Flexible Resource Allocation for Multicast in OFDMA based Wireless Networks

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Abstract

This paper studies an efficient resource allocation scheme for multicast in OFDMA based wireless networks. Apart from the conventional resource allocation schemes for multicast which allocate exactly the same subcarriers to the users in a multicast group, this paper proposes a more flexible scheme to divide the multicast group members into different subgroups by utilising the diversity of channel coefficient of different users. We first formulate an optimisation problem to maximise the overall transmission rate. Given the NP-hardness of the problem, we design a low-complexity heuristic, Flexible Resource Allocation with Geometric programming (FRAG). FRAG is a two-step heuristic to subdivide the multicast groups and allocate resource to corresponding subgroups. In the first step, we propose a greedy algorithm to subdivide groups and allocate subcarriers given the assumption of even power distribution. Then we use geometric programming (GP) to solve the optimal power allocation problem. Numerical results show that FRAG is able to allocate subcarriers and power efficiently and effectively, and it achieves up to 33% improvement in aggregated throughput.

1 Introduction

Orthogonal frequency division multiplexing (OFDM) is one of the key promising techniques for the next generation wireless broadband networks, such as WiMAX and LTE, due to its ability to support high data rate in multi-path fading environments [3]. The multiuser OFDM system is referred as orthogonal frequency division multiple access (OFDMA). In OFDMA systems, the entire available frequency band is subdivided into multiple subcarriers and allocated to different users. How to allocate the available resources by exploiting multiuser diversity gain to improve the system performance has attracted much attention [4, 10, 12, 16]. Generally, the resource allocation problem is cast into two categories: 1) to minimise the total transmission power with the constraints on user's data rate or bit error rate [12], and 2) to maximise system throughput with the constraints on total transmission power or user's achievable data rate [4, 10, 16].

The next generation broadband wireless networks are expected to enable a whole new range of exciting multimedia services, such as IP-TV, on-line games, audio/video conferences. These applications can significantly benefit from multicasting that provides an efficient method to transmit the same data to multiple receivers by utilising the wireless broadcast advantage (WBA) [11]. For conventional multicast resource allocation schemes in OFDMA based networks, all users within the same multicast group share exactly same subcarriers. Moreover, in order to make all users decode the transmitted data successfully, a base station (BS) has to transmit at a rate no more than the minimum of all maximum rate that can be handled by the users within the multicast group. However, this rate allocation policy may result in sub-optimal solution, especially when the users in the same group are spread in the network. Therefore, the individual channel coefficients of users are different to each other. In this paper, we propose a flexible resource allocation scheme by utilising the diversity of individual channel coefficients.

This paper makes the following key contributions:

- A flexible resource allocation scheme for multicast is proposed to provide maximum total transmission rate by utilising the diversity of channel coefficient. We formulate the flexible resource allocation scheme as an optimisation problem.

- Given the NP-hardness of the problem, we propose a low-complexity 2-step heuristic, Flexible Resource Allocation with Geometric programming (FRAG). A greedy algorithm is designed in the first step of FRAG to subdivide multicast groups and allocate subcarriers to different subgroups, by using even power distribution assumption. In the second step, we transform the optimal power allocation problem into posynomials, which can be solved by geometric programming (GP) [1] effectively and efficiently.

The rest of this paper is organised as follows: The motivation of this paper is discussed in Section 2. Section 3 formulates the new resource allocation problem in OFDMA based multicast system. The low-complexity resource allocation scheme is proposed in Section 4. We evaluate the performance of our heuristic in Section 5. Finally, the paper is concluded in Section 7.

Table 2.1: Example of the maximum rate available in different subcarrier

	subcarrier 1	subcarrier 2
user 1	1 Mbps	5 Mbps
user 2	4 Mbps	2 Mbps

2 Motivation

By utilising wireless broadcast advantage, the users in a multicast group can receive multicast data from BS through a single transmission. Therefore, in conventional resource allocation schemes for multicast transmission [5, 6, 8, 14], every user in a multicast group share exactly the same network resource. This means that all users in the multicast group receive data at the same rate. In order for all the users to decode the transmitted data successfully, the BS must transmit data at a rate no more than the maximum transmission rate of the worst member of the group.

