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Blockchain-Driven Innovations in Healthcare: A Comprehensive Review

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Abstract: The field of healthcare is among the many new application opportunities made possible by the rapid growth of blockchain technology. By doing a comprehensive technical examination, the following paper looks at the benefits and drawbacks of contemporary blockchain technology applied in the healthcare sector. In addition to an overview of open themes, research perspectives and current research problems across all healthcare application fields, a comprehensive study of new blockchain-based healthcare technologies and related applications is also given. This paper provides a complete review of the potential uses of blockchain technology in the medical field, as well as an examination of the ways in which such applications impact healthcare markets and create fresh possibilities for business.

Keywords: Blockchain, Healthcare, EHR, IOT, Blockchain applications, Supply chain management, Health insurance, AI.

I. INTRODUCTION

One of the latest and most significant innovations and cutting-edge developments that is now having a big impact on the workplace is *Blockchain* technology. It is an unowned collection of time-tagged, irreversible information files that are updated by a group of computers. The data is organized into blocks that are linked to one another and secured by concepts from cryptography, like chains. Blockchain is very useful since it is dispersed rather than controlled by a single person, its data is cryptographically safe. Its unchangeability implies that no one can change the data it contains and its transparency enables tracking at any point of time, according to [1].

The rapid acceptance of digitization in the medical industry has resulted in the creation of a large number of electronic records for patients. This growth raises enormous aspirations for the security of medical data while it is being used and shared. It is an effort to safeguard all information from getting modified backwards without altering the remaining blocks. Blockchain is a public, decentralized digital ledger that records transactions across multiple computers. It helps in producing a long chain by linking to and validating the earlier block. Since each exchange is publicly documented and confirmed, it provides a high level of transparency. No one can alter any data published in to the Blockchain. It accomplishes this by demonstrating that the data is accurate and unaffected. By revealing a database's susceptibility to attack and keeping data on networks instead, blockchain increases reliability. It offers an excellent structure for competing with well-established businesses and creating new and creative commercial models [2], [3], [4].

II. BLOCKCHAIN AND HEALTHCARE

A decentralized node network called Blockchain is used to store information which is an excellent way of protecting sensitive data within the system. This technology allows the communication of highly confidential data while preserving security and privacy. It is the best way to efficiently save every necessary record in a single spot. Additionally, it speeds up the task of looking through a single patient database to find an applicant who fit certain trial conditions. The Blockchain maintains, stores and records transactional or past information using a decentralized peer-to-peer (P2P) system consisting of independent computers called nodes [5], [6], [7].

Blockchain technology is pillared on three core concepts: blocks, nodes and miners. Blockchain does keeps its data in distributed locations instead of storing it in one place. Data is replicated and distributed via a computer network. This system provides transparency and removes the need for intermediaries or external controllers [2]. Security of data, privacy, exchanging and difficulties with storage in the medical field can be resolved by blockchain technology [8], [9]. One of the requirements for healthcare companies is accessibility. It is the ability to convey information or data among two entities - a human or a machine - in a precise, effective and reliable manner [10], [11], [12], [13]. The goal of interoperability in healthcare is to facilitate the interchange of health-related data, including Electronic Health Records (EHRs), between doctors and patients. This allows the data to be readily transferred between different healthcare organizations and within the environment [14], [15], [16], [17]. Healthcare practitioners can safely share patient medical records thanks to interoperability.

