Blockchain based Approaches For Preventing Drug Counterfeit: A Survey

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Abstract— **During the current spread of COVID-19 tons of people have suffered critical health issues, which in many cases also lead to death. The death rate in the past few months has been on a spike. News channels are flooded with information regarding fake doses of drugs been injected into people, ultimately leading to the death of many. There has been duplication of the antiviral drug 'Remdesivir' and also the important 'Pfizer's' vaccine. The lives of people are at stake with the counterfeit drugs been sold in the market. This generates a sudden need to look upon the matter and define the methods for preventing the counterfeit of drugs to save the lives of people. Through this paper, we review various blockchain-based approaches which can help in preventing drug counterfeit.**

Keywords—Counterfeit, Blockchain, Information Security, Supply chain, COVID-19, Smart Contract, IPFS.

I. INTRODUCTION

Drug counterfeit has been defined as a global problem in a report by World Health Organization. During the past month, police have busted the industrial manufacturing units producing and supplying fake Remdesivir injections in many parts of India. Globally there has been falsification in the crucial Pfizer vaccine. These drugs are part of medicines involved in the treatment of COVID-19 infected people. Counterfeiting or falsification of such important drugs can cost the lives of innocent public. Counterfeit drugs can pose significant risks to individuals and the public [1]. Through this paper, we study anti-counterfeit mechanisms for drugs using blockchain technology. Blockchain is a ledger that can be shared immutable, transparent, and decentralized. Ledger in blockchain can include records of the transactions. Blockchain can be explained as a chain of blocks, where each block contains some data and the ha of the previous block. The blocks in the chain are timestamped according to when they were last modified. It is very difficult to tamper with the data stored in the blockchain as a single updating of transaction in the blockchain involves calculating the proof of work for that specific block and every other block preceding the block which has been modified.

The supply chain in a blockchain is the chain that involves all the major stakeholders through which the information has to pass till it reaches its end user. The supply chain in the case of drug manufacturing can begin right from the raw material supplier who is supposed to provide the raw material for manufacturing the drug and ends at the end consumer of that drug. Various researchers can specify their supply chains depending on the material and the number of stakeholders involved in the supply of that material.

Smart Contracts are the computer programs stored in the blockchain which can execute automatically. It is a transaction protocol that can control the events involved in the transactions when the specific conditions are met. The conditions include the terms of the contract or the agreements signed between the stakeholders of the supply chain.

IPFS is an InterPlanetary File System that is a peer-to-peer kind of network that creates a distributed and permanent web. It helps in storing the data in a tamper-proof manner. When the data is stored in the IPFS, it returns a hash unique to that data. The data loads into the IPFS faster with high bandwidth and without any need for servers. Moreover, it is cost-effective as the stored data can be distributed with no expenditure.

In this survey, we discuss various blockchain-based technologies that are aiding in preventing drug counterfeit. The overview of the technology is presented in section II. Section III presents the literature survey of the referred researches followed by the analysis of literature in section IV. Further in section V, we present research gaps in the referred studies with a comparative analysis, and finally, the conclusions and the future areas for research are discussed in the last section.

List of Abbreviations	
COVID-19	Coronavirus disease of 2019
IPFS	InterPlanetary File System
RFID	Radio frequency identification codes
DApps	Decentralized applications
P2P	Peer to Peer
PoW	Proof of Work
PoS	Proof of Stake
PBFT	Practical Byzantine Fault Tolerance

II. OVERRVIEW OF THE TECHNOLOGY

The technology discussed in this paper is Blockchain. The major components of Blockchain technology are nodes, transactions, and blocks. The blocks are interconnected in a decentralized format maintaining a chain. The new transactions are updated to the blocks of the chain.

