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Blockchain Technology in Healthcare Systems: Applications, Methodology, Problems, and Current Trends

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ABSTRACT
Blockchain Technology (BT) is a secured ledger that has the potential to enhance the safety, quality as well as efficiency of healthcare provision. This will benefit healthcare administrators and healthcare end-users. This paper is focused on expanding the significance of blockchain technology in healthcare information. It identifies those aspects that are not being recorded by many researchers in establishing the prospects of Blockchain Technology in the healthcare domain. Accordingly, the paper looked at Blockchain involvement in administering healthcare services such as telemedicine, health information exchange, and electronic prescribing. The review can discover the huge potential of Blockchain technology in healthcare such as in storing healthcare data on a shared Block that is accessible to concerned stakeholders without undue privacy distresses. This research provides the desired guide and identified open perspectives for researchers that will improve the level of adoption of Blockchain in the healthcare domain.

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INTRODUCTION

Healthcare delivery issues have become a global phenomenon that requires commeasurable solutions to better enhance quality healthcare service delivery. With the growth in the human population across the globe, practicable and impactful alternative methods are needed to scale and automate healthcare service delivery to match up with the increased population of patients' daily visit to several hospitals. A plethora of methods has been conceived by researchers to ensure remote and virtual health monitoring which could lead to a decreased operational cost in healthcare (Kalra, 2014). That was achieved by discouraging hospitalization and making sure that patients gain desired healthcare attention easier and faster. Emerging technologies offered great opportunities in the healthcare industry that have improved the delivery of quality services comprising of collection, retrieval, storage, and transfer of healthcare data electronically. They also have impacted considerably on healthcare services delivery in administrative, clinical efficiencies, documentation, and information dissemination in a wider circulation (Gulavani & Kulkarni, 2010).

Some of the current emerging technologies that find application in healthcare are wireless information communication and Blockchain technologies. They were envisaged to provide solutions to several challenges in the healthcare domain (Gulavani & Kulkarni, 2010). Blockchain technology is a

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decentralized public secure ledger that records all transactions in blocks whence blocks are cryptographically chained together. The distinctive nature of Blockchain which is openness, immutability, security, trustworthiness, and smartness became possible for multiple participants to perform transactions concurrently and securely (Ji, 2018). To provide privacy protection for transactions and data, encryption schemes have been employed in Blockchain applications (Hassan, 2019; Brandão A). Furthermore, when a transaction occurs in Blockchain, information about the transaction is shared amongst the chained blocks. Every transaction in Blockchain is validated, thus whenever a transaction is sent, the sender's software will use its private key to cryptographically sign the transaction to prove ownership and authorize the moment of coins. However, when a node learns about a new transaction, it checks to assure the genuineness of the signature, thus a transaction is ignored if the signature is not valid (Liyanage, 2020). Valid transactions are precipitously broadcasted to the peer nodes in the Blockchain network unlike centralized "Hub and Spoke" (Liyanage, 2020). With the rate of increased challenges in the healthcare industry, Blockchain technology has the potential to innovatively minimize or eliminate challenges in the healthcare industry through the provision of a quick and secured way of data exchange amongst health personnel and patients and the lowering of healthcare access costs for patients. That has improved the overall security and immutability of sensitive records/data.

REVIEW OF APPLICATION AREAS AND BLOCKCHAIN FRAMEWORKS IN HEALTHCARE DOMAIN

In this section, a review of different application areas of Blockchain in healthcare are presented, existing Blockchain frameworks in healthcare, and the problems associated are also provided.

Application Areas of Blockchain in Healthcare

Major application areas of Blockchain technology in healthcare include Electronic medical record exchange, healthcare clinical trial, pharmaceutical supply chain, health insurance, secure remote patient monitoring, and healthcare data analytics (Syed et al., 2019). Blockchains offer the opportunity to deliver secure and highly efficient transactions between patient, provider, and payer. It also ensures a more efficient and seamless interaction between the parties involved (Maleh et al., 2020).

