IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 12, April 2025
Impact Factor: 7.67

Blockchain in Pharmaceutical Supply Chains: A Path to Transparent Drug Traceability

A. V. L. Prasuna[1], Sure Sree Charan Reddy[2], Toom Ritesh Reddy[3]
Assistant Professor, Department of IT, Mahatma Gandhi Institute of Technology, Hyderabad, India[1]
B.Tech Student, Department of IT, Mahatma Gandhi Institute of Technology, Hyderabad, India[2,3]

Abstract: *Drug authenticity becomes very vital in the safety of patients and at the same time ensures efficiency in healthcare. Generally, conventional drug supply chains are prone to illicit counterfeit activities and poor visibility in the delivery of drugs that affect productivity due to manual inefficiencies. There, centralized systems are really not capable to guarantee traceability, transparency, and even data security across diverse participating actors. Therefore, addressing such challenges, this project proposes a decentralized drug traceability system powered by Ethereum blockchain and smart contracts in order to imitate the operations carried out from the sourcing of the raw materials through the entire commercial stages that a pharmaceutical product usually undergoes before reaching its end consumer. In this environment, smart contracts will enable smooth and automated ownership transitions; precise access control; and real-time verification of each entity's role in the supply chain. There is a custom-built pruning mechanism for sustainable growth of the blockchain while there are role-based modules to increase accountability. The proposed system by recording every interaction as a verifiable blockchain transaction would be an effective tool to combat fraud and at the same time reduce operational inefficiencies enabling compliance with regulation like DSCSA. This solution completely redefined an approach to restore trust, transparency, and integrity in the global pharmaceutical supply chain*

Keywords: Blockchain Technology, Pharmaceutical Supply Chain, Drug Traceability, Ethereum Smart Contracts

I. INTRODUCTION

More importantly, the pharmaceutical industry plays an important role in national development through the provision of essential medicines and by ensuring public health is maintained. But the integrity of the health supply chain is jeopardized by counterfeit medicines, inefficient distribution of drugs due to bad roads and warehouse conditions, and lack of transparency. Classical solutions providing drug traceability in the healthcare domain suffer due to security issues, low user control, and poor transparency with counterfeiting and validating drug sources therefore being like a wild goose chase.

Blockchain ensures the hosting character of distributed and tamper-proof environments with high data security, transparency, and trust. The system exploits the Ethereum blockchain, along with cryptographically encrypted data and smart contracts to automate and secure supply chain processes while maintaining privacy.

This utility is tracing and tracking the drug from the manufacturer through the stakeholders to the patient, verifying authenticity along the way, and claiming compliance with the U.S. Drug Supply Chain Security Act (DSCSA) and numerous global regulations. At the same time, it allows real-time auditing and regulatory reporting to eliminate all manual work while enhancing collaboration with shared and verified data. Overall, this approach will present a safe, transparent, and secure environment for the medical and pharmaceutical ecosystem to benefit patients, industries.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 12, April 2025
Impact Factor: 7.67

II. METHODOLOGY

SHA-256 HASHING ALGORITHM

Purpose: SHA-256, the Secure Hash Algorithm, at 256 bits, has a promise in the area of Data Integrity and Tamper Resistance, at all levels in the Pharmaceutical Supply Chain. It is thus an important cryptographic hash function that ensures high confidentiality of sensitive product data and the general trust of end-use manufacturing through distribution processes.

How It Works: Sha-256 compress any data input, in any kind of length, to a constant string of length 256 bits (64 hexadecimal characters). The output, known as the hash, is deterministic and irreversible. This means:
- The same input will always give the same hash.
- A single letter changed will result in a completely different hash.
- It is computationally impossible to retrieve the hash in order to recover the original data which guarantees confidentiality.

