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CRYPTOPHARMACY- BLOCKCHAIN BASED PHARMACY SUPPLY CHAIN

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Abstract: The pharmaceutical sector has a value exceeding $1 trillion and efficient supply chain management (SCM) is crucial for achieving economic, ecological, and social advantages in the supply chain sector. However, conventional SCM procedures often encounter various issues such as inadequate sharing of information, extended wait times for retrieving data, doubts about the reliability of product tracking, and the presence of counterfeit products. Blockchain technology holds a great deal of promise to address these issues due to its main features, including immutability, transparency, and decentralization. A blockchain-based pharmacy supply chain refers to the use of a distributed ledger technology that allows for the tracking of pharmaceutical products as they move through the supply chain, from the manufacturer to the end consumer. This technology provides a tamper-proof and transparent record of all transactions, ensuring that drugs are safely and securely delivered to the intended recipients. Overall, the use of blockchain technology in pharmacy supply chain has the potential to revolutionize the way how drugs are tracked and distributed.

Index Terms **- Blockchain, Traceability, Counterfeit Drugs, Supply Chain Management.**

I. INTRODUCTION

The process of distributing prescription medications to patients is done through a complex and lengthy pharmaceutical supply chain network. This network involves multiple stages that can span over several months and take place across various regions worldwide. The supply chain includes several entities such as suppliers, manufacturers, transporters, wholesalers, distributors, retailers, and others. Tracking each drug throughout the supply chain and tracing it back to its origin can be a cumbersome task. The issue of drug fraud is prevalent across the globe. According to the Health Research Funding organization, between 10 to 30 percent of pharmaceuticals in underdeveloped nations are counterfeit, which raises serious concerns about their impact on human health. About 30% of all medications sold in Africa, Asia, and Latin America are fake, according to the World Health Organization. Contrary to popular belief, the main issue with counterfeit drugs is that they often have different side effects on human health than legitimate medications [13].

The current lack of transparency in the supply chain system makes it difficult for customers or buyers to accurately assess the value of products. Additionally, investigating any suspicious or unethical activities within the supply chain is also challenging due to the lack of clarity. This inefficiency affects vendors, suppliers, and other entities involved in the chain as it becomes difficult to link them and determine their needs. However, blockchain technology can revolutionize this industry. By providing a distributed hyperledger with no centralized control, each transaction in the blockchain becomes immutable, making it impossible to tamper with sensitive data like customer and drug information. The transparency that blockchain provides builds trust between the various entities in the supply chain, such as manufacturers, distributors, suppliers, and end-users. By implementing an event request-response framework, each product can move across the authenticated chain entities, with smart contracts documenting all interactions in the blockchain.

Blockchain is an unconventional platform that alleviates the reliance on a single, centralized authority, yet still supports secure and pseudo-anonymous transactions and agreements directly between interacting parties. Three paramount key features of the blockchain technology are immutable transactions, transparency, distributed ledgers; these unique features brought the attention of the corporate world to engender enterprise blockchain systems (Hyperledger) [12]. Blockchains can facilitate supply chain network information management providing real-time tracking, verifiability, and security. Acquiring information from supply chain networks managed by disparate, sometimes stand-alone, systems, like enterprise resource planning (ERP), is cumbersome. Blockchains can connect the supply chain members and provide real-time data to stakeholders [6].

II. PROBLEM STATEMENT

By incorporating Blockchain technology into Supply Chain Management (SCM), it is possible to enhance the conventional approach and ensure traceability and tracking from the source to the consumer. This, in turn, can lead to greater efficiency in the industry by safeguarding consumers, fostering trust, enhancing service quality, and closing loopholes exploited by malicious actors who distribute fake drugs.

III. SYSTEM IMPLEMENTATION

The algorithms used in the execution of the supply chain are given below:

- Algorithm for Admin Login:

Step 1: Start Admin login

Step 2: Call MetaMask web services to request account address

Step 3: Validate login –

```
If(account_address === admin_account){
        Login as admin ;
        Return admin dashboard;
}else {
        Error? Return to home page
}
```

Step 4: Stop

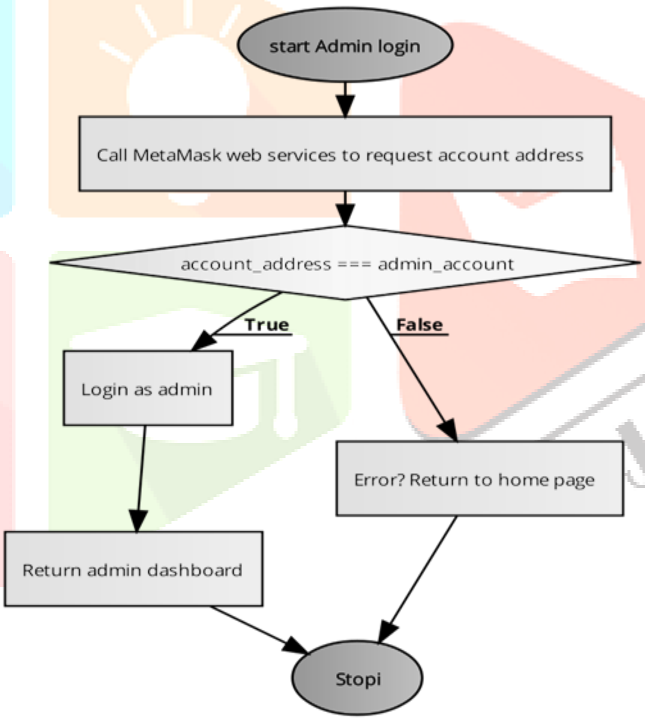


Fig. 1. The above flowchart represents the process for admin login

- Algorithm for User Login:

Step 1: Start User Login

Step 2: Get wallet address

Step 3: Switch user based on wallet address:

```
switch (wallet_address) :
case (wallet_address==Supplier_address)
        return supplier dashboard
break;
case (wallet_address== Manufacturer_address)
        return Manufacturer dashboard
break;
case (wallet_address== Transporter _address)
        return Transporter dashboard
break;
case (wallet_address== Wholesaler_address)
        return Wholesaler dashboard
break;
case (wallet_address== Distrubuter_address)
        return Distrubuter dashboard
break;
case (wallet_address== Pharma_address)
        return Pharma dashboard
break;
default :
        error? Return home page
```

