정보통신설비 학술대회 논문집, 2007. 8.24-25

부반송파 그룹간 기회 비용 상호 비교에 기반한 적응 부반송파 할당 기법

An Adaptive Subcarrier Allocation Scheme based on Comparison of Group Opportunity Cost

김 영 억* , 윤 병 완, 이 영 탁
(Youngok Kim, Byung Wan Yoon, Young Tark Lee)

Abstract : An adaptive subcarrier allocation scheme based on comparative superiority of opportunity cost between groups is proposed for the enhancement of system capacity and its simple implementation at the base station of a multiuser OFDM system. The proposed algorithm is similar to the blockwise or the decentralized subcarrier allocation algorithm proposed by Xiaowen *et al* and Alen *et al*, respectively. In the proposed algorithm, however, all subcarriers are grouped according to the coherence bandwidth and the comparative superiority concept, which swaps the groups between users if the system capacity is increased, is adopted for the enhancement of system capacity. In addition, the proposed algorithm provides a simple solution for the conflict problem among users by reallocating only the conflicted groups and unassigned groups instead of reallocating entire groups. Simulation results demonstrate that the proposed algorithm increases the system capacity effectively over a static, an adaptive blockwise, and a decentralized subcarrier allocation algorithms.

Keywords: subcarrier allocation, system capacity, multiuser OFDM

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a promising multicarrier transmission technique because it not only provides high data rates but also mitigates intersymbol interference (ISI) in broadband transmission over wireless multipath fading channels [1]. In multiuser environments, the multicarriers of OFDM scheme are shared by multiple users to provide various QoS profiles. Multiuser OFDM is a multiple access technique efficiently exploiting the limited resources such as bandwidth and transmit power. Depending on applications, therefore, subcarrier allocation (SA) algorithm in multiuser OFDM system becomes an important issue and various SA algorithms have been developed for the low-cost implementation or the optimized usage of resource at the cost of increased complexity [2]-[4]. In traditional multiuser OFDM systems, the predetermined subcarriers are assigned to each user [2]. However, since different users experience mutually independent fading, adaptive multiuser SA algorithms, which assign subcarriers to each user based on channel state information (CSI), have been addressed to increase system capacity over a frequency-selective fading channel [1][2][5].

Since the computational complexity of the optimal SA algorithm is extremely high, various sub-optimal algorithms, such as the blockwise [6] and the decentralized allocation algorithms [5], have been developed for the realization of adaptive SA algorithm with the reduced complexity. Even though these algorithms allocate subcarriers in groups instead of considering each subcarrier for the reduction of complexity about a factor of group size, the system performances of the algorithms are close to that of the optimal solution.

In this paper, an adaptive subcarrier allocation algorithm based on comparison of group opportunity cost is proposed for the enhancement of system capacity in downlink environment of OFDM systems. The proposed algorithm is similar to the blockwise or the decentralized SA algorithm but all the subcarriers are grouped according to the coherence bandwidth of channel. Moreover, instead of the usage value that was used in the decentralized SA algorithm, the known average channel gain of each group is used to resolve the conflict problem among users in the proposed algorithm. Based on the proposed group allocation algorithm, an adaptive modulation is adopted for the groups of each user to increase the data rates by applying higher order modulation to carry more bits per OFDM symbol.

II. ADAPTIVE SUBCARRIER ALLOCATION ALGORITHMS

1. System Model

The configuration of the multiuser OFDM system is shown in Fig. 1. The system has N subcarriers and all the subcarriers are shared with K users. In the subcarrier allocation schemes, the subcarriers are exclusively assigned to users not to share a subcarrier with more than one user. It is assumed that the transmitter knows the downlink channel gains of all users. Based on the CSI from all users, a certain subset of subcarriers is assigned to each user and the subcarrier allocation information is sent to the receivers via a separate control channel. The adaptive modulation is employed for the enhancement

* 책임저자(Corresponding Author)
논문접수 : 2007. 7. 27., 채택확정 : 2007. 7. 31.
김영억, 윤병완, 이영탁 : Korea Telecom 인프라연구소 차세대무선개발담당 (kimyoungok@kt.co.kr, yoonbw@kt.co.kr, lyt63@kt.co.kr)

