Journal of Engineering and Applied Research (JEAR)

Technical and Vocational University

Winter & Spring 2024, Vol. 1, No. 1, p. 73-92

Journal Homepage: https://jear.tvu.ac.ir/

doi:10.48301/JEAR.2024.444098.1019

TVU

Revolutionizing Product Exchange: Implementing Blockchain-NFT Technology for Ensuring Trust in Product Transactions

Sina Khoshgoftar[1], Hadis Feizi[2], Motahareh Dehghan[3*]

[1,2]MSc, Department of Industrial and Systems Engineering, Tarbiat Modares University, Tehran, Iran.
[3]Assistant Professor, Department of Industrial and Systems Engineering, Tarbiat Modares University, Tehran, Iran.

ARTICLE INFO

Article Type:
Original Research

Received: 02.18.2024
Revised: 03.25.2024
Accepted: 04.07.2024

Keyword:
Product Counterfeit
Blockchain
Smart Contract
Non-Fungible Token
Anti-Counterfeiting

***Corresponding Author:**
Motahareh Dehghan
Email:
m_dehghan@modares.ac.ir

ABSTRACT

Competition for a larger market volume has led to increased production of counterfeit products. The challenge of distinguishing between the original product and the counterfeit leads to losing customer confidence in the products available. This problem can lead to financial losses and significantly negatively impact businesses. In this paper, a novel system architecture based on blockchain technology is developed to ensure the authenticity and identity of products by generating a non-fungible token (NFT) for each product. When the buyer receives the NFT for a purchased product in his wallet, the buyer's payment is automatically transmitted to the seller, providing security to both parties involved in exchanging goods and transactions within the system. The system transaction cost is evaluated by analyzing the gas consumption across various blockchain networks, which shows the potential of the proposed system to mitigate the existing challenges within the supply chain.

E-ISSN: 3060-6357

Introduction

Counterfeiting in supply chains is a critical challenge in global product development. They can significantly impact both human health and the economic viability of companies [1]. The complexity and multiplicity of stakeholders in a supply chain can make it vulnerable to counterfeiting. Counterfeit goods are typically products that are fraudulently manufactured or mislabeled to give the appearance of genuine products, often making false claims about their identity or origin [2]. The consequences of using counterfeit and pirated products can range from mild health complications to severe problems that can even lead to death in extreme cases. In addition to health risks, significant financial costs to industry and national economies cannot be ignored. Unfair competition, often resulting from illegal acts, can adversely affect a brand's reputation and undermine customer confidence [1]. The prevalence of counterfeit products in the marketplace is increasing, resulting in lost sales, damaged reputations, and financial losses. This situation poses a severe threat to uninformed buyers. Manufacturers, in particular, are affected by this challenge and face significant damage in terms of brand integrity and revenue [3].

Implementing an efficient traceability system is an effective measure for preventing counterfeiting and fraud in the supply chain. A traceability system includes various tools and procedures for identifying, linking, recording, storing, verifying, and accessing information. Ensuring product authenticity and trust in exchange, facilitating high-speed, low-cost transactions, and ensuring ease of use for all users are paramount goals of the proposed solution. It is essential to design a user-friendly interface that simplifies the interaction process for all stakeholders involved in the product exchange. Intuitive UI design enhances the system's usability and contributes to building customer trust by providing a seamless and transparent experience. By prioritizing user experience and accessibility in the proposed system design, users were empowered through provided tools and resources necessary to navigate the platform effortlessly regardless of their technical expertise. When defective products are identified, the traceability system provides all the necessary information to recall the problematic product or batch successfully. Thus, it serves as a solution to ensure the security and stability of companies, their rapid response in times of crisis, their protection against malicious acts, and the overall improvement of operations by uncovering the root causes [4].

Given advances in technology and the increasing need for security and prevention of counterfeiting and fraud in the supply chain, various approaches have been explored to ensure the security and reliability of tracking systems [5]. In the past, tracking systems typically functioned separately from anti-counterfeiting systems. However, with this method, consumers have limited access, and the possibility of fraud is greater [6].

As research has progressed, automatic traceability systems have been developed. These systems use barcodes and radio frequency identification (RFID) tags. Product information is stored in a central database, allowing for more accurate tracking [4]. However, retrieving the information from the tags is complicated. The cost of producing electronic tags is high, and these systems can be simulated and imitated, which affects their reliability [7].

Blockchain technology is widely used in this field considering the development of current tracking systems. This technology was first used in 2008 in e-commerce systems. Blockchain is currently used in various industries, including supply chains, transportation, food, pharmaceuticals, and banking, and will likely be the most widely used in the future [8].

