ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 7, July 2013

Role of Contributing Factors MIMO-OFDM in 4G-LTE Wireless Transmission Technologies from Technical Perspective

Pravin K. Patil

Assistant Professor, Department of Computer Science, Miraj Mahavidyalaya, Miraj, India

Abstract: This paper studies the role of MIMO-OFDM as foremost contributing performance factors in 4G LTE Wireless Transmission Technology from a technical perspective. Long Term Evolution (LTE) uses Orthogonal Frequency Division Multiplexing (OFDM) along with MIMO (Multiple Input Multiple Output) antenna technology standard to achieve high radio spectral efficiency and multi-carrier approach for multiple accesses. For the downlink OFDM is used and for the uplink SC-FDM (Single Carrier - Frequency Division Multiplexing) also known as DFT (Discrete Fourier Transform) is used. In this paper Bit-Error-Rate (BER) is calculated and measured with respect to Signal to Noise Ratio (SNR). The higher SNR at the receiver enabled by MIMO, along with OFDM which provides improved coverage and throughput, especially in dense urban areas.

Keywords: Long Term Evolution, Signal-to-Noise Ratio, Bit-Error-Rate, Cyclic Prefix.

I. INTRODUCTION

Long Term Evolution (LTE) is a Fourth Generation 4G wireless broadband technology developed by the 3rd Generation Partnership Project (3GPP), an industry trade group. 3GPP was established in 1998 thereby started working on the radio, core network, and service architecture of a globally applicable Third Generation (3G) technology specification. 3G is specified by European Telecommunications Standards Institute (ETSI) and 3GPP within the framework defined by the International Telecommunication Union (ITU) standard known as International Mobile Telecommunication 2000 (ITU-200) [2]. Even though 3G data rates were already real in theory, initial systems like Universal Mobile Telecommunications System (UMTS) did not immediately meet the IMT-2000 requirements in their practical deployments. Hence the standards needed to be improved to meet or even exceed them. The combination of High Speed Downlink Packet Access (HSDPA) and the subsequent addition of an enhanced dedicated channel, also known as High Speed Uplink Packet Access (HSUPA), led to the development of the technology referred to as High Speed Packet Access (HSPA+) or, more informally, 3.5G [1]. LTE got its name because it represents the next step (4G) in a progression from GSM, a second-generation (2G) wireless network standard, to UMTS, the third-generation 3G technologies based upon GSM (Global System for Mobile Communication) standard. 4G LTE provides significantly higher peak data rates than the earlier 3GPP technologies,

The highest theoretical data rate is 50 Mbps in uplink and with Multiple input multiple output (MIMO) the rate can be as high as 100 Mbps in the downlink with reduced latency, scalable bandwidth capacity, short round trip delay and backwards compatibility with existing GSM and UMTS technology. Unlike its predecessor technologies, however, LTE's upper layers use TCP/IP, enabling all traffic such as data, voice, video and messaging to be carried over all-IP networks.

II. OFDM-MIMO IN WIRELESS COMMUNICATION

A MIMO technology has recently emerged as a new paradigm to achieve very high bandwidth efficiencies and large data rates in modern wireless communications. Conventional MIMO is a cellular wireless technology which enables the use of multiple transmitting and receiving antennas to transfer more data in less time. A MIMO channel is implemented in a wireless link between M transmits and N receive antennas. It consists of M x N elements that represent the MIMO channel coefficients. Fig.1 and Fig. 2 depicts conceptual MIMO system and distributed MIMO system respectively.

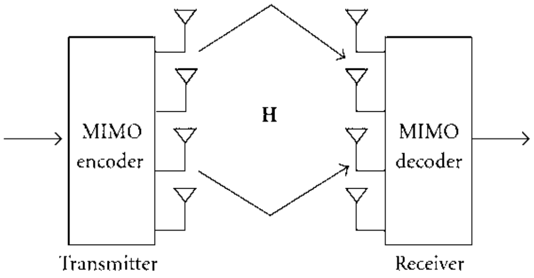
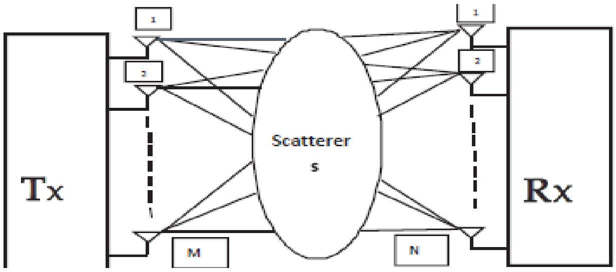


Fig. 1 Conventional MIMO



.

