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QoS Prediction of 5G Network Slices using ML Models

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Abstract: Quality of Service (QoS) is a critical factor in 5G networks, ensuring reliable and efficient communication across diverse applications. In this paper, we introduce Machine Learning (ML) algorithms to predict QoS parameters in 5G network slices, enabling early detection and optimization of service degradation. Our system leverages advanced ML models to analyse key features like Slice Type, User Mobility, Slice Priority, Throughput, Jitter, and other network metrics without relying on manual monitoring. This application predicts QoS parameters and provides insights to improve network performance, ensuring better resource allocation and user experience. The system is trained to distinguish patterns from real-world and synthetic datasets, including parameters such as CPU utilization, memory usage, and environmental conditions (e.g., weather and time of day). Early detection of QoS degradation can prevent major service disruptions, including reduced network reliability, increased latency, and poor user experience in critical applications like autonomous vehicles and telemedicine. Traditional methods for monitoring and optimizing QoS often require manual intervention and substantial computational resources. These approaches may lack the responsiveness and scalability required for modern 5G networks. Our proposed system uses an efficient, automated, and adaptive method to predict QoS by analysing multiple factors simultaneously. The application provides network operators with real-time insights and actionable recommendations to maintain optimal service quality. The process is implemented using advanced ML models, including Random Forest, Linear Regression model and Decision Tree Model, with Random Forest providing the best performance through hyperparameter tuning. We utilize an enhanced QoS dataset collected from Kaggle and enriched with synthetic data to simulate real-world 5G conditions. After dataset preprocessing— such as feature extraction, scaling, and encoding—model training is conducted, and the final optimized model is deployed using Django for real-time predictions and analysis.

Keywords: QoS prediction, 5G network slices, machine learning, Random Forest, Linear Regression model, Decision Tree model, Django.

I. INTRODUCTION

In modern telecommunications, ensuring Quality of Service (QoS) is crucial for delivering seamless and reliable user experiences across diverse applications. With the rapid evolution of 5G technology, the complexity and diversity of services have increased, making QoS prediction a vital aspect of network management. 5G networks, through network slicing, offer the ability to create virtualized and independent network segments tailored to specific use cases. Each slice requires optimized resource allocation to meet diverse performance requirements such as low latency, high throughput, and minimal packet loss. Accurate QoS prediction enables service providers to maintain consistent network performance, optimize resource usage, and improve user satisfaction. The dynamic and heterogeneous nature of 5G networks makes traditional QoS prediction methods ineffective due to their static nature and inability to handle large-scale, real-time data. Machine Learning (ML) approaches offer a powerful alternative by leveraging vast amounts of historical data to identify patterns and predict future QoS metrics. This project aims to develop a ML-based system to predict QoS in 5G network slices, utilizing advanced algorithms such as Random Forest, Decision Tree and Linear Regression. The proposed system follows a comprehensive methodology, including data acquisition, preprocessing, feature extraction, model training, model evaluation, and deployment. By incorporating scalable and efficient machine-learning models, this project ensures accurate predictions, facilitating proactive network management and improved service delivery. Additionally, the trained model is integrated into a Django-based web interface, allowing real time QoS prediction through an intuitive and user-friendly platform. By implementing this QoS prediction system, network operators can enhance decision-making processes, reduce operational costs, and deliver superior quality across various 5G applications, such as autonomous vehicles, remote healthcare, and smart cities. This project not only addresses the existing challenges but also lays the foundation for future advancements in intelligent network management.

II. EXISTING SYSTEM

Several studies have been conducted to predict Quality of Service (QoS) parameters such as latency, jitter, and throughput using traditional and machine learning approaches. Most existing models, however, suffer from limitations in handling the complex, nonlinear nature of network environments.

Linear Regression models have been commonly used due to their simplicity and interpretability. However, they struggle with nonlinear feature interactions and often fail to capture intricate relationships in dynamic network conditions, leading to lower prediction accuracy.

Decision Trees provide better interpretability and can handle nonlinearity to some extent. Nevertheless, they are prone to overfitting and lack robustness in handling high-dimensional input data or noisy features common in real-world network scenarios.

