Implementation of Blockchain Consortium to Prioritize Diabetes Patients' Healthcare in Pandemic Situations

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ABSTRACT

Diabetes is a metabolic disorder caused by high blood sugar levels, which can harm the kidneys, the heart, the eyes, and blood vessels. During the Covid-19 pandemic, diabetes patients were most affected. In the existing healthcare system, medical data is available in paper form or through a central server. Accessing the data from the central system and sharing it with all stakeholders would be a critical task during the pandemic. This research work deals with the design and implementation of a diabetes blockchain consortium. It can help all healthcare stakeholders to efficiently prioritize the needs of diabetes patients during a pandemic, such as oxygen beds, vaccinations, diabetes compensation, telemedicine, 5G-integrated remote location support, and other related records. The Ethereum sandbox simulation design is utilized to secure diabetes patients' healthcare records. The Interplanetary file system (IPFS) encrypts health data and sends it to the blockchain to ensure the privacy of personal healthcare information. The NEM symbol blockchain is used to develop this consortium as a proof-of-concept (PoC) model. Each stakeholder in a consortium is assigned NEM generated QR code to track records as a distributed ledger. A smart contract designed to run the diabetes blockchain application. Attribute-based encryption (ABE) authenticates users and restricts malicious nodes. Certainly, this research suggests aggregation of transactions and blocks in the blockchain, which would increase transaction speed, minimize transaction fees, and consume less power in a future blockchain design.

INDEX TERMS: Attributes based encryption, blockchain, Covid-19, consortium, diabetes, patient, smart contract, healthcare, Interplanetary file system.
I. INTRODUCTION

Blockchain is an emerging technology with unique features, such as distributed ledgers, transparency, and immutable records. Blockchain technology has potential applications in healthcare, aviation, real estate, transportation, and automotive. Globally, 420 million people suffer from diabetes. This study investigates the design and implementation of blockchain for diabetes patients. According to the World Health Organization's diabetes report 2020, 1.6 million deaths occur each year. It is estimated that 570 million people will be affected by this disease by 2030 and 700 million by 2040 [1]. Diabetes can also cause other diseases such as heart attack, kidney failure, and stroke. According to the 2020 report by the National Diabetes Center, 10.5% of the U.S. population has diabetes, and 34.5% of the U.S. adult population has pre-diabetes [2]. Most diabetes patients don't know whether they have type 1 or type 2. Diabetes type 1 occurs when the body does not produce enough insulin. People with type 1 diabetes must take insulin shots every day to survive. When a person has type 2 diabetes, their blood sugar levels are elevated. Patients with type 2 diabetes must take daily medications to control their blood sugar levels [3]. Diabetes types identified with Covid-19 have an astringent effect on patients and destroy insulin-sensitive cells [4]. As a result, many diabetic patients who were infected with Covid-19 died.

![FIGURE 1. Diabetes patients in million region wise report (Data collected from IDF diabetes Atlas).](image)

As shown in Fig.1, the International Diabetes Federation compiled a report on diabetic patients' health status [37]. At present, most emerging and developing countries store their patient records on local hospital servers in hard copy or soft copy. Only a few developed countries store their patient records on a centralized server. Many hospitals do not have access to a central server. Patients are always concerned with the security of their personal information. Patients prefer to keep their information private rather than to make it public. We propose blockchain technology in a categorical blockchain consortium to securely share health records locally or ecumenically. Diabetic patients would benefit greatly from this in the event of an emergency or pandemic. Emerging and developing countries face the greatest challenge in identifying areas with the highest numbers of diabetic patients and prioritizing their treatment. Patients in remote areas and villages often have little knowledge about diabetes and its complications. The existing challenges can be addressed by utilizing distributed ledger technology. Researchers conducted a survey in remote areas of India during the Covid-19 lock-in. The study found that most of the patients did not visit a doctor and people complained that the testing fees were too high and pointed out that telemedicine would be beneficial [5]. In March through April 2020, 287 Covid-19 patients provided medical data. Furthermore, diabetes patients were most likely to be infected with Covid-19 [6]. Overweight obesity is also a risk factor for diabetes patient admission [7]. The Internet of Things (IoT) devices play an important role in health data collection, as they have a limited storage capacity and data can either be transferred to the cloud or a local system [8]. Unauthorized disclosure of patient health information is a concern for patients. In this research paper, we discuss how the blockchain system can be integrated with IPFS (Interplanetary file system) to overcome this challenge. There is also a major issue with the existing healthcare system, which is centralized. A distributed ledger is not used to store the data of Covid-19-infected patients. When patients are transferred from one hospital to another, carrying their medical records is a crucial task during a pandemic [9]. Distributed ledger technology (blockchain) provides the ability to manage emergency situations, minimize delays, provide transparency to the healthcare system, and increase patient confidence that their healthcare information is secure. Companies around the globe are investing in blockchain technology. By 2025, the number is expected to reach 5.61 billion. Medical information can be protected using blockchain [10]. Authenticating medical records of diabetes patients with Covid-19 infection can reduce mortality [11]. Blockchain scalability problems can be solved by using memory optimization [12]. The authors proposed a high-level architecture for improving IoT security in blockchain applications [13], The Ethereum blockchain is discussed in relation to healthcare applications [14]. There are four categories of blockchains. They are private chains, public chains, hybrid chains, and consortium chains. In this study, blockchain technology is used to create a diabetes patient network through a consortium model. Since millions of people suffer from diabetes, a blockchain consortium for diabetics is needed. This consortium involves all stakeholders, including the government, compensation companies, medical practitioners, pharmaceutical companies, hospitals, and diabetes care centers, in order to ensure efficient diabetes management. The architecture of NEM allows applications to be either private, public, hybrid, or blockchain-based consortiums. Blockchain consortiums are like private blockchains, but they bring together people with global interests to develop blockchain applications for good. Our goal with the diabetes consortium was to give diabetes patients the confidence that their health data would be stored securely on a blockchain. Smart contracts were used to execute the diabetes consortium. The attribute-based encryption (ABE) protects the privacy of patient health records and prevents unauthorized access. This article is structured as follows. We discuss the global impact of diabetes in Section I. As a part of Section II, we discuss blockchains, diabetes, and related topics. In Section III, we discuss the challenges diabetic patients face today. A
simulation of the Ethereum sandbox is used in section IV to track diabetes patients’ healthcare data. In Section V, the blockchain consortium is introduced, securing healthcare data by using IPFS. In Section VI, we describe the design and implementation of the NEM symbol blockchain for diabetes patients. In Section VII, we discuss how to encrypt healthcare records using ABE. In Section VIII, we demonstrate how to aggregate transactions and blocks to improve blockchain performance.

