International Journal of Advanced Engineering Research and Science (IJAERS)
Peer-Reviewed Journal
ISSN: 2349-6495(P) | 2456-1908(O)
Vol-8, Issue-5; May, 2021
Journal Home Page Available: https://ijaers.com/
Article DOI: https://dx.doi.org/10.22161/ijaers.85.46

Blockchain: The Key Success of Healthcare Development

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Received: 14 Mar 2021;
Received in revised form:
29 Apr 2021;
Accepted: 14 May 2021;
Available online: 30 May 2021

Keywords— ***Blockchain, Healthcare management, Medical records, Decentralisation.***

Abstract— *Blockchain is a technology for storing and managing sensitive data such as financial information, health records, and transactions. It is a decentralised, distributed public ledger that is maintained by the network of a verified group of individuals or nodes. All nodes need to reach an agreement on whether the data should be kept in the block to guarantee that the data are safe and no corrupt branches. Healthcare is one of the potential fields where blockchain technology can be implemented, especially with the respect to health management. This brings an advantage to healthcare firms because currently patients' data are stored by third parties. This technology allows more security in the data management process and prevents the misuse of data. One of the greatest benefits of using blockchain in healthcare management is that records are stored in a distributed database due to the feature of decentralisation. Data in this system is always kept up to date and records are kept by timestamp. Interestingly, blockchain can be integrated with other advanced technologies such as artificial intelligence (AI) to generate predictive analytics models for patients' treatment and diagnosis*

I. INTRODUCTION

Healthcare has been experiencing privacy and security breaches of healthcare's data every year from centralised networks. Also, communication within healthcare has caused many issues in time management, the effectiveness of healthcare and slow development of future goals, etc. Therefore, the increase in technology implemented in healthcare has led to the acknowledgment of concerns about ownership, interoperability, secured storage, and communication (Talesh, 2017; McCoy & Perlis, 2018; Meinert et al., 2019).

Blockchain technology is one of the advanced technologies that brings a solution to healthcare. Blockchain emerged from digital currencies called cryptocurrencies (Swan, 2015; Agbo et al., 2019) which can be viewed as a technology for storing and managing decentralised data maintained by the network of a verified group of individuals or nodes (Jaoude&Saade, 2019).

II. BLOCKCHAIN TECHNOLOGY

Blockchain is a technology for storing and managing sensitive data such as financial information, health records, and transactions. It is a decentralised, distributed public account that is organised by the network of a verified group of individuals or nodes (Jaoude & Saade, 2019). All nodes need to reach an agreement on whether the data should be kept in the block to guarantee that the data are safe and no corrupt branches (Vukolić, 2015; Christidis and Devetsikiotis, 2016), this is called consensus. There are different Consensus Mechanisms (Mingxiao et al., 2017) such as Proof-of-Work (PoW) which is the most popular. PoW requires computational power from the miners to solve the cryptographic algorithm similar to finding hashes with specific patterns (Antonopoulos, 2014). On the contrary, there is another mechanism called Proof-of-Stake (PoS). PoS separates stake blocks equally to each miner depending on their wealth (Pilkington, 2016). This is the improved version of PoW that the data will be more secure as if a fraud transaction is validated the miner will lose the money that they staked in the blockchain. Moreover, there is an alternative Consensus Mechanism for PoW and PoS called Proof-of-Space. This algorithm uses the free space in the disk and reduces the use of computational power. The blockchain stores the data in a block that is immutable (Hölbl et al., 2018), the data are protected and bound to each other in cryptographic principle (Mendling et al., 2018).

The blockchain network is grouped into several categories (Buterin, 2015; Zheng et al., 2016; Eris Industries, 2016; Christidis and Devetsikiotis, 2016; Kravchenko, 2016; Wood, 2016) according to the network's management and permissions as public, private or federated. It is permissionless in the public blockchain which everyone can be a user or a node miner and can do any operation. The public and federated blockchain are permissions that allow only a list of users that are granted access to the network operation.

Blockchain technology was originally used in digital currencies also known as cryptocurrencies then in the application of smart contracts of the financial domain (Swan, 2015; Agbo et al., 2019). Subsequently, the blockchain evolved and focused on the government, healthcare (Swan, 2015; Miau& Yang, 2018), and culture (Efanov&Roschin, 2018) which are the non-financial areas. Furthermore, this technology is also used in the incorporation of artificial intelligence (Angelis & da Silva, 2019).

