A Multi-Rounds Double Auction Based Resource Trading for Small-Cell Caching System

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***Abstract*—With the burst of mobile data, it is necessary to make use of idle mobile equipment for caching space. Caching in the femto-cells is proposed for reducing transmission latency between the WiFi points and its mobile users (MU) and better user service. In this paper, we firstly take the copyright of the files as the allocation resource and the WiFi points with caching space want to rent these copyrights. We propose a multi-rounds double auction mechanism for this problem and take the popularity parameter of the files as the quality weight. This game can help multiple content providers (CP) lease copyrights of the files to multiple WiFi points effectively. Different from traditional double auctions, it will take the failed buyers and sellers into consideration and they are allowed to change their requests in the next auction process. This mechanism can largely improve efficiency of the game and is budget balanced. We also prove that the allocation process is monotone and with the set of the critical payment rule, we prove the truthfulness of the mechanism. Additionally, we prove that the mechanism can form a conditional equilibrium. Simulation results verify the effectiveness of the proposed mechanism and compare with the traditional one-round double auction.**

***Index Terms*—Caching, cellular networks, auction game, double auction**

I. Introduction

The advancement of mobile communication technologies has enabled more and more mobile users to continue to attract and use smart phones and tablet computers to enjoy a wide range of multimedia services. However, due to the convergence of mobile network architecture, the capacity of wireless links, mobile wireless networks, mobile loops, and mobile core networks can hardly cope with the explosive growth of mobile traffic [1]. With the development of mobile techniques, the data of mobile communication has been emerging and caused data congestion [2]. To solve this problem, caching in embed small cells as well as pico-cells was proposed [3]. As these equipments are close to the mobile users (MUs), these distributed caching can effectively reduce transmission latency and increase communication capacity [4]. As the MUs' downloading of video files accounts for the majority of the data traffic [5], caching popular video resources in the pico-cells will largely reduce data latency and redundancy [6] [7].

Currently, most of the papers concerning caching systems mainly talking about the data placement and data delivery [8]. [9] analyzes content caching strategies in the Evolved Packet Core (EPC) of LTE networks. In order to make the location of content storage closer to the user, [10] studied the content caching strategy in the Radio Access Network (RAN). In [11], a framework was proposed to allocate cached content and provider data at the same time. In [12], the author firstly introduce the commercialized small-cell caching system. And recent works formulate the problem on the basis of device-to-device (D2D) network [13]. In this paper, we focus on the problem of allocation and pricing in the resource trading model between the content providers (CP) and the femto-cells.

As game theory has been widely applied to caching system [14] [15], auction game is adaptive for resource allocation in consideration of the pricing rules and the incentive of the resource owners [16]. In this paper, there are multiple femto-cells and multiple CPs, a many-to-many double auction is adopted for this system model. Double auction has been widely applied to wireless communication in spectrum sharing [17] and cognitive radio network [18]. In [19], a double auction mechanism is designed for a mobile data offloading network. Different from the previous double auction mechanism [20], the multi-rounds double auction can help the buyers who failed to win resources from the previous auction processes.

In this double auction mechanism we proposed, the copyrights of the files are resources that the buyers want, the CPs who own the copyrights of the files are the sellers and the WiFi points are the buyers who want the files. Additionally, there is an auctioneer who is the neutral third party of the auction and controls the process and results of the auction. In this double auction, the auctioneer firstly allocates the initial requests from sides of sellers and buyers, and then gives the results to them. The players who is not satisfied about the allocation can adjust their requests and return it to the auctioneer, and the auctioneer will use the new information to conduct a new round of auction until all of the players will not change and the auction concludes.

