International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 6 Issue 1, January - 2022, Pages:26-37

Performance Evaluation of Optimal Planning Linear Pre-coding in Terms of Energy Efficiency Massive MU-MIMO 5G Systems

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Abstract— *Massive MIMO where BS equipped so with hundreds antennas is then one of promising technologies of 5G networks for meeting the future requirements of wireless new generation. Mobile broadband cellular systems are so increasingly being evolved for meeting these demands of throughput also coverage improvement as well link reliability. Nowadays, tremendous sophisticated terminals are coming to market requesting high capacity with QoS but such demand is not able to be satisfied so due to limiting spectrum scarcity of networks wireless and also cannot reach high energy efficient. Massive MU-MIMO can be proposed to circumvent this shortcoming, in which the beams can be directed more selectively to user terminals, and it can serve simultaneously a much number of so autonomous terminals with high amount data rates. In other word, massive MIMO offers high EE energy-efficiency using simple schemes. For this paper, in order then to capture these promising gains expected from the 5G networks, we propose so two precoding schemes, i.e., simplest linear precoding MRT (maximal-ratio-transmission) and ZF (zero-forcing), to evaluate and compare energy efficiency regarding performance in massive MU-MIMO assuming at BS imperfection channel state information. We take account power circuit consumption and transmit power. Numerical results showed ZF precoding achieves higher EE compare to MRT precoding method, but only at small ratio M/K (M is BS antennas number while K represents user's one) scenario MRT outperforms ZF precoding.*

Keywords— Massive MU-MIMO, 5G, Energy-Efficiency, Linear precoding, Imperfect-CSI.

1. INTRODUCTION

Demands for faster multimedia access and internet access services have increased exponentially recently. The mobile data broadband requirements increase consequently due to demand explosive of services/applications required by rapid proliferation tablets, smart-phones also laptops. For example, global connected devices will be around thirty-nine billons for wireless communication services expected by 2025 [1] [2]. Mobile cellular broadband communication networks are continuously improving to meet or cater the future demands of high rate of data, the reliable link also as well wide area of coverage extension [3]. The satisfaction of this data volume forecasted will forcibly increase consumption energy greatly and consequently the global mobile communications carbon footprint will grow too, as illustrated by 2020 projection[4]. So massive MIMO seems being reasonable technology to support such rapid increasing traffic data and provide higher EE.

Other hand, recent development 4G communication with its relative requirements of cellular mobile devices also the multimedia services has received an exponential growing. In[5] although offering such performance but they still many existing challenges in this current fourth-generation technology, that are, high consumption energy and crisis in spectrum resources.

To take further advantages of resources spectrum scarcity whereas reducing power consumption where new technique based upon hundreds of array elements (antennas) arrangement at BS commonly called massive MIMO[6][7].was pioneered providing many and interesting conclusions about unlimited BS antennas M on massive MIMO. The system relies on TDD operation, problem of fast fading effect, imperfect CSI but also uncorrelated interference by using simplest linear precoding[5] are managed. As we already knew that problem of inter-cellular interference known namely pilot contamination been a bottleneck issue within massive MIMO[8]. However, our model is about single-cellular system that such phenomenon is not concerned in our energy-efficiency regarding performance derivation in downlink. In general, massive MIMO provides better energy-efficiency.

The CSI plays some important key role by exploitation of the channel orthogonality at the BSs in system MU-MIMO[8]. Most of works assumed known CSI perfectly at BS. This effect will lead real channel propagation not matched the pre-coding matrices, therefore resulting among user terminals and data stream interference, drastic capacity degradation[9].

As in literature, the large antenna technique at the BS is seen to boost the emitted EE comparing to fourth generation wireless technologies[5][6]. On the downlink the critical major operation is the pre-coding, that is, mapping the message symbols that are intended to K number of terminals into M-antenna signals(with M>>K) in which antennas in services transmit. Then our work contribution is based so on comparing EE of most prominent schemes MRT/ZF linear precoding as when BS M-antenna number increases assuming downlink concept MIMO.

MIMO technique known to be attracting much attention from wireless systems more than approximately ten years, because this scheme without extra bandwidth can essentially offer important data rate increase, QoS link reliability while boosting radiation power[10]. That means deployment of this scheme MIMO has brought somewhat significant enhancement terms of SE and as well offering a reliable communication by taking diversity advantages also multiplexing of spatial gains. Since MIMO antennas array is large then MU-MIMO performance gains then can particularly be very important. So the main obstacle is to keep energy consumption also its cost very low with respect antenna elements size[11][12], so massive multiuser MIMO is able to perfectly do so.

Combination techniques of the method linear pre-coding in addition the massive array elements useful properties can be permitted and even suitable to enhance performance network in energy-efficiency terms. Such combination concept will then forcibly and greatly bring network interference down or reduce and therefore enhance performance of system consequently. This is why massive MU-MIMO with the M-antenna large has seen BS M-antenna with case to save power transmitted under perfect/imperfect CSI in uplink scenario[13]. In addition, it investigated by[13] that every single-antenna terminal transmit power massive MU-MIMO scales down then proportionally to the BS M-antenna number with case CSI perfect or not (CSI imperfect). This scales down to a square root BS M-antenna number with case CSI imperfect using the simple linear-techniques, by targeting to obtain a same performance like SISO corresponding system. Besides[14] has also inspected the possibility to reduce transmit-power as a square root number BS of M-antenna accompany with the only minor loss of a data-rate under imperfect CSI. Although this can provide major reduction from radiated-power but it is unfortunately bad or insufficient from EE perspective. Energy-efficient should be maximized and while an increasing a transmitter power with a M-antenna for compensating an ever-increasing circuit power consumption[15].

