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A Survey on Blockchain Based Solution for Agriculture Supply Chain Management

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Abstract: ***Agriculture, a practice that spans thousands of years, has always been at the heart of human civilization. Throughout history, agriculture has continuously adapted to meet the needs of growing populations and ensure food quality, traceability, and efficiency. Recent advancements in blockchain technology have brought about significant positive changes in the agricultural sector. Blockchain has found a valuable role in agriculture, enhancing transparency, traceability, and trust throughout the supply chain. This paper provides an in-depth survey of how blockchain has impacted various aspects of agriculture, discusses the challenges it faces, and considers the promising future it holds for the industry. As blockchain adoption in agriculture continues to evolve, it promises to revolutionize the way we produce and distribute food, ensuring a more efficient, secure, and sustainable supply chain.***

Keywords: Agriculture, Blockchain, Supply Chain, Traceability, Transparency.

I. INTRODUCTION

The process of farming innovation and distribution with globalization has placed a renewed emphasis on ensuring the safety, quality, and authenticity of essential elements within the agricultural and food supply chain. The use of tamper-proof, securely stored records is of paramount importance in the Agri-Food sector, serving as a cornerstone for maintaining trust and consistency throughout the supply chain. Ideally, individual participants in these transactions should be able to interact Without the necessity of depending on a central intermediary. These challenges can be effectively addressed through the application of blockchain technology, a decentralized ledger system that operates without dependence on centralized servers. Built on a consensus mechanism supported by a network of widely distributed peers, every record stored in a blockchain is permanent, tamper-resistant, and provides a trustworthy source of information. In the context of traceability systems based on the Internet of Things, secure connections to adjacent peers within a blockchain network become the only requirement, eliminating the need for central cloud access. Consequently, blockchain technology offers a comprehensive solution for decentralizing traceability systems in the food industry while making vital information accessible at any point in the supply chain. Blockchain comprises a digital framework that enables electronic record-keeping, validation, and verification, eliminating the necessity for intermediaries. This technology ensures that data are accessible to all involved parties, making all information transparent and unalterable, effectively preventing any tampering or deletion of records. Blockchain adheres to a set of guiding principles, including governance, accountability, transparency, flexibility, availability, usability, manageability, and sustainability.

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II. RELATED WORK

1) "A Blockchain Maturity Model in Agriculture Supply Chain"

The paper [1] proposes the utilization of a "Blockchain Maturity Model" enables individuals and organizations participating in the Agri-food supply chain, including farmers, gardeners, producers, distributors, and food product sellers, to assess their readiness for the adoption and integration of blockchain technology. By leveraging the outcomes of the maturity level assessment model, departmental managers can strategically plan the implementation of blockchain technology to reach higher levels of maturity. Based on the maturity assessment results from a sample study conducted in Iran, it is evident that company managers must take specific steps to facilitate the adoption of blockchain technology.

In addition to creating a blockchain software platform and deploying smart contracts, these managers must also invest in the acquisition and installation of essential equipment for tracking agricultural products. Furthermore, the support of companies engaged in the food and agriculture sector by the Ministry of Agriculture and the Ministry of Information and Communication Technology of Iran is crucial, as they should provide the necessary infrastructure and telecommunication band width facilities to enhance the sector's capabilities.

2) "Blockchain Based Agriculture Supply Chain"

The paper [2] proposes the blockchain knowledge which can aid to generate a reliable, self-organized, exposed, and environmental smart farming organization that comprises all ecology players, even if they do not belief one other. Agri-BlockIoT combines expertise in Internet of Things (IoT) and Blockchain to create a robust, fault-tolerant, permanent, and auditable data system for agri-food traceability. This approach primarily leverages the Ethereum blockchain and smart contracts to monitor, trace, and execute efficient transactions throughout the agricultural supply chain, eliminating the need for intermediaries and centralized processing centers. In the future, the scope is to enhance the traceability system within the blockchain-based Agricultural Supply Chain. This involves utilizing IoT technology for structured data uploads, reducing the risk of manual errors. Additionally, real-time integration of QR code technology facilitates easier access to service foundations, enhances client operator experience, and streamlines the entire process. Despite the blockchain records being public and decentralized, data remains secure and verifiable. To mitigate vulnerabilities like unauthorized data manipulation, encryption via cryptography is necessary. Here, the emphasis is on leveraging IoT and blockchain technologies to enhance agri-food traceability, reduce errors, and improve the overall customer experience while maintaining data security and integrity.