Many companies are exploring using blockchain technology to ensure product authenticity and combat counterfeiting [3]. A blockchain is a decentralized and distributed digital ledger that securely stores transaction information in interconnected blocks in databases. This decentralized database, managed by a network of participants, is known as distributed ledger technology (DLT), a particular type of DLT that records transactions with immutable cryptographic signatures. The name of the hash was recorded. In addition, blockchain technology enables real-time monitoring and rapid identification of suspicious activities in the supply chain [9]. Owing to the decentralized nature of Blockchain, no single entity can have complete control over data, which reduces the risk of tampering or fraud. Smart contracts, self-executing contracts with predefined rules encoded in the Blockchain, can automate specific verification processes and enforce compliance throughout the supply chain [10]. Blockchain technology has shown promise in preventing the proliferation of counterfeit goods in the marketplace. In addition, some blockchain systems are equipped with smart contracts that set rules and conditions for tracking products. These contracts also enable the automatic and mandatory execution of rules in the system. For example, suppose a product in the supply chain is illegally modified or deviates from the specified path. In that case, the smart contract can trigger actions such as notifying the relevant owners or stopping the product's sale [10].

By combining different traceability approaches and advanced technologies, it is possible to create an effective supply chain traceability system that ensures the safety and sustainability of operations and guarantees the complete traceability of products, quality, and authenticity. In addition, this system can transparently share product information in the supply chain and minimize the possibility of counterfeiting and fraud. Researchers have also explored the integration of radio frequency identification (RFID) technology, barcode scanning, and machine learning as additional features in blockchain-based supply chain technology to combat counterfeiting effectively [11].

The main objective of the proposed study was to develop a secure and reliable product-tracking system based on creating a unique NFT for each product produced by manufacturers, which will improve the detection of counterfeit products and strengthen supply chain security. The primary purpose of this study can be summarized as follows:

- Designing a robust system to enhance customer confidence about the available products in the market. This system used an NFT to ensure the originality of the product.
- Design a system that provides the ability to perform transactions at high speeds with low costs, using the existing resources.
- Designing an easy-to-use system; the system should be easy to use by all users, even those without special technical knowledge.

Related work

The supply chain is a complex and comprehensive system that includes various processes and activities from production to final consumption of products. It includes raw material sourcing, product manufacturing, distribution, delivery, and customer service [12]. However, one of the major challenges in the supply chain is the proliferation of counterfeit products and fraud, leading to a significant loss of public trust and causing economic damage [13]. Due to the critical role of the supply chain in the global economy, extensive research has been conducted to detect and combat counterfeiting [14].

As shown in Figure 1, various approaches have been developed to detect counterfeit products in the supply chain. These are mainly based on item classification and include

- Labeling techniques (both overt and covert technologies),
- Information technology solutions (such as the Internet of Things, Blockchain, and machine learning), and
- Laboratory techniques such as genetic and chemical methods [4].

Figure 1. Classification Framework of Traceability Approaches [4].

Among these approaches, Blockchains have been proposed as an innovative and popular solution to prevent the production and distribution of counterfeit products. This method is recognized as one of the leading methods for product tracking in various industries. In particular, the food and healthcare sectors have become prominent research areas for implementing comprehensive traceability concepts; the following table briefly overviews traceability methods used in various industries [4].

Table 1. Pivot Framework Classification Table [4].

	Automotive	Clothing	Electronics	Food	General	Health	Logistics	Luxury	Total
Blockchain	2	1	1	31	16	22	4	1	78
Chemical Methods				9		2			11
Covert Technologies		2		10	2	2			16
Genetic Methods			1	24		1			26
IoT		1	7	15	14	10	4		51
Machine Learning			1	9	3	3			16
Overt Technologies		1	1	6	5	6			19
Total	2	5	11	104	40	46	8	1	217

In recent years, the use of blockchain technology in tracking systems has attracted much attention in various industries. Several studies have been carried out to prevent counterfeiting in supply chain management. For example, one study presented a product ownership management system that uses an electronic product code (EPC) to allow customers to search for and verify counterfeit products [15]. Another study proposed a blockchain framework for device tracking that includes confirmation-based ownership transfer. In this framework, confirmation of the recipient's transaction is required after the sender initiates the transfer of ownership. This facilitates automatic reporting of product loss in transit, human error, or delivery delays [16]. Another solution presented was to use the distributed ledger tag as a public ledger to record critical supply chain events and ensure that only data hashes of actual product transactions are stored [17]. In addition, a traceability framework for e-commerce supply chains that combines blockchain-based models with a distributed consensus structure, blockchain framework, and data management has been developed. The framework also uses a hierarchical deterministic wallet for key management at different levels. Moreover, a traceable product label has been developed to verify product origin, information, and ownership effectively [8]. Other research includes implementing a blockchain-based architecture for quality tracking and commodity assurance of steel products using the industrial Internet of Things (IoT). This approach addresses common problems of traditional information systems such as incomplete information analysis and poor responsiveness [18]. Similarly, a blockchain-based solution for the supply chain of agricultural products has been proposed to ensure traceability and elimination of counterfeit goods [19].

Traditional supply chains face vulnerabilities, increased costs, complexity, lower quality of service, traceability problems, and the impact of counterfeit products. Although existing solutions have brought improvements, limitations are still related to accurate tracking, presence of goods, fraud, scalability, identity registration, data privacy, and data storage [20]. Since the introduction of blockchain technology, various decentralized storage systems have been used for data storage. By using innovative solutions based on blockchain technology, it is possible to overcome the challenges faced by traditional supply chains and significantly improve their performance and security. One of the proposed solutions is using non-fungible tokens (NFTs) to confirm the authenticity and qualification of products in the supply chain. These tokens act as unique identifiers for each product, minimizing the possibility of fraud and tampering in the supply chain.

