GA Optimized Multi - objective Function of Subcarrier, Bit and Power Allocation for Downlink OFDMA Cellular Systems

الخوارزمية الجينية لحل أمثل لتخصيص الحامل الفرعي وعدد البتات والقدرة للدالة المتعددة الأهداف لحزمة النزول لنظام خليوي OFDMA

Hayder J. Albatat1 **Haider M. AlSabbagh2**

College of Engineering - University of Basrah

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Abstract:-

In this paper we present a technique for resource allocation in orthogonal Frequency Division Multiple Access (OFDMA) systems with a proportional rate constraint which is topical in 4G. This technique deals with compensation between the transmitted rate maximization and power minimization. For this target we suggest a multi-objective problem that is controlled by compensation factor. This strategy is very useful for both maximum throughput applications and power saving one that is because the objective of these two strategies are taken in utility function through compensation factor. Two techniques have been combined for optimization for subcarrier allocation. The first efficiently chooses subcarrier allocation providing subgroups of tones for users. A second objective maximizes the rate which allocated per each subcarrier. A genetic algorithm (GA) is used to optimize a Pareto surface of power allocation and continuous rate. Through the simulated results we have rate between 6 to 8 bit/sec/Hz according to compensation factor, channel environment and power constraint.

I. Introduction

Dynamic radio resource allocation is a novel and timely topic in cellular communications for 4G and beyond. The optimization of radio system resources is not generally straightforward since coding rate, symbol rate, carrier to interference ratio and transmit power may all need to be combined to obtain on maximum throughput [1]. Although separate algorithms exist for each of these metrics any useful search algorithm has to be multi-objective. The optimization technique is therefore constrained. For a similar constrained optimization problems of OFDM environment where channel hostilities are mitigated and throughput is maximized by adaptively selecting code rate, modulation symbol and transmit power. Several adaptive bit and power loading techniques have been investigated in the literature for improvement of transmission rate in combination with orthogonal frequency division multiplexing (OFDM) [1-3]. In previous researches study of the resource allocation problem for OFDMA (multiuser OFDM) has been broadly divided into two manners: Margin Adaptive (MA) and Rate Adaptive (RA). Resource allocation was tackled in [4] using MA scheme, wherein a set of fixed user data rates and the Bit Error Rate (BER) requirements an iterative subcarrier and power allocation algorithm was proposed to minimize the total transmit power given. The MA optimization technique has been dealt with efficiently in [5]. In [6], a rate adaptive method was used wherein the objective was to maximize the total data rates over all users,subject to power and BER constraint. It was shown in [7] that in order to maximize the total capacity each subcarrier with good gain (low attenuation) should be assigned to the user. It was shown that RA optimization can be solved sub-optimally by separating subcarrier allocation and bit loading. The RA optimization problem is a mixed binary integer programming problem. The proportional rate constraint is added to the existing RA optimization problem has been shown in [8]. However, the introduction of this constraint makes the optimization problem non-linear thus increasing the difficulty in finding the optimal solution because the feasible set is not convex (for more details on convexity see [9]).

In the next subsection we present a technique for resource allocation in orthogonal frequency division multiple access

(OFDMA) systems with a proportional rate constraint which is topical in 4G. Two techniques have been combined for optimization. The first efficiently chooses subcarrier allocation providing subgroups of tones for users. A second objective maximizes the rate which allocated per each subcarrier. A genetic algorithm (GA) is used to optimize a Pareto surface of power allocation and continuous rate. The simulation results show a marked improvement in the performance of the algorithm as the number of users increase with low iteration periods suitable for real time systems.

In this paper, our aim is to characterize the resources allocation strategy (power control and subcarrier assignment scheme) allowing to satisfy maximization in rate per each user while spending the least power at the transmitters' side depending on compensation factor. The paper is organized as follows. In Section II we present the system model and problem formulation. The problem consists in maximizing the transmit rate of the considered cell assuming a fixed level of interference such that the rate requirements of users of this cell are satisfied and such that the interference produced by the cell itself is less than a certain value. Section III turns out to the performance and QoS requirements. In Section IV we introduce GA as a useful tool to solve the more complicated multi-cell problem. The rest of the paper for simulated results and conclusion.

