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Performance Analysis of Coordination Strategies in Multi - Tier Heterogeneous Network

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Abstract : **Heterogeneous networks (HetNet) are a hopeful technology for 5g wireless networks, which considerably outcomes with higher capacity and coverage compared with the traditional cellular wireless networks. These networks are made up of a macro base station outfits with a vast number of antenna and dense of small cells. Because of deployment and same frequency band, high level of interference may arise between small cells and macro base station. The proposed system is formed with multiple input multiple output (MIMO) and coordinated beamforming design in a two tie heterogeneous network to alleviate interference. Target of this work is to inspect different beamforming strategies in conjunction with different degrees of coordination between the base stations. The simulation results indicate that the proposed coordinate beamforming scheme outperforms the conventional interference mitigation schemes.**

Keywords — ***Coordinated beamforming, Heterogeneous network, Massive MIMO, Macro Base station, Signal to leakage beamforming, Zero forcing beamforming***

I. INTRODUCTION

Effective network planning is necessary to cope with the growing mobile broadband data subscribers and bandwidth intensive services striving against for limited radio resources [1]. This leads to the development of alternate solution to increase capacity and higher data rates (i.e).to transform conventional homogenous network into heterogeneous networks this consists of adding low power nodes, femto nodes ,relay nodes to the existing homogeneous network [2][3]. The situation worsens as density of node increases i.e both inter cell interference and intra cell interference emanate [4].Thus affecting solemnly the gain attained by the aforesaid schemes[5].This calls for coordinated beamforming that serve to vanish the intra cell and cross tier interference. Evaluating the performance of these schemes is the main focus of the present work.

Coordinated beamforming depends on channel state information between the coordinated base station of both desire and non-desired channels. This channel state information is utilized in the precoding of the transmitted signals in order to vanquish imprudent inter base station interference and optimize a desired network utility. The CSI can be interchanged via backhaul channels. There are two types of namely zero forcing and SLNR of CBF are considered. It has been applied in coordinated MIMO networks in a homogeneous system setting [8].Coordinated ZFBF enables absolute cancellation of intra-cell and inter-cell interference when faultless CSI is obtainable, but demands for least number of transmit antennas tends to diminish the received signal power. Coordinated SLNR-MAX overcomes the limitation of ZFBF in the requirement of number of transmit antennas [7] and also helps to discover the balance between maximizing signal power and vanquish interference. A differentiation between the two precoding techniques in a non-cooperative MU-MIMO system is described in [9] .In this proposed work theoretical analysis is carried out for both coordinated ZFBF and coordinated SLNR-MAX with different degrees of coordination. This study is based on the asymptotic regime in which the number of antennas at the BSs and that of users increase simultaneously large with the same pace, permitting us to tackle mathematical results from random matrix theory.

II. SYSTEM MODEL

For the proposed system we examine TDD downlink transmission in a two-tier heterogeneous network which composed of L cell where cell 1 belongs to macro cell base station and cell 2….L are multiple inner micro base stations. We consider that cell j has only one base station having M_j antennas to serve its linked Kj mono antenna users. We represent $h_{j,l,k}$ the M_j x 1 channel vector between Kth user located in the l-th cell and cell j. The macro cell base station users (MUE) are considered to be distributed uniformly within the entire coverage area and the micro cell users are distributed uniformly over a circle of radius R around their corresponding micro base station. We consider that the j-th base station employ Gaussian codebook and linear precoding . We represent $h_{j,k}$ and $S_{j,k}$ *(N(0,1))* by precoding vector and the data symbol match up with

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transmission between the j-th cell and its corresponding k-th UE. The transmit signal x_j from the j^{th} cell stated as