In particular, we first develop a profit model of our caching system and investigate the profits gained by the CPs and femto-cells from WiFi storage space trading. We bundle the files to satisfy different needs of different mobile users. Different files are distinguished by different popularity and we use the popularity parameter of each file as a weight.Then we maximize the profits of both sides by formulating a multi-

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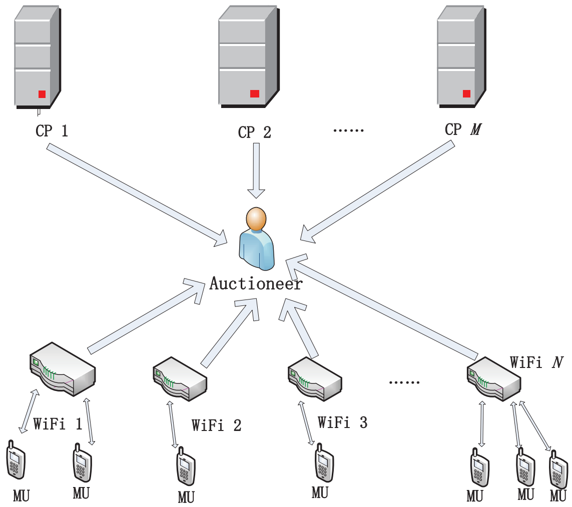

Fig. 1. System model.

rounds double auction problem, in which the auctioneer communicates with both sides of the members and allocate the corresponding results to them and asking for payment from the CPs. We use a critical payment rule to decide the payment price. Next, to be budget balanced, the revenue given up to the CPs can-not be larger than the payment from the WiFi points. As the CPs and WiFi points are individual rational in our algorithm, we prove this forms a conditional equilibrium in the algorithm. Numerical results validate the effectiveness of our proposed scheme for resource allocation and prevent the CPs from cheating in the auction process.

The rest of this paper is organized as follows. We describe the system model in Section II and establish the auction framework in Section III. Numerical results are detailed in Section IV, while our conclusions are provided in Section V.

II. System Model And Problem Formulation

In this paper, the auction system consists multiple CPs with k types of file bundles and multiple WiFi points who want file copyrights from them. The WiFi points are the buyers in our network. The sellers are the CPs who own various kinds of files and they ask for different prices of the file bundles. The auctioneer is the equipment without any resource to trade and any motivation to buy the resource. For the auctioneer, it collects the bids from the buyers and the asking price from the sellers and the popularity parameters of different sellers. At the end of the auction, the auctioneer determines the final allocation results and the payment results according to the bids of the buyers, the price asked by the sellers and the popularity of them. The system model is shown in Fig. 1.

A. Bids definition of Buyers

The buyers submit a 2-tuple bid set (S, B), $S_i = \{s_i^1, s_i^2, \cdots, s_i^k\}$ means the price of each files demanded by the WiFi point. $B_i = \{b_i^1, b_i^2, \cdots, b_i^k\}$ represents the bids for different types of files. Bids represent the file list that a buyer wants. For example, a WiFi point may want two certain files according to its mobile users' preference. As there are N buyers in this network, the request set can be specified as $\boldsymbol{S} = \{S_1, S_2, \cdots, S_N\}$ and the bid set is $\boldsymbol{B} = \{B_1, B_2, \cdots, B_N\}$.

Additionally, we define the true valuation of each buyer toward the bundle it wants as $V_i = \{v_i^1, v_i^2, \cdots, v_i^k\}$. The bid of WiFi i will not exceed its valuation toward the file bundle it wants which means $b_i^k \leq v_i^k$.

B. Asks Definition of Sellers

The sellers submit a 2-tuple bid set (C, A) and $C_j = \{c_j^1, c_j^2, \cdots, c_j^k\}$ indicates the number of each type of files, which can be denoted as $\boldsymbol{C} = \{C_1, C_2, \cdots, C_M\}$ and $\boldsymbol{A} = \{A_1, A_2, \cdots, A_M\}$ represents the ask of the files and $A_j = \{a_j^1, a_j^2, \cdots, a_j^k\}$.

In addition, every seller has a basic cost for each file $G_j = \{g_j^1, g_j^2, \cdots, g_j^k\}$. The ask price of a certain file should cover the cost of it so that there is profit for the file. This means $a_i^k \geq g_i^k$.

