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Energy Efficiency in High Density Networks using Zero Forcing Technique

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ABSTRACT

The demand for high date rate in wireless network can be contented by the metric energy efficiency. It can be achieved by reducing the effect of fading which degrades the system performance by introducing interference in the network. Massive MIMO system is used to combat the effect of fading with the constraint of spectrum limitation. However, network performance gets limited due to increased number of users which introduces interference in the network. It can be compromised by precoding techniques like maximal ratio combining (MRC) and zero forcing(ZF) techniques. The work modeled in this paper is unified with zero forcing for analysis of energy efficiency and it is compared with exiting MRC technique. The attributes considered in performance analysis are energy efficiency and user equipment. Simulation results will prove that MRC is out performed by ZF in terms of maximized energy efficiency.

KEYWORDS— Energy efficiency, Massive MIMO, maximal ratio combining, zero forcing.

I. INTRODUCTION

Wireless networks require seamless connection for transmission of signal, involving high data rate which must be provided by the network [1]. The upgradation in data rate can be contented by MIMO system which combats intersymbol interference instigated by the effect of fading. On reducing the fading effect, the traffic in the network gets reduced. In conventional MIMO system, antennas are limited which in turn limits the data rate in wireless network [2]. To overcome these limitations, 5G wireless system is opted which involves network densification for enhancing the network capacity for the next few decades within the limitation of spectrum. By deploying a highly-densified network, energy efficiency can be maximized which offers seamless connection for communication for standard quality of service (QoS).

Small cell network technology is one of the method for densifying the network [3], deployed with user higher in number. It requires low power and base stations (BSs) of low cost with reduced transmitting power as BSs and user equipments (UEs) are deployed closer involving high circuit power consumption in the network. Massive MIMO is another method to densify a network deploying antennas in large scale [4] where large number of base station antenna M assists k, single user antenna for communicating purpose in the network [5]. Thus, massive MIMO enhances the data rate, capacity of the channel, seamless connection and efficient energy in the high-density network. As seamless connection is accessible in the network, users in the networks get increased in turn increasing the interference un the network. To over the effect of interference precoding schemes like maximal ratio (MR) and zero-forcing (ZF) are incorporated in the network.

MRC uses channel estimation technique to maximize the signal strength in the channel for improving energy efficiency. Emil et al [6] simulated a multiuser MIMO system under perfect and imperfect CSI channel model assuming all UE as generic arbitrary function. The result gave proof for ZF performing better than other precoding schemes. Yi Li et al [7] demonstrated than by ZF better than MRC. The paper presents the work on improving the EE in the high-density region under imperfect CSI channel environment. BS serving its own UE are ssumed to be characterized by Rayleigh distribution and BS which accommodates UE from other BS is characterized as homogenous Poisson process point (PPP).

The work is systematized as follows: System model and ZF precoding technique used in the network are dealt in Section II. Energy efficiency in ZF are formulated for an imperfect CSI system and it is proposed in section

III. Section IV depicts the simulation results and it is compared with MRC precoding technique. Conclusion and further works extension are described in section V.

II. SYSTEM MODEL

The system is modeled for multiuser scenario of a uplink framework developed from a stochastic framework of [8] depicted in figure 1. Each and every BS are placed independently over area A (in Km^2), uniformly with a mean value of λA for M array of BS. All UE are spaced closely to the nearest base station uniformly under the limitation of smaller cells occupying more density than larger cells.

The coherence block length S defines the pilot and data signals represented by $S = T_C W_c$ where is the time resources T_C is denoted in seconds and the frequency resource W_c in hertz. The response of the channel h is represented by h_{ljk} where j is the number of cells, l as base station and k as the UE in the network which possess all values of complex and positive valued numbers.