Step 3 : End

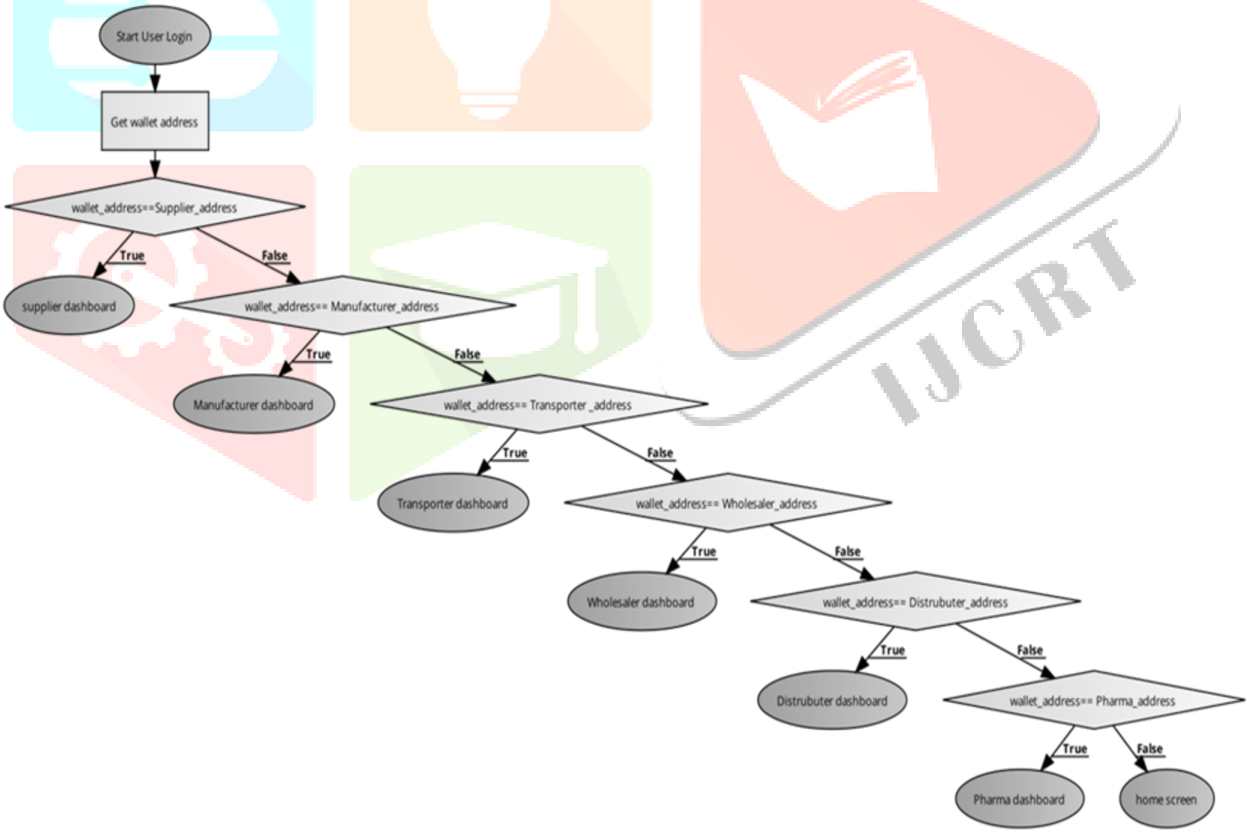


Fig. 2. The above flowchart represents the process for user login

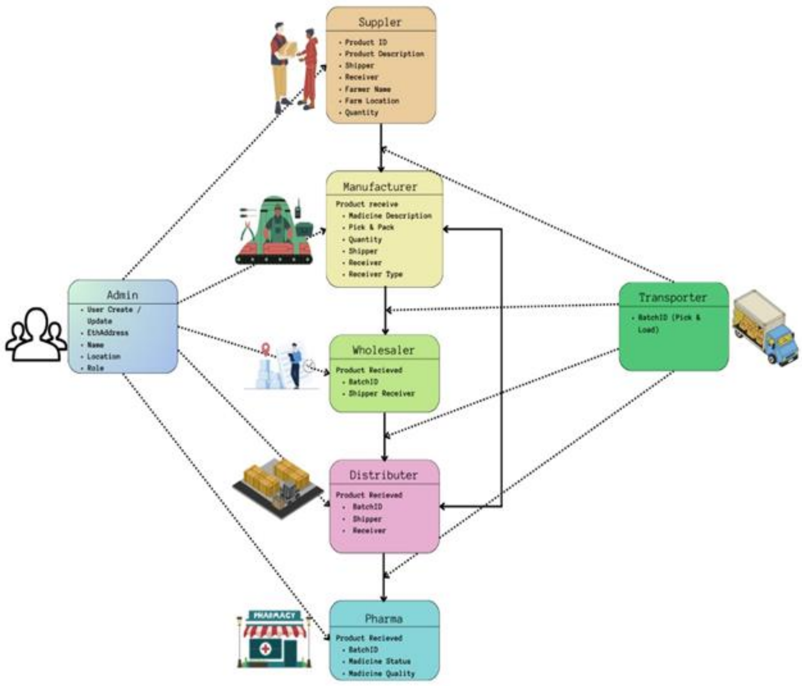


Fig. 3. System Architecture

System architecture involves various users that are involved in the supply chain. These users function and operation results in the proper execution of the pharmacy supply chain. The above diagram gives the brief information about the role of each user.

