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Exploring the Proof of Work Based Block Chain Algorithm for Pharmaceutical Industry Supply Chain Innovation

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ABSTRACT

Block chain technology offers numerous promising opportunities for improving supply chain management. This article provides a brief outline of how Block chain technology is being utilized in the supply chain industry. The article is proposed to explain how the Block chain might help suppliers, manufacturers, regulators, quality assurance labs, and logistics operators by cooperating on a shared ledger, as well as to establish provenance for speciality products at the package level and to reduce income leakage to pharmaceuticals. A Block chain-based pharmacy supply chain management track and trace system could tackle this growing illegal economy by tracking medicine through suppliers, manufacturers, wholesale distributors, pharmacies, hospitals, regulators, and logistics. In this paper it is proposed to display proof of work (PoW) based Block chain algorithm to stop counterfeit medications entering a pharmaceutical supply chain and to enhance transparency, traceability, and security highlighting the merit of PoW algorithm.

1. Introduction

A Block chain is even and distributive exposed public digital ledger of records. Each block in a Block chain stores transaction data, amounts, and parties. Block chain databases store all assets and instructions executed since the first block. Block chain's data provenance makes it ideal for supply chains. Drug manufacturers, shippers, and distributors struggle to track their products, allowing counterfeiters to enter the market. Medical device manufacturers also face counterfeiting issues. The WHO believes that 8% of medical equipment are counterfeit. Counterfeit medications and medical gadgets endanger customers and cost producers' money. Every drug packaging will be serialized or bar-coded by November 2018 under the Drug Supply Chain Security Act (DSCSA). Each medication packaging will have a unique product identity, enabling product authenticity verification. A Block chain can record drug supply chain transactions, creating a distributed provenance ledger. All stakeholders can trace medications along the supply chain. This will stop counterfeit medications entering a pharmaceutical supply chain and reaching naive consumers. The pharmaceutical business

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is investigating Block chain technology for real-world applications. These explorations have garnered pharmaceutical industry motivated with proof-of-concept implementations.

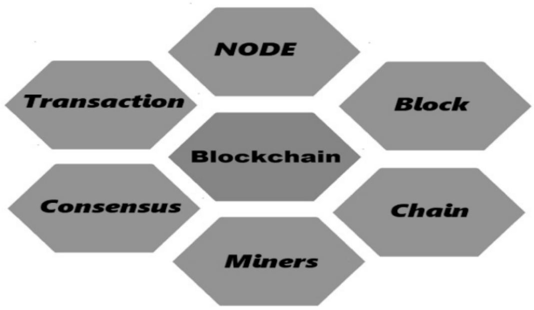

Fig. 1. Basic Components of a Blockchain

2. Consensus Algorithms

Consensus algorithms provide Block chain network integrity and agreement. They determine how network nodes agree on transaction validity and sequence. Bit coin has the Proof of Work (PoW) to validate transactions and create data blocks to the network. Proof of Stake (PoS): Instead of computational work, PoS picks validators based on their crypto currency stake. Delegated Proof-of-Stake (DPoS): DPoS token holders vote for delegates who validate transactions and build blocks for the network. Proof-of-Work (PoW): Miners solve computational challenges to add blocks to the blockchain. Processing power proves miners' worth. The network receives the solution from the initial miner, which other nodes can verify. Bit coin and other crypto currencies use PoW. PoS validators create new blocks based on their bit coin holdings and "stake" in the network. Table 1 shows the various types of block chains and their usage.

Table 1
Common Types of Block Chains

	Public block chain	Hybrid/consortium	Private block chain
Overview	"Proof-of-work" or "Proof-of-ownership" ensures record authenticity in a decentralized system.	A consortium controls record authenticity.	A trusted central authority controls and verifies record authenticity.
Access Permission	Anyone can read and write without permission.	Customizable by an authorized group of users	Authorization — One party control who can make changes.
Verifying transactions	Most "Block chainers" agree on record authenticity.	Consortium verifies transactions.	Transactions are checked by a central body
Data storage	Records are sent around, and every participant in the peer-to-peer network has access to a copy of the full record they've downloaded.	Records are disseminated to all of the members of the consortium.	The central authority is in charge of storing the records.
Cost	Low transaction costs	Cost of transactions that was agreed upon by the consortium	Transaction cost is imposed by one party

3. Benefits of Block Chain in Pharma Supply Chain

The Primary benefits include tracing material supply chains to meet business standards. They can also reduce counterfeit/grey market losses. They improve outsourced contract manufacturing visibility and compliance. The indirect benefits include lessening of paperwork and bureaucracy. It promotes public trust in the company by being more forthcoming about the materials used in their products. It negates negative publicity resulting from supply chain mistakes.