A. Blockchain Architecture

- Node: The nodes in the blockchain architecture can include the computer systems connected to the network. Every node connected in the network has equal privilege as blockchain works on p2p network topology maintaining a distributed architecture. Every node in the architecture has to process and verify the

transactions performed and further put those into a fixed-sized Block. [2]

- Transaction: The smallest and the basic component of the blockchain architecture is a transaction. The major purpose of using Blockchain technology is its ability to store retrieve and access the occurred transactions. Transactions can be understood as the record of the payments and include the addresses of the sender, and the receiver along with the time stamp when the particular transaction took place. [2]

- Block: Every block in the blockchain has a version number. This version number contains the policies that are needed for the validation of the block. Another component of the block structure is the timestamp. Timestamp stores the time of the creation of that block. The blocks have a hash value and the threshold target of that hash value is indicated by nBits. The next major part of the block structure is Nonce. It is a 4-Bytefeild initiating with 0 which keeps on incrementing with hash calculation for the subsequent transactions. Before the verification of the block, nonce has to be calculated and the node that calculates the nonce first as compared to the other nodes in the network is rewarded after verification of its work by all the other participating nodes of the network.
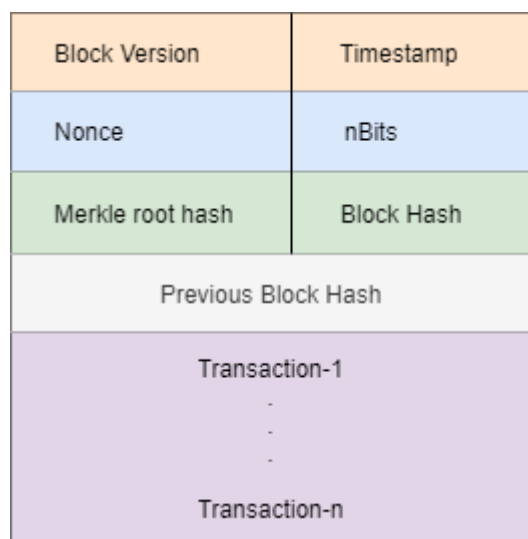

Fig.1: Structure of Block

Next in the structure is the Merkle tree root hash. This hash is calculated from all transactions present in the block. It is the digital fingerprint of the block If any transaction in the block is altered, it would result in the modification of the root hash. It can be simply explained as calculated the hash of the node by the hash of child nodes (Merkle, 1987). The previous block hash is another component of the block structure that contains the hash of the previous block of the chain which is already verified. Every block has the hash of the previous block which forms a chain of blocks thus maintaining the integrity of the network. The hash of the block 'n-1' is stored in the next block of the chain that is the block 'n', where n is an integer. The hash of the current block is calculated from all the transactions stored

