## Role of Blockchain Technology in COVID-19 Crisis

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To obtain adequate performance in resolving issues that are associated with the COVID-19 pandemic, blockchain can be combined with other available technologies to establish a robust healthcare architecture.

Coronavirus COVID-19 blockchain healthcare

## 1. Introduction

In the first quarter of 2020, the world started a new form of life due to the COVID-19 pandemic, with the increasing number of affected to nearly 166 million and over three million deaths in May 2021 <sup>[1]</sup>. Countries had to enforce bans and segregate of people to reduce infection, save lives, and reduce its spread <sup>[2][3][4][5]</sup>. Therefore, significant challenges emerged: governments, technology giants, and regulatory bodies had to find urgent solutions.

These challenges included continuing the provision of essential government services, as it was difficult to maintain social distancing and provide all government offices' services <sup>[3]</sup>. One of the biggest challenges that countries dealt with is combating misinformation about COVID-19 and preventing its spread. For example, misinformation on vaccination turnout was studied on 8001 respondents (4000 from UK and 4001 from the USA). The study's result was that the number of people who had the intention to receive the vaccine decreased to 6.2% after hearing the vaccines' misinformation <sup>[4]</sup>. Also, among the challenges was how to deal with the new learning mechanism, which was the shift to e-learning. Moreover, the health sector has been dramatically affected by the COVID-19 crisis, so it had to deal with complex challenges, such as the constant supply of medicines and health equipment <sup>[3]</sup>, and providing care to patients (not just COVID-19 patients).

Research by Shah et al. proposed a secure blockchain network with compatibility to manage and store Electronic Health Records (EHR) of all patients and ease accessing historic and real-time patient data while reducing the cost of data accommodation <sup>[6]</sup>. But there is no specific explanation and description of specific incentive mechanisms in this model. Furthermore, Kassab et al. in <sup>[7]</sup> analyzed and summarized the existing advantages and challenges of assimilating blockchain in the healthcare domain. Moreover, they explained how this technology conveyed a framework that was based on smart contracts, which can find solutions for the healthcare domain for all interrelated actors.

Therefore, most countries and health sectors have used data tracking applications that are based on Bluetooth proximity tracing or geolocation tracking functionality <sup>[5][8]</sup>. It provides many advantages such as tracking COVID-19

cases, knowing their locations, sharing data, and tracking patients' status by remote medical staff <sup>[9]</sup>. But these apps lack confidentiality and integrity, making it easier to hack and obtain patient information. Thus, governments and technological organizations should take advantage of technological developments in the current era to face these challenges. For example, the use of artificial intelligence (AI), machine learning, the Internet of things (IoT), blockchain, and 3D printing, which can be used to create strategies for managing the epidemic <sup>[3]</sup>. For example, blockchain-based data-tracking applications can replace applications that rely on Bluetooth affinity as the blockchain can maintain confidentiality and integrity.

Blockchain technology has features that enable it to revolutionize various sectors <sup>[6]</sup>, including the health sector, as it is considered one of the most affected sectors by the COVID-19 crisis. Furthermore, according to the European Parliamentary Research Service (EPRS), blockchain is a critical technology to fight COVID-19 <sup>[7]</sup>. Blockchain can be used to increase the security of health data and maintain patients' privacy.

Blockchain is a decentralized technology with unique features such as impenetrable data infrastructure, confidentiality, and built-in crypto security software <sup>[10]</sup>. It is a network of peer-to-peer (P2P) computing nodes that collectively validate transactions within the network <sup>[3]</sup>. The decentralized blockchain platform is tamper-resistant due to the cryptographic infrastructure that is used to authenticate network users <sup>[10]</sup>. Possible employment of blockchain technology to fight COVID-19 includes observing infection transmission through reliable and immutable ledgers in a decentralized structure <sup>[11]</sup>.

### 2. Blockchain and Healthcare

Authors in <sup>[12]</sup> explained how the distributed ledger technology could fit entirely in health services. According to <sup>[13]</sup>, reports from the health research funding organization revealed that 10% to 30% of the drugs that were sold in developing countries involved forgeries. As such, a blockchain can be a perfect solution for the traceability of drugs and patient data management. WHO estimates that 16% of drug forgeries have the wrong ingredients, while 17% contain an imprecise level of the essential components. From an economic point of view, drug forgeries can cause a loss of 10.2 billion euros annually to European pharmaceutical organizations <sup>[14]</sup>. Blockchain can be a solution to address this issue because all the transactions that are added to the distributed ledger are immutable and digitally timestamped.

