MC DS-CDMA: Subcarrier-Allocation Technique for Downlink by using WSA-AVG Algorithms

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ABSTRACT
This paper addresses the subcarrier allocation in multicarrier direct sequence code division multiple access (MC DS-CDMA) systems, where one subcarrier is assigned to several users who are distinguished from each other by their unique direct sequence spreading codes. There are some existing algorithms, there advantages and shortcomings in context to MCDS-CDMA systems are discussed in this paper. Firstly the WSA, WCA, WCF and IWE-WSA algorithms are discussed. Furthermore a new algorithm WSA-AVG is proposed. The error performance is investigated and compared and accordingly figure out the results.

Keywords
Multicarrier, DS-CDMA, MC DS-CDMA, OFDMA, Subcarrier allocation, Complexity

1. INTRODUCTION
Due to fast growth of wireless services (cellular telephones, wireless LAN's,) during last decade gives an efficient modulation technique which can consistently transmit data at high rates. Multicarrier (MC) techniques gained considerable attention due to their good bandwidth efficiency and immunity to channel dispersion [1]. Multicarrier can be combined to CDMA technique to support multiple users. Basically Multicarrier Code Division Multiple Access (MC-CDMA) is a combination of OFDM and CDMA techniques. In the MC-CDMA technique firstly the original data stream is multiplied with the spreading sequence and then modulated on the orthogonal carriers. In the MC DS-CDMA technique firstly data is converted from serial to parallel and then multiplied with the spreading sequence and the resulting spectrum of each subcarrier can satisfy the orthogonality condition [2]. "J. Jhang" investigated Greedy algorithm which aims at maximizing the total sum rate of downlinks [3]. After Greedy algorithm Maximum Greedy Algorithm has been proposed by "T. Liu" [4]. This algorithm selects the best or maximum from various implementations of the greedy algorithm. To overcome the shortcomings of fair greedy algorithm WSA algorithm [4] has been proposed for subcarrier allocation in the downlink for the

OFDMA and FDMA system. WSA was designed so that subcarriers having worst channel qualities can be avoided. WSA has better performance than greedy algorithm. None the algorithm has low value of SNR as compared to greedy algorithm. WSA also improves worst channel quality than greedy algorithm .In this paper firstly there are some existing algorithms like WSA, WCA, WCF, and IWE-WSA that are discussed. Then a new algorithm is proposed.

The rest of the paper is organized as follows. Section 2 explains the system model and some main assumptions. Section 3 explains some existing subcarrier-allocation algorithms and details the proposed algorithms and the IWE scheme. Section 4 provides the BER results and Section 5 provides the conclusions.

2. SYSTEM MODEL
In this paper there are some assumptions for MC DS-CDMA system in which there is one base stations and k mobile users. In this there is one antenna for transmission and receiving. Symbols that are used in this paper are as follows:

K Number of mobile users;

κ Set of user indexes, defined as $\kappa = \{0,1,...,K-1\}$;

N Spreading factor of DS spreading;

M Number of subcarriers of MC DS-CDMA systems;

m Set of subcarrier indexes, defined as $m = \{0,1,...,M-1\}$;

C.G Channel gain of subcarrier j of user k;

F_j Set of indexes for up to N users assigned to subcarrier j;

|F| Cardinality of the set F, representing the number of elements in set F;

P (k) Transmission power for user k;

P Total transmission power of BS, $P = \sum_{k\in K} P(k)$;

C.Q Channel quality of subcarrier j of user k, $C.Q = (C.G)^2/(2\sigma^2)$, where $\sigma^2 = 1/(2\alpha)$ denotes the single-dimensional noise power at a mobile user and α denotes the average signal-to-noise ratio (SNR) per symbol.

In this paper there is assumption that one spreading code is assigned to one subcarrier and there can be possible N users sharing one subcarrier. In this TDD mode is used to operate the uplinks and downlinks. So therefore, uplink and downlink channels are assumed to be reciprocal. In this SNR is $\alpha(k)=P(k)[C.G]^2$ $\alpha=P(k)(C.Q)$ .Clearly, the error rate is low when allocating user k a subcarrier which has higher channel quality it attains higher SNR [10]. In this, only subcarrier allocation is used instead of code-allocation. Second, there exists a trade-off between the number of subcarriers M and the spreading factor N, which determines the bandwidth of subcarriers when total bandwidth of the system is given. In a MC DS-CDMA system some subcarriers experiences flat fading, while other experiences relatively independent fading. According to [12], power and subcarrier-allocation can be carried out separately. Under this power- allocation strategy, user k is allocated the power

$$P(k) = P\left(\sum_{l=1} A_l^{-1}\right)^{-1}(C.Q)^{-1},\ k \in \kappa \qquad (1)$$

