

# A Heuristic Method for Channel Allocation and Scheduling in an OFDMA System

Sungho Hwang, Joongoo Park, Youn Seon Jang, and Ho-Shin Cho

**ABSTRACT**—In this letter, a heuristic channel allocation and scheduling scheme is proposed. By comparing the size of the alternative-factor assessment, which is obtained by simple calculation, we can easily find the most appropriate channel for each user for overall throughput enhancement. Numerical results show that the downlink throughput of the proposed scheme is higher than that of proportional fairness and is almost the same as that of the maximum C/I scheme, while user fairness remains better than that of the maximum C/I scheme.

**Keywords**—Scheduling, resource allocation, proportional fairness, alternative factor; maximum C/I scheme.

## I. Introduction

An attractive feature of orthogonal frequency-division multiple access (OFDMA) for allocation of radio resources is the significant augmentation of the throughput capacity via exploitation of multiuser diversity. This is because it allocates subcarriers and time-slots to the most profitable user. Furthermore, adaptive modulation and coding (AMC) schemes can be subsequently employed with multiuser diversity in order to double the system throughput.

Successful achievement of multiuser diversity gain in OFDMA depends on how radio resources are adaptively managed and how fast the most appropriate channel resources for each user are found. So far, many researchers have dealt with link-adaptable channel allocation schemes based on

channel quality information, such as the so called channel quality indicator [1], [2]. The optimum management scheme for throughput maximization, however, requires a huge computation time to consider all possible combinations of the two dimensional resources of time and frequency combinations for varying channel qualities and various users.

In this letter, a heuristic channel allocation and scheduling scheme is proposed. Comparing the size of the alternative factor assessment which is obtained by simple calculation, we can easily find the most appropriate channel for each user for overall throughput enhancement. Numerical results show that the downlink throughput of the proposed scheme is higher than that of proportional fairness (PF) [3] and is almost the same as that of the maximum C/I scheme [4], while the user fairness remains better than that of the maximum C/I scheme.

## II. System Description

Figure 1 shows an example of OFDMA channel architecture. The sub-band consists of multiple sub-carriers. The frame on the time-axis consists of multiple transmission time intervals (TTIs), and the TTI consists of multiple OFDMA symbols.

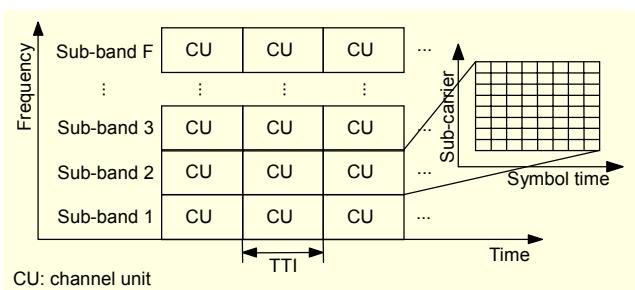


Fig. 1. OFDMA channel architecture.

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One sub-band and one TTI jointly serve as a basic channel unit (CU).

In this system, we assume that the AMC scheme is employed where a radio channel is graded by  $L$  levels. The channel state is assumed not to change during a frame. Each active user reports the channel state vector in every frame, which is defined for user  $j$  by

$$\mathbf{c}_j = (c_{1j}, c_{2j}, \dots, c_{Fj}), \quad (1)$$

where  $c_{ij}$  denotes sub-band  $i$ 's channel state experienced by user  $j$  and has an integer value between 1 (lowest grade) and  $L$  (highest grade). The number of sub-bands is denoted by  $F$ . The base station determines the AMC level based on the channel state information (CSI).

