

Blockchain Application in Contact Tracing Mobile Apps amidst COVID-19: An Exploration of Privacy Implications

Seyedmostafa Safavi
School of Technology
Asia Pacific University of
Technology and Innovation
Kuala Lumpur, Malaysia
seyed.safavi@apu.edu.my

Mohamed Abdulnabi
School of Technology
Asia Pacific University of
Technology and Innovation
Kuala Lumpur, Malaysia
mohamed.shabbir@apu.edu.my

Shahab Alizadeh
School of Technology
Asia Pacific University of
Technology and Innovation
Kuala Lumpur, Malaysia
shahab.alizadeh@apu.edu.my

Abstract—In the throes of the ongoing COVID-19 pandemic, digital solutions like contact tracing mobile applications have taken center stage in managing the spread of the virus. Nonetheless, the advent of these tools has sparked significant privacy concerns due to the sensitive data they handle. This paper presents an exploration of an innovative solution to mitigate these privacy challenges—the incorporation of blockchain technology into contact tracing mobile apps. With blockchain’s defining characteristics of decentralization, transparency, and immutability, it holds a unique proposition for balancing privacy concerns and maintaining the effectiveness of these contact tracing instruments. This paper critically examines various blockchain use-cases within these apps, scrutinizes their implications for user privacy, and offers a series of case studies that demonstrate their practical effectiveness. Our analysis indicates that, when implemented judiciously, blockchain technology can significantly elevate the privacy standards of contact tracing mobile apps, thereby promoting enhanced public trust and participation.

Index Terms—Blockchain Technology, Contact Tracing, COVID-19, Privacy Preservation, Data Security, Decentralization, Scalability, Health Informatics, Technological Adoption, Data Transparency

I. INTRODUCTION

As the world grapples with the unprecedented challenges presented by the COVID-19 pandemic, technological advancements have played a critical role in the response. One promising technology that has been widely adopted is contact tracing applications, which help monitor and control the spread of the virus. Among the several technologies utilized, blockchain, a form of Distributed Ledger Technology (DLT), has shown immense potential due to its unique properties of decentralization, immutability, and transparency [1]. These attributes make it a valuable tool in handling sensitive health data, where issues like privacy, reliability, and speed are of utmost importance. Blockchain-enhanced contact tracing applications offer potential improvements in privacy, efficiency, and accuracy in tracking the transmission of viruses. Traditional contact tracing often relies on labor-intensive and error-prone processes, whereas blockchain-based applications can automate and refine these methods, providing an expedited and precise tracing system. The decentralization feature of blockchain also safe-

guards user data privacy, addressing one of the major concerns - data security - associated with contact tracing applications. This article conducts an in-depth analysis of the integration of blockchain technology with contact tracing applications, specifically focusing on aspects such as privacy, efficiency enhancements, and tracing accuracy. A thorough literature review and comprehensive case studies are utilized to provide a well-rounded perspective on the current advancements and to identify potential challenges and solutions. In addition, the exploration extends to various scenarios and is used to comprehend the practical employment of blockchain in contact tracing applications. Our probe goes beyond privacy enhancement, exploring wider benefits blockchain can contribute to the public health domain, including increased efficiency and improved tracing accuracy. Our primary goal is to shed light on the extensive potential of blockchain technology in public health emergencies, particularly in the realm of contact tracing. As we continue grappling with the long-term impacts of the COVID-19 pandemic and gear up for possible future health crises, the exploration and adoption of innovative solutions that can strengthen our response capabilities become critical.

II. LITERATURE REVIEW

A. Background and Emerging Trends

Contact tracing is a longstanding concept used to curb the spread of infectious diseases. Nonetheless, the onset of the COVID-19 pandemic necessitated the development of more sophisticated, automated, and efficient contact tracing techniques. One such innovation is the fusion of contact tracing with mobile applications, designed to alert individuals when they’ve been near a person who has tested positive for the virus [2]. Simultaneously, blockchain technology has been making notable advancements across various sectors due to its unique attributes like immutability, decentralization, and transparency. Originally designed to support Bitcoin, blockchain has expanded beyond this initial application to offer diverse uses, including health information exchange, and supply chain management, among others [1], [3]. The current trend suggests an intersection of these two fields. Blockchain’s capability

to provide secure, transparent, and decentralized platforms makes it an appealing solution for handling privacy concerns often linked with contact tracing applications. Most importantly, the incorporation of blockchain into contact tracing apps potentially enhances the speed and accuracy of tracing processes, facilitating an efficient response to public health emergencies [4]. As underscored by Mishra, Raaj Anand, et al. [5], blockchain-based solutions for contact tracing have been proposed and implemented globally. These solutions range from decentralized apps ensuring user anonymity to advanced systems leveraging cutting-edge cryptography for secure information sharing. The following sections will delve into more specific case studies, demonstrating the use of blockchain in contact tracing applications across different contexts.

