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Block-chain Revolution in Healthcare: a Comprehensive Review of Benefits and Challenges

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Abstract. Blockchain technology has proven effective in addressing key challenges in healthcare, such as patient confidentiality, data security, and system interoperability. At its core, blockchain is a decentralized and distributed ledger system, allowing medical information to be securely stored and managed across a network of computers, eliminating the need for centralized control and reducing the risks of data theft and tampering. By providing an immutable and transparent record of transactions, blockchain enhances data security, ensuring the integrity and privacy of sensitive patient information. This research article offers a comprehensive review of how blockchain is being leveraged to tackle these challenges, highlighting its applications, benefits, and associated hurdles in the healthcare sector. Blockchain enables the secure management and storage of medical records, reducing the risk of hacking and fostering decentralization by distributing data across a network. Its applications range from streamlining the management of electronic health records (EHRs) to supporting efficient and cost-effective clinical trials, as well as facilitating the exchange of research data. However, to fully unlock blockchain's transformative potential in healthcare, several challenges must be addressed, including issues related to scalability, regulatory compliance, and system integration.

Keywords: Blockchain Technology · Smart Healthcare System · Health- care Sector · Patient-Centric · Decentralized Ledger.

1 Introduction

The healthcare sector [1] is enduring a major change, led by technological progress together with the rising demand for reliable, protected, and patient-focused clinical services. One of the most emerging as well as innovative technologies that have the strength to modernize the medical sector is blockchain. Blockchain technology [2] which was initially designed as the essential improvement for cryptocurrencies such as Bitcoin, has transformed into a capable tool for safeguarding and supervising data in several fields, covering healthcare.

In conventional medical systems [3], patient information is usually preserved in consolidated databases, forming it available to unauthorized access, information tampering, as well as privacy breaches. Blockchain technology gives a distributed and unalterable ledger that can safely preserve and handle health- care details, assuring its reliability, secrecy, and vulnerability. By employing blockchain, medical institutions can improve data privacy, optimize operations, as well as enhance clients feedback.

As per IBM, 70 % of healthcare executives anticipate that the biggest influence of blockchain in the realm of medical field will be enhancement of clinical study supervision, regulatory observance along with giving a distributed frame- work for transmitting digital health records. Additionally, the worldwide market of blockchain technology in the healthcare domain is estimated to crossover $500 million in a couple of years. Even though blockchain technology is regarded to have strength for real advancement of wellness detail systems.

1.1 Blockchain Technology

The data is maintained on a decentralized node network shown in Figure 1 termed blockchain. It is one of the finest technologies for preserving private in- formation inside the network. Significant information can be transferred while maintaining security and confidentiality owing to this technology. It is the ideal solution for securely keeping all the relevant documents in one place. Blockchain also speeds up searching a single patient database for candidates who meet trial requirements. A decentralized peer-to-peer (P2P) net- work of individual computers known as nodes, the blockchain preserves, saves, and documents transactional or historical data [4] [5].

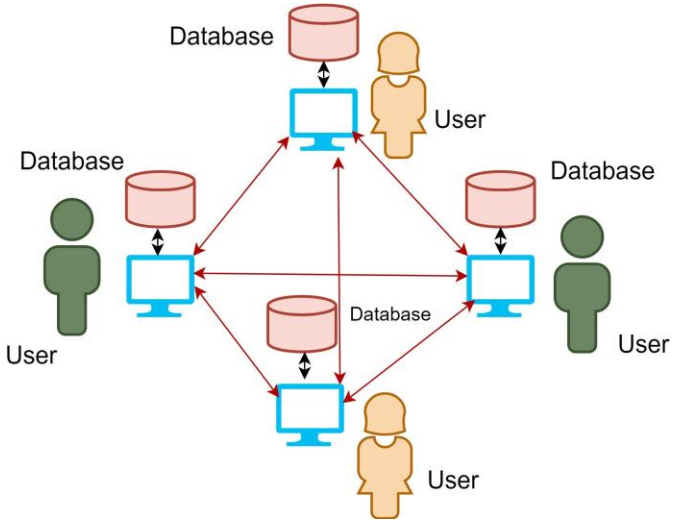

Fig.1. Decentralized Blockchain Model

As every network user can communicate and preserve information, it enables trustworthy collaboration and preserves an uninterrupted log of both past and present events. With the use of such technology, multiple networks can be integrated to reveal the significance of personalized care. As an outcome, blockchain's consistency and integrity are widely acknowledged. The three essential concepts of blockchain are miners, nodes, and blocks. Blockchain avoids storing any of its data in one place. Rather, a computer network replicates and disseminates the blockchain. Structure of Blockchain is shown in Figure 2.

