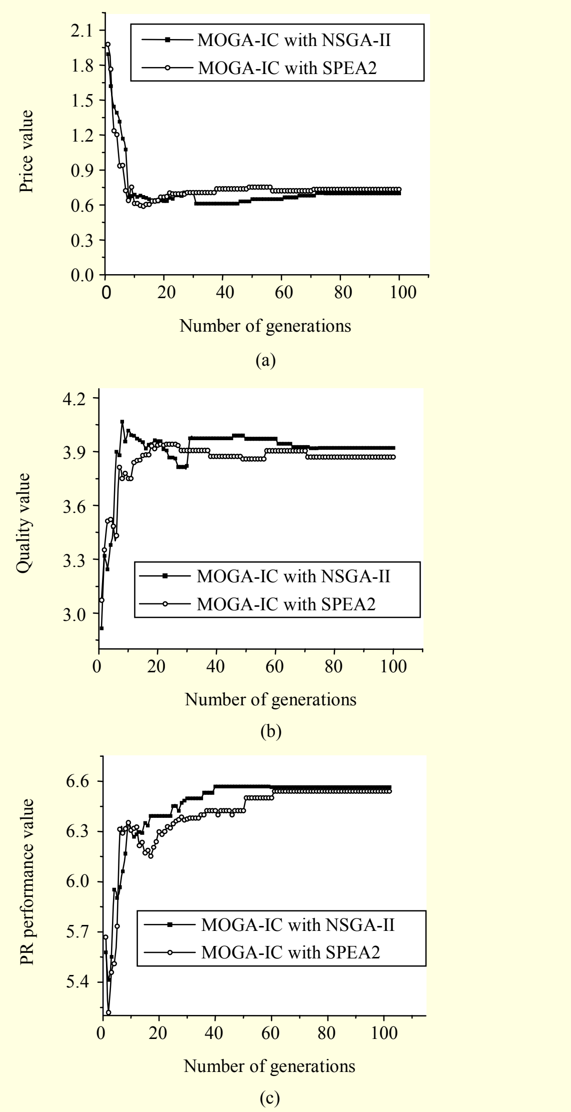

Fig. 2. Average optimized values of different objective functions in the first front of MOGA-IC with NSGA-II and SPEA2 for 100 generations.

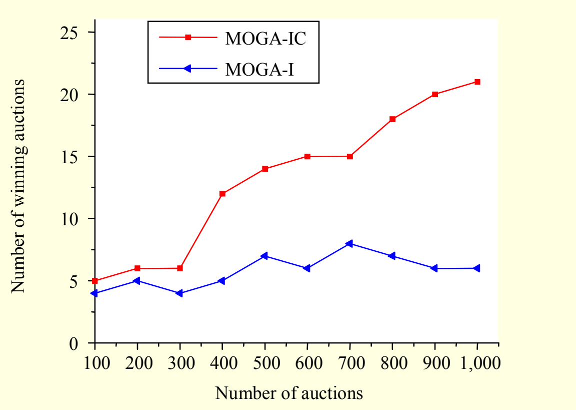

Fig. 3. Comparison of MOGA-IC with MOGA-I in terms of winning auctions.

wins more auctions in comparison to the MOGA-I approach.

V. Conclusion

This letter presents a novel CA-based cloud market model that enables a DC platform among CPs. A new MO optimization model of partner selection using the individual and past collaborative information is also presented. An effective MOGA called MOGA-IC with NSGA-II is then developed to solve the model. In comparison with the existing MOGA-I approach, MOGA-IC with NSGA-II shows better performance results in partner selection among CPs in the CACM model.

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