Project Implementation Details: The details of the project implementation are as follows: The manufacturer has to enter all relevant product information into the system during the batch creation of a product. This would generally consist of the name of the product, its chemical composition or medical use, name of the intended batch number, and the date of expiry. All four together identify a single specific batch of medicine. The system, instead of keeping such information in the raw form, converts those values into a single string, takes the SHA-256 hash of that string, thus giving a hash of fixed length. This hash acts as a secure digital fingerprint for the batch. Any slight change in input data into the system gives completely different output through SHA-256, and thus any change thereafter—be it legitimate, accidental, or intentional—will result in a different hash altogether. This becomes critical for any possibility of verification of product authenticity and integrity by the system in the future. For example, whenever an original hash is compared with the new hash generated from the latest product information, any disparities therein will automatically be flagged as manifesting that the data had been altered, tampered with, or wrongly reported out of error at any point in the supply chain. So, on this ground, the SHA-256 hashing property guarantees that an immutable record of product identity has been created, which presents traceability and verification assurance through the entire product life cycle.

II. ETHEREUM'S TRANSACTION SIGNING AND VERIFICATION

Purpose: It aims to use a transaction signing method in Ethereum, which would allow only authorized participants in a supply chain to create and approve transactions. Such authentication would be extremely important for trust, accountability, and security purposes in a pharmaceutical supply chain.

How It Works: It uses the asymmetric cryptography scheme. In this method, transaction signing/verification is done on the basis of public-private key pairs. Each participant in the supply chain, be it a manufacturer or distributor or pharmacy, has his unique cryptographic identity.

- This private key is securely held by the participant and used to sign the transactions
- The public keys are open to everyone; the network uses them to authenticate those signatures.

This model guarantees that only those who rightfully possess a private key can approve a transaction; while to anyone who has access to its accompanying public key is allowed to verify whether a transaction is authentic.

Project Implementation Details: When a distributor procuring a batch of medicines from the manufacturer initiates a transaction to transfer ownership of that batch, the transaction carries the specifics such as batch identifier and new ownership information. Prior to broadcasting the transaction to the Ethereum network, however, the distributor signs it with their private key, which serves as cryptographic proof of authorization. The signed transaction is then sent to the blockchain network.

DOI: 10.48175/IJARSCT-25992

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 12, April 2025
Impact Factor: 7.67

III. SMART CONTRACT CONNECTION

Purpose: Since smart contracts integrate through Web3.js, the front-end application can quickly access these smart contracts from the user side. This connection allows users to fetch data from the blockchain and perform decentralized transactions directly from the browser without relying on centralized intermediaries.

How It Works: It is just like the magic; Web3.js will make all the powers possible while creating JavaScript interfaces for web applications in communication with Ethereum nodes. It creates bridges for interaction via client-side deployed smart contracts; some of the important parameters that primarily establish communication with Web3.js will be:

• ABI (Application Binary Interface) The ABI can be thought of as a JSON representation of the smart contract methods and events.

• Smart Contract Address: This is a unique place in the blockchain where that smart contract is deployed. These two parameters are the basis on which Web3.js is going to construct a contract for developers to use it with access to all methods available on it (both read-only view functions and state-changing transaction functions). Hence the developer, smart contract methods can call it just like any other JavaScript functions.

Project Implementation: In the Pharma Chain project, Web3.js connects the frontend interface to a deployed smart contract in a blockchain-based supply chain. The operation stars like this:

Node Connection: When the application loads, it first establishes a connection to an Ethereum node. This is typically done via a browser wallet like MetaMask, or alternatively through a local Ethereum node during development.

Smart Contract Loading: Thereafter, the application obtains the ABI and address of the deployed SupplyChain smart contract required to instantiate the said contract in JavaScript.

Contract Instance Creation: The contract instance is created through the documents for the actions performed in it by calling Web3.js in the application.

Interaction Methods with the Blockchain: SupplyChainInstance exposes all the functions as defined in the smart contract.

• Read: Consult with GetProduct(batchId) for product detail.

• Write: Expected to be something like deliveredToTransporter(batchId), which in turn is a function call to modify the status of a product.

• Listen: For tracking product movement; listen for the events, ProductUpdated.