According to <sup>[15]</sup>, the primary concern to address is data integrity within the healthcare industry. As known, each person has unique physical variability. Therefore, appropriate treatment requires a strong, proven, and successful historical medical record of the patient. However, medical data are sensitive and require a secured sharing platform. Shen et al. have proposed Med Chain, which is created based on the blockchain of the permission framework type and it gives the patients complete control of their medical records <sup>[16]</sup>.

## 3. Blockchain and COVID-19 Crisis-Previous Research

Since the very first beginning of 2020, in conjunction with the outbreak of the Coronavirus, the world has been trying many ways to obtain the best resolutions regarding the improvement and experimentation of vaccines to stop or limit the spread of disease. This is in addition to the immediate diagnosis of COVID-19 cases as the Coronavirus is exceptionally infectious. The blockchain's possible implementations in healthcare sectors diversify to provide different needs (e.g., access, security, and data sharing). Other forms of blockchain technologies are also built for performing some forms of clinical observations.

In the case of the current pandemic control, blockchain and its applications are emerging as a promising and effective way of providing a genuine, trustworthy, and reasonable-cost resolution to aid epidemic management, which could efficiently take place in offering a more progressive action against this ongoing pandemic. Blockchain is yielding good prospects to be an invaluable technology for stopping the spread of the Coronavirus. Its implementation would facilitate rapid observation explications, guarantee a direct supply chain of essential goods and contributions, and safe, protected payments.

Ting et al. <sup>[17]</sup> investigated how diverse modern technologies could help control the expansion of the COVID-19 illness. Specifically, the researchers in this paper note how blockchain technology; artificial intelligence (AI), besides big data technology; and the Internet of Things (IoT) technology can contribute to designing simulation patterns that predict the disease scope's expanse; these methods can support establishing a monitoring instrument that can help diagnose and observe the virus's range. Concerning real-life or daily use-cases, the authors said that the blockchain's adoption improves the tracking process of shipments of medicines to China's cases' houses. The core of this study is to state the possible use of cutting-edge methods to minimize the disease's infection. However, this research did not present aspects of specific technical applications or implementations.

In contrast, Torky and Hassanien <sup>[18]</sup> suggest a proposal to employ blockchain to automatically identify COVID-19 infected patients and determine the outbreak risk of the COVID-19 among the public. The writers employed the decentralization characteristic of blockchain to collect the information of the approved COVID-19-patients. The identification of positive-tested records relies on using extra methods, e.g., a disease verifier subsystem.

Furthermore, Nguyen et al. <sup>[19]</sup> recommend an advance to help forecast the extent of the COVID-19 infection and other related pandemics. They advised utilizing AI accompanying blockchain to treat a considerable size of medicinal data with a complicated design. The research illustrated a blockchain-based methodology to support the healthcare supply chain and some donation follow-up. Nevertheless, it does not give professional details about the application of this method.

Zaabar et al. proposed a blockchain-based structure to enhance the robustness of the healthcare management systems as well as to avoid noted security shortcomings in presently applied architectures towards smart healthcare systems <sup>[20]</sup>.

Moreover, Bansal et al. <sup>[21]</sup> explained the use of blockchain in generating online immunity documents. The writers suggested using the immutability attribute of such technology to circumvent the extent of misinformation. The

proposed clarification also tries to discuss the problem of secrecy and anonymity of the test-doers.

Yet, the researchers have not introduced an implementation outline to complete the outcomes of the scheme. Resiere et al. <sup>[22]</sup> offer a system that is based on blockchain technology to revive the healthcare sector in the Caribbean. Accordingly, the research recommended using blockchain to obtain healthcare assistance, plus joint systematic examination to combat the crisis of COVID-19.

Frikha et al. have proposed a blockchain-ethereum-based architecture which is mainly an integrated IoT blockchain web and mobile application to store and check electronic health records (EHRs). The proposal allows the patient and the medical staff to access health information securely <sup>[23]</sup>.

To conclude, Kumar et al. <sup>[24]</sup> have formed a proposal to enhance the identification of COVID-19 cases according to tomography (CT) slabs using a deep learning model. They matched their aimed method with other AI deep learning methods, e.g., AlexNet, DenseNet, VGG16, and Capsule Network. The study applies blockchain technology as a system of distributing information with particular consideration given to preserving secrecy.