However, this transmission scheme does not always provide an optimal solution for the sake of maximising the total transmission rate, especially when the users within the same multicast group spread in the coverage of the base station. As a result, the channel coefficients of different users in the same subcarrier may vary from each other. For example, a base station has 2 subcarriers to allocate to two users in a multicast group. The maximum transmission rate available for each user in 2 subcarriers is shown in Table 2. Under the conventional resource allocation schemes, BS can transmit data at most 1 Mbps for subcarrier 1. Otherwise, user 1 cannot decode the data successfully. Similarly, the maximum transmission rate in subcarrier 2 is 2 Mbps. As a result, the total transmission rate allocated to the multicast group is 3 Mbps and the aggregated throughput is 6 Mbps. However, if we split the multicast group into 2 subgroups, and allocate subcarrier 2 to user 1 and subcarrier 1 to user 2. Although neither user 1 decodes data at subcarrier 1 nor user 2 decodes data at subcarrier 2, user 1 and 2 can get at most 5 Mbps and 4 Mbps respectively. Accordingly, it achieves 9 Mbps aggregated throughput, which is higher than 6 Mbps from the former resource allocation schemes.

Therefore, the goal of this paper is to introduce a new resource allocation scheme with more flexible rate allocation scheme, which achieves higher transmission rate for all multicast users.

3 System Model

In this paper, we consider multicast in a one-cell OFDMA-based wireless system. The total system bandwidth of the BS is denoted as B. BS transmits G downlink traffic flows (representing G multicast groups) to K users over M subcarriers. With no loss of generality, we assume that the whole bandwidth B is allocated to all G multicast groups, and each subcarrier has an equal bandwidth $B_0 = B/M$. In a single transmission, a subcarrier can only be allocated to one multicast group. Besides, we assume that each user receives only one of G flows at a time. This equivalently means that each user is a member of exactly one of the G multicast groups. Let $\mathcal{K}_g (g = 1, \ldots, G)$ denote the user set of group g receiving the gth traffic flow, and $|\mathcal{K}_g|$ represents the number of members in group $\mathcal{K}_g$.

If $|\mathcal{K}| > 1$, the gth traffic is a multicast. The user set containing all K users is denoted by $\mathcal{K} = \bigcup_{g=1}^{G} \mathcal{K}_g$ and $|\mathcal{K}| = \sum_{g=1}^{G} \mathcal{K}_g$.

The BS allocates power and subcarrier resource in a centralised manner, based on the assumption that it can obtain the perfect channel state information (CSI) of all users in the system by dedicated feedback channel. Given a user k at subcarrier m, it is generally known that the maximum transmission rate at which k can receive data reliably is

$$r_{k,m} = \frac{B_0}{B} \log_2 (1 + \frac{|h_{k,m}|^2 P_m}{B_0 N_0}) \ , \tag{3.1}$$

where B_0 is the bandwidth of single subcarrier, P_m denotes the transmission power allocated to subcarrier m, N_0 is the one-sided power spectral density of white Gaussian noise, and $|h_{k,m}|$ is the channel coefficient of user k on subcarrier m. In this paper, we assume that the users are stationary such that the channel conditions do not change for the time duration of interest. That is, we do not consider any time-varying fading effects on the channel.

In order to efficiently utilise the limited network resource, the users in one multicast group can share some common subcarriers, by using wireless broadcast advantage. In other words, one subcarrier can be allocated to the whole or a part of the users in a multicast group in one transmission. However, partial sharing of subcarriers is not allowed for the users in a multicast group because it will result in multicast unsynchronised transmission. Therefore, a multicast group may be divided into multiple sub-groups, where the subcarriers allocated to each sub-group are disjoint. If a multicast group $\mathcal{K}_g$ is divided into I subgroups, a single subgroup is denoted as $\mathcal{S}_i(\mathcal{K}_g) \subseteq \mathcal{K}_g, i = 1, \ldots, I$. It is obvious that $\mathcal{S}_i(\mathcal{K}_g) \cap \mathcal{S}_j(\mathcal{K}_g) = \emptyset, \forall i \neq j$, and $\mathcal{K}_g = \bigcup_{i=1}^{I} \mathcal{S}_i(\mathcal{K}_g)$.

