Chapter 8
Blockchain-Powered Smart E-Healthcare System: Benefits, Use Cases, and Future Research Directions

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Abstract Blockchain technologies are deeply distributed and used in several dominions, including for E-healthcare. Internet of Things (IoT) strategies can arrange real-time sensual information from patients for their treatment. Composed information is aimed to combine for computation, dealing, and storing. Such centralism can be challenging, as it can be the only reason for lack of success, uncertainty, document management, interfering, and confidentiality elusion. Blockchain is able to resolve these kinds of consequent complications by giving distributed computation and proper storage for IoT data records. Consequently, the mixture of blockchain technologies in healthcare can convert into a realistic selection for the scheme of distributed Blockchain-powered smart E-healthcare systems. This paper discusses the background of blockchain technology with its features and categories. The paper explores the collaboration of blockchain with IoT for E-healthcare. Further, this paper highlights some popular consensus algorithms used in blockchain in the circumstance of E-health. Finally, this paper examines some use cases of E-healthcare that illustrate how key characteristics of the IoT and blockchain can be leveraged to maintain healthcare facilities and environments.

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M. A. Ahad et al. (eds.), *Enabling Technologies for Effective Planning and Management in Sustainable Smart Cities*,
https://doi.org/10.1007/978-3-031-22922-0_8

Keywords Blockchain · E-healthcare · Data management · Internet of Things (IoT) · Security · Data analysis

8.1 Introduction

E-healthcare programs or E-healthcare systems are planned to fulfil our healthcare desires, and the necessity for efficacy is growing because of aged people and their movement [1]. For illustration, the current eruption of the 2019 fresh coronavirus (2019-nCoV, also acknowledged as SARS-CoV-2 and COVID-19) determines the significance of sharing data records in real-time. Healthcare styles i.e. Mobile Healthcare (MHealth) and Worldwide Healthcare (WHealth). Whereas mobile and Internet-enabled devices that are mobile and available everywhere (such as Internet-based Medical Devices (IoMD)) have contributed to faster, more effective, more economical, and have also carried new tasks [2] like the most important task in electronic healthcare is the safety of IoT devices, blockchain devices and health statistics substructure. With the advent of IoT and the proliferation of healthcare occupied devices and requests (applications), a large sum of medicinal data is noted down and transmitted hourly, daily, weekly, and so on. Present E-healthcare systems face problems such as collaboration, lengthy procedures, process and diagnostic delays, information sharing delays, high operating costs and procedures, time-consuming and cost-effective insurance procedures, secrecy, safety, data possession, and data mechanism [3].

Blockchain medical devices can support the collection of important patient's information, programmed workflow, deliver the best information about disease indications and mechanisms, contribution to enlarged long-lasting care, and provide better control on patients' treatment to improve their health [4]. With IoT-blockchain-based devices, patients are observed in real-time without any movement of patients as well as doctors. The visits of hospitals and hospital stays or the cost of admittance can be reduced by the E-healthcare system. Blockchain-enabled medical devices can help diagnose using warnings and trigger alerts before they become critical [5]. Sensors implanted in several portions of a patient's medical equipment, may collect and refer information to a hospital, where the physician may diagnose the irregularities. Unquestionably, the growth of blockchain with IoT has managed to the sustained invention in the healthcare sector. Conversely, safe management of *Electronic Medical Records/Electronic Health Records* (EHR/EMR) has turn out to be a major challenge as data is still being distributed to various medical institutions [6]. Most surviving healthcare systems are at risk of single failure and information leaks due to increased cyber security attacks [7]. Leaks of patients' personal and sensitive information can lead to serious follow-up. Likewise, present medical systems fail to provide transparency, reliable tracking, consistency, auditing, secrecy and safety, while handling EHR/EMR [8]. Bearing in mind these challenges in current healthcare systems are very problematic, but blockchain technology can solve them [9]. It is projected that blockchain acquisition could lead to savings of money up to

$110–$160 billion per year by 2026, saving in data breach and reduction of fraud and fake products [10].

In terms of licensing management, the blockchain is distributed into four main classifications; Public blockchain, Private blockchain, Consortium blockchain and Hybrid blockchain [11] are explained in a further section. Depending on the unambiguous needs or circumstances of the use case, health administrations may use any category of blockchain to create a network as they all have their own advantages as well as disadvantage. Blockchain is an auspicious technology that can help simplify health information management tasks by giving unparalleled data efficacy and forcing trust. It proposes a variety of outstanding and built-in characteristics, like shared stowage, transparency, consistency, authenticity, the flexibility of data access, centralized communication, and security, enabling greater use of blockchain technology for healthcare data management. Blockchain uses the idea of smart agreements that introduce terms and circumstances where all healthcare associates elaborate in the network are granted upon, so no mediator is needed. It decreases excessive managerial costs [12]. Furthermore, a summary of the involvement of this effort is enumerated as below:

- The work discusses the background of E-healthcare system and its application.
- The work highlights the development, simple functioning, features and categories of blockchain in detail.
- The work redefines the inspiration for blockchain incorporation with IoT to form an E-healthcare system that eases medical facilities.
- The work explores some recently proposed consensus algorithms and use cases of E-healthcare system based on blockchain technology.

The remainder of the paper is organised as follows. Section 8.2 elaborates the background, features, application and categorisation of blockchain for E-healthcare. Moreover, various blockchain consensus algorithms in E-healthcare are described. Section 8.3 described the benefits of blockchain in healthcare data management. Section 8.4 defined some related use cases of E-healthcare system based on IoT-blockchain technology. Section 8.5 deliberates some recent case studies and ongoing projects towards the blockchain technology that collaborates in E-healthcare. Section 8.6 discusses some future research directions. Finally, the paper concludes with Sect. 8.7.