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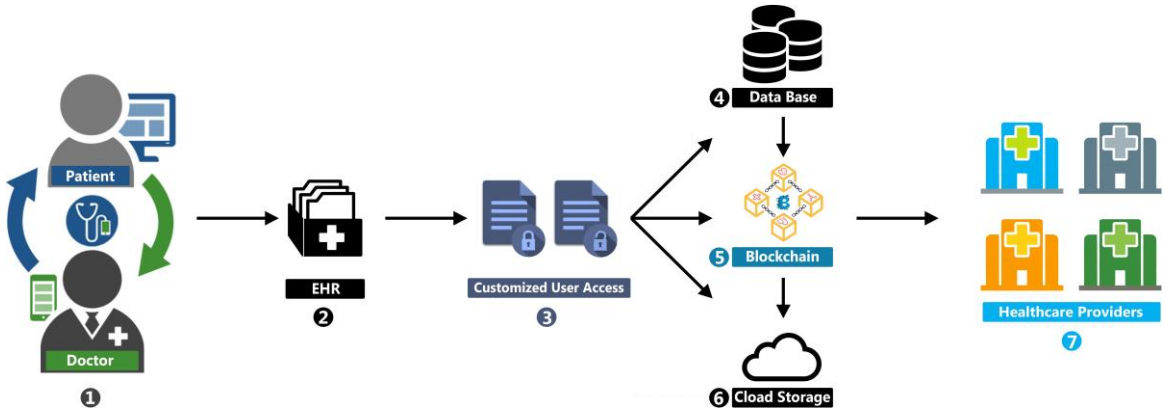

Fig. 1 Healthcare data management in blockchain

III. HEALTHCARE MANAGEMENT APPLICATIONS USING BLOCKCHAIN

Figure 1 shows a blockchain-based technology process for healthcare data management, which will be discussed further in below sections of the paper. Electronic Health Records, Mobile-based apps, data management, data storage and data sharing are all included in this category of blockchain-based applications. Below is a more thorough discussion of these subjects.

- *Step 1*: When a patient discusses with their physicians and experts, the key information is produced. This information includes existing health issues, medical history, along with other physiological details.
- *Step 2*: Based on the information gathered in the first step, an Electronic Health Record (EHR) is generated for every patient. The EHR also contains supplementary health information produced by nursing services, imaging techniques and medication history.
- *Step 3*: The proprietor of the property is granted permission to see each patient who owns a confidential EHR and tailored access management. Anyone wishing to have access to this important data needs to submit an appeal for authorization, which is then sent to the person in charge of the EHR, who decides whoever is allowed access.
- *Step 4, 5,* and *6*: each of these stages form the foundation of the entire process, which also includes cloud-based storage, databases and blockchain. Records are distributedly stored in databases and cloud storage and a blockchain offers the highest-level confidentiality to guarantee personalized, legitimate access by users.
- *Step 7*: The healthcare providers who wish to gain access for reliable and secure healthcare delivery - which will be approved by the owner - include medical centers, community care centers and ad hoc clinics. For instance, your health record will be readily accessible by your phone and authenticated by a distributed ledger like blockchain, to which medical professionals will continue to add over time, regardless of where you receive treatment in the world [18].

IV. VARIOUS CAPABILITIES OF BLOCKCHAIN TECHNOLOGY TO SUPPORT THE HEALTHCARE CULTURE GLOBALLY

To make it easier to provide top-notch healthcare facilities, modern, innovative technology is needed. In this scenario, blockchain technology could become crucial to transforming the medical field. In addition to this, the health system's landscape is changing in favor of an approach centered around patients that places a high priority on two essential mechanisms: always-accessible services and sufficient medical supplies. Another important concern is the safety of data, especially in relation to wearable technology and customized care. The effectiveness and privacy issues of data collection, transfer and consultation across networks that impact patients and healthcare professionals are addressed by blockchain technology [8], [9].

Blockchain is benefiting the medical sector by assisting businesses and other stakeholders in managing information regarding patients, streamlining operations, improving patient happiness, boosting compliance, cutting expenses and making better use of healthcare-related data [19]. To raise the bar for healthcare services and enhance the experience of patients, it is essential to be able to share data without putting user's privacy or confidential information at risk. This is due to the fact that health-related information is considered private and sensitive. Medical organizations

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might not be excited about joining a network which is accessible to everyone because clinical institutions manage highly confidential and restricted data and might not want to communicate with people beyond their own circles. In this situation, public blockchains may not be a practical solution. Contrarily, private blockchain is a distinct type of blockchain that has potential use in healthcare environments [20].

