Assessing Blockchain's Role in Healthcare Security: A Comprehensive Review

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Blockchain, a breakthrough technology, offers solutions to several healthcare challenges, includes Managing and sharing data securely, making different systems work together seamlessly, increasing transparency in the supply chain, giving patients more control over their health information, and adhering to regulations and guidelines. This paper offers an in-depth study of current literature on blockchain in healthcare. It covers areas that have been investigated, studied and implemented by previous research, provides valuable insights, and introduces practical suggestions. Research findings indicate that blockchain has the capacity to improve data security, privacy, and immutability. It can also facilitate effortless data sharing among different parties involved, enhance transparency in pharmaceutical supply chains, empower patients in managing their health information, and address regulatory concerns. The results of this study recommend Healthcare organizations to consider implementing secure transaction protocols to ensure the confidentiality and integrity of their data. Also, to explore the use of Hyperledger Fabric architecture, a blockchain framework specifically designed for enterprise applications, Implementation of Secure Transaction Protocols, Utilization of Blockchain for Data Sharing, Adoption of Lightweight Consensus Protocols. By leveraging blockchain technology, healthcare businesses may securely share data with other trusted parties, improving interoperability and data exchange. Additionally, adopting lightweight consensus methods can help streamline decision-making processes within the organization. Future research shall involve the integration of blockchain technology with artificial intelligence and data analytics, the establishment of decentralized parallel healthcare organizations, the integration of blockchain with cloud computing, and the resolution of regulatory and standards difficultie.

Povzetek: Podana je pregledna analiza uporabe blockchain tehnologije v zdravstvu. Poudarja njene koristi pri varovanju podatkov, interoperabilnosti in upravljanju informacij pacientov, ob hkratnem reševanju regulativnih in tehnoloških izzivov.

1 Introduction

The healthcare systems have a crucial role in addressing the needs of a more mobile and aging population, emphasizing the need of operational effectiveness. The worldwide crisis presented by the unique Covid-19 epidemic highlights the significant importance of telehealth and real-time data exchange within the healthcare sector [1].

In the dynamic realm of healthcare, there has been a shift from conventional patient-centered and clinic-centered models to the adoption of emerging trends such as eHealth (electronic medical services), uHealth (general medical care), and mHealth (mobile medical services) [2]. This transformation has led to the proliferation of healthcare services on a larger scale. The incorporation of Internet of Things (IoT) devices, specifically those pertaining to the Internet of Medical Things (IoMT), has brought about a significant transformation in medical operations, enhancing their adaptability, resilience, and cost-efficiency. However, the emergence of digital transformation created a new set of challenges, particularly related to the protection of Internet of Things (IoT) devices and essential healthcare information systems [2] [3].

The prevalence of security vulnerabilities associated with Internet of Things (IoT) devices, namely mobile devices, and their effect on the healthcare information infrastructure has risen in the era of digital and widespread healthcare. The widespread use of healthcare applications and devices has resulted to a large amount of clinical data being shared and exchanged. This creates several issues for healthcare organizations. The challenges include difficulties in making systems compatible, complex procedures, delays in diagnosing and caring for patients, barriers to data sharing, increased operating costs, lengthy insurance processing times, and ultimately higher overall expenses [4], [5], [6].

To address issues in healthcare, blockchain technology has emerged as an alternative that addresses security and interoperability needs [7]. Blockchain's features include secure data exchange, agreement on updates, tamper-proof record changes, and decentralized permanence, all of which enhance efficiency and security in healthcare systems. The inclusion of consensus protocols and smart contracts in blockchain systems is essential for creating secure and interconnected healthcare networks [8].

Healthcare organizations recognize the importance of data. However, there are many security risks that can affect patient privacy, data access, and data accuracy. Changing medical data can have serious consequences for patient care. Therefore, it is essential to develop secure and effective healthcare systems quickly [7], [9], [8].

This study aims to thoroughly examine the various applications of blockchain technology in healthcare to overcome existing challenges. Blockchain, a decentralized technology, has the potential to address security and interoperability issues faced by healthcare systems [7].

The primary goal of this research is to gain a comprehensive understanding of blockchain's diverse applications in healthcare. Additionally, it intends to identify specific obstacles that hinder the implementation of blockchain in various healthcare sectors. Furthermore, the study seeks to determine the unique technical attributes that distinguish blockchain applications across different healthcare industries.

2 Research problem

The healthcare industry is embracing blockchain technology to improve data security, promote smoother data sharing, and support patient-centric approaches to care. The growing complexity of medical records, due to the surge in health-related data, poses challenges in managing and optimizing them. Data integrity can be compromised by duplication, errors, and limited accessibility within fragmented healthcare systems that use different identifiers and terminology.

Protecting patient information is crucial in medical record management. It requires vigilance to prevent security breaches and unauthorized access to sensitive data. The act of gaining access to patient data without adequate authorization has the potential to lead to the collection or inappropriate usage of such information. The condition described above poses a substantial risk to the privacy of people' personal information, including extensive identifying particulars such as full names, residential addresses, and contact numbers. Ensuring the confidentiality of patient records is crucial for the efficient delivery of healthcare services [10], [11],[12].

Consequently, a multitude of nations have enacted or proposed legislative mandates to bolster healthcare systems against cyber threats, fortify the privacy of patient information, and foster trust in the doctor-patient dynamic. At now, the dominant paradigm in healthcare systems is the use of a client-server architecture, whereby a centralized controlling entity has complete administrative authority. The way the system was designed has risks built into it. These risks could lead to information about patients being shared without their permission if there are problems with the system or if security and privacy controls are not strong enough.

Integrating blockchain technology into healthcare presents significant hurdles in complying with laws, protecting patient privacy, addressing scalability issues, and gaining widespread adoption. To leverage blockchain effectively, it's crucial to thoroughly analyze these challenges, develop pragmatic solutions, and assess the impact of blockchain on healthcare outcomes [11], [13], [14], [15], [16].