Fig. 2 Distributed MIMO

MIMO system uses multiple antennas to achieve spatial diversity. In an isolated link where there is no co-channel interference, the use of larger number of transmit antenna always results in performance enhancement in terms of average capacity, i.e. average mutual information [4]. However, in cellular systems where there is co-channel interference induced from neighboring cells due to frequency reuse, the performance behavior of using larger number of transmit antenna can be different from that in an isolated link. In cellular systems, although the use of more transmit antennas provides larger capacity on the desired link, it may make fierce interference to the neighboring cells, which may result in degradation of total system capacity [5], [6]. Conventional MIMO schemes usually take advantage of the many antennas available at the transmitter by simultaneously transmitting multiple data streams from all of them. OFDM has the capability to cancel multi-path distortion in a spectrally efficient manner. Rapid variation in channel characteristics are caused by multi-path and Doppler spread (due to the different speeds of mobile). Sometimes these time varying channels are characterized by very good SNR (Signal to Noise Ratio), but worse SNR at other times. So a fixed modulation technique cannot achieve the best Spectral efficiency as the system has to be built with a modulation scheme considering the worst case scenario. Hence OFDM for MIMO channels is considered as efficient and suitable scheme in particular for symmetric channels such as the link between two base stations or between two antennas on radio beam transmission [3].

Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, DSL broadband internet access, wireless networks, and 4G mobile communications etc. OFDM is a technique used in modern broadband wireless communications systems. OFDM modulation in a transmitter includes Inverse Fast Fourier transform (IFFT) operation and cyclic prefix insertion. To mitigate the effect of dispersive channel distortion in high data rate OFDM systems, cyclic prefix is introduced to eliminate Inter Symbol Interference (ISI).

In telecommunication, ISI is a form of distortion of a signal in which one symbol interferes with subsequent symbols. This is an unwanted phenomenon as the previous symbols have similar effect as noise, thus making the communication less reliable. ISI is usually caused by multipath propagation or the inherent non-linear frequency response of a channel causing successive symbols to "blur" together. The presence of ISI in the system introduces errors in the decision device at the receiver output. Therefore, in the design of the transmitting and receiving filters, the objective is to minimize the effects of ISI, and thereby deliver the digital data to its destination with the smallest error rate possible [7]. It copies the end section of an IFFT packet to the beginning of an OFDM symbol. Typically, the length of the cyclic prefix must be longer than the length of the dispersive channel to completely remove ISI. In an OFDM receiver, the cyclic prefix is removed before the packet data is sent to FFT for demodulation. In a conventional serial data system, the symbols are transmitted sequentially, with the frequency spectrum of each data symbol allowed to occupy the entire available bandwidth. In a parallel data transmission system several symbols are transmitted at the same time, what offers possibilities for all evicting many of the problems encountered with serial systems. In OFDM, the data is divided among large number of closely spaced carriers also known as sub-channels.

This accounts for the "frequency division multiplex" part of the name. In addition the sub-carriers in an OFDM system are overlapping to maximize spectral efficiency. Ordinarily, overlapping adjacent channels can interfere with one another. However, sub-carriers in an OFDM system are precisely orthogonal to one another. Thus, they are able to overlap without interfering. As a result, OFDM systems are able to maximize spectral efficiency without causing adjacent channel interference. The frequency domain of an OFDM system is represented in the Fig 3.

