



The Impact of Blockchain on the Healthcare Environment

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Abstract

Bitcoin was the first electronic payment system to truly exploit the power of blockchain technology. There is currently the problem of health information inequality and health information leakage. Physicians should conduct essential routine work that wastes human and financial resources and delays treatment processes. Blockchain provides a trust-free and cost-reducing solution to manage and secure valuable health information. The aim of this study is to discuss research into blockchain healthcare applications. It addresses the management of medical data, as well as the sharing of medical information, the sharing of images, and the management of logs. We also discuss papers that overlap with other fields, such as the Internet of Things, information management, drug monitoring along their supply chain, and aspects of security and privacy. Finally, we analyze and compare the research papers in the medical area and also summarize the strategies used in healthcare with their pros and cons.

Keywords

Distributed systems, Health industry, Electronic medical records, Decentralized record management system.

1. Introduction

The field of healthcare is immense societal significance since the problems it tackles are specifically concerned with improving the quality of life that can be accomplished by overcoming real health issues [1]. Over the years, healthcare services have improved and contributed to greater competition. Valuable information on a patient's condition may be generated by historical data contained in computerized healthcare systems. It can now be handled by the users themselves by creating decentralized architecture, and it is possible to have more stable systems. All cities and rural areas can be recorded and used to evaluate epidemics and health services [2]. Such knowledge is great importance to researchers in different fields and can help to explain phenomena and solve complex challenges [3]. The monitoring and management of drug distribution is one of



the different fields where the blockchain can be implemented. Blockchain technologies can also help in controlling drug counterfeiters [4]. Blockchain will function in various healthcare scenarios and has been inspired by the work of [5]. The points chosen in the SWOT analysis and its key features are shown in Figure 1.

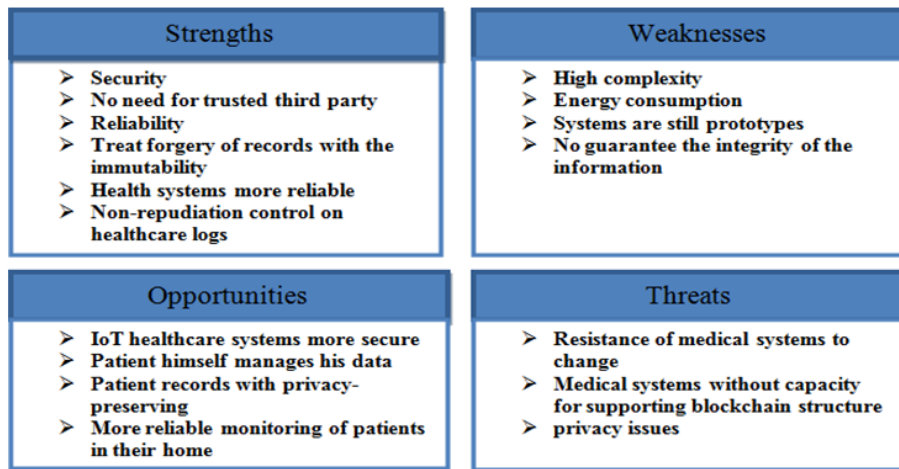


Figure 1. SWOT analysis of blockchain in healthcare context

2. Description of Blockchain Use in the Healthcare Sector

2.1. The Blockchain Technology

Blockchain is an emerging technology that developed around 2008/2009 from crypto currencies [6, 7]. It is currently carrying out unique activities in the areas of banking, health care, transport, public administration or other fields. More reliable and safe ways of recording properties can be created by this new technology [8]. In addition, it can also be viewed as a technology with replicated ledger focused on decentralized peer-to-peer (P2P) networks [9]. The distributed ledger methods have several components; these elements are the cornerstone of operating the blockchain network. The blockchain data structure is represented in Figure 2

