Performance Evaluation of Precoding Schemes for Multi User Massive MIMO System Over Nakagami-m Fading Channel

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Abstract Nowadays, wireless communication system plays great roles in our daily activities and different improvements are requiring because the number of users increase from time to time. At the same time, users need high throughput and link reliability. The forthcoming generation of wireless communication will have to deal with some core requirements for serving large number of users simultaneously, upholding high throughput for each user, assuring less energy consumption, etc. Inter-user interference has a major impact when a wireless communication link has a large number of users. To maintain a particular desired quality of service, sophisticated transmission mechanisms such as interference cancellation need be implemented. As a result, MU-massive MIMO with extremely huge antenna arrays is recommended. The term "MU-massive MIMO" refers to a system with hundreds or thousands of antennas servicing tens of thousands of customers.Inter-user interference was greatly decreased once the channel vectors were closely orthogonal. As a result, high data rates can be

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supplied to multiple users at the same time. In this work, researcher investigated performance evaluation of a MU-massive MIMO utilizing different precoding schemes (like, MMSE, ZF, MRT) over nakagami-m fading channel with CSI at base station and users' terminal. In addition, the researcher analyzed the outcome of pilot reuse factors and shaping (m) parameter.

Keywords Capacity · CSI · Fading · MU-MassiveMIMO · Nakagami-m · Pilot reuse · Precoders

1 Introduction

Multiple-In Multiple-Out (MIMO) technology is now being introduced in modern wireless broadband standards like Long Term Evolution Advanced (LTE Advanced). Rendering to 3GPP LTE standard, LTE permits up to eight antennas at BS [1]. The goal of wireless communication upgrades was to give each user with a high data rate.Because of this, today's wireless technology employs a MIMO system. As a result, increasing the number of BS antennas can increase the SE performance of a system. Massive MIMO not only improves link stability and data throughput, but it also saves transmitter energy due to the array gain [2].Benefits are more appealing in multiuser systems since such systems allow for simultaneous transmission to multiple users. The BS was outfitted with numerous antennas and can accommodate many users thanks to MU-massive MIMO. Typically, numerous users at the BS communicated via orthogonal channels. More precisely, the BS communicated with each user on an individual frequency and time basis [3]. Massive MIMO is a MIMO system in which the base station has exceptionally large antenna arrays that serve hundreds of users at the same time. As the number of BS antennas increases, the random channel vectors between users and BS become virtually orthogonal. Furthermore, massive MIMO allows us to minimize the base station's broadcast power.Power amplifiers, accompanying circuits, and cooling systems absorb a considerable percentage of the electrical BS power in the downlink. [4].The MU-Massive MIMO technique is presently gaining a lot of interest from the industry and academia. This encourages me to continue working on the subject. Most studies looked upon uplink performance, but now the researchers are looking into MU-massive MIMO downstream systems with precoding techniques. There was inter-cell interference between users in MU-massive MIMO, and this was addressed by using precoder schemes (MRT, ZF, and MMSE) and multi-cell channel estimation.

1.1 Related Works

MU-MIMO (Multi-user Multiple-Input Multiple-Output) Reference [6] examined Downlink TDD Systems with Linear Precoding and Downlink Pilots, and they regarded a beamforming training strategy as an effective channel estimation scheme to obtain CSI at each user. They calculated a lower constraint on capacity for MRT and ZF precoding methods in order to evaluate the SE while accounting for the SE loss associated with downlink transmission

Because of its advantage over conventional point-to-point communications, the massive MIMO concept has gained great attention in recent research. The huge MIMO concept has received a lot of attention in recent studies due to its advantages over traditional point-to-point communications. The BER performance of massive MIMO with increasing number of BS antennas, users, and SINR was explored by the author in [7]. Under Perfect CSIT and Imperfect CSIT, they compared the spectral efficiency and BER performance of ZF, MMSE precoding. The performance of a massive MIMO using various precoding techniques (MRT, MMSE, ZF) in a Rayleigh fading channel with both incomplete and complete channel state information at the transmitter (CSIT) is explored.The author in [3], investigated multi-cell massive MIMO in which channels were spatially correlated Rician fading. The channel model was composed of a stochastic non-line-of-sight (NLoS) and a deterministic line-of-sight (LoS) path component describing a practical spatially correlated multipath environment. They derived statistical properties of the minimum mean squared error (MMSE), element-wise MMSE (EW-MMSE), and least-square (LS) channel estimates for this model.In single-cell massive MIMO systems, the authors of reference [8] studied how to apportion pilot and payload power. The authors used spectral efficiency (SE) as a performance metric and calculated a total energy budget for each coherence interval. The topic of power control was framed as an optimization problem with two distinct goal functions: a weighted minimum SE among the users and a weighted maximum SE among the users. The authors came up with a closed form solution for the ideal pilot sequence length.