3) "Agriculture Supply Chain Management Based on Blockchain Architecture and Smart Contracts"

The paper [3] proposes model which aims to provide a possible technique to build practical blockchain-based applications and change the agriculture industry, even though the evolution of blockchain and agriculture research into this subject is still in the early stages of its development. This system serves as an initial version for addressing financial losses and environmental pollution in agriculture. It's designed to help people in the agriculture industry by focusing on three main aspects: the information and data involved, the various activities and methods used, and the people and groups who are affected or involved in the agricultural processes. Adding a cryptocurrency process for the interaction between the entities and registering/tracking the seller's land-related process will be a significant milestone for this blockchain system model.

4) "Blockchain for Sustainable e-agriculture"

The paper [4] proposes the model of blockchain integrated IoT architecture which consists of a presentation layer, business layer, functional layer, integration layer, and blockchain data layer (Hassan et al., 2020). This study introduces a cohesive, step-by-step approach for managing data within the domain of e-agriculture. The approach encompasses data collection, validation, security, storage, and transmission. The key innovation lies in the integration of blockchain technology and IoT networks. By combining these two technologies, this paper addresses data rights and safeguards against data duplication issues. The result is a hybrid platform that establishes an interoperable, decentralized, scalable, and fault-tolerant e-agriculture information system. This contribution has the potential to significantly enhance the e-agriculture landscape. This study offers significant theoretical insights for researchers. It provides valuable perspectives on how various stakeholders can utilize blockchain-enabled distributed decentralization in e-agriculture information systems. As we move towards the era of Agriculture 4.0 and environmental friendly technologies, the study also underscores the importance of smart contracts for financial transactions, the utilization of IoT devices in agriculture, GPS and GIS technologies, mapping tools, drone imagery, and the overall advancement of smart agriculture.

5) "Blockchain in Agriculture Supply Chain Management"

The paper [5] proposes the fusion of Blockchain and IoT technologies is giving rise to a novel concept known as VIoT (Blockchain technology with IoT). This integration is poised to enable the synchronization of physical goods' flow with financial and information streams, facilitating connections with artificial intelligence and various other digital technologies. Nevertheless, growing public demand for transparency and openness in logistics processes may lead to the prominence of independent, public Blockchain networks. These networks offer enhanced visibility and accountability in supply chain transaction records, order tracking, trade-related documents, and the authentication of product certificates and attributes. It's important to note that the utilization of public Blockchain networks doesn't necessarily mean the exposure of personal data to the public Blockchain technology boasts applicability beyond the realm of banking and cryptocurrency. Its main strength is its capacity to rapidly install confidence among the participants involved in diverse business operation, thereby fueling innovation across numerous logistics domains. However, it's worth noting that Blockchain technology and standards continue to evolve. Progress is impeded by resistance from governments and existing intermediaries. Like any emerging technology, integrating Blockchains with ledger technology (DLT) and IoT devices to achieve existing systems and new platforms like IoT, along with the necessary adaptation, demands significant investment.

6) "Supply Chain Management in Agriculture using Blockchain and IoT"

The paper [6] proposes vital role of Blockchain in farmer initiative, serving as a crucial tool for monitoring and tracing the origins of food products throughout the food supply chain. Supply Chain Management (SCM) is a vital business process across various sectors of the economy. SCM employs specific procedures to bridge the gap between producers and consumer demands, creating a seamless chain of supply. Furthermore, the integration of BCT in FARMAR enhances security, rendering hacking or data tampering by intermediaries impossible. As an augmentation to this process, IoT devices, such as a mobile phone-based Android app, are utilized to update real-time information regarding product quality and transit times within FARMAR. FARMAR's objective is to create a web application that establishes an unbroken chain of integrity from the farm to the consumer's table through the utilization of BCT. This supply chain network possesses the geographical coverage and the flexibility to efficiently manage varying levels of supply and demand. Within the blockchain database maintained. When consumers use a mobile application to scan the QR code associated with the asset, they will gain access to a comprehensive record of all transactions related to that asset, along with insightful data analytics from the asset collection within the blockchain database. Farmers, as producers, will receive equitable compensation for their agricultural yields, significantly reducing the risk of exploitation by unscrupulous middlemen who might take advantage of their lack of education. Consumers will also enjoy advantages as they won't have to pay inflated prices for their purchases. Consequently, this will enhance the overall quality of life within society.

