Data Sharing Coordination and Blind Interference Alignment for Cellular Networks

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***Abstract*—We consider coordination in a multi-user multiple input single output cellular system. In contrast with existing base station cooperation methods that rely on sharing CSI with or without user data to manage interference, we propose to share user data only. We consider a system where blind interference alignment (BIA) is applied to serve multiple users in each cell. We apply interference coordination through data sharing to mitigate other-cell interference at the cell-edge users. While BIA mitigates intra-cell interference in MU-MISO systems, it does not address the problem of inter-cell interference. We apply interference coordination through data sharing to mitigate inter-cell interference at the cell-edge users. We propose a new cooperative BIA scheme that takes into account the users whose data is being shared between adjacent base stations. We derive the achievable sum rate with interference mitigation and we compare it to achievable rates with the original BIA strategy. Numerical results show that the achievable sum rate of the cell-edge users with data sharing decreases with increasing number of served users in each cell and increasing number of antennas at the base stations.**

I. Introduction

Coordinating transmissions in a multi-user multiple input single output (MU-MISO) cellular system can mitigate interference and increase data rates [1], [2]. To realize coordination gains, base stations exchange user data and/or channel state information (CSI) via backhaul links. Coordination strategies that share both CSI and transmission data in general achieve the highest sum rates. These gains are however contingent on the availability of sufficiently accurate CSI at the transmitters (CSIT). Unfortunately, in most communication systems, this becomes an issue as CSI has to be estimated at the receivers and fed back, incurring both a signaling overhead and imperfect CSI rate penalty [3], [4]. The gains from conventional base station coordination methods are thus limited by the CSI quality at the transmitters, and coordination schemes that do not require CSIT nor CSIT sharing between the base stations are of interest.

Most prior work on coordination in MU-MISO cellular systems can be divided into coordination using user data and CSI exchange, otherwise known as network MIMO [1], [5] and coordination using CSI exchange only [2]. While most work reported gains assuming perfect CSI at the transmitters, the effects of CSI overhead and distortion on the gains from cooperation were investigated in [3], [4], [6], and shown to limit the gains from coordination [3]. In this paper, we propose coordinating transmissions through user data exchange only to mitigate interference in multi-cell MU-MISO systems. Exchanging user data only removes the dependence of base station coordination on CSI overhead and estimation errors. To realize the benefits of coordination through data sharing, we propose to use a technique known as blind interference alignment (BIA) [7]. BIA has recently emerged as a class of methods that enable the design of MU-MISO systems with no CSI at the transmitters. The BIA scheme uses antenna switching at the receivers to achieve degrees of freedom gains over conventional SU-MIMO systems. BIA performance in a clustered cellular environment has been investigated in [8], [9]. Aligned code structures between adjacent base stations have been shown to yield the best sum rates in cellular networks. Prior work [8], [9] did not consider however an active transmission strategy to mitigate interference in BIA-based MU-MIMO cellular networks.

In this paper, we propose a new cooperative BIA scheme to mitigate interference at the cell-edge users in a two-cell system. We assume that each base station shares the user data of its cell-edge users with the interfering base station to improve the service quality of these users. This one-way sharing scheme enables both base stations to jointly serve the cell-edge users, thereby eliminating their interference. The two base stations then design their BIA codes, taking into account the shared users. To maintain alignment between the BIA codes in both cells, the same number of users are served in the two cells. The non-shared users see interference from data streams corresponding to one user in the adjacent cell. We derive expressions for the achievable sum rates at the shared users and the non-shared users using the new cooperative scheme. We compare the sum rate to that achieved with no cooperation between the two base stations. Numerical results show that the achievable sum rate of the cell-edge users with data sharing decreases with increasing number of served users in each cell, and increasing number of transmit antennas at each base station.

