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Cooperation Stimulating strategy based on demand/supply curve exchange for wireless network

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Abstract: Stimulating cooperation is the critical issue for the successful implementation of cooperative strategy in wireless network. Nodes in the wireless network having limited resources so they naturally ready to take the benefit of cooperation and but are not ready to help others by using their own resource. Buyer-seller market model has the properties to become an efficient stimulating strategy in which source buy help of relay by using virtual currency or token and collected virtual currency can be sent by them to buy help of the other user in the network. We have presented a modified auctioning game, a subset of Game theory to model the interaction between the source and the relay as buyer and seller of identical multiple objects based on their demand & supply curves. Compared to clock-auctioning technique which results in the large delay and computational complexity, our proposed technique is faster with reasonable complexity.
Keyword: Cooperative communication, auction, game theory, cooperation stimulation, demand-supply curve.

Introduction

Cooperative communication has been proved to be very promising concept for next generation wireless communication systems [1-3]. In which multiple nodes in the network help each other's transmission to achieve diversity. Many cooperative relaying strategies are proposed in the literature for optimizing the overall network performance. Out of them, amplify-and-forward (AF) and decode-and-forward (DF) are widely used and showing significant advantages. In AF, the relays simply forward amplified versions of the signals transmitted by the without decoding where as in DF, the relays decode the transmitted signal by the source and transmit the re-encoded signals [1]. Issues of cooperative networks have been discussed in [4-7]. The performance of the physical layer parameter has been extensively studied for the small networks from conceptual view, but there is still large number of issues preventing feasibility of cooperative communication in real life realization through efficient resource allocation.

Resource optimization in centralized requires the knowledge of global channel information i.e. channel state information between each source-relay, relay-destination & source-destination pairs. In addition to that each node has its own resource constraints. Looking at the futuristic heterogeneous network, we are motivated to devise distributed resource allocation algorithm which can satisfy the performance parameters of the users as well as the network. Resource allocation is the key issue in cooperative networks which has attracted attention from the research community for reaping the maximum benefit of the cooperative network. Centralized techniques have been discussed in [7-8] and distributed techniques in [9-11]. In [12], resource allocation for cooperative transmission is done using Stackelberg games.

In all the above mentioned papers, nodes in a network are assumed to be altruistic and willing to cooperate to optimize the overall network performance without any expectation of getting 'something' in return. But in practical networks, however,nodes are selfish and aim to be paid for helping others.

On the other hand, due to limited resources available, multiple selfish users in the network try to get help from others but hesitate in using their resources to help others. For cooperation to sustain and maintain in the distributed network, it is important to find solution in such a way that source and relay both get benefit by cooperating with each and at the same time selfish behavior of the node can be prevented.

To model and analyze the strategy between the nodes, game theory is found to be appropriate in cooperative distributed network where the nodes are independent decision maker who manage their resources to optimize their performance. Game theory as a tool for network designing becomes increasingly popular in recent years. Many papers have appeared in literature, [13-20]. In[13], cooperative game (coalition) is considered for the up link of a network with multiple users and single base station. Here, users form coalitions and share resources and thus forming a virtual multi-antenna system. Bargaining game is employed in [14] for fair bandwidth allocation and power allocation is done in [15] by applying the Nash bargaining solution.

Auction is employed for establishing the buyer-seller relation between the nodes and encouraging relay to remain in cooperation [21-22]. There exits vast variety of types of auction [23]. In ascending / descending or first price/ second price auctions, step by step negotiation takes place between source and relay which results in large delay in establishing cooperation. Particularly in case of time varying wireless channel, the mechanism causing delay cannot sustain.

In this paper, we have proposed a modified auction technique in which during the handshaking phase, relay node collects price based demand function of all the sources in need of its help and then it applies its own supply function and based on that at once determines the allocation of its resource which can earn him maximum revenue. The revenue maximization for the relay is very full proof stimulation for binding him in the cooperation. Review of game in theory and auction is done in section II. Proposed algorithm is discussed in section III. In Section IV, simulation results are presented followed by discussion and conclusion.

Game Theory and Auctioning

In this section, we present a brief review of game theory. Game theory analyzes behavior in strategic situations, in which players influence each other's decision and performance. A game consists of three parts: a set of players, a set of actions of the players, and a set of utilities that represent the players' preference over the other options. Equilibrium is the strategy of a game in which none of the player wants to deviate from her strategy i.e. the best response of each user given the decision of others. The Nash equilibrium is the s equilibrium is in which no player can increase its utility by unilaterally changing its own strategy.

