# Could Blockchain Help With COVID-19 Crisis?

Mohamad Hassan Kassab, *Pennsylvania State University, Malvern, PA, 19355, USA*

Valdemar Vicente Graciano Neto, *Universidade Federal de Goiás, Goiania 74690-900, Brazil*

Giuseppe Destefanis, *Brunel University, Middlesex, Uxbridge, UB83PH, U.K.*

Tarek Malas, *University of Laval, Quebec, QC, G1V 0A6, Canada*

***The novel coronavirus that causes the Coronavirus Disease 2019 (COVID-19) has spread all over the world at an unprecedented rate. With growing recognition of the distributed nature of health services, the technology of blockchain has recently reached the impetus of the healthcare domain. This article provides: 1) a panoramic overview of existing solutions and scenarios incorporating blockchain to combat COVID-19 in the healthcare domain along with their benefits and challenges; as well as 2) a framework that will facilitate new research activities on this subject.***

Blockchain technology's transformative capabilities have been rapidly recognized as a turning point in many use case scenarios beyond the financial sector.[1] The World Economic Forum estimates 10% of the global GDP to be stored using blockchain by 2027. A renowned scientific study and market consulting firm, Gartner, estimated investment decisions worth $3.1 trillion in blockchain technology are projected by 2030.[2]

With growing recognition of the distributed nature of health services, the technology of blockchain has reached the impetus of the healthcare discipline. In Kassab *et al.*,[3] we reported the results of a systematic literature review we conducted to identify, extract, evaluate, and synthesize the studies on the symbiosis of blockchain in healthcare along with the benefits and challenges that this technology brings to the domain. We mapped 52 extracted primary studies into five healthcare-related scenarios. A summary of the mapping is provided at https://bit.ly/32dJ0MS.

The COVID-19 pandemic has added momentum to the interest in leveraging blockchain for healthcare-related scenarios. As of December 2020, more than 3000 articles were found on the PennState LionSearch tool[4] as the result of the search query "blockchain and COVID." Given that the COVID-19 outbreak is still recent, there is a scarcity of peer-reviewed studies on this topic as the search results were dominated by press articles.

Motivated by exploring the potential of blockchain in combating the COVID-19 crisis and based on extending our earlier work[3] by conducting inductive content analysis[5] on the extracted articles from the above search, the contributions of this article are: 1) exploring the landscape of five categories of solutions that incorporate blockchain to combat COVID-19 in the healthcare domain along with their benefits and challenges; and 2) providing a framework that will facilitate new research activities.

## BACKGROUND

Blockchain is a type of distributed ledger technology that is characterized by the Consensus, Decentralization, Immutability, Finality, and Provenance (CoDIFy-Pro) principles, explained as follows.

A blockchain consists of a set of nodes connected through a peer-to-peer network. Each node in the network maintains an exact copy of the blockchain creating a decentralized structure. When a new block is added in the chain, all the nodes of the network need to reach a consensus on the validity of that block. The consensus mechanisms are protocols that ensure all nodes on the network are synchronized with each other and agree on which transactions are valid (and only those are added to the blockchain).

New entries to the blockchain are added by appending them to the end of the ledger. Once recorded, data cannot be altered, and the transaction history is combined into a chain structure without



Digital Object Identifier 10.1109/MITP.2021.3072585 Date of current version 19 August 2021.

the possibility of additional branches of alternative transactions emerging or wedging into the middle of a chain. Each block contains a cryptographic hash and a timestamp creating an immutable record of all the transactions in the network.

The finality principle that characterizes the blockchain means that a single and shared ledger provides one unique place to determine ownership of an asset or completion of a transaction. The Provenance principle implies that network participants have access to the knowledge of where an "asset" came from and how its ownership changed over time.

The blockchain community has been stimulated with the COVID-19 outbreak to conceive solutions to combat the pandemic. The world experienced deadly virus outbreaks over recent years, and there have been some studies proposing blockchain solutions for tackling the surveillance scenario for communicable diseases.[6,7] The difference with COVID-19 is that it is much more highly contagious than the others. In effect, COVID-19 has demonstrated a much larger healthcare and economic burden as a global pandemic, and effective surveillance is only one facet of the solution.

