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A fair multi-attribute combinatorial double auction model for resource allocation in cloud computing

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ABSTRACT

Recently, Cloud computing has emerged as a market where computing related resources are treated as a utility and are priced. There is a big competition among the Cloud service providers and therefore, the providers offer the services strategically. Auction, a market based resource allocation strategy, has received the attention among the Cloud researchers recently. The auction principal of resource allocation is based on demand and supply. This work proposes a multi-attribute combinatorial double auction for the allocation of Cloud resources, which not only considers the price but other quality of service parameters also. Auctioneer extends some of the parameters to the offered bids from the bidders in order to provide fairness and robustness. In case of not meeting the assured quality, a penalty is imposed on the provider and customer is compensated. The reputation of the provider also diminishes in the forthcoming rounds. Performance study of the proposed model is done by simulation which reflects the usefulness of the method.

1. Introduction

Cloud computing is becoming most popular IT service delivery model recently and is still evolving. NIST defines five essential characteristics of Cloud computing as: resource on-demand, elasticity, resource pooling, broad network access and measured service (Mell and Grance, 2009). These characteristics have made the Cloud very popular. Various other computing technologies, evolved over the years, do constitute the Cloud computing. This includes virtualization, distributed computing, utility computing, service-oriented architecture, networking, storage etc.

Cloud computing is basically a business model which offers a plethora of pricing schemes for its variety of services in order to attract its customers. Economy based resource allocation mechanisms have been well pursued in different scenario of resource allocation in distributed computing (AuYoung et al., 2004; Stahl and Whinston, 1994), grid computing (Buyya, 2002; Buyya et al., 2002; Mills and Dabrowski, 2008) and Cloud computing (Xu et al., 2011; Buyya et al., 2009). Fixed pricing, bargaining, auction and distributive justice are some famous economic approaches for pricing and allocation of resources.

Static pricing schemes have been widely used for the allocation and pricing of the resources because of its simplicity in the nascent stage of Cloud. A drawback in static pricing is that the prices of the computing resources cannot be increased or decreased for under and over-utilization of the resources respectively. This encouraged the service providers to offer the dynamic pricing schemes to its customers. In dynamic pricing, prices of the resources vary and depend on the usability and availability of the resources. It results in the improvement of the resource utilization and revenue both. For example, Amazon EC2 (http://aws.amazon.com/ec2/purchasing-options/spot-instances/) has introduced a Spot market (a real approach of dynamic pricing), where it sells the residual resources on the basis of demand and supply of market after reserved and on-demand resource allocation to the customers. This increases the utilization of the resource and the revenue of the providers. But such dynamism creates difficulties to the providers in deciding the prices of the resources. Also, customers find it difficult in accepting the price decided by the providers with planning of their budget.

Auction is the process that may overcome such difficulties. In auction, prices of the resources are decided by the bidder's (customers) willingness to pay and the provider would not face the uncertainty of the best resource price. Also, in auction, winners praise their winning abilities and losers blame other bidders not the auctioneer for the loss (Suter and Hardesty, 2005). In auction, the price of a resource is determined by the current supply and existing demand at any moment, so it seems to be an appropriate mechanism for the Cloud resources. It is because of this, the concept of auction in Cloud computing is not new. In an auction mechanism, called Spot market introduced by Amazon EC2 (http://aws.amazon.com/ec2/purchasing-options/spot-instances/), if the user's bid price exceeds the spot price (decided by

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the provider on the basis of demand and supply), user gets the spot instances (VMs). Meanwhile, when spot price exceeds customer's bid, resources will be aborted from the current users and the spot prices are re-updated. Though, this seems to be a drawback of the spot pricing, the popularity of the spot pricing in the current Cloud market as well as the amount of research work for pricing and allocation of Cloud resources proves that auction has relatively a greater role to play in the Cloud market.

Auction aims to optimize the payoff of the participants (customers and providers in this case). Providers' payoff is to maximize the revenue in the long run and customers' payoff is to execute the job with least pricing and the expected QoS. In auction, revenue maximization in long run is directly related to the number of bidders in the Cloud market. It has been proved that revenue in case of k bidders is at least as high as in case of $k-1$ bidders (Murillo et al., 2008). Thus, for revenue maximization in the long run, the designer of the auction mechanism should ensure sufficient number of participants in the market. Since auction in Cloud comes under recurrent auction (Lee and Szymanski, 2007) (computing resources are re-allocated once free), a bidder (customer in the case) may leave the auction in two cases: first when a bidder is repeatedly losing because of low bidding and second if bidder is not attaining the required QoS. In the former case, bidders with high bidding remain in the market and may create oligopoly (some powerful bidders control the market and provoke a fall in the resource pricing). The act of bidders leaving in recurrent auction because of dissatisfaction (due to oligopoly) is also called bidder drop problem (Murillo et al., 2012). Inclusion of fairness measures in auction can increase bidders' interest in auction, an approach known as egalitarian social welfare approach. Inclusion of fairness measures attracts more customers in the Cloud market, making it a competitive market and increasing the global performance of the auction system.