This research aimed to develop a secure, reliable, and user-friendly system for identifying counterfeit products in the supply chain. This system is based on blockchain technology and the use of NFT, which can confirm the qualification and authenticity of each product and minimize the possibility of fraud in the supply chain. The proposed system features high speed, low computational cost, and ease of use for users. By creating NFT for each product and implementing dynamic authentication, the system improves the efficiency of the supply chain.

Blockchain-based Solution

This section explains the technical terms and the system architecture of the proposed design for detecting counterfeit products.

The aim of this section is to introduce and describe the architecture of the proposed system and its different components. In the proposed solution, blockchain technology and smart contracts enable customers to determine a product's authenticity and identity accurately. This blockchain-based solution involves stakeholders, including product manufacturers, suppliers, regulatory organizations, and final consumers. In this solution, a non-fungible token is used to generate a unique identity for each product in the system. Matching the NFT produced for each product with basic information such as serial number, manufacturer, and quick response code, creating a unique identity for each product, and saving the history of product ownership guarantees that the user is buying the original product.

Each user in the system has specific access to the blockchain network. For instance, only the manufacturer's role can call the NFT creation function in the NFTCreator smart contract while other users can use other functions based on their role within the system. Additionally, it is possible to track the ownership and authenticity of the product during the transaction to ensure its authenticity. Figure

2 displays the proposed solution's general architecture, which is comprised of three fundamental layers. The primary servers of the system, responsible for maintaining transactions and system data, are located at the lowest level. The software layer contains the blockchain network and smart contracts, which provide the necessary platform for transactions and implementing this solution. This section also allows for the use of various types of blockchain networks. Finally, users can access the system at the highest level by joining and utilizing smart contracts.

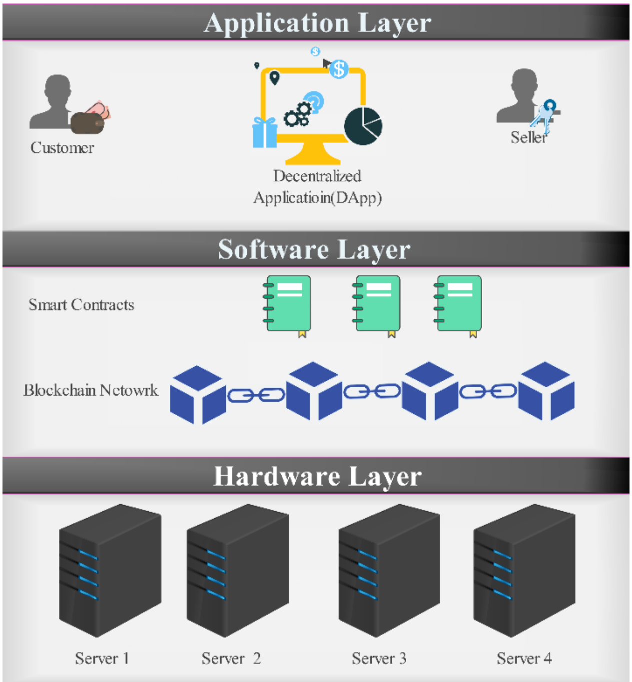

Figure 2. The architecture of the proposed system.

In the proposed system, the process begins with registering a new product. In this phase, the product manufacturer records all the product details in the system. This includes entering product details such as name, price, description, and product image. Once the product is registered in the system, suppliers can view the added products and select the desired ones. When suppliers select the product, they send the payment transaction to the blockchain system and start the process. The tokens required for this transaction are also stored in the system; the supplier buys the required tokens and uses them to purchase the product. In this process, product tokens are purchased by the system and stored in the supplier's wallet. If the purchase request is approved, a non-fungible token (NFT) is generated for the product, and ownership of the product is transferred to the supplier. During this process, an NFT is created with product details such as name, description and ownership, and ownership is transferred from the system to the supplier. If the user wants to buy or sell the product, they start the transaction. They select the desired product and send a buy or sell request to the blockchain system. The blockchain system receives the request and confirms the transaction. This process includes verifying the authenticity of the request, checking the relevance of the transaction (such as stock and the accuracy of the information), and creating a transaction record in the blockchain system; once the transaction has been confirmed, the product is finally sent to the supplier, and the transaction is recorded as a successful activity in the activity diagram. Figure 3 shows the activity diagram of the proposed system.

Figure 3. The activity diagram of the proposed system.

In the first step, this section describes the details and introduction of the critical members of the proposed system, and in the next step, the executive processes for the exchange of goods in the system are described.

Stakeholders and components

In this section, the central role of users in the blockchain-based counterfeit detection system is explained, and their main interactions with the system are outlined. It then presents an innovative blockchain architecture based on non-fungible token (NFT) technology, which serves as a solid foundation for identifying and authenticating each product within the system. The project's technical implementation is then discussed, providing a comprehensive breakdown of the individual smart contracts and enabling a detailed understanding of how the system works.

