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Performance Analysis of 5G Network Based on BDMA and Massive - MIMO

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Abstract: Beyond 4G, 5G is the next generation proposed telecommunications standard that will support large number of users with the introduction of Massive MIMO and beam-forming. Main area of focus of 5G network is capacity enhancement with the deployment of large number of antennas (Massive MIMO) whereas LTE focuses on high speed rather than capacity. LTE-A is the advanced version of LTE with the advancement in its features as well. LTE-A supports bandwidth of 100 MHz to 6GHz, therefore below 6GHz, 5G network will operate on LTE-A network and above 6 GHz range, 5G will offer large bandwidth with small coverage area due to path loss at high frequencies. This work presents capacity analysis with the help of BDMA and Massive MIMO techniques where outage probability considered is 10% and reduction of interference using beam forming.
Keywords: MU-MIMO; BDMA; 4G; 5G, LTE-A.

I. INTRODUCTION

Wireless technology has improved, overcoming the shortcomings of previous generations leading to advent of new technology with enhanced performance. As the world becomes more automated than what it was, a continuous need of higher data transfer rate becomes the need of the hour. A faster network seems more inevitable than ever as more and more devices come online with every passing day. With the current data transfer rates our data network speed may not be able to sustain the continuous influx of device over the internet for very long. Hence the need for the upgraded technology, i.e. 5G, that will cater for increased capacity and reduced interference. 5G deployments also aims at achieving lower latency than what LTE network has achieved and efficient consumption of battery, for implementing internet of things [4]. Currently there is no standard that has been defined for 5G deployments. LTE manages swift hand-offs for fast-moving users and supports broadcast streams [10]. LTE supports both time-division duplexing (TDD) and frequency division duplexing (FDD) bandwidths from 1.4MHz to 20MHz.

II. BDMA

Various multiple access techniques that are in use for the optimum use of common resources by multiple users such as time, frequency, codes etc. has led to the development of FDMA, TDMA, CDMA and OFDM techniques. The main aim here is to provide quality service to the users at affordable price. Multiple users share the most critical resources such as time and frequency using TDMA and FDMA access techniques respectively. The Korean researchers have devised new access technique known as BDMA for the fifth generation of mobile wireless communication systems [2]. BDMA stands for Beam Division Multiple Access. This technique does not utilize time and frequency resource sharing rather it forms beam that covers multiple users in the neighboring area [16].

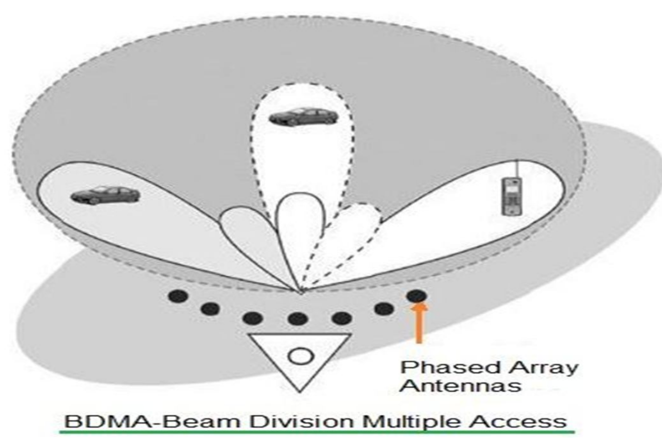

Fig 1.1 Beam Division Multiple Access

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The BDMA figure shown above describes that a separate beam of antenna is allocated to each of the mobile device by base station, which can be done by evaluating each position of mobile devices as well as the speed with which these devices are moving with respect to the base station [17]. This positional information is often communicated by the mobile devices itself. In this way, higher system capacity is achieved using the BDMA technique.
Based on the position and speed of mobile devices, the width and direction of the beam is calculated by the base station for all the users. When all the mobile stations are in LOS they communicate with Base station. All the beams thus given out are distinct for all individual stations; therefore simultaneous transmission of data is possible for different mobile stations at varying angles [2]. The mobile devices that are at the same angles can be served by the same base station based on the direction, width and the number of beams. Beam is further divided 3-dimensionally to support large number of users.

III. MASSIVE MIMO

This antenna technology has gained popularity in wireless communications and has since then been incorporated into many wireless standards like LTE and Wi-Fi. The concept behind deploying large number of antennas at transmitter and receiver end is to increase the possible paths for signal and thereby improving the performance in terms of data rate and reliability of the link [15]. There is a trade-off between performance and price that has to be paid due to high level of complexity of the hardware used and the energy consumption involved in signal processing at both the ends.