The main issue in channel allocation and scheduling is determining how many CUs and which CUs are allocated to each user to maximize the overall data throughput and jointly ensure user fairness. To do this, the base station needs to solve a kind of a composite object function of the value of the variable channel state for various users and sub-bands. The base station uses the channel state matrix defined by

$$\mathbf{C} = \begin{bmatrix} \mathbf{c}_1^T & \mathbf{c}_2^T & \cdots & \mathbf{c}_N^T \end{bmatrix}, \quad (2)$$

where  $N$  is the number of users, and  $T$  means the operation of transpose. The matrix is available at the base station, which aggregates the CSI from all active users and is updated for every frame. If sub-band  $i$  is allocated to user  $j$ , then the modulation and coding scheme for user  $j$  is determined by  $c_{ij}$ . Channel allocation is sequentially performed in the order of TTI within a frame. Sub-band allocation within a TTI is scheduled by our proposed scheme. Only one sub-band is allocated to one user for each TTI, but multiple sub-bands could be allocated to one user across the whole frame.

### III. Proposed Scheme

The proposed scheme has two steps. First, within a TTI, the allocation order of a sub-band is determined based on its quality. The higher quality a sub-band has, the earlier its allocation order is in order to increase the throughput. Then, the most profitable user for a sub-band in the order is selected to obtain the multiuser diversity gain.

#### Step 1. Determine the Order of a Sub-band to Be Allocated

The representative quality of sub-band  $i$  is denoted by  $c_{\max_i}$  and is defined by the highest value among  $c_{ij}$  ( $1 \leq j \leq N$ ). Then, subsequent sub-bands are categorized and grouped according to the representative quality such that

$$G_k = \{\text{sub-band } i \mid c_{\max_i} = k, 1 \leq i \leq F\}, 1 \leq k \leq L. \quad (3)$$

In order to increase the radio spectrum efficiency, it is desirable to allocate the sub-bands of higher representative quality before those of lower representative quality. For example, when

sub-band  $i \in G_k$  and sub-band  $j \in G_l$  for  $k > l$ ,

sub-band  $i$  should be allocated before sub-band  $j$ . At this step, if there exist multiple sub-bands of same representative quality, we separate them in such a way that the overall throughput increases. As a simple means to accomplish this, an alternative factor (AF) of sub-band  $i$  is defined by

$$AF_{\text{sub\_}i} = \prod_{j=1}^N c_{ij}, \quad (4)$$

where a larger value of  $AF_{\text{sub\_}i}$  means that sub-band  $i$  is likely to have better alternative users whose channel quality is fair enough at the sub-band  $i$  even if it is not the highest. Therefore, it is desirable to allocate sub-bands with smaller AFs prior to those with larger AFs.

#### Step 2. Determine the User of the Sub-band

It is reasonable that a selected sub-band should be allocated to the user who has the representative quality at that sub-band. However, if more than two users have the representative quality, the alternative factor of the user, defined by

$$AF_{\text{user\_}j} = \prod_{i=1}^F c_{ij} \quad (5)$$

for user  $j$ , is used in a similar way as in the sub-band selection procedure. A larger  $AF_{\text{user\_}j}$  means that user  $j$  is likely to have better alternative sub-bands. Therefore, it is appropriate that users with smaller AFs are selected prior to those with larger AFs. This means that in competition for sub-bands, the user that has better alternative sub-band makes a concession to those that have poor alternative sub-bands.

Figure 2 shows an example of the channel allocation procedure. The sub-bands are graded as follows:

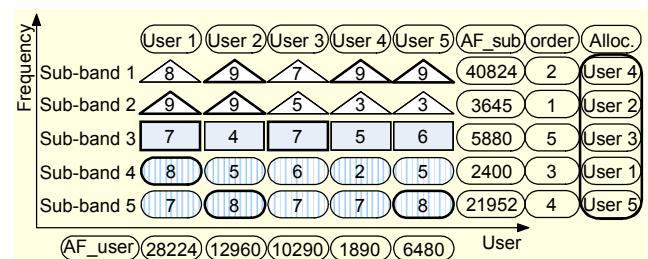


Fig. 2. Example of channel allocation using alternative factor for sub-band and user for one TTI.