Some works have explored statistical and rule-based approaches, which depend heavily on predefined thresholds and domain-specific rules. These methods are less adaptive and perform poorly under rapidly changing network conditions or unexpected usage patterns.

TABLE I
References of existing work

Ref.	Technique	Key Focus	Context	Remarks
[4]	Linear Regression	Fundamental ML model for prediction tasks	General ML theory	Basis for interpreting QoS metrics
[5]	Decision Tree	Applied in slice-based 5G networks	5G Slices, mobile networks	Enables explainable prediction
[7]	Linear Regression	QoS Optimization using ML in 5G	Real Time 5G traffic	Low computational Complexity
[8]	Decision Tree and Ensemble	ML based QoS enhancement for 5G traffic	5G wireless networking	High accuracy in multi-class QoS

III. PROPOSED SYSTEM

A. Motivation

The exponential growth in data traffic, driven by emerging technologies such as the Internet of Things (IoT) and augmented reality (AR), has increased the demand for high-speed, low latency networks. In 5G systems, ensuring consistent QoS is critical for supporting mission critical applications and real-time services. Manual approaches to QoS monitoring and prediction are labour - Intensive and prone to errors, leading to service degradation and increased latency.

The motivation for this project lies in developing an automated, intelligent system that leverages machine learning to accurately predict QoS metrics. Such a system will empower service providers to identify potential performance bottlenecks in advance, ensure seamless connectivity, and deliver improved user experiences across diverse applications. This project bridges the gap between traditional QoS monitoring and intelligent, data-driven approaches.

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B. Problem Statement

5G networks are characterized by their complexity and dynamic nature, making it challenging to maintain consistent Quality of Service (QoS). Traditional QoS prediction methods rely on static models and manual inspection, which are inadequate for handling large-scale and real time data. These methods often fail to capture the intricate patterns and rapid fluctuations in network conditions, leading to inaccurate predictions and service interruptions. This project aims to address these challenges by developing a machine-learning-based framework capable of accurately predicting key QoS parameters, such as latency, throughput, and packet loss. The solution will offer a scalable and automated approach to QoS prediction, enabling real-time decision-making and proactive resource management.

C. Objective

The primary objectives of this project are: To design and implement a machine-learning model for QoS prediction in 5G network slices. To acquire, preprocess, and scale network data using advanced techniques such as Min Max scaling and one-hot encoding to improve model accuracy. To train and evaluate multiple machine-learning models (Random Forest, Linear regression and Decision tree) and compare their performance in terms of accuracy and efficiency. To deploy the trained model using a Django-based web framework, providing a user-friendly interface for real-time QoS prediction. To facilitate proactive network management by predicting potential performance bottlenecks and ensuring consistent service quality across diverse applications.

D. Linear Regression Model

A linear regression model, illustrated in the graph below, examines the relationship between an independent variable (X) on the horizontal axis and a dependent variable (Y) on the vertical axis. The scattered points represent observed data, while the regression line is the best-fit straight line that minimizes prediction errors. This line follows the equation $\mathbf{Y = \beta_0 + \beta_1 X + \epsilon}$, where β_0 is the y-intercept, β_1 is the slope (representing the change in Y for each unit increase in X), and ϵ represents random error. The model is used to predict values of Y based on X. The slope indicates the strength and direction of the relationship—positive if Y rises with X, negative if it falls. The tighter the data points are around the line, the stronger the linear relationship.

