LOGARITHMIC MERKLE AND POST QUANTUM IOT BASED BIG DATA HEALTHCARE ANALYSIS USING BLOCKCHAIN

[1]S.Manikandan M.Sc.,
Lecturer, School of software, East China University of Technology, Nanchang, Jiangxi, China

[2]Dr P. Pushpa M.Sc, M.Phil, PhD,
Lecturer, School of Software, East China University of Technology, Nanchang, Jiangxi, China.

Abstract

The predominant responsibilities carried out all over the data life cycle, including data acquiring, processing, retrieval, and storage, have described the data management. Blockchain-based data management is outlined in healthcare to provide patients dominance over their data. Their consent permits patients and hospital authorities to control who has access to their data and track who has accessed it. For data processing, intelligent contracts-based data-processing-friendly architecture had designed. Finally, as far as data storage is concerned, data storage time, accuracy, and energy consumption remain the primary concern to be focused and this work proposes a novel method called Logarithmic Merkle Quantum-based Legendre Quadratic (LMQ-LQ) IoT-generated healthcare extensive data analysis using Blockchain. The LMQ-LQ process splits into four sections: First, a peer-to-peer network constructs using Blockchain Logarithmic Merkle Tree. Second, the distributed ledger form using the Post Quantum function with the constructed tree. Third, Legendre Quadratic Residue's consensus mechanism design with valid IoT-generated big data. Finally, an intelligent contract model shoots up automatically upon the execution of a transaction. The performance results of the proposed LMQ-LQ IoT generated healthcare extensive data analysis using Blockchain are evaluated in terms of data storage time, data storage accuracy, and energy consumption, respectively.

Keywords: Big Data, Internet of Things, Blockchain, Logarithmic Merkle Tree, Post Quantum, Distributed Ledger, Legendre, Quadratic Residue, Consensus mechanism

1. Introduction

Over the past few years, data generated by the enormous performance and utilisation of the Internet of Things (IoT) has been spreading exponentially. This unparalleled expansion of data acquisition over several fields permits for acquiring significant comprehensive insights. However, extracting meaningful, comprehensive insights from Big Data necessitates a solid framework for ease of data storage, analysis of data, and processing the same in a distributed and scalable manner. Blockchain provides an encouraging framework for scattered ample data storage and protection.

A deep learning-based IoT-enabled real-time health monitoring system had proposed in [1]. Here, wearable medical devices have acquired vital signs and appertained several deep learning methods to extract pertinent information on Sanda athletes. The deep learning algorithms help physicians properly analyse these athletes' conditions and offer the proper medications to them, even if the doctors are away.

The employment of the deep learning model revealed favourable results in terms of precision and recall. Though an excess of neurons with more hidden layers results in improved accuracy, however, raises critical issues, like, time and vanishing gradient. From this aspect, our work used Blockchain Logarithmic Merkle Tree construction. With the aid of Logarithmic Merkle Tree, it saves memory, requiring only a tiny amount of IoT-generated data to transmit for healthcare extensive data analysis.

Over the past few years, as far as the traditional cloud-centric IoT frameworks are concerned, storage volume requirements and computational costs are consistently in the rising phase. Moreover, the reliance on the centralised server solution exploits unique trust concerns and makes it susceptible to security risks. In [2], a layer-based distributed data storage design employed a blockchain-enabled large-scale IoT framework.

Also, to ensure distributed ledger solutions, the Hyperledger Fabric (HLF) platform was designed to provide distributed ledger solutions. The requirement for third-party auditors was to eliminate exploiting HLF peers conducting verifications and auditing of transactions in big data using blockchain technology, therefore considerably reducing the communication overheads. As a result, the response time reduces with higher throughput. However, the energy consumption was not on focus despite improvement observed with higher throughput and response time. To address this aspect by designing the Legendre Quadratic Residue-based Consensus algorithm, the amount of energy consumed by a blockchain can reduce to a greater extent.

Unlike deep learning, IoT-enabled real-time health monitoring system and layer-based distributed data storage design employs several hidden nodes and layers to acquire patients' vital signs and high-level feature extraction via conducting verifications and auditing of transactions in big data using blockchain technology from raw telemedicine data. However, the real-time health monitoring data generated with more hidden layers results in increased time and vanishing gradient, consuming much energy. Therefore there requires standard mechanisms to save memory and energy for further processing.

