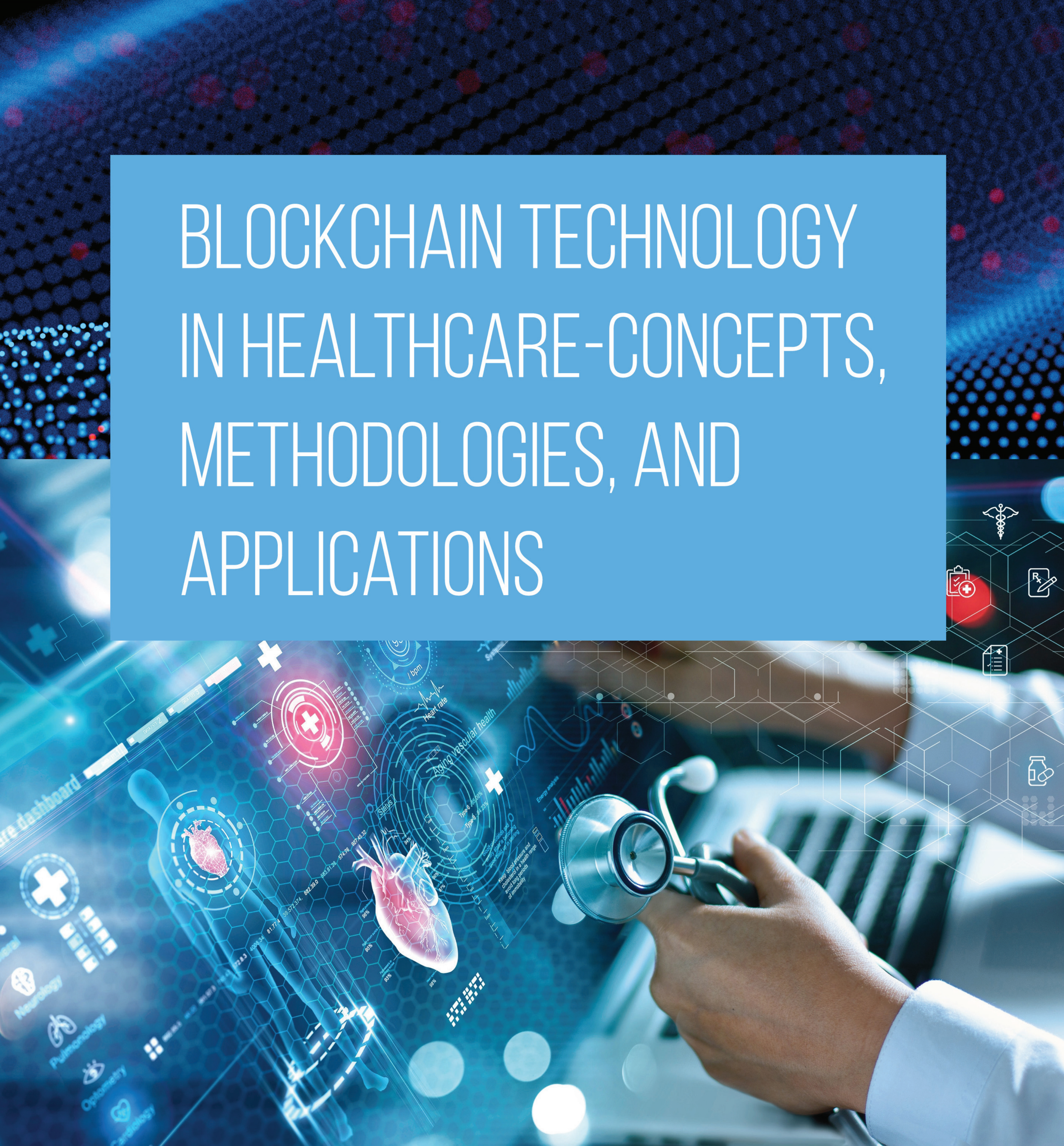

BLOCKCHAIN TECHNOLOGY IN HEALTHCARE-CONCEPTS, METHODOLOGIES, AND APPLICATIONS

Editors:
Nilayam Kumar Kamila
Sujata Dash
Subhendu Kumar Pani

Bentham Books

Applied Artificial Intelligence in Data Science, Cloud Computing and IoT Frameworks

(Volume 1)

Blockchain Technology in Healthcare-Concepts, Methodologies, and Applications

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CONTENTS

FOREWORD

Blockchain technology has successfully revolutionized cryptocurrencies by creating a new form of money transactions without relying on having trust in a centralized/third-party service to function. The blockchain is a special distributed ledger technology with tremendous potential to revolutionize how we change value, transfer ownership, and verify transactions in many industrial sectors. A blockchain system is a shared, immutable, distributed digital ledger system that stores linked blocks of peer-to-peer transactions, agreements, and control records, in which the data stored cannot be tampered with. Relying on established cryptographic algorithms, the blockchain allows each participant in the system to interact without pre-existing trust between each other. Unlike traditional centralized systems, a blockchain system does not have a central authority, and all transactional information is stored in blocks and distributed across all participants in the network. Restrict verification is required before adding any information to the chain, which allows trustless participants to share data without losing control and ownership while maintaining an immutable audit trail of all interactions. The decentralized nature of blockchain allows blockchain to help enterprises build processes and solutions, reducing costs, increasing traceability, verifying ownership and proving identity, improving customer experience, and enhancing security. This book provides a good exploration of e-blockchain technology and details on how it can be used to solve business problems. It also explores what they can achieve in various industrial sectors, specifically in medicine and healthcare. In the healthcare sector, a typical use case of blockchain technology is blockchain-enabled supply chain governance, which integrates blockchain technology into the supply chain management system to create a more traceable, secure, transparent, and reliable supply chain system. Using self-executing smart contracts, the blockchain pharmaceutical supply chain takes into account the requirements and interests of all stakeholders. It offers immutability from lab to bedside and secure data management. Blockchain has a broad field of applications in the medicine and healthcare industry, which can facilitate the immutable and secure exchange of medical records and personal data, manage the pharmaceutical supply chain and maintain the traceability of all information involved. On the other hand, the blockchain is capable of keeping an immutable, traceable, secure, transparent, and decentralized database of all patient data and medical records. The restricted verification using cryptographic algorithms in blockchain technology also allows patients, clinics, healthcare organizations, and healthcare providers to share medical information without privacy leakage concerns. This book brings new insights and opportunities that can make medicine and healthcare sectors secure, efficient, and interoperable by using blockchain technology. The insights and solutions of blockchain highlighted in this work can also be easily ported to other industry sections to address challenges related to transparency, immutability, traceability, and full ecosystem interoperability. This work is expected to prompt the realization of the full potential of blockchain technology in medicine and healthcare and illustrate how to build blockchain application ecosystems.

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PREFACE

Overview

The blockchain revolution has profoundly altered global economics and industry-specific strategic practices. The novel uses of blockchain technology can be viewed as a developing sector in anything from data management, financial services, cyber security, IoT, and food science, to the healthcare business and brain research. While innovative blockchain technology and its applications are still being built and developed, it is crucial that academics and industry professionals gain a more excellent knowledge of this universal phenomenon. An emerging area of study is blockchain in medicine and healthcare. The blockchain combines cryptography, critical public infrastructure and economic modelling with peer-t--peer networking and decentralised consensus to synchronise dispersed databases. Although cutting-edge blockchain technology and its applications are still being created and developed, thus academics and business experts must have a deeper understanding of this global phenomenon. The use of blockchain in healthcare and medicine is a new area of research. The blockchain coordinates scattered databases using peer-to-peer networking, decentralised consensus, critical public infrastructure, economic modelling, and cryptography.

Regarding accurate diagnosis and treatment through safe and secure data sharing, blockchain is also rebuilding conventional healthcare practices more dependably. By integrating all the real-time clinical data about a patient's health and presenting it in an advanced secure healthcare setting, blockchain technology can help us soon provide personalised, authentic, and safe healthcare. Additionally, security, privacy, trust, and scalability considerations are necessary.

Objective

The book "Blockchain Technology in Medicine and Healthcare - Concepts, Methodologies, Tools, and Applications" is intended to report on the most recent advancements and innovations in blockchain in medicine and healthcare. The book will be essential in greatly improving human lives. The blockchain, health informatics, and security fields will significantly help researchers and practitioners. This book would be an excellent compendium of cutting-edge methods for using blockchain in healthcare and medical applications. Knowing the top-performing techniques fast will be incredibly helpful for new researchers and practitioners working in the field.

They could contrast various strategies and continue their research in the most crucial area directly affecting improving human life and health. This book would be beneficial because there is yet to be one on the market that offers a comprehensive compilation of cutting-edge blockchain applications in healthcare. The use of blockchain in biomedical and healthcare research is a relatively new development with few established applications.

This book aims to report on the most recent advancements and breakthroughs in security, health informatics, and blockchain. The book's material is divided into three sections; the following three sections go into greater detail on the coverage and topics of each chapter:

• Blockchain and Clinical Trials for Health Informatics.

• Blockchain for Medical Data Analysis.

• Blockchain for Security and Health Information Exchange.

Organisation

The book, **"Blockchain Technology in Medicine and Healthcare: Concepts, Methodologies, Tools, and Applications"** consists of 13 edited chapters, and the full contents of the book are organised into the following three sections:

• *Part I: Blockchain and Clinical Trials for Health Informatics.*

The application of blockchain to clinical trials in health informatics has been the main emphasis of this section. This section consists of three chapters. The first chapter explains how to use blockchain to gather and store patient data, analyse outcomes in a distributed but secure manner, an exchange that data transparently while maintaining its immutability, and overcome the difficulties associated with conducting clinical trials. The second chapter discusses the difficulties in maintaining the confidentiality, accuracy, and integrity of clinical data while conducting clinical trials. Specifics about the data collection techniques used during the clinical trial's operation and the problems they caused. Additionally, it suggests a secure cloud-based clinical data management system that is blockchain-enabled.

The final chapter thoroughly analyses how revolutionary and disruptive blockchain technology is being applied to the healthcare sector to address the problems mentioned above. In a peer-to-peer (P2P) network, a blockchain ledger that is cryptographically immutable, time-stamped, distributed, and tamper-proof can be created to preserve Electronic Health Records (EHRs) in the healthcare system. With the help of this technology, any transaction in a blockchain network has no intermediaries between the source and destination points. The substance of every transaction in a blockchain network cannot be changed because all transactions are cryptographically lither.

The fourth chapter will provide a broad review of guiding principles, applications of blockchain in the healthcare industry, and potential problems and solutions.

• *Part II: Blockchain for Medical Data Analysis.*

There are six chapters in the second portion. The first contribution looked at numerous cutting-edge blockchain applications in the healthcare industry. The blockchain has more reviews than ever before, but they are constrained. The exoteric study offered in this chapter reveals that, when compared to other applications, this disruptive technology offers clear advantages in the healthcare industry.

The second chapter investigates the current application methods, obstacles faced, open questions, data standards, and compliance issues fundamental to adopting a blockchain-based solution in the healthcare business through a systematic study of the literature on blockchain and healthcare data. The current research also investigates the worries and perspectives of blockchain professionals working in the healthcare sector. The third chapter emphasises blockchain's decentralisation feature and how it will resolve problems. By developing a broad mechanism that connects various personal records, blockchain can help the electronic health records sector by lowering data sharing and interoperability. It can also simulate data sharing by immediately bridging the gap between owners and customers. As a result, this chapter aims to give comprehensive information on using blockchains to advance health research data analysis.