In contrast to[13] beliefs, the authors[16] showed that EE metric here is maximized by opposite strategy actually an increasing power with a M-antenna, where previous beliefs were seen inefficient regarding EE scheme scenario. Paper has considered an objective realistic power-consumption network also large scale fading consideration. This EE realistic approach optimization shows how our parameters interact such the number M-antenna, also active users besides transmitter-power including a circuit power. Therefore, the linear pre-coding MF, ZF and MMSE were intensively inspected for performance analysis perspective, where scenarios uplink/downlink are considered with channel perfect/imperfect conditions.

In addition, [17] studied a beamforming training for an acquisition CSI at each side user in massive MU-MIMO downlink, where it found that the overhead for channel-estimation so can be small and also independent to a BS number of a M-antenna but proportional to number K terminals. It also derived downlink achievable rate using linear precoding cases and then compared the SE beamforming training to[18] for non a beamforming training. In[18] comparison between conjugate/zero-forcing based beamforming in EE/SE terms is done, and where it showed for high EE to conjugate beamforming is better while a SE is low, and whereas a reverse holds for a low-EE and a high-SE for the ZF. However, our paper considered only a radiated EE to an evaluate network performance. Our basic model we mainly consider consumption analog power circuits of the system.

[19] show effect of vector/matrix normalizations on performance system based upon pre-coding normalization under CSI perfect. In which various pre-coding schemes were conducted deriving lower/upper bound rates, where MF works well for the matrix normalization while a ZF performs better for system vector normalization, comparison and analysis are discussed further. However, a MF was a further pointed out performing good in a decentralized structure. While[19] is conducted by case assuming imperfect CSI with a vector normalization considering for comparison and analysis purpose.

In other vision, with CSI perfect scenario transmitted-power at user terminals can make inversely and basically proportional to number BS M-antenna while making inversely and basically proportional to a square root BS M-antenna number in imperfect-CSI scenario without diminishing in performance. However, very large BS M-antenna requires more consumption-power for MIMO RF chains, whereas conventional MIMO pay certain attention to PA power-amplifier consumption-energy. But this has energy cost to pay and also more devices or equipments for acquisition SE enhancement[20]. Moreover, according to[5] the consumption radiated power for each of antennas is so small scenario massive MIMO. Other work inspected that EE/SE with power existing model that takes only into account consumption of transmission power, then incrementing transmission-antenna number can induce huge EE also and SE performance than before one. However, since size of system hardware massive MIMO scenario is also grew, effect of circuit-consumption-power should gradually be increased by factor of BS M-antenna. Therefore, circuit-power (RF) in so addition to radiated-power consumptions must be concerned as a fundamental key in practical case for modeling consumption-power of system. This because circuit-consumption-power grows with BS M-antenna incremental, hence proportionally total-consumption-power is consequently growing[21][22].

Based on our concept, we provide novel consumption power and evaluate massive MIMO EE relying upon our proposed model of consumption power in single-cellular network. After taking an account a circuit-consumption-power of transmission-antenna, an EE would not expected be fundamentally also gradually increased along with an increase of a BS M-antenna. This vision, of our model is further then based on a LTE BS transmission-power with case massive array-elements. Loss factors and a scale factor are applied such as DC-loss, cooling-loss, feeder-loss, main power-loss in our considered model [23].

2. SYSTEM MODEL

Considering single-cellular context massive MIMO from downlink with transmitter M-antenna at BS serves K terminals having only single-antenna that share same resource by assuming TDD operation. Then based upon this TDD mode, the BS acquires downlink CSI via the uplink pilot training. Where the CSI acquired will be used then to form MRT precoding and ZF precoding

International Journal of Engineering and Information Systems (IJEAIS)
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vectors for the downlink (forward-link) spatial multiplexing. This model, BS is supposed to perform these linear pre-codings so in order basically to process signal before transmitting to all K terminals. The assumptions are relied upon that BS has so large BS number of a M-antenna comparatively to number K terminals that are served simultaneously under control of imperfect knowledge CSI. This study, we ignore effect from large scale fading for simplicity reason due to intractability.

