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Healthcare Applications Using Blockchain Technology: Motivations and Challenges

Sadia Ramzan, Aqsa Aqdus, Vinayakumar Ravi, Deepika Koundal, Rashid Amin, and Mohammed A. Al Ghamdi

***Abstract*—Blockchain technology is one of the most important inventions and creative advancements that play a crucial role in today's business world. Blockchain technology is heading in the direction of systematic innovation and revolution. It is a digital ledger of transactions, and every block contains information of transactions linked by cryptographic references. Every block covers information and maintains trust among people based on how far they are. Blockchain is a system used for storing data, and it ensures the security of the system. The resurgence in blockchain technology has encouraged scholars and specialists over the past couple of years to carefully examine new ways of implementing blockchain technology with a wide range in the domain of healthcare. This rapid increase in blockchain technology has generated many endless possibilities. In this article, we provide a review of blockchain technology in healthcare. We present a detailed introduction, history, technical information, and types of blockchain technology. Motivations behind this technology and top healthcare projects completed using this technology are also discussed. This article is classified into three groups based on blockchain applications with their use cases. The evaluation of medical care technologies and relevant applications based on blockchain technology, such as sharing electronic medical records, remote patient monitoring, and supply chain management, are also discussed. In revolutionizing the healthcare industry, we illustrate the potential of blockchain technology. We have also focused on identifying the limitations of previous approaches. Finally, this article is concluded with some open research issues and future research direction.**

***Index Terms*—Blockchain technology, electronic health record (EHR), healthcare issues in technology management, technology intelligence, Internet of Medical Things (IoMT), supply chain management (SCM).**

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I. Introduction

ACCORDING to the United Nations (UN) report of 2019, the population will increase from 7.7 billion to almost 9 billion by 2050 [1]. With a rapidly increasing population, it is a big challenge for healthcare centers to improve their services. However, healthcare's current situation is weak and is facing problems like lack of adequate treatment, high cost, lack of human resources, and medical resources [2]. Besides that, huge volumes of data are produced daily, saved, and retrieved, so all records kept in files or computers are not secure [3]. As the records of healthcare centers are very sensitive and, in these conditions, there were chances of data loss. Thus, these highlight the need for a safe and secure healthcare data management system. So, with time, the demands of healthcare centers are also increased. The researchers tried their best to achieve the goal of better services in healthcare centers that increase efficiency and decrease medical costs.

Blockchain technology is a decentralized and digital ledger used to keep medical records and information of patients in different computers and provides the facility to share this information in the community [4]. This technology stores all data in blocks using cryptography. Only authorized users can open, read, view, and access the data [5]. Cryptography ensures that the data is safe and secure. Every participant is associated with the blockchain network by using a private or public secret key. This technology provides the authenticity and identification of every participant. Thus, blockchain technology plays a significant role in healthcare that protects patients' data from unauthorized users, hackers, or outsiders. Nobody can change or modify your records. Blockchain technology is a peer-to-peer (P2P) network. A person must be part of this network for making any transaction. If any of its members want to make transactions by using some key, the data are sent to all nodes for identification. If the keys are matched and more than 50% of nodes are identified, then it will respond "ok" or "approved" and the transaction will be added to the chain and creates the latest block [6]. Fig. 1 shows how the blockchain process works by using cryptography. Healthcare data-intensive is a clinical domain. All data of patients are very important that are created in a huge amount daily. The process of storing this sensitive data in a safe, secure, and scalable manner is a big challenge. Sometimes we need to share or exchange these records. Blockchain provides electronic health records (EHRs). All data and records are stored electronically, and we can share the patient information among different healthcare providers through EHR [7].

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TABLE I
KEY ELEMENTS OF BLOCKCHAIN TECHNOLOGY [8]

Sr#	Key Elements	Functionality Description
1	Decentralized	It is an open-access database network system, so everyone can connect with the network through the access key and share, monitor, store, and update the data on multiple nodes or systems.
2	Autonomy	Blockchain technology provides an independent and autonomous system. It makes a trustworthy system, you can access, store, change, or update data on each node. Nobody can hack your data.
3	Open Source	Blockchain technology provides an open-source system. You can check your record connected to the node and make your applications.
4	Immutable	Blockchain technology is immutable. Nobody can change your data so easily. When any user sends a request to the node, the transaction is transmitted to all nodes. And provide authenticity. If 51% of nodes approved, then change. So, it is very difficult and impossible for a hacker or unauthorized user.
5	Transparent	Blockchain technology provides a transparent facility to your records or stored data. You can easily update the data.
6	Anonymity	Blockchain technology safe & secure your data. The exchange or transfer of data node to node, identify individually so that your data is more secure and reliable.

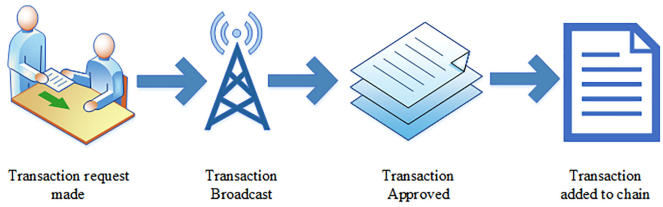

Fig. 1. Workflow of the blockchain process.

Blockchain technology consists of six key elements: 1) decentralization, 2) autonomy, 3) open-source, 4) transparent, 5) immutable, and 6) anonymity, which are discussed in Table I.

Blockchain technology is the most trustworthy and promising distributed ledger. It is implemented successfully in agriculture, banking, Internet of Things (IoT) security, education, healthcare, and e-voting. In the near future, blockchain technology will provide many advantages to the medical industry. Blockchain technology is likely to take medical science to a new level by reducing the monitoring cost, configuration, and availability of a centralized system in the same way healthcare is modified, and telemedicine is introduced [9]. Due to the synchronized digital data availability, the processing time will reduce. Because when a patient enrolls, all of its data will be available in the article [10].

Furthermore, patients would not need to worry about another doctor's opinion because of data transparency. Likely, doctors too do not have to worry about giving patients truthful medical history because of the opportunity to imagine recorded real, original, and accurate data. Blockchain technology in healthcare connects multiple people all around the world, having similar medical situations [8]. In this centralized system [11], people report their medical conditions and feel motivated to fight their diseases. Patients have complete control of their data, and they can share their data with someone else. More study is still required for better understanding, characterizing, and evaluating the value of blockchain. Their research comprised a cryptographically safe blockchain by making a chain of blocks using a different cryptographic technique for security purposes. The researchers are trying their best to overcome these challenges and improve the EHR system.

Contribution of the Article: In this article, we reviewed multiple blockchain studies in the domain of healthcare. We tried to cover most of the terms of blockchain technology in healthcare. Motivations behind this technology and the topmost projects completed under this technology are discussed in detail. We classified healthcare applications of blockchain into three main parts. We explain all aspects, its use cases, strengths, weaknesses, challenges, benefits, and future directions. The main objective is to provide a detailed study of how blockchain makes innovation in this field. In summary, this article provides the following contributions.

1) It provides an in-depth overview of blockchain technology and its background from how it started to the changes over time.
2) Presenting technical information and types of blockchain technology.
3) We are discussing major healthcare projects that are developed by using blockchain technology.
4) Detailed elaboration of healthcare applications and use cases of these applications are provided based on blockchain technology.
5) Comparison of the classified applications with existing methods and critical analysis and discussion is also provided.
6) This article also verifies the merging of traditional healthcare approaches, EHR, and PHR with blockchain technology.
7) We describe the limitations and open issues of previous approaches.

The remainder of this article is organized as follows. In Section II, the history of blockchain technology is discussed. Section III presents the motivation behind this technology, and in Section IV, major healthcare projects are discussed. The applications of blockchain in healthcare and their comparison with previous work are explained in Section V. In Section VI, the challenges of blockchain technology in healthcare are discussed. Table II shows the lists of the acronyms that are used throughout the article. Finally, Section VII concludes the article.