## LEVERAGING BLOCKCHAIN IN COVID-19 HEALTHCARE RELATED SCENARIOS

The inductive analysis we conducted on the extracted articles from LionSearch tool as the result of the search query "blockchain and COVID" guided us to form five categories of scenarios where blockchain can be leveraged to combat COVID-19: 1) establishing disease surveillance; 2) establishing proximity contact tracing; 3) maintaining clinical research results; 4) maintaining a trace for medical supply chain management; and 5) improving the handling of medical insurance claims.

### Disease Surveillance

Most of the existing surveillance processes for communicable diseases face the challenge to keep the information flow seamlessly in close to real time.[7] A typical infectious disease reporting workflow follows a sequential process in which hospitals diagnose and report patients to a higher authority, which in turn report to a final authority. Lack of communication mechanisms with the reporting levels is a concern as there are many intermediary processes for the report to pass from the hospital to the final institution, which can hamper a prompt response. The usage of a central host (e.g., local server, cloud) may inevitably pose a threat as the host can be a single point for an attack.

Because of the "decentralization" feature with blockchain, if used as a platform for infectious disease reporting systems, the data can be automatically reported and shared among parties acting as nodes in the network once transactions are added to the chain. This implies that a final authority can be informed instantly without passing through any intermediary, which results in the improvement of the time-efficiency of data transfer at the time of outbreaks. With the "immutability" feature of a blockchain, the circumstances of the outbreak would be transparent to the participants in the network (without the possibility of data manipulation).[8]

A blockchain network able to connect the World Health Organization (WHO), Health Ministry of each nation, and even relevant nodal hospitals with the possibility of sharing information about any new infectious disease in real time, could have helped the world in promptly and better-organizing policies such as social distancing and quarantines. Blockchain-based syndromic surveillance systems have been implemented already in the Emergency Departments in the U.K. at the national level and in Canada at the regional level.[6] The European Antimicrobial Resistance Surveillance Network[7] is another excellent example. Emerging pragmatic surveillance blockchain-based solutions to combat COVID-19 include:

- **MiPasa**: Cointelegraph reported on March 28, 2020, that the WHO joined forces with IBM, Oracle, Microsoft, and the enterprise firm HACERA in building the open data hub called MiPasa (https://mipasa.org) on the top of Fabric hyperledger. The tool uses various data sources and analytic tools to detect and recognize COVID-19 infection hot spots.
- **HashLog**: With the help of public data from the US Centers for Disease Control and Prevention (CDC) and WHO, Acoer's HashLog visualization engine interacts in real time with Hedera Hashgraph's distributed ledger technology to ensure real-time logging and data visualization of the spread of the disease. Each transaction is recorded through a verified hash reference on Hedera's ledger,[9] which provides epidemiologists with legitimate data.

### Mobile Contact Tracing Applications

Contact tracing is one particular type of surveillance. Before the COVID-19 era, contact tracing was mainly conducted manually. The process involved interviewing infected patients to trace their recent contacts, and then, the authorities reached each identified contact to check for existing symptoms. This typical manual process was relatively slow and requires massive human resources, which cannot effectively cope with the speed that the SARS-CoV-2 virus has been spreading at under loose distancing measures. Starting in the month of April 2020, there has been an avalanche of "proximity contact tracing mobile apps" aiming at automating this process.

While these tracing apps may have slightly different approaches, at their core, they are tracking programs using Bluetooth or GPS to track an individual's exposure to cases. Users elect to share data and are alerted if they have been within proximity to COVID-19 cases. If an individual is found to be infected with the virus, all of the people that have recently been near him/her are alerted and asked to follow the public health authorities' guidelines.

To analyze their current landscape, we investigated a sample of 52 contact tracing mobile apps developed and/or deployed in 29 countries. Figure 1 provides the world-wide distribution for these apps, along with the approximate volume of downloads (as of August 2020) and an aggregated contemporary view of the analyzed apps. We posted an analysis on each analyzed app at https://bit.ly/3bcqR67.

