

Blockchain Tracking System of COVID-19 Vaccination

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ABSTRACT

Ever since the spread of COVID-19 pandemic, the entire pharmaceutical industry responded to the outbreak with combined efforts to develop a reliable vaccine. Currently there are six major manufacturers of COVID-19 vaccinations, Pfizer-BioNTech, Moderna, Johnson & Johnson, Astrazeneca, Sputnik and Sinopharm. The global vaccination campaign started in early December of 2020. On April 19, 2021, more than 905 million vaccine doses were administered worldwide. Because most vaccines needed more than one does to provide adequate protection, and some vaccine types were paused due to potential health risks, an imbalance in the distribution of vaccines among the general population and discrepancy in the vaccination records occurred. The answer to this problem lies in the implementation of a Blockchain vaccination tracking system. This shall provide a reliable solution that shall help governments track the vaccination process and keep accurate, authentic records. A Blockchain system shall provide authentic data about the number of people vaccinated and how many doses each of them received, and the exact date and time of each does. The Blockchain system shall facilitate the shipping, management, and delivery of the COVID-19 vaccine and shall help countries learn, and make decisions on how to plan and manage the vaccination process. In this paper, we propose the development of a Blockchain vaccination tracking system to enable governments deliver COVID-19 vaccine to its citizens effectively and efficiently.

Keywords

Blockchain, COVID-19, vaccination, healthcare

Introduction

The end of 2019 witnessed the outbreak of COVID-19 on a global scale. By March of 2020, the World Health Organization (WHO) labeled COVID-19 a pandemic. COVID-19 transmission rate was very high and worrying in all countries [23]. The number of new cases escalated on a daily basis and spread all over the world. Infection rates was reaching a record high and lead to a large death rates. Countries started to impose lockdowns and curfews for the first time in decades. The WHO started campaigns to educate people about the importance of social distancing and the wearing masks in public places. On a parallel track, scientists began studying the virus and looking for a reliable cure, but their efforts resulted in no success.

Pharmaceutical companies geared its research and development efforts to develop an effective vaccine to tackle the virus [22]. They were under large pressure, and their time schedule was very tight, since there were thousands of new cases and hundreds of deaths on a daily basis. Eventually and after several trials, major pharmaceutical companies developed several vaccines. Pfizer-BioNTech, Moderna were among the first to develop the COVID-19 vaccine.

Countries started contracting with major suppliers and vaccine developers to secure the right amount of vaccinations for their populations [17]. The vaccination process in still ongoing until this point in time, however the supply is limited with shortages for many under developed countries, which rely on funding, donors and support from global organizations.

Each country used its own vaccine administration system. Some systems were manual, and some used mobile applications, to register for the delivery of each dose. These systems did not intend to provide detailed reports to governments about the actual number of people that took the vaccine, how many of them is waiting in line for their next dose, and how many doses were scraped or destroyed [22]. Additionally, side effects data were not recorded, and there is no reliable information provided by the existing vaccination systems. Current systems provide flawed and inadequate data for decision makers to plan for the ordering and the delivery of vaccines.

Therefore, the introduction of a Blockchain COVID-19 vaccination tracking system that provides accurate and verified information for decision makers becomes very crucial [1]. Blockchain is a new internet based technology described as a digitized and a decentralized, public ledger of all transactions. It is growing constantly in the form of blocks residing on decentralized servers all over the internet or World Wide Web [4]. Every transaction is recorded and in a chronological order. Blockchain advantage is the ability to follow and keep track of all recorded transactions which is replicated across hundreds of thousands of Blockchain servers distributed and connected all over the Internet [3]. Blockchain servers or nodes receive a copy of each transaction and updated automatically. The decentralized nature of the Blockchain platform make it a tamperproof system, leading to authentication of each transaction [22, 24]. Blockchain transactions are encrypted using hash-256 code and deposited in the Blockchain, making it impossible to alter the content of deposited timestamped transactions [2]. Confirmed transactions mean that each transaction have been replicated across a large number of nodes, making it even more impossible to delete or update its content.

