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Volume 1

Blockchain Applications in Healthcare

Innovations and Practices

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Jung-Sup Um and Abhishek Bhattacharya

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Dr. Tanupriya Choudhury would like to dedicate this book to The Indian Army for their dedication, sacrifice and excellency towards our motherland India and he would also love to dedicate this book to his parents Sri Mrigendra Choudhury and Smt. Minakshi Choudhury, his beloved wife Rituparna Choudhury and beloved son Rajrup Choudhury for their immense support throughout this work. He would also like to dedicate this book to his research guides Prof. (Dr.) Vivek Kumar, Prof. (Dr.) V Cyril Raj, Prof. Sumathy Eswaran and Dr. Darshika Nigam, who have always mentored him during his master's and doctoral research.

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Prasenjit Chatterjee

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Contents

Foreword

Due to the vast amount of health-related data, Blockchain technology offers a significant answer in applications related to healthcare. With the help of a peer-to-peer network, Blockchain technology records each cryptocurrency transaction. The fundamental goal of Blockchain is to provide high-end security in order to address the problems that arise in handling healthcare data more effectively. Many scholars have focused their efforts on this subject with the goal of providing extensive research on the introduction to Blockchain, its platforms and different consensus algorithms. The movement of its uses towards healthcare and medical-related data has also attracted the attention of researchers. Aside from mentioning Blockchain technology, the writers have also mentioned the use of the IoT (Internet of Things) and AI (Artificial Intelligence), which together define the next technological era. The editors have done an excellent job of combining a number of chapters from autonomic computing with the viewpoint of applications connected to healthcare. The editors have also done a good job of providing a thorough review of the application of Blockchain technology in healthcare. The book helps readers become more knowledgeable about how Blockchain technology is being used in healthcare-related applications, such as maintaining patient monitoring systems. In order to combine the benefits of both technologies, it also elaborates on how Blockchain and the IoT may work together. We strongly believe that the book explores Blockchain and healthcare researchers.

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Preface

The healthcare sector has always been an important part of society. With the recent outbreak of a pandemic, the importance of a robust, efficient, secure and patient-centric healthcare industry has never been more apparent. Blockchain is a new technology that keeps a record of every transaction performed using a cryptocurrency across server computers that are linked in a peer-to-peer network. Blockchain enables transactions to be secure, transparent and reliable. The question of revolutionizing the healthcare sector is being seen across various countries across the world and Blockchain could be integral in achieving this goal. The applicability of Blockchain in the healthcare domain can be seen as a remarkable opportunity by researchers and scientists across the globe for solving pertinent real-world problems dealing with patient records, medical supply chains, wearable diagnostic tools and telemedicine sessions. This book focuses on the fundamentals of Blockchain technology along with the means and methods of its integration with the healthcare industry. It provides an exploration of the current challenges in the healthcare sector and how Blockchain technology can provide solutions to these issues. It dives deep into specific areas where Blockchain technology can be adopted in the healthcare industry, such as patient data privacy protection, pharmaceutical supply chain, clinical trials and genomics. This book serves as a resource for readers to understand the fundamentals of Blockchain and the IoT (Internet of Things) across various application areas of healthcare and identify futuristic problem areas resulting from technological convergence. It also talks through futuristic research areas for the healthcare industry wherein Blockchain and its allied technologies can prove beneficial. However, it is important to note that these are only potential benefits and no guarantees can be made about their effectiveness. This book has a total of 11 chapters.

Chapter 1 proposes a framework for managing and operating a healthcare system using Blockchain technology. The framework aims to present a detailed overview of all the actors in a healthcare ecosystem, their working principles and ways of

communication. Moreover, the authors present a comprehensive integration of other technologies such as the IoT and machine learning with the proposed framework.

Chapter 2 deals with the concept of smart contracts. It discusses the role of smart contracts in ensuring seamless transactions among various intermediaries. This chapter illustrates the creation and working of smart contracts along with their set of benefits. Furthermore, we discuss specific use cases involving the implementation of smart contacts for streamlining complex processes.