3 Methodology

This study focuses on gathering and reviewing existing literature to gain a deep understanding of how blockchain technology is being used in healthcare. The following sections describe the research plan, including data collection, the criteria used to select the literature, and the specific approaches applied:

- **Research design:** We conducted a systematic review to explore and analyze the existing body of work discussing **blockchain's** applications in healthcare. To ensure clarity and rigor, the review adhered strictly to the principles of systematic reviews.
- **Data collection:** Our approach to data collection involved a thorough and methodical exploration of several prominent electronic databases, including PubMed, IEEE Xplore, Google Scholar, Elsevier (ScienceDirect), ACM Digital Library, Web of Science, and Scopus. The search was confined to articles published between 2016 and 2023, a timeframe chosen to capture the most recent and significant advancements in the use of blockchain technology within the healthcare sector. We employed targeted keywords such as 'blockchain,' 'healthcare,' 'data security,' 'interoperability,' and 'privacy' to guide our search efforts.
- **Criteria for inclusion/exclusion:** To ensure that our review maintained a high standard of relevance and quality, we applied specific criteria during the selection process. We focused on scientific publications in peer-reviewed journals, conference papers, and other credible sources that directly addressed the practical applications of blockchain technology in healthcare settings. Studies that did not meet these criteria or were not specifically related to healthcare applications were excluded from our review.
- **Quality assessment**: A **thorough** review was conducted to ensure the reliability and validity of the selected studies. This involved a careful evaluation of each study’s design, methods, and key findings to ensure that only trustworthy and accurate information was included in our analysis.

4 Background

The emergence of technical advancements, specifically in the fields of Artificial Intelligence (AI) and the Internet of Things (IoT), resulted in a significant change in various industries. Artificial intelligence (AI) transforms the

education sector by enabling personalized learning and enhancing industrial operations through automation and data-driven decision-making. The utilization of Internet of Things (IoT) sensors is vital in improving the effective utilization of resources in the agricultural sector. At the same time, the incorporation of blockchain technology helps protect the privacy and accuracy of data in the healthcare industry [17]. Data analytics and machine learning are employed in agriculture to enable precision farming, while virtual reality and augmented reality technology improve educational experiences [18].

Special education has employed artificial intelligence (AI) and virtual reality (VR) technologies to tailor learning experiences to meet diverse individual needs [19], [20] ,[21]. The integration of these technologies across various sectors, including education, industry, agriculture, healthcare, and special education, serves as a comprehensive approach to overcoming challenges and fostering progress [22], [23].

The use of blockchain technology in the healthcare sector provides a means to safeguard electronic health information, improve interoperability, and optimize pharmaceutical supply chains. The aforementioned interwoven use underscores the revolutionary capacity of technology in generating effective, easily accessible, and inclusive solutions across many sectors.

4.1 Blockchain

Blockchain is a shared (P2P) network-based decentralized, conveyed, and unchangeable record framework [9]. Blockchain wipes out trustworthy mediators from the exchange cycle and produces a chain of blocks. Each block is associated with the one preceding it by a particular cryptographic hash. Blockchain as a Counteraction and moderation Answer for Medical care Applications could be classed as permission less (like Ethereum) or permissioned (e.g., Hyperledger Texture). A blockchain with no entrance limitations is totally decentralized and open to all clients. A permissioned blockchain, then again, is fairly decentralized yet has limits on who can partake and play out the tasks. To safeguard the record state, blockchain utilizes agreement methods like Evidence of Work (PoW) and Confirmation of Stake (PoS). A blockchain shrewd agreement is a piece of code that sudden spikes in demand for its own when explicit circumstances are met. Smart contracts do away with trusted middlemen, need less human interaction, have lower enforcement costs, and guard against purposeful or accidental security threats [8].

The circulated record's interior parts are outlined in Figure 1 alongside how the record is coordinated in blockchain networks. With hash default settings, the beginning block is consequently appointed when the organization is made, and more blocks are added to the record after the beginning. It is feasible to add components like the Merkle tree root esteem, nonce, grouping number, timestamp, log, block variant, and the hash from the past block in block structures. As seen by the red line, the Merkle tree is utilized to bunch co-operations into a public blockchain and safely store them. As per the agreement convention being used, the properties dispensed to the block might change [20] [24]. To sum up, this figure shows the highlights integrated into blockchain structures like those utilized in Bit coin and Ethereum executions.

4.2 Types of blockchain

Blockchain can be broken down into a few separate groupings, each of which has its own traits and accurately reflects network behavior. Based on the characteristics listed [12], these blockchains can be categorized as

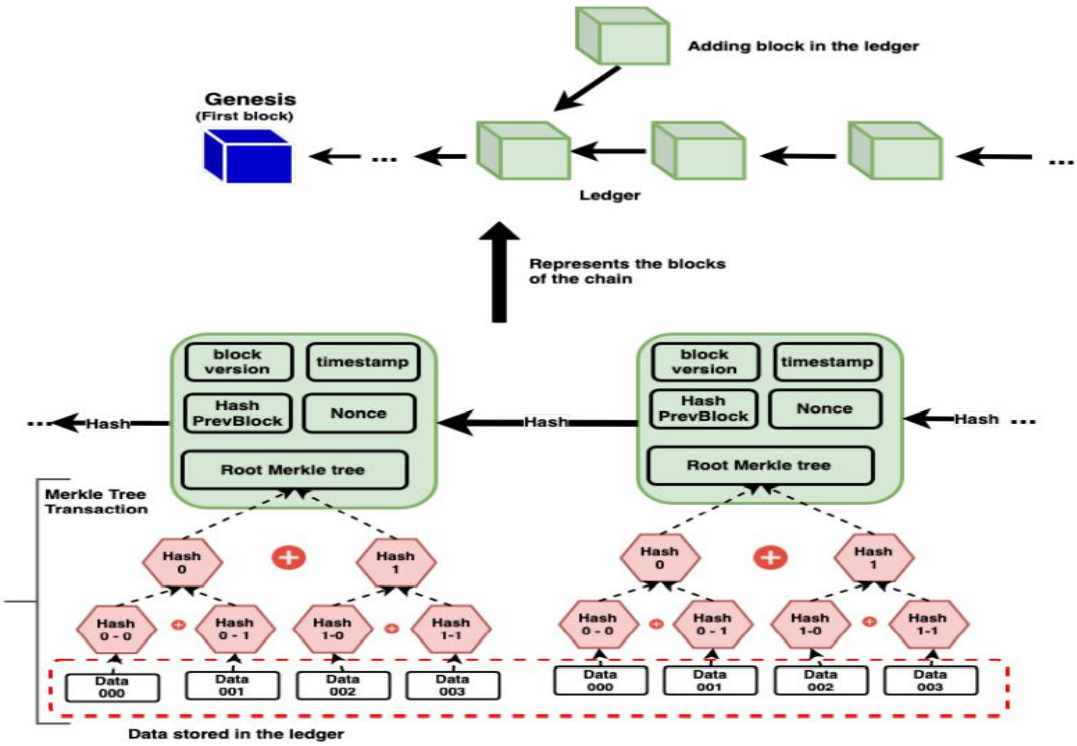

Figure 1: The main blockchain architecture, Source [25].

follows:

- **Public blockchain:** All nodes can see the transactions in real time. Any organization hub can partake in the blockchain agreement techniques to approve the exchange whenever it has been communicated. The hub is unidentified in the organization and doesn't require consent. Hubs in this sort of organization can work together and follow up on a colossal scale. The digital currencies Bitcoin and Ether are an illustration of this kind of network [12].
- **Permissioned blockchain:** It is controlled by a system whose transactions are regulated and whose nodes need permission to join the structure[12]. This form of network has the benefit of ensuring a higher level of privacy because it necessitates authentication in order to access the material. Multi Chain [26] is an illustration of this type of platform.
- **Consortium blockchain:** Since it is normally shown to a gathering and expects distinguishing proof to join the organization, it shares components of the Permissioned blockchain. This specific organization enjoys the benefit that the checking hubs are comprised of a set number of hubs with pre-laid out capacities, permitting them to confirm an exchange. In this kind of network, the selected nodes must come to an agreement, build a new block, and complete the procedure before the transaction can be considered genuine [27].

