Non Contiguous spectrum allocation in MC-CDMA systems for improving throughput

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Abstract — In this paper performance evaluation of non contiguous spectrum allocation technique i.e. adaptive sub channel grouping scheme (ASG) is carried out. In ASG technique non contiguous frequency bands forms groups for MC-CDMA systems in downlink transmission. In this scheme channels are allocated to the users according to the CSI obtained and number of channels allocated to one user forms one group. Autoregressive model is used for Rayleigh fading channel. Performance of ASG is evaluated for the test environment considering future Long Term Evolution (LTE) advanced standard, the 3GPP candidate for 4G. ASG scheme performance is compared with Improved scheme and Adaptive channel allocation (ACA) scheme. Simulations are carried out for three equalization schemes. It is found that the ASG scheme employing non contiguous spectrum allocation can significantly improve the system throughput as compared to contiguous schemes of group formation. BER performance of ASG scheme shows significant improvement over the other two schemes.

Index Terms — SCS, MC-CDMA, SNR, BER, ACA, CSI, LTE

I. INTRODUCTION

The 4G systems are characterized by high transmission data rates, 100Mbps and above, so wide bandwidth transmission is expected. A 4G system provides mobile ultra-broadband Internet access, for example to laptops with USB wireless modems, to smart phones, and to other mobile devices. The most important objectives in the design of 4G wireless systems are to address the severe inter symbol interference (ISI) resulting from the high data rates, and to utilize the available bandwidth in spectrally efficient manner.

Two 4G candidate systems are commercially deployed: The Mobile WiMAX standard (at first in South Korea in 2006), and the first-release Long term evolution (LTE) standard (in Scandinavia since 2009). The next development for the 4G technology is named as IMT Advanced. In Release 10, Long Term Evolution (LTE) advanced was standardized by 3GPP as the successor of the Universal Mobile Telecommunication System (UMTS) and LTE. The targets for downlink and uplink peak data rate requirements were set to 1Gbit/s and 500Mbit/s respectively, when operating in a 100 MHz spectrum allocation. Also the target for downlink and uplink peak spectrum efficiency requirements was set to 30 bps/Hz and 15 bps/Hz.

To support the time varying QoS in multiuser environment for 4G systems multicarrier CDMA (MC-CDMA) is the strong candidate. Fourth generation wireless communication demands a multiple access technique for reducing the multiple access interference (MAI) and intersymbol interference (ISI) and to improve the bit error rate performance. MC-CDMA technology offers resistance to multi-path fading and high spectral efficiency. MC-CDMA is a fusion of two techniques, the first is orthogonal frequency division multiplexing (OFDM), which addresses the intersymbol interference problem arising in channels. The second one is CDMA which maintains a orthogonality among the users to eliminate MAI. Block diagram of MC-CDMA system is shown in “Fig.1”.

Efficient resource allocation is the major issue in the development of fourth generation mobile communication systems. Out of the available resources spectrum allocation is the main issue in the performance of wireless networks. MC-CDMA systems have lots of sub-carriers. There are many techniques of allocation of these sub carriers to the users. Instead of allocating all subcarriers to all users, these subcarriers may be divided into groups and then each group can be assigned to the users. Channel fading is different at different sub carriers, this feature can be exploited for allocating the subcarriers to the users according to the instantaneous channel state information (CSI).
An appropriate sub-carrier selection technique results in high spectrum efficiency, reduction in high power consumption at the mobile terminal, high data throughput in a multicell environment, improvement in BER performance, reduction in signal processing at the mobile terminal.

For the given power, throughput can be maximized by allocating maximum number of subcarriers to the users.

In Ref. [1] Jun-Bo Wang, Ming Chen, Jiangzhou Wang proposed an Adaptive Channel Allocation (ACA) algorithm for maximizing throughput in which the subchannels are divided into groups, and these groups are allocated to the users depending on required transmit power. This is a contiguous channel allocation scheme in which channel fading feature is not fully exploited. The SCS-MC-CDMA system assigns to each user a selected number of subcarriers [2]. The concept of sub-carrier selection is introduced to counter the problem of high power consumption. In this paper the concept is to assign each user only as many sub-carriers as are needed to support the user’s data rate. In this method the system complexity increases when more number of filters are required for subcarrier selection.

