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Blockchain as a foundation to support healthcare systems

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Abstract

In terms of data transparency, provenance, authenticity, verification, data provenance, propositions, reliability, transparency, and safety, today's healthcare data management systems face significant hurdles. Blockchain refers to a decentralized network of computer nodes that may survive together without needing to rely on one another and preserve identical data. The use of blockchain technologies for the provision of safe and confidential healthcare managing data had also attracted considerable interest. In terms of accurate diagnosis and care through safe and secure intelligence sharing, blockchain is also converting traditional care methods into more dependable methods. Blockchain technology has the potential to contribute to personalized, authentic, and secure healthcare in the future by combining every actual relevant data to a particular patient and displaying it in a modern, safe healthcare environment. By using blockchain as a framework, we examine both the recent and current changes in the healthcare industry in this article. Together with problems and answers. This paper identifies challenges and opportunities for implementing blockchain technology in healthcare and summarizes health-related blockchain products and key players offering solutions across different applications. In doing this, our research extends and complements existing blockchain research in healthcare.

Keywords: Blockchain, Authenticity, Verification, Decentralized Network, Electronic Health
2020 MSC: 68M10, 68M12

1 Introduction

Blockchain is a rapidly developing technology that is based on a distributed ledger in which data is kept in blocks. Blockchain technology, which is non-editable, distributed, entirely anonymous, and safe, has a wide range of uses outside of cryptocurrencies, including insurance, supply chain management, and healthcare. There is no single owner or organizing entity in a public blockchain. It is a peer-to-peer distributed network with nodes that are the principal executors of all the essential transactions on a blockchain. Blockchain can be compared to a large-scale database system with full replication that keeps track of all workflow. The networking stores each of these procedures on each contributor location or item [16]. Each collaborating node runs a distributed consensus protocol that manages message exchanges and decisions to ensure network consistency. Consensus protocols are a set of rules used by network participants to determine if a transaction is valid. This assures that all parties are working from the same ledger of

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transactions [2]. As seen in Fig. 1, the general architecture of blockchain is made up of numerous transaction blocks that are integrated using hashes, the most prevalent of which is SHA256 [4].

A timestamp, hash, the relevant transaction data, and the hash of the previous node are all included in each block in a blockchain. The genesis block is the first block of a blockchain that has no previous hash. Our healthcare systems are created to accommodate our requirements. Real-time information sharing (e.g., patient data and symptoms) and telehealth are becoming increasingly significant. Current healthcare trends have changed away from patient-centred and hospital-centred treatment toward (eHealth) "electronic health", (mHealth) "mobile health", and (uHealth) "universal health care". While mobile and ubiquitous Internet of Things (IoT) devices such as the "Internet of Medical Things" (IoMT) devices have helped to make systems greater flexible, productive, and cost-effective, they have also introduced new obstacles [1]. Numerous difficulties in healthcare, such as safety, information interchange privacy, and so on, may be solved with advanced technology such as blockchain by providing improved privacy protection features that are unchangeable. The protection of IoT devices and the underpinning healthcare information infrastructure are the primary challenges in computerized and widespread healthcare [23]. For collaboration clinical decisions, highly scalable and secure data sharing is critical. Traditional clinical data efforts, on the other hand, are frequently compartmentalized, creating barriers to efficient information flow and obstructing good treatment decisions for patients. [29]. Healthcare nowadays is plagued with isolated and fractured data, delayed connections, and diverse workflow tools because of a lack of connectivity. Big issues in healthcare, such as incomplete records at the point of service and limited access to particular patients' medical files, may be addressed with the help of data authenticity, dependability, and accessible attributes. A more effective and functional healthcare system is produced by compliance, which enables application services and technological interfaces to interact safely and easily, transfer information, and use that data across health agencies and application vendors [22]. The risk of losing any papers in the blockchain-based health industry is nearly zero [5]. Blockchain technology can be seen as the basis for improved clinical research methodologies as well as a step into increased transparency to foster trust across the scientific community and between research and client populations.