in it which also includes the hash of the block previous to the current block. [2]
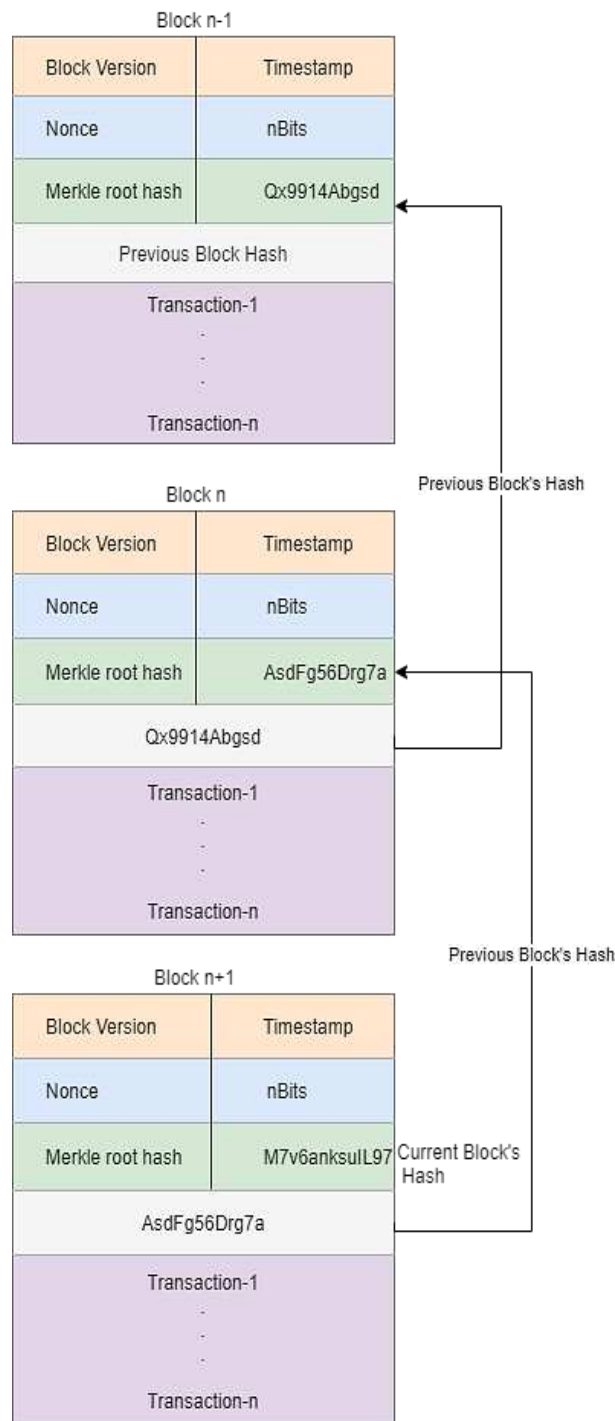
B. Working of Blockchain

Fig.2: Chain of Blocks

The working of blockchain can be explained with the help of an example suppose if one person has to send money to his friend, this simple transaction can be put on the block. This block also contains other transactions and it has a fixed size. The block in Bitcoin has a fixed size of 2MB, when this 2MB is filled up, it is distributed on the network with every other node. [3]

As soon as the transaction occurs, all the participating nodes in the network verify the transaction using the consensus algorithm decided between the participant nodes in the blockchain network. This algorithm in Bitcoin is called PoW (Proof of Work) and in ethereum, it is referred to as PoS (Proof of Stake). The calculation of PoW in Bitcoin takes around 10 minutes.

Each block contains the hash of the previous block and the data of the transactions which creates a chain of blocks, and the consensus algorithm like PoW, PoS, or some other is calculated for each modification in the blocks thus maintaining the integrity of the system and making it impossible to be changed by the third party.

C. Types of Blockchain

There are three kinds of blockchain which include public blockchain, private blockchain, and consortium blockchain.

- Public Blockchain: Bitcoin is the best example of Public Blockchain. It is a kind of Blockchain in which whosoever is interested can participate and become a part of the Blockchain.

- Private Blockchain: this kind of Blockchain there is a central authority that has control over the verification and the validation process. All nodes do not have the authority to be a part of the consensus. Ripple is a well-known example of Private Blockchain.

- Consortium Blockchain: Consortium blockchain can be public or private depending upon the need. In this kind of blockchain, a central authority or a group of nodes have the authority to decide whether the blockchain has to be kept public or private. For example, Hyperledger.

III. LITERATURE SURVEY

Authors in [4] propose a blockchain-based decentralized solution for COVID-19 medical equipment by automating forward supply chain processes. A fully trustworthy, transparent, traceable, and secure information exchange during waste management is provided among all the stakeholders. Integration of interplanetary file systems(IPFS) with the ethereum blockchain is proposed. By using IPFS, secure decentralized storage to securely store, fetch and share the data related to the COVID-19 forward supply chain is well defined. However, vaccination data and its supply chain is missing in this work.

A drug supply system incorporated with blockchain technology for providing a pharmaceutical permission supply chain where only trusted parties can join the network and store or retrieve the data from the blockchain which adds visibility, traceability, and security. Also tracking of drugs from their manufacturing to their delivery to patients is discussed in [5]. Complete decentralization and transparency are still missing. Also, a theoretical model is used to explain the implementation.

