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A Double Auction Mechanism to Allocate and Price the Network Resource

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Abstract: Double auction is one of the most effective ways to solve the issues of resources distribution and transaction in competitive market. But the fact that truthfulness and Pareto efficiency leads to System negative income which needs outside subsidy and it hindered the widespread practical use in the market. In this study, we introduce an interval report strategy which extends the value from a specific number to an interval, using the distribution method ensures maximum utility and pricing strategy based on VCG mechanism and give a bilateral auction mechanism aims to minimize outside subsidy. This mechanism ensures the efficient distribution of resources, under the premise of less negative income system than existing bilateral auction mechanism, when offered better-organized price interval can meet certain conditions which is equal to or larger than the quotient between the product of original system negative income with value range and the decreased liability, the mechanism can be debt-free or even profitable operation.

Key words: VCG, outside subsidy, price interval

INTRODUCTION

Google and Amazon have reduced the price of cloud service, for the Amazon, Google and other companies and cloud service is a great opportunity to generate cash. The demand of cloud computing is expected to continue to grow (Myerson and Satterthwaite, 1983; Zhao *et al*., 2011).

The research on cloud economy is divided into two aspects, intra-organization economics and inter-organization economics. The study points of cloud service economy include pricing strategy (cloud computing provider) and industrial organization theory (such as company's boundary adjustment with warning transaction cost). For cloud providers, they can use a fixed fee, per-use charges and mixing the two programs. Analyzing it by considering the investment decision of computing capacity and quality assurance. After considering the condition of market institutions, providers can choose an appropriate pricing strategy. Researchers can refer to pricing strategy of the existing Web services and Grid computing on resource. Existing mainstream research methods include industrial organization theory and game theory. Recently, IaaS's provider opened a cloud platform named Spot cloud (clearinghouse or market) to sell the unused computing power to intermediate sellers. Intermediate sellers generally look for the computing power that is running well below full capacity. Amazon also allows selling its unused cloud computing capabilities in the spot price. These pricing models open up a new research vision for the auction of environment, transferring the economic benefits to cloud computing provider or the entire value chain (Wei *et al*., 2007).

With cloud services' theoretical research and technology transforming into industrial applications, many economic and social problems such as services' providing, consumption, macro-control and so on, have appeared in succession. However, the existing research lacks of mechanism design of cloud services business process and cannot express agents' goals, preferences and economic attributes and other parameters in the cloud services market behavior. In response to these problems above, the project takes the competition, cooperation and macro-control factor in cloud services business process into account, putting forward a business design mechanism for cloud service idea; designing the competition, cooperation and macro-control's game mechanism from three aspects, including the providers, consumers and regulators of the cloud service. These problems' solving involves the following four basic questions, (1) In connection with similarity of service

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function and difference of the price, quality and reputation, realizing the capacity planning and resource optimization of service providing based on defining the model of quality and price, (2) Starting from the cloud service user's perspective, establishing the basic theory of cloud services business mechanism design (Yen *et al.*, 2011). Researching the existing condition of user together (alliance) equilibrium that aims at function complementation and maximum benefit, (3) Researching cloud service allocation and pricing promising research which is studying the triggering factors and the environment and under the triggering factors and the strategies and market discipline mechanism to provide resources that have uncertain availability. There is another regulatory authorities, (4) Designing a set of algorithm on competition, cooperation and macro-control of cloud services, Problems of resource allocation in recent years have been widely explored. With the wide-spread popularity of Internet, Cloud computing, combination of services, agent technology obtained fast development. Issue of competition for resources, as a very interesting topic, was put forward and studied. Therefore, how to apply bilateral auction mechanism effectively to solve the problem of resource allocation and competition as well as pricing decision has become an important area of research on multi-agent system.

The effectiveness, truthfulness and rational issues of the auction mechanism, are important criteria in research on the design of VCG mechanism. And VCG as the one of important solution to the competition for resources has been widely used. Mechanism Design for Double Auctions with Temporal Constraints (Tsai, 2011) put forward a kind of VCG satisfaction bilateral auction Mechanism. Based on the distribution and pricing strategy following VCG rules, they designed an effective and incentive compatible bilateral auction mechanism.

