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IMMUNIZATION SCHEDULE USING BLOCKCHAIN TECHNOLOGY – A PROTOTYPE DEVELOPMENT APPROACH

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Abstract

Immunization plays a vital role in safeguarding public health by preventing the spread of infectious diseases. Effective immunization programs require accurate scheduling, tracking, and monitoring of vaccinations. However, traditional immunization systems often encounter challenges such as data inconsistencies, privacy concerns, and inefficient communication among stakeholders. To address these issues, this abstract proposes an immunization scheduling system utilizing blockchain technology. Blockchain technology, known for its decentralized and immutable nature, can provide a secure and transparent platform for managing immunization records. The system leverages blockchain's key features, including data immutability, consensus mechanisms, and smart contracts, to ensure the integrity, privacy, and efficiency of immunization scheduling. The immunization scheduling system is kick stared by creating a distributed network of nodes, including healthcare providers, immunization centers, and individuals. Each participant has a unique digital identity stored on the blockchain, allowing for secure access to their

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Immunization, Blockchain technology, hyperledger fabric, data immutability, data inconsistencies, Smart contracts, cryptographic keys

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immunization records. Smart contracts are utilized to define rules and automate processes, such as appointment scheduling, reminders, and vaccine administration. Immunization records are stored as encrypted transactions on the blockchain, ensuring data integrity and privacy. Access to these records is granted through cryptographic keys, giving individuals control over their personal information while maintaining a comprehensive and up to-date repository for healthcare providers. It is hoped that a production grade immunization schedule powered by blockchain technology would be adopted in the nearest future.

INTRODUCTION

Immunization is one of the most effective methods to prevent the outbreak and spread of infectious diseases. However, keeping track of immunization schedules and records can be challenging. In society of today where the filing system is still obtainable and most have moved to a centralized medium of storage, you come across issues like file not be found, system downtime ("Chapter 8: Record Keeping and Documentation," 2021). Immunization schedules play a critical role in safeguarding public health by ensuring timely and appropriate vaccinations for individuals of all ages. Blockchain technology is one of the emerging technologies of the present-day world. Distributed ledger, Reliability and Immutability are among the core properties of Blockchain (Arsheen & Ahmad, 2022). Blockchain technology offers a solution to the problem of missing files caused by human error or file record not available due to system downtime by providing a secure and unalterable record-keeping system (Deka et al., 2020). Blockchain enable a community of users to record transactions in a shared ledger within that community, such that under normal operation of the blockchain network, no transaction can be changed once published (Yaga et al., 2019). The traditional approach to immunization schedule is prone to breaches and data tampering since it relies heavily on centralized database. A number of studies have proposed different use cases for the application of blockchain in healthcare; however, there is a lack of adequate prototype implementations and studies to characterize the effectiveness of these proposed use cases (Agbo et al., 2019a). This paper explores how blockchain technology can be used to improve the management and tracking of immunization schedules. The use of blockchain technology in the proposed system offers several advantages. First, it enhances data accuracy and eliminates inconsistencies by creating a single source of truth

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accessible to all authorized parties. Second, it strengthens data privacy through encryption and decentralized storage, reducing the risk of unauthorized access or data breaches. Third, it enables real-time communication and coordination among stakeholders, improving the efficiency of immunization scheduling and ensuring timely administration of vaccines.

This paper is organized in the following section: Section II presents related work that has been done involving blockchain technology either in the health – related field or any other field. Section III presents the methodology used to undertake this study. Section IV conclude the study.

RELATED WORKS

The growth in the use of blockchain technology in healthcare is remarkable and has a significant impact on the healthcare industry (Hussien et al., 2021). Lots of research has highlighted the potential of blockchain technology in healthcare applications, including electronic health records (EHRs) and medical supply chain management. In the context of immunization, several studies have explored digital solutions for record-keeping, yet few have leveraged blockchain's unique features. Notable projects, such as MediLedger and Guardtime, have demonstrated the viability of blockchain in ensuring data integrity and provenance in healthcare settings (Medina et al., 2023; Nabil et al., 2022; Razzaq et al., 2022).

Blockchain popular use case in healthcare is the management of electronic medical records (EMRs). EMRs, are sometimes used synonymously with electronic health records (EHRs) or personal health records (PHRs). It has to do with the electronic creation, storage and management of patients' personal, medical or health-related data. Blockchain's property of decentralization, immutability, data provenance, reliability, robustness, the smart contracts, security and privacy are being canvassed as the features that make it very suitable for storage and management of patients' electronic medical records (EMR) (Kuo et al., 2017; Liu et al., 2017; Radanović & Likić, 2018).

