Distributed Power Allocation Schemes for precoded Multicell MISO-OFDM Systems

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Abstract - **In this paper we propose distributed power allocation schemes for the downlink of distributed precoded multicell MISO-OFDM systems. The precoders are designed in two phases: first the precoder vectors are computed in a distributed manner at each BS considering two criteria, distributed zero-forcing and virtual signal-to-interference noise ratio; then the system is optimized through distributed power allocation with per-BS power constraint. The proposed power allocation schemes minimize the average virtual bit error rate over all user terminals and the available subcarriers. Both the precoder vectors and the power allocation are computed by assuming that the BSs have only knowledge of local channel state information. The performance of the proposed schemes are compared against other power allocation schemes that have been recently proposed for multicell systems.**

I. INTRODUCTION

Multicell cooperation is one of the fastest growing areas of research, and it is a promising solution for cellular wireless systems to mitigate intercell interference, improving system fairness and increasing capacity in the years to come. This technology is already under study in LTE-Advanced under the coordinated multipoint (CoMP) concept. The problems inherent to co-located MIMO based systems such as shadowing, significant correlation between channels in some environments and intercell interference significantly degrades the capacity gains promised by the MIMO techniques. Thus, in a multicell environment to fully exploit the multiple antenna gain, base station (BS) cooperation is required [1].

There are several CoMP approaches depending on the amount of information shared by the transmitters through the backhaul network and where the processing takes place, i.e., centralized if the processing takes place at the central unit (CU) or distributed if it takes at the different transmitters. Coordinated centralized beamforming approaches, where transmitters exchange both data and CSI for joint signal processing at the CU, promise larger spectral efficiency gains than distributed interference coordination techniques, but typically at the price of larger backhaul requirements and more severe synchronization requirements. In [2], the inner bounds on capacity regions for downlink transmission were derived with or without BS cooperation and under per-antenna power or sum-power constraint. Two centralized multicell precoding schemes based on the waterfilling technique have been proposed in [3].

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It was shown that these techniques achieve a performance, in terms of weighted sum rate, very close to the optimal. In [4], based on the statistical knowledge of the channels CU performs a centralized power allocation that jointly minimizes the outage probability of the UTs. In [5] a clustered BS coordination is enabled through a multicell block diagonalization (BD) strategy to mitigate the effects of interference in multicell MIMO systems. A new BD cooperative multicell scheme has been proposed in [6], to maximize the weighted sum-rate achievable for all the user terminals (UTs).

Distributed precoding approaches, where the precoder vectors are computed at each BS in a distributed fashion, have been proposed in [7] for a particular case of two UTs and generalized for K UTs in [8]. It is assumed that each base station has only the knowledge of local channel state information (CSI) and based on that a parameterization of the beamforming vectors used to achieve the outer boundary of the achievable rate region was derived. In [9], distributed precoding schemes based on zero-forcing criterion with several centralized power allocation based on minimization of the average BER and sum of inverse of signal-to-noise ratio (SNIR) have been derived. These distributed schemes were evaluated and compared with some full centralized multicell schemes in [10].

The aim of this work is to propose distributed power allocation schemes for the downlink of distributed precoded multicell MISO-OFDM systems. Considering the multicell system as a superposition of single cell systems we define the average virtual BER (VBER) as the average BER of one interference-free single cell system, allowing us to compute the power allocation coefficients in a distributed manner at each BS. The precoder is designed in two phases: first the precoder vectors are computed based on distributed zero-forcing (DZF), and distributed virtual signal-to-interference noise ratio (DVSINR) proposed in [8]. Then the system is further optimized by proposing distributed power allocation algorithms, based on minimization of the average VBER, under per-BS power constraint. With the proposed strategy both the precoder vectors and the power allocation are computed at each BS in a distributed manner. The considered criterion for power allocation essentially leads to a redistribution of powers among users and subcarriers, and therefore provide users fairness mainly at the cell edges, which in practical cellular systems may be for the operators a goal as important as throughput maximization.

