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Blockchain-Powered Product Authentication and Anti-Counterfeiting System

[1] K Deepa Shree, [2]Muskan kwatra, [3]Nitish Srinivasa, [4]Rahul Pokala, [5]Pallavi Harish
[1]Assistant Professor, [2] Student, [3]Student, [4]Student, [5]Student
[1]Computer Science and Engineering,
[1] Dayananda Sagar Academy of Technology & Management, Bengaluru, India

Abstract: Supply chain management faces challenges such as redundancy, poor coordination, and lack of transparency, leading to issues like product counterfeiting. Counterfeits harm legitimate businesses and are difficult to detect visually. Existing solutions like RFID tags, AI, and QR codes have limitations, such as susceptibility to duplication or high computational demands.This study proposes a blockchain-powered system to enhance counterfeit detection by securely tracking products' supply chain history. Blockchain's decentralized and immutable nature ensures transparency, traceability, and protection against data tampering, offering a robust solution to mitigate counterfeiting effectively. Its immutable nature prevents data alteration without consensus, thereby safeguarding information and minimizing vulnerabilities. This paper proposes a blockchain- powered system designed to detect and mitigate product counterfeiting effectively.

Keywords- Blockchain Technology, Product Authentication, Anti-Counterfeiting System, Supply Chain Traceability, Decentralized Systems, Immutable Ledger, Counterfeit Detection, Secure Data Sharing, Transparent Supply Chain, Blockchain in Supply Chain Management.

I. INTRODUCTION

The current global market poses a challenge in the sale of counterfeit products, especially affecting luxury goods, electronics, pharmaceuticals, and food industries. Besides causing business loss, it also poses threats to health and safety on the part of the consumers. For example, fake pharmaceutical products may lead to serious health problems, while defective electronics can cause malfunctions and accidents. Counterfeiting is a growing problem that affects almost every industry, with the UN estimating that the counterfeit market is worth US$250 billion annually. Companies face significant risks from counterfeiting, including lost revenue and damage to brand reputation.[1]. Counterfeiting also affects the brand reputation, as consumers unknowingly associate poor-quality counterfeit items with genuine brands, resulting in distrust and negative publicity. A renowned Blockchain application is the cryptocurrency Bitcoin, that has not only been effectively solving the double-spending problem but also it can confirm the legitimacy of transactional records without relying on a centralized system to do so. Therefore, any application using Blockchain technology as the base architecture ensures that the contents of its data are tamper-proof [2]. The need for an effective solution is urgent to protect consumers, restore brand trust, and secure supply chains. Blockchain technology, known for its transparency and immutability, offers a promising approach to addressing this issue. By integrating blockchain with QR codes, smart contracts, and decentralized ledgers, products can be tracked throughout their supply chain, providing consumers and suppliers with reliable authentication tools. Blockchain enables secure storage of product details, including manufacturing and ownership history, ensuring that product authenticity can be verified easily by scanning a QR code. Unlike traditional solutions, a blockchain-based system not only secures product data but also ensures real-time traceability, reducing the risk of tampering at any stage of the supply chain. This approach bridges the gap between manufacturers, suppliers, and consumers, fostering trust and accountability while enhancing operational efficiency. This paper proposes a blockchain-based anti-counterfeiting system designed to mitigate the risks of fake products in the market. By leveraging the decentralized and secure nature of blockchain, combined with supply chain transparency, the

system empowers consumers, vendors, and suppliers to verify product authenticity and trace its history in a tamper-proof environment.

II. LITERATURE REVIEW

2.1 Blockchain in Supply Chain Management

The lack of supply side traceability reduces customers' trust in platforms, resulting in economic and reputation damage to stakeholders [3]. Blockchain technology has changed the mode of supply chain management, since products can now be tracked clearly and securely. Wang et al. (2020) conducted a study identifying a system based on QR code and RFID tag combination as the one for tracing in the supply chain from manufacturers to retailers, through which verification by consumers could be attained via scanning QR codes. Malware detection has been a challenging task due to the ever- evolving nature of malicious software. Blockchain technology has emerged as a promising solution to enhance the security of malware detection systems. Gu et al. (2018) proposed a consortium blockchain-based malware detection system for mobile devices. The system uses a consensus algorithm to detect malware and share the results with other devices in the network [4]. Although the implementation of blockchain technology in a platform can overcome challenges posed by illegal manufacturers, a blockchain-supported platform charges an operating fee to legitimate manufacturers and retailers for product traceability and authentication [5].

