Performance Analysis of OFDMA, MIMO and SC-FDMA Technology in Uplink and Downlink Channels in 4G LTE Networks

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Abstract: Multiple access techniques like OFDMA and antenna technology MIMO has been analyzed using modulation techniques BPSK and 16 QAM based on BER and SNR in LTE network. 3G is a very popular technology amongst the present day users, but they still face some drawbacks such as low data rates, coverage area, high cost, and latency leading to abrupt call drops which annoys the user. New generation is in search of better Quality of Service, high data rate, reduced latency, large coverage area, high spectral efficiency at an affordable cost. Long Term Evolution (LTE) is the technology used in 4G that supports these features. It supports two multiple access techniques namely Orthogonal Frequency-Division Multiple Access (OFDMA) and Single Carrier Frequency Division MultipleAccess (SC-FDMA). OFDMA along with MIMO technology is used for downlink channel and SC-FDMA is used in uplink channel..

Keywords: OFDMA, SC-FDMA, MIMO, BPSK, QAM.

Introduction

Improvements are made in wireless technology from generation to generation due to some weakness in previous generations and hence to overcome these weakness, technology has travelled from 1G to 4G in quest of better services and the search is still on. Wireless technology started its journey from 1G with only voice as its base, later the technology enhanced to data along with voice and now it has reached 4G.With the advent of new technology, it is expected to achieve higher data rates, greater speed, less disruption, wide coverage area and better service. 3G technology was able to cater for these requirements but ever increasing number of users and applications require upgradation in wireless technology. As compared to 3G, current generation technology using 4G LTE network is efficient in terms of providing data rates up to 100Mbps, reduced delay thereby improving latency by 10ms, anti-multipath fading with the use of multiple low power antennas inMIMO technology, reduction in co-channel interference by deploying OFDMA technique[1,2].It is considered as an important technology in 4G LTE network as it has anti-multipath fading characteristics, high spectral efficiency,minimizing interference.Technologies used in 4G are Wi-Max and LTE.Evolution of 4G LTE networks has led to increaseddemand for high speed internetover wireless networks. Video transmission is a popular service provided by 4G network that supportsfast and reliable data transfers. One of the technologies that hascontributed to make it possible is OFDMA. MIMO enhances the performance of system by allowing multiple signals to transmit over parallel channels [10]. In OFDMA, different users are orthogonal. Multiple access technique is regarded as SC/OFDMA scheme, as against usual OFDM/OFDMA techniques, since the transmitted signal is SC signal, but the spectrum allocated to each user is identical to that of OFDMA schemes [6].

Technologies in LTE Network

Orthogonal Frequency Division Multiple Access (OFDMA)

OFDMA is a access technique that is used in LTE cellular systems to allocate a given bandwidth to multiple userswhere these users are orthogonal to each other so as to avoid interference [1,2]. Each band is further sub-divided into number of subcarriers each of which is 15kHz wide.The data that is to be transmitted is then divided into multiple low speed streams of bit which is then modulated onto the subcarriers.This technique is

spectrallyvery efficient and provides very high data rates. Also, it is less affected by effects of multipath propagation. It allows simultaneous transmission of low rate data from different users [9].

Features of OFDMA

- Efficient Spectrum
- High data rates
- Immune to multipath propagation
- Low power

Multiple Input Multiple Output (MIMO)

MIMO is a radio antenna technology that uses multiple antennas at transmitter as well as receiver sides to provide multiple paths to transmit data, choosing differentpaths for each antenna to ensure multiple signal paths are used. These multiple antennas are smaller in size and operate on low power compared to single large antenna [5]. Increased number of antennas adds to the capacity improvement of the system and reduces the incidences of call dropping. MIMO is an essential element of wireless communication system that also includes HSPA+ (3G), IEEE 802.11n (Wi-Fi (4G), IEEE 802.11ac (Wi-Fi), and Long Term Evolution (4G). LTE can achieve downlink rates of up to 300 Mbps, uplink rates of up to 75 Mbps, and low latency [9].

Single Carrier Frequency Division Multiple Access (SC-FDMA)

SC-FDMA is another form of OFDMA, particularly in the uplink channel where low peak-to-average power ratio is beneficial to the mobile device as it has better transmit power efficiency and cost of the power amplifier is also reduced. For each user, bit train transmitted is mapped to symbols using different modulation schemes.Multiple access among users is made possible by providing different users with different sets of non-overlapping Fourier coefficients.The distinguishing feature ofSC-FDMA is that it uses a single-carrier signal, as against OFDMA, which is a multi-carrier signal transmission scheme [9].