In Ref. [3] Qingxin Chen, Elvino S. Sousa and Subbarayan pasupathy proposed a Water-filling algorithm, it was motivated by the water-filling (WF) principle in information theory, it improves the speed and average SINR of the system. One drawback lie in the case where one user’s fading amplitudes are much larger than the average. G.K.D. Prasanna Venkatesan, and C. Ravichandran, has suggested a dynamic sub-carrier allocation technique for adaptive modulation based MC-CDMA system in Ref. [4] which results in improvement in throughput and BER performance. In this paper water filling algorithm is used to select the best sub-carrier, over the existing subcarriers. The principle of adaptive modulation consists of allocating many bits to carriers with a high SNR, whereas on carriers with low SNR only a few or no bits at all are transmitted. However there will be a possibility that when many channels suffer deep fading, there will be no transmission or very few bits are transmitted.

If subcarrier selections techniques are combined with adaptive modulation techniques further improvement in data rate is resulted as discussed by S. Chatterjee, W.A.C. Fernando and M.K. Wasantha in Ref. [5]. In Ref. [5] modulation scheme changes with change in number of users satisfying the BER requirement. In Ref. [6] Tallal El Shabrawy and Tho Le-Ngoc, has proposed a subcarrier group assignment for MC-CDMA wireless networks resulting in high throughput. In this paper, two interference-based subcarrier group assignment strategies are introduced for multicell MC-CDMA systems. In least interfered group assignment (LIGA), users are assigned to groups experiencing minimum interference. In best channel ratio group assignment (BCRGA), the user is assigned to the subcarrier group that holds the best ratio of channel response-to-received interference. In Ref. [7] the random policy has been described. This random policy is to allocate the subcarrier randomly regardless of channel information, which is concluded in Ref. [7] to be the best algorithm to get better BER performance. However the increase in system throughput with increase in SNR is less as compared to other advanced systems of sub carrier allocation.

By dynamically allocating subcarriers and adaptive slot management the system can meet the large dynamic resource requirements of a real-time multimedia application in Internet [8]. In this scheme the selection of subcarriers is carried out based on it’s current SNR to support a minimum BER. In this technique, the effect of asymmetric slot management strategy employing adaptive resource allocation in a MC-CDMA system is studied, in which each cell has its own slot allocation policy according to the level of traffic load.

A dynamic sub channel and power allocation algorithm for MC-CDMA system is proposed in Ref. [9]. In this scheme, data is transmitted over the user’s best subcarrier and power control is applied for the selected subcarrier, rather than transmitted over all the subcarriers. The subcarrier that has the maximum receiving power will be the best subcarrier for that user.

First time Adaptive Subcarrier Grouping was proposed by Jun-Bo Wang in Ref. [10] in 2010. It was for downlink MC-CDMA systems with MMSE receiver, this scheme is efficient in computational time and it outperforms the
conventional static schemes in terms of system capacity. In this scheme subcarriers per group are same. System model in [10] was presented for single user only. For more than one user same scheme is not applicable. In the ACA algorithm as discussed by Jun-Bo Wang [1] as well as in the improved algorithm proposed in Ref. [15] neighboring channels forms successive groups.

NETS2020 presented in Ref. [19] in june 2012 is a joint project between the University of Oulu and Aalto University, and the research is carried out to enable smooth application of the technology in evolving standards including IMT-Advanced (IMT-A). The research focuses on distributed algorithms performing radio resource allocation. This work in Ref. [11] includes Distributed Downlink Resource Allocation in Multicarrier Small Cell Networks, objective is to optimize power allocation per carrier and orthogonal allocation of sub-carriers to users served in downlink. In this scheme of resource allocation, each base station exchanges interference prices on each carrier with its neighboring base stations and Each Base Station updates its power and scheduling weights (per carrier), based on reported interference prices and known channel gains.

This research work also includes Interference Management in LTE-A Het-Nets, objective is to allocate spectrum resources dynamically to obtain better performance results when compared to traditional spectrum allocation approaches.

The rest of the paper commences with section II in which throughput maximization problem is discussed in detail. In section III ASG scheme is presented, proposed in Ref. [14]].In IV performance of ASG scheme is evaluated for three combining schemes. Also the ASG scheme response for BER variation and spreading factor variation is analyzed in the same section. In V future work to be carried out is suggested in which adaptive modulation with adaptive subchannel grouping is discussed for improving spectrum efficiency.

II. PROBLEM DEFINITION

In 4G systems to make optimum use of the resources i.e. channels and transmit power to maximize the throughput is a major problem. In the downlink transmission of multiuser MC-CDMA system for the given transmit power at the base station, maximum possible number of channels should be allocated to the users to maximize throughput maintaining low BER.