Review on Blockchain Application in Electronic Medical Record Exchange

In the work of Peterson et al., (2016), Blockchain was used to deliver secured information and seamless exchange of healthcare data across various stakeholders. It promotes the vertical exchange of healthcare data amongst different institutions, applied a secured technique (Secure Hash Algorithm 256) to hash healthcare data records, and another technique to expedite participation of healthcare networks. In a similar vein, Deloitte, (2018), proposed a novel distributed Blockchain framework that facilitated robust connection and secure exchange of healthcare information through different participants and at various healthcare domains, the proposed framework was designed essentially to provide security and enhance trust among healthcare stakeholders and organizations. Finally, it used both permissioned and permission-less blockchain methods to effectively secure the data. In a view to providing security and privacy for healthcare data as well as patients records

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on a secured network, a Blockchain model was proposed by Kuo & Ohno-Machado, (2018). The model was designed to preserve and secure the electronic sharing of data between concerned stakeholders and the exchange of healthcare information. Similarly, Ekblaw et al., (2016), used blockchain to secure and monitor electronic health records in a decentralized fashion. The proposed system effectively granted patients quick access to medical records while still preserving data integrity. The study underscores the basic characteristic of blockchains such as authentication, interoperability, transparency, and confidentiality and their usage for protecting medical records among patients and healthcare providers.

Review on Blockchain Application in Clinical Trial

In the work of Yue et al, (2016), Blockchain was used to provide access and monitoring of personal clinical data. In Omar et al, (2020), Blockchain was used to provide data traceability that resiliently enhances the safety of healthcare products at the production or experimental procedures. The work affirms that the use of Blockchain in clinical trials will improve the transparent process, accessibility of data, and trackability of clinical trial phases or steps taken during product production or research experiments. Sadiku et al., (2018), suggest that the application of Blockchain in this domain will make clinical trials more reliable at each stage thus keep track of each stage of the trial process. Sadiku et al., (2018) emphasized that the use of Blockchain in clinical trials promotes accountability and transparent procedure and reporting.

Review on Blockchain Application in Pharmaceutical Supply Chain

To enhance the pharmaceutical turnover control system Dorri et al., (2017), proposed the application of Blockchain technology that adopts key fundamental characteristics including client, ordering and endorsing which jointly initiate and process transactions with corresponding transactions status update. Similarly, in Bocek et al., (2017), Blockchain was used to establish access and monitoring of temperature level of pharmaceutical drugs when they are being conveyed from the production base to different healthcare outlets. This essentially provides the healthcare product producers to effectively monitor the temperature of their products on transit.

Review on Blockchain Application in Remote Patient Monitoring

This section presents blockchain applications related to remote patient monitoring in healthcare domains. In Griggs et al., (2018) Blockchain technology was adopted to provide robust security for remote patient monitoring. They proposed the use of specific features of Blockchain technology such as Ethereum and smart contracts, which are used to offer real-time remote monitoring of patients and trigger rapid notification to medical experts and other healthcare personnel. All domains were processed on the Blockchain. As a solution, this model protects remote monitoring devices from various manipulations and prevents security weaknesses. It assures data provenance by keeping track of all events and transactions. Furthermore, it provides maximum protection for patient records by hiding the identity of their record.

Review on Blockchain Application in Health Insurance Claim

In the work of Zhou et al., (2018), Blockchain was used to provide a secure and quality healthcare insurance storage device that has assisted both hospitals and healthcare insurers to effectively manage

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their huge data storage and security concerns. The Blockchain adopted several nodes such as hospitals, healthcare insurers, servers, and record nodes to effectively perform the above-stated functions efficiently. In a similar vein, Breteau (2019), equally described the benefits of blockchain in the healthcare insurance segment specifically concerning the protection of data storage and secure access to healthcare records.

Figure 1.0 represents several areas that blockchain technology can be applied in different fields of human learnings.