To prevent counterfeit drugs, a regulation model named Gcoin blockchain is well defined in [6]. The researchers provided a secure and transparent lifecycle of drugs from drug manufacturing to the post-market. Every stage of the lifecycle is recorded on the blockchain as a transaction. System simulation is missing.

The proposed system [7] helps to track drugs and to accurately determine the authenticity of the drug in Russia. Hyperledger Fabric has been used and for development purposes, Hyperledger composer is used. Authors define a supply chain with major stakeholders including manufacturers, wholesalers, and retailers. These are responsible for producing, transporting, and distributing the drugs in the pharmacies. The supply chain demonstrates the information regarding the identification of the drugs produced in the manufacturing plant and the movement patterns of those drugs in the supply chain to ensure the verification and authenticity of the drugs which are transported to the pharmacies. Only the relational model is thought out, no smart contracts have been created, no use of access lists, no tests have been carried and no prototype model of the system is defined.

A well-defined blockchain system is proposed [8] which addresses the existing problems in the pharmaceutical supply chain of Saudi Arabia. They also explained how IT systems can be integrated with healthcare systems.

A cryptographically secured tracking solution having a decentralized and distributed track and trace system [9]. Make use of radio frequency identification codes(RFID) and barcodes. Provides a detailed and well-explained tracking system from manufacturers to drug serialization process to drug distribution.

A very well-defined and a trusted tracking system for COVID-19 is observed in [10]. Their work proposes an improved data management system for clinical trials, reduced delay in regulatory approvals, and transparent, immutable, and secure communication between all stakeholders in the supply chain. The data relating to new cases recovered cases, and deaths collected from many external trusted sources are stored on the ethereum blockchain. However, in the medical supply chain traceability of only PPE kits and other medical supplies has been explained, the cost of transactions is high and no implementation of DApps.

COVID-19 vaccine supply management [11] is an ethereum based monitor and tracking system implemented on the ropsten network. It gives a detailed view of COVID-19 vaccine registration, storage, and delivery, and after that side effects self-report. All handling rules given by vaccine manufacturers are kept assured in a smart contract.

Authors in [12] present a Blockchain model for drug supply in a Smart Hospital. The presented model is digital, decentralized, and continuous whilst ensuring the transparency and security of the system. Performance is improved concerning throughput and minimal resources have been used which aid in reducing the system latency. However, all the data is stored on the Blockchain which can be a costly process.

In research in [13], the authors have presented a method of legally implementing Blockchain technology in pharmacies. This legal implementation provides a cover for tracking and also supplying drugs in the pharmacies. The delivery process is made transparent with less expenditure on logistics. The problem addressed in this paper is the counterfeiting of the

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drugs and minimization of the operational costs in the supply chain. The research has its context in Europe.

Proof of Ownership is used in the research cited in [14] to establish the anti-counterfeiting in the supply chain of Pharmaceuticals. A transparent and traceable system using Blockchain is implemented. The logistic companies are provided with real-time monitoring of the drugs being transported. Only the parties with ownership have the option to hand over their authorities to some other stakeholders of the supply chain.

A study on how blockchain can assist in preventing drug counterfeit is presented in [15]. The author explains that blockchain technology can completely alter the current mechanisms involved in the drug supply chain. The blockchain implemented technology can also aware customers of the hazardous impacts of counterfeit drugs. The customers can go through the authentication process and check if the product receive by them is genuine or is it a counterfeit drug.

IV. ANALYSIS OF LITERATURE

The literature referred to in this paper discusses the methodologies to prevent the counterfeiting of drugs. The paper cited is all based on blockchain technology and its implementation to prevent drug counterfeit. Most of the papers discuss the mechanisms to authenticate the drugs and their supply chain management. The papers cited in [4-14], [16-22] are based on detecting counterfeit drugs in their supply chain. Many papers also introduce their kinds of blockchain for the supply management and authenticity of the drugs. The main areas covered in the literature are:

- Integration of Blockchain technology for verifying the authenticity of the drugs.