1- **Manufacturer**: This critical role initiates the system by creating the first block for each product. The manufacturer acts as the starting point for each product's journey within the system. They are responsible for creating the initial block or record for every product they produce, including essential details such as the product's serial number, description, specifications, and any other relevant information required for identification and authentication.

2- **Supplier**: The supplier is a key player responsible for purchasing batches of products from the manufacturer and facilitating distribution. They play a critical role in ensuring product authenticity and proper handling throughout the supply chain.

3- **End users**: Individuals who interact with the system, either as buyers or sellers, fall into the category of users. They interact with the system to verify the authenticity of products, make purchases, or sell products, benefiting from the transparency and traceability offered by blockchain technology.

Figure 4 shows the class diagram designed to demonstrate a connection between the system roles. The class diagram is one of the structure diagrams used in software development. This diagram represents the structure and behavior of the system as a graphical representation of classes, attributes, relationships, and operations in relation to the system's objects.

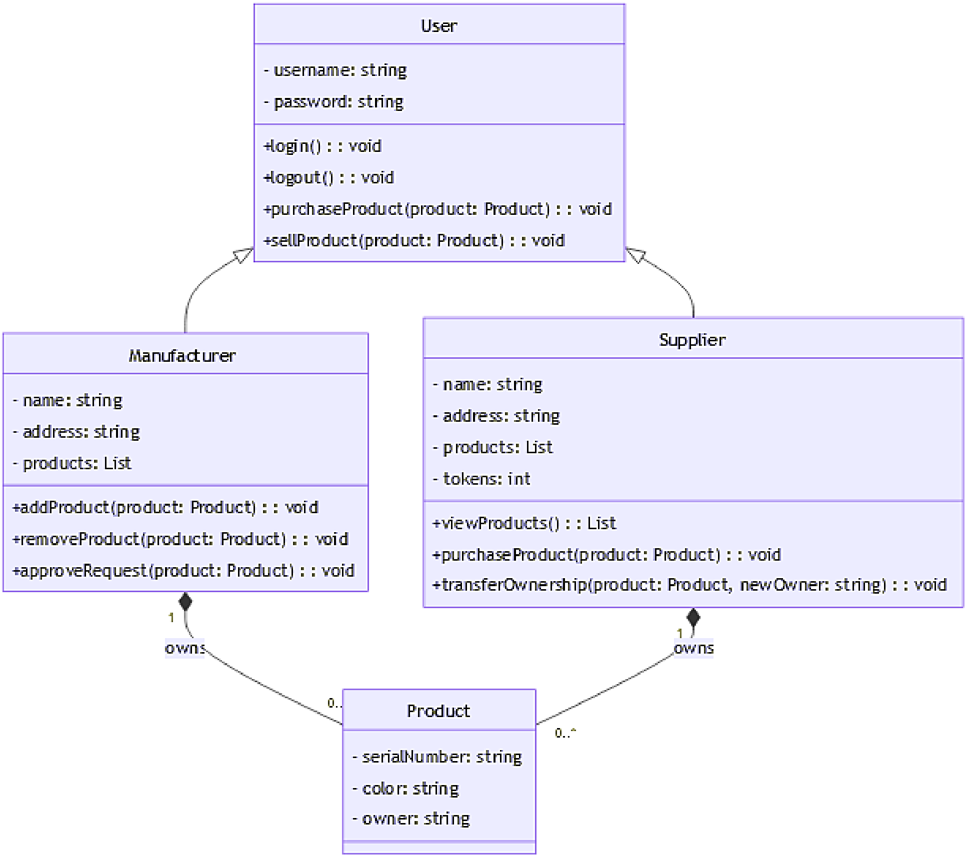

Figure 4. Proposed Systems Class Diagram.

The fundamental concept driving the proposed system is establishing a transparent and immutable path for the products, ensuring clarity at every stage. This guarantees the originality and traceability of the products and allows any user to verify the authenticity and identify the valid owner within the system using NFT and blockchain technology.

System workflow

The system's workflow is designed to accommodate face-to-face and decentralized application (DApp) models, ensuring flexibility and accessibility for users across various transaction modes. Whether users engage in traditional face-to-face transactions or opt for the digital marketplace provided by the DApp, the underlying process remains consistent and seamless. From the manufacturer's initial product listing to the final transfer of ownership between buyers and sellers, the system facilitates transactions with equal efficacy in both settings.

This unified approach underscores the system's versatility and adaptability to user preferences and market dynamics. Regardless of whether users conduct transactions physically or through the DApp platform, they can expect the same level of security, transparency, and efficiency throughout the process. By incorporating support for both face-to-face and DApp models into its workflow, the system maximizes accessibility and convenience based on the needs and preferences of its users.

The process begins with the manufacturer adding a new product to the blockchain system, providing details such as the serial number, color, and other relevant information. The system then automatically creates the product and adds it to the decentralized application market (DApp). This market is a platform for suppliers to buy original products directly from manufacturers.