II. BLOCKCHAIN TECHNOLOGY: HISTORY 1991–2021

The work on blockchain technology was started at the beginning of 1991 [12], by Stuart Haber and W. Scott Stornetta. Their research comprised a cryptographically safe blockchain. Making a chain of blocks by using a different cryptographic technique for security purposes. They both did a lot of research

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TABLE II
ACRONYM LIST

Acronyms	Full form	Acronyms	Full form
UN	United Nations		Healthcare Gateway Data
P2P	Peer-to-Peer Network	EMR	Electronic Medical Records
EHR	Electronic Health Records	MRI	Magnetic Resonance Imaging
PHR	Personal Health Record	IoMT	Internet of Medical Things
PoS	Proof of Stack	IoT	Internet of Things
TPS	Transaction per Second	IT	Information Technology
AION	Australian Institute of Navigation	RFID	Radio Frequency Identification
EOS	Electro-Optical System	WBAN	Wireless Body Area Network
MIA	Management of Identity Access	PSN	Pervasive Social Network
MEDX	MediBlock	ICT	Information and Communication Technology
DCN	Dentacoin	ASCH-IDS	Adaptively Supervised and Clustered Hybrid
SOLVE	Solve	MDSs	Misuse Detections
MTN	Medicalchain		Anomaly Detections
AEN	Aenco	RMP	Remote Monitoring of Patients
SINS	Safe Insure	SCM	Supply Chain Management
HUM	Humans Cape	WHO	World Health Organization
MDS	MediShares	ECC	Elliptic-Curve Cryptography
LYM	Lympo	RPM	Remote Patient Monitoring
FTT	FarmaTrust	HIPAA	Health Insurance Portability and Accountability Act

on it, but they could not succeed then they stopped working on it.

In early 1992, they again started working on it and upgraded their system, and they failed again on it. But other researchers and developers continued working on it to make a secure system by using cryptographic techniques. Different ideas and currencies were invented like in the early days of 1996, e-gold; in 1998, beenz.com was a currency creating a specific motivation in user behavior; in the late days of 1999, Flooz.com invented that is similar to the Beenz model; and in early days of 1999, Internetcash.com was invented that had a monetary system based on prepaid cards.

The Bitcoin era started in 2008 [13]. The name or brain behind blockchain technology is Satoshi Nakamoto (a person or a group of persons) [7]. Bitcoin is a P2P network [14] and decentralized system. Its basic purpose was to send or receive payments to other countries called cross-border payment systems. The first generation of blockchain technology started from 2008 to 2013. It evolves and slowly moves forward, then Bitcoin arrived, and small companies started to use it. Some people understand that Bitcoin and blockchain are the same things. However, this concept is wrong. Bitcoin and blockchain are different things. Blockchain is the underlying technology. We can say that Bitcoin

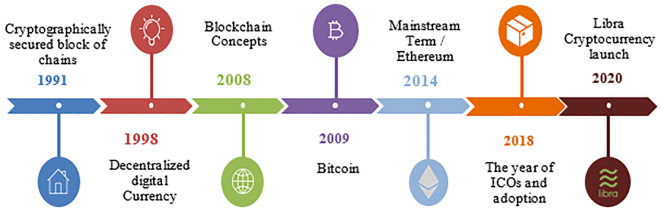

Fig. 2. History of blockchain technology.

is a structure or technology below it. Blockchain handles Bitcoin, e.g., Facebook is an application of the internet; similarly, Bitcoin is an application of blockchain. There are many applications of blockchain in the real world. Many countries adopt it and working on it. Pakistani president initiated blockchain technology and decided to include one year [15].

The second generation of blockchain technology started from 2013 to 2018 with the development of Ethereum. Vitalik Buterin and their team worked on it. If we compare Bitcoin with Ethereum, Ethereum came with more advanced technology than Bitcoin. It gives the concept of Proof of Stack (PoS). It is used for smart contracts. You can contact me on the internet. Many companies used it. You can also use it and launch your projects using blockchain technology. You can make decentralized applications.

The third generation of blockchain technology started in 2018. We can say that we are entering this era, and this is also the future. Create new scalable projects, decentralized applications, and high transaction per second (TPS). Its speed is better than Ethereum. The third generation leading many projects to form the beginning of 2019 is as follows.

1) Cardano is a blockchain platform that includes more advanced features than any other protocol until now. Cardano is just a cryptocurrency, which is used to send or receive digital funds. It is a technical platform that enables financial applications to be run successfully through individuals, organizations, and governments worldwide.
2) Australian Institute of Navigation (AION) is a multitier platform of blockchain. The focus of this platform is interoperability. AION coin works in the same way as Ethereum and Bitcoin.
3) Electro-optical system (EOS) is the newest blockchain project that enters the cryptocurrency market. Its main objective is to build a network capable of millions of transactions processing per second.
4) Zilliqa power is a new application of blockchain that is of high performance, scalable, and provides high security. The history of blockchain from 1991 to 2020 is shown in Fig. 2. It explains all scenarios of how it started using different concepts, and with the passage of time, it replaces with new ones.

A. *Technical Information of Blockchain Technology*

Blockchain is a method of storing data, which makes it very hard to alter, attack, or fool a system. It is a digital log of transactions that is replicated and disseminated across the blockchain's

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complete network of computer systems. Every block consists of a transaction added to each participant's ledger with every new transaction of the blockchain. Distributed ledger technology (DLT) is a decentralized database that various people handle. The properties of DLT include the following: programmable, secure, anonymous, unanimous, time-stamped, immutable, and distributed systems. A blockchain is a DLT in which transactions are recorded using an everlasting cryptographic signature known as a hash. This means that if a single block in a chain is modified, it will be immediately clear that the chain has been dealt with. Hackers would have to change every block across all distributed versions of the chain if they intended to destroy a blockchain system. Blockchains like Bitcoin and Ethereum are constantly growing as new blocks are added to the chain, increasing the ledger's security significantly. Blockchain is a mixture of three cutting-edge technologies: 1) cryptographic keys shared P2P infrastructure, 2) information exchange, and 3) transactions store. Its first part consists of two keys; 1) public key and 2) private key. These keys are used during transactions to provide a secure identity. In blockchain technology, this secure digital identity (also known as a digital signature) is very important and used to control and authorize transactions. The distributed network is combined with the digital signature; many people acting as authorities use the digital signature to arrive at a consensus on transactions and other issues. It is verified mathematically when they approve a transaction, resulting in a successful secured transaction between the two networked users. To summarize, blockchain users use cryptography keys to conduct various digital exchanges across a distributed network. Blockchain improves the trustworthiness, security, openness, and traceability of data shared throughout a company's network while reducing costs through new optimizations.

B. Types of Blockchain Technology

There are various blockchains depending upon the information that is handled, the availability of that data, and the activities that the user can do. These include the following.

1) Public Blockchain: Public blockchains are those anyone can join; there are no participation limitations. Anyone can look at the ledger, read it, write on it, and participate in the consensus mechanism. Bitcoin and many other cryptocurrencies were founded due to public blockchain systems, and it causes widespread adoption of DLT. It also handles certain barriers and difficulties, including centralization and security flaws. DLT distributes data throughout a distributed network instead of storing it in a single location. An agreement is used to certify the veracity of information; two typical consensus algorithms are PoS and proof of work (PoW). Ethereum and Bitcoin are two examples of a public blockchain.

2) Private Blockchain: In a private blockchain system, the network is controlled by a single company. This signifies that the public is not invited to participate. Only the participants involved in a transaction will be aware of it, and no other service providers or participants will have access to it. Private blockchains employ an authentication process to identify which participating member is accessing the platform. As a result, just a few people have access to the system. The Hyperledger Fabric is a well-known example of a private blockchain. Existing participants could decide future entrants, a regulatory authority can grant licenses for participation, or an organization can control future actions.

3) Consortium Blockchain: Consortium blockchains encompass both private and public components, except that numerous companies will manage a single consortium blockchain network. Even though these blockchains are more difficult to set up at first, they can provide greater security when they are fully operational. Furthermore, consortium blockchains are ideal for multiorganization collaboration.

4) Permissioned Blockchain: Permissioned blockchain networks, also known as hybrid blockchains, are private blockchains that grant privileged access to approved individuals. Companies generally designed such blockchains to obtain the perfect combination, allowing for better architecture when determining who may enroll in the system and which transactions they can participate in.

III. Motivations

The motivations in the back of blockchain technology are as follows.

A. Safety and Data Security

The size of digital healthcare data is increasingly expanding, so these data require advanced methods for processing and storing. The most important thing is to guarantee the safety, storage, and transmission of medical data. For this purpose, various studies have been conducted and find that EHR stores patient data significantly and provides better security with blockchain technology.

