# Evaluation of Inter-cell Interference and BER on a Downlink PDSCH of the LTE Network

Owusu Agyeman Antwi
Department of Telecom Engineering
Ghana Technology University College
Accra, Ghana
Email: agyingo1.na@gmail.com

Amevi Acakpovi
Department of Electrical/Electronic Engineering
Accra Technical University
Accra, Ghana
Email: acakpovia@gmail.com

*Abstract* - **In this paper, a comprehensive evaluation of inter-cell interference and BER on the physical downlink channel of an LTE cellular network is undertaken. Because spectrum bandwidth is a scarce resource, operators are compelled to reassign frequency in a process called frequency reuse. However, the downlink channel of the currently deployed LTE network in Ghana, has low average throughput and data rate. This results from the fact that an interfering cell from adjacent eNodeB interrupts with the serving eNodeB. For cell-edge users (CEUs), the effect of inter-cell interference is especially severe. MATLAB was used to build models and to carry out simulations on the evaluation of this form of interference in LTE network. Simulation results were obtained for BER considering different adaptive modulation and also for simulation of the PDSCH transceiver which depicts the effect of inter-cell interference on the downlink throughput.**

***Index Terms - LTE, Frequency reuse, Inter – cell interference, PDSCH, BER***

## I. INTRODUCTION

Wireless communication became more effective after the introduction of digital technology. The emergence of digital technology during 1980 showed that information transmitted digitally are reliable, better signal quality, carry more information per second which increase system capacity [1].

LTE employs an access scheme known as the orthogonal frequency division multiples access (OFDMA) for the downlink and Single Carrier-Frequency Division Multiple Access (SC-FDMA) for the uplink data transmission [2]–[6]. The LTE specification provides downlink peak rates of 100 Mbit/s, and uplink peak rates of 50 Mbit/s. The LTE equally provides quality of service (QOS) permitting a transfer latency of less than 5ms in the radio access network.

In 4G cellular network such as LTE, there is reliance on an intelligent allocation and reuse of channels throughout a coverage region. The capacity of a cellular network depends mainly on the frequency reuse pattern and the interference generated. Since the radio bandwidth is a scarce resource in wireless communications, many operators use frequency reuse to improve efficiency in their cellular networks. Consequently, the most restrictive constraints that impede the capacity of mobile communication systems is interference, caused by transmission on the same frequency within a coverage area [7]–[10] whereby at certain geographical distance, the frequency are reused i.e. the same spectrum band are re-assigned to distant cells [11].

In spite of this, system performance is extremely affected by interference caused by neighboring cells. In LTE network, intra-cell interference is controlled in the PDSCH in the following manner: each user is assigned a subset of subcarrier which are orthogonal to each other and therefore enhance detection [9], [12], [13].

Furthermore, inter-cell interference still remains a major challenge and a threat to the LTE network because of frequency reuse between the serving cell and neighboring cell. This actually affect throughput, spectral efficiency and the overall system performance. The focal point of this paper is to evaluate inter- cell interference and BER on PDSCH in LTE. Cellular network using intelligent algorithms with powerful simulation software suggest effective way to increase throughput and combat inter-cell interference. The current study is a similar one that evaluated analytically and by simulation, proposed algorithm to improve upon LTE communications.

## II. RELATED WORKS

Several theories have been proposed to ascertain the evaluation of inter-cell interference and the bit error rate (BER) on the physical downlink shared channel of LTE network. However, literature embodies a wide diversity of such theories, this review will be centered on three (3) major themes which come up more frequently throughout the literature reviewed.

### *A. Impact of Inter-Cell Interference on the LTE Network*

According to [14], antenna electrical and mechanical down tilts, height and output can be used to minimized inter-cell interference using spectrum band of 800 MHz, 1800 MHz, 2600 MHz frequencies. It was found that intercell interference can be reduced by a careful selection of antenna down tilt, height and output power. Also, to improve the number of UE per sector the electrical down tilt of 5.2% and 1.9% improvement for spectrum allocation of 800 and 2600 MHZ

978-1-7281-0818-6/19/$31.00 ©2019 IEEE
DOI 10.1109/ICCMA.2019.00022

respectively were considered. Antenna height of 27m and transmitter power of 10W were further considered for simulation and optimal results. However some studies in this same direction failed to consider the influence of the transmitted power which greatly influence the overall performance [15].

