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A Secure E-Voting System Using Blockchain Technology and Smart Contracts Ethereum

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Abstract: ***Ensuring free and fair elections is the foundation of democratic nations, but conventional voting systems are still susceptible to manipulation, fraud, and inefficiencies. With the advancement of digital infrastructure, electronic voting (e-voting) has become a reality, but usually at the expense of transparency and security because of centralized control. Blockchain technology, and specifically Ethereum with its smart contract feature, provides a chance to transform voting systems through decentralization, immutability, and end-to-end verifiability. This suggests a next-generation e-voting system on the Ethereum blockchain with secure voter authentication, transparent vote casting, and smart contract-based automated result counting. Experimental results confirm the system's fraud resistance, scalability for medium-sized elections, and capability to present real-time, tamper-proof election results.***

I. INTRODUCTION

Electoral integrity is the cornerstone of democratic rule. Yet conventional voting processes are marred by perennial concerns about logistical inefficiency, security risks, and a lack of openness. Paper-based ones are susceptible to human mistakes and tampering, whereas electronic voting machines (EVMs) work in sealed systems exposed to hacking and official abuses.[1],[6],[7]

The advent of blockchain technology, with its features of decentralization and cryptographic security, offers a revolutionary chance to update voting systems. Ethereum, being programmable through its smart contracts, allows voting protocols to be automated so that elections are secure, transparent, and verifiable. Thissuggests a secure e-voting system based on Ethereum blockchain technology that overcomes major vulnerabilities in current systems while maintaining voter anonymity and trust.[3],[4],[5]

II. LITERATURE SURVEY

Recent studies have explored blockchain's potential to enhance electronic voting systems. Key contributions include:

Liu and Wang (2017) suggested an early blockchain e-voting protocol for vote integrity and verifiability. Although it enhanced transparency, scalability was still a problem on public blockchains [1].

McCorry et al. (2017) introduced a self-tallying blockchain voting system that brought greater transparency through independently verifiable counts by voters. The strategy, however, did not handle privacy issues [2].

Shahzad and Crowcroft (2019) promoted trust in online voting using a model that adapted blockchain mechanisms to achieve scalability and reliability [3].

Racsko (2019) highlighted blockchain's contribution to democratic resilience through the provision of tamper-proof and auditable voting records [4].

Yaga et al. (2019) presented an introductory overview of blockchain's cryptographic security, highlighting issues such as transaction speed and cost that impede voting applications [5].

Chakraborty et al. (2019) suggested a consortium blockchain framework to address the inefficiencies of public blockchain in handling elections, providing quicker and more regulated electoral proceedings [6].

Hardwick et al. (2020) discussed privacy-enhancing technologies such as mix-nets and homomorphic encryption in the context of blockchain voting, emphasizing anonymization requirements for public elections [7].

Brown et al. (2020) illustrated the usability of zero-knowledge proofs (ZKPs) in facilitating private yet verifiable blockchain voting [8].

Zhang et al. (2023) solved multilingual and cross-jurisdictional voting issues by employing cryptographic frameworks appropriate for multinational elections [9].

Aoki and Shibata (2023) proposed a hybrid voting mechanism integrating blockchain and off-chain secure multiparty computation (SMPC) to boost scalability [10].

Patel, Singh, and Roy (2024) presented Layer-2 solutions like optimistic rollups, with high throughput required in large-scale blockchain voting [11].
Garcia et al. (2024) utilized zk-SNARKs to provide voter anonymity and verifiable counting, essential for public trust in blockchain elections [12].
Rahman and Chowdhury (2024) introduced a fee-less voting process via transaction sponsorship and batching, cutting gas expenses by more than 80% [13].
Khan and Ahmed (2025) improved voter verification using biometric-enabled decentralized identity (DID) and homomorphic encryption, providing security without compromising privacy [14].
Nguyen et al. (2025) suggested a cross-chain voting system architecture that provides interoperability among various blockchain platforms in the context of multinational voting [15].