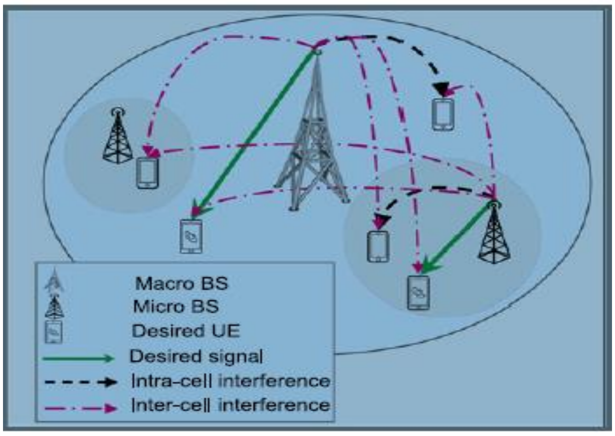

Figure 1 Two-tier Heterogeneous Network

$$X_j = \sum_{k=1}^{Kj} W_{j,k}\ S_{j,k} \qquad (1)$$

where Wj,k is a precoding vector and S j,k refers to data symbols. The received signal in the cell j at the k^{th} user equipment can be decomposed as

$$Y_{j,k} = h^H{}_{j,j,k} W_{j,k} S_{j,k} + \sum_{(l,i)\neq(j,k)} h^H{}_{l,j,k} W_{l,i} S_{l,i} + n_{j,k} \qquad (2)$$

where $n_{j,k} \sim CN(0,\sigma^2 I_{Mj})$ represents additive white Gaussian noise. We presume that all the antennas of all cells are uncorrelated. In this circumstances the channel vector $h_{j,l,k}$ model is given by[13]

$$h_{j,l,k} = \sqrt{P_{j,l,k}}\ z_{j,l,k} \qquad (3)$$

where $z_{j,l,k}$ states that small scale fading channel and $P_{j,l,k}$ refers that the total power received at the k^{th} UE from the j^{th} cell. Consider the model for $P_{j,l,k}$ as in [13]

$$P_{j,l,k} = (P_j / K_j)\alpha_{j,l,k} \qquad (4)$$

where (P_j / K_j) is the amount of power allocated for each user equipment. $\alpha_{j,l,k}$ the average channel attenuation between base station j and user K Considering same model as in [11]

$$\alpha_{j,l,k} = (1/ d_{j,l,k})^{\eta_j}\ \phi_{j,l,k} \qquad (5)$$

where $d_{j,l,k}$ defines the distance between the serving base station and the relevant UE. The exponent η is used as pathloss and ϕ indicates the correlated shadow fading. The SINR at the k-th UE served by BS j is given by **as** in [13]

$$\mathbf{SINR_{j,k}} = \frac{\left|h^H{}_{j,j,k} W_{j,k}\right|^2}{\sum_{i=1,i\neq k}^{k_j}\left|h^H{}_{j,j,k} W_{j,i}\right|^2 + \sum_{l=1,l\neq j}^{L}\sum_{i=1}^{K_j}\left|h^H{}_{l,j,k} W_{l,i}\right|^2 + \sigma^2}$$

$$= \frac{S_{j,k}}{I_{j,k}^{intra} + \sum_{l=1}^{L} I_{l.j.k}^{inter}} \qquad (6)$$

where

$s_{j,k} = |h^H{}_{j,j,k} W_{j,k}|^2$ is the received signal power at user k in the cell j $I_{j,k}^{intra} = \sum_{i=1, i\neq k}^{K_j} |h^H{}_{j,j,k} W_{j,i}|^2$ is the received intra-cell interference at user K $I_{l,j,k}^{inter} = \sum_{i=1}^{K_l} |h^H{}_{l,j,k} W_{l,i}|^2$ is the interference generated by cell l to the user k in cell j

III. Coordination Based Precoding Design

From (6) the execution of the SINR is affected by interferences at each UE. Intra cell interferences causes due to the transmissions from serving cell to other UEs. Inter cell in interference occurs due to the other cells in the network. In order to vanquish the interferences, precoding designs should be applied which exploiting information about intra and inter cell interferences. In TDD, by using coordinated beamforming strategies, it is possible to permitting the BSs to select jointly their precoding to reduce inter cell interference. For channel exchange procedure within the base stations , precoding designs acquire the channel linking them to other cells UEs.

