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Blockchain applications in drug data records

Robert Muliawan Jaya[a,*], Valentino Dhamma Rakkhitta[a], Pranata Sembiring[a], Ivan Sebastian Edbert[a], Derwin Suhartono[a]

[a]*Computer Science Department, School of Computer Science, Bina Nusantara University, Jakarta, 11480, Indonesia*

Abstract

Blockchain is a data storage technique in the form of blocks where the hash system and blocks that cannot be manipulated make blockchain suitable for storing important data. One of them is drug data, where currently in drug data, data manipulation often occurs which leads to drug counterfeiting. From previous research, blockchain in the medical world has been applied in storing patient history by utilizing smart contracts. Goals of blockchain application, drug data from manufacturers can be directly viewed and purchased by buyers. The research more towards innovation, blockchain as a database for storing drug data. Ethereum blockchain can be implemented and stored data can be well integrated with Smart Contract. The existence of smart contracts that support and facilitate transactions between producers and buyers. To maintain data security, system will be implementing access permissions in smart contracts to maintain data integrity and security. Eventually maintaining privacy, decentralization, transparency, and authentication in drug data and every drug transaction can be implemented properly.

Keywords: Blockchain, Ethereum, Decentralization, Drug Data, Smart Contract

1. Introduction

Blockchain is a technology used as a storage system for digital data, protected by cryptography using 2 asymmetric key algorithms and a hash function, its history is contained in blocks of data that are linked together by cryptography, Secure, and data storage integrated and continuous [1]. At the same time, there are different types of

* Corresponding author.
E-mail address: robert.jaya@binus.ac.id

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blockchain development, Bitcoin is the initiator of the use of blockchain in currency, followed by Ethereum as an important competitor.

In terms of popularity, Bitcoin has overtaken Ethereum. Bitcoin, with a market worth of over $870 billion, accounts for almost 41% of the whole crypto market. Ethereum accounts for around 19% of the cryptocurrency market [2]. The Ethereum network, on the other hand, can include executable code, but the data associated with Bitcoin network transactions are normally solely utilized for recordkeeping reasons. Other distinctions include block durations (Ether transactions are validated in seconds, whereas Bitcoin transactions are processed in minutes) and the algorithms they use: Bitcoin's SHA-256 and Ethereum's Ethash [3].

During the development stage of blockchain, many ideas have emerged, ranging from the application of blockchain in the fields of finance, business, supply chain, education, and medical care. The idea of blockchain development in the medical world has already begun, starting with patient records, internal hospital data, and specific data for medicines [4].

Difficulties in product licensing and drug circulation are always faced by drug manufacturers and medical personnel, so a more effective and efficient new data storage system is needed [5]. It is time to increase the use of data decentralization technology using blockchain technology, which can simplify the management of medical data. Currently, drug data centralized systems are mainly owned by governments, private companies, and third parties, and are often exploited by hackers and cyber attacks [6].

We explore if it is an alternative option to make data storage decentralized that is worthy and makes management of medicine data easier for the government, medicine companies, and the medicine consumer itself [1]. Blockchain technology as a drug data storage gives medicine consumers, government, and drug companies easy control of their sensitive information flow, and makes licensing process easier for drug companies that will be published by the government, furthermore this technology will allow medical personnel to validate and track drug usage distribution as well.

The data collection techniques used literature studies by collecting journals or research papers that showed data on drug licensing and distribution. The real data was collected from the BPOM RI Website [7] which has a full list of drug data in Indonesia.

Based on the previous research that has been done from 2018 to 2021, the researcher made some proof of concepts about blockchain for healthcare [8]. They calculated the advantages of using blockchain to manage healthcare data, but some of them didn't make a real project that implemented blockchain to handle the management of healthcare data. Even so, they felt optimistic that blockchain will be a great solution for healthcare data management since the blockchain is still in development [9].

Most of them use Bitcoin Blockchain Methodology and Ethereum Blockchain Methodology [10]. Both of them have similar approaches to healthcare cases and use a public platform blockchain that will allow users to monitor data privacy and less possibility of data breaches or data manipulation. Not only researching the general blockchain and healthcare data management in the blockchain. The previous research also researched accessibility, confidentiality, security, and performance. For accessibility and confidentiality, we can see from the implementation of smart contracts that make the data is easy to access but requires access permission [11].

2. Methodology

2.1. Blockchain Application

Blockchain applications have grown tremendously, so there are 4 categories [12]. First, public blockchains provide a decentralized network where each member has access to the content of the blockchain and participates in the consensus process. Second, private blockchains are dedicated to unique enterprise data exchange monitoring solutions, and participants apply for permission to join the network [6], [13].

