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Weighted Frequency Selective Scheduling for Multi-User MIMO-OFDM System

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ABSTRACT

In this paper, for multi-user multiple-input-multiple-output (MU-MIMO) orthogonal frequency-division multiplexing (OFDM) downlink system, we have proposed a weighted frequency-selective scheduling (WFSS) scheme. This scheme achieves a net throughput enhancement by adjacent subcarriers grouping into chunks and weighting factor which is obtained from earlier period throughput. To solve the overhead issue, optimized chunk size is used here. Comparison of net throughput between the proposed schemes and various other scheduling schemes is performed. The result shows that the weighted FSS scheme achieves improvement in the net throughput and average sum rate

Keywords
Multiuser MIMO-OFDM System, Net Throughput, User Scheduling, Weighting Factor

Introduction

High data rate wireless communications have a great remarkable interest and comprising a challenging research for wireless services in broadband applications. Especially, the implement of multiple number of antennas, which is widely known as the MIMO, to provide high-throughput with limited amount of power in wireless communications. The concepts of MIMO development for wired and wireless systems have been there for many years [1]. MU-MIMO wireless system has attracted sizeable attention in modern years which offer large throughputs in extreme data-traffic areas [2-3].

Multiuser OFDM (MU-OFDM) has high flexibility and is incredibly promising solution for frequency selective fading downlink channel. This is demanded by many applications to access the high rate wireless data [4]. Scheduling algorithm is used in MU-OFDM to choose the suitable user to achieve the highest data rate on a given subcarrier. Then the data of each selected user is modulated by the base station onto a subcarrier. Inter-user interference is nullified by the orthogonality nature of subcarriers. Researchers had proposed a lot of scheduling schemes for MU-OFDM wireless systems.

Literature Review

A user scheduling scheme with feedback reduction schemes are proposed in [5] which is implemented by using preferable feedback mode designed between two modes. Here, the algorithm is categorized into two feedback scheme namely user selection mode based feedback network selection mode feedback. The feedback mode is determined by the entity. These schemes use to improve throughput but causes unnecessary computation overhead.

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In [6], to improve the throughput, a BRS-balanced resource scheduling scheme is developed for OFDMA- Orthogonal Frequency Division Multiple Access systems, which gives outstanding equilibrium between Quality-of-Service assurance & enhancement of throughput with adaptive priority threshold to improve the system throughput. First Priority threshold is calculated and then priority value is compared with priority threshold. If a user priority value is above threshold, the user was scheduled in second stage for RA. Therefore, the BRS with adaptive thresholds (priority) balances both throughput and QoS improvement. to prevent overloading, additional control scheme was used to manage total users. To improve the performance further, multiple numbers of transmitting and receiving antennas can be used with OFDM. Broadband MIMO-OFDM systems have indicated an improvement on capacity; reliability and coverage are very achievable along with the support of MIMO techniques [7]-[10]. A network centric scheduling is proposed in [16], [18]. A multi-parameter based scheduling is used in all base station to coordinate all base station in the network, by which the resource utilization of all base station can be improved. In [17], an effective Failure-based RA Technique (FRAT) was proposed. The different fault tolerance technique was adopted in different proportion according to resource failure. Therefore, MIMO with OFDM is being selected for the high data-rate wireless transmission according to the wireless standards.

In this paper, weighted frequency selective scheduling [FSS] is proposed that enhance the throughput with limited feedback. In WFSS, the base station scheduler compares the weighting factor of all the users for each individual chunk and allocate the user with the best weighting factor for each chunk.

Methods

Consider a MU-MIMO -OFDM downlink system in particular cell with the proposed weighted frequency selective scheduling scheme. It is assumed that the model of system shown in Fig.1, have K number of movable users and every user are equipped with N_r receiving antennas, and M_t transmitting antennas in base station (BS). We assume that, at each one frame beginning, the BS user schedulers assign the number of adjacent subcarrier called as chunk (i.e., Frequency Division Multiplexing (FDM)).