Sequence Diagram

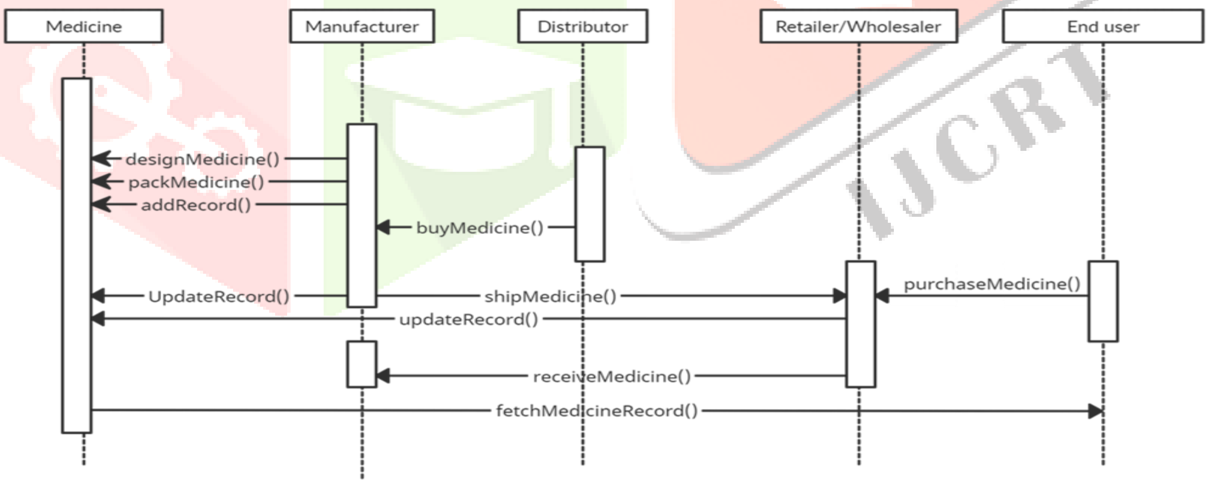


Fig. 4. Sequence Diagram

The above diagram gives the overall sequence of the activities involved in the supply chain process. The supply chain starts from gathering raw materials required for manufacturing a particular drug, then the drug is manufactured and packaged by manufacturer and is sent to the intended receiver through the transporter.
The package is then transported to the wholesaler and eventually to the distributor (retailer) from where the customer can purchase the medicine. This process is secured using blockchain technology so as to reduce and tackle the issue of counterfeit drugs. Using Blockchain technology one can track their package and also verify its authenticity. For each transaction say from supplier to manufacturer a unique Ethereum address is assigned, which reduces fake medicines.

UML Diagrams:

- Multilevel Data Flow Diagram

A data flow diagram (DFD) is a graphical representation of how data flows within a system. It is a tool for modeling and analyzing the flow of data in a system, and is often used in software engineering and business process modeling. A DFD consists of four main components: processes, data stores, data flows, and external entities.

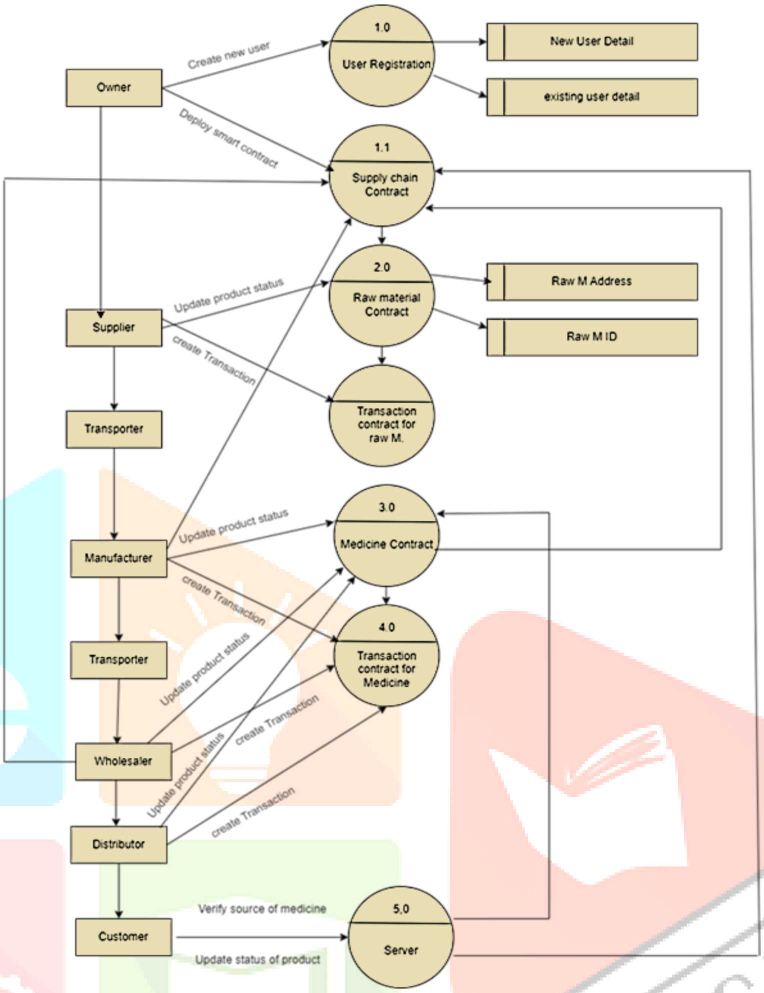


Fig. 5. Data Flow Diagram

- Collaboration diagram

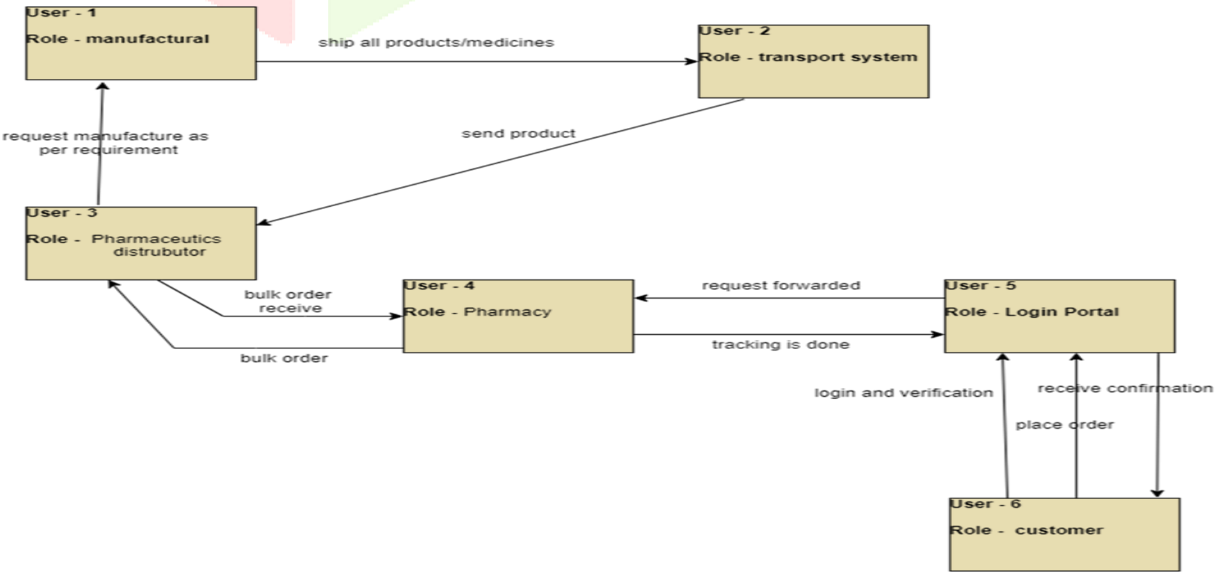


Fig. 6. Collaboration Diagram

A collaboration diagram, also known as a communication diagram, is a type of diagram used in software design to visualize the interactions between objects or components in a system. It is a dynamic diagram that shows the objects and messages involved in a particular scenario or use case.