IV. CONSENSUS MECHANISM

Purpose: In essence, securing any transaction within the blockchain, the Proof of Work consensus protocol is used. This is why the entire network has to agree on the correct configuration of the current state of the ledger. This way, one can be sure that the data being written on the blockchain is being read by all as authentic and eternal. The integrity of transactions along the PharmaChain with respect to the supply chain, like transfer of batches of medicines, is well guarded by this protocol; it is just about impossible to revert and change records from the past. All this proves to be a very potent deterrent against any malafide element due to the energy and time involved.

How It Works: The functioning is like this: Each time a fresh transaction is set to begin (for example, a manufacturer transferring a batch-for-distribution of a medicine), it is batched with other transactions into a block. However, this block cannot just be added to the blockchain-it has to go through the validation process by mining, which involves the solution for the cryptographic puzzle. The first step involves the generation of a pseudo-random number called a nonce. This data, together with the nonce and the block data, will be input into a hashing algorithm, typically the SHA-256 algorithm, which is required to create a hash that reveals a certain number of leading zeros like (for example, 0000...). The number of the leading zeroes is basically a measure of the difficulty imposed by the network at that point in time, and it is readjusted so that blocks will be created at a constant interval. This is purely trial-and-error, and miners spend a lot of time testing millions of nonce values until they find the one providing a hash that meets the conditions delivered by the network. Thus comes the term Proof of

Work-meaning that miners must show proof of their work by greatly expending computational effort in validating a block. Such difficulty also helps maintain decentralization since making the network difficult for a certain entity to dominate or cheat.

Project Implementation: The PharmaChain system establishes a transaction for each batch of medicine that is transferred, such as from a Manufacturer to a Distributor. This is how this record is secured on blockchain:

- The transaction goes into a pool of pending transactions and batches with its peers into a block.
- Miners from around the globe will try to find a valid nonce under which the hash of the block data becomes compliant. The consensus is achieved, blocking and sending it to the network for its acceptance by other nodes.
- With an established consensus, the block is then permanently embedded in the blockchain. Any change attempt to the transaction data (changing the batch recipient or product details) will be an invalidation of the block hash. Since all blocks hash to their immediate predecessors, to alter a single block would demand the re-mining of that block and the rest of the blocks right up to the currently computed one, a task that is virtually impossible computationally, thereby assuring robust immutability and trust. Secondly, it provides an audit trail that can be time-stamped and independently verified, with which regulators and stakeholders can trace back confidently the full history of a product's movement in the supply chain.

V. LITERATURE SURVEY

This review paper analyses the ways in which blockchain technology can revolutionize healthcare supply chains in terms of making them secure, transparent, and traceable. The authors present a critical assessment of the 124 studies wherein identifies the applications of blockchain technology, including the prevention of drug counterfeiting, the enhancement of EHR management, and the rationalization of supply chain operations. It presents current challenges such as scalability, overall cost of implementation, slow speeds of transactions, and concern on privacy in addition to the integration problems of the blockchain to the existing one. It also emphasizes that the regulation compliance issues and the achieving industry-wide standardization have to be addressed for efficient adoption. Though much of the survey remains theoretical, it recognizes the need for empirical studies to complement practical applications in this area. For unlocking the disruptive potential of blockchain in healthcare, there is much more need for cooperation among policymakers, technologists, and industry leaders [1].

This paper discusses a blockchain solution for secure EMR sharing that links consumer devices with Mobile Edge Computing (MEC). The solution employs advanced cryptography (AES, RSA, EdDSA, ECDSA) to ensure access control and data integrity and uses the Inter-Planetary File System (IPFS) for storage. Under the proposed system, the efficiency has been improved when compared to the other solutions, while scalability, the threat of unauthorized access, interoperability issues, resource constraints, and conflicts regarding regulatory compliance remain major challenges for adoption in the health sector. Addressing the potential will need not only the technical innovations but rather a whole rethinking of the current healthcare IT architecture so that it can accommodate sufficiently decentralized solutions [2].

