Chunk-based Resource Allocation in MISO-OFDMA Systems with Fairness Provision

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Abstract—**This paper proposes a chunk-based resource allocation (RA) algorithm for the Multi-Input Single-Output Orthogonal Frequency Division Multiple-Access (MISO-OFDMA) systems. Our proposed algorithm allocates resources chunk-by-chunk to maximize system sum rate under both average bit error rate (BER) and minimum user rate constraints with fairness provision. Simulation results reveal that our proposed algorithm provides efficient trade-off among system sum rate and fairness compared to three reference algorithms in the literature.**

Keywords-component; resource allocation; MISO-OFDMA; multi-user; chunk-based; ZFBF

I. Introduction

Orthogonal frequency division multiple-access (OFDMA) is currently exploited in most of modern wireless standards to permit wide-band data services [1]. Moreover, using multiple antennas at the transmitter in OFDMA systems (i.e. MIMO-OFDMA) increases system, but complicates the resource allocation (RA) process due to the existence of the spatial domain and the problem of interference generated from sub-carriers sharing. To make the RA process more tractable, a group of M contiguous sub-carrier are formed together into one resource unit (known as *chunk*) and RA is done on a *chunk-basis* rather than a *sub-carrier basis*.

Many works have addressed the optimal chunk-based RA under different constraints; bit error rate (BER) constraint [2] and fairness constraint among users [3]. We propose a *chunk-based* RA algorithm for the downlink transmission of *multi-user* MIMO-OFDMA system that maximizes system capacity with joint consideration of BER, quality-of-service (QoS) and fairness among users. Our proposed algorithm exploits spatial correlation for user selection among chunks and zero forcing beamforming (ZFBF) to cancel inter-user interference. The performance of our proposed algorithm, in terms of some system metrics, is compared to the algorithms in [2, 3] and the round robin (RR) algorithm that allocate resources fairly among users.

II. System Model

A. Channel model

We consider a single-cell multi-user OFDMA-based system with N sub-carriers served by one centric base station (BS) equipped with T transmit antennas and single-antenna K users are uniformly distributed such that $K > T$. System chunks are denoted by c, $c = 1,2,\dots,C$ where $C = \left\lfloor \frac{N}{M} \right\rfloor$. The corresponding average channel magnitude vector encountered by user k, $k = 1,2,\dots,K$ over any chunk c is then given by $\boldsymbol{\alpha}_{k,c} = \left(\frac{diag\left(\boldsymbol{H}_{k,c}\boldsymbol{H}_{k,c}^{\dagger}\right)}{M}\right)^{1/2}$ where $\boldsymbol{H}_{k,c} = \left[\boldsymbol{h}_{k,(c-1)M+1} \cdots \boldsymbol{h}_{k,cM}\right]$ is the $T \times M$ complex channel matrix and $\boldsymbol{h}_{k,n}$ is the $T \times 1$ complex channel gain vector of any sub-carrier *n*. To increase system capacity, simultaneous transmission to multiple users through different transmit antennas is allowed and a group of users is selected for transmission for every chunk based on proposed algorithm explained in details in Section III. Inter-user interference (IUI) amongst selected users due to frequency sharing is handled through ZFBF.

B. Power amd bit allocation

User power per sub-carrier n associated with chunk c, denoted as $p_{k,n}$, among the group of users A_c selected for chunk c is allocated through water-filling as $p_{k,n} = b_{k,n}\left[\mu_n - \frac{1}{b_{k,n}}\right]_+$ where $b_{k,n} = \left\{\left[\left(\boldsymbol{H}_n\boldsymbol{H}_n^{\dagger}\right)^{-1}\right]_{k,k}\right\}^{-1}$ and $\boldsymbol{H}_n$ is the $|A_c| \times T$ associated channel matrix, μ_n is obtained by solving the water-filling equation $\sum_{k\in A_c}\left[\mu_n - \frac{1}{b_{k,n}}\right]_+ = P_n$ where P_n is the sub-carrier power. Adaptive $l - ary$ Quadrature Amplitude Modulation (QAM) is exploited to provide link adaptation and satisfy average BER constraint. The associated modulation level $l_{k,n} \in L, L = \{0,4,16,64\}$ is chosen to satisfy that the average BER over the associated chunk c, given by [4] (1)

$$BER_{k,c} = \frac{1}{M}\sum_{n=(c-1)M+1}^{cM} 0.2exp\left(-\frac{1.6\gamma_{k,n}}{l_{k,n}-1}\right) \quad (1)$$

is below a threshold level BER_{th} where $\gamma_{k,n}$ is the associated signal-to-noise ratio (SNR). Modulation level is assumed to be the same within all sub-carriers of the chunk.

