A Modified Greedy Algorithm for Dynamic Chunk Allocation in SC-FDMA System

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ABSTRACT

In this paper, we proposed Dynamic Chunk Allocation based on channel condition using a Modified Greedy Algorithm in SC-FDMA system. Simulation is performed on the uplink direction and it is assumed that channel state information (CSI) of all users are known and have been available at the base station. Number of CSI available to each user is assumed as many as 500 time transmission interval (TTI). Based on the condition of each user's CSI, base station will allocate a chunk (a set of subcarriers) to each user where each user get a different chunk and this allocation will be done dynamically and will be repeated every one transmission time interval. Chunk allocation scheme used is a modified greedy algorithm and the performance of allocation schemes are taken into consideration is the achievement of the maximum user data rate per bandwidth (bandwidth efficiency) and the difference between the maximum data rate and data rate - average for each user to represent fairness. The allocation of chunk in the uplink SC-FDMA system is performed by solving a mathematical model based on the objectivity which is achieved and the constraints of problem. A Modified greedy algorithm was proposed to solve the problem of chunk allocation because it has low complexity and meet the criteria for suboptimal. The proposed algorithm is simulated for the number of users varies from 5 to 30 users and use L-FDMA scheme as subcarrier mapping and also use MMSE (Minimum Mean Square Error) and ZF(Zero Forcing) as ISI cancellation in receiver. The simulation results showed that the proposed algorithm can improve the user throughput up 7.21% at the number of user is 20 and improve fairness up to 4.9 % in the number of users at 30 compared to Enhanced Mean Greedy (EMG) algorithm proposed by Obilor Nwamadi et al with the same algorithm complexity.

Keywords

Greedy, Dynamic Chunk Allocation, SC-FDMA

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing Access (OFDMA) is one of the access technology solutions that have been widely adopted as a standard in the wireless industry including: WLAN IEEE 802 and IEEE 802 11.g. 11.a OFDMA technology is also used for the 3GPP LTE physical layer, IEEE 802.16, to accommodate high-speed service both real time and non real time and to support fixed and mobile subscribers [1] [2].

Besides having several advantages, OFDMA has the loss in signal envelope fluctuations in time domain that would cause the high PAPR (Peak To Average Power Ratio). Due to the high PAPR will hurt the mobile terminal, the SC-FDMA (Single Carrier Frequency Division Multiple Access) is recommended by 3GPP as uplink access scheme in OFDMA systems [2] [7] [9].

In SC-FDMA system, the radio resources used by each user can be adjusted and changed depending on channel conditions. The process of adaptation to change radio resources is performed every 1 time transmission interval (TTI), so in practice we need the radio resource allocation algorithm with low complexity to be implemented. [1] [8] [9] [12].

To reduce the complexity of radio resource allocation algorithm, the available frequency spectrum is divided into resource blocks (RB) or chunks, where each resource block or chunk contains a set of adjacent subcarriers where the total available number of subcarriers in one chunk can up to 1200 subcarriers [2] [9].

Grouping of subcarriers within one chunk in SC-FDMA system can be divided into 2 schemes : L-FDMA (Localized Frequency Division Multiple Access) and I-FDMA (Interleaved Frequency Division Multiple Access). In L-FDMA, subcarriers to be allocated in one chunk is consecutive and in I-FDMA subcarriers allocated in one chunk to users are not consecutive but have the same space between subcarriers. I-FDMA was not included into the LTE standard performance disadvantages due to slight the caused by the requirements of channel estimation accuracy [9]. In this paper, We Consider only of L-FDMA subcarriers as mapping in SC-FDMA uplink.

In [7], subcarrier allocation algorithm in OFDMA with the aim of maximizing the amount of user data rate on the system without considering fairness between users is proposed. Subcarrier is given to users who have the best channel gain on these subcarriers. So a user who has the best average channel gain will be assigned the amount of subcarrier higher than the others.

In [8][9], subcarriers allocation algorithm with the aim of achieving fairness criteria with the assumption of subcarriers of each user to be achieved is known are proposed.

In [12],subcarrier allocation algorithm in SC-FDMA uplink system with the aim of maximizing the amount of user data rate without considering fairness between users is proposed. The subcarrier allocation algorithm is done in each chunk or resource block to reduce the complexity of the algorithm because of increasing the number of users and the number of subcarriers. Grouping subcarrier used in this scheme algorithm is L-FDMA where each chunk contains a consecutive subcarriers.

