A Novel G-OFDM-IDMA Based Downlink Transmission Scheme for Femtocell Networks

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***Abstract*—In this paper, we present a novel grouped OFDM-IDMA based downlink transmission scheme for femtocell networks. To avoid the cross-tier interference, we assign the femto users and marco users into different sub-carrier groups for transmission. IDMA is used to mitigate the co-tier interference within the same group of users. We give the detailed system model as well as the transceiver structure of the proposed scheme. With the notion of SNR evolution function, we investigate the performance of the proposed scheme in terms of spectral efficiency and bit error rate (BER). Both theoretical analysis and simulations indicate that with the assistance of femtocell and grouping, the proposed scheme achieves better performance compared with the traditional OFDM-IDMA systems, while at the same time maintains an even lower complexity at the user terminal than the latter.**

***Index Terms*—grouped OFDM-IDMA (G-OFDM-IDMA), Femtocell, Multi-User Detection (MUD).**

I. Introduction

By combining orthogonal frequency division multiplexing (OFDM) with interleave division multiple access (IDMA), the so-termed OFDM-IDMA system was proposed in [1] [2] and has drawn intensive research interests. In OFDM-IDMA systems, OFDM is employed to avoid the inter symbol interference (ISI) caused by frequency selective fading, while user separation is realized by equipping users with different interleavers. One advantage of OFDM-IDMA is its capability for iterative multi-user detection (MUD), which is proved to be effective in mitigating the multiple access interference (MAI) [3]. It is also reported that the complexity of such MUD is linear with the number of users [4]. Motivated by this feature, grouped OFDM-IDMA (G-OFDM-IDMA) system was proposed in [5] [6], aiming at further reducing the detection complexity. In such a system, the available subcarriers are divided into several groups. Subject to these groups, the total users are partitioned into subsets and each subset of users share one group of subcarriers for their transmission. The users among different subsets are separated by different subcarriers while the users within the same subset are distinguished by IDMA. Consequently, the number of users in each group is smaller than that of the traditional OFDM-IDMA system with the same number of total users, hence leading to a reduced complexity. However, it should be noticed that the complexity of MUD is not only related to the number of users but also to another important metric, i.e., the number of iterations of MUD. To achieve a promising performance, the MUD should work under sufficient number of iterations. The complexity would be still very high if the number of iterations is large. Considering a downlink scenario where the receiver is the mobile user equipment (UE), such complexity may still be a great burden and hence prohibit IDMA from implementation in such a scenario.

The Femtocell network is a novelly emerging architecture which can enhance the performance of the macro cellular systems [7], [8]. One femtocell can be treated as a small cellular network consisted of one femto access point (FAP) with low transmit power and several femto users (FUs) under its coverage. It provides high-quality transmission links thanks to the close transmission range between the FAP and FUs. In addition, the computing capability of FAP allows certain pre-processing operation, such as decoding, before it forwards the information from the macro base station (MBS) to the FUs, which further improves the communication quality. Due to its superior benefits, the concept of femtocell is widely adopted in various standards including Long-term evolution (LTE), where the OFDMA based femtocell is referred to as home evolved node base station (HeNB) [9]. However, despite of its envisioned benefits, additional interference is also caused by introducing femtocell into the existing macrocell. The interference can be classified into two categories, namely cross-tier interference and co-tier interference. The former is caused by simultaneous transmission between the femtocell and macrocell while the latter is due to the simultaneous transmission within/between femtocells [10]. Therefore, it is a challenge to design efficient transmission scheme for femtocell network in present of interference.