Despite the need for contact-tracing at the time of the pandemic, a sphere of challenges can arise with this thread of apps. Only 15% of the analyzed apps were detected collecting anonymous data with no Personally Identifiable Information (PII). Forty-three percent maintain Pseudonymized copies of the data, while the remaining 42% of the apps had no information on the data anonymity. Once collected, 47% then store the data in a centralized location (e.g., authority server), while 26% retained the data locally on the mobile device. Twenty-eight percent of the apps did not report on how the data will be stored. Forty-seven percent of these apps will store data in unencrypted format comparing to only 21% that store encrypted data. Only 21% reported temporary storage, while the remaining 21% store collected data for a period of one year or longer.

Although challenges to preserve privacy remain, recent studies have shown that users feel the need to rely on these apps as the pandemic proceeds. For example, a survey was conducted by Metova firm with 2000 residents of the United States found that 77% of participants would want to be notified via their mobile phone if someone they recently came in contact with tested positive, and 85% are willing to anonymously share a positive status for the greater good.[10]

With the "decentralization" and "consensus" features of blockchain, a user can opt to submit a device's unique Bluetooth identifier, and the other participants on a ledger would be able to validate that a device has opted to share and receive anonymous information. This forms the basis of consent to be a participant in data sharing and subsequent tracking via blockchain.

Everyone participating in the system could see if they have been near another person that owns a device that has been recorded on the network as infected (without that person being identified). The "immutability" feature creates a single source of truth of who opted in, which can be searchable by health authorities while medical information associated with an anonymous device identifier is kept on locally on each device.

We detected five apps from the sample we analyzed as blockchain-based. We provide a comparative analysis of the non-blockchain-based (decentralized and centralized) apps with the currently proposed blockchain-based solutions, along with the list of the PII collected per app, at https://bit.ly/3bcqR67.

## Clinical Research

While there have been efforts by the WHO and health authorities requiring all trials to make their methods and results available, a recent study suggests that fewer than 50% of trials comply.[11] It is also estimated that 85% of research resources are wasted due to findings being exaggerated or even entirely false.

Because clinical trials are the primary source of hope to end the pandemic, it is essential to effectively improve the credibility of scientific results.

Since inadequate data provenance leads to irreproducible clinical trials, using blockchain technology for data storage provides an alternative to address concerns related to data traceability, scalability, and interoperability. The "provenance" feature of blockchain creates a cost-saving for "Source data verification," which is estimated at 20% to 30% of the overall clinical trial budget.[12]

With the "decentralization" feature, researchers can access data in near real time, which would improve clinical care coordination among researchers and public health resources to rapidly detect, isolate, and drive change for environmental conditions that impact public health.

Grapevine world blockchain (https://grapevine-worldtoken.io/) provides an interesting example through a clinical trial solution that enables patients