In (Engelhardt, 2017), the author discusses the Medicalchain project, whose blockchain-based platform will facilitate the sharing of patients' medical records across international healthcare institutions, and the Healthcoin initiative, which aims at constructing a global EMR system.

In a study by (Ahram et al., 2017) a healthcare industry application called "Healthchain", was formalized and developed on the foundation of Blockchain using IBM Blockchain initiative. The concepts are transferable to a wide range of

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industries as finance, government and manufacturing where security, scalability and efficiency must be met. According to (Androulaki et al., 2018) the modular architecture of Hyperledger Fabric enables HealthChain to achieve health data confidentiality, scalability and security. HealthChain also incorporates chaincodes (smart contracts) that control authorizations and access privileges on the blockchain network.

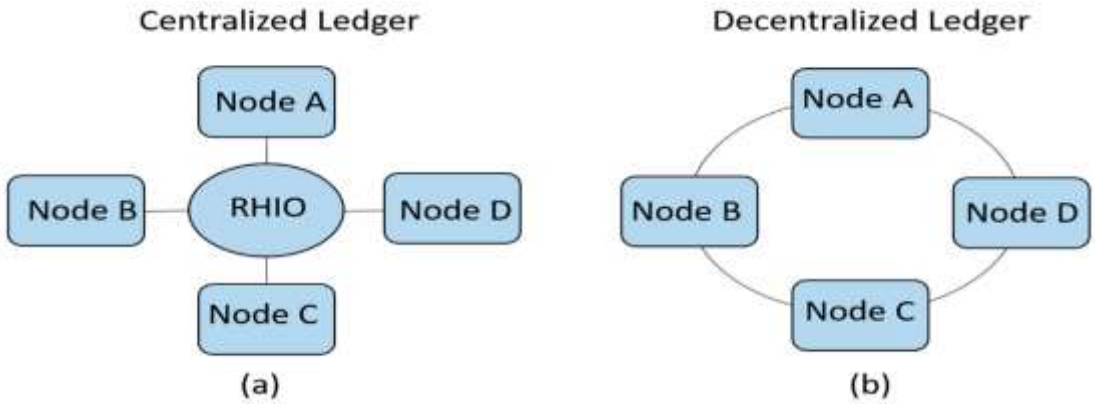

Figure 1: Decentralized nature of Blockchain *(Agbo et al., 2019b)*

METHODOLOGY

For this study, a simple prototype which is the goal of this study was developed. The development consists of the following:

- Hyperledger Fabric Networks
- Smart Contracts
- Client Application.

Hyperledger Fabric Networks

Hyperledger Fabric is an open-source, modular blockchain framework and de facto standard for enterprise blockchain platforms. It is intended as a foundation for developing enterprise-grade applications and industry solutions, with a highly secure, modular, interoperable, and crypto-agnostic architecture. Hyperledger Fabric is built to support enterprise-grade use cases and can support quick transaction throughput from its consensus mechanism.

Setting up a Hyperledger Fabric network requires careful planning, configuration, and deployment. It's a complex task that typically involves several steps. For this study, a network with one organization, one peer, and one channel was created.

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The steps below set up a Hyperledger network; one is always advised to visit the documentation page of Hyperledger[1]. The prerequisites on the system used are:

- Docker: Ensure you have Docker installed and running on your system.
- Docker Compose: Install Docker Compose, as it's used to define and run multi-container Docker applications.
- Hyperledger Fabric Samples: Download the Hyperledger Fabric samples repository from GitHub.
- Ability to run bash code

Step 1: Generate Network Artifacts

In the Fabric samples folder, navigate to the first-network directory:

```
cd fabric-samples/first-network
```

Generate the network artifacts (crypto-material, genesis block, etc.):

```
./byfn.sh generate
```

Step 2: Start the Network

```
./byfn.sh up
```

This command will bring up the network with one organization, one peer, and one channel.

Step 3: Interact with the Network

Create a channel:

```
./byfn.sh createChannel
```

Join the peer to the channel:

```
./byfn.sh joinChannel
```

1 https://hyperledger-fabric.readthedocs.io/en/release-1.2/network/network.html

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Install and instantiate a sample chaincode on the peer:

```
./byfn.sh deployCC
```

This step deploys the simple chaincode that increments a counter.

