Smart Contract for a Smarter Drug Supply Chain: Blockchain Integration from Manufacturer to Pharmacy

Md Facklasur Rahaman, Mohtasin Golam, Ikechi Saviour Igboanusi, Dong-Seong Kim, and Jae-Min Lee
Networked Systems Laboratory, Department of IT Convergence Engineering,
Kumoh National Institute of Technology, Gumi, South Korea.
(facklasur, golam248, ikechisaviour, dskim, and ljmpaul)@kumoh.ac.kr

***Abstract*—The timely delivery of drugs from manufacturers to pharmacies is of utmost importance in the drug supply chain. However, verifying the source of drug manufacturers and maintaining visibility of drug movement among various participants, including manufacturers, distributors, wholesalers, pharmacies, and consumers, proves exceedingly challenging. This situation paves the way for drug counterfeiting and escalating drug prices. In the current supply chain setup, manufacturers lack awareness of the destination of their drugs, and regulatory authorities have limited visibility into the supply chain. This paper introduces a blockchain-based solution for the drug supply chain by eliminating intermediaries, thereby streamlining the distribution process from manufacturers to pharmacies. Furthermore, a smart contract is developed to ensure drug authenticity, effectively addressing the issue of counterfeit drugs in the supply chain.**

***Index Terms*—Blockhain, Smart Contract, Drug Supply Chain, Drug Counterfeiting, Manufacturer, Pharmacy**

I. Introduction

The traditional pharmaceutical supply chain is characterized by its fragmented structure and opaqueness, which poses recurring problems that put public health at risk by limiting medicine access, authenticity, and cost-effectiveness.

The linear pharmaceutical supply chain, shown in Fig. 1, involves manufacturers, distributors, and pharmacies operating independently, resulting in inefficiencies, higher costs, reduced product tracking, and vulnerability to counterfeit drugs, which raises drug prices and compromises patient safety [1].

Fake medicines pose a serious and worsening health risk, especially in developing countries, with both direct and indirect effects [2]. Indirect effects include inadequate dosages and active ingredients, which promote drug-resistant strains and render genuine treatments ineffective. Irregular or impure formulations can introduce harmful substances and cause severe health problems [3].

This article proposes using blockchain and smart contracts to improve the drug supply chain, circumvent wholesalers, and establish a more efficient, cost-effective direct transfer of pharmaceuticals from producers to pharmacies.

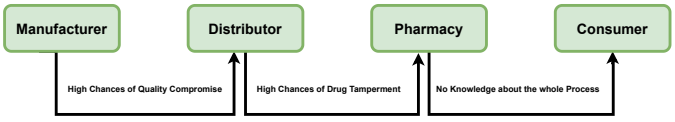

Fig. 1. The conventional flow of the drug supply chain

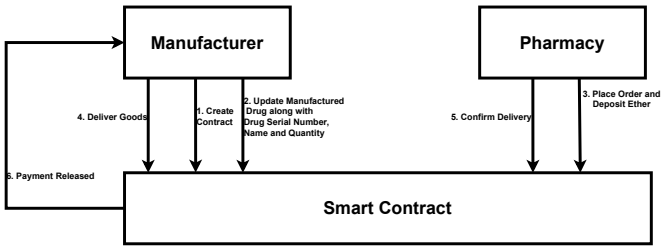

Fig. 2. The proposed blockchain-based solution

Smart contracts automate and transparently boost medicine supply chain efficiency [4]. Slither improves security by proactively discovering holes, guaranteeing medication delivery [5]. Blockchain's main value is transparency and traceability [6], which securely records medicine movements, prevents counterfeiting, and allows regulatory agencies, producers, and pharmacies to verify and monitor drug processes. The main contribution of this articles are as follows :

1) This study presents a proposed solution that leverages blockchain technology, namely Ethereum smart contracts, along with a decentralized storage system. The objective is to enhance the efficiency of the medication supply chain process by eliminating the involvement of intermediaries in the distribution of pharmaceutical products, spanning from manufacturers to pharmacies.
2) The proposed solution is an innovative approach to addressing the issue of counterfeit drugs in the supply chain by implementing a smart contract-based solution. The proposed method aims to ensure the authenticity of drugs, mitigating the risk of counterfeiting.

II. Proposed Blockchain-based Solution

Fig. 2 shows how we use a private Ethereum blockchain to improve information sharing between manufacturers and networked pharmacies, eliminating third-party distributors, reducing counterfeit drug risks in the pharmaceutical supply network, and incorporating smart contracts and Ethereum's integration with IPFS.

