

MediBlock-A Privacy-aware Blockchain to store patients data and effective diagnosis methods

by Alka Vishwa

Thesis submitted in fulfilment of the requirements for
the degree of

Doctor of Philosophy (Ph.D.)

under the supervision of

Supervisor: Associate Professor Farookh Khadeer Hussain

Co-Supervisor: Dr Asif Gill

University of Technology Sydney
Faculty of Engineering and Information Technology

May 2021

Certificate of Original Authorship

I, *ALKA VISHWA* declare that this thesis, is submitted in fulfilment of the requirements for the award of *Doctor of Philosophy (Ph.D.)*, in the *Software Engineering/ Faculty of Engineering and Information Technology* at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This research is supported by the Australian Government Research Training Program.

Signature: Production Note:
Signature removed prior to publication.

Date: 25/05/21

TABLE OF CONTENTS

LIST OF FIGURES	
LIST OF TABLES	
THESIS SUMMARY	
LIST OF PUBLICATIONS	
CHAPTER 1 - INTRODUCTION.....	10
1.1 NEED FOR HEALTH INFORMATION EXCHANGE	10
1.2 PROBLEMS WITH CURRENT SCENARIOS/SYSTEMS IN THE HEALTH SECTOR	12
1.3 BENEFITS OF HEALTH INFORMATION EXCHANGE.....	13
1.4 NEED TO ENHANCE HIE WITH BLOCKCHAIN.....	13
1.5 RESEARCH CHALLENGES.....	14
1.5.1 Blockchain data collection and maintenance	
1.5.2 Privacy-aware Blockchain	
1.5.3 Proactive diagnosis	
1.5.4 Best use of data by sharing with Authorized Stakeholders	
1.6 OUTLINE OF THE THESIS.....	16
1.7 CONCLUSION.....	17
1.8 REFERENCE.....	17
CHAPTER 2 - LITERATURE REVIEW	19
2.1 INTRODUCTION	19
2.2 BRIEF HISTORY OF BLOCKCHAINS.....	21
2.2.1 Cryptocurrency	
2.2.2 Permission-less and permissioned Blockchain	
2.2.3 Ethereum and smart contracts	
2.3 ADOPTED METHODOLOGY FOR SYSTEMATIC LITERATURE REVIEW	23
2.3.1 Selection of the Inclusion and Exclusion criteria	
2.3.2 Selection of data sources and search strategies	
2.3.3 Citation and Inclusion Decision Management	
2.3.4 Decisive selection and quality management	
2.3.5 Data Extraction and Synthesis	
2.4 ANALYSIS OF THE SELECTED PAPERS FROM THE LITERATURE.....	26
2.5 CONCLUSION	34

2.6 REFERENCES	34
CHAPTER 3 - PROBLEM DEFINITION	37
3.1 MEDIBLOCK TERMINOLOGY AND DEFINITIONS.....	37
3.2 RESEARCH CHALLENGES BASED ON LITERATURE REVIEW.....	38
3.2.1 Continuous maintenance of data in Blockchain	
3.2.2 Privacy of data stored in Blockchain	
3.2.3 Effective diagnosis based on reputation value	
3.3.4 Privacy-aware mechanisms to share medical data with selected stakeholders	
3.3 RESEARCH GAPS.....	40
3.4 RESEARCH QUESTIONS.....	42
3.5 RESEARCH OBJECTIVES.....	43
3.6 RESEARCH APPROACH TO PROBLEM SOLVING.....	44
3.6.1 Research Methods	
3.6.2 Choice of Science and Engineering based Research Method	
3.7 CONCLUSION	46
3.8 REFERENCES	47
CHAPTER 4- MEDIBLOCK: SOLUTION OVERVIEW	48
4.1 MEDIBLOCK SYSTEM ARCHITECTURE.....	48
4.2 SOLUTION OVERVIEW FOR THE MAIN RESEARCH QUESTION.....	50
4.3 SOLUTION OVERVIEW TO RESEARCH SUB-QUESTIONS.....	54
4.3.1 Solution Overview to Research Sub-Question 1	
4.3.2 Solution Overview to Research Sub-Question 2	
4.3.3 Solution Overview to Research Sub-Question 3	
4.3.4 Solution Overview to Research Sub-Question 4:	
4.4 CONCLUSION	58
4.5 REFERENCES	58
CHAPTER 5 – MEDIBLOCK: FRAMEWORK FOR INFORMATION COLLECTION AND MAINTENANCE IN HEALTHCARE BLOCKCHAIN	59
5.1 BACKGROUND.....	60
5.2 PROPOSED SOLUTION FOR DATA COLLECTION AND MAINTENANCE-MEDIBLOCK.....	61
5.2.1 Information collection and classification	
5.3 SOLUTION FRAMEWORK	64

5.4 CONCLUSION.....	69
5.5 REFERENCES	70
CHAPTER 6 - MEDIBLOCK: DYNAMIC METHOD TO ENHANCE PRIVACY WITHIN THE BLOCKCHAIN (FOR REFACTORED INFORMATION)	72
6.1 SOLUTION OVERVIEW.....	72
6.1.1. Data Encryption	
6.1.2 Hashing	
6.1.3 Authorization Access	
6.2 CONCLUSION	77
6.3 REFERENCES.....	78
CHAPTER 7 - MEDIBLOCK: REPUTATION VALUE (OR RANK OR STATUS) OF THE TREATMENT METHODS.....	79
7.1 SOLUTION DESIGN AND OVERVIEW	79
7.2 CONCLUSION	83
7.3 REFERENCES	84
CHAPTER 8 - MEDIBLOCK: METHOD TO SHARE HEALTH INFORMATION SECURELY WITH EXTERNAL STAKEHOLDERS	85
8.1 SOLUTION DESIGN AND OVERVIEW.....	86
8.2 CONCLUSION.....	91
8.3 REFERENCES.....	91
CHAPTER 9 - RECAPITULATION AND FUTURE WORK.....	92
9.1 PROBLEMS ADDRESSED IN THIS THESIS.....	92
9.2 RESEARCH SIGNIFICANCE AND CONTRIBUTIONS	93
9.2.1 Scientific contributions	
9.2.2 Social Significance	
9.3 CONCLUSION AND FUTURE WORK.....	94
9.4 REFERENCES	95

