Downlink Resource Allocation Scheme for OFDMA System

Swapna P S, Sakuntala S. Pillai

Abstract*—Orthogonal Frequency Division Multiple Access (OFDMA) is a promising multiple access technique for next generation wireless communication such as WiMAX, LTE, IMT-A etc because of its high spectral efficiency and inherent robustness against frequency selective fading. Inclusion of relays into the system further improves the system performance. The asymmetric radio resource allocation problem for cooperative relay assisted OFDMA wireless networks with the objective of maximizing the data rate is addressed in this paper. In cooperative communication the transmission from base station to mobile stations is assisted by decode-and-forward relays. To reduce the computational complexity of its optimal solution, the proposed scheme is sub-divided into three subsections. The first section is to select the relays and then the subcarrier is allocated to the selected relays. As the next step, power is allocated to each subcarrier. Simulation results shows that the proposed scheme achieves better performance than the existing techniques.

***Index Terms*— Hungarian algorithm, Interference computation, OFDMA, Resource Allocation, Water filling algorithm.**

I. INTRODUCTION AND WORK MOTIVATION

State of the art wireless technologies have emerged with high data rate capabilities based on OFDMA technique. Future International Mobile Telecommunications (IMT)-Advanced mobile system will support very high peak data rates for mobile users, upto 1Gbps in static environments and upto 100 Mbps in high-speed mobile environment [1]. OFDMA have been selected as the multiple access technique for 4G mainly because of the flexibility that it offers by splitting the resources dynamically. Different number of subcarriers can be allocated to the users depending on the QoS requirements. The ability to mitigate frequency selective fading adds on to its advantage. Multiuser diversity is achieved in OFDMA by allowing subcarriers to be shared among multiple users.

The growth of wireless multimedia application requires high-speed and reliable communication, which means that more enhancements are necessary for ambitious throughput and QoS. Cooperative communications have been attracted in this aspect because of its ability to extend coverage and enhance spectrum efficiency. The integration of relays into conventional OFDMA wireless network is one of the most promising architectural upgrade. In Cooperative communication, spatial diversity gain can be achieved without the need of multiple antennas [2].

The performance of a wireless network may be optimized through wise resource allocation schemes. To fully exploit the benefits of the relaying technique in OFDMA system, a careful design of Radio Resource Allocation (RRA) principle is required, where the effective design of source and relay power, subcarrier and selection of relays are performed.

A low complexity adaptive subcarrier, bit and power allocation algorithm for OFDMA system was proposed in [3]. In this algorithm the subcarrier allocation is carried out in two steps- an initial step to guarantee data-rate of each user and the remaining subcarriers are further allocated to reduce the overall transmit power. Power and bit allocation is performed using water filling algorithm. Graphic frameworks are employed for resource allocation in [4],[5].Random bipartite graph is employed for subcarrier allocation in [4].Separate handling of interference management and network capacity can deliver substantial SINR performance [5].The performance of Cooperative OFDMA Systems under subcarrier based duplexing and in particular tradeoffs in realistic conditions is carried out in [6].

Energy efficient resource allocation scheme for OFDMA based cooperative networks is proposed in [7] & [8].Polynomial time complexity using dual decomposition approach was used in [7] .Dinkelbach method was used to solve the optimization problem in [9]. A radio resource allocation with on-the-fly channel state information measurement was implemented in [10]. A low complexity algorithm was proposed in [11] where the subcarriers are split into two partitions based on channel gain ordering.

For power allocation, Hojoong Kwon and Byeong Gi lee in [12] propose a game theory technique that has been exploited in microeconomics to deal with competition among selfish, intelligent decision makers. It can be used to solve many optimization problems such as CDMA power control, cognitive radio and OFDMA resource allocation. Using this technique, total power consumption can be reduced. For better allocation of power, combination of game theory and water filling is used.

In this paper we consider only cooperative communication that is determined by the source, based on the ratio of channel gain between the source and destination. In the cooperative communication system, the radio resource allocation is solved by three sub-problems; relay selection, subcarrier and power allocation with the objective of maximizing the bandwidth efficiency. Here we consider the link to be asymmetric, i.e. source to relay and relay to destination link distance are different.

