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A detailed review of blockchain-based applications for protection against pandemic like COVID-19

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ABSTRACT

The recent corona virus disease (COVID-19) pandemic has brought the issues of technological deficiencies and challenges of security and privacy, validating and maintaining anonymity, user control over records while fully utilizing the available records etc., that can be encountered in an emergency or pandemic condition. Blockchain technology has evolved as a promising solution in conditions that necessitate immutability, record integrity, and proper records authentication. Blockchain can effectively resolve the technical barriers and effectively utilize the available resources and infrastructure in pandemic situations like the current COVID-19. This paper provides an extensive review of various possible use cases of blockchain and available solutions for protection against the COVID-19 like situation. It gives an insight into the benefits and shortcomings of available solutions. It further provides the issues and challenges of adopting blockchain in a situation like COVID-19 and suggest future directions that can offer a platform for further improved and better solutions.

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1. INTRODUCTION

Blockchain has arisen as a highly innovative and secure method for tamper-proof record storage. Blockchain is an evolving field and has been used and suggested in many contexts, mainly where confidence and reliability are the most critical factors. It has been primarily related to blockchain and financial transfers initially but is now being applied in the healthcare and governance fields. In the case of a global pandemic such as the current state of lock-up and large-scale instability due to the corona virus disease (COVID-19) crisis, blockchain will be the perfect information management platform to track, archive, manage multiple data, separate organizations and supply chain processes. In the current situation, the most crucial thing that can aid apart from medical treatment is to maintain confidence in knowledge sharing. When collaborating, monitoring distant areas, monitoring vital medical kits and necessary drugs, recognizing suspicious cases and connections, and monitoring patients, the quarantined community is challenging.

Various internet of thing (IoT)-based smart technologies for tracking and gathering patient data have been introduced [1]. Still, the trust and protection of those data are a significant obstacle to such technologies due to various security problems in IoT-based applications and cloud-based storage due to inherent security issues that can be successfully solved using the Blockchain-based framework [2]-[6].

Aside from controlling infectious diseases, a vaccine is a second choice. In the case of COVID-19, once the vaccine is ready, a safe and efficient supply chain would be a significant concern. Due to emergency and systemic leakage, the risk of misuse of the vaccine or fraud in the supply of miscreants cannot be ruled out. The Blockchain-based supply chain can easily track and monitor the near-automated supply of vaccines, vital drugs and medical devices safely and reliably [7].

In this research, we propose to examine the various factors relevant to the pandemic situation, such as COVID-19 and blockchain application, to resolve such issues. It will help identify the mechanisms to share information, track the critical supply chain, and treat patients using an integrated and safe process, along with the tracing and reliably quarantining of suspicious cases either in their respective homes or in designated government locations.

There is no such cure available as vaccination, and different companies and countries are working together to gather and exchange medical information and maintain the supply chain. Effective surveillance and monitoring of the affected population is the only way to counteract the outbreak. It is possible to predict suspected infection-prone individuals provided successful monitoring of travel and public health reports like heart problems, diabetes is available [8]. Also, it will help in identifying those who would be worst affected. It may have helped to structure the supply chain according to location-based data. This investigation will focus on these criteria and analyze the potential remedial model under these circumstances to efficiently control the disease.

Over the past decade, blockchain has emerged as one of the most exciting technologies, attracting academia and industry attention. In a 2008 white paper, Nakamoto first proposed this definition [9]. It is a type of decentralized ledger offering immutability, integrity and secure transactions. Blockchain evolved from Bitcoin and further applied the smart contract concept to record automated execution of financial transactions and storage in a public ledger [4], [10]. Now the third generation of blockchain is being used in non-financial transactions and record keeping. The inherent capabilities of immutability, decentralization and integrity support healthcare domains and provide cryptographic tools for secure record storage [11].

Blockchain technology is suitable for developing an application to counter the pandemic situation like COVID-19 effectively due to its inherent attributes. This survey reviews the blockchain applications in various healthcare domains suitable for countering the pandemic like contact tracing, clinical trial management, drug supply chain, donation tracking, data storage, maintaining user record privacy, early detection of vulnerable population and outbreak detection. Apart from various advantages, blockchain technology has some limitations, like scalability and interoperability [12]. Table 1 provides a comparative study of Blockchain technology with centralized architecture on various parameters. This paper further highlights the advantages of blockchain adaptation, limitations and future direction so that any new implementation or framework can consider these aspects for a better and reliable solution. This article is organized as follows. Section 2 guides the understanding of blockchain technology and general applications in healthcare. In section 3, we have discussed the specific use cases of blockchain applications for countering COVID-19. Section 4 provides an analytical review of the available solutions while discussing their functionalities and shortcomings, and section 5 offers issues and concerns in its implementation. In last, section 6 provide future directions and end with the conclusion in section 7.