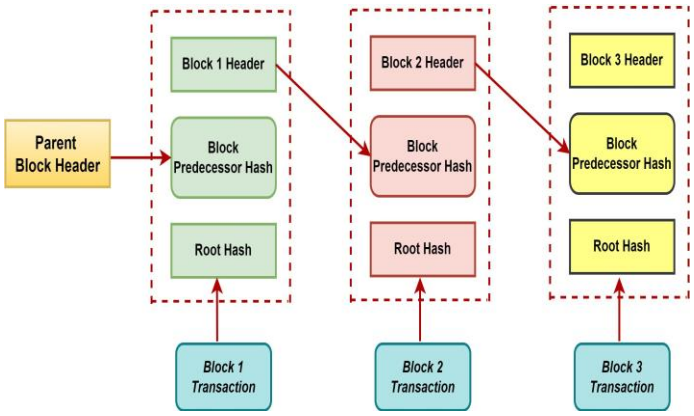

Fig.2. Blockchain Structure

There are basically three main kinds of blockchain technology [6]: hybrid, private, and public blockchains. Public blockchains, including those found in cryptocurrencies like Bitcoin and Ethereum, are decentralized networks in which any individual may participate, and which facilitate transparent, unrestricted operations [7]. On the flip side, private blockchains are restricted systems in which only authorized individuals can access. These networks offer more confidentiality and authority over network governance since they are generally maintained by a centralized organization or consortia [8].

Supply chain management plat- forms as well as business alternatives are two instances of private blockchains. Incorporating public and private models, hybrid blockchains [9] provide a more sophisticated method of implementing blockchain technology. They combine the positive aspects of public as well as private blockchains, enabling a variety of features to satisfy a range of applications. In hybrid blockchains, certain regions of the chain are reachable to all individuals, comparable to in public blockchains, whereas other parts are only available to certified organizations, much as in private blockchains. The hybrid model enhances openness and decentralization for certain transactions whilst permitting restricted usage and secrecy for others, providing an efficient approach that balances competing objectives.

1.2 Characteristics of Blockchain Technology

The characteristics of Blockchain technology [10] comprises various key features that differentiate it from conventional databases and systems. Some of these characteristics are discussed below:

- **Immutability**: The immutability of blockchain technology is certainly one of its most attractive characteristics [11]. This refers to the inability to modify or change the data. Blockchain technology is well known for the potential to give a permanent, unchangeable network, this is one of its key features. A blockchain is immutable, which implies that content cannot be altered. Furthermore, every network member must authorize any information before it gets included to the block, resulting in safe transactions. Mining is the procedure that involves adding transactions to blocks and authenticating them.
- **Decentralization**: Decentralization signifies that no single individual is in authority over the structure or the governing power [12]. A collection of nodes operates distributed networks. It is one of the essential characteristics of blockchain technology. A traditional centralized transaction system necessitates each transaction to be approved by a central authority, resulting in both cost and performance restrictions, as shown in Figure 3. Unlike the centralized mode, blockchain doesn't involve outside interference. Consensus methods [13] keep data consistent over distributed networks. Blockchain acts like both a decentralized and open ledger. In an open ledger, transactions are tracked and made available to everybody, rendering the ledger public. No person or organization controls the transactions. In the blockchain system, every connection has its own replica of the record.

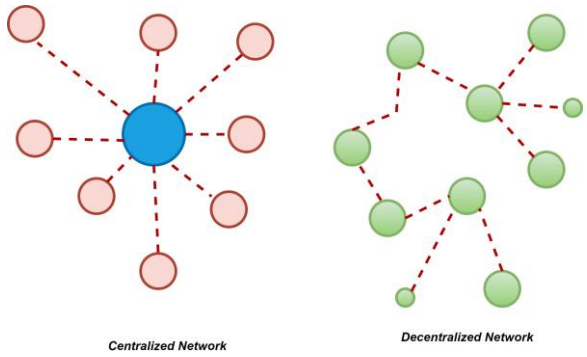

Fig.3. Centralized and Decentralized Network

- **Persistency**: verifying transactions is immediate, because trustworthy miners refuse to accept fraudulent transactions. Whenever a transaction has been recorded in the blockchain, it is unable to be withdrawn or reversed. Invalid transactions in blocks can be recognized instantly. Because a chain's structure enables any transaction or block to be verified, the data stored in it is both permanent and verifiable. In Bitcoin, there is only one ledger that records all transactions, and this ledger is accessible from all nodes, ensuring a complete trail for each coin. This characteristic overcomes the difficulties of fraudulent expenditures.

- **Auditability**: The Unspent Transaction Output (UTXO) [14] framework defined by the Bitcoin blockchain requires that any transaction connect to a preceding unspent transaction. The state of the linked unspent transactions shifts from unspent to spent when the current transaction is saved on the blockchain.

This enables identifying fraud as well as tracking. Information kept on a blockchain is easily traceable and verifiable because transactions are confirmed and timestamped. This allows for easy monitoring of data and verification. The application of computational approaches allows every network participant to access this recording. Such algorithms assure the durability and logical arrangement of data stored on the ledger.