At the transmitter, the OFDM symbols are generated by the time-domain input sequence x_n. These symbols are OFDM modulated for each antenna using N-point IFFT (Inverse Fast Fourier Transform). Cyclic Prefix (CP) extension is used to keep orthogonality. Then the signal passed through various selective frequency fading channels according to the different users. If cyclic prefix length longer compared to the time dispersion maximum value, then inter-symbol interference is softened. For detection, here we use ordered SIC (successive interference cancellation) detection. Using point to point MIMO - SM (Spatial Multiplexing), the mobile user receiver able to recover under the condition that N_r greater than or equal M_t. Here, we considered $N_r = M_t$, and this is reasonable (practical perspective) for small values of M_t.

Assume fading channel is frequency selective and designed with length - L finite-impulse-response filter. The channel matrix of space frequency for k^{th} user at the n^{th} tone can be explained as [11]

$$H_n^{(k)} = \sum_{p=0}^{L-1} \sigma_p F[k,p] \exp\left(-j2\pi \tfrac{n}{N} p\right), \qquad 1 \le n \le N \tag{1}$$

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The $F[k,p]$ matrices of size $M_t \times N_r$ for $p = 0$ *to* $L-1$ represents the k^{th} user impulse response of MIMO channel. It is assumed that the matrices $F[k,p]$ are mutually uncorrelated further assumed that the channel gain in every matrix reveal spatially uncorrelated Rayleigh fading and contain independent N elements. Further to that, $\sigma_p{}^2$ for $p=0$ *to* $L-1$ indicates channel power delay profile of a channel which is normalized by assuming $\sum_{p=0}^{L-1}\sigma_p^2 = 1$. Further the channel is assumed to be quasi static & remains constant for the period of 1 coherence time, and it changes between frame to frame independently. The correlation coefficients for two arbitrary subcarriers n and m between the elements of channel are given by

$$\beta_{n,m} = \left[\left(H_n^{(k)}\right)_{i,j}\left(H_n^{(k)}\right)_{i,j}^{*}\right]$$
$$= \sum_{p=0}^{L-1}\sigma_p^2 exp\left(-j2\pi\left(n-m\right)p/N\right)\delta\left[i-i'\right]\left[j-j'\right] \quad (2)$$

The frequency correlation coefficient depends on the subcarriers difference *i.e.* $(n - m)$, and that does not depend on all subcarriers. Here *ith*&*jth* element of A matrix is denoted as $(A)_{i,j}$, complex conjugate is denoted as $(.)^*$& Dirac's delta function is denoted as $\delta(.)$ Therefore, receives the signal vector as

$$y_n^{(k)} = H_n^{(k)} x_n + n_n^{(k)} \quad (3)$$

where, $H_n{}^{(k)}$ is space frequency channel and x_n is transmitted signal for the n^{th} subcarrier. $n_n{}^{(k)}$ is normalized noise in terms of vector. Hence the SNR value is equal to P_X which define the BS transmit power constraints. Let the R indicates total data rates which is distributed to users by BS in one-time slot. Therefore, the throughput expectation is attained by average transmission rate over the enormous numbers of the $Hn^{(k)}$ realization

$$R_{avg} = E[R] \quad (4)$$

When feedback overhead increases that in turn reduces R *and* R_{net}. Therefore, the net throughput is given by

$$R_{net} = R_{avg}\left(\frac{\left(R_f + R_a\right)T_f}{T}\right) \quad (5)$$

where, T_f is required time to send the value of one quantized feedback term to BS, R_f denotes the feedback value in average for each subcarrier. These values are collected from all users during the coherence time interval. Therefore, the total feedback is the functions of number of transmitting antennas M_t, K users, the coherence time, N subcarriers, and the chunk size B. R_a depends on chunk size B, *q no. of bits sent during Tf and the number of users K*. R_a is found to be the smallest integer to identify each users, that is multiple of $1/B$ with $N \geq log_2(K)/qB$. The term $(R_f + R_a)\ T_f/T$ is Coherence Time portion.

