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Drug Traceability using Blockchain

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Abstract

The medicine supply tracking system that has been built uses blockchain-based technology to address the widespread problem of counterfeit pharmaceuticals. The solution utilizes the decentralized structure of blockchain to guarantee confidentiality and transparency in the prescribed medicine distribution chain. The blockchain tracks an individual drug's path from producer to customer, providing auditable and immutable documentation of its legitimacy and provenance. Smart contracts automate procedures and enforce pre-established guidelines. "Examples include confirming the authenticity of medicines and triggering alarms for questionable activity. The technique reduces the possibility of counterfeit medicines entering the market by eliminating the need for trust in middlemen through decentralized consensus procedures. In the end, the blockchain-based medicine traceability system improves patient safety by enabling the quick identification and removal of fake medicines from the market.

Keywords: Blockchain, Counterfeit, Immutable documentation, Decentralized, Traceability system.

1. Introduction

Drug counterfeiting poses a serious threat to the well-being and security of the general public. These fake medicines, which frequently contain incorrect chemicals, inappropriate doses, or even dangerous compounds, are produced and sold to imitate real medicines. In

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addition to compromising the pharmaceutical sector's credibility, the widespread availability of fake medicines endanger the lives and wellness of customers who mistakenly take these fake products. To guarantee the originality and accountability of medicines across the supply chain, legislatures, regulatory organizations, and medical companies have been resorting to technology-driven solutions in response to the growing threat of counterfeit pharmaceuticals. Drug traceability, made possible by blockchain technology, is one such approach that has gained popularity recently. Guaranteeing transparency, responsibility, and reliability within the pharmaceutical supply chain, lowers the dangers related to fake medicines. This article aims to investigate the idea of drug traceability using the blockchain system as a powerful tool against fake medicines. We will give an outline of the situation with counterfeit drugs [1]. Smart contracts and other blockchain-based solutions fall under the larger scope of Distributed Ledger Technologies (DLT), which includes the Hyperledger Fabric and Hyperledger Besu. These technologies are frequently linked to decentralized systems, in which data is not kept in a single location but is instead dispersed across several network nodes.

1.1 Blockchain

Blockchain is an immutable, distributed, decentralized ledger used to store transaction and data records. Blockchain is a distributed records system that acts on a decentralized network of computers to securely record transactions [2]. It was first developed as the foundational technology for the virtual currency known as Bitcoin, but it has subsequently found use in a number of sectors outside of banking. This is how a blockchain operates:

1. Decentralization: Blockchain runs on a network that is decentralized of computers, sometimes referred to as nodes, in contrast to conventional centralized structures where a single institution (such a bank or a government) owns the data. A copy of the whole blockchain is kept on file by every node in the network, guaranteeing transparency and resistance to manipulation or single-point failures.

2. The blocks and Chains: Groups of transactions are called blocks. The term "blockchain" refers to the sequence of blocks that are created when a set of transactions, a date and time stamp, as well as a link to the preceding block are all included in one block. A chronological and unchangeable record of all network transactions is produced by this series of blocks.

3. Consensus Mechanism: Consensus methods are employed by blockchain networks to reach a consensus over the legitimacy of transactions and the sequence in which they are appended to the blockchain. By doing this, the network's nodes are guaranteed to perceive the transaction history uniformly. Two well-liked consensus techniques are Proof of Stake and Proof of Work, which are employed by Bitcoin.

4. Security and Immutability: A transaction is almost hard to change or remove once it is registered on the blockchain and included in a block. A chain of linked blocks is produced by each block having an encrypted hash of the one before it. The distributed structure of a network and the hashes of cryptography involved make it computationally impossible to change the contents in any block without also affecting the succeeding blocks.

5. Transparency and Trust Lessness: Since each member of the network has access to an identical copy of the ledger, blockchain offers transparency. Transparency and tamper evidence are employed in the verification and recording of transactions.

