Dynamic Driven Chemical Authentication for Enhanced Supply Chain Security

Dr. Chepuri Samson[1*], Dr. L K Suresh Kumar[2]

[1]*Professor, Department of Information Technology, MVSR Engineering College, Hyderabad, Telangana, India*
ORCID iD: 0009-0004-7296-9299

[2] *Associate Professor, Department of computer science and Engineering), University college of Engineering, (A), Osmania University, Hyderabad, Telangana, India*

Abstract:
Precursor chemicals, vital for industries like pharmaceuticals and agriculture, are often diverted into illicit drug production despite strict regulatory frameworks. This paper proposes a blockchain-driven anti-counterfeit mechanism aimed at ensuring product authenticity through a transparent, secure, and tamper-proof system. By leveraging blockchain technology, smart contracts, and decentralized applications, there is a creation of a robust, immutable record for every product's lifecycle from manufacturing to end-consumer purchase. The system enables real time product verification offering both consumers and manufacturers a tool for ensuring authenticity and mitigating the risks associated with fake products. The proposed approach has the potential to revolutionize anti-counterfeit measures in various industries, particularly in high-risk sectors by ensuring transparency and safeguarding consumer trust.

Keywords: Blockchain Technology, Product Counterfeit detection, Dynamic Driven Chemical Authentication, QR Code, Supply Chain Management.

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1. Introduction

In today's globalized economy, the pervasive issue of counterfeit products poses a significant threat to various industries, ranging from pharmaceuticals to luxury goods. Blockchain's potential is harnessed to establish a robust anti-counterfeit mechanism in the realm of product authentication. Blockchain's relevance in the supply chain is clearly given in [1]. It allows 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. The study in [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. This paper, entitled "Blockchain-Driven Anti-Counterfeit Mechanism for Product Authentication," seeks to tackle this challenge by harnessing the power of blockchain technology. The central focus is on creating a transparent and tamper-proof system for product authentication, using technologies such as Solidity, MetaMask, and Ganache.

This paper has a comprehensive scope aimed at harnessing potential of blockchain technology to combat counterfeit products. The paper involves the integration of Solidity to develop smart contracts deployed on Ethereum blockchain. A pivotal aspect of the paper is the implementation of QR code generation system, where each product will be uniquely associated with a QR code linked to blockchain record. This QR code serves as a user-friendly and accessible means for consumers, retailers, and other stakeholders to authenticate legitimacy of a product, enhancing the overall transparency of the supply chain. The scope also encompasses the development of a user friendly decentralized application (Dapp) that acts as interface for users to interact with the blockchain. MetaMask integration ensures secure transactions, while Ganache serves as a local blockchain environment for efficient development and testing. Manufacturers will have the capability to register product details on the blockchain, creating a secure digital identity for each product. The paper further aims to provide real-time authentication feedback to users through smart contracts, reinforcing consumer trust and confidence. Additionally, the exploration of features to enhance supply chain transparency adds a layer of accountability to each stage of the product's journey, contributing to the overarching goal of eradicating counterfeit products from the marketplace.

The surge in counterfeit products across diverse industries represents a pressing challenge in the current global marketplace. This pervasive issue jeopardizes consumer safety, undermines economic stability, and erodes the reputation of authentic brands. The lack of a comprehensive and foolproof mechanism for product authentication exposes consumers to potential risks, particularly in critical sectors such as chemical for pharmaceuticals.

Efforts to combat counterfeiting must prioritize multi-faceted strategies that enhance product traceability and verification. One approach involves leveraging advanced technologies such as blockchain to create an unalterable digital ledger for tracking products throughout the supply chain. This not only increases transparency but also allows for real-time verification of product authenticity. Additionally, implementing robust anti-counterfeit labels and packaging solutions, such as QR codes with detailed product information, can empower consumers to easily verify the legitimacy of their purchases.

The rest of the paper is organized as follows. Section 2 describes the Related Work. Proposed approach is explained in Section 3. Section 4 deals with Results and Discussion. Conclusion is drawn in Section 5.