II. System Model and Problem Formulation

The system has been consisted from 3 cells (i.e. three different bands), with base stations (BSs),Q the number of randomly distributed users in certain BS q is K_q, where $q \in \{1,2,\ldots, Q\}$ and denotes to set of BSs. All of these BSs connected to a central unit for resource arrangement (subcarrier, bit and power) of OFDM system (see Fig.1). The total available bandwidth for each cell in cluster unit is equally divided into N narrowband OFDM subcarriers. Almost of these frequency sub-bands are reused among cells, while some of them are specialized for each cell and finally forbidding subcarriers such as illustrating in Fig. 2. The maximum total power is limited by P_T for each cell. Consider a user k_q^nin base station $q$on subcarrier n where $k_q \in \{1,2,\dots, K_q\}$ and $n \in \{1,2,\dots, N\}$. Adaptively selecting different modulation schemes significantly improves the performance of OFDMA-based system. Various modulation schemes, such as M-ary Frequency Shift Keying (M-ary FSK), M-ary Phase Shift Keying (M-ary PSK) and M-ary QAM, can be used for data transmission based on bandwidth and power efficiency[10]. Moreover, bandwidth efficiency of a M-ary FSK signal decreases with increasing modulation order. But M-ary PSK and M-QAM keep equal bandwidth efficiency for all modulation orders. In terms ofpower of efficiency, M-ary QAM is more efficient than M-ary PSK[10]. Here we assume that there are channel encoder and modulation schemes can attained the required continuous rate. To formulate utility multi-objective function to this system which compromise between rate and power cost, we proposed the following utility function for base station q as

$$\mathrm{U}_q = \sum_{k=1}^{K_q} r_{kq} - \lambda_q \sum_{n=1}^{N} P_q^n + \mu_q \ , \forall\, q \quad (1)$$

where

$$r_{kq} = \sum_{\mathrm{n}=1}^{N} a_{kq}^n . \log_2\left(1 + SINR_{kq}^n\right) \quad (2)$$

and

$$P_q^n = \sum_{k=1}^{K_q} a_{kq}^n . P_{kq}^n \quad (3)$$

where P_q^n and r_{kq} are the power allocated to cell q through subcarrier n and the rate of user k in cell $q . a_{kq}^n \in \{0,1\}$, where $a_{kq}^n = 1$ if subcarrier n is allocated to user k in base station q

and $a_{kq}^{n} = 0$ otherwise, $SINR$ is the signal-to-interference-plus- noise ratio, λ_q is comprehensive of cell q per unit power for trade-off between data rate and power with unit bit/W and μ_q is arbitrary constant to ensure non-negative value. The multi-objective optimization function for this system is

$$\max_{a_{kq}^{n}, P_{kq}^{n}} \mathrm{U} = \sum_{q=1}^{Q} \mathrm{U}_q \qquad (4)$$

or

$$\min_{a_{kq}^{n}, P_{kq}^{n}} \mathrm{U} = -\sum_{q=1}^{Q} \mathrm{U}_q \qquad (5)$$

subject to:

$$r_q \geq \sum_{k=1}^{K_q} \sum_{\mathrm{n}=1}^{N} a_{kq}^{n} . \log_2\left(1 + SINR_{kq}^{n}\right) \qquad (6-a)$$

$$\sum_{q=1}^{Q} \sum_{\mathrm{k}=1}^{\mathrm{K_q}} a_{kq}^{n} . P_{kq}^{n} \leq P_T \qquad (6-\mathrm{b})$$

$$\sum_{q=1}^{Q} \sum_{k=1}^{K_q} a_{kq}^{n} \leq 1 \ , \forall \, n \qquad (6-c)$$

$$a_{kq}^{n} \in \{0,1\} \qquad (6-d)$$

$$P_{kq}^{n} \geq 0 \ , \forall q, k, \qquad (6-e)$$

$$\min_{x} I \ , \forall \, k, n \qquad (6-h)$$

where I is the interference power from the co-channel x cells of the first and second tiers which will define it in next section.

