Optimization of Subcarrier and Power Allocation in Uplink OFDMA Systems

M.Vadivel
Research Scholar, ECE Dept., Sathyabama University, Chennai-600 119, Tamilnadu, India.
E-mail : vadivel.muniyappan@gmail.com

H.Ranganathan
Prof. & Head of department of ECE, Sakthi Mariamman Engineering College,
Chennai-602 195, Tamilnadu, India.
E-mail : ranlal@yahoo.com

Abstract

The allocation of subcarriers and power to users is an important issue for exploiting the advantages of OFDMA systems. The main objective of the traditional OFDMA uplink resource allocation focuses on two aspects: one is to maximize the transmission rate of each user, the other is to minimize power. In this paper, we proposed the joint subcarrier and power allocation in the uplink of an OFDMA system thereby increasing the rate sum capacity of the system with low computational burden. The simulation results shows that the power efficiency of the proposed algorithm increases greatly over that of the Maximum marginal Rate subcarrier and WaterFilling power allocation, which is the optimal algorithm to derive the maximum transmission rate and the power utilization can be minimized.

Index Terms- OFDMA, CP,IDFT

1. Introduction

In recent years, wireless communication systems must support reliable and high data rate transmission for various services. To serve this purpose appropriate allocation of resources like power and subcarriers to users is required. Orthogonal Frequency Division Multiple Access (OFDMA) is regarded as one of the prime multiple schemes for wireless networks.

Allocating subcarriers and power in OFDMA systems has been widely investigated. Most of the papers are dealing with the downlink case only. For downlink, it has been accepted as an optimal solution that each subcarrier is allocated to the user with the best channel condition and power is allocated by the water-filling over subcarrier. However, the optimality in downlink does not hold for uplink due to the distributive nature of power constraint. Frequency-power allocation for uplink case is discussed. The optimal frequency partition turns out to be a simple two-band partition and power allocation follows the multi-user water-filling, but the results are valid only for the case when the channel-gain-to-noise ratios for the two users are the same, which is not applicable to the general mobile communication environments.

1.1 *Aim and Scope*

Our ultimate aim is to maximize the rate sum capacity for increasing number of users in the uplink. To achieve this, we formulate an optimization problem with respect to subcarrier and power constraints and obtain necessary conditions for optimization, from that we obtain combined subcarrier and power allocation algorithms.

From the simulation results we can conclude that proposed scheme enhances the system capacity with low computational complexity, providing almost near to optimal solutions.

1.2 *Literature Survey*

In the existing work[12][4], simulation parameters used are Total power is 1 Watts , Number of users =16, 10 Number of subcarriers N=64,bit error rate BER=1e- 3 , No. of channels =100,Bandwidth = 1MHZ.In my proposed work, simulation parameters used are Total power is 0.75 Watts , Number of users =32,Number of subcarriers N=256,bit error rate BER=1e- 4 , No. of channels =200,Bandwidth = 1MHZ.

2. System Model

The increase in demand for delay sensitive applications with high rate requirements such as mobile gaming and video conferencing has mandated the need for efficient resource allocation schemes in state of the art OFDMA based wireless communication systems. In order to provide delay guarantees for real time services in wireless networks, different resource allocation schemes have been recently proposed for uplink.

2.1 *System Model of Uplink OFDMA System*

An uplink OFDMA block diagram is shown in figure 1.The QAM input symbols are fed into an inverse discrete Fourier transform (IDFT) block. Using channel state information feedback, adaptive resource allocation assigns a set of subcarriers to each user and adjusts bit constellations for the data mapped in the assigned subcarriers.

After IDFT, a cyclic prefix (CP) is added to the front of an OFDMA symbol. As long as the CP length is grater than the wireless channel delay spread only 1- tap frequency domain equalization per subcarrier is required to retrieve the transmission data. The rest of the receiver blocks essentially invert the operations at the transmitter.

