International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Blockchain-Driven Anti-Counterfeit Mechanism with Dynamic Product Authentication for Enhanced Supply Chain Security

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Abstract

In the realm of global trade, counterfeit products persist as a pervasive challenge, eroding consumer trust and posing substantial economic threats. Existing approaches to counter this issue often prove inadequate, necessitating an exploration of innovative alternatives. Beyond addressing the deficiencies of current solutions, our system contributes to secure and transparent trade practices. Our proposed system introduces dynamic product authentication checks conducted at regular intervals. This proactive feature serves as a direct response to the identified inadequacies in existing solutions, aiming to significantly diminish the infiltration of counterfeit goods into the supply chain. The pivotal innovation in our approach lies in its multifaceted nature. Dynamic product authentication checks not only bolster security but also ensure authenticity throughout the product lifecycle. By decentralizing control, we promote transparency in product transactions, aligning seamlessly with blockchain's core attributes of immutability and decentralization. This comprehensive strategy integrates with the decentralized blockchain system to fortify supply chain security, utilizing innovative verification methods. Scanned codes cross-reference with blockchain records, promptly informing consumers of a product's legitimacy or counterfeit status. This paper delineates a comprehensive solution to the challenges posed by counterfeit products in the e-commerce market, grounding its significance in the acknowledged shortcomings of current anti-counterfeit measures. By integrating dynamic product authentication checks with blockchain's inherent strengths, our system offers a practical, efficient, and innovative approach to safeguard product quality and authenticity in the global marketplace. The intersection provides a robust framework for securing e-commerce transactions, thereby bolstering consumer confidence in online trade practices.

Keywords: Blockchain, Smart Contracts, Supply Chain Management, Anti-Counterfeit Mechanism, Decentralization, Distributed Ledger Technology, QR Codes, Authentication, Transparency, Immutable Records, Cryptography, Digital Identity, Traceability, Product Authentication, Data Integrity

1. INTRODUCTION

In the contemporary landscape of a rapidly evolving technological era, blockchain emerges as a revolutionary methodology for securing and authenticating records across decentralized networks.

Originally conceived for Bitcoin transactions, the fundamental concept behind blockchain entails the formation of a sequence of blocks. Each of the blocks contains a timestamp, authenticated transactions, and a distinct hash code. This ingenious architecture, combined with the capability for shared, transparent, and immutable data storage, has paved the way for groundbreaking applications in various industries. Beyond its origins in Bitcoin transactions, blockchain's decentralized nature has fostered unparalleled security and trust in data management.

A. General Introduction

Business operations thrive on the timely and accurate exchange of information. Blockchain facilitates this by offering a swift, shared, and transparent dataset stored on an unalterable ledger, accessible only by authorized network participants. By providing a unified perspective on reality, blockchain enables comprehensive tracking of orders, payments, records, and production processes. Its decentralized nature ensures data integrity, fostering confidence, efficiency, and novel opportunities. In the realm of product authentication, blockchain's potential is harnessed to establish a robust anti-counterfeit mechanism. Blockchain's relevance in the supply chain [1] is particularly evident. It enables organizations to digitize tangible assets, creating a decentralized, immutable record that facilitates tracking from production to end-user consumption. This heightened transparency not only benefits companies by reducing fraud in high-value markets like jewelry and pharmaceuticals but also instills confidence in end-market consumers. A recent study [2] shows that almost 25-30% of all products sold in the country are spurious with counterfeiting being most prevalent in apparel and FMCG sectors, followed by pharmaceutical, automotive, and consumer durables.

B. Problem Statement

In this era of technological advancement and the surge in online transactions, the rampant spread of counterfeit products emerges as a significant and escalating threat across industries. Despite the convenience offered by online shopping, it has unfortunately given way to an alarming increase in counterfeit goods. The global e-commerce industry, although experiencing rapid growth, still constitutes less than one percent of total retail, indicating substantial potential for expansion. However, this nascent stage is not without its challenges, prominently marked by the pressing issue of counterfeit products, which poses a substantial risk to the industry's integrity and consumer trust.