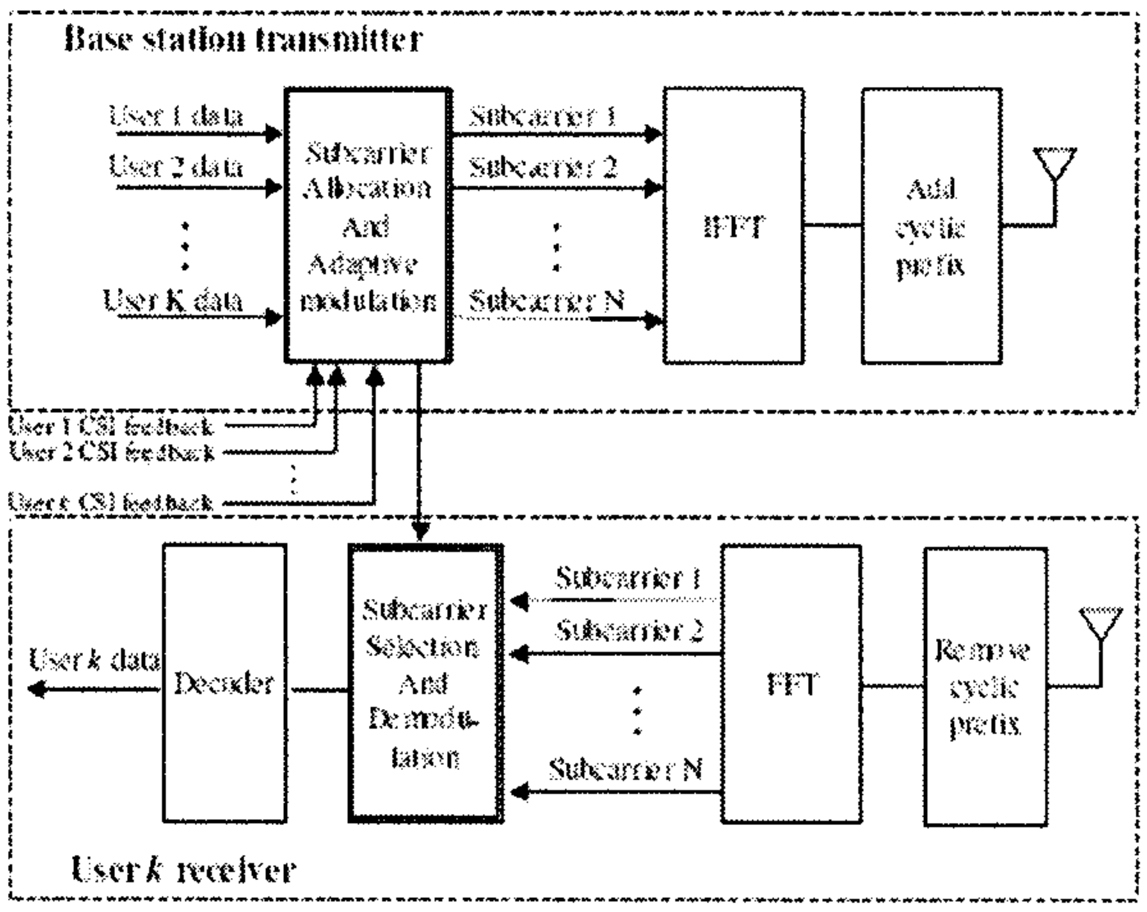

그림 1. 다중사용자 OFDM 시스템.

Fig. 1. A multiuser OFDM system.

of system capacity and the number of bits per a symbol for each subcarrier is determined with the channel gain information. Without loss of generality, it is assumed that all the users experience different frequency selective fading channels independently and the coherence bandwidth of the channel is larger than the bandwidth of a subchannel. Generally, the magnitude response of subchannels within the coherence bandwidth is assumed to be flat. However, the channel gains among subcarriers may have a variation even within the coherence bandwidth as various frequency correlation functions are used for defining the coherence bandwidth [7]. In this paper, the coherence bandwidth is considered as a system parameter related with both system capacity and complexity of SA algorithm. Therefore, the channel gains among subcarriers have a variation within the coherence bandwidth and the average channel gain of each group is considered for the proposed SA algorithm.