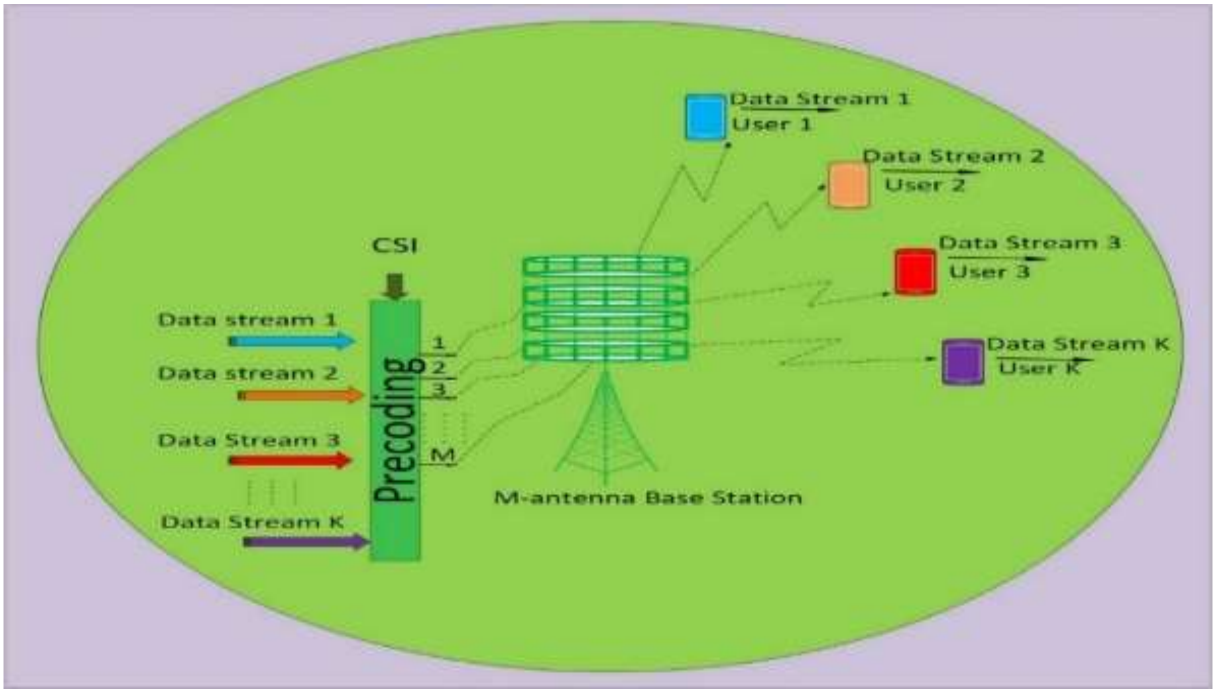

Fig. 1 Downlink multiuser MU Massive MIMO operation mode technology

2.1 IMPERFECT CSI

In perspective of retrieving transmitted vector of data symbol at receiver, accurate CSI of complex gain H channel matrix is allowed. In practical, however, imperfect CSI estimates happen in different wireless practical systems. Assuming imperfect CSI, the BS estimates corresponding channel to design the downlink pre-coding matrix by using channel reciprocity.[5][24] have been discussed about channel imperfection scheme in which BS has CSI imperfect knowledge and then it uses for downlink Tx transmission, where $\hat{H}$ accounts for channel estimates. This channel estimation should satisfy relationship given as

$$H=\xi\hat{H} + \sqrt{\left(1-\xi^2\right)}E, \quad (1)$$

where E denotes estimation error channel matrix, elements $i.i.d.\ CN(0,1)$. While the $\xi \in [0,1]$ controls the accuracy of CSI or more precisely the reliability of estimated channel (it measures CSI quality), where bigger ξ results good CSI. $\hat{H}$ and E are independent with estimator channel MMSE utilization.

2.2 DOWNLINK TRANSMISSION

With single-cellular context massive MIMO concerning system downlink, where BS equipped so with M-antenna transmits to K << M multiplicity terminals single-antenna in order especially to serve them simultaneously. M-antenna and K-terminal are both large and with ratio $\alpha=M/K$ being constant[25]. We assume small-scale case fading with BS CSI imperfection. Using at BS estimated CSI, hence the precoded signals vector are basically formed and then transmitted simultaneously to terminals. Furthermore, BS antennas transmits $M\times 1$ vectors to each antenna and therefore at receiver end the K terminals receive $K\times 1$ signal vector denoted by the symbol y and then given as follow[5]

$$\mathbf{y} = \sqrt{\rho_d}\mathbf{H}^T\mathbf{s} + \mathbf{n}, \quad (2)$$

where ρ_d is downlink transmit Tx power, superscript $(.)^T$ represents transpose of the matrix, and s denotes the precoded version data symbols q, while n is the $K\times 1$ noise vector with $i.i.d.\ CN(0,1)$ entries.

Transmission downlink power is so normalized as $E = \{\|s\|^2\} = 1$, that is, each antenna then transmits at power of ρ_d/M, while term H represents M×K channel matrix that corresponds to small-scale MIMO channel Rayleigh fading also with $i.i.d.$

$CN(0,1)$ entries assumed. Estimated channel is so far assumed instead of accurate channel assumption to evaluate precoding performance in some realistic manner in practice.

2.3 LINEAR PRECODING

How linear pre-codings MRT/ZF are applied in asymptotic approximation performance derivation with CSI imperfect concept to improve especially energy efficiency using very large service BS M-antenna known as the massive MIMO scheme under so-called a favorable propagation. The linear precoders MRT/ZF are studied within this article, which are suitable regarding massive MIMO in order essentially to evaluate precoding performance of system. The intention is how precoder is essentially needed to remove principally interference from received k user signal. Therefore, to jointly mitigate interference term and maximize SINR in order hence to improve highly energy efficiency, these aforementioned pre-coding schemes are applied in this work and where previously highlighted. These two pre-coders must be designed to cancel this interference kind and enhance the pre-coding performance massive MIMO in term of energy-efficiency, which takes consideration of power circuit consumption model, we further, give some details in coming section.

2.4 POWER CONSUMPTION

Consumption energy includes both transmission power and circuit consumption-power in the network, where transmission power is basically related to PA. How to evaluate realistically the EE in presence of circuit consumption power consisting of radio frequency in chains power consideration?