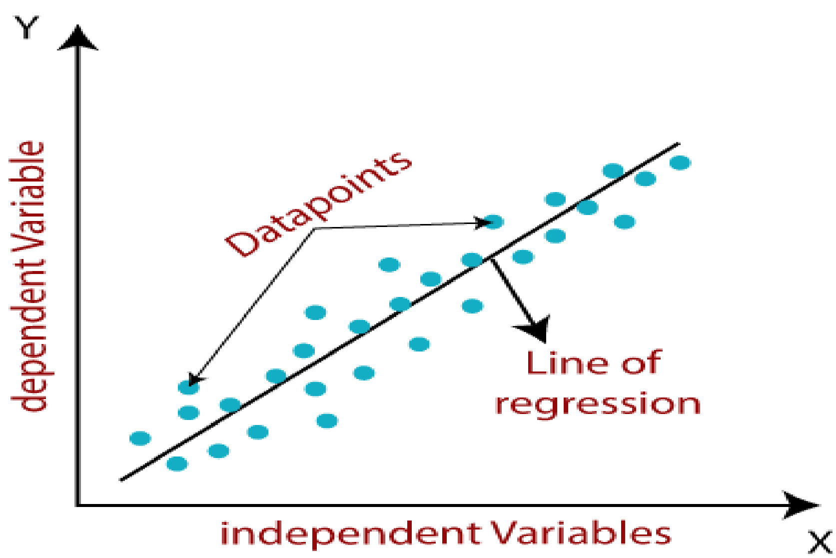

Fig. 1 Linear Regression (source. Towards AI)

E. Decision Tree Regression

A decision tree regression model, as illustrated in the graph, is a hierarchical structure that predicts continuous target values by recursively splitting data into subsets based on feature values.

The process begins at the root node, which represents the entire dataset and is the first decision point. From there, the data is split into branches at internal nodes, each of which applies a condition (e.g., "Feature X ≤ threshold") to partition the data further.

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These splits continue until the data reaches leaf nodes, which are terminal nodes that provide the final predicted value (typically the mean of the target variable for observations in that node). Unlike internal nodes, leaf nodes do not branch further.The tree "learns" optimal splits by minimizing variance within subsets, creating a stepwise model that can capture non-linear relationships. Decision trees are interpretable and handle complex patterns, though they risk overfitting without constraints like pruning or depth limits.

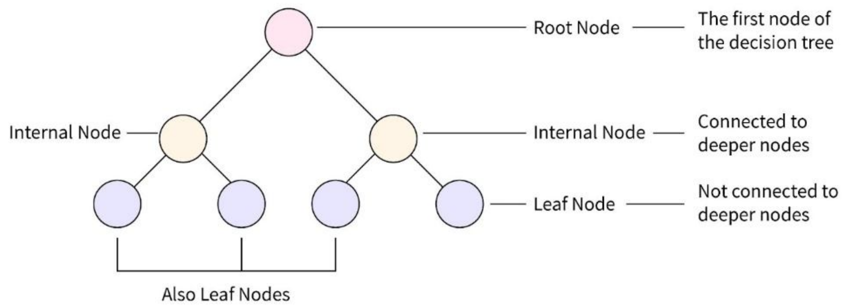

Fig. 2 Decision Tree Regression (source Applied AI course)

F. Random Forest Regression

Random Forest, an ensemble learning method used for both classification and regression tasks. A Random Forest operates by constructing multiple decision trees during training (represented by "Tree 1," "Tree 2," etc.) and aggregating their predictions to produce a final output.

Each tree is trained on a random subset of the data (bootstrapping) and considers only a random subset of features at each split, introducing diversity to reduce overfitting. For regression tasks (as suggested by "Average All Predictions"), the final prediction is the mean of all individual tree predictions, resulting in a more robust and accurate model compared to a single decision tree.

The "Random Forest Prediction" in the image signifies this aggregated output. The method excels in handling noise, non-linear relationships, and high-dimensional data while maintaining interpretability through feature importance metrics. The presence of multiple trees (e.g., "Tree 3," "Tree 4") highlights the ensemble's strength in reducing variance and improving generalization.