2. Previous Approaches

In the blockwise adaptive SA algorithm [6], all the subcarriers are divided into blocks and a certain number of blocks with high average channel gains is assigned to each user based on the r equired data rate. However, there is a possibility that the group with relatively small average channel gain is assigned to a certain user because the group with the highest average channel gain has been assigned already to other user. As the result, the overall system performance may be degraded. Therefore, under consideration of the overall system capacity, the increase of system capacity can be achieved by reallocating blocks among users.

In the decentralized SA algorithm [5], all the subcarriers are divided into a number of partitions and each user selects the partition with the highest average channel gain independently. During the allocation process, the conflict problem, which more than one user attempts to select the same partition simultaneously, occurs. Thus, the re-allocation of partitions among users is performed by comparing the usage value of each group for resolving the conflict problem among users. However, the usage value is updated by indirect measures for the system capacity such as a simple ranking factor, normalization process, the cost values, and a random factor, which provides randomness in re-allocation of the groups over the users. Therefore, the overall system performance may be degraded by using the usage value instead of using the average channel gain of each group alone.

3. The Proposed Subcarrier Allocation Algorithm Using Comparative Superiority

When an equal amount of power is allocated to each subcarrier, the channel capacity of each subcarrier can be regarded as proportional to its channel gain. Thus, overall system capacity can be increased by assigning the subcarriers with high channel gains first [2]. While complying with the above approach, subcarriers can be allocated in group for the reduced complexity of an adaptive SA algorithm likewise the blockwise or the decentralized SA algorithms, which were briefly discussed in the previous section. In the proposed algorithm, each group with the highest average channel gain is selected for the corresponding user and the comparative superiority, which is performed by swapping groups, is adopted for the enhancement of system capacity. It is assumed that each group has the same number of subcarriers and the number of subcarriers for each group is determined by the coherence bandwidth.

The proposed algorithm is similar to the blockwise or the decentralized subcarrier allocation algorithm. However, instead of the usage value that is employed in the decentralized allocation algorithm, the known average channel gain of each group is used to resolve the conflict problem among users in the proposed algorithm. Since the proposed algorithm adopts the comparative superiority concept, which is based on only the comparison of the average channel gains of all groups, for the conflict problem, the system performance can be substantially enhanced more than those of the blockwise algorithm and decentralized algorithm. The proposed algorithm is a two-step group allocation algorithm. Each user attempts to select the best group independently at step 1 and the selected groups are reallocated by comparing the opportunity cost of using groups among users to increase the overall system capacity at step 2. Fig. 2 shows the flow chart for the proposed algorithm, and when the number of groups assigned to each user is predetermined, the algorithm is described briefly as follows

Step 1:

1) All the channel gains of each user are divided into a number of groups based on the strict coherence bandwidth definition (high frequency correlation value).
2) If the number of groups, L, is larger than a predetermined upper limit of number of groups, L_0, relax the coherence bandwidth (low frequency correlation value) and repeat 1).