This paper propose the development of a Blockchain vaccination tracking system, a system designed to provides confidentiality and trust in the data collection and reporting throughout the vaccination process [10]. Such a tracking system is a priority, since many of the currently used systems do not provide trusted, secured, and accurate data for decision makers, and does not guarantee or preserve the privacy of those vaccinated.

Literature Review

This literature review provide background information related to the COVID-19 pandemic vaccination process, and we explain the importance of adopting Blockchain technology in tracking and documenting this process.

COVID-19 Vaccination

COVID-19 global vaccination campaign started in early December of 2020. On April 19, 2021, more than 905 million vaccine doses were administered worldwide [24, 25]. Because most vaccines needed more than one dose to provide adequate protection, and some vaccine types were paused due to potential health risks, an imbalance in the distribution of vaccines among the general population and discrepancy in the vaccination records occurred.

Vaccines help the body to build immunity against the Corona Virus [26]. The vaccination process involves administering the vaccine to humans. The process is safe and simple provided that it provides adequate immunity against COVID-19 [23]. Vaccines help the body build a self-defense

system within the body itself to protect it against future infections. It makes people's immune system prepared to defend itself against the disease. When a body receives the vaccine, it may need following booster shots to build immunity and to keep the immune system prepared for future outbreaks.

There are different types of COVID-19 vaccines. Currently there are six major manufacturers of COVID-19 vaccinations, Pfizer-BioNTech, Moderna, Johnson & Johnson, AstraZeneca, Sputnik and Sinopharm [22]. The supply of each vaccine depends on the manufacturing capacity and demand for each one of them. All available vaccines need shots scheduled three weeks in between except Johnson & Johnson, which requires only single shot.

Each country handles the vaccination process in a different manner, based on the availability of the vaccines and the number of its population. Managing the vaccination process includes a stream flow of activities to insure efficient and reliable process [15]. The process starts with setting an appointment to the person receiving the vaccine and ends with that person receiving his final shot. Some countries issue a certificate of vaccination at the end of the process.

Eligibility for vaccination also plays a crucial role in deciding who takes the vaccine first. Elderly people and people working in the health care, law enforcement, and education sectors are given priorities in most countries [11]. Although it may sound simple, the process is interrupted by several factors ranging from people being sick on the vaccination day, to people refusing to take certain types of vaccines. Such factors make it imperative to re-sequence the vaccination timetable and create discrepancies in the vaccination data.

Vaccination tracking and side effects reporting is also an important aspect of the vaccination process. It starts immediately after the first shot is delivered, and keeps on going until the vaccination body decides no more data is needed from vaccinated people.

A national deployment vaccination plan should incorporate a reliable tracking and reporting system. It follows the vaccination process from start to end and keeps side effects data for future reference. This plan should include the vaccination strategy and the means used to track and monitor the entire process. The deployment of an advanced information system is needed to track and report immunization data. According to the WHO "Each country's NDVP should be developed through a consultative process, led by the country's Ministry of Health and supported by other organizations, including WHO, UNICEF and other relevant partners, to fine-tune the plan until it is complete" [22].

Blockchain research

Blockchain stores information across a network of personal computers making them not just decentralized but distributed. This means no central company or person owns the system. Yet everyone can use it and help run it [8]. This is important because it means it is difficult for any one person to take down the network or corrupt its content. The people, who run the system, use their computers to hold bundles of records submitted by others, known as blocks in a chronological chain [12,13]. The Blockchain uses a form of math called cryptography to ensure that records cannot become counterfeited or hacked by anyone else.

A Blockchain is a chain of blocks that contains information [7, 16]. This technique was originally described in 1991 by a group of researchers and was originally intended to timestamp digital documents so that it is not possible to backdate them or to tamper with them almost like a notary. However, it went by mostly unused until Satoshi Nakamoto adapted it in 2009 to create the digital cryptocurrency Bitcoin [21].