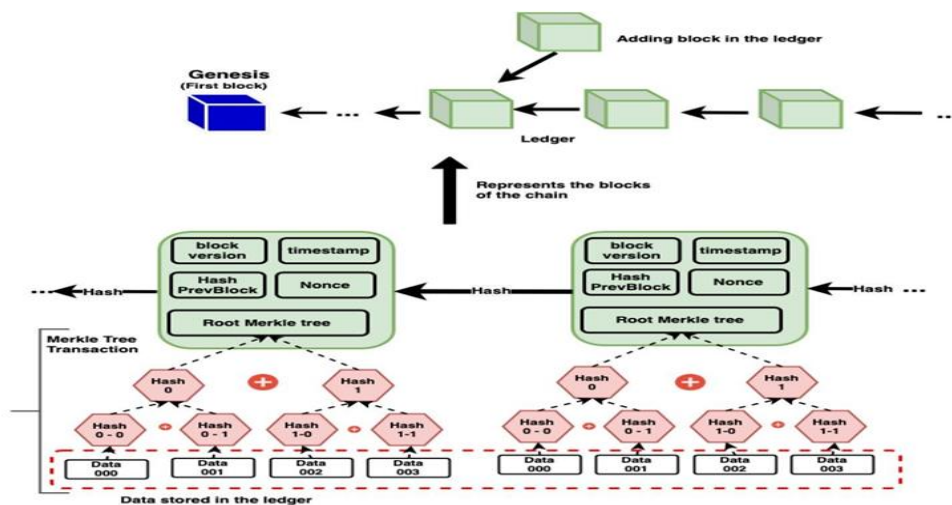


Figure 2. The blockchain structure

2.2. Process of Verification in Blockchain

The validation method is often referred as mining in the blockchain. A consensus algorithm normally performs the process, which also sets out what rules the nodes will obey. This means that they will determine whether to insert the block into the chain [10, 11].

2.3. Smart Contracts

With the introduction of the Ethereum framework [12], smart contracts on blockchain 2.0 have arisen. It is a protocol that must be followed by all transaction in an automated manner [13, 14]. If they are using crypto currencies or sharing other properties, it executed automatically when the transaction corresponds to a certain rule set out in it. This reality will lead automatically to the detection of inconsistencies. It can allow electronic transactions which lead to greater security and efficiency and also, they can play a role in the legal system [15, 16].

2.4. Challenges in Healthcare Using the Blockchain

There are some issues when blockchain technology applied in the healthcare area [17]-[19].

- **Throughput:** High performance is concerned when dealing with healthcare systems; and if there is no easy access, this could negatively impact a diagnosis that could save the life of anyone.
- **Latency:** It takes about 10 minutes to validate a block. Healthcare networks are complicated and accessed all the time. So, it can be adversely affected by any delay.
- **Security:** When an individual is able to take control of 51 percent of the computing power of the network, this can be harmful to system security. Since a health care system that is compromised will mean that healthcare institutions lose reputation, this problem demands a great deal of attention.
- **Resource consumption:** The use of this technology, a lot of energy is expended on the mining process, threatens to entail a significant loss of resources. Energy costs are very high in a healthcare environment, since many devices are required to track patients; however, using the blockchain can also require high costs of computing and energy. Managing these expenses is an issue for organizations.
- **Usability:** In these types of systems, usability is also a concern because they are very difficult to manage. The systems should be clear and intuitive because health practitioners do not have the same degree of technological sophistication as IT practitioners.
- **Centralization:** Some methods tend to centralize the miners, reducing the degree of network efficiency. It may be possible to access the information through malicious attacks.
- **Privacy:** The Bitcoin network is widely believed to guarantee the privacy of its nodes. However, the observations of [20] have not agreed to this assumption. In addition, to give this capability to block chain-based systems, strategies are needed.

3. The Management of Health Details

After addressing the fundamental principles of blockchain technology, this section includes the investigation of health information management. It is of great social significance in the healthcare sector. For this purpose, the calculation may help to minimize the impact of certain issues in this field. Computer science helps in the automation of healthcare records as for example: more reliable data exchange, log management, and uses in other fields. The collection of information will speed up the time required for treatment, as well as help the doctor's decision-making after the patient's symptoms have been diagnosed [21]. The aim of this section is to address issues related to medical information to be exchanged and handled.

3.1. Healthcare Record Sharing



It is difficult to exchange health information because it deals with patient's personal details. Dubovitskaya et al. [22], Azaria et al. [23], and Xia et al. [24] are the primary works in the literature that address this application of blockchain technology. In the work of Azaria et al., one of the most traditional structures in literature is discussed. Several current literature articles have cited this and uses it as a base for develop the new architectures. Some of these architectures, cited in [25-28], are influenced by Azaria et al. MedRec is a feasible idea for use in exchanging health information that can be used by patients, the hospital, and doctors to integrate healthcare. In this way, the reported data in various hospital systems will minimize inconsistencies. As described by Dubovitskaya et.al, the approach presents a cloud computing subject, which can also help create new architectures to exchange health records via blockchain. In order to connect a communication network with nodes, the authors suggest a cloud-based architecture that has embraced the blockchain-based data structure. It uses smart contracts to describe the logic of transactions. One of the potentials aims of these forms of architecture is to exchange photos of radiology and may be conduct research with actual patients. Xia et al. (with MedShare), discussed this issue about seeking a blockchain-based record sharing solution. The solution aims to help provide a better audit environment and monitor access to records and link to the blockchain network when smart contract tasks are performed using activation triggers. The primary aim of the solution type, such as MedShare, is to allow the implementation of certain features of healthcare systems like provenance of data, auditing, and greater systems security. If cloud computing is used by the system, it could be sufficient to satisfy the high data demand.