IV. Zero Forcing Beamforming

Zero forcing beam forming is enhanced processing to eliminate intra cell or inter cell interference by making beam forming vectors to orthogonal to the non-intended channel users. Denote by $H_{j,l} = [h_{j,l,1}\ldots\ldots\ldots, h_{j,l,kl}]$ the aggregate channel matrix between BS j and users in cell l . From (6), it can be seen that, when Mj > Kj , it suffices to consider to mitigate inter cell interference[13].

$$W_{j,k}^{no\text{-}co} = \frac{H_{j,j}(H^H{}_{j,j} H_{j,j})^{-1} e_k}{\left\|H_{j,j}(H^H{}_{j,j} H_{j,j})^{-1} e_k\right\|} \qquad (7)$$

The superscript 'no-co' indicates that beam foaming does not apply coordination. Furthermore, if $Mj \geq \sum_{l=1}^{L} K_l$ choosing

$$W_{j,k}^{co} = \frac{H_j (H^H{}_j H_j)^{-1} e_k}{\left\|(H_j (H^H{}_j H_j)^{-1} e_k\right\|} \qquad (8)$$

where $Hj = H_{j,1\ldots\ldots} H_{j,j,\ldots\ldots\ldots\ldots}, H_{j,l,}$]; allows to eliminate both inter-cell and intra-cell interference. This beamforming uses coordination so that it requires knowledge of the channel with other cell users as the superscript is given as 'co'.

V. Signal To Leakage Noise Ratio

ZFBF enables absolute cancellation of intra-cell and inter-cell interference . But it has mainly two drawbacks firstly demands for least number of transmit antennas at the base stations. Secondly it tends to diminish the received signal

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power. SLNR-MAX overcomes the limitation of ZFBF in the requirement of number of transmit antennas and also helps to discover the balance between maximizing signal power and vanquish interference. Beamforming schemes targeting at the maximization of the relationship between signal power and that of a weighted sum of both intra and inter cell interferences and the noise has been proposed. This ratio, is called as signal to leakage noise ratio and considering only the intra cell interference within the cell j is given by as in [13]

$$\mathrm{SLNR}_{j,k}^{\ intra} = \frac{\left|h^{H}{}_{j,j,k} w_{j,k}\right|^{2}}{\sum_{\substack{i=1\\ i\neq k}}^{Kj} \left|h^{H}{}_{j,j,i} w_{j,k}\right|^{2} + \rho\sigma 2} \qquad (9)$$

Considering both intra and inter cell interference is given by $\mathrm{SLNR}_{j,k}^{\ in,intra}$

$$\frac{\left|h^{H}{}_{j,j,k} w_{j,k}\right|^{2}}{\sum_{\substack{i=1\\ i\neq k}}^{Kj} \left|h^{H}{}_{j,j,i} w_{j,k}\right|^{2} + \beta j \sum_{\substack{l=1\\ l\neq j}}^{L} \sum_{i=1}^{Kl} \left|h^{H}{}_{j,l,i} w_{j,k}\right|^{2} + \rho\sigma^{2}} \qquad (10$$

Asymptotic Analysis

Performing an exact analysis of the averages of the SINRs in (6) is unadaptable, when realistic scenarios are considered. For, substitute large-scale approximation of the SINRs are derived. This analysis is based on random matrix theory. Main results are stated in two theorems. For technical purpose following assumptions are considered.

Assumption 1

We assume that L is fixed while M_i, $K_i \to\infty$ such that for all i, we have: $0 < \lim\inf c_i < \lim\sup ci < \infty$: Let $K = \sum_{i=1}^{L} K_i$ or simplicity, the asymptotic regime in Assumption 1, will be denoted by $K\to\infty$ [13].

Theorem 1**:**

Define for t > 0 and j $\in$ {1……L} $e_j^{no\text{-}co}(t)$ to be the unique positive solution to the following fixed-point equation[13]:

$$e_j^{no\text{-}co}(t) = \frac{P_j}{K_j} \sum_{i=1}^{K_j} \frac{\alpha_{j,j,i}}{t + \dfrac{P_j \alpha_{j,j,i}}{c_j (1 + e_j^{no-co}(t))}} \qquad (11)$$

Theorem 2 **:**

If $\beta_j>0$,define $c_j=(K/M_j)$ and let $e^{co}(t)$ be the unique solution to the following fixed point equation[13].

