Time-Efficient Auditable Blockchain-based Pharma Drug Supply Chain using Delegated Proof-of-Stake

Sakshi Sharma[1], Arshdeep Bahga[2], Trishie Sharma[3] and C. Rama Krishna[4]

[1,4] *NITTTR, Chandigarh, India*
[2] *Cloudemy Technology Labs, Chandigarh, India*
[3] *Jain (Deemed-to-be University) Bangalore, India*

Abstract

Blockchain technology was originally designed for maintaining financial ledgers, but over time it has found applications in many different fields including healthcare. There are numerous uses for blockchain innovation in the Pharmacy Industries, including encouraging patients, doctors, customers, and drug store organizations to get the clinical records; medicine sharing, improvement of the supply chain, following and detailing of clinical preliminary information, supplier credentialing, nature of-care following, drug estimating procedure following an unsociable event tracking and assessment.

In the existing work, the authors have used the most commonly used agreement protocols are Proof-of-Work, Proof-of-Authority, Proof-of-Ownership, and Practical Byzantine Fault Tolerance for implementing Blockchain-enabled pharmacy supply chains. But these protocols incur a large amount of energy and time consumption along with system compromise at times. Hence, there is a need to practice some new and different types of consensus protocols which can produce secure and accurate results without taking much time and energy.

To overcome these drawbacks, we have proposed an approach by using Delegated Proof-of-Stake protocol as the consensus mechanism for a Blockchain-based Pharma Drug Supply Chain. The main focus of this paper is to study Delegated Proof-of-Stake as an approach of agreement among the nodes and to compare its efficiency with other existing consensus protocols for their transactions in terms of time consumption. It is clear from the results that there is a considerable divergence in the throughput of the Delegated Proof-of-Stake i.e. 5000-7000 transactions per second where Proof-of-Work gives 300-500 transactions per second and Practical Byzantine Fault Tolerance gives 1600-1900 transactions per second.

Keywords

DPoS, PBFT, PoW, Pharmacy supply chain, Pharma Net

1. Introduction

The manufacture and circulation of forged drugs is a vital and increasingly crucial universal concern, particularly in budding countries. The marketplace worth of pharmaceutical forging has reached billions of dollars yearly [1].

Envision a circumstance where your kid is experiencing a perilous sickness. Side effects incorporate migraine, perspiring, unsettled stomach, and pyrexia. You take your kid to the most excellent and, confided specialist and governed the medication endorsed by the specialist. At the moment, you consider slightly hassle-free. Be that as it may, the wellbeing state of your kid doesn't improve or even disintegrates, or on the other hand far more terrible, your kid dies, in light of the fact

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EMAIL: imsakshivk@gmail.com (A. 1); arshdeepbahga@gmail.com (A. 2); trishatrix@gmail.com (A. 3); rkc_97@yahoo.com (A. 4)
ORCID: 0000-0001-5089-6587 (A. 1); 0000-0002-7592-0624 (A. 3); 0000-0002-4647-2842 (A. 4)
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that the medication which you have trusted is forged. It's anything but an inaccessible chance; this is genuine for the major emerging countries even for some advanced countries. On the worldwide stage, counterfeit drugs are huge problem. The magnitude, outline, and shade of the drugs, to the bundling precisely resemble the genuine drug. These fraudulent results by adding little amounts of the active components or even none at all or far more terrible a few toxic components. It is miserable, however, the truth of the matter is that India is the heroic centre of assembling counterfeit medications. Presumably, these counterfeit drugs are representing a severe threat to the purchasers and the drug store industry.

One of the causes for medicine faking is the inadequate supply chain organization in pharmacy engineering. Medicine amends rights from producers to wholesalers; distributing authority and then pharmacists before the consumer gets it. In the existing supply chain framework, data isn't pooled between frameworks, producers don't have the foggiest idea of what befallen their products, drug administrative authority has zero ability to see of the framework, reviews are intricate and exorbitant, and organizations can't follow-up patients [1].

For the anticipation of forged drugs, pharmaceutical engineering needs a proficient supply chain management (SCM) system, and the preeminent obtainable answer for building up an ideal SCM framework is Blockchain innovation.

