Iraqi Journal for Computer Science and Mathematics

Journal Homepage: http://journal.esj.edu.iq/index.php/IJCM
ISSN: 2788-7421

Survey: (Blockchain-Based Solution for COVID-19 and Smart Contract Healthcare Certification)

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DOI: https://doi.org/10.52866/ijcsm.2021.02.01.001
Received December 2020; Accepted Januray 2021; Available online January 2021

ABSTRACT: The year 2020 has shown the quick spread and devastating effect of Coronavirus (COVID-19) on the world economy, health, and human life. Combating the COVID-19 pandemic is crucial. Blockchain technology can assist in the fight against the COVID-19 pandemic by assuring safe and reliable medical supplies, accurate identification of virus hot spots, and establishing data provenance to verify genuine personal protective equipment that is decentralized, reliable, traceable, and transparent. A major proportion of current healthcare systems are centralized and are short on privacy and information necessary for the detection of fraud connected to the certification by the COVID-19 vaccine. The quick vaccination rollout and the deployment of a global vaccination campaign are crucial and dependent on the availability of transparent and operational distribution chains, which may be audited by all the necessary parties. Blockchain technology might also be used to assure transparent monitoring, storage, and distribution of COVID19 vaccinations. Smart contracts are built for monitoring and tracking the proper circumstances of vaccine distribution in comparison to safe handling of vaccine producers, informing all network peers. This study aims to investigate the effectiveness of block chain and smart contracts in the health care system. The article presents a model of the decentralized infrastructure of the health care system. The blockchain and intelligent contract technology provided has shown promising results. The proposed solution is economically feasible and ensures data integrity, security, transparency, and traceability. Future work aims to expand the functionalities of smart contracts and the blockchain technology.

Keywords: Blockchain; COVID-19; Healthcare

1. INTRODUCTION

Blockchain technology recently emerged as an important technology in the digital transformation sector of healthcare, and various research studies discovered that the healthcare ecosystem has blockchain potential. The manner in which medical companies and systems were mainstreamed in the health sector has been shifting throughout the last few decades. ICTs are critical to the decentralization and digitalization of health institutions as well as the provision of modern and digital healthcare environments for patients and providers [1–4].

The systems of blockchain data management provide services to physicians, healthcare institutions, and patients in the areas of accessing and monitoring of patient records, medical IoT security management, claims and payment processing, transparency and clinical data verification, and financial audit exchanges. These apps use real-time changes

to an encrypted, anonymous blockchain database to comprehend, track, and manage medical data effectively. Moreover, such apps allow health care companies to prohibit unauthorized access to private information by individuals. Healthcare management during the COVID-19 crisis generally encompasses numerous procedures, such as financial management, employees, patients, logistics, inventory, and legal issues [5, 6].

Medical workflows comprise conventional treatment activities, which may be considered to be a progression of conditions. These activities are intended to increase internal controls, enhance quality, compliance, and profitability, and lower risk, working cycles, and overhead in the hospitals and other health care providers. Avoiding COVID-19 transmission also includes protecting personal data, processing private information, removing third parties, and identity management. Such actions increase trust compared to centralized networks because people do not evaluate the credibility of the middleman or other network players. Gaining the trust of participants in the program is sufficient. The lack of intermediaries also simplifies data protection. Three parties may be rendered redundant by employing blockchain, thus increasing the safety of users and helping preserve the identity of an individual.

The use of blockchain for smart contracts involves utilizing COVID-19 treatment. Prompt and successful implementation of the proposed technique might minimize COVID-19 transmissions and related mortalities, particularly in the areas that have limited access to testing facilities [7].

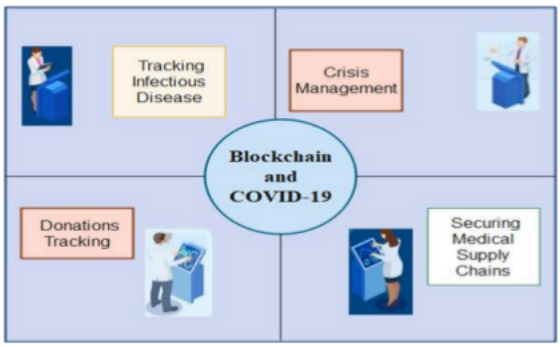

FIGURE 1. BlockchainApplications in Fighting COVID-19.