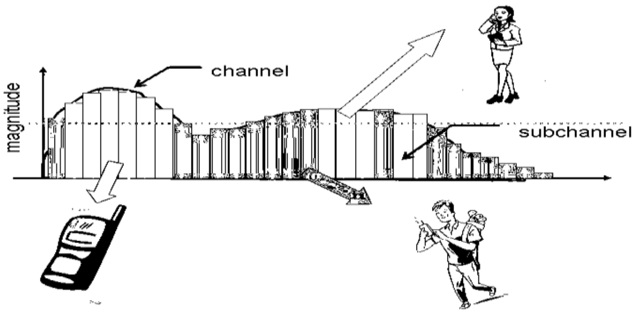


Fig. 3 Frequency Domain of OFDM

III. CONTRIBUTION OF PERFORMANCE FACTORS MIMO-OFDM IN 4G-LTE CELLULAR COMMUNICATIONSYSTEM

One of the changes that contemporary cellular communications systems have brought to wireless transmission is the need for end-to-end performance measurements. The measure of that performance is usually Bit-Error-Rate (BER), which enumerates the consistency of the entire cellular communication system from “bits in” to “bits out” [8]. Signal-to-noise ratio within OFDM is assumed to be the signal margin divided by the noise level (i.e. sigma). Most commonly a SNR is expressed in decibels. A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise. Signal-to-noise ratio is defined as the power ratio between a signal (meaningful information) and the background noise (unwanted signal):

$$\mathrm{SNR} = \frac{P_{\mathrm{signal}}}{P_{\mathrm{noise}}}, \qquad (1)$$

Where, P is an average power. Both signal and noise power must be measured at the same and equivalent points in a system, and within the same system bandwidth. If the signal and the noise are measured across the same impedance, then the SNR can be obtained by calculating the square of the amplitude ratio:

$$\mathrm{SNR} = \frac{P_{\mathrm{signal}}}{P_{\mathrm{noise}}} = \left(\frac{A_{\mathrm{signal}}}{A_{\mathrm{noise}}}\right)^2, \qquad (2)$$

Where, A is root mean square (RMS) amplitude (for example, RMS voltage). Because many signals have a very wide dynamic range, SNRs are often expressed using the logarithmic decibel scale. In decibels, the SNR is defined as:

$$\mathrm{SNR}_{\mathrm{dB}} = 10\log_{10}\left(\frac{P_{\mathrm{signal}}}{P_{\mathrm{noise}}}\right) = P_{\mathrm{signal,dB}} - P_{\mathrm{noise,dB}}, \qquad (3)$$

Bit-Error-Rate (BER) is the ratio between the number of bits received in error to the total number of bits received. In fact BER is the probability of receiving a single bit in error. The packet error rate (PER) is the number of incorrectly received data packets divided by the total number of received packets. A packet is declared incorrect if at least one bit is erroneous. The expectation value of the PER is denoted packet error probability pp, which for a data packet length of N bits can be expressed as:

(4)

Assuming that the bit errors are independent of each other. For small bit error probabilities, this is approximately:

Similar measurements can be carried out for the transmission of frames, blocks, or symbols. The BER is the chance of a bit misinterpretation due to electrical noise: $w(t)$

Considering a bipolar NRZ transmission, we have

for “1” and $x_0(t) = -A + w(t)$

$x_1(t)$ $x_0(t)$

Each of and has a period of T. The noise has a bilateral spectral density $\frac{N_0}{2}$, $x_1(t)$ is $\mathcal{N}\left(A, \frac{N_0}{2T}\right)$ and $x_0(t)$is

Returning to BER, we have the likelihood of a bit misinterpretation: $p_e = p(0|1)p_1 + p(1|0)p_0$

$\mathcal{N}\left(-A, \frac{N_0}{2T}\right)$

and $p(0|1) = 0.5\ \mathrm{erfc}\left(\frac{A-\lambda}{\sqrt{N_o/T}}\right)$

$p(1|0) = 0.5\ \mathrm{erfc}\left(\frac{A+\lambda}{\sqrt{N_o/T}}\right)$ ld of decision, set to 0 when: ise the average energy of the signal to find the final expression as:

$$p_1 = p_0 = 0.5 \qquad p_e = 0.5\ \mathrm{erfc}\left(\sqrt{\frac{E}{N_o}}\right). \qquad (5)$$

IV. THE FOLLOWING MATLAB PROGRAM ILLUSTRATES THE BER CALCULATIONS OVER SNR VALUES USING AN OFDM-BFSK, QPSK AND 16PSK CHANNEL.

```
% BER
const=[1 -1];
size=100000;
iter_max=1000;
EbN0_min=0;
EbN0_max=10;
BER=[];
for EbN0 = EbN0_min:EbN0_max
EbN0_lin=10.^(0.1*EbN0);
noise_var=0.5/(EbN0_lin); % s^2=N0/2
iter = 0;
err = 0;
while (iter <iter_max && err <100),
bits=randsrc(1,size,[0 1]);
s=const(bits+1);
x = s + sqrt(noise_var)*randn(1,size);
bit_hat=(-sign(x)+1)/2;
err = err + sum(bits ~= bit_hat);
iter = iter + 1;
end
SNR =[SNR EbN0];
BER = [BER err/(size*iter)];
end
```

```
semilogy(BER);grid;
xlabel('E_bN_0');ylabel('BER');
TITLE('BER OVER ODFM CHANNEL');
```