If a subcarrier is allocated to a subgroup $\mathcal{S}_i(\mathcal{K}_g)$, the BS must transmit data at a rate no more than the maximum transmission rate of the worst-off member in order for all the users to decode the transmitted data successfully [7]. On subcarrier m, let

$$\beta_{\mathcal{S}_i(\mathcal{K}_g),m} = \min_{k \in \mathcal{S}_k(\mathcal{K}_g)} \frac{|h_{k,m}|^2}{B_0 N_0} \tag{3.2}$$

be the equivalent channel signal-to-noise ratio (CSNR) of the subgroup $\mathcal{S}_i(\mathcal{K}_g)$. Then the maximum rate of all users in subgroup $\mathcal{S}_i(\mathcal{K}_g)$ on subcarrier m on which data can be successfully decoded is

$$r_{\mathcal{S}_i(\mathcal{K}_g),m} = \frac{B_0}{B} \log_2 (1 + \beta_{\mathcal{S}_i(\mathcal{K}_g),m} P_m) \ . \tag{3.3}$$

Denote $\mathcal{M}_i \subseteq \mathcal{M}$ as the set of subcarriers allocated to a subgroup $\mathcal{S}_i(\mathcal{K}_g)$, where $\mathcal{M}$ is the set of all subcarriers. The total transmission rate that the users in $\mathcal{S}_i(\mathcal{K}_g)$ is

$$r_{\mathcal{S}_i(\mathcal{K}_g)} = \sum_{m \in \mathcal{M}_i} \frac{B_0}{B} \log_2 (1 + \beta_{\mathcal{S}_i(\mathcal{K}_g),m} P_m) \ . \tag{3.4}$$

The objective of this paper is to maximise the overall transmission rate by choosing the optimal multicast group subdivision as well as power and subcarrier combination, on the premise of the individual delay guarantee.

3.1 Mathematical formulation

Here, we provide a mixed integer programming (MIP) formulation of the maximum multicast rate problem. Define:

- The BS allocates M subcarriers to K users which belong to G multicast groups. Let $i_g \in \mathcal{K}_g$ be a user in the multicast group g, where $\mathcal{K}_g$ is denoted as the set of all users in group g. Let $s_g \subseteq \mathcal{K}_g$ be a set of users in the group g. Therefore, the number of possible combinations of s_g is $2^{|\mathcal{K}_g|} - 1$.

- The binary variables $\rho_{i_g,m}$, $i_g \in \mathcal{K}_g$, $m \in \mathcal{M}$, given by

$$\rho_{i_g,m} = \begin{cases} 1 & \text{if channel } m \text{ is allocated to user } i_g \in g, \\ 0 & \text{otherwise} \end{cases}$$

- The non-negative variables $\beta_{i_g,m}$ is the equivalent CSNR of i_g when it is allocated subcarrier m.

- The non-negative variables P_m is the power allocated to subcarrier m.

- The binary variables $e_{i_g,s_g,m}$, $s_g \subseteq \mathcal{K}_g$, $i_g \in \mathcal{K}_g$, $m \in \mathcal{M}$, given by

$$e_{i_g,s_g,m} = \begin{cases} 1 & \text{if channel } m \text{ is allocated to the subgroup } s_g \subseteq \mathcal{K}_g, \text{where the user } i_g \in s_g \\ 0 & \text{otherwise} \end{cases}$$

Then the MIP formulation of the maximum multicast rate problem is

$$\max_{\rho_{g,i_g,m},P_m} \sum_{m=1}^{M} \sum_{g=1}^{G} \sum_{i_g=1}^{|\mathcal{K}_g|} \rho_{i_g,m} \cdot \log_2 \left(1 + \beta_{i_g,m} P_m\right) , \tag{3.5}$$

subject to

$$\sum_{m=1}^{M} P_m \leq P_{tot}, \tag{3.6}$$

$$P_m \geq 0, \tag{3.7}$$

$$e_{i_g,s_g,m} = 0, \qquad \forall i_g \notin s_g \tag{3.8}$$

$$\sum_{\forall s_g \subseteq \mathcal{K}_g} e_{i_g,s_g,m} = \rho_{i_g,m}, \qquad \forall i_g \in \mathcal{K}_g \tag{3.9}$$