But in this mechanism there exists negative income in the system, in fact the author of Counter speculation, Auctions and Competitive Sealed Tenders, Nisan (2007) pointed out that the design of a mechanism which meets the truthfulness, in no external allowance, will make the final distribution results meet Pareto efficiency is impossible. It is the universal existence of negative income, in certain circumstances, that limited the extensive application of the mechanism. Aimed at solving the problem of outside subsidy in mechanism, this study designs a feasible scheme of minimizing the outside subsidy. We change the reports of the participants in the quotation from the acceptable values to the acceptable price intervals. If the original quotation for the participants is v, for the buyers, new quotation interval is [v-Δv, v], for the sellers, ne quotation interval is [v, v+Δv]. We find finally the difference between the payments from buyers and the payments for the sellers:

$$\sum_{j\in S} x_j - \sum_{i\in B} x_i$$

reduced compared to the original single value reports. The study reduces the negative income in system by setting a price interval other than a specific price. So the issues of competition for resources can be better promoted.

RELATED WORK

Efficient Mechanisms for Bilateral Trading Chatterjee (1980) and Groves (1973) proved a mechanism to meet Bayesian incentive compatible, individual rational conditions, at the same time, the mechanism must need a minimal outside subsidy.

Counter speculation, Auctions and Competitive Sealed Tenders, Lin *et al.* (2012) show that the design of a mechanism which satisfied participants truthfulness, individual rational and can achieve Pareto-efficient is impossible. Journal of Public Economics Tamma *et al.* (2002) got efficient allocation without outside subsidies by weakening the incentive criterion. But, some individual of this mechanism got negative expected return; this does not meet the demand of individual rational. In other words, under the conditions that some individuals do have their own truthful preferences but have no idea of others' may expect to do worse if no trade took place. In the classical bilateral auction mechanism, the buyers give a highest value he is willing to offer, the sellers provide the lowest price he would like to accept and then according to value of bilateral sides the auctioneer decide how to do the matching (Jin *et al.*, 2010), many modern exchanges are still using this mechanism to trading commodities. for example, The New York Stock Exchange.

It worth mentioning that in recent decades researchers began to study the commodities trading mechanism in dynamic environment, in these mechanism, traders are arriving and departing dynamically, referred to as online mechanism design (Jin *et al.*, 2010) in order to describe the dynamic mechanism, temporal information is used. In the Mechanism Design for Double Auctions with Temporal Constraints (Song *et al.*, 2013; Bichler, 2000) they proved an allocation for the Double auction is efficient if and only if it corresponds to maximum weighted bipartite matching of the graph encoding the incoming. Based on that they designed a efficient, dominated-strategy incentive-compatible VCG of (Smith, 1980) bilateral auction mechanism that allows traders to specify temporal constraints in their order, so that in each period of time the mechanism produces maximum social benefit. By the use of abridging and replacing paths, we can decide allocation and payment for each final trader. In the development of bilateral auction system, VCG mechanism was introduced in distribution process and the pricing strategy, later other researchers introduced time constraints of trading produces which rich bilateral auction in practical application in a good manner. Innovations in the design of bilateral auction mechanism help its rapid development (Barbuceanu and Fox, 1995; Cost *et al*., 2001; Tamma *et al*., 2005).

But in the early papers on double auctions, mostly focus on how to design a mechanism to maximize social benefit (Jennings *et al*., 2001; Zlotkin and Rosenschein, 1989) and rarely paid enough attention to reducing the outside subsidy. This study, we design a bilateral auction price strategy and it effectively reduced the System negative income.

THE MODEL

Double auction is an efficient method to allocate competitive resource on network, where in, Ad auction illustrating as following Fig. 1 is a typical mechanism allocate position resource of search engineering.

Given the market M, there is a group of limited sellers S = {1, 2, 3, ..., n} and buyer B = {1, 2, 3, ..., m}, each seller has one indivisible product A. Each seller only holds an integral part of the commodities or resources; each buyer can get one commodity. Both sides are to give a value report, the buyer has an expected value function expressed as: v^i: $B \rightarrow Z^+$ $i \in B$ and the final value report is an interval $[v^i-\Delta v, v^i]$; For the seller,v^i: $S \rightarrow Z^+$ $j \in S$ and the final value report $[v^j, v^j+\Delta v]$ while $\Delta v \in R^+$ and $\Delta v << v^i$, v^j. For both the seller and the buyer have an ideal trading hours, only buyers and sellers of the trading hours have intersection, trade can occur.

