



# Performance of an Uplink OFDMA System Using Subcarrier Allocation

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**ABSTRACT:** OFDMA (Orthogonal Frequency Division Multiple Access) suffers from destruction of orthogonality if a channel between the mobile user and a base station is rapidly time varying. This channel between the mobile user and a base station is called an Uplink-OFDMA. The OFDMA uplink resource allocation undergoes from Inter carrier interference (ICI), multiuser interference (MUI) if a nearby subcarrier is assigned to different user, high peak to average power ratio (PAPR) and high bit error rate (BER). This results in performance degradation. In order to provide a significant improvement in performance, a practical OFDMA system detection is required. The proposed system consists of a new sub-carrier allocation method using a successive interference cancellation (SIC) detector at the receiver side. The proposed system is designed and simulated using MATLAB tool.

Simulation results show that the proposed subcarrier allocation and —Interleaved AI allocation method has an average Bit error probability of  $10^{-0.5}$  and  $10^{-0.2}$  respectively. Thus Average Bit error probability of around 32% is reduced compared to the —Interleaved AI allocation method. Further, simulations also demonstrate a gradual decrease in MUI power from -15db to -20db for interleaved allocation and subcarrier allocation method respectively.

**KEYWORD:** BER, PAPR, ICI, SIC

## I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is a modulation method that divides a channel into multiple narrow orthogonal bands that are spaced so they don't interfere with one another. Each band is divided into hundreds or even thousands of wide subcarriers. To save the bandwidth, frequencies are made orthogonal to each other, and thus the name orthogonal frequency division multiplexing.

Time slots within each subchannel data stream are used to package the data to be transmitted. Two conditions must be considered for the orthogonality between the subcarriers: Each subcarrier has precisely an integer number of cycles in the FFT interval. The number of cycles between adjacent subcarriers differs by exactly one.

The objective of this paper is to find a resourceful subcarrier allocation algorithm that can improve the performance of an uplink-OFDMA under a nonhomogeneous user environment without increasing the transceiver complexity much. To achieve this objective, all users are classified into three groups: a vehicular users' group of relatively fast-moving users, slow users and a pedestrian users' group of relatively stationary users. Only the vehicular users are assumed to generate the ICI and MUI due to the higher Doppler spreads. Then, the successive interference cancellation (SIC) with a one-tap equalizer becomes a practical candidate, if it can eliminate the ICI and MUI from the vehicular users without error propagation.

Assuming a SIC detector, we state a mutual interference power among the subcarriers allocated to the vehicular users, and formulate , an integer programming to find an optimum subcarrier allocation that minimizes the maximum mutual interference power. Applying a continuous relaxation of the derived integer programming, which becomes a convex programming, a suboptimal algorithm is proposed using the Karush-Kuhn-Tucker (KKT) conditions [11]. Finally, the average bit error rate (BER) with respect to all users will be simulated to show the greater performance of the proposed allocation scheme over the existing schemes in a convolutional coded uplink-OFDMA system.

## II. SYSTEM MODEL

Assume that N total number of subcarriers are allocated to U number of uplink users equally, i.e.,  $N = UC$ , where C is the number of subcarriers per user.

Among the U users, assume S number of vehicular users. In other words, only S numbers of users generate ICI and MUI. Here, the ICI implies interference to the subcarriers allocated to the self-user, while the MUI implies interference to the subcarriers allocated to the other users.