C. Popularity and Preferences

In the proposed auction scheme, the CPs provide different files with different popularity parameter. In order to distinguish the CPs from each other, we use the summation of popularity of each CP's files to represent the popularity parameters of their individual bundles of copyrights.

Denote by $\boldsymbol{\mathcal{F}} = \{\mathcal{F}_1, \mathcal{F}_2, \cdots, \mathcal{F}_F\}$ the file including F files, where each file contains an individual piece of content, e.g., movies, which is frequently requested by the MUs. The MUs make requests of the f-th file $\mathcal{F}_f$, $f = 1, \cdots, F$ independently, with the probability of p_f. Generally, $\mathbf{p}$ can be modeled by the Zipf distribution [21] as

$$p_f = \frac{1/f^\beta}{\sum_{j=1}^{F} 1/j^\beta}, \quad \forall f, \tag{1}$$

where the exponent β is a positive value, characterizing the content popularity. A higher β corresponds to a higher content reuse, where the most popular files account for the majority of download requests. From (1), the file with a smaller v corresponds to a higher popularity. The popularity of the files are used to represent the weight of the file bundles in our auction mechanism. If the popularity of CP_j's files are high, the weight of this bundle is high.

D. Transmission Rate

We define the transmission rate of each WiFi to MU as:

$$R_{n,j} = W \log_2 \left(1 + \frac{P_n h_{n,j}^2 d_{n,j}^{-\alpha}}{\sum_{n' \in \mathcal{I}} P_{n'} h_{n',j}^2 d_{n',j}^{-\alpha} + \sigma^2} \right), \tag{2}$$

where W is the bandwidth of transmission channel. P_n is the transmission power at the femto-cell, $d_{n,j}$ represents the distance between the femto-cell and MU and σ^2 is the Gaussian noise variance. α is the path-loss exponent ad the random channel between the femto-cells and the MUs are Rayleigh fading while the coefficient $h_{n,j}$ has the average power of one.

E. Problem Formulation

1) Utility Function of CPs: The revenue of each CP comes from the rent revenue from the WiFi points which ask for file copyrights from it. Then for the revenue of CP_j, denoted by S_j^{CP}, we have

$$S_j^{\text{CP}} = S^{rent} - C, \tag{3}$$

where C is the payment that CP uses to buy the copyrights from the original producer of the files and we assume that before the auction begins, as the CPs' bundles of files are set up, the total cost C is also set up.

The optimization goal of CP_j is to maximize its utility function. With the resource bound, the utility function of CP_j should be no less than 0 which means $S^{rent} \geq C$ and the ask price should be larger than the cost $a_i^k \geq g_i^k$. With the allocation matrix $x_{ij} \in \{0,1\}, \forall i \in N, \forall j \in M$, the optimization problem for CP_j is:

$$\max S_j^{\text{CP}}, \forall j \in M, \tag{4}$$

$$\text{s.t.} \begin{cases} \sum\limits_{k=1}^{k} c_j^k = C_j, \\ S^{rent} \geq C, \\ a_i^k \geq g_i^k, \\ x_{ij} \in \{0,1\}, \forall i \in N, \forall j \in M. \end{cases} \tag{5}$$

2) Utility Function of Femto-cells: The revenue of the WiFi points comes from providing fast downloading services to the MUs due to the local caching system and the cost of the femto-cell is S^{rent} represents the renting payment. We assume the files set of WiFi i is p_k is the sum of WiFi i's files and assume that there are V files in WiFi i's file bundle. Denoted by $p_k = \sum_{i=1}^{V} p_{k_i}$ while $\{p_{k_1}, p_{k_2}, \cdots, p_{k_i}\}$ is the set of WiFi i's files. γ is a constant parameter and the utility function of the femto-cell is