- Class Diagram

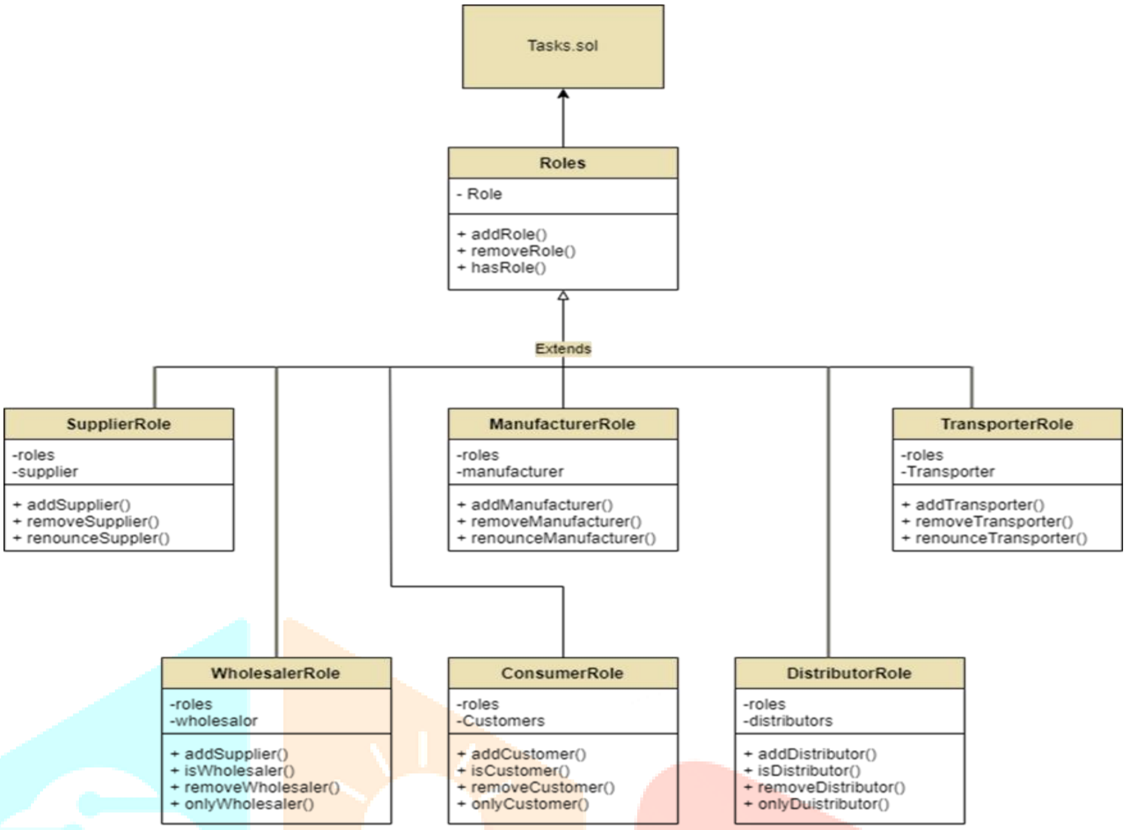


Fig. 7. Class Diagram

The class diagram illustrates a fixed perspective of an application, demonstrating the various types of objects present within the system and their interrelationships. Each class comprises of its own objects and may also acquire properties from other classes. By creating a class diagram, it is possible to visually depict, articulate, and document a variety of elements within the system, as well as develop executable software code.

The algorithms used in the implementation of blockchain technology are given bellow:

Various algorithms are employed in pharmaceutical supply chains based on blockchain technology, and the selection of a specific algorithm is influenced by factors such as the unique demands of the supply chain and the attributes of the blockchain platform implemented.

1) Consensus algorithm

The function of a blockchain is to operate as a decentralized record-keeping system that stores all transactions involving digital coins. As a result, the blockchain grows continuously by appending new blocks over time. Many popular cryptocurrency blockchains are public and accessible through web platforms, allowing anyone to query the transactions they contain. A distributed consensus protocol defines how a network determines which peer will prepare and seal the newest block with still unconfirmed and non-formatted data. The simplest way is to determine it randomly, but such an approach is not effective in terms of network longevity and can even be dangerous for the network, since peers could decide to attack the whole network. The idea behind PoW, PoS and others is the fact that the chosen node (miner) contributes something valuable and the best node is rewarded. The reward promotes competition and a competition where adversaries check each other's work and valuables also mitigates the chances of a possible attack [2].
One of the key features of blockchain is its ability to enable transactions between entities without requiring the involvement of a trusted intermediary. Instead of relying on such third parties, validators such as miners are utilized to confirm transactions in a decentralized manner. This is achieved through a distributed consensus, which facilitates agreement among multiple parties that do not inherently trust each other. In the context of cryptocurrency, this consensus is used to solve the double-spending problem, which involves verifying that a particular amount of digital currency has not already been spent without relying on a trusted third party, such as a bank, to maintain records of transactions and account balances.

2) Proof of Authority (PoA)

The PoA (Proof of Authority) algorithm is utilized in blockchain-based pharmaceutical supply chains to maintain the blockchain and validate transactions. PoA employs a group of trustworthy validators who are pre-approved to verify transactions and add them to the blockchain. These validators are chosen based on their reputation, expertise, and reliability. Unlike other consensus algorithms such as PoW (Proof of Work) and PoS (Proof of Stake), PoA does not require validators to solve complex mathematical problems or stake their own cryptocurrency.

One of the significant advantages of PoA is its efficiency and scalability. As validators are already approved, transaction processing times are faster, and the network can handle a higher volume of transactions. Moreover, since validators do not have to solve complex problems or stake their own cryptocurrency, the energy consumption of PoA is lower than PoW and PoS.
In the context of pharmaceutical supply chains, PoA is particularly useful in ensuring the authenticity and traceability of pharmaceutical products. By relying on a group of trusted validators, PoA prevents the introduction of counterfeit products into the supply chain and ensures that each transaction is accurately recorded and auditable. This can significantly increase patient safety and reduce the risk of fraudulent activity in the pharmaceutical industry.

