

Performance Analysis of Massive MIMO with Different Precoders under Perfect and Imperfect CSIT Condition

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Abstract—The demand for data traffic in wireless communication system is increasing incessantly with the immense growth of the wirelessly connected devices (e.g. Smartphones, laptops, tablets, etc.). The future generation wireless communication system (e.g. 5G communication system) will have to deal with some core requirements for serving a large number of users simultaneously, upholding high throughput for each user, assuring less energy consumption, etc. Researchers have already started to bring new technologies to light to facilitate the next generation communication system. Massive MIMO is one of these promising technologies which have introduced the concept of using hundreds or thousands of antennas at the base station and serving tens or hundreds of users simultaneously. A massive number of antennas will help to concentrate the radiated energy into smaller region hence will improve the throughput and energy efficiency of the system. In this paper, we have investigated the performance of a massive MIMO system utilizing different precoding techniques (e.g. MMSE, ZF, MRT) under Rayleigh fading channel with both complete and incomplete channel state information at the transmitter (CSIT).

Keywords —MIMO, Massive MIMO, Precoding, MMSE, ZF, MRT, Rayleigh, Capacity, CSIT.

I. INTRODUCTION

A massive MIMO is a type wireless communication system, which uses an antenna array with a large number of antennas, on a scale of few hundreds or thousands [1]. These antennas simultaneously serve many tens or hundreds of terminals within the same frequency resource. The basic concept of massive MIMO is to obtain all the benefits of conventional MIMO but on an enormous scale. Massive MIMO relies on the spatial multiplexing that in turn relies on the base station having sufficient channel information or CSIT. This CSIT is accomplished by having the terminals sending pilots to the BS, based on which BS estimates the channel response to each of the

terminals. Precoding is one of the ways to improve the transmission using this CSIT. This channel state information at the transmitter (CSIT) can be exploited to enhance the performance of massive MIMO system using various precoding techniques. The precoders adapt the transmission to the channel using CSIT to improve the performance of the system. Precoding also helps to reduce the inter-user interference by focusing the energy on the desired user. Some well-known precoding techniques are, Minimum Mean Square Error (MMSE) precoding, Zero Forcing (ZF) precoding, Maximum Ratio Transmission (MRT) precoding, Regularized Zero Forcing (RZF) precoding, Tomlinson-Harashima (TH) precoding, etc. In this paper, we have analysed the performance of MMSE, ZF and, MRT precoding in a massive MIMO system considering perfect and imperfect CSIT condition.

There are different types of research investigated the performance of the precoding techniques in MIMO system. Some literature related to the work in this paper are, [2] derived the capacity of MRT and ZF Precoding and evaluated the spectral efficiency of the transmission of the downlink pilots. [3] investigated the BER performance of massive MIMO system with increasing number of BS antenna. They compared BER performance of ZF, MMSE precoding under Perfect and Imperfect CSI. [4] compares the capacity of ZF, regularized inversion, MMSE and block diagonalization precoders using the empirically measured channel data for multi-user MIMO. [5] investigated the achievable rate and energy efficiency of ZF precoder under the Rician fading channel. This paper showed the change of performance of massive MIMO downlink with the Rician channel factor. [6] analysed the performance of ZF and MRT precoding and compared them to a massive MIMO system under Rayleigh fading channel. They compared the achievable rate and transmit power with the increase in the number of BS antenna. [7] shows a performance analysis of a large multi-user MIMO downlink system using ZF, MMSE and MRT precoding under Rayleigh and Rician fading channel and with perfect CSIT. [8] did a performance

analysis of massive MIMO downlink with ZF precoding.

Following the on-going researches provided, this work offers a comprehensive performance analysis of a massive MIMO downlink system with different precoding such as MMSE, ZF and MRT under perfect and imperfect CSIT condition. Rest of the paper is organized as, in Section II, provides a system model of a MIMO system, and shows the equation for the achievable rate of a user in MIMO system. Section III, describes the precoding techniques used in this work. Section IV gives a short description of perfect and imperfect CSIT. It also represents the CSI assumption to assume the imperfect or incomplete CSI values. Section V discusses the research methodology of this work. This methodology includes the process how the capacity and BER of the system is obtained. All the simulation results are presented and analysed in Section VI. Section VII draws a conclusion to the paper and discusses some future work plan.

II. SYSTEM MODEL

Let us consider a single cell massive MIMO system with a base station equipped with N_t number of transmit antenna serving N_u number of single-antenna user terminals. The received complex baseband signal y can be written as,

$$y = H^H s + n \quad (1)$$

where, $y \in \mathbb{C}^{N_u \times 1}$, $s \in \mathbb{C}^{N_t \times 1}$ is the transmitted message signal vector, $H \in \mathbb{C}^{N_u \times N_t}$ is the channel gain matrix, $n \in \mathbb{C}^{N_u \times 1}$ is the additive white Gaussian noise vector and, \mathbb{C} is the set of all complex numbers. Now, if the transmitter is power constrained, then $\mathbb{E}[tr(ss^H)] = P_{tr}$, where, P_{tr} is the total transmit power available at the transmitter. Also, $\mathbb{E}[(nn^H)] = \sigma^2 I_{N_u}$, where, σ^2 is the noise variance at the receive antenna. The average received signal-to-noise ratio (SNR) can be given as, $SNR = P_{tr} / \sigma^2$. Now let, $P \in \mathbb{C}^{N_t \times N_u}$ be the precoding matrix and x is an $N_u \times 1$ information vector. Therefore, the transmitter vector s can be written as,