In this paper we propose to adopt G-OFDM-IDMA for the downlink transmission of femtocell network, aiming at combining the advantages of both. In such a system, cross-tier interference is completely avoided by assigning the MUs and FUs into different subcarrier groups. Within the same group, IDMA is employed to distinguish co-tier users. The number of users per group is reduced

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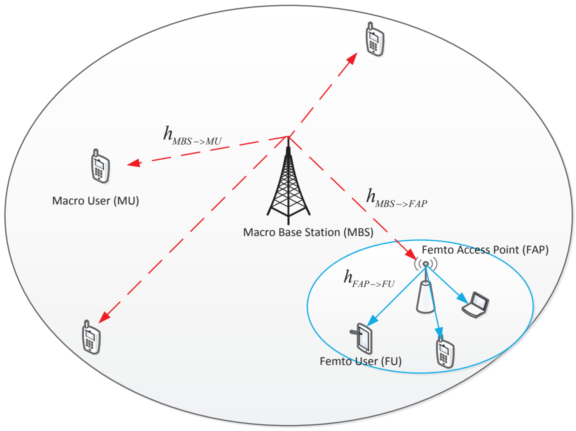


Fig. 1. System model of two-tier femtocell network.

thanks to the grouping operation, which leads to a low complexity. On the other hand, due to the computing capability of FAP, the signal transmitted from MBS to FUs can be first decoded by FAP with sufficient number of iterations, and then forward to FUs with a relatively high received power. The performance of the users is therefore guaranteed even with a small un-sufficient number of iterations. The reduced decoding complexity as well as the good performance make the practical implementation of OFDM-IDMA in downlink possible. We first describe the proposed transmission scheme in detail and then address the achievable spectral efficiency and bit error rate (BER) performance of the proposed scheme. Analysis and simulation results show that with the help of femtocell and grouping, the proposed transmission scheme provides better performance compared with that of the macrocell scenario employing traditional OFDM-IDMA. Furthermore, the decoding complexity at the user end is also greatly decreased.

The rest of this paper is organized as follows. In Section II, we describe the system model and transceiver structure of the G-OFDM-IDMA based femtocell system model. In section III we analyze the spectral efficiency and BER performance of the proposed scheme. Complexity analysis is also included in this section. Based on the forehand analysis, simulation results are provided in Section IV to evaluate the performance of the proposed scheme. Section V concludes the paper.

II. System Model

A. Transmission Model

We consider a downlink two-tier femtocell network with one MBS overlapped with one FAP as shown in Fig. 1, where there are a total number of K users, including K_m macro users (MUs) receiving signals directly from the MBS and K_f femto users (FUs) being served by the FAP. We assume $K_f = K_m$ in order to facilitate our analysis. To overlay the FUs and MUs, the available N subcarriers are evenly divided into two groups with either set of users can only possess one group for their transmission. Furthermore, we adopt interleaved subcarrier allocation (ISA) strategy when partitioning the subcarriers, that is, the subcarriers indexed by $n_g \in \{j + 2i,\ i = 0, 1, \cdots, \frac{N}{2} - 1\}$ will be collected into the g-th group, where $g \in \{1, 2\}$ [11] [12]. It is readily proved that in the ISA mode, as the number of subcarriers per group is larger than the multi-path length of the frequency selective fading channel, the full frequency diversity can always be achieved by seizing only one group of subcarriers. In addition, the average channel gain in each subcarrier group is identical. More detailed proof can be found in literatures like [12] [13] .

As the MUs and FUs are overlaid by different subcarrier groups, we then focus on the transmitter structure in one particular group without distinguishing it belongs to the FUs or MUs. As shown in Fig. 2, in each group different users' data is first encoded by the same repetition encoder and then interleaved by different interleavers, resulting in independent permutated coded sequences. Note that each user owns its unique interleaver as the only identity to distinguish itself from the other users. Then these data sequences are modulated into QPSK symbols, respectively, and superimposed together to be transmitted on the corresponding group of subcarriers. We consider the channel from the MBS to the FAP and each MUs experienced quasi-static frequency selective fading, i.e., the channel coefficient keeps constant during one OFDM block but varies among different OFDM blocks. The received signal at the k-th MU on subcarrier n can be expressed as:

$$\begin{aligned} Y_k(n) = & H_k(n)X_k(n) \\ & + H_k(n) \sum_{\substack{k' \neq k \\ k' \in \boldsymbol{k}_m}} X_{k'}(n) + \omega(n) \,, \end{aligned} \tag{1}$$

where $\boldsymbol{k}_m = \{1, \cdots, K_m\}$ is the set contains the MUs, $n \in \boldsymbol{n}_m$ indexes the corresponding subcarrier belonging to $\boldsymbol{k}_m$, $X_k(n)$ is the data of user k on the n-th subcarrier, $H_k(n)$ denotes the frequency domain channel response on the n-th subcarrier between the MBS and the user k, $\omega(n)$ represents the additive Gaussian noise on the n-th subcarrier with zero mean and variance σ^2.