Chapter 3 discusses various platforms for the implementation of Blockchain technology. This chapter aims to present a detailed analysis of prominent Blockchain platforms such as Ethereum, Hyperledger Fabric, Multichain, etc.

Chapter 4 looks at the variety of challenges faced while implementing techniques from Blockchain technology in healthcare. This may include data protection and data sharing challenges, cross-border information sharing challenges, data security challenges, challenges in stakeholder management using an appropriate permissioned network, and study challenges.

Chapter 5 discusses growing concerns about medical data security in an online ecosystem. This chapter explores present-day data ownership laws and compliance regulations dealing with the administration of medical records. It illustrates the means and methods of creating an interoperable decentralized Blockchain-enabled health record system. Moreover, the authors illustrate the problem faced by many in terms of the number of devices used in a healthcare system and the manageability of the vast variety of data generated.

Chapter 6 presents the proposed system that connects with methods such as on-chain and off-chain communication patterns to allow patients and healthcare professionals to share personal health records. This chapter proposes a scheme that emphasizes the importance of maintaining a true fair-exchange policy when transferring medical records without the involvement of a trusted third party.

Chapter 7 explores ways in which Blockchain can assist in preventing access and misuse of patient data by third part intermediates. The authors illustrate the means of strict and efficient implementation of data privacy laws by the use of smart contracts and consensus algorithms. Identification of data controllers and perspectives on anonymity and pseudonymity are discussed in later parts of the chapter.

Chapter 8 describes a Blockchain-enabled fragmented personal fitness facts ecosystem that enables unique drug discovery, biomarker development and preventative healthcare procedures, as well as secure personal records using

Blockchain and deep learning technologies to connect users and providers of personal records with medical records.

Chapter 9 discusses the life-cycles of software development through the component-based software engineering approach. Furthermore, we discuss how to create a Blockchain-based repository that stores software components and also discuss how Blockchain technology helps to secure our data in healthcare applications. The proposed software development life-cycle model ensures the security of user data and also improves the quality of healthcare applications.

Chapter 10 discusses the role of smart contracts and Blockchain technology in healthcare and other use cases. Smart contracts are computer protocols that facilitate, verify or enforce the negotiation or performance of a contract. Smart contracts were first proposed by Nick Szabo in 1996. He defined a smart contract as "a set of promises, specified in digital form, including protocols within which the parties perform on these promises". Since then, much research has been conducted on smart contracts and their potential applications. Some challenges that have been identified include scalability issues and the need for more user-friendly interfaces. Despite these challenges, many companies are already using smart contracts in various ways. For example, some companies use them to create digital wallets or to streamline supply chain management processes.

Chapter 11 describes the future aspects of Blockchain and the healthcare industry. Blockchain technology has the potential to revolutionize healthcare research by providing a secure, decentralized platform for storing and sharing data. This could potentially allow for more efficient and accurate clinical trials, as well as better tracking of patient outcomes. While there are still some challenges to be overcome, such as ensuring data quality and privacy, the future potential of Blockchain in healthcare is very exciting. These points will be discussed throughout this chapter.

We hope that our efforts are appreciated and the reader benefits from this book.

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Framework for Blockchain in Healthcare

Blockchain technology could be seen as one of the uptakes from the field of digitization that has attracted the attention of researchers and academicians over recent years. A Blockchain is a distributed database with an immutable committed block that provides transparency and robustness, which are the inherent characteristics of the architecture of Blockchain. Blockchain can also be understood as the set of connections which are interconnected to provide the connection in the entire architecture. Blockchain has been recognized as a development for addressing the distribution issues of information with the significant characterization towards data privacy and information security. Thus, the focus here has been to highlight the state of art in terms of Blockchain development, personalization, applications and limitations within the healthcare sector.