LIST OF FIGURES

Figure 1.1 Six domains of healthcare quality	11
Figure 1.1 Frictions affecting business efficiency	14
Figure 2.1 Literature review process	26
Figure 3.1 Overview of workflow in Science and engineering-based research approach	45
Figure 4.1 System Architecture MediBlock	49
Figure 4.2 “MediBlock” Design framework & Overall solution Overview	51
Figure 4.3 Smart contract workflow for “MediBlock”	57
Figure 5.1 Information gathering and classification in blocks	63
Figure 5.2 Authorization Matrix	63
Figure 5.3 User interface to collect data from the user (Doctor)	66
Figure 5.4 Pending transaction list data	67
Figure 5.5 Block Structure in MediBlock after mining	68
Figure 5.6 Child chains formation and data storage in MediBlock	69
Figure 6.1 Encryption of protected data in child chains	73
Figure 6.2 Sample User(Patient) child block and Child chain references	74
Figure 6.3 Sample User(Doctor) child block and Child chain references	75
Figure 6.4 Authorized data access to requester post approval by data owner(Pat_ID_1)	76
Figure 6.5 Sample data map and Child chain references	77
Figure 7.1 Community Feedback Selection and Submission	81
Figure 7.2 Reputation score in Child Chain	83
Figure 8.1 Data Requester raise request to add them as a requester in MediBlock	87
Figure 8.2 Data requester added to child chain	88
Figure 8.3 Data requester raise request to access data of patient(PatID1)	89
Figure 8.4 Data Requester’s request goes to relevant patient for his approval	89
Figure 8.5 Smart contract execution of assigning data to data requester	90

LIST OF TABLES

TABLE 2.1 Search terms or phrases used to find relevant papers from the literature	23
Table 2.2 Scientific assessment process	25
Table 2.3 Criteria to ascertain the applicability, reliability and accuracy of a study	25
Table 2.4 List of papers selected for this study	28
Table 2.5 Critical analysis of literature from the perspective of medical Blockchain	30
Table 2.6 Medical data sharing on Blockchain – Research Gaps	33

THESIS SUMMARY

There is an increasing need for the reliable exchange of healthcare information between the various stakeholders. It is becoming a pressing research problem because of the privacy concerns involved. Currently, the data is either stored and managed by hospitals using their centralized system or by the patient in hard-or soft-copy formats. Whenever there is a need to transport this information, it is usually done by the patient himself because electronic medical records have varying data standards which inhibit interoperability (as the records are not compatible between the systems). The patient data is stored and maintained by the hospitals and doctors. Medical data of a patient should not be leaked or shared with others without the owner's consent as this is a breach of the patient's privacy rights and would also damage the reputation of the stakeholders involved in the information leak. The existing approaches for storing patient's data is usually centralized. These methods are not very useful in terms of data management, utility, protecting the patient's privacy and data sharing.

Blockchain offers a promising new distributed framework that can be leveraged to support the integration and sharing of the patient's healthcare information between the relevant stakeholders, such as doctors, patients, insurance companies, pharmaceuticals, and researchers. The shared data is secure due to the inherent features provided by the Blockchain framework, such as smart contracts, consensus algorithms, and hashing. To identify the shortcomings of the existing approaches (in patient information sharing), we conducted a systematic literature review (SLR) to understand the problems and the solutions which are being used to overcome such challenges. By applying a systematic literature review approach, eighteen relevant studies were identified and were systematically reviewed in this study along multiple dimensions. Critical evaluation and analysis of the selected studies was used to identify the research challenges and corresponding solutions that are presented in this document. The findings from this research serve as a knowledge base and starting point for conducting research and development in the emerging research area of Blockchain-enabled patient information sharing. Some of the key issues that the literature review identified are the need to identify a solution for data storage and management, data sharing and perform data analysis because the healthcare sector needs to be able to retrieve and input data quickly. Another important finding is to make the Blockchain solution privacy-aware because a data leak in this area results in many complications for the patient as well as the healthcare provider. The report concludes with possible solutions to the identified research questions and the timeframes for addressing these issues.

This research presents a privacy-aware Blockchain for medical data sharing that proposes a reputation-based mechanism to quantify and measure the effectiveness of a medical diagnosis. This is the first study to take into account the users' authority over data while sharing it with other stakeholders and first approach that proposes a privacy-aware data sharing for deriving value and insights for various stakeholders.

LIST OF PUBLICATIONS

Publications

- ▶ **Nov 2018, A Blockchain-based approach for multimedia privacy protection and provenance**, 2018 IEEE Symposium Series on Computational Intelligence (SSCI), Bangalore, India, 2018, pp. 1941-1945.
- ▶ **Medical Block Chain: A Systematic Review** – Survey paper submitted to World Wide Web Journal.
- ▶ **MediBlock: Framework for Information classification in healthcare Blockchain** ready and submitted to supervisor for Review.
- ▶ ***Benefits of Smart Contracts and other Blockchain Technologies to Project Managers*** submitted for World Wide Web Journal.