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**A survey on adoption of blockchain in healthcare**

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## A survey on adoption of blockchain in healthcare

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**Abstract:** In this technology and automation era, blockchain technology travels in the direction of consistent studies and adoption in different sectors. Blockchain technology with a chain of the block provides security and establishes a trusted environment between individuals. In the past couple of years, blockchain technology attracted many research scholars, industrialists to study, analyse and apply the technology in their own application needs. The major advantage of blockchain technology is the security, user privacy preserved, transparency. The purpose of this proposed paper is to provide a survey on blockchain scope in healthcare providing high security of patient health information's during sharing and their impact to reduce the operational and capital investments. Also, this paper briefs on the new business opportunities in the health sector integrating blockchain technology.

**Keywords:** healthcare; blockchain; patient health records.

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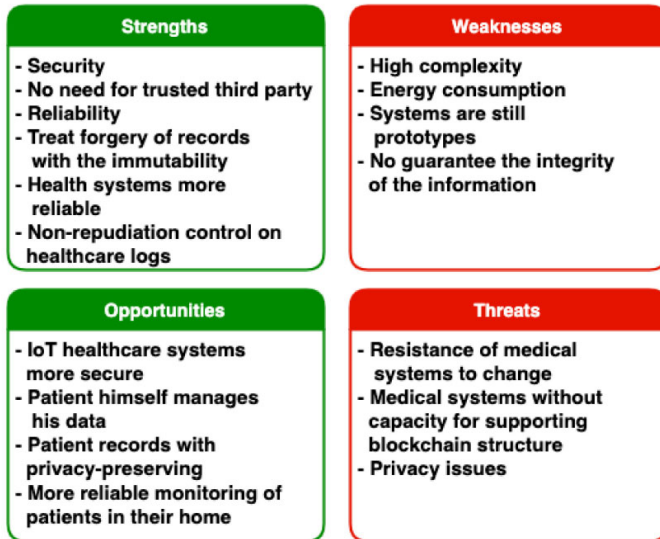
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## 1 Introduction

The current trend towards a digital world in healthcare paves way for a generation of huge electronic health records (EHRs) for patients. This sudden increase of electronic healthcare data asks for user privacy and protection of patient’s health data during transmission. Patients confidentiality and integrity has to be maintained, hence this demands blockchain technology-based data transmission over the traditional approach of encryption techniques (Michael et al., 2018). Blockchain technology provides an open mechanism for storing and transmission health data addressing data privacy, security problems in healthcare (Lee and Pilkington, 2017). Also, the emergence of smart health devices demands security issues to be addressed gaining user trust, and show the strength and weakness in blockchain technology as Figure 1.

**Figure 1** Strength and weakness in blockchain technology (see online version for colours)



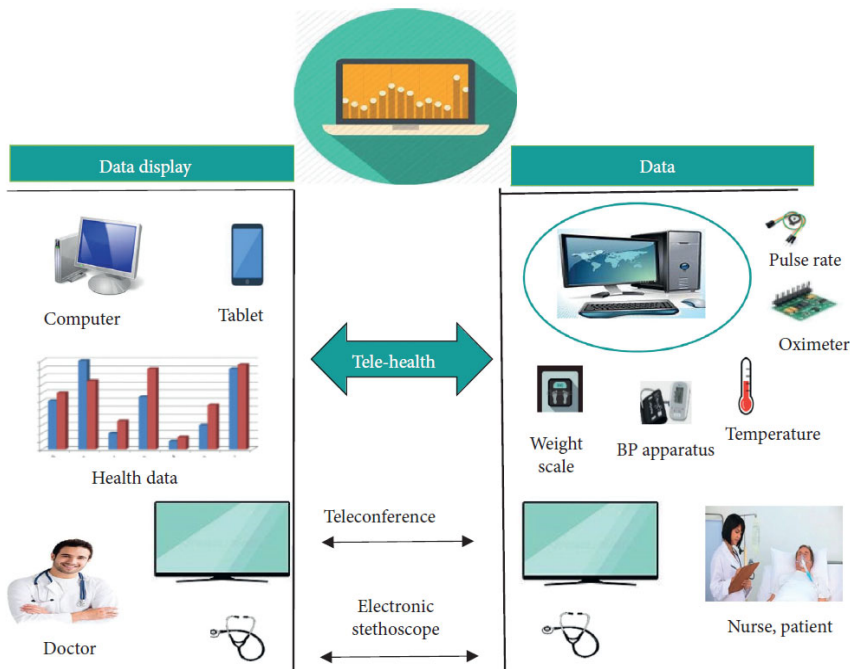
Source: De Aguiar et al. (2020)