TISVSchain is a kind of blockchain framework for managing the vaccine supply chain that optimizes it. It provides transparency, security, and traceability, apart from resolving counterfeit vaccine issues and improving transaction efficiency. Though promising features, scalability, and latency issues in larger networks, synchronization issues when integrated into the system offline present barriers to cost factors of high implementation complexity and costs in adopting it on a wider basis. Future development should be directing more at lightweight blockchain protocols and hybrid models that would provide scalability and robustness in the real environment [3].

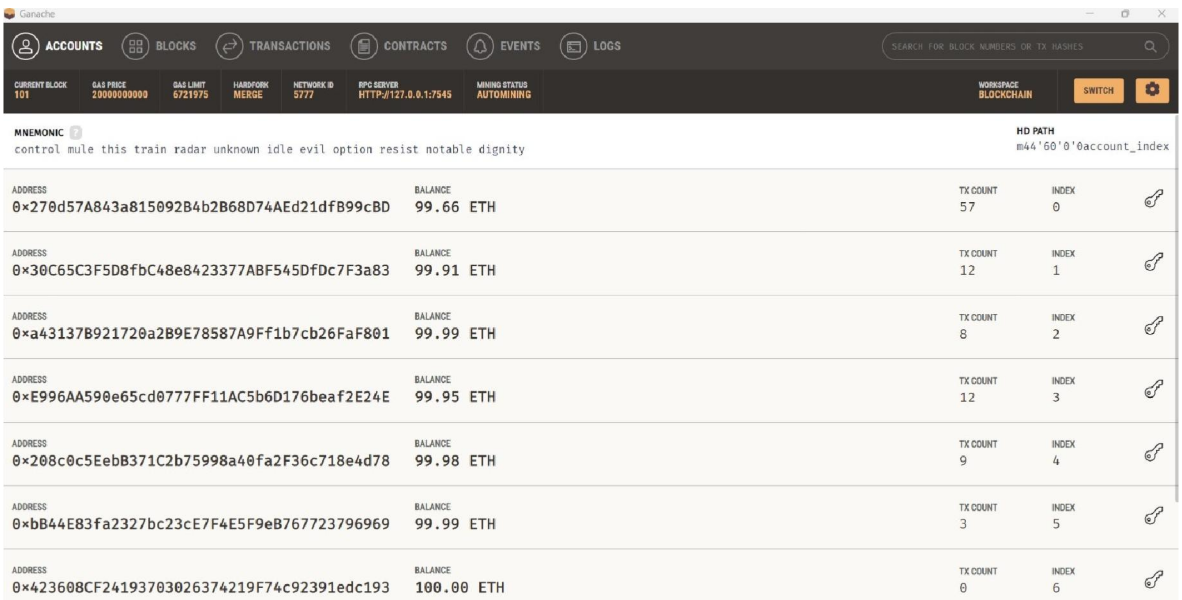
The Blochchain technology backing telehealth systems by BlockHeal mainly guarantees delivery of healthcare with secure transparency and efficiency without being compromised in data management. It combined

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 12, April 2025
Impact Factor: 7.67

decentralized storage and decentralized applications to improve accessibility and integrity of data among telehealth services. There still remain challenges to wide adoption, for example, integration across different healthcare systems, and the technical complexities that come together with these decentralized technologies, such as Hyperledger Fabric and DApps. A continuously innovated user-friendly interface and middleware solutions can assist in bridging the gap between decentralized and traditional healthcare infrastructures [4].