2. Related Work

The landscape of existing solutions for combating counterfeit products reflects array of approaches across industries. Traditional methods often rely on centralized databases and physical authentication features like holograms or barcodes. Emerging technologies have innovative solutions with some companies implementing Radio-Frequency Identification (RFID) tags for real-time tracking. In the digital realm, blockchain technology has emerged as a transformative force in the fight against counterfeiting. Notable examples include IBM's Food Trust Network, which employs blockchain to trace the provenance of food products and Rechains, a blockchain platform that integrates NFC(Near Field Communication chips) to verify the authenticity of luxury goods.

Radio Frequency Identification [3] tags for real-time tracking, while RFID tags for improved traceability providing immutable records of a product's journey from manufacturing to distribution, they do not provide a detailed analysis of cost associated with implementing and maintaining a blockchain based system for fake product detection. This is an important consideration as businesses need to be aware of the potential implications before adopting such a system , whereas generating a QR code for each product and storing the QR code[4] and product information on the blockchain can provide real-time verification and its resistance to counterfeiting. The paper does not address the issue of how to ensure that the information stored and blockchain is accurate and up-to-date. Another approach where manufacturer can add product details and system generates QR code [5] which can be used by retailers and distributors for tracing and even by consumers to ensure purchasing of original products. Manufacturer can be benefitted if product is fake then the location of the user will be accessed with permission and alert will be sent to manufacturer who can take further legal actions on distributor, retailer. some limitations, such as its reliance on user input and its potential for scalability issues.

[6] presents 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. [7] 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 [8], 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. [9] 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. [10] introduces a Quick Response code-based identification system, enabling end-users or distributors to verify product authenticity using smartphones. However, itlacks blockchain or other supply chain tracking mechanisms, leaving room for potential counterfeiting.

3. Proposed Approach

The approach involves QR code based authentication and blockchain backed traceability to verify chemicals in the supply chain. This approach ensures secure, tamper proof tracking and real time counterfeit detection without the need for physical sensors. Each chemical batch is assigned a unique, encrypted QR code linked to its verification details. Blockchain Smart Contracts ensure immutable record keeping, automate validation, and trigger.

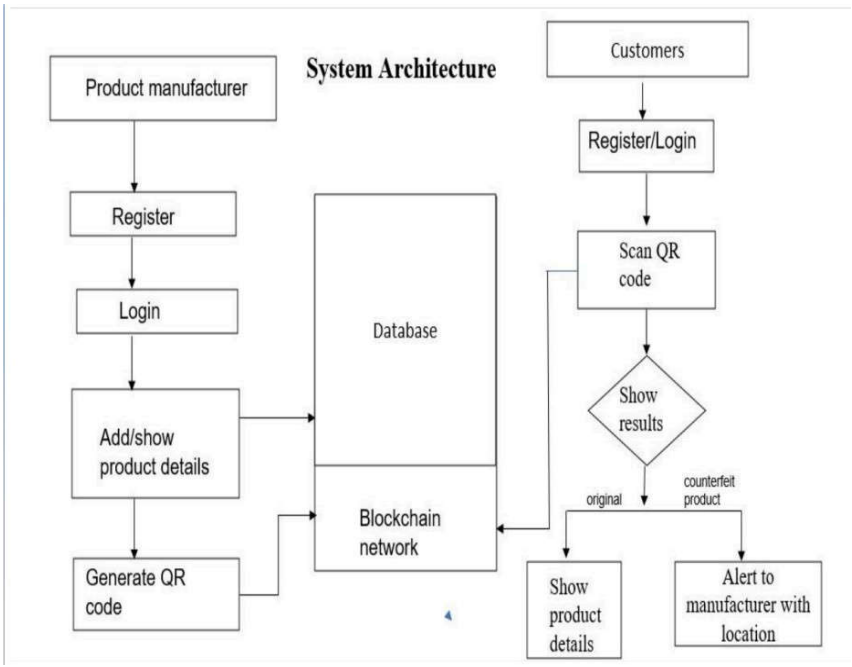

Figure 1, System Architecture

The system architecture depicted in the image outlines a blockchain-based product authentication framework. Manufacturers first register and log in to the system, where they can add or view product details. The system then generates a unique QR code for each product, which is stored in a blockchain network for secure and tamper-proof tracking. Customers, after registering or logging in, can scan the QR code to verify product authenticity. If the product is genuine, its details are displayed. However, if a counterfeit product is detected, the system alerts the manufacturer with the user's location (with permission), allowing legal action to be taken against fraudulent distributors, retailers, or manufacturers. This approach enhances supply chain transparency and helps in combating counterfeiting.