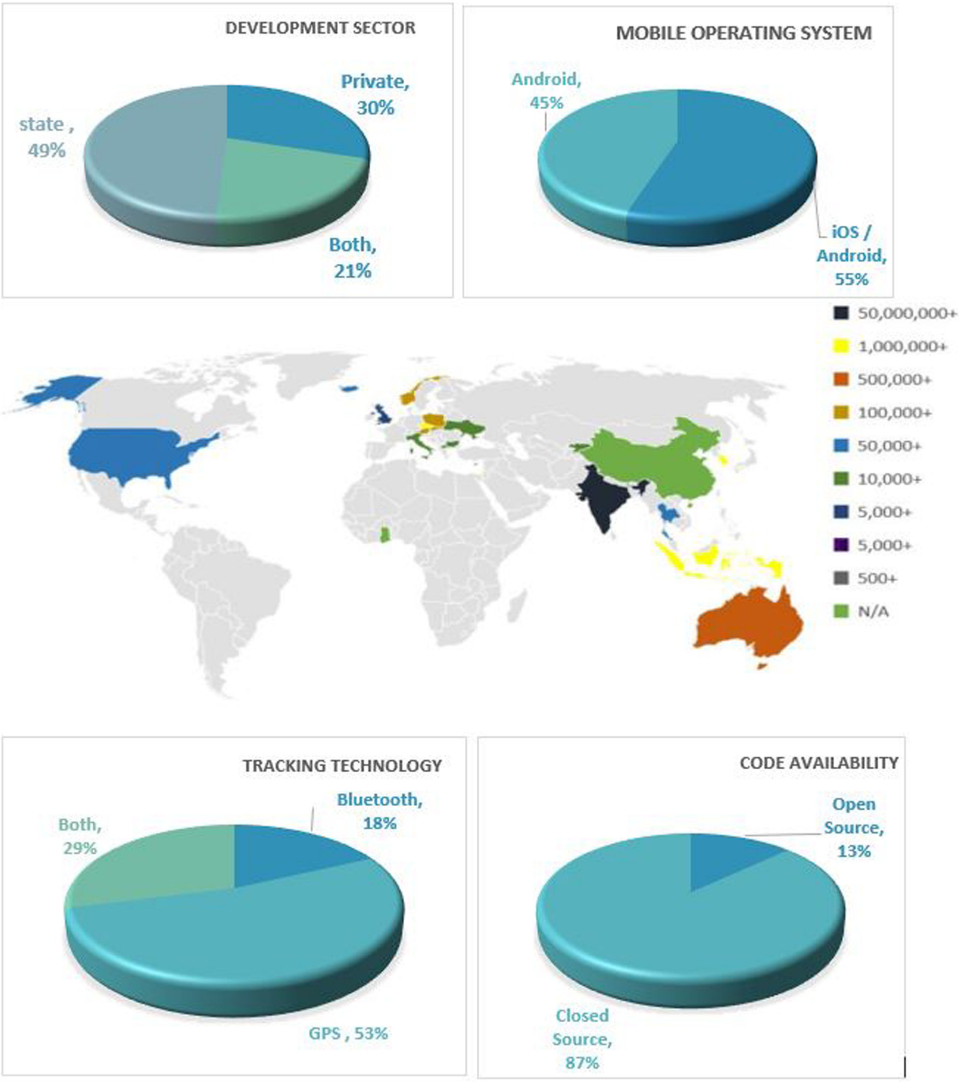


**FIGURE 1.** Distribution of analyzed sample of proximity tracing applications with approximate volume of downloads (as of August 2020).

to opt-in to clinical research while incentivizing them to do so with crypto-tokens. Provenance information for clinical data is managed using the Hyperledger Fabric, while Ethereum based crypto-tokens reward patients for participation.

## Medical Supply Chain

Although the WHO's systems and several global regulations such as the Drug Supply Chain Security Act (DSCSA) were implemented to assist in protecting the integrity of the medical supply chain, the global trade in counterfeit medical supplies is still a large risk to the public. The Organization for Economic Co-operation and Development estimated that 10% of pharmaceutical products and 2.5% of global imports are counterfeit, which adds risks to patient safety.

In the early stages of the COVID-19 pandemic, many healthcare providers were facing shortages of medical supplies (e.g., ventilators, protective equipment, etc.) and turning to new and unproven suppliers around the world to fill these gaps. Vetting and on-boarding new suppliers are time-consuming during the best of times, but in time of the pandemic, the speed is of the essence. Also, there is a risk of price hoarding, quality issues, and even fraud in the network. The medical supply-chain must be transparent and consistent across all industries. A multidisciplinary review of current and emerging digital solutions to combat the counterfeit drug incidences cited blockchain as one of five technologies with the potential to better establish management to drug supply chain.[13]

The single version of the available truth that blockchain provides to all actors in the network enables critical product distribution to where the need is greatest. Proposals to develop a federal reserve-type structure using blockchain to monitor and control the allocation of medical personal protective supplies have been recently in the news.[14] The reallocation of stockpiles from hospital to hospital via blockchain can eliminate waste by not requiring the government to keep supplies for these hospitals that are critically low.[14] Besides, with blockchain, the use of in-kind and monetary donations will become transparent. The person donating would be able to verify the transfer process and easily access a receipt of donated money or in-kind goods. Thus, blockchain can decrease donation corruption and improve social trust.[8] Two noteworthy solutions that emerged in response to COVID-19 were:

- IBM collaboration with Trust Your Supplier (TYS) to create a blockchain-based network that aims at helping healthcare organizations to address equipment shortages by connecting them and find alternative trusted suppliers on time. Recently, IBM and Moderna disclosed a plan to explore blockchain, AI, and hybrid cloud for smarter management of COVID-19 vaccine supply chain and distribution data sharing.
- The Dutch distributed ledger technology firm Tymlez (https://www.tymlez.com/) offering its blockchain platform to map and analyze the medical supply chain to prevent price gouging.