4. Literature Survey

Due to its potentiality to solve counterfeit pharmaceuticals, Traceability and openness in the pharmaceutical supply chain, block chain technology has garnered attention. Key research papers and articles on block chain in the pharmaceutical business have been described [12-14]. F. T. O Donoghue *et al.,* did a thorough evaluation of Block chain technology in healthcare, including pharmaceutical supply chains and identified the Block chain difficulties, benefits, and future scope of work have been explored [11]. H. C. Lin *et al.,* Pharmaceutical Block chain technologies have reviewed for drug traceability, anti-counterfeiting, supply chain management, and clinical trials [19,20].

K. D. Nguyen *et al.,* proposed a Block chain-based traceability solution and to improve the pharmaceutical supply chain. It also reviews the system's design and efficacy in preventing counterfeit pharmaceuticals [8]. X. Yue *et al.,* discusses how Block chain technology can improve data security, privacy, and interoperability in healthcare, focusing on EHRs and how these factors affect pharmaceutical supply chain management [8]. SCM improves materials flow transparency, traceability, and auditability from suppliers to customers. This study examines how block chain affects supply chain traceability in present and future industrial applications [15,16]. Block chain is a real tool that can improve the way how healthcare data is shared and stored because it is decentralized, that it can't be changed, is clear, and can be tracked. But many healthcare organizations are still hesitant to use block chain technology because of risks like security and permissions problems, problems with interoperability, and a lack of technical skills related to block chain technology [18]. Ethereum, the second-largest Block chain platform, used Ethash as its PoW algorithm. Ethash was made memory-hard to prevent ASIC mining and encourage decentralization. Bitcoin uses the Proof of Work (PoW) algorithm SHA-256 (Secure Hash Algorithm 256-bit). Bitcoin's security, immutability, and decentralization depends on the SHA-256 algorithm [1].

5. Challenges in the Pharmaceutical Supply Chain and Limitations in the Study

There is currently no safe way to track medications across their lengthy and varied supply chain. Reasons for this include: Companies no longer operate in silos or within geographical boundaries, making for a more intricate supply chain. They engage in international business. There are many parties involved in the production, packaging, distribution, and retail sale of pharmaceuticals, making up the lengthy and intricate supply chain. There is no way for the receiving stakeholder to verify that the medicine is genuine. Thus, a complicated supply chain with little controls and transparency comes from more stakeholders and nodal points. These stakeholders struggle to follow the product's journey to the pharmacy, including its origin, real-time position, and route.

i. Temperature Sensitivity: Some medications are only active below a certain temperature, so they must be kept at that temperature during transport. The medicine may become ineffective if the temperature rises above the intended range. The consumer and corporation cannot tell if the drug was kept at the right temperature and is still active.
ii. Drug Shortage: Delays in patient treatment represent a major public health risk. In providing life-saving drugs to patient’s pharmaceutical firms, wholesalers, distributors, pharmacies, and health care providers and everyone who involve in life saving drugs to

patients must monitor the absence of shortage of drugs. The intricate supply chain prevents personnel involved from coordinating their requests. Drugs are delayed because manufacturers don't acquire reliable demand data on time. Drug shortages can force doctors and patients to choose fewer effective medications as a time serving strategy.

iii. Drug Recall: Removing dangerous pharmaceuticals off the market protects customers. Manufacturers must pull the medicine from the market immediately. The company's lack of direct interaction with drug buyers is the main issue. Online or advertising drug recalls are common. Thus, customers' knowledge is limited, and he may not be aware of the medicine banned out of the market.

iv. Regulatory Challenge: The FDA struggles to oversee supply chain stakeholders. Thus, it's hard to identify illicit organizations that use fake papers.

Counterfeit medications form a major issue for this market. The counterfeit medication market is worth over $200 billion. Counterfeit pharmaceuticals kill around 500,000 people annually. 1 in 10 medications, vaccinations, and diagnostic kits marketed are false or poor, according to WHO estimates. European Pharmaceutical Review estimates that 30% of developing country medications are fraudulent. Many governments have tightened drug supply chain tracking due to counterfeiting. For instance, the US government's medicine Supply Chain Security Act requires medicine producers to provide a unique ID to identify counterfeit drugs.

6. Proposed PoW-Based Anti-Counterfeit Medication Algorithm

Block chain-based supply chains track ingredient suppliers, manufacturers, logistic partners, wholesalers, distributors, pharmacies, and hospitals. Block chain can prevent counterfeit pharmaceuticals from entering a pharmaceutical supply chain. The shared ledger records drop-off and pick-up activity with time stamps at each supply chain nodal points. After each receiving party validates the shipment's provenance, the Block chain records the physical transfer of ownership. No one, including record-holders, can change Block chain records. Figure 2 depicts the flow of the proposed algorithm.