$$e_{i_g,s_g,m} = e_{i'_g,s_g,m}, \qquad \forall i_g, i'_g \in s_g \tag{3.10}$$

$$e_{i_g,s_g,m} + e_{i_g,s'_g,m} \leq 1, \qquad \forall s_g \neq s'_g \tag{3.11}$$

$$0 \leq \beta_{i_g,m} \leq \rho_{i_g,m} \cdot (\rho_{i'_g,m}\beta_{i'_g,m} + (1 - \rho_{i'_g,m}) \cdot \beta^*), \qquad \forall i'_g \in \mathcal{K}_g \tag{3.12}$$

Constraints (3.6) and (3.7) corresponds the total power limitation of the BS. Constraints (3.8) and (3.9) make sure that if the subcarrier m is allocated to a user i_g, only one subgroup which contains i_g is chosen for the same subcarrier. Constrain (3.10) guarantees that all users in the same subgroup are keeping identical allocation in all subcarriers. On the other hand, constraint (3.11) ensures that the subgroups in one multicast group are disjoint to each other at any subcarrier. Equations (3.12) is used to find suitable equivalent CSNR allocated to subcarrier m. β^* is the a maximum equivalent CSNR found in all users. If the subcarrier m is allocated to user i_g, the $\beta_{i_g,m}$ should be no more than the equivalent CSNR of any user that subcarrier m is also allocated to in the same group. If a user i'_g is not chosen in subcarrier m, where $\rho_{i'_g,m} = 0$, its equivalent CSNR $\beta_{i'_g,m}$ will not be considered for i_g, because at least $\beta_{i_g,m} \leq \beta^*$.

A special case of the problem is where the size of each multicast group is 1, $|\mathcal{K}_g| = 1$. Then it becomes a maximum sum rate (MSR) problem [15] for unicast, which is proven NP-hard in [13]. Therefore, the maximum multicast rate problem defined in equations (3.5) – (3.12) is NP-hard. As a result, exhaustive searching algorithm at the BS within a given time can hardly be applied in practice. To solve this problem, we need a suboptimal algorithm with low complexity for practical implementation. In the next section, we provide an efficient heuristic by using geometric programming to allocate the subcarriers and power.

4 Flexible Resource Allocation with Geometric programming (FRAG) Heuristic

In this section, we propose a low-complexity heuristic, which is called Flexible Resource Allocation with Geometric programming (FRAG) heuristic. Instead of allocating power and subcarrier, as well as subdividing multicast groups jointly, FRAG applies a two-step heuristic. In the first step, FRAG subdivides the multicast groups according to the individual equivalent CSNR and allocates subcarriers to all subgroups given the equal-power assumption. The power distribution over the allocated subcarriers is achieved using the geometric programming in the second step.

4.1 Step 1: Subcarrier allocation with equal power assumption

In the first step, we assume equal power distribution on all subcarriers, where $P_0 = P_{tot}/M$. Accordingly, the objective of this step is to subdivide multicast group based on CSNR, and allocate subcarriers to all subgroups.

Algorithm 1 shows the detail of the two-round group division and subcarrier allocation scheme. The input of the algorithm includes a set of all subcarriers $\mathcal{M}$, the set of all multicast groups $\mathcal{G}$, the set of all users in the networks $\mathcal{K}$. Let $\mathcal{K}_g \subseteq \mathcal{K}$ be the set of users in group g, and i_g be the user in $\mathcal{K}_g$. $\beta_{i_g,m}$ is the known equivalent CSNR of user i_g on subcarrier m. The objective is to divide multicast groups into different disjoint subgroups $\mathcal{S}$, and allocate subcarriers to all users. s_m is the subgroup that m is allocated to, and β_m is the found equivalent CSNR of s_m. The round 1 of the algorithm is to subdivide the multicast group. If a subcarrier m is allocated to a set of users s_g, the equivalent CSNR is decided by the worst member within the set to decode the transmitted data successfully. Therefore, the aggregated transmission rate of s_g is

$$r_{s_g,m} = |s_g| \frac{B_0}{B} \log_2 \left(1 + \beta_{s_g,m} P_0\right) . \tag{4.1}$$