As blockchain can keep an uncorruptible, decentralized and transparent record of all medical data, it is perfect for security applications. Furthermore, Blockchain is easily accessible yet confidential, hiding a person's identification underneath complex and reliable algorithms that can safeguard confidential medical data. Medical professionals, patients and health care workers may swiftly and securely share information because of the system's decentralized structure. Blockchain-based technology has the potential to increase data on patients' accessibility, surveillance, consistency and overall efficiency while also reducing expenses for healthcare practitioners and the industry in general [17]. Additionally, many Blockchain technologies can be customized to manage wide range of applications related to healthcare. This includes themes such as drug traceability, patient consent management, privacy and confidentiality in clinical investigations, micropayment rewards and the secure use of electronic health records (EHRs). It facilitates access to all information at any moment for chemists, physicians and patients. Blockchain technology in the context of medical records is a topic that health care providers are continuously researching, investigation and learning about.

Blockchain technology enables the creation of a sophisticated framework for storing information that records a person's entire healthcare history, comprising diagnoses, outcomes of tests, prior medications and measures from intelligent sensors. A physician can quickly obtain all the data required to provide a precise diagnosis along with recommendations by employing this method. All of the information is stored on a single Blockchain system, which guards against theft and alteration. Blockchain's durability, independence and complete transparency make it an exciting answer for protecting health information. Blockchain will ensure that people's identities and health information remain confidential while the system is stable.

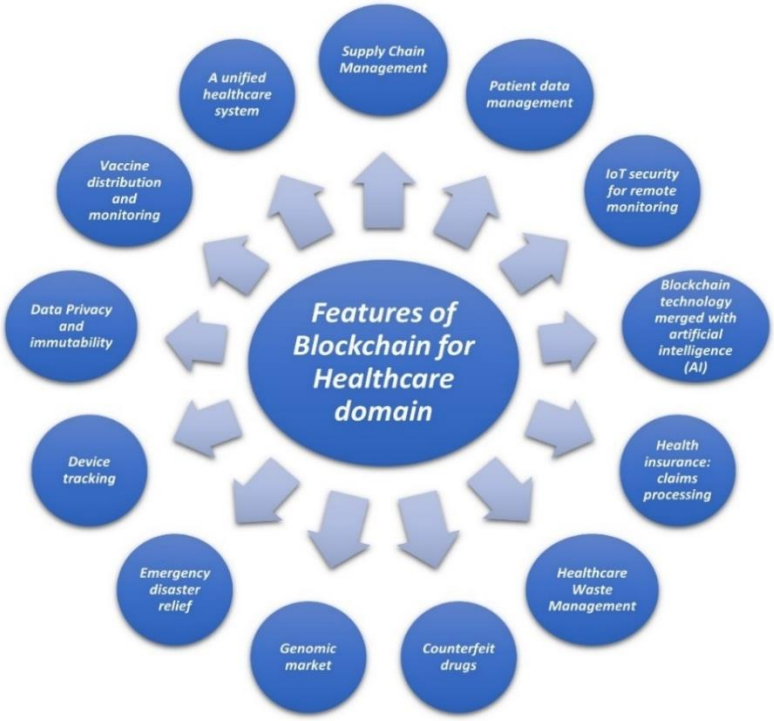

Fig. 2 Blockchain applications for healthcare

1. Supply Chain Management

Supply Chain Management (SCM) integrates the latest market developments to expedite the whole delivery process, from procuring to delivering [21], [22]. Supply chain management in healthcare sector is difficult because of the dispersed ordering of medications, healthcare equipment and many other essential resources. This risk to the supply chain process could compromise patient safety [23], [24]. World Health Organization (WHO) research [25] estimates that about 100,000 Africans lose their lives to incorrect dosages of fake medications purchased from unknown or suspicious suppliers. A healthcare facility's supply chain management can be totally disrupted by missing product registries, packaging problems and counterfeit drugs and supplies [26]. Blockchain is a crucial monitoring tool that can be utilized to supervise the whole flow of medical supplies and pharmaceuticals [27].