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The remainder of the paper is organized as follows: section II presents the multicell MISO-OFDM system model. Section III briefly describes the considered distributed precoder vectors. In Section IV the novel distributed power allocation schemes are derived. Section V presents the main simulation results. The conclusions will be drawn in section VI.

II. SYSTEM MODEL

Throughout this paper, we will use the following notations. Lowercase letters, boldface lowercase letters and boldface uppercase letters are used for scalars, vectors and matrices, respectively. $(.)^H$ represents the conjugate transpose operators, $\mathrm{E}[.]$ represents the expectation operator, $\mathbf{I}_N$ is the identity matrix of size $N \times N$, $\mathcal{CN}(.,.)$ denotes a circular symmetric complex Gaussian vector and χ_n^2 denotes the chi-square random variable with *n* degrees of freedom.

We consider B BSs, each equipped with N_{t_b} antennas, transmitting to K single antenna UTs. Also, we assume an OFDM based system with N_c available subcarriers. Under the assumption of linear precoding, the signal transmitted by the BS *b* on subcarrier l is given by,

$$\mathbf{x}_{b,l} = \sum_{k=1}^{K} \sqrt{p_{b,k,l}}\,\mathbf{w}_{b,k,l} s_{k,l} \tag{1}$$

where $p_{b,k,l}$ represents the power allocated to UT k on sub-carrier l at BS b, $\mathbf{w}_{b,k,l} \in \mathbb{C}^{N_{t_b} \times 1}$ is the precoder of user k at BS b on sub-carrier l with unit norms, i.e., $\|\mathbf{w}_{b,k,l}\| = 1,\ b = 1,...,B,\ k = 1,...,K, l = 1,...,N_c$. The data symbol $s_{k,l}$, with $\mathrm{E}\left[\left|s_{k,l}\right|^2\right] = 1$, is intended for UT k and is assumed to be available at all BSs. The average power transmitted by the BS b is then given by,

$$\mathrm{E}\left[\|\mathbf{x}_b\|^2\right] = \sum_{l=1}^{N_c}\sum_{k=1}^{K} p_{b,k,l} \tag{2}$$

where $\mathbf{x}_b$ is the signal transmitted over the N_c subcarriers. The received signal at the UT k on sub-carrier l, $y_{k,l} \in \mathbb{C}^{1\times 1}$, can be expressed as,

$$y_{k,l} = \sum_{b=1}^{B} \mathbf{h}_{b,k,l}^H \mathbf{x}_{b,l} + n_{k,l} \tag{3}$$

where $\mathbf{h}_{b,k,l} \sim \mathcal{CN}\left(0, \rho_{b,k}\mathbf{I}_{N_{t_b}}\right)$ of size $N_{t_b} \times 1$, represents the channel between user k and BS b on subcarrier l and $\rho_{b,k}$ is the long-term channel power gain between BS b, and UT k and $n_{k,l} \sim \mathcal{CN}\left(0, \sigma^2\right)$ is the noise.

From (1) and (3) the received signal at UT k on sub-carrier l can be decomposed in,

$$y_{k,l} = \underbrace{\sum_{b=1}^{B} \sqrt{p_{b,k,l}}\,\mathbf{h}_{b,k,l}^H \mathbf{w}_{b,k,l} s_{k,l}}_{\text{Desired Signal}} + \underbrace{\sum_{b=1}^{B} \mathbf{h}_{b,k,l}^H \sum_{j=1, j\neq k}^{K} \sqrt{p_{b,j,l}}\,\mathbf{w}_{b,j,l} s_{j,l}}_{\text{Multiuser Multicell Interference}} + \underbrace{n_{k,l}}_{\text{Noise}}, \tag{4}$$

and from (4) the instantaneous SINR of user k on sub-carrier l can be written as,