Businesses and governments are looking for solutions as the coronavirus illness (COVID-19) continues to spread worldwide to lessen its impact. In chapter four, a structured literature review of peer-reviewed articles on blockchain's implementation and adoption in the supply chain management, education, logistics, and finance sectors was carried out to evaluate the effectiveness of blockchain technology in its efforts to lessen the impact of the pandemic and clearly define the challenges and prospects of blockchain.

It is advised that blockchain be used and adopted in all industries since it offers a decentralised network where information is available, and individual privacy and security are ensured, not just in the banking industry. Therefore, blockchain can be used by businesses, governments, and health professionals in the fight against the virus by transforming the challenges into opportunities combined with prominent essential enablers, which would speed up its wider adoption. Blockchain has been widely accepted and implemented in a few sectors of the economy, especially in finance and supply chain management.

The work carried out by numerous researchers over the previous 11 years is methodically reviewed in chapter four. A projection of a new use of the same technology is proposed, specifically the application and influence of blockchain technology in numerous industries, such as crypto-currencies, the health sector, e-governance, banking, and finance. The final chapter covers distributed ledger technology in the healthcare industry, which has been cited as crucial for producing patient data for research, medication adherence, managing multiple patient bedside data, pharmaceutical supply chain, and quality of care. This chapter will outline how Blockchain distributed ledger technologies are applied to the biomedical and healthcare industries.

• *Part III: Blockchain for Security and Health Information Exchange.*

This section consists of three chapters. Blockchain technology is the cure that enables medical service units that are based on various platforms to share electronic health record data. However, given the cost and size of the blockchain, Chapter 2 has emphasised that one of the main issues with this strategy is the difficulty in storing all the electronic health record data on the blockchain. Cloud computing was selected as a potential exit strategy. A unique possibility provided by cloud computing includes storage of scalability and availability. However, because sensitive data is exchanged through a public route, the cloud computing-advantaged electronic health records may be vulnerable to attacks. To effectively manage and combine medical care, it is necessary to share and disseminate medical information and data electronically. Unfortunately, it is challenging to share data securely using the outdated cloud-based electronic medical record storage infrastructure. Due to blockchain technology's tamper resistance and traceability, sharing extremely private health information is possible. As a result, this chapter aims to give comprehensive information on the use of blockchain in medical imaging systems.

The construction of the blockchain, its framework, the advantages and disadvantages of combining these technologies, and the function and significance of machine and deep learning algorithms in fraud detection and prevention in the blockchain are covered in the first section of the second chapter. The reported work is the main topic of the next part, which also highlights the work of other researchers who use Blockchain technology to detect and prevent fraud. The chapter's last section compares numerous performance metrics for each sort of fraud detection utilising blockchain technology, including accuracy, the area under the curve, confidence, true negative, false positive, and genuinely positive results.

The final contribution showcases a cutting-edge healthcare framework that uses the blockchain idea. This article mainly aims to use Blockchain to construct electronic health records (EHR). Its decentralised design eliminates the possibility of a single point of failure and strengthens the system. The proposed method uses an off-chain data source to address the extensibility issue that blockchains all share. The findings show that computers are far safer and fraud-free compared to the conventional health record system. Finally, the suggested technique highlights situations where the new approach should work well, like in an EHR.

Target Audiences

The current volume serves as a reference book for a variety of audiences, including the following:

• Researchers working in this area who want to be aware of the most recent advancements in theory, methodology, and research.

• Biomedical and informatics students and academics interested in deepening their understanding of recent advancements.

• Business and professionals from technical institutes, research and development firms, and fields relating to machine learning, blockchain, the internet of things, cloud computing, biomedical engineering, and health informatics.

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CHAPTER 1

Utilizing Blockchain Technology to Improve Clinical Trials

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Abstract: The development of new drugs by pharmaceutical companies becomes a challenging task as it takes longer timelines, and the clinical trial process involved before the introduction of any new drug is risky and highly unpredictable. The patient data available for the clinical trial process is distributed across several databases, and the data are stored in different formats; hence it becomes difficult to perform clinical trials. Many stakeholders (pharmaceutical companies, research labs, patients, participants, government authorities, and many more) across geography are involved in the clinical trial process. Cooperation among these stakeholders is necessary to conduct a clinical trial. A Clinical trial is a complex and time-consuming procedure that faces a constant challenge of data management, data sharing, and data security, resulting in being an expensive affair.

Blockchain technology can be used to augment the entire workflow of clinical trials and overcome the mentioned challenges. It uses consensus protocol for efficient transmission and communication of data between nodes. Patient recruitment for clinical trials can be easily managed through "Smart contracts". Any computational problem related to patient recruitment for a clinical trial, checking the validity of clinical trials, can be coded with smart contracts. This paper describes the utilization of blockchain to collect and store patient data and analysis results in a distributed yet secured manner, which can be shared in a transparent way and remain immutable as well as allows to tackle the challenges involved in the clinical trial process.

Keywords: Blockchain, Clinical trial, Consensus protocol, Smart contracts, Stakeholders.

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Nilayam Kumar Kamila, Sujata Dash & Subhendu Kumar Pani (Eds.)

1. INTRODUCTION

1.1. Background

Scientific studies conducted to treat, diagnose, screen, or find better ways to treat disease is called clinical trial (CT). CT is also a primary method to test and validate new drugs and therapies. Trials involve multiple sites all over the world, with different trial protocols and government regulations. Due to these reasons, CT process involves a high cost and also consumes a lot of time to complete the entire process. Research institutions and pharma companies involved in clinical trials try hard to reduce the time and cost involved in conducting the CT process. The high cost is incurred by pharma companies due to the unpredictable and risky nature of the CT process. Several factors are involved in the clinical trial process, like patient involvement, laboratory investigation, patient investigation, approval from regulatory bodies, *etc*. Due to these processes, the CT process takes long development timelines, which reduces the chances of introduction of a successful process to zero, which is evident in the COVID-19 pandemic.

1.2. The Problem

The COVID-19 pandemic has discontinuous clinical trials worldwide, with long-lived effects on medical science. Worldwide Disruption in the clinical trial process has occurred due to this pandemic situation. The virus has led to the situation that the flexibility to conduct trials safely and effectively is completely not possible, as the trials have to be conducted to vulnerable patients (subjects) who are exposed to covid-19 [1]. Moreover, several trials are stopped due to the difficulties to conduct trials under the lockdown situation. Even after relaxing the lockdown in some sites, there were great challenges in conducting trials.

In the Indian scenario, the trial process is likely to be conducted in private hospitals as severe covid-19 patients will require intensive care support. This would deprive economically backward people to get the benefit of participating in the trial process. So, the challenge here is the Indian government should set up a supervised trial by the government agency which should allow all covid-19 patients to register for their trial process irrespective of their economic background.

Participants selected for Clinical trials of covid-19 are selective as it requires in-depth attention. This is because it affects the efficiency of therapeutic intervention and evaluation. Following the scientific and ethical principles into practice during the clinical trials of covid-19, is a huge challenge [2].

Due to covid-19, there were huge disruptions in clinical trials [3]. These disruptions were due to the slow or suspension of enrollment and delay in the trial initiation process. Based on the data source provided by global data, it is evident that the delay in the initiation process was steady, and there was an increase in the slow enrollment process. One of the main reasons for subjects not to enroll in a clinical trial was because the chances of contracting covid-19 are high with them due to their previous health issues [4].

The uncertainty created by the covid-19 pandemic poses many glitches to investigators/researchers. The challenges faced by the investigator include producing accurate data, maintaining clinical data privacy, on-time patient enrolment methods, and efficiently sharing personal data across the various stakeholders involved in the clinical trial process. Luckily, there's a new technology that is attracting the attention of investigators and researchers that may help find solutions to all of the problems, which is Blockchain technology. With this technology, many researchers find a lot of highly effective and efficient processes that may help address the challenges faced nowadays. It took nearly two years to help recognize the viability of this technology in addressing the challenges present today in clinical trials, like patient enlisting, auditing the clinical supply chain, restoring integrity to trial information, and helping research institutions to reduce the time and cost to conduct trials [5].

1.3. The Proposed Solution

Blockchain is a time-stamped data structure where it has the 'append-only' option of data. Blockchain works in a distributed environment with a peer-to-peer network. The primary functionality of blockchain is transaction processing. When any new transaction arises in a blockchain, it is verified by the participating node in the network using a consensus algorithm. Blockchain processes transactions in a transparent and secure manner. Due to the digital immutability feature possessed by blockchain, information, once entered into the blockchain can never be altered or changed. Because of these reasons, blockchain has applications in various sectors like Banking, Education, Medical, and electronic health record. Bitcoin is one of the most popular applications of blockchain that helps to transfer money without the need for a third party.

Another important feature of blockchain is smart contracts; with smart contracts, the blockchain can keep track of interactions among nodes in the network without the involvement of any intermediary or third parties. It enables the execution of contracts between parties in a neutral and unbiased way. Hence, a smart contract helps in achieving ethical practices in business. This same technique, if applied in the clinical trial process, will benefit the various stakeholders like Investigators,

CHAPTER 2

Securing Clinical Trials Data with Blockchain

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Abstract: Discovering and developing new drugs/ medicines is very crucial for the pharmaceutical industry. The increasing number of drugs approved in recent years demonstrates the impact of modern drug discovery approaches, digital technologies, and automated drug development methodologies. Drug development is a systematic and methodological process of developing a new pharmaceutical drug once the process of Drug discovery has identified the prime pharmacological component. The structured sequence of steps followed for drug development aims to ensure the safety and efficacy of the drug being developed. It includes pre-clinical research on microorganisms and animals, preparation of detailed data with respect to pharmacology, pharmacokinetics and toxicology details, application and approval by regulatory authorities and conduction of clinical trials. The conduction of clinical trials is an expensive affair as it needs a collaborative effort by multiple stakeholders along with a high level of monitoring and regulation. The data generated during the lifecycle of clinical trials is very critical for pharmacological scientific publications, regulatory approval for the target drug and post-marketing surveillance that ultimately leads to the development of better decision support systems for drug development. Hence, the data integrity of such data is of prime importance. Several Clinical data management (CDM) systems have been developed to ensure seamless collection and management of clinical trial data. These CDM systems enable useful analysis and decisions supported by authentic data. However, such systems face several security challenges with respect to privacy, integrity and authenticity of the clinical data. Another major challenge in conducting the clinical trials is finding the appropriate willing candidate who is physically and clinically suitable for the study. In view of the above, it is highly desirable to have a technology component that can address the above-mentioned issues. In this chapter, the technologies like blockchain and cloud computing have been introduced to address the challenges posed by clinical trial data management. The paper also proposes a blockchain based secure clinical data management system. The proposed system intends to help the data security issues like data integrity, privacy, ease and quick access to immutable clinical trial data with thorough access control enabling greater transparency and accountability.

Keywords: Blockchain, Clinical trials, Clinical data management, Cloud computing, Drug development, Data integrity, Security, Smart contracts.

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Nilayam Kumar Kamila, Sujata Dash & Subhendu Kumar Pani (Eds.)