The Blockchain-based mechanism applied in the proposed work employs Blockchain Logarithmic Merkle Tree construction for designing peer-to-peer networks without human intervention. In addition, Legendre Quadratic

Residue-based Consensus algorithm addressed the energy consumption aspect. For this study, we have considered an augmented health heart rate dataset as our case study, and our results are obtained based on the health status of these patients. The proposed method captures various signs of patients and remotely transmits them for further analysis. The physicians, in turn, perform data management or data analytics to ensure a smooth transition.

1.1 Contributions

The contributions of the work include the following:

- Develop an IoT-based solution for comprehensive Big Healthcare data management with heart rate together blood pressure measurements by an appropriate procedure of wearability.
- Combine, synchronise, and process the augmented health heart rate for medical investigation on the parameters interactions.
- Introduce and develop an innovative peer-to-peer network construction using Blockchain Logarithmic Merkle Tree construction for IoT generated healthcare extensive data monitoring.
- Develop a flexible IoT-based Big Healthcare gateway via Post Quantum-based Distributed Ledger formation for IoT healthcare monitoring physiological parameters.
- Establish an end-to-end communication between the user and medics using Legendre Quadratic Residue-based Consensus algorithm for necessary recommendations to the user.

1.2 The organisation of the paper

The remainder of this paper is structured as follows. Section 2 provides a literature review on the blockchain concept of IoT-based healthcare data using Blockchain and big data. Section 3 describes the system design of the proposed Logarithmic Merkle Quantum-based Legendre Quadratic (LMQ-LQ) IoT generated healthcare extensive data analysis using Blockchain with the aid of block diagram and algorithmic representation. Section 4 presents experimental results and discussion. Finally, Section 5 puts forward the concluding remarks.

2. Related Works

The IoT has received immense awareness from numerous research fields. Different elements from distinct areas are associated with IoT technologies that can share both information and resources without time and distance constraints. Present-day healthcare is one of the most appealing IoT applications.

A novel Dew Computing enabled IoT healthcare method for offline and ultra-low latency decisions is proposed in [3]. Here, numerous healthcare devices were associated and ensured user-specific services even with the scarce Internet connectivity. Here, the computation model was positioned as paramount in place of the cloud to minimise the complexity and enhance user-specific services.

With the recent utilisation of the IoT in healthcare, much patient data is being transmitted and made available online. Therefore, it requires ample security mechanisms to be put in place to circumvent possible cyberattacks. In this regard, different types of authentication mechanisms have developed. For example, a two-way two-stage authentication mechanism proposed in [4] employs hardware security primitives called Physical Unclonable Functions (PUFs). Moreover, in [5], a knowledge graph analysis using IoT for innovative health is presented.

Blockchain is considered the next horizontal innovation among the horizontal innovations in healthcare. Blockchain comprises a time-stamped series of permanent data supervised by a group of computers not held by an entity. Each block, in turn, is secured by employing cryptographic principles and hence bound to each other. Blockchain technology can assist healthcare, and the overall healthcare industry enhances performance, ensuring patient data transparency and accountability by minimising the costs.

Distinct physiological signals like Electro Cardio Gram (ECG), Photo Plethysmo Graphy (PPG), and body temperature are measured using Compact wearable sensor patches designed in [6]. Furthermore, designation of all the components in a rigid-flex structure for remote health monitoring. However, no ensure of data distribution and decentralised infrastructures. Therefore, in [7], a distributed application using Blockchain for smooth and robust communication between individuals and health insurance was proposed.

In [8], A literature review integrating machine learning and blockchain technology investigated healthcare. Then, in [9], several Blockchain use cases were discussed in the healthcare domain and the symbiotic relationship between Blockchain and intelligent health. Finally, in [10], a systematic literature review for Blockchain and healthcare in IoT was investigated in depth.

Internet of Medical Things (IoMT) is the custom-made health category of IoT wherein the doctor estimates numerous patient's health parameters like heart rate, body temperature, and oxygen level in a remote fashion via several sensors positioned in or on the patient's body. Several researchers have also underlined that big data, the Internet of /ings (IoT), and Blockchain have been significant due to several domains' extensive advantages. For example, in [11], using MIoT machine learning technique was applied to monitor older adults.

Over the past few years, technology has been progressing swiftly. Owing to the subsequent influence of intelligent techniques, it has become a global aspect of life. These intelligent techniques have resulted in the appearance of geographically navigated smart cities through advanced information and communication technologies. In [12], detailed IoT and Blockchain for their intelligent initiatives. In this recognition, made concentric efforts to highlight the influence and significance of Blockchain and IoT on healthcare services in smart cities.