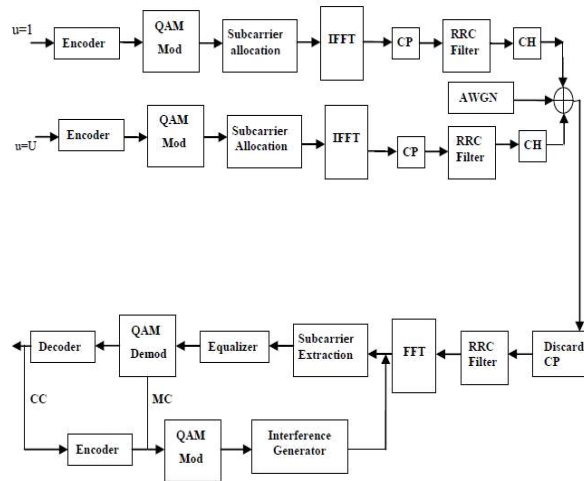


Fig 2.1 Proposed Block diagram of transmitter and receiver for uplink OFDMA

Also the robustness of the proposed scheme against low quality Doppler spread information is shown. In other words, demonstrate through simulation that even if a Doppler spread frequency of each user is quantized into a 2-class, significant performance improvement can still be observable. Hence, the proposed subcarrier allocation method can be effective even with low complexity, i.e., binary Doppler spread frequency feedback information. Figure 2.1 shows a simplified block diagram of the transmitter and receiver for an uplink-OFDMA system.

In the transmitter of each user, a stream of information bits is fed into an encoder and then modulated by a quadrature amplitude modulation (QAM). The modulated symbols are assigned to the subcarriers. Define a set of subcarriers allocated to user  $u$  and an  $N \times 1$  transmitted vector of dimension  $u$  as  $k_u$  and  $x_u$ , respectively. The entry of  $x_u$  denoted by  $x_u(i)$ , is a transmitted QAM symbol if  $i \in k_u$ , and 0 otherwise.

### III. SUBCARRIER ALLOCATION ALGORITHM.

After taking an inverse fast Fourier transform (IFFT) using  $x_u$ , a cyclic prefix (CP) is appended to each OFDM symbol to avoid the ICI and intersymbol interference (ISI) due to the multipath dispersion.

At the receiver in the base station, the CP is discarded and a fast Fourier transform (FFT) is performed. Then, the received signal for the  $k$ -th subcarrier can be written as

$$y(k) = \sum_{u=1}^U \sum_{i \in k_u} H_u(k,i)x_u(i) + w(k), \quad k = 0, 1, \dots, N-1 \dots \dots \dots (3.1)$$

where  $w(k)$  is a zero-mean additive white Gaussian noise (AWGN) of  $\sigma^2$ , and  $H_u(k, i)$  is given by

$$H_u(k,i) = \frac{1}{N} \sum_{n=0}^{N-1} \sum_{l=0}^{L-1} h_u(n,l) \exp\left(-j \frac{2\pi(nk+(l-n)l)}{N}\right) \dots \dots \dots (3.2)$$

Where,  $h_u(n,m)$  is the channel impulse response (CIR) at the  $m^{\text{th}}$  lag and the  $n^{\text{th}}$  instant for the  $u^{\text{th}}$  user and it is modeled as an independent stationary Gaussian process with  $E\{h_u(n, l)\} = 0$  and  $\sum_{l=0}^{L-1} E\{|h_u(n, l)|^2\} = 1$ , Where the length of CIR is  $L$ .

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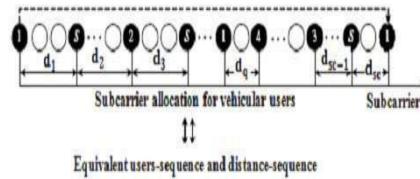


Fig. 3.1 Subcarrier allocation for vehicular users, and corresponding user sequence and distance sequence.