It is a potential technology for a variety of businesses looking to increase efficiency, transparency, and confidence in transactions and data management because of its capacity to offer safe, transparent, and decentralized solutions [3].

1.2 Hyperledger Fabric

The Linux Foundation's Hyperledger networking is responsible for developing Hyperledger Fabric, an open-source permissioned blockchain technology. It offers a scalable, flexible framework for developing high-quality blockchain applications for businesses. Organizations can design and administer blockchain networks with customized characteristics like performance, privacy, and security, thanks to Fabric [4].

Because of Hyperledger Fabric's modular architecture, different components may be customized to meet unique business needs. It is composed of several essential components, such as peers, membership services, customers, and orders. Orders oversee the consensus mechanism and guarantee transaction ordering, while peers administer the ledger and carry out transactions. In Hyperledger Fabric, smart contracts which is also referred to as chain code specify the rules and business logic that control network transactions. Developers may write Chain code in other programming languages, providing them more flexibility [5]. Hyperledger Fabric's channel-based communication makes it possible to divide the primary blockchain network into private subnetworks. Channels guarantee privacy and secrecy by enabling private transactions between certain parties. The endorsement policy mechanism is introduced by Hyperledger Fabric to verify transactions prior to their commit to the blockchain. In accordance with the stated policy, transactions need to be approved by a predetermined group of peers, guaranteeing agreement among authorized users. This system lowers the possibility of fraudulent or incorrect transactions while improving security [6].

1.3 Hyperledger Besu

Hyperledger Besu is a free-to-use Ethereum client developed as part of the Hyperledger project. Besu is far more flexible than the permissioned blockchain architecture of Hyperledger Fabric, as it is designed to handle both open and permissioned networks. It enables businesses to create blockchain-based applications on the network of Ethereum by utilizing the decentralized apps (D Apps), smart contracts, and tool ecosystem that Besu, an Ethereum client, already differs from Fabric in a number of important ways. First of all, interoperability with already-existing smart contracts based on Ethereum and D Apps is made possible by its support for the virtual machine that runs on Ethereum Virtual Machine (EVM). Because of this, developers who are already experienced with Ethereum will find it simpler to switch to Besu and utilize its capabilities to create decentralized apps [7]. Besu is more suited to businesses wishing to use the Ethereum ecosystem to create decentralized apps and take part in permissioned or public Ethereum networks than Hyperledger Fabric. Besu is a better option for Ethereum-based blockchain applications since it seamlessly integrates with current Ethereum tools and smart contracts, whereas Fabric allows more flexibility and control over network governance.

1.4 Smart Contract

Ensuring openness, accountability, and confidence in the supply chain for pharmaceuticals may be greatly enhanced by the implementation of a smart contract for medicine tracking on a blockchain network [8]. An overview of how drug tracing may be achieved with a smart contract is provided below:

The registration of Drug Information: Manufacturers or pharmaceutical businesses can record key details about each batch of pharmaceuticals they make by using a smart contract. Details including the drug's name, batch number, manufacturing and expiration dates, ingredients, and production site may be included in this data.

Verification of Medicine Authenticity: Stakeholders including wholesalers, suppliers, and pharmacies may communicate with a smart contract to confirm the legitimacy of new medicine batches that are added to the supply chain. In order to prevent the distribution of tampered or fake medicines, the smart contract has the ability to verify if the batch information corresponds to the data kept on the blockchain [9]

Tracking and Tracing: Every transaction involving medicines may be documented on the blockchain as they go through the supply chain. This contains details on the people involved in the financial transaction as well as the location and timestamp. The medicines' status may be automatically updated by the smart contract, which can also follow their journey from producer to distributor to drugstore.

Monitoring of Temperature and Storage Conditions: Sensors may be included into the supply chain to keep an eye on temperature, humidity, and other environmental parameters for some medicines that need special storage conditions. Through the use of smart contracts and blockchain technology, the data gathered by these sensors can be recorded, guaranteeing that medicines are maintained properly along the supply chain.