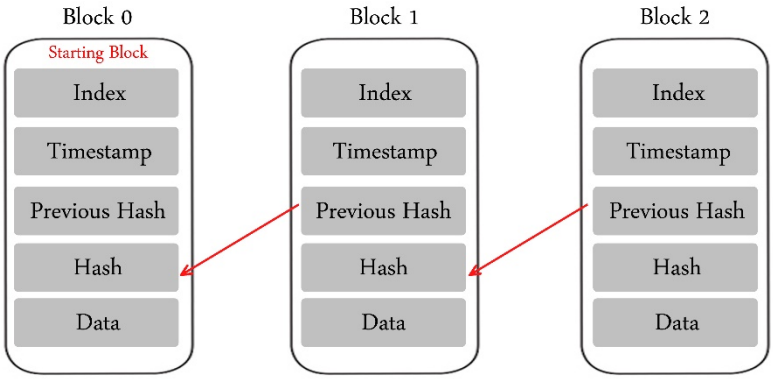

Figure 1: General architecture of blockchain

2 Related Works

There is very little investigation on blockchain in healthcare. The existing literature review provides a survey of the applications that have been created, developed, and/or implemented. The distinctive properties of incentivized consensus protocols in a conventional blockchain system were detailed in [25], with an emphasis on both the viewpoints of decentralized consensus system design and incentive mechanism design. They used game theory to discuss adopting techniques for self-organization by individual nodes in blockchain networks. In 2019, [27] did a study on the most widely used consensus blockchain mechanism. The classical theory of fault tolerance was introduced in this review, which included key definitions and analytical conclusions. Following that, it defined five key components of every blockchain network: block proposal, confirmation, completion, an incentive element, and dissemination of information. Based on these components, some of the most prominent blockchain consensus protocols were analyzed and compared. Their findings gave them a better understanding of the strengths, applicability, and limitations of fault-tolerant, scalable, and disadvantages in terms of fault-tolerant, expandability, and downsides. Many of these protocols were still in development at the time of publication and were susceptible to significant modifications. One of the potential scenarios linked with the Healthcare Data Gateway (HDG) concept, described by [28], is using a private blockchain

to monitor and store clinical data. Individuals have complete control over their clinical data and healthcare summary, which is maintained on a blockchain system. Through enhancing our knowledge of patterns and developments in public health and disease to confirm enhanced care, best strength training suggestions, or doctors going to plan service to create the best use of limited national healthcare funding levels for everyone's health and wellbeing, for instance, sharing patient data will make us everything cleverer [12]. The researchers in [18] proposed a cloud-based concept for creating a national information system that offered a cost-effective method of dealing with patient information in rural locations. Individuals are urged to give personal health information, which will be stored in the health cloud and accessed by healthcare experts and policymakers to provide additional medical services, such as remote disease diagnosis and control. With the proposed system patient data gathered over a period can be utilized to create a depth of knowledge of various diseases, afflicted locations, and causes, allowing policymakers and researchers to take corrective action and organize for disease control. Blockchain use in the health sector offers promising solutions for securing stakeholder communications, delivering clinical reports quickly, and combining multiple types of personal health records on a protected system. As a result, the major goal of [11] is to provide a comprehensive blockchain infrastructure that covers all stakeholders in the healthcare domain, as well as to analyze potential and difficulties by providing a complete with a full framework.

3 Key Features of Blockchain Technology

Six blockchain characteristics that have the potential to significantly improve current health systems are shown in Fig. 2.

3.1 Anonymity and programmability

Public blockchains have several crucial characteristics, including privacy and automation. By maintaining privacy, transactions' senders and recipients' identities are kept secret. With digital currencies, the fully programmable feature lets automating of new transactions and safeguards. The self-executable programs in contracts are built on the agreements between the buyers and sellers. These regulations assist in regulating the implementation of verifiable and irreversible operations. They allow for trusted relationships and transactions to be made between anonymous participants without the need for a 3rd party or external enforcement process [13].

3.2 Decentralization

Decentralization, in its broadest meaning, refers to the absence of a single body in charge of all processes. A new commercial social credit system is essentially being rebuilt through the so-called decentralization. The industrial social credit system may be made more secure and democratic by adding new centers while eradicating the present one. In reality, it has the potential to lower the cost of borrowing in economics. Decentralization in blockchain systems implies that no single person may invalidate transactions in the network, and each request for a transaction needs the approval of the majority of users. Blockchains by definition offer a fundamental amount of decentralization because all users on the network record transactions. The vast majority of blockchain users must validate any modifications to the transactions for them to be accepted as legal. The remainder of the network would prevent any attempts made by a single user or small group of users to change blockchain data in a way that was opposed by the majority of the network [26]. One of the characteristics that make blockchain technology so potent is this one. Additionally, it is a feature that sets blockchains apart significantly from conventional databases, where all data is kept in a single area [3].

