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Evaluating Energy and Spectral Efficiency of Massive MIMO Cellular Networks using random initialization

Amjad Quazi, Dr Sanjeev Kumar Gupta, Monal Sanjay Etankar

[1]*Sagar Institute of Science and Technology, Bhopal, India*

[2]*Rabindranath Tagore University, Bhopal, India*
Amjadquazi185@gmail.com, *sanjeevgupta73@yahoo.com*

Abstract

The use of the large size antenna arrays is capable of bringing the substantial improvements in energy or spectral efficiency of the wireless cellular networks. Improving the energy efficiency is a bit challenging task in hand due to the varying spatial resolution and size of the network which needs variable array gain. Massive MIMO has immerged as the broad field of research in order to improve the capacity and efficacy of the cellular mobile networks as they uses the huge number of antennas at the mobile base stations (BSs). Use of Massive MIMO structure may provide the strong antenna gains and minimizes inter user interference amount. As each of these systems efficiency rely on some assumptions. This paper proposes to assume and model the cellular network using the normal pseudorandom initialization which improves the initial estimations and thus in turn the overall energy efficiency. It is proposed to evaluate the performance of new network model to investigate the energy and spectral efficiency without being much change in the network capacity. The modified massive MIMO system is capable of providing large multiplexing gain and also improves the initial gain of the system. Changing the hardware technology at the massive MIMO is slightly costlier thus current paper proposes to change the distribution model of the network. It is found that the proposed network model improves the energy efficiency and capacity of the network.

Keywords: *Cellular antenna, Massive MIMO, Channel Estimation, energy efficiency, Normal Random Distribution, Hardware Impairment, Channel capacity.*

1. Introduction

In general efficiency of the MASSIVE MIMO framework depends open the proficient structuring and numerical demonstrating of the remote channel parameters and effective pillar shaping. The hypothetical data capacity is the prime central factor for the improving the ghostly efficiency of a remote connection, It is legitimately subject to the Signal to Noise Ration (SNR) execution of the cellular mobile system. Furthermore the efficiency is likewise straightforwardly corresponding to the worldwide and neighborhood natural conditions and spatial relationship with the remote engendering joins between Mobile stations (MS) and the Base Stations (BS). Another major contributing factor for the improved energy efficiency is the exactness of the channel estimation calculations. As the channel estimation is answerable for demonstrating the genuine engendering situation it might be multi way or point to point. Improvement in the transreceiver structure and the signal preparing stream and strategies may likewise influence the energy efficiency of the cellular systems. Presently days there is a critical improvement have happen in the antenna advancements so as to improve the energy efficiency and furthermore to keep up the better channel capacity.

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Massive Multiple-Info Numerous Yield (MIMO) based remote cellular correspondence framework comprises of even several antennas. It has demonstrated an extraordinary potential for the fifth generation (5G) cellular communic4ation frameworks. Advancement of adaptable, exact, and productive channel models is required for planning and assessing the presentation of massive MIMO frameworks, Massive MIMO is an expansion of the current MIMO structures by gathering the antennas at the base station transmitter and collector so as to improve the capacity of the cellular frameworks. Be that as it may, keeping up the energy efficiency of such framework is as yet a difficult undertaking.

As it tends to be seen from the Figure 1 that the fundamental least utilization of intensity used by cellular system at mobile stations (MS), base station (BS) and at arrange level is drawing nearer to Giga Watt levels. This utilization is straightforwardly corresponding to the quantity of clients and is thusly expected to increment sooner rather than later.