Where, C.Q represents the channel quality of the subcarrier assigned to user k. After the power-allocation, it can be shown that the SNR of user k is

$$\alpha(k) = P\left(\sum_{l\in\kappa} A_l^{-1}\right)^{-1},\ k \in \kappa \qquad (2)$$

This is independent of the index k because of that all the users attain the same SNR and, hence, they also have the same error probability. From above equation it is observed that, in order to maximize the SNR, the subcarrier-allocation algorithms should be designed to maximize $\left(\sum_{l\in\kappa} A_l^{-1}\right)^{-1}$, yielding the optimization problem

$$\cup \{F_j\}^{*} = \arg\max \left\{\left(\sum_{l\in\kappa} A_l^{-1}\right)^{-1}\right\}, \text{s.t. } \cup_{j\in M} F_j = \kappa,$$

$$F_j \cap F_l = \emptyset \text{ for } j \neq l \qquad (3)$$

Where 's.t' stands for 'subject to', $\cup \{F_j\}^{*}$ represents subcarrier allocation for all the users. To solve the above optimization problem, exhaustive search may be carried out which states that, when the number of subcarriers and the number of users are relatively high it prevents the algorithm from practical implementations and have high complexity [10].In order to minimize the complexity, focus is on suboptimum algorithms, which maximize the SNR by maximizing the worst channel qualities. According to study in [8] optimization problem can be stated as

$$\cup \{F_j\}^{*} = \arg\max \{\min (A_l)\}, \text{ s.t. } \cup_{j\in M} F_j = \kappa,\ F_j \cap F_l = \emptyset$$

$$\text{for } j \neq l. \qquad (4)$$

Above equation (4) was designed to solve optimization problem for WSA in [8].Our studies shows that our subcarrier allocation algorithm has better error performance than WSA, WCA, WCF and IWE-WSA.

3. SUBCARRIER ALLOCATION ALGORITHMS

In this section firstly the existing algorithms like WSA, WCA, WCF and then iterative scheme of WSA is discussed. Furthermore a new technique is proposed and then compared with the existing techniques. In this, an example is introduced which uses M=4 subcarriers to support K=8 each mobile users and which can be differentiated by their spreading codes of length N=2.

Table I

U \ S	U0	U1	U2	U3	U4	U5	U6	U7
S0	191.5	254.1	259.8	17.4	121.7	258.8	81.6	175.6
S1	71.3	103.2	26.7	241.8	257.7	427.2	544.3	108.8
S2	21.0	83.7	232.1	44.6	46.7	179.7	127.7	33.3
S3	109.3	260.3	234.6	130.9	165.3	25.1	61.6	1.02

Channel Quality Matrix for K=8 users and M=4 Subcarriers

3.1 Worst Subcarrier Avoiding Algorithm

WSA is designed so that subcarriers having worst channel qualities can be avoided [5].This is explained with the help of above Table I.

Firstly find the worst channel qualities for each subcarrier. Worst channel quality for subcarrier 1 is $A_0^{(min)}$=17.4, for subcarrier 2 is $A_1^{(min)}$=26.7,for subcarrier 3 is $A_2^{(min)}$=21.0,for subcarrier 4 is $A_3^{(min)}$=1.02. Then arrange the subcarrier according to the ascending order {3,0,1,2} and worst channel qualities are represented by bold faces. Now according to the above formed matrix allocate the subcarrier to the users. Subcarriers are assigned to the users from first row to last row and allocation results are as follows F(0)={0,5}, F(1)={3,7}, F(2)={4,6}and F(3)={1,2} and are represented as underlined numbers in(5).Then calculate the SNR by using the formula $\alpha=(\sum_{k\epsilon Fj} C.Q)^{-1}$=16.74.Furthermore,find the minimum worst channel quality from the allocated subcarriers is $\min_{k\epsilon\{Fj\}}\{C.Q\}$ =46.7.