A growing interest in blockchain and smart contracts has been observed in recent years, with billions of dollars poured by the largest corporations and organizations of the world to investigate and incorporate this technology into their projects. Blockchain applications include governance, power, smart cities, transportation, and medical services [8].

In addition, blockchain, which was introduced in 2009, is a platform for technology and architecture. Blockchain operates by storing information in the recording of the ledgers, which are de-centrally distributed among all computer devices that comprise the blockchain infrastructure. The peer-to-peer architecture works by having network users (who take part in the transactions) and blockchain miners (facilitating transactions in the distributed ledger). The directory is maintained in a de-centralized network of nodes, which are computed using encryption methods by all miners in the network. Furthermore, the blockchain ledger provides high storage stability because it is created via consensus techniques, digital signatures, and hash chains (Figure 2)[9, 10].

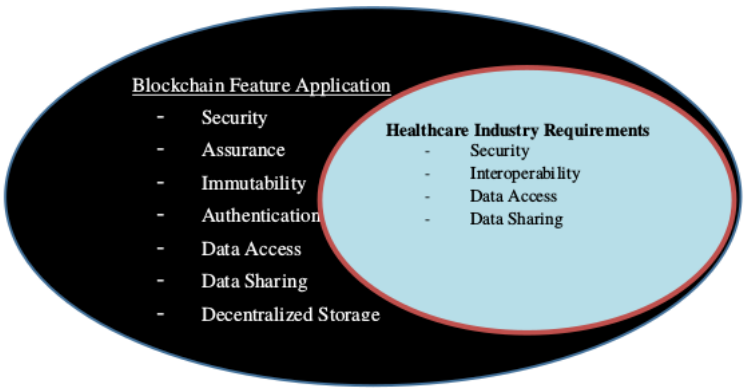

FIGURE 2. How Blockchain Meets Healthcare Requirements.

Blockchain delivers a variety of services, such as integrity, traceability, non-repudiation, and security, while maintaining all the information in a public de-centralized way that preserves privacy because of the aforementioned sophisticated capabilities. The use of blockchain and intelligent contracts enhances the operating efficiency of the system.

This article addresses the advantages and disadvantages of blockchain technology and intelligent contracts and their applications in healthcare. In addition to the distinctive characteristics of smart contracts and blockchain technology, the primary features of blockchain technology lie in the following: its decentralized network, transparency, trusted chain, and unalterable and indestructible potential.

2. PREVIOUS RELATED WORKS

This part discusses a range of recent scholarly research on smart contract protection and blockchain core privacy management.

Hoai Luan Pham et al. (2018) proposed a medical scenario to employ smart contracts based on blockchain for managing information and medical equipment for patients. The medical equipment mechanism is also offered to improve its efficiency in a risky circumstance for the patient, and blockchain is used on the basis of the Ethereum protocol. They also presented a processing framework for the efficient and sparing storage of medical device information consistent with the health state of the patient. Future remote health systems will then be decentralized [11].

Tanesh Kumar et al. (2018) studied a blockchain technology with possible usage of present health systems and emphasized key criteria to address the demand for these systems as transparent and trustless healthcare systems. They also presented the problems and hurdles that must be tackled before successfully adopting blockchain technology in health systems and employing the intelligent healthcare system contract, which is crucial to creating the pre-defined agreements among various players involved. The blockchain technology can play a major role in delivering decentralized solutions and ensuring medical information safety and integrity. Thus, the overview of blockchain technology in the healthcare industry is the main objective. The notion of smart contracts in the healthcare systems based on blockchain is also emphasized [12].