Obviously, it is rational to submit value interval for participants to take part in the auction. Concerning the buyer, his expected value is v^i, the buyer will be happy to buy goods on the cost of $v^i-\Delta v$; Similarly, the expected value of sellers owned commodities is v^j, he would also very willing to sell the product at the price of $v^j-\Delta v$. Obviously, it is rational to submit value interval for participants to take part in the auction. Concerning the buyer, his expected value is v^i, the buyer will be happy to buy goods on the cost of $v^i-\Delta v$; Similarly, the expected value of sellers owned commodities is v^j, he would also very willing to sell the product at the price of $v^j-\Delta v$.

Given the concept of utility, suppose that after distribution, the seller gets profit p_s and the buyer pays p_b, the seller's utility $U_j = p_j-v_j$, $j \in S$, the buyer's utility $U_i = p_i-v_i$, $i \in B$.

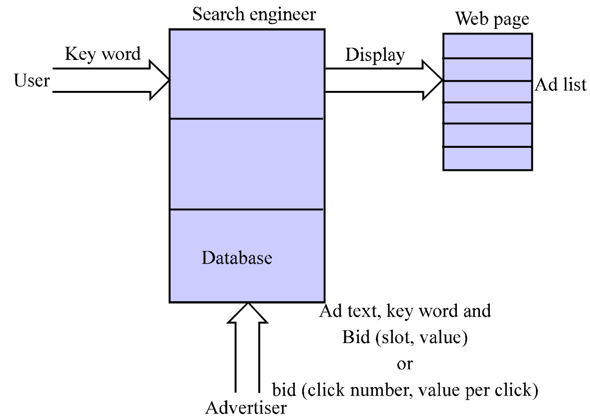

Fig. 1: Flowchart of AD auction on internet

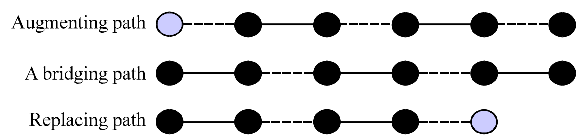

Fig. 2: Tree kind of classic pathes

Definition 1: Efficiency is a description about reports of participants on two sides. If exists $v^i \geq v^j$ $i \in B, j \in S$ and $[s_i, e_i] \cap [s_j, e_j] \neq \varnothing$ we call the exchange between buyer i and seller j is feasible or matchable. We say this pair consists of a buyer and a seller is efficient and the two are potential traders.

Definition 2: System negative income. Suppose in a mechanism, v_i means the value report of participant i, its probable interval is [a, b], U is the participant's expected profits, P (x, y) expresses the rate of trade between trader x and y. So when the mechanism satisfies conditions:

$$\forall_{i \in B \cup S} U(V_i) \geq U(\hat{V}_i)$$

iff V_i and $\hat{V}_i$ in$[a, b]$ and V_i is his final report, $\hat{V}_i$ means all the other vale reports; $\forall_{i \in B \cup S} U(V_i) \geq 0$:

$$P(V_S, V_B) = \begin{cases} 1 & \text{if } V_S \leq V_B \\ 0 & \text{if } V_S \geq V_B \end{cases}$$

The payment on both sides fails to reach a balance, it means the system exists a debt and which is system negative income.

Definition 3: Truthfulness, when the participants give his or her own expected value, he or she could achieve the maximum utility. We suppose the expected value is v_c and the value report is $v_c^{'}$, here comes with the inequality $U_c(v_c) - U_{c'}(v_c^{'}) \geq 0$.

Definition 4: Individual rational, we say a mechanism is individual rational if and only if $\forall_{i\in S\cup B} U_i \geq 0$.

Definition 5: Auction Mechanism, which is a two-tuples (π, ρ), it includes distribution policy φ and pricing policy ρ. $\varphi = \{\pi (1), \pi (2), ..., \pi (m)\}$, $|\varphi|$ is the potential of collection φ, its value equals the number of all the non-zero elements. If $i\in B$ and $j\in S$, the product seller j hold is assigned to buyer i, it records as π (I) = j or π^{-1} (j) = i. If a buyer gets nothing in the auction, π (i) = 0. Obviously, For any $i\neq i'$ and $i\neq i'\in B$, we have $\pi (i)\neq\pi (i')$. ρ is the mapping from any pair to payment, ρ: $\pi\rightarrow Z^+$. If exists π (i) = j, so we have $v^{\pi (I)}\leq\rho (\pi (i))\leq v^i$.

