A WEB BASED INTERFACE OF SUPPLY CHAIN MANAGEMENT IN PHARMACEUTICAL COMPANY USING BLOCKCHAIN

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Abstract.
The usage of counterfeit medications or treatments is growing significantly as a result of poor supply chain management in pharmaceutical corporations. It's required to keep track of drug ownership, shipment of expired medicines, etc. regularly. Blockchain is a trustworthy solution to deal with this. It also helps to maintain transparency within companies. To keep track of transactions about the sale or purchase of medications, Blockchain uses a decentralized database technique. Mainly smart contracts and hash functions are further utilized to store the data and maintain the secrecy of drug information within this. In this paper, we have developed an interface to track drug ownership among stakeholders (from the manufacturer to the distributors). The use of Ethereum Blockchain leads to storing immutable data with multifaceted cryptographic algorithms. Hence, the framework is facilitating end-to-end security along with transparency.

Keywords: Blockchain, Smart Contract, Hash Function, Traceability, Counterfeiting, Decentralized

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1. INTRODUCTION

Recently the world of the internet has evolved to new heights with Web 3.0, which comes with a distributed ledger technology, known as Blockchain. While Web 2.0 is only about creating content and making interactions with websites. Blockchain evolves with the concept of data decentralization i.e., double layer security [1]. Initially, it's widely connected with digital currency and caused the rise of Bitcoin. But its applicability is far more than cryptocurrency [2]. It's facilitating a resourceful and trusted solution for product traceability as it enables the user to share validated and updated ledgers for every transaction [3]. As Blockchain is decentralized, transparent, and also maintains the transactions records of non-trusting stakeholders, widely accepted rapidly. In simple terms, Blockchain can be defined as a conveyed information base, which is shared among and concurred upon by a distributed organization, also known as a peer-to-peer network. In this paper, we are using Ethereum-based Blockchain in Supply Chain Management (SCM) for drug traceability. The supply chain is the sequence of linked stages and checkpoints associated with the manufacturing and delivery of products. SCM is a network, consisting of various entities of dissimilar levels and people [4]. These people are involved at each stage starting from manufacturing to delivery of the products. Due to system reliability, what if the network relies on a centralized server that occasionally experiences congestion-related failures and may result to data loss? Each entity in the SCM has its own network, and typically there is little data shared between these systems for security or policy reasons. It is very important to ensure the integrity of the quantity and type of medicine produced or hold by entities to prevent the counterfeiting of medicines in the supply chain and to ensure that the consumers receive the proper medicine. In order to prevent centralization and to achieve security, traceability, transparency, and reliability within SCM, concept of decentralization comes. It provides the benefit of peer-to-peer ledger system.

Blockchain is a decentralized database that stores the data in form of block and provides security using the asymmetric key and hash functions, shown in Figure 1 [5]. These blocks are linked together. Previously it was widely used to store the patient history with smart contract [6]. Pharmaceutical companies save the drug information in forms of blocks using this. Existing smart contracts maintain data integrity, security & privacy between producers and buyers.

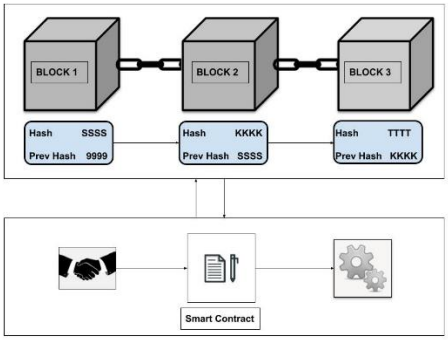

Fig. 1. Hash Function in Blockchain

Rest of the paper is organized as follows: section 2 highlights the motivation of work. Smart Contract helps to execute the terms of an agreement or contract from outside the chain based on predetermined condition. This part is elaborated in section 3. Some viable facts and errors occurred in SCM are discussed in fourth section. Next some review works are given and summarized in table 2. Section 6 tell about our proposed framework of SCM using Ethereum Blockchain. It has different parts such as entities involved in SCM, working flow and technical flow of the model as well. Further section give some screenshots our framework with small discussion. At last we conclude our research work and give some future direction towards reliable and secure SCM.