8.2 Background and Application of Blockchain for E-Healthcare

In this section, the background of blockchain is explained in corelation with its numerous applications that help to build an E-healthcare system to reduce overall cost and offer safety by providing untouchable treatment to the patient by doctors.

8.2.1 Background of Blockchain

Blockchain is a rising list of data, termed as blocks, interconnected through cryptographic techniques. All blocks carry the cryptographic hash function of the preceding block. In easy terms, by blockchain technology consumers can easily convey the data as of A to B in a completely computerized and harmless. One transaction event promises the procedure by building a safe block. This block is validating by lacks of successful transactions, can be millions in count, of a computer that is distributed over the net. A fresh certified block generates a series, which is deposited above the internet, not only creating a distinctive record but a distinctive record with a distinctive history [13].

- Blockchain technology: A blockchain is a public record of everything that has been done (like Bitcoin and Ether) that has been already implemented and sucessful. These ledgers of previous trades call it as a block chain, like a series of blocks. It is constantly evolving, as miners add new blocks to it to keep track of all the latest developments. Blocks are always added sequentially and in chronological order to the blockchain [14].
- Blockchain Mining: Blockchain Mining is the process of addition in record transactions to a public/private blockchain ledger. A blockchain mining worker is connected to a node, for instance, a participant of the same set-up with the ability to authorize a transaction in a particular type of contract.
- 51% Attack*:* 51% attack on blockchain technology talk about a miner or a crowd of miners trying to take access of more than 50% of the grid's retrieving authority along with computer energy and hash function. The individuals in control of such retrieving authority can prevent new transactions from mishappening [15].
- Intelligent Contract: A program developed to obey certain computer principles to facilitate digital work, to verify, or to prosecute partnerships or implementation of contracts. Intelligent contracts allow for unresolved, reliable, complex and tracked transactions without any involvement of third parties [16].

8.2.2 Blockchain Features for E-Healthcare

Some features of blockchain are discussed below that make blockchain so famous and successful in providing security in such an easy way.

- Decentralization: Transferring technology contributes to the ability to store all services (like agreements and official papers), which says that they can be retrieved via the internet. At this time, the owner takes complete access to his/her account; means that the owner having a power to transmission his/her services wherever he/she wishes [17].

- Transparency: Blockchain transparency is based on the statement that the capture and execution of each societies address are exposed to the public. All information used to recognize the consumer is kept protected.
- Blockchain is virtually impossible to break: In the out-dated networks all data files are in one unit so it is easy to modify or discard by attackers. But in blockchain all data files are not in one unit, due to this feature of blockchain, it is difficult to hack as each official call testifies to countless locations of the system.
- Secured: All the internal and confidential data records are remained protected by using encryption or decryption techniques.
- Immutability: If the data record is stowed in a block, then that data record cannot be altered by anyone. Even consumer has not the power to change it during transmission. If any blunder happens during the transaction, a new transaction must be performed to undo that blunder. At that point, both transactions are visible so that blunder and correction can be seen properly [18].
- Blockchain provides encoding, authentication and confirmation: In blockchain technology information is encoded, unchanged and it is already proven that all single data of the blockchain is completely encoded and signed digitally.
- No Third-Party: Distributed feature of the blockchain technology creates it an organisation that doesn't depend on third-party companies; no third-party, no added risk. Blockchain technology is an independent system i.e. not any need for a third person. All the transaction and communication is done between two required persons without any additional interference of any person, no third party, and no additional danger.
- Fewer Scams: Since the blockchain structure works on algorithms, there remains very little chance that people will cheat on you with anything. No one can use the blockchain to their advantage.

8.2.3 Categories of Blockchain

At present-day, there are four natures of blockchain systems, i.e., public, private, consortium, and hybrid. Furthermore, this section discusses all the natures of blockchain in detail.

- Public blockchain: This category of blockchain does not have any kind of restriction applied to it. Every single person can easily connect to the public blockchain through the internet and can do any kind of transaction. Also, it can serve as a main validator (contributing to the competence of the compatibility algorithms of blockchain). Public blockchain tend to depend on commercial motivations to protect the structure over the actual and best use of an exceptional type of consensus algorithm for compliance [19].
- Private blockchain: This nature of blockchain is repeatedly referred to as permitted, i.e., an individual essential to be requested by system superintendent of blockchain, where the job of all involvement and validator stays much constrained.

The association and applications that need treating delicate data records, record-keeping is chosen in particular that prefer a privately approved approach to blockchain infrastructure [20].

- Consortium blockchain: Defined as a semi-dispersed blockchain, in which numerous administrations collectively decide to simplify blockchain service delivery to consumers. Therefore, the permissible approach is modified over consumers while placing rights limitations above the blockchain structure [21].
- Hybrid blockchain: Illuminated as a collection of public and private blockchain system services. Hybrid blockchain is used for legitimacy where public and private data can able to access in the collection is infinitely installed over the consumer. Therefore, the consumer on this blockchain might be granted or able for free access depending on the precise suggestions as required by the application [22]. The differences between previously mentioned categories of the blockchain-based on some properties are shown in Table 8.1.