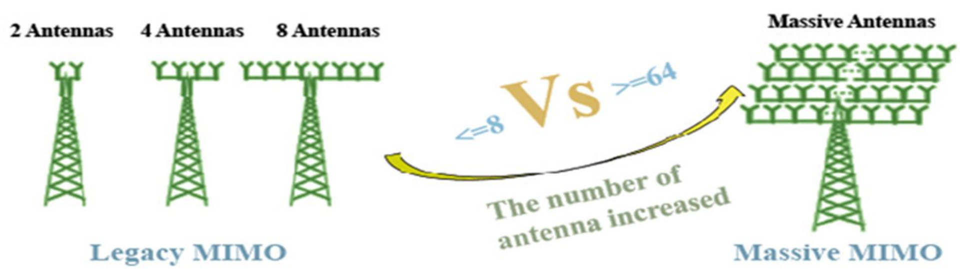

Fig 1.2 Massive MIMO

Massive MIMO that is also known as Very Large MIMO, Large-Scale Antenna Systems and Hyper MIMO brings a change in the current day practice by introducing very large number of antennas at both transmitter and receiver ends that operate in coherent and adaptive manner [3]. These antennas help to cover smaller areas by the method of focusing the transmission and reception signal energy coming from various devices. This leads to significant improvement in throughput and also leads to energy efficiency in case of large number of users [3].
It has other benefits that include the use of low cost and low-power components, reduced weight of antennas and reduced latency, and immune to interference and frequency jamming. The proposed throughput also depends on the propagation media where channels are orthogonal to the terminals [17]. While massive MIMO overcomes traditional problems, it exposes entirely new problems which needs urgent attention; such as, to face the challenge of making multiple low-cost and low-precision components which work together effectively, the need for efficient resource allocation for the newly formed terminals, reducing total internal power consumption thus providing energy efficiency reductions, and finding new areas for deployment.

IV. BEAMFORMING

It is a signal processing technique that uses directional transmission or reception of signal. This directivity is achieved by combining elements of antenna array in such a way that signals at particular angle experience constructive interference while at other angles experience destructive interference [8]. It can be applied to both the transmitting and receiving ends so as to achieve spatial selectivity. There is a significant improvement compared with omni-directional antennas at transmitter and receiver end that is known as the directivity of antenna [6].

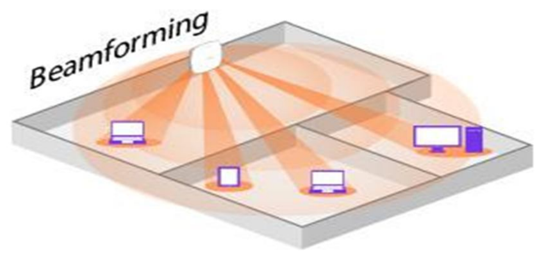

Fig 1.3 Beamforming at various angles

Beamforming has found its application in various utilities viz. radar, sonar, seismology, wireless communications, acoustics and biomedicine. Adaptive beamforming is being used for detecting and estimating the signal-of-interest at the output of antenna by means of optimal spatial filtering and also by interference rejection [15].

The beamforming algorithms in massive MIMO systems are executed at the digital baseband and get very complex. In addition, if beamforming operation is done at the baseband, each antenna will require its own RF feed. With large number of antenna elements at high frequencies, this will be very costly, increased path loss and complexity in the system [8]. Solution to these problems is addressed by hybrid beamforming which is a combination of both analog and digital components.

Beamforming requires antennas that have multiple inputs and multiple outputs thereby using a variety of techniques for signal processing for broadcasting different signals at different antennas via different signal paths, ensuring that these signals interfere in such a way that a stronger signal is broadcasted in a specific direction [15]. Beamforming technique is a type of radio frequency management in which one access point uses multiple antennas to transmit the same signal.

The table below describes the evolution of wireless generations, difference in the technologies used, data rates and bandwidth.