II. RELATED WORK

A hybrid blockchain-based solution based on NEM blockchain technology is proposed to provide transparency in the purchase of medicines. In the future, substandard drugs will not be allowed into the healthcare system [15]. Blockchain-based machine learning solution for analyzing patient health data [16]. Mobile apps were used to collect outpatient data [17]. The use of fog computing and blockchain technology for studying cardiology and diabetes has been reported [18]. They formulated the research questions and discussed the opportunities and challenges of using a mobile application for tracking contact information [20]. A systematic review of a blockchain-based federated learning [BFL] was conducted. This review focused on future developments and their applications [21]. The researchers analyzed the medical records of 373 patients admitted to the hospital between February 22 and May 15, 2020. Machine learning was used to collect and analyze diabetes patient status in order to evaluate healthcare for Covid-19 patients [22]. A discussion of blockchain technology and the challenges and opportunities in healthcare for the elderly was conducted [23]. Smart contracts connect manufacturers, retailers, and other stakeholders within the purchasing community on the Ethereum network [24]. The healthcare sector generates $3 trillion in revenue annually. A great deal of time is spent duplicating tasks in hospitals. Distributed ledger technology can be easily integrated to reduce these duplications. Researchers conducted quantitative studies to establish blockchain technology in healthcare, which allows hospitals, research centers, and labs to share data [27]. Many countries have been affected by the Covid-19 pandemic, and most lack the infrastructure for keeping health records. Blockchain technology may play a major role in securing data sharing [28]. Blockchain technologies were discussed at Covid-19 in relation to their potential applications in supply chains, contact management, data collection, and surveillance [29]. According to a survey on blockchain applications in healthcare, there are no prototype implementations [30]. Event tickets are vulnerable to fraud. Combining both private and public blockchains can solve this problem with hybrid blockchain technology [31]. In a blockchain, a smart contract is a program that executes. In recent years, the demand for smart contracts has grown steadily due to the unique features of blockchain technology, such as transparency, immutability, and distributed ledgers [32]. A significant number of overweight people and diabetics were affected by the Covid-19 pandemic [33]. The consensus mechanisms used in blockchain technology, such as proof of stake and proof of work, have been examined [34]. The UK national health authority provides diabetes reports of Covid-19 infections. The doctors collected information about diabetes patients who died after contracting Covid-19. There was a total of 23804 deaths in the period between March 1, 2020, and May 11, 2020. Among them, 31.4% (7,466) were in patients with type 2 diabetes and 365 (1.5%) were in patients with type 1 diabetes. The report documented more than 30% of deaths associated with diabetes patients [37] [38]. It is crucial to monitor the health records of these patients. Blockchain technology could be used in an emergency to track diabetes patients’ records. It will make it easier for patients to access their records in an emergency. The research focuses on developing a hybrid blockchain framework that can store all health records. This framework combines private and public blockchains. A person’s health data is stored privately, and transactions related to health data may be made publicly available (e.g., hospital visits, Covid-19 vaccination details, and medication purchases using cryptocurrency transactions). We used the NEM symbol blockchain, which has some unique characteristics when compared with other platforms. Table 1 shows the patient’s readings for blood sugar. In the report, there is no information related to the patient’s location or the previous blood sugar level.

III. DIABETES PATIENT CHALLENGES

The following are the major challenges faced by patients with diabetes.

A. Costly drugs

The cost of medications is high in low-income countries. Many health insurance plans do not cover them all. There are cases where patients must pay extra for medications [35]. Patients are not always aware of the cost of medications. Patients could use a blockchain-based tracking system to keep track of the cost of their medicines.

B. Knowledge on diabetes disease

A Gartner report indicates that fewer than 10% of people are aware of diabetes. Most people are unaware of diabetes. The public needs to be educated about diabetes and related diseases. Blockchain technology could make it easier for patients to obtain authenticated information.

| Lab test reference number | Fasting blood sugar (FBS) on 09/10/2021 | Description |
|---------------------------|--------------------------------------|----------------|
| SHL 2116378               | The FBS level was 208 mg/dL. The normal FBS level is between 70 and 100 mg/dL. | In the existing healthcare system, hospital reports are not shared as distributed ledgers. Some hospitals make the report available on a local server, while others give it as a hard copy. |
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### TABLE 2
ANALYSIS OF THE LITERATURE REVIEW AND ISSUES ADDRESSED IN THIS RESEARCH