Our model is considered practical scenario, contrary to some other previous works done in field of EE analysis. Some existing works[13] just focus only upon downlink transmit Tx power to evaluate energy-efficiency in which surely we think and believe that this is really not enough and sufficient towards network energy-efficient analysis. Because there are other parameters, which need for taking account such as circuit consumption power, we think to be important parameter concerning energy-consumption massive MIMO, which can influence tremendously the results. Although considering the circuit-power aspect, we will tackle the aspect of RF chains power-consumption only and ignore baseband processing power consumption within proposed model, where[26] derived EE by considering baseband processing.

3. PERFORMANCE MODELING OF ENERGY EFFICIENCY

Wireless communications are been interested in EE research areas case of technology massive MIMO. For this section, we are investigating downlink multiuser MU massive MIMO energy-efficiency regarding performance evaluation under popular linear precodings that are, MRT/ZF implementations, after then their performances also are compared. In our propose model every terminal is supposed particularly to have single-antenna at the reception while BS equipped then with many service BS M-antenna order of tens or more even hundreds. Performance evaluation done considering CSI imperfection in which large scale fading effect scenario is omitted. Analysis has taken into further account transmit Tx power and analog-circuit power regarding to all devices in the networks, in addition so loss factors consideration coming from certain devices like antenna-feeders, system cooling, main supply power and DC supply power.

3.1 FORMULATION ENERGY-EFFICIENCY

Energy efficiency formulation is related to knowledge of SE spectral efficiency and total power that will be consumed by network in which thereby EE is evaluated. Although EE is seen as number of the information bits transferred per joule energy consumed (bit/Joule), however, this related ratio or definition alone may not capture the entire or whole story, because since the EE improvement is considered to be valuable only when the desired SE is ensured[27]. According to this aspect, our model will characterize EE performance metric as bps/Hz/W, this unit is considered to be an useful metric of determining and evaluating the EE of networks, then the relationship is expressed

$$\eta_{EE} = \frac{R_{Sum}}{P_T} = \frac{\sum_{k=1}^{K} R_k}{P_T} \quad (bps/Hz/W) \tag{3}$$

As clearly shown here that EE depends not only upon sum-rate network R_{sum} (spectral-efficiency) in bps/Hz but it depends also upon the total system power consumption P_T (watt) which then will be later formulated.

3.1.1 MODEL CONSUMPTION POWER

Regarding the most of works done before, the existing ones, the consumption of the circuit power is designed or modeled to be a constant power consumption which represents addition of a power consumed so by various RF analog elements and the processing digital signal circuits [23][28]. Unfortunately, considering this scenario it seems that the EE is increasing without limit, then unbounded EE by incrementing more BS M-antenna, this result comes out because of neglecting in fact that every BS antenna requires specific circuit elements which consume power and also the complexity of signal processing grows relatively with M-antenna[16]. We think this is not a realistic model, when aiming to evaluate especially EE design, an efficient fashion in the communication network by assuming circuit power equals to fix power, which not match realistically.

In wireless system the radio-access base-station is been identified to be the biggest component which consumes more the power in cellular mobile networks. The authors [23] have been inspected power consumption distribution in conventional macrocell (Macro-BS) where the power amplifiers consumption represents 57% of total BS power (including feeder) and baseband BB signal processing occupies 13% while the remaining 30% belongs to RF chains and the components losses factors are mentioned. Therefore, power amplifier consumption depends upon transmit power, RF chains depends upon digital to analog convertor, filtering, mixer and synthesizer and finally components loss factors that consist of antennas feeders, DC power, main supply power and lastly the system cooling. These highlighted points represent the major consumer devices in the system where is approximately attributed 87% of power consumption total for Macro-BS without including baseband consumption power as considered by[26][29]but this is omitted in this study [23]. Our consideration will be limited only to RF chains power consumption modeling in addition power amplifier consumption for the downlink because of large BS M-antenna number massive MIMO.

Our paper interestingly investigates energy consumption analog RF chains only without taking then into account baseband inspection. The model of this energy consumption concentrates on RF chain power consumption while omitting role of power consumed by baseband processing [31]. Besides, our model inspects context of the downlink system, that is, the BS represents the transmitter, while the receiver represents user terminal is not concerned in this power consumption modeling. All antennas share same LO (local oscillator) known as frequency synthesizer.

Additionally, in conventional MIMO each antenna is supposed to be then supported by an expensive radio-frequency chain which includes DAC or ADC convertors, further mixer that plays role of frequency up/down conversions, PA and also band-pass filter[32]. Therefore, the transmitter MIMO block diagram system describes how data signal transmitted will pass via DAC (digital/analog convertor) which is responsible of converting digital signal into analog signal after then a signal passes via the filter in turn remove the noise and after then a signal is further multiplied in mixer with transmitted signal from LO. The mixer output will pass by another filter to suppress further the resulting noise which is added by LO, after then before sending signal to channels it will pass lastly by PA responsible power amplification[32].

It is well-known that massive MIMO requires more antennas at BS, therefore the impact on circuit consumption power will increase consequently in which many prior works have ignored this effect. This is major motivation why we consider circuit-consumption-power model in this study. However, certain works existing considered only radiated-power without circuit-consumption-power association[13]. We focus upon imperfect-CSI, which seems more realistically case by considering circuit-consumption-power. Whereas[20] has inspected using perfect-CSI scenario but this assumption really does not so hold with wireless channels in practice environment. Even though baseband (BB) processing consumes power too due to relationship existing between BS M-antenna, number of the K terminals and different circuit-components, however, we just consider only power consumes by RF chains (analog-circuits). In this paper, model of power-consumption assumed here is based so on some prior works such as [23], the similar work considered by[33] for analyzing EE massive MIMO, besides parameters are related to LTE-BSs assumptions.

