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Performance evaluation of precoding system for massive multiple-input multiple-output

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ABSTRACT

Low latency, high data speeds, and a higher degree of perceived service quality for consumers and base station capacity are only some of the advantages of fifth generation (5G) mobile communications. This paper focuses on the design of a precoding system for downlink transmission of multi-user multiple-input multiple-output (MU-MIMO). For MU-MIMO systems, the traditional precoding techniques investigated are difficult since the transmitter precoding matrices created by singular value decomposition (SVD) are calculated twice. This paper implements different techniques of precoding with channel coding. Two advanced precoding, zero forcing (ZF) and maximum ratio transmitter (MRT) systems will be evaluated to find the best between them. Three different coding channels (turbo, low-density parity-check (LDPC), and polar) are used in this paper. The results indicate that the ZF-MU-MIMO with turbo coding outperforms MRT precoding, and more spatial diversity gain may be gained, in terms of throughput, number of users supported, and lower error rate in downlink and uplink massive MIMO.

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1. INTRODUCTION

Speed, latency, power consumption, and other performance metrics in fifth generation (5G) are 10-100 times better than the preceding 4G system, according to the technology's advances. More than 10 to 100 times the number of wireless devices that may be simultaneously linked to a network [1], [2]. To evaluate quality of service, spectrum efficiency, and reliability, traditionally, the selection of various access methods has had a considerable impact on mobile communication systems.

Orthogonal multiple access includes time-division, frequency-division, and code-division, is the most common kind of multiple access technology, may have serious challenges due to their insufficient resources to handle a large number of linked devices, which may cause serious problems [3]. The data rate needs of future communication systems may differ from device to device due to the usage of multiple access techniques, which may lead to resource wastage. Multi-user (MU) multiple-input multiple-output (MIMO) systems give the opportunity to combine the advantages of MIMO processing with space-division multiple access. For MU-MIMO systems, downlink interference (MUI) is an issue that can be addressed by the use of channel-aware precoding at the base station (BS) [4].

It has been more popular to use MIMO precoding techniques in the recent years because of MU-MIMO, which uses several antennas at the base station to concurrently serve many receivers; however, MIMO comes at the cost of increasing energy consumption, sophisticated network installations, and ongoing maintenance. An further problem for a high-velocity user is that the channel status fluctuates unexpectedly. This results in a decrease in the downlink performance [5]. Precoding schemes, however, require the use of linear algorithms, which are simpler to implement computationally. MUI may still be eliminated using linear precoding methods based on channel inversion, such as zero-forcing channel inversion (ZF-CI) [6].

Block diagonalization (BD) and regularized block diagonalization (RBD) are extensions of the ZF-CI precoding technique for MU-MIMO systems [7], when it comes to MU-MIMO systems, BD precoding is an excellent example of the high level of complexity that may be found in the system. El-abd *et al.* [8] alternative linear precoding (LP) techniques should be examined for their bit error rate (BER) and possible sum-rate performance. Low-cost hybrid precoding systems that can be employed to obtain the same performance as full-digital precoding at a lower cost [9], [10]. An algorithmic solution to the problem of recovering sparse signals under constant modulus limitations inflicted by analog phase shifters is presented [11], [12].

A few cycles of the system are enough to achieve near-optimal performance [11], [13]. It shows that a hybrid design can match the performance of a digital architecture if the number of RF chains is two times the number of data streams [14]. Recent research has focused on zero-forcing precoding for multiple streams per user using a single general antenna and zero-forcing beamforming for single-stream transmissions per user. Many early studies on BD precoding predicted the development of BD-type precoding schemes with lower computational complexity, which has been the focus of certain MU-MIMO research in terms of multiple-stream analysis [15], [16].