The analysis of various classifications of blockchains provides valuable insights into the diverse attributes of blockchain technology and its applicability in several domains. Public blockchains, like as Bitcoin and Ether, provide an unparalleled degree of openness and inclusivity. The system allows for the inclusion of all persons, facilitating the immediate observation of transactions, and operating without the need of formal authorizations. The intrinsic openness of these networks enables widespread cooperation and promotes global-scale innovation.

In contrast, permissioned blockchains provide a heightened level of control and secrecy. The incorporation of authentication and permission mechanisms in these blockchains makes them well-suited for applications that value data security and restricted access. Multi Chain is a notable instance within this specific categorization.

Consortium blockchains, as previously said, establish a state of balance by bringing together acknowledged participants who collectively verify transactions. A significant advantage in this particular context is the facilitation of decentralization by these networks. In this process, selected nodes, sometimes given specific roles, reach consensus before verifying transactions.

4.3 Issues with using blockchain in healthcare

Regardless of whether it is a multidisciplinary thought with troubles and imperatives, blockchain can be utilized in various settings [28]. Analysts in this field are attempting to wipe out or diminish the impacts of these negative components. We feature a couple of issues (specialized hardships) with blockchain innovation[10], [29], [30], [31] when utilized in the medical services industry[32], [33], [34] :

- **Throughput:** More checks should be proceeded as an outcome of the expansion in exchanges and organization hubs, which could bring about a bottleneck. High throughput is an issue while managing medical services frameworks since, without speedy access, it might adversely influence a determination that could save somebody's life.
- **Latency:** Confirming a block requires about 10 minutes, which may be destructive to organize security administrations since effective attacks could happen during that period. Medical care frameworks ought to continuously be gotten to on the grounds that they are dynamic and any deferrals could hurt the assessment of a test[29].
- **Security:** If a third party is able to take over 51% of the network's computing power, security could be compromised. This issue needs to be given a significant amount of consideration because a compromised healthcare system might result in the loss of respect for healthcare organizations.
- **Use of resources:** Since the mining system consumes a lot of energy, the reception of this innovation raises the chance of a critical loss of assets. Since various gadgets are expected to screen patients in a medical care setting, the energy costs are extremely high; in any case, the utilization of the blockchain may likewise bring about critical handling and energy costs. Associations battle to control these consumptions.
- **Usability:** Because these kinds of technologies are so difficult to operate, user experience is also a concern. Also, a Programming interface (Application Programming Point of interaction) with easy-to-use highlights should be created. The systems ought to be simple and straightforward because healthcare providers do not possess the same level of technical expertise as IT specialists.
- **Centralization:** Despite the fact that blockchain is a decentralized design; some techniques have a tendency to centralize the miners, which lowers the level of network dependability. The data it stores can be obtained through malicious assaults because this major factor is exposed and open to attack[12].
- **Anonymity:** It's widely assumed that the Bitcoin architecture makes it possible for blockchain to guarantee the anonymity of its nodes. However, the results of [12] have disproved this hypothesis. Strategies are additionally required to provide this capability to block chain technology systems [12]. The General Data Privacy Regulation (GDPR) must be complied with by blockchain-based systems because of privacy laws and regulations.

To evaluate the complexities involved in the use of Blockchain technology for sensitive applications. One of the prominent challenges faced by scholars and practitioners is on the matter of throughput, which refers

to the velocity or frequency at which transactions are processed. In the healthcare sector, the timely availability of data may have significant consequences for patient outcomes. Any obstacles in transaction processing might lead to serious repercussions. Similarly, the latency, which refers to the delay in processing time, may have detrimental consequences in situations when the fast retrieval of patient records or critical medical data is of utmost importance.

The importance of security in the healthcare business cannot be overstated, and the susceptibility of blockchain networks to a 51% attack is a matter of significant concern. The potential consequences of such an attack involve the exposure of patient data, which could lead to a decrease in trust towards healthcare institutions. Furthermore, the substantial resource requirements linked to blockchain technology, such as energy consumption and processing capability, provide practical difficulties for healthcare providers, who are already burdened with elevated operational expenses.

The rise of usability concerns has been identified as a potential obstacle to the widespread adoption of blockchain technology in the healthcare sector. The significance of prioritizing the development of user-friendly interfaces and technologies specifically designed for healthcare practitioners with minimal technical abilities cannot be overstated. The conversation ultimately underscores the intricate interplay between decentralization and centralization in blockchain networks, underscoring the imperative of achieving a balanced and harmonic equilibrium.

Compliance with data privacy standards, such as the General Data Protection Regulation (GDPR), is of utmost importance in a heavily regulated industry like healthcare, as it is a fundamental obligation. In order to effectively use the potential benefits of blockchain technology in the healthcare industry, it is crucial to address these challenges while simultaneously safeguarding patient privacy, security, and efficient data management.

5 Review on applications of blockchain in healthcare and their network security issues

5.1 Management of electronic medical data

The volume of healthcare data gathered over the last few years has significantly increased. These data are being produced by wearable IoMT-based personal healthcare and fitness devices, as well as by healthcare professionals in the form of electronic medical record and patient histories (often saved locally). The main issues facing healthcare data management at the moment are data segmentation, security, portability, and EMR incompatibility. There are specific ways to address these issues, such as smart cards of patient health care. Some availability and compatibility issues may be resolved by this method, but significant security issues still exist. Since information are allotted to addresses instead of people, and in light of the fact that patients' control keys are connected to the location, the blockchain-based information the executives framework will make it simpler to recognize patients. Security, information beginning, secrecy, and interoperability are completely tended to by this strategy [35].

