Double Auction-based Optimal Relay Assignment for Many-to-Many Cooperative Wireless Networks

Yong Wang[1,2], Yun Li[3,5], Xiaolong Yang[1,4], Chao Liao[3], Quan Chen[3]
[1]School of Communication and Information Engineering,Univ. of Electronic Science and Technology of China,
Chengdu 611731,China
[2]Department of Mathematics and Information Engineering, Chongqing University of Education, Chongqing 400065, China
[3]Key lab of Mobile Communication technology,Chongqing Univ. of Posts and Telecommunications,Chongqing 400065,China
[4]School of Computer and Communication Engineering,Univ. of Science and Technology Beijing,Beijing 100083,China
[5]National Mobile Communications Research Laboratory, Southeast Univ. of China, Nanjing 210096, China

***Abstract*—Recently, as it can increase the capacity of wireless networks greatly through spatial diversity by taking advantage of antennas on other nodes, cooperative communication (CC) has been obtaining more and more attention. However, as the selfish nature, the wireless node may be unwilling to serve as relay node if they can't get the corresponding reward. In this paper, we constructs a real double-auction scenario between source nodes and relay nodes instead of idealized truthful market which may obtain relatively lower system performance. We consider the system performance involving (1) successful source-relay pairs, (2) system capacity and (3) social welfare (SW). We transform the double auction-based optimal relay assignment problem into Maximum Matching (MM) and Maximum Weighted Matching (MWM) problem respectively and solve them using corresponding algorithms. Extensive experiments show that this mechanism can achieve higher system efficiency than truthful auction.**

***Index Terms*—wireless cellular networks, cooperative communication, double auction**

I. INTRODUCTION

To achieve spatial diversity without multiple transceiver antennas on the same node, CC [1]–[3] has demonstrated its potential to increase the channel capacity by the cooperative of other wireless devices (generally called relay nodes). Under CC, each wireless device achieve spatial diversity by exploiting the antenna on cooperative node own to the nature of broadcast. In CC, selecting proper relay node critically influence the whole system performance [4] because an improperly chosen relay node for a source-destination pair may produce an even smaller data rate than that under direct transmission. So, the relay nodes assignment plays an important role in the performance of CC [5] [6].

In CC, due to the selfish nature of user, one must consider the incentives for the participating wireless nodes to serve as relay nodes because they may be unwilling to relay the traffic of another node at the cost of their own resource. One solution to this dilemma is to compensate the relay node in return. As a result, a buyer/seller market is formed between the source nodes demanding relay service and the relay nodes offering such services. Nevertheless, users may not reach a consensus on the amount of money that source node want to pay and relay node intend to receive. As one of the most popular bargaining form, auction can be employed to handle this problem [7]. Traditional auction occurs either between one seller and many buyers or between many sellers and one buyer. This auction scheme is called single-sided auction. It is evident that single-sided auction is not appropriate to CC because there are many nodes acting as buyer or seller at the same time. Recently, double auction theory is applied widely because it can solve multi-buyers and multi-sellers problems which are commonly encountered in the buyer/seller market. In this paper, we use double auction to study the relay node assignment problem in CC which comprise multi-source nodes and multi-relay nodes simultaneously.

In consideration of system performance, we expect that CC system utilize resource reasonably among all relay nodes so that the CC system has the best potential to accommodate as many users as possible. In addition, from economical concept, a market is efficiently if it produce higher social welfare which is defined as the sum of all participators's payoff. Therefore, we also hope that the CC system allocate resource properly so as to acquire as high social welfare as possible.

Our model differs from some previous work [8] which merely emphasize on how to guarantee the truthful bidding. Although designing truthful auction mechanism can simplify the double auction, it may decrease the system performance. To achieve higher system performance, we aim to construct an open market in which the source nodes and relay nodes are not urged to bid(ask) truthfully. After all, to a CC system, system performance is the most important goal instead of the truthful telling merely.