In order to achieve the same signal to noise ratio (SNR) over several channels, adaptive modulation and coding was developed by Lagen *et al.* [17]. The geometric mean decomposition was used to balance the effective channel gain for each stream [18]. Power management or adaptive modulation is difficult to implement in multiple antenna systems owing to complexity and communication overhead. Hybrid processing suffers greatly from hardware failures that degrade performance. When designing a hybrid system's circuit, for example, many more power dividers and combiners are utilized than in standard designs. Power transmission is significantly impacted by the dissipation of these components. Garcia-Rodriguez *et al.* [19] used a realistic RF model to demonstrate hybrid processing approaches for the fully linked structure. Authors developed nonlinear models of hybrid precoding systems' power usage and compared them to each other [20]. Boby *et al.* [21] suggest a hybrid minimum mean square error (MMSE)/successive interference cancellation (SIC) communication method for mm-wave MIMO wireless communication systems. When the transmitter or receiver moves, the orthogonal technique was devised to tackle coordination issues and numerous node identification issues.

Hybrid precoding architectures for MIMO systems over restricted feedback channels are studied by Du *et al.* [22]. In addition, it tests the hybrid precoding system's performance in a more realistic hardware network setting. This paper suggests the extended simultaneous orthogonal matching pursuit as an effective hybrid precoding method. The simulation findings show that in huge MIMO systems, a constant sum-rate may be attained while drastically decreasing power usage [23]. The efficiency of the proposed model based on MU-MIMO is looked at in this study with different types of channel coding.

This paper's primary contributions are as shown in: i) develop a MU-MIMO-capable precoding system and ii) MIMO systems suffers greatly from user mobility, the proposed method can help increase data rate. There will be three sections to the rest of this paper: the precoding models will be discussed in section 2 and the design system model will be presented in section 3. Section 4 covers the results of a system simulation. Section 5 summarizes the conclusions of this article.

2. PRECODING MODEL

There are M broadcast antennas and N reception antennas in a single base station MU-MIMO setup (see Figure 1). Each BS supports K users concurrently through l_k antennas. Without jeopardizing generality, for each user, we assume the resulting antenna numberl_k will be the same. Channel state information (CSI) and BS coordination are best understood at the transmitter, according to our research of a flat fading channel. The kth user group's MIMO flat fading channel matrix connects BS and the user [24]. The vector of the receiver before precoding is equal to:

$$y_k = \sqrt{p} H^H W_s + n \quad (1)$$

The LP or beamforming vector for the kth user is denoted by the letter w, while the system beamforming matrix is denoted by the letter W, the vector of the receiver has the following equation:

$$y_k = \sqrt{p}\, h_k^H W_s s_k + \sqrt{p}\, H_k \sum_{i=1,i\neq k}^{K} h_k^H W_j s_j + n_k \quad (2)$$

The matrix of system channels is as shown in:

$$H_k = \begin{matrix} h_{11} & h_{12} & \dots & h_{1M} \\ h_{21} & h_{22} & \dots & h_{2M} \\ . & . & \dots & . \\ . & . & \dots & . \\ h_{l_k1} & h_{l_k2} & \dots & h_{l_kM} \end{matrix} \quad (3)$$

$$H = [\, H_1^T \quad H_2^T \quad \dots \quad H_k^T]^T \quad (4)$$

The H matrix of the MIMO channel additionally includes precoding and transmission symbol vectors for the k user, and n indicates noise. Formulated in this way, the maximum ratio transmitter (MRT) transmit beamforming techniques' precoding matrix is:

$$W = H' \quad (5)$$

The associated signal-to-interference-plus-noise ratio (SINR) of the kth user is provided as for high values of M and K.

$$SINR = \frac{p\,M}{K(p+1)} \quad (6)$$

In ZF, Precoding and transmission symbol vectors are also included in the H matrix of the MIMO channel for the k user, and n represents noise, the transmit beamforming techniques' precoding matrix is:

$$W = H'(HH')^{-1} \quad (7)$$

$$SINR = p\frac{(M-K)}{K} \quad (8)$$

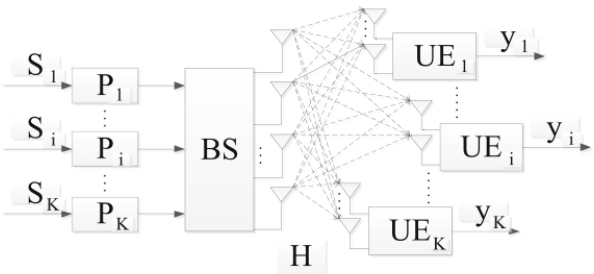

Figure 1. The MU-MIMO model [25]

