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LEVERAGING BLOCKCHAIN TECHNOLOGY FOR SLA ENFORCEMENT IN HEALTH CARE CLOUD PARTNERSHIPS

A Project

Presented to the

Faculty of

California State University,

San Bernardino

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in

Information Systems and Technology

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by

Shivani Uday Jahagirdar

May 2023

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May 2023

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ABSTRACT

The healthcare industry is rapidly adopting cloud-based solutions to improve operational efficiency and patient outcomes. However, healthcare cloud partnerships often face challenges related to the lack of scalability, trust, and Service Level Agreement (SLA) enforcement, and has a notable impact on consumer care quality. To address this issue, the study proposed leveraging blockchain technology to enhance SLA enforcement by using smart contracts in health care cloud partnerships for small and medium-sized facilities. The research questions were: Q.1 What are the current challenges facing small to medium sized healthcare facilities in enforcing SLAs in cloud partnerships? Q.2 How can BC-based smart contracts help enhance scalability in cloud computing systems in healthcare SMEs by enforcing Service Level Agreements (SLAs) in a safe and efficient manner? Q.3 What are the factors that affect the implementation of blockchain-based smart contracts for SLA enforcement in healthcare SMEs cloud partnerships? The project utilized case studies to demonstrate the effectiveness of using BC technology based smart contracts to enhance SLA enforcement and improve patient outcomes. The findings and conclusions were as follows: 1. Current challenges facing healthcare SMEs in enforcing SLAs in cloud partnerships: SMEs may lack bargaining power, resources, and technical expertise to effectively negotiate, monitor, and enforce SLAs in cloud partnerships, leading to service disruptions, compliance issues, and financial losses. 2. BC-based smart contracts can enhance the scalability of cloud computing systems in healthcare SMEs by automating SLA execution, ensuring real-time data integrity, transparency, and accountability, reducing fraud, error, and transaction costs, and enabling decentralized trust among stakeholders. 3. Factors affecting the implementation of BC-based smart contracts to better SLA enforcement in healthcare SMEs cloud partnerships: regulatory uncertainty, interoperability, standardization, privacy, security, cost, complexity, governance, and user adoption, and 4. Unique Trends and challenges in the healthcare industry for its data analysis: increasing demand for real-time, patient-centered, personalized, and evidence-based care, generating and integrating large volumes of diverse and complex data from multiple sources, ensuring data quality, privacy, and security, complying with regulations and standards, and fostering collaboration and innovation across stakeholders. MedRec, SimplyVital Health, and Medical Chain demonstrate how BC provides secure data sharing, encryption and access control mechanisms, and promotes interoperability through standard data formats and protocols. Results showed improved scalability, trust, and SLA enforcement with the use of BC technology. Further research in the other domains of this area is recommended. It is required to address broader aspects related to the topic. The areas for further study that emerged from the findings and conclusions of this project include: 1. interoperability,2. trusted monitoring solutions, 3.user experience, 4. privacy and security,5. med tokens, cost and 6. integration with existing BSS and OSS.

Keywords: Cloud computing, Blockchain technology, SLA enforcement, Smart Contracts, Healthcare cloud, Blockchain-based SLA enforcement, Smart Healthcare, e-healthcare, Scalability.

DEDICATION

To my Beloved Mom and Dad.

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ABBREVATIONS	
1. SMEs:	Small and Medium Enterprises.
2. SLA:	Service Level Agreement.
3. KPI:	Key Performance Indicator.
4. SLO:	Service Level Objective.
5. TTD:	Time to Detect.
6. TTR:	Time to Resolve.
7. RTO:	Recovery Time Objective.
8. OLAs:	Operational Level Agreements.
9. Cisco GCI:	Cisco Global Cloud Index.
10. CAGR:	Compound annual growth rate.
11. BIS Research:	Business Intelligence and Strategy Research
12. COVID-19:	Coronavirus Disease 2019.
13. CSU:	California State University.

CHAPTER ONE

INTRODUCTION

"Blockchain is the biggest opportunity set over the next decade." - Bob Greifeld.

The healthcare sectors have witnessed a rapid acceleration with the introduction of cloud-based solutions. The utilization of cloud associated services has enabled healthcare facilities to enhance their operational efficiency, reduce costs, and improve patient outcomes (Javaid et al., 2022). Even if the cloud computing industry constantly evolves and looks for new ways to improve its services, it’s handling in the healthcare industry comes with several challenges, mainly related to trust, scalability, and accountability (Padhy & Patra, 2012). Since the current cloud computing infrastructure relies on centralized servers and data centers, they are vulnerable to cyber-attacks and data breaches (Al-Issa et al., 2019). Healthcare facilities, particularly small and medium-scale facilities, often face difficulties in ensuring the adherence of service vendors to Service Level Agreements (SLAs).

Blockchain as a technology has earned significant attention recently in many fields, especially the healthcare industry (Gosh et al., 2023). A BC can be explicated as a distributed ledger with a growing catalog of records or blocks securely connected via cryptographic hashes (Soner et al., 2022). Initially developed for use applied in cryptocurrencies like Bitcoin, the potential applications of BC have expanded into other fields, including smart contracts in supply chains and cloud computing. For over a decade, BC technology has revolutionized how we handle transactions and store data (Fanning & Centers, 2016). A 2023-Insider Intelligence website article states, Universal expenditure on BC is predicted to go above $19 billion (about $58 per person in the US) till year 2024, which has a growth rate of 46.4% yearly. Thus, it shows that this is becoming the future of cloud computing.

This project proposes leveraging BC for SLA enforcement in healthcare cloud partnerships for small and medium-scale facilities. (Scheid et al., 2019) states the limited consideration of scalability in this area, additionally although BC-based solutions can help to address scalability challenges, there is limited research on how small to medium sized facilities can leverage BC-based smart contracts to scale their healthcare cloud partnerships. BC technology provides a decentralized, scalable, and transparent mechanism for data management, enabling secure and efficient information sharing among stakeholders (Ghosh et al., 2023). Additionally, integrating smart contracts enables automatic and secure enforcement of SLAs, eliminating the need for intermediaries and reducing the risk of disputes (Lin et al., 2022). This project focuses on demonstrating the prospective of BC technology for enhancing trust and scalability in healthcare cloud partnerships. Ultimately, the project directs to deliver a comprehensive solution to the challenges faced by healthcare SME facilities in ensuring scalable and efficient cloud service delivery.

Problem Statement

1. As cloud computing continues to evolve, scalability remains a critical aspect. Despite this, clouds can't scale infinitely, and service providers may need to accredit tasks to cloud providers to avoid SLA transgression penalties. This situation generates a need to have better Service Compliance and Security Level Agreements between a healthcare organization and its cloud service partner (Patel et al., 2009).
2. The healthcare industry is generating massive amounts of data, which requires secure and scalable storage solutions. The challenge of cloud scalability in healthcare systems is to ensure that data can be accessed quickly and securely, while also accommodating the growing demand for storage and processing power (Tahir et al., 2020).

Research Questions

1. What are the current challenges facing small to medium sized healthcare facilities in enforcing SLAs in cloud partnerships?
2. How can Blockchain smart contracts enhance scalability of cloud computing systems in healthcare SMEs by enforcing Service Level Agreements (SLAs) in a secure and efficient manner?
3. Factors affecting the implementation of blockchain-based smart contracts for SLA enforcement in healthcare SMEs cloud partnerships?

4. What are the unique trends challenges for the healthcare industry for the data analysis?

Organization of the Study

To investigate the adoption and utilization of blockchain ledger among SME's enterprises in the healthcare sector, the project will employ the scrutiny for adoption and utilization of blockchain technology among SME enterprises for healthcare industry, this culminating experience research is organized as follows: Chapter 1 provided the introduction, Problem statement, Addressed Research questions, and motivation of the study. Chapter 2 will provide the literature review. Chapter 3 will provide the methodology techniques used to find the research answers and Chapter 4 will provide the case studies, its conceptual data analysis and findings. Chapter 5 will include the recommendations, discussions, Areas of further study and conclusions.

CHAPTER TWO

LITERATURE REVIEW

Cloud computing has been around for some time, but it has been plagued by poor enforcement of service level agreements. According to Patel et al. (2009), scalability is a crucial part of cloud computing, but they are unable to scale infinitely, leading to SLA management research opportunities. Future work in this area, as suggested by ScheidFuture et al. (2019), may include scalability analysis and in-depth research on trusted monitoring solutions. However, this work highlights the potential of using a distributed system to eliminate intermediaries, thus improving the scalability, and efficiency of SLA enforcement and overcoming many of the challenges in the medical and healthcare systems.

