Integration of Blockchain and Cloud Computing in Telemedicine and Healthcare

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Abstract
Blockchain technology has emerged as one of the most crucial solutions in numerous industries, including healthcare. The combination of blockchain technology and cloud computing results in improving access to high-quality telemedicine and healthcare services. In addition to developments in healthcare, the operational strategy outlined in Vision 2030 is extremely essential to the improvement of the standard of healthcare in Saudi Arabia. The purpose of this survey is to give a thorough analysis of the current state of healthcare technologies that are based on blockchain and cloud computing. We highlight some of the unanswered research questions in this rapidly expanding area and provide some context for them. Furthermore, we demonstrate how blockchain technology can completely alter the medical field and keep health records private; how medical jobs can detect the most critical, dangerous errors with blockchain industries. As it contributes to develop concerns about data manipulation and allows for a new kind of secure data storage pattern to be implemented in healthcare especially in telemedicine fields is discussed diagrammatically.

Keywords:
Blockchain, cloud computing, healthcare, telemedicine, machine learning.

1. Introduction

People have been using numerous mobile and wearable technologies, such as smartphones, smartwatches, and smart bands. It provides a significant amount of data on a person's health, and this data is useful for academic, researchers, commercial, and as well as the entire public healthcare system. It benefits them by using it to realize health-related applications like remote diagnosis, disease monitoring, and elderly care. As a result of the rapid growth of mobile computing, wearable technology, and wireless sensing [1]. Health data is often controlled by individual users as a personal asset, but it is also regularly maintained by numerous service providers, device manufacturers, or across healthcare systems. These centralized data warehouses and authority suppliers are enticing cyberattack targets [2], threatening data security and privacy. Consequently, cryptocurrencies create barriers to data sharing. In recent years, blockchain technology has gained widespread acceptance.

For example, since its incorporation in 2008 [3], Bitcoin has attracted research interest from a variety of academic disciplines and gained widespread popularity due to its unique characteristics [4][5]. On decentralized networks, the absence of centralized control, the presumed high level of anonymity, and distributed compatibility were observed [6]. Blockchain technology may reduce the risk of data breaches by integrating threshold encryption of data with public key infrastructure. It is required several parties' participation to decode data and asymmetric cryptography that used to authenticate communication with system participants. At now, the Saudi Arbia's vision 2030 asks for creative solutions to improve the lives of all Saudi people. To increase the health sector's capacity and manage challenges related to health services by improving their quality and effectiveness, blockchain and cloud computing may be used to help achieve the accomplishments and strategic objectives of the National Transformation Program. This paper provides a comprehensive overview and analysis of blockchain-based healthcare and cloud computing technologies and related applications. Moreover, the current study identifies some of the research gaps in this rapidly expanding topic and describes them in detail.

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This paper is organized as follows. The next section describes the background of the study. Section 3 discusses the review of the literature. In section 4, we provided comparison and analysis of the undergoing study. Section 5 summarizes the results and gives some recommendations. Finally, in section 6, we give some concluding remarks and possible future directions carved out of the study.

2. Background

Blockchain is a technology that can be used to create secure, trusted, and decentralized autonomous intelligent transportation systems (ITS) by cryptography to secure and verify the data stored in it, making it virtually impossible for anyone to tamper with or alter any of its entries without being detected. The technology has primarily been used in cryptocurrency networks, but it can also be applied in other areas. Cloud computing is a type of computing that handles applications using shared computing resources rather than local servers or personal devices. Users can also access their files from any device with an internet connection, without the need for additional software to be installed locally. The use of digital technologies such as video conferencing, phone calls, and text messaging to provide medical care remotely is known as telemedicine. Healthcare also includes services provided by healthcare professionals to maintain or improve a person's health. It includes preventive measures such as vaccinations, illness or injury diagnosis and treatment, rehabilitation after an illness/injury.

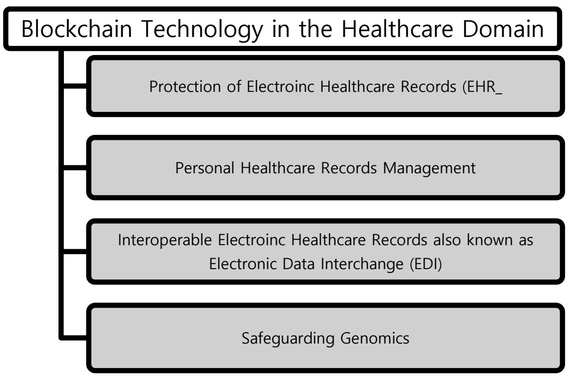

Figure 1. Healthcare and Blockchain Security

Figure 1 shows how blockchain security can be used to protect healthcare features and secure Electronic Healthcare Records (EHR) sharing between various electronic healthcare systems [11].