III. OBJECTIVES

1) *Designing a decentralized and secured supply chain management system:* It involves creating a framework where control and data are distributed across a network of participants, rather than being centralized. By employing blockchain technology, cryptographic security, and smart contracts, this approach can streamline operations, increase trust among participants, and significantly improve the overall efficiency and accountability of the supply chain.
2) *Traceability:* To provide a transparent and immutable record of the origin and journey of agricultural products, helping to track and verify their sources.
3) Reduce Fraud: Minimizing fraudulent activities and counterfeit products by securing the supply chain with immutable records and secure transactions.
4) *Food Safety:* Enhancing food safety by quickly identifying and containing outbreaks or contamination issues, which is crucial for consumer protection.
5) *Efficiency:* Streamlining supply chain operations, reducing paperwork, and administrative tasks, leading to cost savings and improved efficiency.
6) *Fair Pricing:* Ensuring fair compensation for farmers and eliminating price manipulation by intermediaries.
7) *Sustainability:* Supporting sustainable and environmentally friendly agricultural practices by providing data for better decision-making.
8) *Real-time Data:* Offering real-time data on product quality, quantity, and location, aiding in inventory management and decision-making.
9) *Access to Finance:* Facilitating access to financial services for small-scale farmers by providing transparent financial histories on the blockchain.
10) *Consumer Trust:* Building consumer trust by providing transparent information about the products they purchase.

IV. METHODOLOGY

1) *Blockchain-Based Platforms:* Developing dedicated blockchain platforms or networks for agriculture supply chains, Blockchain-based platforms are digital ecosystems that leverage blockchain technology to facilitate secure and transparent transactions, data sharing, and interactions among multiple participants.

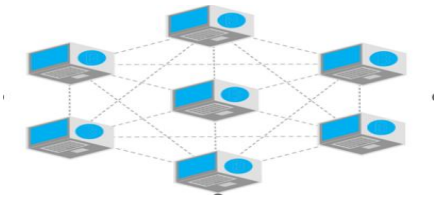

Fig 1. Blockchain Network

These platforms often provide a decentralized and distributed ledger that records and verifies transactions, offering benefits such as immutability, traceability, and enhanced trust. They find application in various sectors, including finance, supply chain management, healthcare, and more, enabling stakeholders to collaborate, automate processes, and streamline operations while ensuring data integrity and reducing the need for intermediaries. Blockchain-based platforms have the potential to revolutionize industries by offering innovative solutions that prioritize security, efficiency, and accountability.

2) *Smart Contracts:* Implementing smart contracts to automate and self-execute predefined supply chain processes and agreements, such as payment upon delivery or quality checks.

Fig 2: Smart Contract

Smart contracts are self-executing, programmable agreements that run on blockchain platforms. They automate and implement the stipulations and provisions outlined in the contract. where all stakeholders can participate and transact securely. This could be a private, consortium, or public blockchain. These agreements are encoded and have the capability to initiate the actions, such as transferring assets, when predefined conditions are met. Smart contracts enhance transparency, security, and efficiency in various applications, including finance, supply chain management, and decentralized applications (DApps). They offer the potential to revolutionize industries by reducing fraud, lowering transaction costs, and enabling trustless interactions among parties while minimizing the risk of disputes.

3) *Traceability Solutions:* Utilizing blockchain to create a traceability system that records the journey of products from farm to consumer, providing transparency and assurance about the product's origin. By leveraging blockchain technology, these solutions create an immutable ledger that tracks and verifies every step in the supply chain. This includes information on the origin of the products, quality assessments, transportation details, and more. These solutions enable consumers, producers, and regulators to access real-time, trustworthy data about the products they are dealing with. This increased transparency not only improves food safety by allowing for quick identification and containment of issues but also helps in fraud prevention, fair compensation for farmers, and compliance with regulations. In addition, traceability solutions enhance consumer trust by providing assurance about the authenticity and quality of agricultural products, ultimately benefiting the entire agricultural industry.

4) *Data Analytics:* Data analytics in agriculture using blockchain technology involves the collection, analysis, and interpretation of agricultural data recorded on a blockchain. By leveraging blockchain's transparent and immutable ledger, this data can include information about crop yields to make informed decisions, optimize farming practices, and improve crop management. It can help identify trends, predict disease outbreaks, and enhance resource allocation. By combining blockchain and data analytics, the agriculture industry can harness the power of big data to increase efficiency, reduce waste, and ultimately improve crop yields and sustainability. This approach holds great potential for transforming agriculture into a data-driven and more productive field.

