# Enhanced Healthcare System with NFT-Prescription

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***Abstract*—In the domain of healthcare management, conventional paper-based prescription systems manifest vulnerabilities. Addressing this, emerging solutions leverage blockchain and Non-Fungible Tokens (NFTs) to augment e-prescription processes. However, existing research needs comprehensive simulation insights into these NFT-based systems. This paper presents a pragmatic NFT-Integrated E-Prescription Management Smart Contract model to bridge this gap. The model capitalizes on blockchain's security and NFTs' attributes to enhance prescription traceability, ownership, and security. It streamlines prescription workflows, facilitating seamless interaction between healthcare providers and pharmacies while also introducing precise ownership control through NFTs. Implemented with a Role-Based Access Control system, authorization is exclusively granted to authorized entities, thereby bolstering security. A comparative analysis reveals distinct disparities in ownership management and prescription expiration. Furthermore, an assessment of cost-effectiveness and robust security measures, encompassing NFT integration, is conducted to safeguard sensitive healthcare data. The model's applicability is demonstrated through public and local test network deployment. This paper addresses the existing research gap by furnishing comprehensive simulation insights, advancing the comprehension of NFT-based prescription systems.**

***Index Terms*—Blockchain, E-Prescription, Healthcare, NFT, Smart Contract**

## I. Introduction

In recent years, the concept of Non-Fungible Tokens (NFTs) has introduced a transformative shift in how digital ownership and authenticity are perceived across various industries. These unique digital assets have demonstrated their value in scenarios such as digital certificates [1] and safeguarding against audio content duplication and counterfeiting [2], [3]. With NFTs already reshaping traditional ownership norms, their application to crucial fields like healthcare carries the promise of innovation.

Conventional paper-based prescription systems have long suffered from vulnerabilities within the healthcare sector, including tampering, unauthorized access, and fraudulent activities [4], [5]. The challenges posed by prescription forgery and fraud necessitate comprehensive solutions that can ensure authenticity, integrity, and combat counterfeit drugs [6]. Furthermore, non-compliance with regulations often impedes effective record auditability, resulting in reduced transparency and accountability [7]. The urgency to address these concerns becomes even more apparent in light of prescription errors and medication-related incidents [8].

This paper addresses these pressing challenges by introducing an efficient blockchain-based e-prescription management system that incorporates NFTs. As NFTs have been a topic of previous research, the focus here is on optimizing the existing prescription model. Instead of striving for uniqueness, the goal is to enhance the prescription management process using Blockchain and NFT technology. The term efficiency encapsulates this approach. The system is designed to significantly reduce computational gas costs on the blockchain network while maintaining the fundamental purpose of prescription management. Additionally, the system introduces digital ownership features for each prescription through NFTs and leverages the decentralized nature of blockchain networks. This efficient solution simplifies prescription management, making it more cost-effective and secure. The subsequent sections delve into the intricacies of the NFT-integrated e-prescription management smart contract's design, performance, real-world application, and benefits, highlighting how the integration of NFTs and blockchain can lead to a transformative shift in healthcare services.

## II. Related Work

This section provides a comprehensive overview of the current state of research in blockchain-based healthcare systems, with a specific focus on the integration of NFTs. These studies collectively explore how blockchain technology, including NFTs, can effectively address the intricacies of healthcare, enhance data security, and establish mechanisms for ensuring authenticity. It's important to note that this section references the comparative analysis presented in Table I, offering a valuable framework for understanding the multifaceted landscape of blockchain applications in healthcare.

Ionescu et al. [9] introduce an electronic prescription system that leverages blockchain and smart contracts for managing patient health records and medical prescriptions. This approach offers an innovative alternative to traditional paper-based and electronic health record systems, with a particular focus on secure prescription validation techniques such as Base64 and SHA256. Additionally, Garcia et al. [10] propose a decentralized e-prescription system that emphasizes the use of blockchain technology and smart contracts. Furthermore, Cilli et al. [11] present "Safe Prescription," a blockchain-based system that utilizes NFTs and specialized smart contracts (ERC-721) to certify and digitize medical prescriptions securely.