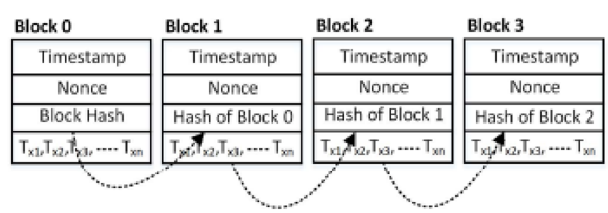
Researchers such as Murthy et al. (2020), Dorsala et al. (2021), and Khanna et al. (2022) have explored how BC-based solutions can enhance cloud computing capabilities. Cloud computing has become integral to modern-day computing, enabling remote data storage and access, but the centralized infrastructure is vulnerable to cyber-attacks and scalability issues, as noted by Alam (2021) and Almutairi et al. (2021). Habib et al. (2022) suggests that the use of BC can increase transparency and scalability in the cloud ecosystem. Smart contracts, as explained by Khan et al. (2021), can be used to enforce SLA's between cloud providers and their consumers.

Moreover, (Uriarte et al., 2020) says this can be particularly beneficial for SMEs healthcare facilities, which may lack the resources to effectively negotiate and monitor SLAs. The Intelligence advisory company IDC (2018) foresees universal overheads on (IoT) will go upto $1.2 trillion by 2022. The IOTs will produce extremely outrageous data amount in need to be analyzed optimally. “The global technology conglomerate Cisco GCI paper estimates that, by the year 2021 over and above 850 Zettabytes data will be produced which is 630 ZB higher than the 220 ZB created in a span of 5 years as compared to 2016”. So, there is and will be tons of data created and streamlined or stored.

The study aims to provide insights into the challenges faced by small to medium healthcare facilities in enforcing SLAs in cloud partnerships and how BC-based smart contracts can help address the threats. Additionally, the project seeks to examine the factors that affect the implementation of such contracts and identify the unique trends and challenges in this area. By addressing these issues, the study aims to contribute to the development of effective strategies for improving SLA enforcement and cloud computing systems' scalability, security, and efficiency in healthcare SMEs.

Figure: 2-1

A Blockchain structure



Note. By (Bebo White et al. 2018) IEEE International Conference.

Blockchain Working

The working of a BC can be summarized as follows: BC is a distributed network where nodes validate, and process transactions initiated by users. BC working includes Distributed Network, Verification, Block Creation, Mining, Consensus, and Security (Zheng, 2017). Transactions are verified for validity and added to a block along with a hash code to ensure integrity. Mining involves adding a latest block to the chain by solving a complex mathematical problem. Consensus is achieved through attestation or proof of stake, ensuring network security. BC is secure due to its distributed nature and use of cryptography, and transactions are immutable once recorded (Justinia, 2019).

Figure: 2-2

Different types of Blockchain Technology

Table 3. Different Types of Blockchain Technology.

Blockchain Technology	Bitcoin	Ethereum	Hyperledger Fabric
Main Purpose	Used for cryptocurrency	Employed for smart contracts	Deploys block chain technology for fabric industries
Data storage type	Transactions of cryptocurrencies	Transactions of cryptocurrencies, smart contract history	Chain coding and smart contract transactions
Languages used	Script	Solidity Serpent	Go
Choice of ecosystem	Open	Open	Restricted
Participation choice	Open-source code from GitHub	Open-source code from GitHub	Needs network membership for user source code
Naïve currency	Bitcoin (BTC)	Ether (ETC) or (ETH)	N/A
Decision-making	Yes	Yes	Unknown
Block release timing	10 min	12 s	Configurable
Size of transaction	250 B	No upper bound	Configurable
Rate of transaction	3TXN/s	No upper bound	>10,000 TNX/s
Mining	Needs proof of work	Needs proof of work using Ethash algorithm	N/A

Note: by (Habib, 2022) MDPI

Blockchain adoption in healthcare

In a Black Book Market Research survey, 93% of healthcare organizations plan to use BC technology by 2025 at 38,747.63 million, at a CAGR of 38.55%. This includes using BC-based cloud solutions for storing and sharing healthcare data. BIS Research estimated that the universal BC healthcare arena contemplated a gain $1.7 billion till 2026. The report also noted that the increasing adoption of BC decentralization in the healthcare industry is due to its ability to ensure data scalability, security, and trust ability. Additionally, (Ng et al., 2021) says that the COVID-19 pandemic is also a factor that has accelerated the adoption of BC cloud solutions in healthcare. With the increased need for secure and remote access to healthcare data, this digital ledger has provided a solution that ensures data scalability.

Overview of Cloud Computing and SLA in Healthcare

Cloud computing is a paradigm for distributing services through the internet, providing access to shared computing resources that can be swiftly provisioned and published. This technology offers various benefits, including scalability, flexibility, cost-effectiveness, and reduced maintenance. In healthcare, cloud computing can facilitate the secure sharing of medical records, improve patient care, and support medical research. It can also enable remote access to medical services and data, enhance the efficiency of healthcare delivery, and reduce costs (Kuo, 2021). SLA are contracts amongst cloud providers and their customers that establish the availability of services. In healthcare, It plays a crucial part in ensuring that the cloud services provided by vendors meet the necessary regulatory, privacy, and security requirements.

SLAs typically include performance metrics such as uptime, response time, and data backup and recovery. They also specify penalties for service disruptions and downtime, as well as remedies to be provided in such cases (Gangadharan & Parrilli 2011). In summary, cloud computing offers significant benefits to healthcare facilities. And SLAs plays a critical task in ensuring that cloud services comply with regulatory and security requirements, providing customers with confidence in the reliability and quality of cloud services.

Challenges of SLA enforcement in healthcare cloud partnerships

Enforcing Service Level Agreements (SLAs) in healthcare cloud partnerships can be challenging, especially when it comes to scalability. Here are some scalability challenges of SLA enforcement in healthcare cloud partnerships: The healthcare ecosystem is complex and ever-changing, which makes it hard to enforce SLAs while dealing with multiple stakeholders who have different requirements and expectations (Manalastas et al., 2021). Healthcare cloud partnerships must be able to scale their infrastructure and resources quickly to accommodate varying workloads and demands. This requires SLAs to be flexible and dynamic with clear provisions for scaling up or down as needed (Sinha et al., 2020). Interoperability between different cloud services and applications can also be a challenge, especially when dealing with multiple vendors and partners (Patel et al., 2009).

SLAs must ensure compatibility between different systems and services. Furthermore, SLAs must ensure that data security and privacy are always maintained, as healthcare data is highly sensitive. Resource allocation and management: SLAs must define clear roles and responsibilities for resource allocation and management to ensure that cloud resources are used efficiently and effectively. This requires collaboration and coordination between different stakeholders, including cloud providers, healthcare organizations, and regulatory bodies (Qureshi et al., 2022). In summary, addressing scalability challenges by designing flexible and dynamic SLAs that can accommodate varying workloads and demands while ensuring data security, privacy, and interoperability is essential for the enforcement of SLAs in healthcare cloud partnerships.

Blockchain-based solutions for SLA enforcement in healthcare cloud partnerships

Here are some ways blockchain-based solutions can address scalability challenges in SLA enforcement:

1. Distributed ledger technology: BC is considered a distributed ledger technology that enables all parties in the healthcare cloud partnership to have a shared and immutable record of transactions. This can help to

improve transparency and accountability, making it easier to enforce SLAs (Cerchione et al., 2022).

2. Smart contracts: These can be automated on the BC to enforce SLAs, without the need for intermediaries. This can help to reduce administrative costs and increase efficiency, making it easier to scale up or down as needed (Khan et al., 2021).
3. Decentralized storage: BC-based solutions can provide decentralized storage for healthcare data, reducing the threat of data breaches and improving data privacy and security. This can help to address scalability challenges by offering a secure and scalable platform for storing and sharing healthcare data (Shuaib et al., 2022).
4. Interoperability: BC-based solutions can help to improve interoperability between different cloud services and applications by providing a standardized platform for data exchange. This can help to reduce the complexity of healthcare cloud partnerships and make it easier to scale up or down as needed (Schmeelk et al., 2022).
5. Consensus mechanisms: BC-based solutions can use consensus mechanisms, such as authentication of work or stakes, for ensuring that everyone in the party in the healthcare cloud partnership agree to the shape of the BC. This can help to ensure that SLAs are enforced fairly and transparently, increasing trust and reducing the risk of disputes (Hasselgren et al. 2020).

In summary, by using distributed ledger technology, smart contracts, decentralized storage, interoperability, and consensus mechanisms, BC-based solutions can help to address scalability challenges and improve the effectiveness, security, and transparency of healthcare cloud partnerships.

Blockchain and Smart contracts in healthcare

In accord with the "U.S. Small-Business Administration," there is around 30.7M small to medium scale traffic from United States as of 2019. While not all these businesses are healthcare facilities, significant segments would likely fall into the small to medium-sized category (Mohsin, 2023). According to (Manalastas et al., 2021), It is also worth noting that SME healthcare facilities may face unique challenges when it comes to implementing and enforcing SLAs in cloud partnerships due to limited resources and expertise in this area. These automatic digital contracts allow parties to enforce terms and conditions without intermediaries. They use BC to provide an efficient and transparent way of executing agreements, making them suitable for various applications, including healthcare. In healthcare, these self-executing agreements can help automate and enforce various processes, such as patient consent management, clinical trial management, insurance claims processing, and supply chain management (Khan et al., 2021).

