

Research Article

Performance Analysis of LTE Technology in Unlicensed Spectrum for Mobile Communication

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Abstract

Long Term Evolution (LTE) is a mobile technology aimed at delivering high-speed internet connectivity. With the rising demand from wireless devices such as smartphones and tablets, interest has grown in operating LTE within the unlicensed spectrum to access broader bandwidths. This study employs systematic literature review and simulation-based analysis to evaluate LTE performance in unlicensed bands. Findings indicate that LTE achieves throughput comparable to licensed operation. However, increasing transmit power and duty cycle enhances LTE performance while significantly degrading Wi-Fi performance. Coexistence methods like Listen Before Talk (LBT) and Carrier Sensing Adaptive Transmission (CSAT) underperform compared to proposed strategies. Effective coexistence mechanisms are essential to prevent interference and ensure balanced performance across technologies.

Keywords

MIMO, LTE, Unlicensed Spectrum, Licensed Spectrum, BER, Coexistence

1. Introduction

Long Term Evolution (LTE) is a high-speed mobile communication technology that offers faster internet connectivity compared to earlier mobile generations [1]. It represents the fourth generation (4G) in the evolution of mobile communication, positioned between the third generation (3G) and the fifth generation (5G), following the progression from 1G and 2G technologies. LTE technology was developed to enhance the capacity and speed of wireless data networks by utilizing advanced digital signal processing techniques [2, 3]. Due to the growing demand for mobile traffic and bandwidth, operators are increasingly exploring the use of unlicensed spectrum as a complementary solution for mobile network communication. In particular, there has been rising interest in utilizing the 5 GHz band-primarily used by Wi-Fi-for Long

Term Evolution (LTE) deployment [4]. LTE is the name given to a project aimed at developing a high-performance air interface for cellular mobile systems. Initiated in 2004 by the Third Generation Partnership Project (3GPP), LTE represents a major step toward fourth-generation (4G) radio technologies, designed to significantly boost network speed and capacity.

The rapid growth of mobile data usage and the emergence of applications like multimedia online gaming, mobile TV, Web 2.0, and streaming content have driven the 3rd Generation Partnership Project (3GPP) to develop Long Term Evolution (LTE) as a step toward 4G technology. Meanwhile, Wi-Fi operates in the low-frequency unlicensed spectrum and is widely used for wireless communication [5]. The combination of LTE and Wi-Fi radio links has been proposed since

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3GPP Since 3GPP Release 13 [6], integrating LTE and Wi-Fi radio links has been proposed, with technologies such as LTE-WLAN Aggregation and LTE-WLAN Radio Level Integration. Coexistence between 802.11 and 802.15.4 radios in the 2.4 GHz ISM band is already established [7, 8]. Recent LTE enhancements also support its deployment in pico and femto cells, enabling coexistence with Wi-Fi in shared spectrum environments. When LTE and Wi-Fi operate in the same unlicensed spectrum band, Wi-Fi performance often degrades due to interference from LTE. Additionally, Wi-Fi devices located near LTE nodes (eNodeBs) can interfere with LTE signals—either at the eNodeB or the user equipment (UE)—due to their high transmission power. The expansion of LTE/LTE-Advanced into unlicensed spectrum is driven by both consumer demand and network capacity needs. However, ensuring fair coexistence between LTE-Unlicensed (LTE-U) and other technologies like Wi-Fi, Bluetooth, and ZigBee remains a major concern. Ongoing discussions focus on preventing performance degradation and promoting harmonious coexistence among these networks [9]. The authors in [10] proposed a fair and quality-driven approach to unlicensed spectrum sharing between Wi-Fi and femtocell networks; however, implementing this solution requires modifications to the existing Wi-Fi infrastructure. In [11], The researcher analyzed the achievable sum-rate in standalone mode using a dual-mode small cell base station; however, Wi-Fi fairness was not taken into account. In contrast, this study will address and incorporate fairness towards Wi-Fi in the analysis. In [12], The author proposed adjusting the contention window size by estimating the number of stations (STAs) based on collision probability to enhance throughput. Additionally, a channel coordination mechanism featuring both synchronous and asynchronous modes was introduced in [13], aimed at improving coexistence between networks.