| S: No | Literature review | Covered                                                                 | Gap analysis                                                                                     | Contributions of the authors to this research                                      |
|-------|-------------------|--------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| 1     | [1][2]            | A report on diabetes was presented by the World Health Organization (WHO). | WHO’s report does not offer any solutions to dealing with diabetes patients in pandemics.       | NEM Blockchain consortium design (PoC) implemented to prioritize diabetes patient care. |
| 2     | [3][4][21]        | Analysis of statistical data of Type 1 and Type 2 patients during the Covid-19 pandemic. | Methods of handling patient data effectively have not been addressed by the authors.            | As diabetes patients join the NEM blockchain network, they will have an address assigned to them. |
| 3     | [6]               | Several diabetics patients who live in rural areas of India were interviewed during the Covid-19 lockdown about their problems. | There is a need for a solution to deal with diabetic patients in emergency situations.          | The integration of blockchain with 5G enables diabetes patients located at remote locations to get access to their healthcare. Patients’ healthcare records are protected by BIP 39. |
| 4     | [7][33]           | Covid-19 patients have a high risk of obesity and diabetes.               | Diabetes patients can access information (regionally) through the system, rather than a distributed ledger. | All stakeholders are involved in this research work, which identifies areas with heavy populations and the use of blockchain as a distributed ledger. |
| 5     | [8]               | In this research work, all stakeholders are involved in blockchain as a distributed ledger and the heavily populated areas are identified. | A 5G integrated blockchain could provide a better solution.                                     | By integrating 5G and blockchain, healthcare providers in remote locations will be better connected. |
| 6     | [12][25]          | On the Blockchain, challenges related to scalability are discussed.       | In terms of scalability, large file sizes are a major problem for blockchain.                    | In this research study, IPFS is integrated with the NEM symbol platform for handling large files. |
| 7     | [17]              | The records of outpatients with Type 2 were stored on a centralized server during the pandemic. | Due to the centralized nature of the existing server system, a significant delay can occur during pandemic conditions. | Using a distributed ledger reduces the delay and makes information available to all stakeholders. |
| 8     | [20]              | The advantages and challenges of maintaining healthcare records in a blockchain were discussed. | The authors discussed the challenges and opportunities of integrating the blockchain with healthcare records. | Diabetes patients can now benefit from the blockchain framework described in this research work. It was tested with an experimental setup. |
| 9     | [21]              | During Covid-19, there was a high hospital mortality rate. The study was conducted in Northern Italy. | In the pandemic of Covid-19 hospital, mortality was higher; this could have been prevented by efficient data management. | By integrating the hospitals with distributed ledgers, hospitals can efficiently handle data during pandemic situations. |
| 10    | [35]              | The number of Covid-19 cases tripled in the diabetes community.          | Providing diabetes patients with the best care during the pandemic was a challenge.             | With our design, we can identify the most affected areas in diabetes patients’ region and prioritize their needs. |
| 11    | [46]              | A Sybil attack on the blockchain is explored in this paper.              | The Sybil attack allows an intruder to create multiple accounts.                                | ABE and zero-knowledge proof algorithm (ZKP) have been implemented among consortium nodes to avoid Sybil attacks. |
| 12    | [47]              | Hashing blocks prevents man-in-the-middle attacks.                      | ZKP makes it possible to enhance the security among diabetes blockchain consortium nodes.       | BIP 39 (mnemonics) is used among the consortium nodes to facilitate validation. |
C. Covid-19 and Diabetes

Covid-19 cases tripled in the diabetes community. The researchers sampled 137 sites and found diabetes type 1 patient had higher hospitalization rates and diabetes type 2 patients had higher illness rates [33]. Researchers collected data from the Scottish Virology Database and analyzed it using logistic regression. People with diabetes are more likely to have astringent infections, and the number of deaths is higher [34]. Table 2 summarizes the results of the literature review.

D. Existing Healthcare system for diabetes patient during Covid-19

Diabetes is currently managed through a centralized healthcare system, where patient data is stored on a hospital server. In Fig.2, the healthcare for diabetes patients is handled by a centralized server. In developing and emerging countries, patient records are kept on paper. One of the most challenging aspects when dealing with emergencies like Covid-19 is prioritizing them. In addition to collecting information from the local hospitals, supplying the drugs becomes a challenge. In the existing system, there is no authenticated report that reveals the number and type of vaccinations that have been given to diabetes patients, such as Sputnik-V, Sinopharm, or other drugs. Only a few countries have authorized two or three vaccinations. This becomes difficult when people travel abroad. They need to bring their vaccination record with them. All of these challenges can be overcome by integrating patients' healthcare information into the blockchain.

FIGURE 2. Existing healthcare record maintenance for diabetes patient.

Fig.3 illustrates how distributed ledger technology can be used to manage diabetes patients' health data efficiently. It connects the Covid-19 vaccination center, diabetes patients' health data, the regime, the compensation companies, and patients. To track diabetes patients' information transparently, the regime and other connected sectors will have access to this blockchain architecture. In a pandemic situation, prioritization of healthcare becomes much easier. As a result of its integration with insurance providers, diabetes patients can be prioritized, track their health care, get support from the government, and have insurance claims transparent.

FIGURE 3. Blockchain consortium design for diabetes patient healthcare (Peer-Peer connectivity among the nodes).

E. Objectives

- Design the Ethereum sandbox simulations to secure diabetes patients' healthcare data with mnemonics and QR code generation.
- Design a blockchain consortium framework for secure handling of diabetes patients' health data and prioritize their needs during a pandemic.
- Apply zero knowledge proof algorithm to validate the transaction between the stakeholders such as hospitals, vaccination centers, pharmacies, government, insurance companies, and other stakeholders in the blockchain consortium.
- Apply the pairing cryptography properties, attribute-based encryption, and aggregation of transactions to preserve the privacy of patient health records and improve transaction speed.
- Security analysis of diabetes patients' health records on a consortium blockchain and fingerprint embedded QR code for making financial and other transactions.