1. INTRODUCTION

Drug development [1] is a long, step-by-step expensive process that has three basic stages: Drug discovery, Drug development and clinical trials. This process needs interdisciplinary knowledge and expertise like pharmaceutical related in-depth knowledge and scientific & technological skills. This also needs a collaborative ecosystem that will enable multidisciplinary professionals to work together, including the pharmaceutical industry, research organizations, government regulators and healthcare professionals. A new drug is a pharmaceutical terminology used to indicate medication or therapy that has not been in clinical practice to treat a disease or health condition. It takes approximately twelve years and an average of $1.8 billion to launch a new drug and make it usable in the market [1]. Fig. (**1**) depicts the lifecycle of any new drug that needs to be brought to market for human use.

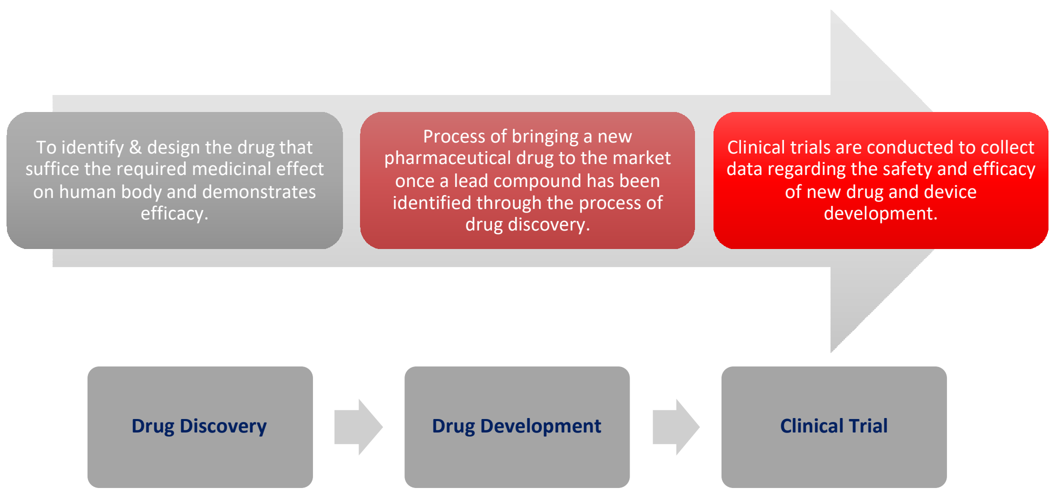

Fig. (1). Lifecycle of Drug Development.

Drug discovery [2] is a complex process of identifying a synthetic molecule or a biomolecule as a potential drug candidate for treating a disease or health condition. This process includes subprocesses like identification of the disease & its unmet need, identification of the best compound to target the disease, finding out the prime components that exhibit potency and optimization to attain efficacy of the identified molecule. Drug development is a systematic and methodological process of developing a new pharmaceutical drug once the prime pharmacological component has been identified by the process of Drug discovery. Clinical trials [3] are research studies performed in humans that aim to evaluate a medical therapy to treat a disease or medical condition through surgical, or behavioural intervention. These studies are the primary mechanism to validate the safety and efficacy of the new pharmaceutical product like a drug or vaccine, or medical device. It can only be conducted if pre-clinical data demonstrate the usefulness of the drug in treating a disease and is proven to be reasonably safe for testing in humans. Clinical Trials have several phases, and at every stage, important data is generated that is useful for various stakeholders of clinical trial. Fig. (**2**) depicts an overview of clinical trial phases with details of data generated at each stage.

Clinical Trial Phases:

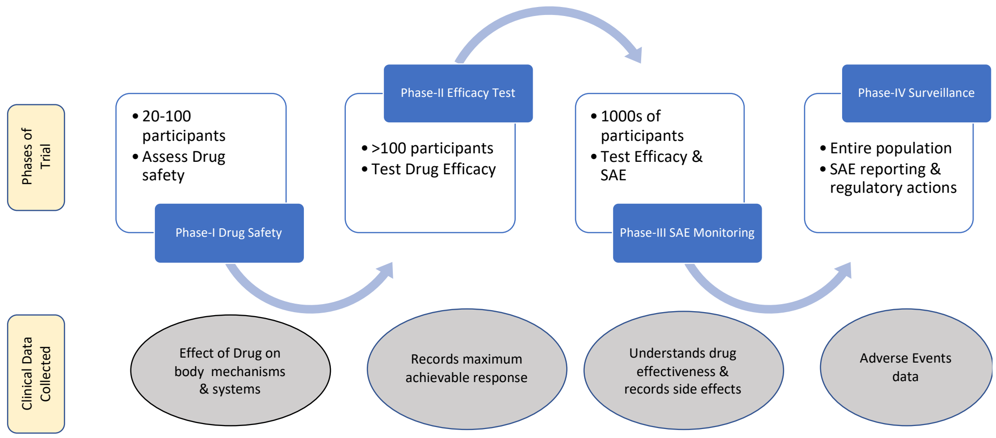

Fig. (2). Phases of Clinical Trial with details of data generated.

As indicated above, a clinical trial is a time taking process and hence, has to be properly designed and planned to provide reliable efficacy and safety data. Standard operating procedures & protocols, along with revision histories, needs to be documented and maintained. This data provides end to end audit trail of the clinical trial. The same needs to be intimated to regulatory authorities, and approval must be secured. The trial is also monitored by the ethics committee. Clinical trials must adhere to rules and guidelines, including the Code of Federal Regulations [4], the Good Clinical Practices (GCPs) [5, 6] guidelines from the International Conference on Harmonization (ICH), state laws, Sponsor Standard Operating Procedures (SOPs), and institutional SOPs.

2. CONDUCTING CLINICAL TRIALS

Clinical trials are conducted to collect data regarding the safety and efficacy of new drugs and device development. There are several steps and stages of approval in the clinical trials process before a drug or device can be sold in the consumer market. The pharmaceutical product is extensively tested in the research laboratory, which can involve years of experiments in animals and human cells.

CHAPTER 3

A Complete Review of Block Chain Technology in the Health Sector

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Abstract: The health sector has been a huge market in recent times. It is drawing minute attention regarding pathological tests, drug manufacturing and supply, clinical trials and diagnosis by doctors and finally, recovery of patients quickly. The technologies used in health care for the last decades are redundant. Clinical trials and diagnoses by doctors can be made more accurate, better and faster with a past medical history of the patient in hand. Drug manufacturing and distribution can be made tampered proof and monitored properly by designing a transparent supply management system for medicine and medical goods. Attempts were made in the past to record the medical history of patients in a centralized database server, which lacks security, immutability and consistency of the records. This paper reports a systematic review of the application of revolutionary and disruptive Blockchain technology in healthcare systems to address the above issues. Blockchain technology can be used to create cryptographically immutable, time-stamped, distributed and tamper-proof ledger in a distributed P2P network to maintain Electronic Health Records (EHR) in the health care system. This technology removes all intermediaries between the source and destination point of any transaction. In a Blockchain network, transactions are cryptographically connected and hence merely difficult to modify the content of any transaction. This review shows that a number of studies in the past have proposed the application of Blockchain in health care. However, many of these used cases lack detailed prototypes and consensus algorithms from an implementation point of view. The review also highlights and depicts in detail the application of Blockchain in EHR and medicine supply management systems. The review further highlights the bottleneck of Blockchain and the area of its research in the near future.

Keywords: Blockchain, Consensus, Distributed ledger, Mining, P2P Network, Supply chain.

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Nilayam Kumar Kamila, Sujata Dash & Subhendu Kumar Pani (Eds.)

1. INTRODUCTION

In recent years, the digitization of health & patient data is undergoing a radical shift for efficient clinical diagnosis. Patient's past medical history in prior will definitely accelerate & precise the diagnosis process by the doctors. Storing patient's data in centralized servers at different stakeholders may sometimes lack privacy, security, consistency, integrity, isolation & accessibility.

Distributed databases [1 - 3] can utilize the benefits of a centralized database, particularly in data sharing. If any breakdown occurs, distributed systems are less affected than a centralized system. If a node breaks down in a distributed system, the system may not halt its functioning due to the presence of other nodes. The topology of the network, communications software and nature of the distributed data are the major parameters that affect the operations and efficiency of a distributed system. Complex data management techniques are introduced in distributed database system to handle issues and problems pertaining to data integrity and concurrency. As data are located and replicated at different locations, it may lead to data inconsistency whenever data is modified [2] at a particular location. Significant challenges are there to implement a distributed system. Data communication can be controlled by advanced networking software that can also address the overhead associated with the system. Fig. (**1**) depicts centralized, decentralized and distributed system.

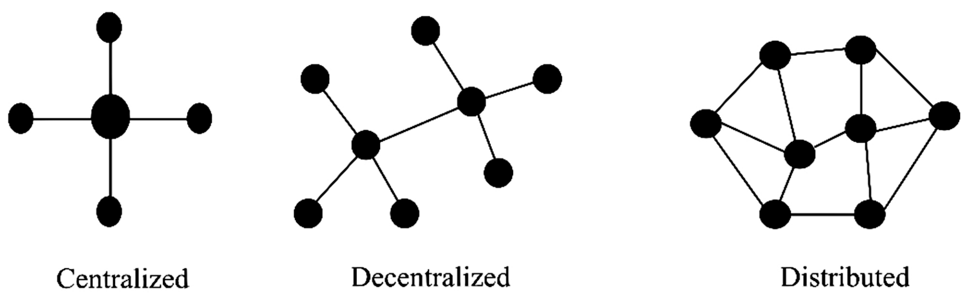

Fig. (1). Centralized, Decentralized & Distributed System.

Moreover, centralized systems are based on some trust-based models, and hence any transaction will involve the intervention of a third party. In decentralized systems, the decision is made by individual nodes. The final result of the system is obtained by the decisions of the individual nodes. Blockchain [4] seems a promising technology in the near future to cater to the above challenges to store patients and other medical data in decentralized manner. The transactions in a blockchain network are not verified by any third-party entity, but rather driven by some consensus mechanism [5].

Blockchain, the technology behind the first cryptocurrency Bitcoin [6, 7], was first proposed by an anonymous person aliasing Satoshi Nakamato [8] in the year 2008. Blockchain-based bitcoin network [7] was meant for transacting cryptocurrencies robustly in a P2P network without the intervention of any third party. Since then, the technology has been buzzing a lot in the market to revolutionize data storage & transactions over a P2P network. The technology is based on distributed Ledger Technology [9], where transactions are time-stamped and added to the network without involving any intermediaries. Transactions are stored in blocks and are added to the network owing to some consensus mechanism. Advantages of this technology include immutable ledger, decentralization, anonymity, transparency, integrity, and security through cryptographic mechanisms [10]. Initially, the scope of blockchain technology was limited to Bitcoin cryptocurrencies [7] which is often termed blockchain 1.0 [11]. Later on, the ethereum [12] network was developed, which uses blockchain technology to implement programming *smart contract* [13], also called blockchain 2.0. Nowadays, researchers are applying blockchain technology to develop decentralized applications (DApps) [14] usable for industry, which are termed as blockchain 3.0 & 4.0. Fig. (**2**) depicts the evolution of Blockchain technology. In spite of many challenges & constraints [15], it is expected that this technology is going to envisage the current infrastructure of internet & communication.

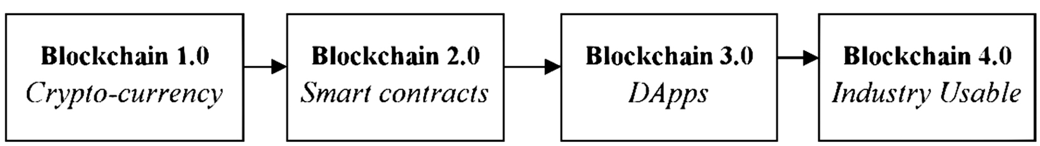

Fig. (2). Evolution of Blockchain Technology.