Auction theory is a subset of Game theory in which interaction between buyer and seller takes place either directly or with the help of some middleman (i.e. auctioneer). It can be buyer centric (reverse) or seller centric (forward) depending on the commodity to be auctioned. If the object to be sold is given to highest bidder and he pays the revenue equals to his bid, it is called first price auction or Dutch auction. If the highest bidder pays second highest price, it is called second price auction or English auction. It is also classified as ascending or descending price depending upon whether the bids starts from lowest and step by step increase to the highest or vice-versa[23].

In all these auction formats, the bid gradually increases in steps to meet the final price. In case of multiple buyer and single seller, it becomes computationally complex for the seller to determine the optimum selling strategies and price i.e. market clear ability. In [24], the issue of Market clear ability is handled by supply-demand curve.

A. Relay-centric Auctioning

We consider a market in which source is the buyer of units of power and relay is the seller having similar identical multiple units to sell. Each bidder (source) submits a demand curve indicating the quantity, say unit of power Q (P) he will accept at each unit price P to the seller (Relay). If his bid is cleared at price R, he receives Q(P) units, for a total price of P*Q (P) The demand curve may take any shape but we have chosen piece-wise linear demand curve as any function can be approximated as piece-wise linear curve.

Let the linear demand be

$$Q = \alpha . P + \beta \qquad (1)$$

in which Q is the quantity, P is the price per unit and α and β are constants and $\alpha < 0$ as demand would decrease with increasing price.

$$\text{RevenueR} = Q(P) * P \qquad (2)$$

$$R = \alpha P^2 + \beta P \qquad (3)$$

For maximizing the revenue, set first derivative of equation (3) to zero. We get

Price at which the revenue is maximized as

$$P^* = -\frac{\beta}{2*\alpha} \qquad (4)$$

In the following section, we build the cooperative scenario to allocate resource (power) of the relay to multiple sources.

System Model

Consider a relay network which consists of one destination node (D), one relay node(R), and several source nodes (S).In our case we have taken three source nodes. Relay node is not in line of sight communication path between S and D. Thus R is employed in order to assist communication between S and D. The source nodes can transmit data to destination node in two ways; either directly or with the help of relay node. The SNR is calculated in both the cases and if transmission through relay is found out to be more resourceful then the assistance of the relay node is taken otherwise direct communication between source node and destination node takes place. The figure [1] given below depicts the system model. Paths D1, D2 andD3 represent direct communication between source and destination. Paths IN1, IN2and IN3 are indirect paths which pass through relay. The relay node supplies power, bandwidth and many other entities. The auction takes place for the communication by paths in presence of relays. The relay nodes cooperative transmission follows amplify and forward (AF) protocol. All sources require the power provided by relay but because the relay has limited capacity, we employ the technique of auctioning for resource allocation. It is assumed that the amount of power put for auction is only for a limited period of time. Each source node can measure the channel coefficient of the link between it and the relay node as well as the destination node.

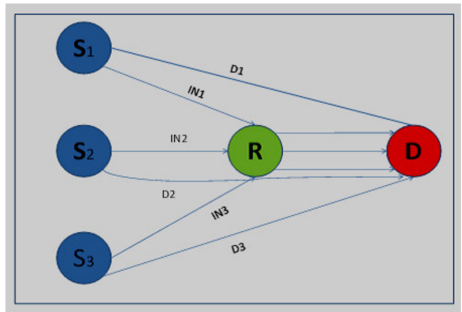

Fig. [1] System model

Based on this they can calculate the SNR of these links. As a result of this each source node can determine the data rate which it can achieve by using the direct links to the destination as well as the data rate which it can achieve by taking the help of the relay node. After evaluating all these factors a source node decides whether it wants to take the help of the relay node or communicate directly with the destination. For the sake of simplicity, we have assumed that each source node wants to take the help of the relay node in order to communicate with the destination node.

The bidding takes place based on the residual power of different sources. The residual power of a node is defined as the amount of power available to the node at any instant of time after the system has been initialized. The residual power is an important parameter for determining the life expectancy of a node. If the residual power of a source is more then it will bid less because the requirement of power is less and if residual power is less then it will bid more according to the requirement.