- Verifying the drugs with unique codes such as RFID codes and barcodes.

- Supply management of the drugs from the manufacturer to the end-user.

- Decentralized drug supply chain with traceability of the supply process.

- Implementing Blockchain in the pharmaceutical environments.

- Tracking and monitoring system on the blockchain network.

The papers cited also have some limitations like most of the implementations are costly and in many of the papers, the practical implementations of the discussed systems are not presented. Some of the papers are also not based on the decentralized architectures and also testing and validation of the discussed approaches are not displayed.
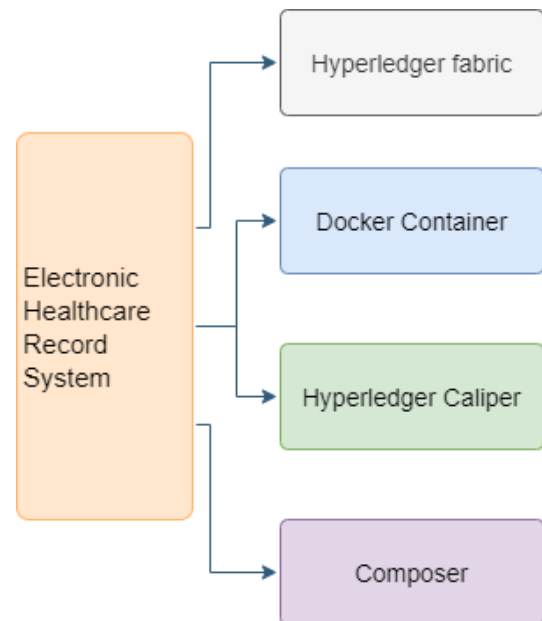
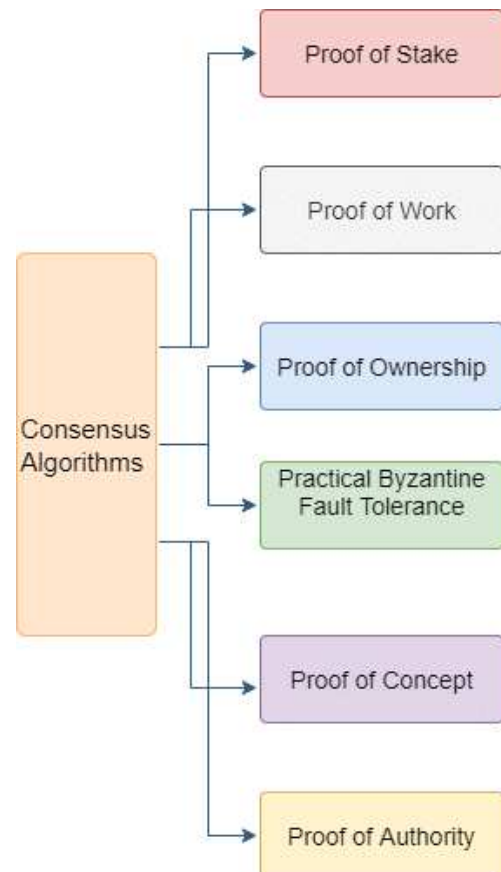Fig.3: Blockchain tools used in referred literature

Fig.4: Consensus algorithms used in referred literature

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TABLE I. COMPARISON OF WORK RELATED TO ANTI COUNTERFEITNG OF DRUGS USING BLOCKCHAIN TECHNOLOGY