Similarly, we can obtain the received signal at the FAP as:

$$Y_b(n) = \quad H_b(n) \sum_{k \in \boldsymbol{k}_f} X_k(n) + \omega(n) \,, \tag{2}$$

where $H_b(n)$ denotes the frequency domain channel response on subcarrier n from the MBS to the FAP, $\boldsymbol{k}_f = \{1, \cdots, K_f\}$ is the set of FUs, $n \in \boldsymbol{n}_f$ denotes the subcarriers belonging to FU set.

B. Receiver Structure at MUs

In this subsection, we describe the receiver structure at the MU. After receiving the transmitted signal, the k-th MU starts to recover its data through MUD [3], [1]. The MUD consists of one Gaussian Approximation

$$e_k^{Re}(n) = \log \frac{P(Y_k(n)|X_k^{Re}(n)=+1)}{P(Y_k(n)|X_k^{Re}(n)=-1)} = 2|H_k(n)|^2 \frac{(H_k^*(n)Y_k(n))^{Re} - E((H_k^*(n)\xi_k(n))^{Re})}{V((H_k^*(n)\xi_k(n))^{Re})}\ , \tag{3}$$

$$e_k^{Im}(n) = \log \frac{P(Y_k(n)|X_k^{Im}(n)=+1)}{P(Y_k(n)|X_k^{Im}(n)=-1)} = 2|H_k(n)|^2 \frac{(H_k^*(n)Y_k(n))^{Im} - E((H_k^*(n)\xi_k(n))^{Im})}{V((H_k^*(n)\xi_k(n))^{Im})}\ , \tag{4}$$

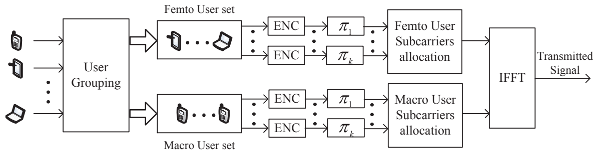


Fig. 2. The transmitter structure of MBS. ENC and π_k denotes the encoder and different interleavers, respectively.

Detector (GAD) as well as K_m decoders which works in an iterative manner. Recall that in Eq. (1), the first part on the right hand side of equality denotes the demand signal of the k-th user while the remaining is the combination of interference from the other MUs and additive noise. Based on the central limit theorem, we can approximate the interference plus noise component as the Gaussian variable since it is the sum of $K_m - 1$ independent sequences and additive noise. As a result, the log-likelihood ratio (LLR) on the real and imaginary part of the demand signal $X_k(n)$ can be calculated in Eq. (3) and Eq. (4), respectively, where $\xi_k(n)$ is the interference plus noise part with respect to $X_k(n)$, $(\cdot)^{Re}$ and $(\cdot)^{Im}$ denotes the real and imaginary part of a variable, $(\cdot)^*$ is the conjugate transpose, $E(\cdot)$ and $V(\cdot)$ is the mean and variance, respectively. The detailed calculation of $E((H_k^*(n)\xi_k(n))$ and $V((H_k^*(n)\xi_k(n))$ can be found in [3], [4]. The LLR $e_k^{Re}(n)$ and $e_k^{Im}(n)$ are then de-interleaved and send to the decoders. The decoders then generates its own LLRs, which are interleaved and fed back to the GAD to update the statistic information of $X_k(n)$ for the next iteration as:

$$E(X_k(n)) = \tanh(\frac{\lambda_{DEC}(X_k(n))}{2})\ , \tag{5}$$

$$V(c_l) = 1 - E^2(X_k(n))\ , \tag{6}$$

where $\lambda_{DEC}(X_k(n))$ is the soft information provided by decoders. This procedure operates in several iterations, say Q_m, and in the final iteration the decoder gives the hard decision $\widehat{X}_k(n)$. Notice that although only $X_k(n)$ is of the interests of user k, it needs to decode the data from all K_m users during the iterative process so that to explore the performance improvement provided by MUD.

