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Research Article

Pricing and Resource Allocation in the Edge Computing Services

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Abstract

A number of studies have recently emerged to address the issue of resource allocation in edge computing environments. However, there are few works considering how to optimize resource allocation while satisfying market's requirements in multiagent technique for distributed allocation of Edge resources in distributed control. This study use trading-based multiagent resource allocation model as an allocation mechanism to optimal allocate resources through genetic algorithm in an Edge computing environment. The proposed model supports the optimal process between Edge computing cases to apply and allows Edge buyers and Edge providers both to derive their own pricing strategies and to analyze the respective impact to their welfare. The k-pricing schemes are adjustly to meet the Edge users/providers requirement and constraints set by composed services.

Keywords: Multiagent; Edge Computing; Resource Allocation

Introduction

Edge computing (EC) has been proposed to complement the cloud to meet the mass traffic demand and accommodate diverse requirements of various services and systems in grid networks. One of the interesting researches that these systems face is the efficient allocation of Edge resources. In Edge environments, resources e.g. pricing, service placement, and resource allocation, can be composed as services, which are offered to other Edge users. Edge service providers have to allocation their resource usage adaptively and be aware of dynamic environment changes of the incoming requests for their services. Therefore, various Edge resource allocation methods are an exciting area of research which have been proposed to address the problem [1]. Some are based on the analogy between the Edge environment and the real market mechanisms. In these market mechanism those methods offer a promising solution [2-4]. In the market trading, Edge service providers are faced with dynamic and unpredictable user behavior. In the dynamic Edge market environment, the way prices are set and the way they are set affects the demand behavior of price-sensitive users [5,6]. Multiagent system (MAS) incorporates the software agents to have preferences over some attributes of the allocation, e.g. trading of Edge service price and allocation of their resources. The trading-based multiagent system also allow for computational and geographical distribution decentralized implementation while providing mechanisms to regulate the behaviors of users.

In this paper we consider the multiagent for trading-based Edge resource allocation, which contain allocation mechanism and pricing mechanism. The Edge resource allocation needs to satisfy the Edge service providers and the users. The pricing mechanism that uses the concept of k-pricing scheme that is iteratively adjusted to find acceptable between a set of demands and a limited supply of Edge resource allocation. Our goal is to devise the trading-based

Edge resource optimal allocation that maximizes the utility across all Edge buyer and Edge service providers (i.e. welfare). Then the following economic requirements can be stated:

1. Trading efficiency: When the trading is economically efficient, it is impossible to increase a participant's welfare without decreasing another participant's welfare; i.e. there is no wasted resource. Maximizing the total welfare is a sufficient condition for economic efficiency. The proposed trading mechanism employs mixed integer programming to strictly maximize the total welfare.
2. Rational bidding: To encourage a fair exchange between Edge resource providers (sellers) and users(buyers), the prices should only depend on the supply demand conditions. The proposed price mechanism is based on the k-pricing scheme [7,8]. Neither the seller nor the buyer has the advantage.

Therefore, the MAS resource allocation in this market environment could be optimal either for the distributed control choosing the allocation. That is, the optimum for properly aggregating the preferences of individual agents in the system (). The rest of the paper is organized as follows. Section 2 deals with system structure related to trading-based multiagent for Edge resource allocation. Simulation experimental results are presented in Section 3 and some conclusions and future works are provided towards the end.

Multiagent for trading-based for Edge resource allocation

The two key roles driving the multiagent for market-based Edge resource allocation system are: Edge Service Providers (ESPs) providing the agents role of sellers or supply and Edge Users (EUs) representing buyer or demand. The market-based MAS environments provide the necessary infrastructure including security, information, transparent access to remote resources, and Edge services that enable us to bring these two entities together. Users interact with their own brokers for managing and scheduling their computations on the Edge. The ESPs make their Edge resources enabled by running software systems along with Edge Trading Services (ETS) model to enable resource trading and execution of user requests directed through EUs. The interaction between EUs and ESPs during resource trading (service cost establishment) is mediated through an Edge Trading Directory (ETD) model (See figure 1). They use various welfare model, K-pricing scheme and interaction protocols for deciding Edge service access price. These models are discussed in Section 3.

Figure 1: The multiagent for trading-based edge resource allocation system.