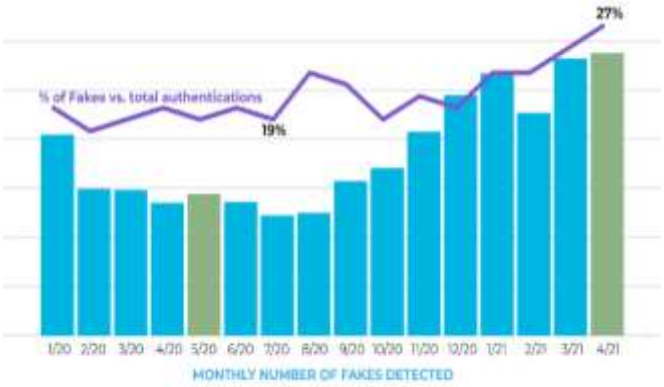

Figure 1: Growth of fake products sold

C. Objectives

The primary objective of the project is to develop a secure, transparent, and tamper-resistant system for authenticating products. Specifically, the project aims to:

- Utilize blockchain's decentralized nature to create a robust anti-counterfeit mechanism.
- Implement QR codes for efficient and user-friendly product authentication.
- Employ Solidity, Metamask, and Ganache to develop smart contracts and a user-friendly decentralized application (DApp).
- Enable manufacturers to register products on the blockchain, generating unique digital identities and QR codes.
- Provide consumers with a reliable means of verifying product authenticity, instilling trust in the marketplace.
- Introduce an annual dynamic authentication process leveraging blockchain's decentralization to enhance anti-counterfeit measures continuously, ensuring ongoing defense against evolving threats in product authentication.

D. *Scope*

The scope of this project is comprehensive, encompassing the integration of Solidity for smart contract development, Metamask for secure transactions, and Ganache for local blockchain development. The project will involve the creation of a user-friendly DApp to facilitate interaction with the blockchain. Manufacturers will register products, generating unique QR codes linked to blockchain records. The QR codes will serve as an accessible means for stakeholders to authenticate products, contributing to enhanced supply chain transparency and the eradication of counterfeit goods. The urgency for such a solution is emphasized by the current inadequacies in traditional authentication methods, making the "Blockchain-Driven Anti-Counterfeit Mechanism for Product Authentication" project a timely and crucial endeavor in the quest for a trustworthy global marketplace.

2. LITERATURE SURVEY

This literature survey undertakes a comprehensive review of five distinct research papers focusing on the identification and mitigation of counterfeit products through the utilization of blockchain technology. Mallegowda, M., et al. [3]argue for leveraging the decentralized and immutable nature of blockchain to create a secure and transparent system for tracking product authenticity in the supply chain. Their proposed system involves assigning a unique identifier to each product and recording it on the blockchain. However, the research gaps identified include a lack of detailed analysis on the costs of implementation, potential collusion risks, and scalability issues within the blockchain network. Similar to the first paper, this research in [4] advocates for the use of blockchain to secure and transparently track product authenticity throughout the supply chain. The proposed system includes, recording digital records on the blockchain, and enabling consumers to verify authenticity through smartphone scans. The paper by G. Vidhya Lakshmi; Subbarao Gogulamudi; Bodapati Nagaeswari; Shaik Reehana [5] introduces a novel approach to inventory management by integrating blockchain technology and QR codes. Similar to the first two papers, the research gaps include the absence of a detailed cost analysis, potential collusion risks, and scalability concerns within the blockchain network. The authors Amogh Gupta and Shivani Trivedi [6] proposed a system using QR codes and blockchain technology to detect fictitious products. The system involves generating a QR code for each product, storing it on the blockchain, and verifying the authenticity through user scans. The research gaps include the absence of a discussion on ensuring accurate and up-to-date information on the blockchain, preventing malicious tampering, and evaluating the system's real-world performance. The paper [7] delves into the use of blockchain technology to combat the sale of counterfeit products, emphasizing tracking product movement through the supply chain using QR codes. The proposed