Step 4: Interact with the Chaincode

To query the counter value:

```
./byfn.sh query
```

To invoke a transaction:

```
./byfn.sh invoke
```

For a case where we have to deploy to production, much work would still need to be done such as, customizing the network, defining our own chaincode, and possibly setting up multiple organizations, channels, and peers. Likewise, implementing a Membership Service Provider (MSP) and Certificate Authority (CA) for identity management. In production, there might also be a need to integrate with external systems and applications using SDKs in any preferred programming language.

Smart Contract

A smart contract is a computer protocol that runs automatically when the prerequisites are met, and it is an entity separate from the original blockchain technology. The smart contract was adopted as a key function of Blockchain 2.0, expanding the application of blockchain technology beyond cryptocurrency, such as Bitcoin of Blockchain 1.0 (Kuo et al., 2017).

A smart contract is a self-executing digital contract with the terms and conditions directly written into code. It's stored and executed on a blockchain, which ensures that the contract is automatically enforced without the need for intermediaries. Smart contracts have gained significant popularity and are a foundational technology for various blockchain platforms, including Ethereum, Binance Smart Chain, and Hyperledger Fabric, among others. They enable the automation of various processes and have the potential to revolutionize many industries by

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reducing the need for intermediaries and increasing the efficiency of transactions and agreements. A smart contract can be written in any programming language depending on the blockchain platform one is working with. Since this study is using Hyperledger Fabric, the smart contract was written in Golang (Go). Other languages used for the Hyperledger Fabric are Java and JavaScript.

```go
package main

import (
    "fmt"

    "github.com/hyperledger/fabric-contract-api-go/contractapi"
)

// SimpleCounterContract is a basic smart contract for managing a counter.
type SimpleCounterContract struct {
    contractapi.Contract
}

// Counter represents the state of the counter.
type Counter struct {
    Value int `json:"value"`
}

// Increment increments the counter value by a specified amount.
func (cc *SimpleCounterContract) Increment(ctx contractapi.TransactionContex
    existingCounter, err := cc.Query(ctx)
    if err != nil {
```

Figure 2: Code Snippet from the Smart Contract written in Go.

In the source code for the smart contract, we define a struct 'SimpleCounterContract' that implements the Contract interface provided by the Hyperledger Fabric Contract API. Inside this contract, we define two methods:
Increment: Increments the counter value by a specified amount. The Increment method retrieves the current counter value, updates it, and then writes the updated value back to the ledger.
Query: Returns the current counter value. The Query method reads the current counter value from the ledger.

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In the main function, we create an instance of SimpleCounterContract and start the chaincode.

In order to build and deploy locally, we ensured that the necessary environment for Hyperledger Fabric development have been set up. Then we replace the existing chaincode in your Hyperledger Fabric project.

Among the limitations of our code was not adding error handling and input validation.

For production grade system, it is recommended to follow the deployment process to package, install, and instantiate the chaincode from the documentation page.

Client Application Interface:

The client application comes in two variants: Healthcare Provider Interface and Patient Interface.

Healthcare Provider Interface: Allows healthcare providers to record immunization data on the blockchain.

Patient Interface: Enables patients to access their immunization records securely.



Figure 3: Screenshot of Immunization Record

CONCLUSION

Immunization schedules are critical for preventing the spread of infectious diseases. However, existing record-keeping systems are so inefficient and fragmented which gives rise to life-threating infectious diseases such as measles,

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mumps, rubella, polo and influenzas, which in the nearest future can lead to brain damage, blindness, deafness, and the host of others. Blockchain technology offers a solution to this problem by providing a secure and unalterable record-keeping system. Implementing a blockchain-based system for managing immunization schedules can lead to several benefits, including improved accuracy and completeness of records, reduced administrative burden, and enhanced accountability and transparency. It is hoped that a production grade immunization schedule powered by blockchain technology would be adopted in the nearest future. Also, it is hoped that performance would be measured comparing the various blockchain platform.