In [15], chunk allocation algorithm in SC-FDMA system with the aim of maximizing the amount of the user data rate without considering fairness between user is proposed. Subcarrier grouping in each chunk is using the L-FDMA and the channel gain in each chunk per user is calculated based on the average of subcarrier gain in each user. The Maximum Greedy algorithm is used to allocate a chunk to the user by searching the the user allocation sequence so obtained the maximum amount of user data rate.

In [16], chunk allocation algorithm in SC-FDMA system for the purpose of maintaining fairness among users while maintaining the amount of user data rates are high is proposed. Subcarrier grouping used is the L-FDMA and the channel gain in each chunk per user is calculated based on the average of subcarrier gain in each user. The Mean enhanced greedy algorithm is used to allocate a chunk to the user by find a user who has the smallest average of chunk gain. Then this user will be get a chunk which has the biggest average of user channel gain.

In this paper, we propose a modified greedy algorithm to allocate the chunk in SC-FDMA system with the aim of improving the achievement of total user data rate and increasing data rate fairness among users. The gain in every chunk per user is determined based on the ISI cancellation detection method used by each user. We use MMSE (Minimum Mean Square Error) and ZF (Zero Forcing) as ISI canecellation detection method. It is assumed that the number of subcarriers per chunk are fixed and the number of available chunks are equal to the number of users. It is also assumed that all the channel state information from each user has been known in base station as many as 500 TTI (Transmission Time Interval). The allocation algorithm begins with the selection of a chunk which has the smallest average of user gain. A Chunk which has the smallest average of user gain is allocated to a user who has the biggest average of chunk gain.

The simulation results show that the proposed algorithm can improve the fairness up to 4.9 % at the number user is 30 and increase the sum of user data rate up to 7.21 % at the number of user is 20.

The paper is organized as follow. Problem formulation is presented in section 2. The proposed algorithm are described in section 3. The proposed algorithm complexity is determined in section 4. The simulation results are presented and discussed in section 5. Finally, conclusions are drawn in section 6.

2. PROBLEM FORMULATION

Chunk allocation algorithm proposed in this paper aims to improve the fairness and keep the amount of user data rate. It is assumed there are N subcarriers, the number of users is K and the number of available chunk is C, where the number of users is equal to the number of available chunks. Grouping of subcarriers for each chunk using the L-FDMA scheme where the number of subcarriers per chunk is $N_k = N / K$.

Chunk allocation algorithm will allocate C chunk for K user using a modified greedy algorithm. It is defined that C_k is a chunk allocated to the user k. In this paper, as realistic solution, we consider equal power allocation for each chunk. Thus we assume that the power assigned to each subcarrier is determined as $p_{n,k}=P_k/N_k$ where P_k is the total power for user k.

SC-FDMA uses a frequency domain equalizer to mitigate inter-symbol interference (ISI). We assume that Minimum Mean Square Equalizer (MMSE) and Zero Forcing (ZF) are used as ISI cancellation detection method, and from [8][14] the SNR of data delivered in a chunk with MMSE and ZF equalization can be re-written as (1) and (2) where C_k is a chunk containts N_k

subcarriers assigned to user k, $\gamma_{n,k}$ is the SNR of subcarrier n of user k after power allocation , σ_n^2 is the noise power of subcarrier n and $H_{n,k}$ is channel gain from CSI of subcarrier n of user k of each TTI.

$$\gamma_k^{MMSE} = \frac{1}{\frac{1}{N_k} \quad {}_{n \in C_k} \frac{\gamma_{n,k}}{\gamma_{n.k}+1}} - 1 \quad ^{-1} \quad , \gamma_{n,k} = \frac{p_{n,k} H_{n,k}}{\sigma_n^2} \tag{1}$$

$$\gamma_k^{ZF} = \frac{1}{\frac{1}{N_k} \quad {}_{n \in C_k} \frac{1}{\gamma_{n.k}}} \quad ^{-1} \quad , \gamma_{n,k} = \frac{p_{n.k} H_{n,k}}{\sigma_n^2} \tag{2}$$

The achievable efficiency of bandwidth (bps/hz) of user k can be expressed as :

$$eff_k^{MMSE} = log_2(1 + \frac{1}{\frac{1}{N_k} \quad {}_{n \in C_k} \frac{\gamma_{n,k}}{\gamma_{n.k}+1}} - 1 \quad ^{-1}) \tag{3}$$

$$eff_k^{ZF} = log_2(1 + \frac{1}{\frac{1}{N_k} \quad {}_{n \in C_k} \frac{1}{\gamma_{n.k}}} \quad ^{-1}) \tag{4}$$

In this paper, we consider a general optimization problem for multiple users (K user) that can be expressed as :

$$Max_{\ (C_k)} \quad \begin{matrix} {}_{k=1}^{K} \ eff_k^{MMSE} \quad , for\ MMSE\ Equalization \\ {}_{k=1}^{K} \ eff_k^{ZF} \quad , for\ ZF\ Equalization \end{matrix} \tag{5}$$