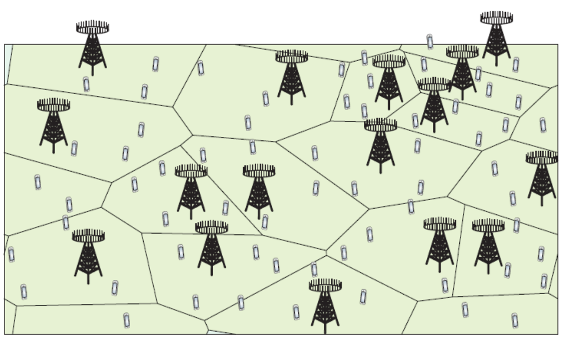

Fig. 1 Poisson-Voronoi cell illustration BS and UE

The response of the channel is represented by $h_{ljk} \sim C\aleph\left(0, \omega^{-1} d_{ljk}^{-\alpha} I_M\right)$ which incorporates the propagation model of Rayleigh fading at a distance d, path loss exponent $\alpha < 2$ and reference distance of the path loss of 1 Km. the UE are uncorrelated and served randomly by the BS. The BS is deployed with k^{th} UE and antenna with n^{th} value designating the channel propagation model under imperfect CSI characterized by channel vector $h_i = \{h_{i,1}, h_{i,2}, h_{i,3} \cdots\cdots\cdots h_{i,M}\}^T \in C^{M\times 1}$ has entries $h_{k,N}$. The combining matrix of uplink is given by $A = \{A_1, A_2, A_3 \cdots\cdots\cdots A_k\}^T \in C^{M\times K}$ with column A_k assigned to k^{th} UE. The analysis of work over MRC and ZF is represented by

$$A = \begin{Bmatrix} H & \text{for MRC} \\ H\left(H^H H\right)^{-1} & \text{for ZF} \end{Bmatrix}$$

where $A = \{h_1, h_2, h_3 \cdots\cdots\cdots h_k\}$ comprising all user channels, $p^{ul} = \{p_1^{ul}, p_2^{ul}, p_3^{ul} \cdots\cdots\cdots p_k^{ul}\}$ and the uplink power of i^{th} UE for transmission is represented by the attribute $p_i^{ul} \geq 0$

III. EE MAXIMIZATION IN ZF PROCESSING FOR IMPERFECT CSI

The work considered under imperfect CSI is modeled in multi-cell multiuser Poisson-Voronoi scenario this paper is modeled in under the assumption of imperfect CSI. The UE and BS are symmetry implying that distributions of users and conditions of base are same in all cells. Considering these assumptions ZF scheme is incorporated in multiuser MIMO uplink and EE is achieved by equation 1

$$B_1 = K\left(\frac{4}{(\alpha-2)^2} + \frac{1}{(1-\alpha)} + \frac{2}{(\alpha-2)}\right) + \frac{M}{\alpha-1}$$

$$B_2 = K\left(1 + \frac{2}{(\alpha-2)}\right) + M$$

With the simulation attribute M and K energy efficiency is determined incorporated in the equation of the signal to interference noise ratio (SINR). The channel is modeled under imperfect CSI leading to the recurrence of pilot symbols [10]. Estimation of EE under imperfect CSI for j cells are defined by $P_j \in \{1, 2, 3 \cdots\cdots\cdots J\}$ .The pilot reuse factor value for $T^{ul} = 4$ yields high EE for ZF schemes used in [9].

IV. SIMULATION RESULTS

Simulation results are explained in this section obtained by ZF and it is compared with that of existing MRC scheme in imperfect CSI under multi-cell scenarios. The channel holds imperfect CSI which uses pilot reuse factor for enhancement of the channel. The simulation parameters tabulated in Table II are used in Poisson Voronoi cell investigation. In multi-cell scenario, the pilot contamination(PC) values differ by increase in reuse factor depending on the value and $W\sigma^2 S_x / \rho = 1.6022$ and I=1:5288. The pilot contamination factors are $I_{PC} \in \{0.5288, 0.1163, 0.0214\}$ and $I^2_{PC} \in \{0.0405, 0.0023, 7.82\times10^{-5}\}$ where intercell interference are obtained numerically from [10]