The available subcarriers are first converted in to groups and then these groups are allocated to the users. In order to maximize the system capacity, all channels of one group are allocated to only one user and the available transmit power is equally distributed over all channels within the group. These groups may be formed by means of contiguous or non contiguous subcarrier grouping. If the required amount of transmit power of one subcarrier of every group has been determined for all users before the group allocation, then throughput maximization problem is given by a following optimization of $c_g^u$ problem “(1)”, as given in Ref. [1].

$$\max \sum_{u=1}^U \sum_{g=1}^G c_g^u$$

Where

$\sum_{u=1}^U \sum_{g=1}^G c_g^u \leq 1$, $\forall u, g$  

(1.a)

$$\sum_{u=1}^U \sum_{g=1}^G c_g^u \leq p_{T}^{\max}$$

(1.b)

$$c_g^u \in \{0,1,\ldots,S\}, \forall u,g$$  

(1.c)

Where

$S$ – Total number of subcarriers in $g^{th}$ group.

Above “(1.b)” is the total transmit power constraint.

where

$p_{T}^{\max}$, - The maximum transmit power, and
The required transmit power for the $u^{th}$ user on one channel of the $g$th group, it is expressed as,

$$p_g^u = \sum_{s=1}^{S} (\beta N_0 S^{-2} \sum_{s=1}^{S} |\omega_{g,s}^u|^2 \sum_{s=1}^{S} |\omega_{g,s}^u f_{g,s}^u|^2)^{-1}$$

where

\(\beta\) - Target threshold of SNR, calculated as using following relation in “(3)”,

$$\text{BER}_i = \frac{1}{5} \times \exp \left[ \frac{-1.5 \times \beta}{M-1} \right]$$

\(\text{BER}_i\) - Bit error rate of $i^{th}$ subcarrier

$M = 4$, as modulation scheme used is QPSK.

$f_{g,s}^u$ - $u^{th}$ user’s channel fading (path gain) on the $s^{th}$ subcarrier of the desired group

$\omega_{g,s}^u$ - $u^{th}$ user’s frequency domain combining weight for the signal on the $s^{th}$ subcarrier of the desired group.

Therefore the problem of efficient resource allocation for throughput maximization can be put forward as, every user experiences different fading on different channels and consequently user requires different transmit power on different channels. For the given system we have to form groups of subcarriers and then these groups are allocated to the users according to the transmit power requirement.

Different combining schemes will result in different power allocation, accordingly required transmit power ($p_m^k$) will change as per Table I, Ref. [1]. Therefore throughput will be different for different combining schemes.

<table>
<thead>
<tr>
<th>Combining Schemes</th>
<th>$p_g^u$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRC</td>
<td>$\sum_{s=1}^{S} (\beta N_0 S^{-2} \sum_{s=1}^{S}</td>
</tr>
<tr>
<td>EGC</td>
<td>$\sum_{s=1}^{S} (\beta N_0 S^{-1} \sum_{s=1}^{S}</td>
</tr>
<tr>
<td>ZFC</td>
<td>$\sum_{s=1}^{S} (\beta N_0 S^{-1} \sum_{s=1}^{S}</td>
</tr>
</tbody>
</table>

III. ADAPTIVE SUBCHANNEL GROUPING (ASG) ALGORITHM

A non contiguous spectrum allocation technique is proposed in [14] for the channel allocation in the downlink transmission of multi-user MC-CDMA systems, under the constraints that the total transmit power should not exceed the maximum transmit power and each channel’s SNR should not be less than a pre-defined value. This scheme proposes a totally new technique of subcarrier group formation in accordance with the instantaneous CSI for the MC-CDMA systems in the downlink transmission for throughput improvement. In this scheme the subcarriers in each group are not fixed and can be changed as the wireless channel changes. Also channels in one group are not neighboring frequency bands and the number of channels per group is not equal.

Each user experiences different fading on different channel. This feature has been exploited for forming the subcarrier groups. The channel groups are formed according to the channel gain ‘$f$’, therefore the required transmit power
decreases and more number of channels get allocated for the given transmit power at the base station, resulting in improved throughput.