C. Receiver Structure at FAP and FUs

We first describe the structure of FAP in this subsection. As aforementioned, FAP can be treated as a small base station that has superior computing capability compared with the individual UE. As a result, we propose to adopt the decode and forward (DF) strategy in FAP [14], that

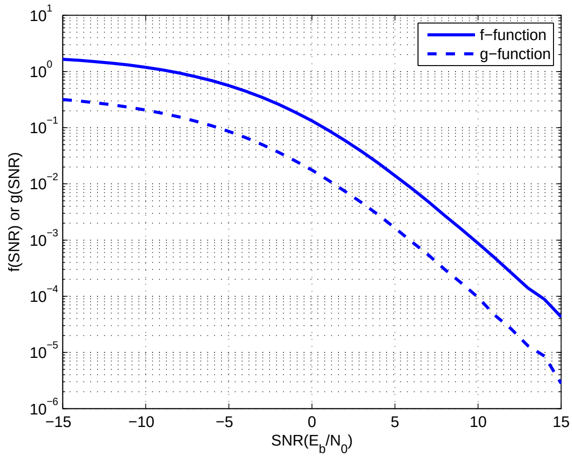


Fig. 3. $f(\cdot)$ and $g(\cdot)$ of 2-grouped OFDM-IDMA in multi-path Rayleigh fading scenario with $L = 3$. Total subcarrier number $N = 512$. Coding length per-group is $S = 8$

is, the transmitted signal is first decoded at the FAP and then forward to the FUs under its coverage. The iterative MUD works in the same manner as that of the MUs except for a larger iteration number, say, Q_b. After MUD, the decoded data $\widehat{X}_k(n)$ is re-encoded, permutated by its unique interleaver and modulated to the subcarriers to be transmitted to the FUs. Note that in general cases the communication range between FAP and FUs is relatively small, hence the signal-to-noise ratio (SNR) at the FUs is usually much higher than that of the case when the FUs directly commutate with the MBS. The receiver structure of the FUs is as the same as the MUs as mentioned in the above subsection. The only difference here is that they work on different frequency band due to the grouping operation in G-OFDM-IDMA system.

III. Performance Analysis

In this section, we analyze the performance of the proposed scheme. Using the notion of SNR evolution function, we first give the analysis on the performance of the proposed scheme in terms of spectral efficiency and BER. Then compared with the traditional OFDM-IDMA system, we calculate the complexity of our proposed scheme.

A. Spectral Efficiency of The Proposed Scheme

We first derive the achievable spectral efficiency of the proposed G-OFDM-IDMA based transmission scheme with the help of the SNR evolution function [3], [15]. To simplify our analysis, we assume equal power allocation among all users and denote the transmit power per coded-bit of the MBS is $P = P_i/S_m$, where S_m is the spreading code length of the MU and P_i is the information bit power. Considering the downlink scenario, the achievable spectral efficiency between the MBS and the k-th MU can be obtained as:

$$C_k = \log_2(1 + \gamma_k^{Q_m}) \ , \tag{7}$$

where $\gamma_k^{Q_m}$ is the SINR of user k after Q_m times of iterations, which can be expressed as:

$$\gamma_k^{Q_m} = \frac{|\bar{H}_k|^2 P}{(K_m - 1)|\bar{H}_k|^2 P f(\gamma_k^{Q_m - 1}) + B_c N \sigma^2/2} \ , \tag{8}$$