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It is simple to quickly confirm the drug's source, supplier and distributor since the blockchain's nodes keep track of each transaction that occurs and the ledger documents all transactions. Furthermore, physicians and healthcare administrators may employ the blockchain's decentralized ledger to confirm vendors' qualifications [28]. Pharmacies and healthcare professionals can guarantee patients who need genuine medications continues receiving them via acquiring additional supply chain information through timely and appropriate authentication procedures. Medical administrators can save patients from dishonest vendors if capability of Blockchain technology's potential is employed for creating reliable vendor network. Drastic improvements are anticipated in demand forecasting, data provenance, fraud prevention and transactions with blockchain technology.

2. Patient data management

Nowadays, blockchain has been used extensively in healthcare management, mostly to increase price-effectiveness and secrecy. It helps to save medical data electronically, visits for patients can be scheduled easily, lab test are conducted and invoicing and funds are managed [29]. These are present in many Electronic Health Record (HER) systems used in medicine. The primary objective is to provide health records that are secure, indestructible and platform-sharing. Blockchain provides a secure means of tracking and maintaining all patient medical data, with multiple levels of administration by patients, doctors, legislators, health care providers, insurance providers and many more. In addition to cutting costs, it might benefit healthcare organizations and the sector as a whole by enhancing patient data monitoring, reliability, effectiveness and visibility.

3. IoT security for remote monitoring

According to [30], the internet of things (IoT) aims to create a fully connected environment in which objects exchange data with one another. Blockchain technology for medical providers ultimately support IoT effectiveness, flexibility and uniformity along with enhancing IoT security and information accessibility. The use of remote surveillance systems offer liability for patients' health across all of the devices that assess key indicators regarding patient constitutes one of the most recent noteworthy advancements in the field of digital healthcare. However, as it protects patient security and privacy and prevents the creation of erroneous data, confidentiality is a major problem in IoT health. Blockchain-enabled Internet of Things (IoT) healthcare devices will assist patients to manage who has access to the data they collect, protecting their equipment from hackers and allowing them to trace who has viewed the data.

In an instance of a severe necessity, such as notifying the elderly person's caretaker of a medical emergency or heart attack, an integrated system may also be necessary. Supports must also be extremely resilient to denial-of-service (DDoS) attacks and other forms of cyberattacks. A user needs a particular set of secret passwords to convert a hash value in order to obtain the original data and blockchain makes guarantee that only those with permission can read private data. Any modifications made to the data originally stored will result in a new hash function, which is how the data is kept on the blockchain. It is particularly difficult to manage medical information that has been stored in the blockchain directory as a hashing function since all of the stored copies must be used. IoT devices can speak with one another directly without the need for a central server, thanks to blockchain's decentralized architecture.

4. Blockchain technology merged with artificial intelligence (AI)

Artificial intelligence and blockchain possess the ability to improve the standard of treatment provided by healthcare institutions. Lowering medical service costs will contribute to more affordable and easily accessible healthcare. AI needs a data encryption method, which blockchain enables. With Blockchain it will be feasible to determine the underlying logic behind decision making. By utilizing artificial intelligence (AI), we can maximize the effectiveness of services and guide operations in a predictive healthcare environment. Situation-appropriate advice can be provided to patients, healthcare professionals and guardians.