$$\mathrm{SINR}_{k,l} = \frac{\left|\sum_{b=1}^{B} \sqrt{p_{b,k,l}}\,\mathbf{h}_{b,k,l}^H \mathbf{w}_{b,k,l}^{(type)}\right|^2}{\sum_{\substack{j=1\\ j\neq k}}^{K} \left|\sum_{b=1}^{B} \sqrt{p_{b,j,l}}\,\mathbf{h}_{b,k,l}^H \mathbf{w}_{b,j,l}^{(type)}\right|^2 + \sigma^2} \tag{5}$$

where type = {DZF,DVSINR}. Assuming M-ary QAM constellations, the instantaneous probability of error for user k and data symbol transmitted on subcarrier l is given by [11],

$$P_{e,k,l} = \psi Q\left(\sqrt{\beta SINR_{k,l}}\right) \tag{6}$$

where $Q(x) = \left(1/\sqrt{2\pi}\right)\int_x^\infty e^{-\left(t^2/2\right)} dt$, $\beta = 3/\left(M-1\right)$ and $\psi = \left(4/\log_2 M\right)\left(1 - 1/\sqrt{M}\right)$.

III. DISTRIBUTED PRECODER VECTORS

In this section we briefly describe the distributed precoding vectors, namely DZF and DVSINR, recently proposed. To design the distributed precoder vector we assume that the BSs share the data symbols and have only knowledge of local CSI, i.e., BS b knows the instantaneous channel vectors $\mathbf{h}_{b,k,l}, \forall k,l$, reducing the feedback load over the backhaul network as compared with the full centralized precoding approach.

A. Distributed Zero Forcing

We derive a distributed ZF transmission scheme with the phase of the received signal at each UT aligned. In this case, $\mathbf{w}_{b,k,l}^{(DZF)}$ in (4) is a unit-norm zero forcing vector orthogonal to $K-1$ channel vectors $\left\{\mathbf{h}_{b,j,l}^H\right\}_{j\neq k}$. Recently, several approaches to compute these precoder vectors have been proposed (e.g. in [8][9]). We briefly present the one derived in [9]. Let $\tilde{\mathbf{H}}_{b,k,l} = \left[\mathbf{h}_{b,1,l} \ \cdots \ \mathbf{h}_{b,k-1,l} \ \ \mathbf{h}_{b,k+1,l} \ \cdots \ \mathbf{h}_{b,K,l}\right]^H$ of size $(K-1)xN_{t_b}$ contain the channels of all users except *k*th. The SVD of $\tilde{\mathbf{H}}_{b,k,l}$ can be partitioned as follows,

$$\tilde{\mathbf{H}}_{b,k,l} = \mathbf{U}_{b,k,l}\boldsymbol{\Omega}_{b,k,l}\left[\ddot{\mathbf{W}}_{b,k,l} \ \ \bar{\mathbf{W}}_{b,k,l}\right]^H \tag{7}$$

where $\bar{\mathbf{W}}_{b,k,l} \in \mathbb{C}^{N_{t_b} \times (N_{t_b} - K + 1)}$ holds the $(N_{t_b} - K + 1)$ singular vectors in the null space of $\{\mathbf{h}_{b,j,l}^H\}_{j \neq k}$.The columns of $\bar{\mathbf{W}}_{b,k,l}$ are candidates for *k*'s precoding vector since they will produce zero interference at the other UTs. It can be shown that an optimal linear combination of these vectors can be given by [9],

$$\mathbf{w}_{b,k,l}^{(DZF)} = \bar{\mathbf{W}}_{b,k,l} \frac{\left(\mathbf{h}_{b,k,l}^H \bar{\mathbf{W}}_{b,k,l}\right)^H}{\left\| \mathbf{h}_{b,k,l}^H \bar{\mathbf{W}}_{b,k,l} \right\|} \quad (8)$$

The equivalent channel between BS b and UT k, on sub-carrier l can be expressed as,

$$\mathbf{h}_{b,k,l}^H \mathbf{w}_{b,k,l}^{(DZF)} = \mathbf{h}_{b,k,l}^H \bar{\mathbf{W}}_{b,k,l} \frac{\left(\mathbf{h}_{b,k,l}^H \bar{\mathbf{W}}_{b,k,l}\right)^H}{\left\| \mathbf{h}_{b,k,l}^H \bar{\mathbf{W}}_{b,k,l} \right\|} = \left\| \mathbf{h}_{b,k,l}^H \bar{\mathbf{W}}_{b,k,l} \right\| \quad (9)$$