The significant outcomes of the presented research paper are as per following: (1) A time-efficient blockchain based pharma drug supply chain framework is recommended that employments the DPoS consensus protocol given by EOSIO which is a blockchain based vertically and horizontally scalable architecture [2], (2) a comparative examination of the Pharma drug supply system, demonstrating major performance improvements in terms of throughput when contrasted with available consensus mechanism, (3) deployment of Pharma Net Dapp (Decentralized Application) is given which includes tasks such as verifying the originality or drug or medicine by entering the details present on the backside. It provides end-users a portal to make it auditable without the need to register to the system so that everyone can check the medicines for their originality and hence tackle the counterfeit problem.

The upcoming of the paper is coordinated as follows: In section 2, we examine the research of other researchers on blockchain related to the pharmacy supply chain. In Section 3, the portrayal of deployment work is presented. In section 4, the correlative study and results are discussed and in section 5 the final observations are listed.

2. Literature Review

In this section, various research papers are analysed and presented based on the solutions that many researchers have provided in an attempt to incorporate Pharmacy Supply Chain and Blockchain to implement decentralization and transparency of the drug or pharmacy product supplies.

T. Bocek et al. [1] introduced Modum.io, a start-up that utilizes IoT (Internet of Things) sensor gadgets utilizing blockchain innovation to declare information permanence and public availability of temperature records while lessening operational expenses in the Pharmacy supply chain. They used Ethereum Virtual machine for the publishing of nodes in the ethereum network. Smart contracts were used to achieve the business logic. Solidity was used to write the smart contracts. The geth Ethereum customer was not steady during the pilot projects, the server limit must be expanded during DoS assaults on Ethereum. Go with the fork holding on to perceive how the fork ends up (DAO (Data Access Object)) needs to resync the blockchain, which may take a few days. Haq et al. [3] suggested using a permissioned ethereum blockchain for implementing a blockchain-based solution for the drug counterfeiting problem. They have suggested how different systems can be implemented and how different people will access the system.

S Jhangir et al. [4] proposed a narrative framework for pharmacy supply chain management which uses an ethereum blockchain. They have used a Proof-of-Concept consensus mechanism. However, this Blockchain has an adaptability issue, and as a result, the transaction speed might be backed down in the proposed system. S R Niya et al. [5] demonstrated the implementation of a Supply Chain Tracking application which uses Ethereum to implement supply chain. They planned a Decentralized

Application (Dapp) which gives equipment and stage free methodology that deftly empowers different item mixes and changes to be followed a utilization case-rationalist plan and use. R Kumar et al. [6] proposed a methodology which is based on Public Key Infrastructure (PKI) and digital signature which can prevent replay and man-in-middle attack. This paper aspires to address the question of drug security utilizing Blockchain and encrypted QR (quick response) code security. The proposed framework tended to a blockchain based secure establishment for clinical chain supply among generous individuals. The elicited structure can offer drug safety as well as authenticity to the creator. This work is only addressing the tracking problem but counterfeiting still exists.

A Kumar et al. [7] used Hyperledger fabric v1.0 for the implementation of the drug supply chain since they want to make a private blockchain that can be accessed by their authorised identities. But if the system can only be accessed by the authorised users then how the end consumer, that is the public, will access the system, is not defined. They implemented this blockchain for improving the scalability issue by increasing the number of transactions per second and achieved 1600 transactions per second processing speed. R Raj et al. [8] proposed a blockchain-based solution to prevent medicine faking and to add tracing ability, security, and vision to the Pharmacy supply chain. Generally, proof-of-work is used as a consensus mechanism for blockchain; they modified it to proof-of-ownership. They used hyperledger fabric for implementation. They only theoretically suggested and validated the system and designed the algorithms in pseudo-code. End users cannot be a part of the system. M. Sahoo et al. [9] used Blockchain technology to explain how to add tracing ability, vision, and sanctuary to the pharmacy supply chain. They have suggested blockchain as a solution for the counterfeiting problem and designed the algorithms for each level of transactions and used the elliptic curve digital signature algorithm (ECDSA) for security enhancement. It is just a proposed system and is not implemented in reality.