The growing volume of data traffic and the rising number of mobile broadband users worldwide have created a need to deploy LTE in unlicensed spectrum [14]. Hence, the 5 GHz spectrum which is in unlicensed free to use, offers a large amount of bandwidth. In [15], the main advantages for LTE-Unlicensed over Wi-Fi technology are better link performance, superior channel access control, special mobility management, and improved coverage. When all these benefits are mixed with the massive amount of available spectrum in the 5GHz band, they make LTE Unlicensed a favorable unlicensed radio access technology. The unlicensed spectrum offers a wide bandwidth, making it an attractive option for LTE deployment. However, the extensive search space for User Equipment (UE) within this spectrum can lead to unavoidable processing delays. To address this issue, LTE-Unlicensed (LTE-U) operations have been restricted to the carrier frequencies within the U-NII-1 and U-NII-3 bands [16]. The simulation is carried out using the LTE system toolbox of MATLAB software. The work is performed in the PDSCH (Physical Downlink Shared Channel) and PUSCH (Physical Uplink Shared Channel) [17]. The PHY layer car-

ryout antenna mapping, modulation, and demodulation coding and decoding. A highly efficient means of conveying both data and control information between mobile UE (User Equipment) and enhanced base station (eNodeB) is the LTE physical layer [18]. This paper discusses the speed of the 4x4 MIMO systems in terms of Mbps. Like 2G or 3G LTE also has its own architecture. It is simply a network of Evolved Packet Core Network and base stations (eNB) as shown in the figure below [19, 20].

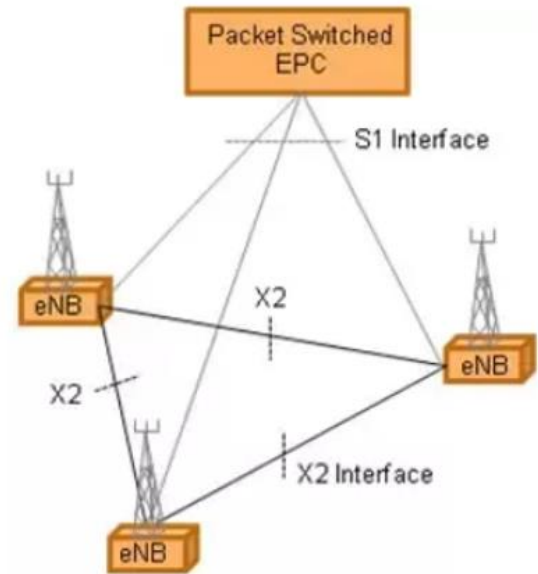


Figure 1. Architecture of LTE [21].

In LTE, there is no centralized intelligent controller. Instead, eNodeB (eNB) systems are interconnected through the X2 interface, while communication with the core network occurs via the S1 interface, as illustrated in Figure 1. This distributed architecture among base stations is designed primarily to accelerate connection setup and minimize handover delays [21].

2. Research Methods

The LTE system architecture facilitates data transmission and reception by processing data through multiple modules in the transmitter before sending it over the unlicensed channel and then through corresponding blocks in the receiver. The Simulink model results for this system are presented in this section. According to [22], quantitative studies are to be done by identifying variables in the study, relate the variables with the research questions and tests. In this study, variables were identified and were related to the questions of research. For example, several parameters influencing the performance of LTE mobile network technologies in unlicensed spectrum and LTE-U technologies were investigated for research question number one which stated: What are the parameters influenc-

ing the performance of LTE network in the unlicensed spectrum? Also, the use of standards of validity and reliability were observed and statistical measurements were used.

The data collected were analyzed and the Performance of LTE Mobile Network Communications in the unlicensed spectrum was done. This analysis was conducted using the performance parameters that were investigated. This study was conducted as an experiment in the computer laboratory. And according to [22], experiment design is done to test how one or more factors can have an impact on other factors. In this study, the researcher observed how unlicensed spectrums affect the performance of LTE mobile communication.