B. Interplay of Blockchain Technology with Contact Tracing Applications

The utilization of blockchain technology in contact tracing apps offers an innovative solution for preserving privacy and boosting efficiency and accuracy in tracking infectious diseases. This intersection signifies a paradigm shift from traditional contact tracing methods, which are often centralized, to a more decentralized approach, where users retain control over their data. Central to this intersection is blockchain technology's unique capacity to establish trust and transparency. Blockchain's immutable records and decentralized nature ensure that once a transaction (in this case, an encounter between individuals) is documented, it cannot be altered or deleted. This immutability brings a high degree of trust and transparency, which is crucial for maintaining accurate records of individual interactions during a pandemic [1]. Further, the deployment of blockchain in contact tracing can offer enhancements in privacy. By using blockchain, personal data can be decentralized, thereby empowering individuals. They can opt to share data only when necessary and remain anonymous otherwise [4]. This marks a significant improvement over traditional contact tracing methods, which often involve the collection and storage of personal data in centralized databases, prone to breaches and misuse [6]. Additionally, the integration of blockchain can also heighten the efficiency and accuracy of contact tracing. With its decentralized nature and the ability to automate processes via smart contracts, blockchain can refine the tracing process, reducing manual intervention and thus, increasing its speed and accuracy [3]. Furthermore, with blockchain, each interaction is time-stamped and accurately documented, thereby enhancing the reliability of the contact tracing data [1]. Despite the promising aspects of using blockchain in contact tracing apps, there exist challenges. The implementation of blockchain in this context requires addressing issues like scalability, technical complexity, and the need for widespread adoption to reach its full potential. These challenges and possible strategies to overcome them will be discussed in the subsequent sections of this paper.

1) Advantages and Challenges of Blockchain in Contact Tracing : The integration of blockchain into contact tracing

apps presents numerous benefits, along with a set of challenges that need resolution for successful implementation. **Advantages** The most notable advantage of employing blockchain technology in contact tracing applications is the preservation of privacy. Traditional contact tracing methods often involve storing personal data in centralized databases, potentially rendering them vulnerable to data breaches or misuse. Conversely, the decentralized nature of blockchain allows for greater data privacy, with individuals retaining control over their data [4]. Blockchain can ensure that users share data only when necessary and stay anonymous otherwise [6]. Blockchain also brings transparency and trust. The immutable and transparent characteristics of blockchain technology can foster a high level of trust in the data stored in the chain. This trust is critical during a pandemic when data accuracy and reliability are paramount [1]. Finally, the use of blockchain in contact tracing applications can lead to improved efficiency and accuracy. The automation of processes via smart contracts can streamline the tracing process, reducing manual intervention and thus enhancing the speed and accuracy of contact tracing efforts [3]. **Challenges** Despite these benefits, several challenges need to be addressed. The technical complexity associated with implementing blockchain technology can be a hurdle, especially for those unfamiliar with the technology. This complexity might hinder the widespread adoption [7]. Additionally, scalability is another concern. Blockchain technology, especially public blockchains, can be slow and resource intensive. If the number of transactions (in this case, individual contacts) increases dramatically, it might lead to issues with scalability [7]. Moreover, widespread adoption is essential for the success of blockchain-based contact tracing apps. Unless a significant number of people use the app, its effectiveness in tracing contacts and slowing the spread of the virus is limited [5], [8].

C. Privacy Implications of Blockchain in Contact Tracing Apps.

Despite the potential benefits of integrating blockchain into contact tracing apps, it is crucial to thoroughly examine its privacy implications. The first consideration revolves around the pseudonymous nature of blockchain. Each transaction can be traced back to a unique identifier, but establishing a link between this identifier and an individual requires additional information [9]. This pseudonymity can preserve a level of user privacy. Nonetheless, if a link between the identifier and an individual is established, either through poor app design or other data leaks, it could compromise user privacy. In this context, the transparency of the blockchain, while advantageous for data accountability, could become a vulnerability. Secondly, the immutability of data on a blockchain, while crucial for ensuring data integrity and trust, poses a challenge to privacy rights such as the right to be forgotten. This right is a central pillar of privacy regulations like the GDPR (General Data Protection Regulation) in the European Union [10]. Fulfilling this regulation, which allows individuals the right to request the deletion of their personal data, is challenging given