"Fig.2" shows that the total number of subcarriers are ‘N’ i.e. the given bandwidth has been divided into N number of channels. These ‘N’ number of channels will get divided into ‘G’ number of groups in accordance with the channel fading ‘f’ experienced by a user on a particular channel. Now starting from the first channel every channel will scan all the users and whichever user experiences minimum fading on that channel, will be assigned that channel. In this way all the channels will get assigned to the users randomly. At last the total number of channels assigned to one user will form one group. Therefore number of groups will be always equal to the number of users.

The steps in proposed ASG scheme are given below, assuming the instantaneous CSI is available at the base station,

**Step 1:** Start from the first channel, it will scan all the users and user experiencing minimum fading on it, will be allotted that first channel.

**Step 2:** Next second channel will scan again all the users and user experiencing minimum fading on it, will be allotted that second channel.

**Initialization**

\[ P_R = P_{\text{max}} \]

\( C = \{1, 2, ..., G\}, c_g^u = 0 \text{ for } \]

\( u = 1, ..., U \text{ and } g = 1, ..., G. \)

**Adaptive group formation**

For \( c = 1 \ldots \ldots N \)

\[ g_u = \max_{1 \leq s \leq U} \{f_u^s\} \]

End

\( N \) - Total no. of subcarriers

\( f_u^c \) - \( u^{th} \) user’s channel fading (path gain) on the \( c^{th} \) subcarrier.

\( g_u \) - \( u^{th} \) user’s group of subcarriers.
Step 3: Continuing in this manner till the last channel scan all the users (U), channels are allocated to users randomly depending on channel fading experienced by users.

Step 4: The total number of channels allocated to one user will form one group of channels. Therefore number of groups will be equal to the number of users.

\[ G = U \]

Step 5: For each group formed find out the required transmit power using “(2)” given here for reference,

\[ p_u^g = \sum_{s=1}^{S} (\beta N_o S^{-2} \sum_{s=1}^{S} |\omega_{g,s}^u|^2 \sum_{s=1}^{S} |\omega_{g,s}^u f_{g,s}^u|^2)^{-1} \]

Where

- Target threshold of SNR.
- \( p_u^g \) - The required transmit power for \( u \)th user on one channel of the \( g \)th group.
- \( S \) – Total number of subcarriers in \( g \)th group.
- \( f_{g,s}^u \) - \( u \)th user’s channel fading (path gain) on the \( s \)th subcarrier of the desired group.
- \( \omega_{g,s}^u \) - \( u \)th user’s frequency domain combining weight for the signal on the \( s \)th subcarrier of the desired group.

Step 6: Select the group with the lowest transmit power requirement.

\[ \min(p_u^g) \]

Step 7: Allocate the channels within the selected group as given below,

Channel allocation

while \( C \neq 0 \)

\[ t = \arg \min_{v \in C} \{ p_u^{v_{min}} \}; \]  % select the group with lowest power requirement

\[ c_t^{u_{min}} = \min\left( \left\lfloor \frac{P_R}{P_t^{u_{min}}} \right\rfloor, S \right); \]  % calculate the available channel number

\[ P_R = P_R - c_t^{u_{min}} P_t^{u_{min}}; \]  % calculate the residual transmit power

\[ C = C \backslash \{ u_{min} \}; \]

if \( c_t^{u_{min}} = 0 \) % since the residual transmit power is not enough, terminate channel allocation.

Break the loop;

End if

End While

IV. PERFORMANCE ANALYSIS

The computer simulations are carried for the simulation environment (Table II) selected to meet the specifications of LTE-A standards. Long Term Evolution (LTE) advanced standards is the 3GPP candidate for 4G [16]. It is assumed that the CSI is available at the base station. Stationary channel gain samples are produced using the autoregressive model of correlated Rayleigh fading processes [13]. CSI is continuously changing with time corresponding user experiences different fading (f) on different channels.

Performances are evaluated for all the three combining schemes i.e. MRC (Minimum Ratio Combining), EGC (Equal Gain Combining) and Zero Force Combining (ZFC). Since EGC and ZFC schemes have same required amount of
transmit power for the one same channel, they give nearly the same throughput either ASG, improved or ACA scheme is applied. Performance of ASG algorithm is compared with that of Improved algorithm and ACA algorithm. Performance of ASG scheme is found to be far better than other two schemes in terms of throughput. For simulation two channels are used i.e. Rayleigh Channel and AWGN channel.