2.2 Cryptographic Techniques for Authentication

Cryptographic techniques play a pivotal role in securing product authentication and preventing counterfeiting in the supply chain. One approach, as proposed by Shaik et al., involves the integration of **public and private keys** embedded into **QR codes** for each product. This ensures that only authorized parties can decrypt and access the product details, providing a layer of security against fraud. When a customer scans the QR code, the app can authenticate the product by decrypting the associated data using cryptographic methods. The system involves a **server-side check**, where the manufacturer or seller verifies whether the information in the QR code matches the product's original details stored in a secure database. However, while this method is effective in many cases, it faces certain challenges. QR codes can be **replicated** or **copied**, which means counterfeiters could potentially create fake QR codes that link to false product information. Therefore, reliance on QR codes alone might not be sufficient to prevent counterfeiting. To address this, Benatia and Baudry suggest integrating **traceability architectures** that enhance monitoring by leveraging **frequent transaction data**. These systems analyse **product trajectories** through the supply chain to detect anomalies and flag counterfeit behavior, ensuring a more reliable form of product authentication. By combining cryptographic QR codes with data analytics, these systems provide an added layer of verification, increasing the overall security of the process.

2.3 RFID-Based Anti-Counterfeiting Solutions

RFID (Radio Frequency Identification) technology is a robust solution for anti-counterfeiting in product tracking and authentication. RFID tags, which contain data about a product's identity, can be attached to products and read through radio waves by specialized RFID readers. While barcodes can only be read when the line-of-sight path is open, RFID tags do not require any such line of sight. This gives them a huge advantage in terms of tracking products through complex supply chains. The two kinds of RFID tags are passive and active. The former have no external power, whereas the latter are fitted with a battery, which emits unique identifiers when interrogated by RFID readers. This makes RFID a go-to technology in retail environments where issues of security and on-point product tracking are highly critical. As mentioned above, Khalil and Doss introduced a dual- protocol system using RFID technology to make the verification of products more reliable. The first protocol in this case refers to tag authentication, where only authorized and genuine tags are allowed to interact with the system. This prevents usage of the counterfeit RFID tags mimicking the genuine ones. In turn, the second protocol allows protection by data correction. By requiring that product information collected both throughout the supply chain remain similar, RFID information becomes impervious to such acts of manipulation or changing which would be necessary if alterations were to be undertaken over the product's pathway, ensuring its authenticity from when leaving the manufacturer to ending as a retail product.Despite the obvious advantages of RFID technology, most significant challenges exist that seriously limit its wider adoption to anti-counterfeiting systems. One such major threat is tag cloning, where counterfeiters manufacture

legitimate RFID tags and attach them on forged products. This can make RFID-based systems fallible because cloned tags mimic legitimate ones. To address this, RFID solutions can incorporate advanced **cryptographic techniques** or **public key infrastructure (PKI)**, where each tag is encrypted and can only be verified by an authorized reader. These encryption methods add an additional layer of security to prevent unauthorized cloning. Overall, RFID-based systems offer significant potential for anti-counterfeiting, but their success depends on addressing vulnerabilities such as **tag cloning** and **DoS attacks**. Combining RFID with other security measures like **cryptography** and **blockchain** can enhance its effectiveness and provide a more comprehensive solution for verifying product authenticity in the modern supply chain.

2.4 AI and Machine Learning in Fake Product Detection

Technological innovations have proven themselves to be potent tools in detecting counterfeit products. AI-based solutions are capable of processing complex patterns in product data, such as logos, aesthetics of packaging, and other visual features, to determine whether a product is authentic or not. Daoud and Vu developed a system based on Faster R- CNN (Region-based Convolutional Neural Networks), which is an advanced deep learning framework, to detect logos on counterfeit items.This methodology is fairly efficient for distinguishing between subtle differences present between authentic and forged logos, making it particularly suitable for identifying imitation luxury products or branded goods. In brief, the methodology includes deep learning algorithm training on both legitimate and counterfeit products using a total database. After the training period has been completed, the algorithm or the model can be used in detection of new images of product to identify anomalies that describe counterfeiting. While AI-based detection systems may have several drawbacks, few of them include: heavy resource requirements for training by seeking large volumes of data alongside strong computational power.In addition, AI models often have difficulties identifying tag reapplication attacks where the counterfeiter removes a legitimate tag from a legitimate product and places it on an illegitimate item. This type of attack exploits the system's reliance on visual features, such as logos, which may appear legitimate even if the product itself is not. This notwithstanding, AI remains a potentially feasible option for counterfeit detection and particularly in combination with technologies such as RFID and blockchain. With advancements in models and improvement, AI models will continue to show greater efficacy in the detection of counterfeits with greater precision and speed.