Although various visions of adopting cutting-edge methods such as IoT and blockchain to improve combating Coronavirus have been investigated, the present study attempts to propose deep procedural specifications <sup>[24]</sup>; in <sup>[23]</sup>, the researchers clarify their deep learning model technical employment in different parts. The explications that are mentioned above do not decrease the spread of the virus by the straightforward method of using blockchain. In most of the mentioned research, blockchain technology is introduced as a likely technology to control the infection, assist in curbing the misinformation campaigns, or guide other technical methods to suggest a whole structure. None of the studies stated or completed resolution that was based on blockchain technology, supporting the need for marking and tracing COVID-19 likely-cases that have been verified by immunity records.

# 4. Applications of Blockchain Technology to Fight against COVID-19

Blockchain has a significant impact in combating the crisis of COVID-19. It is one of the main high-end technologies that plays an important role in this situation. This section provides the main applications of blockchain that help the most affected fields keep them running with the least damage. As shown in **Figure 1**, those applications include contact tracing, sharing information with healthcare collaborators, immunity and vaccination certificate, smart contracts, supply chain management, online education and secure certification, and e-Government.



Figure 1. Contributions of blockchain technology during the COVID-19 pandemic.

#### 4.1. Contact Tracing

Contact tracing is an essential element of the control of dangerous epidemic outbreaks. It intends to stop disease transfer and has played a role in combating the COVID-19 outbreak in several regions <sup>[25]</sup>. It is necessary to calculate the cross ponding physical contact of any case during its' incubation period. This can lead to a lower extent of spread that is caused by COVID-19 <sup>[15]</sup>, according to the researchers in <sup>[3]</sup>, the incubation of SARS-CoV-2(COVID-19) for starting the symptoms would take almost 5.5 days, and as described in previous sections, not all infected people got appearing symptoms <sup>[3]</sup>.

In response to the surprising outbreak of COVID-19, many authorities have presented noticeable trends to mobile contact tracing apps to assist the hard mission of tracking every contact of recently recognized infected people <sup>[26]</sup>. The social interaction can be determined using contact tracing. It aims to decrease the spread of COVID-19 by taking the initiative which includes giving the individuals the analysis of the virus extent. The analysis is followed by instructions that can be diagnosed, advised, and quarantined in real danger where it is needed. Smartphones and

IoT can make this application more effective. Although the users' privacy policy will be violated, the authorities and the healthcare fields adopted the contact-tracing application <sup>[15]</sup>. The data that are collected will have high accuracy and reliability if the blockchain is used in high frequency <sup>[15]</sup>. It gives real-time data for the affected areas. However, the safe zones or free-virus zones are monitored and reported by blockchain <sup>[14][26][27]</sup>. Blockchain technology integrates with other technologies to collect data, such as geographical information systems (GIS) and AI <sup>[14][26]</sup>.

Two systems implement the contact tracing: the mass surveillance system and the P2P-mobile application <sup>[17][27]</sup>. The mass surveillance system depends on e-Governments and IoT devices within the streets of smart cities. In contrast, the P2P-Mobile application uses services to send the surveillance system and the blockchain network the collected data; it can show users the probability of getting infected by COVID-19 <sup>[28]</sup>.

#### 4.2. Sharing Information with Healthcare Collaborators

Sharing the patient data, treatment methods that were used, prevention methods that were used by doctors and healthcare personnel, and so on are important data that must be shared among healthcare collaborators. These data play a fundamental role in COVID-19 research as shared data from health organizations and hospitals can discover new treatment methods that help reduce the number of deaths. Therefore, international bodies and organizations use HIPAA controls to maintain the data's confidentiality, especially patient information <sup>[3]</sup>. However, there are obstacles in implementing the data-sharing system more broadly.

Blockchain features such as decentralization and transparency can be used to improve the healthcare system. It can take advantage of decentralization to increase the security and privacy of patient data, increase data control, and get rid of traditional medical records, which can be stored data in a blockchain-based system, making sharing data between health organizations and hospitals much easier and faster. The transparency feature can also be used to prevent data fraud and protect patients' privacy from abuse or misuse <sup>[3]</sup>.