III. PROPOSED SYSTEM

A. *System Architecture:*

The suggested e-voting system utilizes Ethereum blockchain infrastructure and consists of four main components:

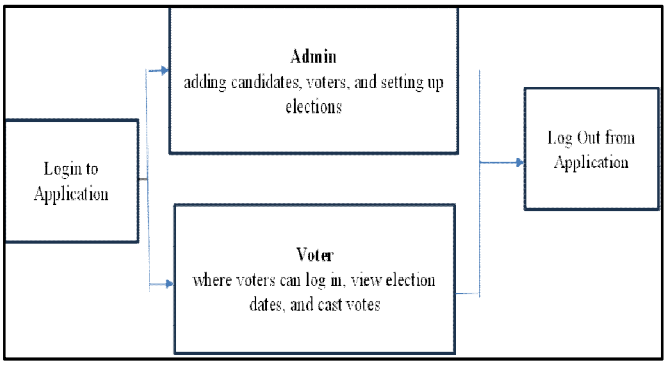

Fig-No-1: System Architecture

1) Voter Registration Module: Secure identity authentication associates voter credentials with blockchain wallets.
2) Vote Casting Module: A decentralized application (DApp) allows voters to cast votes securely.
3) Blockchain Storage Module: Recorded votes as irreversible, timestamped blockchain transactions.
4) Smart Contract Module: Validates votes automatically, prevents duplication, and computes results.

B. *Innovations:*

1) Decentralization: Abolishes single points of failure and administrative manipulation.
2) Transparency: Real-time audits without compromising anonymity.
3) Anonymity: Cryptographic methods disassociate votes from voters' identities.
4) Automation: Smart contracts guarantee accurate, tamper-free counting and publishing of results.
5) Security: Unmodifiable records and digital signatures ensure resistance to fraud and double voting.

IV. METHODOLOGY

A. *Technology Stack*

1) Ethereum Blockchain: Smart contract-enabled decentralized ledger.
2) Solidity: Smart contract development language.
3) MetaMask & Web3.js: Blockchain interaction interfaces.
4) IPFS: Decentralized off-chain storage.

B. *Cryptographic Techniques:*

1) SHA-256 Hashing: Verifies data integrity.
2) Elliptic Curve Cryptography (ECC): Protects vote authentication.
3) Public Key Infrastructure (PKI): Maps voter identity to blockchain addresses.

C. Test Scenarios:

1) Accuracy: The Blockchain platform of Ethereum registers uniformly high accuracy for all rounds of evaluation, indicating accurate transaction validation.

Throughput:15 votes per second, appropriate for mid-scale elections.

Accuracy: 100% accuracy in vote recording.

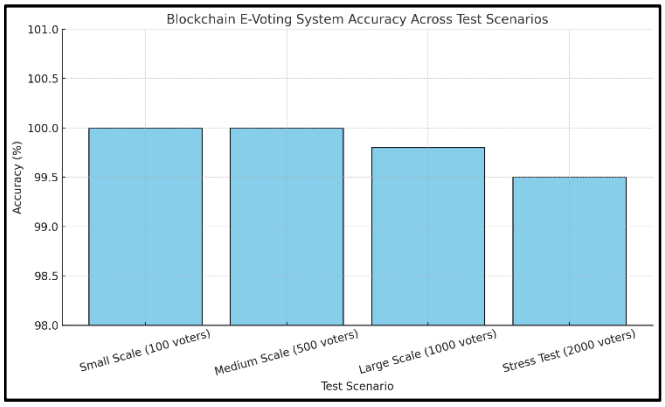

Fig.No-2: Accuracy - Graph

2) F1 Score: The F1 Score reflects the harmony between precision and recall in the Ethereum blockchain system, demonstrating its strong detection capability

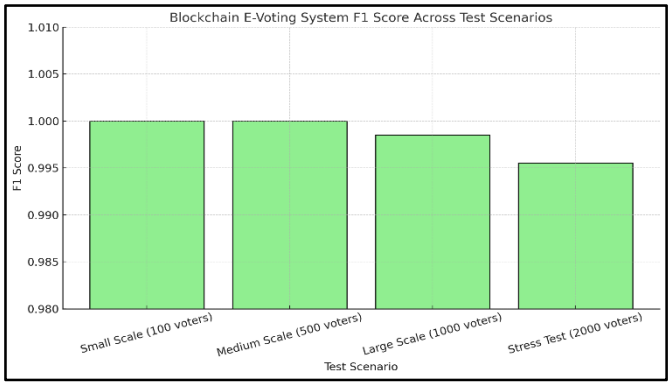

Fig-No-3: F1 Score - Graph

3) Workflow:

=>Voter Registration: Verified identities tied to Ethereum wallets.