II. Problem Formulation

Consider a two-cell MU-MISO system with K active users in each cell, as shown in Figure 1. The two cells can be

This work was done while Salam Akoum was an intern at the department of Network Technologies, Alcatel-Lucent Bell Labs.

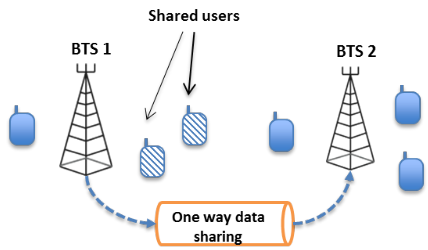

Fig. 1. A two-cell system with one-way data sharing.

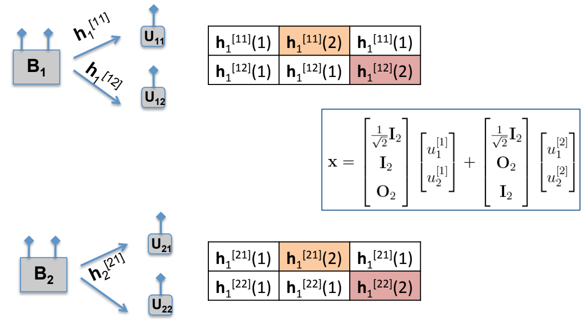

Fig. 2. BIA for $N_\mathrm{t} = 2$ and $K = 2$, with no other-cell interference.

either same-tier interferers such as two macrocells or two small cells, or cross-tier interferers, such as a small cell interfering with a macrocell on the downlink. The base stations are equipped with N_t antennas while the users are equipped with single reconfigurable antennas. The reconfigurable antennas can switch between N_t preset modes, such that each mode sees a channel that is independent of the channels seen by other modes. We denote the channel between base station $\mathrm{B}_i, i \in 1, 2$ and user k in cell j, associated with antenna mode $m \in \{1, 2, \cdots, N_\mathrm{t}\}$ by $\mathbf{h}_i^{[jk]}(m) \in \mathbb{C}^{1\times N_\mathrm{t}}$.

The signal transmitted to the k-th user in the i-th cell is denoted by $\mathbf{u}^{[ik]} = \left[u_1^{[ik]} \cdots u_m^{[ik]} \ \cdots \ u_{N_\mathrm{t}}^{[ik]}\right]^\mathrm{T}$ with $u_m^{[ik]}$ denoting the m-th data stream of user k. The received powers at user k, subject to large scale fading including path-loss and shadowing, are denoted by $\gamma_{k,\mathrm{d}}$ and $\gamma_{k,\mathrm{i}}$ from the desired and interfering base station, respectively. The interfering signal power and the desired signal power are such that $\gamma_{k,\mathrm{d}}/\gamma_{k,\mathrm{i}} = \alpha_k$ where α_k is the signal-to-interference ratio (SIR) at user k. α_k is a function of the user location in the cell and the transmit powers $\mathrm{P}_i, i \in 1, 2$ at the base stations. Without loss of generality, we consider cell 1 to be the cell of interest. The discrete-time input-output relationship for user k in cell 1 is given by

$$y^{[1k]}(n) = \mathbf{h}_1^{[1k]}(m)\mathbf{x}_1(n) + \sqrt{\alpha_k}\mathbf{h}_2^{[1k]}(m)\mathbf{x}_2(n) + z^{[1k]}(n), \tag{1}$$

where $y^{[1k]}(n)$ denotes the received signal at user k in time slot n, and m denotes the antenna mode used during the same slot. The vectors $\mathbf{x}_1(n)$ and $\mathbf{x}_2(n)$ are the n-th transmitted symbols at B_1 and B_2, respectively. $z^{[1k]}(n)$ is the additive white Gaussian noise at user k, with variance 1.

We assume that the base stations do not have CSIT and that blind interference alignment [7] is applied in each cell, to serve the K users. The BIA approach requires $N_\mathrm{t} + K - 1$ time slots to transmit the desired signals, interference-free to the receivers. In what follows, we briefly explain BIA on the downlink, and we show how it is extended to cellular systems. We then proceed to explain the data sharing interference mitigation scheme proposed in this paper.