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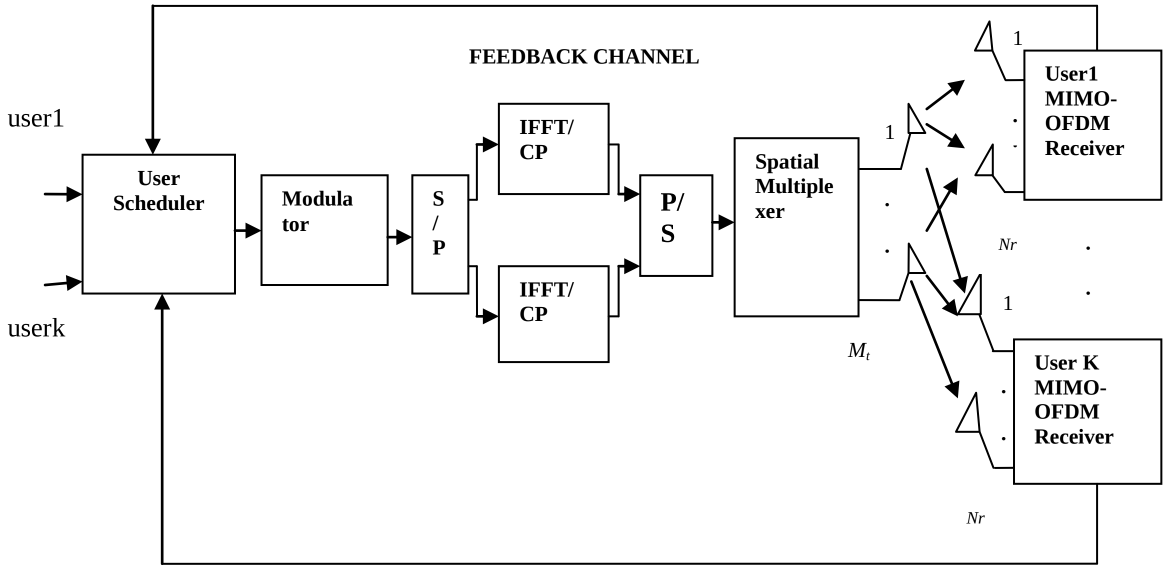

Fig. 1. Model of the MU-MIMO-OFDM downlink System

Methodology

PROPOSED WEIGHTED FREQUENCY SELECTIVE SCHEDULING ALGORITHM:

In this section, our proposed Weighted Frequency Selective Scheduling (WFSS) scheme is presented It performs in two scenarios. First it assigns number of the subcarriers into chunks for each active user and then resources allocated to user randomly. Second, user rate is compared with weighting factor to assign the resources for each user. Therefore, from a resource block, each user is assigned by best resources defined over a time and frequency. This can be easily achieved by applying a user specific weighting factor determined at the BS. First the resources are assigned to the high rate users and then shared among a low rate user to improve their reliable rate. This results in achieving better throughput.

The achievable rate of proposed algorithm on the c^{th} chunk is given by

$$R_w = \max_{k=1\ldots K} \frac{1}{C} \sum_{c=1}^{C} w_k B r_n^{(k)} \qquad (6)$$

where $r_n^{(k)}$ is defined by

$$r_n^{(k)} = \log_2 \det\left(I + \gamma H_n^{(k)} H_n^{(k)H} \right), 0 < n < N-1 \qquad (7)$$

where, $\gamma = P_X / (M_t * C)$ is the open loop capacity rate of the MIMO. This transmission rate of the system is achieved with spatial multiplexing and ordered SIC detection [11]. The weighting factor w_k is then updated are as follows