Equivalent users-sequence and distance-sequence:

$$O = (1, S, 2, S, \dots, 1, 4, \dots, 3, S)$$

$$D = (d_1, d_2, \dots, d_3, \dots, d_q, \dots, d_c)$$

Since there are too many possible candidates in user sequence  $O$  as well as in the integer distance sequence  $D = (d_1, d_2, \dots, d_{sc})$ , it is difficult to find an optimum subcarrier allocation. Therefore, we propose a two-stage sub-optimal algorithm: In the first stage, a proper user sequence  $O$  is determined for the SIC detector, and in the second stage, the optimum distance sequence  $D$  of  $d_q$  is computed for a given sequence  $O$ . Because the SIC detector can detect and cancel the interference generated by the faster-moving users prior to the slower ones, it is desirable to design a user sequence such that the faster-moving users have less interference, i.e., the neighbors of a subcarrier allocated to a faster-moving user should be assigned to a slower user. Keeping this fundamental assignment criteria in mind over the entire sequence search, we count the number of remaining subcarriers that are not assigned in the sequence, and choose a faster (or slower) moving user of the maximum number of remaining subcarriers to be allocated. In each step of the first stage, we find all users whose number of remaining subcarriers to be allocated.

## IV. NUMERICAL RESULTS

A practical OFDMA system with following specifications is used for simulation purpose in MATLAB tool.

The numerical specifications/parameters for the OFDMA system is as given below in the table An available 1MHz bandwidth is divided into 128 tones with 32 time samples for CP, where  $N = 126$ , and two edge subcarriers are not used. Specifications used for project as shown in table 4.1. Simulation of many physical processes and engineering applications often require the help of a generator of random binary values.

PARAMETERS	VALUE
Available Bandwidth used	1 MHz
Carrier frequency used	2.4 GHz
Number of subcarriers used(N)	126
Number of uplink users(U)	21
Number of vehicular users(S)	3
Number of sub carriers per user (C)	$C = N/U = 126/21 = 6$
Size of FFT vector	64
Sub carrier Modulation type	16-QAM
Length of CP used(L)	32 samples

Table 4.1: Numerical parameters for the OFDMA system

The MATLAB simulation accepts inputs of binary data. In this work, the random binary data generator generates random binary data 1000100... as shown figure 4.1. The Transmitter binary input data is encoded by convolutional code of rate 1/2 using a 8 polynomial and puncturing the last 1bit per every 4bits.

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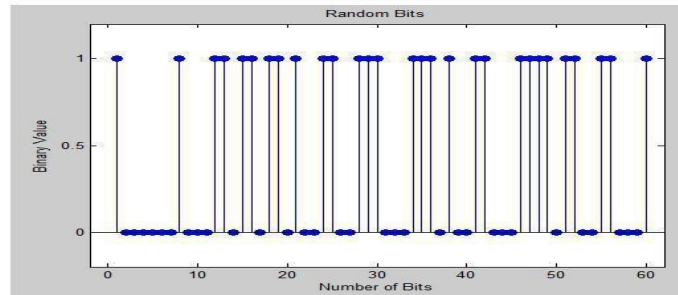


Figure 4.1: Input binary data generation for OFDMA system

The next step is to produce a continuous-time signal. In order to achieve this, a transmit filter-Root rise cosine filter is applied to the complex signal carriers. The figure below shows the generated continuous time signal. The figure 4.2 shows the generated continuous time signal.

In the next step they are transferred in an OFDM link by using a modulation scheme on each subcarrier. The modulation scheme used here is 16-QAM. The modulation scheme is a mapping of data to a real (IN phase) and imaginary (Quadrature) constellation, also known as an IQ constellation.