III. Blind Interference Alignment

BIA enables the design of MU-MISO systems with no CSIT at the base stations. It is a block coding scheme in which a base station serves K users in $N_\mathrm{t} + K - 1$ channel uses. The key to BIA is that even without knowing the channel values at the transmitters, if the channel of the desired signal is changed at the desired receiver while the channels of the interfering signals remain constant, the desired data streams are distinguishable at the desired receiver [7]. Each user gets N_t different looks at his N_t symbols corrupted by the same interference, allowing cancellation by simple subtract. Antenna switching is essential to achieve degrees of freedom gains in BIA. Without antenna switching, all the channels are equivalent and the achievable rate reduces to that of a single user MISO channel with no CSIT. We first consider BIA in a MU-MISO single cell setup, we then review results on BIA in a two-cell scenario with no active interference mitigation.

A. BIA MU-MISO

We define the matrix of channel vectors corresponding to the different antenna modes for user k in cell i as

$$\mathbf{H}^{[ik]} = \left[\mathbf{h}^{[ik]^\mathrm{T}}(1) \cdots \mathbf{h}^{[ik]^\mathrm{T}}(N_\mathrm{t})\right]. \tag{2}$$

We require that the values of the channels $\{\mathbf{h}^{[ik]^\mathrm{T}}(1), \cdots, \mathbf{h}^{[ik]^\mathrm{T}}(N_\mathrm{t})\}$ remain constant for the duration of a single instance of the BIA scheme. To illustrate BIA, consider as a toy example a single cell scenario with $N_\mathrm{t} = 2$ and $K = 2$ as illustrated in Figure 2. Each base station sends 2 scalar symbols to each user in $N_\mathrm{t} + K - 1 = 3$ time slots, achieving $N_\mathrm{t}K/(N_\mathrm{t} + K - 1) = 4/3$ degrees of freedom [8]. In the first time slot, corresponding to alignment block 1, a linear combination of the symbols of both users is transmitted. During the second alignment block, each received symbol is used to remove the interference caused by the data stream corresponding to the other user in the first alignment block. The same antenna mode as that used in the first alignment block is used in this block. One extra slot is needed using the N_t-th antenna mode to transmit the user's desired symbol. For the $K = 2$, $N_\mathrm{t} = 2$ case, the transmitted symbols over 3 time slots is given by

$$\begin{bmatrix} \mathbf{x}_1(1) \\ \mathbf{x}_1(2) \\ \mathbf{x}_1(3) \end{bmatrix} = \begin{bmatrix} \frac{1}{\sqrt{2}}\sum_{k=1}^{2}\mathbf{u}^{[1k]} \\ \mathbf{u}^{[11]} \\ \mathbf{u}^{[12]} \end{bmatrix}, \tag{3}$$

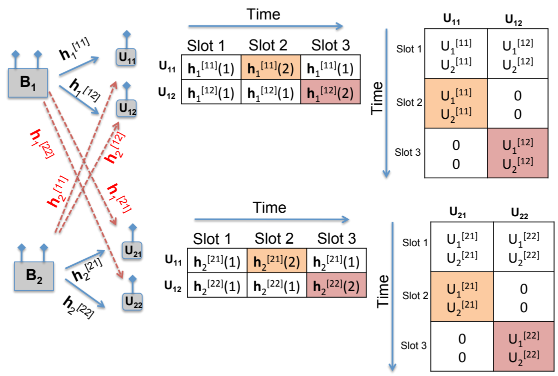

Fig. 3. BIA for $N_\mathrm{t} = 2$ and $K = 2$ in a two cell setup. Cells apply a synchronous aligned BIA code structure.