In the traditional approach, EHRs are paper-oriented and have to be maintained manually with care. It is the biggest challenge to preserve it from damage and this traditional approach does not invoke a consolidated chronological-based approach to view the patient history easily. This provides to the doctor and healthcare providers a good clarity on patient drugs, allergic which avoids maltreatment. Thus, EHR-based chronological approach provides efficient disease management for the doctors. Also makes the decision-making easy and accurate.

As we evolve in a data-driven world, blockchain technology has gained attention from various industries and academicians in the past couple of years. Every sector is trying to adapt blockchain for securing their data. A distributed ledger is a significant part of blockchain technology for peer-to-peer (P2P) networks (Yaeger et al., 2019). In this, the data transmission would be distributed publicly or privately to all users connected within the network. Before the transaction or generation of the block, every type of data would be analysed and verified (Macrinici et al., 2018).

A smart contract is also considered to be an important part of blockchain technology. Smart contracts are nothing but a customised set of rules according to the application which is been agreed by each party (Andoni et al., 2019). These smart contracts are applied in different industrial areas like energy, finance, election, the supply chain for production companies, etc., and healthcare (Treleven et al., 2017). Thus, blockchain reduces the overhead cost for the management team rendering transparency, security eliminating third-party administrative expenses.

**Figure 2** Process of healthcare data (see online version for colours)



The usage of consensus methodology and cryptography is also an important factor in blockchain technology (Pilkington, 2016). This is used to verify the confidentiality of the transaction within the trustless network environment. As we know blockchain is a distributed P2P network, in which a node requests the transaction to another receiving node. The miner validates the node, data, and transaction. If the validation is correct, then it creates the block. The consensus algorithm is useful to validate the data inside each respective block, this is termed as ‘proof-of-work (PoW)’. Each block would be inserted into the chain of blocks once the consensus algorithm is implemented (Lin and Liao, 2017). The most essential application to which blockchain technology needs to be

adapted is healthcare which overcomes the current issues of attacks, privacy (Rawal et al., 2017), security and secure transmission (Engelhardt, 2017).

Another biggest challenge in the healthcare industry is interoperability (Al Ridhawi et al., 2018a). Interoperability is nothing but the exchange of data securely, consistently (Al Ridhawi et al., 2018b). The objective of interoperability towards healthcare is to exchange the electronic medical records of the patients among various healthcare service providers. This allows the process of sharing patients' healthcare records in the safe and secured environment. Interoperability provides healthcare providers to securely access patient health records based on the patient's permission to access, view them irrespective of location (Zhang et al., 2018a), shows in Figure 2.

Many researchers proposed a cloud-based EHR in which patient data are encrypted and stored in a cloud environment, which makes security and storage safety a challenge. This challenge can be addressed using blockchain technology through which the securely and safely the healthcare, patients store, access and share the health data (Casino et al., 2019). The slow adoption of technology in healthcare is the cost of infrastructure needed and the software implementation (Mackey et al., 2019). Thus, blockchain positively resolves the above problems by making the business process easy, secure, gains patients confidentiality, patients health data management, lowers the administrative cost and emerge an option of better utilisation of patients health data to get doctor appointments, virtually obtain the prescription, doctor fee payment, medicine procurement in pharmacy, generation of invoice and health data sharing among other individuals, healthcare service providers and insurance agents, shows in Table 1.