Fig. 2. Flow Diagram of PoW based Blockchain algorithm for anti-counterfeit medication

Figure 3 depicts the proposed algorithm.

```
# Step 1: Define the structure of Blockchain Record
# Define a block structure to store transaction data
class Block:
   def __init__(current, data, previous_hash):
current.data = data
current.previous_hash = previous_hash
current.timestamp = current_timestamp()
current.nonce = 0
current.hash = current.calculate_hash()
   def calculate_hash(current):
      # Calculate hash based on block attributes
      # Include timestamp, data, previous_hash, and
nonce
      return hash_function(current.timestamp +
current.data + current.previous_hash +
str(current.nonce))
# Define blockchain structure to store blocks
class BC:
   def __init__(current):
      chain = [current.create_genesis_block1()]
   def create_genesis_block(current):
      # Create the first block in the chain (genesis block1)
      return Block("Genesis Block", "0")
   def get_latest_block(current):
      # Retrieve the most recent block in the chain
      return current.chain[-1]
   def add_block(current, new_block):
      # Add a new block to the chain
new_block.previous_hash =
current.get_latest_block().hash
new_block.hash = new_block.calculate_hash()
chain.append(new_block)
   def is_chain_valid(current):
      # Validate the integrity of the blockchain
      # by checking the hash of each block and the
previous hash reference
      for i in range(1, len(current.chain)):
current_block = current.chain[i]
previous_block = current.chain[i - 1]
         if current_block.hash !=
current_block.calculate_hash():
            return False
         if current_block.previous_hash !=
previous_block.hash:
            return False
      return True
# Step 2: Implement functions for  Operations  and
validation
def create_transaction(sender, receiver, drug_info):
   # Create a new transaction object with sender,
receiver, and drug information
   return {
      'sender': sender,
      'receiver': receiver,
      'drug_info': drug_info
   }
def verify_transaction(transaction):
   # Implement verification logic for the transaction
   # Check drug authenticity, sender and receiver
credentials, etc.
   # Return True if the transaction is valid, False
otherwise
   # Step 3: Implement the main logic for the
pharmaceutical supply chain
# Initialize the blockchain
blockchain = Blockchain()
# Function to process a new transaction and add it to
the blockchain
def process_transaction(sender, receiver, drug_info):
   # Create a new transaction
   transaction = create_transaction(sender, receiver,
drug_info)

   # Verify the transaction
   if verify_transaction(transaction):
      # Create a new block with the transaction data
new_block = Block(transaction,
blockchain.get_latest_block().hash)
      # Add the block to the blockchain
blockchain.add_block(new_block)
print("Transaction successfully added to the
blockchain.")
   else:
print("Invalid transaction. Rejected.")
# Step 4: Example usage
# Process a new transaction
process_transaction("Manufacturer A", "Distributor B",
"Drug XYZ")
# Validate the blockchain integrity
print("Blockchain is valid:", blockchain.is_chain_valid())
```

Fig. 3. Pseudo code for the Proposed Algorithm

7. Results and Discussion

Using block chain technology to monitor and verify the authenticity of medications has the potential to combat the problem of counterfeit drugs and enhance patient safety. The following is a breakdown of how this mechanism could operate:

i. Central Authority and Node Selection: A pharmaceutical company or consortium of stakeholders will establish and administer the block chain network as the central authority. They will invite participants, including suppliers, logistic partners, distributors, retailers, and even consumers, to join the network as nodes. These nodes will be responsible for logging and validating transactions involving drug movement and ownership changes.
ii. Smart Contracts for Drug Ownership: To represent drug ownership and transfer, smart contracts will be issued. The block chain will retain a unique identifier for each drug. When a drug is manufactured, it is assigned a unique ID, and as the drug travels through the supply chain, ownership of the ID is transferred. This is recorded on the block chain, ensuring its immutability and transparency.
iii. Verification of Medication: When a medication changes hands, the drug's unique identifier is validated on the block chain. The transaction will not be confirmed if a medication lacks a genuine ID or has a duplicate ID (indicating a fake). This mechanism ensures that only legitimate medications with a verifiable history are permitted to join the network.
iv. Access to Tracking and Information: Anyone can verify the authenticity of a medication by scanning the drug's unique identifier with a smart phone or inputting it on the company's website. The distributed ledger will provide information regarding the drug's entire voyage, including its location and transaction timestamps. This transparency enables consumers and stakeholders to confirm the authenticity of the drug.
v. Combating Online Pharmacy Fraud: As you indicated, online pharmacies sell a substantial number of counterfeit drugs. Block chain can play a vital role in verifying the authenticity of online-purchased medications. Prior to making a purchase, consumers can verify the drug's identification on the block chain; if it does not match the authentic product, they can forego the purchase.