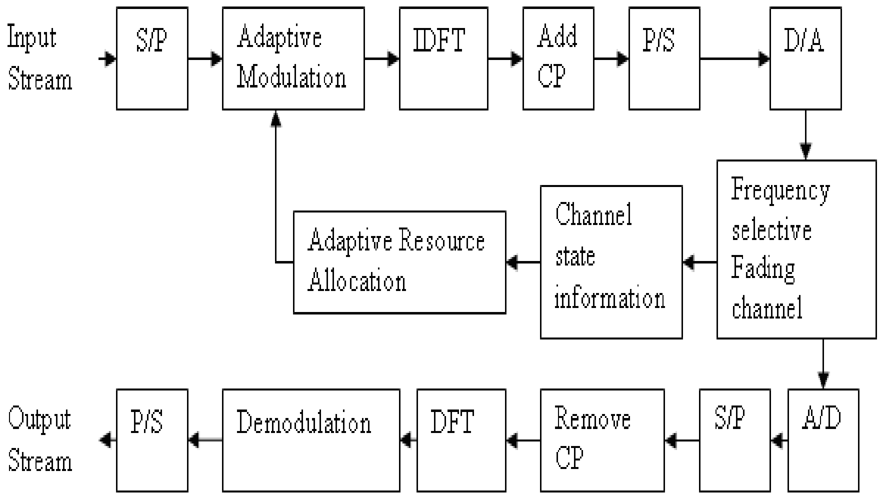

Figure 1. Block Diagram of Uplink OFDMA system

In our proposed system, subcarrier and power allocation in uplink OFDMA system can be implemented by using linear and non linear method in order to maximize the rate-sum capacity. The aim is to maximize the throughput of the system. The approach here is to allocate each subcarrier [2] [13] to the user which ensures that the normalized channel gain reaches its maximum. Given that all subcarriers have been allocated, the remaining goal is then to maximize the rate of each user by power allocation [7[13]].

Each mobile user is given a pricing factor, which is multiplied with the total power used by the mobile. The overall utility is called pricing term that can be added with a quadratic term, which is the difference between the given maximum throughput of the user and the achieved throughput of the user. Hence, the system aims to reach the maximum throughput of each user, while using as little power as possible.

3. Design Methodologies

There are two methods for subchannel assignment and power allocation in uplink OFDMA systems.

1. Non Linear method
2. Linear Method

3.1 *Non Linear Method*

The non linear method describes the resource allocation and is used to determine the total power assigned to the user. This method reduces the computational complexity of solving variables in subcarrier and power allocation [6][9] simultaneously. The proportionality between the number of users and rate sum capacity is not strictly maintained in this algorithm due to non linearity principle. Initially a subchannel is assigned to the user who has the highest channel gain. After assigning all the subchannels, the capacity for each user is calculated by assuming equal power distribution for all the subchannels.

We can write the optimization problem by mathematically

$$\max_{p_{k,n},\rho_{k,n}} \sum_{k=1}^{K}\sum_{n=1}^{N}\frac{\rho_{k,n}}{N}\log_2\left(1+\frac{p_{k,n}h_{k,n}^2}{N_0\frac{B}{N}}\right) \qquad (1)$$

Subject to

$$\sum_{k=1}^{K}\sum_{n=1}^{N}p_{k,n} \le P_{total} \qquad (2)$$

$$p_{k,n} \geq 0 \qquad \text{for all k, n}$$

$$\rho_{k,n} = \{0,1\} \qquad \text{for all k, n}$$

Where

K	- Total number of users
N	- Total number of subchannels
N_0	- Power spectral density of additive white Gaussian noise
B	- Bandwidth
P_{total}	- Total power
$p_{k,n}$	- Power allocated for user k in the subchannel n
$h_{k,n}$	- Channel gain for user k in the subchannel n
$\rho_{k,n}$	- Value of either 1 or 0, indicating whether subchannel n is used by user k or not
$H_{k,n}= h^2_{k,n} /\sigma^2$	- Sub-channel-to-noise ratio
$\sigma^2=N_0 B/N$	- Additive white Gaussian noise (AWGN)

$R_1: R_2: \ldots R_k = \gamma_1: \gamma_2: \ldots \gamma_k$ - Proportional rate constraints

3.2 *Linear Method*

Linear method is a low complexity subcarrier and power allocation algorithm. The equations used in the power allocation can be easily solved by linearity and symmetric principle.