EUs can be charged for access to various resources including storage, software, and network. The ESPs users compose their bundles of service using interaction protocols through ETD. The ETS (working for the ESPs/EUs) can carry out the following steps for Edge resource allocation applications:

1. Identify Edge service providers.
2. Identify suitable Edge resources and establishes their prices (by interacting with ESPs and EUs).
3. Select composed of service that meet its welfare of allocation mechanism (e.g. lower cost and meet deadline requirements). It uses genetic algorithm while optimization Edge resources and mapping requests to users.
4. Use pricing mechanism (working with K-pricing) iteratively adjusted to find acceptable between a set of demands and a limited Edge supply for trading and issues payments as agreed.

Figure 2 shows an illustration the proposed the trading-based multiagent resource allocation model which functions embedded in the system as shown in the figure 1. It mainly functions consist of two inter-dependent mechanism: allocation mechanism and pricing mechanism. There are two sorts of actors in a double side based market: Edge service provider agents and Edge user agents (who represents the Edge market institution). As it shows, the sellers and buyers submit sell orders and bid orders (buy orders) to the market operation, respectively. The market operation sets pairs from these incoming orders according to the allocation and pricing mechanisms that is applied to the trading-based environment.

Figure 2: The trading-based multiagent resource allocation model.

Allocation mechanism

We formulate the allocation mechanism into the linear mixed integer program [9,10].

Object function: Both Edge buyers/sellers' greatest total welfare.

Maximize

$$w = \sum_{j=1}^{|N|} \sum_{k=1}^{|G|} \sum_{t=1}^{T} v_j z_{j,k,t} q_{j,k} - \sum_{i=1}^{|M|} \sum_{j=1}^{|N|} \sum_{k=1}^{|G|} \sum_{t=1}^{T} v_i q_{i,k} y_{i,j,k,t} \quad (1)$$

Where z denotes whether the resource is allocated to the Edge users. y denotes the proportion of quantitu q allocated to the buyer accept v_i is the minimum price per timeslot ($1 \le t \le T$) at which the service provider wish to sell the composed service. Allocation constraints divided into three categories:

(I) The type service limiting:

(a) Composed of service needed by Edge buyer

$$\sum_{k=1}^{|G|} x_{j,k} - |B_j| u_j = 0, \quad 1 \le j \le |N| \quad (2)$$

(b) Edge Service in the time slot and limit

$$\sum_{t=1}^{T} z_{j,k,t} - l_{j,k} x_{j,k} = 0, \quad (3)$$

$$1 \le j \le |B|, 1 \le k \le |S|$$

(II) The proportion of quantity of service limiting

(a) Quantity of proportion of Edge resource paid

$$\sum_{j=1}^{|N|} y_{i,j,k,t} \le 1, \quad (4)$$

$$1 \le i \le |M|, 1 \le k \le |G|, 1 \le t \le T$$

(b) The Edge service amount that the buyer receives is equal to the service amount that all sellers offer

$$q_{j.k} z_{j,k,t} - \sum_{i=1}^{|M|} q_{i,k} y_{i,j,k,t} = 0, \quad (5)$$

$$1 \le j \le |N|, 1 \le k \le |G|, 1 \le t \le T$$

(III) Serve in time slot and limiting

(a) The Edge buyer begins to accept in the period earlier than buyers and need to accept this Edge service period

$$(a_{j,k} - t) z_{j,k,t} \le 0, \quad (6)$$

(b) Time slot when the Edge buyer accepted and can't be later than Edge buyers and need this service this service period finally

$$(t - d_{j,k}) z_{j,k,t} \le 0, \quad (7)$$

$$1 \le j \le |N|, 1 \le k \le |G|, 1 \le t \le T$$

(c) The Edge seller offers service for the earliest period of all Edge buyers'

$$(a_{j,k} - t) \sum_{j=1}^{|N|} y_{i,j,k,t} \le 0, \quad (8)$$

$$1 \le j \le |N|, 1 \le k \le |G|, 1 \le t \le T$$

(d) The Edge seller offers some service for the latest period of all Edge buyers'

$$(t-d_{i,k})\sum_{j=1}^{|N|} y_{i,j,k,t} \le 0, \quad (9)$$

$$1 \le i \le |M|, 1 \le k \le |G|, 1 \le t \le T$$

(e) The Edge buyer acquisite composed of service or not.