To reduce pilot contamination, the authors of [11] suggested an estimating approach that combined joint channel processing with an interference cancellation mechanism. To improve overall performance, users that generate excessive interference in surrounding cells were first identified, followed by shared channel processing. The performance of the suggested technique was compared to that of single-cell MMSE channel estimation and multi-cell MMSE channel estimation.The authors proposed a research in which they demonstrated the impact of perfect CSI and imperfect CSI on the SE in [14]. Zero-forcing precoding and maximum ratio combing precoding were used to investigate spectral efficiency. The suggested channel estimation scheme employed approximately half of the block as coherence data and the rest blocks for training. For single and multi-cell systems, formulas for spectral and energy efficiency optimization were developed. The spectral efficiency was found to be reduced with poor CSI.

The performance of a huge MIMO uplink system was explored in [20] utilizing a nakagami-m fading channel. The maximum ratio combining detection technique and the zero forcing detection approach were contrasted and examined in this paper. The SE grows as the antenna at BS and the value of m increases, according to the data. However, in [21], the authors looked into Imperfect feedback–based linear precoding techniques for MIMO wireless communication, where the input symbol streams are encoded using generalized-orthogonal space-time block codes. To accurately characterize practical wireless channels under various fading, the communication links were assumed to be nakagami-m dispersed.

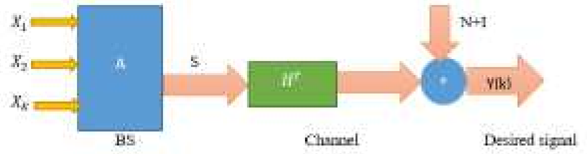

Fig. 1 The system model

2 System Model

2.1 Downlink system and precoding algorithm for MU-Massive MIMO system

M-number of BS antennas, K-number of users, L-number of cells, Y-received signal vector, H-channel matrix, A-linear precoding matrix, I-inter cell interference, and N-additive noise vector were all taken into account by the researcher.As shown in Figure 1, multiple users from the uplink upload pilot sequences at the same time, and the base station estimates the downlink channel based on the channel state information (CSI) from the uplink pilots. When more users have access to the wireless communication link, inter-user interference has a significant impact. To maintain a particular desired quality of service, sophisticated transmission techniques like interference cancellation need be implemented. As a result of these issues, MU-massive MIMO with very large antenna arrays was proposed in this paper, along with precoding methods at the base station and increased pilot reuse factors to increase system capacity. [23]

$$Y_{l,k} = \sum_{l=1}^{l} H_{l,j,k}^{H} X_l + N_{lk} \tag{2.1}$$

Where $w_l i \in C^{M*l}$ is the Precoding matrix used by BS before transmitting signals of its information vector S_k to the k^{th} user. Also, Base band channels crossing through BS to UEs. We assumed that the BS has “Perfect channel – state information (CSI)” [9] and nakagami-m fading channel for all channels involved in this work. The BS transmits a signal that is given by:

$$x = \sum_{k=1}^{k} w_i s_i \tag{2.2}$$

Then,in addition to additive gaussian noise there is interference between users.

$$Y_{l,k} = H_{lk}{}^{jH} W_{lk} S_{lk} + intracellinterference + intercellinterference + N_{lk} \tag{2.3}$$

The orthogonal pilot sequences originated from the K UEs, and they enabled the BS to estimate all downlink channels. Intra-cell interference caused by reuse of the different pilot sequence while inter-cell interference caused by reuse of the same pilot sequence. In this work, the researcher assumed that intra-cell interference was negligible since pilots are assumed as mutually orthogonal.