4. Implementation of the Paper

The implementation of proposed algorithms for both the methods is usually a tradeoff between how close they come to the optimum allocation [10] and how quickly they reach their final allocation.

4.1 *Proposed Non Linear Algorithm*

The rate sum capacity for user k is denoted as Rk and is defined as

$$R_k = \sum_{n=1}^{N} \frac{\rho_{k,n}}{N} \log_2 \left(1 + \frac{p_{k,n} h^2_{k,n}}{N_0 \frac{B}{N}} \right) \qquad (3)$$

The total power for each user is calculated by using the equation

$$P_{k,total} = c_k \left(P_{1,total} \right) d_k \qquad (4)$$

where

$$c_k = \begin{cases} 1 & \text{for k=1} \\ \dfrac{N_k}{(H_{k,1}+1)(W_k+1)} \left\{ \dfrac{H_{1,1} W_1}{(N_1+1)} \right\} d_k & \text{for k=2,3,....K} \end{cases} \qquad (4a)$$

$$d_k = \begin{cases} 1 & \text{for k=1} \\ \dfrac{N_1 \gamma_k}{(H_k+1)(\gamma_1+0.5)} & \text{for k=2,3......K} \end{cases} \qquad (4b)$$

$$P_{1,total} = \left(P_{total} - \sum_{k=2}^{K} \frac{b_k}{(a_{kk}+1)} \right) / \left(1 - \sum_{k=2}^{K} \frac{1}{(a_{kk}+0.5)} \right) \quad (4c)$$

$$a_{kk} = \begin{cases} -1 & \text{for k=1} \\ -\frac{N_1}{(N_k+1)} \left(\frac{H_{k,1} W_k}{(H_{1,1}+1)(W_1+0.5)} \right) & \text{for k=2,3......K} \end{cases} \quad (4d)$$

$$b_k = \begin{cases} 0 & \text{for k=1} \\ \frac{N_1}{(H_{1,1}+1)} \left(W_k - W_1 + \frac{H_{1,1} V_1 W_1}{(N_1+1)} - \frac{H_{k,1} V_k W_k}{(N_k+0.5)} \right) & \text{for k=2,3.....K} \end{cases} \quad (4e)$$

W_k - Sum of the total power allocated to every user cannot exceed the total power in the system
Hk,1 - Lowest SNR allocated to user k

$$W_k = \left(\prod_{n=2}^{N_k} \frac{H_{k,n}}{(H_{k,1}+1)} \right)^{\frac{1}{N_k}} \quad (4f)$$

$$V_k = \sum_{n=2}^{N_k} \frac{H_{k,n} - H_{k,1}}{(H_{k,n}+1).(H_{k,1}+0.5)} \quad (4g)$$

The algorithm for the Non linear Method as follows.

1. Initialize the number of subchannels (N_k) and data rate (R_k) allocated to user k
2. Check the availability of all the subchannels
3. Assign the power equally among all the availability of subchannels
4. Let the largest and unallocated subchannel pick up by the user k
5. Allocate subchannel n to user k and make it no longer available
6. Increment the number of subchannels Nk assigned to user k by 1
7. Recalculate data rate for user k
8. Find the user k with the lowest data rate
9. Repeat the same in 5, 6, 7 and 8

4.2 *Proposed Linear Algorithm*

By using substitution method, the power for individual user is given by the equation

$$P_k = \begin{cases} \frac{\left(P_{total} - \sum_{k=2}^{K} \frac{b_k}{(a_{kk}+0.5)} \right)}{\left(1 - \sum_{k=2}^{K} \frac{1}{(a_{kk}+0.5)} \right)} & \text{for k=1} \\ \frac{(b_k - P_1)}{(a_{kk}+0.5)} & \text{for k= 2,3,...K} \end{cases} \quad (5)$$

The final power allocation across sub carriers per user can be given by

$$P_{k,n} = p_{k,1} + \frac{H_{k,n} - H_{k,1}}{(H_{k,n}+1)(H_{k,1}+0.5)} \quad (6)$$