III. KEY CHARACTERISTICS OF BLOCKCHAIN

First, there are various types of blockchain that are classified by their accessibility and management system. There are three main types of blockchain which comprise public blockchain, consortium blockchain, and private blockchain (Peters and Panayi, 2016). In the public blockchain, every individual has permission to be involved in the validation process. This means that the public has the permission to access the information of the block and it is also fully immutable as information cannot be altered (Zheng et al. 2017). For the consortium blockchain, this type of blockchain refers to partial permission as only a selected group of people will be able to get involved in the consensus process as the permission to access is restricted. Unlike the public blockchain, this enables information inside the block to be manipulated (Lin and Liao, 2017). Likewise, the validation process in the private blockchain belongs to an organisation or an individual. The permission to access is restricted to some individuals only and information inside the block can be altered (Gervais et al., 2016). These properties are essential depending on the implication for certain scenarios (Lin and Liao, 2017).

Secondly, there are various characteristics of blockchain. One of the key features of blockchain is decentralisation. In other words, all data are controlled by a distributed network rather than individuals like the centralised system (Zheng et al., 2017). For instance, in the conventional system, every transaction made by each individual must pass through a banking agency which is considered as a third party. However, if blockchain is introduced into this scenario, third parties will be eliminated from this process as blockchain are decentralised. To put it simply, decentralised systems provide access to resources in a more equitable service (Hölbl et al., 2018). To a certain extent, every user has their own private key in order to make each transaction, so the information inside the network is kept confidential (Johnson, 2001). Furthermore, blockchain can also be centralised. This applies with the private blockchain where consensus belongs to one organisation or an individual; as a result, permission is needed for this type of blockchain (Zheng et al., 2017). Currently, there is a large amount of research focusing on the development of blockchain with respect to its decentralised characteristics (Conoscenti et al., 2016; Christidis and Devetsikiotis, 2016), particularly in the field of managing big data and data-intensive applications (Yang et al., 2019).

Moreover, another important characteristic of blockchain is immutability. This is also known as transparency or persistency. Before information can be stored inside the block, it must undergo a validation process once information is stored (Zheng et al., 2017). The information cannot be changed or altered (Yli-Huumo et al., 2016; Swan, 2015a). For example, transactions can be validated and stored in a block. Due to the unchangeable feature of blockchain, it is impossible to delete or change the transaction details inside the block. As a result, errors or corrupted transactions can be detected easily (Zheng et al., 2017). This leads to the validation mechanism which is known as the consensus mechanism. These algorithms help to preserve and maintain information using cryptographic signatures (Mendling et al., 2018). This mechanism also enables data records to be safely exchanged or updated by the individual in charge of this process (Alla et al., 2018). Currently, there are many new methods being developed and applied to blockchain in order to make the validation process as efficient as possible (Nguyen and Kim, 2018). Furthermore, cryptographic hashing also ensures that information cannot be altered as every block is connected in chronological order. If one block is changed or altered, every subsequent hash value of the chain will also be affected. Hence, the whole complete chain will be disabled (Nakamoto, 2008; Gervais et al., 2016).

Lastly, every process that occurs in the blockchain gets chronologically timestamped, including generating new blocks and storing data (Nakamoto, 2008; Matilla, 2016). This feature leads to the traceability of the data inside the block that are permanently recorded. In the case of a transaction, full details and history of the transaction can be provided to the decentralised network (Zheng et al., 2018). These features can also be combined with cryptographic hashing in a process called "Proof of Existence." The information inside the block can be proved by using this method as it provides the information at a specific time (Gipp et al, 2015).

IV. APPLICATION OF BLOCKCHAIN IN HEALTHCARE

Healthcare is one of the potential fields where blockchain technology can be implemented (Cios et al.,2019; Kuo et al., 2017), especially with the respect to health management (Mettler, 2016). Although there are issues with data ownership and exchange processes in past research (Ji et al., 2018). However, this problem can be overcome by the development of this technology which enables patients to own their data and to be able to address who they desire to share the data with (Dimitrov, 2019). This brings an advantage to healthcare firms because currently patients' data are stored by third parties (Hölbl et al., 2018). This technology allows more security in the data management process and prevents the misuse of data (Ito et al., 2018; Alla et al., 2018).

One of the implications of blockchain technology in the healthcare industry is the subject of healthcare management, especially in Electronic Health Records (EHRs), which has the highest capacity for improvement (Angraal, 2017; Hoy, 2017). Overall, the percentage usage of EHRs is approximately 97% worldwide. The information inside EHRs includes medical records, treatments, and clinical progress of patients. Blockchain technology improves EHRs by maintaining both security and privacy in patients' health data (Azaria et al., 2016; Sullivan, 2017; Medicalchain, 2017). One of the greatest benefits of using blockchain in EHRs is that records are stored in a distributed database due to the feature of decentralisation. Data in this system is always kept up to date and records are kept timestamped (BurstIQ, 2017). However, one of the issues that need to be taken into consideration before implementing this technology is the interoperability barrier. This technology does not allow data to be shared with other systems. In addition, other problems associated with this technology are financial issues, user-related issues, and design flaws (Menachemi et al., 2011).