3.1 Methodology

The system employs QR code-based authentication and blockchain-backed traceability to verify chemicals in the supply chain, ensuring secure tracking and real-time counterfeit detection without physical sensors. Each batch is assigned a unique encrypted QR code linked to verification details, while blockchain smart contracts provide immutable record-keeping, automate validation, and trigger counterfeit alerts. The workflow involves generating unique QR codes storing batch details, verifying products by retrieving blockchain records upon scanning, and authenticating them by checking QR code validity against blockchain entries. If discrepancies arise, the system flags the product as counterfeit and notifies the manufacturer with GPS details. To optimize security and efficiency, dynamic QR code refresh minimizes replication risks, smart contract optimization reduces gas costs, and batch verification enhances concurrent processing. However, challenges such as incomplete requirements, limited resources, changing specifications, and email configuration complexities arise, along with performance issues like browser compatibility, blockchain interaction delays, frontend security risks, and email-sending latency. Solutions include asynchronous processing to handle emails efficiently, using environment variables for secure configurations, and implementing robust error handling and logging for better troubleshooting. These optimizations improve system efficiency, security, and scalability while ensuring a seamless user experience.

4. Results and Discussion

4.1 Experimental setup

The development environment setup involves installing essential tools such as Node.js (v16.20.0), npm (v7.5.1), Truffle (v5.6.7), Ganache (v7.5.0), Solidity (v0.5.16), and Web3.js (v1.7.4). A project directory (DDCAFSCM) is created, dependencies are installed, smart contracts are compiled using Truffle, and a local blockchain is set up with Ganache. MetaMask is configured with network ID 5777 and RPC server

http://127.0.0.1:7545, followed by deploying contracts with Truffle and starting the server via `npm run dev`. The paper structure includes backend, frontend, smart contracts, migrations, and documentation. Technical challenges include incomplete requirements, limited resources, changing specifications, email configuration issues, environment setup complexities, and API endpoint handling. Performance challenges involve browser compatibility, frontend responsiveness, security risks, email latency, and scalability concerns. Solutions include asynchronous processing for efficient email handling, environment variables for secure configuration, and robust error handling and logging for better application performance and reliability. Implementing these strategies ensures a streamlined development process with enhanced security, scalability, and efficiency.