3. Simulation Setting

The model outlines the simulation of the transmitter, receiver, and measurement components. The transmitter includes data generators, a Turbo Channel Coder, and the Transmit PDSCH processing block. Two generated signals are transmitted through a MIMO channel with AWGN. At the receiver, receive processing block handles the incoming data. Data is generated randomly and appended with extra bits for error detection. The Turbo Channel Coder encodes the bits to optimize channel bandwidth, passing them to the PDSCH processing block, which includes a scrambler and modulator. Each data source is processed separately before the layer mapper performs spatial multiplexing, combining them into a single stream. This stream undergoes OFDM modulation and

is transmitted over the MIMO channel with AWGN, representing the unlicensed spectrum. Finally, the data is extracted and passed to the MIMO receiver [21]. The data obtained from the layer is then passed to the demodulator and then to the PDSCH descrambler. The data obtained after descrambling are the received code words [23]. At last, the error introduced by the interference is measured with the speed of transmission. In the measurement section, a MATLAB function block is used to obtain the speed of the communication in terms of Mbps.

Table 1. Simulation Parameters.

Parameter	Value
Channel Bandwidth	5MHz
Duplex mode	FDD
Channel mode	OFDM
Channel type	Flat Static MIMO, EPA 0Hz, EVA 5Hz, EVA 70Hz
Modulation	QPSK, 16-QAM, 64-QAM
SNR	12.1dB
Antenna diversity	4 x 4 MIMO

Simulation Results and Analysis

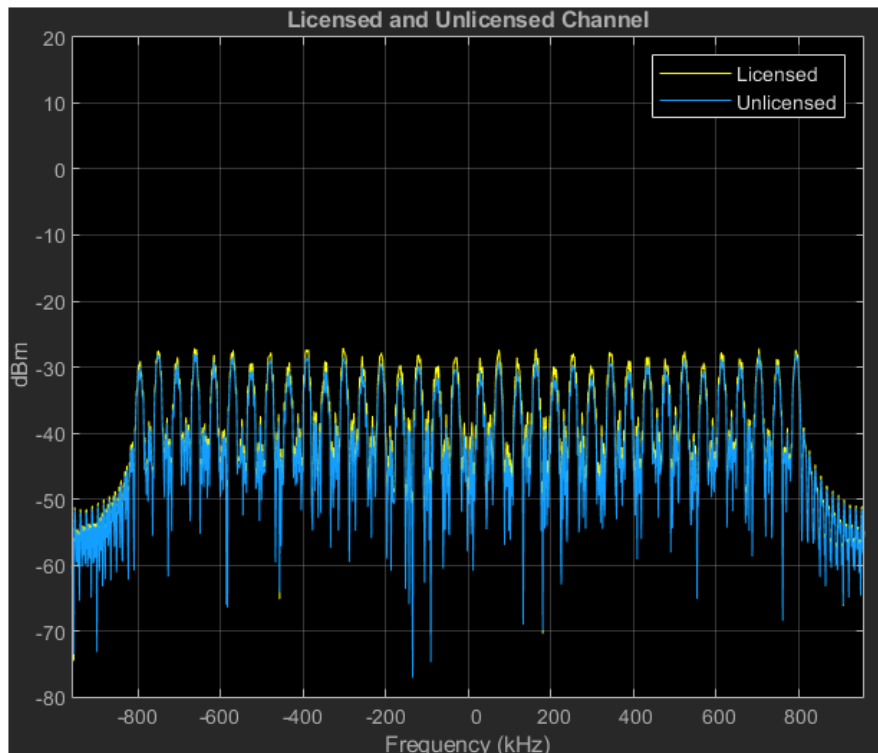


Figure 2. Transmitted Signal in Licensed and Unlicensed spectrum for 16QAM, 4x4, EVA 5Hz channel.