From (9) we can observe that the equivalent channel, $\mathbf{h}_{b,k,l}^H \mathbf{w}_{b,k,l}^{(DZF)}$ is a positive real number and it can be shown that $\mathbf{h}_{b,k,l}^H \mathbf{w}_{b,k,l}^{(DZF)} \sim \chi^2_{2(N_{t_b} - K + 1)}$.

B. Distributed Virtual SINR

Intuitively, the maximal ratio transmission (MRT) is the asymptotically optimal strategy at low SNR, while ZF has good performance at high SNR or as the number of antennas increases. As discussed in [8], the optimal strategy lies in between these two precoders and cannot be determined without global CSI. However, inspired by the uplink-downlink duality for broadcast channels, the authors of [8] have derived a novel distributed virtual SINR precoder. The precoder vectors are achieved by maximizing the SINR-like expression in (10) where the signal power that BS *b* generates at UT k is balanced against the noise and interference power generated at all other UTs. It was named *distributed virtual SINR (DVSINR)* as it originates from the dual virtual uplink and does not directly represent the SINR of any of the links in the downlink. The precoder vectors are computed by

$$\mathbf{w}_{b,k,l}^{(DVSINR)} = \arg \max_{\|w\|^2 = 1} \frac{\left|\mathbf{h}_{b,k,l}^H \mathbf{w}\right|^2}{\sum_{\bar{k} \neq k} \left|\mathbf{h}_{b,\bar{k},l}^H \mathbf{w}\right|^2 + \frac{\sigma^2}{P_{t_b}}} \quad (10)$$

where P_{t_b} is the per-BS power constraints. The solution to (10) is not unique, since the virtual SINR is unaffected by the phase shifts in $\mathbf{w}$. One possible solution can be written as [8],

$$\mathbf{w}_{b,k,l}^{(DVSINR)} = \frac{\mathbf{C}_{b,k,l}^{-1} \mathbf{h}_{b,k,l}}{\left\| \mathbf{C}_{b,k,l}^{-1} \mathbf{h}_{b,k,l} \right\|} \quad (11)$$

where

$$\mathbf{C}_{b,k,l} = \frac{\sigma^2}{P_{t_b}} \mathbf{I}_{N_{t_b}} + \sum_{\bar{k} \neq k} \mathbf{h}_{b,\bar{k},l} \mathbf{h}_{b,\bar{k},l}^H \quad (12)$$

IV. POWER ALLOCATION STRATEGIES

In [9], we proposed power allocation approaches based on minimization of average BER, i.e. $\min_{\{p_{b,k,l}\}} \left(\frac{1}{KN_c} \sum_{l=1}^{N_c} \sum_{k=1}^{K} P_{e,k,l} \right)$ under per-BS power constraint. However, this strategy requires the knowledge of all equivalent channels, $\mathbf{h}_{b,k,l}^H \mathbf{w}_{b,k,l}^{(DZF)}$, $\forall b,k,l$ at the CU, to jointly compute the powers $p_{b,k,l}$, $\forall b,k,l$. In this paper we derive novel heuristic power allocation algorithms, computed at each BS in a distributed manner, based on minimization of the average VBER, defined below, considering only the knowledge of local CSI. It should be mentioned that in [7][8] some distributed power allocation algorithms were proposed to improve the sum rate. In [7] a very simple channel power splitting was considered and no optimization metric was assumed. In [8], a heuristic power allocation based on maximization of a metric related with the sum rate was derived. In this paper, the criteria used to design distributed power allocation essentially lead to a redistribution of powers among users and subcarriers, and therefore provides user fairness namely at the cell edges.