Similarly, Mohammadi et al. [12] propose a healthcare model that harnesses NFTs and smart contracts to enhance data storage, sharing, and exchange within the healthcare domain. Likewise, Taylor et al. [13] introduce VigilRx, a patient-centric prescription management system that leverages blockchain and

TABLE I
COMPARATIVE ANALYSIS OF BLOCKCHAIN-BASED HEALTHCARE SYSTEMS

| Study | Blockchain Technology (Deployment) | Security and Scalability Insight | Traceability and Auditability | Simulation | Methods |
|---|---|---|---|---|---|
| Ionescu (2022) | Ethereum (Private Local) | Not Specified | Not Specified | No | Hash Function, Asymmetric Encryption |
| Garcia et al. (2021) | Hyperledger Fabric (Permissioned) | Not Specified | Not Specified | Yes | Not Specified |
| Cilli et al. (2021) | Ethereum (Private Local) | Not Specified | Yes | No | NFT |
| Mohammadi et al. (2023) | Ethereum (Not Specified) | Yes | Yes | No | NFT |
| Taylor et al. (2022) | Ethereum (Private Local) | Yes | Yes | Yes | Asymmetric Encryption |
| Proposed System | Ethereum (Public & Private Local) | Yes | Yes | Yes | NFT |

smart contracts. These collective studies underscore the potential of blockchain technology, particularly NFTs, to address healthcare challenges and enhance data security.

The NFT-Integrated E-Prescription Management System presented in this paper draws inspiration from these works to address limitations in conventional prescription management. This approach simplifies prescription management, enhances security through NFTs, and ultimately provides a more efficient and user-friendly solution for all stakeholders involved. While NFTs offer clear advantages in terms of data integrity, ownership control, and provenance, it's essential to consider potential drawbacks such as blockchain dependency and scalability challenges when implementing them in healthcare systems.

The growing interest in harnessing blockchain and NFTs to streamline healthcare processes underscores the importance of heightened data security, efficient workflows, and patient-centric care. Building upon these insights, this work introduces an innovative approach that not only aligns with these goals but also introduces a unique system architecture. This architecture emphasizes simplicity, efficiency, and effectiveness, thereby contributing to the ongoing evolution of healthcare services.

## III. SYSTEM DESIGN

In this section, the intricate design of the NFT-Integrated E-Prescription Management Smart Contract is examined. The focus is twofold: crafting a robust architecture to ensure a secure and seamless flow of interactions within the system and harnessing the unique capabilities of NFTs to elevate the security and efficiency of e-prescription management. Key elements, including role authorization, prescription issuance, pharmacy claims, and NFT integration, are explored to provide a comprehensive understanding of the proposed solution.

### A. System Architecture

The intricate design of the system architecture, as depicted in Figure 1, underscores its meticulous construction aimed at enabling seamless and highly secure interactions across the entirety of the ecosystem.

1) **Authorization of Healthcare and Pharmacy:** The contract owner endows healthcare providers and pharmacies with explicit roles and permissions (HEALTHCARE_ROLE and PHARMACY_ROLE) using the Access Control feature. This meticulous authorization ensures that only sanctioned entities partake in the system.
2) **Patient Checkup and Prescription Issuance:** Patients initiate the process by visiting healthcare providers for medical checkups and receiving prescriptions for their required medications.
3) **NFT Prescription Issuance:** Healthcare providers, vested with the HEALTHCARE_ROLE, employ the `issueRx` function to generate NFT prescriptions for patients. These NFT prescriptions are intrinsically linked to individual patients and encompass comprehensive details about prescribed medicines, expiration times, and pertinent particulars.
4) **Patient Visits Pharmacy:** Patients proceed to authorized pharmacies to procure their prescribed medications. The pharmacy validates the prescription's authenticity through the `viewRxHealthcare` function, ensuring prescription existence and the caller's rightful access.
5) **Pharmacy Claims Prescription:** Upon prescription validation, the pharmacy employs the `claimRx` function to finalize the prescription process. Activation of this function marks the `claimed` status as true, signifying successful dispensation to the patient. The `claimedBy` attribute logs the pharmacy's address, and the `claimedTime` captures the precise claim timestamp.