2.2 Precoding Algorithm schemes

The BS precodes the signal and sends the signal vector to the consumers in MU massive MIMO. There are two types of precoding schemes: linear precoding (ZF, MRT, MMSE) and non-linear precoding (DPC, VP, THP, and so on) [4].The precision and complexity of the nonlinear precoding algorithm are higher than the linear precoding algorithm. It has been recognized as a DPC was best in filthy paper precoding because interference power and signal power energy are instantaneously transmitted in the additive Gauss noise channel transmission, and the interference signal and intended signal are not affected. However, because of the large amount of dirty paper precoding calculations, detecting interference and noise proved difficult, and the matrix was deleted entirely.Following interference cancellation (SIC) in the uplink and dirty paper coding (DPC) in the downlink, nonlinear precoding approaches reached the sum capacity under perfect CSI. DPC/SIC eliminates interference during the encoding/decoding process by utilizing information of which interfering streams are present. Linear precoding techniques, on the other hand, can only reject linear projections as a source of interference [5]. Because linear precoding is straightforward to create and implement, the researcher used it in this study [8].

Minimum Mean Square Error (MMSE) Precoding algorithm

In a multi-user large MIMO downlink system, it was the best linear precoding. The mean square error approach was used to create this scheme. The Lagrangian optimization method is employed to construct these precoders since average power at each transmitted antenna is constrained [4]. The optimal of MMSE precoding of vector A can be expressed as:

$$A_{MMSE} = \frac{1}{\beta} H^H (H^T H^H + \frac{K}{P_{tr}} I_K)^{-1} \quad (2.4)$$

Forced Zero (ZF) precoding algorithm

ZF precoding is one technique of linear precoding in which the inter user interference can be cancelled out at each user. This precoding is assumed to implement a pseudo-inverse of the channel matrix. Therefore, the optimal precoding of ZF of vector A can be expressed as:

$$A_{ZF} = \frac{1}{\beta} H^* (H^T H^*)^{-1} \quad (2.5)$$

Maximum Ratio Transmission (MRT) Precoding algorithm

One of the common methods is MRT which maximizes the SINR. MRT works well in the MU-MIMO system where the base station radiates low signal power to the users.The optimal precoding of MRT of vector A can be expressed as:

$$A_{MRT} = \frac{1}{\beta} H^* \quad (2.6)$$

Table 1 Values of different Parameters

Parameters	Values
Number of Cells (L)	3
Number of BS antennas (M)	M=4 to M=400
Number of users in each cell (K)	K=4 to K=80
Signal to interference-noise ratio	-10 to 30dB
Shaping parameter (m)	m=1,3,4
Pilot reuse factor (f)	f=1,3,4
Transmission bandwidth BW	20MHz
Maximum transmit Power at the BS	20dBm

2.3 Problem Formulation

The major tasks in wireless communication are include link reliability, Signal fading, data rate enhancements, coverage, energy efficiency and spectral efficiency. This was due to limited accessible bandwidth, mobility of a wireless nodes and the fading nature of propagation channel. When increasing a number of antennas at BS gains the spectral efficiency for each user in its cell and gains energy efficiency in terms of radiation from the BS. In case of MU-massive MIMO, the transmitter cannot transmit all users with maximum data throughput at the same time, but in single-user systems, each user maximizes the data throughput for itself. This needs more processing to transmit appropriate data to the users. Because of this, by using precoding schemes the performance would be improved and also it was simple and hence, it has low deployment cost. Here, the researcher considered precoding schemes at BS to mitigate pilot contamination and evaluate performance of precoding schemes over nakagami-m fading channel with different SINR. In this work the researcher, investigated the performance of spectral efficiency and energy efficiency, and to analysis the effect of precoders and pilot reuse factors performance in multi-user massive MIMO over nakagami –m fading channel.

3 Results and Discussions

In this section, simulation results and corresponding evaluations are presented following the Algorithm analysis discussed in figure 2. Simulation results are carried out to compare the performance of MU-massive MIMO over nakagami-m fading channel.The performance analysis of simulation for three different cases such as:-
Case 1. Change in capacity with the increase of the number of Base station antenna.
Case 2. Change in capacity with the increase of a number of BS antennas with different shaping parameter (m).
Case 3. Change in capacity with the increase of a number of pilot reuse factors.
However, the limitation of models was that the number of users' K was not greater than the number of antennas M.