It is assumed that each source gives it demand to relay in form of a linear equation based on respective residual power. Based on the summation of the linear demand curves of different sources an aggregate demand curve is generated. The relay also has a linear supply curve with negative slope when compared to the demand curves of source nodes. When these linear curves are plotted together we get a point of intersection of aggregate demand curve and relay supply curve. This intersection point gives the optimum unit price for auctioning of power. The units of power are allocated based on the optimum price decided.

Multi-Unit Auction Algorithm

Our model works on the following algorithm as shown in figure [2].

STEP:1 The node which is acting as the relay node in a particular round of communication broadcast its bid vector. The bid vector consists of the number of units of a resource which the relay wants to put up for auctioning the base of the link between the relay node and the destination node.

STEP:2 The initial power of each node in the network has been assumed to be 1 W. At the instant of time when the bidding process begins the residual power of each source node is calculated. Based on the residual power of a source node it the slope of its linear demand curve is decided. As the network is dynamic in nature at any instant of time the residual power of each node will be different. It is evident from the curves that the slope of the demand curves is directly proportional to the residual power of the source nodes. As the residual power of the third source node is the least the slope of its linear demand curve is the least. This is due to the fact that as it has less power it needs the support of the relay node the most. Hence it is willing to buy more units of power from the relay node even at a higher price as compared to the other source nodes.

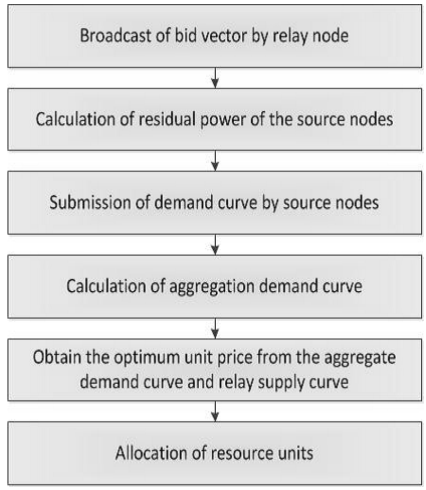

Fig.[2] Algorithm

STEP:3 After the slope has been decided the source nodes submit their demand curves to the relay node. Fig. [3] depicts the demand curves of the source nodes.

STEP:4 After the individual demand curves have been obtained by the relay node it calculates the aggregate demand curve. If the individual demand curves are say y1,y2 and y3 then the aggregate demand curve is y=y1+y2+y3.

STEP:5 The relay supply curve and the aggregate demand curve are compared and the optimum point of intersection is calculated such that the supply becomes equal to the demand. Also while calculating the optimum point the benefit of the relay node as well as the source nodes are considered since we are applying this algorithm in the case of cooperative communication.

STEP:6 After the optimum point has been calculated the allocation of the resources is done by the relay. The optimum point decides the per unit price at which the resources have to be sold. When this price has been decided, the source nodes get the number of units according to the demand curves which they had submitted to the relay. For example, if the unit price turns out to be 9 then each source node is given the units of the resources equal to then number which they had asked for if the per unit price is 9.This ensures that a balanced and fair allocation of resources is carried out by the relay and also that the relay is compensated fairly.

The steps shown above are followed during each round of auctioning of resources in the network. This algorithm is applicable in case of centralized as well as decentralized wireless networks. The role of each node changes in each round because all the nodes can act as source, relay and destination nodes but not simultaneously.