They can streamline processes, reduce costs, and enhance efficiency while ensuring compliance with regulatory and privacy requirements. Overall, these self-executing contracts have the dormant to revolutionize healthcare by yielding a transparent way of automating various processes, reducing costs, enhancing efficiency, and ensuring compliance with regulatory and privacy requirements. These contracts are implemented on a BC, a distributed storage information across a network of computers. These contracts in healthcare can help to increase scalability in several ways. Here are some ways in which BC-based smart contracts can increase scalability in healthcare:

1. Automating administrative processes: Smart contracts can automate administrative processes, such as claims processing, insurance verification, and appointment scheduling, among others. This reduces the need for manual intervention, saving time and resources while increasing efficiency.
2. Streamlining supply chain management: In healthcare, this is critical for ensuring obtainability in medical equipment, drugs, and other supplies. This self-executing agreement can help to streamline the supply chain by automating the ordering, tracking, and delivery of medical supplies.
3. Improving data sharing and interoperability: BC automatic contracts can facilitate secure and seamless data sharing and interoperability between healthcare systems and stakeholders. This reduces the need for intermediaries, saving time and resources while enhancing the quality of care.

4. Enhancing patient engagement: Self-executing agreements can be used to create patient-centric care plans that are personalized and tailored to the needs of individual patients. This can improve patient engagement, adherence to treatment plans, and overall health outcomes.
5. Improving transparency and accountability: Smart contracts on a BC provide auditable transaction record, ensuring accountability eliminating the abuse (Al-mutar, 2022).

In summary, BC-based smart contracts can increase scalability in healthcare by automating administrative processes, streamlining supply chain management, improving data sharing and interoperability, enhancing patient engagement, and improving transparency and accountability. Smart contracts can increase efficiency and reduced costs by reducing the requirement for intermediaries and manual intervention, making healthcare more accessible and affordable.

Factors affecting the administration of BC-based smart contracts for SLA enforcement in healthcare SMEs.

(Khan et al., 2021) states, implementation of BC-based smart-contracts for SLA enforcement in healthcare SMEs cloud partnerships can be influenced by various factors. Some of the key factors include:

1. Regulatory Compliance: Healthcare SMEs need to adhere to strict regulations to ensure patient data scalability and security. The

implementation of BC-based smart contracts should comply with these regulations, which may affect its layout and integration.

2. Technical Expertise: The implementation of BC based smart contracts requires technical expertise in BC technology, smart contract development, and cloud computing. The healthcare SMEs need to have sufficient technical expertise or collaborate with technical partners to develop and implement the smart contract.
3. Integration with Legacy Systems: Many healthcare SMEs may have existing legacy systems, which may not be compatible with BC based automatic contracts. Integration of the self-executing contract with legacy systems may require additional effort and investment.
4. Cost: The execution of BC self-executing contracts may require significant investment in terms of infrastructure, development, and maintenance costs. Healthcare SMEs need to assess the cost-benefit analysis of implementing BC-based smart contracts.
5. Scalability: The scalability of these contracts is another factor that can affect their implementation in healthcare SMEs cloud partnerships. As more participants join the network, the scalability of the smart contract may become a challenge.
6. Trust and Transparency: The usage of BC technology based self-executing contracts can enhance trust and transparency in healthcare SMEs cloud partnerships. However, establishing trust and transparency

among participants may require additional effort in terms of governance and dispute resolution mechanisms.

7. Standardization: Standardization of these contracts can promote interoperability among different healthcare SMEs cloud partnerships. The lack of standardization can limit the adoption and implementation of BC-based smart contracts.

Overall, the successful integration of BC-based SC’s for SLA enforcement for healthcare SMEs cloud partnerships requires careful consideration of these factors, among others, to ensure the technology is effective and feasible in the given context.

Recent Research Results

There is limited literature specifically focused on leveraging BC-based smart contracts for SLA enforcement in healthcare cloud partnerships for small to medium sized facilities. However, some studies have explored the utilization of BC technology and self-executing contracts in the healthcare industry more broadly, and some have touched on SLA enforcement in cloud computing. Here is an overview of some of the existing literature on this topic:

"A survey of cloud scalability and research opportunities in SLA management", by Patil et al., (2021): A recent study published in the “International Journal of Cloud Computing and Services Science” highlights importance for scalability in computing and cons it poses. When resource limitations are encountered, service providers may delegate tasks to cloud providers to avoid substantial SLA violation penalties. This highlights research opportunities in SLA management, which in turn improves the efficiency.

"Blockchain Technology and Healthcare: A comprehensive review" by Mettler (2019): States the applications of BC. It explores the potential benefits of using BC technology for SLA enforcement in healthcare cloud partnerships but does not focus specifically on small to medium sized facilities.

"Blockchain technology for healthcare: Facilitating the transition to patient-driven interoperability" by Peterson and Deeduvanu (2018): Explores the reach of BC to improvise interoperability in healthcare industry. It suggests that smart contracts could be used to enforce SLAs in cloud computing environments but does not focus specifically on small to medium sized facilities.

"A blockchain-based approach for secure data sharing in healthcare scenarios" by Gubbi et al. (2019): The proposal of this paper states that BC solution for safer data exchanging in healthcare scenarios. The solution leverages smart contracts to enforce data access control policies and ensure SLA compliance.

"Towards a blockchain-based secure and transparent clinical trial informed consent process" by Kim et al. (2019): The journal gives a BC-based solution for a transparent and secure informed consent in clinical trials. The solution leverages smart contracts to enforce consent agreements and ensure SLA compliance.

In summary, there is limited literature specifically focused on leveraging BC-based smart contracts for SLA enforcement in healthcare cloud partnerships for small to medium sized facilities. However, some literature explored the potential of using BC and SC for SLA enforcement in cloud computing for the healthcare industry more broadly. These studies suggest that BC-based smart contracts could be an effective solution for SLA enforcement in healthcare cloud partnerships, but more research is needed to specifically address the scalability challenges faced by small to medium sized facilities.

Table: 2-1 Research Synthesis Table

Author	Origin	Purpose	Source	Research Design	Target population	Framework	Framework proposed	Theme
Al-Issa (2019)	US	eHealth Cloud Security Challenges: A Survey	PMC	NA	CS/IT	Conceptual	NA	Recent Work in eHealth Security, Available eHealth Security Solutions, International Standards, Ownership and Privacy of Healthcare Information
Alam (2021)	Saudi Arabia	Cloud-Based IoT Applications and Their Roles in Smart Cities	MDPI	Smart Infrastructure	IT	Theoretical	NA	IoT, Smart applications, Cloud Computing, Small and medium-sized enterprises
Al-mutar (2022)	Turkey	Providing scalability and privacy for smart contracts in the healthcare system. Science Direct.	Science Direct	Scalability for smart contracts	IT, Electrical	Theoretical	NA	Blockchain Technology, Decentralized systems, Distributed systems, healthcare systems
Bai (2019)	NA	Blockchain and smart contract for healthcare: Challenges and opportunities	Journal of medical systems	Challenges and opportunities	IT, Electrical	Conceptual	NA	Blockchain, Smart contracts, Pros, cons, helathcare
NA	NA	Global Blockchain in Healthcare Market	BIS Research	Analysis and Forecast	IT	Analysis, Survey	NA	Blockchain in healthcare, Analysis, Forecast, survey.
Chudasama (2017)	NA	SLA Management in Cloud Federation	Springer Link	Creation and implementation of effective SLA for provisioning of service.	IT	Conceptual	Effective SLA for provisioning of service	SLA, SLA Management, Cloud computing, SLA Violation, cloud federation, SLA Management architecture
Gangadharan (2011)	NA	Service Level Agreements in Cloud Computing: Perspectives of Private Consumers and Small-to-Medium Enterprises.	Research Gate	Analyze the current Cloud SLAs are sufficiently in accordance with rights and business expectations.	CS	Analysis	Service Level Agreements in Cloud Computing: Perspectives	Cloud Computing, Cloud Service, Service Level Agreement, Cloud Provider, Cloud Environment.

CHAPTER THREE

RESEARCH METHODOLOGY

This article explains the research methods used to answer four different questions related to SME healthcare facilities and cloud computing systems undertaking BC technology. The first question is about the challenges faced by healthcare SMEs in enforcing SLAs, which were analyzed through qualitative and conceptual research methods such as surveys and existing literature analysis and case study analytics. The second question is about how BC-based smart contracts can enhance the scalability of cloud computing systems in healthcare SMEs, which was answered through available research articles and case studies. The third question is about the factors affecting the implementation of BC-based smart contracts for SLA enforcement in healthcare SMEs, which were analyzed through qualitative research methods and case studies. Finally, the fourth question is challenges and trends, which were analyzed through the three different case study data analysis.