B. Data Integrity

The other most significant motivation is data integrity because patients are traceable and identifiable from one level to another level. The information built trust among the people. The word trustworthy means precise, reliable, complete, and up-to-date healthcare data. For this purpose, we see a medical insurance storage system that can compromise high reliability to the patients, users, hospitals, insurance providers, and servers with blockchain properties.

C. Data Privacy

The most important thing is the protection of sensitive data coming from unauthorized access. Consequently, the biggest issue with the implementation of healthcare is that personal information was compromised, and private data were leaked. Blockchain maintains considerable attention to privacy due to a decentralized distributed ledger and protects personal data.

D. Authentication

Authentication is a crucial feature of a medical system. Blockchain technology can protect against unauthorized access to the system using data integrity, tracking, and authentication.

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Management of identity access (MIA) will fix issues related to unauthorized access.

E. Interoperability

Healthcare interoperability's main issues are that several healthcare organizations use different data exchange standards in medical, e.g., CDA, FHIR, and HL7 2.x, to share sensitive data between various healthcare practitioners. Blockchain focused on overcoming these challenges by retrieving data through APIs that facilitate data broadcasting faultlessly in EHR communication.

F. Implementation and Efficiency

Blockchain technology has been implemented successfully in several sectors. The information can be effectively collected and implemented in healthcare applications using blockchain technology. Furthermore, the main focus is on the test and implementing such solutions in a real environment.

G. Data Storage

The large amount of data collected from different devices, stores, processes, and security and gain a better awareness of human health. To demonstrate that, blockchain technology can be utilized effectively, store the data safely, and transfer the data in the healthcare organization.

Analysis and discussion: This section covers the motivations behind the use of blockchain technology, which deals with the safety, security, and integrity of shared data for different medical purposes. This part of the article presents data privacy, authenticity, interoperability, and implementation efficiency of the blockchain. Privacy of data is preserved due to blockchain decentralized distributed ledger. Unauthorized access is resisted because of secure and efficient data storage.

IV. Topmost Healthcare Projects in Blockchain Technology Based on Market Capital

Major healthcare projects of blockchain technology, developed in the last three to four years, are discussed as follows.

A. MediBlock (MEDX)

MediBlock [16] is developed by Dr. Allen Wookyun Kho and Dr. Eunsol Lee. It is a safe and revolutionary data platform for healthcare. It provides a facility for patients to get their medical record and share it with researchers and healthcare providers. This platform increases data integrity and security level.

B. Dentacoin (DCN)

Dentacoin [17] is the first blockchain solution in the world of dentistry. It provides dentists with the facility of digital currency and an environment of applications.

C. Solve (SOLVE)

Solve's mission was to decentralize the healthcare administration and its other benefit programs globally.

D. Medicalchain (MTN)

Medicalchain [18] provides a platform to users for sharing their healthcare records with different medical industry stakeholders, such as doctors, pharmacists, laboratories, health insurers, and hospitals, upon their request.

E. Aenco (AEN)

Aenco [19] is the world's first financial solution platform for HealthTech and is supported by its blockchain. It enables healthcare technology sectors and businesses to provide a wide array of impactful real-life applications. It also provides an array of decentralized financial applications to support the business sectors and health tech, users.

F. Safe Insure (SINS)

Safe Insure is a marketplace of decentralized insurance. It stores data of users and insurers to reduce liability, eliminate fraud, and assess risk, resulting in a lower premium. Safe Insure provides modular, personalized, safe data at a low cost. It works on Quark Algorithm, and its max coin supply is 21 000 000 SINS.

G. Humans Cape (HUM)

The humans cape is developing a platform for healthcare data sharing. The purpose of this platform is to develop cures for 7000 incurable diseases all over the world. It collects and compiles individual patients' data in a very systematic way to increase opportunities for clinical participation. Because of humans cape, patients get the motivation to fight their disease as they are highly involved in their treatment.

H. MediShares (MDS)

MediShares is the first global, open-source, mutual insurance marketplace based on Ethereum blockchain. To embed trust into a transaction, it uses blockchain technology. For insurers, it can improve efficiency and reduce operational costs. Anyone can become a part of the mutual aid scheme by joining the MediShares smart contract and profit from it.

I. Lympo (LYM)

Lympo is a mobile health application based on blockchain. It provides a platform for a healthy lifestyle ecosystem. By using this platform, users can monitor their health data and sports. It has a partnership with Samsung health that allows users to withdraw LYM tokens directly to Samsung's blockchain wallet.

J. FarmaTrust (FTT)

FarmaTrust is the most efficient global pharmaceutical tracking system based on "track and trace." It provides security to pharmaceutical companies by eliminating counterfeit drugs and enables the purchase of original medicines online anywhere in the world. FarmaTrust blockchain uses machine learning, Big Data, and Artificial Intelligence to provide efficiency, security, and supply transparency. It is secure, safe, trusted, and

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TABLE III
MAJOR BLOCKCHAIN PROJECTS IN HEALTHCARE—A BRIEF SUMMARY

Sr#	Projects	Market value $US (Bn)	Trading volume $US (Bn)	Twitter Followers
1	MediBloc	0.0250	0.00210	8,374
2	Dentacoin	0.0169	0.00006	20,100
3	Solve	0.1005	0.00709	10,800
4	Medicalchain	0.0025	0.00081	14,700
5	Aenco	0.0076	0.00069	2,953
6	SafeInsure	0.0179	0.00209	971
7	Humanscape	0.0170	0.00012	1,987
8	MediShares	0.0145	0.00108	1,743
9	Lympo	0.0085	0.00014	14,100
10	FarmaTrust	0.0010	0.00005	2,910
11	MediLedger	2003.72	120.92	422
12	Guardtime HSX	N/A	N/A	2,043
13	MedRec	N/A	N/A	1,699

future-proof. Table III shows the different projects of blockchain technology year-wise that are used in the healthcare centers with their market values and trading volume.

K. MediLedger

The MediLedger Network was founded in 2019 by key life sciences and healthcare firms and is managed by Chronicled, a technology company that delivers network modifications and develops applications on top of it. It is a project to create the pharmaceutical industry's first P2P network. The MediLedger Network creates a set of standard, interoperable Protocol Primitives that enable the pharmaceutical business to share data easily between enterprises.

L. Guardtime HSX

Guardtime has released the HSX API platform, which allows developers to create secure distributed health apps. The platform is based on Guardtime's EU-eIDAS certified Trust Service, which provides a single source of truth for data and allows app developers to quickly add features to new and existing health solutions. To address COVID-19-related difficulties, Guardtime is collaborating with governments and strategic partners to build its own solutions on top of the HSX APIs. Contact tracing with privacy protection, immunity passports, early warning alerts of pharmaceutical shortages, the auditable processing of location data, and highly sensitive health are just a few examples.

M. MedRec

MedRec is a free mobile app that allows you to track symptoms, manage prescription plans, and register health data and keep medical papers, communicate information with doctors for remote consultations, and get health advice and news.

Analysis and Discussion: In this section, we discuss the major healthcare projects that have been developed using blockchain technology in the last three to four years. The discussion includes the definitive information, development purpose, users, currency value, and project work. A detailed summary table of these top healthcare projects, including the market capital value, the trading volume, and the social followings, is also provided.

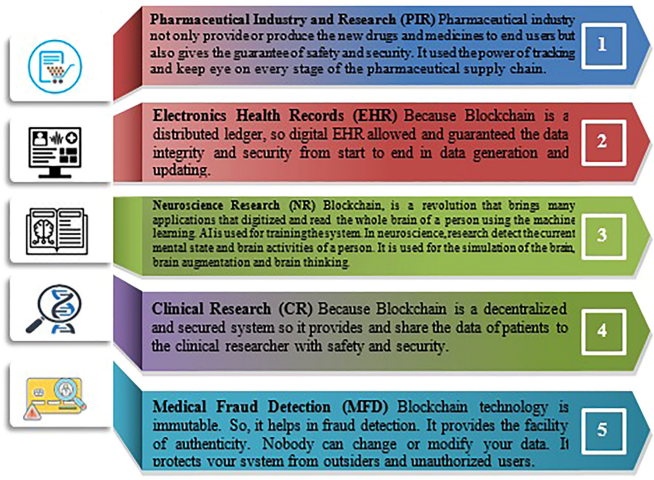

Fig. 3. Applications of blockchain technology in healthcare.