To derive the distributed power allocation we assume that the interference is negligible at both low and high SNR. Thus the same strategy can be used to deduce the power allocation for both precoders. Assuming interference free, (5) can be simplified as,

$$\mathrm{SNR}_{k,l} = \frac{\left| \sum_{b=1}^{B} \sqrt{p_{b,k,l}} \mathbf{h}_{b,k,l}^H \mathbf{w}_{b,k,l}^{(type)} \right|^2}{\sigma^2} \quad (13)$$

The above expression cannot be used to derive distributed power allocation because it requires the knowledge of nonlocal channel gains at BS *b*. Therefore, we define a *virtual* $\mathrm{SNR}_{b,k,l}$ seen by BS *b* to the UT *k* on subcarrier *l* as,

$$\mathrm{VSNR}_{b,k,l} = \left| \sqrt{p_{b,k,l}} \frac{\mathbf{h}_{b,k,l}^H \mathbf{w}_{b,k,l}^{(type)}}{\sigma} + d_{b,k,l} \right|^2 \quad (14)$$

for $d_{b,k,l} = \sum_{j=1, j \neq b}^{B} \sqrt{p_{j,k,l}} \frac{\mathbf{h}_{j,k,l}^H \mathbf{w}_{j,k,l}^{(type)}}{\sigma}$ the $\mathrm{VSNR}_{b,k,l}$ expression corresponds to the $\mathrm{SNR}_{k,l}$ one given by (13). In practice, two strategies can be considered to compute $d_{b,k,l}$, namely, it should be considered according to design parameters and tuned based on measured properties of the actual propagation environments or set it as $d_{b,k,l} = 0$. The latter strategy can be seen as the worst case (WC).

Based on (14) we define the average *virtual* BER as,

$$P_{av,b}^{virtual} = \frac{\psi}{KN_c} \sum_{l=1}^{N_c} \sum_{k=1}^{K} Q\left(\sqrt{\beta \mathrm{VSNR}_{b,k,l}}\right) \tag{15}$$

Note that (15) does not represent any real average BER. Considering the multicell system as a superposition of B single cell systems the overall average *virtual* BER can be seen as the average BER of an interference-free single cell system. The power allocation problem at each BS *b,* with per-BS power constraint, can be formulated as

$$\min_{\{p_{b,k,l} \geq 0\}} \left(\frac{\psi}{KN_c} \sum_{l=1}^{N_c} \sum_{k=1}^{K} Q\left(\sqrt{\beta \mathrm{VSNR}_{b,k,l}}\right) \right) \text{s.t.} \left\{ \sum_{l=1}^{N_c} \sum_{k=1}^{K} p_{b,k,l} \leq P_{t_b}, \forall b \right. \tag{16}$$

The Lagrangian associated with this problem is given by,

$$L\left(p_{b,k,l}, \mu\right) = \frac{\psi}{KN_c} \sum_{l=1}^{N_c} \sum_{k=1}^{K} Q\left(\sqrt{\beta \mathrm{VSNR}_{b,k,l}}\right) + \mu \left(\sum_{l=1}^{N_c} \sum_{k=1}^{K} p_{b,k,l} - P_{t_b} \right) \tag{17}$$

where $\mu \geq 0$ is the Lagrange multiplier [12]. Since the objective function is convex in $p_{b,k,l}$, and the constraint functions are linear, this is a convex optimization problem. It is necessary and sufficient to solve the Karush–Kuhn–Tucker (KKT) conditions. It can be shown that for $d_{b,k,l} = 0$, i.e. for the worst-case, the powers $p_{b,k,l}$ as function of the Lagrange multiplier μ are given by,

$$p_{b,k,l} = \frac{\sigma^2}{\beta \left(h_{b,k,l}^{eq}\right)^2} W_0 \left(\frac{\psi^2 \beta^2 \left(h_{b,k,l}^{eq}\right)^4}{8\pi\sigma^4 K^2 N_c^2 \mu^2} \right) \tag{18}$$

where $h_{b,k,l}^{eq} = \mathbf{h}_{b,k,l}^H \mathbf{w}_{b,k,l}^{(type)}$ and W_0 stands for Lambert's W function of index 0 [13]. This function $W_0(x)$ is an increasing function with $W_0(x) = 0,\ x = 0$ and $W_0(x) > 0,\ x > 0$. Therefore, μ^2 can be easily determined iteratively to satisfy $\sum_{l=1}^{N_c} \sum_{k=1}^{K} p_{b,k,l} = P_{t_b}$, by using the bisection method. This scheme is referred as DZF/VSINR minimum *virtual* BER worst case power allocation (DZF/VSINR MVBER WC).