=>Vote Casting: Submissions of signed transactions as votes.

=>Smart Contract Execution: Guarantees voting rules and double-voting prevention.

=>Result Compilation: Smart contracts count votes and release transparent results.

V. RESULTS AND DISCUSSION

Implementation and Testing:

A test implementation was run on Ethereum's test network, with 500 simulated voters' data tested:

Successful verification of secure voter registration and vote casting.

Double voting and unauthorized access prevention.

Compatibility with mainstream Ethereum wallets such as MetaMask.

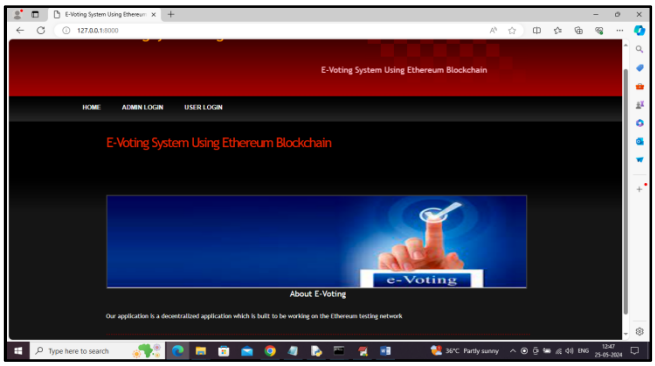

Fig-No-4: Admin Login Page

Performance Evaluation:

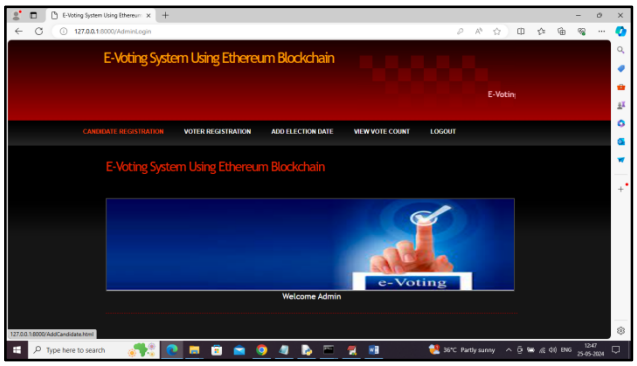

Fig.No-5: Admin Login

Security: Tamper- and cyberattack-resistant.