where $|\bar{H}_k|^2 = \sum_{n \in \boldsymbol{n}_m} |H_k(n)|^2$ is the average channel gain of user k [11], B_c is the bandwidth per-subcarrier. $f(\cdot)$ is the SNR evolution function which present the MAI mitigated per-iteration [3] [15]. It can be obtained through simulating a single user system hence depend on the channel condition and coding scheme adopts. In Fig. 3 we illustrate such a function for an 2-grouped G-OFDM-IDMA system in Rayleigh fading scenario with path-length $L = 3$. Based on Eq. (7), we can obtain the achieved spectral efficiency of the MU set $\boldsymbol{k}_m$ as:

$$C_m = \sum_{k \in \boldsymbol{k}_m} C_k = \sum_{k \in \boldsymbol{k}_m} \log_2(1 + \gamma_k^{Q_m}) \ , \tag{9}$$

On the other hand, the FAP can be treated as a single MU during the MBS broadcasting. Hence following the similar approach, the spectral efficiency between the MBS and the FAP can be calculated as:

$$C_b = \log_2(1 + \gamma_b^{Q_b}) \ , \tag{10}$$

and

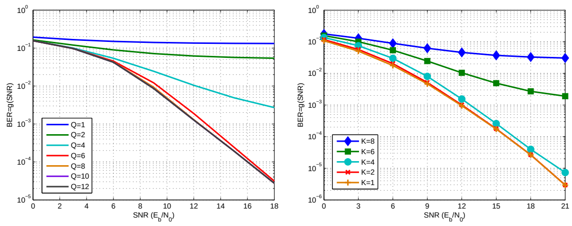
$$\gamma_b^{Q_b} = \frac{|\bar{H}_b|^2 P}{(K_f - 1)|\bar{H}_b|^2 P f(\gamma_k^{Q_b - 1}) + B_c N \sigma^2/2} \ , \tag{11}$$

where $k \in \boldsymbol{k}_f$ is the users in FU set. Q_b denotes the iteration number of FAP and is usually much larger than Q_m thanks to the computing capability of FAP. As aforementioned, the FAP needs to forward the decoded signal to the FUs to complete the entire transmission process. Assuming the channel between FAP and FUs also experiences multi-path Rayleigh fading and the transmit power of FAP is P_b, the spectral efficiency between the FAP and FUs can be represented as:

$$C_f = \sum_{k \in \boldsymbol{k}_f} \log_2(1 + \gamma_k^{Q_f}) \ , \tag{12}$$

$$\gamma_b^{Q_f} = \frac{|\bar{H}_f(k)|^2 P_b}{(K_f - 1)|\bar{H}_f(k)|^2 P_b f(\gamma_k^{Q_f - 1}) + B_c N \sigma^2/2} \ , \tag{13}$$

where $\gamma_k^{Q_f}$ is the SINR of the k-th MU after Q_f iterations. $|\bar{H}_f(k)|^2$ is the average channel gain of FU k. As we assume that the FUs and MUs own the same equipment, their computing capabilities are treated equally with $Q_f = Q_m$. Despite of that, notice that another advantage of the FAP is its close transmission range which leads to the higher initial received signal power at the FUs, that is, $\gamma_{k_f}^0 > \gamma_{k_m}^0$. Therefore C_f usually turns out to be larger than C_m.



(a) Different iteration numbers. (b) Different user numbers.

Fig. 4. Predicted BER performance of 2-grouped OFDM-IDMA with different Q and K. Spreading length per-group $S = 8$. Total subcarrier number $N = 512$.

