Securing Pharmaceutical Supply Chain using Blockchain Technology

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Abstract. The production and distribution of counterfeit drugs is an urgent and increasingly critical worldwide issue, especially in pandemics. The imperfect supply chain system in the pharmaceutical industry is one of the reasons for drug counterfeiting. Drugs ownership changes from manufacturers to wholesaler, distributor, and then pharmacist before it reaches the customer thus making it difficult to keep track of it. In this paper, we have compared the existing proposed architectures of blockchain and IoT based supply chain management systems. The system implemented using hyper ledger fabric ensures sharing, storing, transparency, and traceability of data in each link of the supply chain. On the other hand, Ethereum architecture utilized the features of smart contracts to manage the interactions between sender and receiver. Finally, the study mainly focuses on increasing the safety of pharmaceutical products and reducing the manual operation of the supply chain with the most efficient architecture.

1 Introduction

The supply chain passes through all the various checkpoints associated with assembling and dispersion of the products. These days, a supply chain can include hundreds of stages and numerous geological areas. This makes it hard to follow a fool-proof structure in a supply chain as there are data misfortunes and obstructions in each progression. Additionally, if the supply chain of the pharmaceuticals' sector is taken into consideration, the security of the process flow becomes extremely important. There's a possibility that a counterfeit medication would be loaded up with something more harmful just like floor wax or boric corrosive. Sometimes, it is discovered to be rodent poison. These can make hypersensitive disorders which might cause genuine injury to death.

To improve the supply chain's traceability and security, Blockchain technology has been producing interesting research zones due to its inventive attributes that give productive answers for the current loopholes identified. 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. When a component is annexed to the blockchain, it can't be altered, making a blockchain into a changeless record of past movement, thus helping to improve overall performance and security. To conclude, the features that makes Blockchain an ideal solution are a) Immutability, b) Transparency, c) Verification of information, d) Secured by cryptography.

Blockchain technology mainly offers two types of services: a) Ethereum, b) Hyperledger. These give a base to fathom the responsibility issue. At whatever point products will trade hands, the transaction will be recorded and put away on blockchain for credibility and confirmation. Currently, the trust will be founded on assembling organizations. Crude materials provided to them by the provider will be tried in the laboratory and subsequent testing, as well as the manufacturing cycle, will begin. The main aim of this paper is to share the detailed implementable architecture of the supply chain powered by both the services offered by blockchain. Both the methodologies will be compared based upon various parameters that are vital in the complete cycle.

2 Literature survey

Jianfeng Shi et Al.[1] proposed a Blockchain and IoT based pharma supply chain to ensure the authenticity of data sources, IoT devices, sensors, locators, and QR codes. For this, distributed Ledger was implemented for sharing and storage of data thus maintaining the transparency of data and increasing the safety of products.

Yen-Chih Liao, Bin Chong, Jen-Hung Tseng, and Shih-Wei Liao,[2] put forward a method named Gcoin Blockchain as the base of the drug data flow. It is a combination of a decentralized autonomous organization regulation model and open government which ensures transparent drug transaction of data. It is also proven to be a system that can handle millions of transactions per day unlike Ethereum or hyper ledger blockchain.

Haya Hasana, Esra AlHadhramia, Alia Al Dhaheri, Khaled Salaha, and Raja Jayaraman,[3] proposed a blockchain-based solution which utilized the functionalities of smart contracts in Ethereum blockchain. It manages the transactions between the sender and receiver. IoT sensors are used to monitor and track previously defined shipping conditions such as humidity, temperature, pressure, geographic location, broken seal, light exposure, etc.

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Sunny, J., Undralla, N., Madhusudanan Pillai, V [4] explained the significance of transparency and traceability in any supply chain management system. They also gave an overview of traceability solutions using blockchain in the food, pharmaceutical, consumer electronics, and automobile supply chains. The Proof of Concept was provided by the implementation of solidity smart contracts in Microsoft Azure Blockchain Workbench.

T. Bocek, B. B. Rodrigues, T. Strasser, and B. Stiller, [5] provided the solution developed by modum.io, which uses IoT and Blockchain Technology for ensuring quality control during the shipping of medicines. Measuring the temperature and humidity of medicine containers while shipping using the IoT sensors, this data is stored on a public blockchain architecture provided by Ethereum.