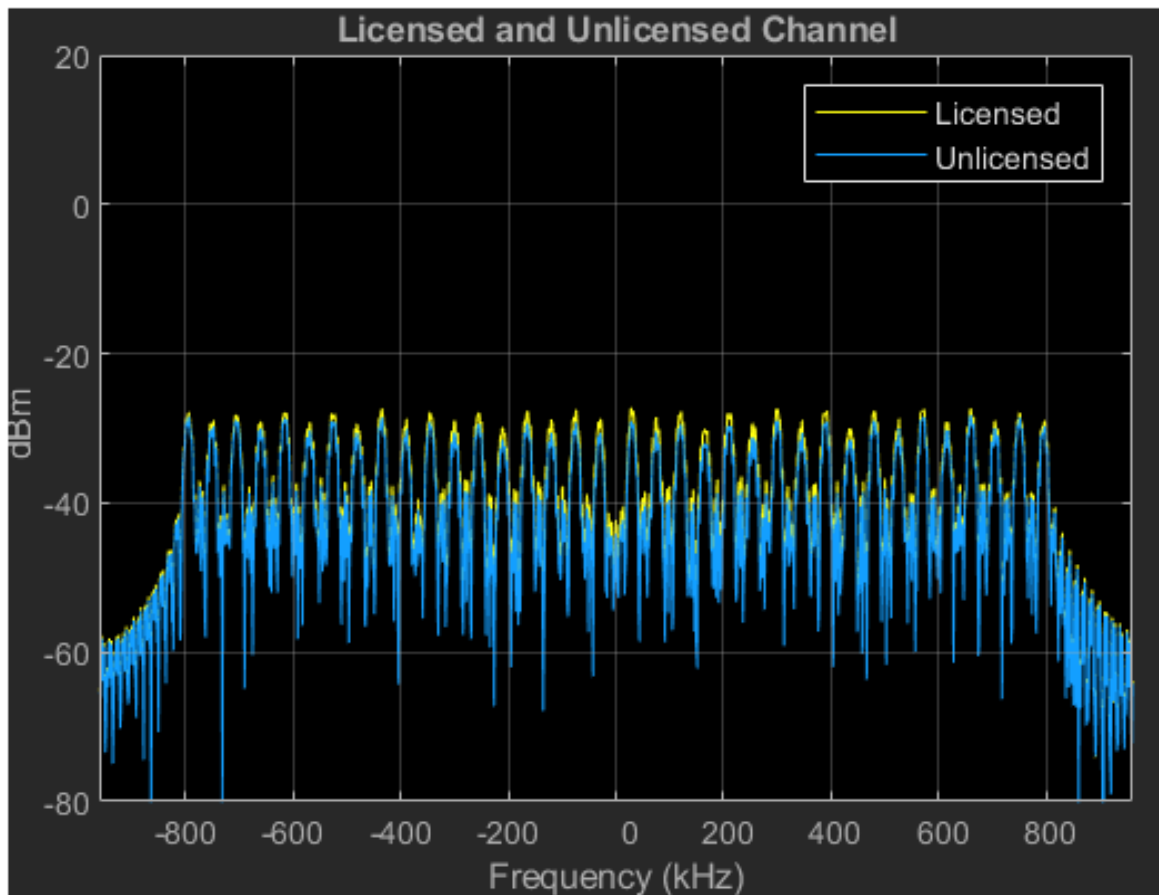


Figure 3. Transmitted and Signals in Unlicensed and Licensed spectrum for 16QAM, 4x4, EVA 5Hz channel.