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$$\frac{1}{w_k} = \left[1 - \frac{1}{w}\right]\frac{1}{\overline{w}_k} + \frac{\overline{R}}{w} \qquad (8)$$

where, $\overline{w}_k$ is the weighting factor for previous average throughput of *kth* user, *w* is the window size of a given subcarrier, which gets multiplied with the previous average rate to maximize the current achievable rate. This weighting factor is used to improve the resources for each user.
Initially, the weighting factor is not applied in the process. First the feedback information from each user will be collected at the BS. With respect to that, the scheduler will then allocate the weighting factor. Here, the weighting factor plays a critical role in assigning the resources. Hence, the user is going to be considered within the resource scheduling process by this weighting factor and yields an average rate for achieving new achievable rate R_w.
Then the average weighted sum rate is

$$R_{avg} = E\left[\frac{1}{C}\sum_{k=1}^{K} R_w\right] \qquad (9)$$

Therefore, it is clear that larger chunk size has less feedback information that results in poorer the system performance. Whereas smaller chunk size gives more feedback information. The feedback overhead is approximated using proposed scheme and is given by

$$R_{th}^{(\max)} = R_{avg}\left(\frac{F_t \times T_f}{T}\right) \qquad (10)$$

Here, the subcarrier average feedback terms are referred as $F_t = K / B^{max}$. Where B^{max}*is chunk size that varies from 1 to N that* maximizes R_{avg}. R_{avg}can be obtained using the value B. Hence, it achieves more resources with limited feedback overhead as number of user increases.

Results and Discussion

In this numerical result, the delay profile is implemented in channel as

$$\sigma_p^2 = \frac{1-\exp\left(-1/W_{\exp}\right)}{1-\exp\left(-L/W_{\exp}\right)}\exp\left(-L/W_{\exp}\right), 0 \le p \le L-1 \qquad (11)$$

where W_{exp} defines the rate of decay profile with respect to *L* and *L* is the no. of resolvable paths. Here if the individual part of impulse response is independent, then the rate of decay will be slow when comparing to system bandwidth. Table 1 illustrates the settings used for the purpose of simulation.The various feedback terms which are used for MIMO-OFDM downlink systems are compared with proposed schemes.This feedback term is considered for subcarrier allocation. Feedback terms are the real quantization values such as sum rate, gain and SNR.In this paper, each feedback term has q = 8 bit quantized value.

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Table 1 Settings of Parameter for Simulation

Value setting	Parameter
N = 2048	Total No. of Subcarriers
K = 1 to 1000	Total No. of users
Px = 10	Transmit Power
Mt = Nr = 3	Transmit & Receive Antennas
P = 8	Total No. of Resolvable path

The results depend on various feedback schemes are described as follows. Fig. 2 shows the of sum rate performance with M_t = N_r= 3 antennas compared to M_t = N_r= 2 antennas with N = 64 subcarriers, fixed chunk size of B = 8.

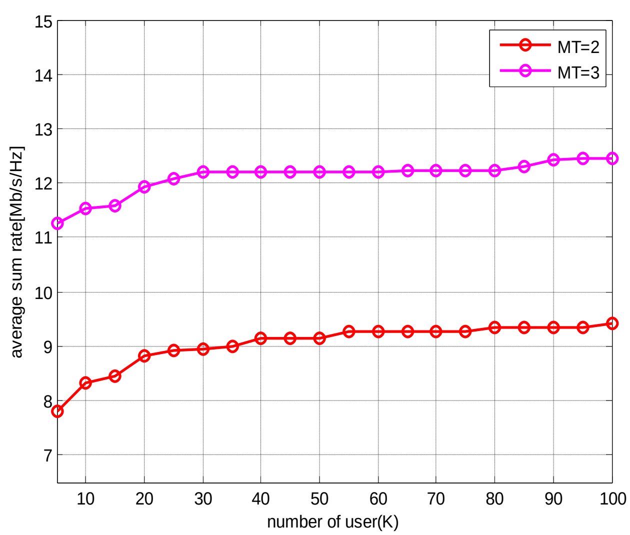

Fig.2. Sum Rate (in average) performance with M_t = N_r= 3 antenna compared to Mt= N_r= 2 antennas.