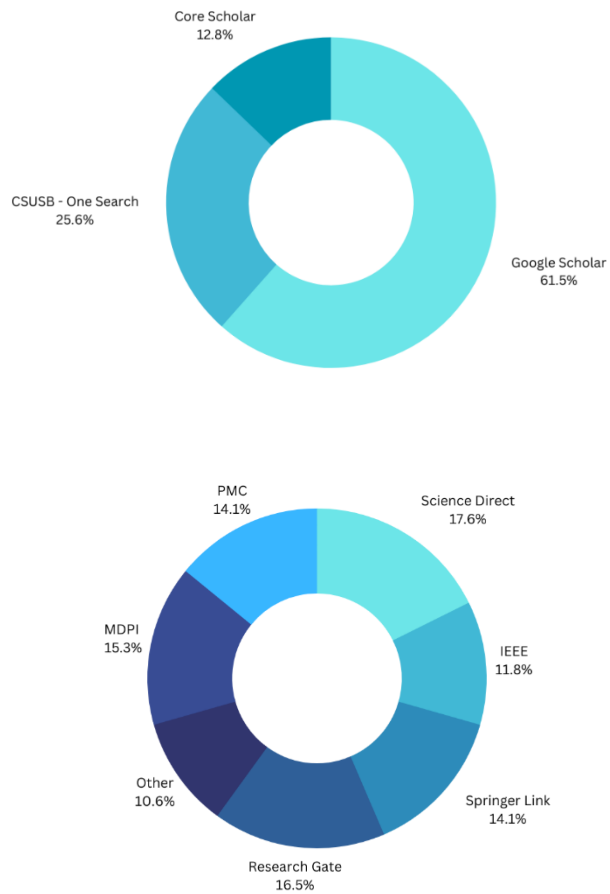
Given the fast-paced development of new technologies and recent trends related to the topic, the scope of research has been limited to literature published from 2009 to the present, covering a span of approximately 13 years. Relevant research literature for this project has been identified using specific search keywords, including Cloud computing, BC technology, SLA enforcement, Smart Contracts, Healthcare cloud, BC-based SLA enforcement, Smart Healthcare, and

E-Healthcare Scalability, which will be used to structure the Table of Contents. To gather relevant literature for the project, the conceptual analysis technique was used: This technique involved analyzing the textual data collected from academic papers, technical and business Journals, Newspapers, and case studies. The content was used to identify the data's the patterns, and categories and draw conclusions based on the findings. A search was conducted on Google Scholar, Core Scholar, One Search, and CSUSB scholar works using the same search terms and date range, with filters such as "include patents" and "include citations."

The initial search yielded over 24,000 results, from which only the first 50 were selected based on traceable, significant to the search parameters filtered freehanded by reading the title and summary of each. The research database can be seen as follows.

Figure: 3-1

Categorical research database



The enduring results were further refined by reading the abstracts, introductions, and areas of further study to determine their relevance to the project's topic. This process resulted in 60 relevant results. Ultimately, the search produced a total of 24 pieces of literature that met the project's criteria. Initially, a study will be undertaken to examine the challenges surrounding Cloud centralization that are unique to the healthcare sector.

Further, this study involved exploring how BC-based smart contracts are utilized to improve service level agreement (SLA) enforcement for SME enterprises in healthcare field, as well as for healthcare providers and patients. Through this investigation, typical obstacles and difficulties encountered in the industry will be identified and analyzed, with an effort to uncover any recurring themes or issues. This literature review examines the research questions in the following steps.

Step 1: Identifying the research problems. Step 2: Literature Review - The first step of the research methodology involves conducting a comprehensive literature review for the current conditions in BC areas and its integration in the healthcare sector. This step will involve identifying and analyzing relevant academic papers, journals, and conference proceedings to gain insights into the research foundations of this and its potential for SLA enforcement in healthcare cloud partnerships. The literature review will also involve identifying potential challenges and limitations of BC in healthcare and exploring strategies to overcome them. Step 3: Conceptual research Data Analysis - The final step of the research involves conducting a case study and analyzing the data to evaluate the effectiveness of BC for SLA enforcement in healthcare cloud partnerships, including assessing its impact on trust, scalability, accountability, patient outcomes, and identifying challenges and potential solutions. Leveraging BC technology using smart contracts in healthcare is crucial for patient privacy, data protection, and efficient SLA enforcement, especially for small to medium-sized facilities facing challenges negotiating with larger cloud providers. The lack of empirical research on BC's application for healthcare underscores the importance of this study. Step 4: Results and findings, and Steps 5 & 6: Conclusion and recommendations.

CHAPTER FOUR

DATA ANALYSIS AND FINDINGS

Several healthcare organizations increasingly rely on cloud computing to store and manage patient data and critical applications (Al-Issa et al., 2019). This shift towards cloud-based solutions has enabled the healthcare industry to operate more efficiently and effectively. However, concerns around scalability, security, privacy, and service level agreements (SLAs) needs for successful adoption of cloud in healthcare (Habib et al., 2022). In these case studies, we will explore the implementation of BC based automated contracts for SLA enforcement in a small healthcare facility called MedRec, SimplyVital Health, and Medicalchain. These case studies will provide insights into the benefits and challenges of using BC-based smart contracts for SLA enforcement in healthcare cloud partnerships for small to medium-sized facilities like MedRec, SimplyVital Health, and Medicalchain. We will explore the challenges faced and lessons learned throughout the project.

To investigate the problems of this research, real-life examples are analyzed. However, the need for case studies on using BC-based smart contracts in small to medium-sized healthcare facilities poses a challenge. This is a temporary issue since research in this area is on the rise. Nonetheless, to gain a wider understanding, three different case studies from healthcare companies will be examined instead of relying on a single in-depth case study. These case studies were selected from healthcare firms that have experienced at least one of the challenges mentioned in Chapter 3 but have successfully overcome them to implement BC-based smart contracts, thus enhancing scalability and SLA enforcement. Their strategies contribute to finding solutions to the research problems of this project. The conceptual data analysis results obtained from the process flow diagrams and SWOT analysis of the case studies suggest that small to medium-sized healthcare facilities face challenges in enforcing SLAs in cloud partnerships. This study will analyze the challenges and factors affecting the implementation of Service Level Agreements (SLAs) in cloud partnerships for small to medium-sized healthcare facilities, explore the potential of BC-based smart contracts in enhancing the scalability of cloud computing systems, and examine the unique challenges and trends.

To achieve these objectives, we will use a combination of qualitative and quantitative research methods, as discussed in Chapter 3. We will conduct case studies to gain an in-depth understanding of SLAs enforcement cons and its potential with BC-based smart contracts in enhancing the scalability of cloud computing systems. We will also use surveys and questionnaires to gather data on the prevalence of these challenges and factors that affect the implementation of BC-based smart contracts for SLA enforcement.

These case studies include MedRec, Simplyvital Health, and MedicalChain, as they are prominent examples of BC-based solutions for healthcare facilities. We will analyze these case studies using our research methods to identify the challenges faced by healthcare SMEs and how these BC-based solutions have helped overcome these challenges. We will also examine the factors that affect the implementation of these solutions and how they can be improved to enhance the scalability of cloud computing systems for healthcare SMEs. Solutions to these research problems may involve investing in technical expertise, conducting regulatory compliance assessments, and implementing standardized data collection and analysis practices. Furthermore, utilizing BC-based smart contracts can help improve efficiency and enforce SLAs in cloud partnerships.

Case 1: MedRec

The diagrams provided showcase the process flow of the MedRec system, which aims to achieve scalable, secure, and transparent access to patient records by utilizing smart contracts. This technology has the potential to automate processes, decrease errors, and boost efficiency in medical records management. Additionally, the diagram contains a SWOT analysis of the MedRec system, outlining its strengths, weaknesses, opportunities, and threats. Through evaluating these factors, the organization can acquire valuable insights into areas that need improvement and potential risks that could impact the system's success. Ultimately, this data can facilitate informed decision-making to enhance operations and ensure sustained success.