$$s = Px \quad (2)$$

Therefore, Eq (1) can be written as,

$$y = H^H Px + n \quad (3)$$

Now, let y_u and x_u be the u^{th} elements of the $N_u \times 1$ vectors y and x respectively. Then, y_u can be expressed as,

$$y_u = h_u^H p_u x_u + \sum_{i=1, i \neq u}^{N_u} h_u^H p_i x_i + n_u \quad (4)$$

The energy of the desired signal in (4) is given by,

$$\mathbb{E} \left[|h_u^H p_u x_u|^2 \right] = |h_u^H p_u|^2 \mathbb{E} \left[|x_u|^2 \right] = |h_u^H p_u|^2 \quad (5)$$

The inter-user interference plus noise energy of (4) can be written as,

$$\begin{aligned} & \mathbb{E} \left[\left| \sum_{i=1, i \neq u}^{N_u} h_u^H p_i x_i + n_u \right|^2 \right] \\ &= \sum_{i=1, i \neq u}^{N_u} |h_u^H p_i|^2 \mathbb{E} \left[|x_i|^2 \right] + \mathbb{E} \left[|n_u|^2 \right] \\ &= \sum_{i=1, i \neq u}^{N_u} |h_u^H p_i|^2 + 1 \end{aligned} \quad (6)$$

Now, from Shannon theorem, the channel capacity over Additive Gaussian Noise Channel is defined by,

$$R = \log_2(1 + SNR) \text{ (bit/s/Hz)}$$

Then, the achievable rate of u^{th} user for the massive MIMO downlink system can be expressed as,

$$R_u = \mathbb{E} \left[\log_2 \left(1 + \frac{|h_u^H p_u|^2}{1 + \sum_{i=1, i \neq u}^{Nu} |h_u p_i|^2} \right) \right] \quad (7)$$

III. PRECODING TECHNIQUES

A. Minimum Mean Square Error (MMSE)

The MMSE precoding technique is generated by using the mean square error (MSE) method. Keeping the average transmitted power at each transmitted antenna at the BS is constrained.

Precoding matrix for MMSE precoding can be written as [7],

$$P_{MMSE} = \frac{1}{\beta} H^H (HH^H + \frac{Nu}{P_{tr}} I_{Nu})^{-1} \quad (8)$$

Therefore, the received vector with MMSE precoding can be written as,

$$y = \frac{1}{\beta} H \left[H^H \left(HH^H + \frac{Nu}{P_{tr}} I_{Nu} \right)^{-1} \right] x + n \quad (9)$$

where,

$$\beta = \sqrt{\frac{\text{tr}(HH^H (HH^H + \frac{Nu}{P_{tr}} I_{Nu})^{-1})}{P_{tr}}}$$

Now, let, y_u , x_u , n_u be the u^{th} elements of $Nu \times 1$ vectors y , x , and n respectively and the u^{th} column of P_{MMSE} is defined as,

$$p_u = H^H \Lambda_u \quad (10)$$

where, Λ_u is the u^{th} column of $(HH^H + \frac{Nu}{P_{tr}} I_{Nu})^{-1}$. Therefore, from, (9) the received vector of u^{th} user with MMSE is given by,

$$y_u = \frac{1}{\beta} h_u H^H \Lambda_u x_u + \frac{1}{\beta} \sum_{i=1, i \neq u}^{Nu} h_u H^H \Lambda_i x_i + n_u \quad (11)$$

Therefore, the achievable rate of the u^{th} user with MMSE precoding is given by,

$$R_u^{MMSE} = \mathbb{E} \left[\log_2 \left(1 + \frac{\frac{1}{\beta^2} |h_u H^H \Lambda_u|^2}{1 + \frac{1}{\beta^2} \sum_{i=1, i \neq u}^{Nu} |h_u H^H \Lambda_i|^2} \right) \right] \quad (12)$$

B. Zero Forcing (ZF) Precoding

ZF is one of the precoding techniques in which the inter-user interference can be cancelled out by each user. This precoding is assumed to implement a pseudo-inverse of the channel matrix. The precoding matrix for ZF precoding can be written as [7],

$$P_{ZF} = \frac{1}{\beta} H^H (HH^H)^{-1} \quad (13)$$

$$\text{where, } \beta = \sqrt{\frac{\text{tr}(BB^H)}{P_{tr}}}$$

$$\text{where, } B = H^H (HH^H)^{-1}$$

Therefore, the received vector with ZF precoding can be written as,

$$y = \frac{1}{\beta} H \left[H^H (HH^H)^{-1} \right] x + n \quad (14)$$

$$\text{where, } \beta = \sqrt{\frac{\text{tr}(HH^H (HH^H)^{-2})}{P_{tr}}}$$

Now let, y_u , x_u and, n_u be the u^{th} elements of $Nu \times 1$ vectors y , x , and n respectively and we define the u^{th} column of P_{ZF} as,

$$p_u = H^H g_u \quad (15)$$

where, g_u is the u^{th} column of $(HH^H)^{-1}$. From (4), the received signal vector of u^{th} user with ZF precoding is given as,

$$y_u = \frac{1}{\beta} h_u H^H g_u x_u + \frac{1}{\beta} \sum_{i=1, i \neq u}^{Nu} h_u H^H g_i x_i + n_u \quad (16)$$