1.3 Significance of Healthcare Data Confidentiality and privacy

Privacy offers numerous benefits, particularly in the healthcare sector, where it significantly impacts mental health. Maintaining privacy facilitates research and public health activities, simplifying access to therapies and new treatments. This confidentiality is especially critical for adolescents seeking medical services independently. For instance, children and adolescents experiencing trauma, such as violent attacks or natural disasters, require confidential healthcare to regain a sense of security. Despite growing knowledge in child and adolescent trauma, safeguarding health privacy remains paramount across all age groups. Research consistently supports the importance of privacy in adolescents' healthcare access, fostering their self-respect and confidence in healthcare professionals. Thus, ensuring health information privacy [15]is indispensable for effective healthcare and patient trust.
The rule Health Insurance Portability and Accountability Act (HIPAA)
[16] in the United States and similar regulations worldwide mandate strict standards for the protection of healthcare data. Everyone values their health confidentiality and aims to maintain it as a private matter. It is crucial to establish a trustworthy doctor-patient relationship in such scenarios. However, certain professionals are entrusted with highly personal patient information, including health data and financial details. Breaches of this data can have severe repercussions, affecting both the patient and the healthcare industry. Therefore, safeguarding health information is both challenging and critical. Fortunately, healthcare organizations leverage information technology to enhance efficiency and quality of care.

1.4 Advantages of Interoperability and Information Exchange in Healthcare

- **Enhanced Continuity of Care:** Seamless access to patient records across various systems and settings ensures better coordination and continuity of care, reducing errors and improving patient outcomes.
- **Increased Patient Safety :** Having access to complete and up-to-date patient information enables healthcare professionals to make informed decisions, thereby minimizing the risk of adverse events and medication errors.
- **Streamlined Workflow :** Interoperable systems simplify administrative tasks like appointment scheduling, billing processing, and resource management, leading to greater efficiency and reduced administrative workload.
- **Cost Reduction :** By eliminating redundant tests and procedures and improving efficiency, interoperability can result in cost savings for both health- care organizations and patients.
- **Public Health Support :** Interoperable systems enable the timely exchange of data needed for monitoring and responding to public health issues such as disease outbreaks and epidemics.
- **Patient Empowerment :** Interoperability provides patients with easier access to their health information, allowing them to actively participate in healthcare decisions and better manage their health.
- **Advancement of Research and Innovation :** Comprehensive datasets from interoperable systems can accelerate medical research, facilitate clinical trials, and drive innovation in healthcare delivery and technology.
- **Regulatory Compliance :** Many healthcare regulations and standards, like HIPAA in the United States, stress the importance of interoperability and secure information exchange to protect patient privacy and ensure data security.

In summary, interoperability and information exchange are pivotal in modernizing healthcare delivery, enhancing patient care, and fostering efficiency and innovation within the healthcare sector.

1.5 Role of Blockchain in Addressing Healthcare Challenges

Blockchain technology enhances transparency in the prescription process from manufacturing to pharmacy shelves. By integrating IoT and Blockchain, congestion, freight direction, and speed can be monitored,

allowing for efficient scheduling of acquisitions to prevent disruptions and shortages in clinics, pharmacies, and other medical facilities. Digital frameworks built on Blockchain ensure that logistics data remain free from unauthorized alterations, thereby increasing trust and preventing the illicit handling of records, payments, and medications. This technology can improve patient outcomes while maintaining cost-effectiveness and preserving funds [17].

Blockchain eliminates barriers in multi-level authentication and maintains an incorruptible, decentralized, and transparent log of all patient data, making it ideal for security applications. It keeps patient identity private through complex and secure algorithms, safeguarding the sensitivity of medical data. Its decentralized structure enables swift and secure information sharing among patients, doctors, and healthcare providers [18].

Blockchain technology facilitates patient-led interoperability by allowing patients to control access to their medical data, enhancing confidentiality and privacy. It addresses quality management and enforcement challenges and helps regulatory authorities trace legal drugs to prevent falsified ones. This ensures that all authorized parties exchange digital transactions containing patient de- tails, simplifying the process for patients moving between medical practitioners.

Blockchain is gaining acceptance in the healthcare industry, with its potential to transform the market by addressing current structural issues. It enables easy access to information for physicians, patients, and pharmacists. Medical firms are actively exploring and implementing Blockchain technologies for health records, proving its value in tracking pharmaceuticals, improving payment options, and decentralizing patient health records. The medical sector increasingly relies on Blockchain, alongside technologies like machine learning and artificial intelligence. Blockchain technology fine-tunes the medical supply chain, demonstrating its impact on the healthcare industry. Blockchain provides a sophisticated data storage framework, recording a person's entire health history, including diagnoses, test reports, prior treatments, and sensor measurements. This allows doctors to access comprehensive information for accurate diagnoses and recommendations. Data stored in a Blockchain system is secure from loss and tampering. Implementing a Blockchain network in a healthcare organization protects against internal and external risks, including cyberattacks and hardware failures. A correctly implemented Blockchain network can prevent rescue attacks and mitigate issues such as computer corruption and hardware failure.