8.2.4 IoT and Blockchain for E-Healthcare

IoT is an Internet connection grant for mobile devices and daily use objects. Internet connection and other kinds of hardware are bound electronically, and this device can be monitored as well as remotely controlled for further communication and interaction. Specified the strong needs of IoT webs, the blockchain appears to be the most suitable for both; may protect the whole network from fraudulent data attacks and can provide a protected environment for all devices on the web. The boundaries of existing models and the capabilities of the blockchain-based E-healthcare IoT model are discussed [23].

- Most recent used IoT systems are built into a client-server model, where everything is recognized, validated, and associated to cloud hubs that require a large

Table 8.1 Difference between categories of blockchain

Properties	Private blockchain	Public blockchain	Consortium blockchain	Hybrid blockchain
Speed	Fastest	Slow	Faster	Slow/faster
Effectiveness	High	Low	High	High/low
Immutability	Yes	Yes	Yes	Yes
Centralised	Yes	No	Partial	Depend on nature
Read agreement	Public/limited	Public	Public/limited	Public/limited
Consensus process	Permissioned	Permission less	Permissioned	Depend on nature
Consensus determination	One organisation	All miner	A selected set of nodes	Miner/one organisation
Network	Partially decentralised	Decentralised	Partially decentralised	Depend on nature
Asset	Any asset	Native asset	Any asset	Native/any

volume of processing and stowage dimensions. In accumulation, if the IoT devices are nearby to another IoT device then communication among these devices must pass through a channel over the internet. Conversely, this model is used for small IoT set-ups, it is not able to measure well [24]. Likewise, the cost of setting up a lot of network connections, central cloud storage and connecting all the tools is important for large IoT systems. In contrast to cost, relying on cloud hubs creates the infrastructure vulnerable to a distinct point of failure. Besides, IoT devices can survive the attack on data and physical modification in data. While selected some recent methods make IoT devices safer, those methods are composite and inappropriate for resource-inhibited IoT devices along with restricted controlling power [25].

- Blockchain launches a peer-to-peer set-up, which reduces the rate of installing and maintaining intermediate clouds, hub systems, record centres, and communication apparatus by sharing computer and storage needs all across the network's devices. One point of failure problem that arrived earlier is now resolved by the communiqué model. Using encryption and decryption algorithms, blockchain addresses all the confidentiality concerns and provides full security to IoT networks. Similarly, it solves the issues of reliance in IoT networks by using interfere-resilient records [26].

Figure 8.1 introduces the standard construction of the IoT-based blockchain structure for E-healthcare. The properties are divided into four functional categories named: IoT E-healthcare, the blockchain environment, communication and IoT devices. The blockchain environment plays a main role in the blockchain data distribution inside the IoT system also in numerous facilities such as law enforcement, buildings and authentication. Investigators believe, using two-aspect and multi-aspect schemes to prove the authenticity of the object, as described consistently. Both certification schemes will allow blockchain site users to interact well with blocks while marking actual certification. Therefore, surviving cyber-physical communication will be brighter and more understandable. The proposed structures have been proven to be better suited to the IoT-based blockchain-centric surroundings [27]. Table 8.2 provides a comparison of blockchain platforms in the state of IoT-based healthcare.

8.2.5 Blockchain Consensus Algorithms in E-Healthcare

In blockchain, consensus is used to deliver a contract between all blockchain nodules. For different cryptocurrency consensus procedures are many types. A list of selected consensus algorithms is declared as follows. These consensus algorithms could be used in various use cases of E-healthcare specifically in E-health facility provisioning [28].

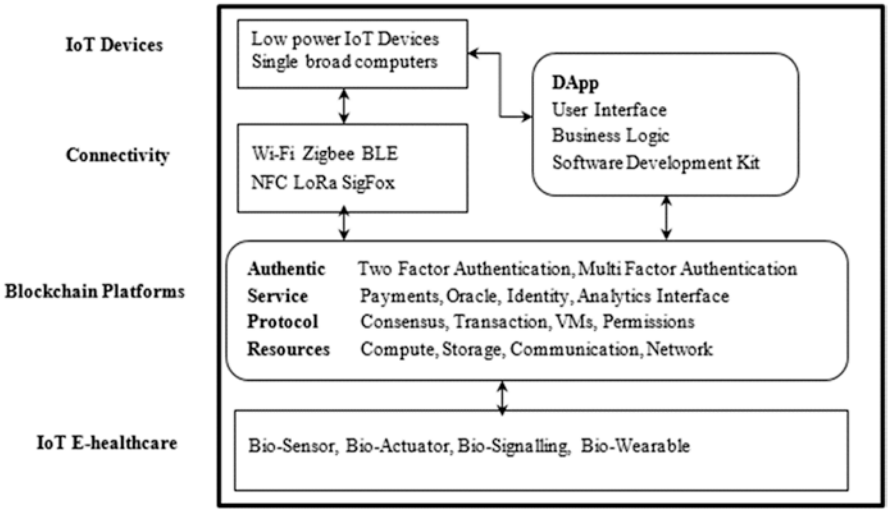

Fig. 8.1 Architecture of IoT for blockchain e-healthcare

8.2.5.1 Proof of Work

This impression was designed and accessible in 1993s magazine article. Originally named and legalized in the 1999, Proof of Work (PoW) is too recognized as the following: *Central Processing Unit (*CPU) charge utility, customer riddle, computer riddle, and CPU estimating function. Not suitable for IoT due to the need for extraordinary grid bandwidth. As PoW is widely used on various platforms, there remains an intermediate chance of finding PoW that is hidden in healthcare services [29].