The main contributions of this paper are the following. (1) We transform the value of source node and the cost of relay node into utility function so that they can be compared under an uniform style. (2) We model the relay assignment problem of CC as double auction mechanism. (3) We consider the avaricious psychology of user by employing markup concept to conform the double auction to more realistic case. (4) we depict the double auction of CC as bipartite grapy and solve it with MM and MWM problem [12].

The outline of this paper is given as follows. In Section 2, we briefly describe the previous works which use auction and double auction in CC. In Section 3, we detail the necessary preliminaries and formulate the problem examined in this

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paper. In Section 4, we formalize the objective function that we use to depict the goal of our mechanism. Subsequently, we transform the problem into the bipartite grapy and describe the detailed algorithm for it. In Section 5, we report the results of numerical validation of our algorithm. Finally, we conclude our paper in Section 6.

II. RELATED WORK

There are two famous double auction mechanisms, Vickrey-Clarke-Groves (VCG) double auction [9] [13] [14] and M-cAfee double auction [15]. Both double auction can satisfy *truthfulness* property. Nevertheless, VCG and McAfee can not achieve system maximal efficiency. In [16], R. B. Myerson alleged that it is impossible for double auction mechanism to satisfy strategy-proof(truthfulness) and system efficiency at the same time. In [18], Minghua He presents a fuzzy logic based bidding strategy instead of truthful telling in double auction. The best ask/bid for an agent is determined by heuristic fuzzy rules and a reasoning mechanism. In [17], author introduce a method for bid strategy acquisition in the double-auction market without regard to the truthfulness. Their methods focus on searching for bid strategies strategically which can increase the probability of success in the auction.

There are many research on the relay assignment problem in CC. In [22], a distributed relay selection and power control for CC networks using stackelberg game is proposed where single source node communicate with a single destination node via multiple relay nodes. In [19], Majid Janzamin propose Stackelberg game method for power allocation taking nodes' selfishness into consideration in CC networks. However, the work consider only two source nodes who act as both buyer and seller. In [20], the paper proposes the SNR auction and the power auction to determine relay selection and relay power allocation in single-relay network and then generalize it to multiple relays networks *under specific conditions*. In [21], a power allocation in wireless ad-hoc networks is proposed where multiple source nodes communicate with a single destination node via a relay node. Nevertheless, all above works do not consider the multi resource nodes versus multi relay nodes scenario. Meanwhile, these work only aim at the individual benefit of agent rather than the whole system performance.

In [8], Yang et al. propose a valuable truthful double auction for CC by adjusting McAfee [15] because the goods in CC is heterogeneous which make it insolvably by McAfee directly. The proposed double auction system meets truthfulness property but system efficiency. That is to say, the system guarantee the strategy-proof property at the expensive of the system efficiency. There is an example as shown in fig.1 in which no selected relay nodes can conclude a transaction using TASC [8]. Meanwhile, In [6], Sharma et al. proposed the relay assignment problem in a cooperative ad hoc network environment where multiple source nodes seek for cooperation from multiple relay nodes in the network. Nevertheless, the system only pursue the maximal minimum capacity among all source nodes other than the system maximal performance.

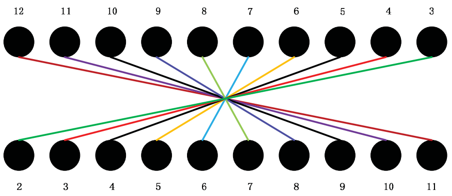

Fig. 1. An example in which all selected relay nodes can not conclude a transaction using TASC [8]

Consequently, we focus on solving optimal relay assignment between multi-users based on double auction theory by considering system performance which is most importantly to the CC system.

III. PRELIMINARIES AND PROBLEM FORMULATION

A. Cooperative Communications

In this section, we describe the capacity expressions of direct transmissions (i.e., no cooperation) and CC. For CC, we utilize the amplify-and-forward (AF) protocol [1] as our system model while other cooperation protocols [1] can be regarded as a similar case.