Theorem 1: Auction mechanism which is efficient, truthful and rational, will lead to system negative income thus needs outside subsidy (Nisan, 2007).

PROMOTED DOUBLE-AUCTION MECHANISM

Abbreviation and acronyms should be defined the first time they appear in the text, even after they have already been defined in the abstract. Do not use abbreviations in the title unless they are unavoidable.

Original works: First, the researchers learned from the previous relevant bilateral auction mechanism design and introduced the concept of trade time, make it more suitable and tally to the actual situation. And then researchers make the reasonable distribution of goods with the objective of maximizing utility.

Later, they use knowledge from Graph Theory to decide the payment.

Augmenting path: Both of the first and last node of the path are unmatched

Reducing path: Both of the first and last node of the path are matched

Replacing path: One of the first or last node of the path is unmatched and the other is unmatched

Promoted auction mechanism: This section, we will introduce how to use the view graph theory to solve the above bilateral auction model. First, given a set of buyers B = {1, 2, 3, ..., m}and a set of sellers S = {1, 2, 3, ..., n}. Everyone participants would report a piece of information $\theta_i (v_i - \Delta v, v_i, s, e)$ $i\in B$ or $\theta_j (v_j, v_j + \Delta v, s, e)$ $j\in S$. We assume that Δv is comparatively tiny value to v. Detailed steps are described below:

Step 1: Traverse all the reports of all the participants and find all the potential pair i, j, we say and are potential mates if and only if $v^i\geq v^j$ $i\in B$, $j\in S$ and $[s_i, e_i]\cap[s_j, e_j]\neq\varnothing$. We connect all the potential mates with dash lines

Step 2: Find a pair in which the buyer and the seller have the largest valuation gap which means v_i-v_j has the maximum value. It also means seller j and buyer i become real traders. We connect them with solid line

Step 3: We try to augment the current path (a, ..., b), if the first and last node of the path is connected with dash line, for example a has potential nodes b_1, b_2 and b has potential nodes a_1, a_2. We choose the one has the bigger valuation gap and add it to the current path. For if b_1 has a greater gap than b_2 with a and a_1 has a greater gap than a_2 with b. So we augment the path to (b_1, a, ..., b, a_1). Do the loop until the first and last nodes of path fail to have potential nodes at the same time

Step 4: Repeat from step 1 to step 3 until there exists more potential pair

Theorem 2: When the value report change from v_i, v_j to an interval $[v_j, v_j + \Delta v],[v_i - \Delta v, v_i]$ $i\in B, j\in S$, the distribution policy will not make a difference.

Proof: We consider the process of distribution. Of all the value reports, we change the value of all the participants to such an equal extent that it will never ever broke the original size relationships of both sides themselves or cross-sides. In details, for any v_i-v_j changing to:

$$\left[v_i - \Delta v, v_i\right] - \left[v_j, v_j + \Delta v\right]$$

it still keep some sort of dynamic equivalent stability. In all the fundamental element of distribution policy is unchanged, so the distribution policy won't change as well.

Consider the pricing problem after allocation. According to the MM-Payment strategy (Min-Max Payment): Suppose buyers pay $x_i (\theta)$ and sellers get $x_j (\theta)$. We give the expression of $x_i (\theta)$ and $x_j (\theta)$:

$$x_i(\theta) = \max_{p\in D\cup R} v(\text{ending}(p)), \quad \text{if } i\in B$$
$$x_j(\theta) = \min_{p\in D\cup R} v(\text{ending}(p)), \quad \text{if } j\in S$$

- D is a set of abridging paths started from θ
- R is a set of replacement paths started from θ
- v (ending (p)) is the other ending point in the path p

For the seller, his payment is the smallest value of last nodes in abridging and alternating paths started from him; For the buyer, his payment is the largest value of last nodes in abridging and alternating paths started from him.