The achievable rate of u^{th} user with ZF precoding technique is written as, (22)

$$R_u^{ZF} = \mathbb{E} \left[\log_2 \left(1 + \frac{\frac{1}{\beta^2} |h_u H^H g_u|^2}{1 + \frac{1}{\beta} \sum_{i=1, i \neq u}^{Nu} |h_u H^H g_i|^2} \right) \right] \quad (17)$$

C. Maximum Ratio Transmission (MRT)

MRT is one of the common methods which maximizes the SNR. The precoding matrix for MRT precoding can be written as,

$$P_{MRT} = \frac{1}{\beta} H^H \quad (18)$$

where, $\beta = \sqrt{\frac{\text{tr}(BB^H)}{P_{tr}}}$

where, $B = H^H$

From (3), the received vector for MRT precoding can be written as,

$$y = \frac{1}{\beta} HH^H x + n \quad (19)$$

where, $\beta = \sqrt{\frac{\text{tr}(HH^H)}{P_{tr}}}$

Let, y_u, x_u and n_u be the u^{th} elements of $Nu \times 1$ vectors y, x , and n respectively and the u^{th} column of P_{MRT} can be written as,

$$p_u = h_u^H \quad (20)$$

From, (4), the received vector of u^{th} user with MRT precoding technique can be written as,

$$y_u = \frac{1}{\beta} h_u h_u^H x_u + \frac{1}{\beta} \sum_{i=1, i \neq u}^{Nu} h_u h_i^H x_i + n_u \quad (21)$$

Therefore, the achievable rate of u^{th} user with MRT precoding technique can be written as,

$$R_u^{MRT} = \mathbb{E} \left[\log_2 \left(1 + \frac{\frac{1}{\beta^2} \|h_u\|^2}{1 + \frac{1}{\beta^2} \sum_{i=1, i \neq u}^{Nu} |h_u h_i^H|^2} \right) \right]$$

IV. CHANNEL STATE INFORMATION

A. Perfect and Imperfect CSIT

Perfect CSIT means that the transmitter knows all the components of H instantaneously and without errors. In an ideal scenario like this, the performance of the system can be increased very much using the CSIT. It is in fact, impossible to achieve perfect CSIT because the transmission should be instantaneous, the precision of the electronics should be infinite, and some other hypothesis that in the reality are impossible. To be more realistic it can be considered that the CSI is incomplete. It means that only a part of the channel is unknown. It can be due to some user not knowing its channel. Then a whole row of H is missing. Or due to some resources constraints in the system that doesn't let know a specific amount of information of the channel. It can also be originated because an error on the obtainment of the CSI or a quantification error. An example of the imperfect CSIT could be like this,

$$H = \begin{pmatrix} h_{11} & h_{12} & h_{13} & h_{14} & h_{15} & h_{16} \\ h_{21} & h_{22} & h_{23} & h_{24} & h_{25} & h_{26} \\ \phi & \phi & h_{33} & \phi & \phi & \phi \\ h_{41} & h_{42} & h_{43} & h_{44} & h_{45} & h_{46} \\ \phi & \phi & \phi & \phi & \phi & h_{55} \end{pmatrix}$$

In this example, it can be seen that the users 1, 2 and 4 transmit all the CSI but users 3 and 5 just transmit the information only for the path from antenna 3 and 6 respectively.

B. Assumption of Channel State Information

If the channel state information at the transmitter (CSIT) is not perfect, there are two options, first is not to perform any precoding and using old transmission using other techniques rather than MIMO techniques, second is the missing values of the CSIT can be assumed. The missing information can be obtained using statistical properties or assuming there is no noise in the channel. In this work, three types of hypothetical assumption are considered to assume the missing information of the CSIT and analysed the performance of the precoders using these assumptions. The assumptions are,

1. Ones Assumption: Ones assumption assumes a perfect channel. It fills the gap in CSIT matrix with ones. This assumption is used when there is no correlation information in the transmission side.

2. **Mean Assumption:** In this types of assumption, the mean of the paths of each antenna is used to get the unknown or incomplete CSI. If the channel is considered Gaussian with zero means, an average of a lot of value tends to be zero.

3. **Random Assumption:** In this assumption, the incomplete components of the CSI are replaced by random number with the same distribution as the channel.

V. RESEARCH METHODOLOGY

The performance analysis is done in two steps. First, the capacity of the system is found in various cases. And second, the BER performance is investigated for different precoders.