4.2 Results

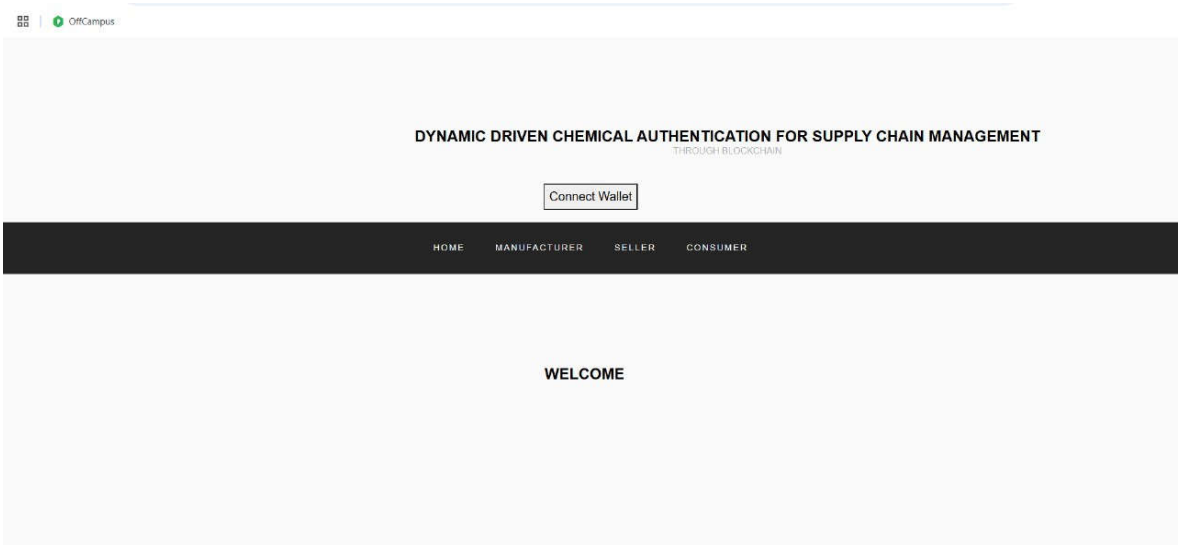

Figure 2. Main Page

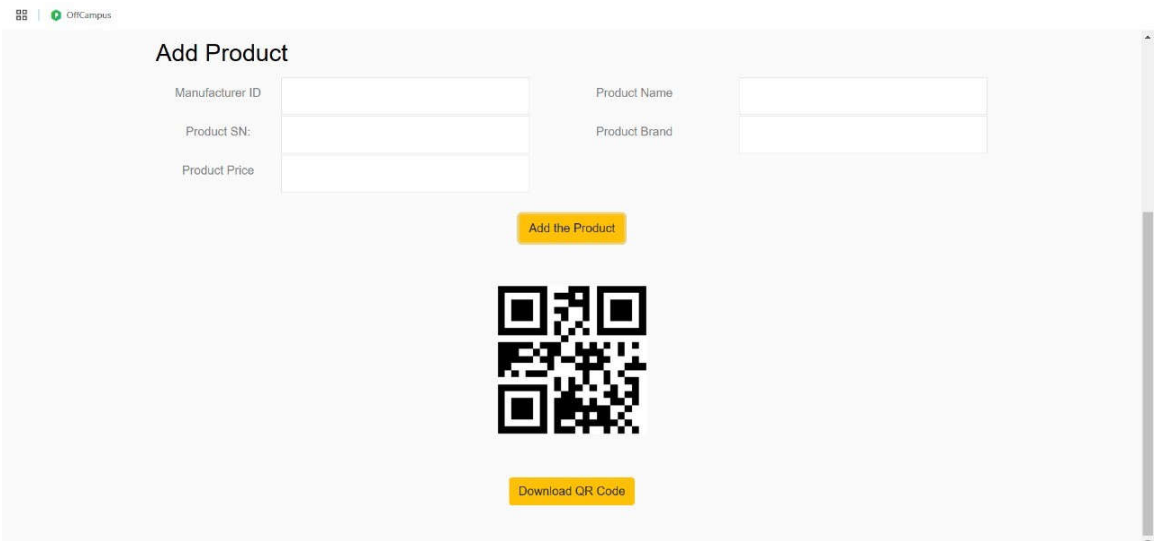

Figure 3 Adding Products

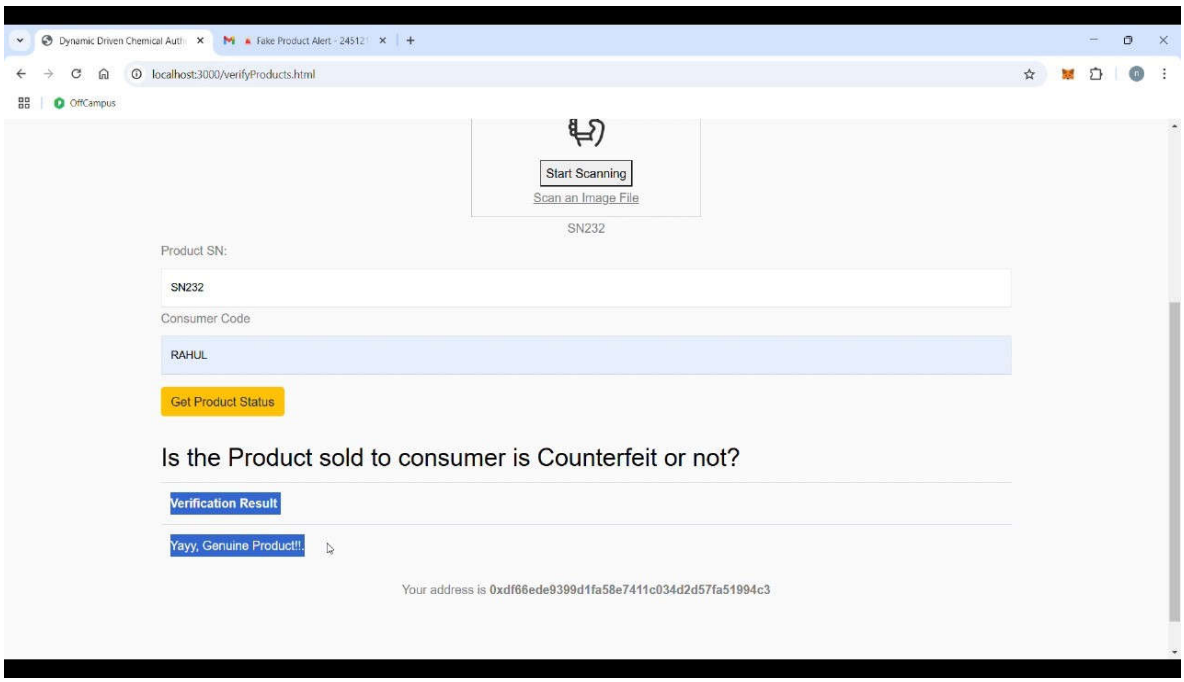

Figure : 4 Counterfiet verification

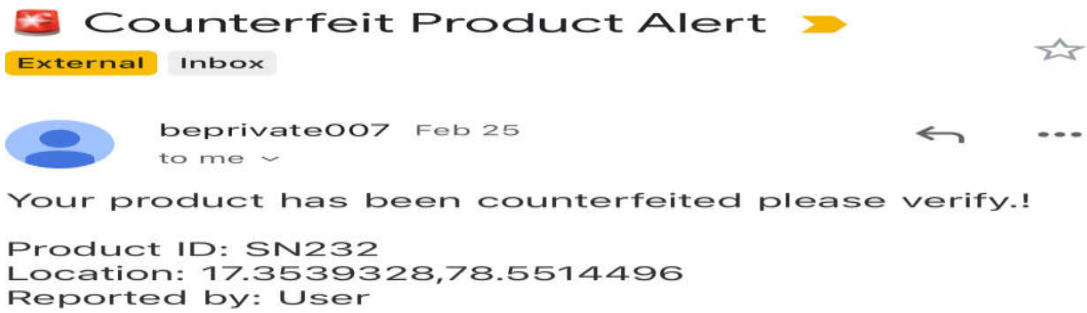

Figure 5. Location to Mail

4.3 Discussion

This blockchain-based system provides a secure and efficient way to combat counterfeit chemical products by assigning each item a unique QR code tied to verifiable digital records. Scanning the QR code allows users to instantly check a product's authenticity, while smart contracts ensure that only authorized parties can modify records or transfer ownership. The system promotes transparency and trust across the supply chain, though successful implementation will depend on industry collaboration and user adoption. Overall, it presents a strong step toward reducing counterfeit risks in the chemical sector.

5. Conclusion

In this paper, we have implemented a novel blockchain based system to combat counterfeit chemical products. The system assigns each chemical product a unique QR code containing its digital identity such as manufacturing details, supplier information, and authenticity certificates that is recorded on an immutable blockchain. When a QR code is scanned using a smartphone, the system retrieves and verifies the product's record, ensuring its genuineness. Smart contracts automate ownership transfers and restrict modifications to authorized parties, preventing counterfeiters from altering records.

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