3.2. Image Sharing in Healthcare

Both data types as well as images can define healthcare details. Some issues with the exchange of healthcare information can also exist in photos at the moment [29]. The solution suggested by [30] could be a beneficial approach because it does not involve an intermediary and an architecture that works for this type of data with some concepts underlying this term. They plan to fundamentally propose an interface for the sharing of images from this work. The patient should exchange photographs of their healthcare in a protected and regulated manner.

3.3. Management of Logs in Healthcare Systems

It is an important concept for computer systems because logs enable the generation of historical data. In the work of Anderson [31], the implementation of these ideas in the healthcare context was discussed. The logging of the security audit is very complicated because the compilation of the collected information can often be useless or lack important pieces of information. In Anderson, a log control strategy, called the Audit Chain, was discussed and is essentially an application that tackles interoperability concerns while providing facilities for the exchange of electronic health records. In implementing this approach, the following components were used: the IBM platform and the Hyperledger Fabric, enabling the process of developing blockchain-based applications. An application is specified that helps to manage audit logs and provides users, i.e. physicians, nurses, and patients, with multilevel access control. Nonetheless, the use of AuditChain has drawbacks, such as the difficulty of locating logs specific to a single user. Also, it is important to construct the query script while carrying out the operation.

3.4. Used Strategies in the Industry

Nowadays, the concept of blockchain is growing in popularity, certain applications that are directly aimed at the industry need to be investigated. Industry plans include steps to resolve unique market-oriented concerns and to raise profits. In the healthcare world focused on blockchain, two techniques involving industry are [32, 33]. Medicalchain varies from other techniques introduced in the literature. In addition to this, there is a blockchain network integration that allows data to be stored



from the wearable devices of a patient. They can be used to track blood pressure, alcohol intake, physical activity that is performed and other areas that can offer valuable information to physicians when diagnosing a patient.

Our analysis also included a survey of industry-focused strategies using the healthcare environment-focused Sandgaard and Wishstar framework. In this way, when designing healthcare apps, it aims to have more protection and transparency. Medchain, as several layers are plugged into it, adopts a modular approach in its architectural applications. The data layer is one of the key layers that the instrument has, and it acts as the foundation for all the others. This layer also allows for the relation of other applications. The basic data layer also offers for Distributed Features (DApps) applications that help patients access their health careless. These are obtained from an application on the user interface that interacts with DApp. The GovTech programme from Estonia (starting in 2011), a use case associated with blockchain in healthcare. Similarly, blockchain technology aims to ensure the safety and protection of government healthcare systems. According to the paper by Heston [34], blockchain offers some advantages when used in this sense, such as the storage and management of health records. Blockchain provides protection, tamper-proof, scalability, and a third trusted portion is not required. This technology can also increase audibility through the development of immutable logs, provide healthcare records with privacy, and even reduce healthcare costs.

3.5. Consensus Protocols Used on Healthcare

Consensus protocols are essential frameworks in blockchain networks. These protocols help to organize the validation of transactions. It also supports tools that use the PBFT consensus protocol. The outcome of this research is shown in Figure 3.

Table 1. Consensus Algorithms Used in Healthcare Context.

Consensus Protocol	Overview
Proof of Work	Sharing healthcare records
	Sharing healthcare records privately and user-friendly
POS	Sharing healthcare imaging
PBFT	Sharing safe and reliable healthcare records
	Management and audit of access logs from healthcare records
	Exchange healthcare

The table 1 presents data relating to the most commonly accepted protocols in healthcare methods, based on the research performed in this study, which are proof-of-work and PBFT. There are two protocols explored known as proof of accessibility and proof of time and space. For proof of accessibility, the algorithm is intended to ensure that access to the data is given even if it is removed from the network by the node that stores it. To carry out this process, the protocol uses data backup, replication, and fragmentation techniques. The data fragmentation technique uses data fragments that are distributed throughout the network to various storage nodes, where more than 50 percent of the fragments of a given database cannot be retained by each node. The protocol proof of time and space checks whether the data has been stored and demands

space at periodic time intervals. The integrity of the stored health records is verified by these criteria, while the nodes involved in these procedures obtain a reward in MedCoins.