### B. Smart Contract Functionality

The smart contract facilitates key functionalities essential to the secure and efficient management of e-prescriptions within the proposed NFT-Integrated E-Prescription Management System. These functionalities empower authorized healthcare providers and pharmacies to seamlessly interact with the system, ensuring the integrity and authenticity of prescription

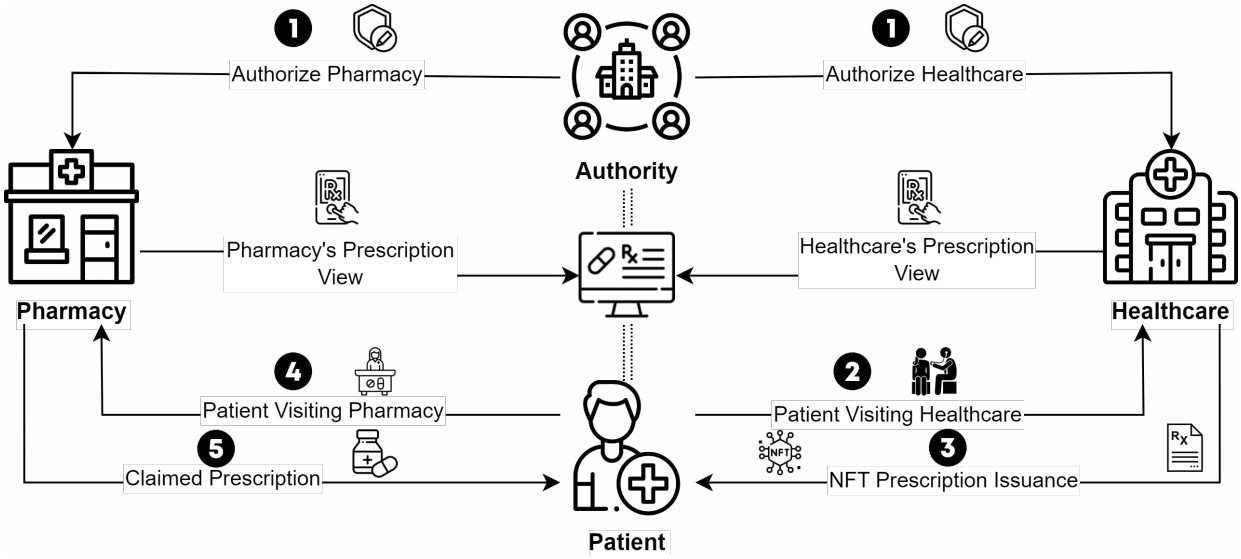


Fig. 1. System Architecture

issuance, claiming, and overall management. The smart contract provides the following integral features:

1) **Prescription Issuance:** Healthcare providers, authorized with the HEALTHCARE_ROLE, can issue prescriptions to patients through the `issueRx` function. The function creates a new NFT prescription associated with the patient's address and captures details of the prescribed medicines and expiry time.
2) **Prescription Claiming:** Authorized pharmacies, holding the PHARMACY_ROLE, can claim prescriptions issued by healthcare providers using the `claimRx` function. This function validates the authenticity and validity of the prescription before allowing the claim.
3) **Prescription Deletion and Associated Restrictions:** The contract owner, with the OWNER_ROLE, can delete prescriptions using the `deleteRx` function under specific restrictions. The prescription can only be deleted if the prescription's claimed time has exceeded the defined FIVE_YEARS period [14]. This ensures that prescription records cannot be tampered with prematurely.
4) **Role-Based Access Control:** The smart contract implements role-based access control using the Access Control feature from OpenZeppelin. This ensures that only authorized entities, such as healthcare providers, pharmacies, and the contract owner, can execute specific functions based on their designated roles.

Through the combination of role management, prescription issuance, prescription filling, ownership of prescriptions, prescription expiry, record deletion after claim, and permission management, the proposed NFT-Integrated E-Prescription Management Smart Contract presents a comprehensive solution to address the challenges associated with traditional prescription management systems.