The total network power consumption needed by signal path can be splitted into further two parts as[33], in one hand, consumption PA and other hand consumption-power of the remaining circuit-components and all accompany by loss factors. In one hand, for communication-system, the EE depends upon required transmission power. Hence, we consider a system to be more EE energy-efficient when transmission power required is less to achieve target rate of information under QoS satisfaction constraint[25]. In turn, energy-consumption PA depends upon this downlink transmission Tx power ρ_d per PA efficiency η and losses belonging to feeder σ_{feed}. Therefore, power-consumed due to amplifiers is related to transmit Tx power and then the relationship is as follow

$$\frac{\rho_d}{\eta\left(1-\sigma_{feed}\right)} \tag{4}$$

where $\eta \leq 1$ denotes PA efficiency.

In other hand, P_{CP} power-consumption for RF chains is given as function of power used for digital/analog conversion operation denoted by P_{DAC}, power used for mixer operation denoted by P_{Mix}, power used for frequency-synthesizer P_{Syn}, and power used at transmitter Tx for active filters is denoted by P_{FiltTx}. Note that circuit consumption-power P_{CP} grows linearly respect to number service BS M-antenna. Therefore, the circuit-consumption-power of total BS number of a M-antenna at transmitter is then formulated by

$$P_{CP} = M\left(P_{DAC} + P_{Mix} + P_{FiltTx}\right) + P_{syn} \tag{53.1.1}$$

With respect large-scale of fading incorporation, then the equation (5) of this kind of system consideration will become intractable to manage so, therefore large-scale of fading effect is omitted in our proposed model.

Additionally, overall system power-consumption is impacted by certain losses incurred due to direct-current to direct-current DC-DC power/main power MS supplies and finally active site cooling. In summary, total consumption-power scales with these loss factors σ_{DC}, σ_{MS} and σ_{Cool}, respectively, and then given as the following

$$P_T = \frac{\frac{\rho_d}{\eta\left(1-\sigma_{feed}\right)} + P_{CP}}{\left(1-\sigma_{DC}\right)\left(1-\sigma_{MS}\right)\left(1-\sigma_{Cool}\right)} \tag{6}$$

3.1.2 MRT Energy Efficiency

Evaluation of overall EE per cell for MRT pre-coding under imperfect CSI taking into then account circuit consumption power of different components used at transmitter and transmit power as well certain loss factors due to antenna feeder, main supply power, direct-current power, efficiency of PA and system active cooling without large-scale of fading effect consideration. Therefore using sum-rate (spectral-efficiency) with total consumption-power eq. (6) will finally so provide us global energy-efficiency eq. (7) for MRT of system as follow

$$\eta_{EE_{MRT}} = \frac{K\log_2\left(1+\frac{\rho_d\ \alpha\ \xi^2}{1+\rho_d}\right)}{\frac{\frac{\rho_d}{\eta\left(1-\sigma_{feed}\right)} + M\left(P_{DAC}+P_{Mix}+P_{FiltTx}\right) + P_{syn}}{\left(1-\sigma_{DC}\right)\left(1-\sigma_{MS}\right)\left(1-\sigma_{Cool}\right)}} \tag{7}$$

MRT SINR may look higher as we desire from any given channel reliability by just scaling BS antennas up. The effective SINR of MRT pre-coding grows linearly with number of service BS transmit M-antenna. With modest number of BS a M-antenna EE can increase considerably. Unfortunately, increasing BS number of a M-antenna without bound will affect circuit-consumption-power and hence decrease energy-efficiency consequently.

According to (7) EE_{MRT}, it is remarkable that when transmit-power increases therefore desired signal power increases but unfortunately the interference power increases too in the denominator of SE, but also total-consumption-power will increase too, so the overall EE will be affected consequently. But this impact should be comparatively less than ZF precoding one only within a small α, as seen the interference power in SE is not related to channel error estimation. That is to say, it depends only upon number of BS a M-antenna that needs to be deployed and number of autonomous user terminals served simultaneously.

3.1.3 ZF Energy Efficiency

The evaluation of overall energy efficiency per cell for ZF precoding under CSI imperfect taking account circuit consumption power of different elements used at transmitter and the transmit-power and as well certain loss factors due to antenna feeder, main power supply, direct-current power, efficiency of PA power amplifier and system active cooling without large-scale of fading effect consideration. Therefore using the sum-rate (spectral-efficiency) with total consumption-power equation (6) will finally provide us global energy-efficiency equation (8) for ZF of the system as follow

$$\eta_{EE_{ZF}} = \frac{K\log_2\left(1+\frac{\rho_d\ \xi^2\left(\alpha-1\right)}{1+\rho_d\left(1-\xi^2\right)}\right)}{\frac{\frac{\rho_d}{\eta\left(1-\sigma_{feed}\right)} + M\left(P_{DAC}+P_{Mix}+P_{FiltTx}\right) + P_{syn}}{\left(1-\sigma_{DC}\right)\left(1-\sigma_{MS}\right)\left(1-\sigma_{Cool}\right)}} \tag{8}$$