Techniques Used in LTE

LTE supports two multiple access techniques namely OFDMA and SC-FDMA. OFDMA along with MIMO is used in downlink channel and SC-FDMA is used in uplink channel.

At OFDMA transmitter, bandwidth is sub-divided into number of orthogonal carriers, further, signal is modulated and passed through Serial to Parallel converter; this digital signal is transmitted through Inverse Fourier Fast Transform (IFFT) block where it is transformed into time domain. This signal in timedomain may cause Inter symbol interference (ISI), therefore to reduce ISI, cyclic code is added to eliminate the problem of ISI.

At receiver,the reverse process is applied to recover the signal in original form. Cyclic code is removed and passed through Parallel to Serial convertor and the time domain signal is converted into frequency domain by FFT module. Then equalizer is used to eliminate signal distortion. Demodulator being the last block is used to recover the original bits.

Serial to Parallel Converter converts sequence of data in time domain in to stream of data that is transmitted simultaneously and reverse is the process in case of Parallel to Serial Converter.

IFFT is an algorithm used to convert frequency domain signal into time domain and FFT is the reverse algorithm of IFFT. Equalizer is used to achieve equalization i.e. to remove the noise component. ISI refers to the distortion of signal due to interference between the subsequent symbols resulting because of multipath propagation. To avoid these errors, cyclic codes are used that correct errors in signal by efficient detection and correction of errors.

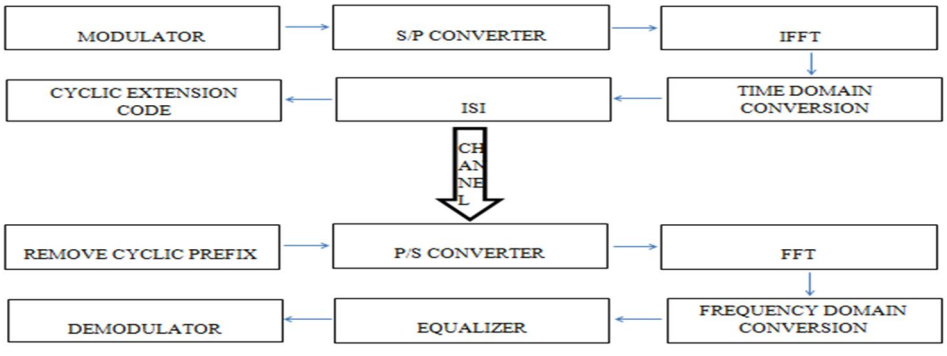

Fig 1.Block representation of communication system[1]

Related Work

Bit Error Rate (BER)

It is expressed as the ratio of the number of noise affected bits out of the total number of bits that are transmitted. It is affected by noise, multi path fading and interference. High BER may lead to loss of data.

$$\textbf{BER} = \frac{\textit{Number of Error Bits}}{\textit{Total no of Transmitted Bits}}$$

As the BER increase, error in the transmitted signal increases and also SNR reduces.

$$\textbf{SNR } \alpha \textbf{ 1/BER}$$

Signal to Noise Ratio (SNR)

It is the ratio of symbol or bit energy to power density of noise that is expressed in dB. SNR and BER are inversely related to each other.

$$\textbf{SNR}= \frac{E_b}{N_o}$$

BPSK

BPSK stands for Binary phase shift keying. It is a modulation scheme in which the data is transmitted by changing the phase of carrier wave. BPSK uses two phases and QPSK uses four phases, likewise any number of phases can be used.

QAM

QAM refers to Quadrature amplitude modulation .In this modulation scheme data is transmitted by varying the amplitudes of the base signal. Data is in the form of bit streams.

Results and Discussion

Performance of OFDMA is analyzed using BPSK and 16 QAM. Signal that reaches better BER while maintaining high SNR provides improved results. As BER decreases, quality of signal improves. It is observed that BPSK provides SNR of 11dB at BER of 10^-1 and 16 QAM provides 11dB at BER of 0.6.

