Vaccine Traceability Using Blockchain

Prof. Thorat S.D[1], Nimbhorkar Mauli[2], Dhale Mamata [2], Ubale Sayali[4]

[1,2,3,4]*SVPM COE Malegaon (BK), Baramati*

Abstract: The pharmaceutical sector faces major hurdles such as the circulation of counterfeit medications—particularly vaccines—and inefficiencies in supply chain management involving transparency, data integrity, and traceability. These challenges are intensified by low public awareness and the increasing presence of online pharmacies, which further expose vulnerabilities in the vaccine distribution network. To address these concerns, we introduce TISVSchain, a blockchain-based solution aimed at improving visibility, trust, and traceability within the vaccine supply chain. This framework supports deployment on both public and private blockchains, offering adaptability in tackling counterfeit vaccine threats. We developed the prototype using Remix IDE and Solidity smart contracts, focusing on optimizing gas usage. System performance was analyzed under varying conditions, including changes in block time and network nodes, to evaluate metrics such as transaction throughput, gas efficiency, and propagation delay. The results indicate that TISVSchain enhances security through unique offline account identities and boosts efficiency by reducing gas costs and block losses while maximizing TPS. In conclusion, TISVSchain presents a robust and efficient approach to securing and streamlining vaccine supply chains.

Keywords: Blockchain, Vaccine Authentication, Supply Chain Security, Smart Contracts, Transparency, Efficiency

I. INTRODUCTION

Managing the vaccine supply chain presents several pressing issues, including insufficient transparency, data manipulation (such as falsifying expiration dates), and the rise of counterfeit vaccines. These problems compromise both the reliability of the supply chain and public health safety. Fake vaccines, in particular, can lead to ineffective immunization or harmful reactions, placing lives at serious risk. Additionally, altered records and lack of visibility in the supply chain disrupt effective vaccine distribution and monitoring, creating vulnerabilities that can be exploited.

Traditionally, governmental regulatory bodies have been responsible for overseeing vaccine distribution to ensure safety and authenticity. However, these mechanisms often fail to prevent crucial issues, such as expired or counterfeit vaccines, due to the ease with which data can be altered. This underscored the importance of a secure logistics system capable of end-to-end vaccine tracking, ensuring proper storage, handling, and delivery conditions.

According to data from the World Health Organization (WHO), fake medicines are responsible for significant mortality rates, particularly in developing nations where approximately 30% of drugs are estimated to be counterfeit. In some countries, like Pakistan, the problem is even more severe, with estimates suggesting that up to 40–50% of drugs may be falsified.

II. RELATED WORKDONE

The use of blockchain technology in supply chain management has attracted significant research interest due to its inherent features of transparency, immutability, and decentralization. Various studies have explored its application in general supply chains, emphasizing how blockchain can eliminate issues such as data tampering and lack of traceability. Its decentralized ledger allows all stakeholders to access and verify transactions, thus ensuring accountability across each stage of the supply process. In the context of the pharmaceutical industry, especially vaccine distribution, blockchain has been proposed as an effective tool to combat the widespread issue of counterfeit medicines. Researchers like Zohdy et al. have introduced frameworks that track pharmaceutical products throughout the supply chain, enabling stakeholders such as manufacturers, distributors, and regulators to confirm product authenticity and integrity.

Further, the integration of blockchain with Internet of Things (IoT) devices has shown promise in managing critical parameters such as storage temperature and transport conditions—factors crucial to vaccine efficacy. For example, Ali et al. developed a solution that uses IoT sensors to monitor cold chain compliance, recording real-time data on the blockchain to enhance transparency and traceability. Additionally, smart contracts have been widely adopted in blockchain-based systems to automate processes such as verifying vaccine authenticity, checking expiry dates, and enforcing compliance rules. Studies by Chakraborty and Sadh demonstrated how smart contracts could reduce human errors and streamline decision-making in vaccine logistics.

To address the issue of counterfeit vaccines specifically, researchers like Wong et al. proposed decentralized systems that log the complete lifecycle of a vaccine, from production to administration, ensuring verifiable and tamper-proof records. Despite these advancements, some limitations persist, including high gas fees, scalability challenges, and difficulties integrating blockchain solutions with existing healthcare infrastructure. To mitigate these, researchers have suggested the use of permissioned blockchains, hybrid architectures, and optimization techniques. Overall, the body of research supports blockchain as a powerful enabler for creating a secure, reliable, and transparent vaccine supply chain.