Where

$$p_{k,1} = \frac{P_k - V_k}{(N_k + 1)} \quad (6a)$$

The algorithm for the Linear Method as follows

1. Calculate the number of subcarriers to be initially assigned.
2. Assigns the subcarriers to each user with highest Channel-to-noise ratio.
3. Picks the user with lowest data rate to allocate Subchannel at the same time.
4. Assigns the remaining subcarriers to the best users. This policy balances achieving Proportional fairness while increasing overall capacity.
5. Initialize the number of subchannels (N_k) and data rate (R_k) allocated to user k
6. Check the availability of all the subchannels
7. Assign the power equally among all the availability of subchannels
8. Allocate subchannel n to user k and make it no longer available
9. Increment the number of subchannels Nk assigned to user k by 1
10. Recalculate data rate for user k11. Find the user k with the lowest data rate
12. Repeat the same in 8, 9, 10, and 11

5. Results and Discussions

The graph plotted against capacity versus number of users we can conclude that more capacity is achieved as the number of user's increases. Also the power allocated for each user is reduced without affecting the capacity

The performance of proposed algorithm can be shown in the simulation results by using MATLAB 7.9.The simulation parameters are Total power is 0.75 Watts , Number of users K=32,Number of subcarriers N=256,bit error rate BER=1e^{-4} , Bandwidth = 1MHZ.

Adaptive Modulation [5] is necessary to handle the time-varying nature of wireless channels which yields very high speed data rates. Channel state Information [8] for each user must be generated before allocation of subchannel and power [11] [7] which constitute an accurate wireless channel model.

5.1 *Simulation Results*

A simulation result shows the relationship between capacity versus number of users we can conclude that more capacity is achieved as the number of users increases [3] [1]. Also the power allocated for each user is reduced without affecting the capacity.

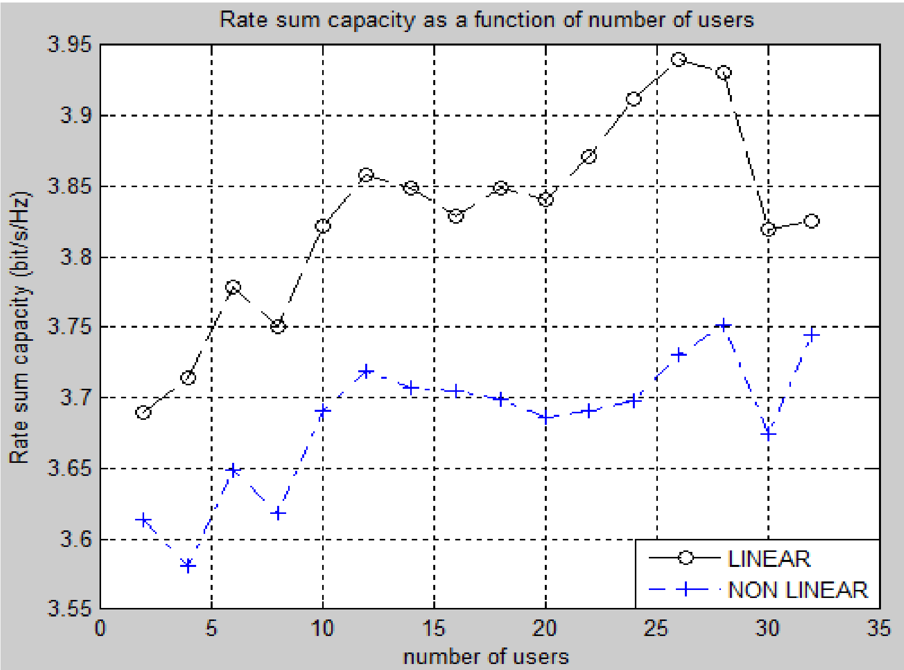

Figure 2. Number of users verses Rate sum capacity in uplink OFDMA system

Figure 2 shows the simulation result of Rate sum capacity as a function of number of users