3) SHA algorithm

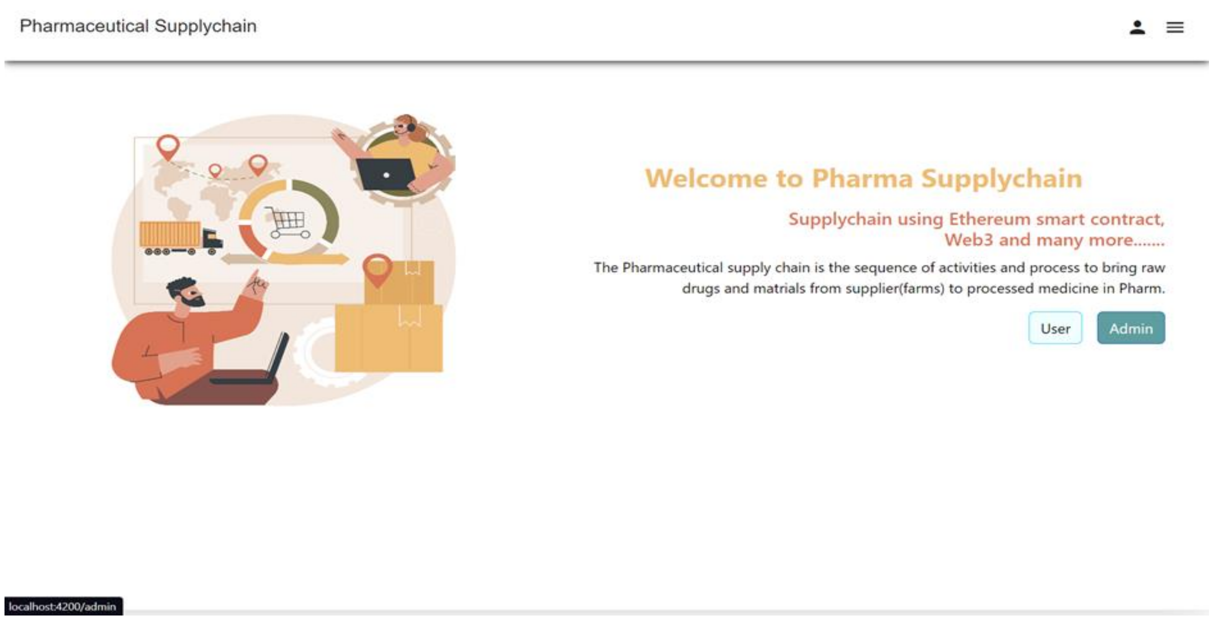
In blockchain-based pharmaceutical supply chains, the SHA (Secure Hash Algorithm) is a cryptographic hash function that is used to safeguard and verify transactions and data. This algorithm generates a fixed-length hash value that is unique to the input data of any size. The hash value serves as a digital fingerprint of the original data and can be employed to authenticate and maintain the integrity of the data. After the hash value is generated, it is added to the blockchain and becomes part of the distributed ledger.
SHA algorithms can be used in various aspects of the supply chain, such as securing product information, transaction records, and identity verification. For instance, the SHA algorithm can ensure that vital product information, including batch numbers and expiration dates, remain unaltered throughout the supply chain. Additionally, the SHA algorithm can verify the identity of different parties in the supply chain, such as manufacturers, distributors, and pharmacies. The Ethereum-based blockchain systems also utilize the SHA algorithm to secure and authenticate transactions and data, just like in other blockchain-based pharmaceutical supply chains. However, Ethereum uses a slightly different hashing algorithm called Keccak-256, which is also known as SHA-3. The Keccak-256 algorithm is based on the SHA-3 standard and is used in Ethereum to hash data, including transactions, blocks, and smart contracts.