Blockchain-based advances likewise empower patients to be completely in charge of their information and whom they decide to discuss it with, forestalling data abuse by getting rid of the unified information the executive's framework. Blockchain can benefit from distributed storage limit as far as the interest for information capacity because of the advantages of good sharing, fast transmission, minimal expense, tremendous extra room, simple induction, and dynamic affiliation [36].

5.2 Integrated healthcare and interoperability

By exchanging patients' medical information among practitioners, the implementation of the EHR system has two key advantages, namely the prevention of data redundancy and medical processes and improvement of treatment quality. Interoperability, a term used to describe these two advantages of exchanging EHRs in the health industry, is incorporated [37]. Current EHR frameworks depend on a siloes design for qualification approval, and they likewise dislike 1) heterogeneities in programming and equipment answers for the EHR frameworks and 2) reason, organization of EHR and heterogeneities in the construction as far as changing medical care frameworks present in different geographic areas [38]. Blockchain can be a clever arrangement that upholds information respectability, security, interoperability, and at-scale collection in any data trade including medical services laborers, their intermediaries, medical services suppliers and patients. Rather than present frameworks, which come up short on single confided in wellspring of accessible personality to total patient clinical records, blockchain can be utilized to solidify patient clinical records. Recuperation possibilities are superfluous on the grounds that blockchain records are unchangeable and accessible to any client inside a patient's organization [38]. Benefits from this reality will build to the two patients and medical services experts. Patients will grasp the meaning of their medical care information and approach their electronic wellbeing records. In light of a full EHR, medical services experts can likewise utilize patient information to improve clinical and monetary results while upgrading wellbeing and health.

5.3 Pharmaceutical supply chain

Quite possibly of the greatest division in medical care is the PSC, which is more complicated and sensitive than normal stock chains. Drug things need a more exact administration framework since they have a sensitive creation process, a fragile life expectancy, and are sensitive to protection conditions. Running against the norm hand, the PSC's globalization has delivered new hardships including the unlawful medication exchange. Subsequently, the requirement for discernibility and straightforwardness all through an item's lifecycle is

expanded by the PSC's intricacy. An extraordinary help identifier, item following convention in the public record, item checking convention, recognition and response recording convention, Food and Medication Organization (FDA) ready convention, and the common record for item and exchange data are only a couple of the essential prerequisites for building a blockchain-based PSC.

The blockchain-based supply framework is partitioned into two levels [39]: 1) The blockchain framework and the savvy contract, which incorporates the guidelines, consents, and commitments is supported by all gatherings prior to being embedded into the blockchain; 2) The recording gadgets and sensors for checking the condition of the drug item. This will ensure programmed adherence to shrewd agreement guidelines during the store network.

In a recent study [40], the researchers examined the significant problem of counterfeit pharmaceuticals in the pharmaceutical supply chain. The issue at hand prompted the enactment of the Drug Supply Chain Security Act (DSCSA) within the United States. In 2010, counterfeit drug sales reached $75 billion globally, posing significant risks to both individual patients and public health. This research highlights the complexities and lack of transparency in the pharmaceutical supply chain. These factors contribute to inefficiencies, financial losses, and a loss of consumer trust.

Blockchain technology can improve trust and transparency in the pharmaceutical supply chain. Consumers can use barcode scanners to track products and verify their legitimacy. This technology keeps records in real-time, makes it easier to manage access, and helps identify and trace counterfeit medications. By doing this, blockchain can solve a major problem in the pharmaceutical industry.

A research study conducted by [41] sought to address the problem of counterfeit drugs in the distribution of medicines. They proposed a dependable system that employs blockchain technology as a solution. The main goals of this initiative are to augment confidence, promote transparency, bolster security measures, and improve the traceability of information. This paper examines the classification, fundamental elements, and advantages of blockchain technology.

Additionally, it provides suggestions for employing front-end technologies such as
HTML, CSS, JavaScript, and React, as well as back-end technologies like JavaScript and Solidity, in conjunction with Agile development concepts. The results underscore the promise of blockchain technology in enhancing the security of pharmaceutical supply chains and its various uses in domains such as medical records and drug supply management. The ultimate objective is to guarantee the authenticity and traceability of medications.

5.4 Blood donation and organ transplantation

The quantity of patients on the organ relocates holding up list keeps on being considerably more noteworthy than how much givers and transfers, according to organ contributor measurements. The hole among market interest continues regardless of enhancements in innovation and medication as well as expanded mindfulness about organ gift. A restricted asset should be gained, matched to a recipient, and a progression of exchanges from assortment to embed should be finished as a feature of the gift cycle. To guarantee the outcome of the transplantation, various variables and check processes are fundamental. These incorporate credible information course, the confirmation of the organ's starting point, the check of the organ production network, interoperability between benefactor foundations, medical clinics, research centers, and other gift or giver family, legal administrator, recorder workplaces, pharmacies, and transportation center points, and so on. Assuming the overall scale for organ transplantation is considered, these variables might be enhanced. [42] Records three advantages of incorporating a blockchain into the organ transplantation framework. In any case, it ensures the unchanging nature of clinical records to make preparations for extortion and misuse. Second, it works on the straightforwardness and discernibility of data coming from numerous partners engaged with the gift and transplantation processes. Thirdly, by disposing of the requirement for unified control, it encourages dependable correspondence among all members all the while.

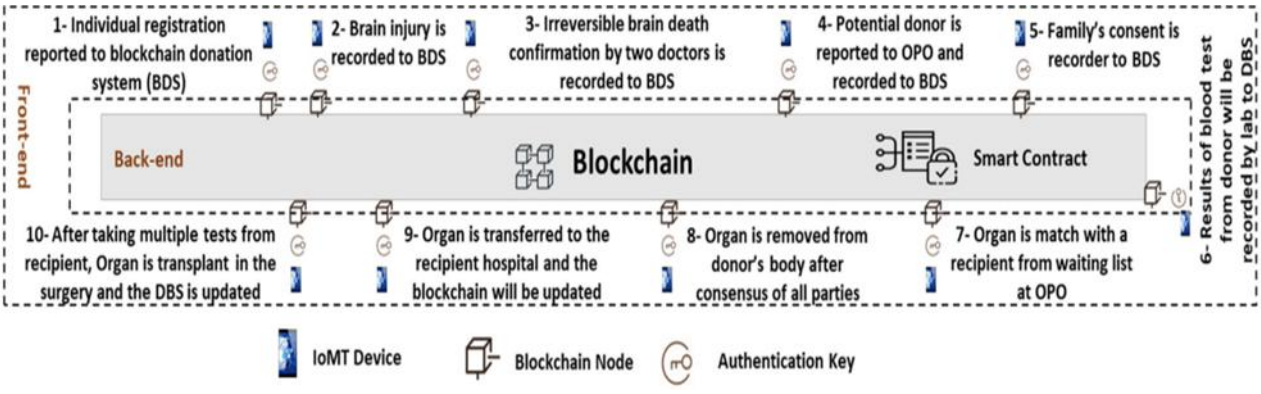

Figure 2: Blockchain-based approach for organ donation, adapted from [42].