$$u_j \in \{0,1\}, \quad (10)$$

$$1 \le j \le |N|$$

(f) The Edge buyer accepts the service or not

$$x_{j,k} \in \{0,1\}, \quad (11)$$

$$1 \le j \le |N|, 1 \le k \le |G|$$

(g) The Edge buyer accepts this service in the time slot or not

$$z_{j,k,t} \in \{0,1\}, \quad (12)$$

$$1 \le j \le |N|, 1 \le k \le |G|, 1 \le t \le T$$

(h) The Edge seller offers the proportion of service

$$0 \le y_{i,j,k,t} \le 1, \quad (13)$$

$$1 \le i \le |M|, 1 \le j \le |N|, 1 \le k \le |G|, 1 \le t \le T$$

One of the main contributions of this study is the use of mathematical planning for the solution. As mentioned before, we have an objective function and 13 constraints and these criteria should be considered simultaneously to find a solution. To achieve this in distributed manner, we employed the genetic algorithm (GA). The evolution of the population takes place following the general GA principles through tournament selection, crossover and mutation. In addition, other genetic operators and techniques can be used to improve the performance of the GA, such as Elitism. It is implemented so that the best solution of every generation is copied to the next so that the possibility of its destruction through a genetic operator is eliminated. The flow chart of figure 3 describes the main steps of the GA procedure.

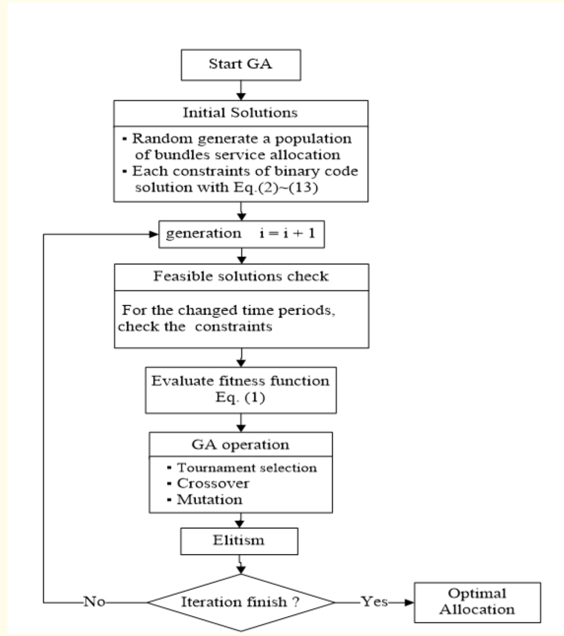

Figure 3: The GA procedure for edge resource allocation model.

Pricing mechanism

As introduced above, besides the allocation model in the trading-based multiagent resource allocation model, model consists pricing mechanism. While the allocation model generally accounts for the technical specifics of the Edge setting, the objective of the pricing component is to induce the selfish participants in the trading-based environment to act towards the general objective, in this case welfare maximization. To this end, in this section k-Pricing scheme is presented that can be used in conjunction with the allocation model. K-Pricing scheme is an alternative trading mechanism to proportional critical value pricing. It was introduced in Schnizler., *et al*. (2008) [11] for double-sided combinatorial auctions. We employ the K-pricing scheme to fix the resource. Let $0 \le k \le 1$ be an arbitrary proportion. The price P is then calculated as: $P_{i,j,k,t} = K(v_j z_{j,k,t}) + (1-K)(v_i y_{i,j,k,t})$ (14)

The basic idea is to distribute the welfare generated by the allocation model between Edge buyers and service providers according to a factor k $\in [0,1]$. K-pricing scheme allows us to separate risk-side discounting from time-side discounting, allowing us to quantify exactly how much of Edge's current price is due to time discounting and how much is due to risk discounting.

For instance, assume an allocation of resources from a specific service provider to a specific Edge buyer. The Edge buyer values these resources at $10 while the Edge service provider has a reserve price of $5. Then the (local) welfare of this transaction is $10-$5 = $5, and k × $5 of the surplus is allotted to the Edge buyer (who thus has to pay $10 - k × $5) and (1- k) × $5 is allotted to the Edge service provider (who thus receives $5+(1-k) × $5).

k-Pricing scheme has two main advantages. The distribution of welfare among users and providers can be flexibly pre-defined by setting the factor k, thus allowing for both fairness and revenue considerations [14].