III. Proposed Chunk-Based Allocation Algorithm

A sub-optimal chunk-based allocation algorithm is proposed to compensate for the optimal exhaustive search solution. The algorithm is initialized with empty set of users of all available chunks. Chunks are allocated sequentially one-by-one and during every chunk allocation, the group of users which didn't achieve a predefined minimum rate R_{min} is set as a candidate set. Then, the user with best channel condition over this chunk is selected for transmission over this chunk and removed from the set of candidate users.

In a subsequent step, additional user selection continues by searching for users with minimum spatial correlation with previously selected users among the set of candidate users and selecting the one which maximize the cumulative rate over this chunk. User selection is terminated if cumulative rate doesn't increase or number of users selected so far becomes T. The algorithm is terminated when all chunks are allocated.

IV. Simulation & Results

A. Simulation Environment

We simulate the downlink of multi-user MISO-OFDMA system with $T = 4$ antennas, bandwidth $B = 100$ MHz divided into 1024 sub-carriers, under Rayleigh fading channel model with exponential power decay profile (PDP). Number of users, K, is set to 10, The BER constraint, BER_{th}, is set to 10^{-3}, the minimum user rate per sub-carrier, R_{min}/N, is set heuristically to 0.5. We compare our proposed algorithm with the algorithm in [2] that maximizes sum rate under power and average BER constraints only, the algorithm in [3] that maximizes sum rate under power, BER and proportional rate constraints among users and the round robin algorithm.

B. Sum rate performance

Fig. 1 shows the average sum rate per sub-carrier for the different algorithms against SNR in dB. Our proposed algorithm considers QoS by preserving a minimum user rate for each user so the sum rate, at low SNR values, is slightly lower compared to reference algorithms in [2, 3]. At high SNR values, our proposed algorithm highly outperforms the algorithm with proportional rate constraints in [3] and slightly exceeds the algorithm in [2].

C. Fairness performance

To further show the effectiveness of our proposed algorithm in terms of fairness among users, Fig. 2 shows the Jain's fairness index (FI) [5], defined as $FI = \frac{\left(\sum_{k=1}^{K} R_k\right)^2}{K \sum_{k=1}^{K} R_k^2}$ against number of users, K, for the different algorithms. It is clear from Fig. 2 that our proposed algorithm highly outperforms the two reference algorithms in [2, 3] with almost stable performance as number of users increases. Further simulation results reveal that fairness index of the reference algorithm in [2] continues to decrease linearly as number of users deployed increases which hinders its efficiency.

V. Conclusion

We proposed a chunk-by-chunk allocation algorithm for the downlink transmission of multi-user MISO-OFDMA systems. The proposed algorithm tends to maximize sum rate under average BER constraint. The proposed algorithm also considers QoS by preserving a minimum user rate chunk allocation. Our proposed algorithm provides efficient trade-off among system sum rate and fairness compared to three different algorithms in the literature.

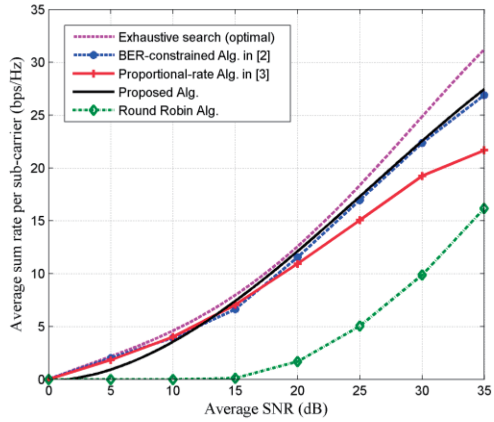

Fig. 1 Avg. Sum Rate per subcarrier vs. SNR.

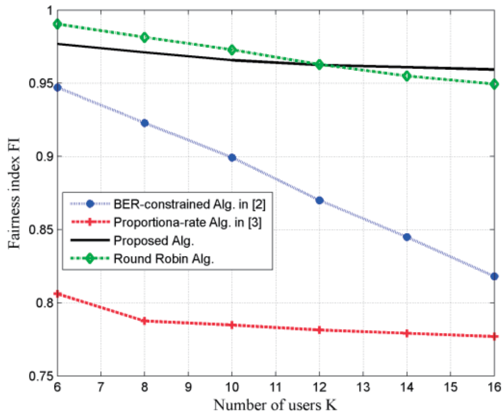

Fig. 2 Fairness index vs. number of users.

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