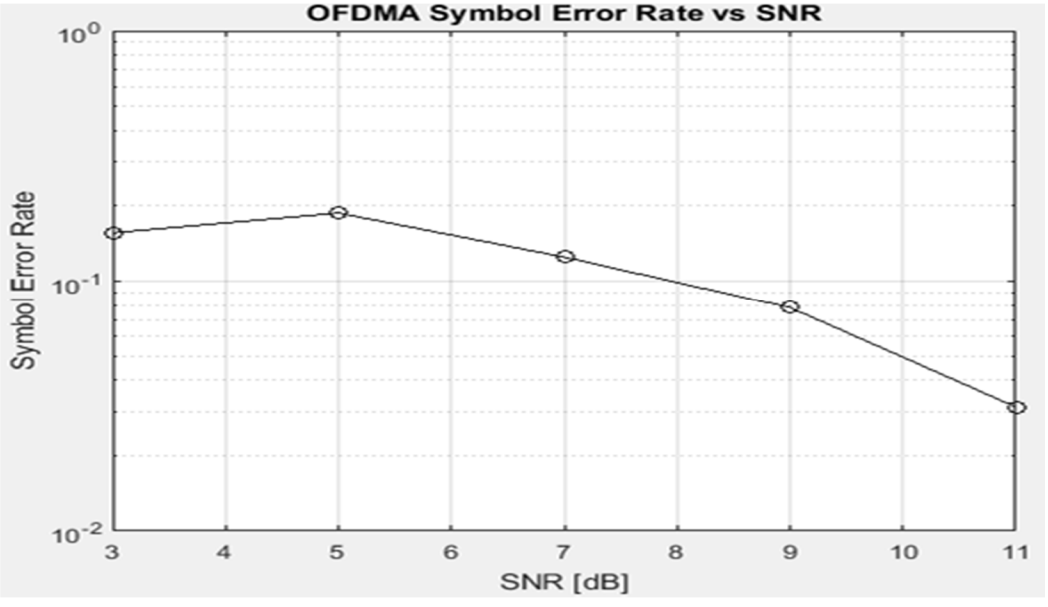

Fig 2.Graph of OFDMA using BPSK

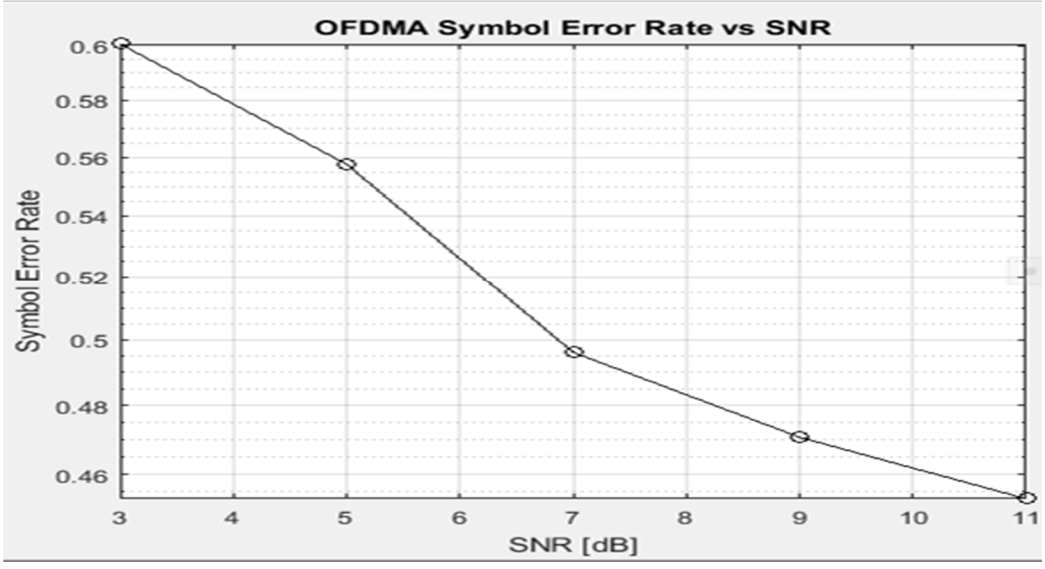

Fig 3. Graph of OFDMA using 16 QAM

Performance of MIMO is observed using BPSK that provides SNR of 7dB for BER of 0.52.OFDMA has better BER for a given SNR. Performance of BPSK is better than 16 QAM as it has better BER at a given SNR. As compared to MIMO, performance of OFDMA is better.