3.3 Transparency

One of the most intriguing aspects of blockchain technology is anonymity. Transparency in health data could contribute to the creation of a fully auditable and legitimate transaction ledger. The healthcare industry's present data processing methods are not capable of offering safety, protection, and openness all at once. Numerous people are involved in data transparency procedures, some of whom may have made contributions to the data itself or the overall transparency record of the data. These parties may get all or a portion of the transparency record. These parties are frequently not/only partially trustworthy. Accepting one side to adhere to integrity laws entails giving that party the authority to disregard them [6]. Additionally, as auditing is a crucial step in the transparency procedure, it is essential that transparency documents be kept secure.

3.4 Data Provenance

While using the capabilities offered by the generic provenance layer, agreements in this layer independently govern a portion of the elements. In this manner, use cases may modify the provenance model to suit their requirements and manage who has access to the features made available by the storage and general provenance layer. Blockchain timestamps actions by computing provenance record hash values and sending them to consensus nodes, which maintain a reliable record of all transactions [21].

3.5 Immutability

Due to their vulnerability to hacking and stealing, one of the main issues with the present centrally controlled healthcare systems is the data integrity of healthcare data. Another intriguing aspect of blockchain technology is immutability. It alludes to a blockchain ledger's capacity for unmodified and impenetrable persistence.

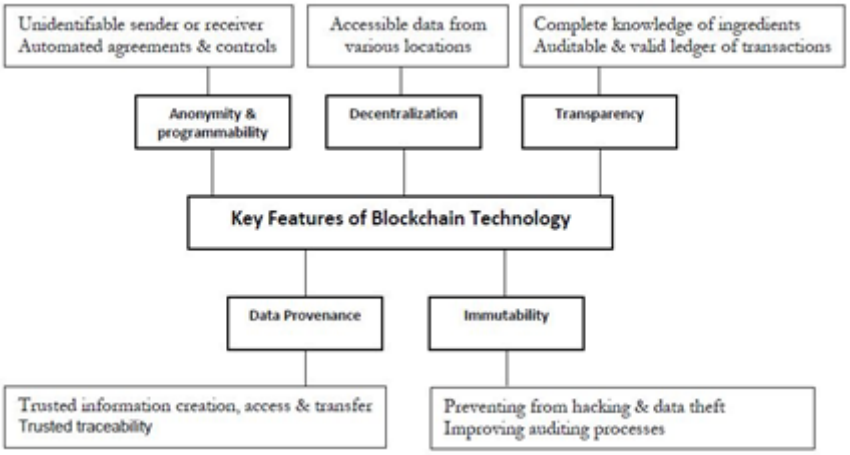

Figure 2: Blockchain characteristics

4 Blockchain as a solution in Healthcare Sector (BaaS-HS): Areas, Issues and Solutions

There is still a big gap in understanding the complete potential of Blockchain technology. Nonetheless, this technology is ready to make profound changes in the healthcare system. In a healthcare system, the data, particularly patient data, needs to be exchanged among multiple users securely without compromising privacy. The distributed and immutable nature of blockchain and the storage of records in blocks linked together using cryptographic hashes helps achieve the goal of information exchange in the healthcare system. A patient record can never be modified because any change in a data block would mean changing all the subsequent blocks in the chain which is impossible without the consensus of the network [29]. In any healthcare system, there could be external entities that collaborate with the system, this should not in any way jeopardize the security, information leak, or increased costs. Blockchain provides a transparent and enhanced security system of information exchange with negligible risk of security leaks or modifications. In the blockchain, there are multiple copies of information shared among multiple nodes on a blockchain network. The integrity, security, and consistency of such distributed systems are ensured by many nodes with special roles on the network. If and when a block is created and added to a blockchain, it cannot be eliminated or changed. There are self-executing programs used in blockchain technology known as smart contracts. These are used to execute code that may be complex without any human intervention, thus reducing the costs of observing and contracting. The smart contracts of blockchain can help make completely autonomous applications that could dramatically reduce intermediate costs in a setting like a healthcare system [30].

The Healthcare industry is in dire need of solving the issues related to secure information exchange, cost reductions, and privacy issues. The distributed nature, permission-less and immutable blockchain network may finally address all the challenges and issues in the healthcare industry. The new and cutting-edge technologies in healthcare systems like wearables and remote patient monitoring could reach a profoundly higher beneficial level using blockchain technology. In any healthcare system, data need not be changed or altered. The data should be securely stored encompassing patients as well as data from any ongoing research or clinical trials. There should also be a real-time observation of

patients. All of these features could be achieved using blockchain technology and in particular smart contracts could easily take up the challenge of real-time monitoring of patients [10]. Blockchain technology can be useful to solve the following issues in healthcare areas.