8.2.5.2 Proof of Stake

Proof of Stake (PoS), Node is selected by random to resolve the succeeding block to mine. There are no mining coin production rewards available but are pleased lone by contract fees. The nothing at stake issue might reason behind the re-awarded of a node in the same contract fees. We accept that it can be used as an effective communication tool for E-health requests [30].

8.2.5.3 Delegated Proof of Stake

Delegated Proof of Stake (DPoS), it is a popular PoS perception, in which network operators do polling and select representatives to verify the succeeding block. It makes for quick transactions but is more expensive to refer to in the middle. A

Table 8.2 Comparison of blockchain environments for IoT-based E-healthcare

Platforms/Features	Qtum	EthereumM	Neo	Wanchain	Lisk	Ark	Eos	Straits	Waves
Symbol	QTUM	ETH	NEO	WAN	LSK	ARK	EOS	STRAT	WAVES
Consensus	PoS	PoW/PoS	dBFT	PoS	DPoS	DPoS	DPoS	PoS	LPoS
Block time in second	120	15	15	Not found	10	8	0.5	60	3
Transaction per second	70	15	1000	Not found	5	25	100K	20k	100
Smart agreement	Yes	Yes	Yes	Yes	In evolution	In evolution	Yes	Yes	In evolution
Atomic switches	Yes	Yes	No	No	No	In evolution	No	No	In evolution
DApps	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Side cables	Yes	Yes	Yes	Yes	In evolution	Yes	No	Yes	In evolution
Software Development Kit (SDK)	Yes	Yes	Yes	In evolution	In evolution	In evolution	Yes	Yes	Yes
Smart agreement language	Solidity	Solidity	C#, Java, Python	Solidity	JavaScript	JavaScript	C, C++	C#, .NET	Scale
Smart agreement	Yes	Yes	Yes	Yes	In evolution	In evolution	Yes	Yes	In evolution

protocol for identifying and selecting a dangerous mediator exists. Therefore, it can be used in healthcare situations with the great openings [31].

8.2.5.4 Leased Proof of Stake

Leased Proof of Stake (LPoS), PoS permits for the resolution of state difficulties in areas with low stabilities and contractual agreements, and divides recompenses per prosperity management. Agree to token owners to "rent" their tokens to complete nodes and receive a pay-out percentage as compensation. In a standard pole authentication platform, each nodule is capable to combine a fresh block to the blockchain. By using such algorithm, the best E-health facility can be maintained [32].

8.2.5.5 Proof of Importance

It is an enhancement of PoS. Checks the equilibrium of network's nodes and the status of nodes. It remains a highly productive set-up. By way of Proof of Importance (PoI), the nodes prerequisite to enter the amount of money to be eligible for the creation of blocks and are nominated to create a block equal to the school that limits their contribution to the network. We agree to use E-healthcare services as physicians' statuses can be demoralized to assist in choice-creating of patients [33].

8.2.5.6 Practical Byzantine Fault Tolerance

Practical Byzantine Fault Tolerance (PBFT) every node of the network could take part in the elective procedure to enhance the subsequent block. Additional 2/3 nodes' agreement is essential. This knowledge is virtuous for remote blockchain and efficient as well as healthier as compare to PoW and PoS. Likewise, it has little broad-mindedness in contradiction of malevolent nodes. We would help it for pretentious usage for E-health facilities [34].

8.2.5.7 Delegated Byzantine Fault Tolerance

It is a development of PBFT. There are additional methods to enable blockchain. Delegated Byzantine Fault Tolerance (dBFT) is a process used to implement an arrangement that makes it difficult to accept blockchain and cryptocurrency. It is a complex idea that not appreciated like PoW or PoS. Nodules are selected as messengers of another place. Therefore, it appears that E-healthcare facilities can-not be fully functional when using dBFT in IoT-blockchain infrastructure [35].

8.2.5.8 Proof of Capacity

It is an enhancement above PoW. Proof of Capacity (PoC) is a valid algorithm used in blockchain that allows mining devices on the system to use their accessible hard drive area to determine mining rules and secure transactions. It desires to accumulate big data to mine blocks following other nodes. Not worthy of the IoT. It is not suggested to be used for blockchain based health-care services [36].

8.2.5.9 Proof of Activity

Proof of Activity (PoA), it is a combination of PoW and PoS. PoW is completed before. After that, a team of verifiers' symbols is composed to enter a transaction in the minor's heads keep an eye on by the PoS. Not appropriate for IoT due to prolonged interruptions; therefore, it is not a worthy selection for E- healthcare [37].

8.2.5.10 Proof of Burn

Proof of Burn (PoB), it talks about distributing coins to an invalid statement. Many hot coins organise for the miner to go to the mine. It is ready for the formation of cryptocurrency and not for IoT because of its pecuniary and financial structure. Because of its improper combustion method, it is not appropriate for health-related applications [38]. A comparison of all the interviewed algorithms discussed is presented in Table 8.3.

8.3 Benefit of Blockchain Technology in E-Healthcare Record Administration

Various benefits of using blockchain technology in E-healthcare record administration are discussed in the subsections below.