Table 1. Comparison between using a centralized vs blockchain architecture

Characteristics	Centralized Architecture	Blockchain Architecture
Data Integrity	Data can be modified	Once data is recorded, it is immutable and can not be altered
Cost of Implementation and Maintainance	Cost is less as it is a standardized model and easy to implement. Experts are easily available	Cost, in the beginning, will be high as it is a new technology and challenging to find experts. The initial transition is also cost high
Fault Tolerance	Susceptible to single-point of failure	Records are distributed, and no risk of single-point of failure. High fault tolerance
Scalability and Performance	Higher chance of scalability and performance	Scalability is a concern, especially for public blockchains. Performance is slower in comparison to a centralized architecture
Data Privacy	Prone to cyber attack	Stored data is secured using cryptographic techniques. High level of data privacy
Transparency	Not very much transparent	Data stored on blockchain are highly transparent and auditable
Anonymity	Not supported	Data can be made available without disclosing the actual owner's identity

2. BLOCKCHAIN TECHNOLOGY

Blockchain technology is an evolving technology that has been successfully applied in several fields, primarily in financial, which record-keeping applications. Various experiments in diverse fields are ongoing to effectively incorporate and evaluate various benefits and disadvantages [10], [13]. Blockchain is commonly used in financial transaction system. Still, many other areas, such as land record management, e-government, supply chain, food supply, IoT protection, electricity, health care and insurance, are catching up [14], [15]. Many new technologies have either been introduced or introduced in the pilot process before being fully implemented [16].

Supply credibility is one of the main elements of supply chain management and the time component of recording. In a pandemic case, the transportation of resources as necessary, controlling demand without storing supply as supply of vital materials such as ventilators, medications, vaccines and emergency kits, are insufficient and needed for each hospital/location. At the same time, maintaining the personal records of patients and offenders, tracking their actions, and sharing this information with total honesty and fairness without affecting an individual's privacy, is equally important in this case.

In both conditions, blockchain can be an ideal technology due to its properties of immutability, stability, decentralization, and faster transaction. This project aims to research the various blockchain variables that can help control the supply chain in a pandemic crisis while ensuring supplies and keeping a transparent record of available organizations with criteria that can help allow the best possible use of resources. Our work deals with blockchain technologies, which can help ensure the efficiency and reliable management of the supply chain and help track patients and suspicious cases effectively while preserving anonymity and confidentiality of details. Blockchain is known to be a public ledger capable of working safely and confidently without involving any third party [3].

Blockchain (BC) technology is recognized as the most crucial trend in information technology that can affect decision-making and record management systems in all fields. Trust maintenance should be relied on when communicating with each other [10]. BC may identify new approaches or ways of tracking transactions, activities and certifying ownership, using the principle of distributed computation and integrating agreement structures to sustain records [17]. Several possible advantages can be classified as cost savings, efficient surveillance, less threat risk, improved social trust protection and decreased theft [18], [19].

Blockchain has been successfully used in several sectors, aside from financial services, which are primary areas of adoption such as e-government, social welfare, land registry, the health sector, the electricity sector and the economic sector. This segment addresses the key features of blockchain technology to help you appreciate the rest of this article.

2.1. Overview and architecture of blockchain

Blockchain is a P2P distributed network-based ledger. The records are stored in the form of block sequences. Each block header kept the hash of the previous block, and these are time-stamped [20]. It provides decentralization and immutability by rendering the ledger open to all users that makes blockchain hack-proof. It is censorship-resistant and provides accessibility by offering a copy to all peers to see all time-stamped transaction information and further provide anonymity.

2.2. Taxonomy of blockchain (types)

Four types of emerging blockchain networks are classified: public, private, consortium and hybrid blockchain [21], [22].