Assumedly, BS has access to the most up-to-date channel status information. Before employing the transmitter symbol, big MIMO systems like frequency division duplexing (FDD) acquire time division mode (TDD) pilots [26], [27]. BS decides on Two different precoding techniques. An individual symbol is presented to each user at the terminal. As a result, the terminal is responsible for generating each user's signal. Ergodicity is measured by the k parameter, which is ergodic.

$$R_k^* = E\{log_2(1 + \frac{p\,|h_k^H W_s|^2}{1+p\,\sum_{i=1,i\neq k}^{K} |h_k^H W_j|^2})\} \quad (9)$$

3. SIMULATION OF SYSTEM MODEL

Two several parts of the 5G technology are used for precoding. Its block diagram is shown in Figure 2, which includes the following elements: the suggested massive MIMO UP to 64 antennas, mapping, and the data generation, advanced channel coding, advanced modulation type, and the precoding. The blue blocks have been incorporated into the 5G system in order to improve its performance. Component of system model is shown in Figure 3. Eight UE are used in simulation with two BS, each of BS is used precoding system. Three types of channel coding are used in the simulation to find the best between them.

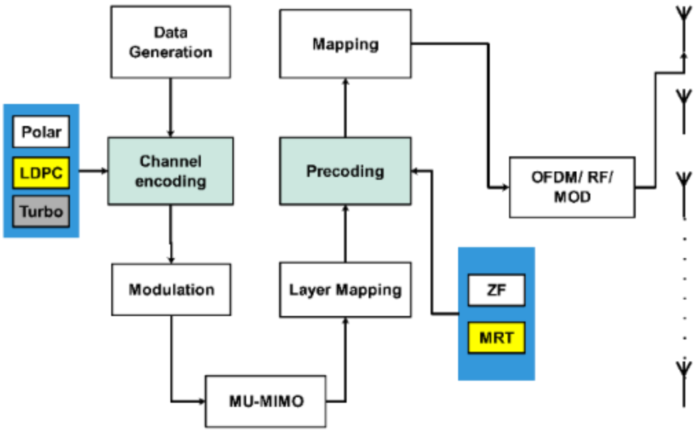

Figure 2. Design of the system model

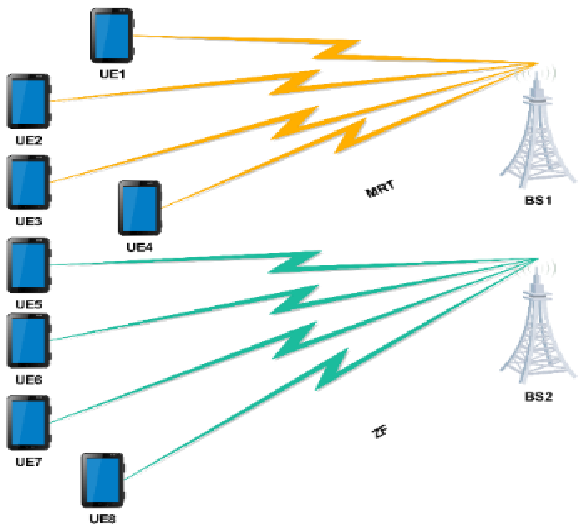

Figure 3. Component of the system model

4. SIMULATION RESULTS AND DISCUSSION

Efficacy of the proposed model system is examined in this section we utilized MATLAB 2020's Monte Carlo simulation to increase our confidence in our findings. Figure 4 depicts the model simulation's two base stations and eight users that may be selected. Table 1 shows the simulation's parameters. There are 72 subcarriers are used in each of BS.