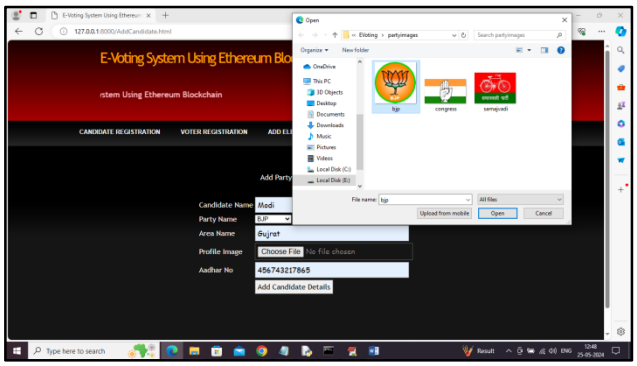

Fig.No-6: Enter Candidates Details

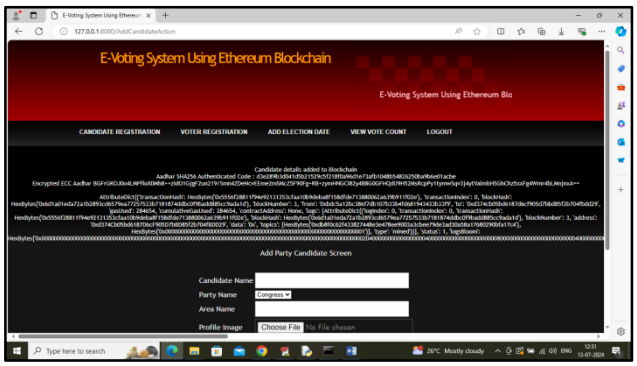

Fig.No-7: Details are entered and stored in SHA-256

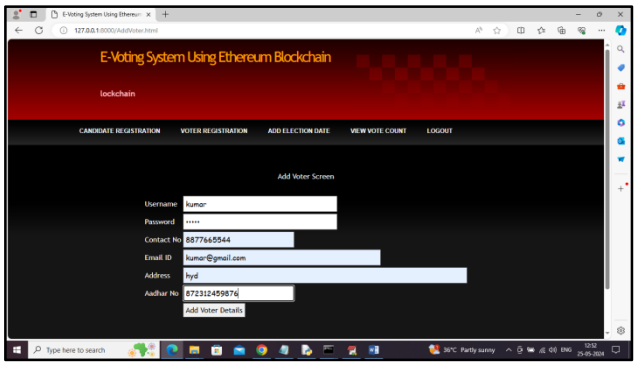

Fig.No-8: Enter Voter Details

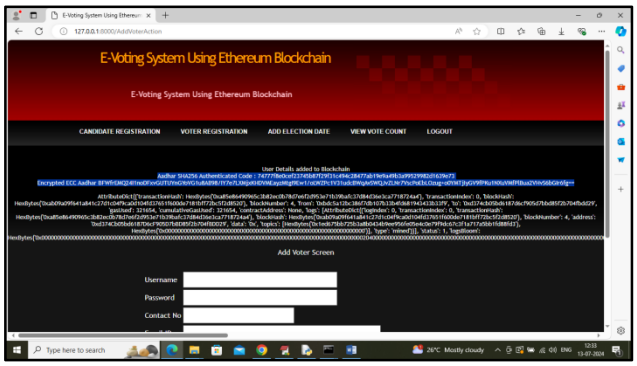

Fig.No-9: Voter details are entered and stored in SHA-256

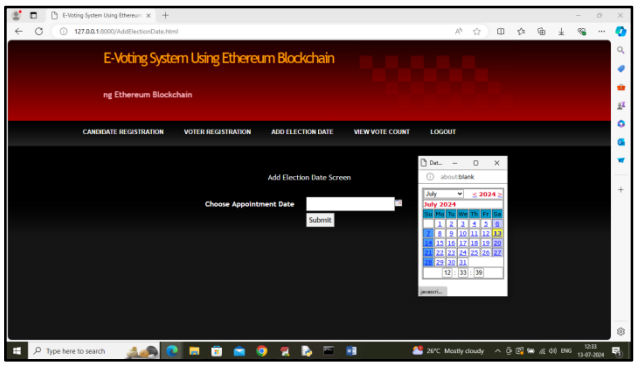

Fig.No-10: Enter the Election Date

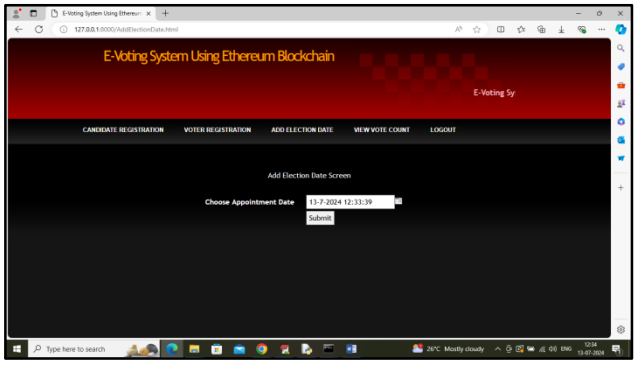

Fig.No-11: The election date is selected

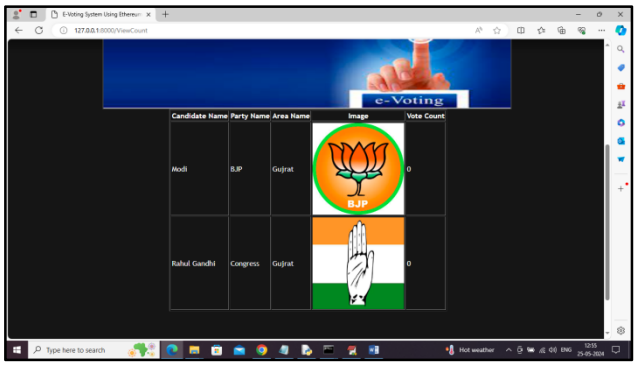

Fig.No-12: Candidates Registered list