The next stage concerns suppliers who want to purchase authentic products from manufacturers and distribute them via their networks. Suppliers can view the available authentic products and their prices on the DApp market. To ensure the authenticity of the manufacturers joining the system, they can go through an authorization process through automated tools or human verification. The system provides for human verification to authenticate the vendors. Once a supplier selects a product, they send the required payment to the blockchain system. At this stage, the first smart contract, 'MyToken', comes into play. The role of this contract is to generate virtual coins (tokens) for users. To participate in the DApp market, users are required to purchase tokens.

Once purchased, the supplier sends the tokens to the system to complete the transaction for the desired product from the market. This triggers another smart contract called 'Money Holder', which freezes the payment until the actual ownership of the product is transferred to the buyer. The system then sends a request to the manufacturer's profile to ensure they can fulfill the supplier's request. The 'NFTCreator' smart contract is activated if the manufacturer approves the request.

The NFTCreator contract generates a non-fungible token (NFT) for each product based on the information stored in the system and transfers ownership from the manufacturer to the supplier. Once the NFT is submitted to the network, the MoneyHolder contract is activated, releasing the payment to the manufacturer's account. Manufacturers can convert the tokens into real money at any time.

The system ensures that users can confidently buy and sell original products without concerns about authenticity or financial transactions. It eliminates the need for a central bank for money transfers and establishes trustless transactions between buyers and sellers. The MoneyHolder mechanism within the system facilitates secure and automated money transfers.

The final part of the system involves users who want to buy or sell products. Users can purchase products from suppliers through face-to-face transactions or the DApp market. In face-to-face transactions, the customer pays the product amount to the seller's wallet. The system freezes the payment using the MoneyHolder contract, creates a new NFT for the customer, and awaits the seller's acceptance of the ownership transfer. Once accepted, the customer receives the NFT in their wallet, and the seller receives the payment from the system. This flow applies to both face-to-face and DApp market transactions. Figures 5 and 6 show the workflow and sequence diagram of the proposed system, respectively.

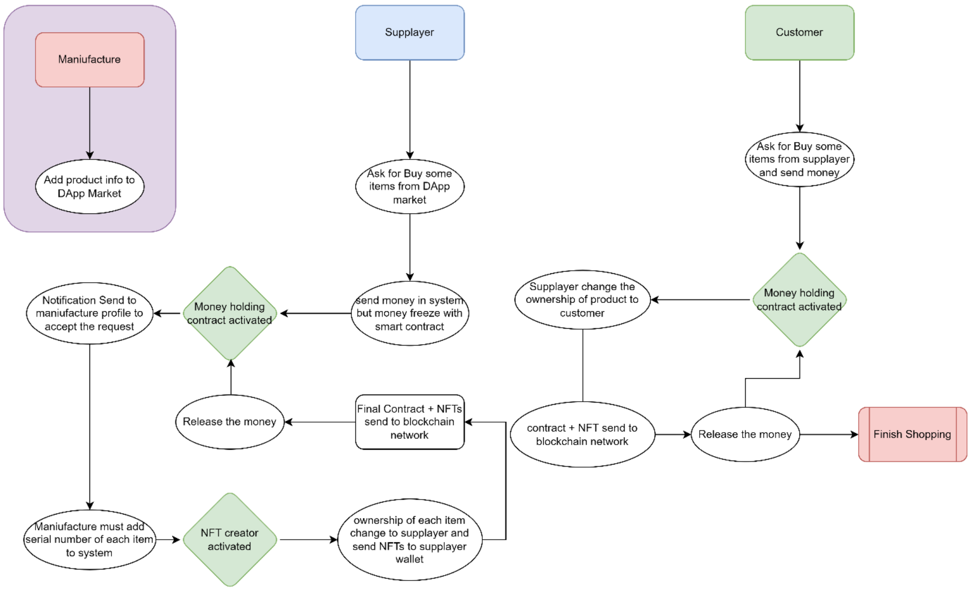

Figure 5. Workflow of the Proposed System.

