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# Minimum Normalized Transmit Rate Based Fair Scheduling Algorithm in Orthogonal Frequency Division Multiplexing (OFDM)

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**Abstract**

The demand on high rate multimedia information has pushed the development of wireless communication systems in an unprecedented pace. System design of fourth generation (4G) technology has already begun, which seeks to support a wide range of services with highest data rates reaching 20Mbps. OFDM is an important candidate technique for the future wireless transmission. It is a multicarrier modulation and access technique which can support high data rates and perform well in wireless environment. However this can be ensured only through good scheduling algorithm to allocate the common resources. The problem is to allocate resources among users fairly. In this paper Minimum Normalized Transmit Rate Based Fair Scheduling Algorithms based on Throughput is discussed also the performance of this algorithm is evaluated through simulation results.

**Key words**: Multicarrier modulation, OFDMA, Fair Scheduling.

## Introduction

Orthogonal Frequency Division Multiplexing (OFDM) has been considered as a very promising solution for supporting high-data-rate transmission in future broadband wireless communication systems. The basic idea of OFDM is to divide the available spectrum into several sub-carriers so that the information symbols are transmitted in parallel on the sub- carrier over the wireless channel. This allows us to design a system supporting high data rates while maintaining symbol durations much longer than the channel delay spread. By doing so, each sub-carrier experiences almost a flat fading and the detrimental effects of the multi-path channels are reduced. OFDM is also attractive from a multi-user perspective. Since the bandwidth is divided into orthogonal sub-carriers, it is possible to schedule different users simultaneously on different frequency bands. The most beneficial properties with the OFDM modulation are:

- Each trans-receiver will have access to all sub-carriers with in a cell layer (this enables very high bit rates)
- There is more or less no need of frequency planning with in cell layer (it is performed with and adaptive allocation algorithm)
- Sub-carrier modulation is performed with a FFT (easy to implement)
- The division of signal into a large number of more or less independent sub-channels will provide the flexibility needed for all future multimedia services (variable bit-tare with different quality of services)

## Scheduling in OFDM

The process of selecting a user out of many users in order to access the common resources of a channel is called scheduling [3]. The function of a scheduling algorithm is to select the user whose data is to be transmitted next. This selection process is based on the QoS requirements of each user. It is desirable for a scheduling algorithm to possess the following features: Efficient link utilization, Fairness, Delay bound, Throughput, and Isolation. In multi-user OFDM system (OFDMA), the channel conditions of mobile users vary in the time domain and different sub carriers experience different channel gains because of frequency selective fading channels. Wireless link capacity is generally a scarce resource that needs to be used efficiently. Therefore, it is important to find an efficient way of supporting Quality of Service (QoS) for each user. Specifically, it is important to maximize the system throughput while providing fairness among users i.e. the resources must be fairly allocated among the users. The criterion for fairness may be latency, throughput or QoS. To maximize the throughput of the system best sub carrier is allocated to each user. Of course, the procedure is not simple since the best sub carrier of the user may also be the best sub carrier of another user who may not have any other good sub carriers. As already said, that at all the time the user with the best channel is selected to maximize the throughput. But in this case, if a user is at a great distance from the base station or its channel is in deep fade, then it will never get a chance to access the channel. Hence there is need to provide fairness among users [2], [4].

## Algorithm Development

### Multicarrier Analysis [1]

In case of multicarrier transmission such as OFDMA where number of user is M and the number of sub carriers is K. Let $SNR_{mk}$ be the SNR corresponding to $m^{th}$ user and $k^{th}$ sub carrier then for adaptive OFDM system, the maximum number of bits assigned to the $k^{th}$ subcarrier of the $m^{th}$ user is decided by the following formula:

$$b_{mk} = \log_2(M) = \log_2\left(1 + \frac{SNR_{mk}}{\Gamma}\right) \quad (1)$$

Where $\Gamma$ represents the signal-to- noise ratio (SNR) gap and for QAM modulation, $\Gamma$ is written as:

$$\Gamma = \frac{-\ln(5BER_{target})}{1.5} \quad (2)$$

Where $BER_{target}$ is the required Bit Error Rate (BER).Let p and $\sigma^2$ denote the transmit power of each carrier and variance of additive white guassian noise, respectively. Let $g_{mk}$ be the channel gain corresponding to $m^{th}$ user and $k^{th}$ sub carrier. Then

$$SNR_{mk} = \frac{g_{mk}p}{\sigma^2} \quad (3)$$

Substituting (3.3) in (3.1), we get

$$b_{mk} = \log_2(M) = \log_2\left(1 + \frac{g_{mk}p}{\Gamma\sigma^2}\right) \quad (4)$$

The above equation tells maximum how many bits a user can allocate on a sub carrier.