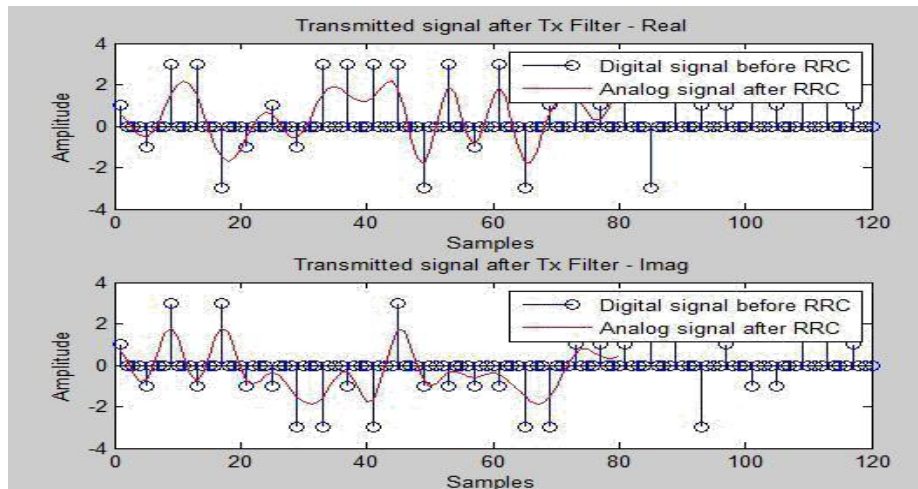


Figure 4.2: Real and imaginary parts of continuous time signal generated by RRC filter

In OFDM an IFFT is used to put the binary numbers onto many frequencies. Due to the math involved in an IFFT, these frequencies do not interfere with each other, (in communication terms, this is called orthogonality). The QAM mapped output obtained with ideal channel as shown in fig 4.3. The eye pattern is created by taking the time domain signal and overlapping the traces for a certain number of symbols. The vertical eye opening or noise margin is related to the SNR and the horizontal eye refers to jitter and sensitivity.

The QAM constellation mapped output without adding noise is simulated and compared with the noise generated AWGN (Additive White Gaussian Noise) channel.

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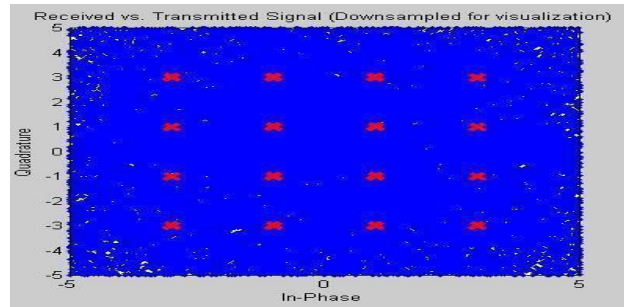


Figure 4.3 QAM mapped output obtained with ideal channel

The QAM constellation mapped output adding noise is simulated as shown in fig 4.4. Once the signal is received, the reverse process is done to recover the original binary data. The constellation demapper takes packets of received constellation points as an input, and outputs data.

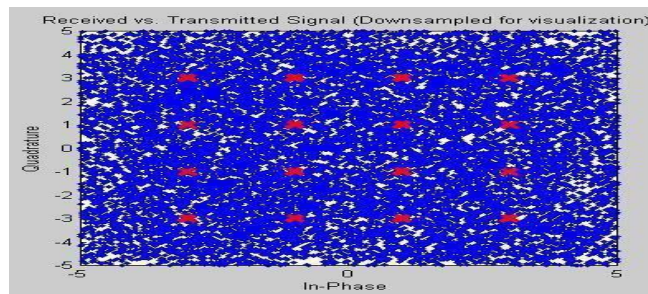


Figure 4.4 QAM mapped output obtained after adding AWGN channel

The average BER performance over all users data is found by simulation of the proposed algorithm.

The bit error rate or bit error ratio (BER) is defined as the ratio of the number of bit errors to the total number of transferred bits during a time interval. In this work, in addition to the proposed subcarrier allocation algorithm, one more method called “interleaved A” is simulated for comparison purpose.

The first allocation method, called “Interleaved A” assigns to user  $v_j$  the subcarriers whose indices are equal to  $(j) U$  where  $(\cdot) U$  is the modulus operator, regardless of the Doppler frequency information. The proposed new sub carrier allocation algorithm takes into effect of normalized Doppler frequencies. The Bit error rate of the two algorithms is compared and the new designed sub carrier allocation algorithm proves to be having less BER than the existing “Interleaved A” algorithm as shown in the figure 4.5.