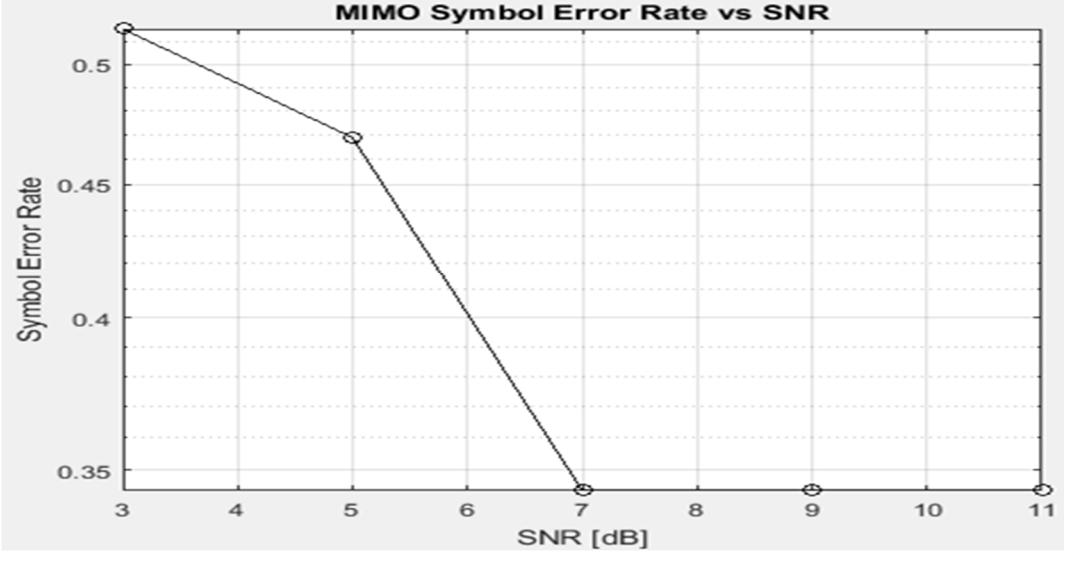

Fig 4. Graph of MIMO using BPSK

Previous work on analysis of LTE network compared the quality of signal obtained using BPSK, QPSK and 16 QAM that showed, that OFDMA provides better results compared to other techniques. Effect of inter symbol interference has been reduced due to availability of multiple paths

Comparison and justification of Results

[Fig 2 and Fig 3] demonstrates the analysis of modulation schemes: BPSK and 16 QAM which is done based on parameters BER and SNR. More the amount of noise in the transmitted signal, higher is the amount of error transmitted. As the amount of noise is reduced, BER is increased proportionally. Results show that BPSK has better SNR as compared to 16 QAM.

Parameters	BER		SNR(dB)	
	Base value	Observed value	Base value	Observed value
BPSK	10^{-15}	10^{-1}	22	11
16 QAM	10^{-15}	0.6	39	11

When compared, BER obtained for OFDMA technology is better than MIMO technology.

Parameters	BER		SNR(dB)	
	Base value	Observed value	Base value	Observed value
BPSK	$10^{-5.6}$	0.525	28	7

Conclusion

Wireless has evolved manifolds and with every development, technology has led to betterment for everyone alike. Initially it had started with 1G, wherein the user was only able to communicate over voice. The last technology in use was 3G, which allowed the users enhanced experience of voice clarity and improved speeds of data
Communication. The technology upgrade from 3G to 4G has improved better Quality of Service, high data rate, low latency, large coverage area and better spectral efficiency at an affordable cost. Multiple Access techniques used is OFDMA and antenna technology used is MIMO. Modulation schemes used are BPSK Performance analysis of LTE network is done on multiple access techniques (OFDMA, SC-AND QAM and performance is analyzed using BER and SNR.
BPSK has low BER and better SNR; hence providing better results in case of OFDMA and OFDMA performs better than MIMO.

Future Scope

After the analysis of the LTE technology and the upgrades suggested in this paper the performance upgrade of LTE can be taken ahead by:

- utilizing other modulation techniques
- analyzing the performance of different techniques using other signal parameters such as
- Congestion
- Power Spectral Density
- Peak to Average Power Ratio etc.

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