In this approach, a random channel matrix is modeled depending upon the type of scheduling to find the average sum rate. From the result, it is seen that the average sum rate improves when more antennas are used. If we increase more number of subcarriers, more resources shall be allocated to reasonably large number of users. But overhead occur due to more number of users with more number of subcarriers, so to avoid this, chunk optimization is done.

Fig. 3 demonstrates the chunk size verses average net throughput for different number of user with number of subcarriers N = 2048 and M_t = N_r= *3* antennas. The Feedback time with respect to one coherence time (T_f/ T) is assumed here as 0.003. It is found that when the chunk size is increased, the average net throughput is getting decreased beyond certain value. Hence

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optimizing the chunk size is very important and it is done based on this graph in our scheduling.

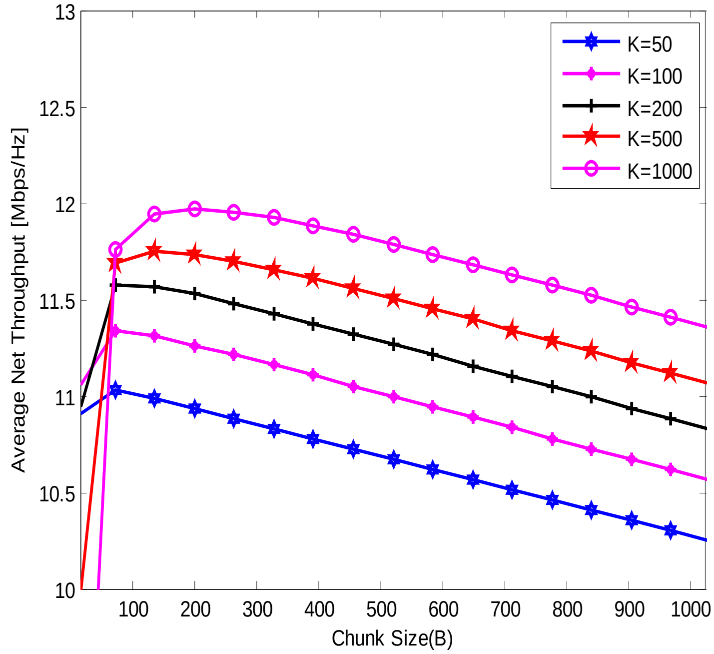

Fig.3. Performance of Average net throughput verses different chunk size with P_X= 10 dB &M_t = N_r= 3 antennas.

Further it is observed from the above figure that the maximum chunk size B for user K = 50 to 1000 *is varying from* 32 to 128. Therefore, as the chunk size increases, the variance for each R_w decreases, the average- sum rate increases.

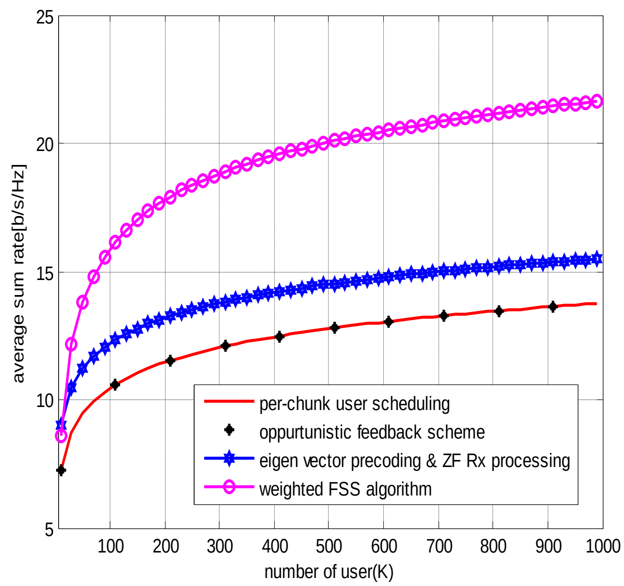

Fig.4. Sum Rate (in average) performance of WFSS compared to other scheme with Mt = Nr = 3 antennas.

