Utilizing Mean Greedy Algorithm using User Grouping for Chunk Allocation in OFDMA Systems with Carrier Aggregation

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***Abstract*— In this paper, utilizing user-order chunk allocation algorithm for OFDMA systems using carrier aggregation environment is proposed and evaluated. Chunk allocation algorithm is performed based on mean greedy algorithm which has low complexity. In order to adopt this algorithm to those system, all users are divided into a certain group in accordance with the number of available aggregated carriers. The simulation results are shown that the performance and time complexity of the proposed scheme is same with the system without user grouping. Therefore, the proposed scheme could be considered to realize in LTE-advanced platform.**

Keywords—Mean Greedy; User Grouping; Chunk Allocation; OFDMA; Carrier Aggregation

I. INTRODUCTION

In wireless multiuser systems, the phenomena of time varying frequency selective channels occur on different users at different time [*1*] [*2*]. Multiuser diversity is a result from independent fading channels across different users [*1*] [*2*]. In order to improve system performance over wireless channels, the multiuser diversity should be exploited by allocating the radio resources to users properly according to the instantaneous channel conditions of active users [*1*] [*2*]. These phenomena are overcomed in LTE system which uses OFDMA systems by dynamically allocating radio resources such as subcarrier to different users every time transmission interval (TTI) [*2*].

The latest works of radio resource allocations for OFDMA systems are developed based on mean greedy-based algorithms since they have low time complexity. Mean greedy (MEG) [*3*], single mean greedy(SMEG) [*3*] and multi-criteria ranking based greedy (MCRG) [*4*]are proposed by performing a user-order allocation based on the user's utility performance. Combined-order algorithm based on mean greedy-based algorithm [*2*] is also investigated to balance between spectral efficiency and fairness by determining a certain decision weighting factor. In above allocation schemes, all available chunks are allocated to all users on user by user basis.

Spectrum aggregation (or carrier aggregation) was introduced by 3GPP in its new LTE-Advanced standards, which is a candidate radio interface technology for IMT-Advanced systems. Carrier aggregation in LTE-A has extended the concept to introduce aggregation of non contiguous spectrums in different spectrum bands. Two or more component carriers (CCs) of different bandwidths in different bands can be aggregated to support wider transmission bandwidth between the E-UTRAN NodeB (eNB) and the user equipment (UE) [*5*]. The illustration of carrier aggregation schemes can be described in figure 1.

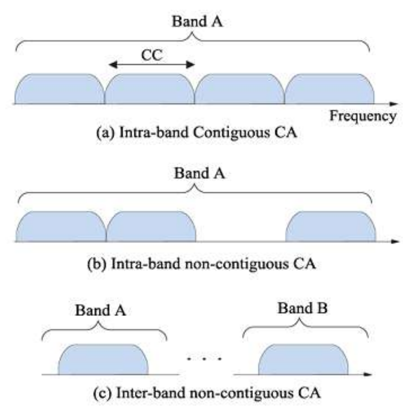

Figure 1. The illustration of carrier aggregation (CA) [*5*]

Since chunk by chunk-based using mean greedy algorithms are emerging subcarrier allocation on previous works, in this paper user-order mean greedy allocation is adopted to LTE-Advanced (LTE-A) systems which use aggregation scheme in OFDMA-based technology. In order to adopt its allocation in LTE-A systems, user grouping is proposed by partitioning all users into some group according to the number of carrier that they can be scheduled on. A group is contain some users who have the similar characteristic of pathloss propagation. The user grouping used in this paper is based on the Pathloss (PL) value suffered by all users on the number of aggregated carriers. The PL value suffered by each user on all aggregated carriers are diverse due to the location different of all user. In [6], user grouping process only done by grouping the users according to the PL of each user to all component carriers. In this paper, its user grouping process is modified by distributing chunk from each component carrier to each group of user before chunk allocation is performed. The proposed user grouping could be realized on LTE-A platform which aggregates two or more carrier components belonging to a single or different frequency bands.

We organize this paper into five sections. After introducing the background in section 1, we describe the model and formulation in section 2. In section 3, the proposed algorithms and their time computational complexities are determined and compared with the previous works. The simulations of the proposed algorithms are described in section 4 and followed by conclusions in section 5.