4.1 Patient Record Management (PRM)

Health records management is one of the most widely used blockchain applications in healthcare. Insurance agencies generally categorize patients' health records, making it simpler to identify a patient's health history without having to contact prior healthcare providers. It takes a lot of time and could lead to blunders brought on by user mistakes. The blockchain, however, makes it possible for patients to view their medical history easily and transparently. When all of the patient's data is housed in one place, it is simpler for patients and doctors to access it. In general, the same patient methods cannot be used due to inter-individual diversity. For the purpose of delivering personal care, having access to all medical records is essential. Additionally, exchanging patient records across the medical establishment has grown to be a serious issue since most healthcare systems today do not guarantee confidentiality, protection, or safety [14]. Table 1 highlight the main issues of PRM in the current healthcare industry and blockchain solutions.

Table 1: Blockchain solutions of PRM issues

Healthcare Area	Main issues in healthcare	Blockchain Solutions
Patient Record Management (PRM)	Lack of entire access to medical records, additional expenses and wait times, and limitations on patients' rights to full ownership of their medical information.	Having access to full medical reports prevents duplicate medical tests, helps new doctors to know about previous patients and Increasing patients' control over their health data.

4.2 Research and Development

The analysis of vast volumes of genetic, market research, and healthcare data is commonplace. Blockchain has the ability to change healthcare before therapy, through clinical trials and studies. Collaboration across several sites and stakeholders is necessary for effective research and clinical trials, as is the cautious management of significant amounts of sensitive data gathered from various sources. Clinical trial research data collecting might become more reliable thanks to blockchain technology. Data integrity is ensured by blockchain technology, which also aids in resolving the issue of publishing inaccurate data. Additionally, it improves data analytics accuracy and transparency when applied to clinical trial information. Clinical supply chain tracing and verification, restoring the validity of trial data, patient recruiting, and reducing overall trial duration are just a few of the problems that blockchain in clinical research may help with [17]. The primary areas for research and development in the existing healthcare sector as well as blockchain alternatives are highlighted in Table 2.

Table 2: Blockchain solutions of research and development issues

Healthcare Area	Main issues in healthcare	Blockchain Solutions
Research and Development	Reporting incorrect clinical trial data and lack of transparency.	Enhance data reliability, enhance data analysis accuracy, and enhance data analytics traceability.

4.3 Telehealth Care Systems

Healthcare geographical restrictions can be overcome through telehealth networks; however, they might also be vulnerable to cyberattacks. If the virtual connection created between a therapist and a patient is cooperative, patients' private information may be compromised. How well security and privacy problems are handled will promote open how efficient telehealth systems are. Blockchain can offer telemedicine systems the necessary trust, security, and privacy protection [7, 9]. The primary problems with the existing telemedicine healthcare systems and blockchain options are highlighted in Table 3.

Table 3: Blockchain solutions of telehealth care systems issues

Healthcare Area	Main issues in healthcare	Blockchain Solutions
Telehealth Care Systems	Virtual connections are vulnerable to security attacks.	eliminating the requirement for middlemen, aids in legal matters, and permits safe, verifiable, and anonymous exchanges.

4.4 Healthcare Billing Systems

In the past, several types of fraud have been able to get through standard patient billing systems. Additionally, producing billing data using the new billing approach takes more time and equipment. The complicated coding required in the medical billing technique is one of the main reasons for accidental billing errors, such as duplicate treatments or erroneous files [19]. Medical billing solutions that combine blockchain and computer-aided coding techniques can be more efficient. Blockchain is a revolutionary technology that might replace traditional billing processes, which typically require a long time to claim invoices, making payments a lot easier and more dependable. More specifically, within a situation of insurance claims, when the payment of bills was previously further delayed by the use of the payment methods in place [8]. Blockchain can get rid of these restrictions by keeping all data in an unchangeable manner, enabling insurance firms to pay claimants more quickly while using fewer resources, money, and time. The primary problems with existing healthcare billing systems are highlighted in Table 4 along with blockchain-based alternatives.

Table 4: Blockchain solutions of healthcare billing systems issues

Healthcare Area	Main issues in healthcare	Blockchain Solutions
Healthcare Billing Systems	Take up extra time and effort, lack clarity, and security aspects	Allow insurance companies to pay compensation claims more quickly by reducing the need for additional resources, time, and money. Make the billing considerably simpler and safe.