This is the great motivation factor to minimize the energy uses age. The Massive MIMO systems are designed in such a manor to improve the energy efficiency of the Cellular networks

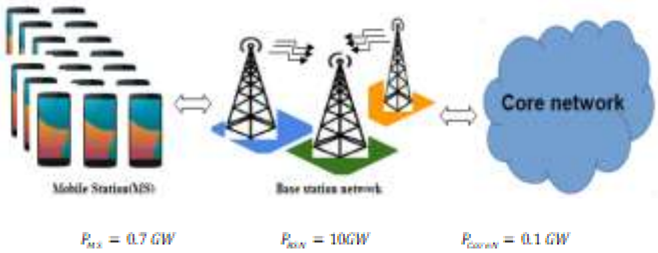

Figure 1: Minimum required estimated power consumption of Mobile network

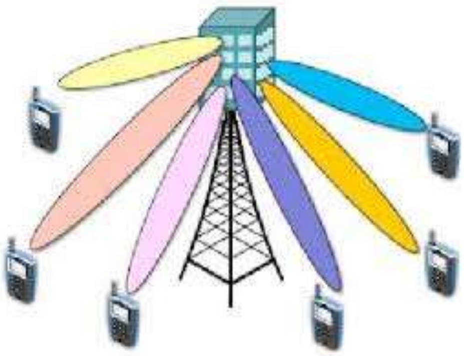

Figure 2: Basic MU-Massive MIMO links

The basic beam structure of the antenna unit installed on the cellular Base stations is shown in the Figure 2. It can be seen that there are both way multiplexed links between the BS and the MS. The number of antennas used in the Massive antenna structure is huge and thus it is slightly costlier and bulkier to install.

Usually the MIMO based systems are used for the implementation of long term evaluation (LTE**)** technology and are termed as **LTE-MIMO.** It is used on the Common Channels as well as the Control and Broadcast channels. Open loop spatial multiplexing: This form of **MIMO** used within the **LTE** system involves sending two information streams which can be transmitted over two or more antennas.

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2. Transceiver Hardware Impairments

Most of papers on massive MIMO frameworks considered the channels with perfect handset hardware. In any case, handy handsets experience the ill effects of hardware impairments that 1) make a confuse between the expected transmit signal and what is really produced and discharged; and 2) distort the got signal in the gathering preparing. The fundamental channel model for the MIMO framework engineering is appeared in the Figure 3

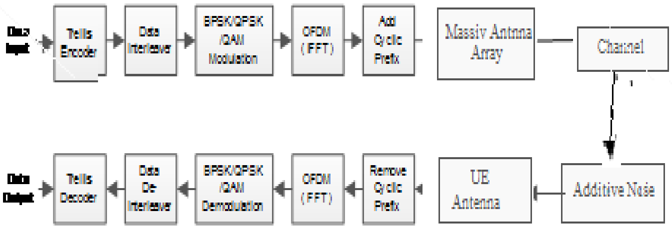

Figure 3 basic channel model and system of cellular LTE

The edge location based watermarking strategies are broadly utilized in change space to improve the vigor and imperceptibility of the watermarking procedure In this paper, we examine how these impairments sway the presentation and key asymptotic properties of massive MIMO frameworks. Physical handset usage comprises of a wide range of hardware parts (e.g., speakers, converters, blenders, channels, and oscillators [3]) and every one distorts the signals in its own specific manner. The hardware blemishes are unavoidable, yet the seriousness of the impairments relies upon designing choices—bigger distortions can be intentionally acquainted with decline the hardware cost and additionally the force utilization [7]. The non-perfect conduct of every part can be displayed in detail to structure remuneration calculations, however considerably after pay their stay lingering handset impairments [1, 2, and 4] for instance, because of deficient demonstrating precision, blemished estimation of model parameters, and time differing qualities prompted by noise. From a framework execution point of view, it is the total impact of all the remaining handset impairments that is significant, not the individual conduct of every hardware part. In wireless communication, more than one signals are transmitted in the channel by using the concept of Orthogonal frequency division multiplexing (OFDM) which efficiently handles the inter symbol interference and utilizes the frequency and available bandwidth efficiently. Whereas for OFDM transmission technique is integrated with MIMO channel which contains multiple transmitter and receiver antenna at both ends. By using MIMO-OFDM system, different signals can be transmitted at the same time by utilizing same frequency and get separated in the space [16].