5) *Tokenization:* Tokenization in agriculture supply chain using blockchain involves representing physical assets, such as crops, livestock, or agricultural products, as digital tokens on a blockchain. Each token corresponds to a real-world asset, and their ownership and transfer are recorded on the blockchain ledger. Tokenization offers several advantages in agriculture supply chains. It allows for the fractional ownership of assets, making it easier for multiple stakeholders to invest in or share ownership of agricultural assets. These digital tokens can be traded, bought, and sold, providing liquidity to otherwise illiquid assets. It also enables easier access to financing and investment opportunities for farmers, helping them secure funds for their agricultural endeavors. By combining blockchain and tokenization, agriculture supply chains can benefit from increased transparency, efficiency, and financial inclusion, ultimately transforming the way agricultural assets are managed and traded.

6) *Quality Assurance:* Quality assurance in the agriculture supply chain using blockchain is a critical application that ensures the consistency and authenticity of agricultural products.

Blockchain technology enables the creation of a transparent and immutable ledger that records information about the quality standards, certifications, and inspection results of agricultural products at each stage of the supply chain. This approach provides stakeholders with real-time access to data environmental conditions, supply chain movements, and more. The use of data analytics in agriculture enables stakeholders that verifies the quality and safety of products. It not only helps in maintaining product integrity but also allows for quick identification and traceability of any quality issues. By reducing the risk of substandard or contaminated products reaching consumers, blockchain-based quality assurance enhances food safety, builds trust, and contributes to the overall improvement of agricultural practices and consumer confidence in the industry.

7) *Supply Chain Finance:* Supply chain finance in agriculture supply chains using blockchain is a financial mechanism that leverages the transparency and security of blockchain technology to provide efficient and accessible financing options for various stakeholders in the agricultural ecosystem. This approach allows participants, particularly small-scale farmers and producers, to secure loans and credit based on the verifiable data recorded on the blockchain. By utilizing blockchain for supply chain finance, lenders can make more informed decisions and offer competitive financing rates, as they have access to real-time data about the flow of products and transactions. This promotes financial inclusion, helps farmers secure funds for their operations, and reduces the dependency on traditional intermediaries. Ultimately, supply chain finance in agriculture using blockchain fosters economic growth, improves cash flow, and ensures the sustainability of the agricultural industry.
8) *Monitoring and Maintenance:* Monitoring and maintenance in agriculture supply chain using blockchain refers to the ongoing oversight and upkeep of the blockchain system that manages the supply chain. Performance monitoring continuously assess the blockchain's performance to ensure that it is operating efficiently. This includes monitoring transaction processing times, network stability, and data storage the information is complete and tamper-proof. Security updates stay vigilant against emerging cybersecurity threats and vulnerabilities. Implement security updates and patches as needed to protect the blockchain from potential attacks. Node Management, manage and maintain the blockchain nodes to ensure their proper functioning. Node operators may need to perform routine tasks like syncing, backing up data, and resolving any issues that may arise. User Training, provide ongoing training and support for all supply chain participants to help them effectively use the blockchain system and its features. Compliance, keep the blockchain system in compliance with evolving agricultural regulations and industry standards. Ensure that the system is adaptable to changing requirements. Scalability Planning, develop a strategy to accommodate the expansion of blockchain system as supply chain grows. Make adjustments to accommodate increased data and user volumes. Documentation, maintain detailed documentation of the blockchain architecture, processes, and performance metrics. This documentation is essential for troubleshooting and future improvement.

V. APPLICATION REQUIREMENTS

1) *Ganache:* Ganache is an open-source tool and is available for free. It is used to create a controlled, user-friendly, and efficient environment for Ethereum developers to build, test, and debug smart contracts and DApps. Ganache is a local development environment, there's no risk of losing real Ether during the development and testing process. It's a safe and isolated environment for experimentation.
2) *MetaMask:* MetaMask is a popular Ethereum wallet and browser extension that can be used in a blockchain-based agriculture supply chain for various purposes. MetaMask serves as a digital wallet for participants in the agriculture supply chain.
3) *Ethereum:* Ethereum is a decentralized blockchain platform that can be used in the agriculture supply chain to bring transparency, efficiency, and trust to various processes. Ethereum allows the creation and execution of smart contracts, which are self-executing agreements with predefined rules.
4) *Solidity:* Solidity is a programming language specifically designed for writing smart contracts on the Ethereum blockchain.

VI. CONCLUSIONS

Based on the findings of this study, blockchain technology is poised to make a substantial impact on the agricultural sector and its associated verticals in the foreseeable future. The potential of blockchain to enhance various facets of agriculture is evident from the cases presented in this survey, highlighting its transformative influence on the industry. With the rapid evolution of blockchain technology, this research consolidates the collective knowledge from prior studies.