Figure: 4-1

Research diagram: Process flow of MedRec

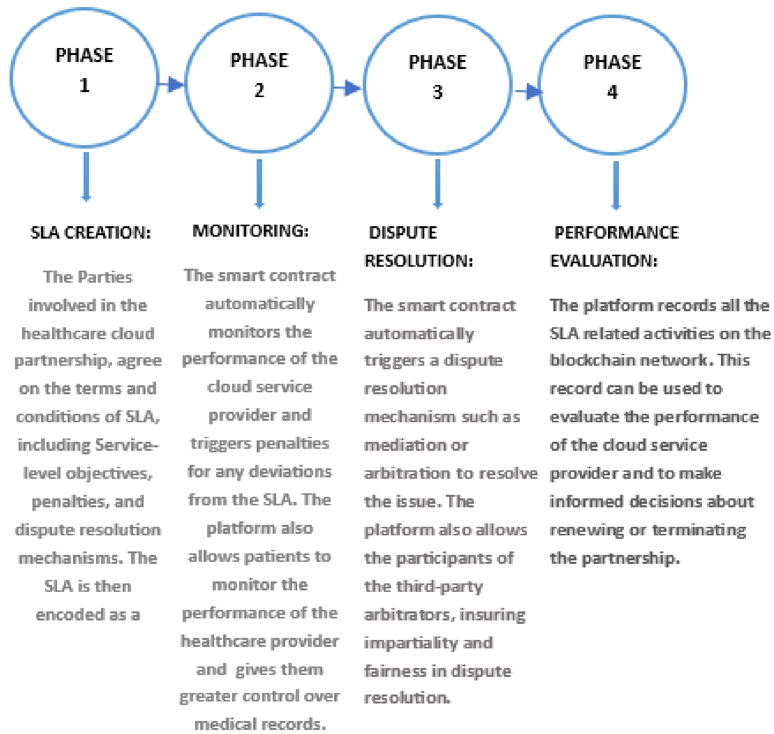
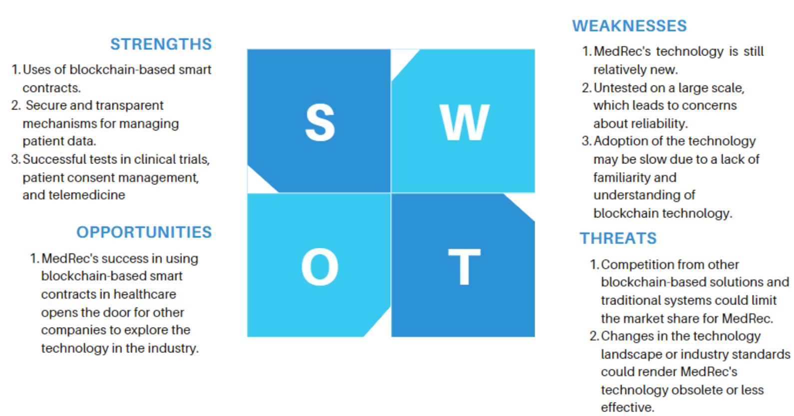


Figure: 4-2

Research Diagram: SWOT Analysis of MedRec



Here analysis results show that integrating BC with cloud computing positively impacts scalability at MedRec by delegating tasks and avoiding SLA violations. BC smart contracts enhance scalability by automating SLA management and creating self-executing agreements. MedRec has made significant progress in using BC for SLA enforcement, demonstrated in pilot studies and successful tests in various healthcare scenarios using BC technology provides a secure, transparent, and efficient mechanism for ensuring timely healthcare services, benefiting providers and patients.

Case 2: Simplyvital Health

The diagrams likely illustrate the process flow of Simplyvital Health's system for ensuring scalable, secure, and transparent access to patient records. The use of smart contracts in medical records management likely helps automate various processes and reduce the potential for errors, thus improving efficiency. Additionally, the diagrams also include a SWOT analysis of Simplyvital Health's system, This analysis helped identify the areas for improvement and potential risks that may affect the system's success. Ultimately, by examining these factors, the organization can make informed decisions to improve its operations and ensure its continued success.

Figure: 4-3

Research diagram: Process flow of SimplyVital health

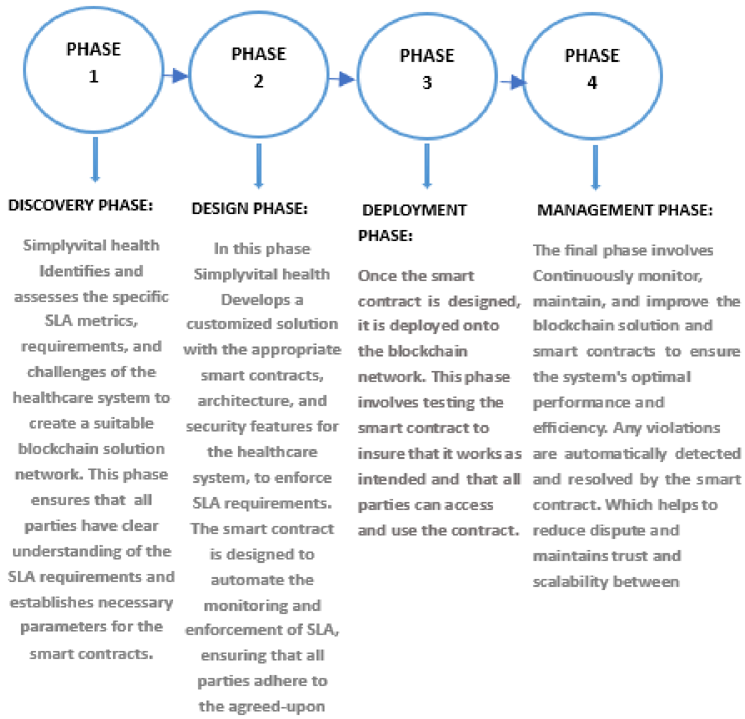
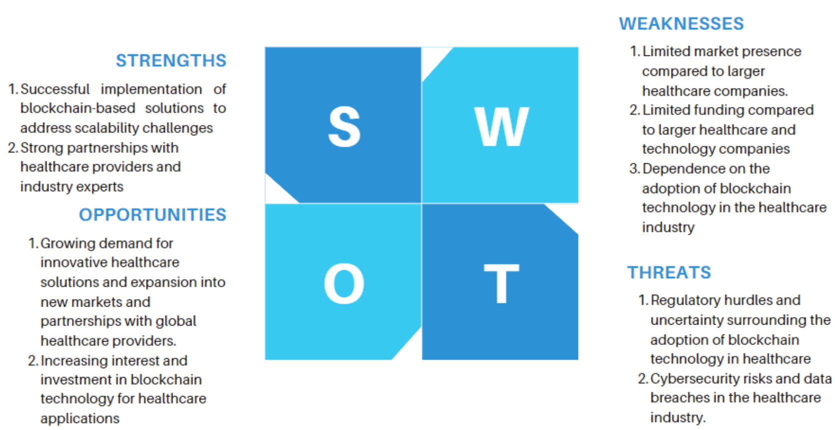


Figure: 4-4

Research Diagram: SWOT Analysis of SimplyVital health



Case study 3: Medicalchain

The diagrams below self-explain the process flow of MedicalChain Health's system for ensuring scalable, secure, and transparent access to patient records. The use of smart contracts in medical records management likely helps automate various processes and reduce the potential for errors, thus improving efficiency. Additionally, the diagrams include a SWOT analysis which can help identify areas for improvement and potential risks to the system's success.

Figure: 4-5

Research diagram: Process flow of MedicalChain.

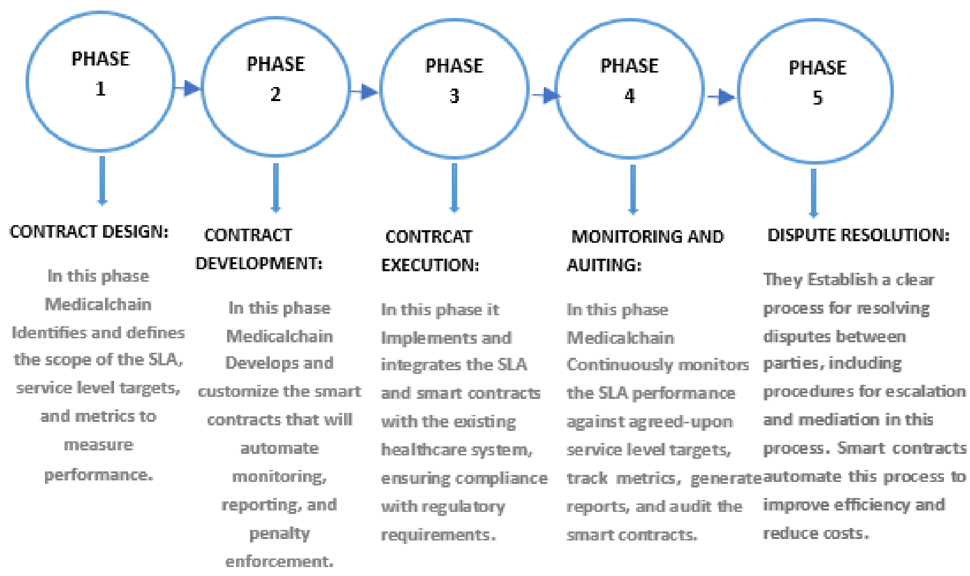
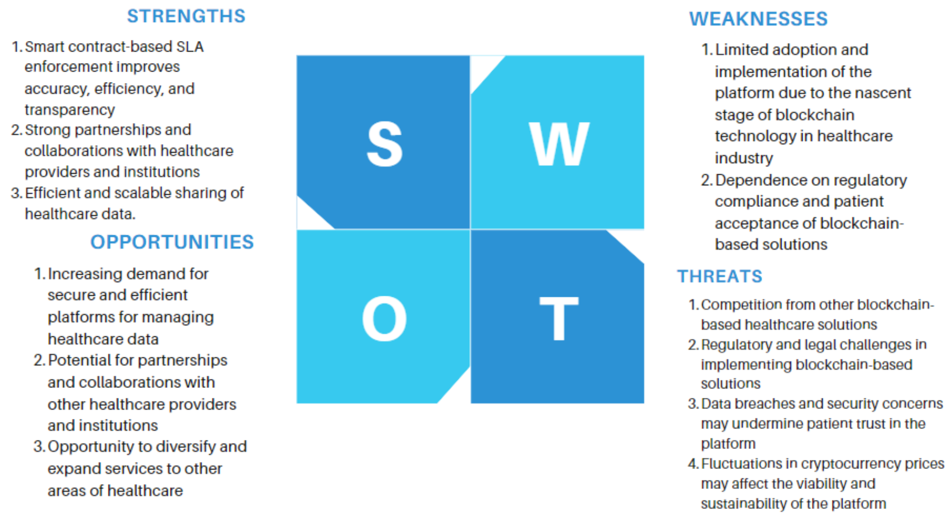