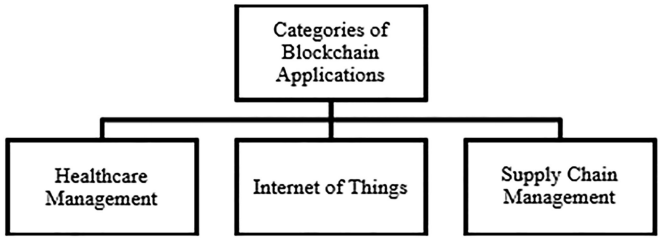

Fig. 4. Categories of blockchain application.

V. APPLICATIONS OF BLOCKCHAIN TECHNOLOGY IN HEALTHCARE

Initially, blockchain technology has been implemented for the best economic and cryptocurrencies performance. Yet, it is also used in many other fields including biomedicine [8], finance [20], government sectors [21], secret data and protection [22], IoT [23], and energy areas [24]. Fig. 3 shows the different applications of blockchain technology that can be used in the field of telemedicine, e-health, genomics, medicine, telemonitoring, neuroscience, customized access to healthcare, and clinical research by establishing safe and secure datasets for users and making different transactions. We can divide applications of blockchain technology into three categories, as shown in Fig. 4.

A. Blockchain-Based Healthcare Management Applications

With the passage of time and evolution in data relating to electronic health, cloud storage data, and patient data with privacy and protection, new opportunities were found in the field of health data management as well as for its user especially for patients to effectively and efficiently store, access, and share data [25]. Data confidentiality, held in the cloud, and making or managing transactions are important parts of an organization, especially in healthcare where blockchain technology handles all these operations through cryptography so that the data can stay safe and secure from unauthorized users.

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TABLE IV
COMPARISON OF DATA HEALTHCARE MANAGEMENT MECHANISMS IN THE BLOCKCHAIN

Sr#	Blockchain Technology	Data Type	Data Sharing	Data availability	Interoperability	Merits	Demerits
1	Platform of MultiChain depends on Private Blockchain	EHR	Privately	✓✓	✓✓	Healthcare data shares and improving the audit logging securely.	There are no anyother cross border country is discussed Excepting for the EU.
2	Private Blockchain	EHR and PHR	Privately	✓	✓	It is based upon Smart App Blockchain that controls and shares healthcare data.	No concern about availability and scalability. Limited data sharing.
3	Consortium Blockchain	Medical records	Privately	✓✓	✓	Provide Signature and Link encryption for robust security.	This system is not fully automatic.
4	Ethereum platform	Healthcare data	Hybrid	✓	✓	The smart contracts are cost-effective.	There is no concept of interoperability among the various parties.
5	Proof-of-work	Location	Privately	✓✓	✓✓	Sharing scheme multi layer location.	No more discussion gives about a patient's critical condition under which location data will be retrieved.
6	Proof-of-stake	Medical image records	Hybrid	✓	✓	The medical images share Safely and Securely.	There is no concern of data searching.

A comparison of healthcare management in blockchain is discussed in Table IV. Blockchain technology, data type, data sharing, data availability, interoperability, merit, and demerits are discussed.

The private blockchain, consortium blockchain, Ethereum platform, PoW, and proof-of-stake indicate the blockchain technologies that preserve records in a way that makes changing, hacking, or cheating the system difficult or impossible. EHR, PHR, medical records, location, and medical image records indicate the blockchain data type used to define blockchain entities in binary forms. Privately and hybrid indicate the data sharing type. The phrases "data availability" and "data interoperability" describe a specific issue that arises in various blockchain scaling solutions. How can nodes be certain when a new block is generated, all of the data in that block were truly broadcast to the network? The problem is that if a block producer does not share all of the data in a block, no one will be able to tell if the block contains a fraudulent transaction. In this article, we look at data availability and interoperability in-depth for healthcare. At the end of the table, we discussed the merits and demerits of blockchain in healthcare centers. For the first time, the main contribution is that we explain everything in this way, which covers blockchain technology, data type, data sharing, data availability, interoperability, merit, and demerits from the perspective of healthcare centers.

Blockchain-based data management system for healthcare offers data between doctor and patient then it is passed out through different procedures and stored in some manners that are shown in Fig. 5. and its working is explained as follows.

Step 1: First, the primary data are generated with the communications of the patient and doctor. This information or data are about patient history, current problems, and medications.

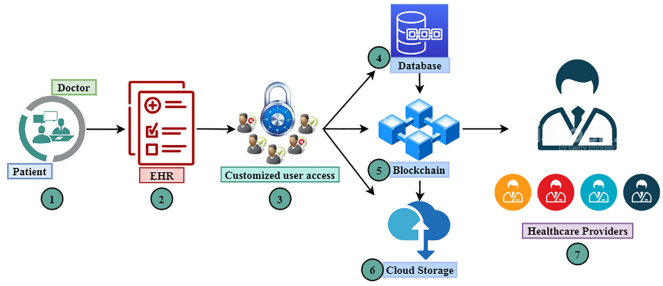

Fig. 5. Blockchain-based healthcare data management system.

Step 2: In the second phase, the EHR collected all information or primary data from the first step, including patient history, drugs, or any other included EHR.

Step 3: The owner of the sensitive EHR is a patient, and the owner also provides customized access control. If someone requires any information, he/she sends a request to the customized access control then the owner decides to give access to data.

Steps 4, 5, and 6: These three-steps are database combinations, blockchain, and cloud storage. Database and cloud storage store the data and information in a distributed manner. However, blockchain technology provides the facility of security and authenticity using cryptography.

Step 7: Healthcare providers are a clinic, hospitals, or other community healthcare centers and end-users that want to access the data with safety and security that will be authorized by the owner by a distributed ledger. Blockchain allows healthcare providers to carry on their work at the moment.

1) Data Management: Every day, many companies, organizations, and institutes, especially healthcare, have been producing or, in this era, generating huge amounts of data, or

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another age such as IoT is getting remarkably large [26], so it is not easy to secure the privacy of data or manage the data. The government and institutes adopt different applications using blockchain technology in this regard. In the following, the blockchain technology highlights its different purposes of development.

MedRec [27] is a decentralized electronic medical records (EMR) management system that permits the record and operation in blockchain and completes the execution through the smart contracts. MedRec connects all suppliers and completes the medical information for authenticity. It provides the facility to its user's immutable data, sharing, auditing, and comprehensive services. Genestier *et al.* [11] proposed a revolutionary concept of reshaping consent policy in the healthcare system that provides the facility to retain or monitor the entire patient records of health by using blockchain technology. However, they do not provide the authorization in this design or implementation.

2) Global Scientific Data Sharing: The sharing of the most important and sensitive health and medical data is a more important step that improves the quality of healthcare providers and makes the healthcare system more intelligent [28]. Data can be shared individually. The patients can share their data with the doctor and can also share their medical history. However, the patients can share their medical records with an organization or insurance company. Sharing could be between individuals or stakeholders. A patient can also share his medical history with the research centers. As the most sensitive data sharing is very difficult, blockchain technology helps in this regard. It plays an important role in enabling and securing a convenient way for sharing data electronically.

Castaldo and Cinque [29] proposed a logging system that would provide the facility to enhance electronic health exchange. The information can be used securely using private blockchain between different countries in Europe. Yue *et al.* [28] proposed Healthcare Data Gateway (HGD) program, which is based on blockchain technology. This HGD keeps the records of healthcare centers or patients safe and secure, and stable, which offers the most effective way to improve healthcare systems knowledge.

Similarly, Fan *et al.* [30] proposed a MedBlock framework that also uses blockchain technology to solve data management and data sharing problems in the EMRs. It makes for better sharing of medical information.

3) Data Storage (Cloud-Based): Nowadays, data are generated in large volumes, and because of their sensitive nature, such as healthcare, it cannot be saved on hard paper or a computer. So, every transaction in healthcare is based on blockchain. A blockchain is a decentralized ledger that stores data in blocks. Healthcare data are stored in HER in an organized way that stores the building blocks of a huge amount of distributed medical storage. It provides security, privacy, and authenticity. Blockchain-technology-based healthcare is an example of IT infrastructure. The advantages of cloud-based storage are that it offers fast communication, good storage space, low cost, data sharing, easy access, and collaborative partnership.