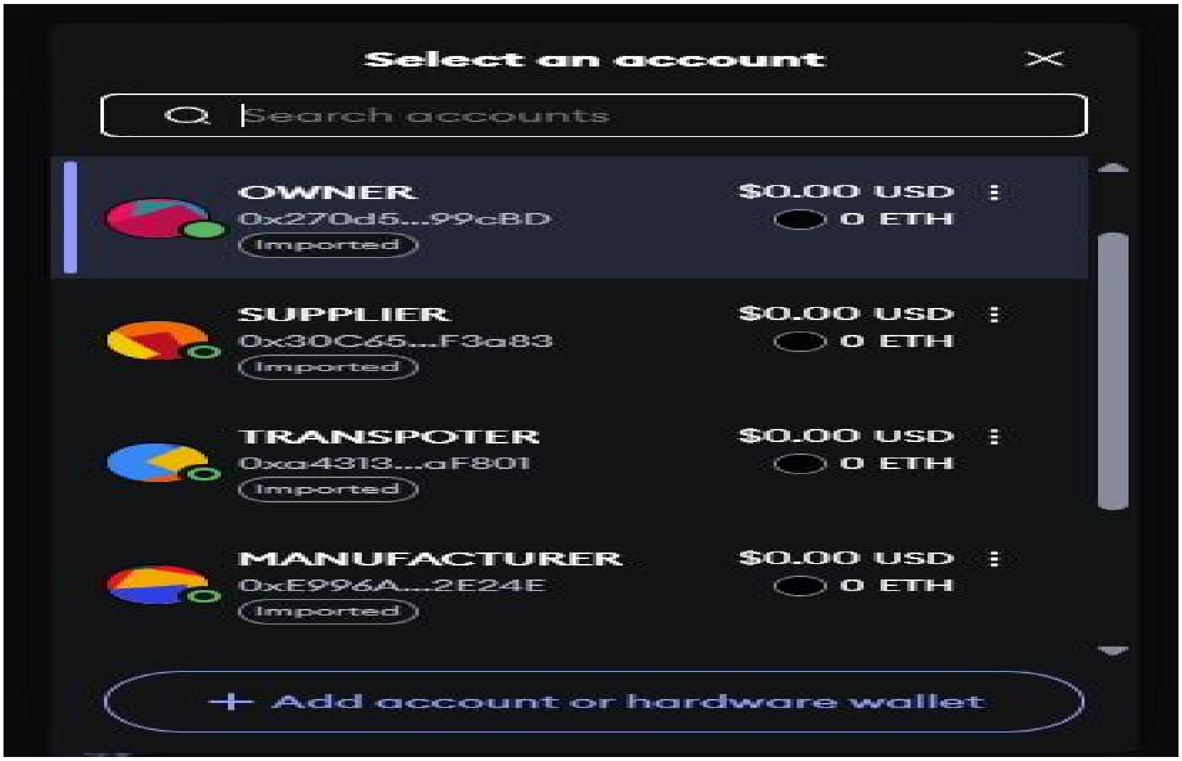
This paper proposes Ethereum-based smart-contract and decentralized-storage blockchain technology to enhance traceability in pharmaceutical supply chains. Counteracting counterfeit drugs, the system secures and transparent data handling. However, some of the limiting factors are data privacy concerns (e.g. in accordance with GDPR), scalability limitations of the chosen technology, issues of interoperability with other blockchains, and efficiency bottlenecks related to smart contracts and consensus mechanisms. In the foreseeable future, improvements in privacy-preserving technologies, including zero-knowledge proofs and Layer-2 solutions, can pave a way for addressing these limitations and enabling a scalable and compliant healthcare blockchain ecosystem [5].