It is perceived from the wide literature review that there are numerous concentrated researches on blockchain technology and its applications in different fields, where health care and pharmacy supply chains are the most popular areas of research.

The pharmacy supply chain is suffering from many issues like improper handling of tracking, security, and counterfeiting of drugs [9]. Out of these, this research covers the counterfeiting problem. Many blockchain-based solutions that promise guaranteed solutions to existing problems like improper tracking and counterfeiting are only suggested in theories but not implemented [8, 9]. Previous blockchain implementations only allow limited actors in the system [3, 5, 6]. Implemented solutions, such as PoW (Proof-of-Work), PBFT (Practical Byzantine Fault Tolerance), PoA (Proof-of-Authority), PoC (Proof-of-Concept), and PoO (Proof-of-Ownership) lack in scalability leading to slow transaction processing in the system [1, 3, 4, 5, 7, 8].

In the following segment, the structural design of the planned Pharma Net Dapp is given along with the performance parameter that is used to contrast diverse agreement mechanisms.

3. Proposed Pharma Net Dapp using Delegated Proof-of-Stake

This segment give details how the planned scheme is implemented and runs on a blockchain based network.

3.1. System Architecture

In the planned system, a dashboard in the form of a Dapp, i.e. a web portal, is provided to the users where they can verify the originality of drugs by entering the details printed on the backside of medicine as QR code/ Bar code, or for now, simple text-based. Once the drug details are entered using the dashboard of Dapp, the transactions as a query are forwarded to the EOSIO network. All the nodes in the EOSIO system first vote for setting the delegates and in the second round, the delegates will vote to get the chance to publish and verify the block on the blockchain, as it is a DPOS based blockchain. For every transactional query, the blockchain is mined by delegates for the results and verified by the winning delegate and then the results are sent back to the portal. If the details of drugs are present in the system then they will be listed on the portal and if not, then an error will be generated. The architecture diagram of the proposed work is shown in figure 1.

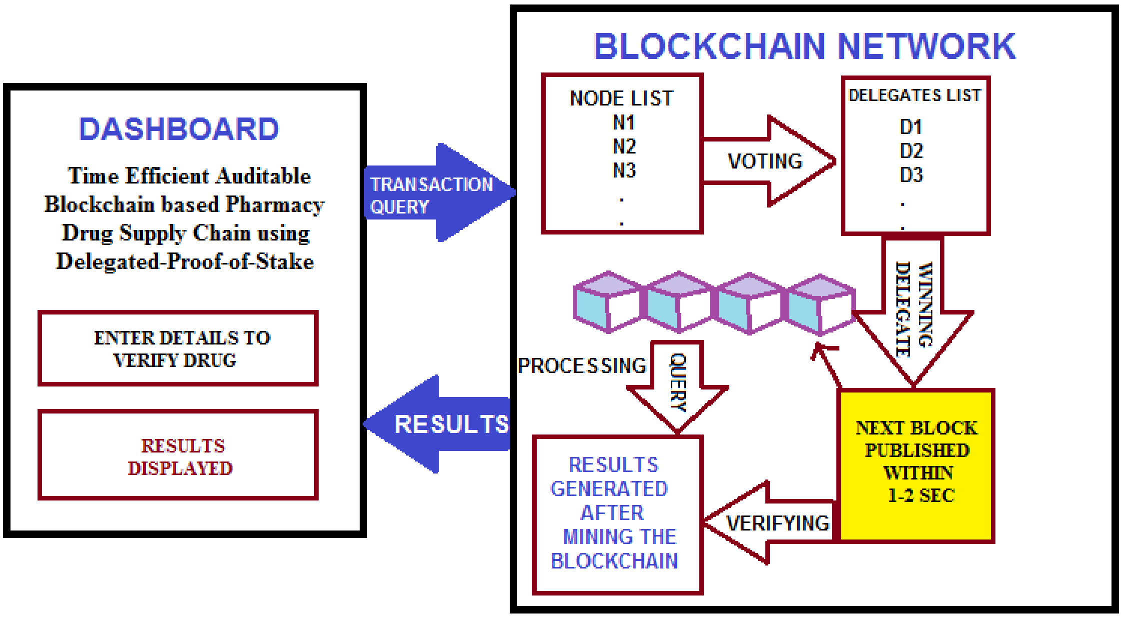

Figure 1: Architecture of Proposed DPOS Auditable System

The workflow of the proposed Pharma Net Dapp system is shown in figure 2.