Multiagent resource allocation simulation experiment

We are developing a simulation environment to evaluate the performance of the proposed market-based multiagent resource allocation model. In this section, we will present the experimental results and comparative the computational performance. The platform for conducting the experiments in a PC with Intel Core i7 10700K and 8GB RAM. All programs are coded in Java programming language in Borland JBuilder 9. The simulation environment consists of buyer/service provider agents and a market exchange. The individual agent has its own preferences to decide the bid according to its budget and the market trend. The prices and payments generated by proportional critical value pricing and k-Pricing with k = 0.5. After we know the basic information, the buyer agents and the service provider agents start to trade with each other which are illustrated as figure 4.

From figure 5 to 8 illustrate a series of trading among seven participants: three Edge service provider agents offer three composed services. Buyer agent 1, 2, 3 and 4 get their need different composed service simultaneously.

As Edge buyer's number increases, the degree of competition among the buyers also increases. When the competition is the stronger, will also be high buyer's bid. They would like to bid by higher than the lowest bid price offered at that timing, we call that jump bidding in this behavior. That is the ratio of jump bidding (ROJB):

$$ROJB = \frac{JumpBidding - Cleaning\,P\ ice}{Cleaning\,P\ ice} \quad (15)$$

Figure 4: Trade exchange for buyer agents and the edge service provider agents.

Figure 5: Buyer agent 1 with all Edge service provider agents resource allocation after trading.

Figure 6: Buyer agent 2 with all Edge service provider agents resource allocation after trading.

Figure 7: Buyer agent 3 with all Edge service provider agents resource allocation after trading.

The higher the K value, the more the cleaning price tends to be the buyer's bid price. This shows that it is comparatively favorable to the seller. Therefore, Edge both buyer/sellers' greatest welfare will increase as shown in table 1.

Different *k* value and ROJB value were produced welfare as the figure 9. The buyer would like to offer it with the higher price, then

Figure 8: Buyer agent 4 with all Edge service provider agents resource allocation after trading.

***K* value**	**ROJB**				
	1	**1.1**	**1.2**	**1.3**	**1.4**
0.3	61.52	73.35	116.01	143.97	144.33
0.5	65.21	82.79	120.21	135.16	146.75
0.7	67.52	97.35	128.39	148.87	203.08

Table 1: Different ROJB and *k* value are produced welfare (*w*).

welfare(*w*) rising also becomes more and more obvious. Safeguard one's own interests and incline to choose higher *k* value. Not only can make welfare value improve like this, but also make the trade succeed.

Therefore, if can accept higher *k* value with the attitude of compromise, both Edge buyers/sellers' greatest total welfare will also increase.

Conclusions and Future Work

In this paper we proposed the trading-based multiagent resource allocation model on Edge computing environment. It allows Edge buyers to order an arbitrary composition of services to different service providers. The proposed trading-based multiagent resource allocation model and pricing mechanism develop MAS

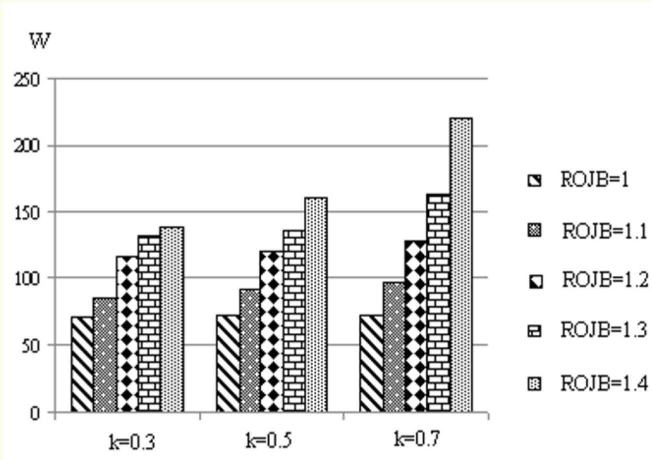

Figure 9: Different welfare (w) in various k and ROJB.

simulation environment to evaluate the performance of the proposed model. The preliminary simulations show that the model works properly. We are interested in the behavior of the trading exchange, particularly the interaction between Edge user agents and Edge service provider agents. Trading-based multiagent resource allocation model shows promise for enhancing resource allocation and pricing. We are now working toward GA and K-pricing scheme find an interesting match between scalability and individual behavior. By means of multiagent simulations, the effect of multiple Edge users and providers strategic behavior might be investigated. Extensions of the heuristic allocation scheme, such as the use of more sophisticated norms in the sorting phase, as well as the study of their impact on the mechanisms' strategic properties, might be further promising areas for future research.

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