Enablers of Blockchain Technology for reviving healthcare services demonstrates the numerous on-ground industrial representatives who showcase Blockchain's capabilities in successfully implementing healthcare perspectives and overall development. Various industrial and medical-care supporters or providers assist in conducting research and investigations to realize Blockchain practices in health- care and its core domains. Observed providers such as BurstIQ, Guardtime, Robomed, Simply Vital, Encrypgen, Chronicled, and Tieion are among the agencies promoting and implementing Blockchain technology at the ground level.

The major contribution of this review paper is mentioned below:

- The paper explores multiple uses of blockchain-based technology for medical purposes, covering secure patient data management, supply chain integrity, clinical research, as well as medical records.
- It addresses blockchain's distinguishing features, especially decentralization, openness, as well as immutability, which make it optimal for resolving specific difficulties in healthcare services.
- The paper highlights the possible benefits of employing blockchain technology for healthcare purposes, like enhanced information security, seamless integration, efficacy, plus improved results for patients.
- The paper discusses the difficulties and possible risks to blockchain imple- mentation in healthcare, covering legal problems, scalability, concerns about data confidentiality, and the need for standardization.
- Furthermore, the paper analyzes the possible future significance of blockchain in healthcare, recommending topics for additional research, possible enhancements, and approaches for resolving current limits.

Section 2 discusses the existing research on the use of blockchain technology in the healthcare industry. Following that, Section 3 covers various applications, characteristics, along with types of blockchain used in the medical sector. Section 4 explores the positive benefits that blockchain provides to healthcare. Section 5 examines the issues and potential risks connected with implementing blockchain technology in healthcare. Ultimately, Section 6 summarizes and illustrates the potential role of blockchain in this industry.

2 Literature Survey

Various research on the implementation of Blockchain technology in healthcare domain including its applications, benefits and limitations also are presented here and highlighted in Table 1.

Dong et al. [19] stated that Blockchain technology facilitates safe, transparent, and distributed handling of information along with transaction processing, with smart contracts enabling automation. It is becoming effective in financial markets, supply chain, and medical treatments, while its unique characteristics surpass the constraints of existing systems. Despite both technical and regulatory issues, an increasing deployment by governments and other entities underlines its revolutionary potential. Further study and development will be essential for improving its capabilities and ensuring effective widespread incorporation.

Ghosh et al. [20] pointed out blockchain's potential in several kinds of health- care applications, namely exchange of data, record management, and remote monitoring of patients, owing to its reliable, unchangeable, and transparent data exchanges. Although blockchain's intriguing features, the study revealed that its influence on healthcare is mainly at the documentation stage, with limited practical uses as well as further study required to address prevailing shortcomings to accomplish the sector's possibilities.

Baysal et al. [21] carried out a multi-vocal survey of the literature to un- cover blockchain application domains and motives for implementing blockchain in healthcare and evaluated both official and unofficial sources to identify problems in developing and implementing blockchain technology, and pro- vide alternatives. Our findings suggested that blockchain is used in electronic health and medical record management, remote patient monitoring, medicine logistics management, clinical research, personalized medicine, health surveil- lance among the public, and medical health insurance, confirming its ability for solving a wide range of healthcare development issues.

Karne et al. [22] presents a brief description of blockchain technology, under- lining its essential qualities, advantages and specific features that set it apart. We examine its various applications, the increasing demand among business organizations and industrial groups, and its substantial effect on computing ap- plications during the last decade. Furthermore, we describe blockchain research and analyze prominent consensus procedures and taxonomies for blockchain net- works, providing useful insights for individuals and businesses interested in this area of study.

Attaran et al. [23] analyzes how blockchain technology might solve the challenges in healthcare sector, and addresses difficulties as well as possibilities for deployment, and specifies health-related blockchain products. Patients and medical professionals have trouble effectively access, manage, and exchange medical records. Improved data access might assist in respond to public health concerns like COVID-19, but existing methods do not provide suitable security, confidentiality, or interoperability.

Wenhua et al. [24] stated that the latest version of healthcare services with Health 5.0 takes advantage of blockchain's decentralization, safe sharing, and high confidentiality characteristics for better EHR security. Securing medical files from threats and assuring verified access pose significant issues. Blockchain's development in healthcare will be centered on technological possibilities, stronger cooperation, and regulatory frameworks. Homomorphic encryption resolves blockchain latency and data privacy challenges by providing secure data access to trusted parties.