The Fig. 4 shows simulation model of Bit Error Rate correlated with MIMO channel capacity per unit bandwidth as a function of SNR

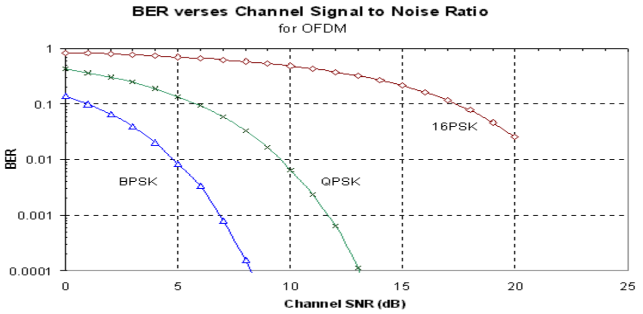


Fig. 4 BER Vs SNR

V. CONCLUSION

In this paper, the contribution of MIMO-OFDM as a performance factor is analyzed using BER Vs Signal to Noise Ratio. The use of multiple antennas at both ends of a wireless link (multiple input multiple output (MIMO) technology) has recently been demonstrated to have the potential of achieving extraordinary data rates in 4G-LTE. Orthogonal frequency division multiplexing (OFDM) significantly reduces receiver complexity in wireless broadband systems. The use of MIMO technology in combination with OFDM i.e., MIMO-OFDM therefore seems to be an attractive solution for future broadband wireless systems.

ACKNOWLEDGMENT

My sincere thanks to Dr. Vinay V. Chougule, Assistant Professor Department of Microbiology, Miraj Mahavidyalaya, Miraj, about his support and motivation to make this paper with fruitful discussion.

REFERENCES

[1] Ian F. Akyildiz, David M. Gutierrez-Estevez, Elias Chavarria Reyes. Broadband Wireless Networking Laboratory, School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA 30332, United States (Physical Communication 3 (2010) 217–244).

[2] Krendzel Andrey, Network Planning Aspects for 3G/4G Mobile Systems, Tampere University of Technology, Publication 545. ISBN 952-15-1436-1, ISSN 1459-2045.

[3] A. Omri and R. Bouallegu, International Journal of Next-Generation Networks (IJNGN) Vol.3, No.1, March 2011.

[4] G. J. Foschini and M. J. Gans, "On Limits of wireless communications in a fading environment when using multiple antennas", Wireless Personal Communication, vol. 6, pp. 311-355,1998.

[5] R. S. Blum, J. H. Winter, and N. R. Sollenberger, "On the capacity of cellular systems with MIMO," IEEE Commun. Lett., vol. 6, pp. 242-244, Jun. 2002.

[6] [6] R. S. Blum, "MIMO capacity with interference," IEEE J. Select. Areas Commun., vol. 21, no. 5, pp. 793-801, Jun. 2003.

[7] http://en.wikipedia.org/wiki/Intersymbol_interference, 23 May 2013 at 03:26.

[8] Ali, S.; Rahman, M.; Hossain, D.; Islam, S.; Islam, M.; ―Simulation and bit error rate performance analysis of 4G OFDM systems ― IEEE Publication Year: 2008 , Page(s): 138 – 143.

[9] Ahmed, A.B.; Osman, W.E.; Rahman, T.A.; Orthogonal ―Frequency Division Multiple Acces System Analysis Using Bit Error Rate Next Generation Mobile Applications, Services and Technologies‖ 2009. NGMAST '09. Third International Conference on Publication Year: 2009 , Page(s): 211 – 214.

[10] Bit Error Rate: Fundamental Concepts and Measurement Issues by Gary Breed.

BIOGRAPHY

Pravin K. Patil, has received B. C. S. and M. Sc. degrees in Computer Science from Shivaji University, Kolhapur and University of Pune, in 2005 and 2007 respectively. He is has been working as an Assistant Professor at the Department of Computer Science, Miraj Mahavidyalaya, Miraj (India), since year 2008. His research interests are in Mobile Computing, Computer Network Security, Software Engineering, Image Processing and Theoretical Computer Science.