Here it is assumed that $P_e$ is maintained constant in all the sub carriers and hence SNR gap is the same for all the sub carriers. The total number of bits transmitted in one OFDM symbol is given by,

$$b = \sum_{k=1}^{K} b_{mk} \quad (5)$$

**Mathematical Model for Algorithm**

As per [1], $a_{mk}$ = l denotes that the sub carrier k is allocated to user m and $a_{mk} = 0$ if sub carrier k is not allocated to user m. Assume that a sub carrier can not be used by more than one user, thus

$$\sum_{m=1}^{M} a_{mk} \leq 1, \forall k \quad (6)$$

For each user the total granted transmit rate is calculated as

$$W_m = \sum_{k=1}^{K} a_{mk} b_{mk} \quad (7)$$

and the normalized transmit rate is $W_m / \Phi_m$, where $\Phi_m$ is the rate weight of user m.

Service Fairness Index (SF1), the maximum difference between the normalized transmit rates, is usually used to measure the fairness of scheduling algorithm, which is represented as:

$$SFI = \max_{m,n} \left| W_m / \Phi_m - W_n / \Phi_n \right| \quad (8)$$

SFI = 0 indicates the ideal fairness, which is unfeasible in real systems. For real systems there an upper bound B is used to measure the fairness, i.e.

$$\max_{m,n} \left| W_m / \Phi_m - W_n / \Phi_n \right| \leq B \tag{9}$$

An efficient fair resource scheduling algorithm should maximize the total throughput while satisfying the fairness requirement. The optimization problem can be expressed as:

$$\max_{a_{mk} \in \{0,1\}} \sum_{m=1}^{M} \sum_{k=1}^{K} a_{mk} b_{mk} \tag{10}$$

Subjected to:

$$\max_m \left[ \frac{\sum_{k=1}^{K} a_{mk} b_{mk}}{\Phi_m} \right] - \min_n \left[ \frac{\sum_{k=1}^{K} a_{mk} b_{mk}}{\Phi_n} \right] \leq B \tag{11}$$

and

$$\sum_{m=1}^{M} a_{mk} \leq 1 \tag{12}$$

**Minimum Normalized Transmit Rate Based Fair Scheduling Algorithm**

In this algorithm, the user with the least normalized transmit rate is allowed to choose a sub carrier. This guarantees the fairness among all users. Then, the sub carrier with the highest utilization efficiency to that user is selected. Thus, a high efficiency can be achieved. This algorithm is divided into K steps where K is the number of sub carriers. The main algorithm is given below:

Step 1: Initialize $a_{mk} = 0$, $W_m = 0$ for m = l, 2,….. M and for k= l,2….. *K*. Set S = {l, 2,………..k*}*.

Step 2: Select $m^* = \arg\min(W_m / \Phi_m)$ for all $k \in S$ calculate the utilization efficiency

$u_{m^*k} = b_{m^*k} / \sum_{m=1}^{M} b_{mk}$. Let $k^* = \arg_k \max\{u_{m^*k}\}$ and set $a_{m^*k^*} = 1$. Update $W_{m^*} = W_{m^*} + b_{m^*k^*}$

and $S = S \setminus \{k^*\}$

Step 3: If $S = \Phi$ then stop. Otherwise, go to Step 2.

## Simulation & Results

A throughput based fair scheduling algorithm [1] has been simulated in MATLAB 7.1 considering only downlink (base station users) resource scheduling in OFDM cellular system. The simulation model considered in [1] is used only difference is in BER which is now taken $10^{-5}$ in simulating the downlink resource scheduling for OFDMA.

**Simulation Parameters**

7 modulation schemes, viz, BPSK, QPSK, 8 PSK, 16 QAM, 32 QAM, 64 QAM AND 128 QAM, are employed in this simulation. The simulation parameters are given in table 4.1.

**Table 4.1:** Simulation Parameters.

| Parameter | Value |
|---|---|
| No. of users (M) | 5 |
| No. of sub carriers (K) | 64 |
| Carrier frequency (fc) | 2 GHz |
| Bit rate | $10^5$bps |
| SNR (P/ $\sigma^2$ ) | 20 dB |
| BER | $10^{-5}$ |
| Doppler frequency ($f_d$) | 100 Hz |

## Results and Discussion

In the simulation, for the same model**,** throughputs of minimum normalized transmit rate based fair resource scheduling algorithm (FRS), maximum resource scheduling algorithm (MRS.) and random resource scheduling algorithm (RRS) have been measured.