$$S^{\text{cell}} = \gamma R_{n,j} p_k - S^{rent}. \tag{6}$$

The optimization objective of WiFi i is to optimize its utility function under resource constraints. With the restriction of its true valuation of the file bundle, the utility of the femto-cell should not be less than zero so $\gamma R_{n,j} p_k \geq S^{rent}$ and as the buyers' bids should be more than 0 and less than the valuation so $b_i^k \leq v_i^k$ and $b_i^k \geq 0$. Additionally, the allocation matrix of x_{ij} should satisfy $x_{ij} \in \{0,1\}, \forall i \in N, \forall j \in M$ and the the optimization problem for WiFi i is:

$$\max S^{\text{cell}}, \forall i \in N, \tag{7}$$

$$\text{s.t.} \begin{cases} \sum\limits_{k=1}^{k} s_i^k b_i^k = B_i, \\ \gamma R_{n,j} p_k \geq S^{rent}, \\ b_i^k \leq v_i^k, \\ b_i^k \geq 0, \\ x_{ij} \in \{0,1\}, \forall i \in N, \forall j \in M. \end{cases} \tag{8}$$

TABLE I
THE MULTI-ROUNDS DOUBLE AUCTION ALGORITHM.

Algorithm 1 The Multi-rounds Double Auction Algorithm.

Input: WiFis' initial request bid B and quantity in need S and the bundles information to the CPs and the CPs' initial asks, supply quantity C and asking price A
Output: Allocation matrix X, payment matrix P
Steps:
1: Collect the information from the WiFi points and the allocation:
2: **for** all WiFi points do
3: $B_i^* = \sum s_i^k b_i^k$, $bd_i = \frac{B_i^*}{\sqrt{\sum s_i^k p_k^i}}$
4: **end for**
5: sort bid densities in the descending order
6: **for** CPs do
7: $A_j^* = \sum c_j^k a_j^k$, $ad_j = \frac{B_j^*}{\sqrt{\sum c_j^k p_k}}$
8: **end for**
9: sort ask densities in the ascending order
10: Initialization $i = 1$, $j = 1$,$x_{ij} = 0$,
11: **for all** the CPs and WiFi points **do**
12: **if** all the requests and asks of a certain WiFi point are satisfied, the file bundles of the CP can cover the demand files of the WiFi and this WiFi's bid is no less than the ask price of the CP, then
13: $x_{ij} = 1$
14: update C(j,k)=C(j,k)-S(i,k); S(i,k)=0
15: **else**
16: $x_{ij} = 0$
17: **end if**
18: **end for**
19: **if** no player in the game changes its price and bid or all of the players get their desired outcome or the files owned by the CPs are sold out then goes to step 22.
20: **else** the players can change and update their asks and prices and give them back to the auctioneer. The WiFi points can put forward their unique demand of the bundles according to their mobile users' preference. The CPs will adjust the bundles of their files' copyrights and the auction process will go back to the beginning.
21: **end if**
22: **Decide the payment of the WiFis**
23: **for all the WiFis do**
24: $P_j = \sum_{k=1}^{K} \sum_{j=1}^{M} \left(x_{ij} s_i{}^k \frac{b_i^k + a_j^k}{2} \right)$
25: **end for**

III. AUCTION PROCESS

A. Bundles of files

In the resource allocation algorithm, the copyrights of the files are provided in the form of bundles. The CPs will bundle the most popular files before the auction and announce the bundles to the WiFis at the beginning of the auction. The WiFis will collect the MUs' preference of the files and will give its bid and price to the CPs. Then the CPs will give each WiFi the suitable file bundles and the asking price to them. The probability that the MUs ask for a file is the preference of the MUs to the files. Different bundles of the file copyrights will have different prices during the auction process.

B. Auction Process

After the bundling process, the CPs will announce the primary price of the bundles and the WiFis will put forward their demand of certain files and the corresponding price. In this system, the CPs own different kinds of popular files. As there are F files, there are k types of the bundles. The WiFi points are buyers who want to rent the bundles of the files from the CPs. In this paper, we assume that the bidders are all single-minded which means that a bidder bid for only one bundle. Different WiFi points have different storage space and own different numbers of mobile users, and want different bundles of files. And there is a neutral third party, which is the auctioneer as the neutral party and allocates information and coordinates between the buyers and sellers.