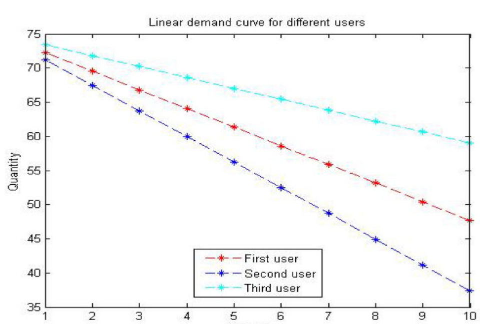

Fig. [3] Linear demand curves of all sources

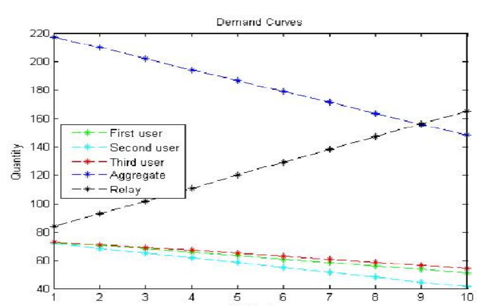

Fig. [4] Aggregate demand curve & Supply curve

Simulation & Results

We have implemented the algorithm and compared it with the ascending or descending clock auction in which number of iterations for reaching the final equilibrium depends on the difference between the bidding price of sources and targeted asking price of the relay. In ascending price auction, all the sources depending on their balance of virtual currency and their need, place the bid. After getting bids from all the sources, relay check with its capability to provide assistance. If the demand is more, relay will increase the asking price per unit of power. Now if price is high, the demand of source will go down and then again relay has to calculate the revenue and its capacity. We have presented simulation which compares the time to reach equilibrium for clock auction and our proposed scheme.

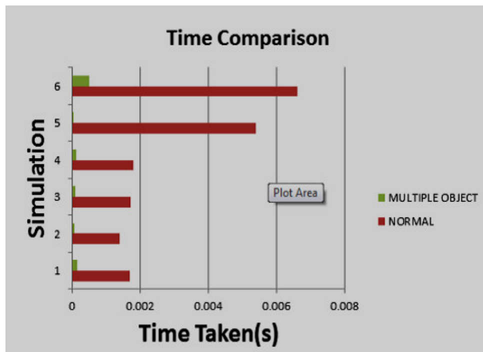

Figure: [5] Comparison between clock (normal) auction & proposed (Multiple object)

The average time taken over 5 simulation runs for the system to reach the optimum point in case of multiple object auctioning is 171 microseconds while in the case of clock-auctioning techniques is 1668 microseconds. Fig 5 shows the comparison in the computation time in both the cases of normal clock auctioning and multiple object auctioning. The number of iterations required to reach the optimum point is also constant. Thus, the time delay reduces considerably which is highly desirable in the context of the system. It has been shown in the simulation results through Fig: 5 that the time delay in the multiple objects auctioning technique is considerably lower over multiple simulation runs as compared to the normal clock auctioning technique. The life expectancy of the nodes also increases as their power consumption per each round of auctioning decreases. However, a drawback of this method is the calculation of the aggregate demand curve from the individual demand curves. This introduces a slight overhead in the technique which is worsened with the increase in the number of nodes in the system. This drawback is acceptable considering the significant improvement in the other areas of the system as compared to the normal clock-auctioning techniques. Comparing both the techniques in terms of computational complexity we have the normal clock auctioning techniques where the complexity is exponential. The computational complexity in the case of multiple object auctioning is considerably lower.

Conclusion

We have proposed a model for stimulating cooperation in cooperative wireless network by modeling source-relay as buyer-seller employing multi-unit auctioning with the help of linear demand-supply curve. It shows remarkable improvement over the traditional auctioning methods. For the sack of simplicity, we consider only linear demand-supply curve in this paper. However, the same concept can be extended for complex relation of resource availability and demand-supply. Demand curve of our sources are generated from power left with it. We will extend this work to generate demand curve based on packet error rate or QoS requirement.

References

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

[2] A. Nosratinia, T. E. Hunter, and A. Hedayat, "Cooperative communication in wireless networks," IEEE CommunicationMagazine, vol. 42, no. 10, pp. 74-80, Oct. 2004.

[3] A. Sendonaris, E. Erkip, and B. Aazhang, "User cooperation diversity - Part I: System description," IEEE Transactions on communications,vol. 51, no. 11, pp. 1927–1938, November 2003.

[4] K. T. Phan, Le-Ngoc Tho, S. A. Vorobyov, and C. Tellambura, "Power allocation in wireless multi-user relay networks,"IEEE Transactions on Wireless Communications, vol. 8, no. 5, pp. 1536-1276, May 2009.

[5] Y. Jing and H. Jafarkhani, "Network beamforming using relays with perfect channel information," IEEE Transactions onInformation Theory, vol. 55, no. 11, pp. 2499-2517, June 2009.

[6] K. T. Phan, Le-Ngoc Tho, S. A. Vorobyov, and C. Tellambura, "Distributed power allocation strategies for parallel relaynetworks," IEEE Transactions on Wireless Communications, vol. 7, no. 2, pp. 552-561, Feb. 2008.