II. MODEL AND FORMULATION

Considering a single cell using non adjacent inter band aggregation scenario. There are 3 component carriers which are f_1, f_2 and f_3, where $f_1 < f_2 < f_3$. Each carrier has transmitted power P_T. Since the impact of fading on high frequency is bigger than the lower ones, it causes the coverage of f_2 is smaller than f_1 and the coverage of f_3 is smaller than f_2. The cell structure model is shown in figure 1. User 1 is out of coverage of f_2 and f_3, so it only could be scheduled on f_1. While user 2 is inside the coverage of f_1 and f_2. User 3 could be scheduled on all carriers.

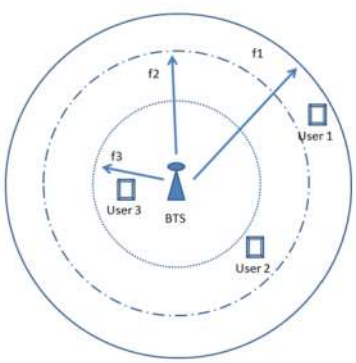

Figure 2. Cell Structure Model

A cell consist of a base station with N users. L is the number of component carrier which could be aggregated. Each component carrier has the same bandwidth. V is the total of chunk on each carrier. With equal power allocation (EPA), each chunk z has transmitted power $p(z)= P_T / V$. A group which consist of aggregated carrier could be defined by :

$$F = \{f_1, f_2, \dots, f_L\}, f_1 < f_2 < \dots < f_L \quad (1)$$

A grouping is done by calculating the maximum value of path loss *(PL)* of all users on each component carrier. A user who has the *PL* value is less then the threshold path loss (PL) could be included into a certain group. The *PL* suffered by user *i* from each component carrier can be obtained using [6] :

$$\Omega_i = \{PL_i^k \mid PL_i^k < PL_{th}, 1 \le k \le L\}, 1 \le i \le N \quad (2)$$

Where PL_i^k is the *PL* value from user *i* on carrier f_k. The element for group Ω_i denoted by N_i. If $N_i = j$, it means total number of carrier that can be scheduled on user i is j. So user could be divided into several groups [6] :

$$\mathrm{M}_j = \{i \mid N_i = j, 1 \le i \le N\}, 1 \le j \le L \quad (3)$$

The pathloss model used in this work is based on the Spatial Channel Model and PL_i^k could be determined as [6]:

$$PL_i^k = 58.83 + 37.6log10\,(d_i) + 21log10(f_k) \quad (4)$$

Where d_i is the distance from user *i* to the base station. The coverage radius of f_k denoted by R_k could be calculated by [6]:

$$PL_{th} = 58.83 + 37.6log10\,(R_k) + 21log10(f_k) \quad (5)$$

It can be obtained that :

$$R_1 > R_2 > \cdots > R_L \quad (6)$$

In [6], user grouping process only done by grouping the user according to the PL of each user to all component carriers. In this paper, its user grouping process is modified so that the user-order chunk allocation based on mean greedy [2] [3] could be conducted. Before this algorithm is performed, the chunk distribution is done to distribute chunk from each component carrier to each group of user.

The total value of PL from all user in group M_j on carrier f_k can be defined as :

$$TM_j^k = \sum_{i=0}^{N_j} PL_i^k \quad (7)$$

Where N_j is the number of total member group M_j. Since the number of chunk from each carrier is *V*, it means that the number of chunk divided from carrier f_k on each group must not greater than *V*. The number of chunk obtained by group M_j from carrier f_k could be calculated by :

$$RM_j^k = \left\lfloor \frac{TM_j^k}{\sum_{l=j}^{L} TM_l^k} \cdot V \right\rfloor \quad (8)$$

$$\sum_{l=j}^{L} RM_l^k \le V \quad (9)$$

The total number of chunk obtained by group M_j from all carrier that can be scheduled is defined by :

$$XM_j = \sum_{m=j}^{L} RM_j^k \quad (10)$$

The chunk allocation is performed on each RM_j^k. In this state, each user group has specific number of chunk of carrier that can be scheduled based on equation (8) and (10). The group of chunk on each user group is introduced in this paper where it is called Group-Chunk-User (GCU). Each GCU contain the signal to noise ratio (SNR) of user - *i* on chunk – *z* which is given by :

$$r_i(z,s) = p(z)xH_i(z,s) \quad (11)$$

$H_i(z,s)$ is the total loss propagation and s is the scheduling slot which is slot within one time transmission interval (TTI). After all SNR of all users on all chunks have been known, chunk allocation is conducted on each GCU. SNR of all chunks on each user are averaged and sort them from the lowest. A user on each GCU who has the lowest SNR choose the best chunk. The algorithm of the proposed allocation is called UG-MG algorithm.