- Public blockchain: This type of blockchain offers a completely open network where each participant can participate in the consensus mechanism.
- Private blockchain: Each user in such a blockchain requires permission to join the network and these participants will be known participants.
- Consortium blockchain: A consortium blockchain works across more than one organization. It works as a public blockchain for the participating organizations.
- Hybrid blockchain: Hybrid blockchains have good properties of both private and public blockchain are combined into the mixed blockchain. Selected predefined nodes like private blockchain do the consensus, but transactions are shared across the network like the public blockchain.

2.3. Blockchain use cases in healthcare

Healthcare is a suitable use-case of blockchain application. One of the significant blockchain fields is healthcare [23]. Some of the significant blockchain applications in healthcare are:

- Electronic health record (EHR)
- Remote patient monitoring
- Health insurance

– Pharma supply chain
– Disease/pandemic management

Blockchain can be effectively used for managing the pandemic situation like current COVID-19 for early detection, vaccine supply chain, contact tracing and other aspects using the available healthcare infrastructure.

3. BLOCKCHAIN APPLICATION FOR COUNTERING PANDEMIC (COVID-19)

Although Blockchain technology was initially developed for managing financial transactions, later on, it was used in each domain where trusted, secure and immutable record-keeping is required. These domains can be healthcare, governance, finance, social security schemes any many more. In pandemic management, the trust and security of record is the most important factor; therefore, it is a very suitable use case for Blockchain adoption. In this section, the possible use-case of applying blockchain for containing and countering the COVID-19 situation has been discussed and analyzed in detail.

3.1. Clinical trial

Each drug should be checked carefully to demonstrate its efficacy and safety and notice potential adverse effects in clinical trials before selling any new medicines or medical devices in the market. A clinical trial with a large number of volunteers or patients is conducted mostly in four stages that make it complicated and resource-intensive. To progress, clinical trials need a fair, consistent management structure. The clinical trial should be able to manage the records in line with regulatory requirements like records to be accessible to stakeholders, privacy and security of records and immutability [24]. Using new technology and inventions while reducing research schedules will help ensure patient protection and privacy. Blockchain technology, in particular, will allow physicians and doctors to record real-time and where available health information. It increases the correctness of records, promotes data sharing, and maintains compliance [24], [25]. It further monitors who accessed all aspects of databases that provide an audit trail for improved data protection and privacy [26].

3.2. Drug and vaccine supply chain

COVID-19's emergency triggered massive interruptions across global supply chains. Two significant factors are playing a vicious role: a large number of factories are closed due to safety and hygiene problems and unprecedented demand for related goods, particularly EPP and medical supplies. Many consumers would purchase goods from uncertain suppliers or prices due to high demand. Long supply chains generate needless obscurity, making estimation and stock planning impossible.

Blockchain can be effectively used for maintaining the medical supply chain, especially in case of a pandemic situation where large scale international cross-border transactions are involved. Once the approved version of the vaccine is available for marketing and sales, there will be chaos in its distribution. Malpractices like fake vaccines, over-pricing dan hoarding of stock can be possible. These issues can be encountered using a blockchain-based medical supply chain.

Because of the COVID-19 pandemic, various blockchain arrangements are regulated [27]. Blockchain speeds up authentication processes by eliminating the need for third parties and unnecessary delays in transactions. Blockchain helps in quicker handling and delivery times, lower costs, minimized operating risks, and faster settlements [28]-[31].

3.3. Contact tracing for contacts of COVID-19 patients

Through proactively identifying, informing and, if necessary, quarantining higher-risk people than others, contact tracing can prevent infection transmission. This monitoring method is useful since smartphones only make the device more functional when security and other issues are overcome [32], [33]. Governments and health facilities engage in contact-tracking programs for patients. Blockchain use, however, still increases data quality and reliability. Blockchain networks can monitor patient activity and offer real-time updates to affected areas [34].

Moreover, to alert the public to secure locations, virus-free zones may be detected. Note that tracking providers can collect this information using various tools, such as AI and GIS. Thus, through following quarantine requirements, blockchain will have usable means to protect communities from virus transmission [35].

3.4. Donation tracking

COVID19 pandemic ravaged the population. Many humanitarians have donated and are ready to donate money and merchandise to overcome this calamity. The main issue comes from the lack of trust and

transparent processing of these donations because cloud-based traditional systems are not secure enough and do not cover the authentication requirements [36]. Many who are willing are hesitant to participate in such philanthropic works as they are apprehensive of its proper utilization [37].