Algorithm 1 Group subdivision and subcarrier allocation scheme

1: **Input:** $\mathcal{M}, \mathcal{G}, \mathcal{K}, \mathcal{K}_g \subseteq \mathcal{K}, i_g \in \mathcal{K}_g, \beta_{i_g,m}$
2: **Start:**
3: // *Initialization*
4: $\rho_{i_g,m} \leftarrow 0$, $\beta_m \leftarrow 0$, $s_m \leftarrow \emptyset$, $\forall i_g \in \mathcal{K}_g, g \in \mathcal{G}, m \in \mathcal{M}$
5: $\mathcal{S} \leftarrow \emptyset$
6: // *Round 1: multicast group subdivision*
7: **while** $\mathcal{K} \neq \emptyset$ **do**
8: **Find** a pair $\{s_g^*, m^*\}$, where $g \in \mathcal{G}, s_g^* \subseteq \mathcal{K}_g$ and $m^* \in \mathcal{M}$, which satisfies $\left|s_g^*\right| \beta_{s_g^*,m*} \geq |s_g| \beta_{s_g,m}, \forall s_g, m$, where $\beta_{s_g,m} = \arg\min_{i_g \in s_g} \beta_{i_g,m}$
9: $\rho_{i_g,m^*} \leftarrow 1$, $\beta_{i_g,m^*} \leftarrow \beta_{s_g,m^*}$, $\forall i_g \in s_g^*$
10: $\mathcal{S} \leftarrow \mathcal{S} \cup s_g^*$
11: $\mathcal{K}_g \leftarrow \mathcal{K}_g \backslash s_g^*$, $\mathcal{M} \leftarrow \mathcal{M} \backslash \{m^*\}$
12: **end while**
13: // *Round 2: remaining subcarrier allocation*
14: **while** $\mathcal{M} \neq \emptyset$ **do**
15: **Find** a pair $\{s^*, m^*\}$, where $s^* \in \mathcal{S}, m^* \in \mathcal{M}$, which satisfies $|s^*| \beta_{s^*,m*} \geq |s| \beta_{s,m}$
16: $\rho_{i_g,m^*} \leftarrow 1$, $\beta_{i_g,m^*} \leftarrow \beta_{s^*,m^*}$, $\forall i_g \in s^*$
17: $\mathcal{M} \leftarrow \mathcal{M} \backslash \{m^*\}$
18: **end while**

As a result, the maximum $|s_g| \beta_{s_g,m}$ represents the maximum aggregated transmission rate at a subcarrier. Line 8 ensures a subset of users in a multicast group will be selected on a best subcarrier. If a subgroup of users in selected, they will be excluded from the following selection in round 1. Lines 9–11 make sure that all users will be allocated to at least one subcarrier, and there is no overlap of user between different subgroups. After round 1 selection, all subgroups $\mathcal{S}$ are found, and each subgroup has been allocated at least one subcarrier. Round 2 is a greedy process to allocate the remaining subcarriers to the subgroup with the maximum aggregated transmission rate.

4.2 Step 2: Power allocation with geometric programming

After the step 1, all users are divided into new subgroups and the subcarrier allocation is accomplished. For a given subcarrier m, the number of users of the subgroup s_m which m is allocated to and the equivalent CSNR of β_m are known. Therefore, the optimisation problem (3.5)–(3.12) become

$$\max_{P_m} \sum_{m=1}^{M} |s_m| \cdot \log_2 \left(1 + \beta_m P_m\right) , \tag{4.2}$$

subject to

$$\sum_{m=1}^{M} P_m \leq P_{tot} \tag{4.3}$$

$$P_m \geq 0 \tag{4.4}$$

In the following part, we use geometric programming (GP) [1] to solve this problem efficiently. For completeness, we first provide a brief overview of GP.