Based on the above derivations, we can find that the spectral efficiency of FU set is lower bounded by the two-stage transmission between the MBS to FAP and the FAP to FUs. Therefore the spectral efficiency of the FU set can be expressed as:

$$\check{C}_f = \min\{C_b \, , C_f\} \ , \tag{14}$$

and the entire spectral efficiency of the system is the sum of that of the two user sets:

$$C_{sys} = \check{C}_f + C_m = \min\{C_b \, , C_f\} + C_m \ , \tag{15}$$

B. BER Performance of The Proposed Scheme

In this subsection, we analyze the BER performance of the proposed G-OFDM-IDMA based scheme. Again using the notion of SNR evolution, we can predict the BER performance of the proposed scheme using the $g(\cdot)$ function shown if Fig. 3, which is a paired function of $f(\cdot)$ and can be obtained through a similar approach [3]. It tracks the relationship between BER and SINR with which the BER of user k can be calculated as:

$$BER(k) = g(\gamma_k^q) \ , \tag{16}$$

$$\gamma_k^q \propto \frac{1}{(K-1) f(\gamma_k^{q-1})} \ , \tag{17}$$

We denote the BER value of the three transmission stages; namely the MBS to MUs, the MBS to FAP and the FAP to FUs as $BER_m(k)$, $BER_b(k)$ and $BER_f(k)$, respectively. As a consequence, the overall BER performance of the proposed scheme can be expressed as:

$$BER_{sys} = E(\overline{BER}_m \, , \overline{BER}_f) \ , \tag{18}$$

where

$$\overline{BER}_m = E(BER_m(k)) = E(g(\gamma_k^{Q_m})) \ , \tag{19}$$

and

$$\begin{aligned} \overline{BER}_f =& E\left(1 - \left(1 - BER_b(k)\right)\left(1 - BER_f(k)\right)\right) \\ =& E(1 - (1 - g(\gamma_k^{Q_b}))(1 - g(\gamma_k^{Q_f}))) \ , \end{aligned} \tag{20}$$

where $E(\cdot)$ takes the expectation over the users.

With the above analysis, we can easily demonstrate that the BER performance strongly relies on the number of users and number of iterations involved in the MUD, as well as the initial SINR value. We examine these relationships in Fig .4. It is clearly shown that to achieve a promising BER performance, sufficient iteration number is needed and the smaller number of users is suggested. In addition, the higher initial SINR value could also benefit the BER performance. The observation just give an insight of the advantages of our proposed scheme:

- With the grouping operation, the number of users per-group is decreased compared with the traditional OFDM-IDMA system.
- Due to the superior computing capability, it is possible for FAP to perform MUD with larger number of iterations.
- Owning to the short transmission range, the FUs could decode the data with higher initial SINR values than that of directly linking to the MBS.

C. Complexity Analysis of The User Ends

In this subsection, we investigate the decoding complexity of our proposed scheme. Due to the constraint on the size and battery life, the decoding capability of UE is strictly limited. As a result, we mainly concern about the complexity issue at the UE. As aforementioned in Section II, each UE (either the MU or the FU) consists of one GAD and K_u decoders, and tries to decode a number of $N_u = N/2$ coded QPSK symbols during one OFDM block, where $K_u = \{K_f, K_m\} = K/2$ is the number of users involved in a MUD. To recover one particular coded symbol of the k-th user, say $X_k(n)$, both the GAD and the k-th decoder needs to generate the corresponding soft information and exchange it during the iterations. We denote such complexity involved in the GAP and decoders per-iteration as ϕ, the overall complexity of MUD to recover one OFDM data block can be calculated as [5]:

$$\Phi = \phi K_u N_u Q_u \ , \tag{21}$$

where Q_u is the number of iterations. Similarly, the complexity of UE in the traditional OFDM-IDMA system with the same number of total users and subcarriers can be expressed as:

$$\Phi_{ref} = \phi K N Q_u = 4\phi K_u N_u Q_u \ . \tag{22}$$

Clearly, the complexity of UE is greatly reduced due to the grouping operation. Furthermore, the reduction on the number of users will facility the decoding process and yield a better performance as we discussed in the previous subsections. This benefit is critical especially in the case when the number of total users in the system is large and the iteration number is strictly limited, i.e., the UE can only support un-sufficient number of iterations. In section IV, we will show in simulations that the proposed scheme achieves better performance than that of the traditional downlink OFDM-IDMA system without femtocell, and at the same time has a lower complexity than the latter.