3. Review of Literature

This section of the study explores some literature reviews about Blockchain and Cloud Computing in Telemedicine and Healthcare and other applications. The purpose of this part is to evaluate the current state of knowledge.

Koshechkin et al. [8] suggest that blockchain technology has the potential to be integrated into telemedicine and healthcare. conducted a review of the feasibility of using blockchain technology. They searched several databases, including Scopus, PubMed, IEEE Xplore, Google Scholar, and Web of Science, as well as web search engines, to identify relevant studies and solutions. A knowledge review on how blockchain technology and telemedicine are related. The search was based on two primary source types, web-based journal databases and conventional web search. The findings of the literature analysis revealed that only 18 of the 40 projects involving the development of blockchain technology and telemedicine met the selection criteria. Medical data access (14 out of 18, 78%), healthcare services processing (14 out of 18, 78%), diagnostic support (10 out of 18, 56%), payment transactions (10 out of 18, 56%), and fund-collecting for telemedical instrument development (5 out of 18, 28%) were the known reasons of these solutions. The authors conclude that blockchain technology has the capabilities to improve telemedicine services and contribute to the ongoing development of digital technologies in the healthcare industry. An analysis of how blockchain technology and artificial intelligence are being used in the healthcare sector was done by Kumar et al. [9]. They have studied the individual domains of blockchain and AI, and then combine them to improve the healthcare sector. Blockchain and AI have been combined in a variety of ways for healthcare applications. For Machine Learning-based methods; Artificial Neural Network (ANN), Naive Bayes, Decision Tree, K-Nearest Neighbor (KNN), K-Means Clustering, Support Vector Machine (SVM) and Random Forest. As for, Deep Learning-based methods; Deep Autoencoder, Deep Reinforcement Learning (DRL), Recurrent Neural Networks, Deep Belief Network, Deep Convolutional Neural Network and Deep Generative Models (DGM). According to the paper's findings, integrating AI and blockchain technology into the healthcare sector has the potential to have a wide range of positive effects. The review provides an overview of 120 research articles on blockchain applications in healthcare powered by AI. The paper highlights the benefits of securing medical records with blockchain technology, maintaining patient privacy, and automating data analysis with AI algorithms. It concludes that there are still some limitations to the current systems, including privacy concerns, legal constraints, and security concerns.

Blockchain and cloud computing technology are discussed in Huang & Lee [10] of how medical data can be secured and kept private. It proposes a scheme that combines the benefits of both blockchain technology and cloud computing and enables secure data sharing, storage, traceability, decentralization, and unalterable healthcare data. The proposed scheme combines proxy re-encryption and attribute-based encryption to perform integrity checks of cloud data as well as more extensive security encryption computations. Also, intelligent hospitals can share their private key to access shared resources without downloading them from the server even if it has the proxy key with itself. Moreover, the data used for experiments is medical data. The proposed scheme ultimately succeeds in securing medical data protection and integrity verification. It can deal with issues like data sharing, high computing complexity, and privacy protection.

Amanat et al. [11] propose a model based on blockchain technology to securely share HER among different healthcare systems. Moreover, the proposed model uses cryptographic techniques such as hashes and digital signatures for authentication purposes, which ensures data immutability and better power consumption over existing systems like Proof-Of-Work (POW), Secure Hash Algorithm (SHA-1), and Message Digest (MD5)/(MD). The main approaches discussed in this paper are: Firstly, Using a Proof of Stake (POS) cryptography consensus mechanism and Secure Hash Algorithm (SHA-1) to authenticate user identity; Secondly, utilizing an (ECDSA) to verify EHR sensors for transmitting and assembling data securely; Lastly, Comparing the suggested solution to current solutions for processing sensitive patient data, such as POW, SHA-1, MD, etc., in terms of authenticity, security, and power consumption. The experiments used data from HER systems. This included patient information such as medical history, diagnosis results, and other sensitive health records which were securely shared among different healthcare stakeholders using the proposed architecture based on blockchain technology. Ultimately, this paper concludes that the proposed architecture based on blockchain technology is a secure and efficient way to share EHR among different healthcare systems.