Akhtar, Mohd & Rizvi, Danish,[6] described two approaches for using blockchain framework in the pharma chain - Ethereum Public Blockchain and HyperLedger Blockchain Framework. They concluded that HyperLedger Blockchain Framework provided better scalability, an identity management system, better TPS, and accountability.

B.M.A.L. Basnayake and C. Rajapakse,[7] proposed an Ethereum based public blockchain for organic food supply chain. Each deployment of product returns an address used to create a Quick Response code which can identify the actual product. A token system was used to indicate the farmer's reputation with their respective products. Solidity based smart transaction model was developed to validate products. IoT devices were used to track product locations.

Ijazul Haq and Olivier Muselemu Esuka,[8] proposed an ethereum based permissioned blockchain to prevent counterfeit drugs in the pharmaceutical industry. Drugs are contemplated as digital assets where every unit has a unique key. The key in the form of QR code will be attached to the product to track it. Any extra information about the drug is stored off chain, it's hash-digest is generated and linked on chain. The effect of the drug is recorded which will be further used by the doctor to suggest a dose to a patient without hampering the patient's privacy.

Krishna Mohan Botcha et. al,[9] proposed usage of IoT edge devices and blockchain to enhance traceability in the pharmaceutical supply chain . The ecosystem of the pharmaceutical industry is elaborated to explain the need of such a system. Edge devices are used to aggregate data from various sensors which help in automation of data collection, processing and validation.The data which is stored on edge devices is further synced to the cloud. Also, feedback is taken from physicians and other beneficiaries for further renovation.

Youness Tribis, Abdelali El Bouchti, Houssine Bouayad,[10] put forward a systematic mapping study of the related parameters in the system architecture of the supply chain based on blockchain. A bubble plot is designed to systematically map the topics against research categories. Topics such as traceability, security, management, performance measurements, quality management were plotted against categories like validation, evaluation, solution, etc. and it was found that most of the articles were based on solutions such as Blockchain ledger and ethereum.

Gregor Blossey, Jannick Eisenhardt, Gerd Hahn,[11] proposed to use Blockchain technology to secure the supply chain. As many as 53 blockchain applications were analyzed in the field of management of supply chain. Predominant use cases cover provenance following of resources just as robotization of supply chain tasks while parts of supply chain account are just upheld once in a while in blockchain applications. Applications of blockchain exclusively center around catching the advantages of executing a novel broadly useful innovation. These issues are identified with the administration model of information possession and ordinarily low information quality in supply chain settings. This paper mostly centered around the issues of assembling and coordination inside SCM.

3 Proposed methodology

Blockchain technology provided the base for the peer-to-peer digital currency and led to the bitcoin platform. But the applications of blockchain technology are far more than crypto-currencies, and it can provide an excellent solution for tracing drugs in the pharma chain. So, let's understand the working of the blockchain network and how it can solve the problem of drug-counterfeiting

Blockchain is nothing but an unchangeable distributed database shared by a group of nodes over a p2p network. Each activity on this network is called a transaction. A group of such transactions forms a block. A block is associated with a timestamp, hash value, and hash of the prior block. This chaining of blocks together makes the ledger tamper-proof and immutable.