$$G_7 = \{\text{sub-band 3}\},$$

$$G_8 = \{\text{sub-band 4, sub-band 5}\},$$

$$G_9 = \{\text{sub-band 1, sub-band 2}\}.$$

Since sub-bands 1 and 2 belong to  $G_9$ , the highest channel quality group, it is desirable to allocate sub-band 1 or 2 before the others. Of the two sub-bands, sub-band 2 is more suitable to be transmitted first because  $AF_{sub\_1} > AF_{sub\_2}$ ; therefore, the user of sub-band 2 should be selected. As shown in Fig. 2, both users 1 and 2 have the representative quality of sub-band 2. Because  $AF_{user\_1} > AF_{user\_2}$  in this case, user 2 acquires sub-band 2. For the remaining sub-bands and users, the same procedure is repeated.

#### IV. Numerical Results

In this section, we numerically compare the proposed scheme with PF and the maximum C/I scheme in terms of overall downlink throughput and user fairness. We consider the OFDMA system specified in [5] as follows: 10 sub-bands, 20 TTIs per frame, and 7 AMC levels. The signal-to-noise ratio of CU is assumed to be an exponentially distributed random variable with a mean of 12 dB or 14 dB [6]. The user queues waiting for transmission are assumed to always be full.

Figure 3 shows the downlink throughput per frame, which is averaged over 8,000 frames. The proposed scheme outperforms PF. Furthermore, it is almost equal to the maximum C/I scheme, which only addresses throughput, not user fairness. This is because the proposed scheme chooses the user who has the best channel quality at every sub-band. This is the same approach as that of the maximum C/I scheme.

On the other hand, as shown in Fig. 4, the Jain index [7] is used to measure user fairness over 8,000 frames. The proposed scheme has greater fairness than the maximum C/I scheme because the proposed scheme prevents monopolization of

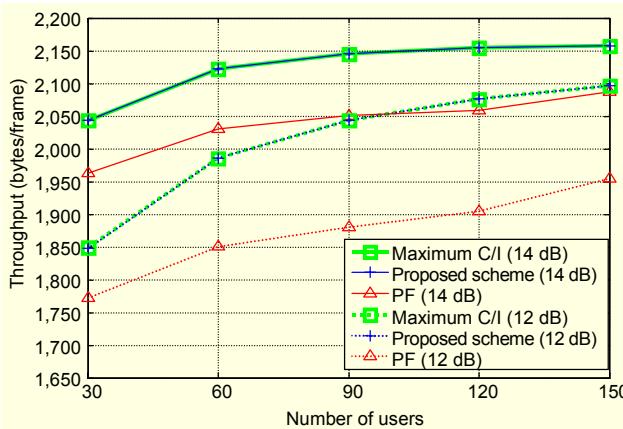


Fig. 3. Downlink throughput.

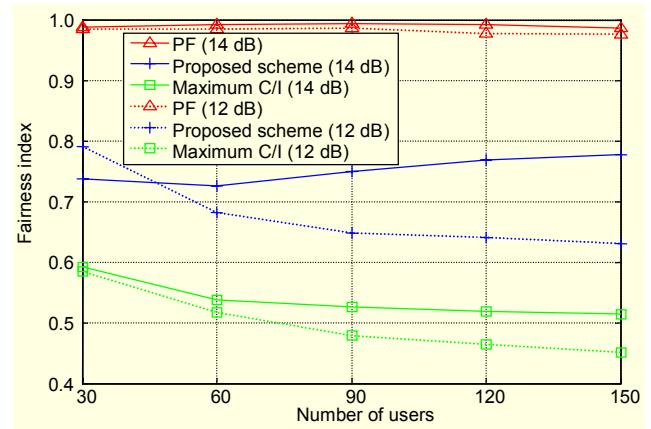


Fig. 4. Jain index for fairness.

channels by one user under tiebreak conditions and tries to distribute the opportunities to as many users as possible.

#### V. Conclusion

In this letter, an alternative factor has been newly defined for channel allocation and scheduling in OFDMA systems. By taking a simple calculation for the alternative factor, the downlink throughput can be increased to the level achieved by the maximum C/I scheme while maintaining sufficient fairness.

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