In this auction game, the auctioneer first collects bids or ask information from the both sides of sellers and buyers. And then, it will sort these bids and asks in order, and make the primary allocation. If a buyer or seller is successfully mates, then it will not change the previous requests and if not, they will choose to change their requests and join in the next auction round until it is successfully mates with an appropriate pair. The CPs who didn't get allocation in the former round will improve its bid and the femto-cells who have remaining caching space can reduce its price in the next round.

After all of the players in the auction have their satisfactory results and will not change their requests, the auction process concludes and the auctioneer will decide the payment of the buyers and give revenue to the sellers. The auction will conclude if all the caching pace of all the femto-cells are sold out or if the bids of the CPs and the asking price of the femto-cells are out of a acceptable rage.

C. Bid Density

Allocation should be fair and take into consideration of all of the bids and asks. In this step, we use the concept of bid density [22] to represent the number of the bids per unit of the allocation. For the CPs' bids set, we will group them in the descending order of the bid density and for the femto-cells asking price, we will sort them in the ascending order.

Before the allocation, we need to determine the rule for choosing the winners. To measure the weight of the bids, we need to define a parameter. Here we define the bid density as the evaluation mechanism as $B^* = \{B_1^*, B_2^*, \cdots, B_n^*\}$, where$B_i^* = \sum s_i^k b_i^k$ and p_k^i is the popularity of allocated bundle of the k-th file bundle demanded by WiFi i. The bid density of the WiFi point is:

$$bd_i = \frac{B_i^*}{\sqrt{\sum s_i^k p_k^i}}. \tag{9}$$

Similarly, the ask density of the CP is:

$$ad_j = \frac{B_j^*}{\sqrt{\sum c_j^k p_k}}, \tag{10}$$

p_k is the popularity of the k-th file bundle of CP_j and is the total of the weight of certain files. Here we use the weight of the file to take the popularity of them as a factor of the ask density of each CP. We use the similar way with [23] to give the critical parameter weights to characterize the different popularity of the file bundles.

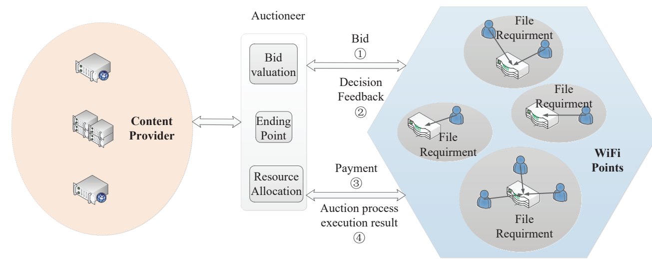

Fig. 2. The structure of the auction process.

D. Allocation Process

At the beginning of the auction, the auctioneer sets $x_{ij} = 0$. If CP_j's file bundle can satisfy the demand of WiFi i, then WiFi i and CP_j can be matched to each other and $x_{ij} = 1$. If not, then $x_{ij} = 0$ and if WiFi i is willing to improve its price, then it will improve bid in the next auction round until its demand is satisfied or the asking price of CP_j is out of its acceptable range. The auction ends when all of the sellers and buyers are matched or when the asks and bids are out of the buyers and sellers' acceptable ranges and no one will change in the final round.

E. Critical Pricing Rule

Pricing rule is vital to motivate all of the game members including the sellers, the buyers and the auctioneer to participate and play according to the strategy of the auction mechanism.