#### 4.3. Immunity and Vaccination Certificate

Immunizer, serology, or antibody tests are the tests that determine if someone has gained immunity to the virus (e.g., COVID-19) upon complete healing from the infection. The immunity (vaccination) certification records the viruses or diseases that he/she have been protected or vaccinated against. The certificate helps limit and restrain the scope of COVID-19 by letting the officials and authorities form plans by supporting cross-border transportation from one place to another for those who hold this certification <sup>[29]</sup>. Accordingly, the certificate's fraud security, robust privacy means, and cost-effectiveness are the governments' fundamental responsibilities to reduce frauds relative to traveling. Employing blockchain-based vaccine certification and immunity testing implements an adequate and reliable data administration policy that is straightforward to manage, non-vulnerable, and cost-effective <sup>[5]</sup>.

Blockchain manipulates asymmetric encryption and decryption patterns <sup>[30]</sup>, as well as uses digital signatures to preserve both tests and certificates. Additionally, the decentralization characteristic confirms the security of such data against malicious attacks or a single point of failure by enhancing users' confidence by maintaining information authenticity and protection.

The above-mentioned certifications can be confirmed in a reliable, advanced manner, and secure the secrecy of the user information. For example, at resuming marketplaces after the COVID- 19 crisis, many businesses can promote and adopt the policies to allow only those workers to turn to work who hold a legitimate electronic vaccination license (immunity passport) to get back to work. Here, blockchain deployment guarantees that only "COVID-19 clear case" employees could resume working in the company. The essential traceability and transparency hallmarks of blockchain support building the data origin of the COVID-19 lab outcomes. It can also considerably help the businesses check the PCR testing kits' validity for the COVID-19 examination. It generates an immunity passport for the user to register it on the ledger.

#### 4.4. Supply Chain Management

The ongoing pandemic is causing massive damage to the supply chain worldwide as factories have been unable to deal with this shutdown due to the new measures, such as physical contact and social distancing. Therefore, the ban has been applied to importing and exporting the global supply chain <sup>[3]</sup>. According to <sup>[31]</sup>, "94% of Fortune 1000 companies are seeing supply chain disruptions from COVID-19", "75% of companies have had negative or strongly negative impacts on their businesses", and "55% of companies plan to downgrade their growth outlooks". Medical and pharmaceutical supply chains are hard to find because of the high demand <sup>[3]</sup>. Furthermore, the supply chains of household needs have also had a high surge in demand <sup>[3]</sup>.

One of the best options to consider managing the supply chain is blockchain. First, it can connect all of the stakeholders through one decentralized universal network, and by its' property transparency, it securely shows the data of the silos. As mentioned in <sup>[15]</sup>, many blockchain networks in the supply chain management field were mentioned. As mentioned in the previous sections, blockchain technology in any field or application provides quick data handling, reduces processing time, and has a lower risk in its operations. One example that was applied in China is the VeChain platform, assuring the credibility and reliability of masks that were imported from China. It checks codes, materials, packages, and all associated tasks <sup>[14][31]</sup>.

#### 4.5. Online Education and Secure Certification

Since many schools and universities have closed in different countries due to the quarantine, this does not mean stopping, or having an intermission in, the education process. Education is irreplaceable and making it an online operation is a challenge itself. Moreover, there are some associated challenges such as poor cross-platform collaboration and difficulty verifying students' credentials (degree, transcripts, and other certificates) <sup>[3]</sup>.

Blockchain-based online education platforms can mitigate these challenges <sup>[3]</sup>. Decentralized blockchain-based storage can provide access to authorized users while keeping the data of others secure <sup>[3]</sup>. As known as a blockchain, it gives secure issuance and sharing of verifiable educational credentials where one of the issuing authorities of an institute uploads a credential to a blockchain-based system <sup>[4]</sup>. One of the best examples is that the MOODLE platform, a global blockchain-based network, offers the mentioned advantages <sup>[3]</sup>.

#### 4.6. E-Government

The Corona pandemic, lockdown, and quarantines have caused the suspension of many businesses and services in the governmental institution's sector. This has prompted many governments that do not primarily depend on information and communications technology (ICT) to facilitate their services to switch and use the concept of electrical Government, also known as e-Government, to digitize all of their services <sup>[3]</sup>. These services can be public utilities (water, gas, electricity, sanitation, etc.), tax collection, salary payment, etc. <sup>[3]</sup>.

Blockchain gives high efficiency to the e-Governments systems by decreasing the delays and reducing the service operations costs. In addition, it gives access to the automation feature with blockchain and the shared databases <sup>[3]</sup>. If any counterfeiting endeavor happens, it will automatically be detected. When it comes to security, blockchain has a lot of ameliorating for data confidentiality and consistency. Data integrity and immutability are some of the benefits that are provided to e-Governments involving blockchain technology <sup>[3]</sup>.

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