III. METHODOLOGY
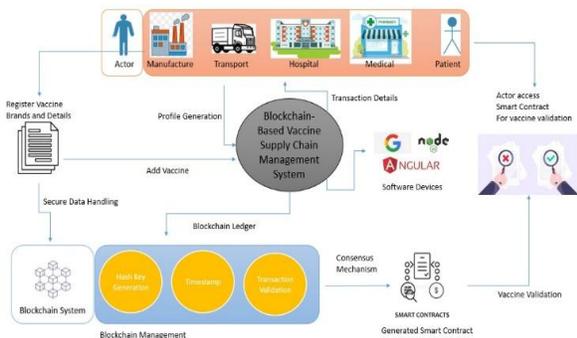

Fig.System Architecture

1. Key Stakeholders
Actor: Any participant who initiates the process, such as manufacturers or regulatory bodies.

Manufacturers, Transport, Hospitals, Medical Stores, and Patients: These entities represent the various stages a vaccine passes through—from production to final delivery.

2. Vaccine Data Registration and Profile Generation
Actors begin by registering vaccine brands and related information into the system.
Once the details are registered, a vaccine profile is generated, which includes all key data required for tracking and verification.

3. Blockchain System and Ledger Integration
The registered vaccine information is handled securely and recorded into the blockchain ledger.
Blockchain management involves:
Hash Key Generation: Ensures unique and secure identification for each transaction.
Timestamping: Logs the exact time of each transaction or update.
Transaction Validation: Confirms the authenticity of vaccine-related transactions using consensus mechanisms.

4. Smart Contracts and Consensus Mechanism
A smart contract is automatically generated for each transaction or vaccine batch.
These smart contracts are validated through a consensus mechanism, which ensures that all parties agree on the transaction's legitimacy before it is added to the blockchain.

5. Software Stack
The system uses modern technologies like:
HTML, CSS, JS (frontend interface), MYSQL (backend server), and Ganache server for building the user interface and handling transactions.

6. End-to-End Vaccine Tracking
As the vaccine moves through the supply chain—from manufacturing to delivery to patients—transaction details are continuously updated and stored on the blockchain.
Medical facilities and patients can access the smart contract to validate the vaccine's authenticity at any point.

7. Vaccine Validation

The final stage involves checking the vaccine through the system interface.
If the smart contract confirms the details, the vaccine is validated as authentic; otherwise, it's flagged as potentially counterfeit or tampered.

IV. PROPOSED SOLUTION

To address the challenges in vaccine distribution, a blockchain-based system can be implemented to offer real-time monitoring, transparency, and integrity across the vaccine supply chain. This system would connect all key stakeholders—such as manufacturers, transporters, healthcare units, and regulators—through a decentralized, distributed ledger that maintains a permanent and tamper-resistant record of all vaccine-related transactions.
Core Blockchain Algorithms and Mechanisms Involved:

1. Consensus Algorithm (e.g., Proof of Authority or Proof of Stake):
Ensures that all transactions added to the blockchain are agreed upon by trusted nodes in the network. This prevents unauthorized data entry and ensures consistent data across all participants.
2. Hashing (SHA-256):
Every transaction is cryptographically hashed to create a unique identifier, securing data from tampering. Even a minor change in transaction data would produce a completely different hash, enabling easy detection of manipulation.
3. Digital Signatures (Asymmetric Encryption):
Each stakeholder digitally signs the data using a private key. These signatures verify the identity of the participant and confirm data authenticity without revealing sensitive information.
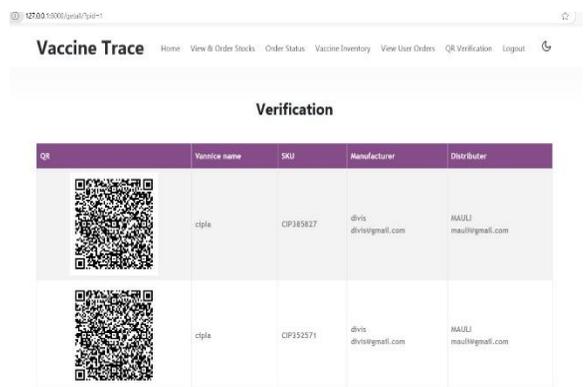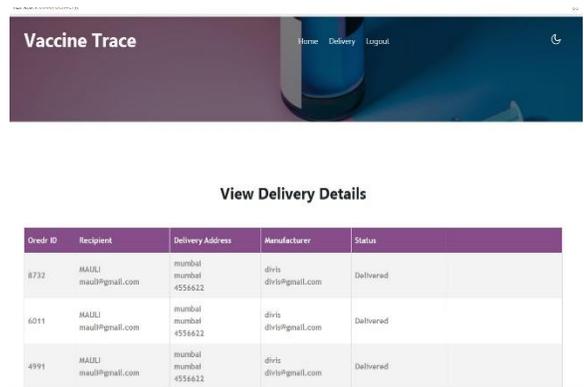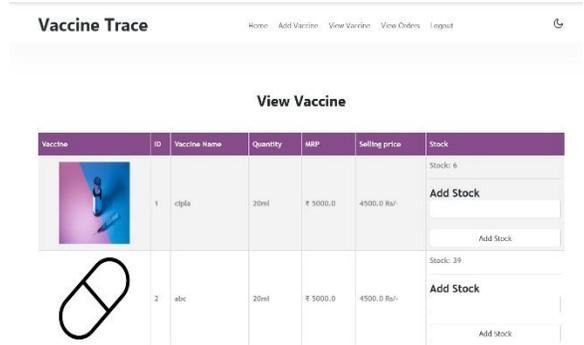4. Smart Contracts (Solidity-based):
Automated logic programmed into the blockchain to execute conditions like validating expiry dates, verifying vaccine source, or triggering alerts for temperature deviations (with IoT integration). These contracts ensure automatic and trustless execution.
5. Timestamping:
Each transaction is time-recorded, allowing chronological tracking of vaccine movements and storage conditions, crucial for cold chain management.