Blockchain technology can be used to store all the details of donations, warehousing and delivery for transparent and reliable processing. The donor can accurately and transparently validate the process of sending and receiving charitable funds. Blockchain will eliminate intermediaries, cut costs, reduce aggression by donating, and promote social peace. Supporting people with medical or economic problems related to infectious disease spread [38] aims to inspire donation activities. It offers a transparent platform for donors to monitor their savings. The blockchain charity network guarantees that donations enter chosen communities directly without intermediaries through verification of need and receipt.

3.5. Data aggregation

Sorting, gathering and accumulating knowledge required to monitor the epidemic, decipher patterns, and administer experiments are vital tools to respond effectively to the pandemic. Blockchain's ability to validate and preserve permanent real-time information guarantees data integrity. Blockchain network creates a foundation for digital science creation by encouraging companies and organizations to exchange their knowledge with innovators, scientists and scholars to explore and integrate this intelligence into innovative devices and solutions [39]. Using a blockchain network offers flexible connectivity through regulatory management, data ownership, and multi-layered auditing. In collaboration with leading tech organizations and governments, Which introduced a global blockchain tech monitoring and communications infrastructure that helps capture, store and analyze data on virus propagation and containment [27].

3.6. User record privacy

Policymakers and healthcare professionals need to collect the patients' records through patent tracking and other measures for better decision making. At the same time, patients privacy and secrecy concerns also need to be handled. During these worrying days, a balancing act between record management and managing privacy concerns of the users must be done to increase confidence in the system.

Blockchain is a possible solution to capture and view patient information, screen patient procedures, and create degrees of social isolation while maintaining their privacy. There's no centralized force, and a blockchain network helps people to monitor their personal details. Although maintaining privacy and identity, they can specifically share their private information regarding awareness of coronavirus relief activities.

3.7. Early detection of vulnerable population

Various AI-based triage programs will theoretically relieve patient anxiety. The online chatbot can help understand initial disease symptoms for early detection and guide them in precautionary measures like social distancing and hand hygiene. If symptoms escalate, alert users to the facilities for medical treatment [40].

Also, phone-based software and IoT sensors can identify and monitor patients information like body temperature and oxygen level at home to avoid unnecessary hospital visits in patients with moderate flu-like symptoms to detect COVID-19. It can further collaborate with AI and machine learning approaches for early and accurate detection. All these aspects need communication of records across various platforms passing through multiple devices, including IoT sensors. Also, the integrity and privacy of patient records are of utmost concern for securing their personal and social values. Due to its computational and memory limitations, IoT devices are not fully compatible with traditional security approaches. The blockchain-based platform can effectively manage these security and privacy concerns [39].

3.8. Outbreak detection

Due to its decentralization functionality, blockchain eliminates the need for outsiders, which will significantly mitigate the incidence of data modification and fictitious reporting and improve the integrity of knowledge for public and healthcare specialists. Incorrect information causes various social and emotional issues like mental trauma, financial loss and uncertainty. Preserving database news and evidence prevents and requires traceable alteration, deleting false content and documents. Blockchain technology offers a viable coronavirus surveillance mechanism as data is stable, trustworthy, tamper-free and consistent across such networks. As a result, politicians will help update the coronavirus pandemic status for better preparedness and control, such as outbreak prevention, potential field isolation, and infection spread monitoring [41].

From an ever-growing collection of public information, Acoer developed a HashLog database to help people understand the scale and trend of spreading infection over time. Furthermore, the knowledge gathered from the CDC, WHO, and social networking website patterns enables Acoer coronavirus HashLog to allow clinical trial-specific data-visualization models [42].

3.9. Future outbreak detection

The recent coronavirus emergence has highlighted the need to forecast potential outbreaks such as COVID-19. COVID disease models for predicting and monitoring an outbreak should be taken into account in coronavirus management activities [27], [43]. AI has recently been applied to predict coronavirus-like outbreaks. For instance, a prediction model for estimating the scale, length, and end time of Covid-19 across China uses AI [44]-[46].

4. REVIEW OF PROPOSED SOLUTIONS

This section reviews the existing IT solutions for countering the COVID-19 pandemic based on the criteria mentioned. These solutions have been further classified based on using blockchain technology or not. Blockchain-based solutions have also been reviewed. The available solutions in different countries, the organization managing these solutions, area of application and used technologies have been summarised in the form of Table 2 (see on appendix).