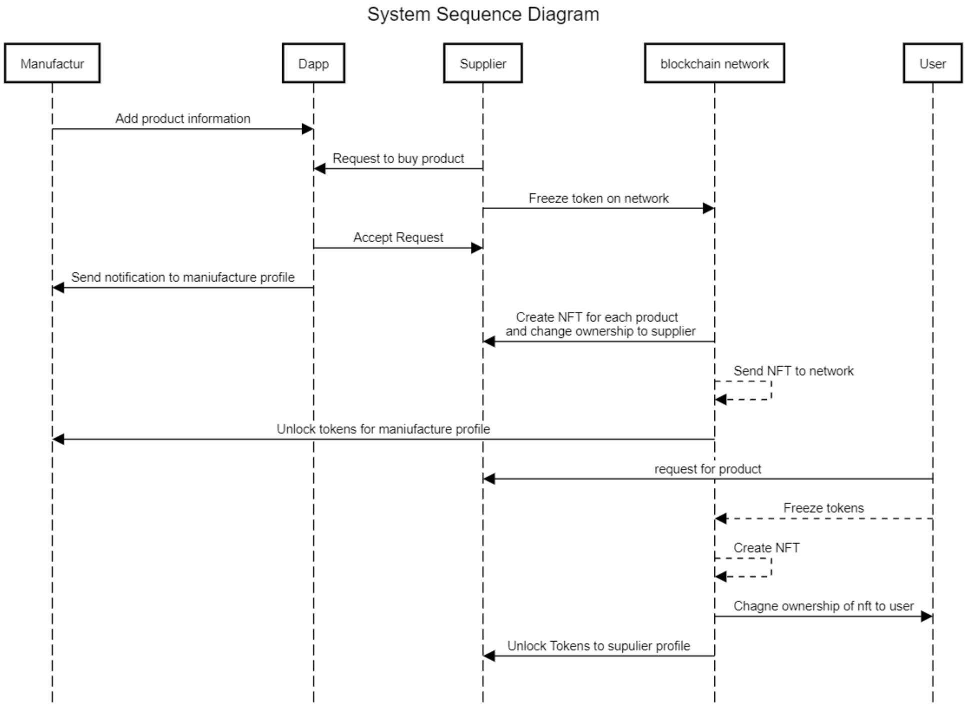

Figure 6. Sequence Diagram of the Proposed System.

Implementation

The system overview presented earlier was implemented using an Ethereum test blockchain. Remix IDE was exploited to deploy smart contracts using the Solidity language. Our solution has different types of smart contracts: MyToken, MoneyHolder, and NFT Creator. These smart contracts are used for various purposes, as explained below.

- **MyToken:** This contract initializes the tokens in the system, as described in Algorithm 1. The number of tokens is limited, and the owner or system administrator determines the initial token supply when deploying the system on the blockchain network. The MyToken contract complies with the ERC20 standard and enables token transfers within the system.

Algorithm 1: MyToken Contract
Attributes: owner, balances (mapping from address to uint)
Constructor:
Initialize owner with deployer's address; Set initial balance for the owner;
Function: balance of address
return balance of the given address;
Function: transfer to value
if the sender has sufficient balance
if sender's balance ≥ value
Transfers tokens from the sender to the specified address;
else
Display an error message:" Insufficient balance";
end
else
Display an error message:" Sender does not have sufficient balance";
End

- **MoneyHolder:** This contract receives tokens from the buyer and the seller's address, freezes the tokens until the NFT is transferred to the buyer, and then automatically sends the tokens to the seller's account. This process is fully automated and requires the buyer's and seller's addresses and the desired NFT address within the system. The details of this contract are described below:

Algorithm 2: MoneyHolder Contract
address public owner
mapping (address =¿ uint256) public lockedTokens
function MONEYHOLDER
owner ← msg.sender
function LOCKTOKENS
lockedTokens [msg.sender] ←msg.value
function SENDTOKENSTOSELLER
address seller←msg.sender
uint256 tokensToSend←lockedTokens[seller]
lockedTokens [seller] ← 0
seller.transfer (tokensToSend)
function GETLOCKEDTOKENS (seller)
return lockedTokens[seller]

- **NFTCreator:** As described in Algorithm 3, NFTCreator contract is responsible for creating NFTs for each product in the system. It uses the ERC721 standard for the creation of NFTs. The contract may include a commission rate for token transfers between users, with the commission being sent to the system owner for maintenance purposes. The NFT

Creator contract contains fields like the product-to-serial number mapping and product transfer commission.

Algorithm 3: NFT Creator

Result: Event indicating the registration of drug complications, Event indicating the tracking of drug complications
Input: *Caller address, Transfer details*
Output: *Success/Failure of NFT creation/transfer,*

Result:

Success/Failure of NFT creation/transfer

Events:

NFTCreated: Triggered upon successful NFT creation. Emits the token ID, name, description, serial number, and owner's address.

NFTTransferred: Triggered upon successful NFT transfer. CommissionWithdrawn: Triggered upon successful commission withdrawal.

MoneyReleased: Triggered when money is released to a seller. Emits the seller's address and the amount released.

function CREATENFT (address to, uint256 tokenId, productInformationList)
if the caller is
anufacturer
Create and transfer a new NFT to the recipient address (addressto) with ID (uint256tokenId) using the product information list (ProductInformation list[]).
Emit the NFTCreated event with token ID, name, description, serial number, and owner's address.
else
Return Failure of NFT creation.
end
function TRANSFERNFT
if the caller is not the system owner (manufacturer) and complies with commission rates
Transfer an NFT from the sender's address (addressfrom) to the recipient ad- dress (addressto) with ID (uint256tokenId).
Emit the NFTTransferred event.
else
Return Failure of NFT transfer.
end
function WITHDRAWCOMMISSION
if the withdrawal deadline has not passed and the caller is the system owner (manufacturer)
Allow manufacturer to withdraw commissions.
Emit the CommissionWithdrawn event.
else
Return Failure of commission withdrawal.
End

Discussion

The present paper presents the development of a secure and reliable product tracking system based on generating a unique non-falsifiable token (NFT) for each manufactured product. This innovative approach aims to improve the detection of counterfeit products and increase supply chain security. The paper comprehensively analyzes the cost implications associated with the proposed system.