V. RESULTS

Data from QR Code

SKU	CIP385827
Blockchian Data	Verified

VIII. CONCLUSION

The developed campus placement system presents a comprehensive and efficient solution aimed at transforming the traditional recruitment process. By leveraging machine learning, it delivers personalized job suggestions based on each student's skills and interests. Automated assessment tools reduce manual effort and ensure objective evaluations, while continuous feedback mechanisms help students enhance their employability. Employers gain access to better-matched candidates, and training and placement officers (TPOs) are equipped with insights to offer more targeted support. Overall, the system fosters a more dynamic, data-driven placement ecosystem that boosts success rates and supports the professional growth of students..

ACKNOWLEDGMENT

REFERENCES

[1] J. Dhandapani and R. Uthayakumar, "An EOQ model for a high cost and most wanted vaccine considering the expiration period," J. Anal., vol. 27, no. 1, pp. 55–73, Mar. 2019.

[2] M. A. Qureshi, K. N. Qureshi, G. Jeon, and F. Piccialli, "Deep learning-based ambient assisted living for self-management of cardiovascular conditions," Neural Comput. Appl., vol. 34, no. 13, pp. 10449–10467, Jul. 2022.

[3] U. H. Kartoglu, K. L. Moore, and J. S. Lloyd, "Logistical challenges for potential SARS-CoV-2 vaccine and a call to research institutions, developers and manufacturers," Vaccine, vol. 38, no. 34, p. 5393, 2020.

[4] K. N. Qureshi, A. Ahmad, F. Piccialli, G. Casolla, and G. Jeon, "Nature-inspired algorithm-based secure data dissemination framework for smart city networks," Neural Comput. Appl., vol. 33, pp. 10637–10656, Apr. 2020.

[5] M. Uddin, "Blockchain medledger: Hyperledger fabric enabled drug traceability system for counterfeit drugs in pharmaceutical industry," Int. J. Pharmaceutics, vol. 597, Mar. 2021, Art. no. 120235.

[6] D. Akunyili, "Fake and counterfeit drugs in the health sector: The role of medical doctors," Ann. Ibadan Postgraduate Med., vol. 2, no. 2, pp. 19–23, Feb. 2007.

[7] M. Westerkamp, F. Victor, and A. Küpper, "Tracing manufacturing processes using blockchain-based token compositions," Digit. Commun. Netw., vol. 6, no. 2, pp. 167–176, May 2020.

[8] S. K. Dwivedi, R. Amin, and S. Vollala, "Blockchain based secured information sharing protocol in supply chain management system with key distribution mechanism," J. Inf. Secur. Appl., vol. 54, Oct. 2020, Art. no. 102554.

[9] G. Arzu Akyuz and T. Erman Erkan, "Supply chain performance measurement: A literature review," Int. J. Prod. Res., vol. 48, no. 17, pp. 5137–5155, Sep. 2010.

[10] S. Saberi, M. Kouhizadeh, J. Sarkis, and L. Shen, "Blockchain technology and its relationships to sustainable supply chain management," Int. J. Prod. Res., vol. 57, no. 7, pp. 2117–2135, Apr. 2019.

[11] S. A. Abeyratne and R. P. Monfared, "Blockchain ready manufacturing supply chain using distributed

ledger," Int. J. Res. Eng. Technol., vol. 5, no. 9, pp. 1–10, 2016.

[12] K. Korpela, J. Hallikas, and T. Dahlberg, "Digital supply chain transformation toward blockchain integration," in Proc. 50th Hawaii Int. Conf.Syst. Sci., 2017, pp. 1–10.

[13] Y. Tribis, A. El Bouchti, and H. Bouayad, "Supply chain management based on blockchain: A systematic mapping study," in Proc. MATEC Web Conf., vol. 200, 2018, p. 00020.

[14] A. Kumar, R. Krishnamurthi, A. Nayyar, K. Sharma, V. Grover, and E. Hossain, "A novel smart healthcare design, simulation, and implementation using healthcare 4.0 processes," IEEE Access, vol. 8, pp. 118433–118471, 2020.