*B. Effect of BER on the LTE network*

In [16], the effect of SNR on the downlink of LTE network was investigated. A carrier frequency of 1800MHz, and a transmission bandwidth of 20MHz were considered with one physical block per one simulator. The simulation outcomes pointed out that using MIMO with more antennas can achieve maximum throughput because more pilot symbols can be embedded in the OFDMA frames as compared to using single antenna (SISO)[16]–[18]. Moreover, it was found that MIMO channels using transmit diversity is superior to spatial multiplexing since it improves SNR. On the other hand, spatial multiplexing has better performances in terms of throughput since it doubles throughput. Multiple versions of the transmitted signal are received and combined to recover the original signal. Alamouti/MRC among others are well known decoding algorithm with interesting decoding capabilities without considering other detectors like lattice receiver (LR) which have good performance and flexible implementation compared to MMSE

*C. Techniques for increasing throughput, spectral efficiency and reducing latency on LTE downlink*

[19]–[21] assessed the performance of adaptive MIMO switching in LTE in terms of cell throughput and throughput gain in collaboration with MIMO configuration. Simulation of different antenna configuration including MIMO (2x2, 4x4), MISO, SIMO and Adaptive MIMO (2x2, 4x4) switching based on spatial multiplexing were achieved and analyzed. Findings show that SIMO performs best at low SNR compared to MISO and SISO which have similar performance, but at higher SNR, MIMO performs better, yet all has good spectral efficiency. Unfortunately, simulation results did not show the spectral efficiency of AMS. It was also found that AMS supersede all the antenna configuration utilizing radio resources and improving overall spectral efficiency of LTE network.

## III. System Model

*A. Basic System Model*

In LTE network, the downlink simulator simulates the downlink communication from the EUTRAN or eNodeB to one user equipment (UE) using a winner channel or AWGN channel. The simulator system model is composed of four sections which includes

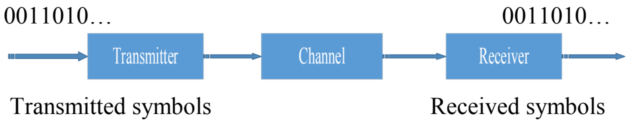



Fig. 1 Basic block diagram LTE downlink physical transceiver

*B. Complete implementation of LTE transceiver*

The implementation of the LTE transceiver design consists of the transmitter channel and receiver integrated together as a whole. In this phase we connect the output of the transmitter model (txsig) to the input port of the channel model. Finally link the three-output port of the channel model ((rxSig, chPathG, nVar) to the input ports of the receiver model block model