Blockchain Frameworks in Healthcare Domain

Blockchain presents an opportunity to improve the healthcare ecosystem, due to its influential characteristics such as transparency, interoperability, openness, immutability, decentralization, anonymity, and autonomy. These made it a credible technology to be adopted in the healthcare industry, particularly in data security, patients' information/privacy, and overall system interoperability. Consequently, these features have been applied and integrated into several parts of healthcare using various frameworks based on organizational peculiarity. Even being at the infancy stage in the healthcare industry, the frameworks have proven that Blockchain has considerable and sustainable potential that will improve and transform the healthcare industry in different aspects such as credible healthcare data exchange, improved and transparent supply chain, increased traceability, data privacy, decentralization of database, interoperability and cost reduction among others. There are several Blockchain frameworks proposed by researchers, some of which are presented as follows:

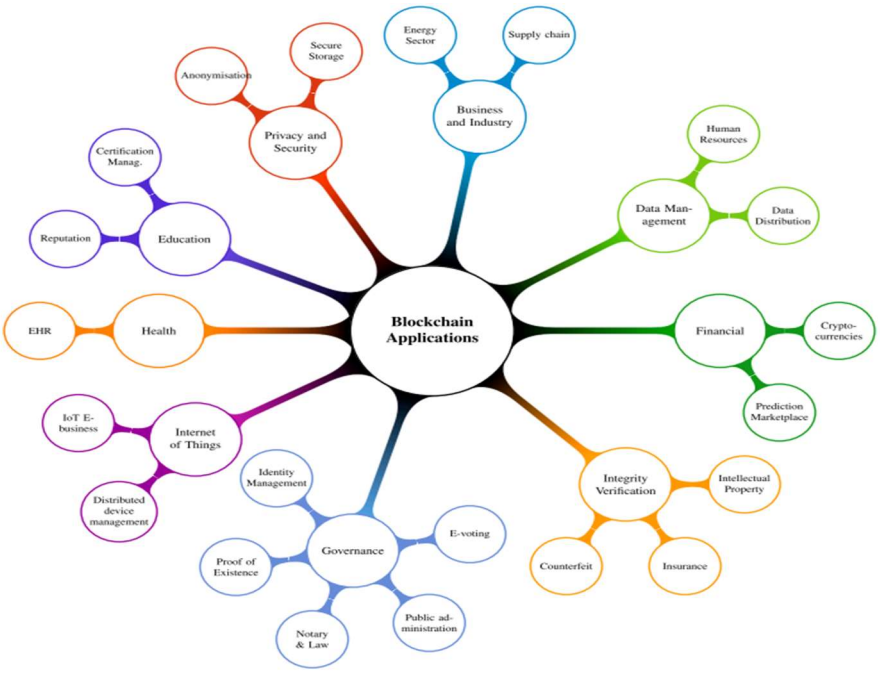

Figure 1.0: Mindmap abstraction of the different types of blockchain applications (Casino et al., 2019)

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Raikwar et al., (2018), designed and developed a Blockchain framework for healthcare insurance transaction processing using Hyperledger fabric. The proposed framework focused on enhancing secure transaction exchange between healthcare insurance companies. The study employed smart contracts to facilitate transaction execution and storing of corresponding results. The framework is comprised of components that allow the exchange of anything of monetary value and use smart contracts to enforce rules for the exchange. Besides, it analyzed and evaluate the latency of the system with different inputs and examines the relationship between transaction latency well as network dimension. The work also evaluated the scalability and robustness of the scheme, from which it showed improved performance as compared to existing technics. Quasim et al., (2020), proposed a secured Blockchain framework intending to provide optimum security for healthcare data. The framework considered some fundamental factors of the devices used in gathering patients' data, such as the computational power of wearable sensors and the requirement of internet of things technology as guides in the implementation of the proposed framework. Consequently, the framework enhanced the privacy and security of the collected healthcare data using low-power wide-area network (LPWAN) gateways. Similarly, to prevent data manipulations and minimize the cost of data management, Choudhury et al., (2019) proposed a Blockchain-enabled data quality approach that provides secure data exchange framework between multiple healthcare organizations. The framework was designed using private Blockchain (permissioned Blockchain) and other Blockchain features such as smart contract and ledger to promote data segregation and confidentiality. The developed framework improved efficiency in data management with a high level of data privacy and throughput. It was tested in medical data exchanges, principally in multi-organizational clinical trials with high scalability. Other frameworks that ensured data transparency and immutability are found in Dharani et al., (2020) and Quasim et al., (2020), The former also tried to promote healthcare interoperability.