Blockchain main logic is to have digital information distributed and not copied forming a new era of the internet, and sometimes industry experts call it Web 3.0. A Blockchain is a distributed ledger that is completely open to anyone. They have an interesting property, once data have been recorded inside the Blockchain; it becomes very difficult to alter or change if not impossible.

Proposed Blockchain Vaccination Tracking System

Blockchain proved to be a reliable technology used for authentication and verification. We propose a Blockchain vaccination tracking system that is secure and allows people to retain ownership over their own data while allowing health care authorities to have full and easy access (see Figure 1) to the vaccination data. The system built on smart contract and public ledger technology, provides a reliable means for tracking the vaccination process without disclosing people identities or private information.

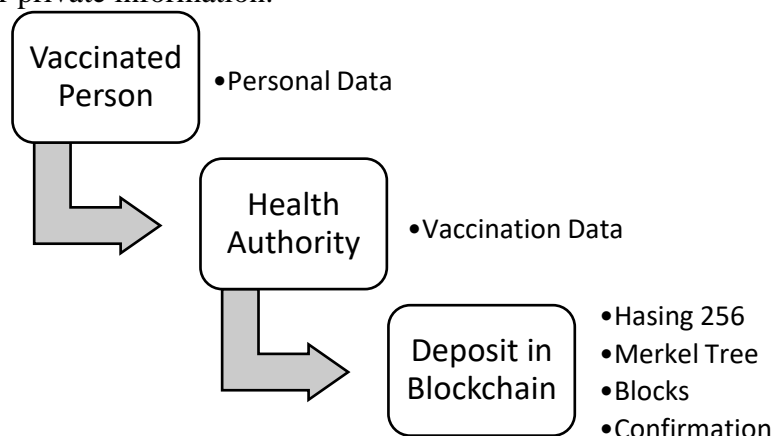


Figure 1. Overview of aproposed Blockchain Vaccination Tracking System

The system collects vaccination data online through a dedicated application available on mobile devices and smart boards. Our proposed system designed based on both Ethereum and Bitcoin services. Third party system that process the creation of each transaction and storing it in the Blockchain is needed to expedite the development process [17]. Each vaccination record is assigned a unique hash generated at the beginning of the vaccination transaction and the hash is then deposited in the Blockchain. Data is encrypted so that Blockchain records are kept private and secured. Thus, the root chunks are securely stored in smart contracts through the Blockchain, and released only under specific conditions.

Hashing

The proposed system uses Blockchain technology to provide a tamper-proof timestamp irrefutably proving the existence of the vaccination transaction [18]. The system encrypt the

transaction into a secure hash, which is, a number generated from the vaccination data as shown below:

```
sha256("COVID-19 Vaccination") =  
9980dce6b96ee0790bb87357f7a0cf3207a8f51e49d62ee08eade3b038ea8e8b
```

The generated hash is deposited in the Blockchain and a timestamp is created for the transaction. It is impossible for the hash to be converted back to its original form (data that was encrypted), it is just impossible to do that realistically [6, 19].

To explain the process, simply let calculate the hash for the sum of number 71, being 8. This sum may also result from adding 62, 53 and 44, therefore it is impossible to reconstruct 71 by reverse engineering. We cannot tell what numbers were added up to 8 if you only know the result.

$\text{digitsum}(71) = 7+1 = 8$

$\text{digitsum}(62) = 6+2 = 8$

$\text{digitsum}(53) = 5+3 = 8$

$\text{digitsum}(44) = 4+4 = 8$

Therefore, it is impossible to know what is the number used to calculate the hash; however, the hash is "unique" for each number used in calculating the hash:

```
sha256(71) = 7f2253d7e228b22a08bda1f09c516f6fead81df6536eb02fa991a34bb38d9be8
```

```
sha256(62) = 81b8a03f97e8787c53fe1a86bda042b6f0de9b0ec9c09357e107c99ba4d6948a
```

```
sha256(53) = 2858dcd1057d3eae7f7d5f782167e24b61153c01551450a628cee722509f6529
```

```
sha256(44) = 71ee45a3c0db9a9865f7313dd3372cf60dca6479d46261f3542eb9346e4a04d6
```

The hash code is calculated locally on the client machine for confidentiality and is kept on the local server [20]. The generated hash is then deposited in a Blockchain transaction and a timestamp is created for each transaction [27]. This time stamp can be used for verification of the time date the transaction was used and it is linked back to the vaccination data through the hash code.