3.6. Patient Monitoring

Patient monitoring is a necessary practice within the healthcare system, and it supports the healthcare provider during the treatment of patient. Sensors produce confidential personal data while tracking patients. There is a need to comply with legislation for the security of personal data, such as the Lei Geral de Proteo a Dados (LGPD) in Brazil [35]. To strengthen and empower conventional structures, many innovations have arisen. The IoT, sensor networks, and wearable devices are some examples of these technologies. It refers to a personal network consisting of many embedded or wearable sensors where there is a central data transmission unit [36]. Figure 3 demonstrates the simplified layout of a WBAN network for block chain patient monitoring [37].

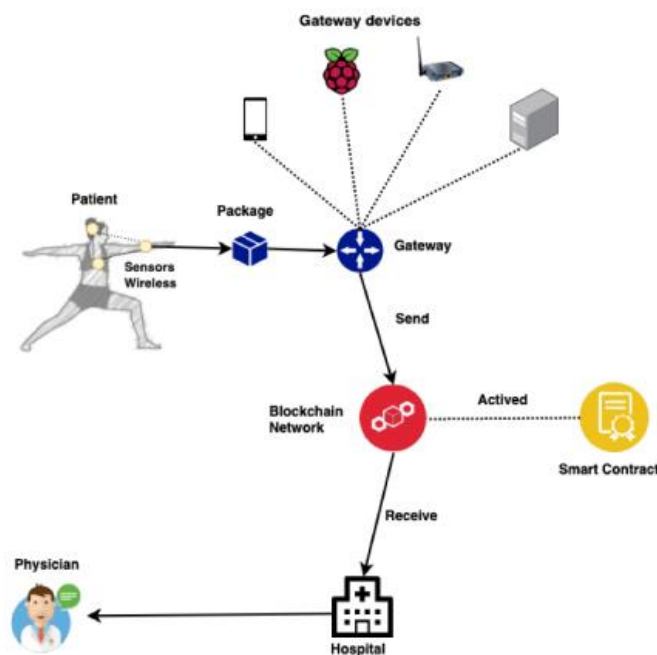


Figure 3. Structure of Wireless Body Area Networks (WBANs) for patient monitoring.

There are some limitations on the reliability, performance, and accuracy of the ability to exchange patient information [38], although blockchain technology can help to resolve these problems. Since it provides a secure means of sharing information between network nodes and uses principles such as immutability and privacy of data. Based on the factors described above, by forming frameworks that can make the process more efficient, blockchain can aid in tracking patients. In the paper, Linn and Koo [39] propose a block chain-based system for exchanging health information. Another example of blockchain technology patient tracking has been discussed by. They investigate the use of personal sensor networks to remotely track patients. This framework also uses blockchain technology to transmit sensor generated data. It should also be noted that a blockchain network structure must be traversed when exchanging data before it reaches the end-users, in order to ensure better protection and reliability [40].

4. Supply Chain Management

It is one of the managerial mechanisms for the creation of an enterprise, since it links a network of participants, ranging from the raw material supplier to the distribution organization. It covers a range of sectors, such as the healthcare sector, and other applications, including blockchain technology, are introduced into this field as a result of technological advances. The management of the supply chain includes the handling of assets from the manufacturing line to their delivery in order to meet the final customer on time and in a good quality state [41]. For certain industries, such as healthcare and the pharmaceutical industry, business planning is a vital factor.

4.1. Blockchain and IoT for Supply Chain

It is possible to apply IoT technology to many applications, including the transmission of real-time information and the tracking of properties in the chain [42]. Furthermore, other IoT-integrated technologies, Hospitals may become smart hospitals with the IoT, enabling such processes for healthcare professionals [43]. The company's goal is to combine IoT principles in order to track improvements in drug conditions (Kshetri [44] and Campbell [45]). The technology tests whether clear transport requirements are fulfilled in order to ensure that quality is preserved before the goods reach their destination. Via a smart contract, the Modum operates a blockchain Ethereum-based framework and checks state of the drug. The prescription will be rejected if there are any issues in the transaction when reviewed.