Fig. 6. Electronic health record.

Al Omar *et al.* [31] developed a patient-oriented healthcare data management system by using blockchain in a cloud environment for storage and providing the facility of privacy. The main objective of this technology is that the sensitive data of healthcare keep safe, secure, accountable, and integrable.

4) Electronic Health Record: Conventional medical reports are in hard form like paper for storing the records of patient health status [32]. The doctor or specialist can improve patient health with the help of the history report [33]. So, records on paper are not a proper or efficient way of saving data. Sometimes it is maltreated, and there are many chances that the patients lose their intensive data. Blockchain technology has been developed to provide the facility for EHR to store their sensitive data efficiently and effectively electronically. So, patients may access their data anywhere or anytime without any threat of loss [34]. EHR enables the physician and patient to store their records with security and authenticity, to improve the quality of treatment. Therefore, many researchers are working on blockchain technology to safely, secure, share, and store EHR data within different sectors. For the protection of data, a secure EHR system is developed by using a cryptosystem [35].

EHRs help and facilitate the sharing of healthcare data among different entities, as shown in Fig. 6. Furthermore, they can access, monitor, or exchange information. This strategy enhances the overall system of security and protection from several attacks of unauthorized users.

5) Use Cases of Blockchain in Healthcare Data Management: Health Education: The key application of blockchain technology is like a computer tracking Bitcoin's digital currency transactions, but this system can be used tremendously in the field of education [36]. The cornerstone of education is to share knowledge with the growth of online learning and skills from

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multiple sources. The health education learners can improve their learning, enhance their knowledge, and can have a great impact on multiple generations of learners [37].

According to Funk *et al.* [38] in the profession of education, blockchain technology increases educational efficiency and educational effects on multiple generation learners. The institute provides the facility to its users without evolving the third party. Blockchain technology has a great impact on medical library management in different ways.

Security: Blockchain technology has achieved great importance in healthcare, and it overcomes the safety challenges of EHR in healthcare [39]. EHR has the power to boost healthcare provision [40]. When a patient is admitted to the hospital, the physician checks out the patient and examines the diagnostic results, such as a magnetic resonance imaging (MRI) scan placed on EHR. Therefore, its importance is also increased day by day, such as for storing sensitive data by using blockchain technology for safe and secure healthcare [41]. Due to its importance, only blockchain technology can be used for securing digital information. Moreover, it plays a significant role in the management of client data for the future.

Enrollment Data Management: Blockchain technology is used in the enrollment of members into healthcare plans, healthcare delivery, and important records, and results in the enrollment of administrative data; the basic procedure is to use data created by small, medium-sized, and large healthcare providers such as a government agency, the federal government, and state governments [42]. However, blockchain technology can store this information to check reliability and relevant records in a short period.

Analysis and Discussion: We covered numerous blockchain applications in the healthcare business, important research programs, and future research potential in this article. We discussed current studies on health data management and how blockchain would empower patients and simplify the health data sharing process. We discovered that academics agree that patient data would be owned and controlled by the data's true owner, the patient, with blockchain technology. Patient information can be time-stamped on the blockchain so that no one can tamper with them after they have been added to the distributor ledger. Patients will also have the ability to control who has access to their data and for what reason. However, there are, indeed, a few unanswered questions that need to be investigated further. For example, cross-border health data sharing, when diverse and frequently conflicting governments exist, may obstruct the benefits of blockchain data exchange. Indeed, depending on government rules, individual privacy expectations differ from one nation to the next. Therefore, future study on legislation, standardization, and cross-border health data retrieval rules, including retention and usage intent, is urgently needed. Another possible issue that has yet to be investigated is the blockchain's capacity to store and handle large data access transactions quickly. The latency of mining blocks in private or public blockchains will grow exponentially as the amount of transactions grows. As a result, unique techniques and algorithms are required to reduce processing delays.

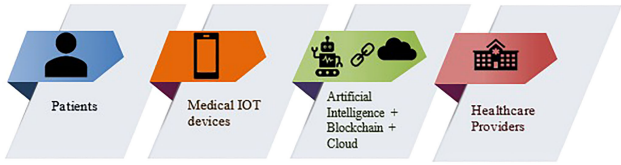

Fig. 7. IoMT in blockchain.

B. Internet of Medical Things

Medical devices and applications connected via the web or online computer networks with healthcare IT systems are called the Internet of Medical Things (IoMT). The basics of IoMT are medical devices that are Wi-Fi enabled and allow machine-to-machine communication that can connect to the cloud platform for data usage. Using these technologies, healthcare devices such as body scanners and heart monitors can capture, store, and exchange real-time data over the Internet. Examples of IoMT include remote monitoring of patients with chronic or long-term conditions. Track medication orders for patients and the location of hospitalized patients. Wearable health devices for the patient can send information to healthcare professionals. Analysis dashboards with sensors that measure patient vital signs and infusion pumps connected to hospital beds are medical devices that can be converted or implemented into IoMT technology.

As with the largest IoT, many consumer mobile devices share information with information technology (IT) systems. Radio frequency identification (RFID) tags can also be placed on medical devices and equipment so that hospital staff can keep track of the inventory. The practice of using an IoMT device to monitor patients remotely in their homes is also known as telemedicine [43]. This type of treatment makes it unnecessary for patients to travel to the hospital or clinic whenever they have a medical question or change in their condition. The following steps can be observed to observe the progress of smart medical devices and IoT healthcare (IoTH) in artificial intelligence.

Step 1: In IoMT, our source of data is patient.

Step 2: Large volumes of data are generated by IoMT devices; they observe patients either attached or remotely.

Step 3: Data that we get from IoT devices are placed on cloud storage or blocks. With the help of blockchain artificial intelligence, it creates virtual agents that will create ledgers autonomously. A decentralized system helps blockchain to reach the highest security in case of sensitive data where security is much necessary [44].

Step 4: End users are the healthcare providers who require safe delivery that is authorized by the owner. Fig. 7 shows the progress of smart medical devices and IoTH using artificial intelligence.

1) Healthcare IoT and Medical Devices: IoT is a kind of computer device with special differentiating qualities, efficient to send data to a network using the Internet Protocol without any interaction between the human and machine. Such a strong, seamless interface makes IoT a big part of the healthcare system [45]. Wireless body area network (WBAN) [46] systems are an important part of IoMT in the

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healthcare industry. WBAN is becoming an important technology for a large number of uses, specifically in healthcare and medical [47]. People use IoT devices for appointments reminders, calories burned, blood pressure changes, and much more.

Advancements in fifth-generation (5G) and beyond communication technology have resulted in the emergence of the IoT applications in a wide range of fields, including business, transportation, health monitoring, manufacturing, and more. The research community faces various issues as a result of these applications. Cybersecurity, reliability, service heterogeneity, privacy, storage, and energy usage are just a few of the challenges. Ali *et al.* [48] emphasize IoT-enabled dependable and secure healthcare infrastructure provision. They proposed a multihop network design problem for the IoT to reduce operational and hardware expenses. Mainly, three evolutionary swarm algorithms implement FOG-assisted IoTH network planning. To objectively examine the performance of the tested algorithms, a *T*-test is used. Their proposed framework is expected for EMR data processing and other healthcare communication that is secure, trustworthy, and cost-effective. Griggs *et al.* [18] introduced blockchain and WBAN integration for real-time secure medical interventions and patient monitoring systems. The customized threshold values that are collected by IoT devices evaluate information through the integration of blockchain. They do that to overcome the logging transfer problem of data transactions in healthcare systems. Rahman *et al.* [49] introduced a smart dyslexia analysis tool with a central Big Data server. It is used to store and then share blockchain with healthcare organizations and individuals. During dyslexia tests, mobile multimedia health data are captured and stored in a large data repository that can be shared for further clinical research and statistical analysis. By using blockchain technology and IoT, Jo *et al.* [50] introduced structural health monitoring for enhancing the scalability and efficiency of blockchain technology; a novel system was proposed. It was divided into core and edge networks to activate its globally decentralized and locally centralized distribution. Zhang *et al.* [51] proposed a securely use model for pervasive social network (PSN)-based healthcare. This model's main purpose is to confirm security by sharing data between the PSN nodes. For addressing this problem, two protocols were introduced by the author. The first protocol is the IEEE 802.15.6 improved version that creates secure connections with unbalanced computational requirements for sensor nodes and mobile devices with limited resources. However, the second protocol is sharing health data between PSN nodes by using the blockchain technique. Ichikawa *et al.* [52] have developed an antitampering framework mobile healthcare system in order to guarantee data fidelity by using blockchain technology. Its main purpose was to develop a mobile health system using a smartphone app for cognitive-behavioral therapy of insomnia.