2.5 Computer Vision-Based Assessment of Autistic Children: Analyzing Interactions, Emotions, Human Pose, and Life Skills

Despite the progress made with technologies like QR codes, RFID, and AI, counterfeit detection systems still face significant limitations. QR codes can easily be copied or replicated, allowing counterfeiters to use fake codes that link to fraudulent product information. Similarly, RFID tags are vulnerable to cloning, and AI systems, while promising, require extensive training data and computational resources, making them unsuitable for real-time detection in some cases. In addition, present systems often do not have traceability of product authenticity throughout the supply chain, thus providing an avenue for counterfeiters to exploit. This would mean that by using blockchain technology, the above problem can be addressed by having a decentralized ledger recording every transaction that involves a product from manufacturing to retail. Every product will have an RFID tag or QR code with a unique identifier linked to its immutable blockchain record, so no information can be altered or falsified. The inherent transparency of the blockchain technology allows all participants of the supply chain, that is, manufacturers and consumers, to receive real-time information regarding the authenticity of a product. This characteristic provides a holistic approach to the problem of counterfeit goods, which ensures that every participant of the supply chain can verify the authenticity of a product before it reaches the consumer.Smart contracts provide a number of benefits over traditional contracts. Because they are written in code and executed automatically on the blockchain, they can be enforced without the need for a third-party intermediary. This makes the execution of the contract more efficient and cost-effective. Additionally, because the terms of the contract are written into the code, they are transparent and easy to verify, reducing the risk of disputes or misunderstandings [6].In summary, blockchain technology addresses many of the limitations faced by traditional authentication systems by providing an immutable, transparent, and decentralized platform for product tracking. Combined with **RFID**, **QR codes**, and **AI**, blockchain creates a powerful ecosystem for ensuring product authenticity and preventing counterfeiting architectures including convolutional neural networks, deep belief networks, autoencoders, generative adversarial networks, and ensembles of networks. These architectures have achieved the best performance on various benchmark datasets as they concentrated on the two most critical issues of overfitting and expression-unrelated variations.

III. RESEARCH METHODOLOGY

Our product anti-counterfeiting system solely based off blockchain, it comprises of three specific roles, **the Manufacturer Role**, **the Supplier Role** and **the Consumer Role.**

3.1 Manufacturer Role:

Login and Product QR Code Generation: The process initiates when the manufacturer logs in into his dedicated account. Each product is required to generate a QR code, wherein essential product details like type, batch number, manufacturing date, and other relevant attributes have to be added.
Blockchain Integration: After the input of product data, the manufacturer uses his Ether wallet and creates a block in Ethereum blockchain. Product information would be stored in it, making sure that their entry would be safe.
Security and Authentication: The user ID in the local database is mapped with their Ethereum wallet address by the manufacturer. This two-factor authentication will only allow an authorized manufacturer to add the product details in the blockchain, which would guarantee data integrity and eliminate the possibility of fraudulent entries. If login credentials or wallet address does not match, the block will not be added, hence the records will be safe and authentic.

3.2 Supplier Role:

QR Code Scanning: The supplier plays a pivotal role in maintaining the flow of the product's information. When a product arrives at the supplier's location, they log into their own account and scan the **QR code** on the product. This QR code contains the product's transaction history and other essential details entered by the manufacturer.
Updating Product Details: After scanning, the supplier can view all relevant product information stored in the blockchain, such as its origin and previous transactions. The supplier then adds their own details, including the **shop destination** or location where the product is being distributed, and pushes this updated information into the blockchain.
Transparency and Access: The updated blockchain record can be accessed by future participants in the supply chain, including customers, ensuring full traceability. All information related to the product's journey remains transparent and secure.

3.3 Customer Role:

Verification and Testing of Product Integrity: Once the product reaches the customer, the recipient can then verify the authenticity of it by scanning the QR code provided. This QR code will allow a detailed account of all the supply chain that is involved in the product-from the manufacturer to its destination.

Counterfeit Detection: If historical supply chain data of a product depicts inconsistency with the actual location or if data depicts inconsistency, then a consumer might feel that QR code has been duplicated, and therefore, the product does not carry any authenticity. In the seller's part, the consumer can verify whether the seller has a sales relationship with the manufacturer and also verify whether the seller's stock hasn't been yet sold out. In the manufacturer's part, the consumers can prove that their identity is consistent with their address and in the case of a well-preserved contract address, the consumers can obtain individual purchase records and product status in their product [2].This framework ensures full traceability from the manufacturer to the end-user, preventing counterfeiting at all points in the supply chain and ensuring authenticity at all times. The application of blockchain technology and QR codes in this framework provides enterprises and consumers with an immutable and transparent record of product transactions.

IV. CONCLUSION

This study shows that blockchain technology can effectively address product counterfeiting and supply chain inefficiencies by enhancing transparency, traceability, and decentralization. Blockchain may not always be beneficial to all stakeholders; however, it can result in increased profits for legitimate manufacturers when their production costs are high and can encourage retailers to trade on blockchain-based platforms, particularly in price-sensitive markets. The study highlights that the blockchain technology overcomes problems of information asymmetry and uncertainty in e-commerce and helps increase trust among stakeholders with a

reduced possibility of counterfeit. However, the still persisting challenges are scalability, latency, and speed of transaction processing. First of all, preliminary investigations into the blockchain technology reveal the ability to securely distribute information along the supply chain, from which consumers can trace and identify counterfeit products, yet issues related to scalability remain unsolved for its feasibility in practical environments. Additional research and subsequent pilot runs are necessary to assess the scalability of blockchain technology, especially with regard to international supply chains, and to determine its compatibility with existing legacy systems.

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