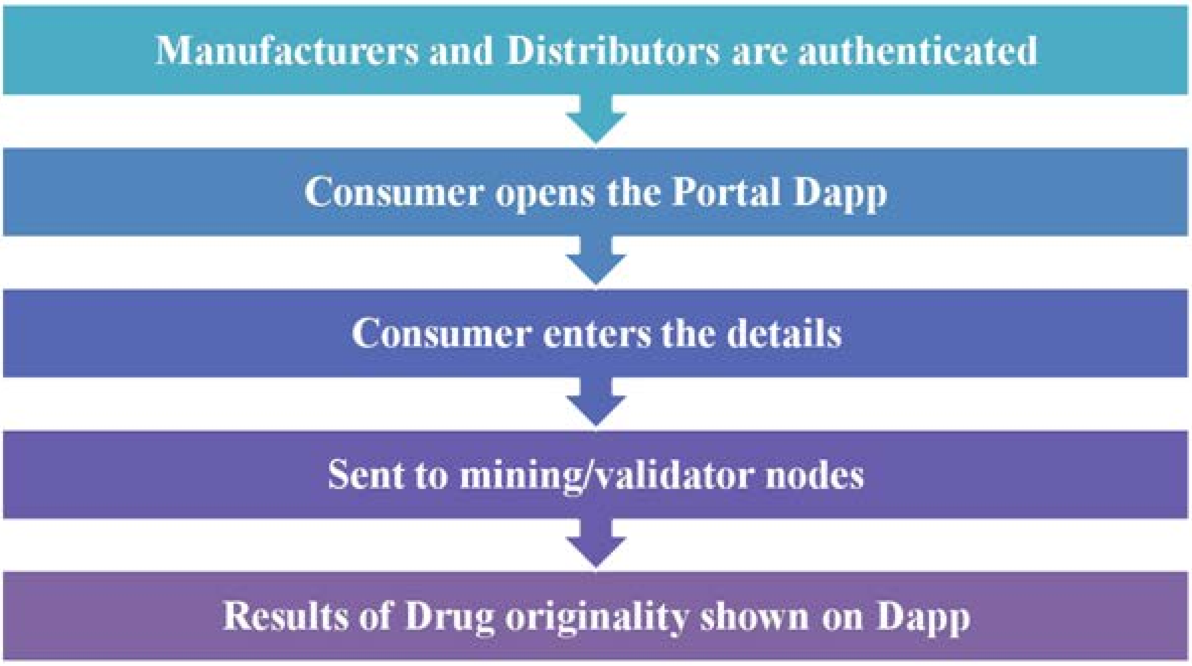

Figure 2: Workflow of Pharma Net Dapp

The framework for the proposed blockchain-based Pharma Drug supply chain has the following major steps.

1. **Creating Manufacturers and Distributors Accounts and linking them**: The manufacturers and distributors accounts turn out to be created using the ‘EOSIO’, a public, private, permissioned, or permissionless blockchain infrastructure, based on Delegated-Proof-of-Stake agreement protocol. For Proof of Work , the accounts were created using Ganache and then added to MetaMask. For PBFT the accounts turn out to be created in hyperlegder fabric.
2. **Design Pharma Net Dapp:** A single portal for entering the details to be verified and then listing the verified drug details has been designed using HTML/CSS and Javascript/Typescript has been used for scripting the web page as shown in figure 3.