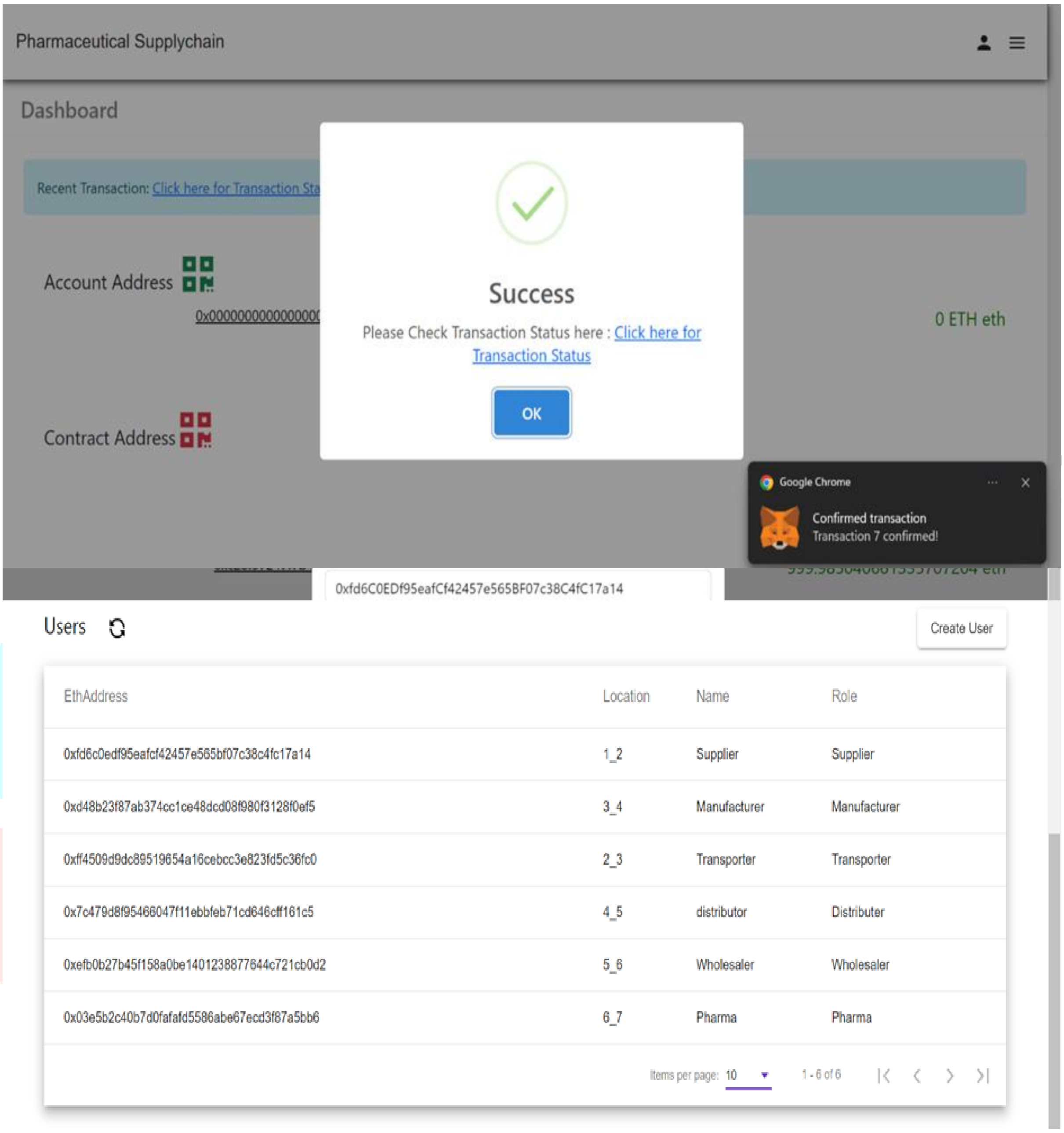
4) PKI algorithm

PKI (Public Key Infrastructure) algorithms, including SHA-1 or RSA, along with digital signatures, are crucial components of the security framework in Ethereum-based pharmaceutical supply chains. In such blockchain systems, digital signatures are used for transaction authentication and non-repudiation, ensuring that a sender cannot deny having sent a particular transaction. To create a digital signature, the sender uses their private key to sign the transaction data, generating a unique digital fingerprint of the transaction, which is then added to the blockchain with the transaction data. PKI algorithms, such as SHA-1 or RSA, are employed to create public-private key pairs that are utilized in the digital signature process. While the private key is kept secret by the sender, the public key is shared with other network participants. The public key is used to validate the digital signature of a transaction, guaranteeing that the transaction was indeed signed by the sender using their private key.
In Ethereum-based pharmaceutical supply chains, PKI algorithms and digital signatures are useful in validating and authenticating transactions between different stakeholders, such as manufacturers, distributors, and pharmacies. Through the use of digital signatures, participants can ensure that transactions are accurately and securely recorded on the blockchain, enhancing transparency and accountability in the supply chain. Overall, the incorporation of PKI algorithms and digital signatures in Ethereum-based pharmaceutical supply chains strengthens the security and integrity of the supply chain data, improving transparency and accountability for all participants in the ecosystem.

IV. PROPOSED OUTCOMES

There are several screenshots attached below used to represent the supply chain process.




Pharmaceutical Supplychain
Dashboard
Recent Transaction: Click here for Transaction Sta
Account Address
Contract Address
Success
Please Check Transaction Status here : Click here for Transaction Status
OK
0 ETH eth
Google Chrome
Confirmed transaction
Transaction 7 confirmed!
0xfd6C0EDf95eafCf42457e565BF07c38C4fC17a14
Users
Create User
EthAddress
Location
Name
Role
0xfd6c0edf95eafcf42457e565bf07c38c4fc17a14
1_2
Supplier
Supplier
0xd48b23f87ab374cc1ce48dcd08f980f3128f0ef5
3_4
Manufacturer
Manufacturer
0xff4509d9dc89519654a16cebcc3e823fd5c36fc0
2_3
Transporter
Transporter
0x7c479d8f95466047f11ebbfeb71cd646cff161c5
4_5
distributor
Distributer
0xefb0b27b45f158a0be1401238877644c721cb0d2
5_6
Wholesaler
Wholesaler
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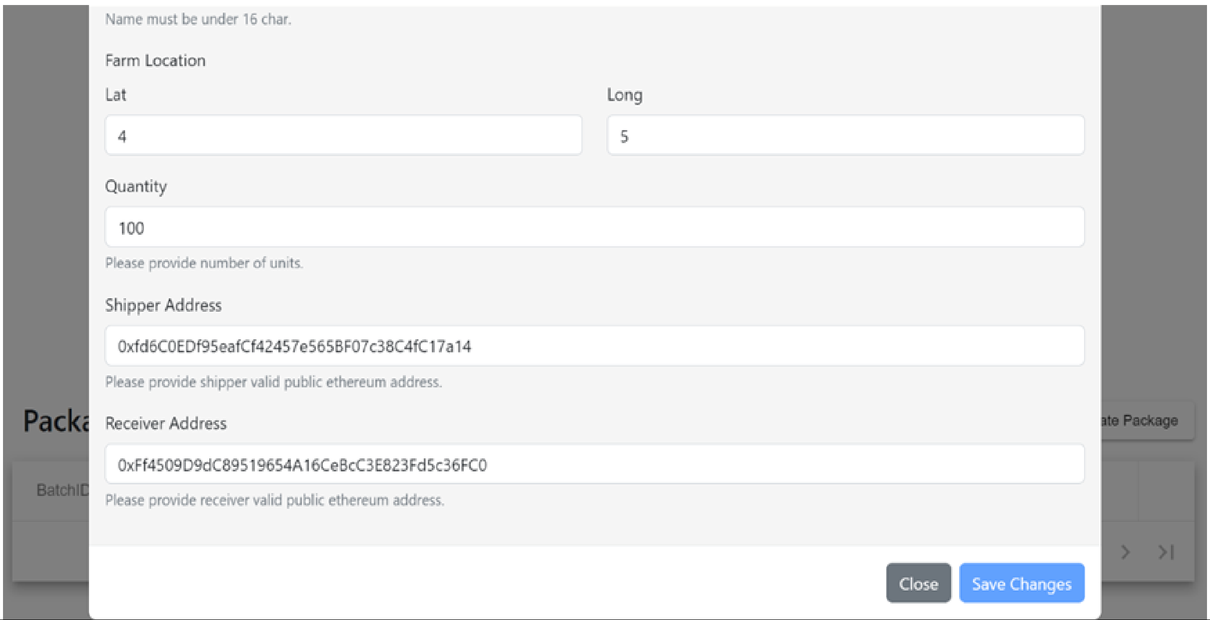
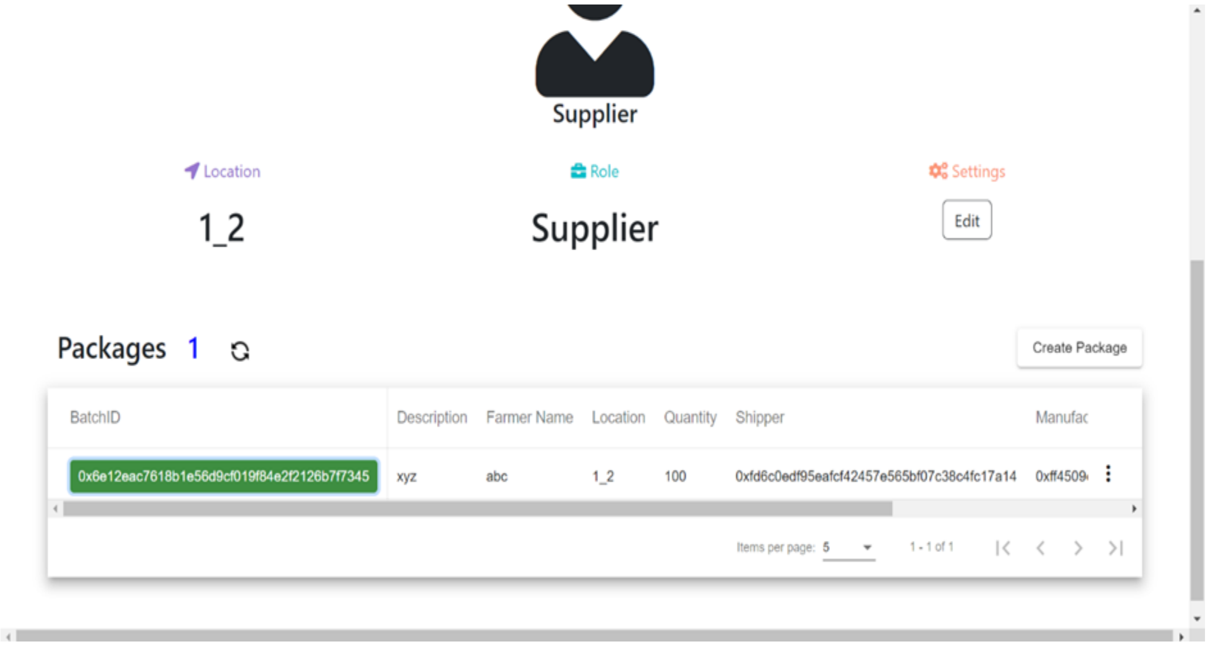
6_7
Pharma
Pharma
Items per page: 10
1 - 6 of 6