**Table 1** Analysed of blockchain technology with security

<i>Reference</i>	<i>Technology</i>	<i>Healthcare</i>	<i>Security</i>
Michael et al. (2018)	Blockchain	Yes	High security
Lee and Pilkington (2017)	Blockchain	Yes	Security is good
Yaeger et al. (2019)	Blockchain	No	Security is average
Macrinici et al. (2018)	Blockchain	No	Security is not poor
Andoni et al. (2019)	Blockchain	No	Low security
Treleaven et al. (2017)	Blockchain	Yes	No security
Pilkington (2016)	Blockchain	No	Low level security
Rawal et al. (2017)	Blockchain	Yes	Average level security
Engelhardt (2017)	No	No	Good
Al Ridhawi et al. (2018a)	No	Yes	No
Al Ridhawi et al. (2018b)	No	No	Good
Zhang et al. (2018a)	Blockchain	Yes	High
Casino et al. (2019)	Blockchain	Yes	Average
Mackey et al. (2019)	No	Yes	No

## 2 Related work

Blockchain has a huge impact on production flow and supply chain management of drugs, medical equipment's which eliminates the risk of fake drugs, changes of expiry

dates of drugs creating human life's in danger across the world. Thus, blockchain plays an important role in making the healthcare sector smart, easy, and better user experience, gaining confidentiality, improvising the quality of the healthcare system sharing patients' data with privacy-preserving and data security.

Our extensive literature survey states there are many research papers addressing applications or adoption of blockchain technology in finance (Mackey and Nayyar, 2017), internet of things (IoT) (Magyar, 2017), energy (Gordon and Catalini, 2018), government (Ahram et al., 2017) and security (Esposito et al., 2018). Only a few research papers are focusing on the application or adaption of blockchain technology in the healthcare sector. Many blockchain platforms are currently been used such as Ethereum, ripple, hyper ledger fabric, etc.

Mettler (Jiang et al., 2018) in his research article briefs usage of blockchain technology in healthcare. This study was the first to explain blockchain technology for healthcare on a high level. But this research paper majorly deals with the functionality aspect and advantages of technology.

Kuo et al. (Ji et al., 2018) research article deals with blockchain technology in the healthcare and biomedical sector. This research paper focuses on certain blockchain features like bitcoin and its architecture. Also, it provides a good knowledge of medical record management, insurance process, medical research and development, and automating health data ledger works. But this paper does not deal with the technical aspect of addressing.

Stagnaro et al. (Uddin et al., 2018) explain certain use cases for applying blockchain technology in the healthcare system. This research paper elaborates interoperability of patient health records. This research paper does not deeply analyse the blockchain integration in healthcare with results.

Hölbl et al. (Mamoshina et al., 2017) explain a detailed analysis of researches about blockchain technology in healthcare. But this research paper eliminated the experimental analysis in the recent studies.

Radanovic and Likic (Zhao et al., 2018) analyse blockchain technology in the medicinal field. This research paper includes insurance, EHRs, drug distribution, supply chain, medical research and development, medicine raw material procurement. This research article does not cover the main concepts of blockchain technology like smart contracts, data sharing, cloud storage and interoperability.

Siyal et al. (Cunningham and Ainsworth, 2017) focus on several new blockchain-based applications such as research on neuroscience, medicinal researches, intruder detection. This research paper ignored many recent research papers.

McGhin et al. (Zhang et al., 2018b) aimed to elaborate reviews on the healthcare sector to protect patient health data using blockchain. The survey paper analyses healthcare applications like OmniPHR (Boulos et al., 2018), Medrec (Tseng et al., 2018) and MeDshare (Yue et al., 2016). Chen et al. (2018) also in their research proposed blockchain-based medical data sharing by explaining cloud-based secure storage for patients' personal and confidential information. In his study, the data owner has complete access rights and control rights of the health data.

Guo et al. (2018) proposed an attribute-based signature with blockchain technology invoking multiple authorities to validate, verify the EHR. This research paper explains the option of group messages avoiding collision attacks.