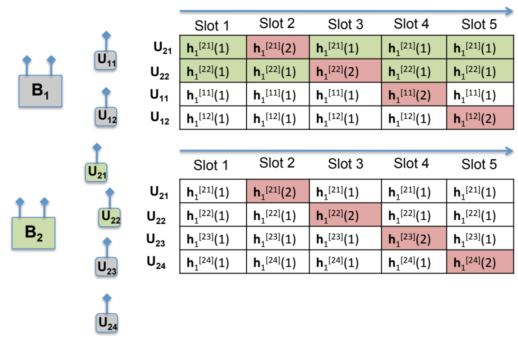

Fig. 4. BIA for $N_\mathrm{t} = 2$, $K = 2$, and $K_\mathrm{sh} = 2$ in a two cell setup. Cells coordinate to jointly serve users 1 and 2 from cell 2, and apply a synchronous aligned BIA code structure over 5 time slots to serve 4 users in total in each cell otherwise.

where the same power constraint is applied on all the time slots. This transmission pattern follows the predetermined switching patterns of the antennas at the receivers, $\{(1),(2),(1)\}$ for receiver 1, and $\{(1),(1),(2)\}$ for receiver 2, as shown in Figure 2. The received signal at user 1 is given by

$$\begin{bmatrix} y^{[11]}(1) \\ y^{[11]}(2) \\ y^{[11]}(3) \end{bmatrix} = \begin{bmatrix} \frac{1}{\sqrt{2}}\mathbf{h}_1^{[11]}(1) \\ \mathbf{h}_1^{[11]}(2) \\ \mathbf{O}_2 \end{bmatrix} \mathbf{u}^{[11]} + \begin{bmatrix} \frac{1}{\sqrt{2}}\mathbf{h}_1^{[11]}(1) \\ \mathbf{O}_2 \\ \mathbf{h}_1^{[11]}(1) \end{bmatrix} \mathbf{u}^{[12]} + \mathbf{z}^{[11]}$$

where $\mathbf{O}_2$ is the zero vector of size 1×2 and $\mathbf{z}^{[11]} = \left[z^{[11]}(1)\ z^{[11]}(2)\ z^{[11]}(3)\right]^\mathrm{T}$ is the vector of thermal noise at receiver 1. To remove the interference, we subtract $y^{[11]}(3)$ from $y^{[11]}(1)$ following a Zero Forcing (ZF) cancellation

$$\begin{bmatrix} \tilde{y}^{[11]}(1) \\ \tilde{y}^{[11]}(2) \end{bmatrix} = \begin{bmatrix} \mathbf{h}_1^{[11]}(1) \\ \mathbf{h}_1^{[11]}(2) \end{bmatrix} \mathbf{u}^{[11]} + \begin{bmatrix} \sqrt{2}z^{[11]}(1) - z^{[11]}(3) \\ z^{[11]}(2) \end{bmatrix}. \quad (4)$$

Although the interference is completely removed at the receivers in (4), the noise power in the first time slot is still amplified. This leads to a lower achievable rate in the low SNR regime.

In general, for the K-user $N_\mathrm{t} \times 1$ MU-MISO channel, a total of $N_\mathrm{t}K/(N_\mathrm{t}+K-1)$ degrees of freedom can be achieved [7]. The achievable sum rate with a constant transmit power constraint on all time slots is given by, [9]

$$\mathrm{R_s} = \sum_{k=1}^{K} \frac{1}{N_\mathrm{t}+K-1} \mathbb{E}\left[\log_2 \det\left(\mathbf{I} + \frac{\mathrm{P}_i}{N_\mathrm{t}} \mathbf{H}^{[ik]} \mathbf{H}^{[ik]^\dagger}\right)\right] \quad (5)$$

where $\mathbf{H}^{[ik]} = \left[\frac{\mathbf{h}^{[ik]^\mathrm{T}}(1)}{\sqrt{2K-1}}, \cdots, \frac{\mathbf{h}^{[ik]^\mathrm{T}}(N_\mathrm{t}-1)}{\sqrt{2K-1}}, \mathbf{h}^{[ik]^\mathrm{T}}(N_\mathrm{t})\right]^\mathrm{T}$.