A critical value ${B_i}^*$ is a certain value for a winning WiFi with any bid $B_i \geq {B_i}^*$ and loses with the bid $B_i \leq {B_i}^*$. In other words, the critical payment is the lower limit that a WiFi can win the auction [24]. We define the final payment of the WiFis as the average of the ask of the CPs and the bids of the femto-cells:

$$P_i = \sum_{k=1}^{K} \sum_{j=1}^{M} \left(x_{ij} {s_i}^k \frac{b_i^k + a_j^k}{2} \right). \tag{11}$$

F. Proof of Properties

As we have denoted $B_i = \{b_i^1, b_i^2, \cdots, b_i^k\}$ as the bids for different types of files and the bid set is $\boldsymbol{B} = \{B_1, B_2, \cdots, B_N\}$. In the following, we will denote by $B_{-j} = (B_1, B_2, \cdots, B_{-j}, \cdots, B_N)$ the vector of all the other users' bids except CP_j. The bid set can be written as $\boldsymbol{B} = \{B_j, B_{-j}\}$.

According to the payment rule of the auction mechanism, we will firdt introduce the following theorem about individual rationality:

Theorem 1: The multi-rounds double auction mechanism is individual rational. Individual rationality means the utilities of both the sellers and the buyers are no less than zero.

Proof: As the pricing mechanism of the auction game is the average of the seller's bid and the buyer's ask, which is no more than the valuation of the buyer and no less than the cost of the seller. It is profitable for both the sellers and the buyers and we can prove that the mechanism is individual rational for both the sellers and the buyers.

$$a_j^k \leq b_i^k, \tag{12}$$

so,

$$\frac{b_i^k + a_j^k}{2} \leq b_i^k, \frac{b_i^k + a_j^k}{2} \geq a_j^k. \tag{13}$$

■

In the folowing theorem, we prove that this algorithm the auction mechanism is budget balanced:

Theorem 2: The multi-rounds double auction is budget balanced. The budget balance means that the auctioneer's income is no less than zero, that is, the buyer's payment does not exceed the seller's payment.

Proof: The total payment of the WiFis is equal to the revenue of the CPs in our auction mechanism, so that our auction mechanism is budget balance.

$$P_i = \sum_{k=1}^{K}\sum_{j=1}^{M}\sum_{i=1}^{N}\left(x_{ij}{s_i}^k\frac{b_i^k + a_j^k}{2}\right). \tag{14}$$

■

Based on the mechanism of the auction algorithm, we have the following theorem that the allocation rule is monotone in our algorithm:

Theorem 3: The allocation mechanism is monotone if the CP still wins the resource when it bids for a higher price than its previous price and when the size of the bundle is smaller than the previous bundle.

Proof: As we have discussed, the algorithm allocates bundles to the WiFis according to descending order of the bid density bd_i. As $bd_i = \frac{B_i^*}{\sqrt{\sum s_i^k p_k^i}}$, a higher value of b_i and a lower value of s_i will be a preference of this mechanism.

Assume the a WiFi can successfully obtain the allocation from CP_j, then if it improve the bid b_i, the it will still in the allocation matrix and because it always wants the same bundle from the same CP, the allocation results will be the same which means the bid is still a winning bid. Additionally, if the WiFi decide to promote a decreased s_i, which means it wants a smaller bundle of resource with the same bid, then obviously it can win the allocation. So that we can conclude that the allocation mechanism we proposed is monotone according to the definition of monotonicity. ■

As the CPs and WiFi points are individual rational and budget balanced according to Theorem 1 and Theorem 2, the following theorem shows the truthfulness of the auction:

Theorem 4: In the auction process, the proposed algorithm will guarantee that WiFis are truthful.

Proof: Cheating means lie to the auctioneer and give a scaling bid instead of its true valuation of the resource. An auction mechanism is truthful is the bidder can obtain its optimal utility for the resources within its restrictive conditions.