Fig. 4a - Fig. 4c show a simulation of securing healthcare records using Ethereum sandboxes. In Fig.4a, the hash function is used to secure healthcare records. Consequently, patients are more confident. The hash code enables patients to access their records. In figure 4b, the mnemonics used to operate diabetes consortium nodes are shown. Figure 4c illustrates the generation of random BIP (mnemonics) that provide a high level of security among the stakeholders, where the mnemonics generation varies with the time until making the non-interactive proof of zero-knowledge.
IV. ETHEREUM BLOCKCHAIN SANDBOX SIMULATIONS TO SECURE HEALTHCARE RECORDS

**FIGURE 4a.** Diabetes patient record encrypted by hash function and converted to QR code

**FIGURE 4b.** Diabetes patient record access authentication provided by BIP [64]

**FIGURE 4c.** Random BIP 39 generation to operate the diabetes consortium nodes in a Non interactive zero-knowledge proof algorithm
V. BLOCKCHAIN CONSORTIUM FRAMEWORK FOR DIABETES HEALTHCARE

There are four types of blockchain frameworks: private, public, hybrid, and consortium available to design the tracking of diabetes patients. The smart contract is used to execute the blockchain.

TABLE 3

| S: No | Layer form of consortium blockchain | Functions |
|-------|-------------------------------------|-----------|
| 1     | Layer 5                             | Application layer (Smart contract, API, DApp) |
| 2     | Layer 4                             | Consensus layer (PoW, PoS, PoET, PoA, RAFT) |
| 3     | Layer 3                             | Peer to Peer network (Consortium nodes for diabetes healthcare) |
| 4     | Layer 2                             | Infrastructure layer (Ethereum virtual machine, Docker container, Local machine) |
| 5     | Layer 1                             | Physical layer (Patients records), laboratory report |

Table 3 shows the layered architecture of the blockchain for the diabetes consortium. Physical layer 1 represents the physical connection through which all medical devices can be connected to transmit data. A layer that represents the infrastructure, which includes local or cloud-based physical machines. The third layer shows the end-to-end connectivity between the nodes in the consortium. Smart contracts facilitate the process. At layer 4, the consensus mechanism controls the blockchain. The application interface - layer 5 - integrates mobile networks and blockchain applications (DApps). IPFS is integrated with a patient's health record which ensures the confidentiality of the health documents before they are transferred to the Blockchain. The lab reports are generated and encrypted by IPFS. The public blockchain uses a defined protocol like Proof of Work (PoW) to work. The private blockchain allows only authorized users and works with an algorithm that requires little energy to operate. The private blockchain is the most secure blockchain. It allows only registered people to participate in the blockchain. Each user is assigned a user ID and a password. The existing blockchain system has limitations of scalability and storage space. The number of transactions is limited due to the existing hardware infrastructure. Each patient's medical data is encrypted by a hash code before it enters the blockchain. This would be possible with an interplanetary file system (IPFS). Since medical records have an immensely colossal file size, it will not be possible to do the transaction on a subsisting blockchain platform. IPFS overcomes the problem. The challenges faced by the healthcare industries are overcome by a hybrid blockchain framework. This blockchain model integrates all nodes through a blockchain network.

These medical records are shared as distributed ledgers. This brings transparency between the stakeholders.

Fig. 5 illustrates how medical data can be encrypted and exchanged securely using private blockchain architecture. The offline storage of data enhances the efficiency of the blockchain. Incoming and outgoing traffic is measured. Table 4 shows the tested patients' health records with different file sizes.

TABLE 4

| File upload specification | File 1 | File 2 | File 3 | File 4 | IPFS |
|---------------------------|--------|--------|--------|--------|------|
| Patient 1                 | 1MB    | 3MB    | 5MB    | 10MB   | Hash 1 |
| Patient 2                 | 2MB    | 1MB    | 4MB    | 7MB    | Hash 2 |
| Patient 3                 | 1MB    | 4MB    | 5MB    | 8MB    | Hash 3 |
| Patient 4                 | 4MB    | 2MB    | 1MB    | 3MB    | Hash 4 |

IPFS CID & Hash for file 1: QmXJXwPwU7AeGFwJnAxqMne5oDdPC7CRUCZBuNUWSvf Zzh6a (CID – Content identifier). sha2-256: (Hash) 8B09ADE3A859829F47FBD593CB8CD5940C15AA3588DD D7F4B99100101FA4B
IPFS CID & Hash for file 2: QmaDKlVxF3g3bH5ANqQwT7UQkAjugJx8sxBv04ES rp sha2-256: B05AC6F3597E8EE84A2A34AD2836421A9C2A381EAB3 53847DD5B4DC49451C5
IPFS CID & Hash for file 3: QmzTR5bcpQD7CcFgT87xqzedw1Wqfbd2ud9QqGPAkK 2V sha2-256: A52C3602030CB912DEFE4DE97002FDADF9D45666C3BE 122A2EFB5DB93C1D5FA6
The following Fig.6 shows the execution of a smart contract.

**Input:** Total number of diabetes patients. Patient assigned with blockchain address. Government healthcare department assigned with address. Blockchain address assigned to hospitals. Address assigned to insurance companies.

1. All the stakeholders come together and create smart contract to execute the diabetes blockchain.
2. Diabetes patients register with blockchain with their Attribute based encryption (ABE) authentication method.
3. Based on patient medical record selected for free insurance or free treatment.
4. Government finance department verify diabetes records on blockchain.

Diabetes patient had emergency.

Go to step 12

7. The application is approved by the government for free treatment.
8. Patient information updated as distributed ledger.
9. The modified smart contract sent to all stakeholders.
10. end
11. else, 12 If the patient is not selected then the application will send back to the applicant.
13. This helps to identify the number of people heavily affected by diabetes.