In the first time slot, source node u transmits its information to destination node b. At the same time, relay node v overhears it due to the broadcast nature. The received signals $y_{u,b}$ and $y_{u,v}$ at node b and node v can be expressed as below.

$$y_{u,b} = \sqrt{P_u G_{u,b}}x + n_{u,b}, \tag{1}$$

$$y_{u,v} = \sqrt{P_u G_{u,v}}x + n_{u,v}, \tag{2}$$

where P_u is the power that node u consumes to broadcast its data, x is the signal transmitted from node u with unit energy. $G_{u,b}$ and $G_{u,v}$ are the path gain of source node u to destination node b and source node u to relay node v channels respectively. $n_{u,b}$ and $n_{u,v}$ are the additive white Gaussian noises (AWGNs) on two channels. Although relatively simple signal and channel models are employed in this paper, the analysis can be extended to more practical and complex models, i.e., OFDM transmission with multipath channels [23]. Without loss of generality, we assume that the noise power is the same for all the links and is denoted by σ^2. We also suppose that the transmission frame length is small compared with the channel coherence time such that all channel gains are stable over the time of interest. Without the help of the relay stations, the signal-to-noise ratio (SNR) that results from the direct transmission at destination b in first time slot can be expressed as

$$SNR_{u,b} = \frac{P_u G_{u,b}}{\sigma^2}. \tag{3}$$

Therefore, the capacity of the direct transmission is

$$C_{u,b} = W \log_2^{(1+SNR_{u,b})}, \tag{4}$$

where W is the total bandwidth exploited by node u and node b. In the second time slot, relay node v amplifies $y_{u,v}$ and forwards it to destination node b consuming power P_v. The received signal at destination node b is

$$y_{v,b} = \sqrt{P_v G_{v,b}} x_{u,v} + n_{v,b}, \tag{5}$$

where

$$x_{u,v} = \frac{y_{u,v}}{|y_{u,v}|} \tag{6}$$

is the normalized transmitted signal $y_{u,v}$ from node v to node b i.e. it has unit energy. $G_{v,b}$ is the channel gain from node v to node b, and $n_{v,b}$ is the received noise. The relay path SNR for node u at the destination b is

$$SNR_{u,v,b} = \frac{SNR_{u,v} SNR_{v,b}}{1 + SNR_{u,v} + SNR_{v,b}}. \tag{7}$$

Assuming a MRC (maximal-ratio combining) receiver at the destination, by (4) and (7), the achieved rate for node u resulted from direct path and relay path is

$$C_{u,v,b} = \frac{W}{2} \log_2^{(1+SNR_{u,b}+SNR_{u,v,b})}, \tag{8}$$

where the coefficient $\frac{1}{2}$ is a bandwidth factor indicating that cooperative transmission under the help of relay node occupies half of the resources(e.g., time slots, frequency bands).

B. Problem Model

In this paper, We study the similar scenario as in [8]. We consider a cell in cellular network which comprise one base-station, M source nodes denoted as $U = \{u_1, u_2, ..., u_M\}$ and N relay nodes denoted as $V = \{v_1, v_2, ..., v_N\}$. We assume the base-station which is all source nodes' destination acts as an auctioneer in the auction scheme.

In this paper, the double auction in CC is a centralizing fashion which conduct at a certain time point. The source nodes act as buyer while the relay nodes act as seller. The relay service is regarded as commodity. If the node are idle, it can provide cooperative service to source nodes. They claim for monetary reward to compensate the expenditure of resources, e.g. energy. Meanwhile, source nodes submit bids to auctioneer and pay it when transactions are reached. Because different relay nodes may provide various capacities for a fixed source node, so the commodities are heterogeneously. Therefore, each source node should value cooperative service from different relay nodes differently. We define t_m^n be the true valuation of buyer u_m to seller v_n which express the willingness that u_m will pay no more than it. Let $T_m = (t_m^1, t_m^2, ..., t_m^N)$ be the true valuation vector of buyer u_m in which $t_m^n > 0$ if $C_{u_m,v_n,b} > C_{u_m,b}$ and $t_m^n = 0$ otherwise. Meanwhile, Let e_n be the actual expenditure of seller v_n denoted as energy consumption. Because the destination is same, so the cost of relay node is identical if we assume it uses the same transmission power. Furthermore, We suppose that each source node seeks for at most one relay node and each relay node can be utilized by only one source node simultaneously.