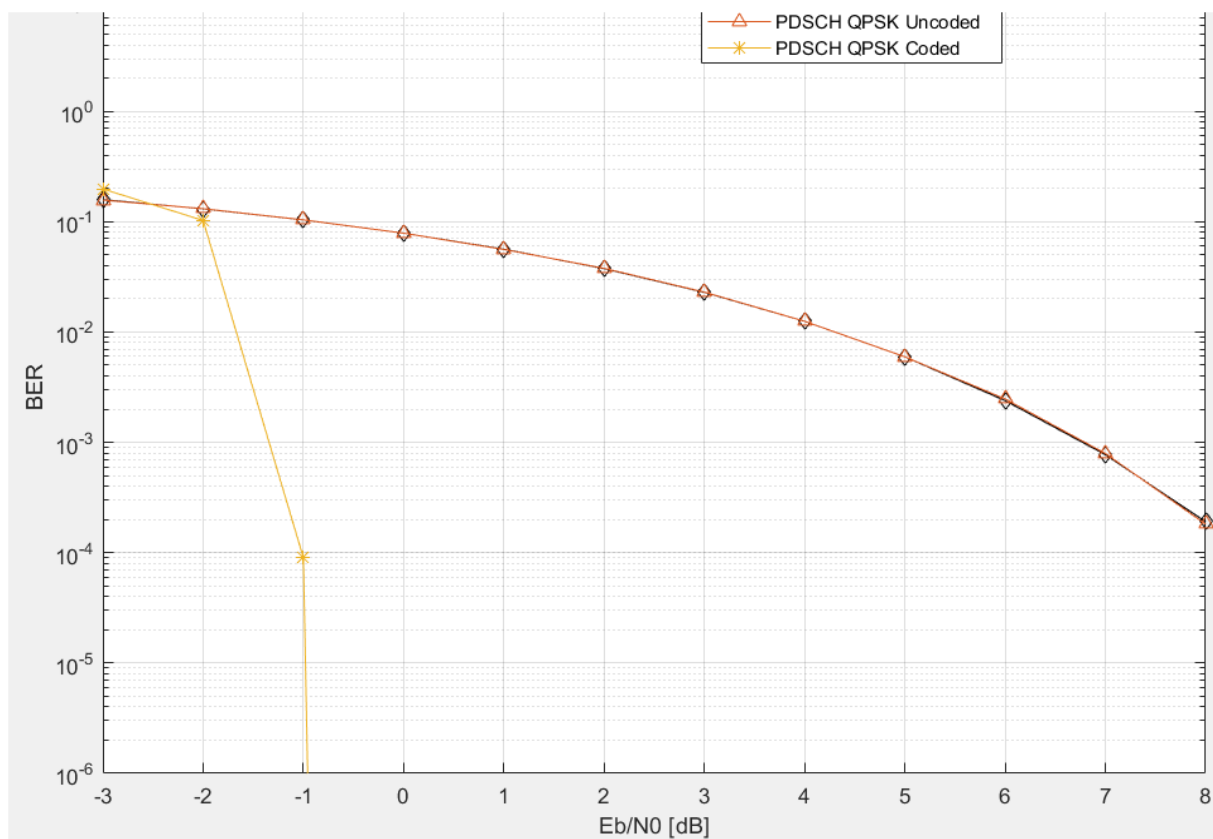


Figure 4. Bit Error Rate of the QPSK Signal.