VI. RESULTS

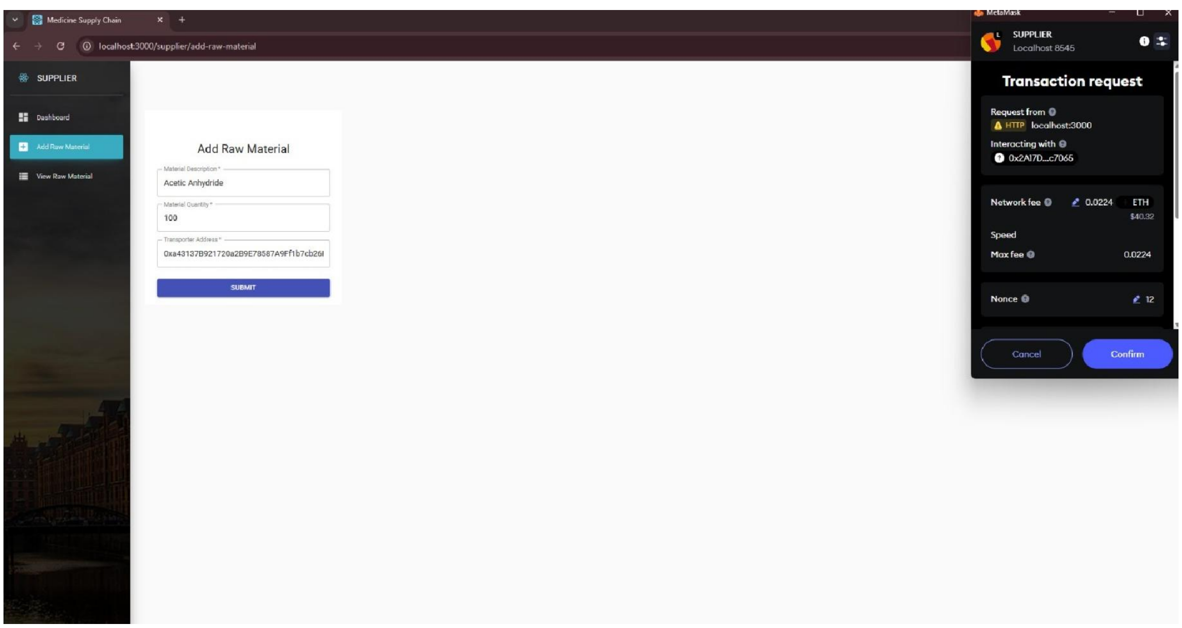


Ganache

ISSN: 2581-9429
Impact Factor: 7.67



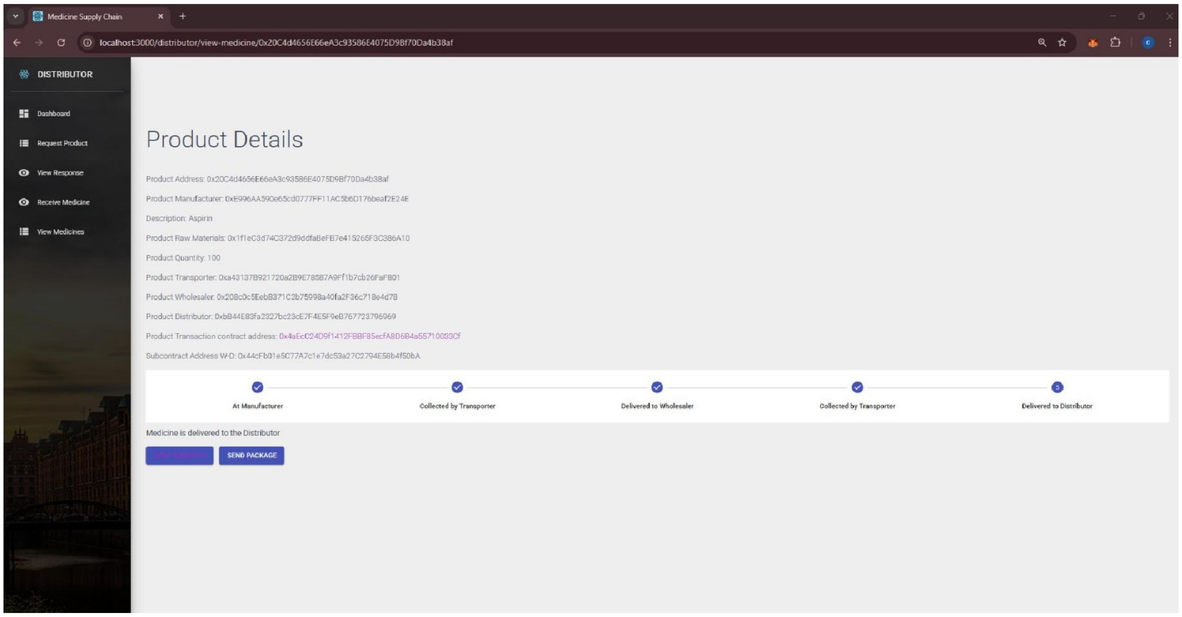
Meta mask Accounts



DOI: 10.48175/IJARSCT-25992

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 12, April 2025
Impact Factor: 7.67

Supplier adding raw materials



Distributor received medicines

VII. CONCLUSION

This is a documentation about the complete blockchain architecture that is aimed at transforming the pharmaceutical supply chain traceability completely. It achieves complete product visibility, secure and transparent transaction recording, and tamper-proof ownership transfer by spreading the work of Ethereum smart contracts. In this way, a lot of centralized authority dependence has been reduced and thus risks relating to data manipulation, product diversion, and counterfeit drug distribution have been reduced to a considerable extent. The proposed system uses immutable transaction log status updates around-the-clock on products to permit full visibility between manufacturers, distributors, regulators, and consumers. It builds public trust, allows smooth regulatory audits, and transfers the pharmaceutical standards into reality using strict compliance conditions. This architecture is the answer to a better and safer supply chain ecosystem in pharmaceuticals, besides being useful for verification, and is now looking to meet the changing global scales for effective supply chain management.

VIII. ACKNOWLEDGMENTS

Indeed, the thanks are extended to all those involved in bringing this project on blockchain architecture for pharmaceutical supply chain traceability to completion. This project would not have been made possible without the strong support of dedicated team members, domain experts, and stakeholders intently guiding and collaborating with the project.