S.No.	Author	Publisher	Problem addressed	Solution	Limitation
1	Sudeep Tanwar et al. (2019)	Elsevier	Automating COVID-19 vaccine forward supply chain	Blockchain based decentralized system has been presented along with the integration of Inter Planetary file system for the storage of the records.	Vaccination data not relevant for block chains of transport.
2	Haq, Ijazul et al. (2018)	IJCA	Traceability of Pharma supply chain	Drug supply system incorporated with Blockchain is presented along with the tracking process.	Complete decentralization and transparency of the system is missing.
3	Tseng et al. (2018)	MDPI	Counterfeit Drug	Gcoin named drug lifecycle is presented including every stage of drug from its manufacturing to post-market.	Simulation data not relevant for block chains.
4	Bryatov, S et al. (2019)	CEUR	Counterfeit Drug	Hyperledger has been used to track and determine the authenticity of the drug throughout its supply chain.	Smart contracts, access lists, and prototype have not been created. Moreover no tests have been carried out.
5	Shaker ALHARTHI et al. (2020)	IBIMA	Problem in pharmaceutical supply of Saudi Arabia	Blockchain system for existing problems in the pharmaceutical supply chain of Saudi Arabia is discussed.	Actual implementation of the system has not been discussed.
6	Shruti Srivastava et al. (2019)	IJSTR	Tracking drug distribution	Tracking solution having decentralized and distributed track and trace system has been presented along with RFID and Barcodes.	The author does not provide any practical implementation.
7	Alaa A. Abd-alrazaq et al. (2021)	Elsevier	Tracking system for COVID-19	Data relating to new cases, recovered cases, and deaths collected from many external trusted sources are stored on the ethereum blockchain.	High cost of transactions, No implementation of DApps.
8	C. Antal et al. (2021)	IEEE	COVID-19 vaccine supply management	Ethereum based monitor and tracking system implemented on the ropsten network.	All the data is stored on Blockchain which is a costly process.
9	Jamil et al. (2019)	MDPI	Counterfeit Drug	A digital, decentralized, and continuous Blockchain model for drug supply in a Smart Hospital is presented model is whilst ensuring the transparency and security of the system.	All the data is stored on Blockchain which is a costly process.
10	Pashkov et al. (2019)	EDP Sciences	Counterfeit Drug, Logistics cost	A method of legally implementing Blockchain technology in pharmacies is presented whilst providing minimization of the operational costs in the supply chain.	This research is only limited to Europe.
11	Raj, R, Rai, N et al. (2019)	IEEE	Counterfeit Drug	Hyperledger based Proof of Ownership is used to establish the anti-counterfeiting in the supply chain of Pharmaceuticals.	All the data is stored on Blockchain which is a costly process.
12	Clark, B et al. (2018)	Oxford University Press	Counterfeit Drug	A study on how blockchain can assist in preventing the drug counterfeit is presented.	There is no practical implementation of the process.

V. RESEARCH GAPS

After having a survey of the literature discussed above, some gaps are noticed which need to be considered in further researches. We can generalize those major and common problems that hindered the authors to get proper results as:

- In most of the papers, the data is stored on Blockchain which is a costly process.

- Complete decentralization and transparency of the system are missing in many referred literature works.

- There is no practical implementation of the proposed process in some cited papers.

- Many of the systems proposed are only limited to specific countries.

VI. CONCLUSION AND FUTURE SCOPES

In this paper, we propose a review of recent researches on blockchain-based approaches which can help in preventing drug counterfeit. Many of the recent researches propose a decentralized supply system with secure and immutable tracking capabilities using blockchain technology. To

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determine the authenticity of the drug throughout its supply chain permissioned Hyperledger blockchain is used along with RFID and Barcodes for user's convenience and security purposes. Through the literature referred we conclude that most of the research done so far is not on a specific drug as many drugs require different handling procedures and environments in their supply chain. So, a new approach is required to handle drugs like COVID-19 vaccines.

Future researches can be done to address the issues found like:

- A new supply chain framework for drugs that require extra handling measures.

- An anti-counterfeit framework using blockchain technology for COVID-19 vaccines.

- Incorporating IPFS along with blockchain for providing decentralized storage to COVID-19 secure supply chain.

- A simulation or an actual implementation of the COVID-19 vaccine anti-counterfeiting framework can be proposed.

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