Subject to :

$${}_{n \in C_k} p_{n,k} = P_k, P_k \geq 0 \ for\ k = 1,2, \ldots . K \tag{6}$$

$${}_{i=1}^{K} N_{ki} \leq N \tag{7}$$

$$C_1 \cup C_2 \ \cup \ldots . . \cup C_k \in C \tag{8}$$

$${}_{k=1}^{K} S_{kc} = 1 \ \ \forall \ c \ \in \ \ 1 \ldots \ldots . C \tag{9}$$

$${}_{c=1}^{C} S_{kc} = 1 \ \ \forall \ k \ \in \ \ 1 \ldots \ldots . K \tag{10}$$

$$S_{kc} \in \ \ 0,1 \tag{11}$$

$$eff_1 \approx eff_2 \approx \cdots \approx eff_k \tag{12}$$

The Optimization of chunk allocation is performed by maximizing the amount of user bandwidth efficiency (5) with the optimization constraints are (6) to (12). s_{kc} are binary variables that denote whether a chunk is allocated (s_{kc} = 1) to a user or not (s_{kc} = 0). Constraints (9), (10) and (11) allows users to use only 1 unique chunk (subcarriers cannot be shared). The optimization algorithm is achieved by selecting a chunk that has the smallest average of user gain. A Chunk that has the smallest average of user gain is allocated to a user who has the biggest average of chunk gain with the power constraint ($P_k \geq 0$). Equation (12) is used to maintain fairness among users. The proposed algorithm is compared with [16] by considering fairness and The sum of bandwidth efficiency users.

3. THE PROPOSED ALGORITHM

Obilor Nwamadi et al [16] proposed the mean enhanced greedy chunk allocation algorithm to maintain fairness among user data rates. The allocation is made by selecting the user first user who will get chunk by selecting a user who has the smallest average of chunk gain. Then this user will be got a chunk which has the biggest average of user channel gain. The gain in each chunk is determined by averaging the channel gain of consecutive subcarriers in one chunk.

In this paper we propose a modified greedy algorithms by modifying the algorithm proposed by obilor et al. There are two modifications that we have done. The first modification is to modify the process by choosing chunk first which will be allocated by selecting a chunk which has the smallest average of user gain. Then this chunk is allocated to a user who has the biggest average of chunk gain. This modification is stated in step 2 until step 3 or equation (14) until (16).

The seccond modification that we have done is by using the equation proposed in [8] and [14] to determine the quality of a chunk where the quality is determined based on the type of equalization used. This modification is stated in step 1 or equation (13).

In our proposes algorithm, it is assumed that in base station $H_{n,k}$ per subcarrier of each user have been known as many as 500 TTI. The algorithm of chunk allocation proposed as follow :

<u>Step 1</u> : SNR per subcarrier which have power allocation per TTI of each user is changed into SNR per chunk of each user using MMSE and ZF detection method based on equation (1) and (2). Subcarrier grouping in one chunk is done using L-FDMA scheme and can be expressed by the following equation :

$$\gamma_{kc}^{MMSE} = \left(\frac{1}{\frac{1}{N_k} \sum_{n=cN_k-N_k+1}^{kN_k} \frac{\gamma_{n,k}}{\gamma_{n.k}+1}} - 1 \right)^{-1} \quad \textit{for } c = 1:C \textit{ and } k = 1:K \qquad (13)$$

$$\gamma_{kc}^{ZF} = \left(\frac{1}{\frac{1}{N_k} \sum_{n=cN_k-N_k+1}^{kN_k} \frac{1}{\gamma_{n.k}}} \right)^{-1} \quad \textit{for } c = 1:C \textit{ and } k = 1:K$$

<u>Step 2</u> : Select a chunk will be allocated by selecting a chunk which has the smallest average of SNR.

$$mean_c = \frac{1}{K} \sum_{k=1}^{K} \gamma_{kc}^{MMSE} \qquad (14)$$

$$mean_c = \frac{1}{K} \sum_{k=1}^{K} \gamma_{kc}^{ZF}$$

$$c = min(mean_c) \qquad (15)$$

c is a chunk to be allocated. The next step is to find a user who will get a chunk c.

<u>Step 3</u> : Choose a user who has the largest SNR in that chunk c.

$$k = \max(\gamma_{kc}^{MMSE}) \qquad (16)$$

$$k = \max(\gamma_{kc}^{ZF})$$

So chunk c is allocated to user k.