The inequality (6-a) represented the rate constraint, (6-b) and (6-e) denote to power constraint, (6-c) and (6-d) show the subcarrier allocation constraint and finally (6-h) for the interference power due to the co-channel x cells of the first and second tiers constraint.

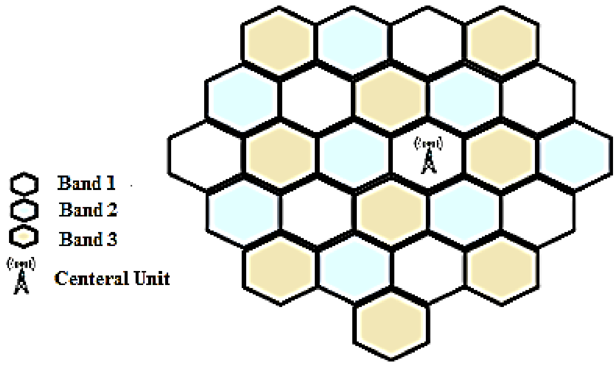

Fig. 1: Cellular block (cluster size of 3) for OFDMA downlink system.

III. The performance and QoS requirements

The OFDMA downlink system can carry various classes of multimedia services[11]. In this work we assume only one type of service for each user. The target BER of user k which is denoted by BER_k^*, is based on the environment of the channel and the traffic type belonging to user k as well. The management of multi-cell interference is one of the major issues in multi-cell cellular networks design and administration [13]. The level of interference experienced by users of the networks is directly related to the value of α defined as[12]

$$\alpha = \frac{\text{number of subcarriers reused by two adjacent sectors}}{N} \quad (7)$$

Parameter α is called the frequency reuse factor. If $\alpha = 1$, then each base station can allocate the totality of the available N subcarriers to its users. This policy is commonly referred to as the all-reuse scheme or as the frequency reuse-of-one scheme. Under this policy, all users of the system are subject to multi-cell interference. If $\alpha = 0$, then no subcarriers are allowed to be used simultaneously in two neighbouring cells. This is the case of an orthogonal reuse scheme. In such a scheme, users do not experience any multi-cell interference. If α is chosen such that $0 < \alpha < 1$, then we obtain the so-called fractional frequency reuse [14]. According to this frequency reuse scheme, the set of available subcarriers is partitioned into two subsets. One subset contains αNsubcarriers that can be reused within all the cells of the system and is thus subject to multi-cell interference. The other subset contains the remaining $(1-\alpha)N$ subcarriers and is divided in an orthogonal way between the different cells. Such subcarriers are thus protected from interference (see Fig. 2). The signal-to-interference-plus- noise ratio (SINR) in base station q on subcarrier n received at user k, denoted by ${SINR_{kq}^{n}}^{*}$, can be obtained by

$$ {SINR_{kq}^{n}}^{*} = \frac{P_{kq}^{n}.\left|H_{kq}^{n}\right|^{2}}{\sigma^{2} + |I_{k}^{n}|} \qquad (8) $$

where H_{kq}^{n} , I_{k}^{n}, and σ^{2}, denote the frequency-domain channel gain, interference power and variance of thermal noise, respectively. Noise here which is assumed to be complex Gaussian with zero mean and standard deviation σ. The maximum transmitted power per cell is shared equally among all its sectors. The average received signal power for a user k at distance d from the base station is given by[12]

$$ P_{ki}^{n} = p_{0}\left(\frac{d}{d_{0}}\right)^{-\delta} \qquad (9) $$

where p_0 is the received power at reference distance d_0 and δ is the path loss exponent. The interference power from the co-channel x cells of the first and second tiers (depends on the cluster size for 3 cells cluster size, $x = 18$, see Fig.2) on subcarrier n is given by[13]

$$ I_{k}^{n} = \sum_{i=1}^{x} |H_{ki}^{n}|^{2}.P_{ki}^{n} \qquad (10) $$

As usual, we assume that $|H_{ki}^{n}|^2$ vanishes with the distance between base station and user , based on a given path loss model. In the sequel, it is convenient to assume (without restriction) that users are numbered from the nearest to the base station to the farthest.