Ahmed & Akhtar Raja [12] focus mostly on methods that make it possible for people to maintain social connections even when they're on the go using supporting technologies like smartphones. Through these eHealthcare models, patients can connect with their doctors and other medical professionals via Internet-enabled mobile phones, portable personal digital assistants (PDAs), or fixed-network computers. With this improvement, medical professionals such as doctors, physician assistants, nurses, and those responding to medical emergencies can access patient records from any location at any time. On the other hand, the disadvantage of this technology it requires a reliable internet connection to access the services provided by virtual hospitals. Additionally, there may be security concerns related to storing and accessing sensitive patient information over an online platform.

Celiz et al. [13] used Blockchain technology, which offers high degrees of transparency by offering one source of distributed truth to all contributors and making sure that the data cannot be changed. It combined with IoT to provide not only visibility but also traceability to show the current state of things which helps in reducing frauds and improving flexibility while ensuring communication between everyone involved. But using Blockchain technology requires a large amount of computing power and energy to maintain the network, which can be costly. Additionally, there are still some security concerns related to blockchain as well as scalability issues due to its limited throughput capacity. To facilitate the exchange of continuous, dynamic health data between individuals.

Zheng et al. [14] offered a conceptual architecture that makes use of blockchain technology and cloud storage. The proposed system's primary objective is to facilitate the safe and secure collection, storage, and dissemination of individual health data in accordance with the requirements of the General Data

Protection Regulation (GDPR). Blockchain technology ensures secure transactions between two parties without any third-party interference while machine learning techniques are used as part of the proposed system's architecture which helps maintain good quality standards when collecting or transferring such sensitive information like healthcare related datasets over networks. This includes using deep learning algorithms used Human Activity Recognition tasks obtaining satisfying results as part of the proposed system's architecture.

A thorough examination of blockchain cloud integration (BcC) in healthcare systems is provided by Ismail et al. [15], who infer two primary topologies, encapsulated and non-encapsulated. As can be seen in Figure 2, an encapsulated design wraps up the blockchain platform and its underlying implementation in the cloud. Healthcare stakeholders should trust their cloud service providers as the essential blockchain is applied and done by them. As a result, security and privacy concerns are not fully resolved in his encapsulated BcC design. In this design, and by a cloud service provider the system is leveled up.

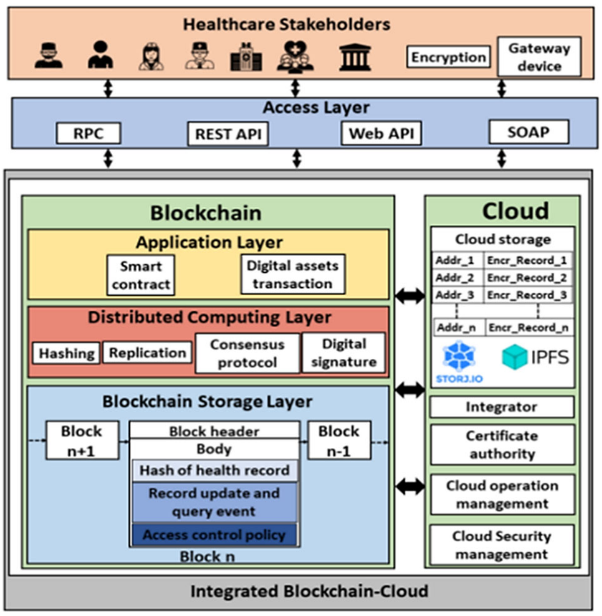

Figure 2. Non-encapsulated BcC design for healthcare

The security and privacy problems present in the encapsulated BcC designs, a non-encapsulated BcC design was suggested where the blockchain and the cloud technologies are combined without encapsulating into each other as shown in Figure 3. Non-encapsulated BcC architectures are more secure and private than encapsulated design, making it suitable for healthcare applications. All healthcare stakeholders have their own copy of the blockchain ledger which is maintained outside the cloud where patient medical records are in the cloud. A cloud service that stores medical data also handles system updates. Both encapsulated and non-encapsulated design use external cloud databases to store patient medical records.

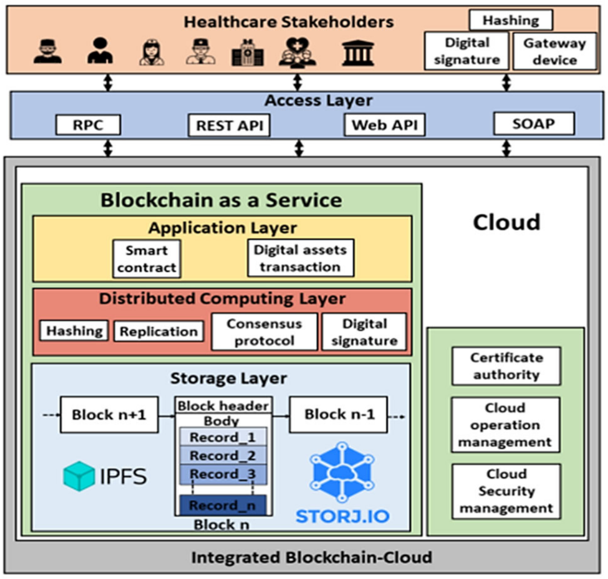

Figure 3. Encapsulated BcC architecture for healthcare.