## IV. System Evaluation

This section comprehensively evaluates the proposed NFT-Integrated E-Prescription Management Smart Contract. The analysis covers its security and traceability features, a feature comparison, and an assessment of gas cost per function and deployment cost. The evaluation was conducted on a Windows 10 Enterprise system (i5-7400 CPU, 3.00 GHz, 16 GB RAM) using Remix IDE v0.34.1 for smart contract development on both Ganache v2.7.1 as a local test network and Sepolia public test network.

### A. Security and Traceability Features

The proposed smart contract harnesses Ethereum blockchain and smart contract technology to establish a comprehensive security and traceability framework within the e-prescription management system. This approach incorporates both decentralized and centralized elements to ensure a well-balanced system. Through Role-Based Access Control (RBAC), precise authorization of healthcare providers and pharmacies is ensured, reducing the risk of unauthorized access and tampering. This centralized authorization process involves a governing authority responsible for granting access permissions only to authorized healthcare facilities. This centralized administration step enhances security by preventing unauthorized access while still benefiting from the efficiency and transparency offered by blockchain technology. NFTs play a pivotal role in enhancing data integrity by enabling precise ownership control of prescription records, thereby combating the issues of tampering, unauthorized access, and fraud often associated with paper-based systems. These mechanisms not only enhance the system's overall security but also address vulnerabilities that have long plagued the traditional prescription management landscape, as highlighted in the background.

Furthermore, the smart contract introduces a proactive prescription expiration feature, where prescriptions are rendered ineligible for claims after their designated expiry time. It

TABLE II
COMPARISON OF PROPOSED MODEL AND VIGILRX SMART CONTRACT MODEL

| Feature | Proposed Smart Contract Model | VigilRx [13] Smart Contract Model |
|---|---|---|
| Role Management | Defined roles for healthcare and pharmacy | Multiple contracts for roles |
| Prescription Issuance | Authorized healthcare directly issues prescriptions | Requires Prescriber contract interaction |
| Prescription Filling | Authorized pharmacy directly fills prescriptions | Requires Pharmacy contract interaction |
| Ownership (Prescriptions) | Managed with NFTs for precise ownership control | Ownership managed through permissioning |
| Prescription Expiry | Expiry set by healthcare, prevents claiming after expiry | N/A |
| Record Deletion (Claimed) | Records auto-delete after 5 years | Records retention without auto-deletion |
| Permission Management | Straightforward role assignment | Involves separate permissioned parties |
| Refill Mechanism | N/A | Via `requestRefill` in Prescription contract |

TABLE III
GAS COSTS FOR SMART CONTRACT FUNCTIONS

| Function | Gas |
|---|---|
| Deployment Contract | 5,198,465 |
| grantHealthcareRole | 51,762 |
| revokeHealthcareRole | 34,730 |
| grantPharmacyRole | 51,818 |
| revokePharmacyRole | 34,654 |
| addAdmin | 53,752 |
| removeAdmin | 36,778 |
| issueRx | 287,599 |
| deleteRx | 136,435 |
| claimRx | 78,367 |
| viewRxHealthcare | N/A |
| viewRxPatient | N/A |
| viewRxPharmacy | N/A |

TABLE IV
COMPARISON OF GAS COSTS BASED ON TRANSACTION PURPOSE

| Transaction Purpose | Proposed Model | VigilRx [13] |
|---|---|---|
| Prescribe | 287599 | 662364 |
| Drug Claim | 78367 | 36138 |
| Refill | N/A | 35181 |
| Permission | 103580 | 48891 |
| Delete | 78835 | N/A |
| Initial Transaction Cycle | 469546 | 747393 |
| Subsequent Cycles | 365966 | 747393 |

prevents the misuse of expired prescriptions, adding an extra layer of security. Through these measures, the system ensures a tamper-proof, auditable, and efficient solution for issuing, claiming, and managing prescriptions, contributing to healthcare record-keeping's overall transparency and accountability. This robust approach addresses the challenges posed by traditional paper-based systems, reflecting a proactive stance towards security and traceability within the e-prescription management domain, while maintaining a centralized authorization process in line with current healthcare practices.