For the case where $d_{b,k,l} \neq 0$, to the best of our knowledge no solution based on Lambert's W function can be derived, but the precoders can be computed by solving directly (16) using for example the interior-point method [14]. One possible selection of $d_{b,k,l}$ should be,

$$d_{b,k,l} = \sqrt{\frac{P_{t_b}}{N_{t_b} N_c}} \sum_{j=1, j \neq b}^{B} \sqrt{\frac{\mathrm{E}\left[\left|\mathbf{h}_{j,k,l}^H \mathbf{w}_{j,k,l}^{(type)}\right|^2\right]}{\sigma^2}} \tag{19}$$

Considering the DZF precoder the average power of the equivalent channels, $\mathbf{h}_{j,k,l}^H \mathbf{w}_{j,k,l}^{(type)}$, is given by,

$$\mathrm{E}\left[\left|\mathbf{h}_{j,k,l}^H \mathbf{w}_{j,k,l}^{(DZF)}\right|^2\right] = \left(N_{t_b} - K + 1\right) \rho_{j,k,l} \tag{20}$$

In this case the long term channel powers, $\rho_{j,k,l}, j \neq k$ should be either feedbacked from the UTs to the BS *b* or shared by the backhaul network. This scheme is referred as DZF minimum *virtual* BER long term channel power allocation (DZF MVBER LTC).

V. Numerical Results

In this section, the performance of the distributed power allocation strategies will be illustrated numerically. The scenario consists of K uniformly distributed single antenna UTs in a square with BSs in each of the corners. The power decay is proportional to $1/r^4$, where r is the distance from a transmitter. We define the SNR at the cell edge as $\mathrm{SNR} = \mathrm{P}_{t_b} \rho_c / N_c \sigma^2$, where the ρ_c represented the long term channel power in the center of the square. This represents a scenario where terminals are moving around in the area covered by 4 base stations each equipped with 4 antennas.

The main parameters used in the simulations are based on LTE standard [15]: FFT size of 1024; number of available subcarriers set to 128; sampling frequency set to 15.36 MHz; useful symbol duration is 66.6 μs, cyclic prefix duration is 5.21 μs; overall OFDM symbol duration is 71.86 μs; sub-carrier separation is 15 kHz, and modulation is QPSK. We used the LTE extended typical urban channel model (ETU) with 9 taps [16].

We compare the performance results of the proposed distributed power allocation schemes, DZF MVBER WC, DZF MVBER LTC and DVSINR MVBER WC. Also, these schemes are compared with two different power allocation strategies: equal power allocation approach, i.e., the power available at each BS is equally divided by the users and subcarrier, $p_{b,k,l} = P_{t_b} / KN_c$,$\forall(b,k,l)$, referred as (DZF EPA and DVSINR EPA); DZF with joint centralized power allocation as proposed in [9], referred to here as DZF centralized MBER power allocation (DZF CMBER).