2. Motivation

The motive behind this manuscript is to maintain ownership of drug supply from the designer to consumer. Between these two drug is go through via different regulators, manufacturers, distributors and retailers as well. Continuous monitoring system of drug delivery may help to resolve the counterfeiting issue in SCM. That's why we are using Ethereum Blockchain as a mainframe network. It facilitates more transparency and traceability of drug. Our model is also aiming to maintain the security and privacy of customer, because data stored in blocks are immutable.

3. Smart Contract in Blockchain

This section of the article examines various Blockchain networks and their distinctive properties. This will enable us to choose the reliable Blockchain that will work best with our prototype's traceability requirements. We are primarily trying to study various Blockchain on the basis of different features such as language, data model, consensus, network permission and hardware requirement. All these are summarized in Table 1. Apart from this, some points are extracted and discussed below w.r.t Blockchain technology.

It may help to take the decision that which one should be utilized [7].

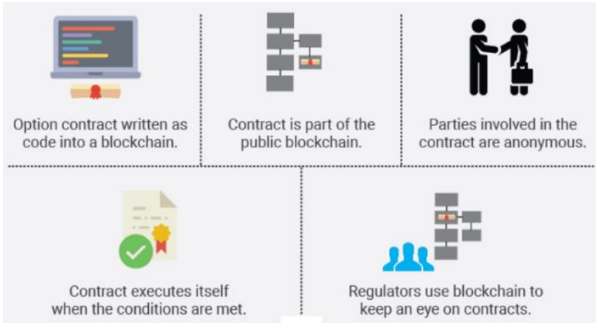

Fig. 2. Working of Smart Contract

3.1 Transaction Fee: The size of the transaction or the amount of data saved onto the Blockchain, as well as the speed at which we want the transaction to be executed, affect transaction costs. The gas (a quantity used to measure how much computing power a transaction requires to register on a Blockchain network) used to store data on the Blockchain should be inexpensive. By submitting smaller transactions with a lower processing priority, we could lower the transaction charge.

3.2 Real Time Data Analysis: The Blockchain network allows for speedier (high transactions per second) data extraction. In the event that we wish to provide real-time data to the SC web application.

3.3 Security: It enables the encryption of data sent from IoT devices to the Blockchain network, which is necessary because the data contains sensitive information.

3.4 Graphical Interface: A Blockchain network that offers an SDK or API for development that the suggested prototype application can use.

3.5 Implementation: A Blockchain that enables the creation of smart contracts for the use of automation, should be performed as an event-based transactions.

Table 1. Smart Contract Based Blockchain [7]

Name of Blockchain	Language	Data Model	Consensus	Network Permissions	Hardware Need
Hyperledger	Golang, Java	Account-based	PBFT	Permissioned	No
Ethereum	Solidity, Serpent, LL	Account-based	Etash (Proof of Work)	Permissionless (Public)	No
Solana	Rust, C, C++ solana-web3.js	Account-based	Proof of Stack based on Tower Consensus	Permissionless (Public)	No
Tezos	Tezos contract script, SmartPy	Account-based	Proof of Stake (PoS)	Permissioned	No
Corda	Java, Kotlin	UTXO based	The transaction is accepted by contracts by signatures	Permissioned	No
Sawtooth	Python, Go, Rust	UTXO based	Proof of Elapsed Time	Permissioned or Permissionless	No
Avalanche	Solidity	Account-based	Avalanche consensus (a combination of Avalanche, Snowball, and Slush algorithms)	Permissionless (Public)	No
Polkadot	Rust, Solidity	Account-based	Nominated Proof-of-Stake (NPoS)	Permissioned or Permissionless	Minimum 4 core CPU Processor, 8GB RAM, 100GB SSD
Cardano	Haskell(Plutus)	Account-based	Proof-of-Stake (PoS)	Permissionless (Public)	10 GB RAM, 24 GB hard disk space
Algorand	Python(PyTeal)	Account-based	Proof-of-Stake (PoS)	Permissionless (Public)	No

4. VIABLE & OBJECTIONABLE FACTS OF USING BLOCKCHAIN IN SCM

Adaption of Blockchain in pharmaceutical companies become a big boon against counterfeit drug distribution. Below we are giving an overview of some viable facts of using Blockchain in SCM [7, 8].