As of late, another framework model has been proposed in [4]–[9] where the total remaining hardware impairments are demonstrated by free added substance distortion noises at the BS just as at the UE. We embrace this model in this due its expository tractability and the trial confirmations in [5]–[7]. The subtleties of the DL and UL framework models are given in the following subsections, and these are then utilized in Segments III–VI to break down various parts of massive MIMO frameworks. Conceivable model refinements are then given in Segment VII, alongside talks on how these might affect the fundamental aftereffects of this paper.

3. Channel Model

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A basic channel model is given in Figure 4 which represents the fading channel model. This fading occurs when the channel bandwidth and delay spread spectrum of a signal at the receiver is higher than the channel bandwidth and symbol period and is called as flat fading.

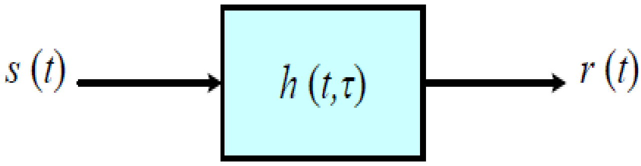

Figure 4 Modelling basic fading channel

The conventional wireless down link channel down link is modelled as;

$$r(t)=s(t)*h(t,\tau) \qquad (1)$$

Where r is the received impulse response delay spread. The h is channel impulse response, now let us considers the additional noise of the channel as n. This channel is modified by considering the hardware impairment as,

$$r(t)=(s+\delta^{BS})*(h+\delta^{UE}) + n(t) \qquad (2)$$

Where δ^{BS} and δ^{UE} are hardware impairments based noises,

For analytical clarity, the major part of this paper analyzes the fundamental spectral and energy efficiency limits of a single link, which operates under arbitrary interference conditions. The link is established between an N-antenna BS and single-antenna user equipment (UE). A main characteristic in the analysis is that the number of antennas N can be very large. We consider a TDD protocol that toggles between uplink (UL) and downlink (DL) transmission on the same flat-fading subcarrier. This enables efficient channel estimation even when N is large, because the estimation accuracy and overhead in the UL is independent of N. We assume a block fading structure where each channel is static for a coherence period of Tcoher channel uses. The channel realizations are generated randomly and are independent between blocks. For simplicity, Tcoher is the same for the useful channel and any interfering channels, and the coherence periods are synchronized

3.1 Downlink System Model

The downlink (DL) channel is used for data transmission and pilot-based channel estimation; see Figure. 2. The received DL signal y 2 C in a flat-fading multiple-input single-output (MISO) channel is conventionally modelled as

$$y=h^T S+n \qquad (3)$$

Where s is the deterministic pilot signal.

4. Proposed Model

The basic cellular network representation and distribution is being shown in the Figure 5. It can be observed that each BS is responsible for the transmission and reception from multiple user equipments UE’s. It can be observed that the network is distributed in terms of the clustered hierarchy. The each cluster is having at least one BS.

The impact of channel estimation model on the BS operation frequency on energy savings is investigated. It is shown that the efficient channel estimation and modeling plays a central role in the design of dynamic BS operation strategy. In, a theoretical framework for BS energy saving that encompasses dynamic BS operation and user

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association is proposed and the optimal user association and BS massive MIMO structure operation is investigated considering both energy saving and flow level delay

In the research studied the design of energy efficient cellular networks through the employment of massive MIMO structures on the BS for the small cells networks. And network is investigated the performance issues associated with massive MIMO techniques under channel estimation design. A new estimation method based energy saving algorithm is proposed. These works mainly focus on BS In this research investigates the impact of channel estimation on capacity bounds and on the spectral efficiency of the system

(1) Derive the network SINR distribution while considering network traffic load. Then we further derive network spectral and energy efficiency.

(2) Present a sufficient condition for a cellular network to be interference-limited.

(3) Analyze the impact of hardware impairment of transceiver on the network spectral and energy efficiency.