Downlink throughput is seen in Figure 5. Mb/s is the throughput measurement unit for two BSs (MRT and ZF) using three-channel coding types (low-density parity-check (LDPC), polar, and turbo coding). overall, the ZF-turbo model is the highest throughput and MRT-LDPC the lowest, ZF provides the best throughput performance of approximately 19 Mb/s with a three of channel coding, while ZF with polar coding offers a throughput at 14.8 Mb/s, which is higher than ZF with LDPC at 4.7 Mb/s. Figure 6 presents the uplink throughput for two BSs (MRT and ZF) with three-channel coding types (LDPC, polar and turbo coding). General, the ZF with LDPC and Polar are the highest throughput provide the best throughput performance of approximately 7.3 and 7.1 Mb/s respectively. MRT-LDPC provides is the worse throughput performance, ZF with a three of channel coding, offers a throughput is range 6.5 to 7.3 Mb/s.

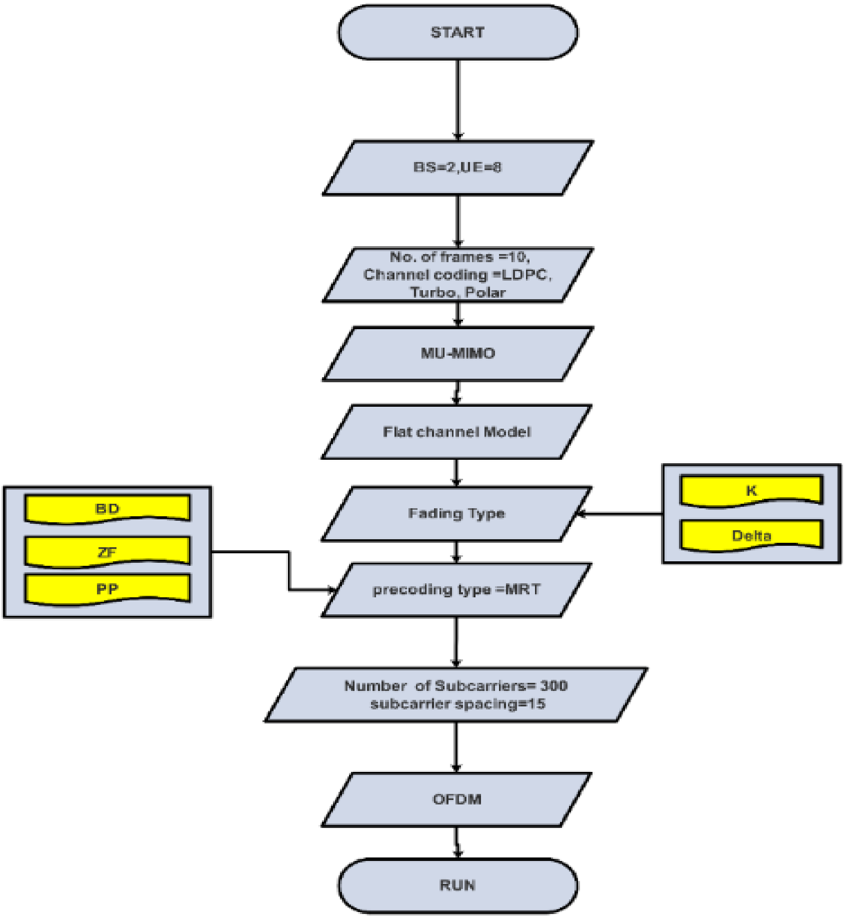

Figure 4. Simulation steps of the system model

Table 1. Parameters of model

Parameters of the system	Values
Center frequency (GHZ)	2.5
No. of frames	10
Frame structure type	FDD
Subcarrier spacing (kHz)	15
Velocity (km/h)	15
No. of subcarriers	72
Pathloss (dB)	100
power delay profile model	Pedestrian A
Channel modulation	QPSK, QAM 1024
Number of antennae	0 to 64 MU-MIMO
Channel coding	Polar, LDPC, Turbo
LDPC decoding	Min-Sum
Polar decoding	List-SC
Turbo decoding	Linear-log-MAP
Decoding Iterations	8 for Turbo and polar, 16 for LDPC