- *Transparency:* Data is immutable for all transactions. This is the reason to facilitate transparent information to the customers and also able to track the product correctly.
- *Transaction Control:* Payment criteria, such as a transaction's visibility so that it can only be seen by authorized parties, can be automatically pre-programmed.
- *Prior Approval of Transaction Charge:* Banks only deducts the transaction commission when the transaction is complete, or, to be more precise,

after passing through a large number of the intermediary banks that have been handling this transaction. With Blockchain, you are aware of the costs in advance.

- *Auditable:* Since all transactions are immediately available to authorized persons, no information added to the Blockchain can be altered, deleted, or kept secret.
- *Reliability:* Blockchain does not have a single point of failure because it is distributed. The risks of fraud are further reduced by the immutability and irrevocability of every transaction executed on the Blockchain.
- *No Censorship:* Blockchain technology is free from censorship because it is not controlled by any one party thanks to the idea of trustworthy nodes for validation and consensus processes that authorize transactions utilizing smart contracts.

As we know, any technology comes up with to some challenges for further exploring the new ideas. Here some points are discussed as errors [9, 10].

- *Implementation & Development Cost:* Due to the lack of expertise and low standards of pharmaceutical industries, cost is getting higher.
- *Scalability:* Storing the data on Blockchain is expensive. It's also difficult to maintain the privacy, because stakeholders need to facilitate third party access to relevant information not identifiable.
- *Immaturity:* People do not have much faith in Blockchain and are not yet willing to invest in it because it is just a couple of years old. Numerous applications based on Blockchain are making headway across numerous industries, but more people's confidence is still needed before it can be recognized for its full potential.
- *Legal Issues:* The central government has developed and is in charge of all contemporary money throughout the entire planet. The inability of Bitcoin to be accepted by the established banking institutions becomes a barrier.
- *Storage Management:* Blockchain ledgers have the potential to become very huge. Currently, it needs about only 200 GB of storage. The network runs the danger of losing nodes if the Blockchain grows to a size that is too enormous for users to download and store because the current growth in Blockchain size looks to be outpacing the expansion in hard drives.

5. LITERATURE REVIEW

The system they designed achieved consistency, availability, and partition tolerance using CAP's theory and ZKP proof. Siby et. al. proposed a Blockchain and web-based supply chain management system for a Pharma company [1]. It's facilitated a conflicting comparison between the database system and Blockchain-based on transparency and security. Initially, they used cloud based supply chain for its flexibility and simplicity but issues followed which lead to a Blockchain-based supply chain for better security and extended traceability. They introduced IPFS (Inter Planetary File System) for cryptographic hashes that can be easily stored on the Blockchain. To allow the traceability of a generic product from sender to receiver, authors gave the idea of software architecture based on Blockchain and IoT [5]. Due to speed and transaction cost, Solana Blockchain is used to implement the business logic and supply chain. Also, IoT devices store the sensory information related to light, temperature, humidity, location, vibration etc. In [6], authors proposed a combined framework to store and encrypt the data along with access rules. Records of drug data are stored on network nodes using Ethereum smart contracts. The gas fee is needed to verify the data block and sanction the transaction. It utilizes the concept of role-based access rules, because only trusted people can access the data. Zakari et. al., described a systematic literature review (SLR) focusing on the use of Blockchain technology in the pharmaceutical industry on parameters viz. tracking and tracing, counterfeit prevention, distribution, and data security [7]. They reported meta-analysis process on 21 success factors and selected five most important: namely, trust, tracking, transparency, traceability, and real-time. Four review questions were raised those are RQ1 aims to review previous studies of Blockchain technology in the pharmaceutical industry. RQ2 defined four primary areas. RQ3 aims to identify the limitations while RQ4 explores future research directions proposed in the literature. Lingayat et. al analyzed the implementable architecture of Blockchain for pharmaceutical companies [11]. It is done by comparing two approaches i.e., Ethereum Public Blockchain and Hyperledger Blockchain Framework. Different parameters viz. transparency, centralization, scalability, security, and privacy are taken. Results show that platforms like Ethereum and Gcoin scale work well but don't suit an identity management system (IMS). Furthermore, the proof of work consensus technique is a computationally expensive process whereas, Hyperledger facilitates an IMS along with scalability, better tracking, and a tracing system. A unique approach called pBFT- Byzantine is utilized for fault tolerance. Uddin et. al., proposed two Blockchain-based drug traceability using Hyperledger Besu and Hyperledger Fabric architectures [12]. Furthermore, they compared