ZF SNR may look higher as we desire for any given channel reliability by just scaling BS antennas up. The effective SNR of ZF precoding grows linearly so with DoF, that is, difference between number of BS a M-antenna and number of autonomous K terminals, M-K which comes from (α-1). It is so notable that in a modest BS number of a M-antenna, the EE can increase considerably. Unfortunately, ever-increasing BS number of a M-antenna without bound will increase the circuit consumption power forcibly and therefore decrease energy-efficiency consequently. When the channel error estimation is small then energy-efficiency will be greatly impacted but when it grows large the performance increases and when it goes very large such like one then the system becomes perfect CSI, hence it results a better performance. Transmission power used can also influence energy-efficiency as we see in both

EE equations that higher transmit power can decrease EE considerably because of transmit power will amplify power desired signal in SE but also in denominator of EE, it also increases total consumption power. Note that the small factor of (M-K)/K corresponding to (α-1), in other word small DoF for ZF pre-coding can make ZF pre-coding performance worse compared to MRT pre-coding.

From the ZF EE equation (8), we note particularly that when transmitter Tx power increases then desired signal of power increases and as well interference power, and also total consumption power will increase too, so the overall EE will be affected but the impact is less compare to MRT because of channel error estimation mitigates interference power term. When M antennas increases therefore precoding ZF performance would be better than an MRT because of interference power is diminished due to channel reliability in this interference power term, which not available in MRT interference power term. Unfortunately, the small cell BS number of a M-antenna or α will not benefit to ZF precoding performance, but rather MRT precoding can work better under poor (DoF) operation.

Comparing two precoders energy-efficiency equations (7) and (8) for same transmission power and a constant number terminals, as BS number M-antenna increases (taking M >> K consideration account) we say precoding ZF achieves EE high performance than an MRT precoding.

4. SIMULATION & RESULTS

We present in this section the results of the simulation to confirm our proposed model accuracy regarding massive MIMO performance evaluation linear precodings concept techniques in EE terms. That is to say, this section will implement the simulation for massive MIMO technology with MRT/ZF pre-coding schemes under various parameter considerations of the system in perspective essentially to validate our energy-efficiency model and also theoretical analysis, besides we evaluate spectral efficiency achievement performance tradeoff with energy-efficiency regarding performance achievement.

4.1 SIMULATION PARAMETERS

To evaluate To evaluate our EE performance massive MIMO with MRT/ZF precoding schemes, there will be listed some related parameters provided to analyze proposed model. Model does consider only small-scale of fading and ignore effect of case large-scale of fading in our channel modeling as we already mentioned before. Regarding small-scale of fading, hence we assume channel between each transmitter antenna and corresponding receiver antenna is chosen as Rayleigh distributed.

The parameters used essentially in our basic proposed model for energy efficiency precoding performance evaluation are shown table 5.1. Besides, those parameters highlighted in table, their values taken by referring or according to [23][31][32][33] . They concern circuit consumption power and relative loss factors values which will be then used essentially to evaluate energy efficiency precoding performance. In all the scenarios, noise power at all receivers' side assumes to one.

Table 4.1 System Parameters

Description	Symbol (Parameter)	Value
Consumed power in Digital/analog convertor	P_{DAC}	15.6 mW
Consumed power in mixer	P_{MIX}	30.3 mW
Consumed power in filter at TX	P_{FILT}	20 mW
Consumed power in LO	P_{SYN}	50 mW
Loss due to feeder of antenna	σ_{feed}	0.5
Loss due to the direct-current power	σ_{DC}	0.06
Loss due to main supply power	σ_{MS}	0.07
Loss due to system cooling	σ_{Cool}	0.09
Efficiency of PA	η	0.38

4.2 NUMERICAL RESULTS

In order so to evaluate precoding performance of proposed model, we provide results based upon simulation of energy-efficiency and spectral-efficiency as well, and compare different precoder performance and differ to beliefs that circuit power is a fixed power. To illustrate behavior of EE in contrast to where circuit-power consideration was ignored with very-large BS M-antenna energy-consumption model design in the literature.

International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 6 Issue 1, January - 2022, Pages:26-37

4.2.1 SCENARIO 1 DISCUSSION

Fig.5.1 illustrate EE versus BS number of a M-antenna where the system serves 15 user terminals simultaneously with CSI imperfect, assuming (ξ^2 =0.50) channel error estimation and 10dB transmit power, other parameters are found by table 5.1. In proposed model, energy-efficiency precoding performance of two differents linear pre-coding, that are, MRT/ZF, are compared. The proposed model evaluates energy-efficiency based on circuit consumption concept power and very-large BS number of a M-antenna. Hence, results show as BS number of a M-antenna increases then both precoding performances increase at first. Realistic EE model behaves firstly appearing to increase until their maximum values by increasing M-antenna and then it decreases later due to growing of circuit consumption power which grows linearly so with M-antenna as shown from fig.5.2.

