iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** VI **Month of publication:** June 2025

DOI: https://doi.org/10.22214/ijraset.2025.67871

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

Optimizing Urban Mobility: A Comprehensive Traffic Reward System using Algorithms

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Abstract: ***This exploration presents the development of a new business price system designed to encourage adherence to business signals and promote road safety. The system utilizes RFID technology and Arduino microcontrollers to cover vehicle movements and determine compliance with business signals. When a vehicle equipped with an RFID label passes through an crossroad, the system verifies whether the vehicle progressed through the crossroad during a green signal. When the motorist is awarded points, if compliance is verified. These accumulated points can also be redeemed for abatements or offers on colorful products or services. By furnishing palpable impulses for responsible driving, this system aims to foster a more disciplined and safe driving terrain.***

Keywords: Radio Frequency Identification (RFID); Internet of Things (IoT); V2X (Vehicle-to-Everything); Deep Reinforcement Learning (DRL); Adaptive Traffic Signal Control (ATSC).

I. INTRODUCTION

Traffic congestion is a persistent urban challenge that significantly impacts various aspects of daily life, economic productivity, and environmental sustainability. The problem of traffic congestion has been tackled through multiple strategies, including infrastructure improvements and public transportation initiatives. However, one crucial component that remains is promoting responsible driving behavior among individuals. Numerous studies have demonstrated the efficacy of incentivized approaches in fostering safer driving practices.

For instance, studies have shown that offering rewards for adherence to traffic regulations can lead to a reduction in speeding and reckless driving. By incentivizing drivers to follow traffic laws, there is a noticeable improvement in road safety. Furthermore, incorporating gamification elements, such as points and leaderboards, has been highlighted as an effective means of motivating individuals to adopt safer driving habits. Gamification leverages the natural human tendency to compete and achieve, thus encouraging drivers to adhere to traffic rules more diligently.

Building upon these findings, this research proposes a novel traffic reward system that leverages emerging technologies to incentivize compliance with traffic signals. The proposed system employs RFID technology to track vehicle movements and Arduino microcontrollers to monitor signal status. This combination aims to provide a reliable and efficient means of rewarding responsible drivers. By aligning with the growing trend of using technology to promote sustainable and responsible behavior, the system seeks to address the issue of traffic congestion in urban environments.

The core idea of this traffic reward system is to create a positive reinforcement loop that encourages drivers to prioritize road safety. Drivers can earn points by following traffic signalsstopping when the signal is red and proceeding only when it turns green. The poi nts accumulated by drivers can then be redeemed on a dedicated website, offering a variety of products and services at discounted pr ices. By providing tangible incentives, the system motivates drivers to consistently adhere to traffic rules, resulting in safer driving p ractices.

Moreover, the implementation of this system is expected to yield multiple benefits. Firstly, it can lead to a reduction in the number o f traffic accidents. When drivers are motivated to follow traffic signals, the likelihood of collisions and other trafficrelated incidents decreases significantly. Secondly, the system can address cognitive issues associated with driving. By consistently practicing safe dr iving habits, drivers enhance their cognitive skills related to road safety and traffic awareness. This continuous reinforcement of safe practices can lead to long-term behavioral changes.

Furthermore, the system's positive reinforcement model can have a broader impact on urban traffic management. As more drivers p articipate and earn rewards for safe driving, the overall traffic flow is expected to improve. Reduced traffic congestion can lead to en hanced economic productivity, as less time is wasted in traffic jams. Additionally, better traffic management contributes to environ mental sustainability by reducing fuel consumption and emissions.

II. RELATED WORK

The referenced paper, titled "Adaptive traffic signal control system using composite reward architecture based deep reinforcement learning," focuses on optimizing traffic signal control using deep reinforcement learning (DRL). This paper introduces an adaptive traffic signal control (ATSC) system that leverages real-time traffic information to control traffic signals, thereby improving traffic flow[1].

The proposed system employs RFID technology and Arduino microcontrollers, whereas the referenced paper focuses on deep reinforcement learning and composite reward architecture. The proposed system aims to incentivize drivers through a reward-based approach, offering points redeemable for discounts. In contrast, the referenced paper emphasizes optimizing traffic signal control using a reward architecture. The proposed system seeks to encourage compliance with traffic signals and promote responsible driving behaviour. In contrast, the referenced paper aims to optimize traffic signal timing and coordination to enhance traffic flow[1].