Mehdi Sookhak et al. (2020) adopted an EHR in the healthcare providers, which put the privacy of the patients and the security of their information at data breach risk. The introduction of smart contracts and blockchain technology has paved the way toward the development of efficient EHR access control approaches for supporting secure identification, authorization, and authentication of clients and studying state-of-the-art blockchain-based approaches of the access control in the healthcare industry. A thematic classification of blockchain-based access control approaches has been suggested to obtain the following objectives: recognize the security problems that are related to available approaches, highlight the main requirements of security for designing a granular access control approach, and examine the differences and similarities of the conventional approaches of access control and some of the important and outstanding challenges as future directions [13].

Thomas McGhin et al. (2019) studied the industry and academia by exploring the applications that have been geared toward healthcare use. Even with these enhancements, the blockchain technology still has its specific problems and vulnerabilities, such as mining attacks, key management, and mining incentives, that must be addressed. Notably, the blockchain technology can be potentially utilized to address several existing problems in the healthcare sector. The available applications are focused on problems that are related to integrity, authentication, interoperability, record sharing, edge host security, patient empowerment, and IoT security. These applications aim to give ownership and control to patients over the sharing of their medical data, only allowing selected individuals to see the data in a secure environment. However, blockchain still has several potential issues despite the aforementioned enhancements. Healthcare and any other industries that want to utilize blockchain-enabled devices require continued studies on those areas to help improve and create a strong ecosystem that may be utilized to establish an enhanced patient-centered data empowerment age [14].

Cornelius C. Agbo et al. (2019) used blockchain technology in healthcare and conducted a holistic evaluation that employed the systematic mapping approach to map all relevant research. Their study specifically aimed to find cases of blockchain technology use in healthcare. They reported that blockchain has a wide range of healthcare applications, including the management of electronic medical records and the medication and pharmaceutical supply chain, biomedical research and teaching, remote patient monitoring, and health data analysis. A total of 65 publications were evaluated using the search and article selection method to address the study subjects. Nonetheless, further research is necessary to comprehend, describe, and assess the applicability of blockchain technology in medical care [15].

Asad Ali Siyal et al. (2019) demonstrated considerable interest to the use of blockchain technology for the secure and safe management of health data. Blockchain also transforms the practice of health care into a reliable diagnostic and treatment approach through safe and secure data sharing. Notably, blockchain may be a technology that helps customize genuine and secure healthcare in the future by combining all real-time clinical data on a patient's health in a secure health environment. Present and prospective healthcare improvements can be tracked by using blockchain as a model. They also addressed blockchain uses, difficulties, and future scenarios [16].

Asma Khatoon et al. (2020) used blockchain technology smart contract-based in the program of the healthcare management and demonstrated the application of de-centralization concepts on large-scale data processing in the medical environment, streamlining the complicated medical processes, and medical record handling, which offers auditability, transparency, and interoperability via the smart contracts. They also presented a system of data sharing and management that focused on the requirements. Ensuring the utilization of the blockchain technology, protection, privacy, availability, and fine-grained control of patient data access is possible. Utilizing the blockchain aims to strengthen the healthcare processes and the patient outcomes to combat (COVID-19) infection. Blockchains may be helpful in several ways: minimizing the transaction costs by using smart contracts, which can be described as embedded protocols for the general purposes of simplifying the process, eliminating the administrative burdens, and removing the intermediaries [17].

Marbouh, Dounia et al. (2020) indicated that a blockchain-based system of tracking is significant for ensuring the reliability of the obtained information by government agencies and the public. The spread of misinformation throughout the outbreaks and the lack in capability of the existing platforms for the validation of data authenticity resulted in irrational behaviors and public panic. Thus, the authors have used, implemented, and evaluated a blockchain-based system utilizing the oracles and Ethereum smart contracts for the tracking of reported data associated with the number of new cases, recovered cases, and deaths obtained from reliable sources. In addition to using algorithms to capture the interaction between the stakeholders in a network, the suggested solution has also been proven to be economically feasible and ensured data integrity, transparency, security, and traceability among the stakeholders [18].