Third, the consortium blockchain is an authorized and public network only for privileged groups. It serves as a securely synchronized, distributable, revised database that tracks the exchange of data between participants. Fourth, hybrid blockchains combine the benefits of private and public blockchains. Therefore, using a public blockchain to make a book available and running a private blockchain in the background can control access to book changes.[6].

Among public blockchains, there are two known types of blockchains, the Ethereum blockchain and the Bitcoin blockchain [10]. Ethereum is a complete programming language that allows anyone to write smart contracts and decentralized applications (dApps), where they can create arbitrary ownership rules, transaction formats, and government transfer functions.

The contract in the Ethereum contract is a low-level byte stock-based token, also known as the Ethereum virtual machine token or EVM token. The code consists of an array of bytes, with each byte representing a process. Code execution is usually an endless loop of repetitive operations on the current program counter (starting at zero), then incrementing the program counter to 1 until the code expires or an error or command occurs. Stop or return is marked [14].

2.2. Medicine Dataset

Here is the medicine dataset for this research, see Table 1.

Table 1. Origin Medicine Dataset

Registration Number	Production Date	Best Before	Product Name	Drug Type	Composition	Producer
GKL2202365101A1	19-04-2022	19-04-2027	FLUCONAZOLE	CAPSULE	FLUCONAZOLE	BERNOFARM
DKI1746700144A1	19-04-2022	19-04-2027	FLUDARA	POWDER	FLUDARABINE PHOSPHATE	BAXTER ONCOLOGY GMBH
DKL2233317710B1	19-04-2022	19-04-2027	NORSE 10	TABLE	AMLODIPINE BESYLATE	MERSIFARMA TIRMAKU MERCUSANA
GKL9812415901A1	19-04-2022	19-04-2027	TRAMADOL HCL	CAPSULE	TRAMADOL HYDROCHLORIDE	KIMIA FARMA TBK
DTL7219929710A1	02-02-2022	02-02-2027	ANTIMO	TABLET	DIMENHYDRINATE	PHAPROS Tbk

2.3. Blockchain Architectures

A blockchain is a blockchain that contains specific information (database) but is grouped in a network (peer-to-peer) securely and authentically. The blockchain architecture is a distributed and decentralized network in which each participant can maintain, approve and update new entries [15]. The whole system is controlled by the participants. Participants ensure that all databases are well organized to facilitate data validation and data security. The following are the components that make up the blockchain architecture such as; Transaction, Block, P2P Network, and Consensus Algorithms [16].

A transaction is the smallest building block of a blockchain system. A transaction usually consists of a recipient address, a sender address, and a value. The owner transfers the value by signing a digitally generated hash adding to the previous transaction. Blocks contain information such as block headers and transactions. A block is a data structure whose purpose is to combine sets of transactions and are replicated to all nodes in the network. A blockchain is a peer-to-peer (P2P) network that runs on the IP protocol. A P2P network is a flat topology without a central node. All nodes equally provide and can use the service while collaborating through a consensus algorithm. Peers contribute to the computing and storage power required for network maintenance. All copies of this one ledger are synchronized using a consensus algorithm. The consensus mechanism ensures that whatever local copies each party has, are consistent with each other and are up to date. The copies each node has are identical or similar to each other. The consensus algorithm consists of Proof-of-Work (POW), Simplified Byzantine Fault Tolerance (SBFT), and Proof of Stake (POS)[17].

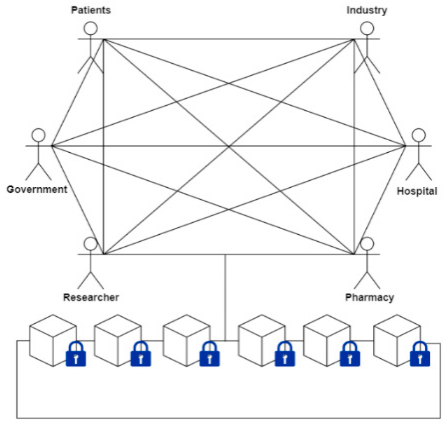

Fig. 1. Decentralization Scheme.

In Fig. 1, Decentralization in blockchain refers to the transfer of control and decision-making from a centralized entity to a distributed network [18]. So, decentralization blockchain allows databases to be stored in several locations (nodes) in one network. As a result, if someone tries to change a record in one instance of the database, the other nodes won't be changed [19]. Then, the decentralization of blockchain also increases the transparency of the data, because all people can view and track all transactions [19].