Expiration Date Management: The smart contract has the ability to keep track of medicine expiration dates and to send out warnings when a medicine is about to expire. By doing this, you can guarantee that patients receive safe and effective medicine and help stop the spread of outdated pharmaceuticals.

Compliance and Regulatory Reporting: Smart contracts can simplify compliance with regulatory standards by automating data collecting and record-keeping procedures. Because blockchain technology is immutable, every transaction and information are securely recorded, offering a clear audit trail that may be used for regulatory reporting.

Recall Management: A smart contract can help quickly identify and recall impacted batches in the case of a medicine recall or other safety concern. This can decrease the effect on public health and safety by swiftly removing dangerous medicines from the distribution network.

1.5 IPFS

Blockchain technology uses IPFS (Interplanetary File System) mostly for content addressing and decentralized file storage. Blockchain systems use IPFS to store big data and files off-chain, which relieves the primary blockchain network's storage load. In order to provide redundancy and availability, IPFS divides files into smaller pieces and distributes them over a decentralized network of nodes. A distinct cryptographic hash is issued to every file, which functions as a based-on content address for data integrity checks and access. Blockchain apps may increase scalability, lower transaction costs, and prevent the blockchain from being bloated with pointless data by storing data on IPFS. Additionally, by facilitating peer-to-peer transfer of files, teamwork, and content dissemination without depending on centralized servers, IPFS improves the security and decentralization of blockchain applications [10].

2. Related Work

The technology used for free to use, accessible to everyone, and private blockchain networks are called the Hyperledger Fabric and Hyperledger Besu. Public networks are used to verify medicine authenticity. The complexity and lack of data accessibility in the pharmaceutical supply chain present issues regarding drug traceability and counterfeit pharmaceuticals. Security and scalability are two issues with traditional technologies such as bar codes and RFID tags. Decentralized tracking and tracing of transactions is made possible by blockchain technology, which provides an unchangeable and transparent solution. Through its integration with current technologies, such as RFID and e-pedigree, it improves interoperability and offers more integrated solutions. Blockchain does, however, have certain drawbacks in terms of scalability, privacy, and security [11].

The drawbacks include the need to set up complicated configurations and the risk of network outages or disruptions when using a public network [12]. wherein all authorities must obtain digital signatures from certifying agencies and registration from providers (Regulatory Bodies). Participants can rely on the digital signature since it will be supplied by the certifying authority. Workflow of the suggested work. The steps involved in a drug safety transaction are the sender's public key, digital signature, and recipient's public key, and the sent information will all be included in the transaction between the parties. benefits include peer-to-peer transactions being made easier by Ethereum technology, which provides a strong framework for developing decentralized applications. The drawbacks of Ethereum technology are its scalability problems, expensive transaction costs during network overload, and the possibility of security threats arising from smart contract vulnerabilities [13].

By utilizing smart contracts created on Ethereum in supply chain management, problems like fake goods and supply chain delays can be resolved by ensuring material authenticity and prompt delivery. On the other hand, a major drawback is that to minimize any financial losses, complete end-to-end tracking mechanisms must be implemented [14]. Ethereum has limitations even if its distributed application and smart contract features allow for a variety of transactions, including peer-to-peer exchanges. The strength of Ethereum resides in its data immutability and data integrity features, which guarantee that data added to the ledger cannot be changed or withdrawn. This immutability, however, limits the system's flexibility, which can be a drawback in situations when mistakes need to be fixed or data needs to be updated. Although smart contracts can help automate processes and save costs in areas like insurance and payment, poorly implemented software might make it more difficult for hospitals to support e-healthcare projects. This undermines trust in the system and compromises the security of patient data. Smart contracts that are poorly conceived or executed run the risk of creating vulnerabilities that could allow for hacks or unauthorized use of private medical data. Strong software development procedures and stringent security controls are necessary to lessen these drawbacks and increase public confidence in e-healthcare systems [15]. Med ledger is a medicine traceability solution that helps supply chain operations among stakeholders by using Hyperledger Fabric and network codes for storage rule enforcement. On the other hand, disadvantages include excessive use of power and the possibility of network configuration problems. Because of the potential to reduce supply chain operations, raise operating costs, and affect system efficiency, these problems must be carefully considered and managed during deployment [16].