them w.r.t several parameters of security, privacy, accessibility, transparency, etc. and outlined the challenges faced in adoption of such technology in pharma chain. Zoughalian et. al., proposed a solution for achieving transparency in the pharmaceutical distribution system using blockchain technology and python programming language [13]. Each node of Blockchain system undergo various authentication and participate in the decision-making process thereby ensuring the integrity of the data inputted by the user. The major components working for this transparency are a timestamp, a unique identifier ID (UUID), and a list of transactions. Tiwari et. al., examined the transactions of supply chain w.r.t third-party logistics (3PL) which is highly affected by its inadequacies thereby favoring digitalization [14]. The authors provided detailed structure and a roadmap to adopt Blockchain Technology (BCT) in place of 3PL along with the challenges faced by the logistics on parameters of accuracy, security, data quality etc. In [15] the authors proposed a generic web-based model only applicable to the coffee industry supply chain using Blockchain on parameters viz. traceability, transparency, tamper-proof etc. The prototype was implemented and evaluated in Indonesia's coffee industry using Polygon where data from each stakeholder was entered in the network providing a good transparency to the users. In [16] the authors compared the implementation of Blockchain in different emerging and developing countries w.r.t projects undertaken by Russian companies in all sectors. They majorly used three important factors of the supply chain naming upstream, production and downstream. The results conclude that these areas require joint public and private funding. IoT devices are integrated with Blockchain to provide better traceability in the supply chain [17]. The authors used Non-Fungible Tokens (NFTs) based approach along with an IoT environment that ensures data provenance and data integrity. They used Raspberry PI and GPS sensors to gather data and provided a web-based user interface for services viz. drug IoT tokenization, license upload etc. Anthony et. al., proposed an anti-counterfeiting distribution system using Remix IDE and Solidity [18]. Authenticity of a product in this system is ensured using Ethereum and along with it the model also works well on parameters of product traceability thereby achieving transparency in the network. The gas fee is needed to verify the data block and sanction the transaction. Shannan et. al., developed a distributed traceability platform using barcodes, RFID tags and sensors [19]. Visibility of the supply chain is verified and protection of private data is achieved using zero-knowledge proof. An improved PBFT algorithm is used where large-scale network nodes is divided into small consensus sets thereby increasing throughput and security with traceability scale. In [20] the authors proposed the proof of concept model integrating it with Hyperledger Fabric Blockchain platform and Odoo Enterprise Resource Planning (ERP) framework. They used a three layer architecture and supply chain consisting of Manufacturer, Consumer and Logistic partner. Low-level development was used to synchronize communication between Odoo and Hyperledger Fabric.

Table 2. Literature Review with Methodology, Advantages & Drawback

Authors' Name, Year	Methodology	Advantages	Drawback
Ashraf et. al., 2023 [5]	Develop a software architecture for IoT & Blockchain	Works with real time data collected from Sigfox sensor in LPWAN	It's only can connect with LPWAN IoT networks.
Jaya et. al., 2023 [6]	Propose a combined framework for data storage and access rules.	Provides privacy, decentralization, transparency, and authentication	Gas fee can be minimized with verification smart contact module
Zakari et. al., 2022 [7]	SLR on state-of-the-art Blockchain involving 38 papers viz. parameters of counterfeit drug prevention, distribution, tracking etc.	A SLR developed to help upcoming researchers identify and fill gaps including insights on real world applications.	Needs an adaptive environment to integrate latest technology such as big data and cloud computing
Shahaab et. al., 2023 [9]	Framework for adopting Blockchain for increasing public value.	Provides a guideline to develop strategy to maximize public values.	Complex problem of data integrity is not solved due to generalized framework.
Lingayat et. al., 2021[11]	Compares Ethereum and Hyperledger Blockchain framework w.r.t IMS, security, scalability etc.	Ensures the safety of pharmaceutical products along with diminishes the manual operation	Ethereum Blockchain framework doesn't provide IMS and better tracking approach.