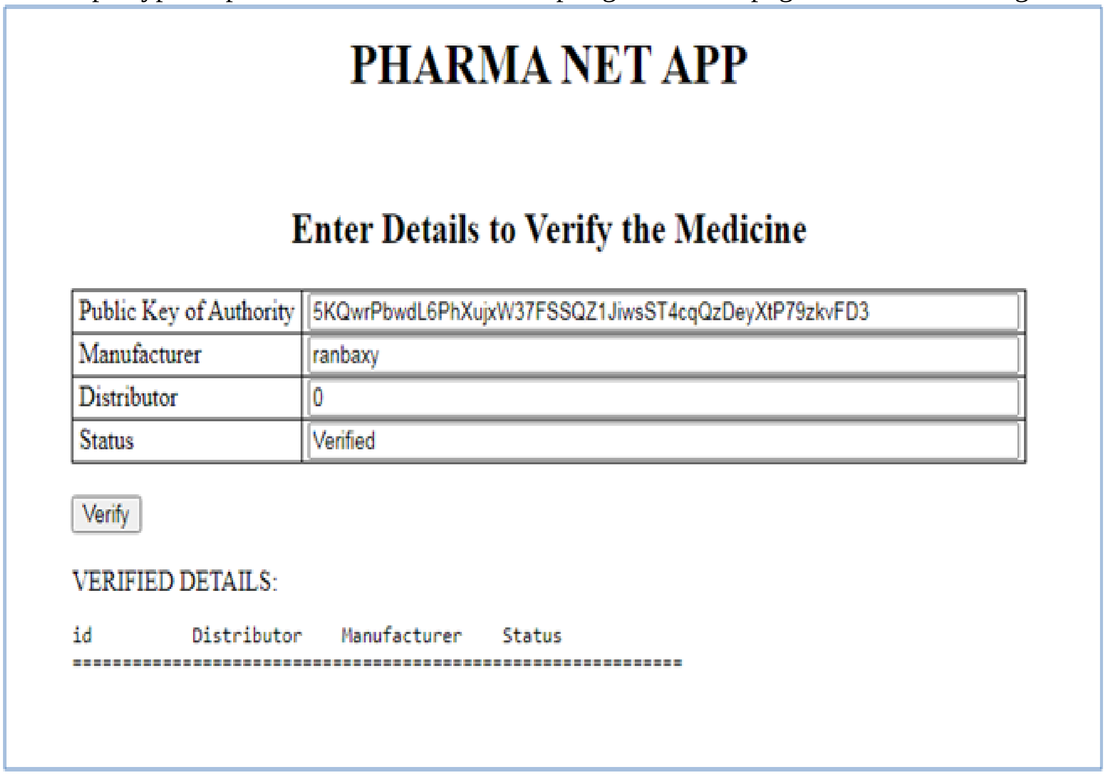

Figure 3: Portal for Pharma Net Dapp

In figure 3, the portal for Pharma Net Dapp displays the following:

- **Public Key of Authority:** This is the public key of the authority who is verifying the particular details of the drugs. This ensures the verified system as the accounts for manufacturers and distributors are created using the ‘cleos’ (an inbuilt command line for EOSIO) and they are linked using a set of public and private keys.
- **Manufacturer:** It is assumed that the manufacturer name/id is listed on the drug that is desired to be tested. One can enter any name here but if that name is not in the system loaded then it will create an error and that drug will not be verified.
- **Distributor:** It is assumed that the distributor name/id is listed on the drug that is desired to be tested. One can enter any name here but if that name is not in the system loaded then it will create an error and that drug will not be verified.
- **Status:** Status will be shown as “verified” if the private key, manufacturer, and distributor entered are verified by the system. The details will also be listed on the portal for future reference. But if the drug is not verified, the status will be “not verified” and if tried to verify it again then it will generate an error.
- **Verified Details:** A table of all the verified records will be generated and records will keep adding when they are searched.

3. **Selecting the agreement mechanism type:** The planned work will be juxtaposed with the existing agreement protocols, i.e., Proof-of-Work and Practical Byzantine Fault Tolerance, different methods turn out to be utilized for every one of them.

- **Proof-of-Work:** The beginning files (genesis) were produced using ‘Ganache’ and the descriptions of the accounts created are detailed in it. The accounts are linked using Metamask using the RPC URL of localhost: 8545.
- **Practical Byzantine Fault Tolerance:** Hyperledger fabric (v1.4.3) is used to make a PBFT based blockchain network. As the basic consensus mechanism in Hyperledger fabric is PBFT, the accounts were created and then the business logic was setup and achieved using the codechains.
- **Delegated Proof-of-Stakes:** EOSIO (v2.0) blockchain is used as it is based on DPOS and PBFT. So the network was configured using the DPOS using nodeos. Then the accounts for the manufacturers and distributors were created using the cleos and connected by the same private key of authority. Every time this system is tested, we have to first compile the smart contract that is written in c++ and has the main business logic. The ‘wasm’ and ‘abi’ files are created after the successful execution of the smart contract. Then the drugs can be verified via the portal and the same ‘wasm’ and ‘abi’ files are tested on the ‘Testnet’ of the EOSIO network.