Maha Filali et al. (2021) developed a blockchain-based system to manage vaccination registration, storage, and delivery. They also offered a solution to service the blockchain-based immunization campaign of Covid-19 with a web of things. This system covered the entire process of the following: vaccination, vaccine monitoring, and citizen registration; immunization organization and traffic surveillance; reporting the adverse events, side effects, and post-vaccination. Notably, the suggested BIoT architecture offered an immutable, secure, and transparent platform, allowing the verification of vaccine slot states, which are represented by parameters obtained by the device layer, and determining whether guidelines and conditions that have been defined by the manufacturers of the vaccines are followed. The proposed platform may also be utilized for any vaccination process [19].

3. BLOCKCHAIN TECHNOLOGY AND SMART CONTRACT

Blockchain may be defined as a tamper-resistant distributed ledger, wherein no central authorities have control over the information. Blockchain works in peer-to-peer concept, in which all the nodes interact with one another. The blockchain at the basic level can enable the nodes that belong to one network from recording the transactions in a shared network ledger. The invention of the Bitcoin in 2008 has exposed the world to a new idea, which has comprehensively revolutionized the society. It has been something which had a potential for influencing any industry. This new concept is blockchain, which has been first introduced in the cryptocurrency context. The potential of the technology and its possible use in other fields were recognized later in 2013 by academics and developers. Being independent of a distributed peer network, together with encryption methods, enables Blockchain is safe and robust in attempting to modify data in the digital directory [20].

Rapid developments in the emerging field of blockchain technology resulted in the introduction of “smart contracts,” which are computerized protocols of transaction that autonomously execute the contract terms. The smart contracts are disintermediated and are generally transparent, thus potentially increasing commercial efficiency and lowering legal transaction costs and anonymous transactions. The business world has been actively investigating blockchain technology utilizations for a variety of commercial applications [21].

The blockchain platforms support the executions of code pieces. The smart contracts can perform the computations inside a blockchain. For instance, a smart contract could be utilized for automatically releasing a certain amount of cryptocurrency upon satisfying a condition that has been agreed upon by two parties. Such a condition has made this technology interesting to application scenarios, asking for verifiable, transactional, and reliable code execution [22, 23].

3.1 Blockchain Technology Applications

Smart contract, which is a part of an entire project, is conducted in the decentralized network using the agreement mechanism for the operation of an event series; thus, this contract is used to remove the involvement between third parties and even automate the system [24]. Four applications are defined by smart contract for the blockchain network in the following points.

1-Supply Chain: Blockchain technology has produced encouraging outcomes in the latest applications to enhance the supply chain in the networks. If the smart contracts are utilized in the framework of the blockchain, then the network can be highly secure and autonomous. The works of blockchain assist the supply chain in taking responsibility through the intelligent contracts, thereby easily producing a trustworthy re-establishing trade and circulating products [25].

2-Internet of Things (IoT): IoT can become self-reliant when the smart contract is combined into the blockchain network [26].

3-Healthcare System: Blockchain technology aims to ensure patient safety and data protection in the public ledger environment. Thus, the smart contract should be used to increase the trust and efficiency of the program. The users will compose other terms and conditions that will be enforced as obtained data. Instead, these smart contracts are implemented, thus leading to incidents [27].

4-Insurance: Premium collection for conventional insurance schemes requires a considerable amount of time. Substantial confusion between various teams is also observed during its production. The smart contract program will streamline the mechanism, thus protecting anything without the need for a third-party interference utilizing blockchain technologies [28].

The blockchain technology was created in consideration of its most notable use in the domains of economics and cryptocurrencies. However, the value of this technology is rapidly increasing in a variety of other sectors, including biomedicine.