2) Healthcare IoT Infrastructure and Data Security: The health information and communication technology (ICT) structure consists of IoT devices and networks that include diagnostic tools, terminals, wireless access points, sensors, etc. This design allows portable tools and remote monitoring systems to exchange and distribute data with clinicians about the patient's vital conditions. Data transmits through unknown communication networks (e.g., WAN) during the transmission process that may be vulnerable to privacy violations and security [53]. There are many cases (for example, in Catawba Valley Medical Center in North Carolina three phishing, attacks cost a violation of 20 000 patient data) where malicious attackers tirelessly try to discover any of the severe vulnerability to penetrate the healthcare network and the undervaluation of the provider information [54]. For security challenges in healthcare IoT, researchers protect users' data from illegal hacking by exploring different technologies. Nikoloudakis *et al.* [55] introduced a software-defined network for building a resistant network against malware attacks by virtualizing the network infrastructure into many simplified levels. The authors present the adaptively supervised and clustered hybrid (ASCH-IDS) approach to improve intrusion detection systems (IDSs) on the IoT network, classifying possible disputers from sensory data collection. Two detection subsystems feed different proportions of total sensory traffic: misuse detection (MDSs) and Anomaly detection (ADSs) for performance improvement. On 0.25% sensory data proportions for MD, the system shows excessive accuracy. System performance increases with increased sensory data proportion. To reduce the RFID security vulnerability in IoTH infrastructure, Catarinucciet *et al.* [56] introduced a smart hospital system consisting of a hybrid detection network using a restricted application protocol, an IoT smart gateway, and a user interface to empower patients with a health surveillance system. However, data obtained from IoT systems are stored in a central database, which is likely to be falsified. It can be solved using scattered systems. According to the discussion above, we can conclude that while traditional security systems offer more security, hacking systems cannot be ensured. Many people believe that blockchain is a potential solution, among other advanced technologies for implementation in small and medium healthcare business IoT systems. The comparison of IoT for blockchain technology in healthcare is discussed in Table V. Comparison table discuss blockchain technology, data type, data sharing, data availability, interoperability, merits, and demerits. Proof-of-concept, public blockchain, Ethereum and hyperledger platform. Proof-of-information and private blockchain are examples of blockchain technologies that preserve records in such a way that tampering, hacking, or cheating the system is difficult or impossible. Sensor data, multimedia IoT data, and medical records indicate the blockchain data types that are used to define blockchain entities in binary forms. Public, private, and hybrid indicate the data sharing type. The terms "data availability" and "data interoperability" are used to identify a specific problem that might occur while expanding blockchain technologies. How can nodes be sure that when a new block is formed, all of the data included in that block was broadcast to the network? The issue is that no one will be able to identify if a block contains a fraudulent transaction if the block producer does not publish all of the data in the block. In this article, we examine data availability and interoperability in healthcare in depth. We reviewed the benefits and drawbacks of blockchain in healthcare settings at the conclusion of the discussion. The primary contribution is that this is the first time we have covered blockchain technology, data

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TABLE V
COMPARISON OF IOT MECHANISMS FOR HEALTHCARE IN THE BLOCKCHAIN

Sr#	Blockchain Technology	Data Type	Data Sharing	Data availability	Interoperability	Merits	Demerits
1	Proof-of-concept	Sensor data	Publicaly	✓✓	✓✓	Smart contracts for securely using Integration of WBAN and automatic patient monitoring.	Not efficient for data consumption.
2	Public Blockchain	Sensor data	Publicaly	✓✓	✓	Security of sensor systems in a wireless network robust localization.	In such a huge and complex network, the implementation of Blockchain will eventually be susceptible to malicious attack.
3	Ethereum and Hyperledger	Multimedia IoT data	Hybrid	✓✓	✓	The data is safely exchanged with Remote Health Experts Diagnosis of dyslexia.	Required more time for upload.
4	Proof-of-information	Medical records	Privately	✓✓	✓✓	Increased privacy in medical health forecast model.	Susceptible to attack.
5	Private Blockchain	Medical records	Privately	✓✓	✓✓	Includes Artificial intelligence healthcare systems.	It has contained scenarios for limited treatment.

types, data sharing, data availability, interoperability, benefits, and demerits from the standpoint of healthcare institutions.

3) Use Cases of Blockchain in IoMT: Limited Standardization: Healthcare industries are increasing their speed toward adopting IoMT technology in huge amounts. IoMT provides access to medical services for widespread patient access, as well as healthcare providers. Consistently, it is also the basis for health monitoring applications as wireless devices associated with biosignal capture. As a result, unauthorized transfer of medical data is essential [15]. This issue is caused by high communication protocol heterogeneity, medical devices, and platforms called lack of standardization between IoMT manufacturers. In the current perspective, protection of the above standardized variable transmission medium is difficult. Modern technologies, like blockchain, can be implemented to get access to data transmission over an undefined network as heterogeneous communication. Blockchain performance is not affected by system standards. Moreover, even the intervention data block demands huge computing power and a consensus of 51% between its mining nodes before transmission to the entire network to be added to the chain.

Remote Monitoring of Patients: A remote patient monitoring system (RMP) is a healthcare service technique that allows a client to have a supervised practitioner performs a remote monthly check-up using data given by a remote gadget. The patient's data in this gadget are then sent to a remote location, generally in the cloud, where the supervised practitioner may review it later. The client's data, including stream data, are sent further into the clouds.

Medical Data Management: The use of blockchain technology in healthcare has begun to be examined in a number of pilot projects throughout the world. Last year, Booz Allen Hamilton Consultant in the United States created and executed a blockchain-based pilot system to assist the Food and Drug Admin's Center of Translational Sciences in determining how to employ the technology for healthcare data management. The pilot program uses Ethereum to govern information exchange via virtual private networks is presently being deployed at four large hospitals. The program is based on IPFS, which allows it to use encryption and prevent data duplication by utilizing off-chain cloud resources and cryptographic techniques to enable user access.

Analysis and Discussion: Finally, we discussed how blockchain may be used in IoMT. The healthcare systems of the 21st century will be made up of various technologies that connect patients with their caregivers (e.g., remote healthcare services, wearable gadgets, etc.). These systems continually create data and are vulnerable to malicious attacks while in transit at various layers of the underlying communication network. We covered numerous research papers that suggest tamper-resistant solutions for ensuring the accuracy of health data utilizing blockchain technology. The primary issue, in our opinion, that has to be addressed by researchers is how the blockchain will function in complicated and different communication networks. The IoMT delivery system will rely on communication networks operated by several service providers, each with its own set of data access regulations. We require a study into blockchain techniques that encourage a single global access policy for the whole network if blockchain technology operates in such a scenario.

In the above categories, the first section of blockchain categories defines the different applications of blockchain in management applications regarding different aspects in healthcare. First of all, it tells about different steps performed in data management of healthcare centers by blockchain data management application. It explains how data are shared globally, managed, and stored on cloud storage. After that, its use cases are discussed in healthcare, such as how it is secure. The second section describes the application of blockchain, that is, the supply chain in healthcare. It tells how the data are transferred from the very start to the end of the process of manufacturing healthcare products. It also presents the use cases of the supply chain in healthcare. The last part of the blockchain applications category introduces the IoT and how it is integrated with blockchain to provide data security. It also describes healthcare smart systems' processes and their use for patients and doctors in healthcare centers.