Downlink throughput for two BSs (MRT and ZF) with three-channel coding types (LDPC, polar, and turbo coding) across SNR is shown in Figure 7, overall, the ZF-Turbo model is the highest throughput and MRT-LDPC the lowest, ZF provides the best throughput performance of approximately 13.6 Mb/s, while MRT with turbo coding offers a throughput at 6.1 Mb/s, which is higher than MRT with polar at 1.67Mb/s. Figure 8 presents the uplink throughput, ZF with LDPC, and polar coding are provides the highest throughput provide the best throughput performance of approximately 3.4 Mb/s and 3.01 Mb/s respectively. MRT-LDPC provides is the worse throughput performance of approximately 0.96 Mb/s. Downlink BER is seen in Figure 9. MRT and ZF have three-channel coding types (e.g. LDPC, polar, and turbo) for the two BSs. In turbo channel coding, the ZF provides BER lower than MRT, as shown in Figure 9, when SNR is -8 dB, and it provides a BER of about 0.108 while MRT is about 0.217. LDPC channel coding case, MRT also provides a BER is twice as lower as that of the MRT system, BER reached approximately 0.02 in ZF, while is provided 0.05 in MRT when SNR is

14 db. Turbo channel coding provides the best performance BER with a different of precoding system, it needs a lower SNR than that LDPC and polar to provide a best BER. Figure 10 presents the uplink BER. MRT-Turbo provides is the lowest BER performance of approximately 0.003, while the MRT-LDPC and MRT-Polar provide BER of about 0.195 and 0.47 respectively. Summary of the result is presented in Table 2.