To enhance data verification and validation, Hussen et al., (2018), presented a Blockchain-enabled conceptual framework for healthcare providers. The study delineated several steps to follow to fully develop the proposed conceptual system and its area of applicability in healthcare virtual domains. Security weaknesses, experienced by existing frameworks were tackled in Yeng et al., (2019). The work presented a conceptual healthcare security framework entitled HSPAMI framework that reduced data breaches, protect healthcare personnel and patient records and significantly enhance overall healthcare security practices and data privacy. Lee et al., (2019), presented a secure healthcare data sharing scheme entitled SHAREChain with standards (Fast Healthcare Interoperability and Cross-Enterprise Document Sharing) with a focus on reliability and interoperability of data.

The developed framework was to proffer solutions to problems inherent in the existing frameworks. The allowed for secured data exchangeability amongst concerned participants in the healthcare domain. In the work of Brannan, (2018), a Blockchain framework titled HealthCoin was developed for healthcare insurers and Government institutions. The aim was to prevent diabetes as well as facilitate public awareness to the larger members of the society while ensuring data integrity. In a similar vein, Blockchain-Health was developed by Singer, (2018) to establish a

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secure connection between concerned healthcare participants, to share healthcare research data securely devoid of any form of data manipulations.

Problem with existing Blockchain frameworks in healthcare

Several problems hinder the acceptance and integration of Blockchain frameworks into the healthcare domain, the most notable ones are High latency and interoperability, resulting from the addition of a high number of nodes in the framework, which require endorsement and validation (Raikwar et al., (2018); Choudhury et al., (2019b)). The lack of a standardization mechanism for data retention and cross-border data sharing is another pertinent challenge that has caught the attention of researchers (Quasim et al., (2020)). Furthermore, the challenge of high financial and processing cost of integration is another problem that discourages wide adoption (Hussen et al., (2018); Yeng et al., (2019)). A detailed summary of these problems and others is provided in Table 1.0.

Table 1.0: Summary of problems with existing Blockchain frameworks in healthcare

References	Application Areas	Methodology	Performance	Problem
Yue et al., (2016)	Monitor personal clinical data	Healthcare data Gateway	Provide secure access to healthcare records	Lack of secured access control and deficiency in system interoperability
Ivan, (2016)	Secure health data storage	Decentralized database system	Improves better access to clinical data	Depicts low data integrity and system scalability
Jiang et al., (2018)	Healthcare information exchange for electronic medical records and personal healthcare data.	BloCHIE	Evaluate Healthcare data sharing	Has limitation in data interoperability and integrity as well as access control
Shubbar, (2017)	Assisting dermatology patients	DermoNet	Tele-dermatology monitoring	Lacks Data integrity and low data provenance
StClaire, (2017)	Support transactions among participants, Protect patients' digital identity	Smart contracts, Master Patient Identifier	Facilitate peer-to-peer interoperability, Provide unique identifier for patients	Has limitation in quality attributes such as access control, security, and interoperability
Siyal et al., (2019)	Electronic health records	Distributed ledger	Data generation, Point of data retrieval	Scalability, limited data storage capacity
Xia et al., (2017)	Share medical data, Maintain electronic health records	MeDshare	Secured medical data exchange among untrusted parties.	Scalability, data storage, and interoperability.
Griggs et al., (2018)	Support real-time monitoring of the	Ethereum Based public blockchain	Improve security vulnerabilities and prevent	Lack of access control, data