In the past few years, many researchers have proposed the use cases of Blockchain technology in several areas like cryptocurrencies [16 - 20], Internet of Things (IoT) [21 - 25] and health sectors [26 - 35]. But this potential technology could address many vital areas of the healthcare industry to a great extent. Researchers are emphasizing blockchain technology which can yield industry-usable products. But health sector is trending a lot for the evolution of this technology to a great extent. Few areas where Blockchain can impact the health sector are maintaining patient's database [27], drugs supply chain management systems [28], health insurance [29], *etc*.

This paper systematically reviews the application of *revolutionary* and *disruptive* Blockchain technology in the healthcare industry. It also explains various use cases for healthcare management and applications using blockchain. This paper also aims to discuss the potential challenges of Blockchain technology in the

CHAPTER 4

Blockchain and Clinical Trials for Health Informatics

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Abstract: Blockchain is part of the disruptive novel technology stemming from the cryptocurrency and bitcoin, which became large-scale around the year 2011. Subsequently, these technologies have triggered much need attention through the development and growth of more novel cryptocurrencies resulting in transactions, elections, peer reviews, democratic decision-making, identification and audit trails. The health sector has benefited immensely from the rapid advancement in blockchain, such as growth in biomedical research, drug traceability in the pharmaceutical sector, clinical trials, biological testing, patient's data management, health informatics, data sharing, supply chain management of medical goods, legal medicine, telemedicine, health record, remote patient monitoring, payment services and security. Thus, this chapter will give a general overview of the principles, and applications of blockchain in healthcare industries and possible challenges with ways to resolve them.

Keywords: Bitcoin, Blockchain, Cryptocurrency, Health sector, Technology.

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1. INTRODUCTION

Studies have revealed that blockchain, as part of the disruptive novel technology, stems from cryptocurrency and bitcoin, which became large-scale around the year 2011. Subsequently, these technologies have triggered much need attention through the development and growth of more novel cryptocurrencies resulting in transactions, elections, peer reviews, democratic decision-making, identification and audit trails [1 - 9]. In particular, the health sector has benefited immensely from the rapid advancement in blockchain, such as growth in biomedical research, drug traceability in the pharmaceutical sector, clinical trials, biological testing, patient's data management, health informatics, data sharing, supply chain management of medical goods, legal medicine, telemedicine, health record, Remote Patient Monitoring, payment services and security [10]. Blockchain in the medical and healthcare sector has the advantage of preserving data from corruption to make it secure. The decentralization healthcare management using blockchain can be the backbone where stakeholders can utilize patient's data or records without any hindrance or obstacle. Blockchain data cannot be altered, corrupted and retrieved due to encryption appended in chronological pattern and time stamped using cryptographic key. Esmaeilzadeh *et al*. [11], in their study examined the perceptions of patients toward the utilization of blockchain mediated health information exchange networks and the arch significance of blockchain knowledge from the perspectives of consumers in the healthcare industry. The authors created seventeen knowledge-based exchange situations for regulated Web-based trials. The results indicated that the views of patients varied concerning various information exchanges as far as patients' privacy was concerned. The work showed both the promising roles of health information exchange and the limitations. Blockchain helps patients to detect any misuse emanating from any stakeholder, thereby providing data ownership and privacy with cryptographic protocols and smart contracts. Even though so many beneficial properties have been presented about blockchain in healthcare industries, there are still contending challenges, such as storage issues and large amounts of computational power [12]. Thus, this chapter will give a general overview, principles, and applications of blockchain in healthcare industries and their possible challenges with ways to resolve them.

2. PRINCIPLES OF BLOCKCHAIN

Blockchain, a public ledger of transactions, has operational principles. For instance, in blockchain, there is no need for a central regulator or a third party. There is no need for any hardware. Instead all participants are involved in data authentication. In fact, blockchain technology utilizes no central server, and the network is *i.e* P2P protocol. All nodes in the P2P network exhibit identical network power. Crossby *et al*. [13], reported that blockchain is a system where dispersed consensus in the arithmetical world is created to enable individual entities to understand that a digital activity happened by creating a correct score in a public blockchain ledger. It creates room for the development of a scalable and open arithmetical economy from a central one. Another important concept is transparency and openness.

In the blockchain approach, data is accessible to everyone. It is, therefore, possible for anyone to critique or question blockchain data. Applications can also be created *via* a shared interface. In blockchain, all data properties are grouped into the nodes linking every blockchain arrangement. Data external to the blockchain arrangement are inhibited. All information and activities within the arrangement are open and apparent to all the nodes that are in the system. Through the integration of hash encryption and asymmetric encryption, the blockchain provides high transparency of data [14, 15]. Apart from openness and transparency, another concept is independence. The blockchain is managed by its own node. No manual intervention is involved in the implementation of its data proof mechanism [14].

Like the works of Zheng *et al*. [15], Crosby *et al*. [13], Lin and Liao [14], Lansiti and Lakhani [16], reviewed principles underlying blockchain technology. In the blockchain, there is data distribution, openness and transparency. This implies that no one regulates blockchain data and it is possible for anecdotal data to be checked by every partner directly. Blockchain is decentralized, and as such, no communication involves a central node, but partners communicate directly. Another important concept of blockchain is that once records have been updated, alterations cannot be affected. There are many computational algorithms which made transactions permanent. Lastly, blockchain transactions are programmed. This means that participants can put forth algorithms between nodes that instigate transactions automatically.

3. TYPES OF BLOCKCHAIN

Studies have revealed the existence of three kinds of blockchain-based permission levels federated blockchain, public blockchain and private blockchain. Concerning public blockchain, it is permissionless transaction validity anonymity, easy to operate by the public community such as Bitcoin, Waves, Ethereum, Bit shares, and Dash. The federate blockchain is based on permission with group operating protocols like consortiums like EWF, B3i and R3 Corda. The private blockchain is also a permission centralized blockchain which is faster but highly vulnerable to security issues such as private Ethereum, Hyper Ledger with Sawtooth, and Monax.

CHAPTER 5

Blockchain Technology: A Vehicle for Efficient and Comprehensive Medical Application Solutions

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Abstract: Blockchain technology is the technology of the twenty-first century. Web 3.0 is the name given to the next digital revolution. It was first developed to provide a secure payment mechanism, but it was later adapted and utilized in various industries. Healthcare is one of the domains where this technology has been deployed in the last few years and has yielded considerable results. The fast adoption of digital technology in the clinical sector has led to the construction of massive health records. As a result of this growth, there are never-before-seen requirements for clinical information security throughout usage and exchange. This adoption of the blockchain method as a reasonable and effective data storage and handling platform is opening up new opportunities in healthcare for tackling key data privacy, security, and integrity issues. Patients and healthcare providers have difficulty accessing, storing, integrating, and transmitting health information. Individuals are likely to access and control their medical information from everywhere on the planet, process and report their clinical findings, grant permissions, and even securely exchange that data with certain medical professionals. Straightforward health information access and an even more complete digital information architecture might help the medical industry better prepare for public health threats like COVID-19. We will examine several of the numerous ways that blockchain methodology has been employed in the clinical area, as well as its prospective scopes and possibilities for a better tomorrow, in this research.

Keywords: Blockchain, Healthcare, Health records, Medical applications.

1. INTRODUCTION

R. Vidhyuth and Dr.T. Manoranjitham [1] explained Blockchain is a decentralized network that was first introduced as part of the Bitcoin movement. This is a p2p infrastructure system that runs *via* the internet and is initially represented in a

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research work done by Satoshi Nakamoto (pseudo name), a Japanese (proclaimed) researcher, in October 2008. The author introduced the world to Bitcoin, the digital money that will be used as a secure online payment mechanism. This Cryptocurrency system was designed to cope with the complexity of peer-to-peer (P2P) duplicate spending. This digital currency was built on the blockchain database approach, and this virtual currency system could issue currency, transfer ownership, and validate transactions without using a central authority. Abu-elezz and coworkers [2] have explained, in a public blockchain, a block consists of four main components: the content, the hash of the continuing block (classifying identifier), the hash of the previous block, along with the date-time when every new block is chained toward the prior block. Fekih and Lahami [3] have explained that, as a consequence, these blocks form a chain or data set, with every block constructed on the former ones. As per Zhang and coworkers [4], whenever a block gets added to the network, the historical record of its transactions is encrypted to protect against tampering.

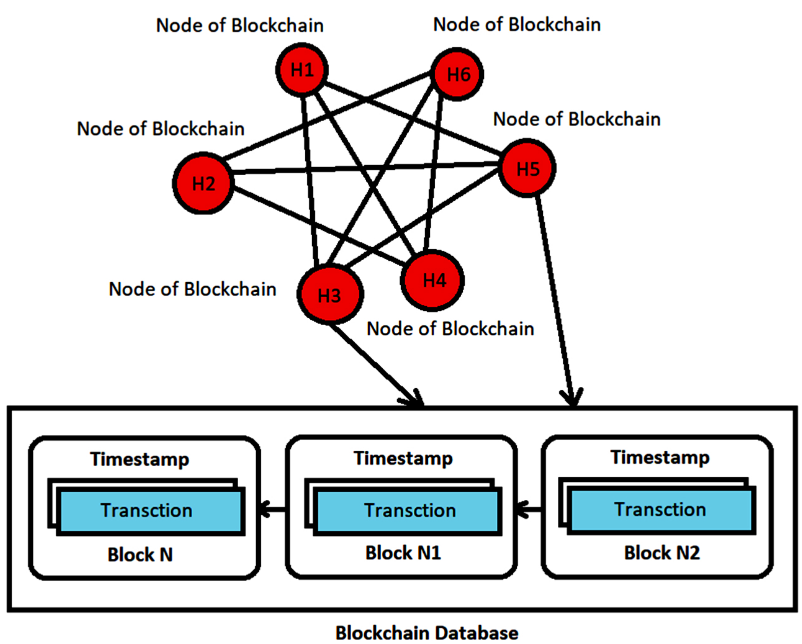

Fig. (1). A Typical Blockchain Network Architecture.

Currently, Blockchain is being divided into four categories: (i) Public, (ii) Private, (iii) Consortium, and (iv) Hybrid. The public blockchain network is quite open. Every user has access to the consensus process and can participate in it. One-story solutions leverage private blockchain to track data transfers between agencies and individuals. Each user must agree to join the network, and the user will be informed when the network has been consolidated. The Blockchain Conglomerate is indeed a reliable and established initiative. To record data transactions between members, it's being utilized as a highly coordinated decentralized platform that can be audited. Public and private cryptographic protocols are merged in hybrid blockchain systems. The database is publicly disclosed by utilizing a decentralized backend system that limits access to the ledger's updates explained in Fig. (**1**).