### Insurance Claims

Health insurance claim fraud is real and very costly to everyone. It is estimated at 10% of the $3.9 trillion healthcare expenditures, where 41% of the fraud goes in the form of duplicate billing and 26% in the form of falsifying claims. Fraud can become even more of a challenge with COVID-19 with telehealth.[15]

The "immutable" audit trail that blockchain provides is a fundamental feature that can decrease fraud in the insurance industry. Existing research has already implemented blockchain-based apps to support the storage of insurance claim data. For example, in Zhou *et al.*,[16] the authors proposed an app called MIStore, which allows hospitals and insurance companies to share insurance data in real time while utilizing a Practical Byzantine Fault-tolerance (PBFT) algorithm to guarantee consensus between the blockchain nodes.

Accessing information on the blockchain can also reduce the printing and delivery of diagnosis letters. By eliminating these processes, physical contact and the risk of infection could be reduced.[8]

## DISCUSSIONS AND FUTURE RESEARCH DIRECTIONS

A report published by a global public policy firm for the tech sector recalled that 49% of the world remains digitally unconnected and affirms that "*virus fightback must start with the adoption of policies that enable countries to take advantage of great leaps in pandemic-busting ingenuity.*"[17] While it can offer an opportunity to digitally connect the healthcare sphere, in its current state, blockchain still has to overcome challenges to address the aforementioned scenarios. More specifically, these concerns are related to: 1) privacy; 2) scalability and performance; and 3) technology and social constraints.

**Privacy**: In healthcare, the need to match patients to their distributed care records is complex. In the U.S., the Centers for Medicare and Medicaid Services (CMS) have placed much greater emphasis on healthcare interoperability with its "Promoting Interoperability Program," intended to make patient records access to/from stakeholders easier. However, compared to the centralized data storage alternatives, the blockchain technology does not reach far enough upstream to resolve the following questions: How do we ensure the identity of who is accessing patient records in the first place? Who is the real endpoint?

Because of the blockchain's "immutability" characteristic, users' records cannot be changed or removed from the network. Will this be appropriate when a lockdown is lifted? In the context of the blockchain-based contact tracing apps, for example, the "finality" characteristic can also diverge from existing legislation such as the European GDPR or the recently announced Brazilian LGPD that provide all citizens the capacity to govern their own data, including the right to request an institution to delete personal data being processed based upon consent.

Even if big health datasets are kept in distributed databases outside the blockchain, then it would be interesting to know how data will travel between blockchain and distributed databases seamlessly without any privacy breach. In Dasgupta *et al.*,[18] the authors provided a taxonomy on the potential security attacks that blockchain technology may face. The high level of the taxonomy includes eight types of attacks that need to be addressed: Key attack, identity attack, manipulation attack, quantum attack, service attack, Malware attack, application attack, and reputation attack.

The integration of unobtrusive biometrics that does not infringe on privacy regulations on the top of a blockchain could be a start to better define the effect of the unidentified on overall healthcare expenditures. The most widely accessible biometrics already in circulation include fingerprints, facial recognition, retinal scanners, and heart-based readings (crude EKG, heart rate monitors). Some have alluded to a combo for a valid ID. There has to be preceding research though on the significant hurdles to overcome between establishing privacy policy on the use of the biometric.

**Scalability and Performance**: The growth of healthcare transactions is in quadratic fashion, but storing large medical files (e.g., ECG and X-ray) as transactions directly on a chain is complex. This challenge was discussed in Li *et al.*[12] in the context of clinical trials.