Table 1.1 Comparison of wireless generations [6]

Generation	Data rate	Technology	Time period	Applications	Bandwidth
3G	5-30 Mbps	Wideband Code Division Multiple Access (WCDMA) and Universal Mobile Telecommunication Systems (UMTS)	2009-2015	Online gaming, video calling and high definition TV	5 MHz
4G	100-200Mbps	Long term evolution, Orthogonal Frequency Division Multiple Access (OFDMA), SC-FDMA	2007-2016	Online gaming + high definition applications	1.8 GHz to 20 GHz
5G	10-50Gbps	Long term evolution-Advanced(LTE-A), Beam Division Multiple Access (BDMA) and Filter Bank Multicarrier (FBMC)access	Deployment expected by 2020	Ultra high definition video + Virtual reality applications	60 GHz

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V. METHODOLOGY

A. Analyze the performance of 5G network based on the parameters BER and SNR.
B. Determine the cell capacity of 5G networks by selecting different number of users at transmitting and receiving end.
C. Analyze the plots for interference reduction using beamforming.

VI. RESULTS

A. Simulation of LTE-A and 5G network using Massive MIMO and BDMA

Capacity analysis of LTE-A and 5G systems is done using Shannon's theorem. It gives the maximum rate possible for transmission of information over a communications channel of a particular bandwidth in the presence of noise. Shannon's channel capacity for a particular communication link, is also given out in this theorem which is bound on the maximum amount of error-free information per time unit which can then be transmitted with a particular bandwidth in the presence of noise interference, assuming that the signal power is bounded, and also that the Gaussian noise process is given by a known power or power spectral density. It is formulated by:

$$C = B.\log_2(1+SNR)$$

Where, C is Channel capacity in bits per second.
B is Bandwidth in Hertz.
and SNR is Signal to noise ratio in dB.

The above relation shows that Capacity is directly proportional to SNR, i.e. as the capacity of the system is improved so does the SNR value. Outage probability is an apparent measure of performance which is defined as the probability when mutual information is less than the given threshold. The importance of outage probability is that when outage occurs, there is a higher probability of having a decoding failure. It is basically a typical error.

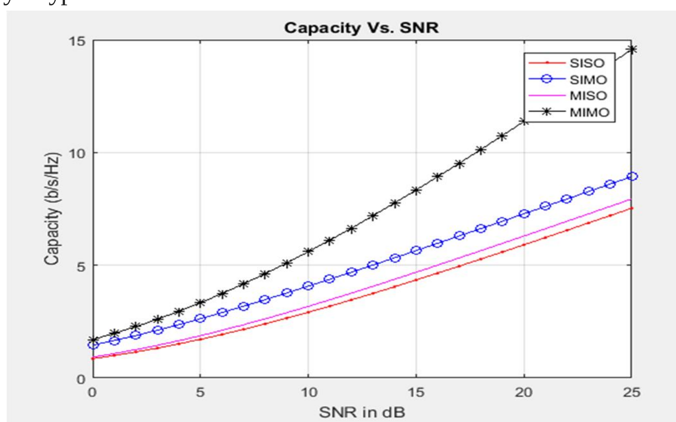

Fig 7.1 Graph of Capacity vs SNR for LTE-A (nT=2, mR=2)

The graph plotted above between capacity and SNR is for LTE-A network where MIMO technology is used by deploying 2 antennas each at transmitter and receiver end.

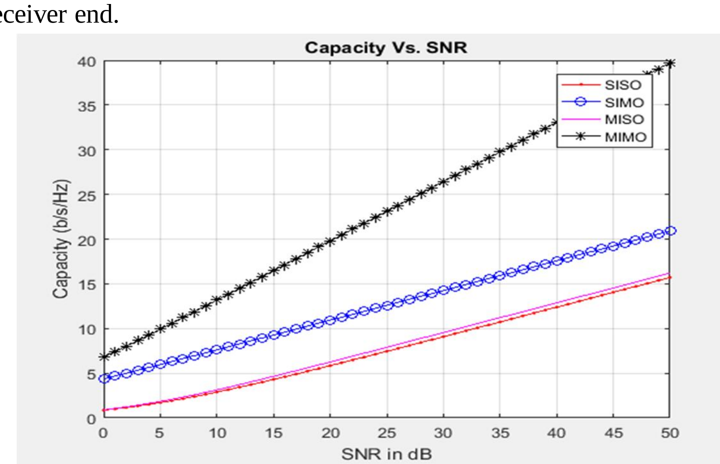

Fig 7.2 Graph of Capacity vs SNR for 5G (nT=2, mR=20)