Efficiency and transparency gains can be realized by using an Ethereum smart contract to handle important transactions in conjunction with a supply chain stakeholder website. However, giving anybody access to medication information without the necessary identification raises serious concerns about security, privacy, trust, responsibility, and compliance. Unauthorized access to personal medication information by healthcare professionals, such as physicians and pharmacists, may result in patient privacy violations, noncompliance with regulations, and possible data abuse. It is imperative to establish strong authentication protocols and access restrictions to address these drawbacks and guarantee the confidentiality and integrity of drug-related data. Cryptography is the main technology used in digital traceability systems to mitigate security and privacy problems with data. Cryptography includes methods for data security and safe communication using digital signatures, hashing, and encryption.

Risks to Data Security and Privacy: Pharmaceutical product sensitive data is gathered, stored, and shared through the digital traceability systems, which raises worries about the security of information and privacy breaches—especially in light of the growing frequency of cyberattacks. The PSC is the chain that delivers the completed medicines to the patients and carries genuine APIs to the producers for manufacturing. Assuring quantity, timeliness, safety, quality, and cost, PSCs are essential in the transportation of authentic Active Pharmaceutical Ingredients (APIs) to producers and the delivery of completed medicines to patients. One disadvantage of authentic Pharmaceutical Supply Chains (PSCs) is the possibility of encountering fake medicines. Although they are accountable for the delivery of genuine APIs (active pharmaceutical ingredients) and the timely and cost-effective provision of safe, high-quality medicines, the intrusion of fake medicines compromises their credibility and puts the safety of patients and healthcare effectiveness at risk.

A smart contract on the Ethereum network controls important transactions as a separate codebase that provides application binary interfaces (ABIs) for use. Data submission on a specific website for supply chain participants requires authentication. However, without identification, medicine information is available to all consumers, including physicians and pharmacists. Although making pharmacological information accessible can appear advantageous, doing so without appropriate authentication poses serious dangers and presents difficulties in compliance, security, privacy, and accountability [17] .

3. Proposed Work

The medical field encounters a number of difficulties, such as:

Drug counterfeiting: Drug counterfeiting is a serious risk to public health and safety. They may include dangerous drugs, ineffective doses, or incorrect components, which might result in unfavourable responses or unsuccessful treatments. Authentication and strong supply chain management are needed to combat counterfeit medicines.

Regulatory Compliance: Strict regulations are in place to protect the quality, safety, and efficacy of pharmaceuticals. Pharmaceutical firms may find it difficult and resource-intensive to comply with rules like pharmacovigilance, the Good Manufacturing Practices (GMP), and Good Clinical Practices (GCP).

Data Security and Privacy: Sensitive patient data, such as clinical trial data, medical records, and private health information, are handled by the medical business. In order to preserve patient confidence

Drug shortages: A number of circumstances, such as production problems, supply chain interruptions, legal difficulties, and changes in the market, can lead to shortages of necessary pharmaceuticals. Drug shortages have the potential to jeopardize public health and patient care, underscoring the necessity of effective supply chain management and risk reduction techniques.

To overcome this, we use with this initiative, we have improved upon conventional techniques by separately integrating each module onto the blockchain. All stakeholders, including distributors, suppliers, and users, are now directly connected to the blockchain. The goal is to make it simple to find any errors that could arise during the procedure. For example, when a user places an order for tablets, the manufacturer logs on the blockchain that the tablets were sent to the distributor. The distributor then modifies the blockchain to indicate delivering the tablets to the customer. Each module is linked to a distinct block, making it easy to identify any mistakes—like the manufacturer providing the incorrect tablets—when they occur. Every participant can now see the whole process thanks to the increased transparency, which ensures responsibility and reduces errors and with this, we can quickly identify the medicine scarcity as well. The screenshots of sign-in and signup are shown in Figure 1.