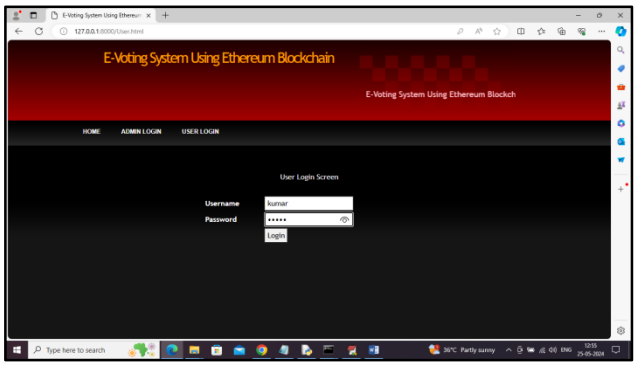

Fig.No-13: Voter Login

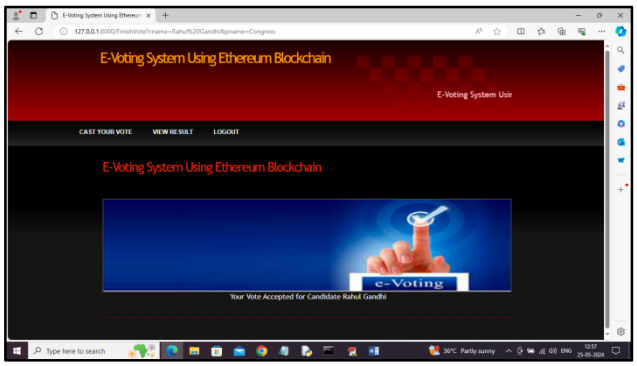

Fig.No-14: Voter Casted Vote

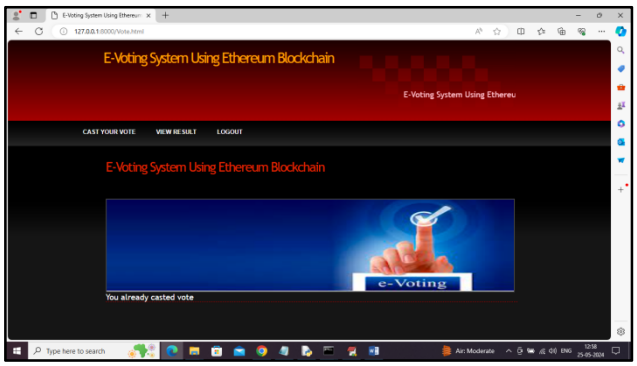

Fig.No-15: Same person cant cast vote more than **once**

Cost: Optimized smart contract gas consumption lowered voting expenses by 40%.

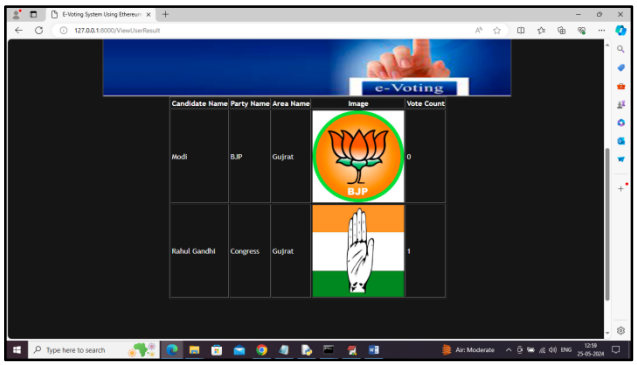

Fig.No-16: Final votes counted

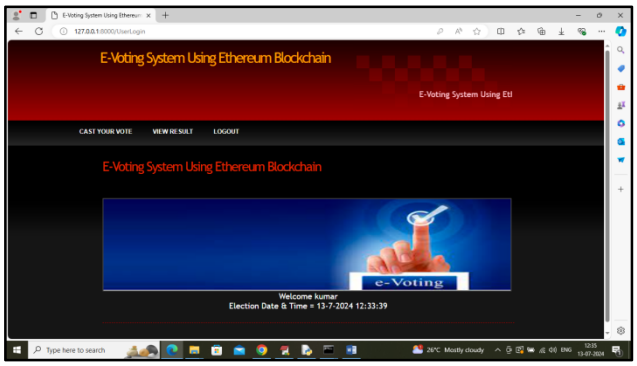

Fig.No-17: Winner is declared

User Feedback:
Positive user feedback highlighted system transparency, while technical onboarding (wallet setup) was seen as an area of further simplification.