Bitcoin technology was deployed one year after the publication, and its technology was made open source. Because of the publicly available data, many academics and technologists have stepped forward to understand and apply this technology to other applications. Other digital currencies, such as Litecoin, Name coin, Peercoin, Dogecoin, and others, were created in response to Bitcoin's flexibility and acceptability. This was the initial generation of the blockchain implementation, or version 1.0. “Smart Contracts” are a set of digitally declared commitments and mechanisms for the signatories to serve upon those commitments. According to the authors [5], these contracts are commonly used to authenticate contracts among multiple signatories. Smart contracts and their properties are related to blockchain technology's second generation or 2.0 version. As per Zhuang and coworkers [6], these contracts are computer programs that specify the regulations for governing and administering intelligent properties. For example, smart contracts may be used to manage transactions by enforcing the interoperability standard of sent data. Durneva and coworkers [7] have explained that interoperability is indeed the capacity of diverse gadgets, data systems, and implementations (systems) to acquire, interchange, incorporate, and constructively utilize information in a synchronized way, both inside and beyond operational, territorial, and governmental borders, to offer faster and more reliable data adaptability. JinYoon [8] has stated that the transformation beyond organization piloted into consumer-focused interoperability will be aided by blockchain methodology.

According to Tanesh and coworkers [9], when compared to previous contracts, a smart contract is not only quicker, but it also reduces the time it takes to execute and disseminate patient data. As per the authors [10], QTUM, Ethereum Classic, Ethereum, and NEO are a few examples of blockchain 2.0. Non-Fungible Tokens, or NFTs as they are currently known, are an example of these smart contracts and may be conceived as a bridge between Web 2.0 and Web 3.0. As a result of the preceding, non-monetary blockchain implementations are the primary goal of the new era of blockchain systems (blockchain 3.0). In order to help other businesses and use cases, attempts have been undertaken to redesign blockchain methods outside of banks. As a result, blockchain is gaining traction as a general-purpose

CHAPTER 6

Blockchain: Blocking Hassles in Healthcare

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Abstract: Healthcare institutions around the world are increasingly reliant on digital databases for the storage of medical data. The unprecedented growth of healthcare data's scale and velocity has made it of paramount concern for the modern age. Digital databases are vulnerable and adversely affect both the patient and the healthcare industry as a whole. The risk of cyber threats can breach data and disrupt its integrity. Maintaining both data integrity and patient privacy is critical to healthcare organizations. Regulatory frameworks such as GDPR in the EU and HIPAA in the US are both bodies for compliance rules for maintaining healthcare data privacy. Unfortunately, the tendency of healthcare institutions to use proprietary systems creates isolated silos of data that become difficult to secure using traditional methods.

A blockchain-based method provides a novel way of securing electronic healthcare records using a decentralized peer-to-peer based network on top of these isolated silos. Each block contains information and links to the other, forming a collective chain. This chain enables it to regulate on its own to store and share information instead of relying on a centralized system. Blockchain has many potential use cases in healthcare applications and can help in patient monitoring, storage, securing data, health information exchange, and clinical trial management, among others. The principle of decentralization and cryptography, at its core, will help transform the Healthcare system by improving the accessibility and security of patient information for the modern age.

Through a systematic review of literature on Blockchain and healthcare data, this paper aims to explore the current application methods, challenges faced, open questions, data standards, and compliance issues that are core to implementing a Blockchain-based solution in the Healthcare industry. Further, the present study seeks to explore the concerns and scope of the blockchain experts operating in the healthcare industry.

Keywords: Blockchain, Cyberthreat, Data privacy, GDPR, HIPAA, Healthcare, Patients privacy.

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1. INTRODUCTION

Out of all the industries, healthcare is the most sensitive concern to human. Though artificial intelligence has hit human beings hard yet the blockchain that emanates from cryptocurrency has evolved itself in various modes and dimensions. The relevance of online mechanisms has been indisputably realized in the pandemic times. The applications of blockchain have been profoundly realized, especially in the healthcare sector, a brief of which is presented as follows:

1.1. Electronic Health Records

Medrec is among the most cited initiatives in the Blockchain-based patient record management domain. It is an open-source Blockchain platform that has been developed, specifically for EHR management. Health Suite Insights, developed by Philips' Healthcare division, is experimenting with Verifiable Data Exchange Process, that would allow members in a hospital to exchange medical data among themselves. Medshare, also similar to Health Suite Insights, enables data exchange processes based on Blockchain technology. The data can be shared between the untrusted parties utilizing auditing, trailing and data provenance that is developed using blockchain-based smart contracts and access control mechanisms. It enables administrators to track the data behaviors and revoke access if a violation occurs. Iryo [1] is developing a global repository of health information, and the format used is Open EHR. There are several other projects that are included under it, such as Gem Health [2], OMNI PHR [3], Patientory [4] and others.

Blockchain in EHR is plagued by challenges of interoperability among the several Blockchain-based solutions that have come up in the recent past. Interoperability itself springs forth because of missing standards within Blockchain EHRs. Scalability issues are yet another concern, and so is the maintenance and management of privacy and security, given the nature and volume of healthcare data.

1.2. Personal Health Records Management

These are patient-centric applications that have several similarities with EHRs. The development of these applications based on Blockchain will assist patients in handling their data in a secure manner. A Blockchain-based PHR management works best with a device like a modern smartphone with a 4G/5G enabled network. A system on such a modern smartphone can help provide access to all three layers, a storage layer that is secure and reliable, a data management layer and a data usage layer. Emergency Access Control Management System, EACMS, is one of the applications that are based on permissioned Blockchain Hyperledger fabric and composer. The PHR permissions are handled by the patients on the basis of the same. Healthcare Data Gateway, HDG, as proposed in [5], is also a patient-centric application developed using Blockchain technology. The prime use case being, that a patient can on-demand generate a token that would allow the practitioner limited or timed access to their health data. The provider's HDG will comprise the patient data replica, and the practitioner will be able to access only the authorized information as an outcome. Also, the HDGs will ensure that automated replica destruction is done once the authorized time period is expired.

1.3. Remote Patient Monitoring

Remote Patient Monitoring or RPM utilizes IoT-enabled devices or body area sensors to capture biomedical information of the patients. The captured data, helps in diagnosing the status and condition of the patient. The data generated is real-time and can be accessed by a practitioner, who may not necessarily be present in the same facility. Blockchain technology and networks can be used to manage and store the biomedical information that is gathered for the purpose of RPM [6]. The research conducted in [7] showcases the mechanisms by which smart contracts used on Ethereum-based Blockchain can be used to handle real-time patient information in a secure environment. Patient-Centric Agent, PCA has been developed to provide end-to-end security for continuous RPM applications [8]. Handheld devices are used to make sure that the exchange of data is done in a secure Blockchain-enabled technology [9]. The study [10] includes a Hyperledger-based Blockchain implementation for data gathering and transfers, especially in mobile healthcare applications [11]. SMEAD is one of the Blockchain-based mobile healthcare applications that are developed to monitor and manage diabetes patients and their information [12].

1.4. Clinical Trial Management

Patient recruitments for clinical trials are among the most challenging processes, and the inability to recruit them in a prescribed timeframe can have a negative outlook and be a waste of funds. Blockchain can be used to avoid such issues or challenges by helping in eliminating false data and avoiding underreporting in clinical trials [13]. Patient consent can be easily obtained as anonymity is guaranteed with the involvement of Blockchain. The research conducted in [14] proposes a Blockchain framework that makes use of the master smart contracts for matching the patients with the trial-based contracts. This can lead to significant time savings and can also lead to the identification of the potential subjects. Using Blockchain ensures that there are no violations of data security

CHAPTER 7

Advancing Health Research Data Analysis with Blockchain Technology

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Abstract: It has been discovered that the storage problem of complex health records and data has been addressed, but there were still several issues with data security sharing with cloud technology. The decentralization attribute of blockchain will help in solving the problem. In electronic health records, blockchain can assist in reducing data sharing and interoperability in the industry by creating an overarching mechanism connecting different personal forms. It can also mimic data sharing by directly bridging the gap between owners and buyers. Therefore, this chapter will provide detailed information on Advancing health research data analysis with blockchain.

Keywords: Blockchain, Cloud technology, Data, Health record, Security.

1. INTRODUCTION

There are several advancements in the application of Blockchain, especially in academicians and healthcare. One of the significant challenges encountered in healthcare literature is data management [1]. Therefore, several the utilization of blockchain technology has been identified as a sustainable means that could help several problems encountered in various sectors of healthcare systems, especially

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in the management of data [1]. Data management faces several challenges, such as failure to maintain security and confidentiality, lack of interoperability, and loss of diagnosis data, especially those containing patient health records.

Also, it has been documented that medical centres' governments have several roles to play in contributing to the development of the health sector through advancing technology that could maintain human health [2 - 9] and documentation of proper records [10]. Moreover, numerous challenges are associated with healthcare information systems [11]. But introducing blockchain technology will go a long way in mitigating several challenges in healthcare and provide opportunities that could help combat several challenges in the healthcare domain [12].

Moreover, public and private healthcare organisations have established various sharing techniques that could improve information exchange advantages [13]. Several investigations have shown the three significant exchange models that could be utilized using healthcare individuals to electronically communicate patient health information, such as patient-centred exchange, query-based, and direct. These modes can enhance communication and coordination, especially among healthcare organisations managing several illnesses by steadily substituting identifiable patient data. Also, these modes enhance the steady covering of identifiable data of patients. That enables the sender to recognize the recipient's details and records of the patient medical information, which can be substituted directly from one healthcare organization, primarily through extensively embraced email protocols [14 - 17]. This chapter provides comprehensive information on advancing health research data analysis using blockchain.

2. BITCOIN AND PRIVATE BLOCKCHAIN LIMITATIONS FOR HEALTH CARE APPLICATIONS

Bitcoin is an acephalic digital payment platform that employs blockchain technology. Although Bitcoin has many controversies, it has functioned flawlessly and has been applied in many fields, including medicine. Personal health record platforms could be converted to a decentralized network using Blockchain technology [18]. Blockchain is faced with many challenges. In their review, Kamel *et al*. [19] identified challenges associated with blockchain, including privacy, confidentiality and security. Privacy and protection of personal medical data are crucial and confidential. They must be handled cautiously, just like in the conventional medical record share in which, for example, the HIV laboratory test result of a patient is forwarded to the doctor's office without the awareness of the patient, and health reports are susceptible.

Unfortunately, with blockchain, leakage to a third party is not impossible. One of the sources of such leakage is cyber-attack, any unauthorized, offensive invasion targeting information communication systems, personal computers and networks. This occurs through stealing, modulation and alteration, or a particular target's destruction through hacking.

Another challenge that is associated with blockchain is scalability and performance issues. The scalability of blockchain is the tendency to support an increasing quantum of transactions and a rising number of nodes in the network [20]. Specifically, the Bitcoin blockchain scalability issue refers to the Bitcoin system's capability limitation to manage big data in the shortest time frame on its platform. This implies that the Bitcoin blockchain exhibits minor frequency and size. Consensus protocol or algorithm is one factor that can influence blockchain technology's scalability and performance. The consensus algorithm describes how a blockchain network's propagation, validation and finalization occur. Network latency is another determinant of blockchain scalability and performance. Blockchain nodes comprise a database and runtime engine hosted on the cloud or premise. When dedicated infrastructure resources are unavailable, node performance may be inhibited. A node can affect blockchain scalability and performance. The more the number of nodes, the longer it will take to propagate a transaction. The next factor is bright contract complexity. Concerning the number of reads and writes from or to the ledger and validation logic, the processing latency will also increase when smart contracts are more complex. The size of the transaction payload also affects blockchain scalability. The larger the loads, the longer it takes for replication across nodes. Database efficiency is another factor influencing blockchain network performance. The last is transaction queuing. The blockchain network comprises many nodes that work together to provide high availability. However, each node's handling capacity shows the number of transactions accepted for further processing from the client applications.