The blocks are appended to the network after verification by the Proof-of-Work consensus or any other custom consensus algorithm, which provides accountability and integrity to the blockchain network. The ability to store the transactions based on their sequence makes blockchain an ideal candidate for solving traceability problems in the supply chain management system.
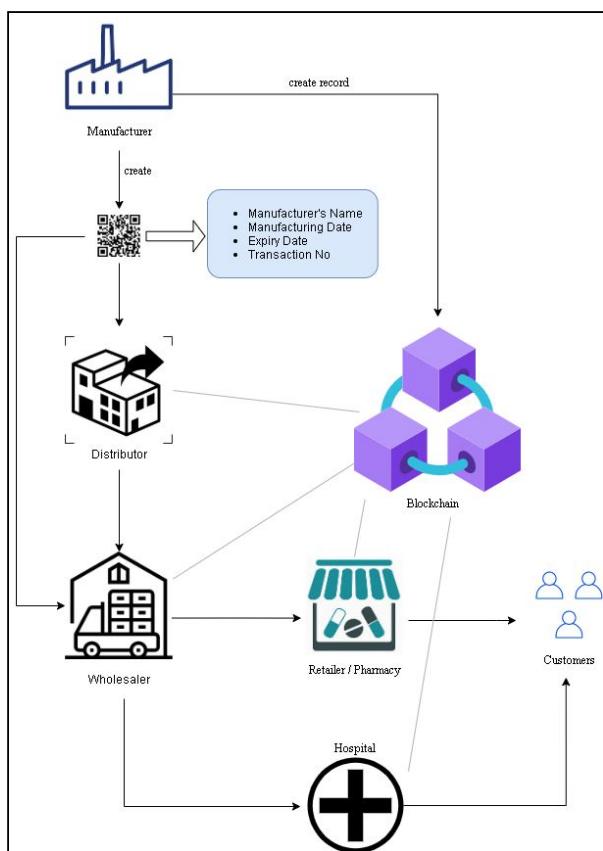
Fig. 1. System Architecture

Initially, the manufacturer will create a QR code containing the manufacturer's name, manufacturing date, expiry date, and transaction number. The transaction number will help in identifying the medicine on the blockchain. Then the distributor will scan the QR code and check for validity. When the shipment leaves the distributor's storage, the distributor should add his signature details in the medicine's record. The wholesalers, retailers, and pharmacies will carry out the same tasks at their end. By recording the transactions at each stage of the supply chain, tracking and traceability can be made possible in the drug supply chain.

Each square has a hash, timestamp, and the hash of the past square. Past hash keeps from adjusting blocks in the middle. Along these lines, the organization is altered, straightforward, and permanent. Blockchain in short is a disseminated permanent record that keeps up the uprightness of the organization by accomplishing agreement through calculations like Proof of Work or Evidence of Authority or own custom agreement calculations.
Furthermore, there are two kinds of blockchain - Public and Private which have some drawbacks. These all give a base to address the responsibility issue. Presently, at whatever point products will trade hands, it will be recorded and put away on blockchain for genuineness and confirmation. Presently, our base trust will be founded on assembling organizations. Crude materials provided to them by the provider will be tried

in the lab and subsequent testing manufac- turing interaction will begin. The principal cycle of these assembling organizations like Sun Pharma, Abbott, Pfizer, Cipla, and so on is to create a remarkable QR code name that will contain the name of the producer, expiry date, and exchange number or square number on the medi- cine pack itself. At the point when the medication is produced, they will be put away and their QR code will be filtered, and it will go about as the confirmation of the medication from their side. Presently when this medication will leave the production line, the merchant should filter the medication to realize that it is coming from the assembling industrial facility plant and not from other off-putting places. They will at that point add his particular subtleties and further send it to various wholesalers, retailers, and so forth With this procedure we will accomplish FTP (Production line to Pharmacy), and all the exchanges will be recorded on the blockchain furthermore, the client can basically check this by filtering the QR code at the nearby phar- macy store or in medical clinics. All the stages will be recorded on the blockchain and it will tackle the issue for fake prescriptions.

Blockchain is worked for certain advantages. Be that as it may, out of many, no one but few can be acquired at this purpose of time, due to being in early stages of advancement of blockchain. Consequently, execution component for responsibility in our writing study will be in view of the accompanying:

Decentralization or centralization?

Frankly, why you will not confide in your Government or Ministry of Health to keep your information Blockchain, in principle, states to decentralize establishments by giving no focal position. Be that as it may, we are not inspired by the decentralization particular. On the off chance that we are utilizing any stages like, we will basically let hubs and excavators do the work without getting profound into centralization versus decentralization. So if a solution is incorporated or decentralized, both will be considered as equivalent.

Transparency

Are exchanges straightforward for anybody to confirm on the blockchain. This will be a significant factor.

Security and Privacy

Indeed, the framework will be gotten consistently, and we can likewise follow back the stock chain to recognize who traded right medications with the fake ones.