Following economic terminology, we call the price information submitted by source node and relay node *bid* and *ask* respectively. After the last auction finish, the auctioneer begins to receive the bid vector $Q_m = (q_m^1, ...q_m^n, ..., q_m^N)$ in which q_m^n is the bid of u_m to v_n. Meanwhile, the auctioneer receives the asks of all relay nodes. When the bid(ask) deadline arrive, auctioneer launch the auction. The double system uses a matrix $Q = (Q_1; ...; Q_M)$ to accommodate the bids from all source nodes. The vector $O = (o_1, ..., o_N)$ is employed to contain all the asks.

The gains of source node u_m through the cooperation of relay node v_n can be expressed as

$$C_m^+ = C_{u_m,v_n,b} - C_{u_m,b}, \tag{9}$$

where C_m^+ can be regarded as the true valuation t_m^n.

Next, we compute the loss of the relay node during the cooperation action. For simplicity, we only consider the power loss. However, the power loss can not be compared with the increased channel capacity because they are inhomogeneity.

Therefore, we need to transform both the increased channel capacity and the power loss into an uniform form which can be compared. We employ the transformation function [11] as below to depict the utility of the source node and the relay node,

$$F(C) = \begin{cases} \alpha(1 - \exp(-\beta C)), & C > 0\ , \\ 0, & C \leq 0, \end{cases} \tag{10}$$

where $F(C)$ is the function of channel capacity C, α and β are strictly positive real numbers which α represents the upper limit of the utility, and β determines the shape of the curve.

According to (4) (8) and (10), if source node u_m get the help of relay node v_n , he will obtain extra utility

$$I_m^n = F(C_{u_m,v_n,b}) - F(C_{u_m,b}). \tag{11}$$

For relay node v_n, it expends power P to relay signals and its loss can be expressed as

$$L_n = F(C_{v_n,b}(P_n)) - F(C_{v_n,b}(P_n - P)), \tag{12}$$

where P_n is the energy of relay v_n before cooperation, and P is the transmission power. We assume all nodes use the same power P for signal transmission.

Due to the profit motive, traders are often reluctant to reveal their true value/cost of the commodity. Therefore, the buyer u_m may submit a bid lower than its value. Similarly, the seller v_n may submit an ask higher than its actual cost. In economics terminology, these extra part is called *marks-up*.

We define the marks-up of u_m and v_n as k_m^s and k_n^r respectively. Taking the marks-up into consideration, the source node u_m bids as

$$q_m^n = t_m^n \exp(-k_m^s) = I_m^n \exp(-k_m^s). \tag{13}$$

Accordingly, considering the marks-up, the relay node v_n asks as

$$o_n = e_n \exp(k_n^r) = L_n \exp(k_n^r). \tag{14}$$

We assume the base-station is zero economic profit in double auction market. In fact, although the base-station gain nothing in double auction, he provide higher QoS for customer which can attract more user to join in.

Finally, the base-station determine the Pay_m and $Recei_n$ as below

$$Pay_m = Recei_n = \frac{q_m^n + o_n}{2}, \tag{15}$$

where Pay_m is the money that buyer u_m need to pay and $Recei_n$ is the money that seller v_n should receive.

Then, the payoff(denoted as PO) of u_m and v_n is expressed as below

$$PO_{u_m} = t_m^n - Pay_m. \tag{16}$$

$$PO_{v_n} = Recei_n - e_n. \tag{17}$$

Therefore, the social welfare(denoted as SW) can be expressed as

$$SW = \sum_{m=1}^{M}\sum_{n=1}^{N}(PO_{u_m} + PO_{v_n}) = \sum_{m=1}^{M}\sum_{n=1}^{N}(t_m^n - e_n). \tag{18}$$

In the next section, we will solve the double auction problem for CC.

IV. THE DOUBLE AUCTION MECHANISM

It is evidently that an efficient CC system should maximize the source-relay pairs to satisfy more user. Meanwhile, a CC system should also give it's best to achieve maximal social welfare by allocating the resource reasonably.