Over the past decade, significant advancements have been made in intelligent traffic control systems aimed at reducing traffic congestion and supporting the development of smart cities. A key innovation in this area is edge computing, which enables real-time data exchange between vehicles and roadside units to help alleviate congestion. This study presents a novel edge computing-based deep reinforcement learning (DRL) system that uses a carefully designed, multi-objective reward function to optimize various traffic management goals simultaneously. [2]

In the past decade, intelligent traffic control technologies have made significant strides in addressing the ongoing challenge of traffic congestion, which poses a major issue for smart cities. One notable advancement in this field is edge computing, which enables real-time data transmission between vehicles and roadside units, effectively helping to manage and reduce congestion. This study introduces a novel deep reinforcement learning (DRL) system powered by edge computing, designed to optimize traffic flow through a multi objective reward function. The system overcomes the challenge of evaluating actions with simple numerical rewards by carefully selecting reward functions that guide the agent to learn the ideal behaviour for managing multiple traffic signals in a large-scale road network.[3]

A “Reward-Based Adaptive Traffic Light System” is an innovative approach to traffic management that uses real-time data and adaptive algorithms to optimize traffic flow at intersections. Traditional traffic lights often operate on fixed timers or basic sensors, which can lead to inefficiencies such as long waiting times, congestion, and wasted fuel. In contrast, a reward-based adaptive system leverages techniques from reinforcement learning, where the system "rewards" certain actions—like minimizing wait times or reducing stops—to achieve optimal outcomes. In this setup, traffic lights "learn" to make better decisions by adjusting signal timings based on the current traffic conditions and the outcomes of previous actions.[4]

Gamification of Traffic Management introduces a novel approach to alleviating traffic congestion and promoting safer, eco-friendly driving habits by incentivizing drivers through a rewards system. Unlike traditional traffic management, which relies solely on infrastructural changes and enforcement, gamification taps into drivers' intrinsic motivation by offering rewards for positive driving behaviors, such as obeying speed limits, avoiding aggressive acceleration, or choosing less congested routes.

In this system, drivers can earn points or rewards (such as discounts, coupons, or digital badges) for behaviors that align with traffic management goals, like reducing congestion or lowering emissions. For example, a driver who consistently maintains safe speeds or chooses less crowded roads during peak hours could accumulate points redeemable for real-world rewards.[5]

An “Intelligent Traffic Control System Using Reinforcement Learning” represents a cutting-edge approach to modernizing traffic management by enabling traffic lights to make real-time decisions based on continuously evolving traffic conditions. Traditional traffic control systems, which often rely on fixed timings or basic sensor data, lack the adaptability needed to handle varying traffic volumes and unpredictable congestion patterns effectively. Reinforcement learning (RL), a type of machine learning, offers a solution by allowing the traffic control system to "learn" optimal signal timings through trial and error..[6]

A “Blockchain-Based Traffic Reward System for Smart Cities” is an innovative solution that combines blockchain technology and traffic management to incentivize drivers for positive behaviours that improve urban mobility. With the rapid growth of urban populations, smart cities are looking for ways to address congestion, pollution, and road safety. Traditional traffic management solutions often rely on fines or infrastructure changes, but a blockchain-based reward system offers an alternative by using incentives to encourage drivers to make traffic-friendly choices..[7]

“Incentive-based Traffic Management Using Mobile Applications” is a modern approach to improving traffic flow and encouraging safer, eco-friendly driving by rewarding drivers directly through mobile apps. Unlike traditional traffic systems, which often rely on infrastructure changes or penalties for enforcement, this approach uses mobile technology to incentivize drivers for positive behaviors such as avoiding congested routes, obeying speed limits, or using eco-friendly driving techniques.