**FIGURE 6.** Smart contract execution of diabetes chain

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### Table 5: Comparison of Different Blockchain Platform

| Blockchain Platform | Public | Privacy | Hybrid | Protocol | Transaction Fees |
|---------------------|--------|---------|--------|----------|-----------------|
| Ethereum            | Yes    | Yes     | Yes    | PoW/PoS | High ($4.02)    |
| NEM Symbol          | Yes    | Yes     | Yes    | PoS+     | 0.7 (XYM)       |
| IBM                 | No     | Yes     | No     | User defined | Tokens     |
| Oracle              | No     | Yes     | No     | User defined | Tokens     |
| IPFS                | No     | Yes     | No     | RAFT     | Voting          |

The NEM symbol blockchain was launched in January 2021 [39]. It supports both private and public blockchains, consumes less power and has very low transaction fees.

### Table 6: Hardware/Software used for experimentation

| S. No | Hardware/Software used for experimentation | Number of nodes used for testing consortium. |
|-------|-------------------------------------------|---------------------------------------------|
| 1     | CPU i7 – 1065G7, RAM 8GB, Hard disk 1TB. | 6                                           |
| 2     | Operating system Ubuntu 18.04-LTS         | 6                                           |
| 3     | Protocol used                            | Zero Knowledge Proof within consortium nodes. (mnemonics verification) |

The NEM symbol blockchain network was designed and tested using the hardware/software shown in Table 6. Six NEM symbol blockchain nodes have been tested for the diabetes consortium blockchain. Each node has the same hardware configuration. Using BIP 39 (Mnemonics), the zero-knowledge proof algorithm communicates with other nodes. The Symbol blockchain explorer tracks truncations and block details. In order to make real-time blockchain transactions, the test currency (XYM) is received from the following link: http://faucet.testnet.symboldev.network/. NEM symbol addresses are required for receiving test currency. Each address is associated with a wallet. Each wallet can be accessed using a QR code. Every user has a mnemonic that helps secure their wallet. Mnemonics are confidential. The wallet can be recovered if someone loses their login credentials. The Testnet platform allows us to test applications using the NEM symbol blockchain. This can be seen in our sample address by the letter T. We created all six nodes using the same process: TBVUNG-5RXEYT-B4PUTK-3W4YRP-6BSJXW-Y5KGID-4NQ.
FIGURE 7. NEM blockchain architecture and IPFS integrated with symbol blockchain.

The above Fig.7 shows the NEM blockchain architecture, which is connected to a desktop client/mobile client. It can connect private and public blockchains. The blockchain network can be accessed by third-party applications through the API (Application Programming Interface) server. The transactions are performed with the cryptocurrency with the NEM symbol (XYM). In this research, IPFS servers encrypt diabetes patients' health data before it is transferred to the blockchain. In order to develop the diabetes patient consortium, NEM symbol blockchain technology was used [39]. The consortium's nodes communicate by using an interactive zero-knowledge proof algorithm. In this way, malicious nodes are prevented from becoming a part of the blockchain consortium. Transactions pertaining to health records are hashed to ensure their authenticity. Patients could select attributes from a pool of options. The same is verified before a transaction is completed. It is possible to classify diabetes patients into two groups. Symbol blockchain is connected to each hospital; each hospital is a node in the blockchain consortium. Each node represents a patient identifier. Each node has a QR code that tracks all transactions [40]. Transparency is the hallmark of the blockchain. In the event of a pandemic, this system can readily identify patients infected with Covid-19 and provide compulsory support. A crypto wallet was assigned to each patient to test the proof-of-concept model. In order to test the application, 10,000 XYM crypto coins were provided with the NEM symbol blockchain wallet. There are emerging innovations related to the Internet of Things that could connect the data of diabetic patients (Type 1 and Type 2). The system is thus capable of detecting areas with a high density of diabetes patients. The first step involves collecting the diabetes patients' data through a private blockchain with IPFS. Second, a distributed ledger would be created with all stakeholders to prioritize the process for diabetes patients. In the third step, remote patients without access to sophisticated equipment would be filtered. With the 5G mobile network, we can offer telemedicine to more people. For the elderly, this could be a simple solution. In this way, close family members of diabetic patients have access to their health data. ABE algorithms facilitate this access.

VI. DIABETES CHAIN CONSORTIUM IMPLEMENTATION USING NEM SYMBOL BLOCKCHAIN CRYPTOCURRENCY TRANSACTION

NEM's blockchain has a namespace and a mosaic. Namespace is designed to include diseases associated with patients with type 1, type 2, and diabetes. Covid-19-infected diabetes records can be prioritized for treatment. Mosaic has information related to insulin. The consortium can keep track of injections needed by each region on a daily basis. In addition, it prioritizes vaccination for patients with a high diabetes density. The hash code, transaction ID, or block number can be used to track each transaction. Considering that all diabetes chains are connected by a distributed ledger, the regime could mobilize the desire data of diabetes patients the most effectively, thereby reducing the number of diabetes patients who die in the future. This system is designed with a unique security feature mnemonic passphrase that protects the consortium's privacy. Fig.8 illustrates the NEM blockchain design for diabetes patients.
The following table lists the NEM addresses assigned to each patient for tracking their medical records. In order to make the transactions, each account is credited with 10,000 XYM. Table 7 shows the NEM address.

**TABLE 7**

| S: No | NEM address for a patient | NEM code associate with the address | Block height | XYM credited for the transaction |
|-------|--------------------------|-------------------------------------|--------------|----------------------------------|
| 1     | TB5UKFE23RJDCEPXVTOWZHRAW67WBFXNDCCSKY. (Patient1) | $1404 | 10,000 XYM |
| 2     | TBVUN5RXEYTB4PUTK3WYRPG8BSXWY5K9ID4NQ (Patient 2) | $8656 | 10,000 XYM |

Each transaction requires the consent of multiple parties, then it is designed according to an algorithm. Consider the example of a blockchain consortium whereby the signatures of five individuals are required before the transaction is processed. This can be achieved with the NEM symbol (5/10). Once all five people approve the transaction, it will proceed smoothly.