We define the binary variable x_m^n to indicate whether the source node u_m is assisted by relay node v_n. Then, we can express the source-relay pair maximization problem (denoted as $P1$) and the social welfare maximization problem (denoted as $P2$) as the following integer linear program (ILP):

$$\begin{aligned} P1 : Maximize & \sum_n \sum_m x_m^n \\ P2 : Maximize & \sum_n \sum_m (t_m^n - e_n) x_m^n \\ SubjectTo : & \sum_{n \in V} x_m^n \leq 1,\ \forall\ m \\ & \sum_{m \in U} x_m^n \leq 1,\ \forall\ n \\ C_{u_m,v_n,b} > C_{u_m,b},\ & if\ x_m^n = 1 \\ q_m^n \geq o_n,\ & if\ x_m^n = 1 \\ x_m^n \in & \{0,1\},\ \forall\ m, \forall\ n \end{aligned}$$

The first constrain reflects that each source node is assisted by at most one relay node simultaneously. The second restriction indicates that each relay node help no more than one source node at the same time. The third restraint show the necessary conditions of CC. Without this requirement, the source node will not select CC mode. The fourth restriction expresses the pith of business. If dissatisfying this condition, the transaction can not be concluded.

To solve the above two integer linear program problem, we first characterize the double auction scheme as a bipartite graph. We construct a bipartite graph $G(\pi, \zeta, \xi, \varphi)$ in which vertices set π and ζ represent the buyer set and the seller set respectively. ξ is edges set and φ denote weight on edges. Consequently, we transform $P1$ and $P2$ into the MM problem and the MWM problem [12] respectively and solve it using corresponding algorithms.

The detailed pseudo-code is illustrated in Algorithm 1.

```
input : a set $U$ including all source nodes,
        a set $V$ comprising all relay nodes.
output: a relay assignment $\psi$.
        payment and price for all winning nodes.
Step 1: Bipartite graph formation;
Construct a set $\pi$ of $M$ vertices corresponding to $U$ ;
Construct a set $\zeta$ of $N$ vertices corresponding to $V$;
Construct a edges set $\xi = \emptyset$;
for all $u_m$ in $\pi$ do
    for all $v_n$ in $\zeta$ do
        if $q_m^n \geq o_n$ and $C_{u_m,v_n,b} > C_{u_m,b}$ then
            $\xi \leftarrow \xi \cup (u_m, v_n)$
            $\varphi(u_m, v_n) = t_m^n - e_n$
        end
    end
end
Step 2: Relay assignment and Winner determination;
(1)to achieve maximal transactions, use the Maximum
Matching algorithm(MM)[13];
(2)to earn maximal social welfare, employ the
Maximum Weighted Matching algorithm(MWM)[13];
Step 3:Price and payment determination ;
for all winning source nodes $u_m$ do
    if corresponding relay node is $v_n$ then
        $u_m$ pays $\frac{q_m^n+o_n}{2}$;
        $v_n$ receives $\frac{q_m^n+o_n}{2}$;
    end
end
```

Algorithm 1: Double Auction for Relay Assignment Problem

V. NUMERICAL RESULTS

We consider a wireless network where nodes are distributed in a 1000×1000 square randomly. We assume the number of source nodes are equal to that of relay nodes, namely, $M = N$. Following the parameter settings in [8], we assume W = 22 MHz bandwidth for each channel. The transmission power P at each node is set to 1 W. Each relay node employs AF mode for CC. The channel gain between any two nodes is given by $G_{m,n} = d_{m,n}^{-\nu}$, where $d_{m,n}$ is the distance between two nodes u_m and v_n and the path-loss exponent ν is set to 4. For the AWGN channel, we assume the noise is 10^{-10}.