3 Blockchain based Healthcare

Blockchain-based healthcare as shown in Figure 4, is taking advantage of blockchain technology in the medical field for better privacy of information, seamless integration, and efficiency. Blockchain, a distributed and immutable ledger system, provides a reliable and open method for storing, managing, and sharing medical data with authorized parties [25] [26]. Its encryption techniques safeguard critical patient data from unwanted access and breaches, preserving confidentiality and integrity. Blockchain enhances treatment coordination along with medical results by allowing diverse healthcare systems to share and

exchange information more efficiently.

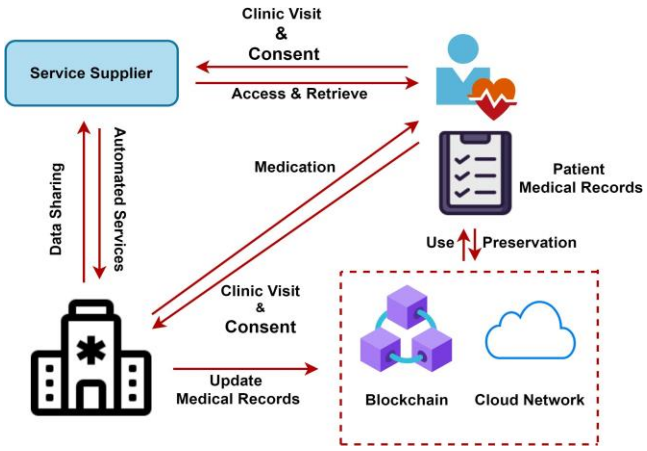

Fig.4. Blockchain enabled Healthcare Domain

Table 1. Summary of Literature

Study	Author's Name	Focus	Key Points
Ref [19]	S. Dong, K. Abbas, M. Li, J. Kamruzzaman	Illustrating the broad utilization of blockchain technology within several areas, such as financial management and healthcare.	Blockchain permits safe, open and decentralized processing of data as well as automation through smart contracts. Despite both technological and regulatory barriers, use cases for banking, logistical management, and healthcare are emerging.
Ref [20]	P. K. Ghosh, A. Chakraborty, M. Hasan, K. Rashid, A. H. Siddique	Analyzing blockchain's confined but significant influence on medical services, with solutions for additional research.	Blockchain technology has possibility in healthcare to enable information inter- change, record administration, as well as distant monitoring, although its in- fluence mainly lies in documentation, with further study required for implementation in practice.
Ref [21]	M. V. Baysal, O. Ozcan-Top, A. Betin-Can	Evaluating and identifying relevant uses for blockchain technology in health services.	A multi-vocal questionnaire was conducted to determine the possible usage of blockchain in digital medical records, distant monitoring, medicine scheduling, clinical trials, customized medical care, public health monitoring, along with medical insurance, indicating the ability to handle a wide range of health- care concerns.
Ref [22]	K. K. Vaigandla, R. Karne, M. Siluveru, M. Kesoju	Providing an in-depth description of the blockchain system along with its significance for the use of computers.	A brief description of blockchain technology, showing its main features, primary uses, and major effect on computers throughout the past decade, and providing understandings of voting procedures and vocabularies for blockchain- based networks.
Ref [23]	M. Attaran	Examining how blockchain might help medical institutions to resolve specific issues, particularly in managing information.	Blockchain technology may contribute to resolving healthcare difficulties by considering safety, integrity, and inter- operability while safeguarding medical records and reacting to public health hazards such as COVID-19.

Ref [24]	Z. Wenhua, F. Qamar, T.-A. N. Abdali, R. Hassan, S. T. A. Jafri, Q. N. Nguyen	Studying the incorporation of blockchain in Health 5.0, as well as security alternatives including homomorphic data encryption.	Health 5.0 leverages blockchain's decentralized systems, safe communication, and anonymity for better EHR reliability. The focus is on technology potential, cooperation, and legislative frameworks, with homomorphic encryption technologies being proposed to solve delay and issues related to privacy.

The immutability of blockchain assures that once data is collected, it cannot be changed or erased [27], guaranteeing the accuracy and dependability of medical records while decreasing inaccuracies and fraud. Smart contracts, or self- executing agreements, automate and enforce terms, increasing administrative efficiency and lowering expenses [28]. Furthermore, blockchain records medications and medical devices throughout their supply chain, ensuring authenticity and addressing counterfeit products. Blockchain allows patients with ownership over their wellness data, allowing them to grant or cancel access to their medical histories as needed.

The important role of blockchain in the medical sector stems from its ability to transform the way health information is organized and distributed. It improves information safety along with anonymity [29], which are crucial for retaining patient trust and adhering to severe healthcare standards. Blockchain also enhances interoperability and data integrity, which are critical for providing high-quality care and eliminating medical errors and it has the potential to greatly decrease expenses and increase effectiveness through improving administrative operations and supply chain management.