Theorem 3: The liabilities of the system would be optimized after expanding the single value to an interval. According to the MM-Payment strategy (Min-Max Payment):

$$x_i(\theta)=\begin{cases}\min_{p\in D\cup R} v(\text{ending}(p)), & \text{if } i\in S\\ \max_{p\in D\cup R} v(\text{ending}(p)), & \text{if } i\in B\end{cases}$$

- D is a set of abridging paths started from θ
- R is a set of replacement paths started from θ
- v (ending (p)) is the other ending point in the path p

When a potential matching is large enough, numbers of the ending point vector_1 in the buyer and seller are in line with X~N (n, 1) in which n is the final matched number which is half of the actual traders. For the seller, assuming that the original payment x_i (i∈S) and it equals the smallest value of ending points of all the path. After the introduction of interval, For the seller's payment: x'_i (i∈S) equals $v_{\text{vector}_1}, \text{vector}_1 \in S$ (vector_1 finally in seller side, the same as original case) or $v_{\text{vector}_1} - \Delta v, \text{vector}_1 \in B$ (Vector_1 finally located in the buyer side, set a probability α, liabilities reduce, payment to the seller decreases); For the buyer, assuming that the original payment x_i (i∈B) and due to taking the largest value of the path. So x'_i (I∈B) $v_{\text{vector}_1} + \Delta v, \text{vector}_1 \in S$ (vector_1 finally located in seller side, set a probability β, liabilities reduced, payment to the system increases) or $v_{\text{vector}_1}, \text{vector}_1 \in B$ (vector_1 finally located in the buyer side, the same as original case);. System negative income reduces by $n(\alpha+\beta)\times\Delta v\ (\alpha,\beta\geq 0)$.

In conclusion:

$$\sum_{i\in S} x_i - \sum_{i\in B} x_i \succ \sum_{i\in S} x'_i - \sum_{i\in B} x'_i$$

so debt of the auction system reduces and even may turn into profit. It depends on the value of Δx and the number of participants in the final match which has further explanation in example in Section 5.

Theorem 4: MM payment accords with VCG mechanism. Proof: From valid statistics, Clarke payment is:

$$c(\theta_i)=\left|V^{\pi}(\theta_{-i})-V^{\pi}_{-i}(\theta)\right|$$

to prove that the MM payment is in line with VCG, is to prove the new match, get rid of the node i through its abridging path or alternating path to find, is the very match with the biggest weight.

First, the allocation is monotonic:

For each participant, we define a priority symbol: $\leq_I$ in the collection of pricing:

$$\theta'_i \leq_i \theta''_i \text{ iff } \begin{cases} v'_i \geq v''_i \text{ and } [s'_i, e'_i]\subseteq[s''_i, e''_i], \text{if } i\in S\\ v'_i \leq v''_i \text{ and } [s'_i, e'_i]\subseteq[s''_i, e''_i], \text{if } i\in B\end{cases}$$

While $\theta'_i=(v'_i,s'_i,e'_i)$ and $\theta''_i=(v''_i,s''_i,e''_i)$, we say that an allocation is monotonic if $\pi_i(\theta'_i,\theta_{-i})=1$ we have $\pi_i(\theta_i'', \theta_{-i}) = 1$.

Set M the maximum weight matching, M' is the maximum weight matching except for i which is the seller. Because the allocation is monotonic and M is the maximum weight matching, all the matched sellers except i should be in M' We know $A_M\setminus\{\theta_i\}\subseteq A_{M'}$ and $B_{M'}\subseteq B_M$. As:

$$|A_M|=|B_M| \text{ and } |A_{M'}|=|B_{M'}|$$

then we get:

$$|A_{M'}|=|A_M| \text{ or } |A_{M'}|=|A_M|-1$$

If there are another potential match which means using the replacing path and the number of matching pairs are the same; if there is no such path, then the matched number minus one. Suppose that in addition to i, there is a new node k_1, k_1∉M in the node outside replace k, k∈M\θ_i into a new maximum weight matching collection M', then when i is contained, M is of course not the maximum weight matching, unless node k_1 is included. This is contrary to the above hypothesis. So MM-payment strategy, in fact, is following the essence of

the VCG that a participant's payment should equal to the influence he caused to all the other participants in the system. Essentially, the theory of the pricing policy has nothing to do with the match pairs but with those participants who become the final traders and should pay or get payments. In this study, the objection is to design a efficient method to allocate network resource and a pricing rule to determine the payments of different buyers who have been allotted a network resource.