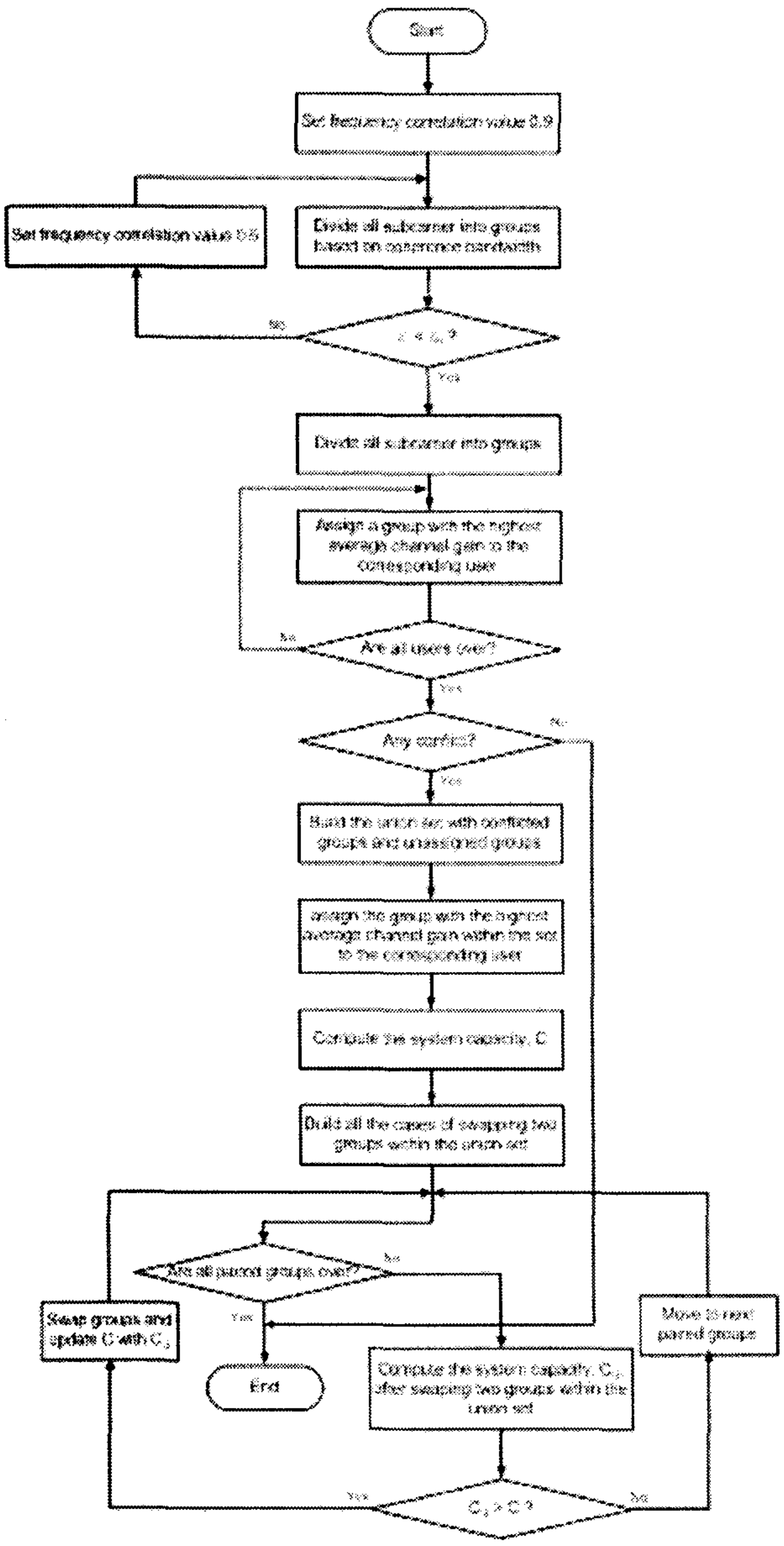

그림 2. 제안된 부반송파 할당 알고리즘의 순서도.

Fig. 2. Flow chart for the proposed subcarrier allocation algorithm.

3) Select the groups with the highest average channel gain of each user and assign them to the corresponding user.
4) If there are any groups that more than one user attempt to select simultaneously, then move to the step 2 for reallocation.
5) Otherwise, exit the allocation process.

Step 2:
1) Build a union set, S, by combining the set of unassigned groups and the set of groups conflicting with more than one user
2) After reordering the groups within the union set according to the average channel gain of each group, initialize the allocation by assigning the group with the highest average channel gain within the union set to the corresponding user and then do iteration for capacity enhancement.
3) Iteration:
   a) Within the union set, S, build all the cases for swapping groups between any paired users.
   b) Compute the increase of system capacity, Δ C, with the following equation for all the swapping cases from a).
   $$\Delta C = C_{i,j} - C \quad (1)$$
   where C is the system capacity before swapping and $C_{i,j}$ is system capacity after swapping group i and group j, and $i, j \in S$.
   c) If Δ C is positive, swap the groups between users and update C with $C_{i,j}$ and move to next case.
   d) Otherwise, skip the case and move to next case.
   e) Repeat the iteration until $\forall \Delta C \le 0$.