$$\begin{pmatrix} & U0 & U1 & U2 & U3 & U4 & U5 & U6 & U7 \\ S3 & 109.3 & \underline{260.3} & \underline{234.6} & 130.9 & 165.3 & 25.1 & 61.6 & \mathbf{1.02} \\ S0 & \underline{191.5} & 254.1 & 259.8 & \mathbf{17.4} & 121.7 & \underline{258.8} & 81.6 & 175.6 \\ S2 & \mathbf{21.0} & 83.7 & 232.1 & 44.6 & \underline{46.7} & 179.7 & \underline{127.8} & 33.3 \\ S1 & 71.3 & 103.2 & \mathbf{26.7} & \underline{241.8} & 257.7 & 427.7 & 544.3 & 108.8 \end{pmatrix} \qquad (5)$$

3.2 Worst Case Avoiding Algorithm

WSA algorithm is a subcarrier oriented algorithm which avoids the assigning the (M-1) worst channels from a total of M subcarriers. When no of users are more than the subcarriers than use the user oriented mode for allocation of subcarriers to achieve better error performance and avoid assigning more of the worst channels [10]. In WCA as many as possible worst channels can be avoided. WCA is a user oriented mode not a Subcarrier oriented mode like WSA.

$$\begin{pmatrix} & U7 & U3 & U0 & U5 & U2 & U4 & U6 & U1 \\ S0 & \underline{175.6} & \mathbf{17.4} & \underline{191.5} & 258.8 & 259.8 & 121.7 & 81.6 & 254.1 \\ S1 & 108.8 & \underline{241.8} & 71.3 & \underline{427.2} & \mathbf{26.7} & 257.7 & 544.3 & 103.2 \\ S2 & 33.3 & 44.6 & \mathbf{21.0} & 179.7 & 232.1 & \mathbf{46.7} & \underline{127.8} & \mathbf{83.7} \\ S3 & \mathbf{1.02} & 130.9 & 109.3 & \mathbf{25.1} & 234.6 & 165.3 & \mathbf{61.6} & 260.3 \end{pmatrix} \qquad (6)$$

In this firstly arrange the users in ascending order according to their minimum worst channel qualities{7,3,0,5,2,4,6,1} and in the matrix they are denoted by bold faces .According to new matrix(6) subcarrier allocation is carried out and the allocation results are as follows F(0)={7,0},F(1)={3,5}, F(2)={6,1}, F(3)={2,4}, represented by the underlined numbers in(6).Then calculate the SNR by using the formula $\alpha=(\sum_{k\epsilon Fj} C.Q)^{-1}$=21.06. Furthermore, find the minimum worst channel quality from the allocated subcarriers by using formula $\min_{k\epsilon\{Fj\}}\{C.Q\}$ =83.70.

Straightforwardly, the WCA algorithm has better results in comparison to the WSA algorithm. The worst channel quality and SNR are improved as compared with the WSA algorithm.

3.3 Worst Case First Algorithm

According to the WCA algorithm user 2 is allocated at the fifth stage as its worst channel quality is A(2,1)=26.7. But from the above matrix (6) it is observed that subcarrier 0 and 1 cannot be allocated to user 2 as they are already allocated to other users. Now in the case of user 2 worst channel quality becomes A(2,2)=232.1,which is much larger than the users 4,6,1.So in order to increase the system reliability allocate user 4,6,1 before user 2.

According to WCF, reorder the users according to the worst channel qualities. During each stage, the algorithm first finds the worst channel quality of the unassigned users among only the subcarriers available for allocation, rather than finding the worst channel quality of the unassigned users among all the subcarriers as done by WCA algorithm [15].Then find the minimum channel quality for each user and are shown by boldfaces in the matrix (7).

After this start the allocation according to user oriented mode. Find the best channel quality among the user and start allocating them. For subcarrier 0 and 1 allocation is as follows F(0)={7,0},F(1)={3,5}.But after this as in the matrix(6) the minimum channel quality of user 2 is higher than user 4,6,1 so rearrange them according to the minimum channel quality.

	U7	U3	U0	U5	U4	U6	U1	U2
S0	175.6	**17.4**	191.5	258.8	121.7	81.6	254.1	259.8
S1	108.8	241.8	71.3	427.2	257.7	544.3	103.2	26.7
S2	33.3	44.6	**21.0**	179.7	**46.7**	127.8	**83.7**	**232.1**
S3	**1.02**	130.9	109.3	**25.1**	165.3	**61.6**	260.3	234.6

(7)

Then start the allocation for the remaining users according to the user oriented mode. Now according to new arrangement after user 5 there are user 4,6,1,2.Allocation results of 2 and 3 is F(2)={6,2}and F(3)={4,1}. SNR of the system is α= 25.37 and minimum worst channel quality of the allocated subcarriers is min $_{k\epsilon\{Fj\}}$ {C.Q} =127.8. WCF algorithm yields highest SNR and also worst channel quality in comparison to WCA and WSA algorithm. WCF algorithm provides more trustworthy and resourceful way of subcarrier allocation and it also has all the advantages of WCA algorithm.