system allows consumers to verify authenticity through QR code scans. The research gaps include the need for a detailed cost analysis, addressing security risks associated with blockchain, and evaluating the effectiveness of the proposed system in real-world scenarios. Dr. R. Jayavadivel [8] explores various methods for detecting counterfeit products, such as Bar codes, QR codes, RFID, and watermarking algorithms. The survey offers an overview of counterfeit product detection techniques, detailing their advantages and limitations. In [9], the authors suggest safeguarding the wine industry by employing smart tags and cloud technologies. Integrating smart tags, Quick Response codes, and functional inks with a cloud system enables two-way communication between winemakers and end-users. [10] proposes a blockchain-based framework, serving as a theoretical foundation for supply chain quality management and providing a platform for managing information resources in distributed, virtual enterprises. A Scoping Review by George Drosatos and Eleni Kaldoudi [11] underscores the diverse applications of Blockchain technology in governance and healthcare. It emphasizes its role in data management, financial and integrity verification, as well as privacy and security. [12] introduces a Quick Response code-based identification system, enabling end-users or distributors to verify product authenticity using smartphones. However, it lacks blockchain or other supply chain tracking mechanisms, leaving room for potential counterfeiting. To address supply chain challenges, [13] and [14] propose blockchain-based systems for traceability and visibility in drug and agri-food supply chains. While [14] introduces RFID applications, [15] presents a comprehensive anti-product forgery system involving manufacturers, sellers, and consumers, relying on blockchain and web3 technologies. Each supply chain step undergoes verification using encryption algorithms, claiming to be the first of its kind. The author of [14] evaluates the pros and cons of integrating RFID [15] with Blockchain technology in the supply chain, focusing on the information management process within Blockchain applications. The author asserts that, due to the characteristics of Blockchain, the information stored on it can be entirely relied upon. In the case study addressing product traceability [16, 17], the implemented system is referred to as originChain. This system achieves product traceability by substituting the conventional centralized database with Blockchain data storage. The primary concept behind this system is to document the results of product sample testing conducted in the laboratory. While these research papers collectively contribute valuable insights into leveraging blockchain for anti-counterfeiting measures, a critical analysis reveals recurring research gaps. The absence of detailed cost analyses, insufficient consideration of potential collusion risks, scalability concerns within the blockchain network, and a lack of focus on real-world applicability highlight areas for future research. Addressing these gaps is crucial for ensuring the practical viability and effectiveness of blockchain-based anti-counterfeiting solutions.

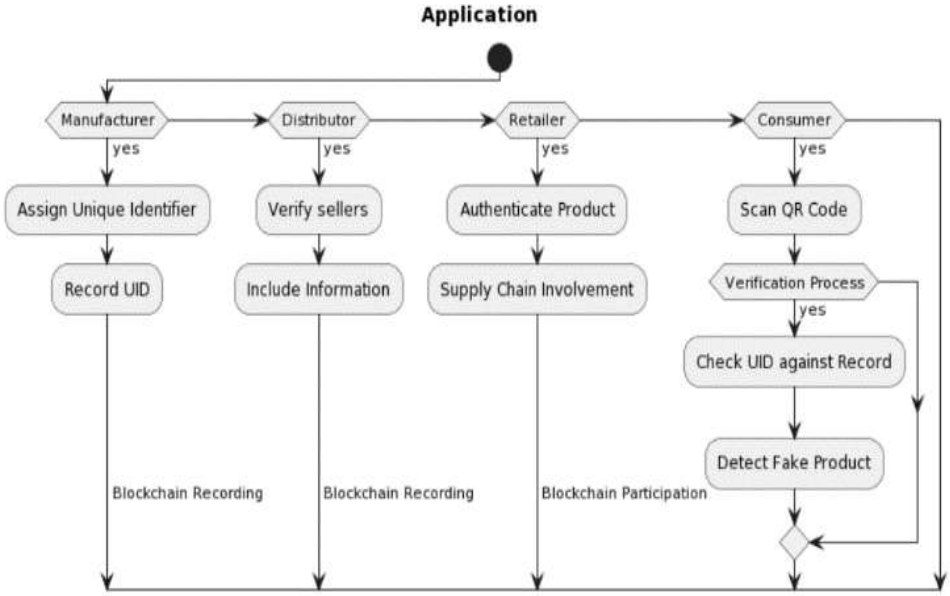

Figure 2: Flow of the application

3. METHODOLOGY

The pervasive issue of counterfeit goods has spurred global concern, impacting organizations, manufacturers, and consumers. In response to this escalating challenge, a transformative methodology is proposed, leveraging the capabilities of blockchain technology to establish a decentralized application (Dapp). The primary goals are to thwart counterfeit products, fortify transparency in supply chains, and enhance traceability and accountability.

E. System Architecture

Ethereum's smart contract functionality plays a pivotal role in ensuring the efficacy of the proposed system. The process involves the creation of self-executing contracts with pre-defined rules and conditions:

- UID Recording: The manufacturer module assigns a UID to a product and records it on the Ethereum blockchain.
- Verification Automation: Smart contracts automate the verification process, cross-referencing the product's UID against the blockchain record to authenticate its genuineness.
- Streamlining Processes: Smart contracts streamline the verification process, mitigating the need for intermediaries and ensuring the integrity of the supply chain.