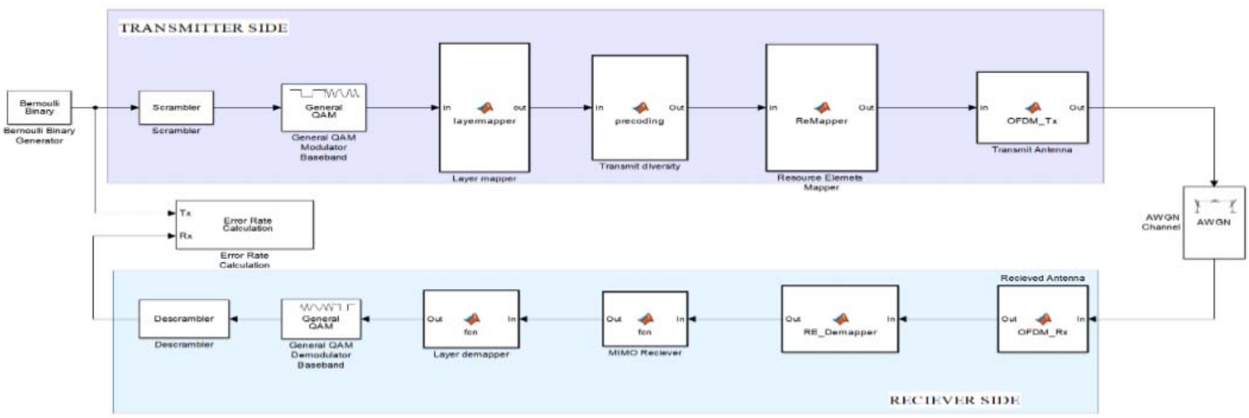



Fig. 2 Simulink implementation transmitter, channel and receiver

## C. Experimental Setup

To implement the design, flowchart is used to describe the methodology and the simulation process. The process begins from the start. The next step is the initialization of parameters.

After the initialization process, the data source module generates a continuous random bit stream which provide input to the system. A cyclic prefix (CP) of different sizes are added to the end of each transmitted symbol to acts as a guard interval to alleviate intersymbol interference (ISI) before modulating the data

Source in a modulation scheme format (QPSK, 16QAM, 64QAM). The OFDM modulator convert the coded bits into OFDM symbols and transmit them over the channel.

At the receiver side, the OFDMA symbols that were transmitted over the channel are therefore demodulated and decoded to recover the original signals back to its original form. The received signal is now compared to symbols transmitted from the transmitter to make sure correct bits were received. However, if bits are not received correctly an acknowledgment is sent back to the data source using FEC but if received correctly then goes ahead to calculate the bits error rate.

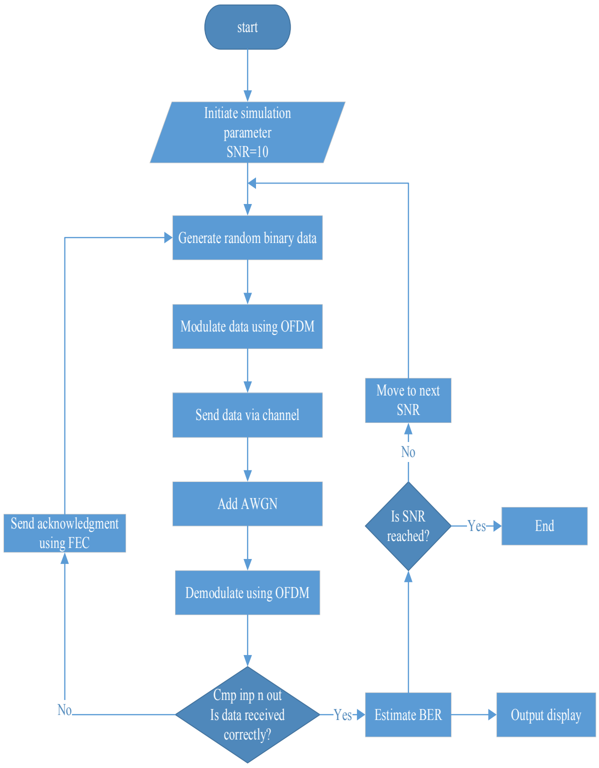



Fig. 2 Simulation Flow Chart

## D. Proposed Work

**Inter-Cell Interference Level**

Excessive frequency reuse may increase the inter cell interference level in the network. This effect decrease the entire system throughput, spectral effect and causes overall poor system performance.

Cell $A_2$ and $B_2$ are in different cell location and uses the same frequency resource (f) to communicate with each other using low transmitter power. However, no interference level is exhibited between them.

On the other hand, Cell $A_1$ and $B_1$ share the same frequency resource $f_3$ and utilize high transmitter power in communicating with their serving cells. Because they operate in the same cell zone, they operating as cell edge users which causes interference between each other. Inter-cell interference becomes very severe because all the neighboring cells can provide services over the entire system band especially for cell edge users.