Step 1: Patients are assigned with NEM blockchain address to be part of the consortium.
Step 2: The QR code generated from the blockchain address is used as a blockchain wallet to perform cryptocurrency transactions.
Step 3: XYM 10000 is assigned to each participant to perform cryptocurrency transactions.
Step 4: All patients are connected to the blockchain cloud services that provide unlimited storage.
Step 5: Tracking or accessing diabetes patients with the ABE authentication process of the consortium nodes.
Step 6: The smart contract is designed to execute the diabetes consortium blockchain. A zero-knowledge proof algorithm is used to maintain the privacy of the consortium nodes [42]. Merkle tree design is used to track all the transactions in a blockchain. Each transaction has the hash function associated with it. The following are the routes of Merkle tree to track the transaction.

- AccountState
- 4fb1a48250639e9f296153d0bdc3b32b10e9bbdf5608caf2b2c33148c63661b8. Namespace - e21e25be07e6c63ff6409bfee02c0d9218029dc3b2939a76b8b89b38ac445. Mosaic - 1481badd2717c20ce469db477d5b167d57dd92b2605ba2174f7a7f5363a979. Multi signature - 9ca47202298b517f29da6e1ed3b3e4902710a8d500e7ff45bf980d488d42d196. Hashlockinfo - 691dc4871e5a538452c699e8902aa4e7bf42412b9a9a4fb9b973c7007f4ad452

Fig. 9 and 10 show the cryptocurrency assigned to each consortium node for marking transactions. The figure illustrates the paper wallet of the NEM blockchain for each diabetes patient. Each transaction includes a date and time in order to track patient health data. Table 7 shows the QR code, which is assigned to each account, giving all participants easy access. One of the features of the NEM blockchain is the multi-signature rule [41].
The diabetes network is illustrated in Fig. 11, which depicts the blockchain formation. It begins with block 0, is followed by blocks 1, 2, 3, and perpetuates. Each account has a mnemonic (Zero knowledge proof algorithm) to ensure the privacy of patients [42]. Labels are only applied to the individual participants of the consortium. The integrated 5G blockchain architecture in Fig. 12 will prioritize the healthcare of diabetic patients. In the diagram, we have divided the implementation of the diabetes chain into three categories. To begin with, each patient is assigned a blockchain address, which allows the regime to identify the regions with the most diabetes patients. Blockchain addresses are public keys. Everyone has access to them. The second segment focuses on telemedicine and drug distribution using the blockchain to enhance remote patient care. As a result, they could have authenticated diabetes medicines. As a third step, the distributed ledger would connect the regime accommodations. It would enable the regime to orchestrate vaccinations, oxygen beds, and other accommodations. All stakeholders work together to manage diabetes patients' health data in the blockchain consortium. To ensure end-to-end security, pairing cryptography features are included. We would be able to determine the number of diabetes patients, emergency room visits, number of deaths of patients infected by Covid-19, managing vaccinations efficiently, and assigning priority vaccinations to diabetes patients based on our model. Further, this system can be integrated with indemnification companies or ascendant entities for immutable records of healthcare transactions with hospitals. Due to the availability of records as distributed ledgers, indemnification claims, and fraud transactions are shortened.

**TABLE 8**  
5G INTEGRATED BLOCKCHAIN DIABETES CENTRE.

| S. No | Group | Blockchain uses | Goals |
|-------|-------|-----------------|-------|
| 1     | Telemedicine using blockchain for diabetes. | Provide support for remotely located patients (immutable records and participation in a consortium). | Educate the public about the benefits of telemedicine for patients located remotely. |
| 2     | Future smart cities include diabetes patients integrated with local hospitals. | It helps to identify the dense regions in Type 1 and Type 2 patients. | Track the health records of each diabetes patient. |
| 3     | Diabetes network of the federal government. | Using blockchain technology, diabetes patients' data can be prioritized. | Connect states and assists them in pandemic situations. |
Table 8 shows the uses of blockchain at different groups, as well as effective record management for preserving lives.

VI. SECURITY ANALYSIS IN DIABETES BLOCKCHAIN CONSORTIUM

In this section, we discuss the types of attacks that could target health data and the zero-erudition proof algorithm that may be used to ensure secure transactions between consortium nodes. To accomplish this, the health data could be encrypted with ABE to ensure privacy. In addition, the possibilities of introducing dactylogram embedded QR codes between consortium nodes were discussed.

A. QR code for payment

Most digital payments are processed through QR codes today. Crypto wallets have QR codes that can be used to make cryptocurrency payments on the blockchain. It is possible for someone to misuse a QR code if it is stored on a mobile phone or laptop. However, we can overcome this problem and develop new technologies. Dactylograms embedded with QR codes provide privacy and security [43][44]. Fig.13 shows the fingerprint embedded QR code.

![Fingerprint enabled QR for cryptocurrency payment](Unique wallet)

FIGURE 13. Fingerprint embedded QR code to secure the crypto wallet.

B. Sybil attack

The Sybil attack is one of the most common on IoT devices. Creating multiple malicious accounts or adding multiple malicious nodes that slow down the system. In online transaction systems like Bitcoin, one person can take control of the entire network by creating multiple online accounts. The existing cryptocurrency payment system, QR code, is widely used for digital payments. This leads to one person generating several unauthorized QR codes to access the system [45-46].

C. Man-in-the-middle attack

This attacker is mostly interested in stealing personal information, such as bank account information. Since the health records are connected to IoT devices, an eavesdropper could obtain personal information by hacking the system Wi-Fi. [47].

D. Denial of Service

This attack can completely cripple the system or computers. Mostly, this attack is done on servers, banks, and high-performance systems. Blockchain with zero proof knowledge algorithm could limit unauthorized access [48].