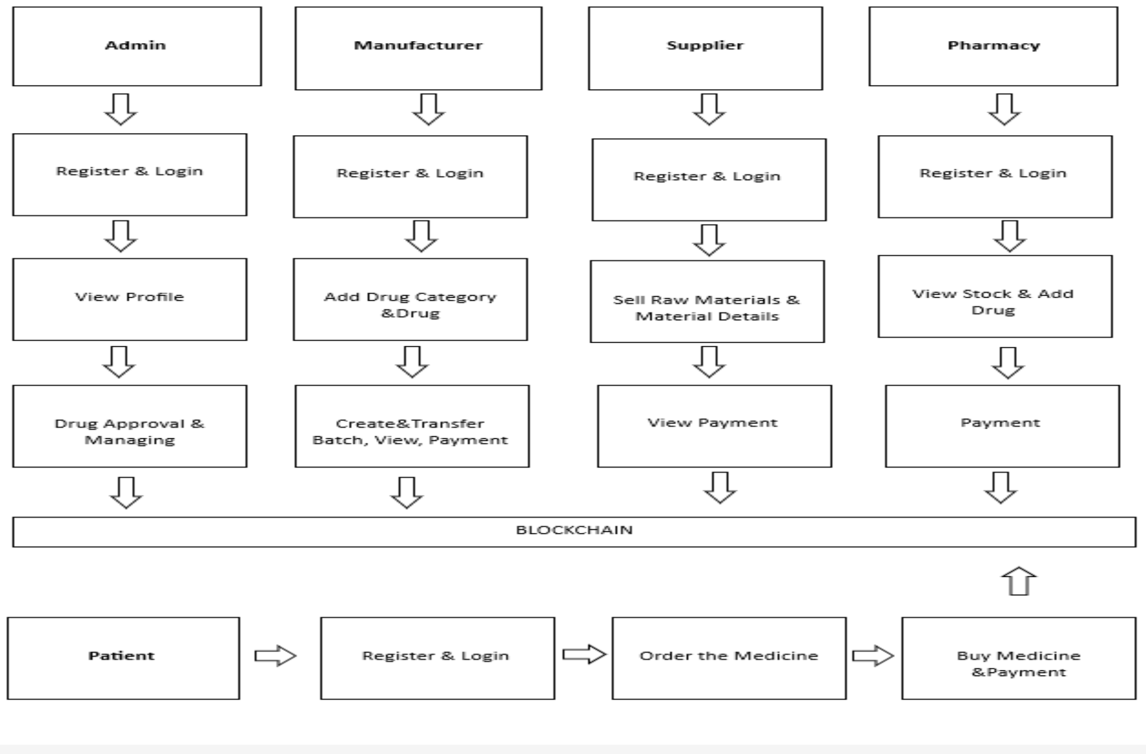


Figure 1. Flow Diagram of the Proposed Work

We've incorporated IPFS so that authorized users can have certain access privileges. We guarantee that only authorized individuals have access to pertinent data within the blockchain network by utilizing IPFS. Suppliers, distributors, and users are among the modules that have separate connections to the blockchain. For example, when a user places an order for tablets, the distributor updates the blockchain to reflect the transfer to the user when the manufacturer logs the transaction on the blockchain. This procedure is made easier by IPFS, which enables the safe distribution and storing of sensitive data, including user and transaction details. Transparency and accountability across the supply chain are ensured through IPFS, which allows authorized individuals to securely access and interact with the blockchain. The screenshots of sign-in and signup are shown in Figure 2.

