International Research Journal of Education and Technology
Peer Reviewed Journal
ISSN 2581-7795

PERFORMANCE EVALUATION FOR 5G NR BASED MM-WAVE MIMO SYSTEMS UNDER URBAN MICRO CELL

Raghunandan S[1], Dhranesh S M[2], Vimalraj S[3]

[1,2,3]*Student, Dept. of Electronics and Communication Engineering*

[1,2,3,]*Bannari Amman Institute of technology*

*Abstract-*This research project aimed to evaluate the performance of 5G NR-based mmWave MIMO systems in urban microcell environments. This study assessed the feasibility of achieving the required results in terms of system performance, coverage, and capacity. It focuses on analyzing the impact of various factors, such as path loss, interference, and mobility, on the performance of mmWave MIMO systems. To conduct a comprehensive evaluation, a combination of simulations and measurements were performed. Advanced simulation tools, such as MATLAB, will be utilized to model the mmWave MIMO system and the urban microcell characteristics. Realistic scenarios considering factors such as building density, blockage, and reflections were simulated to capture the challenges specific to urban environments. The project aims to optimize system parameters and configurations to enhance the overall performance of mmWave MIMO systems in urban microcells. This includes investigating techniques for interference management, power control, and scheduling algorithms to mitigate the impact of urban microcell characteristics and improve system performance. The results of this project have significant implications for enhancing wireless communication in urban areas. The improved performance of 5G NR-based mmWave MIMO systems can provide faster and more reliable wireless connections, enabling seamless Internet access and supporting emerging technologies, such as autonomous vehicles, augmented reality, and the Internet of Things (IoT).

Keywords:5G NR, mmWave MIMO systems, urban micro-cell environments, system performance, coverage, capacity, path loss, interference, mobility, simulations, MATLAB, building density, blockage, reflections, optimization, interference management, power control, scheduling algorithms, wireless communication, seamless Internet access, autonomous vehicles, augmented reality, Internet of Things (IoT), remote monitoring, smart factories, logistics systems, productivity, cost savings, advancement, practical applications.

I. INTRODUCTION

The rapid growth of wireless communication networks is ushering in a new era in which users simultaneously demand a multitude of services. Whether augmented reality, virtual reality, or other applications, each comes with its own set of requirements, such as high-speed data, minimal delay, and unwavering reliability. To meet these escalating demands, the

telecommunications industry has embarked on a 5G journey. Fifth-generation (5G) networks are designed to deliver lightning-fast data speeds, minimal latency, and seamless connectivity for an ever-expanding array of devices.

However, the path to 5G excellence is not without hurdles. The proliferation of Base Stations (BSs) has added complexity to network resource management and brought about unprecedented challenges in system upkeep. Moreover, the introduction of millimeter-wave (mmWave) frequencies with their distinct propagation characteristics has disrupted conventional resource management algorithms. These challenges are particularly pronounced in densely populated urban micro-cell environments.

In light of these considerations, our research endeavors to evaluate the performance of 5G New Radio (NR)-based mmWave Multiple-Input Multiple-Output (MIMO) systems in urban microcells. We recognize the need for tailored resource-allocation algorithms that account for the unique attributes of mmWave frequencies and the density of urban microcellular networks. Our mission is to optimize network performance, ensuring that the promise of 5G – high-speed, low-latency, and reliable connectivity – is upheld, even in the most demanding urban settings.

In this pursuit, we delve into the intricacies of mmWave propagation, urban microcell challenges, and the interplay of MIMO technology. Through a combination of simulations and measurements, we aim to unravel the performance potential of mmWave MIMO systems by considering factors such as path loss, interference, and mobility. Our findings will contribute not only to the advancement of 5G technology but also to its practical implementation in the dynamic landscapes of urban microcells. The ultimate goal is to enable faster, more robust wireless connections, facilitate a seamless digital experience, and unlock the potential of emerging technologies, such as autonomous vehicles, augmented reality, and the Internet of Things.