The proposed decentralized application (Dapp) is strategically built upon the Ethereum blockchain, acting as the foundational infrastructure for recording and managing all transactions related to products. The intricate system architecture comprises various modules as depicted in Figure 2:

1. ***Manufacturer Module:***

- Unique Identifier Assignment: Manufacturers assign a Unique Identifier (UID) to each product, akin to a 16-digit Unique Aadhaar Card number.
- Blockchain Recording: Utilizing their MetaMask wallet, manufacturers record the UID on the Ethereum blockchain, creating an immutable digital identity for each product.

2. ***Distributor Module:***

- Digital Record Contribution: As products traverse the supply chain, distributors contribute digital records to the blockchain.

- Inclusive Information: The blockchain records encompass crucial information about the product, including its location, buyer details, pricing, brand, and seller particulars.

3. Retailer Module:

- Blockchain Participation: Retailers actively contribute digital records to the blockchain as the product moves through the supply chain.
- Supply Chain Involvement: Retailers add their unique insights, ensuring a comprehensive and unalterable record of the product's journey.

4. Consumer Module:

- Authentication Process: Consumers utilize their smartphones to scan the product's QR code, initiating a robust verification process.
- Access to Digital Records: Consumers gain access to all digital records associated with the product on the blockchain, starting from the manufacturer's entry to subsequent contributions by the supply chain modules.
- Fake Product Detection: The absence of valid records upon scanning the unique identifier (QR code) indicates the presence of a counterfeit.

F. *Verification Process*

The verification process unfolds systematically:

- UID Check: The product's UID is compared against the blockchain record.
- Smart Contract Actions: Smart contracts trigger predefined actions, such as payments to the manufacturer or distributor, upon successful verification.
- Fake Product Detection: In the event of a fake product, the smart contract unequivocally labels the verification status as "fake product."

G. *System Roles*

The proposed system is designed around four principal roles:

1. Manufacturer Module

Responsibilities: Manufacturers log into their accounts, generate QR codes for products, and add comprehensive product details to the Ethereum blockchain using their MetaMask wallet.

2. Distributor Module

Contributions: Distributors actively contribute digital records to the blockchain, ensuring a seamless and transparent supply chain.

3. Retailer Module

Active Participation: Retailers add their unique insights to the blockchain, actively participating in maintaining an immutable product journey record.

4. Consumer Module

Verification Process: Consumers utilize QR code scanning to validate the authenticity of the product, with the system displaying the verification status.

H. *System Operation*

The proposed system operates cohesively:

1. Manufacturer Module Activities:

Manufacturers log in, generate QR codes, and add comprehensive product details to the Ethereum blockchain using their MetaMask wallet.

2. Distributor and Retailer Module :

Distributors and retailers actively contribute digital records to the blockchain, ensuring a comprehensive

and unalterable record of the product's journey.

3. Consumer Module Verification:

Consumers utilize QR code scanning to validate the authenticity of the product. The system promptly displays the verification status, assisting consumers in distinguishing genuine products from counterfeits. This comprehensive methodology harnesses the synergy of blockchain technology, Ethereum, and smart contracts to combat counterfeiting effectively. By empowering consumers, enhancing transparency in supply chains, and automating the verification process, the proposed system aspires to safeguard manufacturers' reputations, prevent economic losses, and ensure customer satisfaction through the provision of only authentic products. The methodology signifies a pivotal step towards revolutionizing how we combat counterfeit products in the modern marketplace.