The major operations in step 1 and step 2 are sorting and swapping respectively. Therefore, the computational complexity of the proposed algorithm can be approximated by estimating the two major operations. If K groups are available for K users, the computational complexity of sorting process in step 1 is approximated as $O(K \cdot K\log K)$. When the number of groups in the set S is $L(\le K)$, the all possible swapping cases is $O(C_2^L) \approx O(L^2)$. Thus, the total computation complexity can be approximated as $O(K^2\log K + L^2)$.

III. SIMULATION RESULTS

The comparison of the overall system capacity has been performed through the simulations for a static, an adaptive blockwise, a decentralized, and the proposed SA algorithms. It is assumed that an equal amount of power is allocated to each subcarrier and each user is allocated with an equal number of subcarriers. In addition, the same number of groups is used in all allocation schemes for a fair comparison. The system capacity is defined as follows

$$\sum_{i=1}^{L} R(h_i) = \sum_{i=1}^{L} \frac{B}{L} \log_2(1 + SNR \cdot h_i^2) \quad (2)$$

where B is a bandwidth, L is the number of groups, SNR is a signal-to-noise ratio and h_i is the average channel gain of ith group, which is selected for a certain user in terms of higher system capacity.

For the performance comparison, all algorithms are simulated under the same condition. It is assumed that K(= 8) users share N(= 1024) subcarriers over a B(= 10MHz) band in the system. The allocation plan of all subcarrier allocation algorithms except for a static scheme is updated after every 1000 OFDM symbols in a frequency selective Rayleigh fading channel with an exponential power delay profile.

Fig. 3 shows the comparison of the overall system capacity for a static, an adaptive blockwise, an adaptive decentralized, and the proposed SA algorithm. As shown in the figure, the overall system capacity of the proposed algorithm is much larger than that of a static