The blockchain replaces repetitive and copy electronic records, any wasteful and contradictory exchange framework and manual article records, in the organ relocate store network since it guarantees straightforwardness and constant exchange [43]. Fig. 2 outlines how an organ relocates functions inside the blockchain framework. The framework will promptly stop the organ transplantation methodology to protect the beneficiary's life in the event that there is ever a contention with the standards overseeing the gift and relocate frameworks.

All gatherings associated with the gift interaction can see the status, area, and accessibility of the organ for the proper beneficiary at the suitable second because of the straightforwardness gave by the blockchain innovation. One more kind of relocate that is urgent for helping people with health-related crises or explicit circumstances is blood gift (e.g., malignant growth, blood problems extreme draining in coincidental case and leukemia). A blockchain can foster a shrewd framework that empowers clinics and clinical offices to rapidly question and get blood supplies from nearby offices [44].

Because of the prerequisite for various gatherings to convey information, update data, and affirm records and occurrences, protection organizations make brilliant blockchain applicants. In the protection framework, go-betweens likewise increment process costs, intricacy, time responsiveness, and exchange reliance. Health care coverage can utilize blockchain in different ways, contingent upon how the innovation is utilized to gather wellbeing information and execute arrangements. Practical protection techniques, online protection trades, upgraded client care, less extortion in clinical reports and claims submitted through the cycle by providers, petitioners, or candidates, close continuous observing of wellbeing status, more unique evaluating by back up plans, and diminished overt repetitiveness in clinical reports are a couple of these [45]. However, the necessity for laborious data entry will be reduced when acquiring or renewing insurance policies thanks to blockchain-based identity verification technologies. Patients will have control over the sharing of their medical information with healthcare professionals and insurance providers [46].

5.5 Insurance

Table 1: Summary of literature review

Area	Method	Findings	Ref.
Electronic Medical Data management	Smart Card for patient	The advantages of good sharing, fast transmission, minimal expense, tremendous extra room, simple induction, and dynamic affiliation	[36]
Integrated healthcare and Interoperability	EHR System	Medical services experts can likewise utilize patient information to improve clinical and monetary results while upgrading wellbeing and health.	[38]
Pharmaceutical Supply chain	Modum	The recording gadgets and sensors for checking the condition of the drug item.	[57]
	LifeCrypter	The stakeholders involved in the pharmaceutical supply chain are able to significantly enhance their operational effectiveness when distributing authenticated drugs globally. In contrast, patients can benefit from the ability to autonomously verify products through our user-friendly end-point solution, which is an easily accessible application.	[40]
	Client-side scripting (HTML, CSS, JavaScript, React) for the front end and JavaScript and Solidity for the backend	Identify blockchain's potential in securing pharmaceutical supply chains across various areas such as electronic medical records, biomedical research, remote patient monitoring, and drug/pharmaceutical supply chain management. Highlight blockchain's security features contributing to the system's security.	[41]
Blood donation and Organ transplantation	Smart Contract	These incorporate credible information course, the confirmation of the organ's starting point, the check of the organ production network, interoperability between benefactor foundations, medical clinics, research centers, and other gift or giver family, legal administrator, recorder workplaces, pharmacies, and transportation center points, and so on.	[42]
Insurance	Decentralized consensus protocol	Patients will have control over the sharing of their medical information with healthcare professionals and insurance providers	[46]

5.6 Protocols of consensus used in healthcare systems

Consensus protocols are essential components for the blockchain networks' transaction environment to function. By adhering to a precise rule outlined by the algorithm, these protocols help to coordinate the verification of the transactions. They essentially aid the validating nodes in coming to a consensus because there is a chance that transactions delivered to the network come from a hostile node [47]. As a result, the validation procedure can help to prevent harmful transactions from being processed [48]. It is also important to note IBM Hyperledger Fabric, a technology that has been implemented in efforts involving blockchain in healthcare systems, among the protocols looked at. Additionally, it provides PBFT consensus protocol-based tools for creating a full blockchain network [49].

Table 2 presented data linked to the most generally used protocols in healthcare methods, which are (i) proof-of-work and (ii) PBFT, based on the investigation carried out in this survey. The former is due to its popularity in numerous fields as well as it was the first to appear. The latter is because it bases the IBM Blockchains platform, which is well-known and facilitates the blockchain networking process, and because it gives the network low latency. The terms "proof of accessibility" and "proof of time and space" refer to two protocols that are being researched in the business world [50]. The algorithm for accessibility proof is designed to ensure that access to the data is possible even if the node that contains it is disconnected from the network. The protocol executes this process using backup data, replication, and fragmentation mechanisms. The data fragmentation approach uses data chunks that are propagated to various storage nodes across the network, with node being able to hold more than 50percent of total of the fragments of a specific database [51]. The proof of time and spatial protocol checks to see if the data was stored and periodically asks a proof of space. These specifications verify the accuracy of the saved medical records, and the nodes that participate in these operations are rewarded in MedCoins [52].

Additionally, other areas like Internet of things and supply chain are investigated using the consensus methods that have been given. Due to the restricted hardware in IoT devices, light consensus methods are required, such as PBFT, Stellar Consensus Protocol (SCP), modified PoS, and others [53], [54]Similar to Supply Chain, the application determines the protocol to utilise; however, in this study, we concentrated on healthcare applications.

Table 2: An overview of the methods for healthcare on blockchain, including benefits and drawbacks for each application area.

Area	Methods	Ref.	Pros	Cons
Health information transmission	MedRec	[55]	Boost the quality of data used in medical research	Absence of contract encryption
			Interoperability of systems	It is merely a prototype.
	Meddicalchain	[56]	Market for health data	Tokens were only usable within Medicalchain.
			MedTokens provide patient-controlled access.	The MedTokens are not without risk.
	MediChain	[52]	May benefit from a web application and a mobile interface	Patient access key lost
			Decreases the likelihood that the patient will be identified from leaking data	Difficulties with privacy
Healthcare supply chain	Modum	[57]	Utilizes GDPR best practices	Centered only on business
			Uses NFC to keep track of the pharmaceutical supply chain	Complexity and poor documentation
Privacy and Security	Decentralized Sharing of Health Records (DSHR)	[58]	Ensures privacy through attribute-based encryption	Complexity to use
			Stores private information off-chain	Cost goes up as the number of qualities goes up.
		[59]	A system for searching blockchain cryptographic techniques	Use an artificial environment
			Smart contracts are encrypted	Block mining is expensive.