Fig. 4.1 shows the throughput of each user in case of FRS, MRS and RRS. The average channel gain and rate weight of $2^{nd}$ user is set to1. It is clear from the figure that maximum throughput is achieved in case of MRS because it allocates 100% of the subcarriers to the best user whose average channel gain is higher but it is unfair because zero throughputs are achieved for the users whose gains are less or who are in deep fade. In case of RRS, although the throughput of each user is same and, therefore, it is a fair algorithm, but throughput is less around 2% because it allocates the sub carriers to each user randomly. FRS provides a compromise between the above two algorithms. In this case, the throughput of each user is same and is 20%. This is higher than that in case of RRS, since each user in the FRS algorithm selects a best subcarrier instead of random subcarrier in RRS case.

The relationship between average number of loaded bits with $\phi_5$ for different values $\sigma_5$ is shown in fig.4.2.in this case when average channel gain of fifth user is greater than 0.4, the average number of loaded bits increases with increase in $\phi_5$,because in this case more bandwidth is allocated to the user which has good channel condition.Fig.4.3 and fig.4.4 show the relationship between average number of loaded bits per subcarrier versus $\phi_5$ for SNR=25db and SNR=30db.Figures shows that as the SNR increases, average number of bits loaded increases, so performance of algorithm improves with increasing SNR. In this case the results obtained through simulation are not exactly matching as results obtained by [1] but the nature of result is same.