Uddin et. al., 2021 [12]	Proposed Hyperledger Besu and fabric architecture w.r.t security, transparency etc.	Outlined the challenges faced by the adoption of Blockchain technology in field of pharmaceutical drug traceability.	The user interface Dapps of proposed architecture is not built.
Zoughalian et. al., [13]	Proposed a solution providing transparency in the pharmaceutical distribution system.	Ensures transparency, consistency, availability using timestamp, a unique identifier ID (UUID), and a list of transactions.	Model was tested only on a limited users and consensus decisions for only one block at a time can be made.
Sunil et. al., 2023 [14]	Examined the inadequacies in 3PL and challenges faced in adoption of BCT	Provides roadmap for challenges faced by logistics adopt BCT	Needed to adapt financial implementations in logistic network
Alamsyah et. al., 2023 [15]	Designed a generic web based Polygon application for coffee industry	Benefits the farmers to get fair prices for the quality of coffee beans they supply.	Additional charges were added as transaction and a better user interface required
Teodorescu et. al., 2021 [16]	Analyze the role of Blockchain in supply chain i.e. upstream, production & downstream	Review reveals that automation & efficiency is enhanced	Private and public funding was required in major areas in Russia for pharmaceutical companies.
Turki et.al., 2023 [17]	Explore an idea to trace the drug	Data provenance & integrity as well are ensured	Cost is increased w.r.t non-fungible tokens
Anthony et. al., 2023 [18]	Anti-counterfeiting distribution system for supply chain	Ensures authenticity of every product existing in the system and provides traceability	It's static because manual inputs are required.
Liu et. al., 2023 [19]	Model and algorithms to authorize nodes and link to the network using encryption.	ensures transaction latency and security with reduced communication.	High system consumption of PBFT algorithm
Belhi et. al., 2021 [20]	Integrate Hyper ledger Fabric & Odoo ERP framework.	Security and tamper-proofness is achieved in the business ERP framework.	SDK (Software Development Kit) tools need to be improved.

6. PROPOSED FRAMEWORK

Figure 2 elaborates the major entities viz. designers, regulators, manufacturer, distributor, retailer and consumers involved in SCM. Each entities involves in this framework is considered as a node in Blockchain and also responsible to achieve end-to-end security. Our proposed framework provides a general solution to manage the drug distribution among sellers, producers and customers [6]. Furthermore, Blockchain ensures the recording of all transactions in verifiable manner enables a secure and traceable flow of products in the supply chain to regulate the process. It's also able to detect the drug counterfeiting.

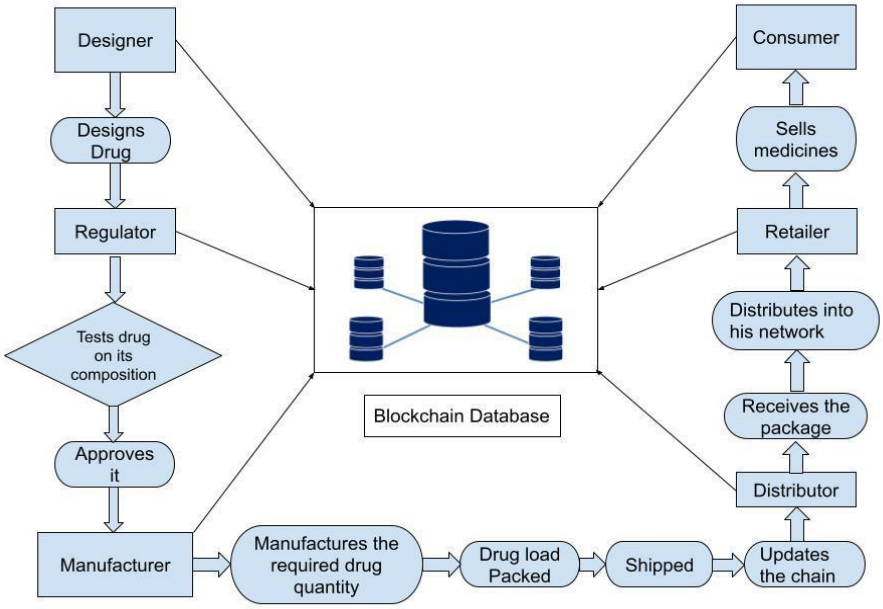

Fig. 3. Framework of SCM in Pharmaceutical Companies

6.1Entities Involves in Proposed Framework

6.1.1 Designer

The flow of medicine in the supply chain starts from the designer, the one who designs the drug and decides the drug compositions considering health hazards caused by the proposed medicine.