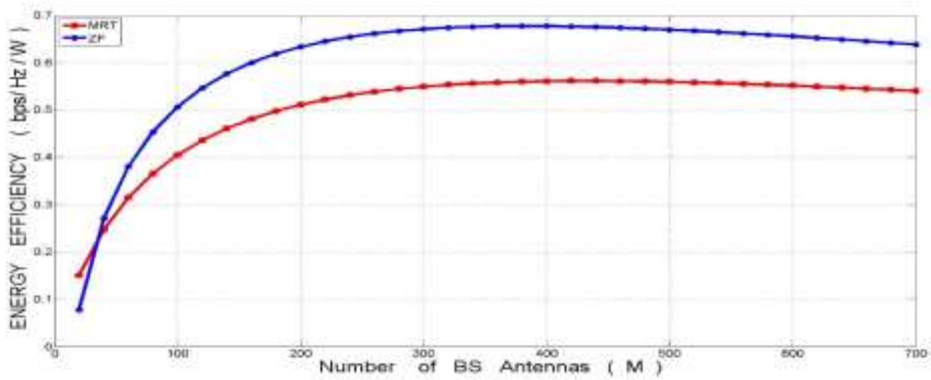

Fig. 4.2.1.1 Energy-efficiency precoding performance versus BS number of a M-antenna in downlink single-cellular system massive MIMO (ρd=10dB, K=15, ξ^2 =0.50)

In fig.5.1 accordingly, when BS has small number of a M-antenna (small $\alpha=M/K$) compared to number K terminals then MRT precoding performance is better than the ZF pre-coding performance in that particular scenario belonging to low scenario SNR region, although the gap is slightly modest. While ZF pre-coding performance outperforms MRT precoder one in the scenario of large BS number of a M-antenna (large $\alpha=M/K$) and the gap is slightly important as M-antenna increases. That means very large BS number of a M-antenna compare to number K terminals belongs to high-SNR. Firstly, we observe from the curves that advantage of MRT precoding performance is basically vanishing whereas ZF one increases as BS number of a M-antenna increases. Due to ZF spatial DoF increases but also it takes advantages of suppressing inter-user (IU) interference completely but effect of the channel error estimation still due to CSI imperfect, which limits the precoding performance while MRT does not cancel completely interference.

4.2.2 SCENARIO 2 DISCUSSION

Fig.5.2 plots EE of two precoders where 15 user terminals are served simultaneously with CSI imperfect assuming (ξ^2 =0.50) estimation error channel and 10dB given transmit power. The results show MRT precoding performance outperforms ZF precoding performance within a small cell BS number M-antenna deployment scenario comparatively to terminals K number (from 20 antennas to an approximately 40). Whereas ZF precoding performance is better than MRT one when BS number of a M-antenna is very-large compared to number K terminals in which gap between both them is slightly considerable compared to MRT scheme one.

The results demonstrate and confirm one of our key motivations, that is, how far the difference is between two scenarios with and without circuit power considerations, where the results show clearly that without circuit power consideration the energy-efficiency is increasing without limit. In contrast, this belief from literature, our new model shows that EE is not really unbounded when M-antenna increases very-large. Furthermore, we observe the optimal EE value for each precoder, approximately with 0.6773 bps/W/Hz using 380 antennas in service while 0.5612 bps/W/Hz with 440 antennas, respectively for ZF and MRT precoders. Even though, our model of EE increases, but later on it decreases. Compared to scenario where circuit consumption power was not especially considered so EE increases infinitely as M-antenna increases, we prove further that this belief does effectively not hold true practically, and also validated by our proposed model.

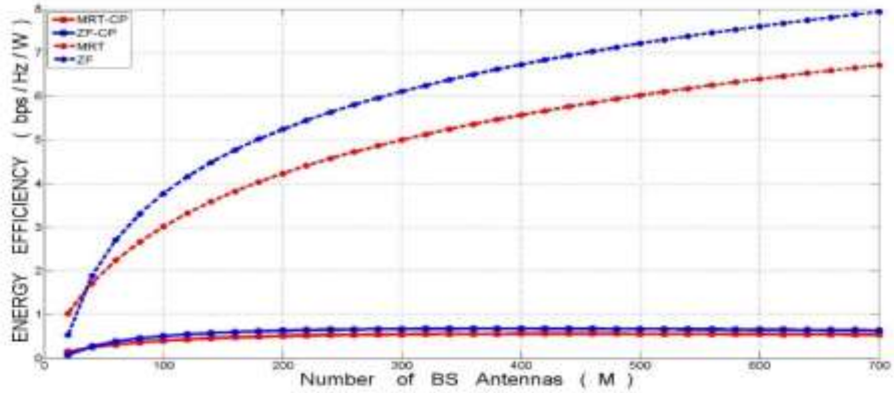

Fig.4.2.2 Energy-efficiency precoding performance versus BS number of a M-antenna with and without circuit-power considerations in downlink single-cellular system massive MIMO (*K=15*, ξ^2 =0.50, ρ_d*=10dB*).

4.2.3 Scenario 3 Discussion

In fig.5.3, we plot EE for two precoders versus BS number of a M-antenna with two different number user terminals (K=10 & 30) that are simultaneously served under 10dB transmit-power with CSI imperfect assuming (ξ^2 =0.50) for channel error estimation. Results demonstrate and confirm that an efficient-energy can achieve by allowing so more and more users to access the channel simultaneously, thanks to massive MIMO that illustrates one 5G-example expectations. We observe energy efficiency regarding performance that accommodates 30 users is slightly higher compared to 10 users' accommodation. Additionally, performance gap increases between two schemes as terminals number increased. Both cases, ZF precoding performance outperforms MRT within large BS number M-antenna comparatively to number K terminals belonging to high SNR while MRT outperforms ZF within a small range number of service BS M-antenna belonging to low-SNR scenario region, where M-antenna cross-point is used to compare performance precoding two schemes. Both cases, at first energy-efficiency result performance increases when BS M-antenna service increases and then decreases later because of circuit consumption power increases linearly so with M antennas.