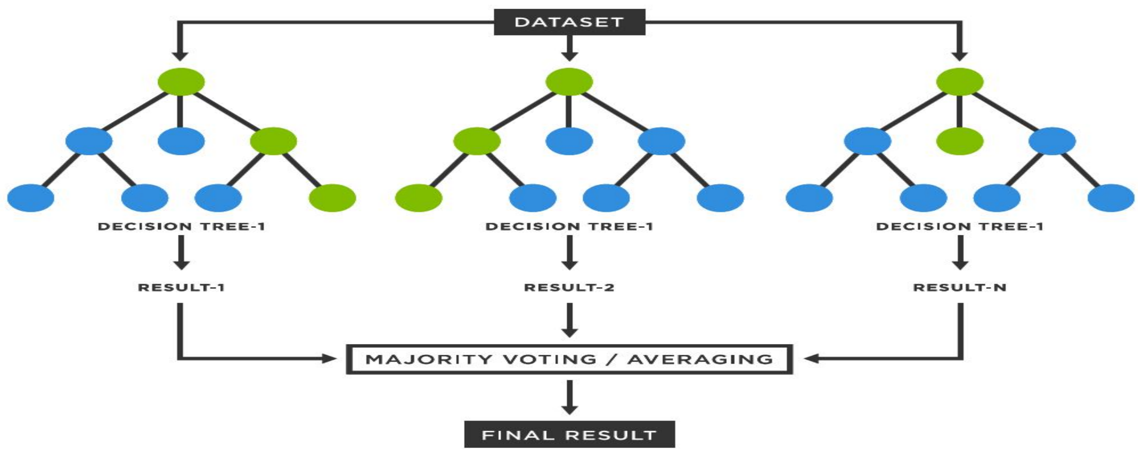

Fig. 3 Random Forest Regression

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The proposed system is a Django-based web application that predicts Quality of Service (QoS) metrics—latency, jitter, and throughput—using a Random Forest machine learning model. Key Features:

1) *User Input Form:* Collects network parameters (signal strength, bandwidth allocation, CPU/memory usage, etc.). Includes application type (video call, streaming, etc.), weather conditions, and mobility status.
2) *Machine Learning Backend:* Uses a pre-trained Random Forest model to predict QoS metrics based on input features. Handles numerical and categorical data (one-hot encoded).
3) *Prediction Output:* Displays the predicted values for latency (ms), jitter (ms), and throughput (Mbps).
4) *Deployment-Ready:* Built with Django for scalability. Can be containerized (Docker) and deployed on cloud platforms.

This system helps network administrators optimize QoS by predicting performance metrics before deployment. Future work may include real-time monitoring and visualization. The block diagram of the proposed system is shown in the below diagram.