the permanent records on a blockchain. Thirdly, although the decentralization of blockchain eliminates single-point failures and reduces the risk of data breaches, it introduces regulatory challenges. The enforcement of privacy laws can become complex in such a decentralized system due to jurisdictional issues. Reconciling differing privacy requirements of various regulatory bodies in a globally distributed, decentralized system can be intricate [11]. In addition, as blockchain technology evolves, so do the potential attacks against its security, and consequently, privacy. While blockchain has demonstrated resilience against traditional cyber threats, novel attacks tailored to its unique structure and technology are emerging [12]. As such, continuous research and advancements are required to protect privacy while leveraging the benefits of blockchain in contact tracing apps. Finally, public perception and trust in the privacy of blockchain technology can influence its adoption in contact tracing apps. Despite the technical privacy features of blockchain, misconceptions or a lack of understanding about the technology can deter users from using these apps, thereby undermining their effectiveness [7].

To further elucidate the challenges of blockchain adoption, let's consider a healthcare scenario. While blockchain can secure patient data, integrating it with existing Electronic Health Record (EHR) systems is complex and costly. Regarding privacy, a specific example would be the use of blockchain in contact tracing apps. While the decentralized nature ensures data privacy, if not properly designed, metadata could reveal a user's identity.

III. RESEARCH APPROACH

This study adopts a qualitative and interpretive methodological approach, investigating the interplay between blockchain technology and contact tracing applications in the backdrop of the COVID-19 pandemic. The main research method is grounded in a systematic and comprehensive literature review. The chosen literature spans a wide array of sources, including academic journals, scientific articles, technical reports, case studies, and industry publications. In this literature review, we begin by laying a solid groundwork on the fundamentals of blockchain technology and its integration with contact tracing applications. Our aim is to offer a clear understanding of the technological components and principals involved. As part of this, we provide a comprehensive exposition of how blockchain technology functions, focusing particularly on its distinct attributes of decentralization, immutability, and transparency. Following this, we delve into the fusion of blockchain technology and contact tracing applications, investigating the potential advantages and difficulties of utilizing blockchain technology in this specific field. The scope of this part of the review isn't confined to privacy issues, but also includes the potential to enhance efficiency and accuracy in contact tracing. A crucial aspect of our research approach includes case studies drawn from a variety of contexts. We closely examine different practical applications of blockchain in contact tracing, scrutinizing the technical facets and evaluating the effectiveness of these applications in real-life scenarios. The selection of these

case studies hinges on their pertinence, scalability, and their achievement in meeting the goals of privacy, efficiency, and accuracy. In addition to evaluating the current state-of-the-art, the research also aims to identify and propose strategies to tackle potential challenges, leveraging insights from the case studies and existing literature. The research concludes with a consolidated analysis of the potential of blockchain technology in contact tracing applications for managing future disease outbreaks, based on the insights from the literature review and case studies.

IV. CASE STUDIES

Several global initiatives have started exploring the usage of blockchain technology in contact tracing applications. This section analyzes two significant examples.

A. COVI-ID (South Africa)

COVI-ID, developed in South Africa, uses self-sovereign identity (SSI) and blockchain technology to address privacy concerns in contact tracing [13]. Users control their data, and personal information isn't stored on a central server but kept on the user's device. A unique QR code tied to a blockchain entry is created for each user interaction, ensuring a high level of privacy while still enabling effective contact tracing. The system is acclaimed for its innovative approach to preserving privacy and its potential applicability beyond the pandemic.

B. TraceSafe (Canada)

Canadian enterprise TraceSafe has developed privacy-focused contact tracing solutions using blockchain technology [14]. The company's wristbands, used in settings like workplaces and cruise ships, use blockchain to securely store contact event data. The system's emphasis on privacy and security, along with its user-friendly wearable technology, has led to successful deployments in various industries and countries. Both cases, however, spotlight challenges in implementing blockchain-based contact tracing. Despite the privacy benefits, user adoption may be hampered by a lack of understanding or trust in the technology. Moreover, interoperability between different systems and compliance with various international privacy regulations remain ongoing challenges.

C. COVID-19 Credentials Initiative (CCI)

CCI is a global, cross-sector community developing digital solutions to address COVID-19. CCI uses decentralized identity (DID) and verifiable credentials technologies to create privacy-preserving verifiable health credentials, including blockchain [15]. CCI's solution maintains privacy by letting individuals prove their health status through a digital certificate without disclosing other personal information.

D. Decentralized Privacy-Preserving Proximity Tracing (DP-3T)

DP-3T, created by a group of European researchers, is a decentralized contact tracing solution designed to minimize privacy risks while ensuring an effective contact tracing [16]. Rather than a central server, ephemeral identifiers of contacts

are stored locally on users' devices. If a user is diagnosed with COVID-19, they can choose to upload their identifiers to a server. Other users can then cross-check these identifiers against their own list, preserving privacy while still enabling at-risk individuals to be notified. The blockchain is used to ensure the integrity of the uploaded identifiers.