Cost Analysis

Ethereum smart contract functions spend gas when triggered. The gas cost of a function is contingent on the function in the smart contract comprising its inputs, outputs, size of the Solidity code, and its complexity. These form the execution gas cost of the transaction. In addition, the cost of sending the transaction to the Blockchain is added to the execution gas cost to make up the transaction gas cost. The actual price paid by the Blockchain platform client depends on the gas price that it sets. The gas price chosen by the client is multiplied by the gas price of the transaction to compute the number of ethers to be paid. Higher gas prices guarantee faster transaction execution as it would be more compelling to miners for higher rewards. Miners have little interest in mining transactions with low gas prices and would hardly pick them.

Table 1 presents the various methods in all the aforementioned smart contracts with the transaction and execution cost in gas as reported by the IDE. The gas costs are converted to fiat currency (USD) to improve readability. The calculation of gas fees for the largest networks with different transaction speeds in dollars for all smart contracts was calculated via the online platform [21]. As mentioned earlier, the actual cost of the transaction depends on the gas price of the Network client.

Table 2. Proposed system gas costs of Blockchain Networks in USD.

Smart Contract	Gas	Ethereum		Binance Smart Chain		Polygon		Celo		Fantom	
		Standard	Fast	Standard	Fast	Standard	Fast	Standard	Fast	Standard	Fast
My Token (Transaction cost)	675081	30.3658	27.2798	0.6467	0.6467	0.1410	0.1438	0.0006	0.0006	0.0197	0.0218
My Token (Execution cost)	579553	26.0689	26.0689	0.5589	0.5589	0.1336	0.1605	0.0005	0.0005	0.0241	0.0265
MoneyHolder (Transaction cost)	1207449	54.3122	54.3122	1.1644	1.1644	0.2784	0.3344	0.0010	0.0010	0.0503	0.0552
MoneyHolder (Execution cost)	1060313	47.6939	47.6939	1.0225	1.0225	0.2445	0.2936	0.0009	0.0009	0.0442	0.0442
NFTCreator (Transaction cost)	1700436	76.4873	76.4873	1.6399	1.6399	0.3921	0.47809	0.0015	0.0015	0.708	0.777
NFTCreator (Execution cost)	1500313	67.4855	67.4855	1.4469	1.4469	0.3460	0.4155	0.0013	0.0013	0.625	0.655

Conclusion

In this research, a blockchain-based system was designed to exchange goods from manufacturers to consumers securely. The system employs three smart contracts to create automatically, utilizing non-fungible tokens (NFTs) for each product and facilitating the seamless transfer of ownership. The smart contracts were implemented on a remix platform, and the cost analysis of executing these smart contracts was evaluated across five different blockchain networks using an online platform. The results demonstrate the economic feasibility and efficiency of the proposed solution. The main contribution of the present research is the development of a new Blockchain solution that uses NFT and smart contracts, which can guarantee the originality of the product and reduce the risk of fraud in the supply chain. The primary difference between using NFT as an anti-counterfeit solution and previous solutions such as quick-response code is that NFT cannot be replicated and contains unique product information. The use of NFTs ensures the uniqueness and authenticity of each product, enhancing traceability and reducing the risk of fraud. Additionally, the security analysis conducted throughout the development process aimed to identify and mitigate potential security vulnerabilities, ensuring a trustworthy and reliable exchange mechanism.

This blockchain-based system presents a viable and secure solution for exchanging goods, leveraging the benefits of NFTs and blockchain networks. The proposed architecture, shaped by our discussions, showcases adaptability and robustness in the face of security challenges, emphasizing its potential for real-world implementation in decentralized exchanges.

Disclosure statement and funding

The authors declare no potential conflicts of interest. The present study received no financial support from any organization or institution.

Acknowledgment

We would like to give special thanks to all the participants in this study.

Reference

[1] Ludasi, K., Jójárt-Laczkovich, O., Sovány, T., Hopp, B., Smausz, T., Andrásik, A., Gera, T., Kovács, Z., & Regdon jr, G. (2021). Anti-counterfeiting protection, personalized medicines – Development of 2D identification methods using laser technology. *International Journal of Pharmaceutics*, *605*(74), 120793. https://doi.org/10.1016/j.ijpharm.2021 .120793

[2] Bolla, A. S., Patel, A. R., & Priefer, R. (2020). The silent development of counterfeit medications in developing countries – A systematic review of detection technologies. *International Journal of Pharmaceutics*, *587*(8), 119702. https://doi.org/10.1016/j.ijpharm.2020. 119702

[3] Lavanya, P. M., Ananthi, N., Kumaran, K., Abinaya, M., Kalaivani, B., Krithika, V., & Rahul, S. S. (2021, December 16-17). *Fake Product Detection using Blockchain.* 4th International Conference on Computing and Communications Technologies, Chennai, India. https://doi.org/10.1109/ICCCT53315.2021.9711899