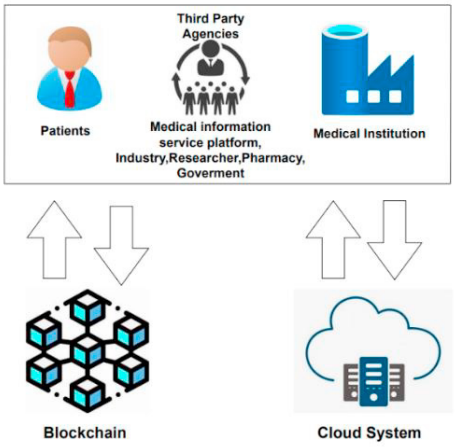

Fig. 2. Drug Data Storage.

Blockchain-based drug data storage scheme uses cloud storage technology to ensure drug data security, ease of data access, and data storage efficiency see Fig. 2. The drug data storage blockchain architecture is shown in the image above. Medical institutions, patients, and third parties (such as information service platforms, governments, health insurance companies, etc.) are the main entities in transactions on the drug blockchain. Medical institutions, are in charge of the diagnosis and treatment of patients as well as keeping records of drug use. Third-party institutions can provide several services, such as recommendations for medical institutions, validation of drug authenticity, drug distribution data, and evidence of drug legality. Different types of institutions have different transaction rights. The licenses for the three transactions of the three entities are shown in the Table 2. below [20].

Table 2. The Permission Types of Each Party.

Access Type	Patients	Third-Party	Medical Institutions
Read/Write access to itself drug data	Available	Available	Available
Read access to other's drug data	Can be accessed from an open source but if from a closed source authorization from the owner is required	Can be accessed from an open source but if from a closed source authorization from the owner is required	Can be accessed without permission
Write access to other's drug data	Not available	Can be accessed from an open source but if from a closed source authorization from the owner is required	Can be accessed from an open source but if from a closed source authorization from the owner is required

As a transaction book, blockchain technology primarily has two transaction methods, namely data storage and data access control. Drug data must be encrypted and stored outside the blockchain. In this schema, drug data is stored in cloud storage. Access control is defined by permissions, and different transactions have different access control permissions. In Fig. 3, patients and healthcare institutions can view data on the distribution and legality of drug data. The drug blockchain provides storage security, privacy, usability, and tamper-resistant interoperability. Drug Data Blockchain is a distributed and decentralized method of storing and managing drug data. [21].

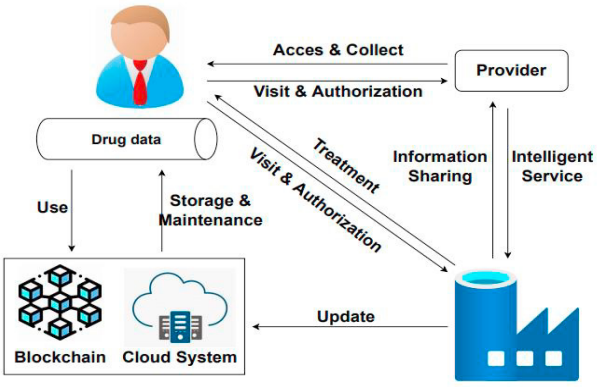

Fig. 3. Data Flow Framework.

The storage of various data needed to support the operations of pharmacy drug companies drug distributors hospitals and the performance of medical personnel is an important center of attention to maximize the performance and effectiveness of the application of blockchain technology in the distribution of drug data. Each transaction that will occur between nodes will be validated by a smart contract which will only be executed if all conditions are met so that any data information cannot be changed or deleted using the latest hashing technology such as sha3-256. Information stored on the blockchain will be automatically stored on a user's computer which can be accessed by other users with an access scheme using cloud technology. Each validator in the application of blockchain technology will automatically store transaction data from any distribution of data that has occurred previously or is being processed by the validator. The access right to the data information on the node will be regulated using a smart contract protocol scheme. [22].

Convenient interoperability is also an important feature of the pharmaceutical data blockchain. The drug data blockchain can not only store the drug data of medical institutions, but also the data of many drug service providers such as researchers, pharmaceutical companies, and pharmaceutical companies. The integrated medication data can be widely used for medication verification by medical institutions and third-party service providers [22], [23].