In this system, a mobile app tracks drivers' behaviors in real-time, offering rewards like points, discounts, or special privileges for actions that align with broader traffic management goals. For instance, a driver who takes an alternative route to avoid high-traffic zones during peak hours may earn points redeemable for rewards, such as discounted fuel, toll credits, or vouchers. Mobile apps also enable cities to communicate real-time traffic conditions, alternative routes, and other relevant data, making it easier for drivers to make informed choices.[8]

Improving Traffic Signal Efficiency through a Reward-Penalty Framework introduces an innovative approach to optimizing traffic signal timings by incorporating a system of rewards and penalties. Traditional traffic signal systems often operate on preset timings or basic detection sensors, which may not adapt effectively to fluctuating traffic conditions. In contrast, a reward-penalty framework uses principles from reinforcement learning to enhance signal efficiency by continuously adapting to real-time traffic flow and patterns..[9]

“Reward-Based Traffic Management with Real-Time Feedback” is an innovative approach that uses rewards and immediate feedback to encourage drivers to adopt behaviours that improve traffic flow, reduce congestion, and promote road safety. Traditional traffic management relies heavily on passive enforcement methods and infrastructure changes, but a reward-based system takes a proactive approach by offering incentives for drivers who make traffic-friendly choices in real-time.10]

“Reinforcement Learning for Traffic Signal Control with a Focus on Driver Behaviour” is an advanced approach to traffic management that leverages machine learning to optimize signal timings based not only on traffic flow but also on the real-time behaviours of drivers at intersections. Traditional traffic signal systems are typically designed to follow fixed schedules or respond to basic sensor data, which may not be sufficient to handle the complex, dynamic interactions between vehicles. Reinforcement learning (RL), however, enables traffic signals to "learn" from experience, making it possible to adapt dynamically to changes in traffic patterns..[11]

“Crowd-sourced Traffic Monitoring with Reward-Based Participation” is an innovative approach to gathering real-time traffic data by incentivizing everyday drivers to contribute information about road conditions, traffic flow, and incidents. Traditional traffic monitoring systems often rely on costly infrastructure, like cameras and sensors, which may not provide full coverage of all areas. Crowd-sourcing offers a flexible, scalable alternative by allowing drivers to report and share live traffic updates through mobile apps. [12]

III. TOOLS AND TECHNIQUES

A. Tools for Activity Remuneration Framework

The enhancement and arrangement of a visitors' laud machine require a variety of instruments to guarantee smooth operation, real-time monitoring, and proficient records handling. The essential interface for clients can be a versatile software application. For this, Ripple or React Native can be utilized to create a cross-platform app that works seamlessly on both iOS and Android devices.This app will permit clients to engage with the system, track their compliance with activity rules, and display their gathered rewards in real-time. Android Studio or Xcode can be utilized as the integrated development environments (IDEs) to test and install the app, ensuring that it functions efficiently on different devices.

IoT contraptions are crucial for checking real-time activity compliance. These include cameras, infrared sensors, and GPS sensors, which can be installed at intersections and along streets to monitor vehicles and ensure adherence to traffic signals and speed limits. IoT sensors will capture information, including whether a car stops at a red light, the vehicle’s speed, and its location, feeding this data into the system for processing.

GPS is particularly crucial as it allows for precise tracking of vehicle movements and compliance with geofenced areas, such as school zones or pedestrian crossings, where traffic rules must be strictly enforced.

The backbone of the system is the backend infrastructure, powered by cloud services like AWS, Google Cloud, or Microsoft Azure. These cloud platforms provide the computational power and storage necessary to handle the vast amount of real-time data generated by traffic signals, user devices, and IoT sensors. Cloud services will process the data to determine user compliance, distribute rewards, and store long-term traffic patterns for future optimization.

A database management system such as MySQL or MongoDB can be used to manage and store user profiles, reward points, and violation records. These databases ensure that data is easily accessible and securely stored.

To ensure the system’s scalability and real-time responsiveness, big data tools like Apache Spark and Hadoop can be used. These tools are capable of processing large datasets efficiently, making them ideal for analyzing traffic patterns and user compliance on a large scale. They also provide the capability to process data in real time, ensuring that users receive instant feedback on their behavior and rewards.

Security and transparency are essential for the success of the reward system. One optional but valuable tool for this purpose is blockchain technology. By integrating blockchain, the system can securely store and manage reward points in a decentralized ledger, ensuring that no data can be tampered with or altered. Blockchain provides users with confidence that their points and rewards are secure, immutable, and transparent, fostering trust in the system.

Finally, real-time communication and feedback mechanisms are crucial for user engagement. Technologies like Firebase or WebSockets will allow the system to provide instant updates and notifications to users regarding their compliance and rewards. These tools enable real-time synchronization between the user's app and the backend system, ensuring users are promptly informed of their points and reward status after complying with traffic regulations.