4. **Setup the mining/delegate nodes:** The figure of complete nodes for all association is dissimilar, for existing blockchain, a mean postulation of 10 nodes symbolizes a practical standard and presents the practical values for approximately every systems [10]. Keeping this under deliberation, 10 mining nodes turn out to be setup for Proof-of-Work consensus, and 10 nodes turn out to be setup for Practical Byzantine Fault Tolerance consensus. For PoW, nodes were created with the Geth console [11]. For DPoS, nodes were created using the nodeos docker console of hyperledger fabric. 5 delegate nodes and 5 additional nodes, in simple mode, were setup for Delegate-Proof-of-Stake mechanism and for generating the nodes; the nodeos docker console of EOSIO were used.
5. **Setup and launch the Pharma Net Dapp:** The smart contract has been formed for the pharmacy drug supply chain and then it will be setup for every agreement mechanism. The performance is measure using predefined metrics for every consensus mechanism, i.e. Transaction per Second (TPS).
6. **Consumer Enquiry about the drug:** The end-user will be able to access the portal and verify the drug just by entering the details present at the backside.
7. **Compare and analyse the results:** The performance of each consensus protocol will be then compared based on the following parameter.
    a. TPS (transactions per second)
    Distinctive blockchain frameworks demonstrate various speeds for deploying, summoning, and implementing smart agreements. We observe the throughput in a timeframe that is the numeral transaction per second [12]. During a timeframe from t_i to t_j, the accompanying equation can be used to determined Transactions per Second of node u

$$TPS_U = \frac{Count(Tx\ \ in\ (t_i, t_j))}{t_j - t_i}(txs/s),$$

TPS for N nodes can be obtain by taking the average using following equation

$$\underline{TPS} = \frac{\sum_U TPS_U}{N}(txs/s)$$

The subsequent section discusses the outcomes with the comparison study for PoW, PBFT, and DPoS mechanisms as per the described performance parameters.

4. Results and Discussion

The planned scheme introduced a conceptualization of a time-efficient Blockchain based Pharma supply chain portal with an enhanced throughput. The outcomes of this planned scheme are premeditated on a system with 8 GB RAM and an i5 processor in terms of throughput which is premeditated in terms of Transaction-per-Second (TPS). The results recorded are tabulated in Table 1.

Table 1: Comparison of Throughput in terms of Transaction-per-Second for Proposed Pharma Net Dapp using DPoS with PBFT and PoW

Consensus Mechanism Used	Time (per Transaction in µs)	Transaction-per-Second (TPS)
PoW	2305.202	434
PBFT	528.311	1892
DPoS	165.264	6051

4.1. Throughput (TPS)

It is observed that the proposed Pharma Net Dapp system on the Blockchain network was capable to deal the uppermost number of transactions with the DPoS mechanism as contrast to the PoW and PBFT consensus, from Table 1. The DPoS mechanism based arrangement achieved a throughput of 6051 TPS; PBFT reached 1892 TPS while PoW possibly can lever only 434 TPS as shown in figure 4. These observations were attained by recording the time taken for a solo transaction on a blockchain network. Next, this time is transformed in terms of the number of transactions which can be executed in one second. The total time taken to complete a transaction using DPoS protocol (165.264 µs) is very less as compared to the PoW (2305.202 µs) and PBFT (528.311 µs) as shown in figure 5. The cause for the high throughput attained by the DPoS mechanism is its block confirmation time of 1-2 seconds [2], as compared with PBFT which has a block time of 15 seconds [13], and PoW having block time near about 9-10 minutes [14].