8.3.1 Health Records Exactness

Patient medicinal data is often distributed across multiple locations, medicinal care facilities, and assurance suppliers. To obtain all relevant patient medicinal olden times, all sections of patient information prerequisite to be compiled in a computerised fashion. This can be accomplished by keeping whole patient medical information (such as, his or her documentation, symptom details, curing process, developed properties, payment details, and some additional statistics) in a continually

Table 8.3 Comparison among various blockchain consensus algorithms

Characteristics	PoW [29]	PoS [30]	DPoS [31]	LPoS [32]	PoL [33]	PBFT [34]	dBFT [35]	PoC [36]	PoA [37]	PoB [38]
Self-conscious	No	No	Partial	Partial	No	No	No	No	No	No
Flexibility	High	High	Med	Med	Med	Low	Low	Low	Med	Very low
Acceptance	Very high	Very high	Med	Med	Med	Low	Low	Low	Low	Low
Ease of access	Exposed	Exposed	Exposed	Exposed	Exposed	Prop	Prop	Exposed	Prop	Prop
E-health sustenance	Med	High	High	High	High	High	Low	Low	Low	Low
IoT acquiescent	No	Partial	Partial	Partial	No	No	No	No	No	No
Simple idea	CPU	Stake	PoS	PoS	PoS	67% node	PBFT	PoW	PoW-PoS	Burn coin
Liveliness	Very high	Med	Med	Med	Med	Low	Low	Low	Med	High
Illustration	Bitcoin	Etherium	Bitshare	Waves	NEM	Hyperledger	NEO	Burstcoin	Bitcoin	Slimcoin

up-to-date blockchain, tracked, and records disruptive. This supports healthcare professionals to provide patients with effective, timely, and appropriate care. Healthcare suppliers can have a comprehensive representation of the medicinal history of patients using blockchain technology. All information stored in the blockchain is undeniable, recognizable, noticeable, and protected [39].

8.3.2 Health Records Interoperability

Collaboration speaks to the capability to exchange statistics amid programs, developed by unlike constructors. Maximum EHR/EMR goods are constructed on a variety of scientific technologies, mechanical stipulations, and operational competencies. Such variations postpone the creation and sharing of facts in a single set-up. In the best instance, single-built EHR structures are unusable because they are designed to meet the specific needs and preferences of a health organization. For the two EHR systems to work together, the transmission of messages must be based on standard coded data. However, the lack of standard data is a serious problem that binds the ability to share information electronically inpatient care. This limit can be overcome by using a blockchain-based healthcare data management system. All HER/EMR stored in a blockchain system follows a standard data code, so it can be easily accessed and used in any area related to healthcare [40].

8.3.3 Health Records Safety

In the past, numerous healthcare administrations have condemned victims to preventable cyber security attacks. A huge amount of healthcare activities used hands-based infrastructure systems to manage digital medicinal accounts. These organizations are out-dated, so they can be effortlessly replaced for fake purposes. Likewise, health records may disappear in the event of usual disasters since the focus is on one area of failure. Blockchain can support eliminate the risk of data theft or abuse of the static aspect of cryptographic terms. The health data stored in the blockchain is also protected from injury from natural disasters or medical facility failure because the same data is stored in multiple locations, so there is no significant point of disappointment [41].

8.3.4 Health Data Managing Costs

Extraordinary managing cost connected through patient documents records recovery and data transmission is one more main anxiety upraised by existing healthcare systems. Patient medical prescription is divided towards numerous health services.

Gathering comprehensive medical prescription and data logs of the patients from verbal or unsystematic hospital data administration schemes can lead to extra time and charges. Blockchain technology can aid to decrease the managerial price modelled by third person associations in existing healthcare systems. Similarly, it empowers elastic access of data files to the patient medical prescription, which is collected and stowed from several foundations, likewise patient records, private carry able and hand handling expedients. Towards this mode, blockchain can contribute to decreasing the expenses of medicinal corporations since they can straightforwardly operate far-reaching patients' data files deprived of moving to various positions wherever these data files used to be deposited [42].

8.3.5 Worldwide Health Records Distribution

In some medicinal emergencies, a systematic awareness of past medical history is required before any appropriate medical treatment. For instance, a patient with a serious illness has travelled abroad, and he may need to consult a physician in a situation of a crisis. In this case, the medicinal specialised will regularly need a patient's previous data to provide healthier and qualitative health facilities. A patient's past medicinal records can assist physicians to evaluate a variety of factors, such as past medical history, details of drug and drug allergies, and previous treatment records, which can lead to the development of more effective treatment strategies. On the other hand, most of the present health managing networks are based on personal and preventive measures, and therefore do not suggest worldwide accessibility and tracking structures [43]. These structures can be accessed via blockchain machinery.

8.3.6 Enhanced Healthcare Records Audit

Audits are performed in the healthcare industry to determine whether or not compliance with policies, processes, guidelines, protocols, and rules set by health facilities. The audit procedure helps to assess the efficiency of the healthcare acquiescence system through systematic and targeted valuation [44]. Many modern health data organization systems are hands-on and absent of brainy integration and assimilation purposes. Besides, they are at risk of document openings and illegal modifications. As a result, such restrictions interfere with the audit procedure and its excellence. Blockchain technology enables healthcare professionals to achieve their data in a secure, confusing, and sustainable technique, thus demonstrating the reliability of the health information. This allows examiners to effortlessly validate communications made on blockchain structure. Blockchain-based healthcare testing can help advance the excellence of patient services, as well as preserving health facilities in line with important lawful necessities. Likewise, it may aid to escape needless data breaks [45].