3.4 Iterative Worst Excluding Algorithm

IWE (Iterative Worst Excluding) algorithm is used to achieve an improved BER performance by iteratively updating the channel quality matrix [15].In this process it removes the worst channel qualities of the subcarriers or the users before the allocation. For convenience the main steps of IWE is explained in the flow chart (1).In detail, during the first step of the algorithm apply the chosen algorithm and carry out the subcarrier allocation during the first iteration. After initialization carry out the second iteration and in that WE process is carried out. According to this process worst channel qualities are excluded. Then it checks the mentioned conditions and if it satisfies the condition then carry out the subcarrier allocation.

Otherwise algorithm stops and result of previous iteration is taken as the final result. If next iteration is carried out then its results are compared to the previous iteration against the performance matrix. If the performance improves then next iteration is carried out otherwise IWE algorithm stops and allocation result of the previous iteration is taken as the final results. SNR =16.74.In second iteration remove the worst channel qualities of the subcarriers.

Second iteration is showed in (8) where "-----"stands for worst channel qualities of the users which are removed before subcarrier allocation. As observed in (8) that every subcarrier have six users to allocate and check the conditions. In order to fulfill the allocation two conditions have to be met.

Condition (a): The number of candidate users of each subcarrier exceeds, K/M, of the no of users to be assigned to one subcarrier.

Condition (b): Each subcarrier can only be assigned to K/M different users and each user is only assigned one subcarrier.

	U0	U1	U2	U3	U4	U5	U6	U7
S3	109.3	260.3	234.6	130.9	165.3	**25.1**	61.6	------
S0	191.5	254.1	259.8	------	121.7	258.8	**81.6**	175.6
S2	------	83.7	232.1	44.6	46.7	179.7	127.8	**33.3**
S1	**71.3**	103.2	------	241.8	257.7	427.7	544.3	108.8

(8)

As observed in the given example it satisfies the conditions. Thus it guarantees that each subcarrier can be allocated to two different users and each user attains one subcarrier. So further precede the process and start the subcarrier allocation. Then find the worst channel qualities and they represented by bold faces in (8).Allocation results are as follows F(0)={0,5},F(1)={3,7},F(2)={4,6},F(3)={1,2} Then find SNR and achievable SNR is α= 24.93 and minimum worst channel quality of the allocated subcarrier is 25.1.

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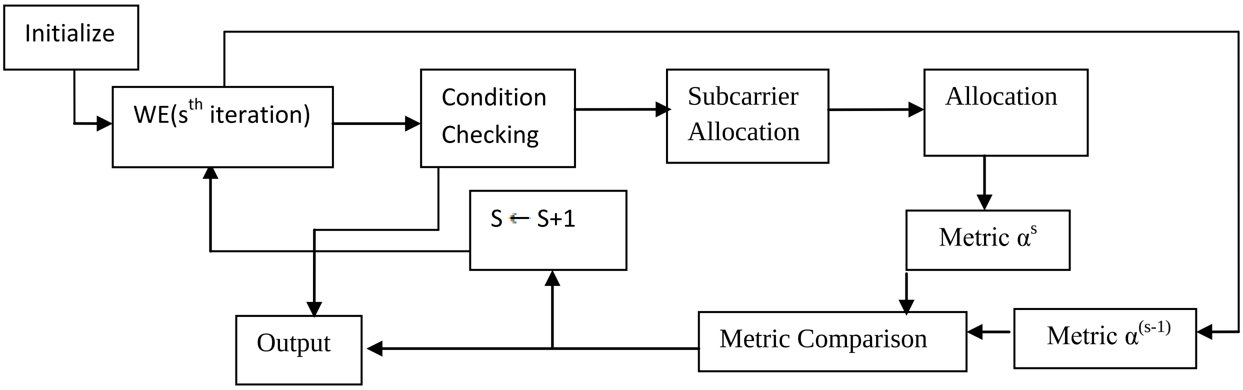

Fig 1: Flow Chart showing the steps of IWE Algorithm

As SNR for 2nd iteration is greater than 1st so now repeat the process of iteration.