B. BIA MU-MISO in a Two Cell System

Single cell blind interference alignment can be applied on the downlink of a MU-MISO system to cancel intra-cell interference, but cannot mitigate other-cell interference. An aligned BIA structure was proposed in [8] to minimize other-cell interference at the receivers. Aligning the BIA code structures at the interfering base stations allows the receivers to see inter-cell interference corresponding to only one user's data stream, thus eliminating a significant portion of the observed inter-cell interference. For the aligned BIA code, $\mathbf{x}_1$ and $\mathbf{x}_2$ in (1) follow the same code structure. We consider for illustration the $(N_\mathrm{t} = 2, K = 2)$ example as shown in Figure 3. The transmitted symbols $\mathbf{x}_2$ intended for users in cell 2 are given by (3), replacing $\mathbf{u}^{[1k]}$ by $\mathbf{u}^{[2k]}$. The post-ZF received signal at receiver 1 in cell 1 with other-cell interference is given by

$$\tilde{\mathbf{y}}^{[11]} = \begin{bmatrix} \mathbf{h}_1^{[11]}(1) \\ \mathbf{h}_1^{[11]}(2) \end{bmatrix} \mathbf{u}^{[11]} + \sqrt{\alpha_1} \begin{bmatrix} \mathbf{h}_2^{[11]}(1) \\ \mathbf{h}_2^{[11]}(2) \end{bmatrix} \mathbf{u}^{[21]} + \tilde{\mathbf{z}}^{[11]}, \quad (6)$$

where user 1's coded transmission in cell 1 is synchronized with user 1's transmission in cell 2. Thus receiver 1 in cell 1 sees inter-cell interference from user 1 in cell 2.

In general, for synchronous aligned BIA transmission structure in a two-cell system, the achievable sum rate in the cell of interest, assuming the instantaneous covariance of the interference signal is unknown at the k-th receiver, is given by, [9]

$$\mathrm{R_{AL}} = \sum_{k=1}^{K} \frac{1}{N_\mathrm{t}+K-1} \times \mathbb{E}\left[\log_2 \det\left(\mathbf{I} + \frac{\mathrm{P}_i}{N_\mathrm{t}} \mathbf{H}^{[ik]} \mathbf{H}^{[ik]^\dagger} \left(\mathbf{R}_\mathrm{I}\right)^{-1}\right)\right] \quad (7)$$

where $\mathbf{R}_\mathrm{I} = \mathbf{R}_{\tilde{z}} + \frac{\mathrm{P}_i}{N_\mathrm{t}}\alpha_k N_\mathrm{t}\mathbf{I}$,

$$\text{and } \mathbf{R}_{\tilde{z}} = \begin{bmatrix} (2K-1)\mathbf{I}_{N_\mathrm{t}-1} & \mathbf{O} \\ \mathbf{O} & 1 \end{bmatrix}.$$

IV. Cellular BIA with Data Sharing

The synchronous aligned BIA transmission structure, although minimizing interference at each receiver, does not actively mitigate inter-cell interference. This inter-cell interference is especially harmful for the cell-edge users. To overcome interference, and increase the average rate of cell-edge users, with no CSIT at the base stations, we propose interference mitigation through information data exchange or data sharing between the base stations.