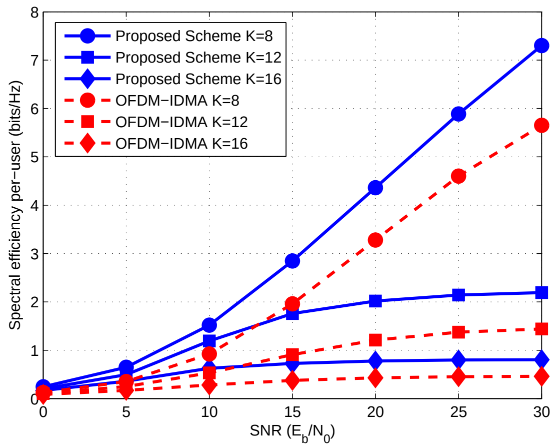


Fig. 5. Spectral efficiency per-user of the proposed scheme with single femtocell and traditional OFDM-IDMA. $S_u = 8$, $N = 512$, $P_b = P + 12$dB. $K_f = K_m = K/2$. $Q_u = 4$ and $Q_b = 12$.

IV. Simulations and Discussions

In this section, we evaluate the performance of the proposed femtocell assisted G-OFDM-IDMA system through simulations. Consider a downlink OFDM scenario with $N = 512$ subcarriers. The subcarriers are pre-allocated into 2 groups in ISA mode, with one group assigned to the MU set and another assigned to the FU set. Accordingly, the total number of users are evenly divided into MU set and FU set. The spreading code length of each user $S_u = 8$. The channels of MBS to FAP, MBS to MUs and FAP to FUs are assumed to be independent frequency-selective Rayleigh fading with path-length $L = 3$. The number of iterations at each UE is assumed to be $Q_u = 4$ while that of the FAP is set to be $Q_b = 12$. Furthermore, due to the close distance between FAP and FUs, we assumed the received SNR at FUs is 12dB larger than that of MUs. To compare, we also simulate the traditional downlink OFDM-IDMA case without femtocell as a benchmark. In such a case, the total users in the system can share the entire N subcarriers. To maintain the same data rate, the spreading code length is set to be $S = 2S_u = 16$. As a result, the complexity at the UE is 4 times higher than that of the proposed scheme.

A. Achievable Spectral Efficiency

We first examine the achievable spectral efficiency of the proposed scheme. In Fig. 5, we show the theoretical per-user spectral efficiency of the system, that is, the achievable system spectral efficiency is averaged by the number of users. The total user number is $K = [8, 12, 16]$, where accordingly $K_f = K_m = [4, 6, 8]$, respectively. We can see from the figure that the proposed scheme outperforms the traditional OFDM-IDMA case regardless of the number of users. The superior performance comes from two ways. First, compared with the OFDM-IDMA case adopting the same number of iterations at UEs, the reduced number of user per-group facilities the MUD to

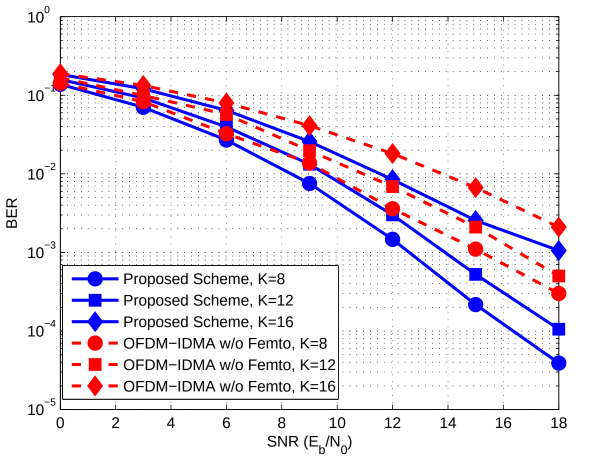


Fig. 6. BER comparision between the proposed scheme with single femtocell and traditional OFDM-IDMA. $S_u = 8$, $N = 512$, $P_b = P + 12$dB. $K_f = K_m = K/2$. $Q_u = 4$ and $Q_b = 12$.