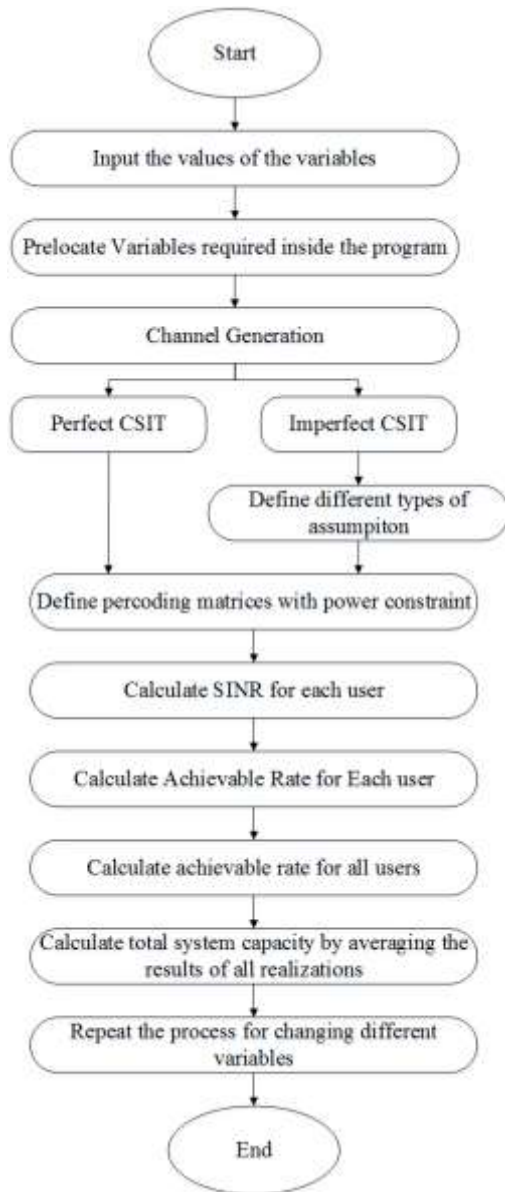


Figure 1. Flow chart for the simulation of capacity analysis

Figure 1 shows the flow diagram to calculate the capacity of the system. Main steps of calculating the

capacity of the system are, generating channel, defining precoding matrices with their power constraints, calculating SINR for each user, calculating the achievable rate of each user, calculating total capacity of all users hence total capacity of the system and finally taking an average of all realization (in this paper 1000) to find the final system capacity.

To find the BER performance, a random message signal is generated and transmitted using QPSK (Quadrature Phase Shift Keying) modulation. Before transmission, the message signal is precoded using different precoding techniques mentioned in section III. The total process is shown in Figure 2.

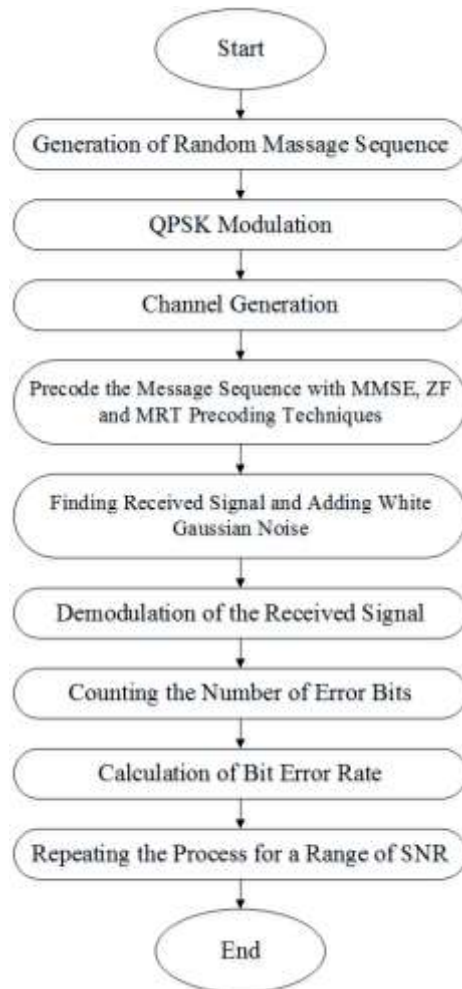


Figure 2. Flow chart to find the BER performance of the system

Values of different parameters used for simulation is given in Table I.

Table I: Value of different parameters

Parameter	Values
SNR (When Fixed)	10dB
SNR (Range)	-20 to 20 dB, 0 to 20 dB
Number of BS Antenna (Fixed)	32

Range of BS antenna (When varied)	30 to 100
Number of users (Fixed)	14
Range of User (When varied)	5 to 30
Number of user with incomplete CSI (Fixed)	5
Number of user with incomplete CSI (varied)	1 to 13
Number of realization	1000
Number of frames	10
Number of packets	200
Number of bit for QPSK symbol	2

VI. RESULTS AND ANALYSIS

We have done the performance analysis simulation for four different cases such as,

- Case 1.** Change in capacity with the increase of SNR.
- Case 2.** Change in capacity with the increase of the number of Base station antenna.
- Case 3.** Change in capacity with the increase of the number of users. Lastly,
- Case 4.** Change in capacity with the increase of a number of user having incomplete CSIT.

And secondly, we have shown the bit error rate performance (BER) of the precoding techniques. All simulation is done under Rayleigh Channel Model.