Hussein et al. (2018) proposed a secure medical record application with sharing using blockchain technology. The proposed research article explains an enhanced cryptographic hash generator for the generation of key and MD5 algorithm for the generation of hash values for each block. This generates 128-bit hash values for the blocks, and shows Table 2.

**Table 2** Different source of process in healthcare

<i>Reference</i>	<i>Technology</i>	<i>Healthcare</i>	<i>Source of process</i>
Mackey and Nayyar (2017)	Blockchain	Yes	Finance
Magyar (2017)	Bloackchain	Yes	Internet of things
Gordon and Catalini (2018)	Blockchain	Yes	Energy
Ahram et al. (2017)	Bloackchain	Yes	Government
Esposito et al. (2018)	Blockchain	Yes	Security
Jiang et al. (2018)	Blockchain	Yes	High level
Ji et al. (2018)	Blockchain	Yes	Insurance
Uddin et al. (2018)	Blockchain	Yes	-
Mamoshina et al. (2017)	Blockchain	Yes	Recent studies
Zhao et al. (2018)	Blockchain	Yes	Drugs and insurance
Cunningham and Ainsworth (2017)	Blockchain	Yes	Neuroscience
Zhang et al. (2018b)	Blockchain	Yes	Applications
Boulos et al. (2018)	Blockchain	Yes	OmniPHR
Tseng et al. (2018)	Blockchain	Yes	Medrec
Yue et al. (2016)	Blockchain	Yes	MeDshare
Chen et al. (2018)	Blockchain	Yes	Storing data
Guo et al. (2018)	Blockchain	Yes	Validation and verification
Hussein et al. (2018)	Blockchain	Yes	Security

### 3 Healthcare applications

Our survey paper aims to analyse the technical aspect of a blockchain-based healthcare system focusing on the latest research developments and how blockchain can be adapted in each healthcare area.

#### 3.1 Blockchain-based healthcare applications

Blockchain technology plays a significant role in healthcare applications rendering abilities to store, share medical data and perform payments using cryptocurrencies like bitcoin, Ethereum, etc. The input data would be obtained from medical devices, smart cyber-physical devices, labs, etc. which are kept increasing each day. The blockchain contains many features like consensus algorithm, smart contracts, gas value, cryptocurrency, and public, private blockchain platforms for transactions.

With the increase in EHR, new opportunities in technology are essential for patients' health data storage, privacy protection policies, and patients' health information

management. Blockchain is capable of providing secure data storage, smooth and secure transaction for the healthcare system. Thus in the future blockchain would be playing a crucial part in the healthcare system (Zhang et al., 2018c).

## 4 Data management

### 4.1 Health data management

Many healthcare providers, health data management companies, insurance companies, healthcare labs are data-driven nowadays. The quantity of data is kept on increasing because of the demand, emergence of IoT.

Smart healthcare devices provide a huge set of health data regularly to the healthcare service provider cloud servers. Data security and data owner privacy are been lost in the existing system through man-in-the-middle attacks and cloud attacks.

Due to this several healthcare providers have lost end-user confidentiality and reliability. In blockchain technology, there are several roles for the users which would be monitored by miners within the network. Also, the health data are stored in the cloud with roles and rights to access thus preserving patient's privacy.

MedRec (Azaria et al., 2016) is a decentralised electronic medical record management application in which health data management is stored in the blockchain and each execution is performed by verifying the smart contracts.

Health data management also includes enrolment of patients into the admission process, appointment process, healthcare plan depending on the disease, credentials, follow-up process makes the administrative process more complex.

The complexity invokes collection and managing all these patient data manually and validating the patient health data takes much time, acting as a barrier in making an efficient healthcare system adding security concerns. To make the administrative process simple and secure, a blockchain-based healthcare system is suggested for addressing the security challenges of EHR (Alonso et al., 2019).

*Example:* Assume a brain tumour patient is admitted to a hospital for surgery, the doctor provides the diagnosis based on the MRI scan only. So the MRI-based digital information is the most important data. Thus, blockchain performs a tremendous part in securing the data keeping the value unchanged reducing the data storage cost for the healthcare provider.