E. A 51% attack on the blockchain

There is a small group of miners that controls more than fifty percent of the mining hash rate. The attacker accumulated more than 50% of the hash rate. In Bitcoin and Ethereum, the Proof of Work (PoW) protocol is used. Solving complex mathematical equations requires high-end hardware and a lot of processing power [49].

F. Phishing

Currently, QR codes are used to connect to websites. As a result, phishing attacks such as the theft of credit card information and personal health information become possible. The attribute-based encryption (ABE) algorithm could prevent this by using paring cryptography [50].

G. Types of QR codes

Numerous QR code types are available on the market, and there are a few mobile applications and websites that can create QR codes. The existing system QR codes are mainly associated with websites.

H. Attributes based encryption for diabetes patient health records

Zero Knowledge Proof (ZKP) analyzes security between consortium nodes. As diabetes patients' health data is at stake, authenticated access to documents is of utmost importance. Thus, patients will be more confident about the security of their data in a blockchain consortium. The Zero-Knowledge Proof (ZKP) algorithm could achieve this [51]. It uses a concept of a verifier and a prover. The prover must prove that the attributes of the verifier match. A transaction is only created on the blockchain once the verifier confirms a match with the prover. There are two types of Zero-knowledge proof: interactive and non-interactive. As part of this design, we used interactive attribute-based encryption (ABE) using pairing cryptography. The result offers high levels of security for medical documents. The attributes act as private keys for securing the patient's documents. A patient's date of birth, location, personal identification information, and other details can be stored as attributes. Diabetes patients’ health records can be accessed using non-interactive attribute-based authentication. For instance, zero cognizance proof can be applied among consortium nodes before updating or integrating a new node into the blockchain. In the attributes, we have the letters (A, B, C, D......Z), (0,1,2,3.......9), and other symbols can be added, considering all three ways to keep OR, AND the design logical functions that ABE. The process becomes easier when many transactions need to be validated within a short period of time.

![Monotonic access structure](image)

FIGURE 14. ABE encryption to maintain the privacy of diabetes patient's healthcare data.
The letters in the attributes would be (A, B, C... Z), (a, b, c, d...z), (0, 1, 2, 3...9), and other symbols can be included if we keep the combinations of OR, AND design logical functions that ABE. The process is simplified when many transactions need to be validated within a relatively short period of time. In Table 7, the attributes associated with patient records are shown. Scenario1: Monotonic access to patient records. Fig 14 illustrates how monotonic access encryption is used to access health information. Pairing cryptography incorporates certain features, such as attribute-based encryption. The attributes are specified by the patients to protect their health information. Data is retrieved by correctly entering three attributes. Scenario 2: The user is assigned the following logic to retrieve medical records. Consider these four attributes: I, J, K, L. Patient 1 is assigned a key for the attributes {I, J}, while patient 2 is assigned a key for the attribute {L}. The ciphertext can be decrypted by patient 2 using condition (I AND K) or L, but not by patient 1.

![FIGURE 15. ABE authentication process for diabetes consortium](image)

### TABLE 9
ATTIBUTES BASED ENCRYPTION USED FOR SECURING PATIENTS RECORDS

| S: No | Attributes | Patient records |
|-------|------------|-----------------|
| 1     | The date of birth, identity mark, and location are three of the five attributes that can be used to match an individual’s records. | Patient records 1 |
| 2     | Additionally, birthdates, last hospital visits, and blood groups are factors that can be used to identify a patient's records. | Patient records 2 |

Scenario 3:
Diabetes patients are assigned a unique ID for quick access. Considering the pandemic situation and diabetes patients, rapid access during an emergency could be given as policy {Z}. Z allows access only to diabetes patients; this helps the health sector as priority patients. Fig. 15 shows the ABE based authentication for the blockchain consortium.

### I. Fingerprint embedded cryptocurrency wallet for making healthcare transaction

Crypto wallets embedded with fingerprints provide a high level of security for healthcare transactions. Table 8 compares different IoT devices used in the healthcare industry. Fingerprint embedded authentication solves all security issues in IoT blockchain integration [52-56]. It eliminates the man-in-the-middle attack to protect patient privacy [57-59]. Access to medical laboratories is controlled by radio frequency identification [60]. Barcodes and NFC are used to collect blood samples from patients. Patients' health records have been embedded with QR codes in recent years, but a single QR code is insufficient for tracking a patient's medical records. The existing health system generates medical reports using a variety of QR codes. A patient's report can be tracked via a QR code included with the Covid-19 vaccination. The results of lab tests such as blood tests, urine tests, and others are linked to QR codes. Table 10 compares various attacks against IoT devices, and QR codes embedded with fingerprints can be used to prevent attacks.

### TABLE 10
SECURITY ANALYSIS OF IoT DEVICES FOR HEALTHCARE APPLICATIONS

| S: No | IoT devices | Sybil attack | Man-in-the-Middle attack | Denial of service (DoS) | Reverse engineering |
|-------|-------------|--------------|--------------------------|-------------------------|-------------------|
| 1     | RFID (Radio frequency identification) | ✓ | ✓ | ✓ | ✓ |
| 2     | NFC (Near field communication) | ✓ | ✓ | ✓ | ✓ |
| 3     | Barcode | ✓ | ✓ | ✓ | ✓ |
| 4     | QR code | ✓ | ✓ | ✓ | ✓ |
| 5     | Finger print embedded QR code | ✗ | ✗ | ✗ | ✗ |

Based on the comparison, we can find that fingerprint embedded QR code gives a higher level of authentication.
Another major issue is that not every hospital has the IT infrastructure needed to generate the report. By combining the fingerprint embedded QR code with blockchain, these issues can be resolved. The QR code can also be used to encode information about a patient or drug details related to a patient. Sybil attacks could be prevented if a consortium had access to the fingerprints in the blockchain. Private, public, hybrid, and blockchain consortiums can make use of the technology. A QR code embedded in a fingerprint can be used in a variety of ways, as shown in Fig.17. In addition to healthcare documents and electric vehicles, this design can also be used for important assets documents. Authenticated access is possible for hospitals located in different cities or countries.