Roy & Singh [16] reviewed and analyzed several blockchain approaches for securing health data that is being stored in the cloud. The main drawback of cloud storage is that users have no control over the data that is being stored in the cloud and can only depend on the service provider to keep the data safe. External dependencies make data highly vulnerable, and security needs to be resolved. By decentralizing the network, blockchain makes the network more stable and stops unauthorized mediation interventions.

To ensure the safety of electronic health records (EHRs) when being shared between multiple patients and medical providers, Nguyen et al. [17] proposed designing a dependable access control system based on smart contracts. A prototype of the suggested framework is constructed, and it is tested using real-world data-sharing scenarios on the Amazon cloud computing platform using the Ethereum blockchain.

Then, evaluating system performance, security analysis, and user experience based on the empirical outcomes of mobile app experiments. The implementation results of paper [17] show that the framework enables the sharing of medical data from medical users through mobile cloud environments in a dependable and expedient manner. Also, the e-health system's access control can prevent and discover any unauthorized users.

4. Comparison and Analysis

In this section, we will compare and analyze our findings on Integration of Blockchain and Cloud Computing in Telemedicine and Healthcare. Table 1 demonstrates our comparison of the various studies. The studies were compared based on various parameters, such as the Blockchain technology, Cloud Computing technology, type of data, merits, and limitations.

Based on the analyses of the reviewed paper, we have observed the variety in the use of blockchain and cloud computing with other technologies such as ML, Deep learning, and Sky Computing. Most of the solutions have focused on achieving secure protection and integrity verification of medical data. A study in [18], uses three approaches in blockchain which are Bitcoin, Ethereum, and Juno to achieve tracking and a chain of custody from the maker to the patient Since these are immutable. Alternately, in study [14] blockchain technology, a Distributed ledger system, is combined with ML to secure personal health-related information while allowing researchers and commercial entities to access it transparently manner and benefits from the use of high-quality personal health datasets. Using the Hyperledger open-source platform, a suggested approach by study [13] enables high degrees of transparency like those presented in study [14], but with the added benefit of providing all participants with a single, unified truth. The study in [12] relies on Google App Engine's cloud computing service and sky computing has the potential to revolutionize healthcare services to provide ubiquitous access and secure data archiving. The simulation experiment in study conducted by [10] proves that the proposed scheme is effective and can achieve secure protection and integrity verification of medical data using Consortium chains. Consortium chains are private blockchains where only pre-selected nodes can participate as validators or miners for transaction validation process. Likewise, research in [15] uses blockchain technologies Ethereum and Hyperledger Fabric. The integrated BcC architecture provides a secure, reliable, and cost-effective solution for healthcare applications by combining the advantages of cloud computing technologies with blockchain. [8] has two main source types of web-based journal databases and conventional web search resulted with Medical data access (78%), medical service processing (78%), diagnostic support (56%), payment transactions (56%), and fundraising for telemedical instrument development (28%) [9]. It covers 120 research articles on AI-powered blockchain applications in healthcare and provides a comprehensive overview of the subject. [11] The proposed solution performs better than existing solutions in terms of power consumption, authenticity, and security for healthcare records. On a nutshell, several healthcare studies focused on ML application and secure transactions [19-30].

5. Findings and Discussion

The findings of the studies suggest that blockchain technology and cloud computing can be effectively utilized in the healthcare industry to improve various aspects of medical data management, including secure data sharing and storage, privacy and security of medical records, and traceability of information. In all the studies, the use of blockchain and cloud computing in healthcare resulted in improved data access, processing of medical services, and support for diagnostics, as well as secure payment transactions and fundraising. However, each study also highlights the limitations and challenges that need to be addressed, such as limited scalability, privacy issues, security concerns, and legal restrictions. Additionally, the need for expert assessment and relevance to centralized systems were also mentioned as limitations in some of the studies. Overall, these studies provide a comprehensive overview of the potential of blockchain and cloud computing in healthcare and demonstrate that these technologies have the potential to revolutionize the healthcare industry by providing secure and efficient medical data management. Several other studies have also been conducted to address the substantial issues potentially caused by data exchange [31-50].