4.5 Ensuring permissions consistency

Healthcare workers need fast access to patient information in case of an emergency. Inconsistent permissions may prevent access to a patient's medical record in an emergency, endangering the patient's life. Blockchain technology can offer two methods for simple and safe authorization management. Accessibility could be granted based on established rules that have been agreed upon by all parties engaged in the contract using smart contracts built on the blockchain. Access control may be managed by patients thanks to encryption techniques. Every patient will be given a master key that assists in unlocking medical data. The patient is free to give a copy of it to medical personnel or institutions as needed. Additionally, both read and write access capabilities may be added via smart contracts [15, 24]. Blockchain-based cryptographic keys and smart contacts can help to reduce errors brought on by human error [20]. The key problems with the present healthcare sector and the blockchain approach for maintaining permit validity are highlighted in Table 5.

Table 5: Blockchain solutions of ensuring permissions consistency issues

Healthcare Area	Main issues in healthcare	Blockchain Solutions
Ensuring permissions consistency	Access control and credentials that are irregular take much longer.	Reduces the time needed to acquire patient data by giving instant access to patient information.

5 Discussion and SWOT analysis

Blockchain is a futuristic technology with seemingly a plethora of applications in almost every area. In healthcare, blockchain provides a tremendous potential for improvement in the current setting of the healthcare environment; from storing and accessing medical records to treatments and drug supply chain management. It was observed that we are still in the infancy of integrating blockchain with healthcare. A digital revolution is underway in the healthcare sector as a result of the quick advancements in ICT. As academics look at many facets of blockchain healthcare systems,

the excitement around the use of blockchain in healthcare appears to become reality in the near future. Offering safe and secure ways to access patients' clinical records across the process is the top priority in the healthcare industry. Just legitimate users may access medical data thanks to blockchain technology, which is seen to be one of the best methods for storing and distributing medical data. Various interested parties are beginning to recognize the potential of blockchain in healthcare and its enormous influence to improve the healthcare sector in terms of improved hospital facilities for the necessary patients and increased healthcare economies and revenues. Blockchain technology appears to have a bright future in the healthcare industry. Blockchain applications for the healthcare industry have not yet been extensively evaluated for their viability. However, the present healthcare systems would be able to provide better and more high-quality healthcare services with the characteristics that blockchain promises to offer. Blockchain technology will provide patients with more control over their medical information and the ability to handle it in a way that will help them manage their overall health issues. We have used a SWOT analysis technique, as shown in Table 6, to better comprehend, investigate, and analyze the strong points, vulnerabilities, chances, and risks posed by blockchain technology in the healthcare industry.

Table 6: SWOT analysis of using blockchain in healthcare sector

SWOT	Features
Strength	Accessibility to medical data quickly, autonomy, and tamper-proof information exchange.
Weakness	Fewer software and systems providers, less scalability, and insufficient storage space for big amounts of data
Opportunities	Reduced chances of fraud in the medical chain, more data processing for users, opportunity for entrepreneurs and healthcare partnerships, and data privacy will aid in medical research.
Threats	Digitalization in society is hesitant due to non-standardization, cultural barriers, worries about trust, and problems with interoperability.

6 Conclusion

Throughout this paper, we addressed the benefits of blockchain technology for the healthcare industry and how it may be applied to digitize health records. In addition to guaranteeing immutability and tamper-proof health data archiving, it demonstrated how blockchain may assist healthcare firms to handle huge data in a decentralized, open, accessible, traceable, auditable, trustworthy, and stable manner. To show how blockchain technology may be used to its fullest advantage in handling large data in healthcare, we looked over its advantages and features. We talked about the key uses of this technology in the healthcare sector. We outlined many examples to show how this technology has benefited and enhanced various healthcare systems. Additionally, blockchain ensures integrity and tamper-proof preservation of health data. To demonstrate how blockchain technology may fully utilize its capabilities for healthcare data management, we covered its benefits and features. We spoke about the most significant prospects that blockchain presents to the healthcare sector. To demonstrate how diverse healthcare systems have been aided and enhanced by blockchain technology, we highlighted several case studies. The critical open research issues that are impeding the mainstream use of blockchain technology in the healthcare sector were identified and examined.

By significantly enhancing operational effectiveness, data security, healthcare staff management, and prices, blockchain can redefine and disrupt the healthcare sectors. Nevertheless, there are some technical issues that should be resolved when integrating healthcare systems with blockchain, including blockchain immaturity, scalability, interoperability, stand-alone projects, challenging integration with current healthcare systems, difficulty, and a lack of blockchain talent.

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