Scalability

Who can take part, and are there any limitations? What will be the size of the blockchain after a particular time period?
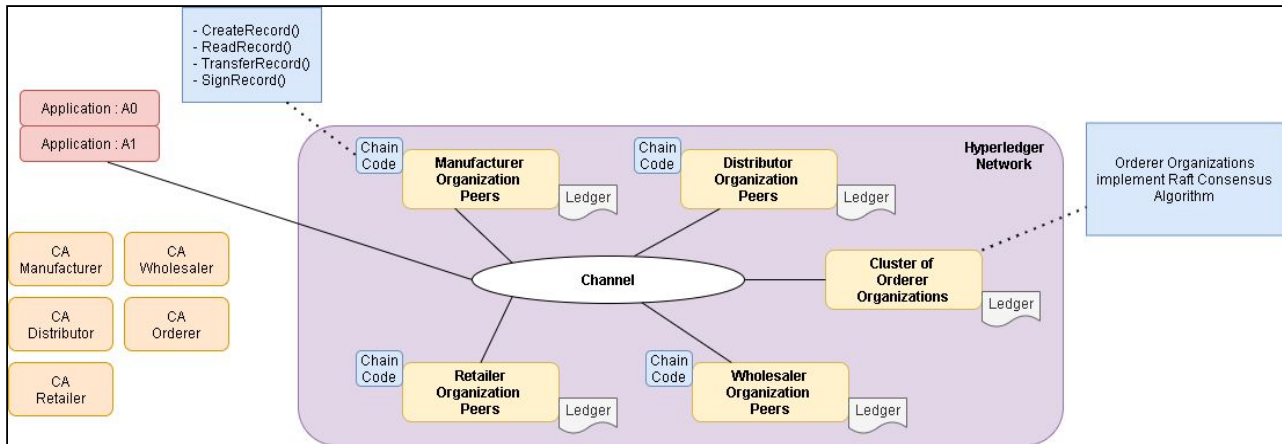
Fig. 2. Hyperledger Network

The Raft consensus algorithm -
Raft is a calculation for dealing with a duplicated log of the structure. Raft executes agreement by first choosing a recognized leader, at that point giving the leader total obligation regarding dealing with the recreated log. The leader acknowledges log sections from customers, repeats them on different workers, also, advises workers when it is protected to apply log sections to their state machines. Having a leader improves on the administration of the imitated log. For instance, the leader can choose where to put new sections in the log without speaking with different workers, and information streams in a straightforward design from the leader to different workers. A leader can fizzle or get separated from different workers, in which case another leader is chosen.

Raft basics -
A Raft group contains a few workers; five is a common number, which permits the framework to endure two disappointments. At some random time every worker is in one of three states: leader, adherent, or up-and-comer. In ordinary activity there is actually one leader and the entirety of different workers are supporters. Devotees are detached: they issue no solicitations on their own yet essentially react to demands from leaders also, applicants. The leader handles all customer demands (if a customer contacts an adherent, the supporter diverts it to the leader). The third state, applicant, is utilized to choose another leader. Raft separates time into terms of self-assertive length. Terms are numbered with continuous whole numbers. Each term starts with a political decision, in which one or on the other hand more up-and-comers endeavor to become leader. In the event that an applicant wins the political race, it fills in as leader for the remainder of the term. In certain circumstances a political race will bring about a split vote. For this situation the term will end with no leader.

Leader election -
Raft utilizes a heartbeat component to trigger leader political races. At the point when workers fire up, they start as supporters. A worker stays in an adherent state as long as it gets substantial 5 RPCs from a leader or up-and-comer. leaders send intermittent pulses (AppendEntries RPCs that convey no log passages) to all supporters to keep up their power. On the off chance that a supporter gets no correspondence throughout some undefined time frame called the political race break, at that point it expects there is no feasible leader and starts

a political race to pick another leader. To start a political race, an adherent additions its current term and changes to competitor state. It at that point votes in favor of itself and issues RequestVote RPCs corresponding to each of different workers in the group. An applicant