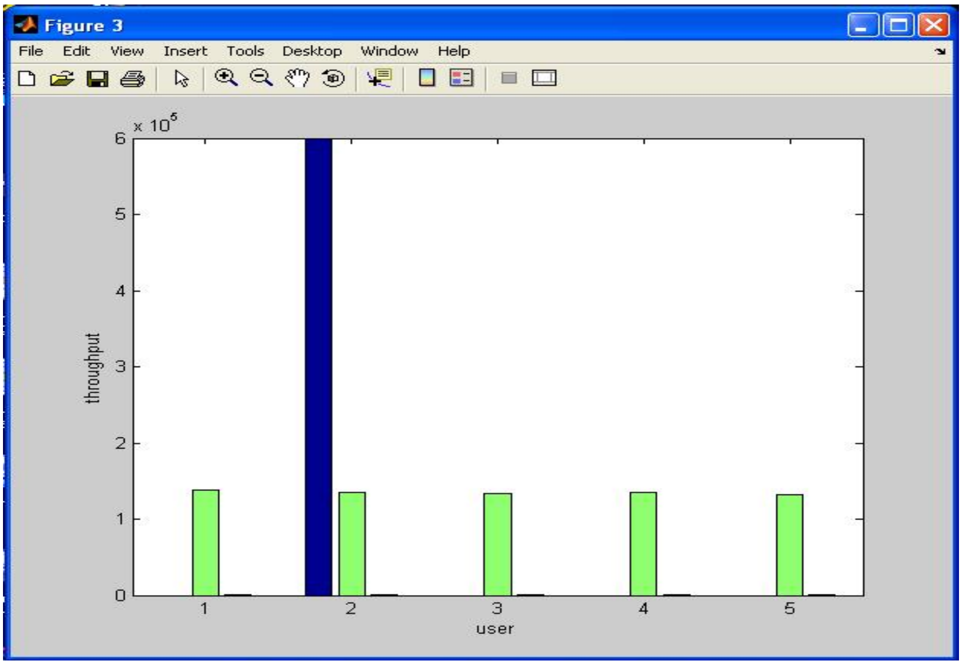


**Figure 4.1:** Achieved Throughput of each user with channel 2 has maximum gain.

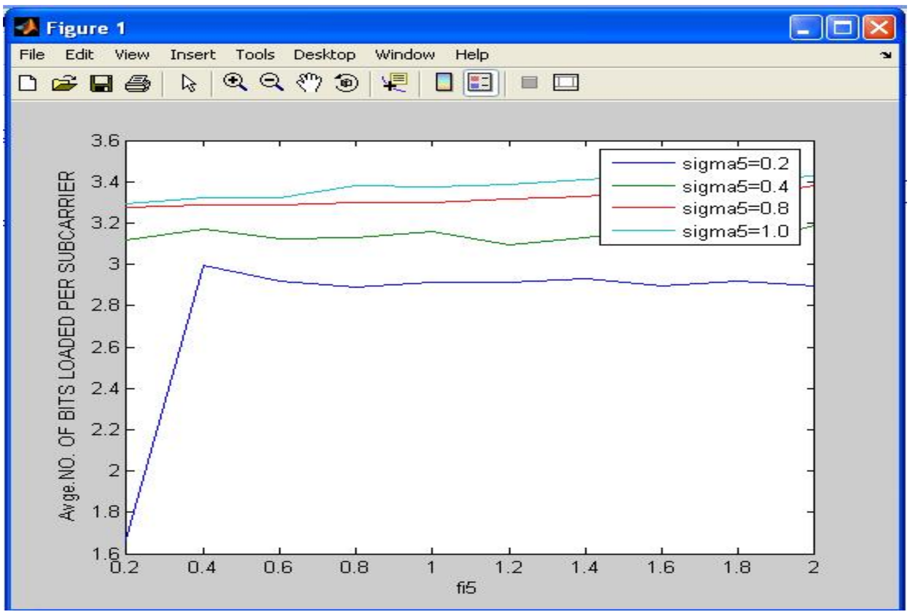


**Figure 4.2:** Average loaded bits per subcarrier versus $\phi_5$ for SNR=20db.

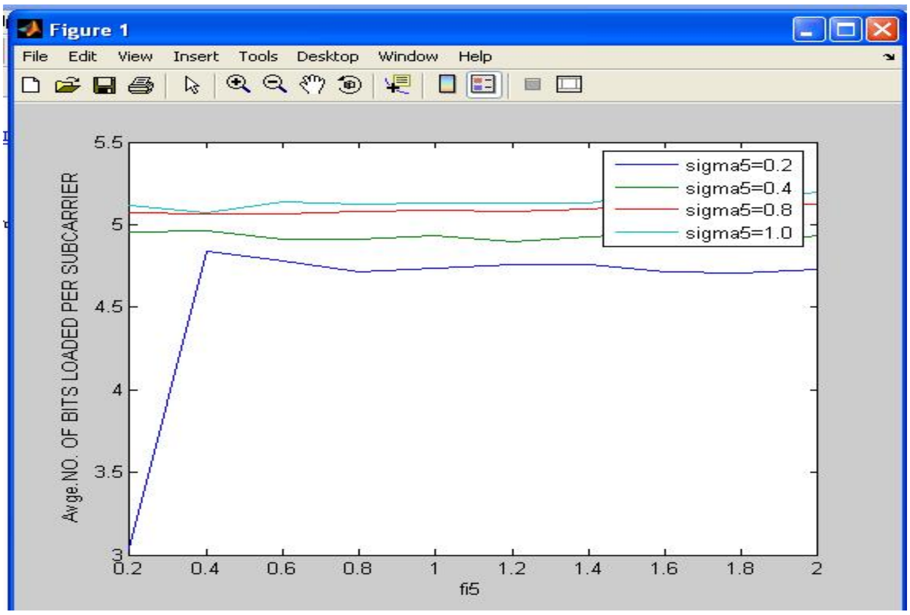


**Figure 4.3:** Average loaded bits per subcarrier versus $\phi_5$ for SNR=25db.

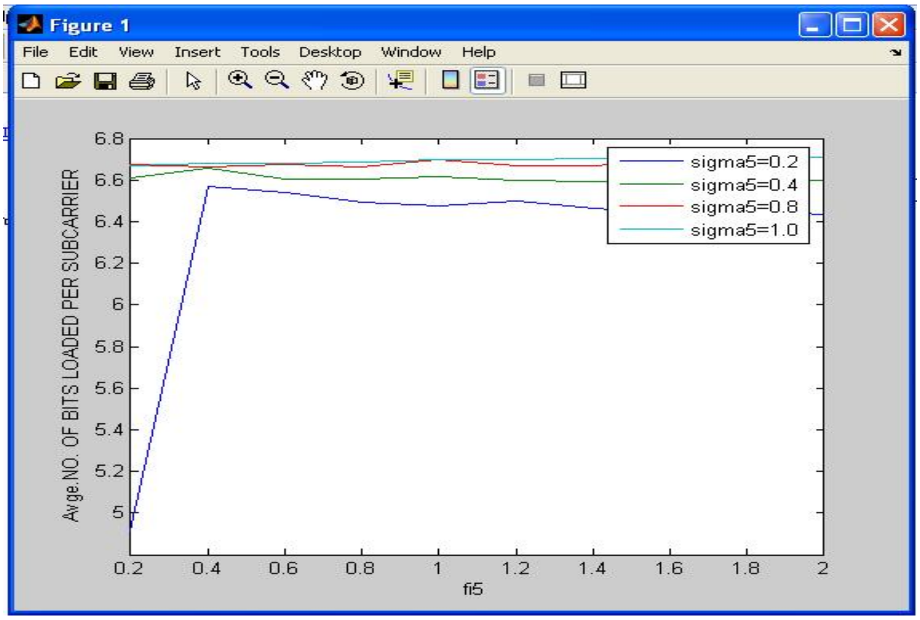


**Figure 4.4:** Average loaded bits per subcarrier versus $\phi_5$ for SNR=30db.

## Conclusion

The performance of minimum normalized transmit rate based fair scheduling algorithm has been evaluated through simulation. The performance of this algorithm is compared with that of maximum resource scheduler (MRS) and random resource scheduler (RRS). It is evident from the simulation results that the fair scheduling algorithm provides almost 20% throughput with fairness among the users. Simulation results show that the performance of algorithm improves with increasing SNR.

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