Figure: 4-6

Research Diagram: SWOT Analysis of MedicalChain



This association can impact scalability in cloud services in Medicalchain by providing secure and decentralized healthcare data storage and sharing. The use of BC smart contracts effectively addressed the scalability challenges faced by Medicalchain by improving the efficiency of data access and sharing and ensuring transparency and accountability of SLA compliance. Table 5.1 provides a summary of the challenges the three companies faced, and Table 5.2 provides cases and how they overcame these challenges through their relevance to each of the research questions.

Table 5.1

Challenges faced by MedRec, Simplyvital, Medicalchain

CASE 1: MedRec	**CASE 2:** SimplyVital	**CASE 3:** MedicalChain
1. Integration: Integrating blockchain-based systems with existing healthcare infrastructure can be a complex and time-consuming process.	1. Scalability: SimplyVital Health faced scalability issues with its cloud computing systems due to increasing healthcare data volume, burdening centralized cloud servers and slowing down data access and sharing.	1. Storage Capacity: MedicalChain had to find a way to efficiently store and access large amounts of medical data in a secure and scalable manner.
2. Regulation: The healthcare industry is highly regulated, and there may be legal and regulatory barriers to the adoption of blockchain-based systems.	2. Interoperability: Another challenge faced by SimplyVital Health made it difficult to share patient data securely and efficiently between different healthcare providers.	2 Data Processing Speed: MedicalChain needed to ensure that its platform could process data quickly and efficiently to meet the demands of its users.
3 Data standardization: Ensuring interoperability and data standardization across different healthcare providers can be challenging, which may affect the effectiveness of SLA enforcement.	3. Regulatory compliance: As a result, they needed to ensure that their solutions complied with strict regulations such as HIPAA to maintain trust with their customers.	4. Network Bandwidth: With the growing number of users and devices accessing MedicalChain's platform, network bandwidth became a major concern.

Table 5.2

Case study summary and its relationship with the research

	Question 1: How does the integration of blockchain technology with cloud computing impact the scalability of cloud services?	Question 2: How can Blockchain-based smart contracts enhance the scalability of cloud computing systems by enforcing Service Level Agreements (SLAs) in a secure and efficient manner?	Question 3: Can the use of blockchain smart contracts effectively address the scalability challenges faced by cloud computing?	Question 4: What are the trends and unique challenges for the healthcare industry regarding data collection and analysis?
Case 1: MedRec	The integration of blockchain technology with cloud computing has positively impacted the scalability of cloud services at MedRec. By utilizing blockchain-based solutions, MedRec can delegate tasks to other cloud providers in a transparent manner, thereby avoiding significant SLA violation penalties.	It can be seen through the aquired data that, Blockchain-based smart contracts have enhanced the scalability of cloud computing systems at MedRec by enforcing Service Level Agreements (SLAs) in a secure and efficient manner. Smart contracts help automate the SLA management process by creating self-executing agreements between MedRec and its clients. This ensures that all parties involved comply with the agreed-upon SLAs, which helps improve the efficiency and security of the cloud services.	Blockchain smart contracts can effectively address scalability challenges in cloud computing by automating the SLA management process and delegating tasks transparently. However, effectiveness depends on implementation and specific use cases. MedRec has made significant progress using this technology in healthcare, demonstrating feasibility and effectiveness through successful tests in clinical trials, patient consent management, and telemedicine.	MedRec did not have a way to collect and analyze the data. They had hardware installed and used an online dashboard for analytics.
Case 2: SimplyVital	The integration of blockchain technology with cloud computing can impact the scalability of cloud services in SimplyVital Health by enabling the delegation of tasks to other cloud providers when a resource limitation is encountered. This can be done in a transparent manner to the consumer to avoid significant SLA violation penalties, thereby improving the scalability of the cloud services.	Blockchain-based smart contracts can enhance the scalability of cloud computing systems by enforcing Service Level Agreements (SLAs) in a secure and efficient manner in SimplyVital Health. These smart contracts can automatically verify the compliance of cloud providers with SLAs, and trigger penalties or rewards based on their performance. This can improve the overall efficiency of cloud computing systems and enhance their scalability.	SimplyVital Health improved scalability, efficiency, and healthcare services by using blockchain smart contracts to delegate tasks transparently and enforce SLAs securely and efficiently. The technology reduced dispute resolution time and costs by up to 75%, improving dispute resolution, patient satisfaction, and trust between patients and healthcare providers.	SimplyVital did not have a way to collect and analyze the data. They had hardware installed and used an online dashboard for analytics.
Case 3: MedicalChain	Integrating blockchain technology with cloud computing can improve scalability in Medicalchain by providing a decentralized and secure way to store and share healthcare data. This reduces the burden on centralized cloud servers and improves data access and sharing efficiency while ensuring the privacy and security of sensitive healthcare data.	Blockchain-based smart contracts enhanced the scalability of Medicalchain's cloud computing systems by automating the enforcement of SLAs in a secure and transparent manner, delegating tasks to other cloud providers and reducing the burden on centralized servers. Additionally, this technology ensured the privacy and security of healthcare data, which is crucial in the healthcare industry.	The integration of blockchain technology and smart contracts helped Medicalchain address scalability challenges by providing a secure and efficient way to manage SLAs, which improved the trust between the company and its customers. Medicalchain's success in using smart contracts to enforce SLAs has demonstrated the potential for blockchain technology to address the scalability challenge faced by cloud computing.	MedicalChain did not have a way to collect and analyze the data. They had hardware installed and used an online dashboard for analytics.

CHAPTER FIVE

SUMMARY AND RECCOMENDATIONS

Discussions

As per the insights from MarketsandMarkets, the universal BC in the healthcare to height $34.4M from 2020 to $1.6 B till 2025, with a surge to 78.3%. So undoubtedly, the implementation of BC technology can bring significant advantages for production managers, as demonstrated by this project (Gosh et al., 2023). The case studies presented in the project highlighted the remarkable benefits, including cost reduction, improved performance, and enhanced decision-making capabilities. Therefore, production managers should be interested in incorporating BC technology into their operations to leverage these advantages. The implementation of BC technology with cloud is been the topic of interest due to its potential benefits (Murthy et al., 2020). The research project focused on leveraging BC technology for smart contracts for SLA enforcement in small to medium-sized healthcare cloud partnerships to improve scalability.

The study's findings are noteworthy as they highlight the prospect of BC technology and its competence and security of cloud-based systems. BC-based smart contracts, the research proposes an innovative approach to enforce service level agreements (SLAs) in healthcare cloud partnerships, which can be particularly challenging for SME facilities because they have limited resources. Integrating BC technology with cloud computing can provide several benefits, including enhanced security, transparency, and accountability (Li et al., 2021). Smart contracts can ensure that SLAs are automatically enforced, reducing the risk of disputes and enabling healthcare facilities to focus on providing high-quality patient care (Bai, 2019). The study's findings are relevant to healthcare and other industries that rely on cloud-based systems. As BC technology continues to evolve, more innovative applications are expected to emerge, enabling businesses to streamline their operations, enhance security, and improve customer satisfaction (Fanning & Centers, 2016).

Overall, the research project highlights the potential of blockchain technology to transform how we approach cloud computing and offers practical insights on how this technology can be leveraged to address specific challenges for health maintenance sectors. As adoption of BC continues to grow, it will be interesting to see how it shapes the future of cloud computing and other industries.