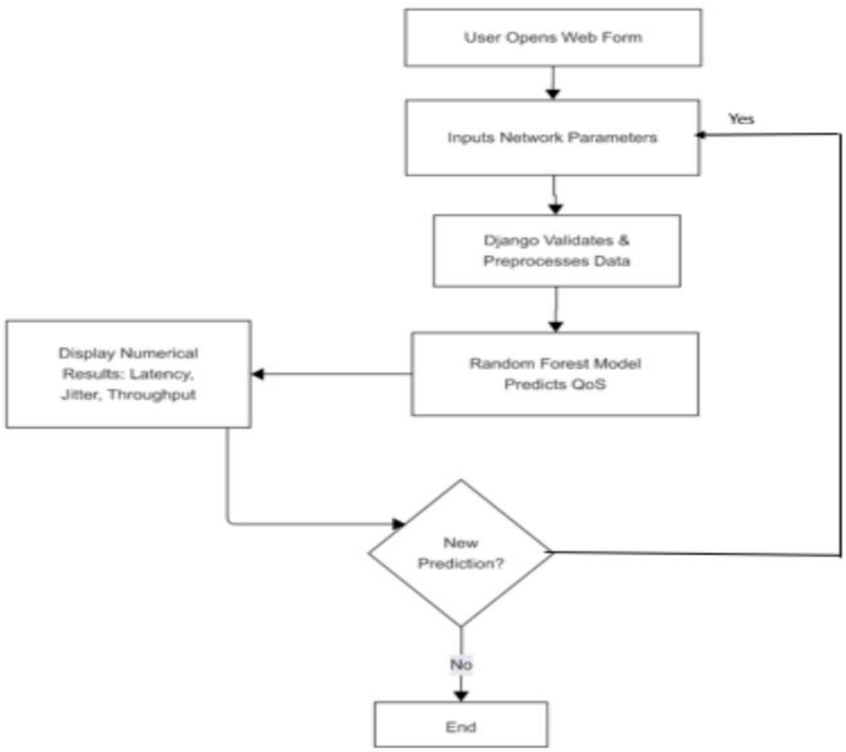

Fig. 4 Flow Diagram

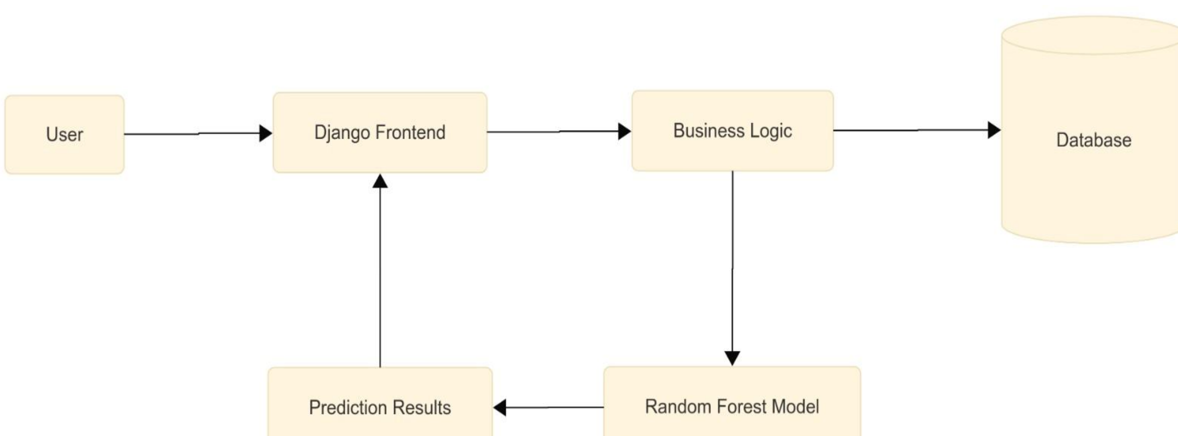

Fig. 5 Architecture

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The Fig 4 illustrates the data flow of the application. It begins when a user opens a web form and inputs relevant network parameters. The Django backend framework then validates and preprocesses the input data before passing it to a Random Forest model, which predicts QoS metrics such as latency, jitter, and throughput. The results are displayed to the user, and the process can be repeated for new predictions. This flow effectively demonstrates the interaction between the user and the predictive system in a looped and dynamic manner.

The Fig 5 presents the system's architecture. It shows a structured interaction between different components, beginning with the user interface, which communicates with the Django frontend. This frontend connects to the business logic layer, where input handling, database operations, and model integration occur. The Random Forest model operates within this business logic to generate predictions, which are then routed back through the frontend to the user. The architecture emphasizes modularity and separation of concerns, making the system scalable and easier to manage.