To illustrate this concept, consider for example the two cell system depicted in Figure 1. Each base station serves multiple active users in each cell. Users 1 and 2 are subject to strong interference from base station 2, these users are dubbed *victim* users and their serving base station is dubbed victim base station. Strong interference can occur for example in a one-tier cellular system, when users are at the cell-edge, or in a two-tier cellular network, when a mobile user attached to a macro base station is subject to strong interference from an adjacent small cell base station. To improve the service quality of the *victim* users, the interfering base station acquires their data information. The information can be shared from the victim base station on the backhaul link or can be provided directly from the network controller. The victim and interfering base stations then cooperate to jointly serve the victim users. Note that data sharing in this scenario is triggered on demand, in the event of unsatisfactory quality of service at the mobile users. It is a one-way sharing scheme, in the sense that information exchange occurs from victim to interfering base station only, with no exchange required in the other direction.

As the base stations have no CSIT, and apply an aligned BIA code structure on the downlink to serve their respective users, we propose an augmented aligned BIA structure to accomodate the shared users in the victim and interfering cells. The augmented code at both base stations is aligned to minimize interference at the non-shared users, while completely eliminating interference at the shared (victim) users. For illustration, assume that 2 users $k = 1, 2$ in cell 2 are victim users, and their information is shared with base station 1, as shown in Figure 4. Base station 1 now applies BIA to serve 4 users in $N_\mathrm{t} + K + K_\mathrm{sh} - 1 = 5$ time slots, where K_sh is the number of shared users. To completely eliminate interference at the shared users, their data streams need to be transmitted synchronously at both base stations. In the example illustrated in Figure 4, the shared users' data streams occupy the first slots in the alignment blocks at B_1 and B_2. Furthermore, to minimize inter-cell interference at the non-shared users, an aligned BIA structure with ($N_\mathrm{t} = 2$, $K+K_\mathrm{sh}$) is applied at both cells. The aligned BIA structure requires 5 time slots to serve the users in cell 1. To avoid wasting time resources, base station 2 schedules two new non-victim users to be served in the same BIA instance. Consequently, the base stations serve in total 6 users in 5 time slots. The post-ZF received signal at victim user 1 is given by

$$\begin{bmatrix} \tilde{y}^{[21]}(1) \\ \tilde{y}^{[21]}(2) \end{bmatrix} = \begin{bmatrix} \mathbf{h}_2^{[21]}(1) + \sqrt{\alpha_1}\mathbf{h}_1^{[21]}(1) \\ \mathbf{h}_2^{[21]}(2) + \sqrt{\alpha_1}\mathbf{h}_1^{[21]}(2) \end{bmatrix} \mathbf{u}^{[21]} + \tilde{\mathbf{z}}^{[21]}.$$

For the non-shared users, the post-ZF received signal is given by (6) with the transmitted powers adjusted according to the new number of users, $K + K_\mathrm{sh}$ in each cell.

In the general N_t, K case, with data sharing BIA, the number of users increase from K to $K+K_\mathrm{sh}$ in each cell. For the shared users, the achievable sum rate with ZF interference cancellation is given by

$$\mathrm{R}_\mathrm{shared} = \sum_{k=1}^{K_\mathrm{sh}} \frac{1}{N_\mathrm{t} + K + K_\mathrm{sh} - 1} \times \mathbb{E}\left[\log_2 \det\left(\mathbf{I} + \frac{\mathrm{P}_i}{N_\mathrm{t}}\tilde{\mathbf{H}}^{[ik]}\tilde{\mathbf{H}}^{[ik]\dagger}\right)\right] \quad (8)$$

where

$$\tilde{\mathbf{H}}^{[ik]} = \left[\frac{\mathbf{h}_i^{[ik]^\mathrm{T}}(1)+\sqrt{\alpha_k}\mathbf{h}_j^{[ik]^\mathrm{T}}(1)}{\sqrt{2(K+K_\mathrm{sh})-1}} \cdots \frac{\mathbf{h}_i^{[ik]^\mathrm{T}}(N_\mathrm{t}-1)+\sqrt{\alpha_k}\mathbf{h}_j^{[ik]^\mathrm{T}}(N_\mathrm{t}-1)}{\sqrt{2(K+K_\mathrm{sh})-1}} \quad \mathbf{h}_i^{[ik]^\mathrm{T}}(N_\mathrm{t}) + \sqrt{\alpha_k}\mathbf{h}_j^{[ik]^\mathrm{T}}(N_\mathrm{t})\right]^\mathrm{T}.$$