A. Participants and Constituents Elements

We outline the responsibilities of each participant and the constituents elements in the proposed system in the following sections.

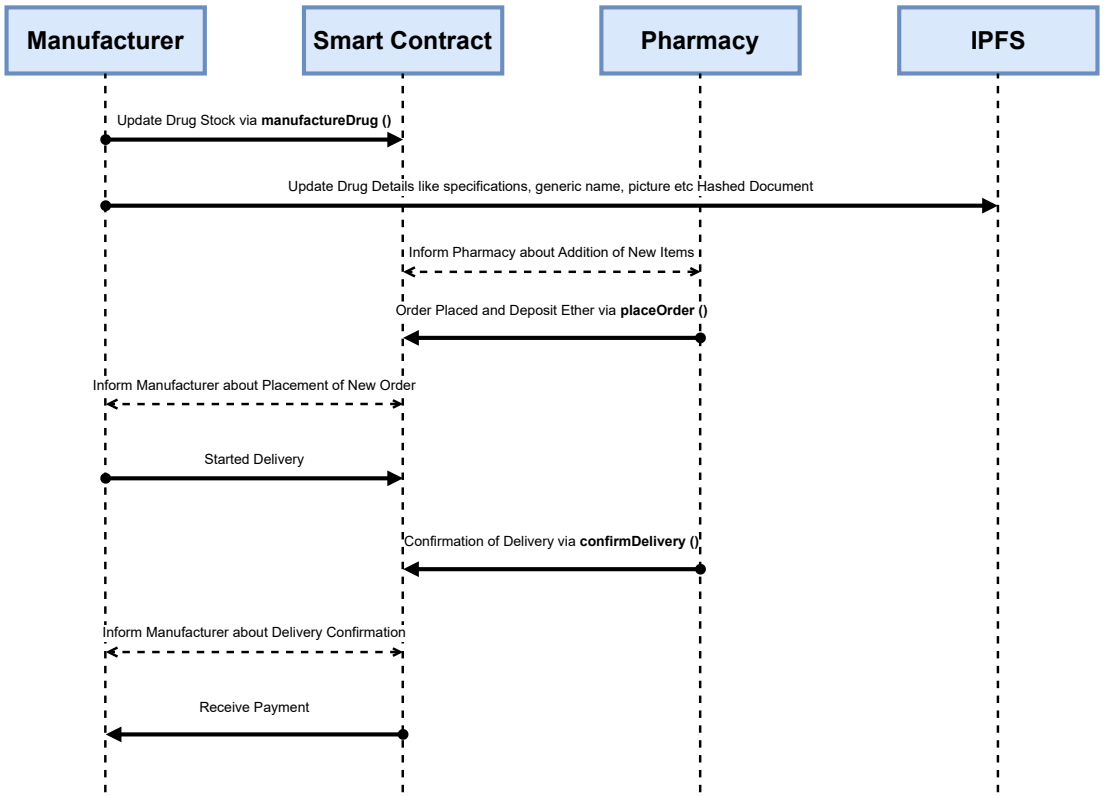

Fig. 3. The sequence diagram illustrating the overall process

Manufacturer: Manufacturers do market research, identify vital items, estimate demand, and predict shortages due to natural catastrophes or pandemics while adhering to regulatory norms.

Pharmacy: Pharmacy receives and dispenses pharmaceuticals while collaborating with manufacturers to guarantee timely availability, inventory management, and regulatory compliance for safe and effective patient care.

Ethereum Smart Contract: The Ethereum smart contract powers this blockchain-driven medicine supply chain, allowing manufacturers and pharmacies to directly engage, automate, and trust each other while securely recording drug data, orders, and delivery.

IPFS (Interplanetary File System): IPFS (Interplanetary File System) improves data storage and sharing, enabling decentralized and resilient dissemination of drug-related documents and records throughout the Ethereum network for quick access to vital information with data integrity and availability.

B. Methodology

The study's methodology involves implementing the "DrugSupplyChain" Solidity smart contract on the Ethereum blockchain to revolutionize the drug supply chain dynamics. This contract offers functions like "manufactureDrug()" for manufacturers to register drug info and images on IPFS, "placeOrder()" for pharmacies to initiate orders with ether deposits, and "confirmDelivery()" to validate and transfer ether upon successful delivery. Key events, such as "DrugManufactured," "OrderPlaced," and "OrderDelivered," provide real-time updates to stakeholders. This approach eliminates intermediaries, fostering transparency, trust, and operational efficiency within the drug supply chain ecosystem, as depicted in Fig. 3

III. Implementation, Testing and Validation

In this section, we delve into the practical aspects of putting our permissioned blockchain solution into action. Our goal is to facilitate drug supply chain management between manufacturer and pharmacy within a network. To achieve this, we implemented the system overview we discussed earlier on a test Ethereum blockchain. To make this happen, we used the Remix IDE (Integrated Development Environment) to deploy smart contracts, making use of the Solidity programming language.