We summarized a few approaches and uses of blockchain in healthcare that are relevant to each of the knowledge domains mentioned in our survey. To provide a comparison point between different strategies, Table 1 and 2 lists the benefits and drawbacks of each. Future study can use a baseline.

6 Results analysis

Literature investigation and reviews revealed a number of significant discoveries related to the utilization of blockchain technology in the healthcare sector:

1. Blockchain technology has the potential to solve issues related to the electronic medical data management,

such as data segmentation, security, and interoperability [36]. Multiple research projects suggested the utilizing of blockchain technology to enhance the management and distribution of electronic medical records [36], [38].

2. Blockchain technology has the ability to enhance interoperability and facilitate seamless data sharing among healthcare systems and stakeholders. However, there are still obstacles to overcome when it comes to incorporating blockchain into the current healthcare infrastructure and ensuring that it is aligned with regulatory standards [37], [38]. In literature, number of studies emphasize the significance of blockchain technology in improving transparency, traceability, and authenticity in the pharmaceutical supply chain. Blockchain technology has been suggested as a valid technique to solve problems like the production of fake medications, maintaining the integrity of supply chains, and ensuring compliance with regulations [39], [40], [41].
3. Patient Empowerment: Blockchain technology facilitates patients in employing more authority over their own health data and later for its dissemination to healthcare professionals. Multiple research papers have investigated the possible advantages of blockchain technology in enabling patients to take control of their medical information, obtain healthcare services, and engage in clinical research [36], [46].
4. Regulatory Considerations: The literature also discussed the significance of regulatory supervision and adherence in the implementation of blockchain technology in the healthcare sector. Policymakers and regulators should establish explicit norms and criteria for the utilization of blockchain technology in order to safeguard patient confidentiality, protect data integrity, and assure adherence to regulatory requirements [33,] [72].

Investigating the literature has revealed numerous noteworthy findings in relation to the application of blockchain technology in the healthcare sector. The results highlight the capacity of blockchain technology to tackle significant issues in the management of electronic medical data, boost the ability of different systems to work together, increase transparency in the pharmaceutical supply chain, give patients more control, and circumvent regulatory concerns. Researchers, policymakers, and healthcare stakeholders must continue to investigate the potential benefits and address the obstacles of incorporating blockchain technology into the healthcare system. With a clear goal to enhance the efficiency, security, and patient-centered care.

7 Research gaps

The presentation of blockchain innovation has set out new exploration open doors in the medical care industry for information uprightness, smooth clinical protection claims, speedy information trade, and patient responsibility for information. Indeed, even with these progressions, there are as yet calculated ambiguities and semantic holes in regards to blockchain innovation. These worries incorporate key administration, mining motivating forces, and mining attacks. This audit study accentuates the way that various medical care applications have specific requirements that are not being met by a lot of people of the blockchain drives now viable.

Despite all the sophisticated capabilities that Blockchain offers, there are still a number of restrictions and problems that need to be resolved. Lack of standardization, privacy breach, key management of medical health records, IoT latency, and vulnerabilities [60] in the blockchain and its supporting software are the specific issues to be covered in this study.

As a result, we reviewed and analyzed the network security risks in blockchain technology usage associated with conventional healthcare applications and how further proposals might be used to mitigate those risks.

8 Findings

Based on the principles used for blockchain technology's healthcare information management that were covered in this study, protocols are used to regulate transactions. These ideas also support greater security, data immutability, privacy, and the exchange of electronic health records. Consensus protocols like Proof-of-work, PBFT, and Proof-of-stake are the main protocols engaged in the system trust building processes. Additionally, we came across various research using the hyper ledger Fabric architecture and PBFT consensus methods while creating blockchain-based apps. The possibility of sharing health data, sharing photographs in healthcare, monitoring healthcare application files, and managing healthcare data for industry-wide negotiation proposals are other topics covered in this section.

Each of them highlights various approaches to problem-solving and discusses the benefits of this kind of solution in the context of healthcare. Finally, we went through some guidelines and looked at various studies that looked at patient monitoring using personal sensors. This study looked into ways to save energy expenditures while also improving the reliability and safety of data transit. It should be emphasized that blockchain, a relatively new idea in computing, can help with reliability and patient monitoring using sensors and low-cost technology. Additionally, as consensus protocols evolve, they can be applied to devices with limited resources (like Internet of Things devices) thanks to lightweight consensus protocols like PBFT and SCP [61]. The findings of this study are presented in Table 3.

Table 3: Studies that focus on the healthcare context use consensus algorithms

Consensus Protocol	Ref.	Overview
Proof of work	[62]	Clinical Health data sharing
	[63]	Clinical Health data sharing
	[64]	Sharing of medical information confidentially
	[65]	Sharing easily accessible and confidential medical records
PBFT	[66]	Distributing trustworthy medical records
	[14]	Controlling and monitoring access logs for medical records
	[52]	Clinical Health data sharing
	[56]	MedTokens are used in a marketplace to exchange healthcare data.
Proof of Stake	[68]	Sharing medical image data

8 Recommendations

Based on the facts presented in this study regarding the principles and procedures employed in blockchain technology for managing healthcare information, we can derive many recommendations:

A. Implementation of secure transaction protocols: Healthcare institutions needs to employ blockchain

B. Technology for the purpose of protecting and monitoring electronic health records: Core features of blockchain, such as Proof-of-Work, PBFT, and Proof-of-Stake, enable secure transactions, immutable data, and optimal confidentiality. Healthcare institutions can establish a reliable system with the main purpose of managing sensitive patient data by implementing blockchain technology.

C. Exploration of hyperledger fabric architecture:
Healthcare application developers who are utilizing blockchain technology should explore the utilization of Hyperledger Fabric's architecture. This architecture provides strong capabilities for constructing blockchain networks that possess both strong security measures and the ability to handle large-scale operations. Also, by utilizing PBFT
consensus methods can enhance the level of trust and dependability in the management of healthcare data.

D. Utilization of blockchain for data sharing:
Healthcare stakeholders need to explore how blockchain technology can enhance data exchange within healthcare systems. This involves sharing medical histories, scans, monitoring health app data, and handling data in industry negotiations. By using blockchain, data sharing can become more transparent, traceable, and trustworthy.