For the non-shared users, the achievable sum rate with ZF interference cancellation in the victim cell follows from that of the synchronous aligned BIA transmission rate, with K replaced by $K + K_\mathrm{sh}$,

$$\mathrm{R}_\mathrm{Au-AL} = \sum_{k=1}^{K} \frac{1}{N_\mathrm{t} + K + K_\mathrm{sh} - 1} \times \mathbb{E}\left[\log_2 \det\left(\mathbf{I} + \frac{\mathrm{P}_i}{N_\mathrm{t}}\mathbf{H}^{[ik]}\mathbf{H}^{[ik]\dagger}(\mathbf{R}_\mathrm{I})^{-1}\right)\right] \quad (9)$$

where $\mathbf{H}^{[ik]}$ is given by (2), $\mathbf{R}_\mathrm{I} = \mathbf{R}_{\tilde{z}} + \frac{\mathrm{P}_i}{N_\mathrm{t}}\alpha_k N_\mathrm{t}\mathbf{I}$,

$$\text{and } \mathbf{R}_{\tilde{z}} = \begin{bmatrix} (2(K+K_\mathrm{sh})-1)\mathbf{I}_{N_\mathrm{t}-1} & \mathbf{O} \\ \mathbf{O} & 1 \end{bmatrix}.$$

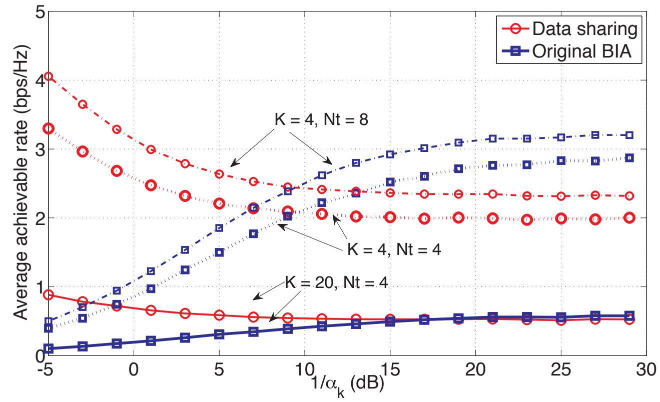

Fig. 5. Average achievable rate of victim users with and without interference mitigation through data sharing. SNR at the users is fixed at 15 dB and the number of shared users is $K_\mathrm{sh} = 2$. The figure shows the average achievable sum rate for different K and N_t values.

V. Simulation Results and Discussion

In this section, we present simulation results to illustrate the performance of interference mitigation through data sharing. We compare the performance of BIA with data sharing (original BIA), to that of BIA with no data sharing, in a two-cell setup, with varying signal-to-interference-ratio at the receivers.

Figure 5 plots the achievable sum rate of the victim users versus the path-loss ratio $\gamma_{i,k}/\gamma_{i,d} = 1/\alpha_k$. We assume that the SNR at the victim user is fixed at 15 dB, and we vary

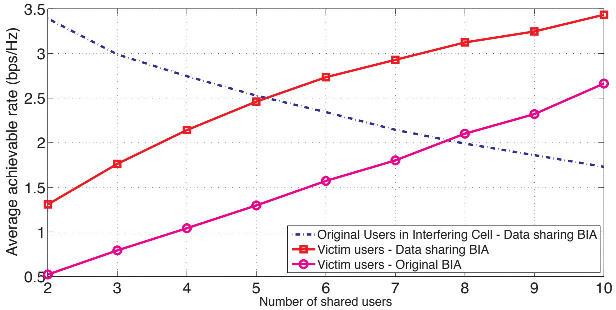

Fig. 6. Average achievable rate of victim and legacy users (not shared users in helper cell) with and without interference mitigation through data sharing versus the number of shared users. SNR is fixed at 15 dB and the number of legacy users is $K = 8$. The number of antennas at the base stations $N_{\mathrm{t}} = 4$.