We varied the number of nodes from 20 to 110 with increment of 10. For each topology, we randomly generated 100 instances and averaged the results. All the tests were run on a windows XP Notepad with 2.1 GHz Intel Core i3 CPU and 4.0 GB memory. The marks-up of users are randomly distributed over [0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0]. The performance metrics involve the number of successful source-relay pairs, total system capacity, social welfare. For narrate convenience, we denote the MM based TASC [8] as MM-TASC and the MWM based TASC as MWM-TASC respectively.

To verify the performance of our methods on three system efficiency metrics, namely, successful source-relay pairs, total system capacity, social welfare, we compare the MM with MM-TASC and compare the MWM with MWM-TASC respectively. In Figure 2 and Figure 3, we depict the evolution of average successful source-relay pairs along with the mobile user increase. Firstly, we note that the successful source-relay pairs obtained by MM and MWM is larger than that of MM-TASC and MWM-TASC respectively. The reason resulting in this phenomenon is that TASC has to discard some candidate trade which can come to a transaction to guarantee the truthful property while our methods do not. Obviously, due to the random changing topology of CC networks, the successful source-relay pairs do not increase monotonously as the mobile user increase. Secondly, the successful source-relay pairs in Figure 2 excel that of Figure 3 because MM and MM-TASC focus on maximum source-relay pairs while MWM and MWM-TASC aims at maximal weight-sum, namely, social welfare.

Similarly, we show the variation of system capacity with the mobile user increase via Fig. 4 and Fig. 5. Firstly, it is evidently that the total system capacity obtained by MM and MWM is also larger than that of MM-TASC and MWM-TASC respectively because our methods do not abandon any candidate cooperation to safeguard strategy-proof property. Secondly, it is shown that the system capacity in Figure 4 excel that of Figure 5. Investigate its reason, it is because that the weight of MWM and MWM-TASC is $t_m^n - e_n$ rather than capacity of each source-relay pair. Moreover, from table I and table II, we can see that the gap between our methods and TASC is about 10%, denoting that our methods can improve the system social welfare than TASC. Furthermore, it is displayed that the social welfare obtained by MM and MM-TASC in Table I are largely less than that of Table II. Investigating into it, the reason is that the MWM and MWM-TASC employ $t_m^n - e_n$ as the weight of each source-relay pair and try its best to obtain maximal social welfare while the objective of MM and MM-TASC is maximum source-relay pairs.

From numerical results, it can be concluded that our methods can achieve higher system performance than TASC and can enhance system throughput and QoS of cooperative cellular network greatly.

VI. CONCLUSIONS AND FUTURE WORK

The system performance of CC hinges upon the assignment of relay nodes in the network. In this paper, we study this problem by constructing a double auction scenario, where multiple source nodes compete for the chance to increase capacity and multiple relay nodes strive for the opportunity to sell service. Our objective is to assign the available relay nodes to different source nodes so as to (1) maximize the successful source-relay pair and (2) maximize the social welfare. The main contribution of this paper is that we construct a realistic market using double auction in consideration of the selfish nature of user. We used numerical results to demonstrate its efficacy. Although we offered a outline of the implementation, a number of issues remain challenging in practice. In particular, the value of the markup should be determined on the basis of the node