<u>Step 4</u> : Calculate the bandwidth efficiency is achieved by user k who get chunk c using equation (3) and (4).

<u>Step 5</u> : The chunk that already allocated and the user who already get a chunk are removed from the process and repeat step 2 through step 5 until all chunks are allocated and all users are got the chunk.

The focus of this algorithm is to maintain fairness between users by allocating chunks that have the smallest average of SNR to user who have the biggest average of SNR and still maintain the achievement of high user bandwidth efficiency. The main difference with the greedy algorithm is in step 2 and Step 3 where the selected chunk is a chunk that has the smallest average of SNR while in the greedy algorithm trying all possible allocation and thus require a high complexity due to the increasing number of users.

When compared with the mean enhanced greedy algorithm (EMG) in [16], the main difference is in step 1 until step 3 where the proposed algorithm is performed by selecting chunk first that will be allocated, while in the EMG select user first who will get the chunk. And in the proposed algorithm to obtain the SNR per chunk is determined by using MMSE or ZF detection scheme, while the EMG is determined by averaging SNR per subcarrier in one chunk. However, a proposed algorithm has the same level of algorithm complexity with algorithms EMG when the number of chunk is equal to number of user.

4. ALGORITHM COMPLEXITY ANALYSIS

The proposed algorithm has three main processes. The first process is to determine the average SNR of each chunk, the second process is to find a chunk that has the smallest average of SNR and the third process is to allocate a chunk to the user who has the biggest average of SNR. The first process require K - 1 addition operation and 1 division operation, so the first process requires K - 1 + 1 = K operation. The second process requires C - 1 operation and the third process requires K - 1 operation. So for one time allocation requires K + (C - 1) + (K - 1) = 2K + C - 2 operations. The number of available chunks is C, so the allocation process would be as many as $2KC + C^2 - 2C$ operations.

The proposed algoritma is compared with EMG algorithm in [16]. In EMG, the first process require C - 1 addition operations and 1 division operations, so the first proses require C – 1 + 1 = C operations. The second proses require K – 1 operasi and the third process require C – 1 operations. So for one time allocation require C + (K – 1) + (C – 1) = 2C + K – 2 operations. The number of user is K, So the allocation process would be as many as $2KC + K^2 – 2K$ operations.

If the number of available chunk is equal to number of user (C = K) then the complexity of those algorithm will become the same $3C^2 – 2C$ or $3K^2 – 2K$.

5. RESULTS AND DISCUSSIONS

In this paper, we compare the performance of the proposed chunk allocation algorithm with those of the algorithm proposed by obilor nwamadi et al [16]. It is assumed that in base stasion already available SNR per subcarrier of all users for 500 time transmission interval. The number of users varies from 5 until 30 and all user are located at the same distance from base stasion. The number of available subcarriers is 60 subcarrier and number of chunk is equal to number of users.

The maximum transmit power for one user is 1 watt. $H_{n,k}$/noise power of each subcarrier per user is accumulation of fading channel using jakes model, pathloss model and AWGN (Additive White Gaussian Noise). It is assumed that frequency is 2 Ghz and the velocity of all user is 0 km/hour. Jakes fading model has 8 scatterers and pathloss model is modeled by 138.6 + 37.6 $\log_{10}$d which is proposed by 3GPP as pathloss model where d is the distance of user from base stasion. AWGN has normal distribution with mean 0 and deviation 1.

The algorithm of chunk allocation is performed every one TTI and duration of 1 TTI is 1 ms. We consider the sum of bandwidth efficiency user and difference between maximum and mean of bandwidth efficiency as performance of chunk allocation. The sum of bandwidth efficiency user to represent user throughput and difference between maximum and mean of bandwidth efficiency to represent fairness among users. The performance of chunk allocation is averaged over 500 TTI and compared with performance in [16]. The simulation result showed in figure 1 and figure 2. From figure 1 showed that the proposed algorithm can improve throughput up to 7.21 % by using MMSE detection method and up to 1.01 % by using ZF detection method. And from figure 2 showed that the proposed algorithm can improve fairness up to 3.9 % by using MMSE detection method and up to 4.9 % by using ZF detection method. The highest throughput improvement is reached when the number of user is 20 and use MMSE as detection method. The highest fairness improvement is reached when the number of user is 30 and use ZF as detection method.