5. ISSUES AND CONCERNS

Issues associated with blockchain operations are also relevant in the case of these applications designed for COVID19 applications. Scalability, interoperability, standardization, cultural resistance, security and privacy concerns are some of the significant concerns. For applications storing a large volume of data, scalability is a significant challenge due to the limitations of computing resources. Different organizations are using different platforms to develop these applications and frameworks, and due to the lack of any industry or regulatory guidelines, interoperability of these records is not possible. In the current scenario, the developed applications are working as a standalone system and little or no collaboration possible among them [50]. People are hesitant in sharing their personal details due to a lack of confidence and cultural resistance; data collection is not easy without government interference. The collected data need to maintain privacy and security concerns. Users have to be educated about the security features and guarantee their privacy to allay privacy and security concerns [78]. Specifically, the tracing apps collect location and other movement records that infringes the user privacy, and this information needs to be collected anonymously. Although blockchain can handle any sort of data breach and integrity, privacy needs to be guaranteed using suitable mechanisms.

6. FUTURE DIRECTIONS

In future, with the standardization of records, the interoperability of the different applications and systems need to be handled so that other applications or states can use data collected by one application/system. It will minimize the data duplication efforts as well be updated of previous infection and health status. For example, if a person was infected previously or has some medical conditions, they can not hide from other organizations or states' authorities. Better artificial intelligence (AI) and machine learning approaches can further improve the successful detection and prediction rates. The collected data can be further shared with research organizations and insurance firms for claim processing and future research while maintaining anonymity by integrating these modules with electronic health record (EHR) modules.

7. CONCLUSION

This paper reviews the possible applications and use cases of blockchain in countering the COVID-19 like pandemics. Blockchain is a suitable technique for such applications due to its inherent capabilities of immutability, anonymity and privacy. Various domains for countering COVID-19 has been highlighted. The existing applications and frameworks have also been evaluated and classified based on their application. The available applications are mainly in the domain of contact tracing, but then it can be effectively applied for other domains like early detection, secure and reliable data aggregation, record sharing and need more work in this direction. Apart from the advantages, some concerns like scalability, interoperability, and standardization in blockchain adaptation need to be resolved for effective implementation. Lastly, this paper highlights future directions for countering the COVID-19 pandemic, like using AI and machine learning solutions and blockchain for effective and reliable solutions.

APPENDIX

Table 2. Review of COVID-19 solutions

Ref	Application	Organization	Country	Use case	Blockchain used	Used Technology	Framework or Implementation
[47]	Tabaud	Saudi Data and Artificial Intelligence Authority (SDAIA)	KSA	Contact Tracing	No	Bluetooth	Implemented App
[48]	Tawakkalna	Saudi Data and Artificial Intelligence Authority (SDAIA)	KSA	Movement Tracking	No	GPS	Implemented App
[49]	BeepTrace	Author Specific	Author Specific	Contact Tracing	Yes	GPS, Bluetooth, Cellular, Blockchain	Framework
[50]	ALHOSN	Ministry of Health and Prevention	UAE	Contact Tracing, Health Testing	No	Bluetooth	Implemented App
[51]	Civitas	Emerge software solution, Canada	Latin America	Social Distancing, Public Safety	Yes	Blockchain	Implemented App
[52]	VeChain E-HCert App	VeChain and I-Dante	Cyprus	medical data management	Yes	Blockchain	Implemented App
[53]	MiPasa	HACERA, IBM, Oracle	WHO, CDC	data sharing platform, public health analysis	Yes	Blockchain	Implemented App
[54]	Coalition	Open Garden, Inc.	USA	exposure notification (Contact Tracing)	No	Bluetooth	Implemented App
[55]	VirusBlockchain	Public Health Blockchain Consortium (PHBC)	A consortium of various organizations	monitoring blockchain for restricted uninfected population	Yes	RFID, Blockchain	Implemented App
[56]	Hyperchain Shanzong	Hyperchain and China Xiong'an Group	China	Donation Tracking	Yes	Blockchain	Implemented Platform
[22]	HashLog	Acoer	Atlanta USA	Data Gathering and Visualization	Yes	Blockchain	Implemented Platform
[57]	Bluedot COVID Data Suite	Bluedot Corporation	Canada	Pandemic Prediction	No	AI, big data analytics	Implemented Platform
[58]	Infervision InferRead CT Lung Covid-19	Infervision enterprise	China	COVID19 detection	No	Artificial Intelligence, Deep learning	Implemented Platform
[59]	AlphaFold DeepMind	DeepMind Inc.	USA	Drug Discovery[59]	No	Artificial Intelligence, deep learning	Implemented Platform
[60]	TraceTogether	Singapore Government	Singapore	Contact Tracing	No	Bluetooth and Wearable Sensors	Implemented App
[61]	Aaroyga Setu	National Informatics Centre	India	Contact Tracing	No	Bluetooth	Implemented App
[62]	Hamagen	Ministry of Health	Israel	Contact Tracing	No	Bluetooth, GPS	Implemented App
[63]	COVIDSafe	Department of Health	Australia	Contact Tracing	No	Bluetooth	Implemented App
[64]	Covid-Watch	University of Arizona	United States	exposure notification	No	Bluetooth,	Implemented App and Platform
[65]	WeTrace [16]	DXFORM INC.	Cebu provincial government	Contact Tracing	No	Bluetooth	Implemented App