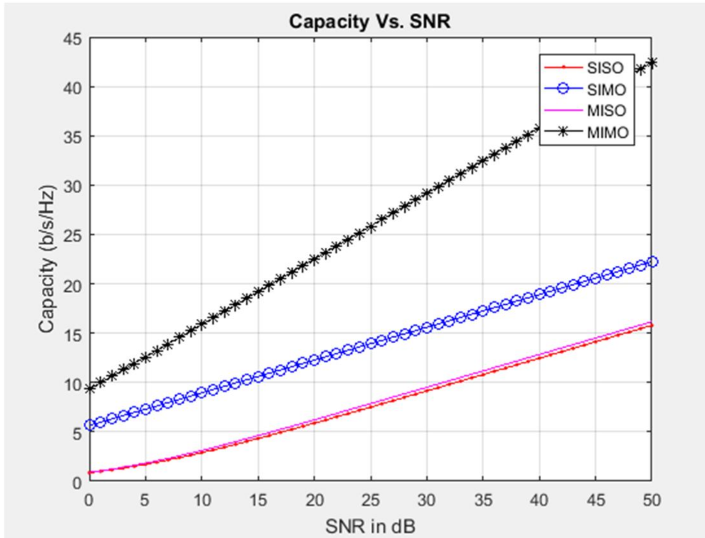

Fig 7.3 Graph of Capacity vs SNR for 5G (nT=2, mR=50)

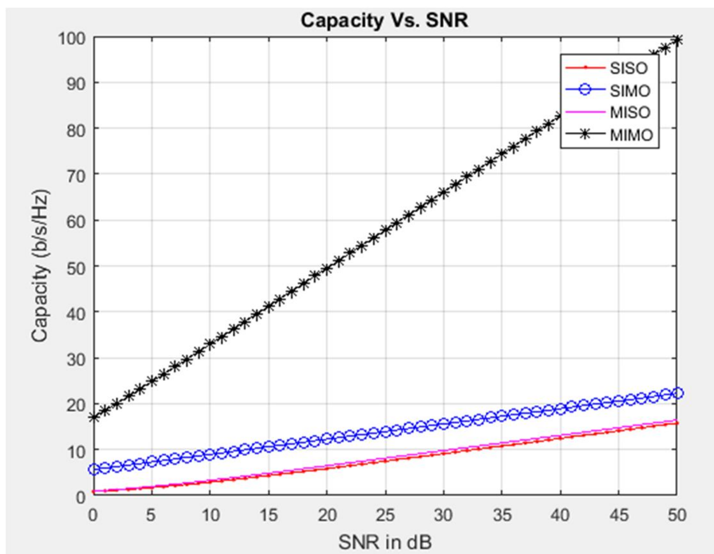

Fig 7.4 Graph of Capacity vs SNR for 5G (nT=5, mR=50)

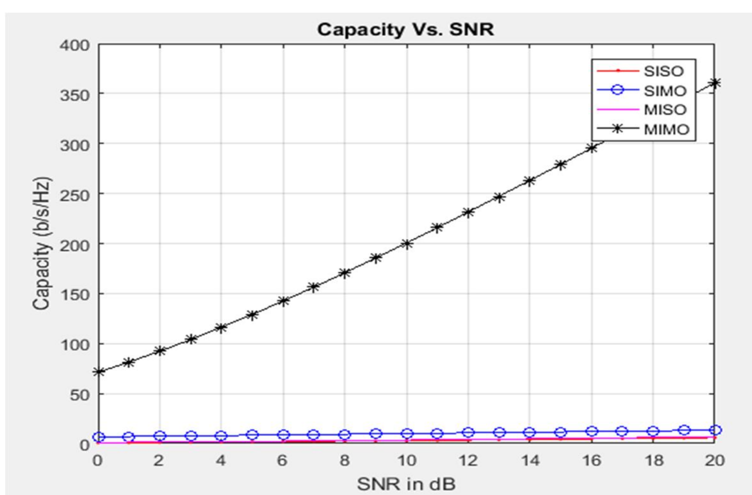

Fig 7.5 Graph of Capacity vs SNR for 5G (nT=50, mR=100)