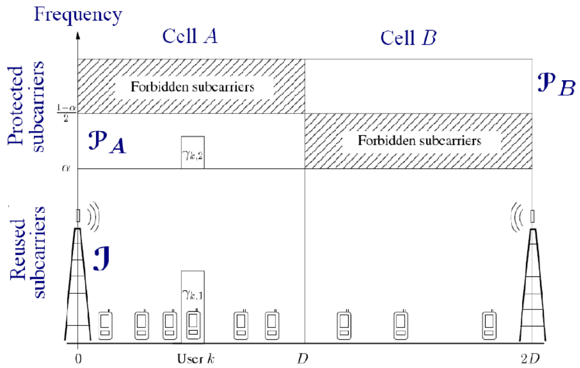

Fig. 2: Subcarrier distribution schemes. Where D is the radius of the cell. This subcarrier distribution model from [12]

IV. GA for user , subcarrier and power allocation

Dynamic radio resource allocation of OFDMA problem of (5) and (6) may be solved analytically using the method of Lagrange multipliers that provide a strategy for finding the local maxima and minima of a function subject to equality constraint. This approach requires a huge search processes to achieve the optimal allocation of the resources, which yields a high computational complexity However, for the optimization of multi-dimensional functions the same results can be achieved numerically using

a Genetic Algorithm (GA), that can yield a solution without prior knowledge of a closed form. In this paper we have used a GA to solve the multi-objective function for maximization of the overall rate of an OFDMA system. The flow chart of the GA is sketched in Fig. 3. Thorough treatments of the GA and multi-objective searches are given in [11] and [13]. The GA method was chosen since it was known to be a search algorithm that was not prone to getting stuck in local minima and effectively searches several points across a functions range simultaneously.

It was also shown in [13] that multi-objective functions could be optimised on a multi-dimensional Pareto surface,

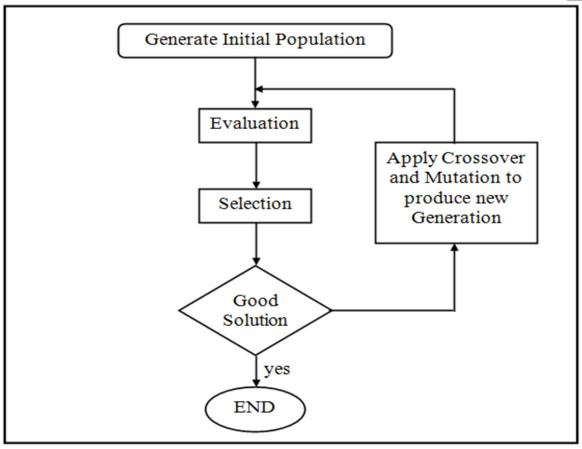

Fig. 3: GA flow chart

The sequence of the Adaptive resource of the OFDMA by using GA is

1- 64 subcarriers have been taken for this system, it's the same number of genes, and each 64 genes construct the chromosome.

2- Each gene contains from 3 digits, the first and two for user subcarrier allocation and the reminder for the power levels, so the layout form of the chromosome is shown in Table 1. Then each subcarrier (gene) has the layout is shown in Table 2.

3- Number of users is assumed 10 for each cell.

Subcarrier 1	Subcarrier 2	…	Subcarrier 64

Table 1 : The layout form of each chromosome

In the beginning subcarriers and power must be distributed among the users in arbitrary way.