The reports of Hussein *et al.* [18] and Hussein *et al.* [12], even though blockchain applications are spreading over many fields, including agriculture, reputation system, the economic sphere and medicine, Zheng *et al.* [21] also reiterated a barrage of uphill concerns about blockchain technology, especially scalability and data security problems. In their study, Kuo *et al*. [22] highlighted the uphill associated with blockchain, such as privacy and data security. Sun *et al*. [23] posited that preserving electronic health information and record and synchronization have always posed a considerable challenge.

Blockchain applications and implementations are increasing, but the issue is variations in underlying technologies. Therefore, it may be difficult and impracticable for all of them to work together. Insidious intrigues are often

CHAPTER 8

Blockchain Technology as a Tool for Prediction and Prevention of the Spread of COVID-19

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Abstract: Blockchain is predicted to greatly transform the conventional methods of transacting between users, covering almost all sectors of the economy. While the expectations of blockchain technology are high, the actual impacts and benefits are still unclear, causing delays and skepticism in its adoption. As the coronavirus disease (COVID-19) continues to affect the world, businesses and governments scramble for answers in attempting to limit the impact of the pandemic. In order to assess the ability of blockchain technology in its efforts to minimize the impact of the pandemic and clearly define the challenges and prospects of blockchain, a structured literature review of peer-reviewed articles on block chain's implementation and adoption in supply chain management, education, logistics and finance sectors was conducted. It is recommended that block chain's implementation and adoption is not limited to the finance sector but can be applied in any sector, where it provides a decentralized network in which information is accessible and personal privacy and security are guaranteed. Therefore, the wider acceptance and implementation of blockchain in selected sectors of the economy, especially in finance and supply chain management, has proven that blockchain can be utilized by businesses, governments and health professionals in the fight against the virus by transforming the challenges into opportunities combined with the prominent essential enablers would fast track its wider adoption.

Keywords: Adoption, Blockchain, Challenges, COVID-19, Implementation, Prospects.

1. INTRODUCTION

Blockchain technology is a distributed network of historical transactions where transactions are stored in a database that is safe and protected by cryptography

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and reliable mechanisms [1]. The database contains smart contracts where records and programs run without interference and the risk of interruption, restriction or fraud [2]. Not only is blockchain regarded as the enabler of cryptocurrencies like Bitcoin, but is also more valuable in enabling certain economic and social activities such as asset tracking and digital recording of asset proprietorship. This happens due to the de-centralized nature of the information that enables tracking asset movements easier and limits tampering with the record of transactions.

The widespread organizational use of blockchain symbolizes the increase and tremendous impact that new trends in technology have on organizations and governments that cushion the drastic negative effects of environmental forces [3, 4]. Blockchain is regarded as one of the new trends in the vast array of technologies which has instigated extensive interest and discussion about its applications and facilitation amid many debates concerning security and trust issues. Blockchain is predicted to drastically transform the interactions and transactions that people have with each other paving the way for virtual business models with huge potential [5]. Therefore, the applications of blockchain transcend beyond the mere notion of buying and selling but branch out into governments, businesses and public domains, completely affecting and revolutionizing the way in which these important sectors operate [6].

The impact of coronavirus disease (COVID-19) on important sectors of the economy has affected key industries that generate huge revenues. A number of key sectors are shut down as a result of government interventions to control the spread of the virus combined with the public refusal to use services in fear of exposing themselves to COVID-19 [7, 8]. As a result, governments and economic bodies are trying to limit the impact of COVID-19 on important economic industries, including airlines, tourism and hospitality sectors like hotels, restaurants, clubs, entertainment and events venues and the retail industries. The ripple effect on these sectors trickles down to taxi and cab operators who commute between airports ferrying tourists and travelers to their destinations and *vice versa* because the airports are closed from international and domestic flights, and more and more people are working from home, resulting in significant losses of revenues. Furthermore, the withdrawal by parents from their jobs has drastically increased due to the suspension of schools and childcare facilities. The isolation of infected patients and those in hospitals and quarantine facilities has put massive pressure on the economy and health systems. On the contrary, some businesses like supermarkets, online retailers, and medical equipment manufacturers will continue to gain from the impacts of the virus. In contrast, most non-food businesses will recover in the near future because mobility is restricted, culminating in reduced spending [9].

Industry expectations on blockchain and its benefits are countless amid the chaos of COVID-19, reaching extravagant proportions where dis-similarities exist between the expectation and experience. Given the newness of the blockchain phenomenon and outbreak and elevation in status of COVID-19 to pandemic proportions, the expectations of blockchain far outweigh the experience acquired from the actual applications in businesses' skepticism about the genuineness and value creation attributes accorded to it in this uncertain business context continues to gain momentum. The lack of broader acceptance of its applications threatens its rise and universal use from already established systems. However, the benefits that blockchain endows businesses cannot be undermined in the face of COVID-19, including eliminating intermediaries by allowing suppliers and customers to interact and transact directly, and accessibility to a secure database whereby customers can easily access information and make purchases. Therefore, blockchain must be bestowed the prominence and recognition it deserves to nurture wider acceptance of this new technological trend, and the benefits users can derive from it [6] as governments and businesses scramble to answer the pandemic.

2. PROBLEM STATEMENT

In the last eight months, the impact of the deadly coronavirus disease pandemic has decimated businesses and heavily crippled the economy of countries around the world. According to reported news from media sources, the airline industry, tourism and hospitality sectors and the economy as a whole have absorbed the impact of the COVID-19 pandemic as countries scramble to mitigate its effects. As the world comes to terms with COVID-19 by providing medical assistance with the staunch support of the world health organization (WHO) and leading economic powers like the great eight (G8) and great twenty (G20) countries, reported cases to continue to rise to the hundreds of thousands despite their combined efforts. Thus, as a measure of controlling the infection rate of the virus, governments are instituting lockdowns and restricting human interactions and mobility aimed at containing and minimizing the rapid rates of infections. These restrictive measures have reformed the traditional business methods of business and client interactions. With the COVID-19 control protocols in place, human interactions have been restricted, engendering new economic practices where businesses are forced to interact through virtual platforms. As a result, the need for blockchain technology continues to gain popularity among organizations with substantial benefits such as reduction of intermediary involvement where the direct supplier and customer transaction is facilitated, nullifying the desire for reconciliations and updated system for tracking asset movements and guaranteed quality data [10] seem to be applicable in the current situation. Therefore, this

CHAPTER 9

Blockchain Technology: The Future of Decentralized Applications

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Abstract: The advances in computer science & technology have gone to new levels. The process of computational technology and ubiquitous computing is expanding exponentially daily. The computer system & its related inventions have become an integral part of our lives. People & services are migrating towards clouds and decentralized platforms. Nowadays, commerce & finance on the Internet rely on trusted third parties like banks to process electronic online payments. Though it fits well with most transactions, it still suffers from the inherent weakness of trust-based models. Blockchain Technology- the technology behind the cryptocurrency Bitcoin is buzzing a lot nowadays to invent and witness the future of data storage & processing in an efficient, decentralized, tamper-proof, and peer-to-peer (P2P) network. Nowadays, the use of blockchain is not confined to crypto-currencies only. This revolutionary technology is drawing its impact & use in many fields and applications. Primarily, a blockchain network can be used for storing, sharing & transparently transferring data without the intervention of third parties and other intermediaries. In a blockchain network, blocks are added using a consensus algorithm & connected cryptographically. Hence it is merely impossible to delete and modify the content of blocks stored in a blockchain network. Other advantages of this technology include consistency, security, transparency, distributed ledger, decentralized network, *etc*. This paper systematically reviews the work accomplished by many researchers for the past 11 years. Specifically, the application & impact of blockchain technology in various fields like crypto-currencies, the health sector, e-governance, banking, finance, and food supply management systems have been discussed, and a projection of a novel application of the same technology has been proposed.

Keywords: Blockchain, P2P network, Distributed ledger, Decentralized, Consensus, Systematic review.

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1. INTRODUCTION

Most of today's transactions over the Internet are routed through third-party systems, which indeed are based upon some trust-based model, *i.e.*, centralized (Fig. (**1**) depicts a centralized and decentralized system). Blockchain technology eliminates all such intermediaries in a transaction. It was first used by researchers in 1991 to time stamp documents. But the emergence of Bitcoin [1, 2] in 2009, again revived by Satoshi Nakamoto [3], paved a new direction for the design of distributed ledger in a peer-to-peer(P2P) network which was cryptographic based and eliminated all intermediaries in a transaction involving bitcoin cryptocurrency. The foundation of bitcoin technology was laid through the revolutionary blockchain technology. The major credentials of blockchain technology are a miniaturization of third-party's involvement, blocks are cryptographically linked, which makes it almost impossible to delete or change the content of a block once it is added to the blockchain network, use of decentralized & distributed P2P network, *etc*. The development of Bitcoin in 2009 by Satoshi Nakamoto, an anonymous identity, laid down the foundation of blockchain technology with few limitations [4]. Firstly, the transaction time for adding a new block to the blockchain network is about 10 minutes. Secondly, it is not turning complete [5, 6]. And more often, huge computation power & electric energy is required for mining blocks, where mining is the process used to add a block to a blockchain network. In 2013, Ethereum Whitepaper [7] was published by Vitalik Buterin. Ethereum network's block time is about 20 seconds. In an Ethereum network that uses blockchain technology, developers can write a program using *smart contracts* [8]. Then blockchain technology was intended for *DApp, a* Decentralized application & making it usable for the industry. Fig. (**2**) depicts the evolution of blockchain technology, starting from its application to Bitcoin to industry-usable applications.

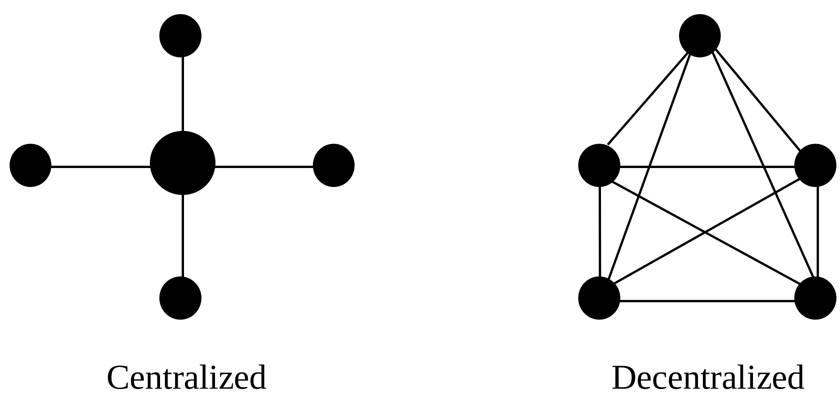

Fig. (1). Centralized & decentralized Network.

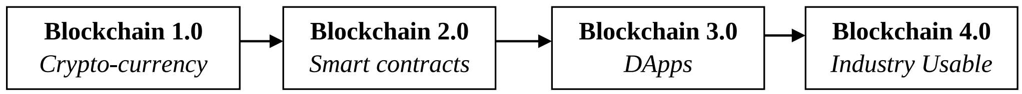

Fig. (2). Evolution of Blockchain.

The main focus of this technology is to decentralize the network applications by maintaining a distributed ledger and removing all trusted third parties, ensuring data integrity & security.

This paper highlights & discusses the primitives of blockchain technology with different dimensions of its applications & utilities, especially to cryptocurrency. Also, the areas like the health sector, IoT, and supply chain management where blockchain application looks significant are briefly introduced. Finally, a few possible areas where blockchain can be applied are listed.