REFERENCES

Agbo, C., Mahmoud, Q., & Eklund, J. (2019a). Blockchain Technology in Healthcare: A Systematic Review. *Healthcare*, *7*(2), 56. https://doi.org/10.3390/healthcare7020056

Agbo, C., Mahmoud, Q., & Eklund, J. (2019b). Blockchain Technology in Healthcare: A Systematic Review. *Healthcare*, *7*(2), 56. https://doi.org/10.3390/healthcare7020056

Ahram, T., Sargolzaei, A., Sargolzaei, S., Daniels, J., & Amaba, B. (2017). Blockchain technology innovations. *2017 IEEE Technology & Engineering Management Conference (TEMSCON)*, 137–141. https://doi.org/10.1109/TEMSCON.2017.7998367

Androulaki, E., Barger, A., Bortnikov, V., Cachin, C., Christidis, K., De Caro, A., Enyeart, D., Ferris, C., Laventman, G., Manevich, Y., Muralidharan, S., Murthy, C., Nguyen, B., Sethi, M., Singh, G., Smith, K., Sorniotti, A., Stathakopoulou, C., Vukolić, M., … Yellick, J. (2018). Hyperledger fabric. *Proceedings of the Thirteenth EuroSys Conference*, 1–15. https://doi.org/10.1145/3190508.3190538

Arsheen, S., & Ahmad, K. (2022). Blockchain-Enabled Immunization System: A Novel Idea to Leverage Reliability and Traceability. *2022 3rd International Conference for Emerging Technology (INCET)*, 1–5. https://doi.org/10.1109/INCET54531.2022.9824500

Chapter 8: Record Keeping and Documentation. (2021). In *Immunization Handbook for Pharmacists, 5th Edition*. The American Pharmacists Association. https://doi.org/10.21019/9781582123653.ch8

Deka, S. K., Goswami, S., & Anand, A. (2020). A Blockchain Based Technique for Storing Vaccination Records. *2020 IEEE Bombay Section Signature Conference (IBSSC)*, 135–139. https://doi.org/10.1109/IBSSC51096.2020.9332171

Engelhardt, M. A. (2017). Hitching Healthcare to the Chain: An Introduction to Blockchain Technology in the Healthcare Sector. *Technology Innovation Management Review*, *7*(10), 22–34. https://doi.org/10.22215/timreview/1111

Hussien, H. M., Yasin, S. M., Udzir, N. I., Ninggal, M. I. H., & Salman, S. (2021). Blockchain technology in the healthcare industry: Trends and opportunities. *Journal of Industrial Information Integration*, *22*, 100217. https://doi.org/10.1016/j.jii.2021.100217

Kuo, T.-T., Kim, H.-E., & Ohno-Machado, L. (2017). Blockchain distributed ledger technologies for biomedical and health care applications. *Journal of the American Medical Informatics Association*, *24*(6), 1211–1220. https://doi.org/10.1093/jamia/ocx068

Liu, W., Zhu, S. S., Mundie, T., & Krieger, U. (2017). Advanced block-chain architecture for e-health systems. *2017 IEEE 19th International Conference on E-Health Networking, Applications and Services (Healthcom)*, 1–6. https://doi.org/10.1109/HealthCom.2017.8210847

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Medina, J., Rojas-Cessa, R., Dong, Z., & Umpaichitra, V. (2023). A global blockchain for recording high rates of COVID-19 vaccinations. *Computers in Biology and Medicine*, *163*, 107074. https://doi.org/10.1016/j.compbiomed.2023.107074

Nabil, S. S., Alam Pran, M. S., Al Haque, A. A., Chakraborty, N. R., Chowdhury, M. J. M., & Ferdous, M. S. (2022). Blockchain-based COVID vaccination registration and monitoring. *Blockchain: Research and Applications*, *3*(4), 100092. https://doi.org/10.1016/j.bcra.2022.100092

Radanović, I., & Likić, R. (2018). Opportunities for Use of Blockchain Technology in Medicine. *Applied Health Economics and Health Policy*, *16*(5), 583–590. https://doi.org/10.1007/s40258-018-0412-8

Razzaq, A., Mohsan, S. A. H., Ghayyur, S. A. K., Al-Kahtani, N., Alkahtani, H. K., & Mostafa, S. M. (2022). Blockchain in Healthcare: A Decentralized Platform for Digital Health Passport of COVID-19 Based on Vaccination and Immunity Certificates. *Healthcare*, *10*(12), 2453. https://doi.org/10.3390/healthcare10122453

Yaga, D., Mell, P., Roby, N., & Scarfone, K. (2019). *Blockchain Technology Overview*. https://doi.org/10.6028/NIST.IR.8202

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