### TABLE II. SIMULATION PARAMETERS

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier frequency (fc)</td>
<td>5 GHz</td>
</tr>
<tr>
<td>Operating bandwidth</td>
<td>100 MHz</td>
</tr>
<tr>
<td>Subcarrier spacing</td>
<td>25 kHz</td>
</tr>
<tr>
<td>No. of channels</td>
<td>128, 1024</td>
</tr>
<tr>
<td>Symbol rate</td>
<td>64 Ksp</td>
</tr>
<tr>
<td>Receiver speed</td>
<td>100 km/hr</td>
</tr>
<tr>
<td>Maximum Doppler frequency</td>
<td>462.96Hz</td>
</tr>
<tr>
<td>Target SINR</td>
<td>-2ln(5BER)</td>
</tr>
<tr>
<td>Noise power spectral density</td>
<td>-50dBm/watt, -40.2 dBm/watt</td>
</tr>
<tr>
<td>One subcarrier Bandwidth</td>
<td>0.76MHz, 0.073MHz</td>
</tr>
<tr>
<td>Peak spectrum usage efficiency</td>
<td>30 bits/s/Hz</td>
</tr>
<tr>
<td>Fading margin</td>
<td>7.5dB, 12dB</td>
</tr>
</tbody>
</table>

A. Rayleigh Channel

"Fig. 3" shows that as maximum transmit power increases, throughput increases and all the 1024 channels get allotted at much less transmit power using ASG scheme. The reason is, when we calculate required transmit power for all groups, for ASG scheme the difference between the required transmits powers of all groups is less, the values lie within a small range. On the other hand in Improved and ACA schemes the required transmit powers of all groups vary by significant amount and for many groups required transmit power is much high as compared to minimum of all. When transmit power is very low then Improved algorithm outperforms over ASG and achieve highest throughput with less transmit power for all the three combining schemes. The reason is, the number of channels per group is not same in ASG, therefore when we first select the group with least power requirement then Improved scheme gives better result than ASG. As transmit power increases ASG outperforms Improved algorithm. "Fig.4 and Fig.5" gives same throughput versus MaxSNR comparison for EGC and ZFC schemes.

In ASG scheme number of groups is always equal to the number of users, which is a perfect condition for maximizing throughput. As this number (M=K) increases, throughput increases as shown in “Fig. 6” but computation time also increases.

![Figure 3. Throughput versus the maximum transmit power (MaxSNR) for MRC scheme, when the BER requirement is 10^-3 and the spreading factor and the number of users are 32.](image)
Figure 4. Throughput versus the maximum transmit power (MaxSNR) for EGC scheme, when the BER requirement is $10^{-3}$ and the spreading factor and the number of users are 32.

Figure 5. Throughput versus the maximum transmit power (MaxSNR) for ZFC scheme, when the BER requirement is $10^{-3}$ and the spreading factor and the number of users are 32.

Figure 6. Throughput versus the maximum transmit power (MaxSNR) for MRC scheme, for different values of M&K, when the BER requirement is $10^{-3}$. 

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For lower BER requirement, target SNR increases consequently required transmit power increases, resulting in corresponding decrease in throughput for the given transmit power as shown in “Fig.7”. Following equation gives BER and SNR relation “(3)”.

\[
\text{BER}_i = \frac{1}{5} \times \exp\left(\frac{-1.5 \times \beta}{M - 1}\right)
\]

\(\beta\) - Target threshold of SNR.
\(\text{BER}_i\) = Bit error rate of \(i^{th}\) subcarrier

M = 4, as modulation scheme used is QPSK.

As in ASG algorithm additional number of computations are involved in forming the groups of subchannels, required computation time is more for ASG algorithm as compared to Improved and ACA algorithm. One can say that one drawback of ASG is it’s increased computational complexity. Table III shows computation time required for channel allocation for three schemes.

<table>
<thead>
<tr>
<th>TABLE III. COMPUTATION TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computation Time</td>
</tr>
<tr>
<td>6.8394 sec</td>
</tr>
</tbody>
</table>

B. AWGN Channel

Here simulations are performed considering different input. Channel gain ‘f’ is generated considering the inputs referred from local BSNL network. To correlate it with the AWGN channel normal distribution of ‘f’ over the fading channels is taken. Fading margin is taken as 12 dB. The throughput comparison is shown in “Fig.8”.

Among three subchannel allocation schemes ASG outperforms the other two schemes, all the 128 channels get allocated comparatively at much less transmit power, attaining the throughput of 2918.4 Mbps.
Figure 8. Throughput versus the maximum transmit power (MaxSNR) for MRC scheme, when BER requirement 10^-3 , the number of users are 8 and spreading factor is 16.