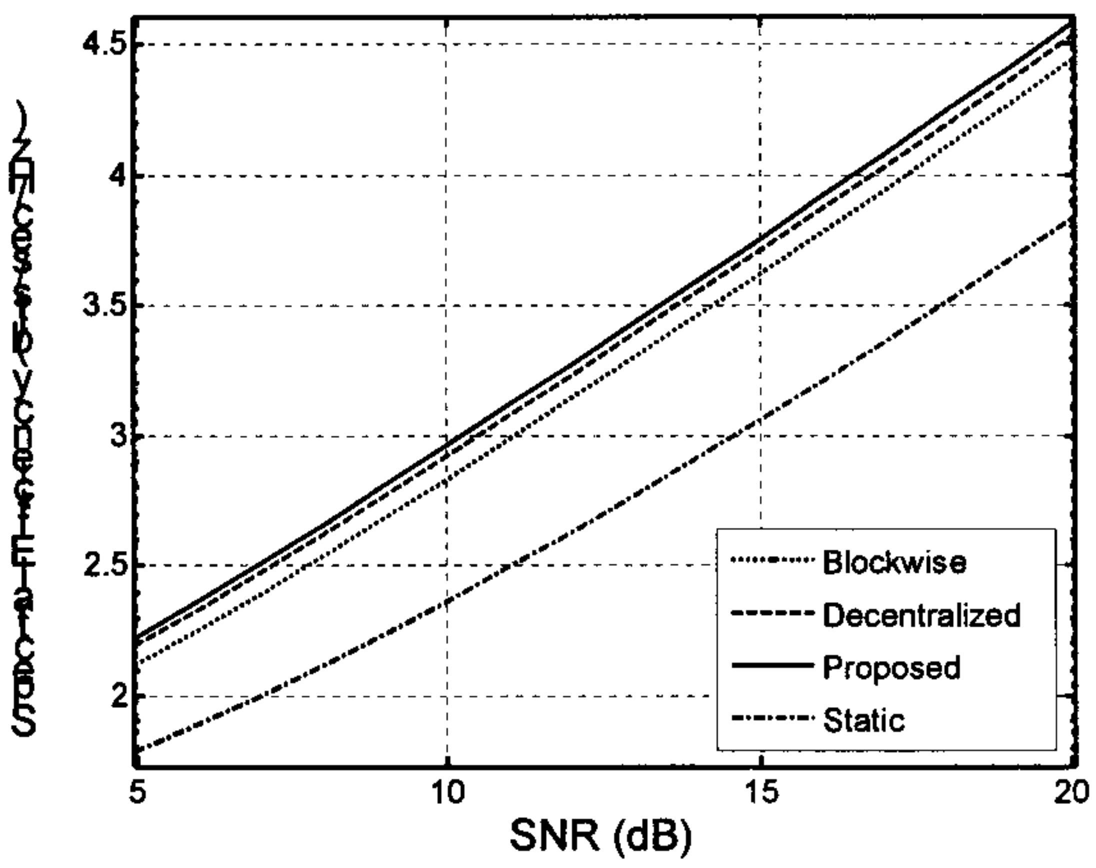

그림 3. 제안된 부반송파 할당 방식과 Blockwise, Decentralized, 및 S tatic 부반송파 할당의 성능 비교.

Fig. 3. Performance comparison for the blockwise, the decentralized, the proposed, and static subcarrier allocation algorithms.

SA algorithm at the same *SNR*. Furthermore, the proposed algorithm outperforms the alternative schemes in terms of system capacity even though the increase of system capacity is relatively small.

IV. CONCLUSION

An adaptive SA algorithm based on comparative superiority of opportunity cost between groups is proposed for the enhancement of system capacity in a multiuser OFDM system. In the proposed algorithm, assuming that the CSI of all users are known, all subcarriers are divided into groups over its coherence bandwidth and the groups with high average channel gain are assigned to the corresponding user for the enhancement of system capacity. The comparative superiority concept, which swaps the groups between users if the system capacity is increased, is adopted in the re-allocation process for the enhancement of system performance. Based on the proposed group allocation algorithm, an adaptive modulation is adopted for the groups of each user to increase the data rates by applying higher order modulation to carry more bits per OFDM symbol. Simulation results demonstrate that the proposed algorithm increases the system capacity effectively over a static, an adaptive blockwise, and a decentralized SA algorithms.

REFERENCES

[1] R. van Nee and R. Prasad, *OFDM for Wireless Multimedia Communications.* Boston: Artech House, 2000.
[2] E. Lawrey, "Multicarrier OFDM," in *Proc. IEEE International Symposium on Signal Processing and its applications*, vol. 2, pp. 761-764, Aug. 1999.
[3] W. Rhee and J. M. Cioffi, "Increase in capacity of multiuser OFDM system using dynamic subchannel allocation," in *Proc. IEEE Vehicular Technology Conf.*, vol. 2, pp. 1085-1089, May 2000.
[4] C. Y. Wong, R. S. Cheng, K. B. Letaief, and R. D. Murch, "Multiuser OFDM with adaptive subcarrier, bit and power allocation," *IEEE J. Select. Areas Commun.*, vol. 17, pp. 1747-1757, Oct. 1999.
[5] T. C. Alen, A. S. Madhukumar, and F. Chin, "Capacity enhancement of a multi-user OFDM system using dynamic frequency allocation," in *IEEE Trans. Broadcast.*, vol. 49, No.4, pp. 344-353, Dec. 2003.
[6] L. Xiaowen and Z. Jinkang, "An adaptive subcarrier allocation algorithm for multiuser OFDM system," in *Proc. IEEE Vehicular Technology Conf.*, vol. 3, pp. 1502-1506, Oct. 2003.
[7] T. S. Rappaport, *Wireless Communications: Principles and Practice*, 2nd ed. Englewood Cliffs, NJ: Prentice-Hall, 2002.