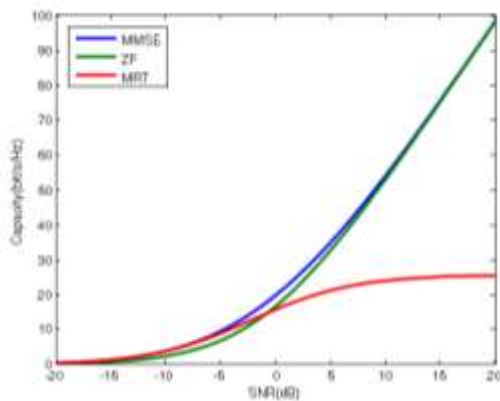


Figure 3. Change in system capacity with the increase of SNR with perfect CSIT

Figure 3 shows the change in capacity with the increase of SNR with different precoding under perfect CSIT condition and for a 32×14 system. In this figure, for low SNR MMSE and MRT precoding performs similarly and better than ZF precoding. As soon as, The SNR crossed the 0dB, the capacity with

MRT precoding starts to fall. For high SNR (i.e. 0-20 dB in this figure), MMSE and ZF perform much better than MRT. At 20 dB, the capacity using MRT precoding is about 25bit/s/Hz whereas, the capacity of MMSE and ZF are about 98bit/s/Hz.

In Figure 4, the CSIT of the system is considered incomplete, and ones assumption is applied as mentioned in section IV. Due to imperfect CSIT, the capacity of all precoder falls than the capacity with perfect CSIT. In this case, ZF performs worst among the three precoders in the low SNR region and a large portion of high SNR region (i.e. 0-15dB). For example, at 5dB, the capacity using MMSE and MRT precoding are about 18bit/s/Hz and 14bit/s/Hz respectively whereas, capacity with ZF precoding is about 6bit/z/Hz. After 15dB, ZF again starts to perform better than MRT.

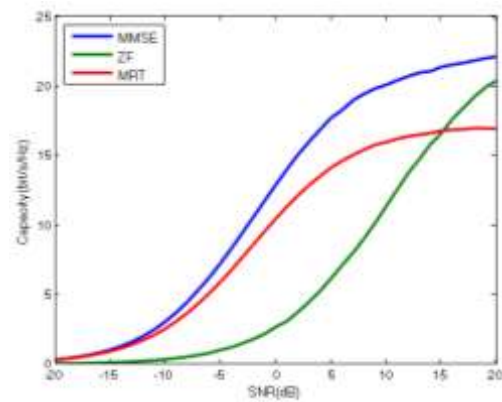


Figure 4. System capacity with the increase of SNR under incomplete CSIT and ones assumption

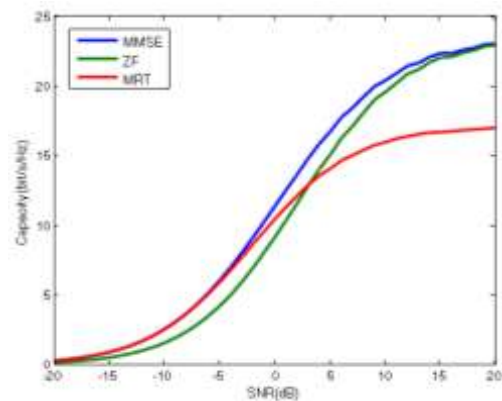


Figure 5. System capacity with the increase of SNR under incomplete CSIT and random assumption

In the case of random assumption in Figure 5, similar to case 1, MRT performs similarly to MMSE at low SNR. And at high SNR, it again falls behind. Figure 6, shows the capacity with mean CSIT assumption. Similar to ones assumption, for a large portion of SNR (in this case, -20 to 9dB) MMSE and

MRT perform better than ZF. For whole range MMSE performs best among the three precoders.

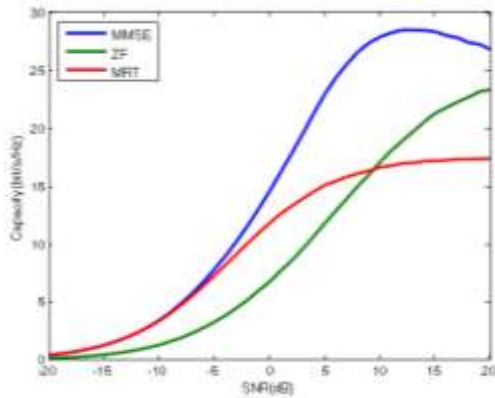


Figure 6. System capacity with the increase of SNR under incomplete CSIT and mean assumption

For the second case where change in capacity is presented with the increase in the number of BS antenna from 30 to 100 and keeping the number of users fixed at 14. From Figure 7, under perfect CSIT condition and 10dB SNR, MMSE and ZF performs much better than MRT. For example, with 30 BS antenna, MMSE and ZF gives about 52bit/s/Hz whereas, with MRT the capacity is 23bit/s/Hz again, with 100 antennas, ZF and MMSE have a capacity of 82bit/s/Hz.