C. Supply Chain Management

Supply chain management (SCM) is designed for good delivery processes from ordering to supply by using best practices of the industry [57]. In healthcare, blockchain is of a challenging prospect, with the scattered ordering of drugs and medical supplies. There might exists a direct impact on patients'

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TABLE VI
COMPARISON OF SCM MECHANISMS FOR HEALTHCARE IN THE BLOCKCHAIN

Sr#	Blockchain Technology	Data Type	Data Sharing	Data availability	Inter-operability	Merits	Demerits
1	Proof-of-concept	Clinical trial records	Privately	✓✓	✓	Enhancement in data processing that improves traceability of consent protocol and transparency.	The relationship between the physical and the digital identities of patients is unclear.
2	Private Blockchain	Transaction records	Privately	✓✓	✓✓	Generating and shifting transparent data of drug transactions from regulation to net surveillance (e.g., govt. audits).	The operational charge is not discussed.
3	Ethereum platform	Clinical trial records	Hybrid	✓	✓	It is based upon smart contracts and make clinical trials more transparent.	Serious concerns can be about Scalability.
4	Ethereum and Hyperledger Fabric	Transaction records the traceability of fake drug	Hybrid	✓ ✓	✓	Using simulated network the system is established.	There is no guarantee that the official distribution chains will not track fake drugs externally.
5	Undefined	Medical Records	Publicaly	✓	✓	It provides better support about precision medicine.	Lack of consistency.

Fig. 8. Supply chain management.

safety. By the World Health Organization (WHO) study, [58], in Africa, by using medicines from untrusted vendors, more than 100 000 people die [15]. Blockchain is an important technology for medical products and drug movement in the whole process. Blockchain technology works for creating a network of trusted vendors to protect patients from fake suppliers [59]. Using blockchain technology, pharmaceutical SCM can be explained in Fig. 8 and its comparison is discussed in Table VI. Blockchain technology, data type, data sharing, data availability, interoperability, merits, and demerits are discussed. Proof-of-concept, private blockchain, Ethereum platform, Ethereum hyperledger, and fabric platform are the blockchain technologies, which preserve records in a way that makes changing, hacking, or cheating the system difficult or impossible. Clinical trial records, transaction records, and medical records indicate the blockchain data types that are used to define blockchain entities in binary forms. Private, public, and hybrid indicate the data sharing type. The phrases "data availability" and "data interoperability" are used to describe a specific issue that arises in various blockchain scaling solutions. How can nodes be certain that when a new block is generated, all of the data in that block were truly broadcast to the network? The problem is that if a block producer does not share all of the data in a block, no one will be able to tell if the block contains a fraudulent transaction. In this article, we are looking at data availability and interoperability in depth for healthcare. At the end of the table, we discussed the merits and demerits of blockchain in healthcare centers. The key contribution is that for the first time we are describing everything in this way that covers blockchain technology, data type, data sharing, data availability, interoperability, merits, and demerits in the perspective of healthcare data centers.

1) Clinical Trials: Clinical studies face other issues, such as patient data protection [60], [61]. To overcome these problems, blockchain technology is being used. It gives the facility to share data that will provide transparency [60]. Choudhury *et al.* [15] introduced a blockchain-based data management system. The purpose of this article was to lessen the burden of administration, effort, and time.

2) Pharmaceutical: Many pharmaceutical companies are trying to introduce new medicines as well as improving the quality of existing medicines. For the safety and protection of patients, these medicines are required to go through a lengthy process [62]. Years pass in the completion of these processes. As a result, such a long process can be malicious. This hurdle can be removed by using blockchain technology in a complete pharmaceutical process. By using a distributed ledger, we can ensure security and privacy [62].

3) Use Cases of Blockchain in SCM: Quality Management: Medicines are considered to be harmful if they contain improper ingredients. In SCM, the efficiency of these drugs is the main factor [63]. Customers using these medicines are not aware of their exact source and quality and using malicious drugs is a big threat to patient's life [64]. This can also threaten the original pharmaceutical companies' repute. Blockchain technology authenticates pharmaceutical manufacturer companies' data by using product serial numbers or package numbers to solve these challenges.

Claims and Billing Management: The healthcare industry is worth a cost of millions of dollars, and each healthcare service has its own cost that is increasing gradually [65]. The medical billing process is an important part because proper delivery of services cannot be ensured without this. This billing process starts with patients' admitted time to the patent's checkout time. This requires several steps and the whole scheme can be challenging due to a lack of confidence and accountability among doctors. Claiming and the blockchain transparency factor can solve insurance issues in the healthcare organization. Blockchain involves all stakeholders in the systems and ensures transparency [66].

Supply Chain Finance (SCF): There has been a lot of buzz about blockchain and supply chain finance (SCF) solutions since they can improve vendor payment efficiently and deliver more reliable and secure payments. Vendor payment periods are

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TABLE VII
OPPORTUNITIES AND CHALLENGES IN BLOCKCHAIN NETWORK

Sr	Opportunities	Challenges
1	Transparent	Interoperability
2	Reduced Transaction Time	Scalability
3	Secure	Storage
4	Cost-Efficient	Social Acceptance
5	Irreversible Transaction	Requires Standardization

typically 30 days but can be considerably longer. You may use a consensus protocol to trigger immediate payments when the product is delivered and signed for by merging supply chain financing with DLT.

Supply Chain Logistics (SCL): Contact is a key issue in contemporary supply chains with several grabs, so much backward and forward between participants. As a result, instead of communicating directly with each other (e.g., suppliers, providers, and customers) through third-party businesses. As per DHL, blockchain in SCL promises that operations may be validated, documented, and organized automatically without the involvement of third entities, removing a whole degree of complexity from global supply chains.

Analysis and Discussion: We reviewed the latest blockchain studies in healthcare SCM—The potential for blockchain to alleviate trust erosion and improve data openness in clinical trials, in particular. Several scholars advocate using blockchain to improve the scientific legitimacy of clinical trial outcomes, which can be harmed by issues such as missing data and selective reporting. We also talked about drug tracking; blockchain technology will be a critical tool for pharmacists and healthcare professionals to accurately and quickly validate the flow of authorized pharmaceuticals and their delivery to patients. However, more research into reliable monitoring techniques to monitor product registration is required. Current tracking systems that depend on RFIDs and Barcodes are vulnerable to tampering since these codes are delivered as fixed values in the SCM, which scammers can alter or copy. Other scenarios, such as billing and payment administration, were proposed as potential study topics in this report. Claims and billing in the healthcare industry are often misused; however, they may be handled or reduced by implementing a transparent system like blockchain.

VI. RESEARCH CHALLENGES AND FUTURE DIRECTION

Some of the challenges identified in developing blockchain-based applications consisting of interoperability, scalability, privacy and security, speed, and patient involvement [67]. Interoperability is the exchange, communication of data and information between different software applications and the use of exchanged data. A major challenge for blockchain-based healthcare systems is scalability, especially in the large volume of data. This can cause performance degradation by process delay if there is more load of data. To involve patients in managing their data health is also a challenge, as some elderly or young are not interested or able to participate. Table VII explains the opportunities and challenges in blockchain network.

A. Security and Privacy of Data

For the security and privacy of blockchain-based healthcare applications, it is considered that despite the encryption techniques that may be used, it may still be possible to disclose the information of a patient in a public blockchain by linking together adequate data to which they are associated [30]. Furthermore, it can be said that there is still the potential risk of security and malicious attacks by criminals on the healthcare blockchains or even by government agencies that can compromise the security of patient's private data. Many cases of attacks like that and the power of these attacks on different networks blockchain cryptocurrencies. Private keys that we use for data encryption and decryption can also access healthcare data unofficially.

B. Managing Storage Capacity

Blockchain storage is storing data on a localized network by using unused disk space [68]. The localized infrastructure can solve many problems of a centralized system and is an alternative to a centralized cloud. In blockchain, large volume of data storage leads to low performance. So, managing storage in blockchain healthcare systems cause a scalability challenge.

C. Interoperability and Scalability

Blockchain projects are separated from each other, working with the same technology. Interoperability [68] in the blockchain is the exchange of data between different blockchains as if there are no boundaries in the blockchain that is challenging for effective data sharing.

Another challenge for the blockchain system is scalability due to increasing overhead and computational resources in IoMT devices [69]. Because rapidly increased number of system participants. This challenge could lead to the entire blockchain infrastructure to computational requirements. If several smart devices or sensors exist, then the situation becomes an increasingly tough issue because these devices have less computational capabilities than the average computer. In a blockchain network, the IoT devices are high-demand computations, which comprise high overhead bandwidth and significant processing power.