$$e^{co}(t) = \frac{P_j}{K}\left[\sum_{i=1}^{K_j} \frac{\alpha_{j,j,i}}{t + \dfrac{P_j \alpha_{j,j,i}}{\breve{c}_j (1 + e_j(t))}} + \beta_j \sum_{\substack{l=1\\ l\neq j}}^{L} \sum_{i=1}^{K_l} \frac{\alpha_{j,l,i}}{t + \dfrac{\beta_j P_j \alpha_{j,l,i}}{\breve{c}_j (1 + e_j(t))}}\right] \qquad (12)$$

Let Sco and Sno-co be the index of base stations .The asymptotic approximations of the SINRs for the users are given by:[13]

- User k in BSj where j $\in$ Sno-co

$$\overline{SINR_{j,k}} = \frac{\bar{S}_{j,k}{}^{no-co}}{\bar{I}_{j,k}{}^{intra,no-co} + \sum_{l\in Sno-co-\{j\}} \bar{I}_{l,j,k}{}^{inter,no-co} + \sum_{l\in Sco} \bar{I}_{l,j,k}{}^{inter,co} + \sigma^{2}} \qquad (13)$$

- User k in BSj where j $\in$ Sco

$$\overline{SINR_{j,k}} = \frac{\bar{S}_{j,k}{}^{co}}{\bar{I}_{j,k}{}^{intra,co} + \sum_{l\in Sno-co} \bar{I}_{l,j,k}{}^{inter,no-co} + \sum_{l\in Sco-\{j\}} \bar{I}_{l,j,k}{}^{inter,co} + \sigma^{2}} \qquad (14)$$

VI. Results

The results obtained in this work are discussed and analyzed, the performance of the each cell j in terms of average-per-user sum rate is evaluated by the following equation [13] $rj = {}^{1}\!/_{Kj}\, E[\sum_{k=1}^{Kj} \log(1 + SINRj,k)]$, j = 1,2,3 (14)

Monte Carlo simulations are used over 10000 channel relations to compute numerical results.

Table 1 Simulation parameters

Radius of macro base station	250m
Radius of micro base station	35m
d_{min}	40
d_{max}	249m
P	1
Transmit power of macro base station	46dBm
Transmit power of micro base station	30dBm
Channel attenuation η	4
Standard deviation	8
Reference distance	10m

A. Figures

The performance of coordinated beam forming is analysed in three different coordination strategies i.e. full coordination, macro-only coordination and no coordination. In full coordination all the base stations employs coordination where as in macro-only coordination , only the macro base station employs coordination. The base station performs single cell processing in no coordination case.

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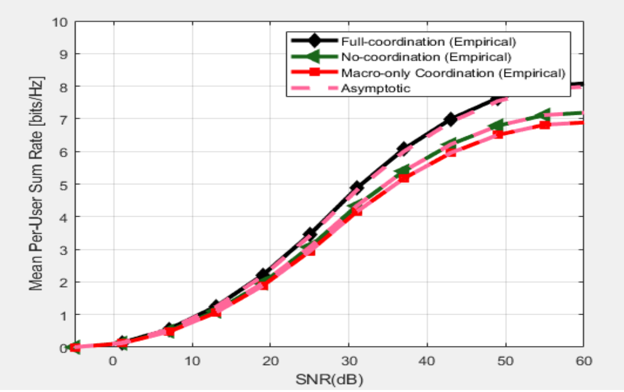

Figure 2 Macro cell Mean per user sum rate Vs SNR

Figure 2 shows that when the macro cell is under full coordination, maximum mean-per user sum rate is achieved and under no coordination the sum rate is decreased for M_{macro}= 240, K_{macro}= 80, M_{micro}= 70, K_{micro}= 35 and SLNR-MAX precoding is applied.