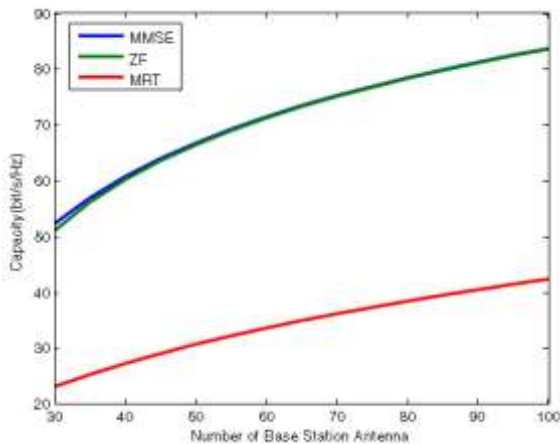


Figure 7. System capacity with the increase of number of BS antenna with perfect CSIT

Now with imperfect CSIT and ones assumption in Figure 8, ZF falls much more behind MMSE and MRT. Even, for some number of BS antenna the capacity falls the below the average capacity (in this case for 35, 60, 65 BS antenna the capacity falls than the average). Therefore, the performance of ZF is unstable in this case.

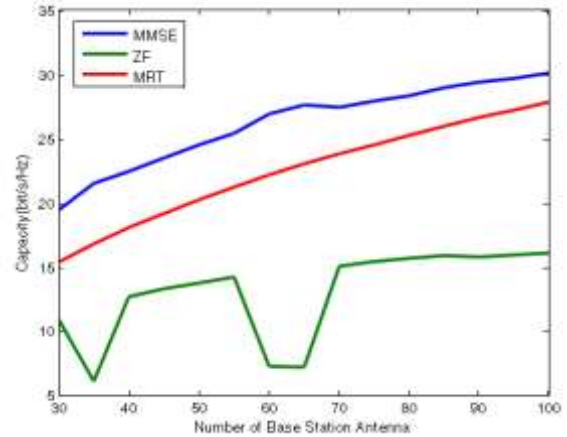


Figure 8. System capacity with the increase in number of BS antenna under incomplete CSIT and ones assumption

In case of random assumption in Figure 9, the behaviour of the precoder is almost same as perfect CSIT condition shown in Figure 7, except the capacity in this case is slightly less. Here, MMSE and ZF performs better than MRT.

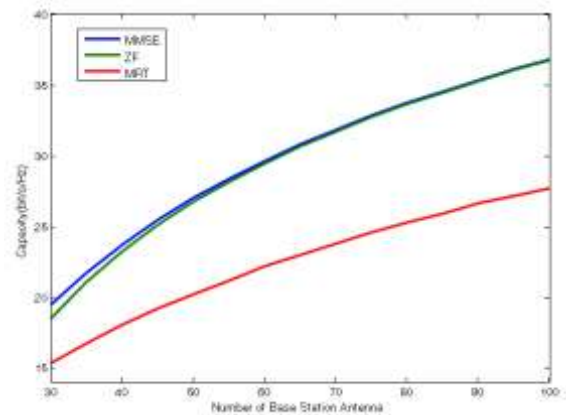


Figure 9. System capacity with the increase of BS antenna under incomplete CSIT and random assumption

Now, with mean assumption in Figure 10, MMSE performs as it is as Figure 7 and 9 but, this time ZF performs close to MRT instead of MMSE. It performs slightly better than MRT.

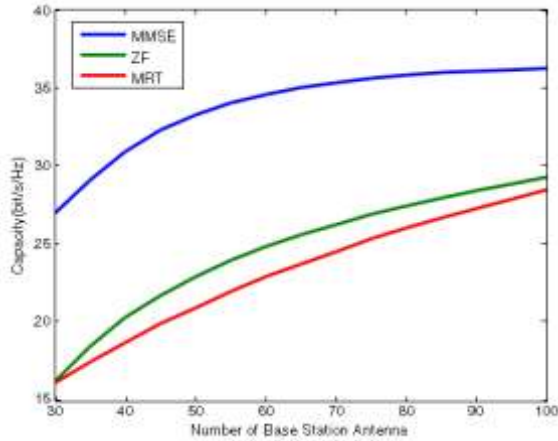


Figure 10. System capacity with the increase of BS antenna under incomplete CSIT and mean assumption

In case 3, the change in capacity is presented with the increase in the number of users and keeping the number of BS antenna fixed at 34. From Figure 11, the capacity of the precoder increases with the increase of the number of users. After a certain number of users, the capacity starts to fall. For example, in this figure, capacity using MMSE precoding begins to fall after 25 number of user and ZF fall after reaching about 17 users. MRT does not fall in the whole region, the capacity of MRT precoder is always increasing with the number of the users but the value of capacity is much less than MMSE and ZF. Although after a certain number of ZF falls behind MRT again. In Figure 11 after reaching close to 30 capacity of ZF become less than MRT.