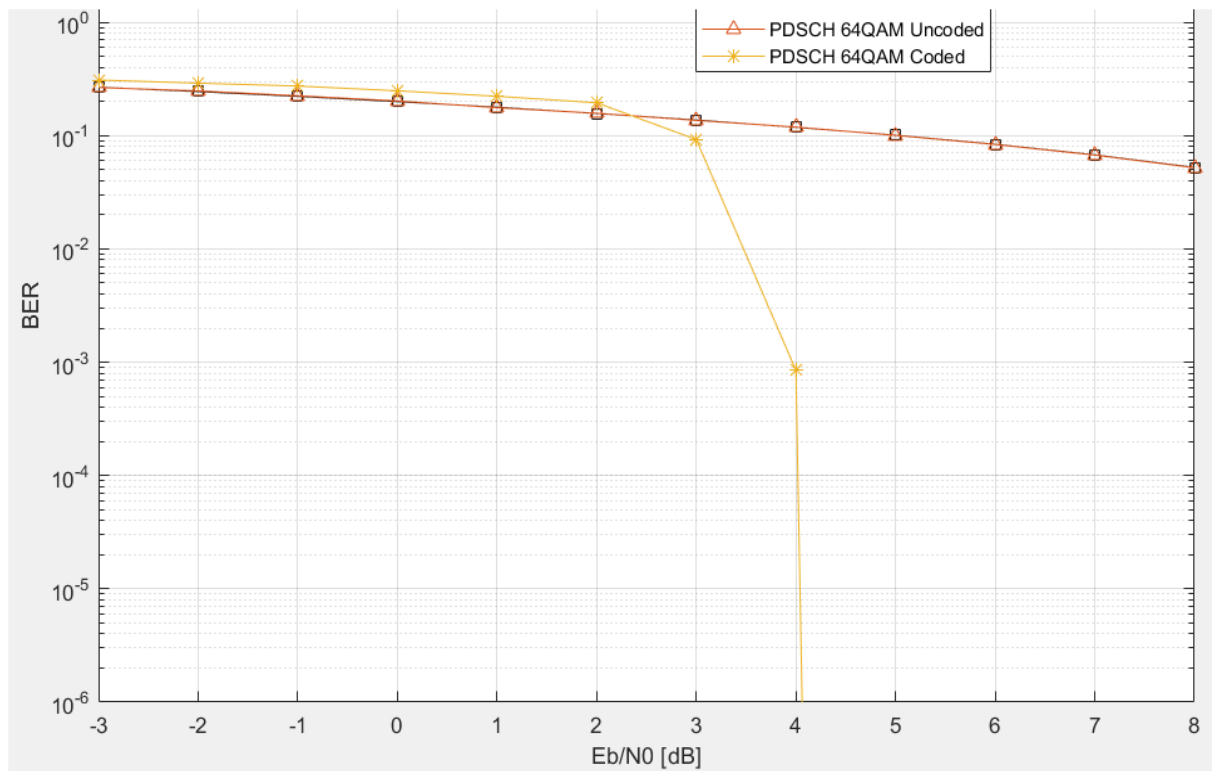


Figure 5. Bit Error Rate of the 64-QAM Signal.