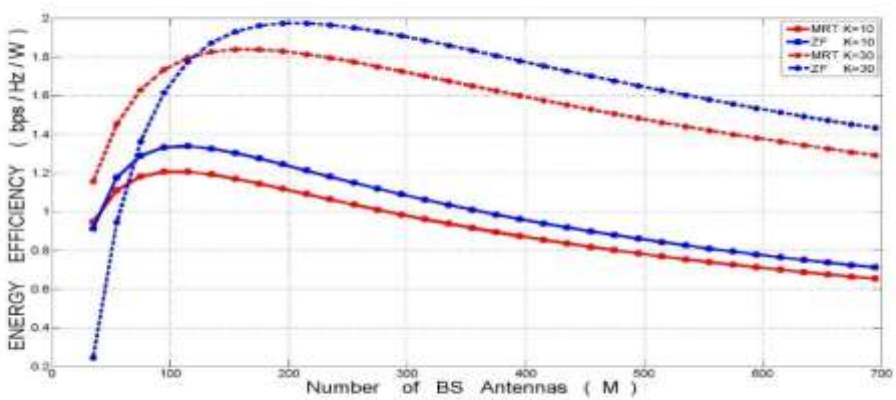

Fig.4.2.3 Energy-efficiency comparison precoding performance versus BS number of a M-antenna in downlink single-cellular system massive MIMO (ρ_d*=0dB, K=10 & 30*, ξ^2 =0.50)

Fig.5.4 illustrates relationship between an energy efficiency with number of the K terminals by fixing M-antenna number at BS to 150 and transmit power to 10dB with CSI imperfect assuming (ξ^2 =0.50) for channel error estimation. Curves show that EE can increase at beginning by increasing K terminals number; we further observe an appropriate value so that energy-efficiency can let be maximized. Besides, regarding both curves clearly we observe as K number increases then EE of MRT precoding performance increases, however, ZF energy efficiency precoding performance grows first and then later decreases. This reason explains fact that when ZF precoding is performed then it must exist one optimal K terminals number for the highest EE. In addition further to ZF precoding performance improvement issue, we see the corresponding optimum values terms of K number user terminals and its related energy-efficiency are smaller because effect of CSI imperfect that limits highest optimum value reach-ability.

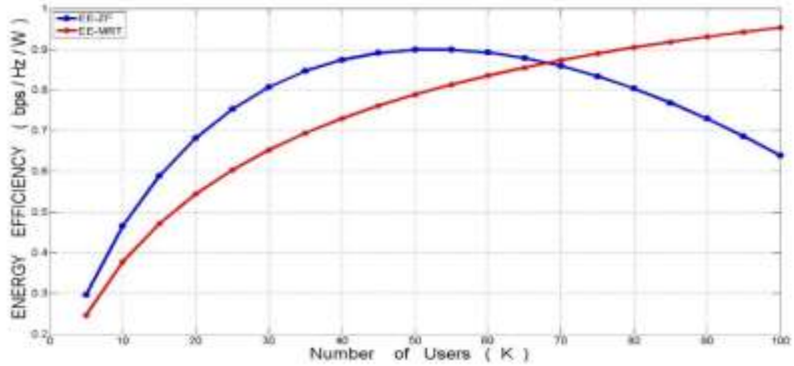

Fig.4.2.3 Energy-efficiency precoding performance versus number of the K terminals in downlink single-cellular system massive MIMO (ρ_d*=10dB, M=150,* ξ^2 *=0.50)*

Another observation is ZF precoding performance falls down quickly under MRT precoding performance which was best efficiently before because of K terminals number is so becoming increasingly closer to a BS number of a M-antenna that will not fulfill the inequality assumption as required by ZF, that is, BS M-antenna should be very large compared to K terminals, $M >> K$.

5. CONCLUSION

This work proposes the new model to evaluate also and compare EE of linear precoding performance in a downlink single-cellular massive (MU) multiuser MIMO where certain key scenarios are explored experimentally in order so to have fundamental concept ideas about EE behavior towards green communication. The paper has covered precoding performance taking account the parameters as EE, total circuit consumption power and the radiated power for MRT/ZF schemes. The results numerically prove that the ZF pre-coding method achieves high EE as compare to MRT precoding method, but only at small ratio α=M/K scenario the MRT outperforms method based ZF precoding. Our results further demonstrate and confirm one of key motivations, i.e., how far the difference is between the scenarios with and without circuit power considerations, where the results show then clearly that without circuit power considerations energy-efficiency is increasing without limit. Our novel model shows that energy-efficiency is not really unbounded when the BS antennas number increases very large. Moreover, we find that incrementing number of terminals can result more energy-efficient as antennas increase; besides when we fix antennas number while increasing terminals number then the results show at first both EE increase in ZF favor, however, later the MRT precoding performance still increasing while ZF EE gradually decreases meaning that exists optimal terminals number which maximizes ZF energy-efficiency. Future works will be concentrated on more general concept such as multi-cellular systems, so by combining and introducing heterogeneous concept networks, the baseband circuit processing tasks will be added to power consumption model so that we will have practically complete circuit power model of whole network. Besides, optimization concept will be considered with respect optimum BS number M-antenna, transmit power also number user terminals serve simultaneously. Finally, we will be really motivated to study how SE and EE can be balanced in order principally to profit both performances significantly in higher order.

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International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 6 Issue 1, January - 2022, Pages:26-37

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