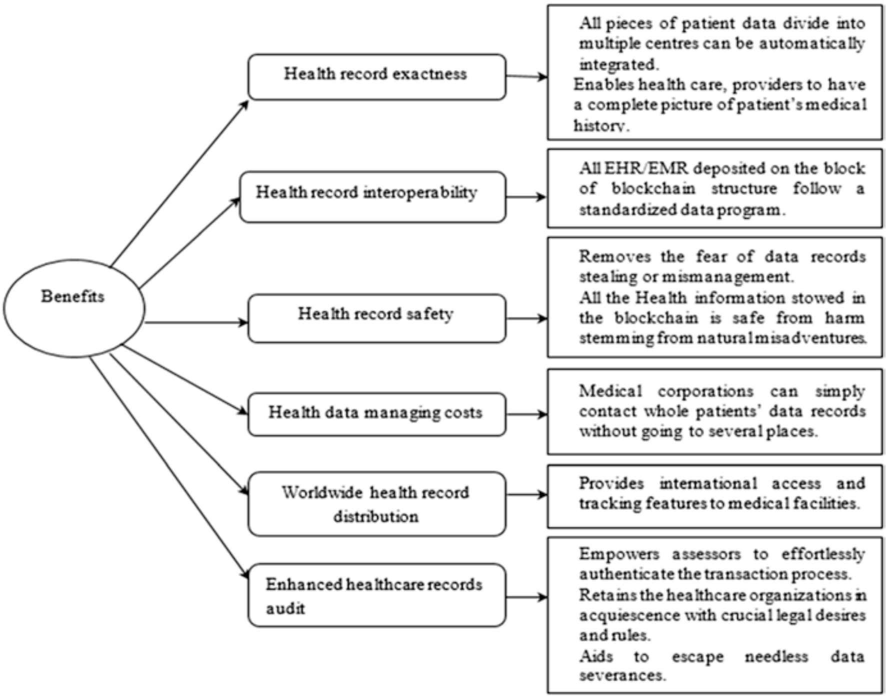

Fig. 8.2 Benefits of leveraging blockchain technology for E-healthcare record administration systems

Figure 8.2 summarizes the key reimbursements of leveraging blockchain technology for E-healthcare record administration.

8.4 Use Cases of E-Healthcare System

These are some use cases of E-healthcare system based on blockchain listed in subsection that is very important and mandatory to fulfil all the use cases required to generate a successful E-healthcare system that based on blockchain as well as IoT.

8.4.1 Medical Record Access

A mixture in a healthcare incrusted environment is projected relating to a smart meeting organization, patient-driven interactions and blockchain incorporation in a composite IoT-based methodology. The art of architecture can serve the patient through interferences from the Local Health Organization (LHO) or healthcare administrations, in established professional contracts [46]. Business integration is done within n number of healthcare organizations, where patient-determined and blockchain-based is integrated seamlessly with IoT-grounded sensor, actuator, and facilities. A Patient-Based novel Applications Programming Interface (APIs) can be used to obtain patient EHR data from such administrations. The patient is enabled by smart indentures to approve the distribution of EHR amongst 1 and n organizations, where past business associations may not exist. The blockchain layer lastingly adheres to all rules relating to permission, the patient's public key, and EHR access data logs. Many organizations can accomplish the intelligent communication of a patient's public key to their private patient company individually while exercising whole liberty for patients to access their EHR data [47].

8.4.2 EHR Claim and Billing Valuation

Fake claims and billing are the utmost important sufferers in E-healthcare that requisite to be escaped and rejected. Such deceitful payment-linked actions occur in the general health sector. Claims relating to the charging of unused E-healthcare facilities, overpricing of real E-health facilities, misuse of non-medical E-health amenities of a patient, improper representation of unattended healthcare services often lead to such actions. While the surviving situation permits mediators to verify and adjudicate information related to a claim, it does not have active communication amid the person elaborate in the payment of the bill. The IoT-enabled blockchain E-healthcare ecology can support alleviate much of these challenges by making the required workflow and allowing teams to distribute a solitary replica of business deal and agreement statistics while claiming litigation and payment procedures are not fraudulent [48].

8.4.3 Medical Research

Medical trials necessitate highly targeted patient records. The procedure of integrating patient data identification takes a lot of time and determination, therefore, a great increase in costs. The main experiment in determining the accuracy of the results of basic clinical examinations depends on the findings of analysis and availability of a huge patient database, which essential to be recognized [49]. Meta-investigation is similarly required in the next stage of practice, which requires ensuring that the mainstream of E-health customers are prepared to give their EHR with medical examination and studies, as long as confidentiality and confidentiality are preserved. That kind of power-saving effort can be seen in building a blockchain, with excessive transparency. A full-fledged E-health patient could use IoT formats to publicly convert and confidentially store EHR data with the help of a combined hybrid blockchain. One can use a hybrid key encryption technique to give

Distributed Ledger Technology (DLT) to simplify safe clinical information between community-based research and community-based study. IoT blockchain-based patients can quickly access and manage their EHR and open up the rights to allowance or rescind EHR-data access to the medicinal maintenance public, thereby providing greater sustenance to medical organizations to access DLT with more accurate EHR data with complete clinical data [50].

8.4.4 Drug Supply Chain Administration

Each and all year, huge numbers of patient's pain or expire from the use of counterfeit drugs. Next to similar, pharmacists are experiencing huge financial and psychological losses as a result of that drug. From drug production to the patient, the procurement procedure may include the succeeding categories: transference, management, storage, redistribution and marketing. The situation may be tense because of human error or the target's behavior. In its place of using the out-dated procurement management system, the creation of an IoT-based blockchain can take part in this procedure to make every step visible. Drug purchase records can be easily incorporated into a blockchain DLT that is perpetual, stable, and enabled to debug. Therefore, the risk of fraudulent activities can be completely reduced [51].