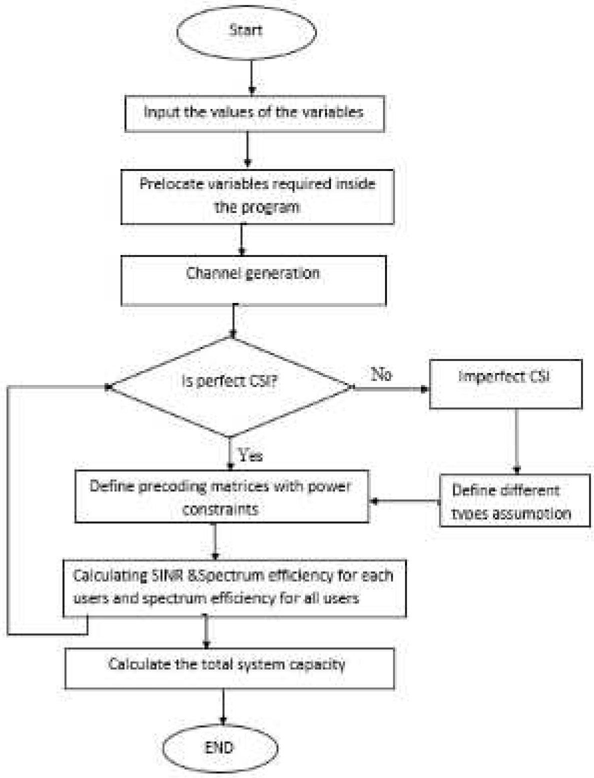

Fig. 2 Block diagram of system model design

3.1 performance Evaluation

Case 1. Change in capacity with the increase of the number of Base station antenna.
In figure 3, base station antenna M=4 and number of users K=4, spectral efficiency of users increased as number of antennas increased. All the outcomes show the performance of system was improved. The spectral efficiency of MMSE, ZF, and MRT were increased by increasing number of BS antennas. Besides this, the performance of MRT is near optimum at low SINRs, while ZF is asymptotically best at high SINRs. MMSE scheme was a more flexible scheme that combines respective asymptotic properties of ZF and MRT with good performance at intermediate SINRs. Increasing the number of antennas makes ZF able to be used at low SINR.

In figure 4, there was definitely a performance gap between the capacity-achieved by DPC/SIC and suboptimal ZF. Nonlinear precoding only provides a large gain over linear precoders when M more greater than K, while the gain was small in Massive MIMO system cases with M/K greater than two.Interestingly, we could achieve the same performance as with DPC/SIC by using ZF processing with a more BS antennas which was a reasonable price to pay for the much relaxed computational complexity

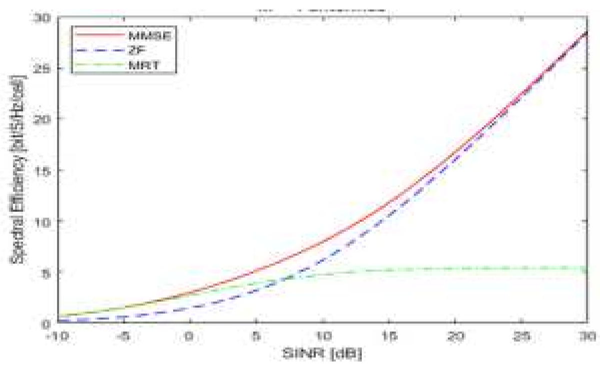

Fig. 3 spectral efficiency versus SINR

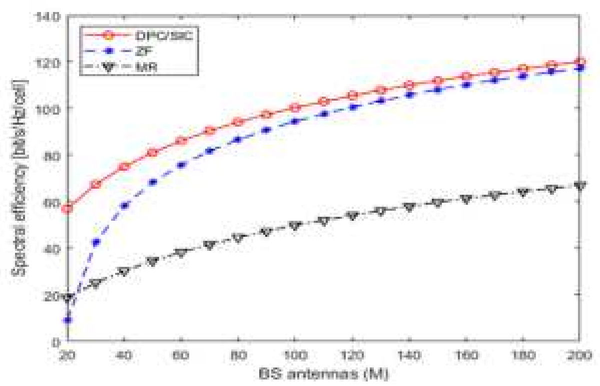

Fig. 4 SE versus number of BS antennas over different precoding schemes

of ZF.