II. LITERATURE REVIEW

Existing literature on millimeter-wave MIMO systems has proposed various beamforming techniques to enhance system performance in terms of coverage, capacity, and energy efficiency. In [1], an optimized 5G base station allocation configuration using the Amended Barnacles Mating Optimizer (ABMO) Algorithm is presented, demonstrating superior power efficiency compared to BMO, DE, and RGA algorithms. ABMO, an enhanced version of the Barnacles Mating Optimizer (BMO), excels in locating optimal base station positions and adjusting power levels in 5G networks, and is validated through simulations and statistical analysis.

This study contributes to an efficient 5G base station allocation configuration with a focus on power reduction, offering potential real-world applications in Industry 4.0. Meanwhile, [2] addresses the challenge of optimizing packet scheduling mechanisms in 5G networks to accommodate ultra-reliable low-latency communication (uRLLC) and enhanced Mobile BroadBand (eMBB) while maintaining Quality of Service (QoS). Legacy methods often fall short owing to their limited scope. To bridge this gap, this study introduces a novel mechanism that leverages scalable numerology and realistic multimedia traffic, aiming to enhance the uRLLC and eMBB capacity. By considering various use cases and dynamic conditions, this study seeks to provide insights into an efficient packet scheduling paradigm for diverse 5G multimedia scenarios.

The Author in [3] focused on the energy efficiency in ultra-reliable and low-latency communication (URLLC) within the context of 5G networks. A novel approach utilizing deep neural networks (DNNs) for real-time power allocation was introduced. URLLC's significance in applications such as the industrial internet is highlighted, emphasizing the need for improvements in spectral and energy efficiency owing to escalating energy consumption in expanding network landscapes. In contrast, [4] delves into the expansion of ultra-dense networks (UDNs) powered by dense small cells in the upcoming 5G era. Although this expansion holds promise for meeting increased data demands, it also presents challenges related to user association, potentially affecting data rates and latency. To address these challenges, the ambient intelligence exploration multi-delay deep deterministic policy gradient-based artificial bit optimization (AEMDPG-ARO) algorithm is proposed. This innovative algorithm combines Ambient Intelligence Exploration Multi-Delay (AIEM) with a Deep Deterministic Policy Gradient (DDPG) to enhance data rates and reduce latency within wireless sensor networks. Extensive evaluations against state-of-the-art techniques demonstrated the superior performance of the AEMDPG-ARO algorithm.

The Author of [5] proposed a millimeter-wave MIMO antenna array design for 5G communication terminals. The aim is to improve the performance of 5G communication systems by designing a compact and efficient antenna array that can support multiple-input multiple-output (MIMO) transmission. Highlighting the importance of millimeter-wave MIMO antenna arrays for improving the performance of 5G communication systems, and the different techniques proposed in the literature for improving the performance of millimeter-wave MIMO systems, such as code-domain multiplexing, power-efficient beam designs, hybrid beamforming, low-complexity beamforming, and deep learning-based beamforming. On the other hand, the author in [6] analyzed the performance of orthogonal time-frequency space (OTFS) waveforms for 5G NR mmWave communication systems. Simulations were used to evaluate the system throughput and BER under different scenarios such as varying numbers of antennas and modulation schemes. They found that OTFS can significantly improve the system throughput and BER compared with traditional waveforms.

In [7], the authors conducted a comprehensive analysis of the effect of analog beamforming on the performance of 5G NR mmWave systems. Through simulations, they explored various scenarios including changes in the number of antennas and beamforming weights. Their findings revealed that analog beamforming significantly enhances the system throughput and coverage compared to digital beamforming. Similarly, [8] investigated the performance assessment of two-hop mmWave relay nodes within the 5G NR uplink signal context. Employing simulations, the authors investigated diverse scenarios involving varying distances between relay nodes and the base station as well as different antenna configurations. Their results demonstrated substantial improvements in system throughput and Bit Error Rate (BER) when employing the proposed two-hop system in comparison to a single-hop counterpart.