V. DISCUSSION

While our discussion has primarily focused on the immediate challenges and solutions related to blockchain in contact tracing, it's crucial to zoom out and consider the broader implications. The adoption of blockchain in public health isn't just a technological upgrade; it's a paradigm shift that could redefine how we approach data privacy and security in healthcare. Moreover, the learnings from this could serve as a blueprint for adopting other emerging technologies in public health, thereby accelerating digital transformation in this critical sector. The intersection of blockchain technology and contact tracing applications for managing the COVID-19 pandemic reveals both significant opportunities and challenges. The introduction of blockchain into these applications offers improvements in privacy preservation, transparency, and the efficiency and accuracy of the tracing process. At the same time, the challenges of technical complexity, scalability, and the necessity of widespread adoption should not be overlooked. Privacy preservation emerges as a crucial benefit when implementing blockchain in contact tracing. The capability to give individuals control over their data while maintaining the essential functionality of contact tracing is a significant step toward addressing privacy concerns [4]. Nevertheless, ensuring users fully understand these privacy enhancements and trust the system remains a challenge. It underscores the importance of public education about blockchain technology and transparency about how personal data is used and protected. The potential of blockchain to improve efficiency and accuracy in contact tracing is notable. Reducing manual intervention through the automation of processes and having a reliable record of interactions can speed up the tracing process and enhance its accuracy [3]. Nonetheless, to leverage these benefits fully, overcoming technical complexities is essential. Streamlining the user experience and providing user-friendly interfaces could enhance the acceptance and use of blockchain-based contact tracing apps. Scalability remains a critical concern in the context of blockchain-based contact tracing. Blockchain solutions need to be designed to handle the high volume of transactions (interactions between individuals) in a scalable way, ensuring quick and reliable tracing [7]. It is important to explore different types of blockchains, like private or hybrid models, that may offer a solution to these scalability issues. Lastly, for the system to be effective, widespread adoption is necessary. Strategies should be developed to encourage users to download and use these apps. This may include public education campaigns, incentives, or regulations [5]. To sum up, despite blockchain's capacity to offer inventive solutions to many challenges associated with conventional

contact tracing methods, its effective integration necessitates tackling the highlighted issues.

A. Long-term Viability of Blockchain Solutions in Contact Tracing

The COVID-19 pandemic has demonstrated the critical role of contact tracing in managing public health crises. Blockchain has emerged as a valuable tool in this endeavor, offering a decentralized, secure approach that respects user privacy. Nonetheless, the utility of blockchain isn't confined to the current pandemic. Looking ahead, the technology can be adapted to manage other infectious diseases like flu or tuberculosis. In essence, blockchain offers a sustainable, long-term solution for public health challenges, well beyond the pandemic era.

CONCLUSION

To elucidate the importance of blockchain technology within the realm of contact tracing, one may engage in a comparative analysis with alternative methodologies such as centralized databases. Centralized data repositories offer the advantage of ease of implementation; however, they present substantial vulnerabilities in terms of data privacy due to the unifocal storage of information. In contrast, blockchain employs a decentralized architecture that amplifies data security. This comes at the cost of introducing issues related to scalability and system complexity.

The global health crisis caused by COVID-19 has emphasized the crucial role that effective contact tracing plays in mitigating the spread of infectious diseases. The adoption of technology, in particular mobile applications, has ushered in novel possibilities for contact tracing. Nonetheless, this has also brought about substantial concerns regarding privacy. The capability of blockchain technology to alleviate these privacy concerns, while providing added benefits like efficiency and accuracy enhancements, represents a promising area of research.

Throughout this paper, we have navigated the overlap between blockchain technology and contact tracing apps, given an overview of current trends, and spotlighted some particularly noteworthy case studies. We discussed the primary advantages of employing blockchain within contact tracing applications, which include bolstered privacy, transparency, and operational efficiency. Yet, the use of blockchain technology in the realm of contact tracing is not free from challenges. Obstacles such as technical intricacy, scalability, and the need for broad adoption must be surmounted to achieve successful integration. Possible solutions could comprise the creation of user-friendly interfaces, the use of private or hybrid blockchain models to circumvent scalability issues, and the establishment of strategies that encourage widespread adoption. In essence, the integration of blockchain technology within contact tracing applications represents a promising pathway toward improving privacy preservation and process efficiency. Future research and practical implementations should concentrate on address-

ing the pinpointed challenges, to fully harness the potential of blockchain in this crucial public health instrument.

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