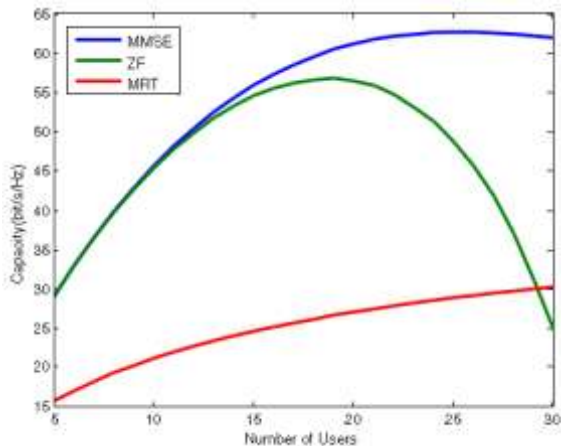


Figure 11. System capacity with the increase of number of user with perfect CSIT

Now for ones assumption, again ZF performs worst as in Figure 8 and case 2. For a different number of users, ZF achieves lower capacity than the average

(e.g. In this case, for 10, 14, 23 and 26 capacity of ZF falls below the average). MMSE still performs best among the three.

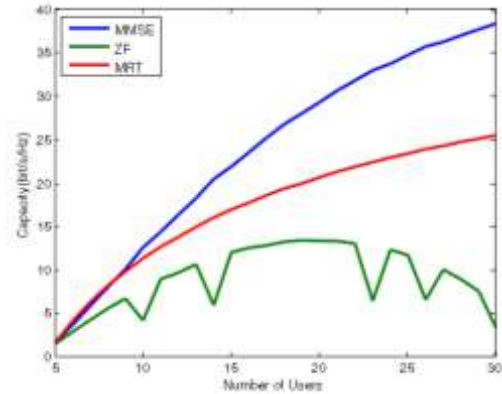


Figure 12. Capacity of the system with the increase in the number of user under incomplete CSIT and ones assumption

In Figure 13 for the random assumption, It shows a similar pattern as perfect CSIT except the decreased capacity. In this case, the performance of MRT precoding become close to MMSE and ZF. In another word, the performance of MRT is less affected by random assumption than ZF and MMSE.

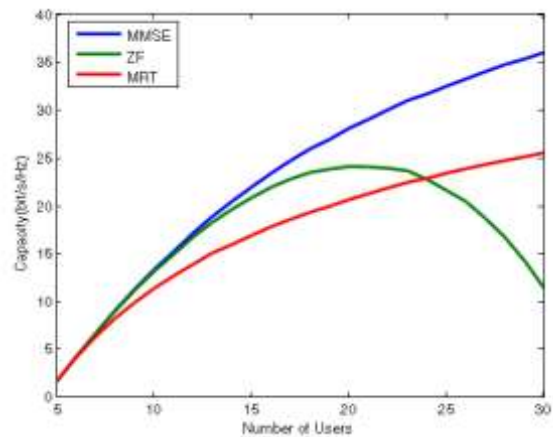


Figure 13. System capacity with the increase of the number of user under incomplete CSIT and random assumption

For mean assumption in Figure 14, with the increase of a number of user the capacity of ZF drastically falls. Although, MMSE and MRT perform almost same as random assumption, after the number of antenna reaching about 13 the capacity of ZF falls behind MRT and continuously falls through the end.

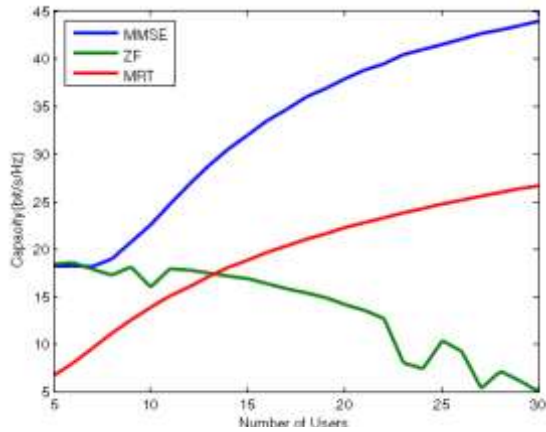


Figure 14. System capacity with the increase of the number of user under incomplete CSIT and mean assumption

Finally, in case 4, the capacity is shown with the increase in a number of user having incomplete CSIT. Figure 15 shows that, with the increased number of user with incomplete CSIT, the performance of all precoders decreases. In this figure, for one assumption, MMSE and ZF start at a better position than MRT. With the increase of the number of user with incomplete CSIT, the capacity of the system with MMSE and MRT become similar (in this figure after reaching 8 user with incomplete CSIT). But ZF suffers for the whole range. After the number of user with incomplete CSIT reaches 3 the capacity of ZF precoding starts to fall behind MMSE and MRT, and continues falling till the end. In case of random assumption, ZF and MMSE perform better than MRT. And with the increase of a number of user with incomplete CSIT performance of three precoder falls. In this case, after reaching 8 number of user with incomplete CSI, MRT starts to show slightly better performance than MMSE and ZF.