Recommendations

Insights from the research project the following recommendations can be made for small to medium-sized healthcare facilities looking to implement and leverage blockchain technology:

1. Identify key areas where BC technology can be integrated: Before integrating BC technology, it is important to identify key areas where it can be most beneficial. For small to medium-sized healthcare facilities, this

may include areas such as patient data management, inventory management, and supply chain management.

2. Collaborate with technology experts: Small to medium-sized healthcare facilities may not have the expertise or resources to develop and implement BC technology solutions on their own. Therefore, it is recommended to collaborate with BC technology experts who can provide guidance and support throughout the process.
3. Develop a roadmap for implementation: Developing a roadmap for implementation is crucial to ensure that the integration of BC technology is successful. The roadmap should include a detailed plan for implementation, timeline, and budget.
4. Invest in Training employees on BC technology: The importance to train employees to use of BC to ensure that they can use it effectively. This includes training on how to use BC-based smart contracts, as well as the security and privacy implications of BC technology.
5. Monitor and evaluate the implementation: It is crucial to gain insights to ensure that it is meeting the intended goals and objectives. This includes tracking key performance indicators (KPIs) and adjusting as needed.
6. Evaluate potential cost savings: Healthcare facilities should evaluate the potential cost savings associated with implementing BC technology for SLA enforcement. While there may be upfront costs associated with

implementing BC-based solutions, the long-term benefits, such as improved efficiency and reduced disputes, may justify the investment.

7. Stay up to date on the latest BC developments: By staying informed, healthcare facilities can identify new opportunities for leveraging BC technology to improve their operations.

Overall, leveraging BC technology for smart contracts for SLA enforcement in small to medium-sized healthcare cloud partnerships facilities can improve scalability and offer numerous benefits. By following these recommendations, small to medium-sized healthcare facilities can successfully integrate BC technology and realize its potential benefits.

Addressing Research Limitations of Project

As with any research project, there may be limitations that should be acknowledged. The following limitations addressed are as follows:

1. Small sample size: The project's case studies focused on a small number of healthcare facilities, which might have limited findings. Further study could explore the use of BC in a larger sample of facilities to validate the results of this project.
2. Limited timeframe: The project was conducted over a limited timeframe, which may have restricted the depth of the analysis. Longer-term studies could provide more detailed insights into challenges of using BC for SLA enforcement in healthcare-cloud partnerships.’

3. Lack of diversity: The case studies in the project focused solely on small to medium-sized healthcare facilities, which may not be representative of larger healthcare organizations. Future research could investigate usage of BC in larger facilities for the assessment of scalability for the proposed solution.
4. Lack of empirical data: The project relied on case studies and expert opinions, which may not provide empirical evidence to support the findings.
5. Technical barriers: Implementing BC technology requires technical expertise and infrastructure, which may not be readily available in all healthcare facilities.

Future Work

This work sheds light on the current topic, addressing the need for better Service Compliance and Security Level Agreements to ensure cloud scalability in healthcare systems, given the massive amount of information. Future study may aim at these scenarios as a resource. It is also essential to investigate what implementation steps can be performed in-house versus those that require outsourcing. Although there is existing literature on leveraging BC-smart contracts in SLA enforcement in healthcare cloud partnerships, there are still some gaps in the literature, particularly in relation to small to medium sized facilities (Qureshi et al., 2022). Further research is required to address broader aspects related to the topic. Here are some of the gaps in the existing literature: These gaps include limited research on small to medium sized facilities, lack of empirical studies, limited focus on regulatory and legal considerations, limited consideration of interoperability, and limited consideration of scalability. Addressing these gaps can help to provide more comprehensive guidance on how small to medium sized facilities can leverage BC-based smart contracts to enforce SLAs in healthcare cloud partnerships. Hence areas of future studies may include interoperability, trusted monitoring solutions, user experience, privacy and security, med tokens, cost, and integration with existing BSS and OSS.

Conclusion

In conclusion, to sum up, this research study focused on examining why BC technology should integrate to improve the scalability of cloud services. The study was conducted using case studies to explore the influence of BC technology on the scalability of services in healthcare organizations, specifically analyzing the examples of MedRec, SimplyVital Health, and Medicalchain. The main objective was to address the research questions and provide insights into the potential benefits of this integration.

Through conceptual data analysis and case studies, the study found that this can enhance the scalability of cloud services. BC-based smart contracts can enforce SLAs securely and efficiently, improving cloud computing systems' scalability. The study also identified potential benefits such as improved scalability, a trustless environment, and better decision-making. The findings of this study suggest that integrating BC technology with cloud computing can have significant benefits for scalability. BC-based smart contracts can enhance scalability by providing a secure and efficient means of enforcing SLAs. However, the study also identified limitations, such as the possibility of missing relevant studies and the need for further empirical research to validate the theoretical findings.

Based on the study's findings, recommendations were provided for healthcare facilities to leverage BC technology for smart contracts for SLA enforcement to improve scalability. Future research should focus on conducting empirical studies to evaluate the effectiveness of BC-based solutions, investigating interoperability issues, exploring other BC solutions, considering ethical and legal implications, and collaborating with stakeholders to develop tailored solutions. However, the study also identified limitations, such as the possibility of missing relevant studies and literature due to limited search databases and specific search terms in English. To address these limitations, this study highlights the potential of BC technology to enhance the scalability of cloud computing systems. It provides valuable insights for healthcare organizations looking to leverage this technology.

Future research should consider conducting further empirical studies to evaluate the effectiveness of BC-based solutions for SLA enforcement in healthcare cloud partnerships. Future research should also investigate interoperability issues, explore other blockchain-based solutions for healthcare operations, consider ethical and legal implications, and collaborate with technology providers and stakeholders to develop tailored solutions.

Footnotes: None.

Data Availability Statement: None.

Financial support: None declared:

Conflicts of Interest: None.

APPENDIX A

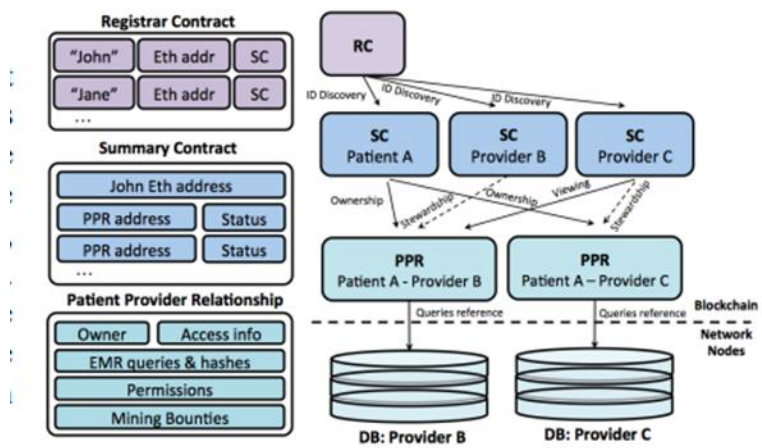
CASE STUDIES

Case 1: MedRec

Introduction and Background: MedRec is a healthcare DBMS company utilizing BC-technology to provide scalable, secure, decentralized, and tamper-resistant environment for patient data sharing. MedRec aims to overcome the challenges associated with centralized healthcare data systems, such as lack of interoperability, data silos, and security concerns. One of the key features of MedRec is its ability to enforce Service Level Agreements (SLAs) between healthcare providers and patients using blockchain-based smart contracts. This ensures that healthcare providers deliver high-quality services within the agreed-upon timeframe. In this case study analysis report, we will examine how MedRec uses blockchain-based smart contracts to enforce SLAs, the benefits it offers to both healthcare providers and patients, and the challenges it faces in implementing this technology (MIT Media Lab n.d). MedRec was founded in 2016 in MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL).

The team identified a requirement of interoperable healthcare data management system that could address the shortcomings of existing centralized systems. MedRec uses Ethereum BC, which gives a secure and decentralized base to data storage and sharing. MedRec uses smart contracts to enforce SLAs between healthcare providers and patients (Ekblaw et al., 2016). The case study helps answer all three of the research questions. The analysis results show that integrating blockchain with cloud computing positively impacts scalability at MedRec by delegating tasks and avoiding SLA violations. Blockchain smart contracts enhance scalability by automating SLA management and creating self-executing agreements.

Figure: 4-1



Note: by (Ekblaw, 2016), MIT white Paper

Although effectiveness depends on implementation, MedRec has made significant progress in using blockchain for SLA enforcement, demonstrated in pilot studies and successful tests in various healthcare scenarios. Blockchain technology provides a secure, transparent, and efficient mechanism for ensuring timely healthcare services, benefiting providers and patients.

Case 2: SimplyVital Health

This case study describes the use of blockchain technology by SimplyVital Health, a healthcare technology company that provides blockchain-based solutions for healthcare data management. The healthcare industry has always been plagued with challenges in the SLA area between healthcare vendors and patients. It is often difficult to ensure that healthcare providers deliver the services they promise, while patients are expected to pay for the services they receive. SimplyVital Health, a healthcare technology company, has developed a solution to this problem by leveraging blockchain-based smart contracts to enforce SLAs (SimplyVital Health, n.d.).