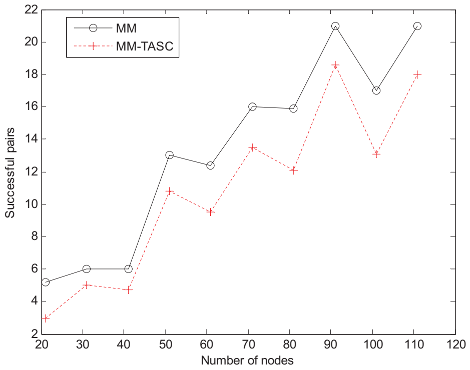

Fig. 2. Successful pairs by employing MM over MM-TASC

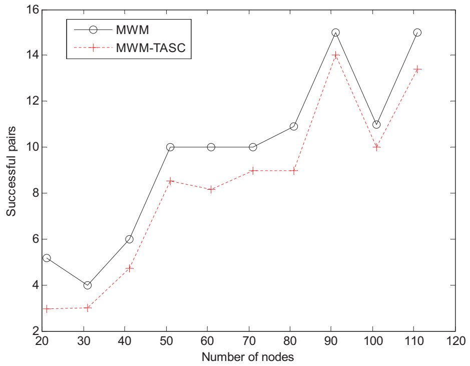

Fig. 3. Successful pairs by employing MWM over MWM-TASC

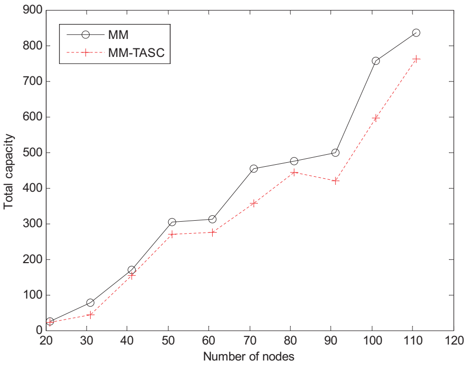

Fig. 4. Total capacity by employing MM over MM-TASC

TABLE I
SOCIAL WELFARE BY EMPLOYING MM OVER MM-TASC

Topology Number	1	2	3	4	5	6	7	8	9	10	11	12
SW using MM	70.9	86.9	107.2	85.8	98.0	99.5	104.1	84.2	88.6	93.1	103.2	101.4
SW using MM-TASC	63.6	78.6	96.2	78.6	90.6	90.8	94.9	75.6	81.4	84.5	95.0	91.3
Rate of Increase(%)	11.5	10.7	11.3	9.1	8.7	9.6	9.6	11.3	8.8	10.2	8.5	11.0

TABLE II
SOCIAL WELFARE BY EMPLOYING MWM OVER MWM-TASC

Topology Number	1	2	3	4	5	6	7	8	9	10	11	12
SW using MWM	193.7	202.0	226.1	197.7	213.6	200.7	190.6	244.5	223.8	201.3	239.7	172.9
SW using MWM-TASC	179.1	183.7	208.7	182.6	1980.	181.2	174.0	217.3	207.6	178.7	220.2	155.4
Rate of Increase(%)	8.2	10.0	8.3	8.3	7.8	10.8	9.5	12.5	7.8	12.6	8.8	11.2

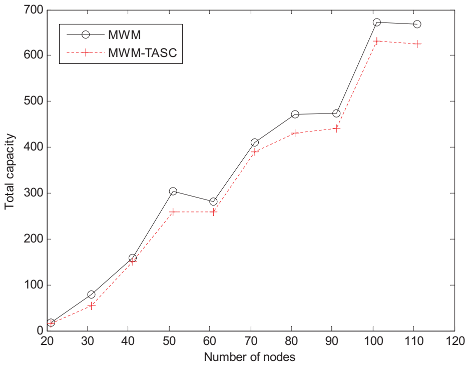

Fig. 5. Total capacity by employing MWM over MWM-TASC

status(such as residual energy) dynamically.

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REFERENCES

[1] J.N.Laneman, D.N.C.T., and G.W.Wornell, "Cooperative diversity in wireless networks:Efficient protocols and outage behavior," *IEEE Transactions on Information Theory*, vol. 50, no. 12, pp. 3062-3080, Dec. 2004.

[2] A. Sendonaris, E.E., and B. Aazhang, "User cooperation diversity - part I: System description," *IEEE Transactions on Communications*, vol. 51, no. 11, pp. 1927-1938, Nov. 2003.

[3] A. Sendonaris, E.E., and B. Aazhang, "User cooperation diversity- part II: implementation aspects and performance analysis," *IEEE Transactions on Communications*, vol. 51, no. 11, pp. 1939-1948, Nov. 2003.

[4] J. Cai, S.S., J.W. Mark, and A.S. Alfa, "Semi-distributed user relaying algorithm for amplify-and-forward wireless relay networks," *IEEE Transactions on Wireless Communication*, vol. 7, no. 4, pp. 1348-1357, April 2008.