II. SYSTEM MODEL

Consider a single cell relay enhanced OFDMA system with M users, N amplify and forward (AF) relays and a base station, where the relays are shared by all users. No direct transmission is taken into consideration and the link is asymmetric. Rayleigh channel is considered and it is assumed that the channel state information is available at the transmitter. Let R denote the set of all accessible frequencies

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which consists of R orthogonal subchannels. In the case of OFDMA, a particular OFDM subchannel can be used by at most one user in that cell at a given time. To reduce the complexity of assigning subchannels into each user, the resource allocation problem is

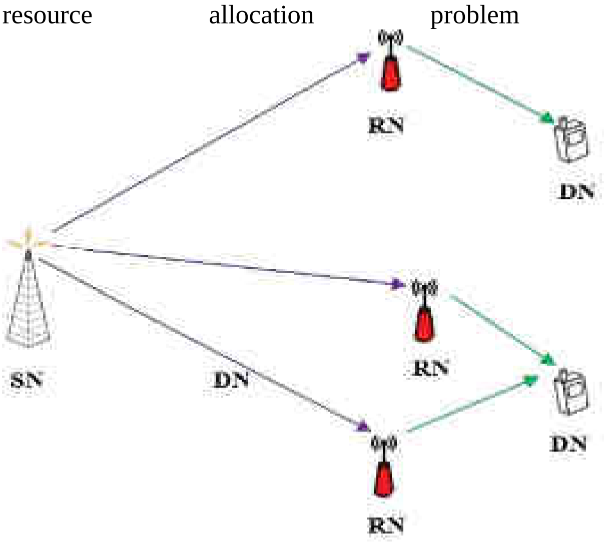

Fig 1: System Model

divided into subchannel allocation and power allocation. Binary relay selection and subcarrier allocation is considered. The subchannel allocation matrix is defined as,

$$S(m,r) = S^r_m \quad (1)$$

$$= \begin{cases} 1, \textit{if subchannel r is allocated to user m} \\ 0, \textit{otherwise} \end{cases}$$

$$S(n,r) = S^r_n \quad (2)$$

$$= \begin{cases} 1, \textit{if relay n uses subchannel r} \\ 0, \textit{otherwise} \end{cases}$$

The transmit power of m[th] user in r[th] subcarrier is $P^r_{s,m}$ and the transmit power of the n[th] relay in the r[th] subcarrier is $P^r_{b,n}$. The noise variance per subcarrier in the user to relay link is denoted by $\sigma^2_{m,n}$, relay to destination is denoted by $\sigma^2_{n,d}$ .The data rate of m[th] user in r[th] subcarrier and n[th] relay is then given by,

$$R^r_{m,n} = \frac{1}{2}\left[\log_2\left(1 + P^r_{s,m}\alpha^r_{s,m} + P^r_{h,n}\alpha^r_{h,n}\right)\right] \quad (3)$$

where $\alpha^r_{s,m}$ is the signal to noise ratio (SNR) in the user to relay link, $\alpha^r_{b,n}$ is the SNR in the relay to BS link. The SNR is given by the ratio of channel coefficient (h) to the noise variance (σ^2) of corresponding link. We assume that each relay supports multiple users and each user is aided by a single relay.

III. Joint Subchannel And Power Allocation

Resource allocation is the process of assigning different sets of subchannels and power dynamically to users depending on their channel states to satisfy the Quality of Service requirements. In this paper, initially the subcarriers that are totally available are allotted to the relays which in turn is distributed among the users depending on the interference between the subcarriers which is computed initially. The interference computed is given as a cost matrix to Hungarian algorithm. The Hungarian method is an algorithm which finds an optimal assignment for the given cost matrix. It is a combinational optimization algorithm that solves the assignment problem in polynomial time The steps involved in Hungarian algorithm are summarized as follows. Helpful Hints

A. Subchannel allocation

Let S denotes the subchannel allocation matrix of order N. Then following operations are carried out.

- Subtract the smallest entry in each row from all the entries of its row.
- Subtract the smallest entry in each column from all the entries of its column.
- Draw lines through appropriate rows and columns so that all the zero entries of the cost matrix are covered and the minimum number of such lines is used.
- If the number of covering lines is N, an optimal assignment of zeros is possible and is finished.
- If the number of covering lines is less than N, an optimal assignment of zeros is not yet possible. In that case proceed to next step.
- Determine the smallest entry not covered by any line. Subtract this entry from each uncovered row, and then add it to each covered column. Return to step 3.