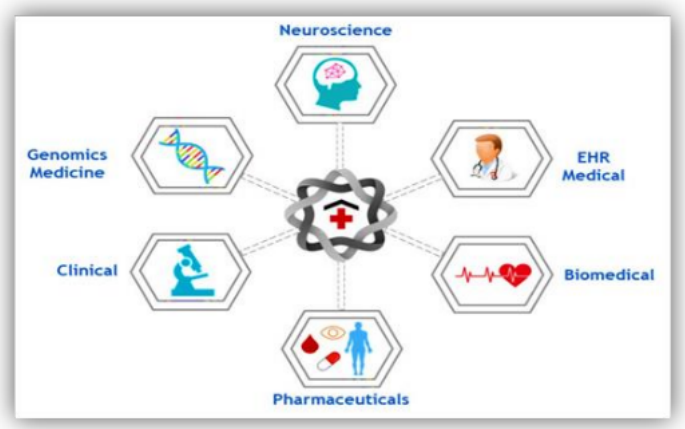

FIGURE 3. Applicationsof Blockchain in Healthcare.

The capability of blockchain technology to stabilize and secure the data set with which users may engage through various sorts of transactions (as represented in the model) can be found in the domains of medicine, genomics, telemedicine, telemonitoring, e-health, neuroscience, and customized healthcare applications (Figure 3)[29].

3.1.1. Characteristics of the Smart Contract

Several important characteristics of the intelligent contracts have been identified. A summary of these characteristics is provided in the following six points [30, 31].

1. Electronic nature: A traditional contract is normally produced verbally or by handwriting. By contrast, electronic contracts are often differentiated as e-commerce because they are processed electronically. However, some paperwork, such as receipts and invoices, may be involved as evidence. Electronic contracts are also associated with electronic data, which can be self-reliant and depend on authenticated digital signatures [32].
2. Conditional nature: Software codes obey “if then” conditions, which is the same with smart contracts. These contracts must follow certain settings wherein the parties set down their terms and conditions using a contractual provision to execute the deal [33].
3. Self-sufficiency: Smart contracts can be conducted by acquiring computing power or storage, which will ensure the self-sufficiency of the contract.
4. De-centralization: Smart contracts are decentralized because they are not distributed and performed through a single network node on a single centralized system.

3.1.2. Characteristics of the Blockchain

Block chain technology has many features, which are underlined throughout the following detentions to emphasize their meaning.

1. Decentralized validation: Network nodes without intermediaries are used to validate transactions available to all the parties in distributed locations, and real-time updates are implemented with the sequentially chained blocks. Therefore, handling information tracing and verification is easy.
2. Security: Threat structure is essential to identify attack type and scope for ensuring the security of blockchain networks. This structure is also important because of the decentralized network, which makes it powerful against cyber-attacks.
3. Data immutability: Unable to alter, change, or erase the data contained in the block chain, the cryptography systems ensure that the signed paper cannot be rejected by the receiver, thus establishing high confidence between the senders and the receivers [34].
4. Transparency: The blockchain and the transactions held therein may be interpreted by all parties.

4. HEALTHCARE INDUSTRY

The healthcare industry has a distinctive set of requirements that are related to privacy and security due to additional legal requirements for the protection of the medical information of the patients. Data and record sharing has become prevalent in the era of the Internet due to cloud storage and adoption of mobile health devices, thus increasing the risk of malicious attacks and compromised private information during sharing. Obtaining health information is easy via smart devices, and patients travel to several different doctors; thus, information sharing and privacy are gaining increasing concern. The distinctive requirements encountered by the healthcare industry include interoperability, authentication, and transfer of medical records, data sharing, and considerations for the mobile health.

Table 1. Smart Contract and Block-chain Literature a Surveys Relating to Health-care