In the algorithm we proposed, the critical payment rule associates with the monotone allocation mechanism is exhibited by $p_i \leq v_i$ when WiFi i wins the allocation and $p_i = 0$ if it loses the allocation. This means that the winning WiFi pays the payment according to the critical payment rule and the WiFi who loses the allocation pays zero. According to [25], as the algorithm is monotone and the payment rule is critical.In our auction mechanism, if a bidder cheats, then the bid density list will change and the bidder may be assigned to the seller with a higher ask price or a seller with a low popularity. This will cause a lost to the bidder's utility, we can conclude that our proposed mechanism can guarantee truthfulness. ■

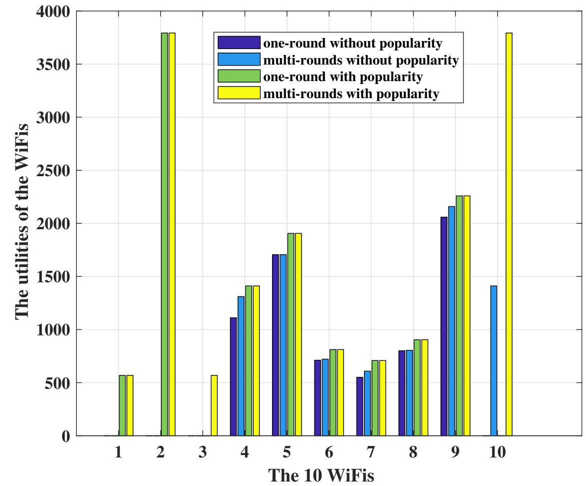

Fig. 3. WiFi's utilities under different mechanisms.

Based on the above theorems, we have the following theorem about conditional equilibrium in our auction mechanism:

Theorem 5: In the auction process, the proposed algorithm will form a conditional equilibrium. According to [26], an algorithm will form a conditional equilibrium if it satisfies the following conditions:

(1) Individual Rationality: $S_j^{\text{CP}} \geq 0$ and $S^{\text{cell}} \geq 0$.

(2) Outward Stability: $v_i^k \leq p_i^k$.

Proof: The payment price and the allocation matrix is outward stable if there is no CP and no WiFi will change the bundle of the files at the current bid.

In the algorithm that we proposed, the CPs and the WiFi points can change their asks and bids in the next round of the auction until reach the threshold of their true value. In addition, the algorithm we proposed meets the requirement of individual rationality and outward stability. So that at the end of the auction, the CPs and WiFi points have no incentive to deviate from the allocation results. ■

IV. Numerical Results

In this section, we set that there are 6 CPs and 10 WiFi points and set the path loss to $\alpha = 4$, the transmit power to $P = 2$, and the noise power to $\sigma^2 = 10^{-10}$. We use 'one-round' to represent the traditional double auction with only one round auction process to determine the result of the game.

We compare the utilities of the WiFis from the perspective of one-round auction and multi-round auction processes in

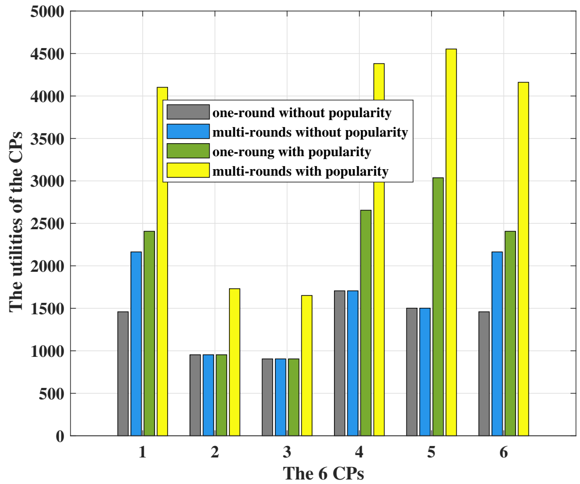

Fig. 4. CP's utilities under different mechanisms.