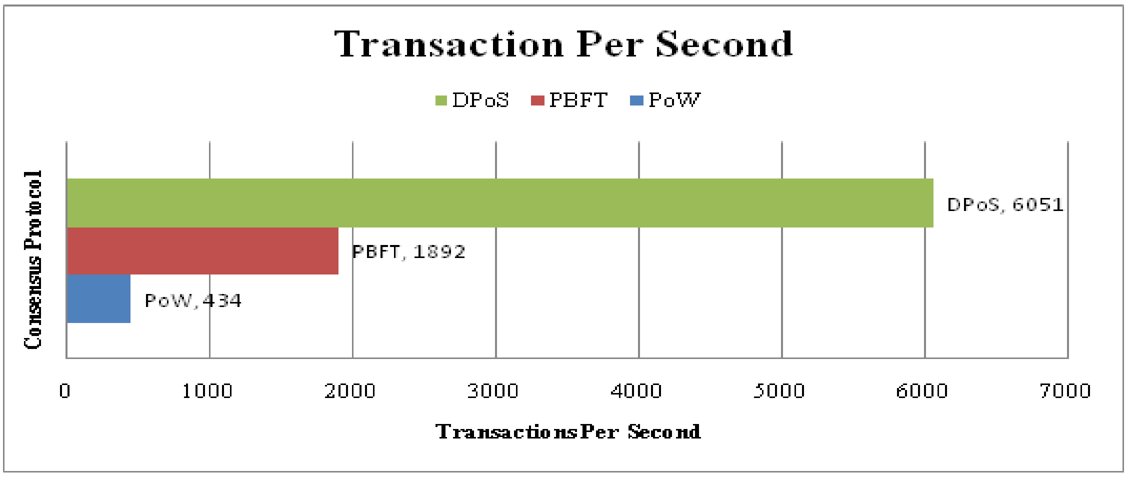

Figure 4: Comparison of Transaction per second of proposed DPoS Pharma Net with PoW and PBFT

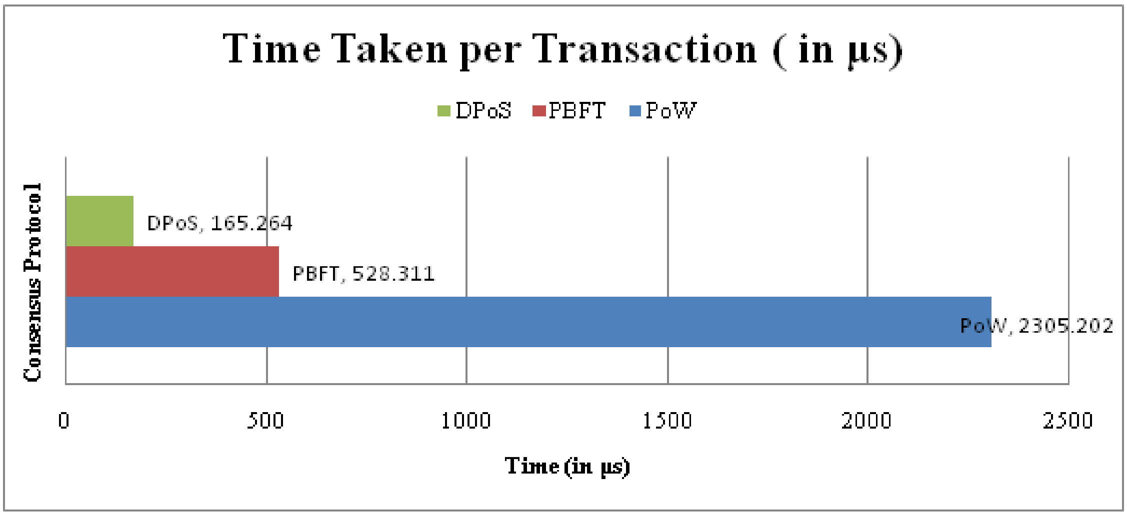

Figure 5: Comparison of Time taken by proposed DPoS based Pharma Net with PoW and PBFT

5. Conclusions

This paper aims on implementation of a blockchain based pharma drug supply system that amplifies the throughput and makes the end-user capable to audit the medicines without the need to be a part of the system. The DPoS protocol offers an excellent throughput of 6051 transactions per second that would help to improve the scalability of the scheme in a Blockchain network. In the future, IoT devices can be integrated to add other features like traceability of drugs.

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