6.1.2 Regulator

The regulator is the entity who plays the most important role in the whole supply chain and is responsible for testing the drug based on the composition designed by the designer thereby approving or rejecting it.

6.1.3 Manufacturer

After the approval of the drug the whole data is passed on to the manufacturer who manufactures the required quantity of drug load based on the proper composition, packs it and shipps it to the network for flow into the market.

6.1.4 Distributor

The distributor receives the package shipped by the manufacturer, verifies it in the Blockchain database, updates the chain and distributes the medicine into various distribution centres and ensures proper flow to entities such as pharmacies, hospitals and retailers.

6.1.5 Retailer

Retailers are known as pharmacists, who collects the medicines from distributors, verifies the source of the product received and handles the delivery of the product to end clients.

6.1.6 Consumer

The consumer buys the medicine from the retailers as per their need, checks and verifies the flow of medicine in the supply chain and reports if any counterfeit is found.

6.2Technical Model of Proposed Framework

In this section, the technical view of the model is depicted. It gives a clear understanding about all entities involved with all security measures at each level. In the designer forum, we have two entities- designer who gives the composition of the drug and the regulator who approves the composition after confirming no health hazards from it. With a confirmation of approval the drug is assigned to manufacturer to produce a certain quantity. Here comes the Ethereum Blockchain network where the manufacturer stores all details about the medicine and generates it public key thereby updating the block and mentioning the next hand. The Ethereum chain is accessed by all the entities involved in the supply chain network and is updated at each level whenever a transfer is made. The medicine travels the whole of supply chain network and thereby it reaches to last entity- the consumer. They provide the application with a UDPC code for the verification of their product and gets all the necessary details about the required medicine.

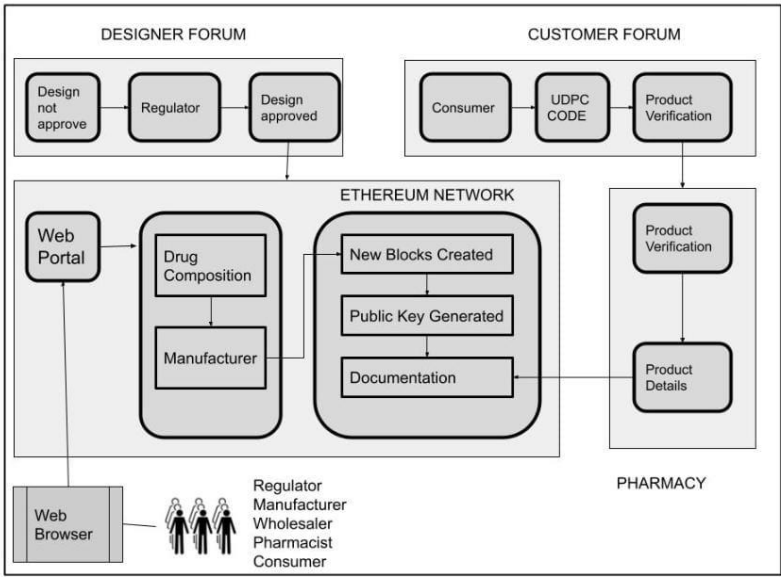

Fig. 4. Technical Model of SCM in Pharmaceutical Companies

6.3 Working Description of Proposed Framework

At first, we have developed a web-interface using an open-source platform & front-end library called Node.js & React respectively. Node.js is mainly used for server-side programming and generating dynamic page content whereas react is mainly used for smart contracts development. Furthermore, we have used Ethereum as a decentralized platform for data storage in form of blocks. Metamask wallet of

Ethereum Blockchain is used to connect to localhost and manage all accounts and transactions happening in our interface. This supply chain involves the flow of medicine transfer from the designer to the regulator. Designers design the drug compositions and regulator tests the drug on its composition. Then manufacturer produces the drug and transports it into the market to the distributor. Thereafter the particular medicines are circulated among various entities viz. pharmacies, hospitals, and retailers. These entities are responsible to provide the correct medicines for the patients. Given table II provides some important functions, used in the proposed framework to achieve security in SCM.