In other to increase the throughput of cell edge users and increase coverage Inter-cell interference must be alleviated. Inter-cell interference coordination (ICIC) schemes is a technology that utilize power control and scheduling of the eNodeB to mitigate ICI. It divides the entire system bandwidth into several frequency band. However the cell edge users are schedule in the portion of the band that can effectively combat the Inter-cell interference. There are also few techniques like interference randomization, interference cancellation and avoidance of Interference that can also use to reduce the interference level in the network.

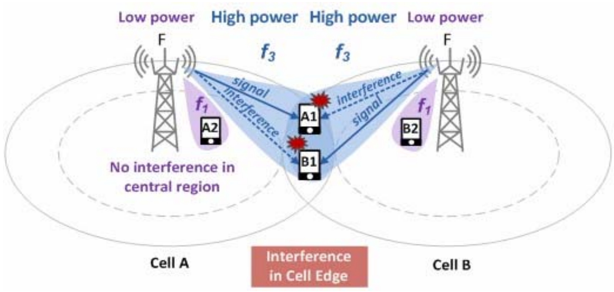



Fig. 3 Concept of inter-cell interference

## V. MATHEMATICAL MODEL OF THE SYSTEM

**Additive White Gaussian Noise**

The mathematical AWGN is the most commonly used channel model in FDMA. Additive means the noise has being superimposed to the electrical signal that blocks the signal and confuses the receiver in order not to make accurate symbol decisions. White means the spectrum is flat for all Gaussian distribution function [18]. For a received signal that passes through AWGN is expressed mathematically as

$$r(t) = s(t) + n(t) \quad (1)$$

Where s(t) is the transmitted signal and n(t) is the noise added

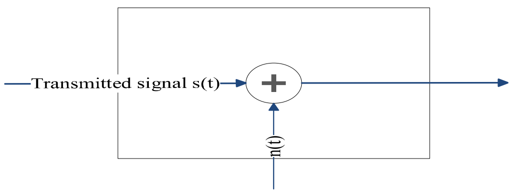



Fig.4 Mathematical model for AWGN

**BER for Different Modulation Scheme under AWGN**

The theoretical BER performance in the presence of AWGN and multipath fading for BPSK, QPSK, 16QAM and 64QAM is explained below. BER is the number of bits errors divided by the total number of transferred bits.

Mathematically BER is given by

$$\text{BER} = \frac{\text{Number of Errors}}{\text{Number of Bits Transmitted}} \quad (2)$$

For different modulation schemes such as QPSK, 16QAM, 64QAM with transmitted bits per symbol of (2, 4, 6) respectively.

Mathematically the number of bits per symbol (k) transmitted over a channel depends on such modulation scheme and also used to determines the spectral efficiency of a communication system which is given by $K = log_2(M)$ (3)

Where M is the signal constellation level

The phase carriers are spread in one of the four equal values as 0, π/2, π and 3π/4, where each value corresponding to the phase gives a special combination to the message bit.

The base signal for QPSK can be expressed as (QPSK)

$$\sqrt{E_s}\cos\left(\frac{\pi}{2}(i-1)\right)\Phi_1(t) \quad (4)$$

$$\sqrt{E_s}\cos\left(\frac{\pi}{2}(i-1)\right)\Phi_2(t) \quad (5)$$

Where i=1, 2, 3, 4 and are the phase angles, and ($E_s$) level is the energy of the signal. One essential advantage of QPSK over BPSK is that they have identical bit error probability and can send multiple data using the same bandwidth.

The probability of bit error for M QAM is dependent on whether the number of bits per symbol is even or odd

$$S_{MQAM} = \sqrt{\frac{2E_{min}}{T_s}}\,a_1\cos(2\pi ft) + \sqrt{\frac{2E_{min}}{T_s}}\,b_1\sin(2\pi ft) \quad (6)$$

Where $T_s$ is the period of the modulated signal and $E_{min}$ is the energy of the signal with lowest amplitude integer. $a_1$ and $b_1$ are selected based on the location of a signal point. For a square M-QAM, where m= is even, the $P_b$ can be evaluated mathematically

as $$P_b = \frac{2P_0 - P_0^2}{log_2(M)} \quad (7)$$

Mathematically, $$P_0 = \frac{2(\sqrt{M}-1)}{\sqrt{M}}\,\text{erf}\left\{\sqrt{\frac{3log_2(M)}{M-1}\frac{E_b}{N_0}}\right\} \quad (8)$$