Furthermore, developing an intelligent healthcare system via blockchain is another aspect to which researchers are currently paying attention. Blockchain is an interesting prospect technology that helps the improvement of e-health (Casado-Vara and Corchado, 2019). Not only does blockchain improve e-health systems, but it also improves telemedical information. This is tremendously beneficial for the provision of healthcare in the future to reach out in a remote area (Hyla and Pejas, 2019; Ji et al., 2018). For instance, the records made by doctors during telemedical appointments could be recorded in the blockchain network to prevent the loss of information and mishandling of data. However, there are problems with this application of blockchain as the validation process might take a long time in order for data to be stored, and lack of research in these areas of application (Hyla and Pejas, 2019).

Interestingly, blockchain can be integrated with other advanced technologies such as artificial intelligence (AI) to generate predictive analytics models for patients' treatment and diagnosis (Mamoshina et al., 2018; Li et al., 2019). For example, blockchain could be used to gather valid and secure data from clinical laboratories, hospitals, and other sources. The AI system then analyses the data front the blockchain and generates a predictive model which promotes the development of new drugs and treatment (Mamoshina et al., 2018). In addition, future research could focus more on this integration topic as there are a number of areas in healthcare where this technology could be applied such as drug prescription management (Hölbl et al., 2018) and digital rights management (Jaoude and Saade, 2019).

V. APPLICATION OF BLOCKCHAIN IN OTHER FIELDS

Due to the immutability of the blockchain, the technology of blockchain is expected to increase in transparency and become more which allowing a more elastic value chain in the supply chain network (Ahram et al., 2017; Kshetri, 2017; Kshetri, 2018; O'Leary, 2017). The blockchain has been accepted in supply chain management (SCM) and logistics (Kshetri, 2018). In addition, the blockchain can be used in the logistics by detecting the knock-off product, tracking the product (Hackius and Petersen, 2017; Kennedy et al., 2017; Lee and Pilkington, 2017; Toyoda et al., 2017; Tan et al., 2018), reduce paper load as well as enabling a direct transaction between the buyer and seller (Subramanian, 2017).

Consequently, it has been shown that the supply chain that using the application of blockchain have improved security

(Dorri et al., 2017a), lead to more comprehensive contract management for combating asymmetry (Polim et al., 2017), enhances tracking mechanisms, and traceability assurance (Apte and Petrovsky, 2016; Tian et al., 2016; Düdder and Ross, 2017; Heber and Groll, 2017; Lu and Xu, 2017; Tian, 2017), giving more reliable information for better information management (Infosys Limited, 2017; O'Leary et al., 2017; Turk and Klinc, 2017), food safety (Ahmed and Broek, 2017) and giving better customer services (Frey et al., 2016a; Frey et al., 2016b). Lastly, it has the potential to enhance smart transportation networks (Yuan and Wang, 2016; Lei et al., 2017; Leiding et al., 2016) and include modern decentralised manufacturing architectures (SyncFab, 2018).In addition, Tradelens is an example of a blockchain-based logistic company (Tradelens, 2018). Tradelens uses blockchain which enables unprecedented transparency, collaboration, and efficiency in global supply chains by providing innovative apps to every stakeholder in the supply chain for controlling and managing data.

Through strengthening, optimizing, and automating enterprise processes, blockchain has the ability to become a major source of innovative developments in business and management (Tapscott and Tapscott, 2017; Bogner et al., 2016; Ying et al., 2018). As the popularity of the blockchain increases in various industries, the European Commission released a report in April 2016 that blockchain will take over the current business model. Based on the Blockchain technology, it was estimated that smart contracts could reduce infrastructure costs by 4.6 billion euros per year by 2022 (Probst et al., 2016).