VII. ENHANCE TRANSACTION SPEED IN THE DIABETES PATIENTS BLOCKCHAIN CONSORTIUM BY USING PARING CRYPTOGRAPHY PRINCIPLES

Currently, each blockchain block contains a transaction, and each transaction has a fee. A study of the transaction speed and the generation of blocks on the NEM blockchain was conducted in this research work. Our experiments were conducted on the symbol blockchain platform. Parameters such as the number of transactions, the number of blocks generated, the time to complete a transaction, and the blocks in Tables 11 and 12 were observed and analyzed. We have considered 649391 to 649413 as part of our analysis. During the 11 minutes and 10 seconds of analysis, 22 blocks were created. These blocks took an average of two minutes to produce. Block 649391 has single transaction, and the 1518 nodes were participated as part of the transaction.

### TABLE 11
BLOCK NUMBER 649391 DETAILS

| Blockchain platform/Parameters | NEM Symbol blockchain |
|-------------------------------|-----------------------|
| Total transactions            | 1                     |
| Size of block                 | 552 bytes             |
| Difficulty                    | 105.39                |
| Number of nodes               | 1518                  |
| Block hash                    | D785C1BD1CE43480A0CDA3414D62629 46071DEA682FA3F40B780234ABABFB3 1E |
| Time stamp                    | 2021-10-28 15:42:19   |

### TABLE 12
BLOCK NUMBER 649413 DETAILS

| Blockchain platform/Parameters | NEM Symbol |
|-------------------------------|------------|
| Total transactions            | 2          |
| Size of block                 | 752 bytes  |
| Difficulty                    | 107.8      |
| Number of nodes               | 1518       |
| Time stamp                    | 2021-10-28 15:53:09 |

Blockchain technology has a limited number of transactions per second in comparison to existing centralized servers. By aggregating transactions, it would be possible to overcome this issue and aggregating blocks would improve blockchain operations and reduce transaction fees. The number of hash code generated also significantly reduced. The As illustrated in Fig.18, aggregating the number of diabetes transactions into a single block will truncate the transaction fees for each patient. A practical scenario billions of people who suffer from diabetes needs to be connected to a blockchain platform. In the presence of a larger diabetes population, more transactions occur per second. In order to minimize the delay in processing these transactions, they can be dispatched instantly. Consolidating transactions into a single block and accumulating several blocks could minimize delays in transaction execution. Since we utilize mnemonics and ABE for authentication, we are significantly truncating the probability of malevolent attacks, since only sanctioned nodes are members of this blockchain consortium [61] [62]. Take the example shown in Fig.18 where the transactions T1, T2, and T3 form the block Bo that has three transactions, similarly, block B1 consists of three transactions, and block B2 consists of two transactions (T1, T2). Blocks are associated with the block hashes H0, H1, and H2. An aggregate design is proposed that cumulates the blocks B0, B1 and B2 to compose the incipient block A1. The blockchain will be able to process transactions more quickly. In the real-world scenario of a blockchain consortium for healthcare, there are a lot of hospitals, doctors, labs, and pharmacies, so the number of transactions is high. The merging of blocks (B0 + B1 + B2 = A1), would minimize the amplitude of the blockchain's paramount delay. As an example, if we consider 10 transactions, and each takes 20 seconds to complete, then total transaction time would be equal to (10 x 10 = 200 seconds). The proposed design shown in Fig.18 would execute 9 transactions in a single block whereas symbol blockchain need at least 4 blocks to create the same transaction. This also reduce the blockchain height otherwise blockchain height is incremented for each transaction. Using a NEM symbol blockchain, the sender could set the maximum transaction fee as follows: Max Fee = Transaction: Size Network: Median Fee Multiplier. Furthermore, the aggregation of blocks can increase transaction speeds, and medical records can be validated outside the blockchain by the approved data center. Later, they can be integrated with the consortium. There are two types of intelligent contracts in blockchain design, either deterministic or nondeterministic. The deterministic method on the blockchain gives all blockchain nodes enough information to execute the smart contract and make the decision.Authenticated information is required for nondeterministic, which is a component of the blockchain consortium. Once the data has been received, the astute contract is then executed among the consortium nodes to reach a decision. In addition to reducing transactional time, the data is not directly stored on the blockchain, which facilitates the connection of multiple care providers as part of the consortium. Privacy is ensured with an algorithm that does not sanction cognition. Blocks and transactions are aggregated in order to reduce bitcoin miners' power consumption. This research diabetes chain was built using the PoS+ algorithm on the NEM symbol blockchain. Local computers, laptops, and cloud services can be used as nodes. Running the blockchain does not require dedicated computers [63].
FIGURE 17. Fingerprint embedded QR code enhance the security in blockchain applications

FIGURE 18. Aggregate transaction using pairing cryptography principle to enhance performance of blockchain and reduces delay.
IX. CONCLUSION

This research study provides an effective method of storing diabetic patient medical records via the NEM symbol blockchain. The blockchain consortium is designed for health record keeping. The consortium node has hospitals, a vaccination center, a regime, and other stakeholders. Medical records are kept private through the ABE algorithm. A stakeholder in the NEM blockchain is allocated 10,000 XYM to conduct transactions between consortium nodes. NEM symbol blockchain has been used as a proof-of-concept model. A security analysis of the existing blockchain and QR code embedded in the fingerprint is conducted. This allows nodes in the consortium to exchange messages without requiring any knowledge of each other’s identity. A 5G blockchain architecture is proposed to connect diabetic patients remotely. As a result of the above features integrated with an existing blockchain, transactions will be faster and more secure for the community. As transactions are aggregated, the transaction speed between consortium nodes will change.

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