Name must be under 16 char.
Farm Location
Lat
4
Long
5
Quantity
100
Please provide number of units.
Shipper Address
0xfd6C0EDf95eafCf42457e565BF07c38C4fC17a14
Please provide shipper valid public ethereum address.
Receiver Address
0xFf4509D9dC89519654A16CeBcC3E823Fd5c36FC0
Please provide receiver valid public ethereum address.
Close
Save Changes


Supplier
Location
Role
Settings
1_2
Supplier
Edit
Packages 1
Create Package
BatchID
Description
Farmer Name
Location
Quantity
Shipper
Manufac
0x6e12eac7618b1e56d9cf019f84e2f2126b7f7345
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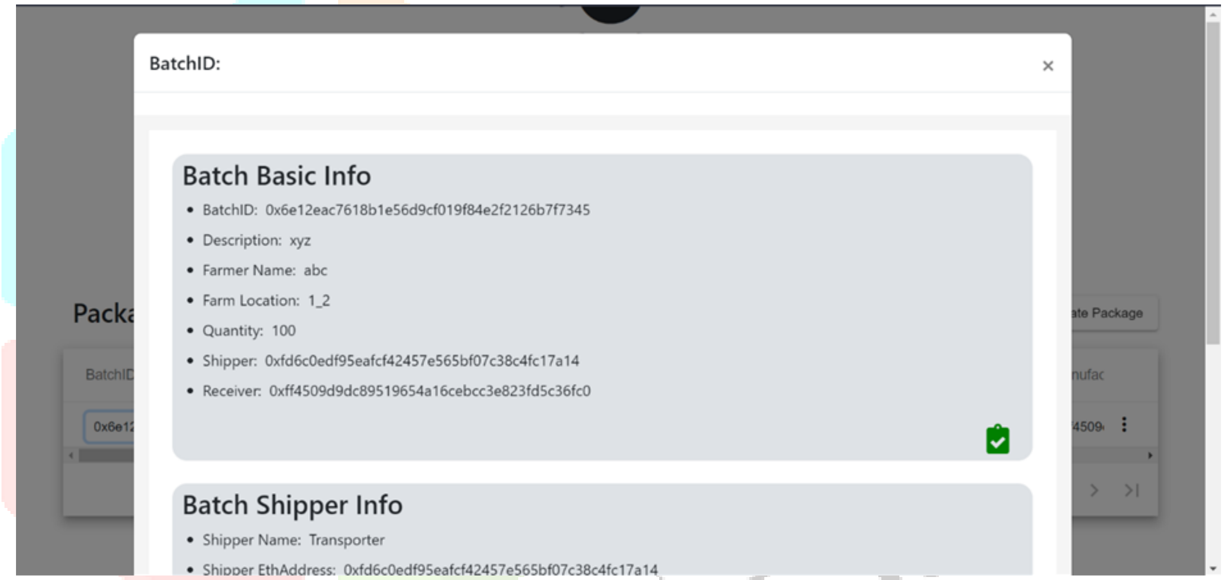
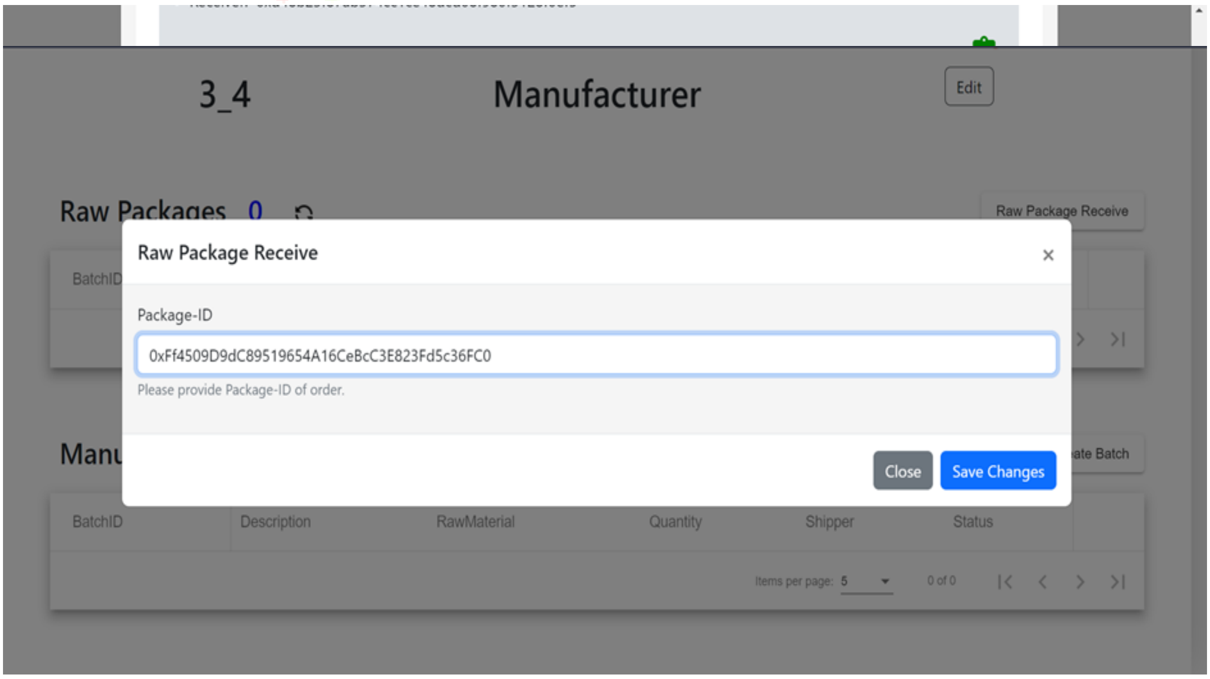
Items per page: 5
1 - 1 of 1