(4) Run numerical simulations to verify the analytic results

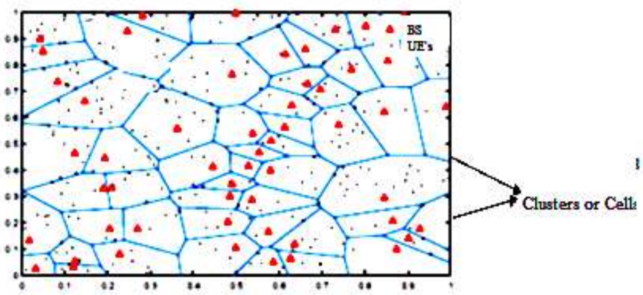

Figure 5 basic representation of the BS and UE's in the Cellular network

In order to improve the spectral and energy efficiency of the massive MIMO system paper propose to initialize the channel parameters using the normal pseudorandom distribution for channel estimation in place of uniform random distribution. Using the normal random distribution improves the better initial estimates thus increase the system efficiency. Mathematical relations for both distributions are as follows:

Uniform pseudo random probability distribution;

$$f(x)_{URD}=\begin{cases} 1/(a2-a1) & \text{for } a1\le x\le a2 \\ 0 & \text{for } x<a1 \text{ or } x>a2 \end{cases} \quad (4)$$

Normal probability random distribution is given as;

$$f(x)_{NRD}=\frac{1}{\sigma\sqrt{2\pi}} e^{\left((x-\mu)^2/(2\sigma^2)\right)} \quad (5)$$

Where σ is the standard deviation and μ is the mean of random variable x. Functions $f(x)_{URD}$ and $f(x)_{NRD}$ are uniform distribution and normal distributions probability density functions respectively. The comparison of the x coordinates randomly generated using uniform and normal distributions for network initialization. It can be observed that the normal distribution gives more initial values. Thus more distance between nodes.

5. Network Model

The N number of BS massive MIMO antennas is used for testing. In the current study the N=75 is taken and the antenna range is tuned on a random predefined

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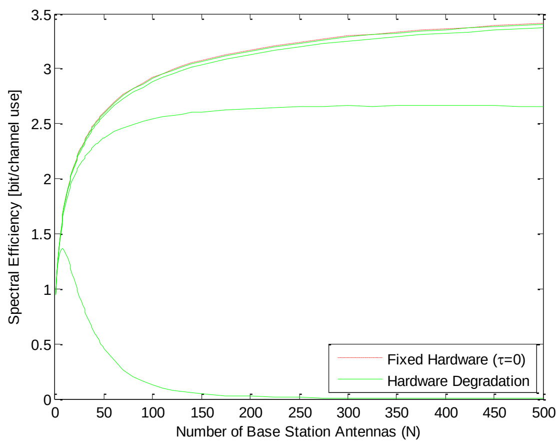
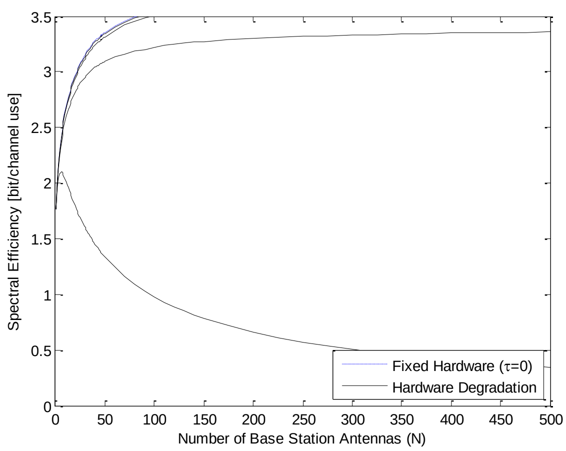
structure as used by [2]. Thus out of 500 antennas the 75 antennas are used to transmit at a time. In order to model the network the basic hardware impairment is considered and the amount of impairment is modeled using tkapa values at BS and UE''s the channel is propose to modeled using the normal random initialization instead of the uniform.