2. BACKGROUND

In this section, the fundamentals & prerequisites of blockchain technology are discussed.

2.1. What is Blockchain?

Blockchain can be defined as a group of blocks that are linked together cryptographically, where each block holds the actual transactional data. The main motive of this technique is to create a growing list of records that are linked securely & immutable. It is intended to work in a decentralized manner, where any computer can add blocks to the blockchain network, confirming some consensus mechanism. It can be used for transferring items, like money, contracts, properties, *etc*., without the involvement of third-party intermediaries like banks or any other financial or non-financial institutions. It is very difficult to modify the data once they are recorded inside a blockchain network. Formally, a blockchain is a linked list of blocks, where each block is connected to its previous block as shown in Fig. (**3**) and maintains the following properties:

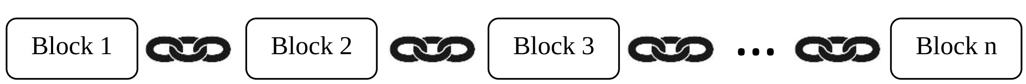

Fig. (3). Blockchain as Linked list.

CHAPTER 10

Blockchain Distributed Ledger Technologies for Biomedical and Healthcare Applications

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Abstract: The distributed ledger technology in the healthcare sector has been reported to be very important in generating patient information for research, medication adherence, management of several bedside information about patients, pharmaceutical supply chain, and quality of care. Its application has been documented in the biomedical domain and blockchain technology such as custom, IOTA, NEM, Gcoin, JUICE, TenderMint, Multichain, Hyperledger Fabric, Ethereum, Bitcoin, as well as in data integrity, data auditing, data provenance, data versioning, access control and non-repudiation. Therefore, this chapter will give an overview based on the applications of Blockchain distributed ledger technologies for biomedical and healthcare systems.

Keywords: Blockchain, Biomedical, Distributed ledger, Healthcare sector, Patient.

1. INTRODUCTION

The advancement of technologies in healthcare sector has brought about several innovations in blockchain distributed ledger technology. Knowledge sharing

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about patient's information using technology can be useful in predictive models and advanced visualization of patients' conditions for diagnostic purposes. Blockchain distributed ledger technology serves as a complementary approach to digital medical platforms. Blockchain distributed ledger technology serves as a good platform for fast retrieval of patient's information due to the large amount of data generated from healthcare. Studies have revealed that many emerging applications from advanced technologies are beginning to form the basis of clinical trials, biomedical research and databases, medical insurance, and data protection. The potential benefits of distributed Ledger technology in the maintenance of health care data collection, medical transactions record for finance and clinical trials. Drosatos and Kaldoudi [1] reported that distributed ledger technology in the biomedical domain comprises of 1) blockchain technology like custom, IOTA, NEM, Gcoin, JUICE, TenderMint, Multichain, Hyperledger, Fabric, Ethereum, Bitcoin, 2) Maturity of the approach like evaluation, implementation, architecture, proposal, 3) Biomedical data like financial data, database queries, ambient temperature, transaction records, consent forms, persona records, clinical trial records, medical records, location and sensor data, 4) application areas such as biomedical database, clinical trials, health records, wearables, medicines insurance, mhealth and embedded, and 5) reason for using blockchain like data integrity, data auditing, data provenance, data versioning, access control and non-repudiation. Distributed Ledger Technology can utilize public and private identifiers *via* cryptography to protect patient's data, thereby suppressing non-compatibility. This system identifies and aggregates large amounts of data, like a data lake, to enhance decision-making, legislation, reporting, census and research. Distributed Ledger technology can be utilized for enhanced health records and management, provider directory, historical care data of patient ledgers, patient directory, improved insurance claim analysis, care plans, increased pharma/ health research, and ADT back office part. Also information such as global patient ID software, full-featured electronic health record systems, and public health data access cannot be operated with distributed ledger technology [2 - 9]. The chapter will give an overview of the applications of blockchain distributed ledger approaches for health care and biomedical systems.

2. ESSENTIAL ROLES OF BLOCKCHAIN DISTRIBUTED DATABASES FOR HEALTHCARE/ BIOMEDICAL APPLICATIONS

Currently, there has been a transition from an old healthcare system to modern healthcare systems such as Mobile health (telecommunications, wearable sensors and Internet of Things for healthcare delivery. Major shortcomings have always been security, transparency and privacy of medical data. Blockchain technology is one plausible way out due to its decentralization and immutability. Investments into blockchain tools were estimated to attain $400 million US in 2019. Roman-

Belmonte *et al*. [10], examined the advantage of blockchain technology in the medical field. It enables a secure and stable data set, which makes it possible for users to interact *via* transaction. It is also possible for clinical data to be operated without any compromise occurring to other data. Another major benefit of blockchain is decentralization and maintenance of the entire network. With blockchain technology, reliance on organizations for storage is required. Block code, apart from being open, can be used, modified and revised. The promising applications include research, electronic medical records, big medical data, medical service payment and legal medicine.

Zhang *et al*. [11], designed a background for evaluating the activity of blockchain enterprises holistically in the provision of value-added care through the extension of the balance scorecard evaluation. In the study, the balanced scorecard was extended. The framework evaluated the performance and appropriateness of blockchain initiatives in the medical system. Radanovic *et al*. [12], reported that the salutary advantage of blockchain technology lies in its decentralized database, which makes it capable of storing a registry of transactions and assets through a peer-to-peer computer system. Utilizations of blockchain technology include public and financial records, cryptocurrencies, digital contracts and technological ownership. The application includes science, medicine, scholarly property, and education and distribution chain management.

Kamel *et al*. [13], reviewed studies on blockchain technology. The specific advantage of blockchain technology includes cryptographic security, decentralization and immutability, and these features make the blockchain technology an influential contender in reconstructing the healthcare landscape worldwide. Blockchain technology is applied in the aspect of patient and healthcare givers' identities, handling health and pharmaceutical materials supply chains, research and data monetization, detection of health fraud, public health monitoring and surveillance, facilitation of open and public geo-tagged data, energization of multiple Internet of Things-connected autonomous technology such as drones, wearables, vehicles and augmentation of reality in the mapping of crisis and recovery scenarios. Despite its challenges, blockchain technologies are expected to become increasingly strong and powerful, especially when they are integrated with artificial intelligence in healthcare solutions.

Mackey *et al*. [14], reported that blockchain, shared transmitted digital ledger tools, offers better data security and management, demonstrating a tendency to improve healthcare. Blockchain is utilized in the optimization of stakeholders for the optimization of business processes, causing a reduction in costs, improvement in patient outcomes, enhancement of compliance, and enablement of better use of healthcare data.

CHAPTER 11

Medical Imaging Systems Using Blockchain

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Abstract: It has been discovered that in the old electronic health record platform, each health service unit managed its health records, making sharing difficult on the different medical platforms. However, it has been discovered that blockchain technology is a panacea that makes it possible to enable medical service units that are based on different platforms to share electronic health record data. However, one major challenge with this approach is the difficulty in storing whole electronic health record data in the blockchain, given the price and size of the blockchain. As a way out, cloud computing was ticked as a potential solution. Cloud computing affords a unique opportunity, including storage of scalability and availability. But again, the electronic health record with cloud computing advantage may be susceptible to attacks because sensitive data is transferred through a public channel. The task of sharing and disseminating medical information and records electronically is inevitable as far as medical management and treatment combination are concerned. Unfortunately, the old cloud-based electronic medical record storage platform is hard to achieve data security sharing. Given the tamper resistance and traceability, blockchain technology makes it possible for highly sensitive health data to be shared. Therefore, this chapter intends to provide detailed information on the application of medical imaging systems using blockchain.

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Keywords: Blockchain, Cloud computing, Data, Health records, Medical imaging.

1. INTRODUCTION

Blockchain has been recognized as a reliable technology which has become popular, especially in the prevalent accepted cryptocurrency markets. This has several uses in sectors, such as healthcare, industry most especially in medical imagining, where they are applied in the storage of data through distributed cryptographic databases where data associated with access, creation, and update could be kept in a proper way [1].

It has been discovered that numerous people that utilized blockchain, such as scientists, patients, radiologists, and physicians, could be applied in regulating how and through whom healthcare data could be applied. Moreover, it has been stated that Blockchain could be applied in several areas, such as image annotations, ownership and tracking of images, which all have numerous relationships with artificial intelligence [2, 3].

The application of Blockchain can be applied for the tracking of all alterations in the database. Also, it has been established that Blockchain applied cryptography for the authenticity of data, verifiability and immutability of data, and transparency. They also play a crucial role in making data to become mere reliable, especially through a distributed trust network, without using a central, trustworthy master copy. Also, their application in the tracking of radiological data has been established [4].

2. MEDICAL IMAGE SHARING AND IMAGE TRANSFER

In conventional settings, methods such as shipping, posting, vendors and the use of videos and many more have been utilized in the dissemination of medical information [5]. However, technology now enables information to be transferred through the clouds without any actual physical transit. Medical image sharing can be defined as the transfer and dissemination of medical images electronically from healthcare providers and healthcare receivers. A good example of medical image sharing is the 2009 'radiological society of North America's image share project'. Usually, the transferred images are usually in the form of 'digital imaging and communication in medicine' or 'portable document format'. Sharing of images between two quarters is regulated by a platform, an example of which is 'Enterprise Document Sharing'.

In the work conducted by Sandberg *et al*. [6], determined the experiences of healthcare providers and healthcare receivers concerning image sharing. One of the main intentions of the authors was to know if utilization of the urge to devise imaging depends on the location or the specialty of the providers and how healthcare providers and their staff were able to access medical imaging outside. Using semi-structured interviews for 85 health personnel, it was reported that physicians who were situated in pediatric and family medicine depended on written reports majorly instead of X-rays and hence claimed no difficulties. While subspecialists reported having hiccups and delay in getting imaging information on portable media, those of them that were situated in small towns, urban and sub-urban areas claimed to have received imaging studies *via* electronic communication.

In the work conducted by Jung *et al*. [7], looked at the discrepancy in accessing radiological images in comparison to text-only reports *via* information dissemination platforms. In the study, 1,670 medical doctors and non-medic were recruited. It was shown that the likelihood of accessing medical images was about 4% greater for those who were in specialty care when compared to primary care medics. Instead of text-only reports, specialty medics showed an 18% greater likelihood of getting real images.

Alvin *et al*. [8], hypothesized that specialists such as neurologists, otolaryngologists and neurosurgeons viewed neuroradiology images most often, while neuroradiology reports as the least common of all medical specialties. The authors collected ordering data on radiological studies for 4 weeks. 85.7% and 53.2% of studies were viewed, while 13.1% were not viewed. It was also gathered that neurosurgeons who attended to in-patients viewed both reports and images.

In the work conducted by Langer *et al*. [9], the need to create a successor technique that will eliminate the role of physical media was highlighted. This becomes necessary to view the barrage of difficulties that characterize the latest medical information dissemination paradigm. Such included hiccups that may occur when patients' information, such as reports and images, is transferred from one healthcare provider to another or healthcare provider to healthcare receiver.

Rosenkrantz *et al*. [10], looked at the assessment of the perception of emergency health providers and radiologists. 34 radiologists and 38 emergency health providers responded, with 32.4 percent of radiologists and 55.3 percent of emergency health providers showing a preference in image quality transferred from the exterior. 29.4% of emergency providers indicated that getting information from outside will diminish image repetition. 40.6% of radiologists believed that an outside report will halt extra image recommendation, 43.8% claimed confidence in new examination interpretation, and 15.6% believed that new examination interpretation will be altered by the report.