Table 1. Summary of Related Studies

Study	Year	Blockchain Technology	Cloud Technology	Type of Data	Merits	Limitations
[18]	2018	Bitcoin, Ethereum, and Juno.	RSA public key system.	Patient Records between 26 and 44 petabytes of data on its 9 million	Accenture identified blockchain as one of three innovations that will transform the financial services industry	System that stops physicians from using patient data until a key has been released
[14]	2018	Distributed ledger system with ML	PKI	EHR	Enables users to own, control and share their personal health data securely in (GDPR)	Requires a large amount of computing power and storage capacity to handle continuous-dynamic health data
[13]	2018	Hyperledger open-source platform	Amazon cloud server	Real-time product data from the temperature, humidity and location sensors found within the existing systems owned by private health institutions	It provides visibility, traceability, and communication between all parties. The information cannot be altered or tampered	It is limited to private health institutions in Peru. There may be a lack of understanding from the users due to its complexity
[12]	2018	Not used, sky computing technology instead	Google App Engine	Clinical data using Apache Hadoop open-source software with SkyDrive	Enables ubiquitous services on an anywhere-and-anytime basis.	The need for trust between cooperating CSPs and SLAs covering all stakeholders. data security and privacy that must be addressed
[10]	2020	Consortium Chain	Proxy Reencryption (PRE)	Patient records such as health history, diagnosis results and treatment plans stored in electronic form.	The proposed scheme can help to securely share, and store distributed, decentralized, traceable and unalterable healthcare data. The cloud computing technology used helps reduce complexity by providing access control mechanisms such as PRE or attribute-based encryption (ABE).	The proposed scheme does not provide fine-grained control of cloud data and may lead to storage overhead due to redundant data. It also has limited scalability as the consensus mechanism needs improvement.
[15]	2021	Ethereum and Hyperledger Fabric	On-demand service, pay-per-use model, and multi-tenancy	EHR	The integrated BcC architecture offers a secure, reliable, and cost-effective solution for healthcare applications.	The number of health records is continuously increasing. Cloud computing and blockchain are energy intensive. Medical records are stored in a third-party cloud and no local copy.
[8]	2021	Web-based journal databases and conventional web search.	Telemedicine services.	81,476 pediatric records	Using blockchain technology to improve access to medical data, processing of medical	Limited number of relevant studies, Lack of publications, Potential for bias,

					services, and support for diagnostics, as well as enable payment transactions and raise funds for telemedicine instrument development.	Need for expert assessment, Relevance to centralized systems
[9]	2022	ML methods; ANN, Naive Bayes, Decision Tree, KNN, K-Means Clustering, SVM and Random Forest.As for, Deep Learning-based methods; Recurrent Neural Networks, Deep Autoencoder, Deep Belief Network, Deep Convolutional Neural Network, DGM, DRL.	Remote healthcare services.	40 projects	Highlights the various ways AI and blockchain are being used in healthcare, such as in the management of electronic health records (EHR), remote patient monitoring, telemedicine, genomics, drug research, and testing, and outbreak prediction.	Privacy issues, legal restrictions, and security concerns.
[11]	2022	Cryptographic techniques such as hashes and digital signatures for authentication purposes. POS cryptography algorithm ECDSA Algorithm	Cloud Mining	EHR	The proposed architecture provides robust, traceable, and unchangeable data sharing and storage facilities relative to traditional healthcare systems.	The algorithms used previously such as POW, MD5 and SHA-1 can be less efficient when compared with newer technologies like ECDSA or SHA256

6. Conclusion and Future work

To sum up, the aim of all the methods proposed in this research are to ensure that data is always accessible and secure. All this effort was put in because there were a few sources that reviewed the history of blockchain and cloud computing together. As well as the National Transformation Program which aims to improve the quality and efficiency of health services and increase the sector's capacity, blockchain and cloud computing can be utilized to do both things. As a result of our comprehensive literature review on blockchain and cloud computing we have identified some significant technological challenges and suggested methods. Moreover, outline some of the research gaps that have been discovered in this fast-growing field. We plan to implement the mechanism in the future with aim of making it more suitable for use in the real world, in particularly in Saudi Arabia. Further, to ensure that the blockchain's capabilities can accommodate a wider range of medical institutions' requirements and focus on developing fine-grained control over cloud data and better performance using variety of approaches in data science, AI, machine learning and deep learning [61-75].

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