	U0	U1	U2	U3	U4	U5	U6	U7
S3	109.3	260.3	234.6	130.9	165.3	-----	**61.6**	------
S2	------	83.7	232.1	**44.6**	46.7	179.7	127.8	------
S1	------	**103.2**	------	241.8	257.7	427.7	544.3	108.8
S0	191.5	254.1	259.8	------	**121.7**	258.8	------	175.6

(9)

Now, firstly rearrange the subcarriers according to the minimum value and the exclude the worst subcarriers. Then start the allocation. Allocation results are as follows F(0)={0,7}, F(1)={3,4}, F(2)={5,6}, F(3)={1,2}.Then find SNR and achievable SNR is α=25 and minimum worst channel quality of allocated subcarriers is min $_{k\epsilon\{Fj\}}$\{C.Q\}=44.6.As SNR for 3rd iteration is greater than previous so now can repeat the process of iteration.

	U0	U1	U2	U3	U4	U5	U6	U7
S2	------	83.7	232.1	**44.6**	46.7	179.7	127.8	------
S3	109.3	260.3	234.6	130.9	165.3	-----	**61.6**	------
S1	------	**103.2**	------	241.8	257.7	427.7	544.3	108.8
S0	191.5	254.1	259.8	------	**121.7**	258.8	------	175.6

(10)

Now, firstly rearrange the subcarriers according to the minimum value and the exclude the worst subcarriers. Then start the allocation. Allocation results are as follows F(0)={0,7}, F(1)={3,6}, F(2)={2,3}, F(3)={1,4}.Then find SNR and achievable SNR is 27.54 and minimum worst channel quality of the allocated subcarriers is min $_{k\epsilon\{Fj\}}$\{C.Q\}=44.6.

As SNR for 4th iteration is greater than previous so now repeat the process of iteration. Again repeat the process of rearranging the subcarriers according to the minimum value and then exclude the worst subcarriers and start the subcarrier allocation. Allocation results are as follows F(0)={0,7}, F(1)={4,6}, F(2)={2,5}, F(3)={1,3}.Then find SNR and achievable SNR is 26.59 and min value is min $_{k\epsilon\{Fj\}}$\{C.Q\}=46.7. As the value of SNR of 5th iteration is smaller than the 4th iteration so it doesn't satisfy the condition (a) algorithm hence stops. Hence a result obtained from the last iteration is taken as the final result.

	U0	U1	U2	U3	U4	U5	U6	U7
S2	------	83.7	232.1	------	**46.7**	179.7	127.8	------
S1	------	------	------	241.8	257.7	427.7	544.3	**108.8**
S3	**109.3**	260.3	234.6	130.9	165.3	-----	------	------
S0	191.5	254.1	259.8	------	------	258.8	------	**175.6**

(11)

IWE algorithm has advantages in the sense of improving the error performance in comparison to the other allocation algorithms. IWE algorithms use less number of iterations, which ensures a low complexity for implementation.

3.5 Worst Subcarrier Allocation Average Algorithm

All the Algorithms that are discussed above they are based on the minimum worst channel qualities. This work on subcarrier oriented mode as WSA algorithm works. To achieve a better error performance the subcarrier-allocation is carried by mean of worst channel quality not the minimum worst channel quality. In this firstly find the mean of the each subcarrier. Then arrange the subcarrier according to the ascending order {2, 3, 0, 1}.

	U0	U1	U2	U3	U4	U5	U6	U7
S2	21.0	83.7	232.1	44.6	46.7	179.7	127.8	33.3
S3	109.3	260.3	234.6	130.9	165.3	25.1	61.6	1.02
S0	191.5	254.1	259.8	17.4	121.7	258.8	81.6	175.6
S1	71.3	103.2	26.7	241.8	257.7	427.7	544.3	108.8

(12)

According to new matrix (12) subcarrier allocation is carried out. Consequently, the allocation results are F(0)={2,7} ,F(1)={6,3} ,F(2)={2,5} ,F(3)={1,4}, corresponding to the underlined numbers in (12).Then calculate the SNR by using the formula $\alpha=(\sum_{k\epsilon Fj} C.Q)^{-1}$ = 27.2. Furthermore, find the minimum worst channel quality of the allocated subcarriers is min $_{k\epsilon\{Fj\}}$\{C.Q\} =165.3.

Straightforwardly, the proposed WSA-AVG algorithm is capable of achieving better allocation results than the above explained algorithms. For the considered example SNR is improved in comparison to that of other algorithms. It provides a reliable and efficient way of subcarrier allocation.