III. THE PROPOSED ALGORITHM

The UG-MG algorithm consist of 2 step, the first step is user grouping process and followed by chunk allocation process. The steps of the proposed algoritm could be described as follow :

1. For all users, calculate the PL_i^k of all aggregated component carriers according to (4).
2. All users are divided into specific group using (2) and (3).
3. Determining GCU by distributing all chunks on each carrier into related user group based on (8), (9) and (10). Each user group has specific number of chunk from the carrier that can be scheduled on.
4. On each GCU :
   i. Calculate SNR of all users on each chunk.
   ii. Calculate the average of chunk's SNR on each user.
   iii. Choose one user who has the lowest chunk's SNR. This user can selects a chunk which has the best SNR.
   iv. Repeat step iii to iv until all chunks have allocated.
5. Calculate average throughput and fairness of all users. Where throughput system could be defined as [*7*]:

$$R_T = \frac{B}{N}\sum_{i=1}^{N}\sum_{z=1}^{V} S_{i,z} log_2\left(1 + SNR_{i,z}\right) \quad (10)$$

R_T is the throughput system and $S_{i,z}$ is chunk assignment index. B is bandwidth system and $SNR_{i,z}$ is SNR of user-*i* on chunk-*z*.

The fairness is based on [*8*] :

$$F = \frac{(\sum_{i\in N} R_i)^2}{N\sum_{i\in N} R_i^2} \quad (11)$$

Where F is fairness index and R_i is throughput of user-*i*.

An algorithm complexity of the proposed algorithm is investigated using asymptotic approach in [*9*] to quantify its time complexity. Investigating of time complexity is as follow:

1. Step one need *O(LN)*, since number of aggregated carrier is less than the user number, step one would be *O(N)*
2. Step two need *O(LN)+O(LN) = O(LN)* since number of aggregated carrier is less than the user number, step two would be *O(N)*
3. Step three need $O(L^2)+O(L^2)=O(L^2)$. Due to the number of aggregated carrier is less than the user number, it means that this step is constant and it could be ignored.
4. Step four need *O(NV)+O(1)+O(V)+O(V)=O(NV)*.

The tota time complexity of the proposed allocation is then *O(N)+O(N)+O(NV) = O(NV)*. The time complexity of mean greedy in [*2*] [*3*] are given by *O(NV)*. It means that the proposed algorithm has the same time complexity with the previous mean greedy algorithms however user grouping step is performed before chunk allocation process.

IV. SIMULATIONS AND RESULTS

In order to evaluate the proposed scheme, the computer simulation is performed using montecarlo method. The number of simulation trial is equal to the number of time transmission interval.

TABLE I. SIMULATION PARAMETERS [*6*]

Parameter	Value
Bandwitdh per carrier	5 Mhz
Number of chunk per carrier	25 chunk
TTI	200 TTI
Cell radius	250 meter
Cell Layout	Single cell
Component carrier frequency	700 Mhz, 800 Mhz, 1800 Mhz
Chunk bandwith	180 kHz
Propagation Model	Spatial Model Channel, Rayleigh channel
Gain eNB	18 dBi
Gain UE	0 dBi
Noise Figure	7 dB
eNB transmitted power	40 Watt (46 dBm)
Penetration Loss	20 dB
Number of user	5 - 80

The simulation is conducted for downlink path of LTE-Advanced with non-contiguous interband carrier aggregation. The simulation is done by varying the number of users from 5 to 80 users within a cell. The performances of the proposed schemes is compared with mean greedy algorithm (MG) [*3*] which does not conduct the user grouping before chunk allocation. The average throughput and fairness index of both schemes are compared and evaluated. The simulation parameters are listed in Table I.

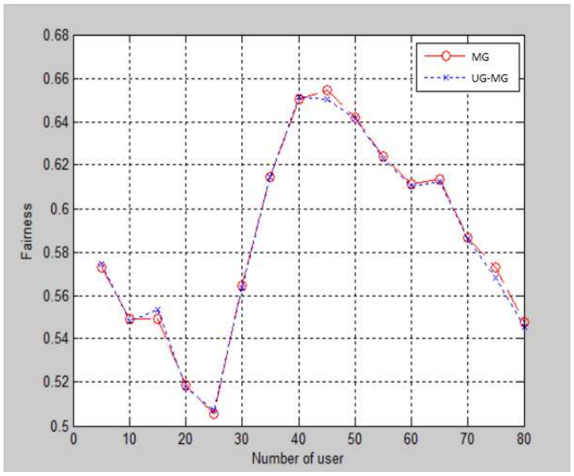

Figure 3. The fairness comparison

As the results of simulations, they are shown in figure 3 and figure 4 that the proposed scheme has the same performances in term of fairness and average of throughput as well. In figure 3, it is shown that there are a little bit difference of fairness between MG and UG-MG algorithms for all users. The differences among them are in the range between 0% until 0.05%. It could be concluded that there are no the difference fairness value between MG and UG-MG.