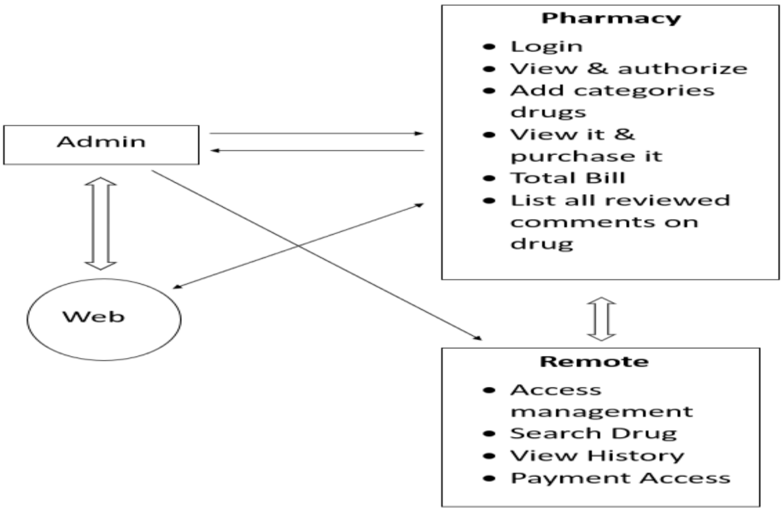


Figure 2. IPFS Flowchart

4. Result and Discussion

We are creating a blockchain-based drug traceability system that will monitor medicines through the supply chain for healthcare. The supply chain for healthcare involves many different parties, including producers, distributors, suppliers, hospitals, pharmacies, and so on. There are a chance that one of the parties involved will mislabel or counterfeit the medication while it's being supplied by the manufacturer to the patient or client. To prevent this, we suggest using smart contract technology in our system, which offers push warnings in addition to real-time, traceability Table No. 1.

Users must either create an account for the first time by supplying the required information or sign in using their current credentials to use the site. Authorized access to the functions of the supply chain platform is ensured by authentication. The screenshots of sign-in and signup are shown in Figure 3 and 4,5. All participant's data is gathered to get specifics about their medicine order, such as sender and receiver information and the drug name. To ensure accountability and transparency throughout the transaction process., a distinct block is subsequently generated for every participant inside the blockchain network. The screenshots of create are shown in Figure 3 and 5. Click on any relevant transactions to obtain more information once you've located them. The transaction timestamp, date, hash value, sender and recipient addresses, and other metadata. The screenshots of view a block are shown in Figure 3 and 5. Every transaction on the blockchain is identified by a distinct hash value. Check the integrity and validity of the transaction hash by verifying it. examine data about users who have placed drug orders and provide pertinent information for each user's transaction, including the hash value, date, and timestamp. It's crucial to remember that the precise procedure may change based on the blockchain network and the accessible tools.

The user is asked to log in or create an account when they first use the portal. They are sent to the home page upon successful completion of the authentication procedure. Users may access functions like placing an order and starting transactions from this home page. Users of the site may also check the specifics of a block linked to a fresh order and build new blocks. This involves showing data such the block index, amount, date, and transaction evidence. To put it simply, allows users to do tasks like order formation, transaction initiation, and block administration with ease.