2.4. Proof of Works (PoW)

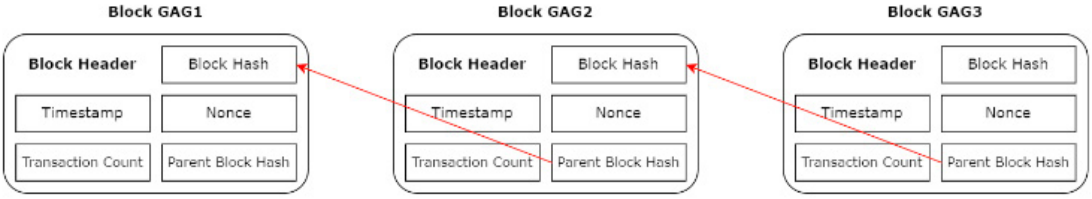

Fig. 4. Block Hash.

A hash is a mathematical function that converts an arbitrary-length input into an encrypted output of a defined length. Hash function (block hash that shown in Fig. 4) is used on the blockchain as a secure key or identity for blockchain transactions, so data integrity is always maintained. Block hash works by converting an input string into a hash value. And if there's a single change, then it will output a different hash value [24], [25].

Every blockchain has its own set of blocks, first block in the blockchain is called the Genesis Block and has no Parent Block Hash value [26]. Then each block has a block header. The Block Header identifies a block over the whole blockchain and is hashed repeatedly to provide a proof-of-work mining reward.

Block headers are also used in blockchain developer documentation to assist developers record activities more rapidly. There are three types of block metadata in the Block Header: a 32-byte hash of the preceding block, a 32-byte Merkle root, a 4-byte block timestamp, a 4-byte block difficulty target, and a 4-byte nonce. Version 4 of the blockchain [27], [28].

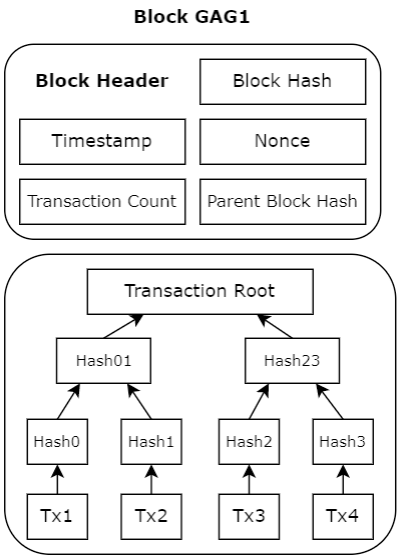

Fig. 5. Transaction Root.

Transaction in Fig. 5 is a section called transaction count. Transaction Count has a function as a counter of transactions in blocks [26]. Every transaction includes several fields and miners in the network prioritize the transactions based on the "**gas_used**" field in Table 2. The transaction root contains the detail for each transaction and their hashing [29]. If several transactions are requested by the same account, miners would calculate by the nonce value. The nonce field is equal to the number of operations sent by an account, this value will be incremented if a new transaction is requested [30]. There are 18 fields in each block of data in blockchain [31], [32].

Ethereum can be viewed as a transaction-based state machine and runs a state transaction function to make sure the transaction from the current state leads to a new valid state. The formal explanations of valid states can be seen in Formula 1. Y is the Ethereum state transaction function and T represents the transaction [30].

$$\sigma_{t+1} \equiv Y(\sigma_t, T) \tag{1}$$

Ethereum uses Ethash as a proof-of-work algorithm, which is memory-intensive and not very suitable for ASIC mining. Ethash is a modification of the Dagger-Hashimoto algorithm [33]. The Ethereum protocol requires miners to find the nonce for a block through intense trial-and-error competition. Only blocks with valid nonce can be added to the chain. Once generated, this is very easy to verify for other miners and clients [34].

3. Result and Discussion

In creating drug data records, the Ethereum Smart Contract system is used to record intelligent representations stored in network nodes. The created smart contract contains metadata containing data ownership, license, and data integrity. Using Ethereum to implement drug data storage, each transaction will be stored in a large block that can hold a large amount of data. To implement smart contracts, the gas fee required to confirm transactions and verify blocks is kept to a minimum. As can be seen in Fig. 6, the execution step is directly proportional to the gas fee. the fewer steps, the less gas is required. In implementing blockchain to store drug data, more than one smart contract can be created, but the smart contract that needs to be executed, the more gas fee is required, and making each transaction to be confirmed and verified will be more wasteful. So, using one smart contract will be more efficient, namely the Drug Contract smart contract. The Ethereum Blockchain has no block size limit so it can be used to store large amounts of data.