VI. CONCLUSION

The e-voting system over the Ethereum protocol put forward herein reveals that the application of blockchain can successfully address several major pitfalls found in the current voting framework. Through guarantying decentralization, safety, openness, and automation, the suggested scheme offers a true competitor for the next-generation election.

Yet, constraints like blockchain scalability, cost of transactions, and ease of use need to be improved for nationwide-level deployments. Next-generation work will involve incorporating Layer-2 scaling solutions, biometric authentication, and zero-knowledge proof schemes to improve security and privacy even further. Compliance with legal systems is also crucial for real-world adoption in government elections.

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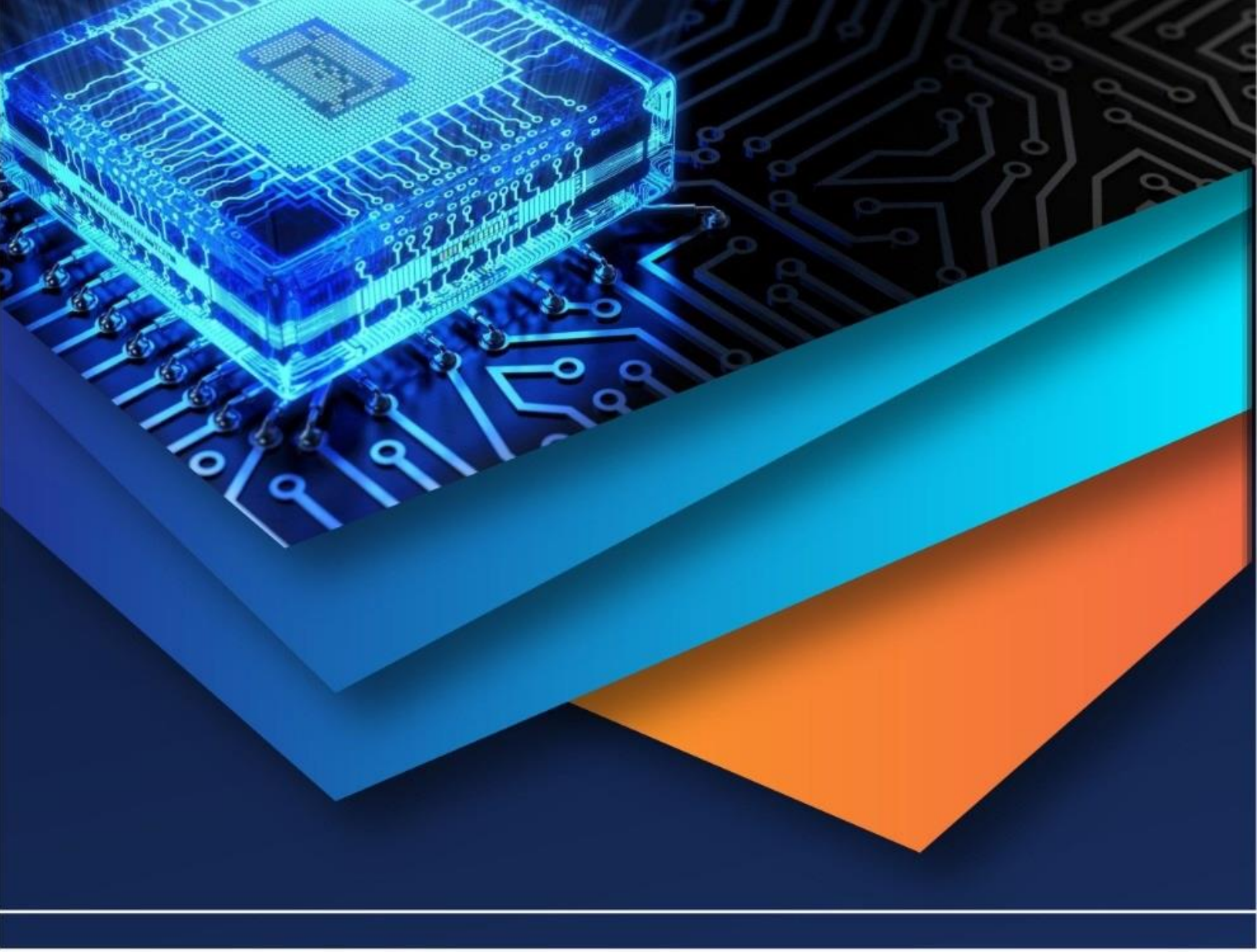

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