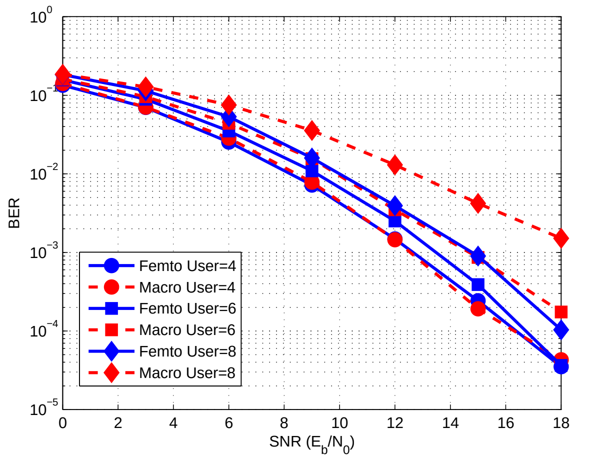


Fig. 7. BER performance of femto user set and macro user set. $S_u = 8$, $N = 512$, $P_b = P + 12$dB. $K_f = K_m = K/2$. $Q_u = 4$ and $Q_b = 12$.

be more likely to converge to the better performance in both the MU set and FU set. In addition, the decode and forward strategy adopted in the FAP brings extra performance enhancement to the FU set and hence improves the performance of the entire system. We can also find that the performance enhancement increases as the number of users decreases. It is because that as the number of total users increases, the limited iteration number generally turns out to be insufficient for the MU set despite of the grouping, hence leaving smaller performance improvement. Although with the help of FAP, the FU set can still perform well (which will be shown in the following simulations), the entire system performance will be dragged down due to the poor performance of MU set.

B. BER Performance

In Fig. 6, we compare the BER performance of the proposed system under different number of total users, in order to show the advantage of our proposed scheme from another prospective. The performance of traditional OFDM-IDMA system is also illustrated here as the baseline. Same observation as in Fig. 5 can be also found in this simulation. Our proposed scheme always outperforms its OFDM-IDMA counterpart and the performance gap increases as the number of total users decreases. It again proves that by introducing femtocell and grouping, the system performance can be greatly enhanced.

In order to evaluate the performance enhancement brought by grouping and femtocell independently, we illustrate the BER performance of MU set and FU set of the proposed scheme, i.e., $\overline{BER_m}$ and $\overline{BER_f}$, as shown in Fig. 7. We can discover from the figure that the FU set always performs better than the MU set. That is because the FU set not only benefits from the grouping operation, but also gains additional help from the FAP. Interestingly, we also find that the gap between $\overline{BER_m}$ and $\overline{BER_f}$ is narrowed along with the decreasing of the number of users. The performance of these two sets turns out to be almost identical when $K_f = K_m = 4$. It shows that as the number of users in the system is small, solely adopting grouping is quite enough to guarantee the MUD to converge with the fixed iteration number. Notice that the BER performance of the FU set is bounded by BER_b and BER_f as mentioned in Eq. (20), while that of the MU set depends on BER_m in Eq. (19). As BER_m can converge to the same performance as BER_b in such a case, The additional number of iterations of MUD from FAP provides neglectable effort to improve the performance of FUs. This observation provides useful reference for the network engineers to deploy the FAP in the network accordingly.

V. Conclusion

In this paper, we have proposed a novel downlink transmission scheme which integrates the advantages of G-OFDM-IDMA with femtocell. The cross-tier and co-tier interference is avoided by different subcarrier groups and different interleavers, respectively. We have illustrated the system model and transceiver structure of the proposed scheme in details. The spectral efficiency and BER performance of the proposed scheme has been investigated through both theoretical analysis and simulations. It has been shown that by introducing grouping operation as well as femtocell, the performance of the system is markly enhanced compared with the traditional OFDM-IDMA system. In addition, the complexity of UEs is also reduced with the proposed scheme.

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