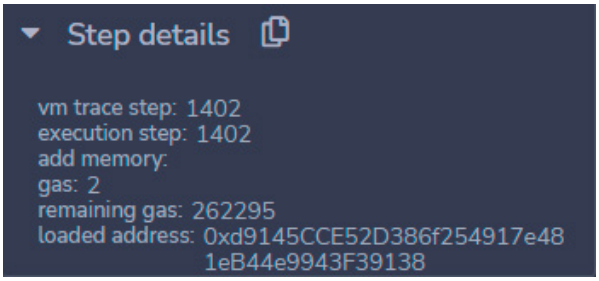

Fig. 6. Step and Gas for Adding New Drug.

We implement the framework proposed to be applied to blockchain technology using Solidity programming language on the Remix platform. Solidity language that has been provided by Ethereum and has encapsulated the Python, Java, and JavaScript programming languages are used to write code for smart contracts. The smart contract that has been created uses two structs to store drug data, named Drug struct, and to store transaction data, named Transaction struct. Drug Contract smart contract has some features, such as drug data storing, updating drug data, searching drug data, making transactions, and validating transactions. In Figure 7, the process of storing a new data need such as _id, _productionDate, _bestBefore, _name, _drugType, _composition, _stock.

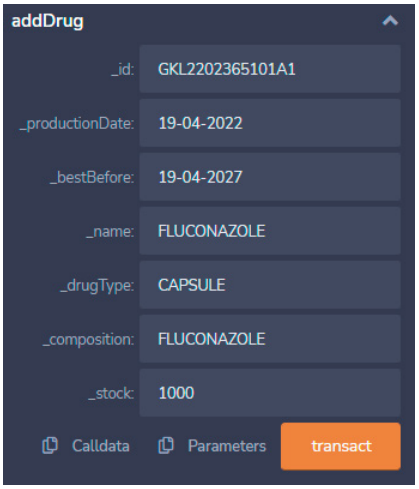

Fig. 7. Adding New Drug.

In Figure 8, show the result of searching drug data. It will show id, productionDate, bestBefore, name, drugType, composition, stock.

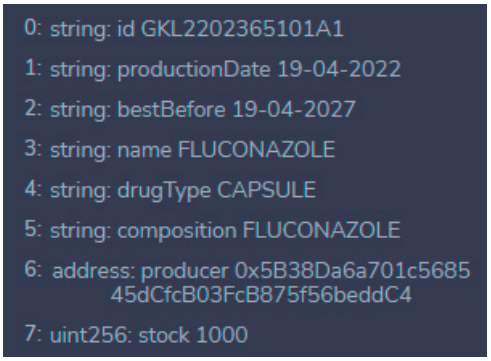

Fig. 8. View Drug Data.

A drug data storage system using blockchain is a breakthrough, the application of blockchain to store drug data can be a better alternative to provide the same function. Table 3 shows the advantages and limitations of using blockchain technology according to the system we offer.

Table 3. Advantages and Disadvantages of Blockchain Implementation.

Benefits	Speed	Transaction speed is affected by the length of time for verification of each block.
	Immutability	Once verified blocks are impossible to modify or manipulate.
	Privacy	An anonymous address will protect the identity of data downloaders, researchers, or anyone who conducts data transactions, so that the relationship between the parties conducting the transactions.
	Transparency	Anyone has direct control over each drug's data and can perform live remote monitoring of that data to maintain privacy and control.
	Decentralized	Drug data records and transactions in the blockchain will be distributed throughout the network.

Limitations	Capacity	Too much data storage and large size will cause capacity problems, decrease transaction speed, and increase verification time.
	Skill Requirements	Blockchain is a breakthrough whose benefits are not well understood so it is quite difficult for blockchain to replace the old system used in this service.
	Standardization	There are no clear standards and procedures for use and regulations for blockchain making it difficult to apply in certain fields.

4. Conclusion

In this research, we try to discuss how breakthrough technologies such as blockchain technology can play a role in healthcare and how they can be used for data storage of drug information. Although the commonly used traditional drug data storage system is constantly being developed and updated, the traditional system still faces some problems, which can be solved by blockchain technology. Our proposed framework is a combination of drug data storage with access rules and encryption of stored data. The framework we provide provides a better system for maintaining privacy, decentralization, transparency, and authentication. The system also benefits from role-based access rules, as only people you trust can access medication data records. It also solves the problem of information manipulation asymmetry in traditional systems.

In the future, we plan to implement a verification smart contract module within the existing framework to keep gas fees to a minimum. For this, we need to make certain considerations as we need to decide how many parties will be adding new blocks to store data on a decentralized system on top of the blockchain. We also need to ensure that certain policies and rules in line with the principles of the healthcare industry are applied to the blockchain system.

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