User index	Subcarrier allocation coefficient	Allocated power

Table 2 the layout of each gene (subcarrier)

V. Simulated results

For OFDMA system with 64 subcarriers and not fair scheduling scenario for subcarrier allocation (which means a certain subcarrier *n* allocated to user *k* of best channel to noise radio (CNR) between the base station and the user *k* through subchannel *n*). Frequency selective Rayleigh channel is considered here. If the subcarrier *n* is allocated to user *k* then this subcarrier cannot attained to another user in the same time any user may be used more than one subcarrier. Fitness value for different values of compensation factor versus iteration index is illustrated in Fig. 4 . The map of allocating subcarrier

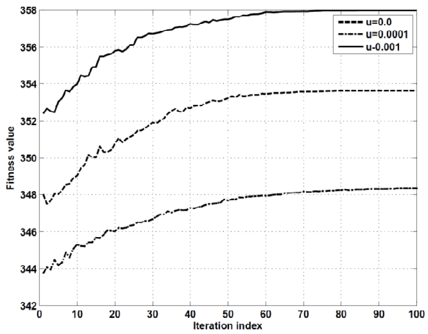

Fig. 4: Fitness value versus Iteration index

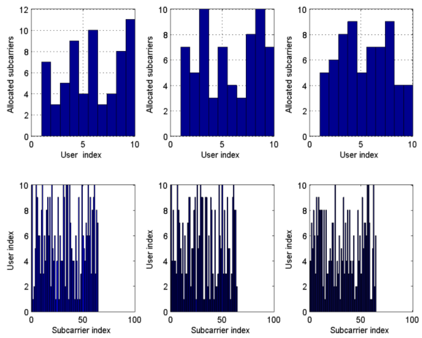

Fig. 5: User and subcarrier allocation

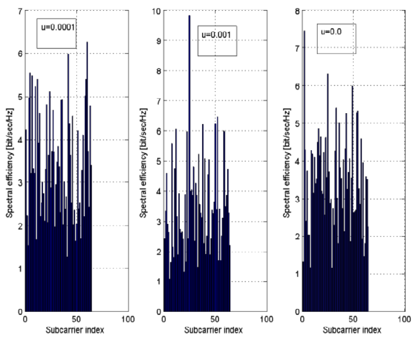

Fig. 6: Spectral efficiency per subcarrier

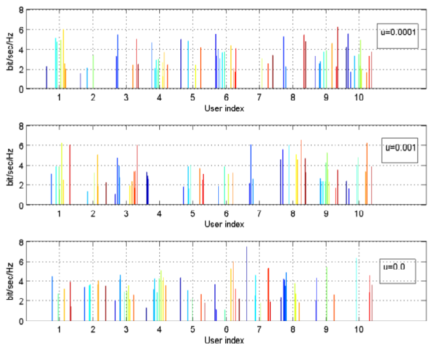

Fig. 7: Spectral efficiency per user index for $\mu = 0.0001, 0.001,$ and 0.00

VI. Conclusion

Here we investigated our compensation way between the objective functions (maximize the spectral efficiency and minimize the transmitted power) to attained the best solution which depends on the trade-off cost. There are many compensation level μ to obtain on demand figures. Three levels of μ , 0.001,.001 and 0.0 is covered. Through rate graphs (Fig. 6 and 7) we have bit/sec/Hz between 6 to 8 according to the μ factor as well the channel environments.

الخلاصة:ـ

الخوارزمية الجينية لحل أمثل لتخصيص الحامل الفرعي وعدد البتات والقدرة للدالة المتعددة الأهداف لحزمة النزول لنظام خليوي OFDMA

في هذا البحث, تم تقديم تقنية لتخصيص الموارد الراديوية لنظام (OFDMA) مقيد بالمعدل النسبي للبيانات الملائم لتطبيقات الجيل الرابع.هذه التقنية تهتم بالمقايضة بين تعظيم معدل الإرسال وتقليل القدرة. هذه التقانة في غاية الأهمية لتطبيقي الإرسال ذو متطلبات السعة العالية وذو الاحتفاظ بالقدرة ذلك بسبب اعتناء الدالة متعددة الأهداف للنظام بالهدفين من خلال عامل تعويض بينهما. تم اعتماد طريقتين الخصيص الحوامل الفرعية للمستخدمين. خلال النتائج العددية تم الحصول على حمل بين (6 to 8 bit/sec/Hz) تبعا لعامل التعويض وظروف القناة.

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