Geometric programming is an efficient way to solve optimisation problems designed to determine the minimum value while the objective function and the constraints follow a special form:

$$\begin{array}{rll} \text{minimize} & f_0(x) & \\ \text{subject to} & f_i(x) \leq 1, & i = 1, \cdots, m \\ & h_j(x) = 1, & j = 1, \cdots, n \end{array} \tag{4.5}$$

where f_0 and f_i are posynomials and h_j are monomials. A monomial is defined as a function $h : \mathbf{R}^n_{++} \to \mathbf{R}$:

$$h(\mathbf{x}) = c x_1^{a_1} x_2^{a_2} \cdots x_n^{a_n} \ , \tag{4.6}$$

where $c \geq 0$ and $a_i \in \mathbf{R}, i = 1, 2, \cdots, n$. A posynomial is a sum of monomials:

$$f(\mathbf{x}) = \sum_{k=1}^{K} c_k x_1^{a_1 k} x_2^{a_2 k} \cdots x_n^{a_n k} \ . \tag{4.7}$$

GP theory and very efficient GP algorithms are already well-developed [1]. In the next step, we convert the optimisation problem (4.2)-(4.4) into the form of posynomials so that it can be solved as a GP.

Transformation process

The optimisation problem (4.2)–(4.4) cannot be solved by GP directly, since the objective function is not a posynomial. In [1], the authors introduce several extensions to transform a function to a generalised posynomial. An optimisation problem composed of generalised posynomials is called generalised geometric programming (GGP), which can be converted to equivalent GP. In this part, we use this technique to transform the problem to a GP. First, the objective function (4.2) equals to

$$\max_{P_m} \qquad 2^{\sum_{m=1}^{M} \log_2 (1+\beta_m P_m)^{|s_m|}} = \Pi_{m=1}^{M} (1 + \beta_m P_m)^{|s_m|} \ . \tag{4.8}$$

The maximisation problem (4.8) can be converted to a minimisation problem

$$\min_{P_m} \quad \prod_{m=1}^{M} (1 + \beta_m P_m)^{-|s_m|} \ . \tag{4.9}$$

Let $r_m = 1 + \beta_m P_m$, then

$$P_m = \frac{1}{\beta_m} r_m - \frac{1}{\beta_m} \ . \tag{4.10}$$

Replace P_m with r_m in equations (4.3) and (4.4) by (4.10), then we get a new optimisation problem

$$\min_{r_m} \quad f_0(r) = \prod_{m_1}^{M} r_m^{-|s_m|} \ , \tag{4.11}$$

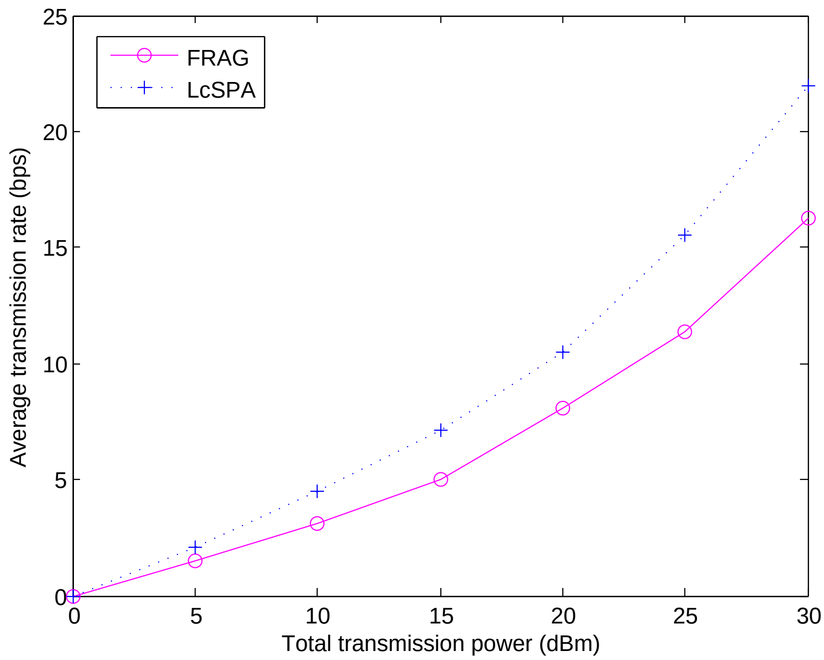

Figure 5.1: Comparison of average transmission rate between FRAG and Lc-SPA.

subject to

$$f_1(r) = \frac{1}{P_{tot} + \sum_{m=1}^{M} 1/\beta_m} \sum_{m=1}^{M} \frac{1}{\beta_m} r_m \leq 1 \tag{4.12}$$

$$f_2(r) = r_m^{-1} \leq 1 \tag{4.13}$$

Equations (4.11)–(4.13) satisfy the form of posynomial. Then the problem can now be solved easily by using GP.