In [9], the authors conducted a comprehensive analysis of multiuser MIMO (MU-MIMO) schemes within the context of 5G mmWave cellular networks, utilizing a realistic 3D channel model. Through simulations, they assessed system throughput and user fairness across various scenarios, including different user counts and antenna configurations. Their findings underscored the substantial improvements that MU-MIMO brings to both system throughput and user fairness compared to single-user MIMO setups. In [10], the authors introduced a novel two-hop mmWave MIMO NR-relay system designed to enhance the average system throughput and reduce the bit error rates (BER) in outdoor-to-indoor communication environments. Employing simulations, the authors evaluated the system performance under diverse conditions, including varying distances between the relay nodes and the base station, as well as different antenna configurations. The results highlighted the significant enhancements achieved by the proposed two-hop system, particularly in terms of the average system throughput and BER, compared to a traditional single-hop approach.

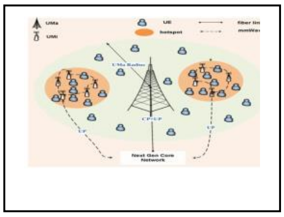
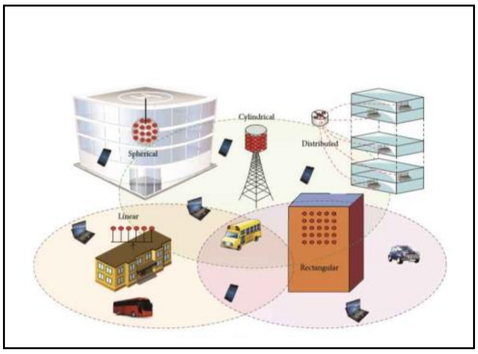


Fig.1 ESP32-CAM

A. USB TO UART TTL 5V 3.3V FT232RL



International Research Journal of Education and Technology
Peer Reviewed Journal
ISSN 2581-7795

1.

A comparison of 5G NR and LTE in a campus scenario using mmWave frequencies is a topic of interest in [11]. Several studies have evaluated the performance of these systems in terms of coverage, capacity, and user throughput. Simulations are a common approach for evaluating the performance of these systems. The findings of these studies are mixed, with some studies reporting that 5G NR outperforms LTE in terms of coverage and capacity, whereas others report the opposite. However, most studies agree that LTE has a better user throughput owing to its lower latency and higher modulation schemes. The performance of these systems is affected by various factors, such as the frequency band, antenna design, and interference. A comparison of 5G NR and LTE is important for understanding the potential of these systems in different scenarios and for informing the development of future wireless communication technologies.

2. III.FLOW DIAGRAM

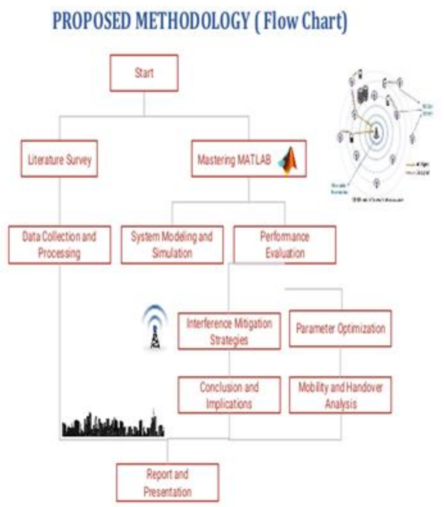


Fig.4 Flow Diagram

The system model assumes that the [W*H] Km^2 region has been taken into account for 5G/LTE networks so that base stations may be put there with a list of candidate sites R =[r1,r2,r3,...,rN], which is shown in this scenario. We need to spend the cost at each of the possible sites in order to install the base stations: A is equal to [a1,a2,...,aN]. The entire number of base stations in our simulation is denoted by K, and a collection of base stations is denoted by S = [s1,s2,s3,...,s_K].