Blockchain is one of the most innovative and crucial advancements in the technology world. It belongs to the professional world, bringing together the distributed ledger technology with its architecture and applications in the medical field. This framework will include the evolution and ownership aspects of Blockchain along with the working principles and the different methods in the healthcare ecosystem. Since Blockchain is one of the technologies which is being used in the improvement of the prevailing standards of data sharing, handling and security, the growing anticipation of Blockchain, with its data management ranging from the traditional to its extensions, will be discussed. Emphasizing the benefits of Blockchain in healthcare, this chapter will also go over the challenges and limitations of Blockchain. The present editorial will also make efforts to approach the challenges of Blockchain in healthcare. A comprehensive interpretability in Blockchain with its open issues and future trends will be described. This

Chapter written by Neha MEHTA, Jyoti AHLAWAT and Leena ARYA.

enhancement in the medical field has also set the path of a new revolution in transforming the individual sectors in the healthcare industry. Thus, the focus has been on showing the direction of persistent revolution towards the potential of Blockchain technology in making efforts to establish innovation in the healthcare industry.

1.1. Concept of Blockchain

A Blockchain is a system for storing data in a manner so that it becomes impossible or extremely difficult to hack or change the system. Blockchain is generally a book of digital transactions, which are first copied and circulated across the complete network of systems present in the Blockchain architecture. All the blocks present in the chain are made up of a number of complete transactions, including each time any new transaction occurs for the system of Blockchain, a newly entered transaction is entered into each participant's book. And whenever there are multiple participants, the multiple participant architecture is managed by the decentralized database, which is popularly called distributed ledger technology (DLT). *Blockchain* may be marked as a common and permanent book that organizes the activity of record keeping in a network of blocks through input transactions, new insertions and asset tracking. According to Ahram et al. (2017), Blockchain presents a safer way for exchanging service and information transactions.

An asset might be physical (e.g. a car) or intangible (e.g. land), physical (patient treatment) or intellectual (creative property, patents, copyrights, branding) data or medical records (personal information, laboratory results, medical findings, history of diseases, doctor's prescription). Things of value can be followed virtually and can also be alternated on a network of Blockchain, via cost cutting, along with the reduced risk for all those users involved in it. Blockchain is a DLT in which all the transactions are documented through an enduring cryptographic signature known as a hash.

Blockchain has provided a platform that can improve the transparency as well as authenticity of healthcare data, maintaining permissions and also streamlining the claim process (Angraal et al. 2017).

Blockchain is a form of dashed information. The quicker it is received, the more accuracy it preserves. Blockchain provides each shared piece of data and all of the entirely transparent data that is stored on an accounting book immediately, but only the network's members that have permission have access to it. Hence, according to the researchers, Blockchain is considered to be an ideal way for delivering

information, although Blockchain has always faced the limiting issues of latency and throughput, solutions to which have been given by many researchers such as ECBC produced by Xu et al. (2017). A Blockchain can track prescriptions, records, clinical data, payments, medication, a patient's accounts much more, where people can believe that every single piece data is true, and the user can see all the details of the transactions to give greater confidence, end-to-end communication, new efficiencies and greater opportunities. But, due to the newly developed technology, it still has a very limited number of users (Aru 2017), along with certain challenges and limitations towards the development of Blockchain applications, including security, scalability, speed, privacy, interoperability and patient management (Agbo et al. 2018).

How does Blockchain initiate?

Blockchain rests on three major concepts: **the Blocks, the Miners and the Nodes.**

The Blocks

Every Blockchain consists of various numbers of blocks, along with the three primary elements in each block, which are:

– **data**: acting as an input for the block;

– **nonce**: a 32-bit entity based number referred to as a **nonce.** When any block is created, the nonce is generated randomly which further achieves a "hash" as a block header;

– **hash:** a 256-bit number and linked to the nonce, which appears with a large number of 0s.

A nonce develops the cryptographic hash, whenever the initial (first) block of a Blockchain emerges. Then, the acknowledgement is done for unless it is dug, the data in the block is signed and connected to the nonce and hash.

The Miners' association

The newly developed blocks in the chain are generated through a development procedure known as mining. Every block in the Blockchain mining of a block is not evident, especially for the larger chains, because each block has its unique nonce and hash, as well as the hash of the previous block in the chain. Miners are special pieces of software that solve the strangely complex math nonce finding problem that