## 5 Data storage and pharmaceutical

### 5.1 Data storage

Once an EHR for a patient is generated by the patient, a block is generated appending a hash value to it. The block is added to a chain of the block within the network. Each block is interconnected by previous block hash values making unauthorised access or intrusion impossible.

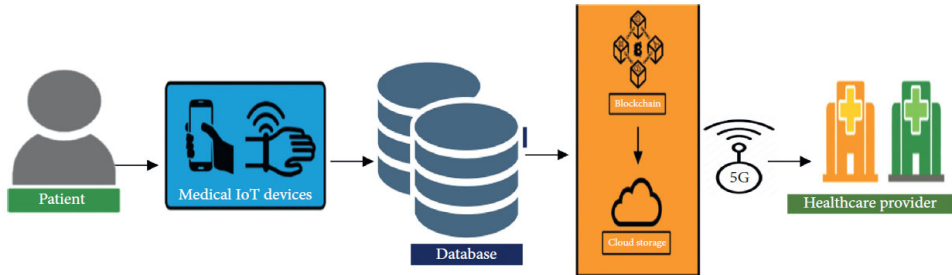
Due to the huge volume of health data generated from smart health devices, huge health data storage is needed. Cloud-based infrastructure storage is suggested providing



large storage capacity, low cost, sharing made easy, access irrespective of location, less time, etc.

Kaur et al. (2018) identified a new terminology named ‘block cloud’ which explains how blockchain can be integrated into a cloud environment. The main objective is to develop a distributed health data making data available without invoking a third party thus preserving privacy and enhancing security, show Figure 3.

**Figure 3** Technology of blockchain (see online version for colours)



Source: Hameed et al. (2021)

## 5.2 Health education

Blockchain technology can be adopted for the education sector in which the potential is huge. Knowledge sharing is tremendous and assessment implementation for rendering certification is mandatory paving an opportunity for blockchain technology adoption. In education, it can be online or traditional approach, knowledge trade happens from multiple sources. Also, trust and reliability of the knowledge is a challenge. The educational institutions, online e-learning platforms on adapting blockchain can able to render certifications for learners progress on their own eliminating third party interventions. Implementation of blockchain in education would make sure that the knowledge would be the same and secure without intrusion supporting the next generation of learners. This would provide good clarity on which particular block is more efficiently requested and accessed without any third-party help or analysis. Also, the final grade based on each assessment can be easily analysed using blockchain technology without any manual error.

## 5.3 Blockchain for pharmaceutical

The pharmaceutical industries or labs work round the clock to increase the quality of drugs and also predict and start inventing new drugs for emerging diseases. Before the drug hits the market, it has to go through a sequence of the process such as patent filing, safety certification, test reports, validity test data's and it has to be verified, validated, approved by the regulatory members.

On average, this sequence of processes takes could of years before the drug is commercialised. Every process is documented manually. Thus, security and privacy of data tampering, misuse of sensitive data is a major concern. Thus, blockchain address this challenge by providing secure data transmission preserving privacy and with distributed

ledger concept, the testing data can be shared to all the blockchain nodes (Xu et al., 2019).