Also, within a blockchain deployment, the "decentralization," "provenance," and "consensus" imply that all the blocks are stored on every fully participating client node within the network, which leads to large disk space coverage. As the health data volume will be on a constant increase, a demand on each participating node will also increase to provide the required scalability. In the last two years, Bitcoin blockchain ledger size has grown at a rate of 50 GB per year from 150 to 250 GB. The Ethereum size has been growing at three times more than that of Bitcoins. While according to Moore's law, hard disk storage prices will decrease with time, the blockchain-based platform that maintains a significantly large volume of healthcare data has to be proven in production settings as of yet.

In Cichosz *et al.*,[19] a possible solution to this challenge is to combine on-chain solutions (recorded on a distributed ledger itself) with off-chain ones (actions that occur off of the ledger). Access transactions, metadata, and emergency data could be stored on a blockchain system. A link embedded in a block would act as a pointer to an off the blockchain API that would allow access to larger extensive medical files which will be accommodated off-chain.

**Technology and Social Constraints**: For success at maintaining the integrity of the consensus algorithm of the blockchain and securing the minimum number of validations signatures, it is crucial to have a sufficient amount of nodes online at any time. For such a sufficient number to be justified from a financial perspective, there must be a sufficient number of generated transactions generated from a sufficient number of users. In the context of the "Contact-tracing" applications, a recent study by the University of Oxford's Big Data Institute estimates that at least 60% of the population in a given area would need to use an automated application that traces contacts and notifies users of exposure for it to be effective in containing the virus. On March 20, 2020, Singapore became one of the first countries to deploy a voluntary contact-tracing app, "TraceTogether," but only about 26% of the population installed it two months after its inauguration. While some compliance is better than none, the low rates of adoption in many areas is a challenge for blockchain-based applications to provide a breakthrough.

In addition, creating an extensive network of connected nodes is creating a major monetarily driven challenge. For example, very recently, many large health systems, incentivized by the governments worldwide, invested millions of dollars in building commercial EHR systems. To request an immediate replacement of the current record systems with a digital ledger seems to be irresponsible spending on behalf of taxpayers and will be a disservice to the medical field.

As the sphere of using blockchain in the discussed scenarios grows, the interoperability in Business-to-Business (B2B) middle-ware integrated with enterprise systems at different locations worldwide will be critical for success. Blockchain does not deliver interoperability by itself but depends on it. Hence, blockchain should maximize the use of existing applicable interoperability standards, e.g., Fast Healthcare Interoperability Resources (FHIR). The ability to transmit digital information freely among countries can be a constraint as well due to governmental regulations.

## CONCLUSION

So could blockchain help with the COVID-19 crisis? Definitely! While blockchain, like any technology, is not a solution itself, it can act as an enabler to the early detection of outbreaks through a network of connected nodes whose only purpose is to remain alert about outbreaks. Blockchain can also help in orchestrating transparent fast-tracking trials and efficient management to the medical supply chain and insurance claims processes.

The current COVID-19 crisis has highlighted blockchain potential in the healthcare domain more than before. Nevertheless, this review also demonstrated that there are challenges that still exist in utilizing blockchain systems in healthcare. These challenges should be considered as research opportunities.

Finally, Swan[20] presented seven technical challenges and limitations for the adaptation of blockchain in the future: 1) throughput; 2) latency; 3) size and bandwidth; 4) security; 5) usability; 6) wasted resources; and 7) versioning, hard forks, and multiple chains. We could find that the extracted studies in this review established an early discussion on the first five challenges, but we could not identify any discussion regarding wasted resources and versioning, hard forks, multiple chains in the current literature on blockchain for healthcare. This void area requires more research shortly.