Considering a scenario of a case study related to the COVID-19 case. The COVID-19 pandemic brought enormous hurdles to the world's medical establishment. It has been discovered that electronic health care is suitable for offering creative approaches to the epidemic. Among the solutions are the development of telehealth, cutting-edge testing and clinical decision-making instruments, increasing the use of disposables for physiological indicator tracking, producing reliable surveillance systems and interactive chat services to make people aware about COVID-19. A significant effort has been made to improve the Healthcare Waste Management (HCWM) system in an effort to reduce COVID-19 waste's negative effects on the environment and public health. Blockchain enables the safe exchange of data while protecting the privacy of data from healthcare facilities, primary care physicians, pediatricians, medical laboratories and many more sources. To analyze data, artificial intelligence (AI) methods are employed. By quickly identifying and caring for COVID-19 patients using Blockchain and AI, pharmacological recommendations for possible future epidemics may be created.

5. Health insurance: claims processing

The rise in medical problems has made health insurance a basic need in people's life. It may be tough for individuals

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who cannot arrange for high medical expenses to deal with health problems. Health insurance helps with emergency medical price coverage and offers financial security against debt worries. With regard to health insurance along with all of its advantages, worries about scams, confidentiality and safety may arise. Scams have been a major concern in the healthcare insurance industry in recent times because it may cause enormous losses for individuals, businesses and governments. For the advantage of national authorities as well as commercial organizations, it hence becomes essential that technologies need to be developed to detect fraudulent events and transactions.

Payer-provider processes are typically intricate, involving multiple manual steps and are sometimes the consequence of poor communication as well as technology. All stakeholders in the healthcare sector are able to access one ledger containing the entitlements and smart contracts of the patient which preserve the prior authorization criteria, thanks to blockchain technology. With automatic data gathering and sharing procedure benefits to be computed instantly. Blockchain-based pre-authorization offers a number of advantages, including reduced administrative costs, precise provider payment, timely patient care, reduced transaction settlement that enhances cash flow and the removal of redundant record-keeping.

In a Blockchain-enabled system, all stakeholders part of the claim information and reimbursement rules are held responsible. Blockchain uses smart contracts to negotiate and store agreements between suppliers, customers, payers and public authorities. Healthcare providers would precisely know in advance about the information needed for submitting a claim. Claim data can be easily processed by the providers to ensure that every detail is recorded without error as the Blockchain mandates that all data be supplied accurately and correctly. These detailed checks save time and effort for all parties involved because fewer or no claims are denied for lack of information. With its potential to disrupt and boost efficiency for all industry participants, blockchain is becoming more and more significant in the heath care IT sector. Health organizations must recognize and assess blockchain technology now in order to ensure they are ready for future changes.

6. Healthcare Waste Management

Healthcare waste management has become more challenging as a result of the COVID-19 epidemic. The primary sources of garbage increase include medical and immunization waste. For ensuring the protection of employees and patients, the healthcare needs to carry extra safety gear as medical waste may consist of used face masks, contaminated blood, body and tissue fragments, medications, chemicals and radioactive materials.

The overproduction and underutilization of vaccines brought on by mass vaccination production is another source of waste. The tools and procedures presently in use for handling waste data related to COVID-19 vaccinations generally lack security safeguards, accountability, openness, accountability and trustworthiness. To handle this situation, a five-phase, blockchain technology strategy was proposed. The system built on blockchain encompasses waste analysis, manufacturing and distribution, utilization and involvement. Many smart contracts regulate the entire COVID-19 vaccine life cycle with the aim of ensuring accountability for each action carried out by the parties associated and minimizing any additional waste brought on by overproduction, overordering or underconsumption. Regulators were able to utilize smart contracts and alter the blockchain's setup to suit their needs by using a private, authorized blockchain with no centralized authority by inclusion of the commitment smart contract, which warranted that every organization was responsible for any waste generated hence resulting in reduced trash.