Table 2. Review of COVID-19 solutions (continue)

Ref	Application	Organization	Country	Use case	Blockchain used	Used Technology	Framework or Implementation
[66]	Covid-19 BlockChain Framework [17]	Author based proposal (Torky *et al*.)	Propriety	Contact Tracing, Record Storage, Status Verification and Predictive Analysis	Yes	Blockchain	Framework
[67]	CovidChain	Author based proposal (Choudhury *et al*.)	Propriety	Contact Tracing, Record Storage, Status Verification, Digital Passport	Yes	Bluetooth, GPS, Blockchain	Framework
[68]	BlueTrace	Government Technology Agency	Singapore	Contact Tracing	No	Bluetooth	Protocol
[69]	Exposure Notification APIs	Joint Project of Apple and Google Inc.	USA	contact tracing	No	Bluetooth	Protocol
[70]	Private Automatic Contact Tracing (PACT)	Massachusetts Institute of Technology	USA	contact tracing	No	Bluetooth	Protocol
[71]	SwissCovid - DP-3T	Federal Office of Public Health FOPH	Switzerland	contact tracing	No	Bluetooth	Implemented App
[72]	Decentralized Privacy-Preserving Proximity Tracing (DP-3T)	École Polytechnique fédérale de Lausanne (EPFL)	Switzerland	contact tracing	No	Bluetooth	protocol
[73]	Pronto-C2	Author based proposal (Gennaro *et al*.)	Propriety	contact tracing	Yes	Blockchain	Framework
[74]	COVID Safepaths	PathCheck Foundation, MIT	USA	Contact Tracing	No	Bluetooth, GPS	Implemented App
[75]	DESIRE	National Institute for Research in Digital Science and Technology (Inria)	France	Contact Tracing	No	Bluetooth	Implemented App
[76]	ConTra Corona	Author based proposal (Beskorovajnov *et al.)*	Propriety	Contact Tracing	No	Bluetooth	Framework
[77]	TraceCovid	Department of Health	Abu Dhabi, UAE	Contact tracing	No	Bluetooth, Secure Tracing Identifier (STI)	Implemented App
[50]	BeAware Bahrain	Information & eGovernment Authority	Bahrain	Contact Tracing, COVID-19 Test Appointment, COVID-19 Test Certificate, Data Aggregation	No	GPS	Implemented App
[78]	StayHome	Department of Health	Abu Dhabi, UAE	Quarantine Tracking	No	GPS	Implemented App
[79]	Theseus	Emerge software solution, Canada	Canada	Supply chain	Yes	IoT, Blockchain	Implemented System
[80]	COVID Credentials initiative (CCI)	A consortium of organizations and individuals	Global	Immunity passport, credential management	Yes	Verifiable Credential, Blockchain	Knowledge sharing platform

Table 2. Review of COVID-19 solutions (continue)

Ref	Application	Organization	Country	Use case	Blockch ain used	Used Technology	Framework or Implementation
[82]	StopCovid (Robert)	National Institute for Research in Digital Science and Technology (Inria)	France	Contact tracing	No	Bluetooth, Equipment Identification	Implemented App
[83]	Alipay Health Code	Health Commission and Committee of Economic and Information technology	China	health status update for citizens	Yes	Blockchain	Implemented Platform
[84]	GeoHealthApp	GeoHealthApp gGmbH Inc.	Germany	Contact tracing	No	GPS	Implemented App

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