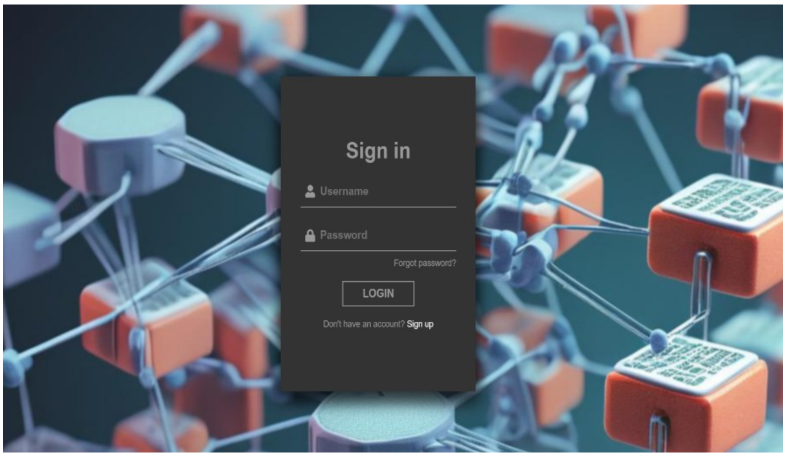


Figure 3. Sign In

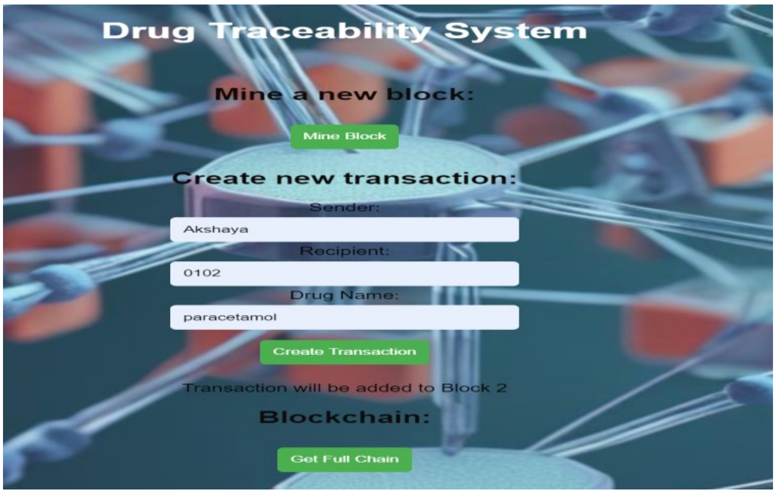
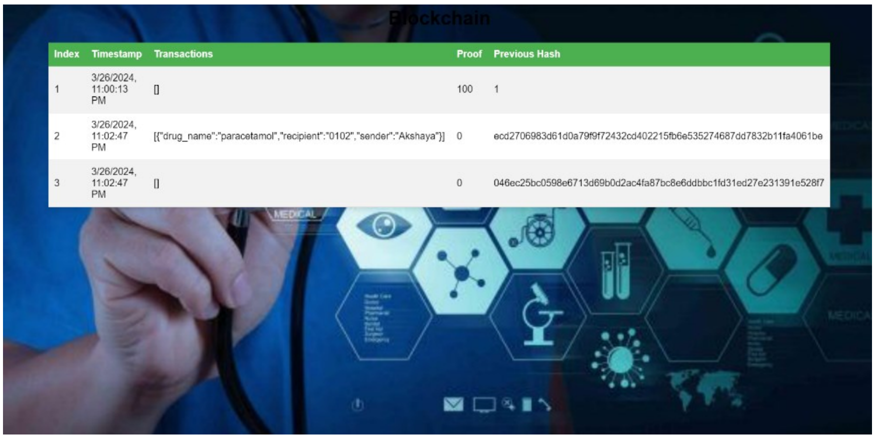


Figure 4. Create a Block



Blockchain

Index	Timestamp	Transactions	Proof	Previous Hash
1	3/26/2024, 11:00:13 PM	[]	100	1
2	3/26/2024, 11:02:47 PM	[{"drug_name":"paracetamol","recipient":"0102","sender":"Akshaya"}]	0	ecd2706983d61d0a79f9f72432cd402215fb6e535274687dd7832b11fa4061be
3	3/26/2024, 11:02:47 PM	[]	0	046ec25bc0598e6713d69b0d2ac4fa87bc8e6ddbbc1fd31ed27e231391e528f7

Figure 5. View the Block

4.1 The Reason for Using Blockchain

All things considered, blockchain offers a safe, open, and effective way to track drugs. It has advantages over traditional databases, including immutability, decentralization, enhanced safety, compliance, and cost savings and Please see Table. 1.