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S.No	PARAMETER	SYMBOLS	VALUE
1	Maximal number of antennas	M	300
2	Maximal number of users	K	40
3	Path loss exponent	α	3.76
4	Transmission bandwidth	W	20 MHz
5	Channel coherence bandwidth	B_c	180 kHz
6	Coherence time	T_c	10 ms
7	Coherence block	S	1800
8	Pilot Reuse factor	T^{ul}	4

TABLE I SIMULATION PARAMETERS

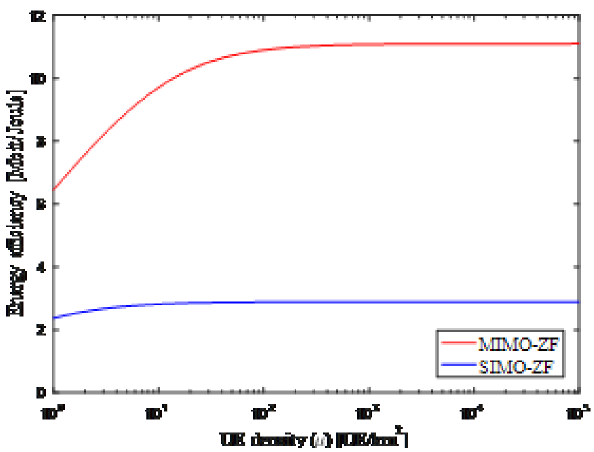

Fig 2 Performance of energy efficiency in high density network using ZF processing schemes

Figure 2 depicts the energy efficiency variation in high density network with respect to the user equipment in the network. The energy efficiency obtained from MIMO-ZF has the value of 11 Mbits/Joule as more user equipment's are served in high density region hence ZF cancels the interference and provides more energy efficiency. The energy efficiency obtained is 2.8 Mbits/Joule for SIMO-ZF as users are reduced in number the occurrence of interference is low hence it offers service at low rate.

Figure 3 depicts the comparison of energy efficiency in high density network for MRC and ZF processing schemes. In massive MIMO, ZF has high energy efficiency than MRC by reducing the interference in the network occurred due to more number of UE. ZF also offers high energy efficiency in low UE density region comparatively but gets constant only in the high-density region. In SIMO-ZF, MRC performs better as it improves the signal strength the level of signal will not interfere each other as user are low in SIMO.

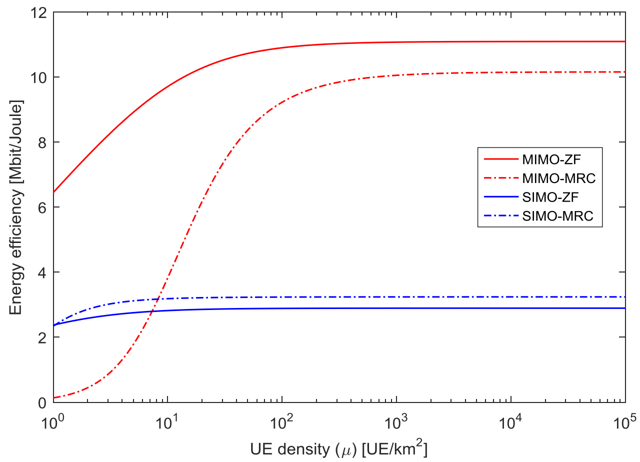

Fig 3 Comparison of EE in high density network for MRC and ZF processing schemes

S.No.	Processing schemes	Energy efficiency (Mbits/Joule)
1	MIMO-ZF	11
2	MIMO-MRC	10
3	SIMO-ZF	3
4	SIMO-MRC	3.5

TABLE II:COMPARISON OF ENERGY WITH DIFFERENT PROCESSING SCHEMES

V. CONCLUSION

The research work is compiled on energy efficiency of ZF processing scheme in multicell scenario of heterogenous environment. Energy efficiency obtained through ZF is compared with MRC and it proves that ZF performs well in high density region by providing more energy efficiency in the network. Further work is extended by optimizing energy efficiency with respect to the number of users and number of antennas deployed in the network.

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