Blockchain technology

Generating a time stamp from the hash is where the Blockchain technology come into play. The Blockchain is a digital chain of blocks, each block contains transactions, this where hash is encoded into a timestamp [14]. The Blockchain works by linking blocks together, each block depends on its predecessor in a way such that any attempt to change or alter the content of any transaction is impossible [9]. The next step in the Blockchain is confirmation of blocks using several concepts including (Proof of Work and Proof of Stake). This is where Blockchain stake holder are rewarded with digital tokens for investing time, computational energy to preserve the Blockchain in a stable agreed upon state.

Hash to private key

The final step in the proposed system handles how to insert the vaccination transaction hash into a Blockchain block. To be able to do that, we need to create a private key from the vaccination-

generated hash, and a transaction involving the generated public key is then submitted to the Blockchain [5, 8]. This takes us to a reliable tamper proof chain of the original vaccination data to a tamper-proof timestamp generated and preserved in the Blockchain:

- 1- Generate the hash for the vaccination data
- 2- Aggregate the vaccination hash and many others generated hashes through a Merkle Tree into a new aggregated hash (to lower the costs of the transaction)
- 3- Generate a private key from that aggregated vaccination hash, and from that a public key / address.
- 4- Submit a transaction involving this public key / address
- 5- Once the transaction is confirmed by the Blockchain network, which usually needs about an hour, the vaccination timestamp is irrevocably embedded in the Blockchain

Discussions

Since the COVID-19 pandemic is a new issue. There are no prior literature covering this domain. Some Blockchain applications have been in use in limited areas of the supply chain systems in the health care field, but none has explained the importance of Blockchain-based healthcare solutions use in the vaccination of large number of populations. Governments and healthcare organizations can use the proposed system to improve streamline of the vaccination process to tackle the existing COVID-19 pandemic.

Our proposed Blockchain vaccination tracking system shall preserve and deposit vaccination data in the Blockchain a secure private manner. The system help health care agencies to record and track the number of vaccination scheduled, delivered, and the any possible side effects that each type of vaccine may have on the general population.

This research has the potential to make a significant impact on governments and healthcare agencies through presenting the importance of deploying a Blockchain vaccination tracking system. Governments and healthcare agencies shall appreciate the use of the Blockchain technology to assist in tracking and monitoring of the COVID-19 vaccination process. The implementation of Blockchain vaccination tracking system will facilitate communication in real time, identify any issues during vaccination, and allow for better efficiency in the use of limited resources. The implementation of Blockchain to vaccination process in health care can help track each step of the vaccination process from procurement of the vaccine to the delivery to the recipient. The major advantage of using Blockchain technology are: improved assistance in scheduling vaccination appointments, improved assistance in tracking vaccinations and vaccinated people, improved overall vaccination productivity and efficiency.

Conclusion

In this paper, we introduced a Blockchain-based tracking system for tracking, and monitoring COVID-19 vaccination records. The proposed Blockchain-based solution promotes trust, transparency, and traceability. It also streamlines the communication between stakeholders. Research about Blockchain's applications in healthcare is currently limited; however, more research becomes available every day. Our presented system addresses the problems governments and health care organizations is facing in the current pandemic. The system

provides a reliable solution that shall help governments track the vaccination process and keep accurate, authentic records. A Blockchain system shall provide authentic data about the number of people vaccinated and how many doses each of them received, and the exact date and time of each does. The Blockchain system shall facilitate the shipping, management, and delivery of the COVID-19 vaccine and shall help countries learn, and make decisions on how to plan and manage the vaccination process. In this paper, we propose the development of a Blockchain vaccination tracking system to enable governments deliver COVID-19 vaccine to its citizens effectively and efficiently.

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