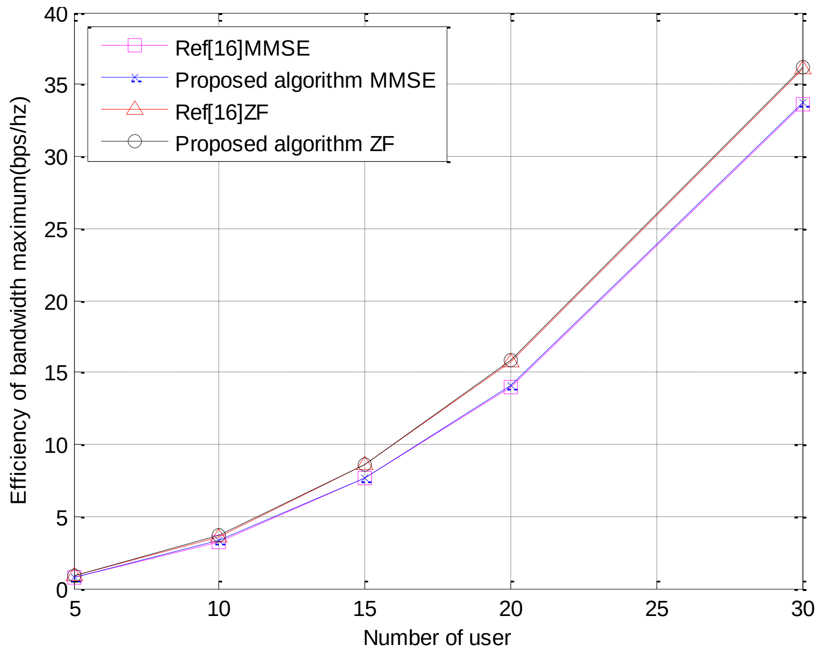

Figure 1. Efficiency of Bandwidth Maksimum over 500 TTI using MMSE and ZF equalization to represent maximum throughput when all users are the same distance from base stasion

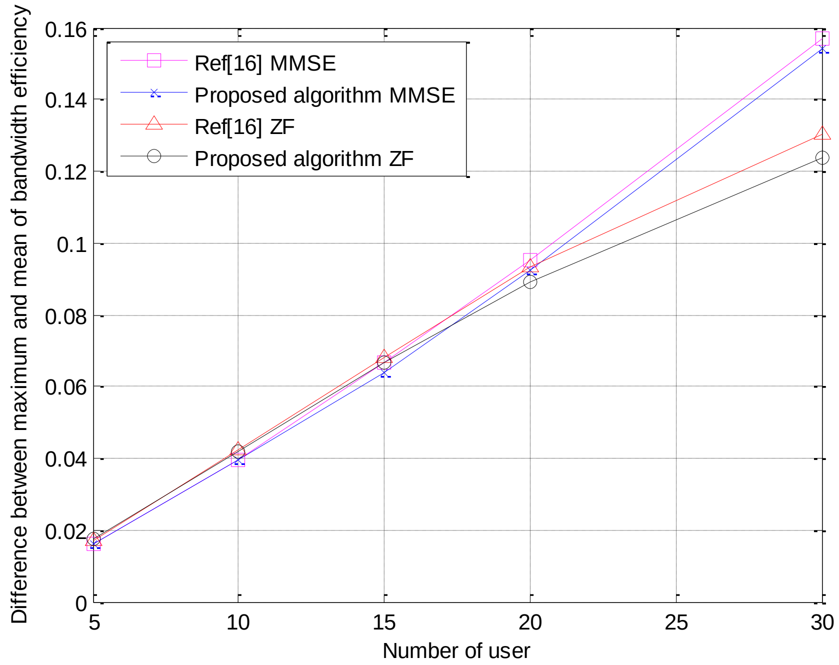

Figure 2. Difference between maximum and mean of bandwidth efficiency using MMSE and ZF equalization to represent fairness between user when all users are the same distance from base station

6. CONCLUSION

From the simulation results showed that the proposed algorithm can improve user throughput and fairness among users compared with algorithm proposed by Obilor Nwamadi et al. The proposed algorithm can improve throughput up to 7.21 % by using MMSE detection method and up to 1.01 % by using ZF detection method. And the proposed algorithm can improve fairness up to 3.9 % by using MMSE detection method and up to 4.9 % by using ZF detection method. The highest throughput improvement is reached when the number of user is 20 and use MMSE as detection method. The highest fairness improvement is reached when the number of user is 30 and use ZF as detection method. The proposed algorithm has the same complexity level with the algorithm proposed by Obilor Nwamadi et al if the number of chunks is equal to number of users.

ACKNOWLEDGMENT

The first author is recently a lecturer in Telecommunication Engineering Department, Faculty of Electrical and Communication, Telkom Institute of Technology, Bandung, Indonesia and now pursuing towards the Ph.D degree in Electrical Engineering Department, University of Indonesia, Indonesia under Yayasan Pendidikan Telkom (YPT) Scholarship

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