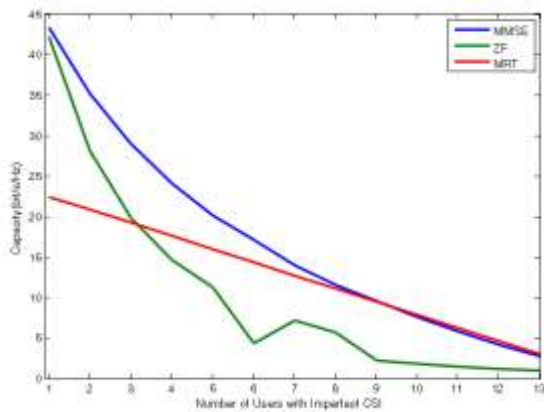


Figure 15. System capacity with the increase of number of user with incomplete CSIT under incomplete CSIT and one's assumption

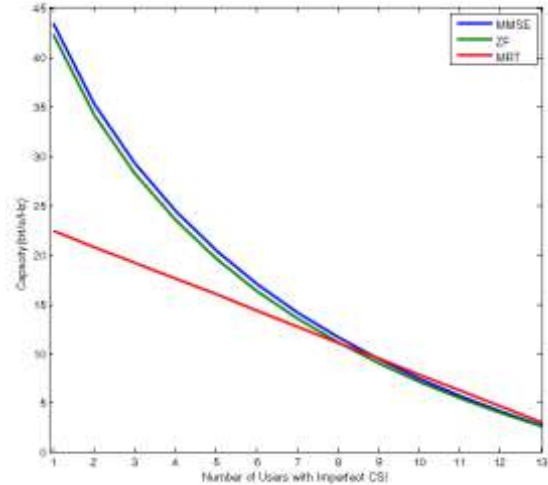


Figure 16. System capacity with the increase of number of user with incomplete CSIT under incomplete CSIT and random assumption

For mean assumption in Figure 17, at first, the capacity of the system with all the precoder start to fall. But after a while, the Capacity of ZF and MMSE begins to increase except MRT, which continues decreasing with the number of the number of user with incomplete CSIT. MMSE start with the best performance among the three, ZF and MRT begin with almost same capacity performance. But with the increase of the number of users with incomplete CSIT, ZF tends to perform close to MMSE precoding, MRT falls behind.

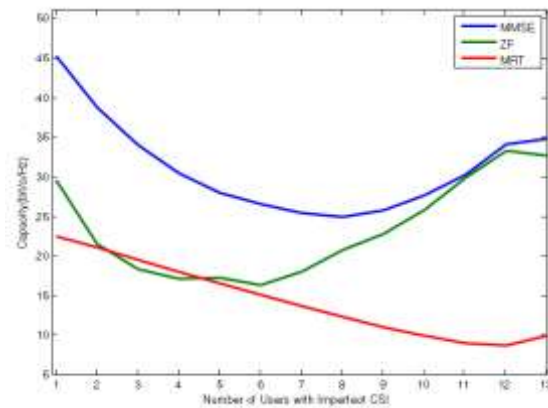


Figure 17. System capacity with the increase of number of user with incomplete CSIT under incomplete CSIT and mean assumption

Finally, we have shown the BER performance of the system with different precoding techniques. From Figure 18 it is observed that at low SNR MRT performs better than MMSE and ZF. And high SNR BER of MRT goes higher than MMSE and MRT. Therefore, MRT performs better in low SNR in

terms of bit error rate (BER) performance. MMSE shows the average performance for both high and low SNR.

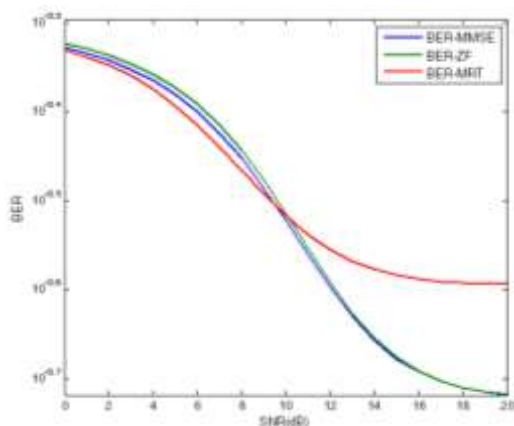


Figure 18. BER performance of the system with different precoding

Therefore, the summary of the results is, MMSE performs best in all cases. MRT performs better in low SNR than ZF, but at high SNR ZF performs better. Again this part is only valid for perfect CSIT. Under imperfect CSIT, ZF suffers most among the three precoders. For ones assumption and mean assumption ZF suffers most. Considering all the factors, MMSE shows the best performance in all purposes, it shows higher capacity and stable performance in all the cases. Then MRT performs better. Although the capacity is lower than MMSE ZF in several cases, but the performance is consistent. And ZF is better than MRT in high SNR and perfect CSIT. But, in reality, perfect CSIT is not a possible option. Overall MMSE is the best option and after that MRT is the second best option among MMSE, ZF and MRT precoding techniques.

VII. CONCLUSION AND FUTURE WORK

According to the work was done by, Selvan, Iqbal, and Al-Raweshidy in [7], MRT performs better in low SNR and ZF performs better in high SNR. We have shown that ZF does not always perform better in high SNR. The performance depends on the availability of CSIT. Our future works will include, analysing the performance of massive MIMO in multicellular condition, find other limitations of this precoders and designing new precoding techniques with good overall performance in both perfect and imperfect CSIT condition.

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