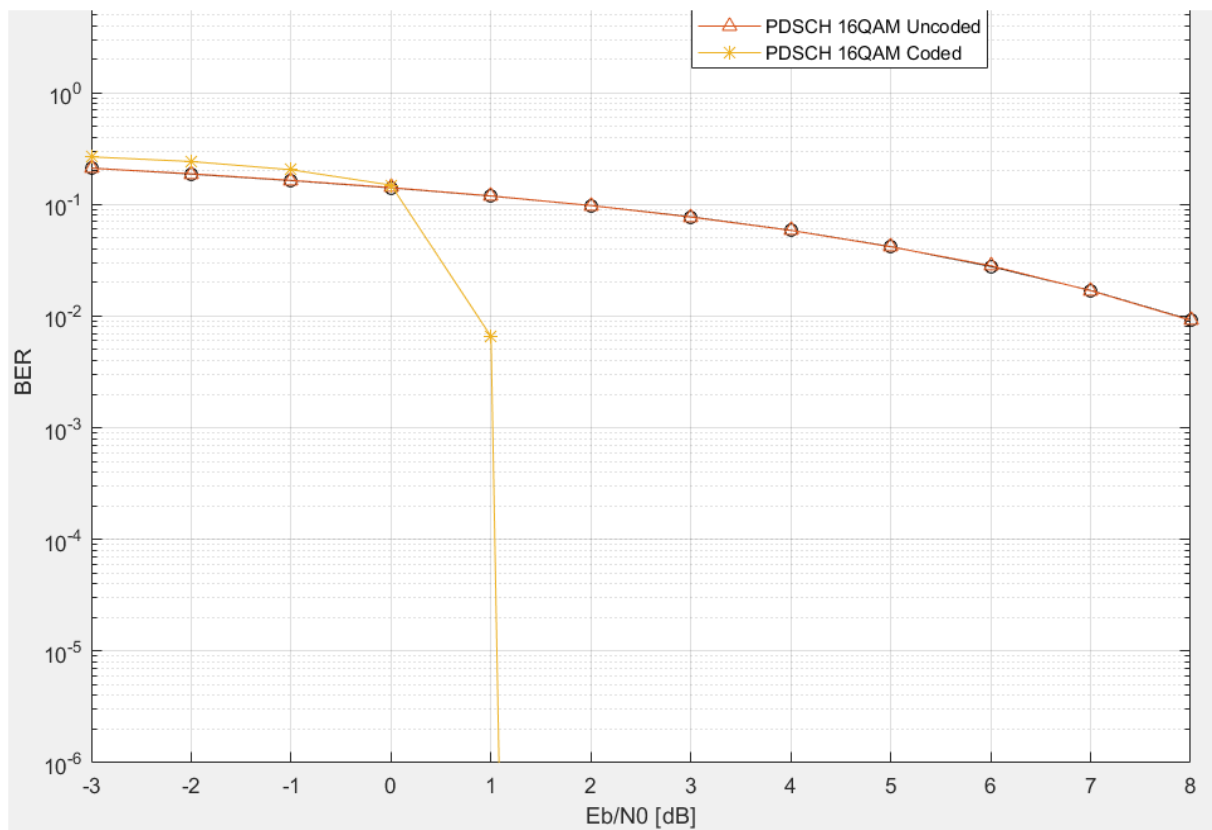


Figure 6. Bit Error Rate of the 16-QAM Signal.

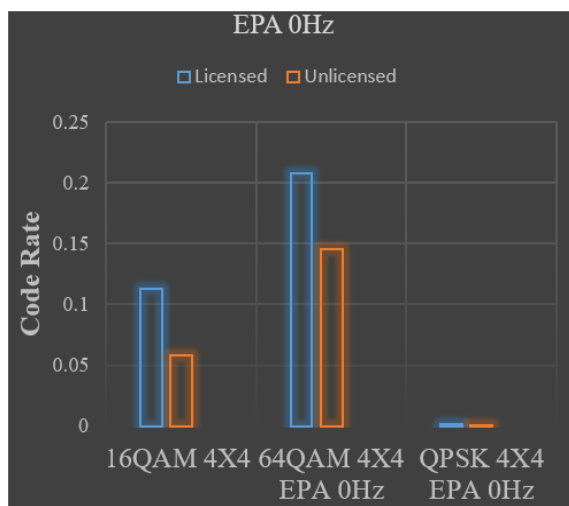


Figure 7. Received Data for 16-QAM, 2x2, EVA 5Hz channel.

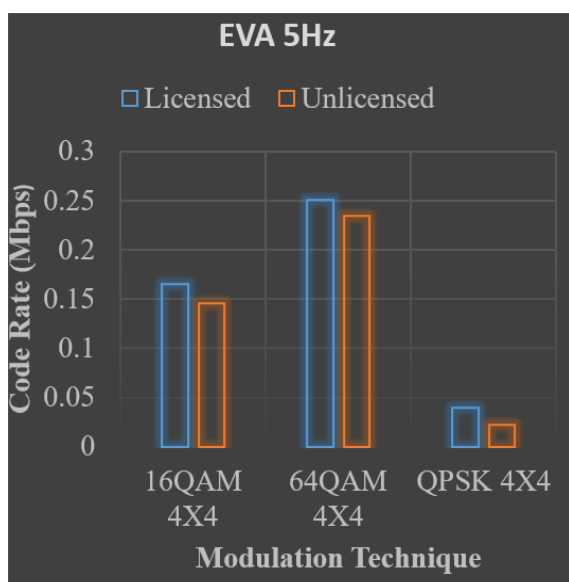


Figure 8. Received Data for 64-QAM, 4x4, EVA 5Hz channel.

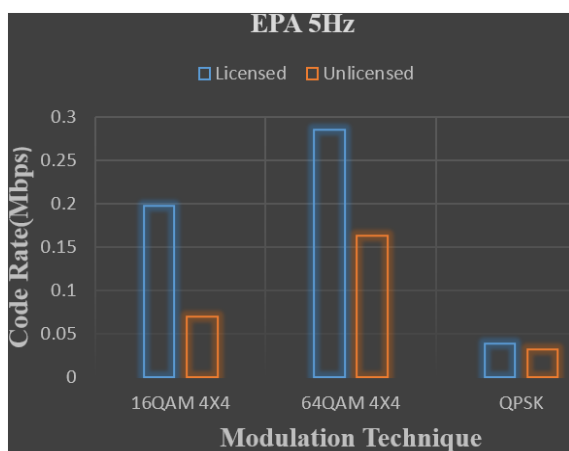


Figure 9. Received Data for 64-QAM, 4x4, EVA 5Hz channel.