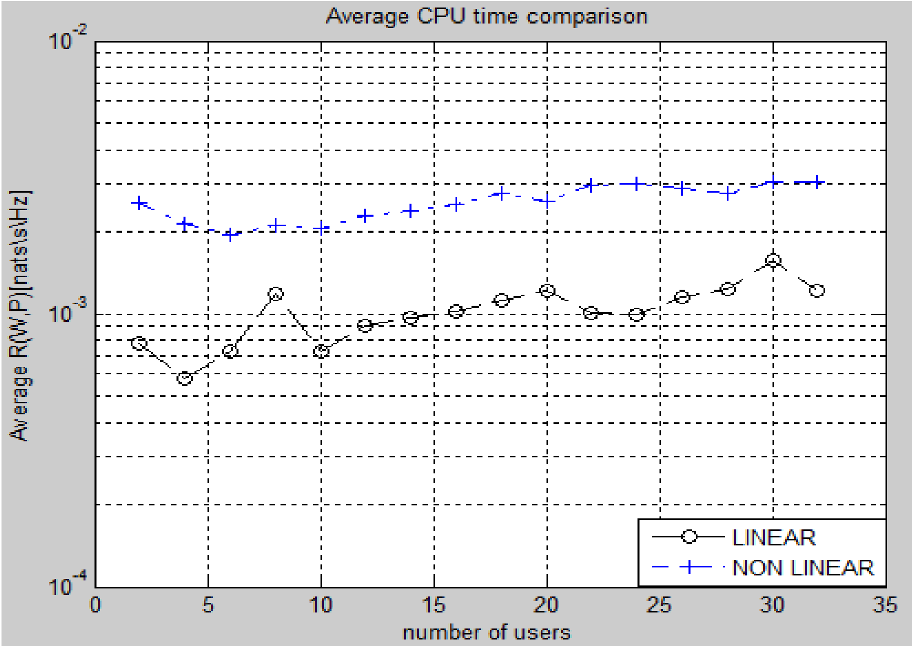

Figure 3. Number of users verses Average Rate time in uplink OFDMA system

Figure 3 shows the simulation result of average CPU time comparision for number of users.

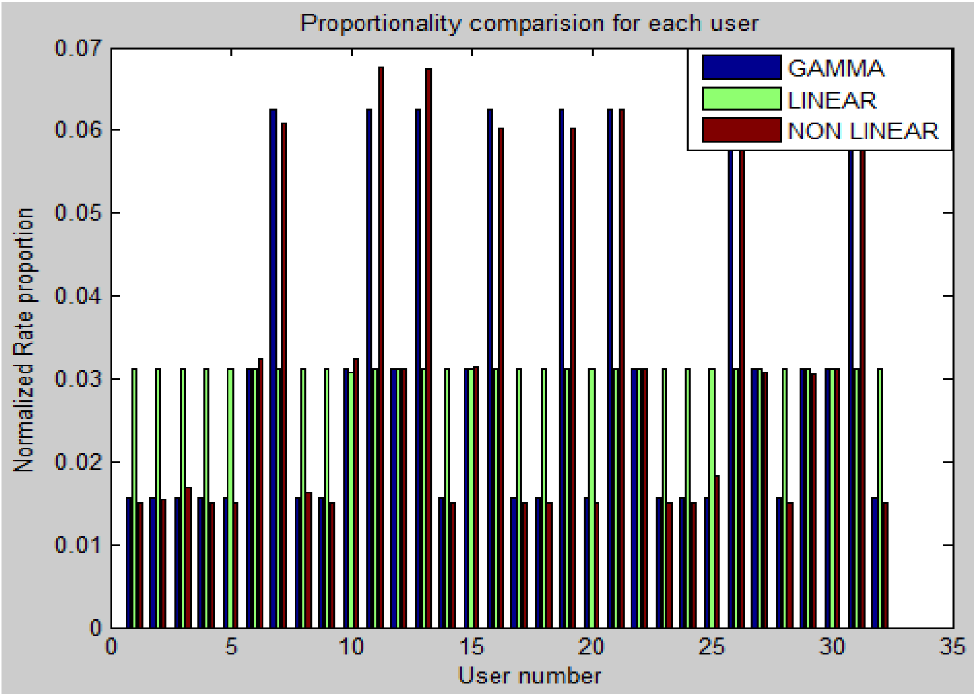

Figure 4. User number verses normalized rate proportions in uplink OFDMA system

Figure 4 gives the Normalized rate proportion for each user up to 32 users averaged over 200 channels, with the required Gamma for each user. The LINEAR method has minimal deviation from the required proportions, but proposed scheme is much better for large number of users