Survey context	Language and DB		Specific Challenges in Blockchain Addressed	Benefits	Published
A secure remote healthcare system for hospitals using blockchain smart contracts	EVM protocol	Hai Luan Pham et al.	Centralized storage	Protection of information and data processing Use of mechanism to increase efficiency	2018
Blockchain utilization in healthcare: Key requirements and challenges	EVM	Tanesh Kumar et al.	Scalability restrictions, high development cost, cultural resistance, regulatory uncertainty, security and privacy concerns, unwillingness to share, complexity	Clinical and global data sharing, drug supply chain management, billing/payers	2018
Blockchain and smart contract for access control in healthcare	None	Mehdi Sookhak et al.	Considerably developed blockchain	Authentication, authorization, secure	2020
Blockchain in healthcare applications: Research challenges and opportunities	None	Thomas McGhin et al	Mining incentives, mining attacks, key management	Decentralized storage, authentication, distributed ledger, decentralized storage, security, integrity, IoT security	2019
Use of blockchain technology to curb novel Coronavirus Disease (COVID-19) transmission	EVM	Asma Khatoon	Strengthen the processes of healthcare	Secure data sharing, operations management, tracking of relevant information, speed process, non-manipulation, transparency, privacy, protection, minimizing transaction costs	2020
Blockchain for COVID-19: Review, Opportunities, and a Trusted Tracking System	EVM, oracle	Marbouh, Dounia et al.	Increase gas price, shortage of skilled workforce, scalability, legal issues, privacy concerns	Enhancing the healthcare, improvements to clinical trials, managing supply chain operations, contact Tracing, privacy, non-repudiation, integrity, authorization	2020

5. CONCLUSION AND FUTURE WORK

Overall, the blockchain technology and smart contract have been regarded as possible applications to some challenges encountered by the healthcare industry. The strongest potential of blockchain technology in the healthcare area lies in its extensively studied applications, which include integrity, security, availability, de-centralized nature, and principles of authentication, resulting in a general ledger and block-associated infrastructure. In the context of COVID-19, rapid vaccination rollout and implementation of a worldwide immunization campaign are crucial. Such strategies are also dependent on the availability of a transparent and operational chain of distribution that may be audited by all the relevant stakeholders. Blockchain technology may help fight the COVID-19 pandemic by assuring safe and reliable medical supplies, accurate identification of virus hot spots, and establishing data provenance to verify the genuine personal protective equipment that is decentralized, trustworthy, traceable, and transparent. This technology may also be used to assure transparent COVID19 vaccination registration tracing, delivery, and storage as well as self-reporting of the side effects. Moreover, the blockchain technology has been utilized to ensure immutability and integrity of the data in the registration of a beneficiary for the vaccine, reducing identity theft and impersonation. Smart contracts have been defined for the monitoring and tracking of proper conditions of the vaccine distribution against safe handling rules as indicated by the producers of the vaccine, enabling awareness of all the network peers. A tamper-proof and transparent solution of the self-reporting of side effects has been provided for the administration of the vaccination, thereby considering person identification and administrated vaccine association. The suggested blockchain and smart contract system showed promising outcomes based on the current study, and the results can be used to address some of the existing healthcare issues. The proposed solution is also economically feasible and ensures data integrity, security, transparency, and data traceability. Future work aims to expand the functionalities of smart contract and the blockchain technology to enable participant interaction with smart contracts. Potential research agenda include the following.

1. Further research is necessary to focus on particular difficulties and hazards linked to blockchain.
2. Further investigation is needed in the area of blockchain-enabled medical scalability. Scalability is a considerable challenge in the healthcare sector, particularly with the aging of the population. The number of users or patients on the system is rising, and operating blockchain-enabled applications will become increasingly challenging.
3. Further study with open-source real-world datasets is required for other academics to assess results and discuss findings. Numerous studies were proof of concept, and cooperation opportunities must be explored to evaluate the proposed solutions by leveraging real-world healthcare information from medical organizations (e.g., security, performance, scalability, and other essential properties, such as privacy preservation).
4. Further study on key management and safety and the capability to replace lost or affected key quickly should be undertaken.
5. Identity verification is another subject that must be investigated. Most of the trials focused on allowing patients to access their medical information in advance. However, emergency backup plans or protocols that may be utilized to enable a doctor to access medical records without an emergency authorization must be determined. Blockchain offers several benefits that may be utilized by the health business to tackle a variety of data sharing and safety problems. However, blockchain does not apply to all circumstances. The healthcare business should undergo a complete review of particular difficulties in the blockchain and their impacts. The assaults on the block chain are remarkably accurate, thus stopping the entire system.

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