8.4.5 IoBHealth

Researchers introduced the formation of an E-healthcare structure based on IoT united with blockchain (IoBHealth) data stream to simplify all-in-one incorporation between IoT and blockchain for the provision of health-related facilities. This agenda contains three key sub-methods: IoT-constructed health administrative nodule, IoT-blockchain structure and IoT-built healthcare patient's nodule. Nodule of healthcare suppliers and patient nodule these two nodules of blockchain used. Both of these nodes are intended with the support of an EHR appliance, a back collection, a gate caretaker and a cryptocurrency user. Nodes are permissible to accumulate certain service information and transaction data [52].

8.5 Recent Case Studies

This segment deliberates the recent case studies and on-going real-time projects in the direction of the disposition of blockchain technology worldwide. The main purpose is to demonstrate how blockchain technology has been leveraged to convey inventions and evolutions in relation to healthcare data administration.

8.5.1 Estonian E-Healthcare System

The speedy invention in calculating techniques besides employment of E-explanations has transfigured Estonia's health organisation. In Estonia, 95.98–98.99% of patients have electrical health documents (like medicaments, their inquiries, and payment information) that can be chased and retrieved authoritatively through the E-patient online portal. An E-portal empowers a surgeon to access patients' records (medical reports and X-rays) from one file [53]. In 2016, the Estonian administration originated a blockchain-based assignment to protect the health data records and network access of its 1.5 million occupants. The purpose of the project is to stock record files that support maintaining a track status of all data handling happenings achieved on the health records. Key welfare of blockchain technology may be to reduce the danger of data breaks due to a mischievous hacker or a fake insider in the healthcare region. A personal digital block ledger was used to keep an eye and timestamp every minute to retrieve the patient's medicinal data records. Cryptographic hash functions generate an immutable review track of patient personal data. The assignment has the capability to attain the objective of having real-time attentiveness of the truthfulness of stowed patient personal data, which allows superintendents to recognize violations and act on time to restrict harm. Additionally, it improves the cost-efficiency, strength, and efficacy of Estonian healthcare systems in a way to be distributed, safe, translucent, interfere-proof, irreversible, and perceptible [54].

8.5.2 Healthcare and Pharma Data in UAE Using Blockchain

The UAE Ministry of Health and Prevention (MoHAP) has declared to introduce a platform based on blockchain for stowing healthcare data (such as healthcare services, medicinal physicians and medicines). The main concern of the platform is to increase stowage and toughen data safety in nationwide health organisations. The structure constructed on a blockchain is projected through examinations aimed at healthiness doctors, their medicinal warrant data, pharmacological documents, and MoHAP's application to government and private facilities. This application is similarly predictable to offer the utmost trustworthy and irreplaceable pharmaceutical facts in relation to industrial, permitted mediator, vigorous material, and charge. MoHAP's solutions could be leveraged to keep noticed data logs of health employees and administrations, bring about relaxed authentication of government institutions. In addition, it supports increasing records authentication plus stability, additional implements a higher level of transparency also faiths in the healthcare area. Grounded on unchallengeable records, all healthcare suppliers may have admittance to dependable data that helps in making suitable conclusions. Besides, MoHAP's resolution can help systematise working procedures and expand stability and functioning competence [55].

8.5.3 *Medical Device Tracking in Swiss Hospitals by Permission Blockchain*

Swiss hospitals have seen several embed and fake scams in current decades. On the way to overwhelm such matters, Swiss hospitals have designed a healthcare system constructed on blockchain that permits well-organized and reliable chasing of medicinal strategies. On an agreement basis among hospitals, all connections are stowed in the blockchain in an unchallengeable and noticeable method. This stage is grounded on hyper-laser technology allowing a blockchain. All communication formats of the transaction are associated with the Global Standard 1 (GS1) (Switzerland: GS1FG EDI 3.1 XML). Not like out-dated structures, this substructure removes the requirement of a third person when gathering medicinal strategies. Every dealing phase in a stockchain is stowed in the blockchain network atmosphere. The specific recogniser of every medicinal expedient permits the blockchain to create it noticeable, thereby enlightening patient security. The platform based on a blockchain allows incorporation amongst all performers (from producer to clever logistics, and data records) into the stock chain, creating it conceivable to create a safe and detectable stage for medicinal strategies in Swiss hospitals [56]. A summarised view of the above discussed cases is presented in Table 8.4.

8.6 Future Research Directions

The pragmatic study in the collected works is regularly around the plan and training of blockchain environment or structure. On the other hand, understudied regions continue, which need further study to resolve the present challenging problems already put on the blockchain-based healthcare system to real-life systems [57]. For this objective, fresh investigation in *Artificial Intelligence* (AI), Machine Learning (ML), fog computing, big data, data analytics and cloud computing can be co-operative through the distributed perception of blockchain. Likewise, some worries in systems constructed on the blockchain, the stress-free guideline in addition to normalization of these organizations.