Researchers can leverage this survey as a valuable starting point for exploring the adoption of blockchain within specific agricultural verticals of interest. By offering a comprehensive list of past applications and research directions, this survey expedites the research process.

The investigation successfully fulfills its objective of examining blockchain applications in agriculture and its verticals, demonstrating how blockchain's fundamental characteristics, including trust, transparency, resistance to tampering, and decentralization, efficiently address the essential requirements of the agriculture domain. Furthermore, the core attributes of blockchain contribute to improved governance and management throughout the agricultural sector. Despite the advantages, challenges such as implementation, integration, and contracts written in Solidity can store data on the Ethereum blockchain, which can be exploration of these challenges and the development of strategies to mitigate them.

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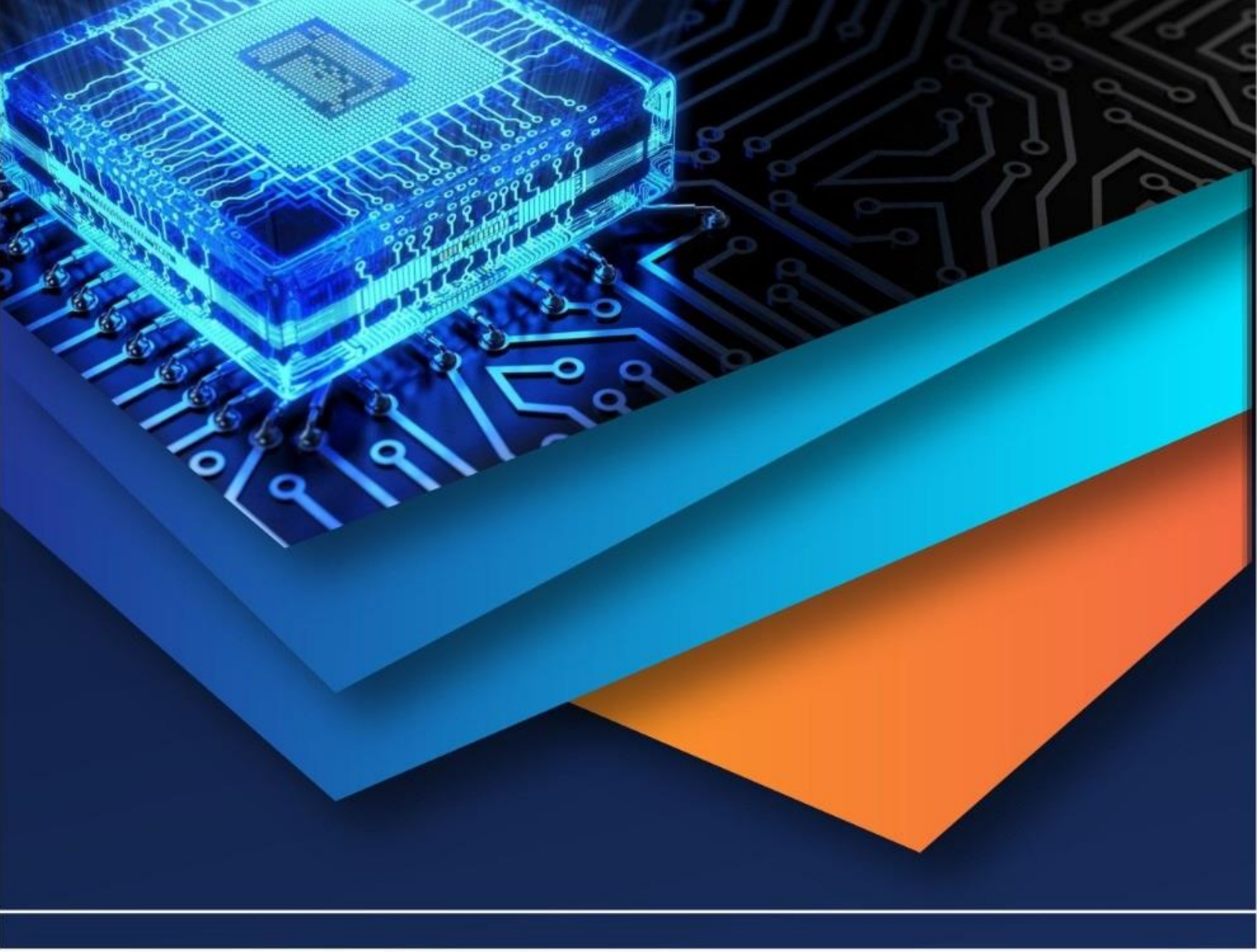

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