3.1 Various Features of Blockchain Technology for Advancing Healthcare Sector

Blockchain technology provides an array of features as shown in Figure 5, that have the potential to significantly change the healthcare sector in the future. Its decentralized design and cryptographic safety give strong protection for essential patient information, minimizing the possibility of breaches and unintentional access. Furthermore, blockchain raises interoperability by enabling seamless ex- change of information amongst medical professionals, which improves care coordination and patient satisfaction.

The unchangeable ledger of blockchain technology assures the confidentiality and auditability of medical records, therefore reducing inaccuracies and theft. Smart contracts automate and enforce agreements, resulting in increased administrative efficiency and lower expenses. Blockchain technology further enhances supply chain management by tracing drugs and medical supplies, verifying authenticity and preventing counterfeiting. Additionally, it promotes the open ex- change of scientific data, which fosters collaboration and accelerates medical advances. Another significant advantage of blockchain is that it allows individuals to safely manage and share their medical information. Ultimately, blockchain helps with regulatory compliance by minimizing conformity to healthcare standards and privacy legislation, which promises major improvements in healthcare efficiency, transparency, and patient-centered treatment.

3.2 Types of Blockchain in Healthcare System: Public, Private and Consortium

A public blockchain is an accessible as well as distributed network in which any- body can join and contribute [30]. In medical treatment, public blockchains

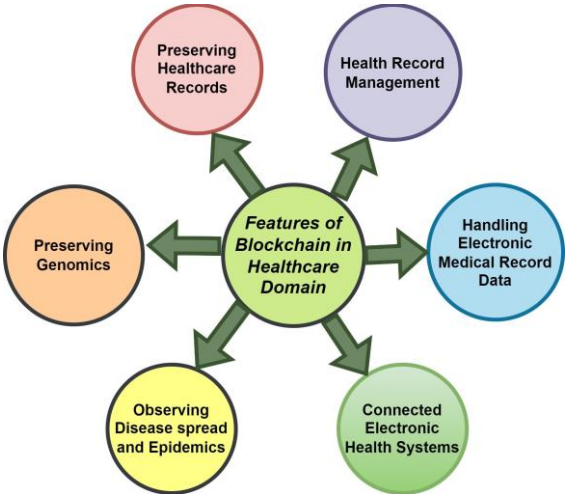

Fig.5. Features of Blockchain in Healthcare Sector

may be utilized to share general wellness data, including public health statis- tics or study findings, where transparency and broad availability are desirable [31]. The primary benefits are transparency and safety, as all transactions are accessible and immutable. However, because the network is open, scalability and privacy concerns can be difficult to address. Equations 1, 2, 3 describe the connection among the total number of participants, control (or governance), along with the degree of encryption in each type of blockchain.

$$P = n \tag{1}$$

$$G = \frac{1}{n} \tag{2}$$

$$S = f(n) \tag{3}$$

A private blockchain is a closed and centered network to which only one company or a group of entities has access [32]. In healthcare, private blockchains are perfect for maintaining valuable patient details, internal documents, and confidential information. They provide better control over data access and are more efficient and scalable than public blockchains. Privacy is enhanced, and data access can be limited to authorized parties, guaranteeing compliance with rules like as HIPAA [33]. Equations 4, 5, 6 describe the connection among the total number of participants, control (or governance), along with the degree of encryption in each type of blockchain.

$$P = m \tag{4}$$

$$G = 1 \tag{5}$$

$$S = f(m) \tag{6}$$

A consortium blockchain is a hybrid approach handled by various entities rather than a single entity [34]. In the healthcare industry, consortium blockchains can let medical facilities, research institutes, insurance firms, and other stake- holders share data and collaborate more effectively [35]. This architecture strikes a balance between the transparency of public blockchains and the control of private ones. It protects data integrity and security while letting various trusted parties to connect to the network, developing seamless integration and collaboration. Equations 7, 8, 9 describe the connection among the total number of participants, control (or governance), along with the degree of encryption in each type of blockchain.

$$P = m \tag{7}$$

$$G = \frac{1}{k} \tag{8}$$

$$S = f(k) \tag{9}$$

Table 2 analyzes the features of public, private, and consortium blockchains in healthcare services. Public blockchains give accessibility and security, but they address scalability and privacy issues. Private blockchains offer improved privacy and control, rendering them ideal to safeguard confidential patient data. Consortium blockchains provide a balance between transparency and control, allowing for collaboration among many healthcare entities [36]. Each type has distinct advantages customized to certain healthcare uses and requirements.