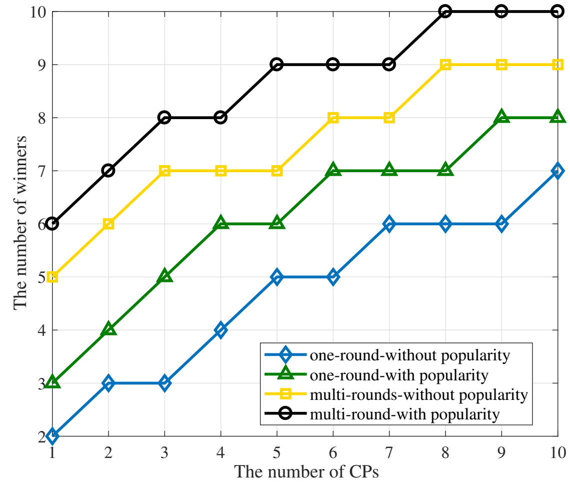

Fig. 5. Number of winners according to different auction mechanisms.

Fig. 3. It also shows the utilities of the WiFis under multi-rounds double auction without consideration of the popularity weight of the files. From Fig. 3, we can see that the multi-rounds auction mechanism which takes the popularity of the files into consideration is more profitable for the WiFis. This is because when the popularity of the mobile users' needs is satisfied, the transmission asks from the mobile users will increase, the caching profit from decreasing transmission latency will increase. In Fig. 3, the utilities of the multi-rounds auction are obviously higher than the one-round mechanism. For the WiFis, the multi-rounds double auction is more efficient and incentive for them.

We compare the utilities of the CPs in the one-round auction mechanism and our proposed multi-rounds double auction with consideration of popularity weights Fig. 4. And it shows that the utilities of the CPs in the multi-rounds double auction with the consideration of popularity is more profitable than the one-round mechanism. In Fig. 4, we also show the utilities of the CPs under one-round auction and multi-rounds auction without consideration of popularity weight. From Fig. 4, the utilities of CPs without considering popularity weight is smaller than the mechanism with popularity weight, we can also conclude that the mechanism which taking the popular parameter as a weight is more incentive for the CPs.

In Fig. 5, we compare the number of the WiFis who successfully get the resources from the CPs in addition to different numbers of CPs. In this figure, we can conclude that with different numbers of CPs, the winners numbers of the multi-round auction considering the popularity parameters is larger than the one-round auction and the multi-rounds auction without considering popularity parameters. We can conclude that the mechanism is more efficient in resource allocation.

In Fig. 6, the relation between the average delay and the number of mobile users under different algorithms is given. It can be seen that the average delay of the algorithm proposed is less than that of other algorithms. And the average delay

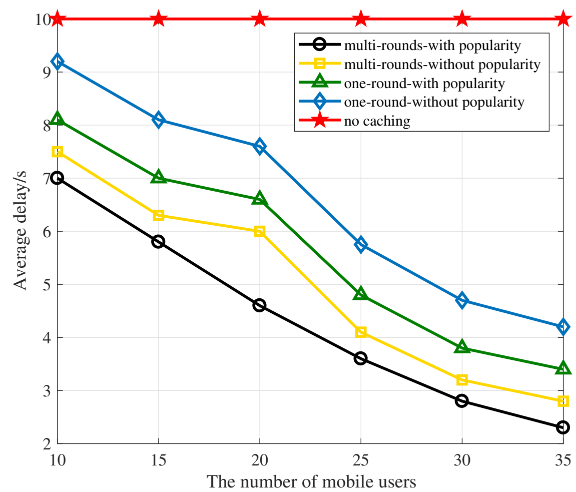

Fig. 6. Average dalay according to different auction mechanisms.

of mobile users is greatly reduced compared with the case where the file is not cached in the WiFis. It can be seen that the algorithm can be effective in the allocation of caching to improve network transmission efficiency.

V. Conclusion

Caching popular files in WiFi points can provide better service for the mobile users. In this paper, we propose a multiple rounds double auction mechanism for the CPs to rent copyrights of the files to the WiFi points. The popularity of the files is considered as a weight parameter. We will bundle the files according to its popularity. This auction mechanism is individual rational and budget balanced. We also prove that the allocation process is monotone and truthful and will form a conditional equilibrium. Simulation results show that the algorithm can effectively reduce transmission latency and improve network performance.

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