6. Implementation Details

In this section some of our experimental results were discussed on massive MIMO system design under hardware impairments. The per channel element relative estimation error defined as $MSE_{Total}=MSE/(tr(R))$ is a function of the SNR in the UL link.



a) Results of the efficiency by Emil [2]



b) Result of proposed spectral efficiency

Figure 6 Comparison of the lower capacity bounds for the BS for the different values of the scaling parameters taken as τ=[0,1/4,1/2,1,2}

Figure 6 Estimation errors per antenna element for the LMMSE estimator [2]
The SNR is defined as;

$$SNR^{UL}=P^{UL}\frac{tr(R)}{N\sigma^2_{BS}} \qquad (6)$$

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In Figure 6 the relative estimation error for LMMSE estimation are given for the average SNR values it can be observed that for the uplink and downlink design the LMMSE estimation improves the error performance.

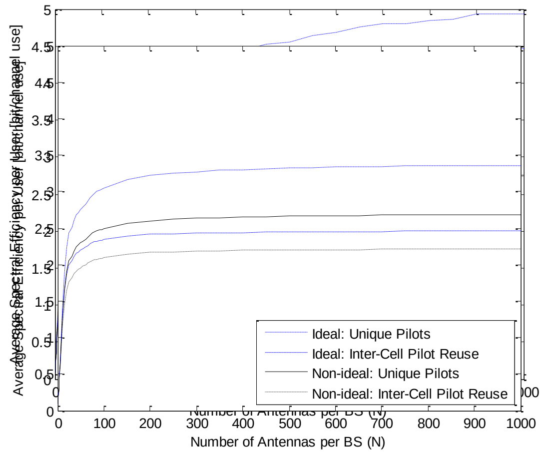
As another experiment the spectral efficiency of massive MIMO system are compared with the performance of the Emil [1] and our proposed method with modified channel modeling. It can be observed from Figure 7 a) and b) that the proposed methods spectral efficiency is far better than the existing method performance. Even for τ=1 with higher scaling our method performance better.

A Spectral Efficiency of Non Ideal Link.

The comparison of the UL spectral efficiency for the ideal and non ideal link environment under hardware impairment is given in the Figure 8. It can be observed from the Figure 8 b) that the non-ideal pilot performance of our proposed method is better than the ideal intra cell pilot performance. While in case of the Emil [2] there is a significant performance gap in the ideal and the non ideal performance. Although, there is no degradation in the spectral efficiency of non ideal case of pilot channel.

Table 1: Simulation Parameter

Parameter	Value
Inter-site distance of the macro base station	1000 m
Inter-site distance for 8the micro base station	500 m
Basic path losses in dB	15.3+37.6log(d)
Shadow fading deviation range	STD deviation 8 dB
Hardware impairments range	K = [0 – 0.2]
The scaling factor range	$\tau = [0, \frac{1}{4}, \frac{1}{2}, 1, 2\}$
Number of base station antenna range	75
Estimation method	LMMSE
No of montecarlo simulaon	10000



a) Results of the average spectral efficiency by Emil

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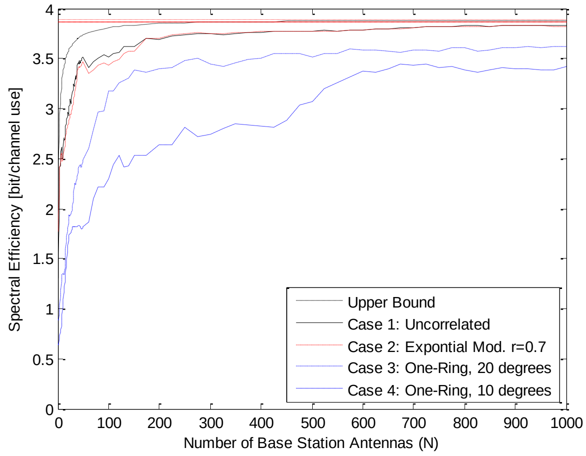

b) Result of proposed average spectral efficiency

Figure 7 Comparison of the achievable UL spectral efficiency for an average user in the multi-cell scenario depicted