Table 1. Blockchain vs Database

Feature	Blockchain	Traditional Database
Data Structure	An immutable, append-only transaction.	Mutable data kept in tables.
Decentralization	Distributed nodes in a decentralized network.	Centralized design with one master access point.
Consensus Mechanism	Consensus amongst dispersed nodes (Pow, PoS, etc.).	A consensus process or centralized authority inside the database system.
Security	Tamper-proof transactions and cryptographic security.	Depends on encryption, access limits, and other security precautions.
Transparency	Transparent and auditable history of transactions.	Restricted transparency in terms of permits and access control.
Trust	Cryptographic algorithms are used to build confidence in a trust less system.	Depends on having faith in the administrator or central authority.

Scalability	Challenges to scalability as network capacity & number of transactions grow.	More scalable, although it might not be able to handle large datasets.
Speed	slower transaction processing as a result of decentralization and consensus techniques.	improved query execution along with quicker transaction processing.

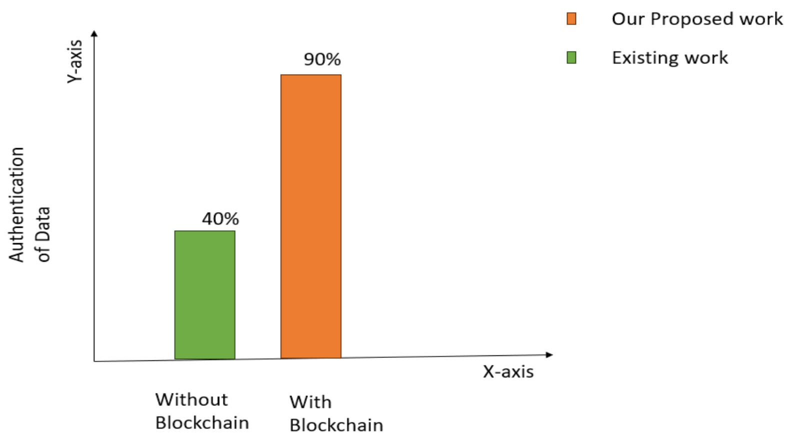


Figure 6. Compare Graph for Existing vs Proposed

A relatively new development, the use of blockchain technology for medical data storage is usually linked to the "digital" or "information age" generation, which started in the late 20th century and is still going strong today. Although blockchain technology was first introduced in 2008 with the launch of Bitcoin, its use in the healthcare sector only began to gain popularity in the mid- to late-2010s. This time frame corresponds with the continuous digital revolution taking place throughout several sectors, such as healthcare. For the storage of medical data, blockchain technology has a number of potential advantages, including improved data integrity, security, and interoperability. Blockchain can help safeguard medical records, guarantee their immutability, and enable safe data transfer between patients and healthcare providers by utilizing decentralized and cryptographic techniques. This is shown in Table 1.

In the past, centralized Database Management Systems (DBMS) were used for data storage. But as blockchain technology has developed, decentralized ledgers have become a viable substitute. Blockchain provides a distributed, impenetrable database by using hash values to guarantee the integrity of earlier transactions. In contrast to DBMS, which stores data in a single location, blockchain distributes data among several nodes in a network, improving security and transparency. By acting as distinct identifiers for every transaction, hash values enable historical record verification without the requirement for a central authority. This decentralized method transforms data storage and fosters dependability and trust across a range of industries. The comparison of traditional and the blockchain is illustrated in Figure 6.

It's important to remember that blockchain technology is still in its infancy and that there are still a number of obstacles to overcome, including as interoperability with current systems, scalability limitations, and regulatory concerns. However, there is a rising interest in using blockchain technology to enhance data security and management in the medical business, as evidenced by ongoing studies.

5. Conclusion

False medicines seriously endanger the safety and health of the public, disrupt the integrity of the supply chain for pharmaceuticals, and endanger the lives of consumers all over the world. Drug traceability is a widespread issue that has not been effectively addressed by traditional methods due to data inadequacies, centralized systems, and interoperability problems. The problems associated with drug tracking may be resolved in part because of blockchain technology, which offers a decentralized, transparent, and unchangeable platform for transaction recording and verification. Drug traceability systems can ensure accountability and transparency by using blockchain technology to produce a tamper-proof record of each drug's travel through the supply chain.

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