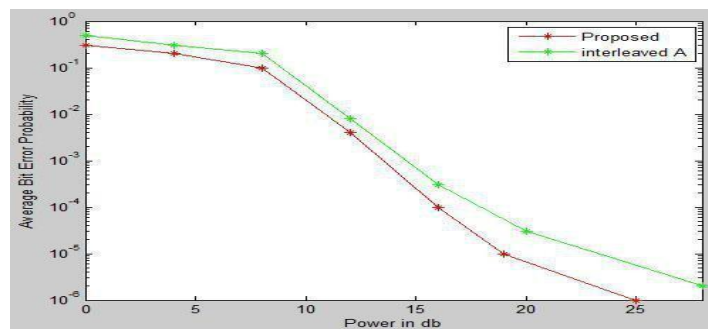


Figure 4.5 Average BER for the “interleaved a” and proposed sub carrier allocation method

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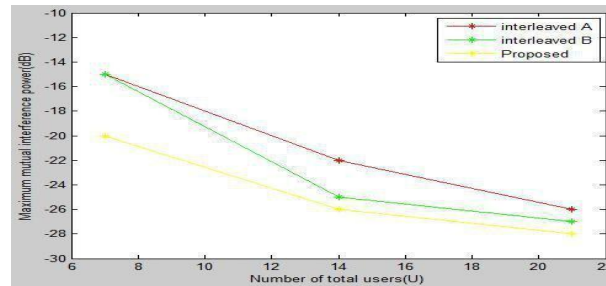


Figure 4.6: MUI simulated for interleaved a and interleaved b and proposed sub carrier allocation.

The MUI plotted below shows the gradual decrease in the power consumed for the various numbers of users having sub carrier allocated. Simulation results show that the proposed subcarrier allocation and “Interleaved A” allocation method has an average Bit error probability of  $10^{-0.5}$  and  $10^{-0.2}$  respectively. Thus Average Bit error probability of around 32% is reduced compared to the “Interleaved A” allocation method. For the accurate analysis, two new allocation algorithm known as “Interleaved A” and “Interleaved B” methods have been simulated and compared with the proposed sub carrier allocation algorithm for the MUI parameter. The simulated graph of MUI expressed in power is db.

In the “Interleaved A” allocation method, since the vehicular users can be assigned to the adjacent subcarriers, MUI does not decrease, regardless of the number of total users  $U=21$ . The second allocation called “Interleaved B,” randomly assigns the first  $U$  number of subcarriers to each user one by one, and this allocation pattern is repeatedly used for the remaining subcarriers, also regardless of the Doppler frequency information. Due to the randomness of the “Interleaved B” allocation method, MUI slightly decreases as shown in the fig 4.6

Number of users(u) per interfering cell	MUI (db)		
	Interleaved A	Interleaved B	Proposed Sub carrier allocation
7	-15	-15	-20
14	-21	-23	-25
21	-25	-26	-27

Table 4.2 Comparison of the results obtained between interleaved allocation method and proposed allocation method for different Users.

Simulation results show that the proposed subcarrier allocation and “Interleaved A” allocation method has an average Bit error probability of  $10^{-0.5}$  and  $10^{-0.2}$  respectively. Thus Average Bit error probability of around 32% is reduced compared to the “Interleaved A” allocation method. Further, simulations also demonstrate a gradual decrease in MUI power from -15db to -20db for interleaved allocation and subcarrier allocation method respectively.

## V CONCLUSION

This paper proposed an effective subcarrier allocation scheme for an uplink-OFDMA system to reduce the effects of ICI and MUI due to Doppler spreads.

Furthermore, it was found through numerical simulations that the proposed method is robust against the inaccurate Doppler-frequency estimation. Therefore, the proposed method can be useful for current and future wireless communication systems that may allow a classification of users into low, medium, and high velocities by counting the number of handovers.

This work can be used as a reference for improving PAPR performance parameter of OFDMA.



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