In figure 4 it is also shown that there are a slightly difference average of throughput occurred among MG and UG-MG for all users. The difference range is between 0 until 3.3 kbps. It could be concluded that both schemes have almost the same fairness.

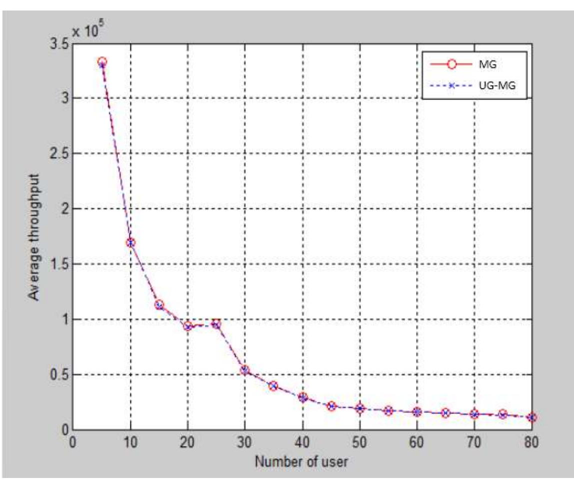

Figure 4. The average user throughput comparison

Considering the results altogether, it can be concluded that the proposed scheme have the same performances and time complexity as well with previous scheme in [*3*] however user grouping is performed. Hence, the proposed scheme could be considered to be applied in LTE-Advanced system which apply carrier aggregation.

V. CONCLUSIONS

In this work, a utilizing mean greedy algorithm which combined with user-grouping is proposed and evaluated. This scheme is applied on LTE-A system which conduct carrier aggregation in OFDMA-based technology. Its scheme is called UG-MG algorithm. Varying the number of of users, the proposed scheme gives the same performances and time complexity. Therefore, it could be considered to apply in LTE-A platform.

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References

[1] Huiling Zhu and Jiangzhou Wang, "Chunk-Based Resource Allocation in OFDMA Systems - Part 1 : Chunk Allocation," *IEEE Transactions on Communications*, vol. 57, no. 9, pp. 2734-2744, September 2009.

[2] Arfianto Fahmi, Muhamad Asvial, and Dadang Gunawan, "Combined-order Algorithm using Promethee Mrthod Approach and Analytic Hierarchy Decision for Chunk Allocation in LTE Uplink Systems," *International Journal of Communication Networks and Information Security (IJCNIS)*, vol. 5, no. 1, pp. 39-47, April 2013.

[3] Obilor Nwamadi, Xu Zhu, and Asoke K Nandi, "Dynamic Physical Resource Block Allocation Algorithm for Uplink Long Term Evolution," *IET Communications*, vol. 5, no. 7, pp. 1020 - 1027, 2011.

[4] Obilor Nwamadi, Xu Zhu, and Asoke K. Nandi, "Multicriteria ranking based greedy algorithm for Physical Resource Block Allocation in Multicarrier Wireless Communications," *Elsevier Signal Processing*, vol. 92, pp. 2706-2717, 2012.

[5] Haeyoung Lee, Seiamak Vahid, and Klaus Moessner, "A Survey of Radio Resource Management for Spectrum Aggregation in LTE-Advanced," *IEEE Communications Surveys and Tutorials*, vol. 16, no. 2, pp. 745 - 760, 2014.

[6] Shi Songsong, Feng Chunyan, and Caili Guo, "A Resource Scheduling Algorithm Based on User Grouping for LTE-Advanced System with Carrier Aggregation," *IEEE 2009 International Symposium on Computer Network and Multimedia Technology*, 2009.

[7] Sanam Sadr, A Anpalagan, and K Raahemifar, "Radio Resource Allocation for the Downlink of Multiuser OFDM Communication Systems," *IEEE Communication Surveys & Tutorials*, vol. 11, no. 3, pp. 92-106, 2009.

[8] R Jain, M Chiu, and W Have, "A Quantitative Masure of Fairness and Discrimination for Resource Allocation in Shared Systems," Eastern Research Lab, DEC Research Report TR 301 1984.

[9] Kennet H Rosen, *Discrete Mathematics and Its Applications*.: Mc Graw Hill, 2007.