## REFERENCES


1. A. M. Antonopoulos, *Mastering Bitcoin: Unlocking Digital Cryptocurrencies*. Newton, MA, USA: O'Reilly Media, Inc., 2014.
2. R. Kandaswamy and D. Furlonger, "Blockchain-based transformation: A gartner trend insight report," 2018. [Online]. Available: https://gtnr.it/2Y0SRmW.
3. M. Kassab, J. DeFranco, T. Malas, P. Laplante, V. V. G. Neto, and G. destefanis, "Exploring research in blockchain for healthcare and a roadmap for the future," *IEEE Trans. Emerg. Topics Comput.*, to be published, doi: 10.1109/TETC.2019.2936881.
4. *PennState Univ. Libraries*, 2020. [Online]. Available: https://psu.summon.serialssolutions.com/#!/
5. K. Petersen, R. Feldt, S. Mujtaba, and M. Mattsson, "Systematic mapping studies in software engineering," in *Proc. 12th Int. Conf. Eval. Assessment Softw. Eng.*, 2008, vol. 8, pp. 68–77.
6. S. Bhattacharya, A. Singh, and M. M. Hossain, "Strengthening public health surveillance through blockchain technology," *AIMS Public Health*, vol. 6, no. 3, 2019, Art. no. 326.
7. V. K. Chattu, A. Nanda, S. K. Chattu, S. M. Kadri, and A. W. Knight, "The emerging role of blockchain technology applications in routine disease surveillance systems to strengthen global health security," *Big Data Cogn. Comput.*, vol. 3, no. 2, 2019, Art. no. 25.
8. M. C. Chang and D. Park, "How can blockchain help people in the event of pandemics such as the COVID-19?," *J. Med. Syst.*, vol. 44, pp. 1–2, 2020.
9. L. Baird, M. Harmon, and P. Madsen, "Hedera: A public hashgraph network & governing council," *White Paper*, vol. 1, 2019.
10. *Marketing Technol. Insights*, "New survey reveals growing acceptance around COVID-19 contact tracing and exposure notification apps." Jun. 2020. [Online]. Available: http://tiny.cc/n47asz.
11. M. L. Anderson, K. Chiswell, E. D. Peterson, A. Tasneem, J. Topping, and R. M. Califf, "Compliance with results reporting at ClinicalTrials.gov," *New England J. Med.*, vol. 372, no. 11, pp. 1031–1039, 2015.
12. H. Li, L. Zhu, M. Shen, F. Gao, X. Tao, and S. Liu, "Blockchain-based data preservation system for medical data," *J. Med. Syst.*, vol. 42, no. 8, 2018, Art. no. 141.
13. T. K. Mackey and G. Nayyar, "A review of existing and emerging digital technologies to combat the global trade in fake medicines," *Expert Opinion Drug Safety*, vol. 16, no. 5, pp. 587–602, 2017.
14. A. Klotsche, "How blockchain could help manage PPE allocation," 2020. [Online]. Available: https://bit.ly/2QzRcBM. Accessed: Aug. 2020.
15. Coalition Against Insurance Fraud, 2021. [Online]. Available: https://insurancefraud.org/fraud-stats/
16. L. Zhou, L. Wang, and Y. Sun, "Mistore: A. blockchain-based medical insurance storage system," *J. Med. Syst.*, vol. 42, no. 8, 2018, Art. no. 149.
17. Access Partnership, "Digital contact tracing: A comparative global study," 2020. [Online]. Available: https://bit.ly/36MZnSH.
18. D. Dasgupta, J. M. Shrein, and K. D. Gupta, "A survey of blockchain from security perspective," *J. Bank. Financial Technol.*, vol. 3, no. 1, pp. 1–17, 2019.
19. S. L. Cichosz, M. N. Stausholm, T. Kronborg, P. Vestergaard, and O. Hejlesen, "How to use blockchain for diabetes health care data and access management: An operational concept," *J. Diabetes Sci. Technol.*, vol. 13, no. 2, pp. 248–253, 2018.
20. M. Swan, *Blockchain: Blueprint for a New Economy*. Sebastopol, CA, USA: O'Reilly Media, 2015.



**MOHAMAD HASSAN KASSAB** is currently Pennsylvania State University, Malvern, PA, USA. Contact him at muk36@psu.edu.

**VALDEMAR VICENTE GRACIANO NETO** is currently Universidade Federal de Goiás, Goiania, Brazil. Contact him at valdemarneto@ufg.br.

**GIUSEPPE DESTEFANIS** is currently Brunel University, Middlesex, Uxbridge, U.K. Contact him at giuseppe.destefanis@brunel.ac.uk.

**TAREK MALAS** is currently University of Laval, Quebec, QC, Canada. Contact him at tarek.malas@gmail.com.