IV. RESULTS

A. *Comparision between ML Models*

Fig. 5 Comparision between ML models

B. *Input Form*

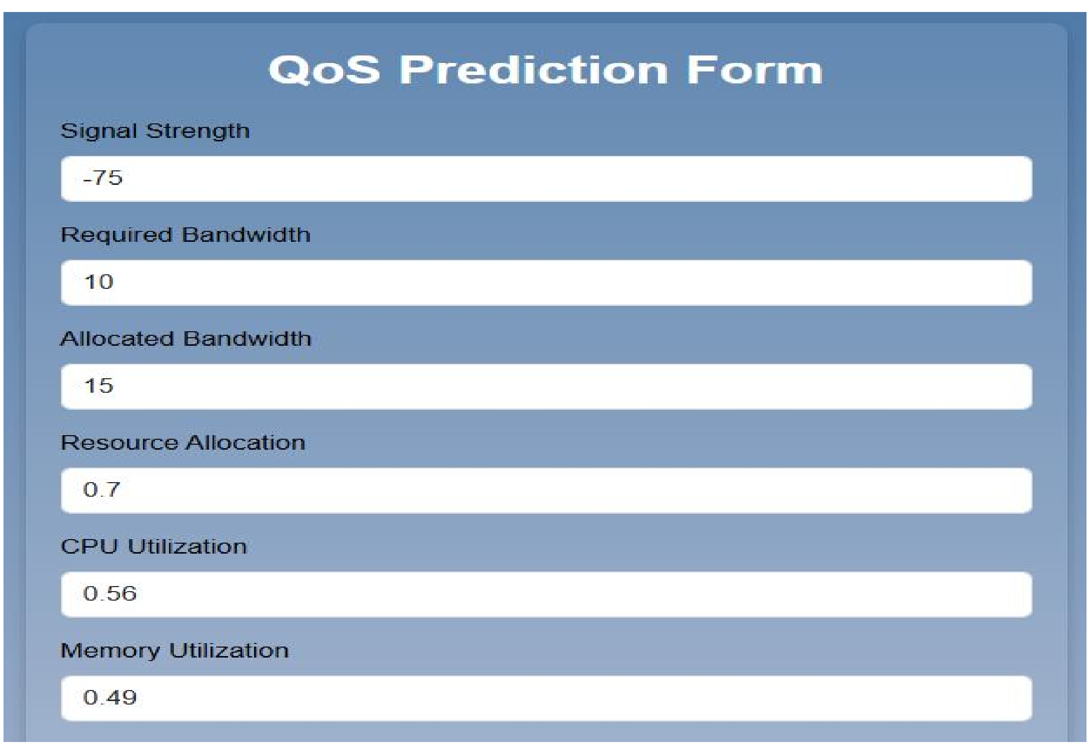

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Fig. 6 Prediction Form

C. Prediction Results

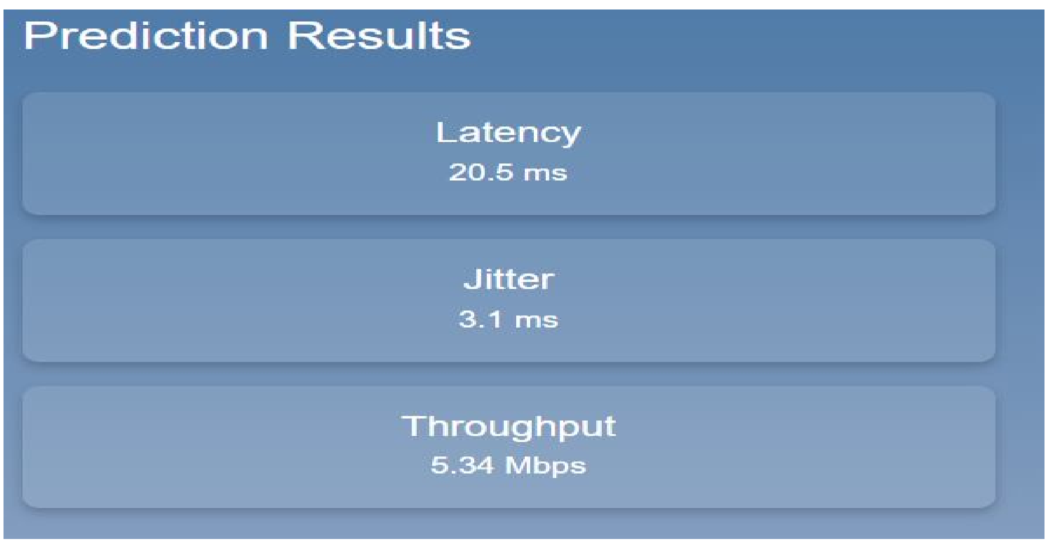

Fig. 7 Result

V. CONCLUSIONS

The QoS Prediction in 5G Network Slices project successfully applies machine learning and web technologies to predict key Quality of Service (QoS) metrics like latency, jitter, and throughput, enabling efficient network resource allocation and improved performance. Using algorithm such as Random Forest, the project achieved reliable predictions from diverse input features, while a Django-based web application provided a user-friendly interface for seamless interaction. Despite challenges like data acquisition and integration, the project delivers a scalable, practical solution with potential applications in fields like telemedicine and autonomous vehicles, paving the way for smarter and more adaptive 5G networks.