EXPERIMENT EXAMPLES AND CONTRASTS

In the following charts, the circles represent buyers and sellers in the auction. Each participant give their own expected reports includes: Price range and the transaction time interval. The form of the seller and the buyers' reports expressed as [v_i-Δv, v_i, s, e], i∈B; [v_j, v_j+Δv, s, e], j∈S. The dash line indicates a potential match between a buyer and a seller which means they may access to transactions path (a_2, b_1, a_1, b_2). And this path can't be augmented any longer.

As the above chart, for seller a_1, there's only one abridging path (a_1, b_2) and the price range for b_2 is [8.5, 9]. For seller a_2, there's one alternative path (a_2, b_1, a_3, b_4, a_4) and two abridging path (a_2, b_1, a_1, b_2), (a_2, b_1, a_3, b_4) and the price range for b_1 is [9.5, 10], for b_2 is [8.5, 9], for a_4 is [5, 5.5] and we set it the left boundary value of a_4 as 5. For seller a_3, there's one alternative path (a_3, b_4, a_4) and one abridging path (a_3, b_4) and the price range for a_4 is [5, 5.5], for b_4 is [6.5, 7] and set it the left boundary value of a_4 which is 5. For buyer b_1, there's one abridging path (b_1, a_2) and the price range for a_2 is [3, 3.5] and apparently we adopt the right boundary value as 3.5. For buyer b_2, there's one abridging path (b_2, a_1, b_1, a_2) and one alternative path (b_2, a_1, b_3), the price range for a_2 is [3, 3.5], for b_3 is [7.5, 8] and apparently we adopt the right boundary value of b_3 as 8. For buyer b_4, there're two abridging paths (b_4, a_3, b_1, a_2) and (b_4, a_3) and the right boundary value of a_3 as 4.5 is adopted.

Just can be seen from the above, all of the path are drawn from different parties of agent, buyers or sellers. In order to reduce the subsidy which derive from the truthful property of VCG mechanism, we change the bidding as a real price to a interval of reals.

The final payment that sellers gain from the system is 19 = 9+5+5 and the final payment that buyers pay is 15 = 3+8+4. The system liability is 4. Obviously it is imbalanced, the system has negative income. This will bring the extra outside subsidy to finance the system.

Suppose to introduce a "vague policy", it can better reduce system negative income and promote the healthy development of bilateral auction. The prices of participants on both sides are no longer specific values but a limited price range. Often it is also correspond with the common sense; the value of a good is decided by labor value, supply and demand situations and other factors. But as the fluctuation of market, the three factors above are not constant. So in bilateral auction, price range or interval is necessary and reasonable.

In addition, the introduction of the price range can reduce the system negative income efficiently and ensure the auction to work normally and orderly, promoting the auction market to be in prosperity and stability.

The above chart (on the right): We extended the valuation report from a single number to a range. For the sellers, the final payment is 18.5 = 8.5+5+5, for the buyer, it is 16 = 3.5+8+4.5. The outside subsidy of the system is 2.5, it's significantly lower than the former. Although both sides of the price changed from a value to an interval but it will not affect the allocation model of system. Because the expansion based on the original reports for all buyers and sellers are balanced. What's more, we may find that the outside subsidy decreased by 1.5 after the introduction of interval with 0.5 length. It is simple as it stands, if we change the interval length to:

$$0.5 \times \frac{4}{1.5} \approx 1.33$$

it is expected to remove the system negative income. When the interval length surpasses 1.33, it would make a profit.

CONCLUSION

On the basis of the double auction mechanism with temporal constraints, we reduced the outside subsidy by reducing sellers' income and increasing the payment of the buyers in the way of introducing the concept of price interval (or value range). It enables the system to work smoothly with less outside subsidy. So it has a better application prospect.

This study focus on reducing subsidy of a double auction mechanism by which to allocate the competitive network resource and it is easy to find that this method can be adopt to deal with other issue in where there is a competition of resources or services.

In the future, we hope to express the quantitative relationship between the length of valuation interval and outside subsidy, so that we can calculate the length of the interval precisely if we want to eliminate the system negative income. Furthermore, we intend to improve allocation and pricing strategy to make the mechanism more practical and directive as well as take more considerations to the interests of the participants to promote the strategies of distribution and pricing in double auction.

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