Table 2. Features of Public, Private and Consortium Blockchain

Feature	Public Blockchain	Private Blockchain	Consortium Blockchain
Availability	Open for everyone	Restricted to approved parties	Restricted to approved participants
Authorization	Permissionless	Permissioned	Permissioned
Administration	Decentralized	Centralized	Centralized
Scalability	Limited	More scalable than public	More scalable than public
Consensus	Proof of Work, Proof of Stake	Various consensus mechanisms	Various consensus mechanisms
Effectiveness	Gradual	High	High

4. Benefits of Blockchain in Healthcare

In the medical field, blockchain enables people to store and exchange their confidential medical data securely and reliably with medical institutions and third- party agencies [37]. The ideal medical blockchain system includes patient ownership, storing safety, confidentiality assurance, tamper-proofing, and easy interoperability [38]. The medical blockchain enables a decentralized approach to storing and managing medical information. This technique eliminates the information silos of conventional health care systems, allowing individuals to focus on their personal medical data from several institutions. Patient offers complete control over his or her personal medical information. Others must submit a re- quest and obtain the necessary approval before they can access the patient's pertinent medical information. The patient may also withdraw their consent at any moment.

Table 3. Benefits of Blockchain Technology in Medical Field

Benefits	Description
Improved Data Safety	Gives robust protection for confidential patient wellness in- formation through decentralization and cryptographic methods, minimizing breach risks.
Enhanced Data Accuracy	Assures that healthcare records and transactions are unchangeable and protected, preserving the accuracy and reliability of health records.
Seamless Supply Chain Management	Improves openness and trackability in the pharmaceutical sup- ply chain, addressing counterfeiting and assuring authenticity.
Patient Self-Determination	Permits patients to manage them health records, control access, and exchange information selectively, resulting to better engagement and customized treatment.

Table 3 highlights the benefits, along with their descriptions of blockchain technology in medical field. A significant benefit of the medical blockchain [39] is storage of information privacy. Three perspectives are considered while analyzing the safe keeping of medical data: public availability, data generation, and data receipt. Blocks provide the public information about medical data, including its hash value, store address, and access for medical data [40]. Although it is available to the public, this information cannot be altered. The public key of the patient is encrypted using the hash value, which is authenticated, and

the patient's record and signature. Hashing methods are utilized to handle data produced by medical facilities. This paperwork is preserved in the chain's cloud server. By using his private key [41] to unlock the ciphertext, the patient can retrieve the signature and hash of the medical facility's record.

With the goal to maintain their privacy, patients are presently taking part in anonymous blockchain transactions. For every transaction, clients have the option to create unique pairings of public and private keys. Medical records are kept in cloud storage beneath the chain and are encrypted. Without the patient's encryption key, it is impossible to figure out the plaintext information contained in the medical data. As a result, true information regarding medical data cannot be obtained from public medical information.

Medical blockchains [42] emphasize interoperability for ease of use. The medical blockchain stores data from both medical institutions and service suppliers. Connected medical information may greatly enhance treatment at medical facilities and third-party entities. The medical blockchain allows consumers to access medical data from anywhere via the internet.

4 Challenges

Blockchain technology in the field of healthcare faces several essential challenges as shown in Figure 6, that must be overcome before it can be efficiently employed. Scalability is a big concern, since massive quantities of healthcare data can overwhelm blockchain networks, resulting in slow transaction rates and high operational expenses. Although blockchain is basically secure because to its distributed and cryptographic attributes, potential weaknesses, bad implementation, and illegal access may threaten the system's security and patient confidentiality [43].

Fig.6. Challenges of Blockchain in Healthcare Sector

Securing data privacy inside the structure of blockchain is challenging because it must adhere to rules including HIPAA yet conserving openness as well as access control [44] [45]. The massive storing requirements of health information, especially patient records and imaging scans, provide practical concerns about limited on-chain storage space and associated expenses. Additionally, blockchain's decentralized authentication mechanism can cause slower rates of processing, limiting timely decision-making and patient care. Employing blockchain technology has substantial technical and infrastructure hurdles, including integrating with current systems, assuring interoperability, and man- aging the move from traditional databases to blockchain solutions. Furthermore, a lack of technical understanding among healthcare personnel may impede the adoption process.

4.1 Threats of Blockchain Technology in Healthcare

Threats of blockchain technology in healthcare as shown in Figure 7, are emerging risks and difficulties that could affect the performance, safety, effectiveness, and adoption of blockchain systems [46]. These dangers may arise from a few factors, such as technical limitations, ecological problems, human considerations, as well as societal viewpoints [47].

Particularly, threats to the application of blockchain technology are as follows:

- **Scalability Challenge-** Blockchain technology addresses major scalability issues, notably when dealing with the massive number of transactions and information seen in the medical field [48]. When the blockchain grows in the number of participants and transactions, processing of transactions speeds may slow down. This latency arises from the necessity for consensus methods, involving Proof of Work or Proof of Stake, to verify every transaction, which can be taking time. likewise, every transaction generates another block in the chain, growing the blockchain's size and demanding more computing and storage capacity [49]. The growing demand may result in greater operating expenses because additional computing resources are required to sustain the network.