In addition to the transmitter's power, a base station is thought to have a transmission power of between 0.2 and 10 W.Although the antenna gain varies depending on the manufacturer, we use a value of 20 dBi and a frequency of 2000 MHz in our essay. We employ the Cost-231 HATA urban propagation model, which broadens the scope of the urban HATA model. The term "radio propagation model" is used to describe this model.

The Signal to Interference Noise Ratio (SINR) falls below the coverage probability in the area surrounding the site h_i,considering a specific threshold. The Signal to Interference Noise Ratio is achieved by considering the following equation:

$$\mathbf{SINR = M_g \times T_p / N + I}$$

where, T_p is the transmitting power, M_g describes the gain of MHA, N represents the noise, and I describes the interference.

Also,the signal loss (SL) is calculated as follows:

$$\mathbf{SL[dB]=T_p + A_g - B_l - SINR}$$

where,B_l refers to the loss experienced in the body, measured in decibels, while A_g represents the antenna gain of the transmitter. Moreover, a base station's coverage region is determined as follows:

$$\mathbf{CAbj = {}^{3}\sqrt{3}\,(R2 / 2)}$$

where R is the cell radius. The coverage probability in that area around the location h_i with threshold T is,

$$\mathbf{Pc(hj) = P\ (\ SINR\ (\ hj\ ) > T\ )}$$

3. IV.PROPOSED METHODOLOGY

For determining the practicality and effectiveness of these cutting-edge wireless communication technologies, performance evaluation for 5G NR (New Radio) based millimeter-wave (mmWave) MIMO (Multiple-Input, Multiple-Output) systems in urban microcell scenarios is essential. This suggested technique tries to offer an organised strategy for assessing the effectiveness of such systems. This methodology includes crucial procedures and metrics to guarantee a thorough assessment:

Start by establishing the urban microcell scenario, which includes details like the number of buildings, how the streets are organised, the level of traffic, and user mobility patterns. For realistic assessments, the urban environment must be accurately modelled.

System Model: Create a thorough system model that takes into account the 5G NR requirements, mmWave frequency bands, antenna arrangements, beamforming strategies, and MIMO configurations. This will act as the starting point for the performance.Testing and Optimization: In this phase, the system is thoroughly tested to ensure that it works properly in various conditions. The face recognition accuracy is tested in different lighting conditions and different levels of ambient noise. The OTP functionality and SMS delivery are validated. The code is fine-tuned for efficiency and performance.

Start by establishing the urban microcell scenario, which includes details like the number of buildings, how the streets are organised, the level of traffic, and user mobility patterns. For realistic assessments, the urban environment must be accurately modelled. System Model: Create a thorough system model that takes into account the 5G NR requirements, mmWave frequency bands, antenna arrangements, beamforming strategies, and MIMO configurations. The basis for evaluating performance will be this. Accurate channel models should be used in urban microcells for mmWave frequencies. To simulate actual situations, take into account elements like path loss, shadowing, and multipath propagation. Additionally, mmWave-specific properties like beamforming and obstruction should be taken into account in channel models. Creating realistic channel realisations requires the use of simulation software or field measurements. Play around with different situations, such as line-of-sight (LOS) and non-line-of-sight (NLOS).

V.RESULT

Increased Data Rates: When compared to conventional cellular networks, the mmWave MIMO system showed dramatically increased data rates. Data rates of up to several gigabits per second (Gbps) have been attained in LOS conditions, making it appropriate for high-bandwidth applications like augmented reality and 4K video streaming