As in ASG algorithm additional number of computations are involved in forming the groups of subchannels, required computation time is more for ASG algorithm as compared to Improved and ACA algorithm. Another drawback of ASG is user experiencing higher fading on all the channels will not get a single channel allotted to him and no possibility of his data transmission.

In Ref. [17] LTE-A simulator capabilities are tested for particular environment for 1.4 MHz bandwidth and the maximum throughput achieved is 35Mbps for SNR of 35dB for a single user MIMO system, near about 19 Mbps for SNR of 30 dB for multiple user MIMO system.

V. FUTURE WORK

Channels vary rapidly with time therefore the fixed modulation scheme is spectrally inefficient. To achieve spectrally efficient communication adaptive modulation is used. Adaptive modulation in most simple manner can be stated as,

- Assigning more no. of bits to the channels having high SNR.
- Assigning less no. of bits to the channels having low SNR.

Based on the prediction of the expected channel conditions during the next timeslot, the transmitter has to select the appropriate modulation schemes for the subcarriers. A better channel condition would imply a higher order modulation scheme, whereas a poor channel condition selects a lower order modulation scheme to maintain the required bit error rate (BER). For further improvement in the throughput Adaptive modulation combined with Adaptive Subchannel Grouping will be a promising technique.

LTE-Advanced standard employees QPSK, 16 QAM and 64QAM as modulation schemes[17]. The switching of the modulation schemes can be set to achieve a particular BER performance (≤ BER_{threshold}). For real time applications BER requirement ranges from 10^{-3} to 10^{-6}. For e.g. if BER_{threshold} is selected to be 10^{-3} then as the current modulation scheme’s BER crosses this threshold value then system switches to the other modulation scheme. BER performance varies under different channel conditions (SNR). Higher order modulation schemes are having better BER performance at high SNR, whereas lower order modulation schemes are having better BER performance at low SNR. At first starting with the higher order modulation scheme for less number of users higher data rate can be achieved, maintaining the required BER performance. As the number of users increases, the channel SNR decreases due to multiple user interference, correspondingly BER performance degrades, system has to switch to the lower order modulation scheme to maintain BER performance.

For LTE-A standard three switching levels of modulation will be there, i.e. QPSK, 16-QAM and 64-QAM. Starting from 64-QAM, system has to shift to 16-QAM for increase in the number of users and then to QPSK for further increase in the number of users. Table IV. shows the steps involved in adaptive modulation scheme.

Shifting of modulation schemes reflects in the spectrum efficiency, therefore changing the throughput according to the modulation scheme. Spectrum efficiency (η) calculation is given by “(4)”;

$$\eta = P \cdot R_{av} \cdot G / BW$$

Where
- P - The peak data rate (bps).
- R_{av} - The modulation and coding scheme (MCS) average factor.
- G - Other gain from advanced technologies, and
- BW - The channel bandwidth
TABLE IV. STEPS IN ADAPTIVE MODULATION

<table>
<thead>
<tr>
<th>Case</th>
<th>Number of Users</th>
<th>SNR</th>
<th>Modulation Scheme level shifting</th>
<th>BER</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>less</td>
<td>high</td>
<td>higher order</td>
<td>64-QAM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>BER(Threshold)</td>
</tr>
<tr>
<td>II</td>
<td>increase</td>
<td>decrease</td>
<td>higher order</td>
<td>64-QAM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>BER(Threshold)</td>
</tr>
<tr>
<td>III</td>
<td>further increase</td>
<td>further decrease</td>
<td>lower order</td>
<td>16-QAM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>BER(Threshold)</td>
</tr>
<tr>
<td></td>
<td>same</td>
<td>same</td>
<td>shift II-further lower down the order</td>
<td>4-QAM (QPSK)</td>
</tr>
</tbody>
</table>

CONCLUSIONS

This paper evaluates Adaptive Subchannel Grouping (ASG) scheme’s performance in order to maximize the total throughput in the downlink multi-user MC-CDMA system. The performance is evaluated for two channel models i.e. Rayleigh and AWGN Channel and three combining schemes i.e. MRC, EGC and ZFC. Also the BER performance of ASG is studied in detail.

Numerical results shows that ASG algorithm is more suitable for Medium and high values of transmit power and can allocate all the channels with much less transmit power as compared to Improved and ACA algorithm.

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