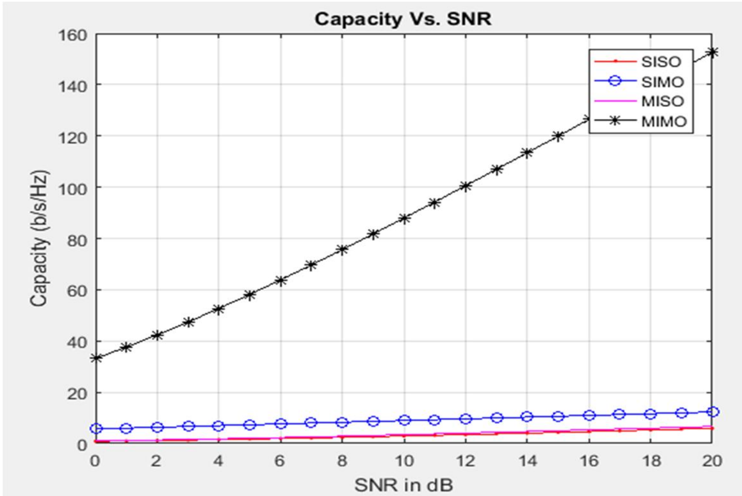

Fig 7.6 Graph of Capacity vs SNR for 5G (nT=20, mR=50)

The above graphs are plotted for different combinations of transmitting and receiving antennas in 5G network that uses Massive MIMO technology, where number of antennas is increased. Variation in number of antennas shows that as the number of antennas is increased, capacity of the system increases drastically.

Table 7.1 Capacity in 5G networks for different number of antennas

Number of transmit antenna, nT	Number of receive antenna ,mR	Capacity (b/s/Hz)
2	2	2
2	20	7
2	50	10
5	15	18
50	100	70
20	50	35

B. Simulation of LTE-A and 5G network using Massive MIMO and beamforming for interference

Interference is one of the major concerns in wireless communication which can be caused by signal transmission from the adjacent cells within the same cluster or by the cells in neighboring cluster.

To mitigate the effect of interference, beamforming technique is used in 5G network. The effect of introducing beamforming can be studied from the graphs of BER and SNR, where, beamforming improves the performance of system by reducing the BER to a great extent as compared to no beamforming.

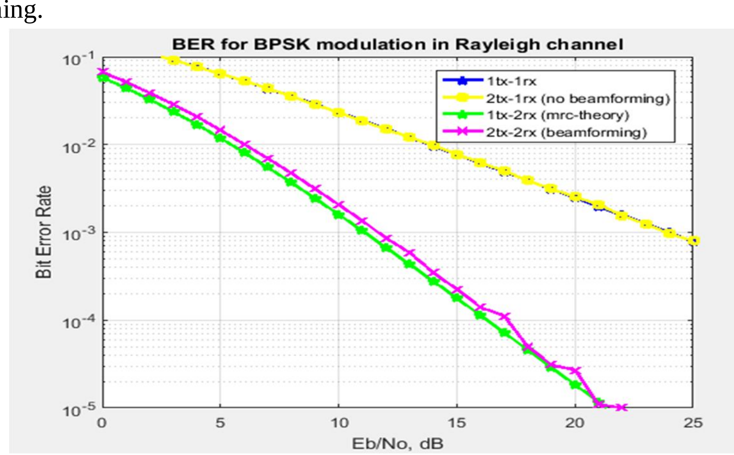

Fig 5.12 Graph of BER vs SNR with beamforming (N=2)

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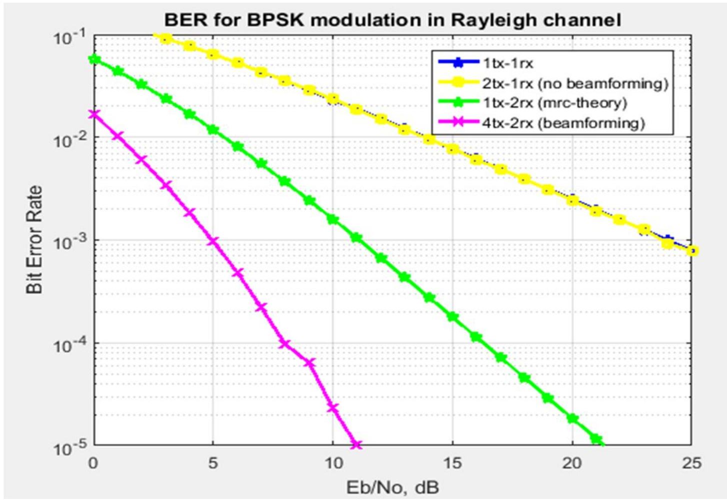

Fig 7.7 Graph of BER vs SNR with beamforming (N=4)