E. Adoption of lightweight consensus protocols:
As blockchain technology evolves, it can now be implemented on resource-constrained devices like those used in the Internet of Things (IoT). Lean and efficient consensus protocols like PBFT and SCP enable secure and seamless data exchange. This is particularly beneficial in healthcare, where patient monitoring devices can leverage sensors to track vitals. These protocols help IoT devices conserve energy while maintaining the integrity and security of data transmission, enhancing the efficiency and security of healthcare applications.
Implementing these recommendations allows healthcare entities to utilize blockchain's capabilities to enhance data management, increase data protection, and advance healthcare provision. To drive meaningful healthcare transformation, organizations must continuously monitor blockchain advancements and seek collaborations and knowledge exchange opportunities.
Based on the findings and recommendations outlined above, we propose the "Blockchain Framework for Secure Healthcare Operations" framework, illustrated in Figure 3. This framework prioritizes the implementation of secure transaction protocols, exploration of Hyperledger Fabric architecture, utilization of blockchain for data sharing, and adoption of lightweight consensus protocols. Moreover, it incorporates mechanisms for feedback collection and an evaluation process to ensure ongoing refinement and improvement.
The proposed framework offers a step-by-step guide for healthcare organizations to adopt blockchain technology in their operations. Following its guidelines, healthcare institutions can strengthen their data handling, security, and teamwork, leading to better patient care and results

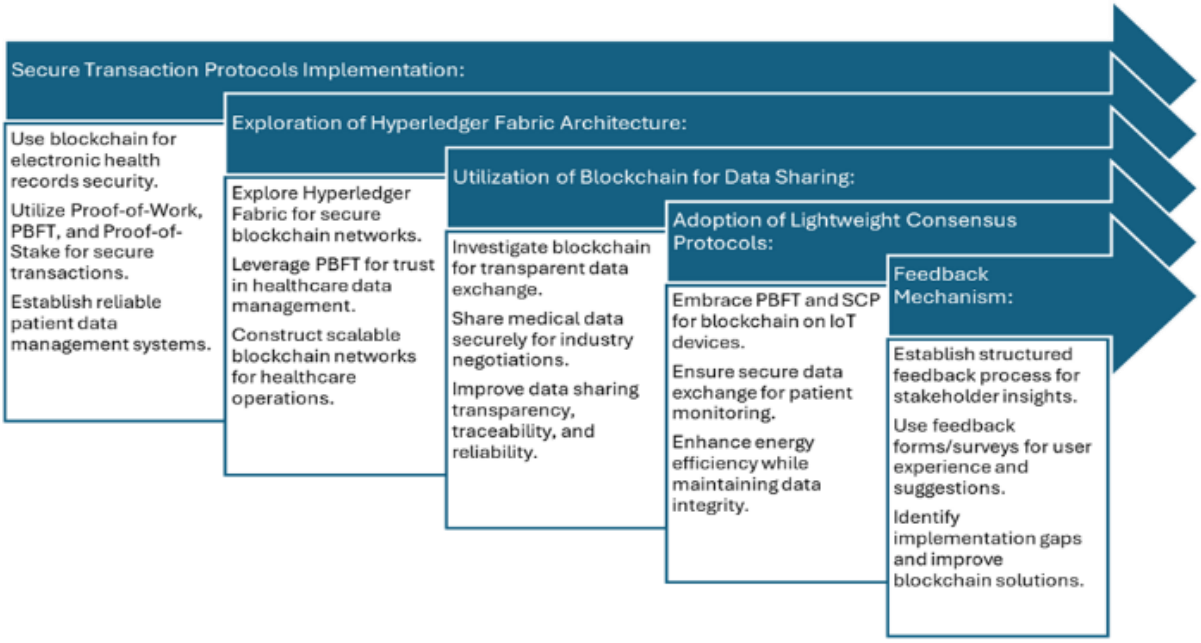

Figure 3: Blockchain framework for secure healthcare operation

9 Limitation and challenges

While blockchain technology offers significant potential for enhancing data security and interoperability in healthcare, there are several critical challenges that must be addressed to fully realize these benefits.

One of the most pressing concerns is the high computational and energy costs associated with blockchain, particularly with consensus mechanisms like Proof-of-Work (PoW) [50], [51]. The energy consumption required for blockchain mining is substantial, raising both financial and environmental concerns. For healthcare organizations operating on tight budgets, these costs can be a significant barrier to adoption. To overcome this, the development of more energy-efficient consensus algorithms, such as Proof-of-Stake (PoS), is essential [50].

Scalability presents another major challenge. As blockchain networks grow in size, the number of transactions and network nodes increases, which can lead to bottlenecks that delay critical healthcare operations [51]. In a field where timely access to data can directly impact patient outcomes, these delays are unacceptable. Innovative solutions are needed to enhance blockchain's scalability without compromising its integrity.

The complexity of integrating blockchain with existing healthcare IT systems also poses a significant hurdle. Many healthcare organizations rely on legacy systems that were not designed to interact with blockchain technology [36]. The integration process can be time-consuming and resource-intensive, requiring a careful balancing act to ensure that all systems communicate effectively. Moreover, this complexity is compounded by the need to navigate strict regulatory frameworks, which vary across regions and are often difficult to align with new technologies [33], [72].

Security, while a strength of blockchain, is not without its challenges. The decentralized and immutable nature of blockchain provides robust protection against unauthorized data tampering [8]. However, blockchain is not entirely immune to threats. For example, a '51% attack,' where a single entity gains control of the majority of the network's computational power, could still compromise the system [50]. Although such an attack is unlikely in large, established networks, it remains a concern for smaller or emerging implementations.

Lastly, usability is a challenge that should not be overlooked. Blockchain technology, while powerful, is complex and often requires a high level of technical expertise to implement and manage [53]. For healthcare professionals, who may not have specialized IT knowledge, navigating these systems can be daunting. Ensuring that blockchain systems are user-friendly and accessible to all stakeholders is crucial for widespread adoption.

10 Contributions

This research makes a substantial contribution to our knowledge of the connection between healthcare and blockchain technology. It brings together and examines present research to provide a thorough overview of the topic, offering a better comprehension of its potential and implications.

10.1 Contribution to the field

This paper addresses the difficulties encountered in the management of digital health data, including problems related to fragmentation, security vulnerabilities, and interoperability. By utilizing scholarly ideas, this study examines how blockchain technology might efficiently tackle these difficulties. It provides a comprehensive

examination of its potential to bring about significant changes in the healthcare industry.