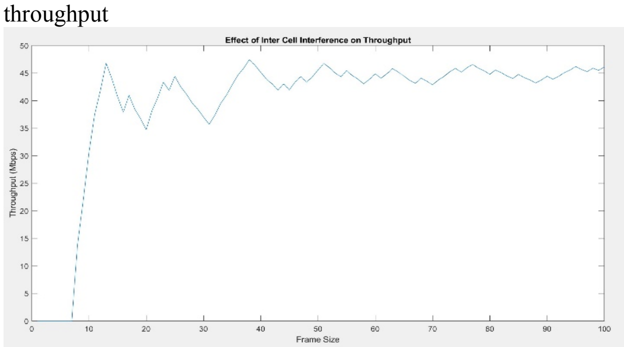
For a rectangular QAM where m = $log_2(M)$ is odd, then $P_b$ can be written mathematically as

$$P_b \le \frac{1}{log_{2(M)}}\left[1 - \left[1 - 2erf\left(\sqrt{\frac{3log_2(M)}{M-1}\frac{E_b}{N_0}}\right)\right.\right. \quad (9)$$

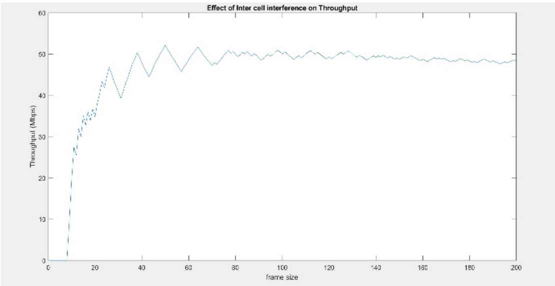
In equation below, erf is describe as the error function which differ for individual modulation scheme. $\frac{E_b}{N_o}$ is a form that of signal to noise ratio, whiles $E_b$ is the bit energy and $N_o$ noise spectral density.

## IV. SIMULATION RESULTS AND ANALYSIS

The performance of the LTE network depends on BER, spectral efficiency, throughput and cell coverage. Therefore, to measure the performance of LTE network this metrics parameters should be considered. We used Matlab to simulate the effect of inter cell interference and to predict the BER of different adaptive modulation scheme to increase the network throughput

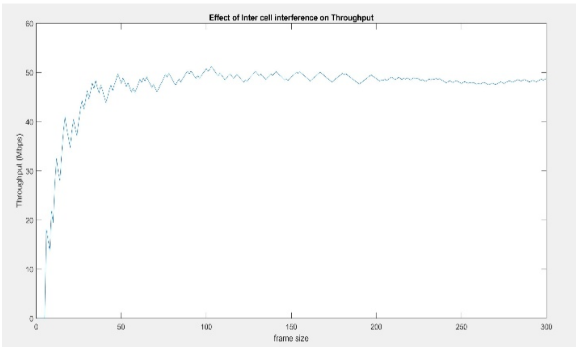



(a)

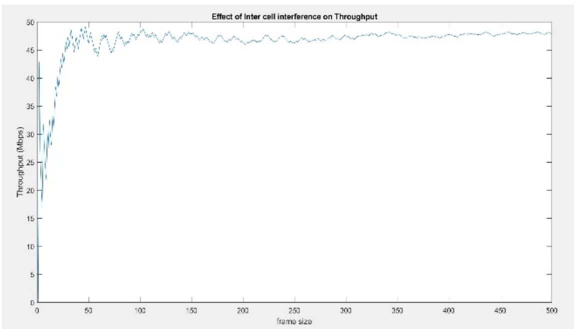



(b)

Fig. 5.1 shows Effect of ICI on throughout for (a) 10 frames and (b) 20 frames




( c)




(d)

Fig.5.2 shows Effect of ICI on throughout for (c) 80 frames and (d) 100 frames

In these results three eNodeBs are considered, one is used as a serving cell whiles the other two are used as an interfering cells. The achieved throughput is estimated and a graph is depicted that shows the effect of the inter cell interference on the network performance. From the results obtain, transmitting certain number of frames has an effect on the throughput.