Fig. 1 shows the performance results considering $K = 4$. The results are presented in terms of the average BER as a function of cell-edge SNR defined above. From the figure we can see that the performance of the proposed distributed power allocation schemes of the two approaches outperforms their equal power i.e. the DZF EPA and DVSINR EPA approaches, because they redistribute the powers across the different users and subchannels more efficiently. As can be seen in Fig. 1 the gain of power allocation schemes (DZF MVBER WC and DVSINR MVBER WC) is approximately 1dB (at target BER of 10^{-3}) when compared with the equal power strategy. The results show that knowing the non local LTC powers at each BS the performance can be improved namely at high SNR regime, we can observe a gain of approximately 0.5dB of the DZF MVBER WC against DZF MVBER LTC, at target BER of 10^{-3}. Also, the performance can be much improved whether the powers are computed, to minimize the real average BER,

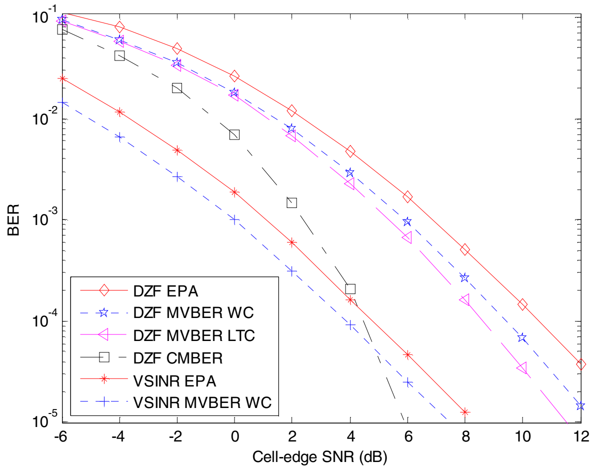

Fig. 1: Performance evaluation of the distributed power allocation schemes for $K = 4$.

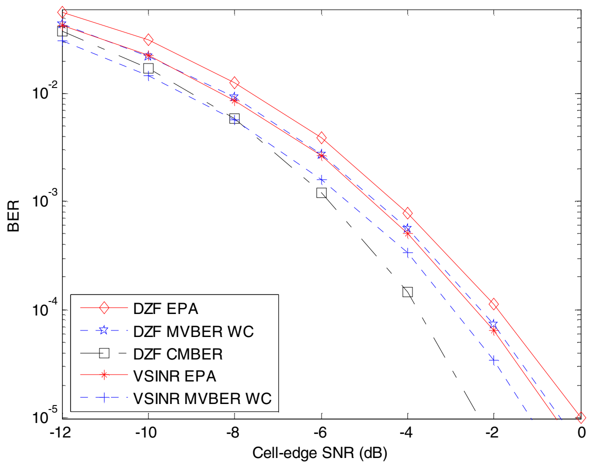

Fig. 2: Performance evaluation of the distributed power allocation schemes for $K = 2$.

jointly at the CU (≈3 dB gain of the DZF CMBER PA against the DZF MVBER WC at target BER of 10^{-3}). However, this strategy requires more feedback load over the backhaul network as compared with the full distributed approaches.

Fig. 2 shows the performance results when the number of UTs is reduced to 2. In this scenario the DoF of the equivalent ZF channels variables, given by $2\left(N_{t_b} - K + 1\right)$, increases from 2 to 6. It can be observed that increasing the DoF, the DZF tends to the DVSINR. This behaviour is similar to the single cell systems where the precoders based on ZF criterion tends to the ones based on MMSE as the number of transmit antennas (or DoF) increases or at high SNR. From the results we can see that the gains obtained with power allocation schemes are lower, as compared to EPA, than in the previous scenario. Also, the gain obtained with the centralized power allocation is lower than the one achieved with full distributed approaches. In this plot, the curve for the approach DZF MVBER LTC is omitted for clarity, since its performance is approximately the same as DZF MVBER WC.

VI. Conclusions

We proposed novel heuristics distributed power allocation schemes for distributed precoding schemes, namely DZF and DVSINR, and for the downlink multicell MISO-OFDM based systems. Both the precoders and power allocation schemes were computed at each base station just by assuming the knowledge of local CSI or long term channel non local statistics. The metric used to derive the power allocation schemes especially provides user's fairness at the cell edges. The results have shown that the proposed distributed power allocation schemes outperform the equal power ones, at cost of moderate complexity. Also, when the number of DoF of the equivalent channel variables increases the performance of the distributed approaches tends to the centralized power allocation ones recently proposed.

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