[7] A. Nosratinia and T. E. Hunter, "Grouping and partner selection in cooperative wireless networks," IEEE Journal on Selected Areas in Communications, vol 25, no. 2, pp. 369-378, February 2007.

[8] T. Ng and W. Yu, "Joint optimization of relay strategies and resourceallocations in cooperative cellular networks," IEEE Journal on SelectedAreas in Communications, vol 25, no. 2, pp. 328-339, February 2007.

[9] A. Bletsas, A. Lippman, and D. P. Reed, "A simple distributed methodfor relay selection in cooperative diversity wireless networks, basedon reciprocity and channel measurements", Proceedings of the IEEEVehicular Technology Conference Spring, Stockholm, Sweden, May2005.

[10] S. Savazzi and U. Spagnolini, "Energy aware power allocation strategiesfor multihop-cooperative transmission schemes," IEEE Journal onSelected Areas in Communications, vol 25, no. 2, pp. 318-327, February2007.

[11] T. Himsoon, W. Siriwongpairat, Z. Han, and K. J. R. Liu, "Lifetimemaximization framework by cooperative nodes and relay deploymentin wireless networks", IEEE Journal on Selected Areas in Communications,vol. 25, no. 2, p.p. 306-317, February, 2007.

[12] B. Wang, Z. Han, and K. J. R. Liu, "Distributed Relay Selection andPower Control for Multiuser Cooperative Communication Networks UsingBuyer / Seller Game", Proceedings of IEEE INFOCOM, Anchorage,AK, May 2007.

[13] W. Saad, Z. Han, M. Debbah, and A. Hjørungnes, "A distributed coalition formation framework for fair user cooperationin wireless networks," IEEE Transactions on Wireless Communications, vol. 8, no. 9, pp. 4580-4593, Sep. 2009.

[14] Z. Zhang, J. Shi, H. Chen, M. Guizani, and P. Qiu, "A cooperation strategy based on Nash bargaining solution in cooperativerelay networks," IEEE Transactions on Vehicular Technology, vol. 57, no. 4, pp. 2570-2577, July 2008.

[15] G. Zhang, H. Zhang, L. Zhao, W. Wang, and L. Cong, "Fair resource sharing for cooperative relay networks using Nashbargaining solutions," IEEE Communications Letters, vol. 13, no. 6, pp. 381-383, June 2009.

[16] S. Ren and M. van der Schaar, "Distributed power allocation in multi-user multi-channel cellular relay networks,"IEEETransactions on Wireless Communications, vol. 9, no. 6, pp. 1952-1964, June 2010.

[17] N. Shastry and R. S. Adve, "Stimulating cooperative diversity in wireless ad hoc networks through pricing," in Proc. IEEEInt. Conf. Commun., Jun. 2006.

[18] O. Ileri, S. C. Mau, and N. B. Mandayam, "Pricing for enabling forwarding in self-configuring ad hoc networks," IEEEJournal on Selected Areas in Communications, vol. 23, no. 1, pp. 151-162, Jan. 2005.

[19] B. Wang, Z. Han, and K. J. R. Liu, "Distributed relay selection and power control for multiuser cooperative communicationnetworks using Stackelberg Game," IEEE Transactions on Mobile Computing, vol. 8, no. 7, pp. 975-990, July 2009.

[20] S. Ren and M. van der Schaar, "Pricing and distributed power control in wireless relay networks," IEEE Transactions onSignal Processing, vol. 59, no. 6, pp. 2913-2926, June 2011.

[21] Amitav Mukherjee, Hyuck M. Kwon, "General Auction-Theoretic Strategies for Distributed Partner Selection in Cooperative Wireless Networks', IEEE Transactions on Communications, Vol. 58, No. 10, October 2010

[22] Mohammed W. Baidas and Allen B. MacKenzie, "Auction-Based Power Allocation for Many-to-OneCooperative Wireless Networks" Proc. 7th International ofWireless Communications and Mobile Computing Conference (IWCMC), July 2011 , P;1677-82

[23] V. Krishna, Auction Theory. Academic Press, 2002.

[24] Tuomas Sandholm , Subhash Suri, "Optimal Clearing of Supply/Demand Curves",Proc of 13th annual International symposium on algorithms and computation, 2002, p-15-22, ISSA publisher