6. Conclusion

The rate sum capacity achieved by the proposed LINEAR method is consistently higher than for the NONLINEAR method for a system up to 32 users

From the simulation results we can conclude that the proposed method improves on the previous work with respect to subcarrier and power allocation constraints with necessary conditions for optimization which enhances the system capacity with low computational complexity, providing almost near to optimal solutions.

In future work we can extend the same work for by increasing Number of users, Number of subcarriers and decreasing Total power used with necessary conditions for optimization which enhances the system capacity with low computational complexity.

References

[1] Abolfazl Falahati Majid, Ardestani.R, (2007) "An Improved Low-Complexity Resource Allocation Algorithm for OFDMA Systems with Proportional Data Rate Constraint", ICACT2007, pp 606-611.

[2] Cheng.R.S, Wong.C.Y, Letaief.K.B and Murch.R.D, (1999), "Multiuser OFDM with Adaptive Subcarrier, Bit, and Power Allocation", IEEE Journal on Selected Areas in Communications, vol. 17, no. 10, pp. 1747-1758.

[3] Guanding Yu, Zhao yang Zhang, Yan Chen, Peng Cheng and Peiliang Qiu, (2006),"Subcarrier and Bit Allocation for OFDMA Systems with Proportional Fairness", IEEE, pp 1717-1722.

[4] Gunaseelan.K, Venkateswari.R, Kandaswamy.A, (2008), "A Novel Efficient Resource Allocation Algorithm for Multiuser OFDM Systems", IETE Technical Review, Vol. 25, Issue 4

[5] Ho Seok Kim, Jin Sam Kwak, Jung Min Choi, and Jae Hong Lee, (2004), "Efficient Subcarrier and Bit Allocation Algorithm for OFDMA System with Adaptive Modulation", IEEE Korea, pp 1816- 1820.

[6] Mohanram.C and Bhashyam.S, (2005), "A sub optimal joint subcarrier and power allocation algorithm for Multiuser OFDM", IEEE communications letters, Vol.9, No.8, PP. 685-687.

[7] Natalia Y. Ermolova and Boris Makarevitch, (2007), "Low Complexity Adaptive Power and Subcarrier Allocation for OFDMA", IEEE TRANSACTIONS ON WIRELESS COMM., VOL. 6, NO. 2, pp 433-437.

[8] Parag.P, Bhashyam.S, and Aravind.R, (2005), "A subcarrier allocation algorithm for OFDMA using buffer and channel State information", in Proc. 62nd IEEE Veh. Technol. Conf., vol. 1, pp. 622–625.

[9] Pietrzyk.S, and Janssen.G.J.M, (2004),"Performance Evaluation of Bit Loading, Sub-carrier Allocation and Power Control Algorithms for Cellular OFDMA Systems", PWC 2004 International Conference on Personal Wireless Communications, LNCS 3260, Springer- Verlag, pp. 349-363.

[10] Shen.Z, Andrews.J.G and Evans.B.L, (2003) ,"Optimal Power Allocation in Multiuser OFDM Systems, in Proc", IEEE Global Communications Conference, San Francisco, pp. 337 -341.

[11] Varun.C and Sathyaraj.P, (2012) "Resource Allocation for Multiuser OFDM Systems", Bonfring International Journal of Research in Communication Engineering, Vol. 2, Part 1, pp 83-89.

[12] Wong.C.Y, Shen.Z, Andrews.J.G, and Evans.B.L, (2004), "A Low Complexity Algorithm for Proportional Resource Allocation in OFDMA Systems", Proc. IEEE Int. Work. Signal Processing Systems,

[13] Zukang Shen, Jeffrey G. Andrews and Brian L. Evans, (2005), "Adaptive Resource Allocation in Multiuser OFDM Systems with Proportional Rate Constraints", IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 4, NO. 6, pp 2726 – 2737.