proceeds in this state until one of three things occurs: (a) it wins the political race, (b) another worker builds up itself as leader, or (c) a timeframe passes by with no victor. These results are talked about independently in the passages underneath. An up-and-comer wins a political decision in the event that it gets votes from a larger part of the workers in the full group for the equivalent term. Every worker will decide in favor of all things considered one applicant in a given term, on a first-start things out served premise. The larger part guarantees that at most one competitor can win the political race for a specific term (the Election Safety Property). When a competitor wins a political race, it becomes a leader. It at that point sends heartbeat messages to all of different workers to build up its position and forestall new decisions. While hanging tight for votes, an up-and-comer may get an AppendEntries RPC from another worker professing to be leader. On the off chance that the leader's term (remembered for its RPC) is at any rate as extensive as the applicant's present term, at that point the up-and-comer perceives the leader as authentic and gets back to the supporter state.

On the off chance that the term in the RPC is more modest than the competitor's current term, at that point the up-and-comer dismisses the RPC and proceeds in competitor state. The third conceivable result is that a competitor not one or the other wins or loses the political decision: if numerous adherents become

applicants simultaneously, votes could be part so that no applicant acquires a larger part. At the point when this occurs, each applicant will break and begin another political decision by augmenting its term and starting another round of RequestVote RPCs.

Log replication -

When a leader has been chosen, it starts adjusting customer demands. Every customer demand contains an order to be executed by the duplicated state machines. The leader affixes the order to its log as another section, at that point issues AppendEntries RPCs in corresponding to every one of the other workers to duplicate the section. At the point when the section has been securely duplicated, the leader applies the section to its state machine and returns the aftereffect of that execution to the customer. On the off chance that supporters crash or run gradually, or then again if network bundles are lost, the leader retries AppendEntries RPCs uncertainly (even after it has reacted to the customer) until all devotees at last store all log passages. Each log passage stores a state machine order alongside the term number when the passage was gotten by the leader. The term numbers in log passages are utilized to identify irregularities among logs and to guarantee a portion of the properties. Each log section additionally has a number record distinguishing its situation in the log. The leader chooses when it is protected to apply a log passage to the state machines; such a section is called dedicated. Raft ensures that submitted passages are sturdy furthermore, will in the long run be executed by the entirety of the accessible state machines. A log passage is submitted once the leader that made the passage has duplicated it on a greater part of the workers. This additionally submits all previous sections in the leader's log, including passages made by past leaders. It talks about a few nuances while applying this standard after leader changes, furthermore, it additionally shows that this meaning of responsibility is safe. The leader monitors the most noteworthy record it knows to be submitted, and it remembers that list for future AppendEntries RPCs (counting pulses) with the goal that the different workers at last discover. When a devotee learns that a log section is submitted, it applies the passage to its nearby state machine (in log request).

4 Results

Blockchain platforms like Ethereum and Gcoin scale well but they fail in providing an identity management system. Moreover, they make use of proof of work consensus technique which is a computationally expensive process. Hyperledger Fabric provides a scalable blockchain platform which not only has an identity management system but also makes use of an unique approach for consensus based on the algorithm pBFT - Byzantine Fault Tolerance. Hyperledger is better suited for building a decentralized platform for

tracking and traceability in the pharmaceutical supply chain. Thus, we have compared the existing proposed architectures of blockchain and IoT based supply chain management systems. The system implemented using hyperledger fabric ensures sharing, storing, transparency, and traceability of data in each link of the supply chain. On the other hand, Ethereum architecture utilized the features of smart contracts to manage the interactions between sender and receiver. Basically, the study mainly focuses on increasing the safety of pharmaceutical products and reducing the manual operation of the supply chain with the most efficient architecture.

5 Conclusion

There exists no proper traceability system for the pharmaceutical industry supply chain and hence counterfeit drugs are increasing and it is hard to track them. This paper focused on the need of a blockchain equipped supply chain system in the pharmaceutical industry. This application of blockchain leads to transparency by guaranteeing both tracing and tracking thus preventing the supply chain from counterfeit drugs and also reaching the consumer. Unique ID was generated for each product which was used to create a Quick response(QR) code. QR code was identified as a practical and cost-effective method. Also, consumer feedback was considered which was used for further analysis and rating the actors of the supply chain.

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