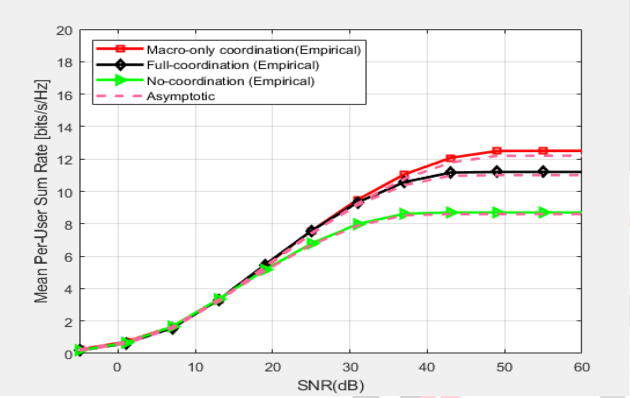

Figure 3 Micro cell user per sum rate Vs SNR

Figure 3 shows that when the micro cell is under full coordination, maximum mean-per user sum rate is achieved and under no coordination the sum rate is decreased for M_{macro}= 240, K_{macro}= 80, M_{micro}= 70, K_{micro}= 35 and SLNR-MAX precoding is applied. This confirms that when the BS coordinates, it mimimize the interference it cause. From figure 2 and 3 we understand that the part of coordinated beamforming diminishes inter-cell interference and the total power is equivalent to this interference of that user interest undergo from the interfering base station.

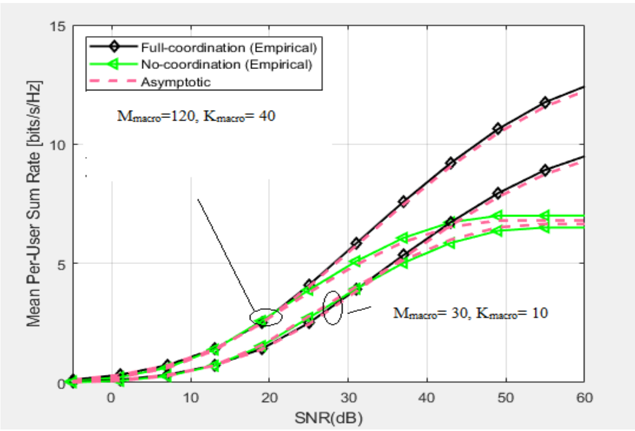

Figure 4 Macro cell Mean per user sum rate Vs SNR for different Magnitude of M and K

From the figure 4 it is inferred that with different orders of magnitude the macrocell performance is better under full coordination than under no coordination. M_{macro}=120, K_{macro}= 40, M_{macro}= 30, K_{macro}= 10 and SLNR-MAX precoding is applied. From the figure 5 it is inferred that with different orders of magnitude the microcell performance is better under full coordination than under no coordination. M_{micro}= 60, K_{micro}= 20, M_{micro}= 10, K_{micro}= 3 and SLNR-MAX precoding is applied. From figure 4 and 5 we understand that ,in non-coordinated case the intra-cell

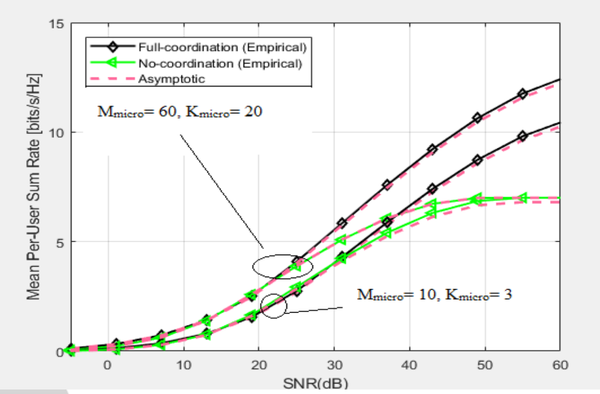

Figure 5 Micro cell Mean per user sum rate Vs SNR for different magnitude of M and K

interference vanquished entirely while the inter-cell interference remains unaltered. But in coordinated case, both inter-cell interference and intra-cell interference totally eliminated. And perfect match is obtained between empirical and asymptotic results when M_{micro}=10 and K_{micro}= 3.

VII. Conclusion

In this paper, the implementation of two types of precoding namely ZFBF and SLNR-MAX are carried out. Coordinated beam forming technique is utilized in two-tier heterogeneous network for the mitigation of interference. Based on asymptotic SINR, theoretical analysis is carried out for both SLNR-MAX and ZFBF. Their performance is analyzed for different levels of coordination and the average rate is approximated. Such analyze has established that the beam forming strategy and coordination level impact the performance of each tier in the network.

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