- **Insufficient Knowledge Gap-** Establishing and upholding blockchain technology requires related technical expertise, which are frequently missing in healthcare organizations [50]. This talent gap might give rise to unsuccessful installation, greater safety risks, and operational weaknesses [51]. As a result, healthcare organizations may struggle to fully grasp the prospective advantages of blockchain technology, including increased data security and interoperability.

- **Setup and Transaction Charges-** Blockchain technology for healthcare poses many monetary issues in terms of setup and transaction expenses. The first expenses of setting up a blockchain network can be high, covering hardware, software, and system setup. Continuing operating costs, such as

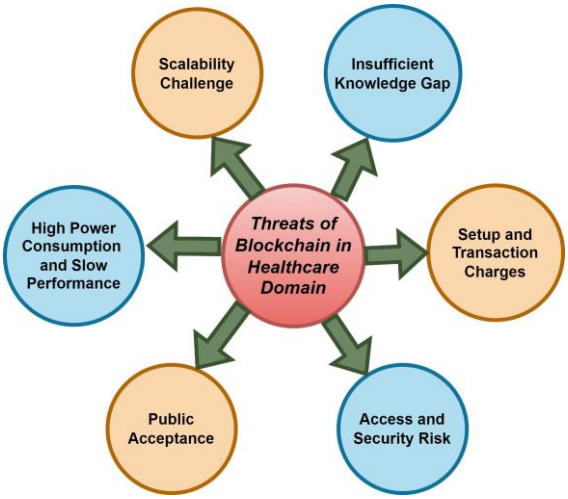

Fig.7. Threats of Blockchain Technology

maintaining servers, network management, and, most significantly, power consumption, increase the financial strain [52]. Transaction costs, which fluctuate depending on network activity and consensus methods, can add up, raising costs. As the blockchain network expands with new transactions and individuals, the expenses of additional processing resources and storing rise. Such variables may prevent healthcare companies from implementing blockchain technology, especially those with confined finances, so it is critical to carefully consider the cost-benefit ratio before adoption [53].

- **Access and Security Risk-**

As blockchain enables improved safety features, it is not without vulnerabilities. Unapproved access and privacy failures are still possible, particularly if the network is not properly maintained or if there are security flaws in deployment. In the medical field, where security and confidentiality of information are critical, any compromise can have major impacts. A manipulated blockchain may reveal critical medical data, resulting in financial loss, theft of identity, along with a loss of patient trust [55]. likewise, breaches may give rise to monetary penalties and legal complications for medical professionals. Effective security measures are required to limit data availability to only legally permitted individuals, guaranteeing that confidential data is not corrupted [56].

- **Public Acceptance-**
  The use of Blockchain is still in the beginning stages of acceptability among the public along with medical professionals. Issues regarding security of information, the multifaceted nature of the technology, and an absence of awareness can all hinder its widespread adoption [57] [58]. To be effectively implemented into the health care industry, blockchain must first gain the confidence and belief of patients, medical professionals, and other participants. The support of the public is necessary for the technology to fully grasp its abilities in modifying the way healthcare is provided.

- **High Power Consumption and Slow Performance-** The power usage associated with blockchain networks, specifically those based on proof-of- work consensus algorithms, is an important concern. In medical services, where energy conservation is essential the enormous power needs for pre- serving and confirming blockchain transactions can be barriers [59]. This challenge not only raises operating costs but also creates ecological sustain- ability concerns, which can be a major disadvantage for healthcare organizations seeking to minimize their carbon impact [60].

  The distributed nature of blockchains can result in slower processing rates than conventional centralized databases. In healthcare, where rapidly retrieval of patient records and immediate processing of data are important, poor processing speed can be an important drawback. Slowdowns in data availability and transactional certainty can have an influence on patient care, medical decisions, and overall operational effectiveness.

5 Conclusion

In conclusion, the use of blockchain technology has the potential to boost health- care by improving privacy, confidentiality, and interoperability. Its distributed structure and unchangeable maintaining records enable effective methods for managing digital medical records, allowing confidential information sharing, and increasing the openness and effectiveness of healthcare systems. Regarding its positive aspects, the application of blockchain for medical purposes confronts several problems, including technical difficulties, scalability issues, legislative challenges, as well as the necessity for broad acceptance. Overcoming such challenges with continuing study, improvement, and collaboration between stake- holders will be essential for achieving blockchain's potential in medical services. As medical technology advances, blockchain is expected to serve an essential part in developing a more reliable, effective, and patient-centered healthcare system.

Moving into the future, the potential of blockchain for medical applications is enormous. As technology improves, we should expect to see larger general acceptance in areas including customized therapy, immediate time patient mon- itoring, as well as secure medical information transfers. Improvements in associated technologies, such as homomorphic data encryption along with digital contracts, will improve blockchain's scalability and adaptability to the health- care sector's unique needs. Furthermore, greater collaboration among industry stakeholders, regulatory authorities, and technology developers will be required to overcome current obstacles and build standardized frameworks for blockchain implementation.

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