[4] Gayialis, S. P., Kechagias, E. P., Papadopoulos, G. A., & Masouras, D. (2022). A Review and Classification Framework of Traceability Approaches for Identifying Product Supply Chain Counterfeiting. *Sustainability*, *14*(11), 6666. https://doi.org/10.3390/su14116666

[5] Xie, S., & Tan, H-Z. (2021). An Anti-Counterfeiting Architecture for Traceability System Based on Modified Two-Level Quick Response Codes. *Electronics*, *10*(3), 320. http s://doi.org/10.3390/electronics10030320

[6] Shaikh, S., Butala, M., Butala, R., & Creado, M. (2019, March 29-31). *AgroVita using Blockchain.* 5th International Conference for Convergence in Technology, Bombay, India. https: //doi.org/10.1109/I2CT45611.2019.9033705

[7] Li, L. (2013). Technology designed to combat fakes in the global supply chain. *Business Horizons*, *56*(2), 167-177. https://doi.org/10.1016/j.bushor.2012.11.010

[8] Liu, Z., & Li, Z. (2020). A blockchain-based framework of cross-border e-commerce supply chain. *International Journal of Information Management*, *52*(10), 102059. https://d oi.org/10.1016/j.ijinfomgt.2019.102059

[9] Panwar, A., & Bhatnagar, V. (2021). A cognitive approach for blockchain-based cryptographic curve hash signature (BC-CCHS) technique to secure healthcare data in Data Lake. *Soft Computing*, 1-15. https://doi.org/10.1007/s00500-021-06513-7

[10] Bandhu, K. C., Litoriya, R., Lowanshi, P., Jindal, M., Chouhan, L., & Jain, S. (2023). Making drug supply chain secure traceable and efficient: a Blockchain and smart contract based implementation. *Multimedia Tools and Applications*, *82*(15), 23541-23568. https://d oi.org/10.1007/s11042-022-14238-4

[11] Singh, S., Choudhary, G., Shandilya, S. K., Sihag, V., & Choudhary, A. (2021). Counterfeited product identification in a supply chain using blockchain technology. *Research Briefs on Information & Communication Technology Evolution*, *7*, 20-34. https://doi.org/1 0.56801/rebicte.v7i.115

[12] Anupama Kumar, S., & Anusha, M. (2023). Blockchain Enabled Supply Chain Management. *SN Computer Science*, *4*(2), 179. https://doi.org/10.1007/s4297 9-022-01621-z

[13] Khanna, A., Jain, S., Burgio, A., Bolshev, V., & Panchenko, V. (2022). Blockchain-enabled supply chain platform for Indian dairy industry: Safety and traceability. *Foods*, *11*(17), 2716. https://doi.org/10.3390/foods11172716

[14] Soon, J. M., & Manning, L. (2019). Developing anti-counterfeiting measures: The role of smart packaging. *Food Research International*, *123*, 135-143. https://doi.org/1 0.1016/j.fo odres.2019.04.049

[15] Toyoda, K., Mathiopoulos, P. T., Sasase, I., & Ohtsuki, T. (2017). A Novel Blockchain-Based Product Ownership Management System (POMS) for Anti-Counterfeits in the Post Supply Chain. *Institute of Electrical and Electronics Engineers Access*, *5*, 17465-17477. https://doi.org/10.1109/ACCESS.2017.2720760

[16] Cui, P., Dixon, J., Guin, U., & Dimase, D. (2019). A Blockchain-Based Framework for Supply Chain Provenance. *Institute of Electrical and Electronics Engineers Access*, *7*, 157113-157125. https://doi.org/10.1109/ACCESS.2019.2949951

[17] Benčić, F. M., Skočir, P., & Žarko, I. P. (2019). DL-Tags: DLT and Smart Tags for Decentralized, Privacy-Preserving, and Verifiable Supply Chain Management. *Institute of Electrical and Electronics Engineers Access*, *7*, 46198-46209. https:// doi.org/10. 1109/ACCESS.2019.2909170

[18] Cao, Y., Jia, F., & Manogaran, G. (2020). Efficient Traceability Systems of Steel Products Using Blockchain-Based Industrial Internet of Things. *Institute of Electrical and Electronics Engineers Transactions on Industrial Informatics*, *16*(9), 6004-6012. htt ps://doi.org/10.1109/TII.2019.2942211

[19] Shahid, A., Almogren, A., Javaid, N., Al-Zahrani, F. A., Zuair, M., & Alam, M. (2020). Blockchain-Based Agri-Food Supply Chain: A Complete Solution. *Institute of Electrical and Electronics Engineers Access*, *8*, 69230-69243. https://doi.org/1 0.1109/ACCES S.2020.2986257

[20] Mani, V., Prakash, M., & Lai, W. C. (2022). Cloud-based blockchain technology to identify counterfeits. *Journal of Cloud Computing*, *11*(1), 67. https://doi.org/1 0.1186/s1367 7-022-00341-2

[21] Vemmer, F. (2024, May 1). *Gas Fees Calculator*. cryptoneur. https://www.crypto neur.x yz/en/gas-fees-calculator