5 Performance Evaluation

In this section, we provide some numerical simulations to evaluate the performance of the proposed algorithm in different configurations. Assume that all subcarriers undergo flat Rayleigh fading, and the average channel gain $E(|h_{k,m}|^2)$ is normalised to be one. For each subcarrier, the independent channel coefficient $\{h_{k,m}\}$ is randomly generated according to Rayleigh distribution. For the simplicity, the noise power in each subcarrier N_0 and the individual subcarrier bandwidth B_0 are both normalised to be one. We compare the performance of FRAG with the low-complexity subcarrier and power allocation algorithm (Lc-SPA) proposed in [6]. Here the geometric programming in the step 2 of FRAG is solved by the toolbox GGPLAB [2].

In the first group of tests, we consider an OFDMA network with $M = 64$ subcarriers, $K = 16$ users belonging to $G = 3$ multicast groups, where $|\mathcal{K}_1| = 7, |\mathcal{K}_2| = 5, |\mathcal{K}_3| = 4$. We increase the total transmission power from 0 dBm

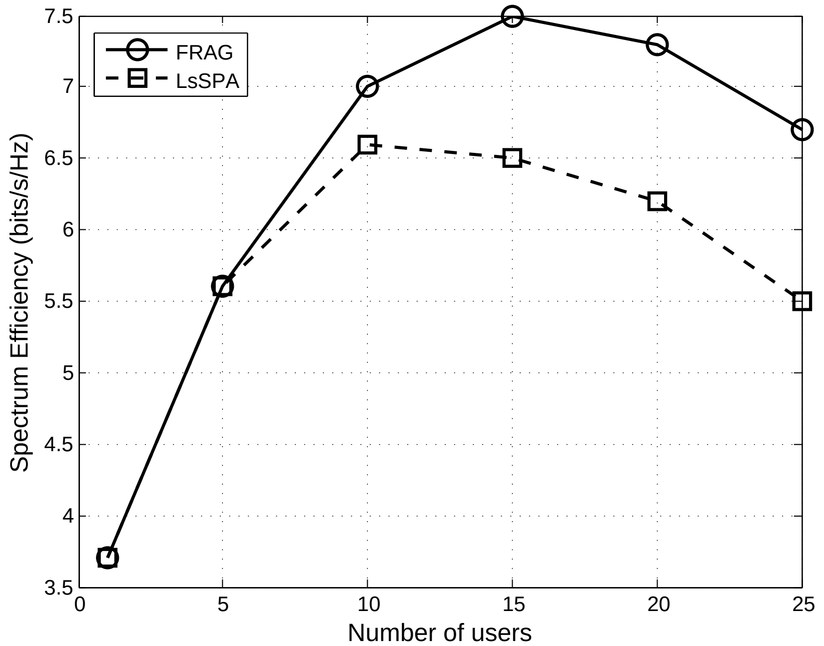

Figure 5.2: Comparison of spectrum efficiency.

to 30 dBm. Figure 5.1 shows the comparison of total transmission rate in this scenario. With the increase of the total transmission power, both heuristics improve the sum rate. In LcSPA, a subcarrier will be allocated to a whole multicast group, so that the equivalent CSNR is constrained by the worst user. However, FRAG can utilise the diversity of individual channel coefficients. If the individual channel coefficients of the users in a multicast group are far from each other, FRAG can divide the multicast group into several subgroups and allocate the subcarrier to the best subgroup. Accordingly, FRAG improves LcSPA in all of the test and it achieves up to 33% improvement.

Figure 5.3 indicates the total transmission rate obtained by two algorithms with the increase of total number of users. The users are randomly chosen to a multicast group, and the total transmission power is fixed at 20 dBm. It is noteworthy that FRAG outperforms LcSPA in most tests. It is observed that the gap increases with the number of users. This is because when the number of users rises, the variant of individual channel coefficients in a multicast group also increases. FRAG can effectively exploit this variance by subdivision of the multicast group.