CHAPTER 12

Effectiveness of Machine and Deep Learning for Blockchain Technology in Fraud Detection and Prevention

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Abstract: Blockchain was formerly originated to prevent fraud in digital currency exchanges. Blockchain refers to a collective decentralised ledger that is unaffected by tinkering. It provides the confirmed contributor access to the store, views, and shares the digital information in a situation that is rich in safety, which in turn supports the development of trust, liability, and transparent business associations. Identity theft and fraud safety are endless challenges for everyone in buying and selling. With each novelty in security technology, hackers and fraudsters learn how to outsmart the technology and breach these networks. The first section of the chapter describes the structure of the blockchain, its framework, the pros and cons of combining these technologies, and the role and importance of machine and deep learning algorithms in fraud detection and prevention in the blockchain. The next section focuses on the reported work, highlighting different researchers' work for fraud detection and prevention using Blockchain technology. The chapter's final section comprises a comparative analysis based on various performance parameters such as accuracy, the area under the curve, confidence, true negative, false positive, and truly positive for a different type of fraud detection using blockchain technology.

Keywords: Artificial intelligence, Blockchain technology, Deep learning, Fraud detection, Fraud prevention, Machine learning.

1. INTRODUCTION

The emergence of machine learning or deep learning algorithms in various domains is evident. These algorithms have provided immense power in analyzing and making decisions using the collected data. But, for the model to be efficient and accurate requires training with enormous data [1]. Data sharing within organi-

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zations can lead to various threats like tampering with data, attacks by various hackers, and decentralization of data. Another technology, Blockchain, possesses the capabilities which can overcome all the described shortcomings. The amalgamation of these technologies results in systems that are resistant to ticketing, robust, decentralized, and secure [2]. One such application of such systems has been studied in this chapter, fraud detection and prevention using blockchain and machine learning or deep learning algorithms. An unknown group, Satoshi Nakamoto, behind Bitcoin, described the importance of blockchain technology in solving the problem of maintaining the order of transactions. Bitcoins consist of blocks that are constrained-size structures containing transactions. These blocks relate to the help of hash values [3] present in the previous blocks. As described, Blockchain was formerly originated to prevent fraud in digital currency exchanges. Blockchain, unaffected by tinkering, gives the confirmed contributors access to store, view, and share digital material in a situation rich in safety, which supports the development of trust, liability, and transparency in business relations. To capitalize on this specified assistance, companies have now started exploring ways in which Blockchain technology could be used to prevent fraud in numerous industry verticals [4]. Fig. (**1**) describes the structure of blockchain technology. It is visible from Fig. (**1**) that each block is a collection of transactions occurring at the same timestamp. It also contains the hash value of the next block in a chain [5].

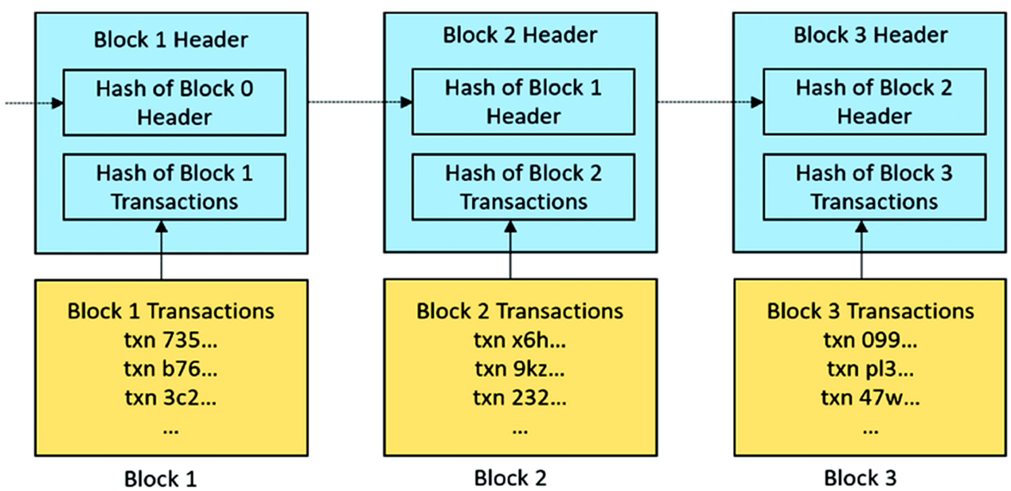

Fig. (1). Structure of Blockchain [6].

Protection from identity theft and fraud is an endless challenge for everyone to elaborate on buying and selling. Merchants, consumers, issuers, and acquirers know there are susceptibilities in how payments and data are secured. With each novelty in security technology, hackers and fraudsters learn how to outsmart the technology and breach these networks. Blockchain seems to possess capabilities that help to overcome the described problems [6].

Fig. (**2**) displays the various properties of blockchain:

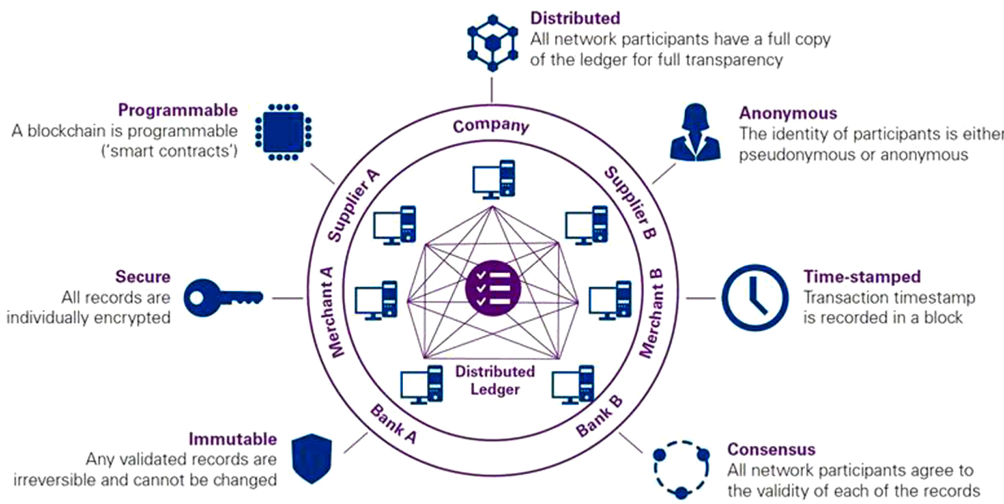

Fig. (2). Properties of Blockchain [11].

● **Programmable:** Blockchain uses the concept of smart contracts (SC). SCs can be defined as: "a computerized transaction protocol which helps in executing the terms of a contract", which minimizes external risks. In the context of blockchain, SCs can be defined as scripts that run in a decentralized manner [7] without relying on third parties.

● **Distributed:** This is one of the biggest strengths of blockchain. In this, all the computers (nodes) in a network have a copy of the full ledger to ensure transparency [8].

● **Immutable:** The data present in the ledger cannot tamper. Hence, making the blockchain robust.

● **Consensus:** Since the data present in the ledger is transparent and distributed so all the nodes in a network agree to the validity of the records.

● **Secure:** All the records present in the blockchain are encrypted individually.

CHAPTER 13

A Blockchain Approach for Health Care Sector to Prevent Fraudulent Activities in Medical Records

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Abstract: The Electronic Health Record (EHR) systems provide health information about patients. Data security, integrity, and management of EHR are crucial problems. Records can be modified and altered by different stockholders as the different users may be using them in more than one form. Medical records management is a suitable application for blockchain-enabled records that can be stored, tracked, and managed by all the transactions to prevent fraudulent activities. A novel framework has been presented here in the healthcare sector by using the blockchain concept. The major goal of this article is to implement BlockChain for electronic health records (EHR), and its decentralized approach eliminates the chance of a single point of failure, making the system robust. The proposed work also covers the extensible problem faced by BlockChain in common with the help of an off-chain repository of the data. The results indicate that computing is much more secure and free from a scam than the traditional health record system. Finally, the proposed approach suggests scenarios such as EHR where the introduced approach should prove adequate.

Keywords: Blockchain, Consensus, Decentralization, Firebase, Scalability, Smart contract, Solidity and ethereum.

I. INTRODUCTION

Blockchain technology was basically tailor-made for keeping a distributive financial ledger, but the Blockchain paradigm can be generalized to make a decentralized ledger to store information of any specific domain. The transactions between what is referred to as the singleton state-machine are secured by cryptography. Whenever a new data entry is made, the node encodes the logic, thus, validating it before uploading it to the Blockchain. The Blockchain technology-based ledgers used for storing data are primarily based on the use of

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"smart contracts" which allows automation and tracking of data-related characteristics such as Viewership Records new data entries [1].

The viewership and ownership permissions are shared through the peer-to-peer network, accessible to private members. In the smart contracts available on the Ethereum framework for Blockchain, we define the relationships between two entities and formulate the viewing instructions and data retrieval permissions for them to be available for external databases. Through this system, patients can choose and allow the sharing of their medical data among trusted providers, whereas providers are capable of adding new entries related to the patient. All these data transactions are secured by adding a cryptographic hash of the record on the blockchain, ensuring data integrity. Thus, validating and keeping the users indulged in the evolution of the data makes it more secure [2].

Traditional patient records require a large number of human work-hours. For instance, suppose a patient visits a clinic or a hospital, now his/her documents must be found and then transported to the required department, and then the actual examination of the patient can start. Besides, the high chances of mishandling the patient record files exist [2]. Fig. (**1**) shows the traditional medical record system.

Fig. (1). Traditional Medical Record System.

The medical care industry, specifically, frequently has been a significant objective for data robbery as prosperity records consistently contain private information like the names, government-upheld retirement numbers, and addresses of patients. Through blockchain, every record is protected with a unique blockchain ID that protects the records and makes them easily accessible to authorized personnel only. In the healthcare industry, doctors and their helpers receive a decentralized blockchain system; they have control over their patients' credentials and can simply check their histories [3].

The fundamental requirements of the medical care framework are the issues of legitimacy, information transportation, interoperability, contemplations of portable well-being, and the exchange of well-being records. For more information on this, check out the explanations for each of these crucial parameters below.

1.1. Healthcare System Security

Medical findings can be anything like patient records or the data that has been received from the patient's using sensors. Patient records are generally translated from paper-records to digitized medium, so they require more security and authority to be put in the right place to secure the medical findings and records [36]. Medical services records are being put away in information bases; just approved people have the option to get to those data, and access should be verified and approved. Current strategies to ensure records have demonstrated not to be as manipulated and replicate a patient's health records can have genuine outcomes [4].

1.2. Health Record Sharing

Healthcare systems are joint efforts of health and information technologies. The digitized way of data sharing can raise the chances of security problems along with the problem of civilian medical records. Healthcare record sharing can be tedious because the same individual's records can be stored in multiple places, which will raise the situation of duplicity in the system. A primary issue with well-being record sharing is interoperability [5].

1.3. Data Interoperability

Interoperability is the phenomenon of sharing and transporting medical records among various sources. The major drawback to interoperability is the usage of centralized data storage in medical organizations. Centralized information storage is an issue for medical care providers as they store all records in a single focal data set. The particular issues that emerge from concentrated information storage are the fragmentation of information, quality for health record exploration, slow access to health information, information quality, and the absence of framework interoperability. Numerous records are produced every day and are put away in a

SUBJECT INDEX

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