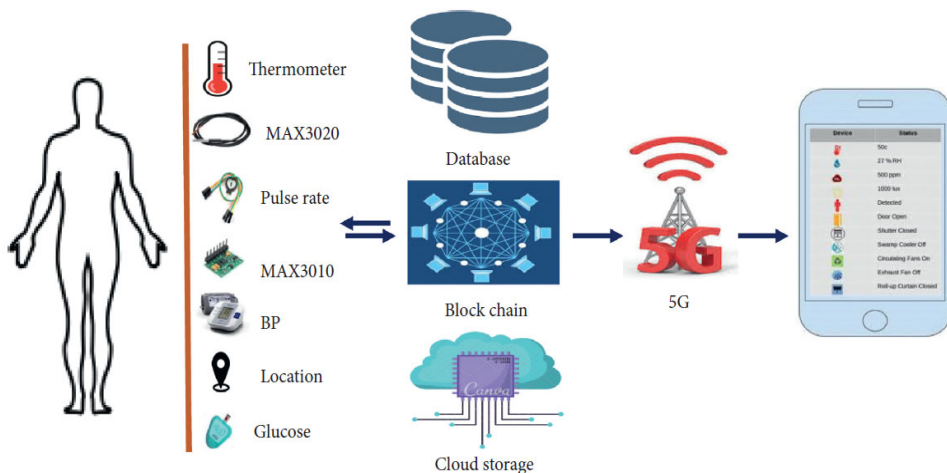
Tseng et al. (2018) recommended Gcoin blockchain-based transparent drug supply chain management. This invokes all players such as manufactures, distributors, wholesalers, retailers, clinics and end-users. Blockchain-based drug supply chain management makes government auditing easy and efficient and also provides complete transparency to end-users. Ethereum-based blockchain platforms (Toyoda et al., 2017) and with its wallet, the vulnerabilities, intrusion, unauthorised changes can be avoided throughout the drug supply chain cycle.

## 6 IoT for medical applications

The IoT plays a significant part in health management systems (Chiuchisan et al., 2014). With the evolution of IoT (De Aguiar et al., 2020), the patient's scan provide their health information's remotely using sensors like a heartbeat, blood pressure, ECG, EEG and EHR (Murugan et al., 2020) temperature. These sensors obtain health information from wearable devices and share through the internet which can be accessed by authorised peoples (Gadekallu et al., 2021).

To address the security and privacy concerns blockchain-based medical IoT proposed which stores each health information's in the block and all health information's are updated in the ledger (Hameed et al., 2021), shows in Figure 4.

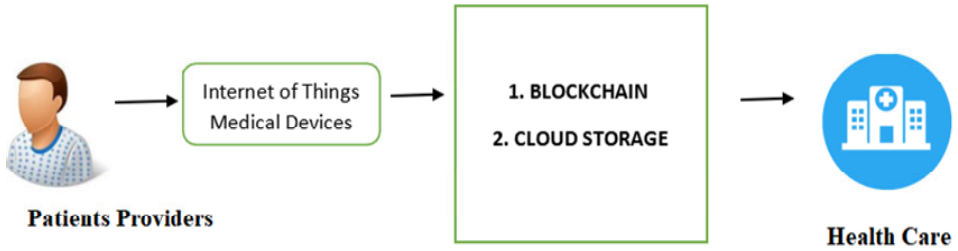
**Figure 4** Human body checked through sensor (see online version for colours)



Besides integration of blockchain technology with IoT is a challenging task, as blockchain technology cannot be adapted with IoT technology directly (Feng et al., 2021a; Tan et al., 2021a, 2021b; Feng et al., 2021b; Banupriya et al., 2021; Kottursamy et al., 2021). Thus, blockchain with hypergraphs can be applied to smart health, home, industry applications providing security, and the probability of attack or data tampering is highly reduced. Also, this system provides all health transactions happening within the blockchain are transparent rendering secure communication between IoT devices. Thus,

this system provides security during health information exchange and trading are shown in Figure 5.

**Figure 5** IoT for medical applications (see online version for colours)



## 7 Conclusions

This paper provides an extensive study on blockchain technology for healthcare which has attracted many individuals, organise decentralised-based blockchain efficiently addresses the existing concerns of privacy, security while patient's health records, medicine are shared. Thus, this decentralised-based blockchain not only provides transparency but time stamp quality of the health care record be enhanced reducing the cost involved. Blockchain network provides high security from attackers by appending time to each patient's health record with the previous block hash value. Thus, no attacker would be able to tamper patient data once the block becomes a part of the distributed ledger. The data owner can set the rights who can and cannot access the patients' records. In this paper, we brief the impact of blockchain in other industrial sectors as well. Though blockchain is secure there are few setbacks like scalability, flexibility and governance. Once these concerns are addressed, blockchain technology would be adapted to all enterprise software and products.

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