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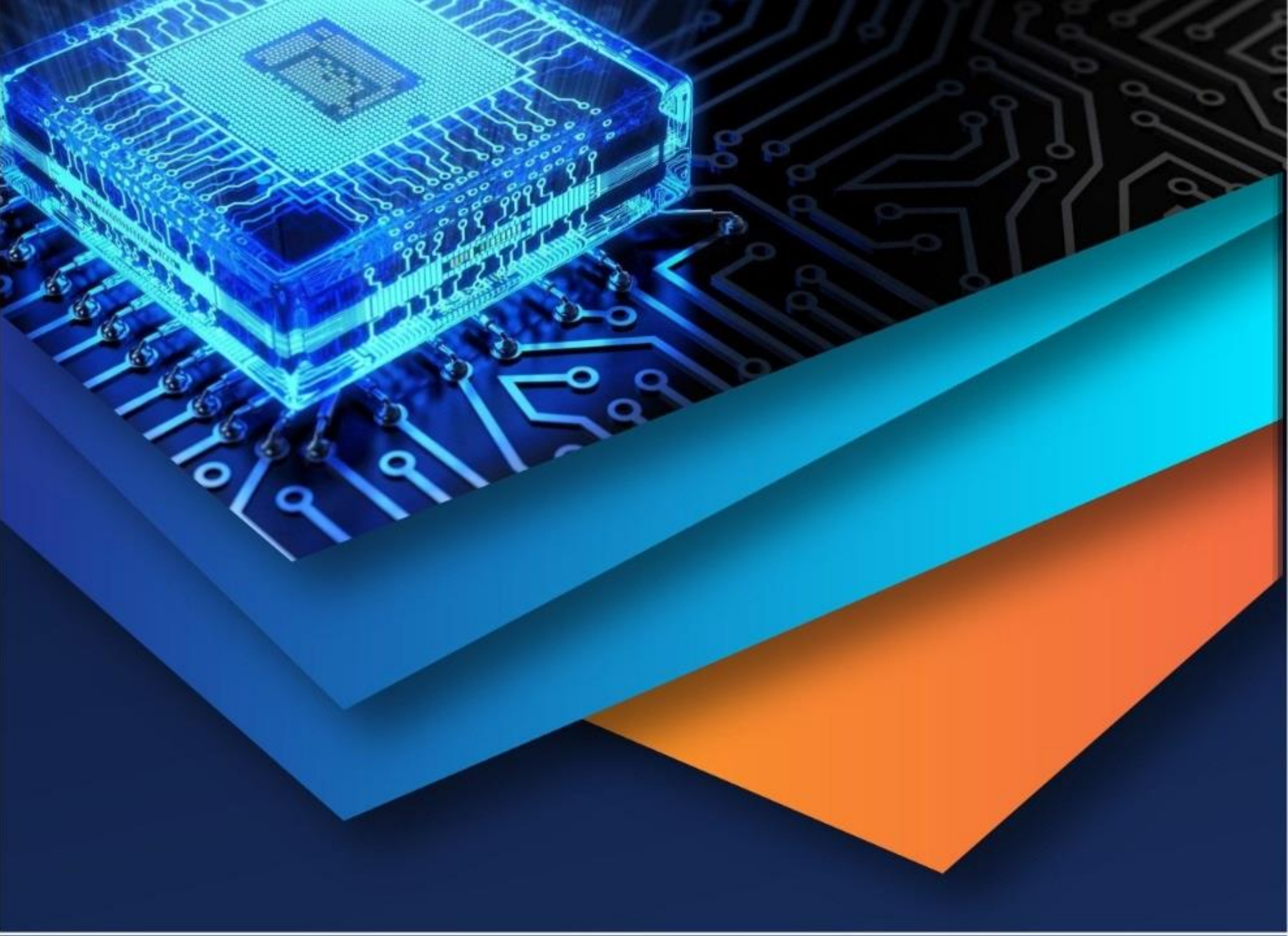

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