4.2. Management of Health Assets in the Supply Chain

The management of the supply chains is monitoring this problem by blockchain-based supply chains [46]. The paper by Erhun et al. [47] explores the value of drug distribution management in Nigeria, where there is a shortage of medicines, and relies on imported medicines to address the problem. The poorly drug control occurred in Nigeria in 1990, after taking a dose of medicine several children under the age of four died, the medications had toxic effects. This case highlights the urgent need, by poorly controlled supply chains, to monitor the compounds that are added to the medications. Thus, the traceability of these assets is important and it must be addressed appropriately in the distribution of drugs. This is because, depending on the type of medicine, or even stolen for illegal sale. It ensures that the blockchain ledger (i.e., the drug log records) records all the assets that are distributed; therefore, it can no longer change significantly once the data is stored.

5. Privacy and Security in the Healthcare Blockchain

Some considerations that relate to the blockchain with regard to safety in healthcare systems are discussed in this section. First of all, blockchain health care systems will boost cryptography-related systems. This paper [48] sets out a method for looking for the best smart contract cryptography models. Nevertheless, blockchain privacy concerns are not completely discussed. Some areas of privacy need to be investigated when submitting information and when the transaction is related to patient data [49]. The use of patient health records gives rise to a question about patient privacy, because personal information is included in the information aggregated in these records. Such records which consist of a personal identification number, the credit card number used by the patient to make a private network payment, and other things. Several approaches in the literature that can help solve these issues are discussed by [50]. The HIPAA law helps to (a) enhance the exchange of information in healthcare settings, (b) establish national standards, and (c) protect personal health data. These rules offer greater reliability and personal data protection for users of healthcare systems. Blockchain technology will enhance the protection and reliability of personal patient information with the help of privacy rules [51]. The use of blockchain is another tool that can be used to improve privacy when exchanging healthcare data. With the support of this system, since they are extracted from the blockchain network, healthcare organizations will not have to worry about the reliability of the results, and therefore the consumers themselves will be able to handle them [54-62]. The multimedia data (e.g., images,



sounds, and videos) is one form of healthcare data. Patel's paper explores digital imaging that relates to the blockchain. It should be stressed that in a healthcare environment, data protection is important, and blockchain technology can help ensure security for this environment. In addition, there is an emerging development in the use of cryptography techniques to boost the degree of privacy in healthcare systems, which includes a differential privacy-based blockchain [52, 53].

6. Conclusion and Future Work

Blockchain technology is a new phenomenon, and its implementation in the field of healthcare started in 2016. The approach discussed is to guarantee privacy when sharing health information and the most relevant publications in this area between 2016 and 2020. Blockchain may make a major contribution to maintaining privacy. In order to retain this service on the network, hospitals will have to spend a lot of money on infrastructure. The purpose of this research was to present a series of works for researchers interested in implementing healthcare systems based on blockchain. We also addressed some of the frameworks for developing healthcare applications based on blockchain, presenting their drawbacks and benefits. As a result, we can observe from the development of this research that blockchain technology can be applied to various perspectives in the field of healthcare. One of them worth exploring more thoroughly is the IoT-integrated monitoring of healthcare equipment. Along with these innovations, it is important to note the possibilities of providing fitness and mental health monitoring environments with more protection of patient data may be mitigated with the help of blockchain technology. Finally, we summarized several techniques and applications used for healthcare by blockchain, which are relevant to each area of knowledge. In order to form a point of reference between these methods, Figure 5 shows the pros and cons of these strategies. For future studies, a baseline can be used.

Table 2. Methods Used on Blockchain to Healthcare with Pros and Cons

Area	Methods	Pros	Cons
Sharing health information	MedRec	Improve data quality for medical researches	Not have contract encryption
		System interoperability	It's just a prototype
	MediChain	Could use mobile interface and a web application	Loss of patient access key
		Reduces risk to identify the patient from data leaked	Problems with privacy
	Medicalchain	Health data marketplace	Tokens could be used just within Medicalchain
		Patient control access with MedTokens	There are risks for acquiring the MedTokens
Remote care with IoT	Patient centric agent (PCA)	Provide access control role-based	Requires devices with high power processing for encryption
		Uses a protocol to improve security and authentication of patient's smartphone	Vulnerable to man in middle attack
Supply chain for healthcare	Modum	Uses good practice of the GDPR	Business oriented
		Monitors the pharma chain with NFC	Poor documentation and complex
Security and privacy	Decentralized Sharing of Health Records (DSHR)	Uses attribute-based encryption to ensure privacy	Complexity to use
		Stores sensitive data in off-chain	Increases cost as the number of attributes increases

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