7. Counterfeit drugs

Drug counterfeiting is a threat in today's world. The annual death toll from it ranges from 120,000 to 1 million. It represents a major problem in the supply chain for the medical industry. Ten to thirty percent of medications in underdeveloped nations are counterfeit, according to the Health Research Funding Organization. According to statistics from the World Health Organization (WHO), more than 30% of medications supplied in Asia, Africa and Latin America are counterfeit. Blockchain technology may be useful in resolving these problems [31]. Supply chain anticipates eliminating fake drugs and boost productivity by fusing blockchain technology with artificial intelligence and progressive data analytics. Businesses, storage facilities and logistical and shipping companies will be incorporated into the operations of hospitals and pharmacies. Each drug packet can be tracked in the Blockchain. The mobile app provides a number of advantages, including the ability for the user to confirm the authenticity of a drug. The supply chain does not contain counterfeit medications. AI and data analytics improve delivery system’s effectiveness.

8. Genomic market

Genomic medicine uses genetic information to accurately detect, forecast and achieve a range of inherited illnesses. Through genomic treatments, the genetic makeup of an individual is generated to determine therapy options which are specific to their needs and illness susceptibility. However, there are also certain problems with the spread of genetic data, including access to data, confidentiality and security. This is where Blockchain comes in. The unalterable, time-tagged structure of data blocks used by blockchain technology is accessible to everybody with a connected device, wherever in the globe, as long as they have the appropriate authorization to access it. Blockchain provides a trustworthy

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database for research and the development of innovative rare disease diagnostics and treatment strategies by reducing the likelihood of data tampering and modification with the application of cryptographic blocks.

9. Emergency disaster relief

Blockchain facilitates to reimagine processes and demonstrate the actual potential of collaboration in a crucial disaster relief situation [32]. Inaccurate information gathered from multiple unaffiliated sources, such emails or social media, may make it more challenging for relief operations to efficiently and promptly coordinate aid. Multiple parties' interactions can be streamlined and complexity can be reduced with a single system of record. Blockchain makes it possible to connect multiple independent systems over a decentralized network, doing away with the requirement for a single entity to oversee the data systems.

The ability to team up directly with other organizations on a business process is one of the most crucial elements. Almost all Blockchain use cases share a common feature. Blockchain ensures each participant's privacy, openness and detachment from intermediaries. The effectiveness of the distributed system is shared by all and the costs are also borne by all. This is just one example among many.

10. Device tracking

Monitoring medical gears from the time of creation until they are decommissioned is a crucial component of another revolutionary approach to healthcare. Every hospital has the issue of managing an inventory of medical equipment used by various departments and patients. It takes time to locate the appropriate resources in a medical crisis. Consequently, medical equipment monitoring and tracking are crucial for enabling speedy equipment recovery, eliminating redundant repurchasing and preventing fraud analytics of the supply chain to decommissioning [33]. There are several benefits when comparing a blockchain-based system to conservative location tracking methods. The most notable properties of blockchain are its confidentiality and secure nature. To encourage compliance with rules an immutable history of the gadget's current and previous locations, along with its manufacturer, reseller and serial number, might be created using blockchain technology. A malicious party can't alter or remove a device's reported position from the database using this blockchain-based technique. Blockchain confirms that the leased medical equipment is in an authorized location, provides us with crucial information about how it is used and eventually guarantees that customers use it. Among the benefits include the ability to quickly locate equipment in an emergency, maintain an inventory process log and automate the utilization process.

11. Data Privacy and immutability

The healthcare supply chain contains more extremely private information. Patients are less likely to share private health data with outside groups. Thus, architects and owners of healthcare blockchains need to pay extra attention to data protection [34]. The two most important features of blockchain are decentralization and authenticity. Users can take control of their information through these capabilities, and any changes made to the records will be openly evaluated to show how and by whom they have changed through the years [35].

12. Vaccine distribution and monitoring

The best way to reduce spreading of viral illnesses is through vaccination. The short shelf life of the products and the need for strict storage and transportation regulations to protect the public's safety and health set the expectations from vaccine supply chain different as compared to regular supply chains [36]. Inefficiencies include insufficient distribution plans or the absence of interoperability cause interruptions or delays in immunization supplies. In addition, because a mass vaccination campaign requires a huge number of doses, proper logistical network needs to be set up by government and plan for a timely and effective immunization distribution in the event of a pandemic.