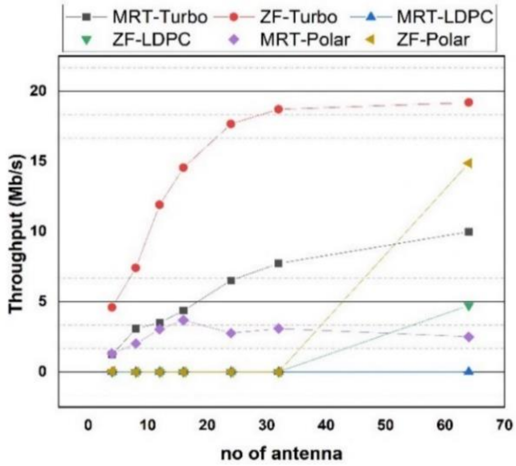

Figure 5. Sum of the downlink throughput in precoding system models

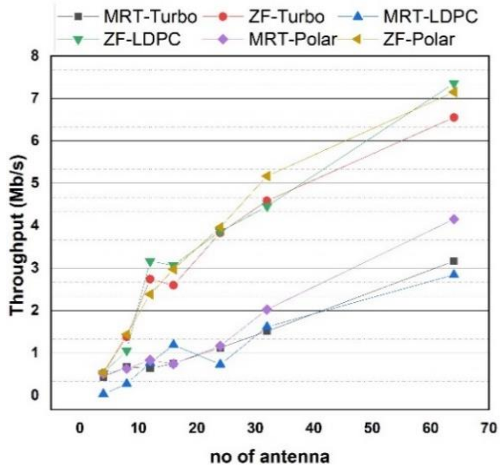

Figure 6. Sum of the uplink throughput in precoding system models

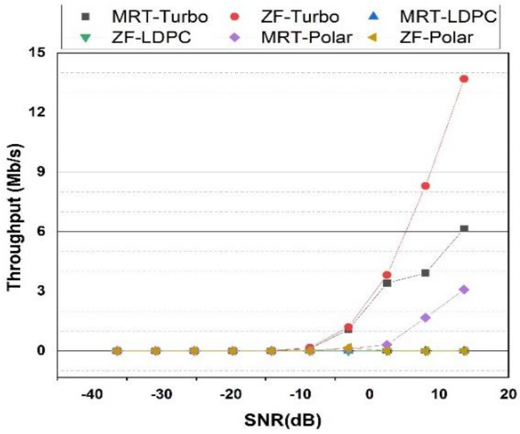

Figure 7. The downlink throughput vs SNR in precoding system models

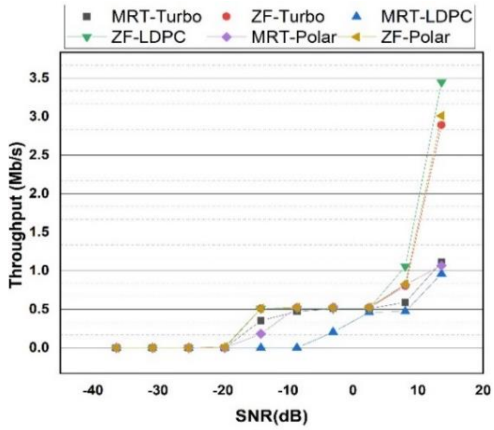

Figure 8. The uplink throughput vs SNR in precoding system models

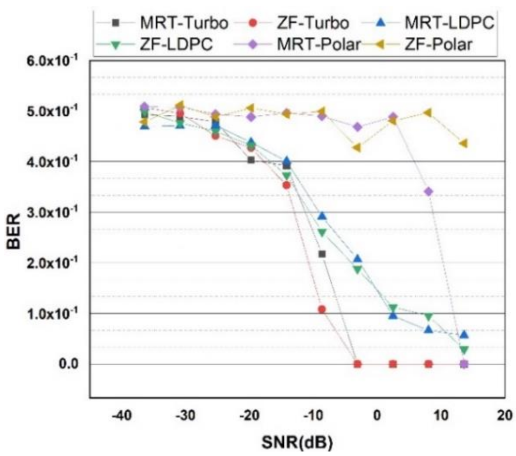

Figure 9. Downlink of BER vs SNR in precoding system models

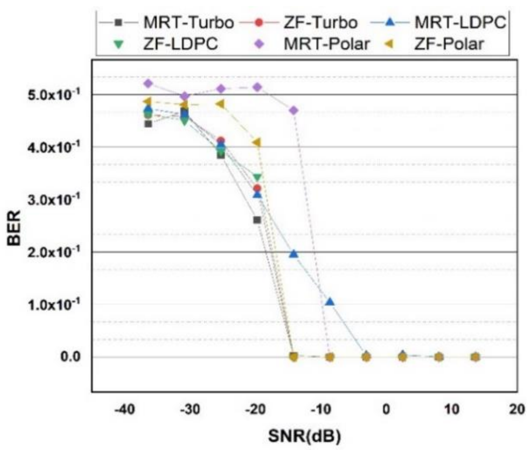

Figure 10. Uplink of BER vs SNR in precoding system models

Table 2. Average of throughput result

Precoding	Channel coding	Downlink	Uplink
MRT	Turbo	5.2032	1.189
	LDPC	0	1.067
	Polar	2.627	1.439
ZF	Turbo	13.439	3.177
	LDPC	0.676	3.358
	Polar	2.132	3.376

5. CONCLUSION

In this paper, three types of channel coding were suggested with the aim of locating the best among them. According to the results, the ZF system performed twice as well as the MRT system, with peak data flow rates of roughly 19 Mb/s in the ZF and around 9 Mb/s in the MRT. While the ZF with three channels of coding gives a throughput range of between 6.5 and 7.3 Mb/s in uplink, the MRT-LDPC delivers the worst throughput performance in the 1 to 3 Mb/s range. The BER findings show that for ZF and MRT in the Pedestrian A channel with varied channel coding, the superiority of ZF-based BER over MRT-based BER in the -14 to 13 dB SNR range is observed. In order to get the best BER, ZF with turbo coding needs to have a lower SNR than LDPC and polar.

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