This research explores into the applications of blockchain in healthcare. It highlights the significance of regulations to ensure its safe and ethical implementation. The study stresses the necessity of robust policies and standards to safeguard patient privacy and data integrity. It maintains that new technologies should adhere to established governance frameworks. The article emphasizes the imperative for stringent regulations to ensure the responsible and ethical use of blockchain technology in healthcare. These principles are established through rigorous research and insightful analysis.

This study investigates the potential of blockchain technology to empower patients by enabling them to have control over and share their health information. Using concrete instances from reality, it demonstrates how blockchain applications that prioritize patients can enhance the management of medical records and increase accessibility to healthcare. This study examines the ways in which blockchain technology empowers patients, making a valuable contribution to conversations around the shifting dynamics between patients and healthcare providers in the digital age.

10.2 Other contributions

Our research significantly enhances the understanding of how blockchain technology can be used in healthcare. We analyzed key factors and provided insights to help guide its application. These contributions include:

i. **Enhanced security insights:** This research offers a comprehensive examination of security vulnerabilities in healthcare services and proposes robust protections based on blockchain technology. Through the analysis of possible vulnerabilities and the proposal of effective solutions, our research makes a valuable contribution to enhancing security measures in the healthcare sector.

ii. **Comprehensive examination of blockchain applications:** Our study offers a thorough examination of the many uses of blockchain technology in the healthcare sector. This report provides a comprehensive examination of the possible implications of blockchain technology across many healthcare sectors, including electronic health record management, interoperability, integrated healthcare systems, pharmaceutical supply chains, blood donation, organ transplantation, and medical insurance.

iii. **In-Depth analysis of ongoing blockchain projects:** This report is notable for its comprehensive and current examination of existing blockchain initiatives in the healthcare sector. Through the elucidation of contemporary advancements and endeavors, our contribution enhances the communal repository of information, hence furnishing academics and practitioners with invaluable discernments pertaining to the present state of blockchain integration in the healthcare sector.

iv. **The use of blockchain technology for the purpose of enhancing privacy:** Our study makes a noteworthy contribution by examining privacy tools within the healthcare industry and investigating the potential of blockchain technology to improve privacy protections. This study examines the methods via which blockchain technology maintains privacy and explores its potential implications for enhancing privacy in healthcare operations.

v. **Advancements in data access control in medical records:** This research study participates in a comprehensive and intricate analysis of the potential of blockchain technology in enhancing data access control within the realm of medical records. Through an examination of the complexities inherent in decentralized control methods, our analysis contributes to the scholarly conversation around the enhancement of data access management. This research aims to establish a harmonious equilibrium between the accessibility and security of healthcare information.

11 Future work directions

The application of blockchain technology in healthcare is still in its early stages, and several key areas need further exploration to address current limitations and pave the way for broader implementation. The following are critical directions for future research:

i. **Combining blockchain technology with ai and data analytics:** Integrating blockchain with artificial intelligence (AI) techniques, such as deep learning and machine learning, alongside big data analytics, has the potential to revolutionize clinical trials, medical research, and treatment decisions. Although there is significant promise, the accuracy and validity of predictions made using blockchain and AI in healthcare need further investigation [69].

ii. **Parallel blockchain-based healthcare organizations:** Developing decentralized parallel healthcare organizations (DPHOs) that integrate decentralized autonomous organizations (DAOs) with parallel healthcare systems is another promising direction for blockchain-based healthcare research. This approach would enable various healthcare stakeholders—patients, hospitals, health organizations, researchers, and insurers—to participate in the co-ownership, development, and co-sharing of healthcare resources within a blockchain ecosystem [70].

iii. **Combining blockchain technology with cloud computing:** One of the significant challenges in blockchain technology is managing the vast amount of data generated and stored across network nodes. This issue becomes more pronounced with the growth of IoT devices, which often lack sufficient computational and storage power. Future research should focus on reducing data generation or increasing storage capacity, along with improving mining processes to reduce energy consumption and enhance efficiency. Additionally, integrating cloud computing with blockchain could offer a solution to these challenges by providing scalable storage and computational resources [71].

iv. **Regulations and standardization for blockchain-based healthcare:** The lack of clear regulations and standardized guidelines for blockchain technology in healthcare remains a significant barrier to its adoption. Cross-border electronic health record (EHR) sharing is particularly challenging due to varying and sometimes conflicting legal frameworks. Developing a compliance code with uniform rules, standardizations, and international guidelines for using blockchain in specific medical fields is crucial for overcoming these obstacles [72]. Moreover, legal frameworks such as HIPAA must be adhered to, even though they may pose challenges to development efforts. Therefore, another critical area for future research is creating a standard user-friendly interface that meets both client requirements and regulatory standards.

v. **Energy-Efficient consensus algorithms:** As blockchain technology becomes more widely adopted, the energy consumption associated with current consensus methods, particularly Proof-of-Work (PoW), is a growing concern [50]. Research into alternative algorithms, such as Proof-of-Stake (PoS) and other innovative consensus mechanisms, is essential to reduce the environmental impact and operational costs associated with blockchain networks. These advancements would make blockchain more sustainable and accessible for healthcare applications.

vi. **Establishing interoperable standards:** Given the fragmented nature of healthcare infrastructure, establishing universal standards for blockchain integration across different platforms and institutions is essential [36], [37]. Future research should explore how these standards can be developed and adopted on a global scale, considering the varying regulatory requirements across regions. This will ensure that blockchain solutions can be effectively deployed and integrated into existing healthcare IT systems.

vii. **Real-World pilot projects:** Conducting real-world pilot projects in diverse healthcare settings, such as hospitals, pharmaceutical supply chains, and public health systems, will provide valuable insights into the practical benefits and challenges of blockchain technology [36]. These pilot projects will help identify best practices and potential pitfalls, offering concrete guidance for wider adoption.

12 Conclusion

This study broke down chosen pieces of the exploration that are connected with the blockchain innovation application in the field of medical services. The request has additionally investigated related points like medical care data protection and security. The main papers on the utilization of blockchain innovation in the field of medication have just been distributed somewhere in the range of 2016 and 2021. Thus, early examinations in the field principally settled expansive phrasing. The administration of medication supply chains, the sharing of medical services information, and patient observing frameworks have all seen early utilizations of this innovation. As an arising prevalence as of late, the methodology that has been considered is guaranteeing security while imparting wellbeing records. With the approach of individual information security guidelines, the subject of protection is expanding interest and offers promising review valuable open doors (LGPD, HIPAA, and GDPR). The freedoms and commitments that associations have while getting the individual data of their clients are represented by security regulations. By utilizing methods like essential element cryptography, zero-knowledge proof, and immutability of data, among others, blockchain can significantly contribute to ensuring privacy.

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