B. Power allocation

Since cooperative communication is considered, the total power is split among the transmitter and the relays. The total power constraint is that the total power available in the network should be less than or equal to the sum of power available to all users plus relays in the network and is expressed as,

$$P_T \leq \sum_{m=1}^{M} P_m + P_r \quad (4)$$

where P_T is the sum of all the power available in the network and P_r is the power allocated for the relays. Our goal is to maximize the achievable rate subject to a total power constraint, considering the simplicity of the problem formulations and lower computational complexity under the sum power constraint. Once the subcarriers are allocated then power at the transmitter is distributed to the subcarriers according to the water filling algorithm. In this paper water filling is used as the power allocation scheme. Water filling algorithm aims at maximizing the total capacity and ensures that the user performance is not affected. The basic principle in the water filling algorithm is to allocate power to subcarriers that experience higher channel gain, while allocating little or no power to the subcarriers having low channel gain. Using OFDM channel, maximum rate for reliable transmission is,

$$R = \sum_{n=1}^{N-1} \log\left(1 + \frac{|h_n|^2 P_n}{N_0}\right) \quad (5)$$

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where, N_0 is the power density of the noise and P_n is the power allocated to the subcarriers. Therefore the power allocation can be done in such a way that it maximizes the rate in (5). Thus power allocation is the solution to the optimization problem:

$$R_N = \max_{P_0 P_{N-1}} \sum_{n=1}^{N-1} \log\left(1 + \frac{|h_n|^2 P_n}{N_0}\right) \quad (6)$$

The optimization problem can be solved using Lagrangian method.

$$L(\lambda, P_0 P_{N-1}) = \sum_{n=1}^{N-1} \log\left(1 + \frac{|h_n|^2 P_n}{N_0}\right) - \lambda \sum_{n=1}^{N-1} P_n \quad (7)$$

Where, λ is the Lagrange multiplier. The Kuhn-Tucker condition for the optimal solution is

$$\left.\begin{array}{l} \frac{dL}{dP_n} = 0, \text{if } P_n > 0 \\ \frac{dL}{dP_n} \leq 0, \text{if } P_n = 0 \end{array}\right\} \quad (8)$$

Power allocation can be expressed as,

$$P_n^+ = \left(\frac{1}{\lambda} - \frac{N_0}{|h_n|^2}\right)^+ \quad (9)$$

$$\sum_{n=1}^{N-1} \left(\frac{1}{\lambda} - \frac{N_0}{|h_n|^2}\right)^+ = P_{total} \quad (10)$$

If the Lagrangian multiplier λ satisfies the above condition, then (8) gives the optimal solution. The inverse of the Lagrangian multiplier λ is known as the water level.

Let S denote the subchannel allocation matrix and P denote the power allocation matrix, then SINR achieved at the base station B_m due to the transmission of user m over subchannel r relays can be represented as,

$$\Gamma_m^n(S,P) = \frac{h_{Bm}^n P_m^n s_m^n}{\sum_{j \in U_{Bm}} h_{Bmj}^n P_j^n s_m^n + \eta_{Bm}^n} \quad (11)$$

$$= \frac{P_m^n s_m^n}{I_m^n(S,P)}$$

where, $I_m^r(S,P)$ is the effective interference of user m on subchannel r.

$I_m^n(S,P)$ is ,

$$I_m^n(S,P) \triangleq \frac{\sum_{j \in U_{Bm}} h_{Bmj}^n P_j^n s_m^n + \eta_{Bm}^n}{h_{Bm\,m}^n} \quad (12)$$

III. RESULTS

In this section simulations of the proposed algorithm are presented and the simulations are carried out in Matlab. In this paper, joint Hungarian and water filling is used for subchannel allocation and power allocation.