Physical constraints include a shortage of amenities, limited storage facilities and inadequate medical staff. To ensure longevity, the vaccines need to be preserved with specialized equipment. Due to the storage and accessibility limitations of freezers, a strong management system is required to handle vaccine validity time. Supply chain participants need to have a strong communication network else it may cause both supply and demand for vaccines to become unpredictable, which could result in inefficiencies and regional disparities. Maintaining the accuracy of this information is crucial when it comes to security concerns, particularly those that include potential cyberattacks or misuse of data.

13. A unified healthcare system

Many organizations have partial or fragmented patient health data making it one of the main problems of the healthcare system in modern day. This issue can be resolved by using Blockchain transactions for medical records [15]. A smart contract can be used to grant restricted access to a patient's electronic medical records and build an intelligent healthcare system. Doctors will conduct tests, scan records and complete paperwork; these activities are now all documented as transactions. Every time a member of the pharmacy staff gives out medication, the Blockchain records the transaction. In order to track medication and compensation, the patient gives their insurance company limited access. Patients employ

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clever contracts to their advantage. Doctors will be able to evaluate patient condition without being physically present and provide guidance. Tokens or discounted rates will be used by health insurers to monitor the development and physical well-being of its insured clients. Additionally, research organizations can temporarily access patients' medical records for diagnostic testing. In order to protect electronic health data, transfer value and make payments utilizing information from wearable fitness devices, patients can acquire tokens to use on the Blockchain. The blockchain-based healthcare ecosystem will empower developers to produce smart apps that analyze health data and provide advice on exercise and diet plans.

V. LIMITATIONS AND FUTURE SCOPE

Limited knowledge is the biggest problem with healthcare facilities utilizing this cutting-edge technology. However, it is important to discuss whether blockchain technology will be the next major development in healthcare. There are a lot of hypes about blockchain being the answer to all system issues and number of startups might try incorporate use blockchain technology to solve certain problems. But they need to be asked two questions: First, what domain of blockchain are they using; is it public or private? Second, do they really need blockchain? If the response to the first question is a private blockchain, then nothing really revolutionary is taking place here. In response to the second question, they might go over the primary justification for the Blockchain's creation, which is the dangers of centralization. But only when the stakes are high these dangers matter. One alternative to blockchain technology is the centralized control of the pharmaceutical line.

Blockchain technology is tremendously efficient at decentralizing, but it comes with its own limitations. It is also slow, ineffective and energy-intensive. For example, a transaction on the Bitcoin network generally takes about ten minutes to be completed. This is hardly the ideal moment to stand in line at a coffee shop for a cup of coffee. The usage of blockchain technology should be limited to situations where centralization is the problem. If decentralization is not necessary, a system might be more effective taking a centralized method and probably wouldn't require to use blockchain technology.

VI. CONCLUSION

Blockchain technology offers a number of innovative applications in the medical industry because to its inherent decentralization and encryption. It protects the integrity of electronic medical data of the patients, promotes the monetization of health information, fosters teamwork healthcare organizations and helps combat forged drugs. Blockchain technology can potentially revolutionize many different areas of healthcare. The digital agreements using intelligent contracts in the healthcare sector are arguably one of the most substantial applications of blockchain technology. Because smart contracts eliminate middlemen from the payment process, they lower costs. The ecosystem's adoption of related cutting-edge technologies will determine how well blockchain technology works in the healthcare sector. Included are system tracking, drug tracing, clinical studies and health insurance. Even during their whole life cycle, hospitals can use device monitoring to map their services using a blockchain architecture. Medical record administration could be improved by blockchain technology, especially in the areas of insurance mediation and tracking, which would make clinical procedures faster and preserve the standards of data quality. All things considered, this type of technology can potentially and significantly improve healthcare services and eventually change the way how physicians and patients manage and utilize clinical information.

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