8.6.1 *AI and Data Analytics in Combination with Blockchain*

Uniting blockchain technology with AI technology as well as data analytics can support in transformation of medicinal cure choices, health research, and clinical trials. Healthcare seeks to combine blockchain and AI to expand records administration and medicinal cure decision constructing. The accurateness and legitimacy of expectation are discussed, and extra deep investigation is required. One key challenge in implementing blockchain with AI in the healthcare environment is the

Table 8.4 Recent case studies of E-Healthcare

Case studies	Year	Description
Estonian E-health system	2016	Estonia stayed the first country in the universe to execute the EHR structure, recording almost every history of the population since birth to death Estonia used its surviving digital software identified as X-road to build the EHR system The Estonian program was supervised by the Department of Public Affairs till Estonia was established at the Health Foundation. Meanwhile, its inception, 95% of health information has been used The cost of this program was € 7.50 for a single individual at the period of formation
Healthcare and pharma data in the UAE using blockchain	2020 (accessed)	The key apprehension is to improve data security in health systems across the country This system will support and protect a consistent, fragmented and encoded record with great safety to ensure data accuracy and dependability Medical information based on drug inhale by community and reserved hospitals and healthcare workers can be noted on the MoHAP blockchain such as this one is there so that the public can be used
Medical device tracking in Swiss hospitals by permission blockchain	2020 (accessed)	Swiss hospitals have developed a healthcare system that is grounded on blockchain that allows for systematic and trustworthy monitoring of medical equipment The structure is centered on hyperactive record machinery All types of transactional messages comply with the GS1 standard Distinct out-dated structures, this organisation removes the necessity for the third person during the collection of medicinal equipment
Patientory Decentralized Application (DApp) solution	2020 (accessed)	Patientory has industrialised an application-sharing solution named DApp, which uses a reserved blockchain to offer elastic access to EMR in a collaborative and safe method Confirms that whole business deal or sharing of records have proof of interference and are consistent DApp is an essential healthcare resolution, also an exceptional instrument for handling appropriateness and nutrition

phonological to social changes of EHR structures worldwide. The conversion of medicinal information as of one phonologic to alternative is remaining a challenging task in medicinal exploration and medical trials. Conversely, if universal structure files and infers reports for alike analysis and cure, AI methods like ordinary philological handling and other data analytics resolutions make more real transformation or explanation of medicinal policy approaching from surgeons in diverse nations may facilitate.

8.6.2 Parallel Blockchain-Based Healthcare Organizations

Additional future investigation way for healthcare systems constructed on the blockchain is to design then implement corresponding healthcare systems in conjunction with blockchain's distributed independent bodies to integrate parallel healthcare systems and dissimilar healthcare dominions. Altogether healthcare groups, together with patients, medicine stores, hospitals, billing, health administrations, medicinal scholars, healthcare associations, and health assurance corporations, participate in the "Co-proprietorship, Co-creation and Co-distributing" of the Decentralized Parallel Healthcare Organizations (DPHO) ecology. The grouping of equivalent blockchain, healthcare structures, big data and data mining allows for an authoritative medical cure decision sustenance device.

8.6.3 Cloud Computing in Combination with Blockchain

Another most significant task of blockchain is to properly manage the enormous quantity of data records that are produced and protected hooked on every node of a network. A growth in the total amount of network nodes and communications will strengthen this experiment; added, IoT strategies had not sufficient computing ability and storing capability. Hence, one important future indicator is to reduce the volume of data manufactured or increase accessible stowage volume and further research on improving the mining process with power, time, resources and the use of new technologies in IoMT devices to expand computer energy and speed. Numerous scholars have deliberated the effectiveness of cloud and fog computing in healthcare system dominions. Other investigations have similarly established healthcare organisations that manage data extra efficiently as well as securely in healthcare using cloud computing.

8.6.4 Healthcare Regulations and Standardization Based on Blockchain

Presently, designers and scientists are going in the direction of designing. On the other hand, some blockades derivative from the absence of standards and authorized control creates through designed structures even more interesting and problematic. There is a silent controlling challenge for illuminating the relations of usage and instruct all related peoples of real-world systems. Due to, cross-edge distribution of EHR, wherever repeatedly varied and self-contradictory authorities may reduce the profits of blockchain data records distribution. Thus, developing a compliance code becomes a most significant future direction, containing united rules, normalizations, and cross-edge guidelines for smearing a blockchain to all definite healthcare dominion. Also, controlling barricades alike Health Insurance Portability and Accountability Act (HIPAA) are compulsory to guarantee the suitable usage of records though attacker can interrupt developing determinations.

8.6.5 Development of E-Healthcare System Considering Blockchain

With the growth of research on merging AI, edge computing, cloud computing, deep learning and blockchain, several additional entrances will be exposed to numerous dominions, containing healthcare study. Besides the continuing investigation, many essential stages to be followed however, emerging healthcare applications that built on blockchain, counting the succeeding.

- Examining the key features of the exact system of healthcare dominion centred on a blockchain.
- Threat examination of the use of blockchain locally and universally.
- Trade-off examination of blockchain uses.
- Smart agreement expansion

8.7 Conclusion

The paper explored how blockchain and IoT technology could be used to expand E-healthcare programs and facilities. Blockchain is a novel branch allocation that can renovate out-dated trades into a safe and reliable organization. Existing safety, confidentiality, and collaboration concerns in out-dated healthcare systems have enlarged the ability to use blockchain in this dominion. EHR is a key area where blockchain can be used to resolve data administration and uniqueness administration. In other healthcare facilities, the blockchain can be used to recover the efficacy and excellence of procedures at a low cost. Thus, this paper discusses a brief background, features, categories and application of blockchain. Furthermore, the paper enlightens the need for collaboration of blockchain with IoT to provide an improved E-healthcare system. Additionally, the paper elaborates some famous consensus algorithms used in blockchain in circumstance of E-healthcare system. Moreover, the paper deliberates the benefit of blockchain technology in healthcare data management. Besides, some use cases are systematically specified to demonstrate how some important structures of IoT with blockchain can be leveraged to sustenance E-healthcare facilities and ecologies. Finally, the paper presents some recent case studies along with some future research directions. In addition, we want to study more in this domain and will provide enhanced version of security with proper collaboration and adoption of new technologies along with ease.

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