4. DISCUSSION

The envisioned system offers a collaborative platform for manufacturers and suppliers, empowering them to seamlessly contribute their distinct transaction details to the blockchain without altering each other's blocks. In the course of local testing, the system relies on the Ganache network, providing a controlled environment for testing the functionality. Truffle serves as the deployment tool for compiling and deploying smart contracts, ensuring the integrity and efficiency of the blockchain operations. To enable interaction with the Ethereum blockchain, the system integrates the Web3.js library. This library facilitates crucial actions such as reading and writing data from smart contracts, enhancing the overall functionality and responsiveness of the system. For seamless interaction with the Ethereum blockchain, the system leverages the MetaMask wallet, a browser extension designed for securely managing cryptocurrency transactions. Manufacturers and suppliers import their accounts from Ganache into MetaMask, creating a streamlined connection between the local testing environment and the Ethereum blockchain. To add supplier and manufacturer blocks to the blockchain, a secure confirmation process is implemented through MetaMask, ensuring the integrity and authenticity of each transaction. End-users are provided with a tangible means of verifying the supply chain's integrity by scanning a QR code associated with the product. This real-time system introduces a robust mechanism to distinguish between counterfeit and genuine products, offering consumers the assurance they need in their purchasing decisions. The QR code scanning functionality acts as a gateway for consumers to validate the authenticity of received products, adding an extra layer of trust to the supply chain. The adaptability of this real-time system extends beyond its initial application, offering a scalable solution that can be employed across diverse industries. Its potential goes beyond the singular purpose of distinguishing between counterfeit and original products; it lays the groundwork for a broader implementation in areas such as logistics, quality control, and supply chain management. In essence, the proposed system not only showcases the technical prowess of blockchain technology but also emphasizes the seamless integration of various tools and technologies to create a comprehensive and reliable solution. As industries continue to grapple with challenges related to product authenticity and supply chain transparency, this system emerges as a beacon of innovation, offering a practical and effective means of ensuring the integrity of goods in real-time scenarios.

A. Cost Analysis

The total gas you pay is divided into two components: the base fee and the priority fee (tip). The base fee is set by the protocol - you have to pay at least this amount for your transaction to be considered valid. The priority fee is a tip that you add to the base fee to make your transaction attractive to validators so that they choose it for inclusion in the next block [18]. A transaction that only pays the base fee is technically

valid but unlikely to be included because it offers no incentive to the validators to choose it over any other transaction. So the total fee will be as per eq 1

Gas units used * (base fee + priority fee) (1)

Consider an ETH transfer requires 21,000 units of gas, and the base fee is 10 gwei and a tip of 2 gwei. The total fee would now be equal to:

21,000 * (10 + 2) = 252,000 gwei (0.000252 ETH). [18]

5. CONCLUSION

The integration of blockchain technology into manufacturing processes not only grants manufacturers the ability to establish a unique and unalterable digital identity for each individual product, but also facilitates the seamless tracking and verification of critical product data throughout the entire supply chain. This revolutionary approach not only enhances transparency but also empowers consumers with the ability to effortlessly authenticate the legitimacy of a product, significantly mitigating the risks associated with counterfeit or fraudulent goods.

Moreover, by leveraging blockchain, manufacturers and suppliers gain a robust system to securely store product details, benefiting from the inherent properties of blockchain such as heightened security and data privacy. This ensures that sensitive information remains safeguarded on the network. As customers access the comprehensive supply chain history of a product, they can confidently verify its authenticity, instilling a sense of trust in the integrity of the goods they intend to purchase. This innovative system not only serves as a powerful deterrent to counterfeiting but also contributes to economic growth by fostering a marketplace built on genuine products.

The potential for transformation that is inherent in blockchain technology surpasses the boundaries of manufacturing and possesses the capability to be employed in order to tackle a multitude of obstacles across a wide range of sectors. The same decentralized and secure framework can be applied to combat fraud in healthcare, fortify the integrity of voting systems, enhance security in online shopping, and bolster confidence in banking transactions. The adaptability of blockchain promises a ripple effect across industries, ushering in an era of heightened reliability and trust in digital interactions.

Moreover, the deployment of blockchain systems that operate in real-time provides opportunities for the establishment of decentralized marketplaces that place emphasis on genuineness and openness. This not only reinforces consumer confidence but also serves as a formidable deterrent to fraud and counterfeiting in online transactions. As the traction of these decentralized marketplaces increases, there exists the potential to fundamentally alter the digital commerce landscape. This alteration will foster an environment where trust and authenticity are of the utmost importance, ultimately leading to a higher level of integrity within the digital economy. Our proposition of a decentralized blockchain system presents an innovative solution by incorporating progressive measures, whereby periodic dynamic verifications of product authenticity are implemented to enhance the mitigation of counterfeit products infiltrating the supply chain.

In summary, the incorporation of blockchain technology into manufacturing operations not only serves as a safeguard against the production of counterfeit products, but also establishes the basis for a profound transformation in diverse sectors. The capacity to guarantee genuineness, openness, and protection through blockchain possesses extensive consequences, offering the potential to reconfigure our approach to conducting transactions and engaging in digital interactions. As we persist in investigating the extensive capabilities of blockchain, its consequential influence on trust, security, and genuineness is positioned to make an enduring impression on the prospects of commerce and technology.

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