B. Techniques used in traffic reward system

A Traffic Reward System relies on a variety of advanced techniques to ensure effective monitoring, accurate reward distribution, an d user engagement. Below are the key techniques employed in such a system:

1) Reinforcement Learning

One of the key techniques employed is reinforcement learning, a branch of machine learning that can dynamically adjust traffic sign al timings and reward allocations based on realtime data from the traffic environment. Reinforcement learning allows the system to continuously learn from user behavior and improve its ability to manage traffic flow and reward compliant drivers. Over time, the sy stem becomes more efficient, reducing congestion and encouraging better driving habits.

2) Gamification

Gamification is another powerful technique used in theTraffic Reward System to encourage user participation. By incorporating ele ments like leaderboards, badges, challenges, and tiered rewards, the system transforms traffic compliance into a gamelike experienc e. Users can earn points for following traffic rules, compare their performance with others, and aim for higher ranks or special rewar ds. This gamification approach significantly boosts user motivation and engagement, making compliance with traffic rules both rew arding and enjoyable.

3) Integration of IoT Devices

The integration of IoT devices is a cornerstone of the system, enabling it to monitor realtime traffic conditions and user compliance. IoT devices such as smart cameras, traffic signals, and road sensors continuously collect data on vehicle movements, compliance wit h traffic signals, and adherence to speed limits. This realtime data is sent to the cloud for processing, where it is used to calculate re wards for compliant users. The seamless integration of IoT technology ensures that the system has constant access to accurate, up-to-date information, enabling timely and fair reward distribution.

4) GPS Tracking and Geo-fencing

GPS tracking and geofencing play a crucial role in monitoring user behavior and ensuring compliance in specific areas. GPS allows the system to track vehicle locations in realtime, ensuring that drivers follow speed limits and stop at red lights. Geofencing creates virtual boundaries around certain areas, such as school zones or pedestrian crossings, where traffic rules must be strictly enforced. If a driver complies with traffic rules within these geo-fenced areas, they are rewarded accordingly, encouraging safe driving in high-risk zones.

5) Blockchain Technology

To ensure transparency and security, blockchain technology can be used to record and verify reward points transactions. Blockchain provides a decentralized ledger that is immutable and tamperproof, ensuring that all transactions are secure and verifiable. This tech nique is particularly beneficial for maintaining user trust, as it guarantees that the reward system is fair and transparent. By using blo ckchain, the system ensures that no one can manipulate reward points, and users can track their points history with confidence.

6) Predictive Analytics

Predictive analytics is another advanced technique employed in the system to optimize traffic management. By analyzing historical t raffic data and user behavior, the system can predict future traffic patterns and adjust traffic signals accordingly. This predictive capa bility allows the system to anticipate and alleviate congestion before it occurs, improving traffic flow and reducing waiting times at i ntersections. Predictive analytics also helps optimize the reward system by identifying patterns in user behavior and adjusting rewar d criteria to encourage better compliance.

7) V2X (Vehicle-to-Everything) Communication

V2X (Vehicle-to-Everything)
communication is a cuttingedge technique that enables realtime data exchange between vehicles and traffic systems. V2X communi cation allows vehicles to share information about their speed, location, and road conditions with nearby traffic systems. This data ex change enables the system to make realtime adjustments to traffic signals and reward calculations, ensuring smoother traffic flow an d more accurate reward distribution. V2X enhances the overall efficiency of the reward system by providing vehicles with uptodate i nformation about traffic conditions, allowing them to make informed decisions and comply with traffic rules more effectively.

8) Crowdsourcing Data

Finally, crowdsourcing data is an optional technique that can enhance the system by allowing users to report violations or unsafe dri ving behaviors. This community-
driven approach encourages user participation and promotes a sense of collective responsibility for improving road safety. Users can earn additional rewards for reporting violations, helping the system enforce traffic rules more effectively and ensuring safer roads f or everyone. Crowdsourcing adds an extra layer of data to the system, improving its ability to monitor and enforce traffic rules.

IV. SIMULATION

Traffic congestion and road safety are pressing concerns in urban environments. To address these issues, a Traffic Reward System ca n be implemented, which incentivizes drivers to follow traffic signals by awarding points. These points can be redeemed on a dedica ted website for discounts on products and services. This simulation model demonstrates how the Traffic Reward System can be desi gned, operated, and its impact on user behavior.