Case 2. Change in capacity with the increase of a number of BS antennas with different shaping parameter (m).

In figure 5, as shaping parameters (m) increase the fading would get weaker and spectral efficiency would tend to increase slowly as m increases. The simulation outcomes show that as m increases, the spectral efficiency increases gradually, but it rises significantly with the increase of the number of base station antennas.

Case 3. Change in capacity with the increase of a number of pilot reuse factors.

In figure 6, with fixed BS antenna (M)=200, users (K)=1 to 100 and coherence interval of the symbol =200 symbols, the cells with different colors use different subsets of the pilot sequences. The cells with the similar color use exactly the same subsection of pilots and therefore cause pilot contamination to each other, while there was no contamination between cells with different colors.Because, as the number of

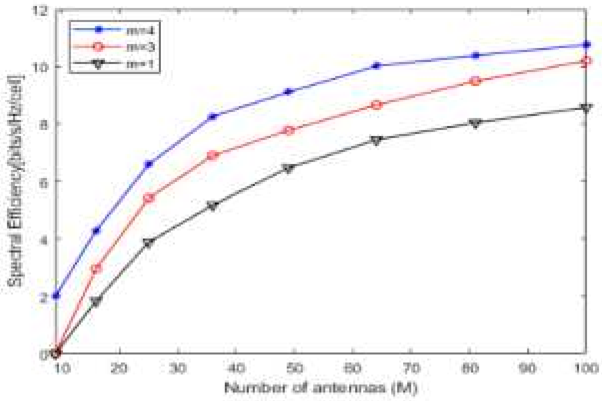

Fig. 5 SE versus number of BS antennas over different nakagami-m shaping parameters

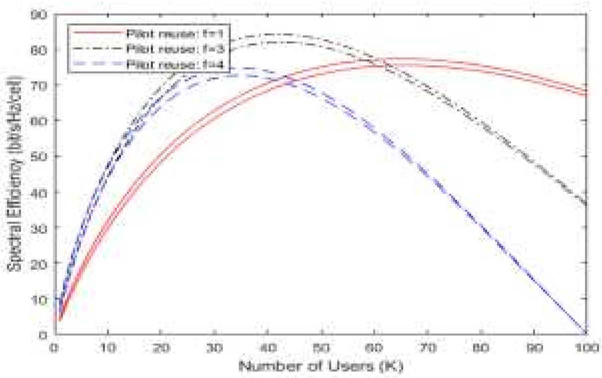

Fig. 6 SE versus number of users over different value of pilot reuse factors

users were increasing interferences between users were increasing so, the spectral efficiency was started to declined. By increasing the pilot reuse factor, there were more colors and therefore fewer interfering cells in each group. And the researcher notice that different pilot reuse factors were desirable at different number of users K. In generally, the pilot reuse factors were an important design parameter in Massive MIMO networks and the best choice depends on the user load (number of users).

4 Conclusion

Multiuser-massive MIMO introduces the opportunity of increasing spectral efficiency and improving energy efficiency at the same time. It was able to use simple precoding schemes at base station and channel estimation via uplink. Besides this, a propagation environment does not affect much on system performance. By using the nakagami-m fading channel, the MU-massive MIMO with precoding improves the performance of the system when a number of antennas was rise. In general, ZF gives better performances at high transmission power whereas MRT gives enhanced performance at low transmission power. However, MMSE offers best performance at intermediate transmission power. The researcher, concluded that a MU-massive MIMO was a crucial for next generation wireless communication.In this study, an orthogonal transmission approach was investigated, which has the potential to reduce spectrum usage efficiency; dealing with a non-orthogonal transmission strategy would be preferable. And also MU-massive MIMO system were evaluated in TDD mode in this paper, further works can extend these with FDD mode for multi-cell wireless system.

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