Moreover, blockchain has the significant potential for product improvement and commercialisation (White, 2017; Klems et al., 2017; Kogure et al., 2017), also improving the trustworthiness in e- commerce. Last but not least, the use of blockchain in the business and industry has improved the progress of the work by better organisation, saving more time and lower cost of the process (Weber et al., 2016; López-Pintado et al., 2017; Prybila, 2017; Rimba et al., 2017; Mendling et al., 2018). For instance, Propertyclub is a real estate company in New York which uses blockchain to improve the way people market and buy and sell properties as well as using a smart contract to conduct transactions digitally using cryptocurrencies (Propertyclub, 2018)

VI. DISCUSSION

As reviewed in this study, there are many benefits of using blockchain technology in healthcare, especially from the perspective of health management where there are lots of potential for growth in development (Mettler, 2016). Blockchain enhances a secure and transparent environment for the network of patients' data for all hospitals when information is stored in the system. In the traditional method, there are challenges in this data management process as the data might be inaccurate because health records could be altered. This might lead to a reduction in the quality of service and care provided. As a result, our innovation ensures that patients' data and records are safely secured via Hash codes (see Methodology). All records are stored in a form of a block that is irreversible which prevents the risk of fraudulent purpose to patients medical records. This is an essential benefit as patients' data are currently stored by third parties (Hölbl et al., 2018).

Furthermore, blockchain also enables patients to own their data and to be able to choose recipients with whom they desire to share the data (Dimitrov, 2019). It provides the ability to use the public address and private key to overcome the problem of privacy and confidentiality in patients' records as well as the issue of data ownership and exchange processes in past research (Ji et al., 2018). Not everyone in the decentralised network can access each individual's block, but only people with permission can access the system. This system architecture also prevents the misuse of patients' data.

Moreover, blockchain can aid the interoperability problem due to the characteristics of decentralised networks. One of the major problems in healthcare is the exchange of health data and records across healthcare organisations (Iroju et al., 2013). When patients want to change their health insurance plan or their hospital, new health records must be set up. Oftentimes, these records might be inaccurate and unreliable because this process relies solely on the patients themselves (Baron et al., 2005). This might lead to a reduction in the quality of care given by healthcare providers. Our decentralised blockchain network enables data to be efficiently and securely exchanged. This will solve the problem proposed in the past research regarding the lack of understanding in the interoperability framework (Dagher et al., 2018). In addition, our system contains timestamps; as a result, all of the patients' medical records and their appointment history at any particular time can be accessed electronically and viewed quickly and immediately. Overall, this will strengthen the validity of electronic health records (EHRs) among various medical institutions.

Despite all the advanced features of the blockchain, there are still various hindrances and challenges in the usage of blockchain. Many countries are considering the adoption of blockchain in government settings (Ølnes et al., 2017; Hou, 2017). However blockchain is a new, advanced, complex, and still an immature technology, there are no existing standards or regulations to operate it which can slow down the development of the blockchain-based application (Ølnes et al., 2017). No standardisation of blockchain in the application of healthcare means that the applications that are developed by different vendors on different platforms may make it difficult to cooperate and exchange information.

Furthermore, decentralised storage is one of the core characteristics of blockchain which allows the users to share the data among different services, but this can lead to data leakage. When the user wants to retrieve data from the blockchain, they need to verify their identity by entering the private key or password to decipher the hashed or the cryptograph text into normal text. The cryptographic data are shared by all the individuals who participate and are stored publicly (Zhao et al., 2017). If all the participants team up and use their computational power they can solve the hash and cause data leakage.

Additionally, one of the key problems related to the blockchain is scalability. Due to the advancement of the data analytic tools in medical care and medical imaging, real-time availability of the data, insurance companies, and more, the data are increasing in volume. This rapidly increasing data volume leads to the risk of bulking the overall system, and immense stress on the limited hardware storage, and hence the response time from the system will increase (Gervais et al., 2018).

Moreover, the assumptions made are one of the main constraints in this study. The use of blockchain in healthcare assumes that the patients will always use the smartphone effectively to collect and store their medical data. This is because the devices are not able to verify that the data was submitted by the actual patient or in other words, confirm that the data was submitted by the actual patient (Roehrs et al.,2017).

More importantly, there is another limitation that goes beyond the technical boundaries such as energy consumption, blockchain developers, and cost. Firstly, the validation procedure of blockchain, blockchain is a complex algorithm, which means that several computers are required and need to operate simultaneously. This leads to an increase in the consumption of energy. As a result, this may contribute to the scarcity of the energy supply and cause global environmental issues. Next, initially, the number of people trained in blockchain technology is low but the demand for blockchain is increasing. This is due to the lack of understanding and the availability of resources and technology. Finally, the cost is the primary constraint of the blockchain. There are many costs that hinder development such as protocol cost and the execution cost based on variable inputs of string length and size (Al Omar et al., 2019).

VII. CONCLUSION

The study above aims to advance existing trends of blockchain into healthcare. To provide an alternative route for all hospitals, all healthcare departments, all healthcare professions, and all patients to combine as one family network. The findings are merged to synthesise a transparent network that provides reliable security and privacy of data, efficient eco-storage, and approachability by components in blocks such as consensus algorithm of hash values (‘Proof-of-space’) and decentralisation.

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