A. System Overview

The Traffic Reward System consists of several key components:

1) Traffic Signal Compliance Detection: Using IoT devices like smart cameras and sensors to monitor driver compliance with traff ic signals.
2) Point Allocation Mechanism: Assigning points to users for adhering to traffic rules.
3) User Interface: Mobile application for users to track their points and compliance.
4) Backend Infrastructure: Cloudbased system for data processing and storage.
5) Reward Redemption Platform: Website where users can redeem their points for discounts.

B. Simulation Environment Setup

1) Traffic Compliance Detection

Smart cameras and sensors installed at intersections.
These devices capture real-time data on vehicle movements, signal compliance, and speed.

2) Data Processing

Real-time data is transmitted to a cloud server.
The server processes data to determine compliance and assigns points to users.

3) User Interface

A mobile application developed using Flutter or React Native.
The app displays user points, compliance history, and available rewards.

4) Reward Redemption

A website where users can log in to redeem their points.
Users can view a catalog of products and services available for discounts.

C. Simulation Steps

1) Initialization

Set up the traffic environment with intersections, traffic signals, and IoT devices.
Initialize user profiles with unique IDs and initial point balances.

2) Traffic Signal Monitoring

IoT devices continuously monitor traffic signals and vehicle compliance.
Capture data on whether vehicles stop at red lights and go at green lights.

3) Data Transmission

Realtime data from IoT devices is sent to the cloud server.
The server processes the data to identify compliant and non-compliant users.

4) Point Allocation

For each compliant action (e.g., stopping at a red light), users are awarded points.
Points are updated in the user profiles and displayed on the mobile app.

5) User Engagement

Users receive notifications about their points and available rewards through the mobile app.
Gamification elements like leaderboards and badges encourage user participation.

6) Reward Redemption

Users log in to the reward redemption website.
They can view and select products or services to redeem their points for discounts.

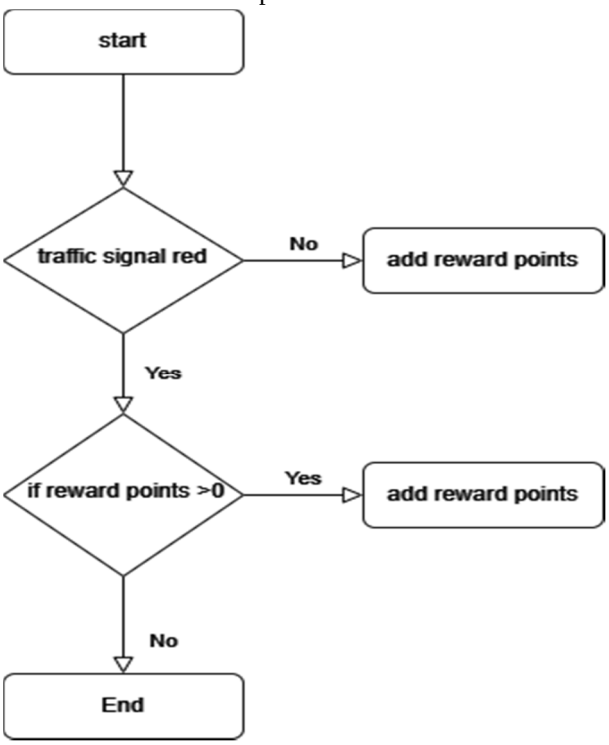

Fig 1. Flow of Traffic Reward System

D. Simulation Output

1) Compliance Reports

Generate reports on traffic signal compliance rates.
Monitor the impact of the reward system on driving behavior over time.

2) User Engagement Metrics

Track user participation in the reward system.
Analyze the effectiveness of gamification elements in maintaining user interest.

3) Traffic Flow Improvements

Assess the impact on traffic congestion and flow.

Compare traffic conditions before and after implementing the reward system.

4) Environmental Impact

Measure the reduction in fuel consumption and emissions.

Evaluate the contribution to environmental sustainability.