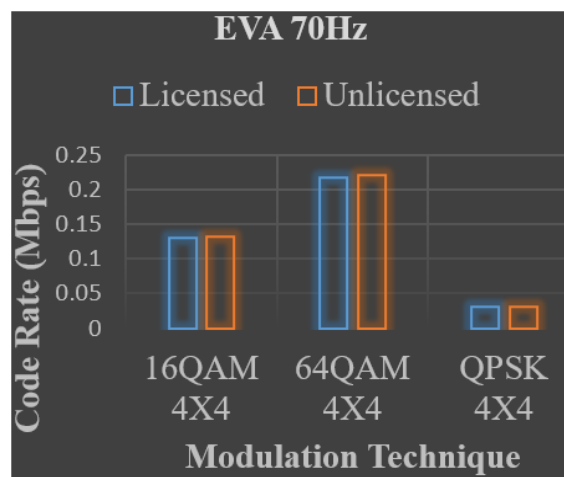


Figure 10. Received Data for 64-QAM, 4x4, EVA 5Hz channel.

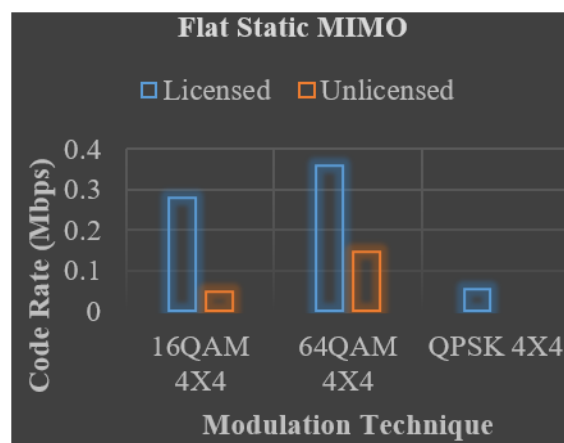


Figure 11. Received Data for 64-QAM, 4x4, EVA 5Hz channel.

Speed for different Modulation techniques configured system are analyzed in table 2.

Table 2. Different Modulation Techniques for LTE Throughput.

Configuration	Speed in Mbps
16QAM, 4x4, EPA 0Hz	12.86
64QAM, 4x4, EPA 0Hz	19.8
QPSK, 4x4, EPA 0Hz	6.4
16QAM, 4x4 EVA 5Hz	12.96
64QAM, 4x4 EVA 5Hz	19.88
QPSK, 4x4, EVA 5Hz	6.3
16QAM, 4x4 EPA 5Hz	13.1
64QAM, 4x4 EPA 5Hz	20.1
QPSK, 4x4, EPA 5Hz	6.0
16QAM, 4x4, EVA 70Hz	12.90

Configuration	Speed in Mbps
64QAM, 4x4, EVA 70Hz	19.87
QPSK, 4x4, EVA 70Hz	6.23
16QAM, 4x4, Flat Static MIMO	13.01
64QAM, 4x4, Flat Static MIMO	19.02
QPSK, 4x4, Flat Static MIMO	6.43

4. Conclusion

The results presented in Table 2 compare the performance of various modulation schemes-16QAM, 64QAM, and QPSK-using OFDM within an unlicensed spectrum and a 4x4 MIMO configuration. While system speed remains constant across all modulation types, the Code Rate varies notably, as illustrated in Figures 7-11. The lowest Code Rate in the unlicensed spectrum occurs with QPSK under a 4x4 MIMO setup and EPA 0Hz conditions. Similarly, in the licensed spectrum, the lowest rate is observed with QPSK under flat static conditions. QPSK consistently produces the lowest Code Rate in both environments, indicating reduced data throughput. Furthermore, the Bit Error Rate (BER) remains consistent across different channel types in the unlicensed spectrum, varying only with the modulation scheme, suggesting minimal impact from the unlicensed environment on BER.

Abbreviations

AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
CSAT	Carrier Sensing Adaptive Transmission
EPA	Evolved Pedestrian a Model
LBT	Listen Before Talk
LTE	Long Term Evolution
MIMO	Multiple-input Multiple-output
PDSCH	Physical Downlink Shared Channel
PUSCH	Physical Uplink Shared Channel
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
SNR	Signal to Noise Ratio
UE	User Equipment

Conflicts of Interest

The authors declare no conflicts of interest.

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