6 Related Work

Most resource allocation algorithms for OFDMA systems are designed for unicast. Researchers in [15] propose a maximum sum rate (MSR) algorithm to maximise the sum rate of all users, given a total transmit power constraint. A maximum fairness algorithm is proposed in [9] to allocate the subcarriers and

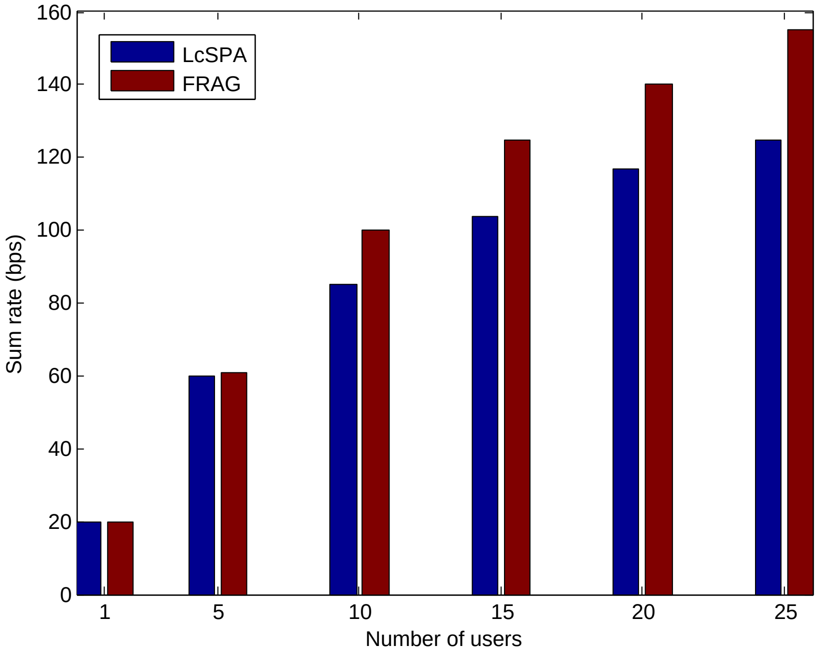

Figure 5.3: Comparison of sum rate between FRAG and LcSPA.

power so that the minimum user's data rate is maximised with the equal rate constraint. There are also some research on resource allocation of multicast in OFDMA systems. Minimum power consumption resource allocation for multicast is studied in [5], where a heuristic is proposed to find the minimum number of OFDM symbols users can receive, thereby resulting in saving power. Random network coding (RNC) is utilised in [14] for multicast resource allocation to minimise the total transmission power. Liu et al. extend maximum sum rate problem to multicast, and formulate an optimisation problem to maximise the system throughput in [6]. The optimal result is obtained by solving a relaxed convex optimisation problem, and a low-complexity heuristic is proposed by assigning subcarrier and power separately. However, this scheme allocates exactly the same resource to all users within a multicast group, so it achieves suboptimal results due to the lack of the utilisation of the diversity of channel coefficient of different users. The study in [8] extend the maximum throughput problem by introducing one more bandwidth constraint. Three genetic algorithm (GA) based low-complexity heuristics are proposed to guarantee the minimum number of subcarriers to be assigned to individual groups.

7 Conclusion

In this paper, we study efficient resource allocation for multicast in OFDMA based wireless networks. This paper proposes a flexible scheme to divide the multicast group members into different subgroups by utilising the diversity of channel coefficient of different users. We first formulate the optimisation problem to maximise the overall transmission rate. Given the NP-hardness of the problem, we design a low-complexity heuristic, Flexible Resource Allocation with Geometric programming (FRAG), which is a two-step heuristic to subdivide the multicast groups and allocate resource to corresponding subgroups. Numerical results show that the proposed algorithm is able to allocate subcarriers and power efficiently and effectively.

For future work, we plan to propose an algorithm to find the optimal solution of the problem, and complete the complexity analysis. Moreover, quite a few multicast applications require some bandwidth guarantee in order to achieve expected performance. For example, the mobile IPTV uses minimum 2 Mbps to provide contents to mobile users, and ideal conferencing using H.264 codec requires at least 256 Kbps bandwidth. Therefore, the further work will add QoS guarantee for the optimisation problem.

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