V. CONCLUSION

A traffic reward system offers numerous benefits, addressing critical urban challenges such as congestion, road safety, and environmental sustainability. By incentivizing behaviors like using public transportation and choosing less crowded routes, the system helps ease traffic congestion, reducing travel times and boosting economic efficiency through smoother delivery of goods and services. Moreover, rewarding drivers for safe practices, such as adhering to speed limits and yielding to pedestrians, promotes a culture of safety, reducing accidents and fostering long-term safer road habits. Environmentally, fewer cars on the road lead to reduced fuel consumption and emissions, improving air quality and supporting sustainable urban development. Encouraging public transportation and minimizing stop-and-go traffic further lowers the city's carbon footprint, aligning with global efforts to combat climate change. This multifaceted approach enhances urban living while promoting sustainability for future generations.

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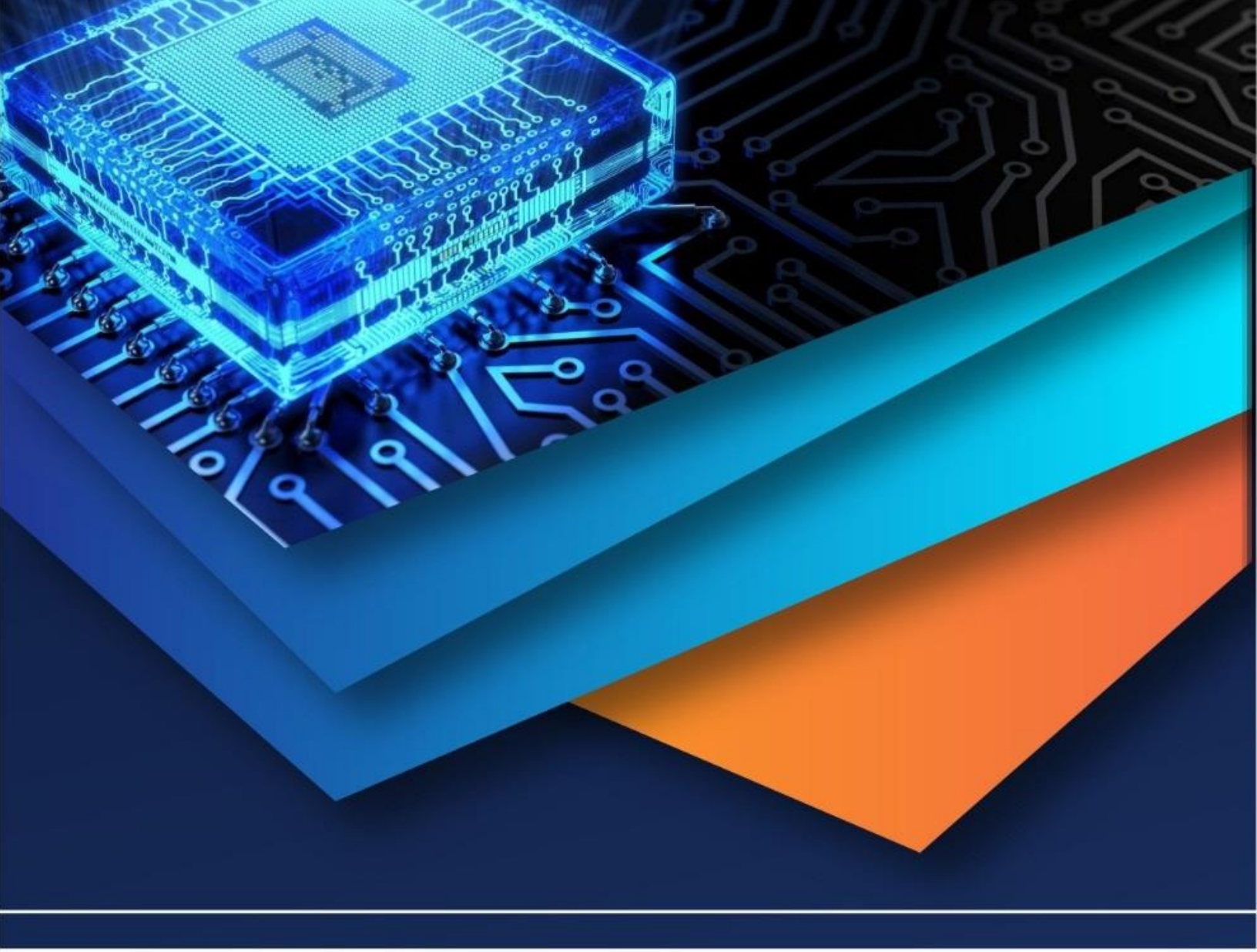

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