Increasing the Traceability and Transparency of the Drug Supply Chain Block chain technology improves supply chain transparency and traceability. It helps authorities identify the points in the supply chain where counterfeit drugs may infiltrate, allowing them to take appropriate action against those responsible. Implementing block chain technology in pharmaceutical supply chains can ultimately save lives by reducing the circulation of counterfeit medications. Patients can have greater assurance that their medications are authentic and secure. Notably, the implementation of such a system would necessitate collaboration among numerous stakeholders, including pharmaceutical companies, regulatory agencies, and others. In addition, privacy and data security concerns must be meticulously addressed in order to safeguard sensitive information and maintain supply chain transparency. Nevertheless, block chain technology bears great promise for ensuring the authenticity and safety of medications.

Table 2
Merits of the proposed PoW based Block chain for Pharmaceutical Supply Chain

Feature	Proof of Stake (PoS)	Practical Byzantine Fault Tolerance (PBFT):	Proposed PoW based Blockchain algorithm
Security	Low	Requires pre-determined number of participants	High. Does not require pre-determined number of participants.
Immutability	High	High	High
Decentralization	Leads to the possibility of Centralization in the hands of wealthy participants	offers decentralized control among the known participants	Anyone with computational power to participate in the consensus process
Sybil Attack	Not Resistant	Not Resistant	Resistant

From the above table featuring of the POS, PBFT and PoW, with respect to security, immutability, decentralization and sybil attack the following exhibit may be observed.

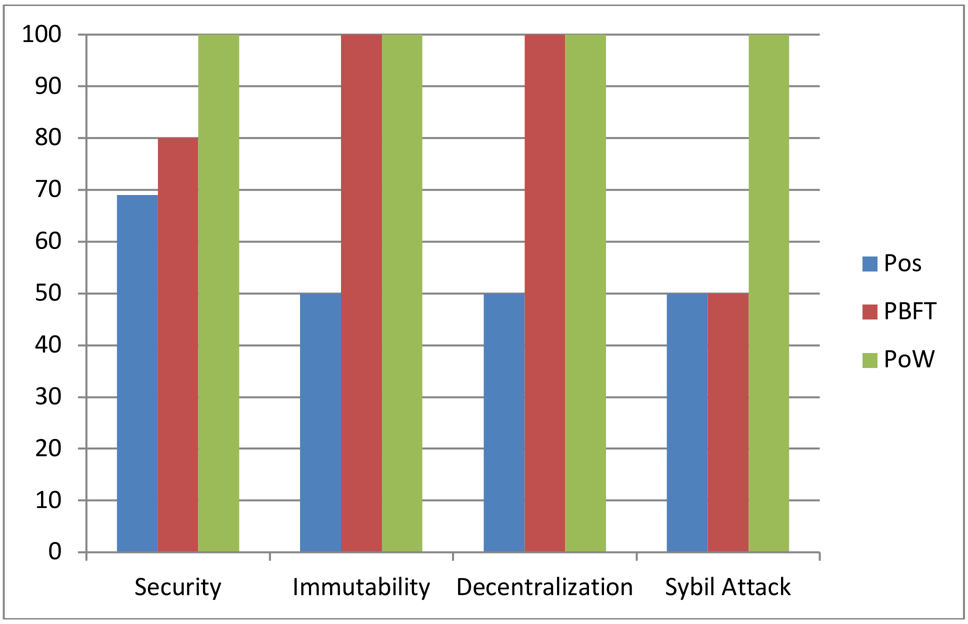

Fig. 4. Graph Highlighting Performance of Proof of Work Algorithm

From the above graph it is found that comparing PoS,PBFT and PoW , the Proof of Work approach promises better findings to locate fake medications making supply chain stable and condusive.

8. Conclusion and Future Work

In conclusion, the exploration of PoW-based block chain algorithms in the pharmaceutical supply chain holds immense potential for revolutionizing the industry. By bolstering transparency, security, and efficiency, this technology can mitigate risks, improve patient safety, and promote trust among all stakeholders. The issue of counterfeit medications has been addressed in the results found in the implementation of the algorithms proposed. The pharmaceutical supply chain's block chain technology application may affect outputs and outcomes. Implementation success depends on factors including block chain network scalability, data privacy, stakeholder participation, and system integration. PoW's downsides include excessive energy consumption and scalability difficulties. PoS and PBFT are alternatives to these constraints. PoW can detect counterfeit medicines securely. To fully realize these benefits, a collaborative effort between industry players, regulatory bodies, and technology experts is required to ensure responsible implementation and address the associated challenges. As the pharmaceutical supply chain continues to evolve, embracing innovative technologies like block chain can pave the way for a safer, more reliable, and resilient ecosystem.

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