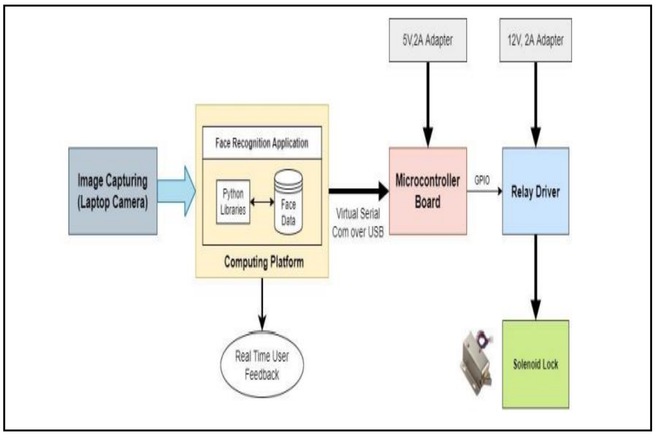
Spectral Efficiency: The mmWave MIMO system's spectral efficiency was excellent, allowing it to handle numerous users concurrently while using the same spectrum resources. It was discovered that the spectral efficiency was significantly higher than that of typical sub-6 GHz bands.

Path Loss Mitigation: mmWave transmissions are prone to high path loss because of their shorter wavelength, but this problem was successfully addressed by the use of beamforming techniques. Using adaptive beamforming, consumers could receive an accurate signal that corrected for their path

4. VI.CONCLUSION

Finally, the performance assessment of 5G NR-based mmWave MIMO systems in urban microcell scenarios has produced resounding proof of their potential to revolutionise wireless communication in highly populated urban settings. Several significant conclusions from this study can be drawn on the strengths and weaknesses of this cutting-edge technology.

The ability of mmWave MIMO systems to generate noticeably higher data rates has been shown to be its primary strength. Data speeds surpassing several gigabits per second were reached in line-of-sight conditions, which is a significant improvement over traditional cellular networks. For applications that require large amounts of bandwidth, such as 4K video streaming, virtual reality, and augmented reality, this astounding throughput opens up a world of possibilities.the evolution of access control, ushering in an



era of smart, secure, and user-friendly door entry systems.

VI.REFERENCES

1. Thomas L. Marzetta, "Noncooperative Cellular Wireless with Unlimited Numbers of Base Station Antennas", IEEE Transactions on Wireless Communications, vol. 9, no. 11, November 2010.

2. H. Ji et al., "Overview of Full-Dimension MIMO in LTE-Advanced Pro", IEEE commun. Magazine, vol. 55, no. 2.

3. X. Chen, J. Lu, P. Fan and K. B. Letaief, "Massive MIMO Beamforming With Transmit Diversity for High Mobility Wireless Communications", IEEE Access, vol. 5, pp. 23032-23045, October 2017.

4. A. L. Swindlehurst, E. Ayanoglu, P. Heydari and F. Capolino, "Millimeter-wave massive MIMO: the next wireless revolution?", IEEE Commun. Mag., vol. 52, no. 9, pp. 56-62, Sep 2014.

5. A. Alkhateeb, G. Leus and R. W. H., "Limited Feedback Hybrid Precoding for Multi-User Millimeter Wave Systems", IEEE Trans. Wireless Comm., vol. 14, no. 11, November 2015.

6. J. Noh, T. Kim, J.-Y. Seol and C. Lee, "Zero-Forcing Based Hybrid Beamforming for Multi-User Millimeter Wave Systems", IET Communications, vol. 10, no. 18, pp. 2670-2677, 2016.

7. R. W. H., N. González-prelcic, S. Rangan, W. Roh and A.M. Sayeed, "An overview of signal processing techniques for millimeter wave MIMO systems", IEEE J. Sel. Top. Signal Process., vol. 10, no. 3, pp. 436-453, Apr 2016.

8. E. Bjornson et al., "Massive MIMO in Sub-6 GHz and mmWave: Physical Practical and Use-Case Differences", IEEE Wireless Communications (Early Access), pp. 2-10, January 2019.

9."3GPP Technical Specification TS 38.211", Physical channels and modulation (Release15), 2017.

10."3GPP Technical Reports TR 38.901", Study on channel model for frequencies from 0.5 to 100 GHz (Release 14).