The most prevalent DLT scalability strategies are based on sharding, which divides the complete number of trades into smaller divisions. In 1988, the term "shard" was used to describe the use of additional hardware to allow data duplication. In DLT, sharding generally refers to horizontal segmentation, in which records of a database are maintained independently by several servers, constituting a single partition. Numerous blockchain projects, including Ethereum, Zilliqa, and Polkadot, presently focus on sharding methods. Besides that, the IOTA ledger's directed acyclic graph (DAG) topology is an ideal starting point for creating a scalable DLT. A DAG-based system avoids the theoretical congestion in the blockchain; all messages must be ordered in their entirety, resulting in inescapable protocol frictions. There seems to be no central authority in IOTA that determines the generation of the next block of transactions. IOTA is also a leaderless protocol. Every node can have a different vision of the ledger state while still agreeing on which

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transactions are legitimate and which are not. In conclusion, all messages in IOTA equal speedier completion.

D. Related to Computing Power Limitations

In the blockchain, data are gathered through IoMT devices that are often computationally, and power is limited. The mechanisms of cryptography are not being used. Many applications are related to health-used cryptosystems with resource-constraint devices that handle sensors and mechanisms of security. They have very limited computational resources regarding processing power and memory. So, they opposed modern secure public-key cryptography schemes. In blockchain, the majority prefers and utilized public-key cryptosystems that are based upon elliptic-curve cryptography (ECC) [70]. It also lacks efficiency and security issues, so it is very difficult and challenging to select the appropriate cryptography.

E. Related to Blockchain Size

When different devices handle transactions like EHR and IoT-remote patient monitoring (RPM) [68], blockchain continually becomes complex and requires the use of powerful miners. The conventional resource limitations of IoMT devices are not capable of managing even the nominal size of blockchains. So, in this regard, compression methods should be studied in the blockchain with alternative methods, like miniblockchains.

F. Related to Latency and Throughput Restrictions

Much will take time for any agreement on blockchain technology and validation of any transactions. In healthcare applications, this leads to a problem that performs different events and collects real-time implementation data. In transaction delay cases, the blockchain takes time to process transactions [71]. For instance, the Bitcoin latency time in blockchain needs 10 min to validate any transaction in the network. There are five or six blocks to be added to the chain before any transaction and confirmation are made. The recommendation is to wait around an hour for each transaction to be confirmed. In comparison, many conventional database systems need just a few seconds to validate a transaction. The RPM and EHR in IoT, based on a usually needs to handle large transaction volumes per second. So, blockchains are a big challenge. Throughput is also a necessary factor to be considered in the selection of the appropriate blockchain for IoMT utilization.

G. Standardization Challenges

Blockchain technology is still in its infancy. It is also in the direction of realistic application in pharmacy, pharmacy, and healthcare. Sure, it will face many challenges of standardization. There are several numbers of accredited standards, and global standardization organizations will need to provide well-authenticated standards. These standards are very helpful that are predefined to evaluate the size, format, and nature of data, which exchanges information in applications with blockchain. Such requirements do not only analyze shared data but also act as precautionary protection measures, in essence.

H. Uncertainty and Data Ownership

The concept of blockchain is not extensively used. There are only a few successful enterprises that are based on modern technology at this time. So, it is a major obstacle because we do not have various successful blockchain replicas to follow, creating undefined circumstances.

Who is the owner of healthcare data? Who will permit access and share it? That kind of department or organization or procedure has not yet been established.

I. Cost

The cost or charges of maintaining and establishing a healthcare blockchain are not known until now. Nobody can be serious about this type of technology without knowing about its charges and expenses at that time.

All transactions contain a blockchain fee for high-speed Bitcoin conversions and trades. Although the fee is normally minor, higher fees may be required to complete the transaction or exchange. The question is why this occurs and how to prevent paying large blockchain fees in the future. So, the cost of transactions on the blockchain is determined by several factors, such as network oscillations, transaction confirmation delays, and transaction volume. In other terms, if the blockchain network is currently busy or overloaded, you may have to pay greater blockchain charges. The charge rises in response to rapid blockchain rate swings and important global events. Your cryptocurrency account has a record of microdeposits. If your account has a lot of little payments, your transactions will be larger since it will have a lot of entries. The blockchain charges rise in proportion to the transaction volume. The following is common recommendations for lowering cost in blockchain for the masses.

1) Aggregate all microdeposits in a different third-party account, and then transfer a greater sum to Wirex in one operation. This will help you save money on future trades and transactions by lowering the blockchain charge.
2) If you are used to transferring tiny sums regularly, using greater quantities may be beneficial.
3) Keep track of the network's median blockchain fee. You can wait until the median charge amount reduces if your transfer is not time-sensitive. This information can be found on large Bitcoin trading, block searchers, and websites like BitcoinFees.

J. Rules and Regulations

There are no proper rules of regulation available for the use of blockchain in the healthcare department. It is also undefined as to how new policies are concerning healthcare. Blockchain will follow current privacy rules and regulations such as the Health Insurance Portability and Accountability Act (HIPAA) act [72].

K. Implementation and Data Handling in Healthcare

Blockchain implementation in healthcare necessitates the best infrastructure and interconnections, which the establishment cannot bear and afford easily. If healthcare data are not managed,

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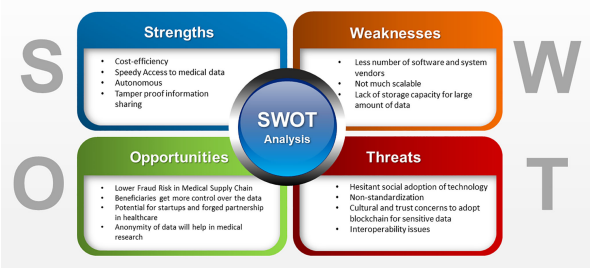

Fig. 9. SWOT analysis of blockchain technology.

recognized, predicted and organized correctly, then the data collected may be going under incorrect hands.

L. Knowledge Gap Increases Technical Barriers

To successfully implement blockchain technology in the healthcare department, correct and decent infrastructure, interconnectivity, technicians, and experts are required. Although the prominent issue is that people do not know much and have enough knowledge about blockchain technology completely, this is the big and most challenging aspect.

M. Social Challenges

Blockchain technology faces social challenges like a cultural shift. Adopting other than traditional technologies is not quite easy. Slow adoption of technology and policies are not trustworthy. It is time to move from paperwork to technology. For further understanding, we have depicted an SWOT analysis approach [73] that shows in Fig. 9.

The following research directions may also be adopted.

1) There is a need to contemplate the practical issues regarding the implementations of blockchain technology in the future.
2) It is also required to investigate how blockchain technology might assist in securing the integrity of medical data.
3) A key concern is finding suitable technical personnel who can install, manage, and handle technical challenges connected to blockchain technology.
4) Latency problems caused by transaction processing speed and off-chain data load should also be examined.
5) It is also needed to deal with data storage capacity and standardization.
6) Furthermore, scalability and interoperability concerns are also important considerations for current and future research.

Analysis and Discussion: In this part of the article, we discuss the challenges identified during the implementation of blockchain-based applications. Data handling, size of the blockchain, data ownership, throughput restriction, knowledge gap, social challenges, standardization challenges, storage capacity, security of data, scalability, cost, and implementation of blockchain technology are some common challenges faced by blockchain technology. We discuss these challenges with the future directions that can be opted for improvements in current studies.

VII. Conclusion

The current work of blockchain technology is important in all fields of life. Adopting this technology provides a transparent and secure process with good quality at less cost. Its dispersion, audibility, continuity, and anonymity features can transform the healthcare industry. This article aims to identify the present state of blockchain research, use cases in healthcare, as well as applications that are being established for all these use cases, research challenges, and the future direction of blockchain in the healthcare industry. To achieve this objective, we have reviewed multiple studies and classified them into three main categories, i.e., healthcare management, IoT, and SCM, based on blockchain applications in healthcare. Our focus is to discuss all aspects of blockchain technology in healthcare. For this purpose, we explained major healthcare projects, motivations behind this technology, healthcare applications, and its use cases with all strengths, weaknesses, and challenges. The use cases of blockchain applications, including SCM, electronic medical records, remote patient monitoring, and health data analysis, are discussed. According to our observations, blockchain development and use in healthcare are on the rise. Blockchain research in healthcare shows that it is usually utilized for access control, data sharing, and EHRs, but it is rarely employed for other situations like medicine prescription management. As a result, much of blockchain's potential remains unexplored. Moreover, technical details related to blockchain technology are not discussed before, which we have elaborated on in this article. Future research guidelines are provided for further improvements in the existing approaches.

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