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	patient, storage of transactions records	with smart contracts	manipulation of data remotely	integrity, and security
GEMOS, (2018)	Secured access and sharing of healthcare data	GEMOS (Blockchain-based OS)	Improve healthcare and supply chain and secure data driving the economy	Lacks data integrity, security, and interoperability
Dorri et al., (2017)	Pharmaceutical turnover control	Blockchain-based Hyperledger fabric	Improves transaction between stakeholders and depicts corresponding transactions status update.	Lacks credible system interoperability and data integrity
Brannan, (2018)	Creation of diabetes preventions and awareness	Health Coin	Improved publicity of diabetes awareness	Do not have firm access control and data security mechanism
Singer, (2018)	Make secure connections between stakeholders in the healthcare domain.	Blockchain Health	Facilitate healthcare research data sharing with maximum security	Has deficiencies in interoperability and access control
Casino et al., (2019)	Healthcare supply chain, data remote monitoring.	Distributed peer to peer network	Streamline classification of blockchain-enabled applications and data management in different sectors	Lack of commeasurable security, interoperability, scalability, and latency
Ensor et al., (2019)	Healthcare financial transactions.	Secure Consensus protocols	Improve and support machine-to-machine payment processes	Insufficient hardware requirements and System interoperability
Quasim et al., (2020)	Electronic health records	LPWAN gateways, local acquisition node	Facilitate data exchange and improve data security and privacy	Standardization, Cross-border exchange of healthcare information and data retention.
Dharani et al, (2020)	Diabetes prediction	Ethereum and precision algorithms	Support data interoperability and improves transparency and immutability of healthcare records	Works best in a public blockchain, not application in private blockchain
Raikwar et al, (2018)	Healthcare insurance transaction processes	Hyperledger Fabric	Assures transparent insurant transactions between	Lack secure database, access control; database not encrypted.

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			concerned stakeholders	
Choudhury et al., (2019b)	Medical research and clinical data transactions	Hyperledger Fabric v1.4, smart contracts	Maintains high throughput of clinical transactions, demonstrates high data quality, scalability.	Has limitations in data access control and latency
Hussen, (2018.)	Electronic healthcare data verification and validation	Blockchain-based VBE and VO healthcare	Enhances user identity as well as information verification and validation challenges	Lacks essential data security metrics.
Yeng et al., (2019)	Healthcare security practices and patients records.	HSPAMI	Improve data and healthcare information security.	Access control requires huge resources for implementation and adoption.
Lee et al., (2019)	Healthcare data sharing	SHAREChain	Support and enhance data traceability, reliability, and interoperability.	Has deficiency in data throughput, latency, and access control.

OPEN RESEARCH PERSPECTIVES

To expand the possibility of Blockchain adoption and integration into the existing healthcare framework, the challenges mentioned in the last section of this paper must be practically addressed. Potential researchers interested in Blockchain development should make effort in providing practicable and verifiable solutions to the identified problems, specifically in the areas of data privacy and security, seamless secured data exchange, system interoperability, data access, and control. Furthermore, systematic solutions should be provided to improve latency in the frameworks, this will significantly improve system performance, rapid development, and credible transactions among other things. More so, scalability is a pertinent aspect that requires concerted attention. Investigation into novel methods that could aid scaling existing Blockchain-based systems without committing huge resources is required. Data is frequently exchanged in the healthcare industry by various stakeholders and thus expensive to maintain due to their sensitive nature and volume, as such, innovative methods should be fashioned out to reconfigure data storage capacity being witnessed in the existing blockchain-based healthcare systems to streamline the exchange of data efficiently.

CONCLUSION

Blockchain offers considerable potential to improve healthcare ecosystems. It supports the secured exchange of health information and prevents data manipulation among concerned stakeholders. It allows autonomy, reinforces data security and personal privacy while prohibiting data repudiation. As a consequence, verified data or transactions are saved on the block and thus blocks are cryptographically connected, which makes it computationally impossible to manipulate. Accordingly, the

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digitalization of healthcare records offers opportunities for further medical trends and evaluates the quality of care administered. This paper has reviewed several use cases of Blockchain in healthcare, existing frameworks in healthcare, their performance, and the inherent problems therein. Evidently, despite technical challenges such as data security, data privacy, latency, storage capacity, and interoperability, Blockchain has been adopted in the healthcare domain. This study has opened some research perspectives to make Blockchain integration into healthcare more productive with less requirement.

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