A. Implementation Details

The method we suggest involves using smart contracts that play a role in various parts of this solution's processes. We've outlined these smart contract actions in the algorithms that follow. These algorithms aim to give a brief summary of how the code of the smart contracts works.

Algorithm 1 outlines how the manufacturer adds or increases inventory items, inputting name, serial number, and quantity for new or existing items, and dispatches updated details as an event for retailer awareness.

The smart contract acts as the bridge for pharmacy purchase orders, outlined in Algorithm 2. The pharmacy provides the drug's serial number and desired quantity, with the manufacturer's acceptance ensuring serial number authenticity and reducing the risk of counterfeit drugs entering the market.

Algorithm 1 Adding Drug Items to Manufacturer's Stock

Input: Drug Serial Number, Name, Quantity to be added
Modifier: Only Manufacturer
Manufacturer registers in the smart contract
Manufacturer enters item details to add in the smart contract
if *name already exists* **then**
| Increase the quantity with new serial number
end
else
| Set the name, serial number, and quantity and add it
end
Broadcast the quantity update by triggering the appropriate event

Algorithm 2 Purchase Order by Pharmacy

Input: Drug Serial Number, Quantity
Modifier: Only Pharmacy
Pharmacy registers in the smart contract
Pharmacy places a purchase order in the smart contract and deposit ether
if *Serial Number is valid* **then**
| Get the desired drug items and deposit ether
end
else
| Revert transaction
end
Broadcast this update by triggering the appropriate event

B. Testing and Validation

Remix IDE (Integrated Development Environment), which replicates the Ethereum network, rigorously tests the system's smart contracts. Debugging deployed code in the IDE (Integrated Development Environment) and evaluating transaction logs, outputs, events, gas prices, and exceptions were part of the validation process to verify functionality matches expectations.

Smart contracts were deployed and participants received accounts. Drug manufacturers entered name, serial number, and quantity, and triggered events depicted in Fig. 4 updated pharmacy information. Pharmacies deposit ether as collateral to order and secure transactions depicted in Fig. 5, and confirmed delivery transfers ether to the manufacturer depicted in Fig. 6.

Fig. 4. Event showing the updated quantity of the added items

Fig. 5. Event showing the order placement by the pharmacy

Fig. 6. Event showing the delivery confirmation by the pharmacy

IV. Conclusion

This research successfully addresses pharmaceutical supply chain challenges by leveraging smart contracts and blockchain technology, improving transparency, reducing costs, and enhancing patient safety. Further research could explore scalability and integration with IoT for real-time monitoring. Collaboration between regulatory agencies and stakeholders is crucial for industry-wide adoption and standards development, fostering a safer and patient-centric pharmaceutical supply chain.

V. ACKNOWLEDGEMENT

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References

[1] S. Abdallah and N. Nizamuddin, "Blockchain-based solution for pharma supply chain industry," *Computers & Industrial Engineering*, vol. 177, p. 108997, 2023.
[2] C. G. Nato, L. Tabacco, and F. Bilotta, "Fraud and retraction in perioperative medicine publications: what we learned and what can be implemented to prevent future recurrence," *Journal of Medical Ethics*, vol. 48, no. 7, pp. 479–484, 2022.
[3] S. Roy and M. Jerremy, "African counterfeit pharmaceutical epidemic: The road ahead," *ACAPPP*, vol. 2009, 2009.
[4] I. A. Omar, R. Jayaraman, K. Salah, M. Debe, and M. Omar, "Enhancing vendor managed inventory supply chain operations using blockchain smart contracts," *IEEE Access*, vol. 8, pp. 182 704–182 719, 2020.
[5] M. F. Rahaman, G. A. Haryadi, D.-S. Kim, and J.-M. Lee, "A comprehensive study on vulnerabilities in ethereum smart contracts for offline transactional hybrid wallet."
[6] I. S. Igboanusi, K. P. Dirgantoro, J.-M. Lee, and D.-S. Kim, "Blockchain side implementation of pure wallet (pw): An offline transaction architecture," *ICT Express*, vol. 7, no. 3, pp. 327–334, 2021.