BatchID:
Batch Basic Info
BatchID: 0x6e12eac7618b1e56d9cf019f84e2f2126b7f7345
Description: xyz
Farmer Name: abc
Farm Location: 1_2
Quantity: 100
Shipper: 0xfd6c0edf95eafcf42457e565bf07c38c4fc17a14
Receiver: 0xff4509d9dc89519654a16cebcc3e823fd5c36fc0
Batch Shipper Info
Shipper Name: Transporter
Shipper EthAddress: 0xfd6c0edf95eafcf42457e565bf07c38c4fc17a14


3_4
Manufacturer
Edit
Raw Packages 0
Raw Package Receive
Raw Package Receive
Package-ID
0xFf4509D9dC89519654A16CeBcC3E823Fd5c36FC0
Please provide Package-ID of order.
Close
Save Changes
BatchID
Description
RawMaterial
Quantity
Shipper
Status
Items per page: 5
0 of 0

The above picture indicates the successful completion of first part of the transaction, from supplier to manufacturer through the transporter. The raw package is received by manufacturer and this is how the process is continued for the rest of the chain involving other users.

V. ADVANTAGES AND DISADVANTAGES

Some of the advantages of the technology are as follows:

- Trust:

The decentralized and unalterable nature of blockchain data instills trust among supply chain participants who rely on this data. This is in contrast to the conventional supply chain data storage system, where each participant maintains their own records, leading to disagreements when these records don't align.

- Efficiency:

With blockchain technology, all data related to a product's journey through the supply chain is recorded and visible to every member involved. This means that if there is a nonconformance issue like a product defect or missing quantity, it is easy to pinpoint where the issue occurred in the supply chain. This eliminates the need for time-consuming email and phone call exchanges to track down the root cause. Additionally, because the relevant documents are stored on a shared ledger, there is less need for physical paperwork.

- Transparency:

Blockchain technology promotes transparency in the supply chain by automatically recording all data with a timestamp, including details that are typically not recorded in traditional supply chain systems such as production steps or purchase order receipts. Additionally, end-to-end tracking of the supply chain can be achieved through blockchain technology, which provides transparency to all members on the blockchain. Compared to traditional supply chain systems, disputes can be resolved more quickly due to the transparency provided by blockchain technology.

Some of the disadvantages are explained below:

- Permissioned Blockchains:

A blockchain that is not open to the public, known as a permissioned blockchain, is typically used to protect sensitive supply chain information. However, this type of system is less secure due to the smaller number of nodes that make up the blockchain, and the fact that these nodes are usually familiar with each other. This familiarity could result in collusion, making it easier to change a block on the blockchain.

- The Human Element:

Although it is valuable for every member of a supply chain to know that the data on a blockchain cannot be altered once it has been established, errors or intentional misconduct can still occur when entering initial data into the blockchain. This means that the information on the blockchain may not be entirely accurate and could even be fraudulent. Essentially, the use of blockchain technology does not prevent incorrect data from being added to the chain; it simply allows all users to verify that the data has not changed since a particular point in time. As blockchain technology is typically immutable, fraudulent data added to the chain can cause problems.

- Scaling:

Compared to traditional databases, blockchain solutions are significantly slower in processing transactions because transactions require validation from numerous computers or servers. Also, for a supply chain with a large number of transactions, utilizing a permissionless blockchain could be expensive due to the transaction fees miners charge to create blocks. As some supply chains process millions of transactions each day, scalability must be considered when implementing blockchain technology.

- Upfront Costs:

Implementing a blockchain solution can be expensive, as there are several upfront costs involved. For instance, hiring blockchain developers can be more costly than hiring traditional developers, due to their specialized skillset. Additionally, planning, licensing, and maintenance costs can also add up and result in a substantial overall cost.

VI. CONCLUSION

To prevent counterfeit products in supply chain management, it's important to secure all stages of the process. However, current architecture can't track all system malfunctions that may lead to the introduction of duplicate products. Therefore, Blockchain technology can be used to improve the efficiency and security of the system. By tracking the location of introduction of any duplicate products, the proposed architecture enables reverse tracking of the system.

The paper proposes a smart anti-counterfeit drug supply chain system based on Blockchain technology. The system uses smart contracts and product registration and transferring to permanently register all product transferring records in an unchangeable ledger. This enables tracking of products, and consumers can participate in preserving information flows. The system has decentralized characteristics, which reduces the possibility of data tampering. Additionally, an event request-response process verifies the authenticity of all parties' signatures in the event. All events are logged in the Blockchain and can be viewed in real-time.

VII. FUTURE SCOPE

The future scope of blockchain-based pharmacy supply chains is vast and promising. As blockchain technology continues to evolve, it has the potential to bring even greater transparency, efficiency, and security to the pharmaceutical industry.

One possible area of potential development is the use of smart contracts and automated processes to streamline supply chain operations. Smart contracts can be used to automatically trigger payments, verify product authenticity, and ensure compliance with regulatory requirements.

Another area of potential development is using image processing technology in facial recognition which can be integrated into the process of issuing identity documents, typically in conjunction with other biometric technologies like fingerprint recognition. AI-powered Chat bots can be implemented to track medication orders and verify the details of retailers and sellers.

In addition, blockchain technology could be used to create a decentralized network of pharmacies and suppliers, allowing for greater collaboration and information sharing. This could lead to more efficient distribution channels and better patient outcomes.

Overall, the future of blockchain-based pharmacy supply chains looks bright, with the potential to bring significant benefits to patients, healthcare providers, and the pharmaceutical industry as a whole.

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