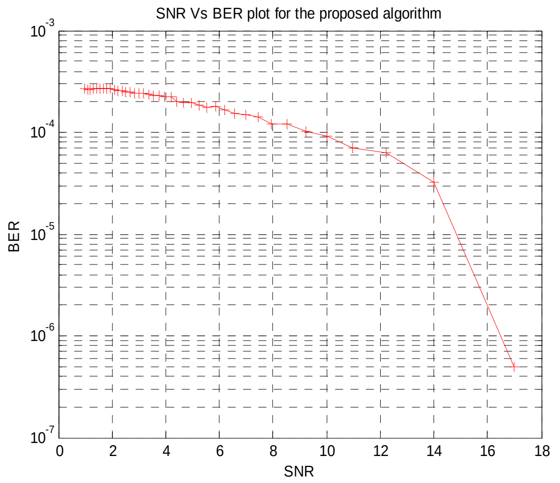

Fig 2:SNR Vs BER for the proposed algorithm

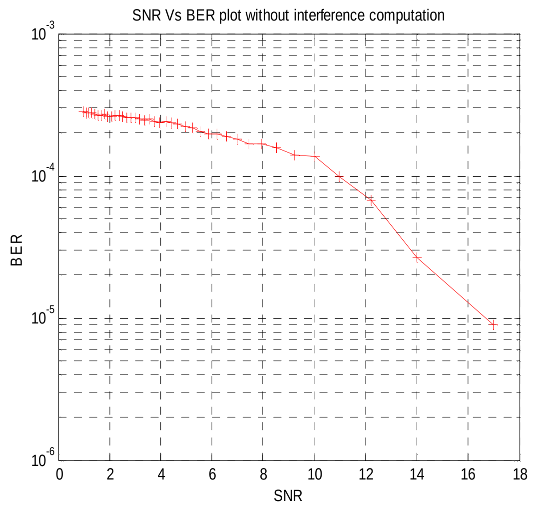

Fig 3: SNR Vs BER without computing interference

The BER is seen to drop at higher SNR for the proposed algorithm where the interference is initially computed and subcarriers are assigned accordingly. Due to this better performance is achieved compared to the algorithm using Hungarian and water filling directly. This can be further extended for multicell OFDMA scenario, where the interference between multiple cells are to be computed.

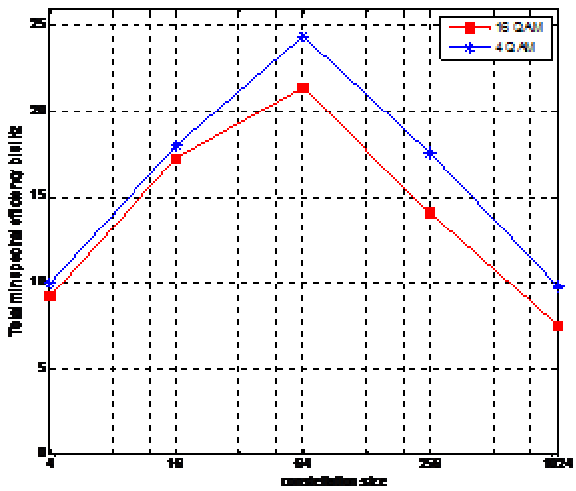

Fig 4: Spectral efficiency of the proposed algorithm

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Fig. 4 shows the total minimum spectral efficiency of each user versus the constellation size of QAM modulation scheme. The figure shows that when the constellation size increases spectral efficiency increases and then decreases. That is, higher constellation sizes have higher target SINRs, which require higher transmission power and produce more interference to other users in the networks. Therefore, for higher constellation sizes 256 and 1024 the power constraint of are more likely to be violated, which limits the number of subchannels allocated for each user. For low constellation sizes, the spectral efficiency on each assigned subchannel increases when the modulation level increases. But the number of assigned subchannels for each user does not decrease too much.

IV. CONCLUSION

In this work, we propose a resource allocation algorithm for the downlink relay based OFDMA System. This algorithm focuses on computing the interference between the subcarriers before allocating power and subcarriers. The separate handling of interference computation before resource allocation can deliver a substantial BER performance which was confirmed by computer simulation. Earlier works have reported BER of 10^{-5} for a SNR of 16 , whereas using the proposed scheme a BER of 10^{-6} is achieved for a SNR of 16.The complexity of the optimization problem is also reduced since in the proposed scheme the problem is divided into sub problems, namely - relay, subchannel and power allocation; thereby providing a viable option for usage in the next generation cellular systems.

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