Background, History and evolution - SimplyVital Health is a healthcare technology company that was founded in 2015 by Katherine Kuzmeskas and Lucas Hendren, with the goal of developing innovative healthcare technology solutions. The company's initial focus was on developing a BC-based healthcare platform that gives access to patients for owning, manage their health data securely. Later, the company shifted its focus to developing a solution for SLA enforcement using blockchain-based smart contracts. The company is headquartered in Connecticut, USA, and aims to improve patient care and reduce healthcare costs using blockchain technology (SimplyVital Health, 2018). Initially, SimplyVital Health focused on developing a blockchain-based platform called ConnectingCare, which aimed to provide healthcare providers with secure access to patient data. The platform was designed to enable healthcare providers to easily share data and collaborate on patient care, while ensuring patient privacy and data security (Forbes, 2018). In 2017, SimplyVital Health raised $3.3 million in a token sale for its blockchain-based platform (SimplyVital Health, 2018).

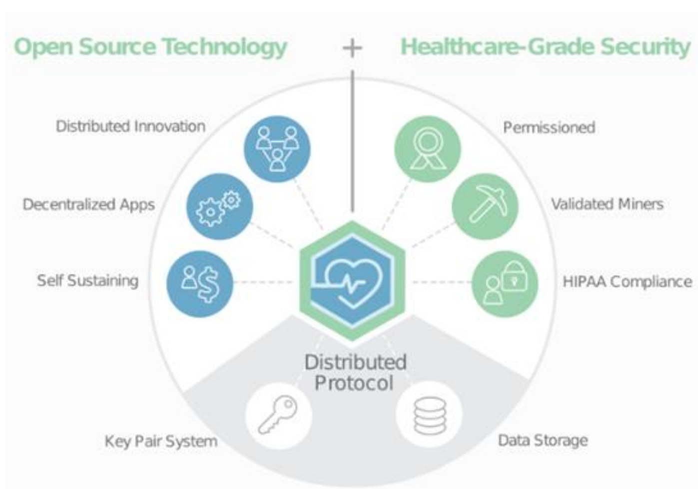
The company also received a grant from the National Science Foundation (National Science Foundation, 2018). Since then, SimplyVital Health has continued to develop and expand its blockchain-based platform and has also begun to focus on developing smart contract solutions for the healthcare industry. The company's focus on smart contract solutions is aimed at improving the efficiency and transparency of healthcare transactions, while also reducing costs and improving patient outcomes (SimplyVital Health. n.d.). SimplyVital Health's system uses blockchain to enforce SLAs between healthcare providers and cloud service providers, ensuring that data is stored securely and that providers are compensated fairly for their services. SimplyVital Health is leveraging smart contracts and blockchain technology to enhance the interoperability of healthcare data and improve patient outcomes. The company uses blockchain to create a secure and transparent platform for sharing patient data, which allows providers to collaborate more effectively and make better-informed decisions (Benartzi, 2020).

Smart contracts are used to add automation to the processes involved in healthcare data sharing, such as data access requests, consent management, and billing (Benkhelifa, 2021). By using smart contracts, SimplyVital Health can enforce service level agreements (SLAs) between providers and patients, ensuring that data is shared securely and efficiently.

Challenges it faced and solutions it implemented - SimplyVital Health faced scalability problems due to the increasing number of patients using its platform. The company realized that traditional centralized systems were not able to handle the increasing demand and that it needed to adopt a decentralized approach to ensure scalability. To address this challenge, SimplyVital Health leveraged BC technology and implemented smart contracts to create a decentralized network. This enabled the company to distribute the workload across multiple nodes in the network, which increased its capacity to handle a larger number of patients. By leveraging BC-based smart contracts, SimplyVital Health was able to automate and streamline various healthcare-related processes, which reduced the workload on healthcare providers.

Figure: 4-4

Simplyvital health Blockchain Protocol



Note: by (Damiani, 2017), Forbes.

This, in turn, enabled healthcare providers to focus more on patient care and the overall quality of care. The execution of blockchain-based smart contracts also provided patients with more control over their healthcare data, as they could now share their data securely and selectively with different healthcare providers. Overall, the adoption of BC-based smart contracts helped SimplyVital Health to address the scalability challenges it faced, while also improving the efficiency, security, and quality of services given to patients (SimplyVital Health. n.d.).

Case study 3: Medicalchain

This case study examined the use of BC technology by Medicalchain, a UK-based healthcare company that executes BC to secure medical records and enable patients to share their records securely with healthcare providers. Medicalchain's system uses smart contracts to enforce SLAs between healthcare providers and cloud service providers, ensuring that patient data is stored securely and that providers are held accountable for any breaches of the SLA.

Introduction and Background: Medicalchain is a healthcare BC platform that provides patients with the chance to store and share their medical records in a decentralized method. The platform aims to improve the efficiency and transparency of healthcare by leveraging blockchain technology (Medical Chain, n.d.). In this case study analysis, we will explore how Medicalchain is using smart contracts to enforce service level agreements (SLAs) between healthcare providers and patients, and the results they have achieved. Medicalchain was founded in 2017 with the goal of “revolutionizing healthcare by creating a safer and trustless environment to share medical records” (Abdullah, 2019). The platform is built on BC technology, which provides a decentralized and immutable ledger which is tamper-proof and secure (Medical Chain, n.d.). Medicalchain allows consumers the access-control over their medical records, eliminating a need for paper-based records and streamlining the healthcare process (Ramesh, 2021).

SLA Enforcement with Smart Contracts: Medicalchain is using BC-based smart contracts to enforce SLAs between healthcare providers and patients. Medicalchain's smart contracts are designed to enforce SLAs between healthcare providers and patients, ensuring that both parties meet their obligations. The smart contracts are programmed with the terms of the SLA, including the services to be provided, the timeframe for delivery, and the penalties for non-compliance. The smart contracts are also designed to automate the payment process, ensuring that healthcare providers are paid promptly for their services (Benkhelifa, 2021). By using smart contracts to enforce SLAs, Medicalchain is able to increase transparency and trust between healthcare providers and patients, while also reducing the administrative burden of managing SLAs (Zou, 2021

APPENDIX B

SAMPLE SOLIDITY SMART CONTRACT CODE THAT ENFORCES SLA REQUIREMENTS FOR A SMES HEALTHCARE FACILITY.

```
pragma solidity ^0.8.0;

#In this example, the SLA agreement is between a healthcare cloud provider and client, with an uptime requirement and penalty rate.
#The emit statements are used to trigger events that can be monitored by external systems.
#The following smart contract can be deployed to the Ethereum blockchain and interact with it using a blockchain wallet or a blockchain development framework like Truffle or Hardhat.

contract HealthCloudSLA {
    address public provider;
    address public client;
    uint public uptimeRequirement; // in percent
    uint public penaltyRate; // in percent

    enum Status { Active, Inactive }
    Status public status;

    event SLACreated(address provider, address client, uint uptimeRequirement, uint penaltyRate);
    event SLAUpdated(uint uptimeRequirement, uint penaltyRate);
    event SLAActivated();
    event SLADeactivated();
    event SLAViolation(uint timestamp);
    event PenaltyApplied(uint amount);

    constructor(address _provider, address _client, uint _uptimeRequirement, uint _penaltyRate) {
        provider = _provider;
        client = _client;
        uptimeRequirement = _uptimeRequirement;
        penaltyRate = _penaltyRate;
        status = Status.Active;
        emit SLACreated(provider, client, uptimeRequirement, penaltyRate);
    }

    function updateSLA(uint _uptimeRequirement, uint _penaltyRate) public {
        require(msg.sender == client, "Only client can update the SLA");
        uptimeRequirement = _uptimeRequirement;
        penaltyRate = _penaltyRate;
        emit SLAUpdated(uptimeRequirement, penaltyRate);
    }

    function activateSLA() public {
        require(msg.sender == client, "Only client can activate the SLA");
        require(status == Status.Inactive, "SLA is already active");
        status = Status.Active;
        emit SLAActivated();
    }



    function reportUptime(uint _uptime) public {
        require(msg.sender == provider, "Only provider can report uptime");
        require(status == Status.Active, "SLA is inactive");
        require(_uptime >= uptimeRequirement, "Uptime requirement not met");
        // do something with the uptime report
    }

    function reportDowntime(uint _downtime) public {
        require(msg.sender == provider, "Only provider can report downtime");
        require(status == Status.Active, "SLA is inactive");
        require(_downtime < uptimeRequirement, "Uptime requirement violated");
        emit SLAViolation(block.timestamp);
        uint penaltyAmount = _downtime * penaltyRate;
        // do something with the penalty amount, such as transfer it to the client's account
        emit PenaltyApplied(penaltyAmount);
    }
}
```

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