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Fig 4 displays the sum rate performance of the weighted FSS different no. of users with N = 2048 subcarriers and $M_t = N_r =$ 3 antennas. In the proposed method, the weighting factor is used to boost up the resources for each user along with the optimized chunk size. Because of the usage of optimized chunk size, the feedback overhead is reduced and that increases the sum rate. From figure 4, it's observed that the sum rate performance of proposed WFSS is improved compared to other scheme. In addition, it is observed that when user number increases, the sum rate in average increases in proposed method when compared to other schemes.

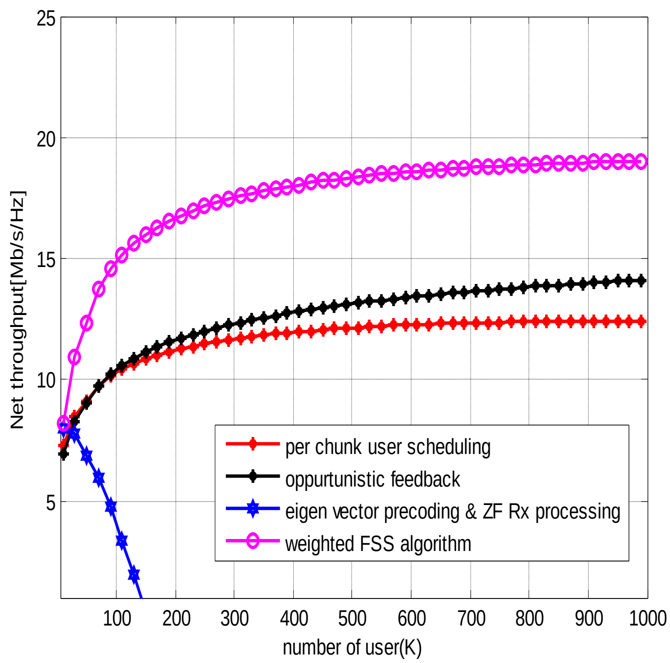

Fig. 5. Net Throughput (in average) performance of WFSS with other scheme

Fig. 5 demonstrates net throughput performance of WFSS compared to other scheduling namely per chunk user scheduling(PCUS), opportunistic scheduling and Eigen vector precoding. When the no. of the user's increases, the average net throughput of Eigen vector precoding for moderate K values becomes zero due to increase in the amount of feedback with K users.

Table 2 Performance Comparison of WFSS with various scheduling schemes (No. of users K=100)

Scheduling Algorithm	Average Net Throughput (Mbps)	Average Net Sum Rate (b/s/hz)
Eigen Vector Precoding and ZF-Rx Processing	4	12
Per-Chunk User Scheduling Scheme	11	11
Opportunistic FeedbackScheme	11.2	11
Weighted Frequency Selective Scheduling Scheme	15	16

It is seen that the net throughput of Eigen vector precoding drops when number of user increases. This is due to more feedback overhead. With the use of chunk in the per-chunk based user scheduling, the average net throughput is maintained. To improve the average net throughput further, a proposed scheme WFSS is introduced with limited feedback. It's also shown that the WFSS scheme average net throughput is improved when compared to other schemes. Performance improvement of WFSS is given in Table 2.

It is found from the table that the proposed WFSS has better throughput and sum rate. In addition, it is observed that there is 26% improvement in net throughput and 31% improvement in sum rate performance compared to other scheduling scheme.

Conclusion

This paper has proposed a weighted FSS scheme for MU- MIMO-OFDM systems to improve the net throughput and average sum rate. It performs two state functions for resource allocation. By assigning suitable weight factor and chunk size, it is found that Weighted FSS scheme assign resources properly to improve the net throughput and average sum rate. Simulation result shows that WFSS scheme net throughput performance is increased by 26% compared to PCUS & Opportunistic feedback scheme and 31 % improvement in average sum rate.

Limitations and Future Studies

Sometimes resource utilization may be low because of the chunk size value.This arises when the large number of user's mobility changes from near field to far field.This works further can be extended by using optimized chunk size using various optimization techniques to suit massive MIMO systems.

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