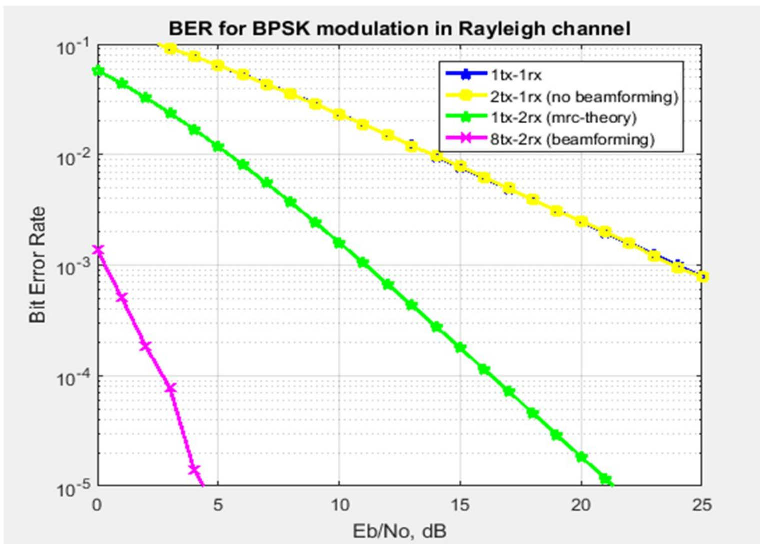

Fig 7.8 Graph of BER vs SNR with beamforming (N=8)

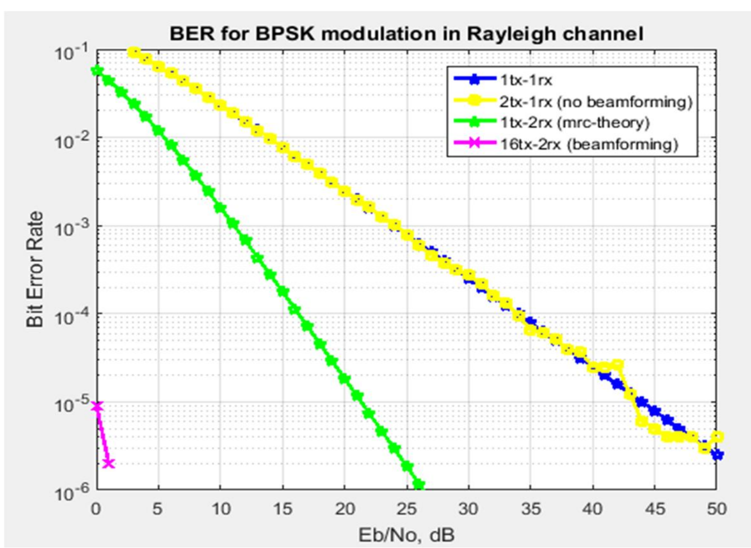

Fig 7.9 Graph of BER vs SNR with beamforming (N=16)

It is observed that as compared to base values mentioned in (Suban et al., 2013), SNR values have improved when N=2 and N=4. We have also performed the analysis for N=8 and N=16, where BER has been observed to decrease but SNR also decreases along with BER.

Table 7.2 Comparison of BER for different number of antennas

Number of transmit antennas, N	BER		SNR (dB)		% Improvement
	Previous work	Proposed work	Previous work	Proposed work	
2	10^{-4}	10^{-1}	13	23	43.47
4	10^{-4}	10^{-2}	2	11	81.81
8		10^{-3}		4	
16		10^{-5}		2	

The above graphs are obtained by varying number of transmitting antennas the effect of varying the number with beamforming is reflected upon BER. As the number of antennas increase, BER reduces. The modulation scheme used is BPSK in Rayleigh fading channel.

VII. CONCLUSION

Capacity analysis of LTE-A and 5G networks is done using MIMO and M-MIMO respectively and the results show improvement in system capacity as we increase the number of transmit and receive antennas. We have analyzed the results starting from 2 transmit and receive (MIMO) antennas to 50 to 100 transmit and receive antennas (M-MIMO) and the capacity has drastically improved from 2b/s/Hz to 70b/s/Hz showing improvement of about 65%.

To mitigate the effect of interference in 5G network, beamforming technique is used. By varying the number of transmit antennas from N=2 to N=16 using BPSK modulation scheme it is observed that BER has improved from 10^{-1} to 10^{-5} showing improvement of about 60%.