Reason for leaving the auction in later case is not meeting the expected QoS. To the authors' best knowledge, most of the current research works related to auction in Cloud propose the auction mechanisms based on price only. It rarely gives emphasis, if customers do not get the required resources based on the desired QoS (e.g. response time). Thus, truthful bidding based on the price only is not a good solution. Therefore, auction mechanism designer should consider various other attributes in auction. Service providers are always encouraged for the truthful bidding though it is quite possible that a provider may give false QoS assurance to win an auction e.g. not meeting the expected response time after allocation of resources to the customers. To avoid such false bidding, a concept of penalty imposition may be introduced.

The proposed work deals with the allocation and the pricing of the resources in Cloud computing and is named fair multi-attribute combinatorial double auction model (FMCDAM). This work is an extension of the work CDARA which uses a double combinatorial auction model proposed by Samimi et al. (2014). It considers a number of attributes such as fairness, reputation etc. and introduces the concept of imposing penalty on the providers making a false QoS assurance in order to win the auction.

The outline of the paper is as follows. After the introduction in Section 1, Section 2 introduces some current related work on Cloud auction. In Section 3, the proposed FMCDAM model is formulated along with a view of cloud market for FMCDAM. The considered multiple attributes in auction or FMCDAM are also briefed in Section 3. Performance of the FMCDAM is evaluated in Section 4 based on the experiments and auction properties. Finally Section 5 makes a discussion on the work in line with the experiments and concludes the work.

2. Related work

Auction, a concept of economics, is very popular for allocation of the resource and pricing in a competitive multi-agent system (Chevaleyre et al., 2006). Different types of available auctions ease its adaptation for various types of situations. In Cloud computing, varied auction mechanisms e.g. single sided auction, double sided auction, first price auction, second price auction etc. are used in different situations for resource allocation and pricing. Spot pricing (http://aws.amazon.com/ec2/purchasing-options/spot-instances/), an auction mechanism proposed by Amazon, is successfully accepted in the current Cloud market and literature (Yi et al., 2012, 2010; Jung et al., 2011). This section lists some recent research works related to Cloud auction.

Alrawahi and Lee (2012) and Shang et al. (2010) give a helpful insight about the framework for Cloud auction market. A framework of multi-attribute combinatorial auction market in Cloud computing is proposed in Alrawahi and Lee (2012) in which it is assumed that the attributes related to the Cloud resources can be quantified to some integer values resulting in final pricing of the resources. Providers may offer the resources individually or in form of a bundle along with the attributes of the resources. The work in Alrawahi and Lee (2012) discusses some matching algorithms that can be used to find a best match of provider and customer. Similar to Alrawahi and Lee (2012), Shang et al. (2010) also propose a Cloud market framework which allocates the resources based on a double auction. Although both these works provide a flexible and competitive framework, no formulation of the problem as well as its implementation and analysis is done in these works.

Second-pricing auction mechanism is proposed in Lin et al. (2010) who use the concept of marginal bid to decide the price of the Cloud resources where marginal bid is the highest bid among all the unsuccessful bids. Thus, in case of large number of users and resources, the model in Lin et al. (2010) overcomes strategic deviation and revenue inferiority defined in Lin et al. (2010).

Zaman and Grosu (2013) used a combinatorial one-to-many auction for pricing and VM allocation and proposed two mechanisms for auction; CA-LP (combinatorial auction-linear programming) and CA-GREEDY (combinatorial auction-Greedy). It compared CA-LP and CA-GREEDY with fixed pricing scheme and observed that the proposed schemes perform better. The drawback of one-to-many auction is the monopoly of one side.

A model called Reverse Batch Making Auction (RBMA) is proposed in Wang et al. (2012). It uses an immune evolutionary algorithm for optimal resource allocation for three evaluation metric; market efficiency, user satisfaction and quality of service. RBMA also used twice-punishment mechanism to punish the malicious bidders based on the historical information of the service quality.

A periodical auction model, based on limited English combinatorial model for allocation of resources to determine the resource prices between providers and users is proposed in Xing-Wei et al. (2012). It aims to allocate the resources optimally using genetic algorithm with the objectives to maximize the profit of the provider and reduction in job execution time in the determination of a winner.

A combinatorial auction, based on one sided auction model, is proposed in Song et al. (2009) in which user submits her requirements and providers submit their offers as bids. The conspicuous feature of this model is that providers use the concept of mutual business relationship and form a group. This group acts as a single bidder. Such collaboration, among the providers in group formation, reduces the conflicts among them. Although Song et al. (2009) consider QoS as an effective parameter in auction, in the problem formulation it did not clearly define that how the QoS is used in a winner determination.

Double auction is widely accepted many-to-many auction that prevents monopoly. It is more efficient than one-to-many auction as in this both sides submit their bids. To form a standard for interoperability, a challenging issue in Cloud, Shang et al. (2010) first proposed a framework for forming global Cloud market and then proposed a knowledge-based continuous double auction (CDA) model that uses