In transmitting (20, 40, 60, 100) number of frames, the available throughput estimated was (46, 48, 48 and 49) % respectively. However, increasing the number of frames increases the throughput and reduces inter cell interference. However, a steady state is reached where average throughput becomes stable and cannot increase any further. For a larger number of frames to be transmitted it takes a longer time for the receiver to make a decision.

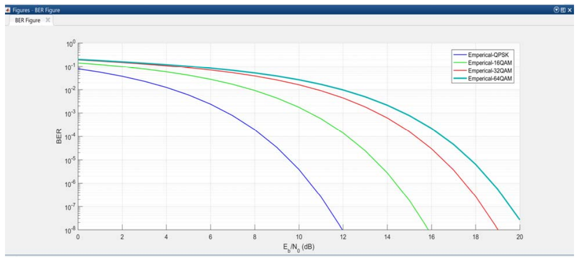



Fig. 6 shows BER curves for different adaptive modulation scheme under AWGN

Figure 6. shows BER for different adaptive modulation scheme in the presence of Additive White Gaussian Noise (AWGN). Four adaptive modulation schemes QPSK, 16QAM, 32QAM and 64QAM were considered.

This shows that QPSK degrade faster than all the others whereas it takes a longer time for 64QAM to degrade. This is because QPSK contains 2bits/symbol which can be transmitted quickly with less power, whereas 16QAM and 32QAM with (4, 5) bits/symbol will take little while to deteriorate.

Moreover, in a case of higher order modulation such as 64 QAM which contains 6bits/symbol transmitting these bits in each quadrant will require higher transmitter power which comes at a cost and also leads to bits errors

From figure the graph for BER value of 10 ^ -2 the Eb/No or SNR per bit is (4, 8, 11, 12) for QPSK, 16-QAM, 32-QAM and 64-QAM respectively. This implies that the energy or power required to transmit a bit is higher for 64QAM followed by 32-QAM, 16-QAM and to QPSK therefore, you need more power to transmit a QAM bit and less energy for QPSK.

TABLE 1

Relationship between BER and SNR for different adaptive modulation scheme

| Modulation Scheme | SNR | BER | Relationship |
|---|---|---|---|
| QPSK | 12 | 0.08 | increasing |
| 16-QAM | 16 | 0.12 | increasing |
| 32-QAM | 19 | 0.14 | increasing |
| 64-QAM | 20 | 0.14 | ≈ 32-QAM |

## VI. CONCLUSIONS

The objectives of this research work are to evaluate inter-cell interference and BER in an LTE network. Different adaptive modulation schemes were examined with the application of additive white Gaussian noise (AWGN) and the BER were plotted against the Eb/No. In addition, the effect of inter-cell interference on throughput of the PDSCH was simulated taking into consideration the number of frames transmitted.

The test results of the BER against the signal to noise ratio per bit depict that, QPSK modulation scheme can be applied in channel with worst channel conditions because it gives less errors as compared to 16QAM, 32QAM and 64QAM. However, using higher modulation scheme such as 64QAM provides faster data rate and boost spectral efficiency under bad channel conditions. Less bit errors will be obtained when using QPSK than QAM but to achieve faster data rate and better spectral efficiency operators needs to resort to using 64QAM which also comes with pit fall.

## REFERENCES


[1] G. M. Dwarakinath, "Impact of Downlink Reference Signal Planning on LTE Network Performance Impact of Downlink Reference Signal Planning on LTE Network Performance Govardhan Madhugiri Dwarakinath," no. October, p. 91, 2013.

[2] T. W. Paper, "Long Term Evolution ( LTE ): A Technical Overview," *White Pap.*, 2007.

[3] "LTE eNodeB, MME and SAE Function in Short _ TELETOPIX," *Essentials of LTE and LTE-A*, 2018. .