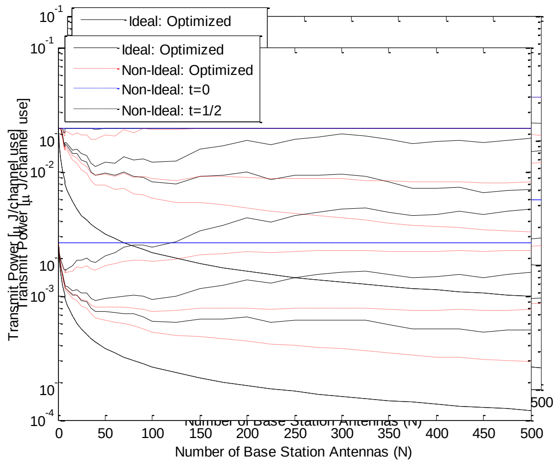

Figure 8 comparison of the transmitted power for the achievable energy efficiency with for the ideal structure or the non-ideal hardware system for the fixed amount of transmit power

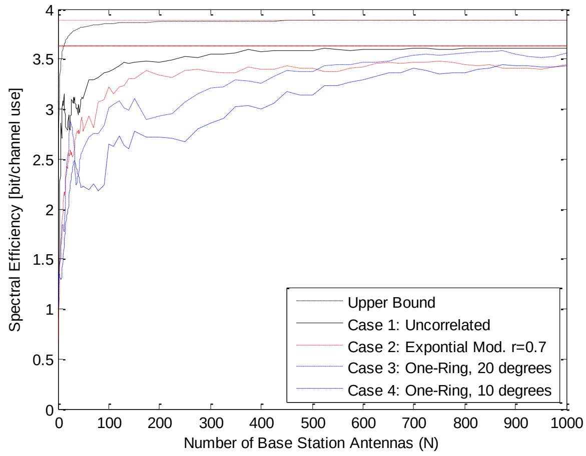

Figure 9 Spectral efficiency for the pilot contamination for the Emil a[2] and our method

B. Spectral Efficiency of Non Ideal Lin

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The comparison of transmitted power of the UL energy efficiency for the ideal and non ideal link environment under hardware impairment is given in the Figure 9. The Figure 9 b) depicts that the non-ideal pilot of our proposed method needs less power for the transition and is better than the ideal intra cell pilot performance. In Figure 10 t2he performance is compared under the pilot contamination for the energy efficiency. Even for large contamination method performs better and the spectral efficiency per channel is more due to use of normal pseudo random channel initialization.

7. Conclusions

In this paper, the new channel modeling is proposed for improving the energy and spectral efficiency of the Massive MIMO system for the 5G LTE system evaluation. The design of energy efficient system is investigated for the cellular networks by modifying the performance the channel estimation method by using the normal random initialization. Impact of the hardware impairment is considered for the channel modeling.

The performance of modified estimation strategy is compared for improving the energy and spectral efficiency. Performance is tested under different degree of hardware scaling factor τ, and for different number of antennas at the BS. Performance is also tested under the different pilot contamination. The transmitted power is also evaluated

Energy and spectral efficiency under proposed channel modeling strategy is found to be far better than the existing method of Emil [2]. The power consumption minimization and energy efficiency maximization is better with proposed normal distribution for the same estimation model.

It is found that non-ideal pilot of our proposed method needs less power for the transition and is better than the ideal intra cell pilot performance. Also for large contamination method performs better and the spectral efficiency per channel is more due to use of normal pseudo random channel initialization. The performance of beam forming can be considered in the future.

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Authors

Prof Mohd Amzad has joined Sagar Group in July 2013 .He is pursuing PhD in Communication & Antenna design from AISECT university Bhopal. He has 12 years of experience in teaching and year experience in industry. He has conducted several skill development program and workshops for students

Dr. Sanjeev Kumar Gupta is PhD and is currently working as a Prof in RNTU technical university Bhopal India. His field of interest are signal processing. He is guiding numbers of dissertations and PhD Thesis and he is a true motivator.

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