To our technical advisors: thank you very much for invaluable input in Ethereum smart contract development and secure system design; it is that which literally defined this tamper-proof, transparent, and decentralized solution. Lastly, we appreciate verbal givings from the pharmaceutical partners and regulatory consultants regarding their experiences from the field.

Thanks to the research and development team for their unending efforts towards formulation of a sturdy architecture that will make changing supply chain visibility, minimizing counterfeiting risks, and beefing public confidence with immutable transaction logs.

It is a collective event meant to raise the bar for integrity, safety, and scalability in the global pharmaceutical supply chains.

REFERENCES

[1]. Ahmad Musamih; Khaled Salah; Raja Jayaraman; Junaid Arshad; Mazin Debe, et. al., "A Blockchain-Based Approach for Drug Traceability in Healthcare Supply Chain" published in ieee open Access, available at https://ieeexplore.ieee.org/document/9316803.

[2]. Mueen Uddin, Khaled Salahand Samer Ellahham; et. al., "Blockchain for drug traceability: Architectures and open challenges" published in journals open Access, available at https://journals.sagepub.com/doi/10.1177/14604582211011228.

[3]. Nazik Zakari,Muna Al-Razgan, Amani Alsaadi, Haya Alshareef, Heba Al saigh, Lamia Alashaikh., et. al., "Blockchain technology in the pharmaceutical industry: a systematic review" https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9137953/.

[4]. Kailash Chandra Bandhu, Ratnesh Litoriya, Pradeep Lowanshi, Manav Jindal, Lokendra Chouhan & Suresh Jain, et. al., "Making drug supply chain secure traceable and efficient: a Blockchain and smart contract based implementation" published in springer open Access, available at https://link.springer.com/article/10.1007/s11042-022-14238-4.

[5]. Sandeep Nair, Tushar Sharma, Saurabh Yadav, Raj Singh, Ashwini Kumar Verma, et. al., "HEALTHCARE SUPPLY CHAIN USING BLOCKCHAIN" published in irjmets open Access, available https://www.irjmets.com/uploadedfiles/paper/issue_5_may_2023/40812/final/fin_irjmets16854 31727.pdf