[5] L. Ding, T.M., S. Batalama, and J. Matyjas, "Distributed routing, relay selection, and spectrum allocation in cognitive and cooperative ad hoc networks," *2010 7th Annual IEEE Communications Society Conference on Sensor Mesh and Ad Hoc Communications and Networks (SECON)* , Boston, Massachusetts, USA, June 2010.

[6] S. Sharma, Y.S., Y. T. Hou, and S. Kompella, "An optimal algorithm for relay node assignment in cooperative ad hoc networks," *IEEE/ACM Trans. Netw*, vol. 19, no. 3, pp. 879-892, Jun. 2010.

[7] Krishna, V., "Auction Theory," *Academic Press*, March 2002.

[8] Dejun Yang, X.F., and Guoliang Xue, "Truthful Auction for Cooperative Communications," *ACM MobiHoc 2011*, Paris, France, May 2011.

[9] W. Vickrey, "Counterspeculation, auctions, and competitive sealed tenders," *The Journal of Finance*, Vol. 16, No. 1, pp. 8-37, Mar. 1961.

[10] Y. Zhao, R.A., and T. J. Lim, "Improving amplify-and-forward relay networks: Optimal power allocation versus selection," *IEEE Transactions on Wireless Communications,* Vol. 6, No. 8, pp. 3114 - 3123, August 2007.

[11] Yu, T.N.a.W., "Joint Optimization of Relay Strategies and Resource Allocations in Cooperative Cellular Networks," *IEEE J. Selected Areas in Comm*, Vol. 25, No. 2, pp. 328-339, August 2007.

[12] D.B.West, "Introduction to Graph Theory: Second edition," *Prentice Hall*, 2001.

[13] E. H. Clarke, "Multipart pricing of public goods," *Public Choice*, Vol. 11, No. 1, pp. 17-33, September 1971.

[14] T. Groves, "Incentives in teams," *Econometrica*, Vol. 41, No. 4, pp. 617-31, July 1973.

[15] R. P. McAfee, "A dominant strategy double auction," *Journal of Economic Theory*, Vol. 56, No. 2, pp. 434-450, April 1992.

[16] R. B. Myerson and M. A. Satterthwaite, "Efficient mechanisms for bilateral trading,". *Journal of Economic Theory*, Vol. 29, No. 2, pp. 265-281, April 1983.

[17] Phelps, S., McBurney, P., and Parsons, S., "A novel method for strategy acquisition and its application to a double-auction market," *IEEE Transactions on Systems, Man, and Cybernetics, Part B: Cybernetics,* Vol. 40, No. 3, pp. 668-674, June 2010.

[18] Minghua He and Ho-fung Leung, "An agent bidding strategy based on fuzzy logic in a continuous double auction," *Proceedings of the fifth international conference on Autonomous agents,* ACM, New York, NY, USA, Oct 2001.

[19] Janzamin Majid, Pakravan MohammadReza, Sedghi Hanie, "A Game-Theoretic Approach for Power Allocation in Bidirectional Cooperative Communication," *2010 IEEE Wireless Communications and Networking Conference (WCNC)*, April 2010.

[20] Jianwei H., Zhu Han, Mung Chiang, and H. Vincent Poor, "Auction-Based Resource Allocation for Cooperative Communications," *IEEE Journal on Selected Areas in Communications,* vol. 26, no. 7, pp. 1226-1237, September 2008.

[21] Baidas M.W., MacKenzie A.B., "Auction-based power allocation for many-to-one cooperative wireless networks," *2011 7th International Wireless Communications and Mobile Computing Conference (IWCMC)*, pp.1677-1682, July 2011.

[22] Beibei Wang, Zhu Han, and K.J. Ray Liu, "Distributed Relay Selection and Power Control for Multiuser Cooperative Communication Networks Using Stackelberg Game," *IEEE Transactions on Mobile Computing*, Vol. 8, No. 7, pp. 975 - 990, July 2009.

[23] Y. Zhou, J. Wang, and M. Sawahashi, Downlink transmission of broadband OFCDM systems—Part I: Hybrid Detection, IEEE Trans. Commun., vol. COM-53, no. 4, pp. 718-729, April 2005.