Table 3. Functions used in proposed framework

Sl.No	Function Name	Description
1.	whoAmI ()	Returns the role of entity.
2.	restricted ()	Checks whether the entity claiming for the role is real.
3.	setCompleted ()	Checks for the previous entity to get migrated.
4.	Upgrade ()	Transfers the address of the last migration and updates setCompleted.
5.	isTested ()	Tests the counterfeiting drugs
6.	isApproved ()	Composition of given drug is accurate and is approved by regulator.
7.	upForSale ()	The required quantity of medicine is produced and are ready to be distributed.
8.	purchaseDrugDesign ()	The required quantity of medicine is purchased by the succeeding entity.
9.	fetchDrugDesignData ()	To track the whole history of
10.	Kill ()	Kill a role if required.

7. Result Analysis

Some screenshots of the proposed framework are discussed in this part. Figure 5 tells about the way to add the newly designed drug. Only designers are allowed to add the drug after proper validation, nobody can alter. Hence, it's maintaining the security and privacy. Metamask wallet is playing a big role to perform this.

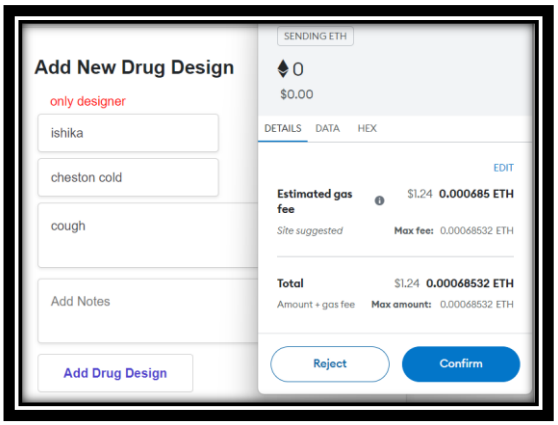

Fig.5. Addition of new Drug Design through Metamask Wallet

Figure 6 shows, how regulator approve the newly designed drugs. This newly drug composition is provided by the designers. Once it's approved, estimated gas fee of Metamask wallet is getting change. The words Data and Hex shown in the same, tells about the wallet in which transaction is being occurred.

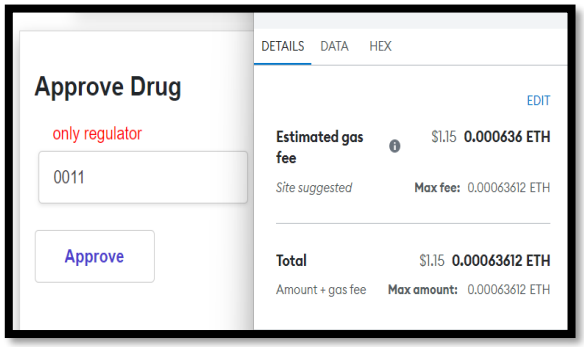

Fig.6. Approval of new drug design through metamask wallet

8. Conclusion

In this paper, we have developed a web-based SCM platform for pharmaceutical organizations. It uses the Ethereum Blockchain technology. As removing the counterfeiting of drugs is a prior concern nowadays, we are primarily focused on them only. Because it affects the health of humans deadly. Firstly an administrator is authorized to assign different roles such as designer, regulator, manufacturer, distributor, and retailer. They are considered an integral part of the SCM and perform transactions privately. At each transaction data is stored in the Blockchain Ethereum network. The user, which is the consumer can trace the whole path of the medicine through its Id. This process

makes the tracing of the product easier thereby ensuring no counterfeit medicines in the pharmaceutical SCM. Since data is stored in a decentralized network of Blockchain, security is also achieved. As future work, we can integrate artificial intelligence with our existing framework to limit the nodes entering data into the Blockchain to minimize the gas fee code thus making it cheaper in long run.

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