the distance from the user to the interfering base station. The number of victim users is equal to $K_{\mathrm{sh}} = 2$. The achievable sum rate for both the proposed data sharing strategy and the original BIA strategy are shown. Figure 5 shows that as the victim users move away from the interfering base station, the benefits from coordination through data sharing decreases, and the crossing point between the achievable sum rate with coordination and without coordination depends on the number of users K served simultaneously in each cell, and the number of antennas N_{t} at each base station. For large number of users $K = 20$, the crossing point for data sharing and no data sharing occurs at $-10\log_{10}(\alpha_k)$ of 15 dB. The achievable sum rate at higher $-10\log_{10}(\alpha_k)$ values is almost the same for both schemes. This is because the resources of the interfering cell are divided among a large number of users, and the ratio of the added users K_{sh} to the number of users K is small. When the number of users in the system is small, however, the crossing point occurs earlier, at an average $-10\log_{10}(\alpha_k)$ of 9 dB for $K = 4$ and $N_{\mathrm{t}} = 4$. Similarly, when the number of antennas at the base stations is increased from $N_{\mathrm{t}} = 4$ to $N_{\mathrm{t}} = 8$, for a fixed number of users $K = 4$, the crossing point shifts to 10 dB, and a higher sum rate in achieved. In general, coordination is most beneficial at low SIR values. The achievable sum rate of the victim users increases when the number of users served simultaneously in each cell decreases, or when the number of antennas at each base station increases.

Figure 6 plots the achievable sum rate versus the number of shared or victim users K_{sh}. We assume that the transmit power at the cell of interest is fixed at 15 dB, and the SIR at the victim users is on average 2 dB. The SIR at the non-victim users is assumed on average to be 10 dB. The number of users served per cell, before data sharing, is fixed at $K = 8$, and the number of antennas at each base station is $N_{\mathrm{t}} = 4$. Figure 6 shows that the achievable sum rate of the victim users, when shared, is on average twice that of the achievable rate without sharing, using the original synchronous aligned BIA scheme. The achievable sum rate for both BIA-sharing and the original BIA increases with increasing number of victim users.

Figure 6 also shows the achievable sum rate at the receivers in the interfering cell, whose resources are being shared with the victim users from the other cell. Consider for example the scenario where a small cell is helping the victim users of the macro cell by serving them through data sharing. Although the rate of the shared macrocell receivers increases, the average sum rate of the small cell users decreases, as their resources are now being shared among more receivers $(K + K_{\mathrm{sh}})$. As the number of victim users increases, the achievable sum rate for the *original* receivers in the interfering cell decreases.

VI. Conclusion

In this paper, we proposed interference mitigation through exchange of user data only in a MU-MISO cellular system. We designed a BIA transmission scheme that takes into account shared users between the adjacent base stations. We derived expressions for the achievable sum rates at the shared and the non-shared users, as a function of the number of users in each cell, the number of antennas at each base station, and the signal-to-interference ratio at the shared users. We showed that data coordination provides considerable gains in cellular networks, when the users are at the cell-edge. These gains increase with increasing number of antennas, and decreasing number of scheduled users in each cell. The main takeaway from this paper is that cooperative schemes through exchange of user data only are beneficial for cellular systems. Such coordination does not suffer from CSI overhead and imperfections, and should be considered to improve the service quality of cell-edge users in both homogeneous and heterogeneous cellular networks. Future work includes investigating the overhead of the BIA techniques in terms of information required at the receiver, and time slots extensions needed to transmit the data streams. It also includes generalizing the current system to a system with multiple interferers.

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