4. PERFORMANCE RESULTS

In this section, there is wide range of simulation results are considered in order to demonstrate and compare the error performance of MC DS-CDMA system by employing the proposed and the other subcarrier allocation algorithms. In this there is assumption of the quadrature phase-shift keying (QPSK) baseband modulation and all subcarriers experience independent flat Rayleigh fading. In this number of users supported are K=MN where M is the number of subcarriers and N is the length of spreading codes.

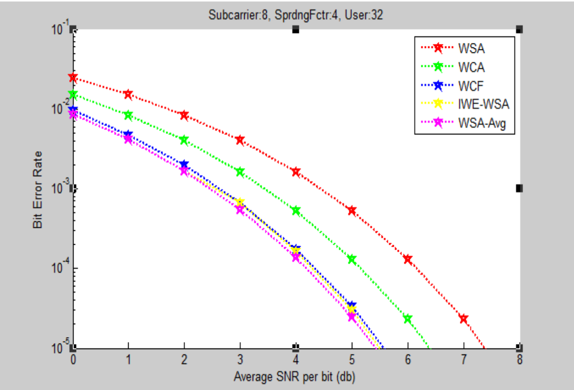

Fig 2. BER comparison of the downlink MC DS-CDMA systems employing various subcarrier-allocation algorithms

Fig 2 demonstrates the BER performance of the MC DS-CDMA system employing several of subcarrier-allocation algorithms, when K =32 users are supported by M =8 subcarriers. Hence, each subcarrier supports 2 users. According to the above graph WSA algorithm has a worst error performance as compared to the other algorithms. WCA and WCF have a better error performance as compared to WSA.As discussed in the section II WSA algorithm assigns the subcarriers according to the subcarrier oriented mode. Hence, its performance depends on the frequency-selective diversity. In this case, the WCA and WCF algorithms avoid the worst channel qualities in a user-oriented mode and achieve much higher diversity than the WSA scheme [10].WSA, WCA, WCF, and IWE-WSA algorithms are based on minimum value. But as observed from the above graph that the proposed algorithms gives the better performance as compared to the other algorithms.

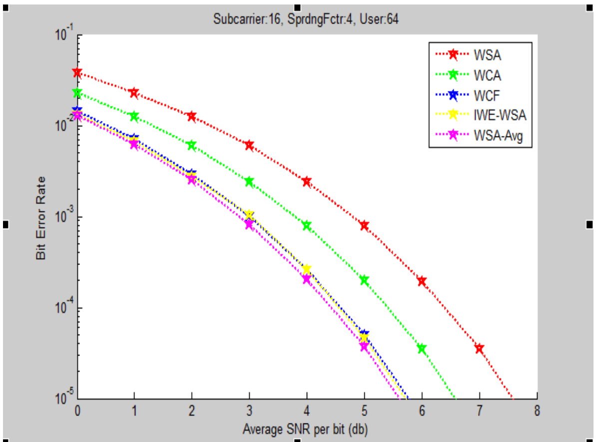

Fig 3. BER comparison of the downlink MC DS-CDMA systems employing various subcarrier-allocation algorithms

Fig 3 demonstrates the BER performance of the MC DS-CDMA system employing various subcarrier-allocation algorithms, when K =64 users are supported by M =16 subcarriers. Hence, each subcarrier supports 4 users. From the figure, it is observed that both the proposed algorithms give the better performance as compared to the other algorithms. In proposed algorithm there is change in the concept of declaring the subcarrier as weakest and introduced the concept of average of channel qualities and on the basis of these average decide the order of subcarriers which will allocate first subcarrier having overall weak users and give best results than existing algorithms.

5. CONCLUSION

In this paper range of algorithms are discussed and a new algorithm is proposed and there is comparison of the algorithms on the basis of error performance. WSA algorithm is beneficial to the systems with subcarriers more than users. Further analyze other algorithm WCA and WCF. They have better error performance as compared to WSA. They are capable of further improving the reliability of MC-DS-CDMA systems. In the proposed algorithm change the concept of declaring this subcarrier as weakest and introduced the concept of average of channel qualities and on the basis of these average decide the order of subcarriers which will allocate first subcarrier having overall weak users and give best results than existing algorithms. In proposed algorithm WSA-AVG gives better error performance in comparison to the other algorithms. In this research a novel technique is proposed using the concept of averaging the channel qualities which improves the BER than the existing techniques. In future further the work can be executed or tried to build hybrid method of these existing techniques in combination with optimization techniques to search best result in the search space of these evolutionary algorithms and to allocate best sub carriers to the users to further reduce the BER. Also various power allocation techniques can be applied and reduction of Peak to Average Power (PAPR) can be achieved.

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