It can be concluded that there is a trade-off between BER and SNR. BER improves at the cost of SNR. Also the speed and capacity that is improved comes at the cost of introducing new device, it cannot be achieved with the current device. As the technology advances, so does the need to upgrade to new device that supports new technology.

VIII. FUTURE SCOPE

The improvement areas that can be addressed in future include following:

A. There is a trade-off between BER and SNR, BER improves as we vary the number of antennas but SNR reduces therefore, SNR can be improved.

B. Work can be also be extended to mitigate co-channel interference when the number of antennas is increased.

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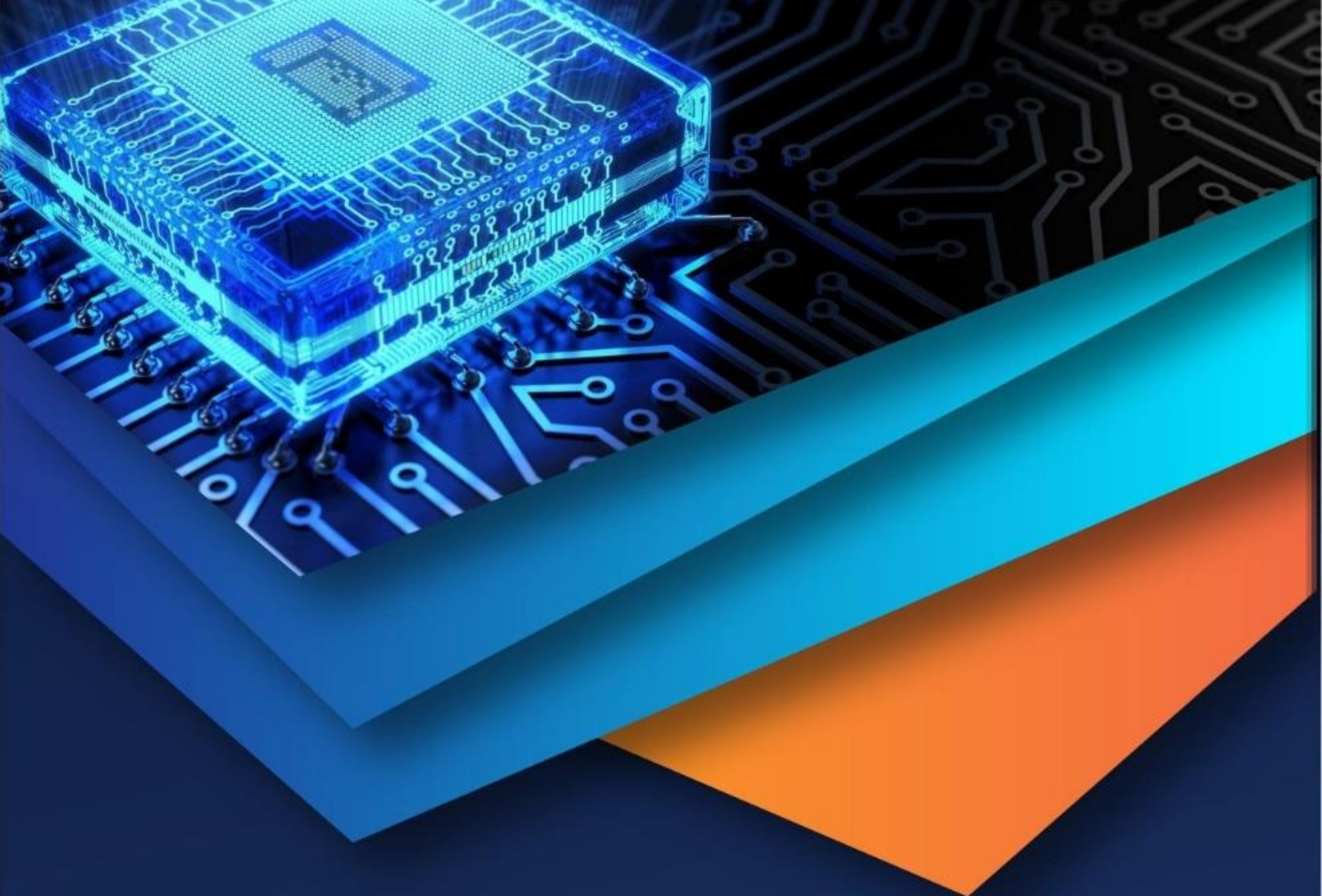

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