[4] S. Sesia, "The LTE Network Architecture," *LTE — UMTS Long Term Evol. From Theory to Pract.*, no. Wiley, pp. 23–50, 2009.

[5] A. Ghosh and R. Ratasuk, *Essentials of LTE and LTE-A*, vol. 9780521768. 2011.

[6] A. Acakpovi, A. Iddrisu, N. Y. Asabere, and J. Kwofie, "Performance Comparison of Cyclic Prefix OFDM and Unique Word OFDM in the LTE Downlink," vol. 7, no. 2, pp. 9–14, 2016.

[7] A. Acakpovi and D. Kogue, "Inteference Mitigation in Femtocellular Networks," *Int. J. ...*, pp. 2–7, 2014.

[8] A. Acakpovi and H. Sewordor, "Performance Analysis Of Femtocell in an Indoor Cellular Network," vol. 3, no. June, pp. 281–286, 2013.

[9] N. Okubo, A. Umesh, M. Iwamura, and H. Atarashi, "E-UTRAN: The Long Term Evolution (LTE) high speed and low latency radio access network," *NTT DOCOMO Tech. J.*, vol. 13, no. 1, pp. 10–19, 2010.

[10] G. Piro, L. A. Grieco, G. Boggia, F. Capozzi, and P. Camarda, "Simulating LTE Cellular Systems : an Open Source Framework," *IEEE Trans. Veh. Technol.*, vol. 60, no. 2, pp. 498–513, 2011.

[11] S. Sbit, M. B. Dadi, and B. Chibani, "Co and Adjacent Channel Interference Evaluation in GSM and UMTS Cellular Networks," *Ijarcce*, vol. 4, no. 11, pp. 462–465, 2015.

[12] J. Zhu and H. Li, "On the performance of LTE physical downlink shared channel," *Proc. 2011 Int. Conf. Comput. Sci. Netw. Technol. ICCSNT 2011*, vol. 2, pp. 983–986, 2011.

[13] G. Singh and D. S. Chauhan, "Simulation and Modeling of Hydro Power Plant to Study Time Response during Different Gate States," *Int. J. Adv. Eng. Sci. Technol.*, vol. 10, no. 10, pp. 42–47, 2011.

[14] D. X. Almeida, "Inter-Cell Interference Impact on LTE Performance in Urban Scenarios," *Gr. Res. Wirel.*, pp. 1–10, 2013.

[15] D. P. Agrawal and Q.-A. Zeng, *Introduction to Wireless and Mobile System*, 3rd ed., vol. 162. USA: Global Engineering: Christopher M. Shortt, 2011.

[16] M. U. Sheikh, R. Jagusz, and J. Lempiäinen, "Performance Evaluation of Adaptive MIMO Switching in Long Term Evolution," *Configurations*, pp. 866–870, 2011.

[17] Y. Q. Bian, A. R. Nix, Y. Sun, and P. Strauch, "Performance evaluation of mobile WiMAX with MIMO and relay extensions," in *IEEE Wireless Communications and Networking Conference, WCNC*, 2007.

[18] H. Singh and M. Singh, "Optimization Method for Analysis of Bit Error Rate with BPSK Modulation Technique," vol. 3, no. 6, pp. 1–4, 2012.

[19] G. Y. Li, J. Niu, D. Lee, J. Fan, and Y. Fu, "Multi-Cell coordinated scheduling and MIMO in LTE," *IEEE Commun. Surv. Tutorials*, 2014.

[20] L. Liu, R. Chen, S. Geirhofer, K. Sayana, Z. Shi, and Y. Zhou, "Downlink MIMO in LTE-advanced: SU-MIMO vs. MU-MIMO," *IEEE Commun. Mag.*, 2012.

[21] Q. Li, G. Li, W. Lee, M. Il Lee, D. Mazzarese, B. Clerckx, and Z. Li, "MIMO techniques in WiMAX and LTE: A feature overview," *IEEE Commun. Mag.*, 2010.