### B. Smart Contract Feature Comparison

Table II provides an in-depth comparison between the proposed smart contract model and the VigilRx model, highlighting significant differences in prescription management. These contrasts encompass role-based access control, prescription issuance and filling, ownership and security mechanisms, the approach to record deletion, and the presence of a refill function in VigilRx. This comprehensive analysis underscores the distinct advantages of the proposed model, emphasizing its enhanced efficiency, security, and user-friendliness. The proposed model's straightforward role-based access control, direct prescription actions, NFT-based ownership, automated record deletion, and absence of a refill function collectively contribute to its functionality, security, and user experience. It sets the proposed e-prescription management model as a more efficient, secure, and user-centric alternative to the VigilRx [13] approach.

### C. Gas Cost and Deployment Analysis

The gas cost analysis for the NFT-Integrated E-Prescription Management System's smart contract provides valuable insights into the computational efficiency of various functions in both testing environments, including the Sepolia and Ganache test networks. Gas costs are measured in Ethereum's native unit, "Gas," reflecting the computational resources required for specific blockchain operations. Notably, the contract employs the access control feature from a library for role-based authorization, which slightly increases gas costs compared to simple modifiers. However, this choice significantly enhances security by ensuring proper role management and permissions.

The analysis also highlights certain functions with relatively higher gas costs, such as "issueRx" and "deleteRx." The complexity of the "issueRx" function is attributed to the process of minting a NFT associated with each prescription. Minting NFTs involves several steps, including token ID management and metadata creation, contributing to higher gas consumption. Additionally, it's important to consider the impact of the deployment environment on gas costs. Testing on the public Sepolia test network may yield different results compared to local Ganache deployment due to the network's conditions, such as congestion and gas prices. These insights provide a

comprehensive understanding of the factors influencing gas costs and help in making informed decisions for optimizing function efficiency while maintaining the desired level of security within the proposed smart contract system.

### D. Transaction Cost Comparison Analysis

In the transaction cost comparison analysis, several key observations underscore the cost-efficiency and simplicity of the proposed model, as illustrated in Table IV. Firstly, in the Prescribe purpose, the model excels by offering significantly lower gas costs compared to VigilRx [13]. This efficiency stems from the incorporation of NFTs for ownership, reducing computational overhead. Secondly, while the Drug Claim purpose in the model incurs a slightly higher gas cost, it encompasses the drug claim process, benefiting from NFT ownership and enhanced security. Thirdly, the model's Permission purpose stands out as more cost-effective, requiring authorization only once for healthcare and pharmacy entities, as opposed to VigilRx [13], which repeatedly utilizes permission for prescription issuance and claiming. Notably, the Refill purpose is not applicable in the proposed design, as it is implemented using immutable NFTs. Lastly, the Delete purpose in the model ensures scalability while aligning with pharmacy regulations [14], a feature lacking in VigilRx [13]. Additionally, the analysis includes the initial transaction cycle and subsequent cycle, demonstrating that the model consistently offers cost-effective solutions across various transaction purposes. These insights reaffirm that the model offers a cost-effective and simplified solution for e-prescription management, leveraging the benefits of NFTs and blockchain technology to enhance patient care and streamline healthcare processes.

## V. Conclusion

In conclusion, the integration of a smart contract framework with NFTs presents a targeted solution to enhance e-prescription management and tackle critical healthcare challenges. This approach harnesses NFTs and blockchain technology to establish a secure, efficient, and transparent system for prescription management. Through a thorough analysis and practical implementation, the model's effectiveness has been demonstrated in comparison to existing solutions. Notable features such as role-based access control, precise ownership management, secure prescription issuance, and drug claim collectively contribute to a robust and secure healthcare ecosystem.

Furthermore, the gas cost analysis provides valuable insights into the delicate balance between security and efficiency. Although adopting Access Control roles may result in higher gas costs, these costs are justified by the corresponding enhancement in security. Examination of gas costs associated with NFT prescription issuance highlights an area where optimization is possible, offering crucial guidance for stakeholders considering blockchain-based healthcare systems. These contributions underscore the potential of streamlined models to effectively address complex healthcare challenges, ultimately facilitating seamless and secure healthcare service operations.

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