Over the recent few years, the blockchain-based Internet of Medical Things (IoMT) has kicked off to acquire more awareness in the healthcare sector. It enhances the care quality by employing continuous monitoring and reduces the case cost involved. As a result, however, an understandable inclination arises to incorporate several entities in IoMT systems. Some are sensor nodes and wearable medical devices used, patients involved in the process, healthcare centres, and insurance provided by financial institutions. Persuaded by this examination, in [13],

in detail investigated a review of the state-of-the-art blockchain-IoMT systems.

However, the association of these IoT-based sensors with several entities results in security inadequacies wherein the malicious user makes the most of the susceptibilities owing to the directness of the data. Hence, there remains a crucial uneasiness, specifically in the healthcare sector, where data change from sensors subsequently changes the course of diagnosis, resulting in substantial health issues. Hence, a decoupled blockchain-based approach was proposed in [14] to stop patients' data tempering and privacy preservation.

Despite attempts made and the protections elevated to attain the security purpose, technological advancement has not come to an end to generating loopholes utilised to attack. Therefore, an integrated low-powered IoT blockchain framework proposed healthcare applications in [15] based on the Blockchain Ethereum. It included a web and mobile application permitting the patient and the medical staff to have secure access to health information.

In [16], IoT's prioritisation system is utilised to prioritise sensitive information, followed by which applied LSTM deep neural network in classifying and monitoring patients' conditions remotely, which is considered an essential feature.

However, In[17] proposed another customisable and flexible framework for the complete monitoring of parameters based on the appropriate procedure of wearability. The IoT gateway utilised an intervening hub between wearables and IoT-server. This association fixed bidirectional communication between end-user and medics in a real-time fashion. Hence, the fusion of IoT and Blockchain has become the robust selection for designing decentralised IoT-based e-healthcare systems. In [18], an elaborate environment on Blockchain, followed by consensus algorithms utilised Blockchain, was discussed, and finally, a brief review of the blockchain environment on IoT-based e-healthcare.

A novel machine learning technique with the Kennard stone Balance algorithm was proposed in [19] to enhance the accuracy of IoT sonar monitoring. However, these techniques sustain from proceedings like elevated misapprehension rate, high cost, and low efficiency. A collaborative AI-IoT-based solution (WMHPR) that embeds an advanced AI-assisted method was proposed in [20] to address these aspects. Here, multi-posture recognition (MPR) is implemented based on an offline algorithm, therefore, enhancing both reliability and accuracy to a greater extent.

Motivated by the above said state-of-the-art methods, in this work, a technique called Logarithmic Merkle Quantum-based Legendre Quadratic (LMQ-LQ) for robust and accurate data analytics with IoT generated big healthcare data via Blockchain is proposed. A detailed description of the proposed LMQ-LQ method is in the following sections.

3. Logarithmic Merkle Quantum-based Legendre Quadratic (LMQ-LQ) IoT generated healthcare extensive data analysis using Blockchain

The healthcare sector consists of publicly traded companies assisting in all aspects of the healthcare sector. It comprises preventive treatment services, including doctors, nurses, hospitals, and diagnostic laboratories. On the other hand, Blockchain technology can interest all sectors of the healthcare system. Nevertheless, a careful selection of Blockchain classes is requisite for efficient execution. For example, one of the most significant health issues the medical committee faces is several fragmented health records about patients. To address this issue, we can add blockchain medical record transactions.

Moreover, on the other hand, an intelligent contract assists in creating an intelligent health ecosystem to provide the patient's electronic health record with limited access. For example, doctors write prescriptions, insert scan reports, and report test results as transactions. On the other hand, the pharmacy records transaction on Blockchain when it provides medication to the patient. Finally, the patient gives their limited access to payments. Followed by which doctors remotely review the medical cases for medical analysis. Also, blockchain data can obtain from wearable sensors for storing electronic health records.

Figure 1 shows the working process on IoT-based healthcare for Augmented Health Rate.

The Augmented Health Heart Rate, based upon an IoT-enabled e-health system, is used to predict heart conditions, where collected health data via wearable intelligent devices. Every individual patient data is thoroughly monitored and recognised through the data collected from wearable devices. The patient's data such as ID, age, sex, systolic blood pressure, diastolic blood pressure, heart rate, weight, height, and body mass index. In addition, the patient's heart conditions are continuously monitored and analysed for susceptible symptoms. The storage paths like database centres assist in storing the acquired data for further processing and analysis.

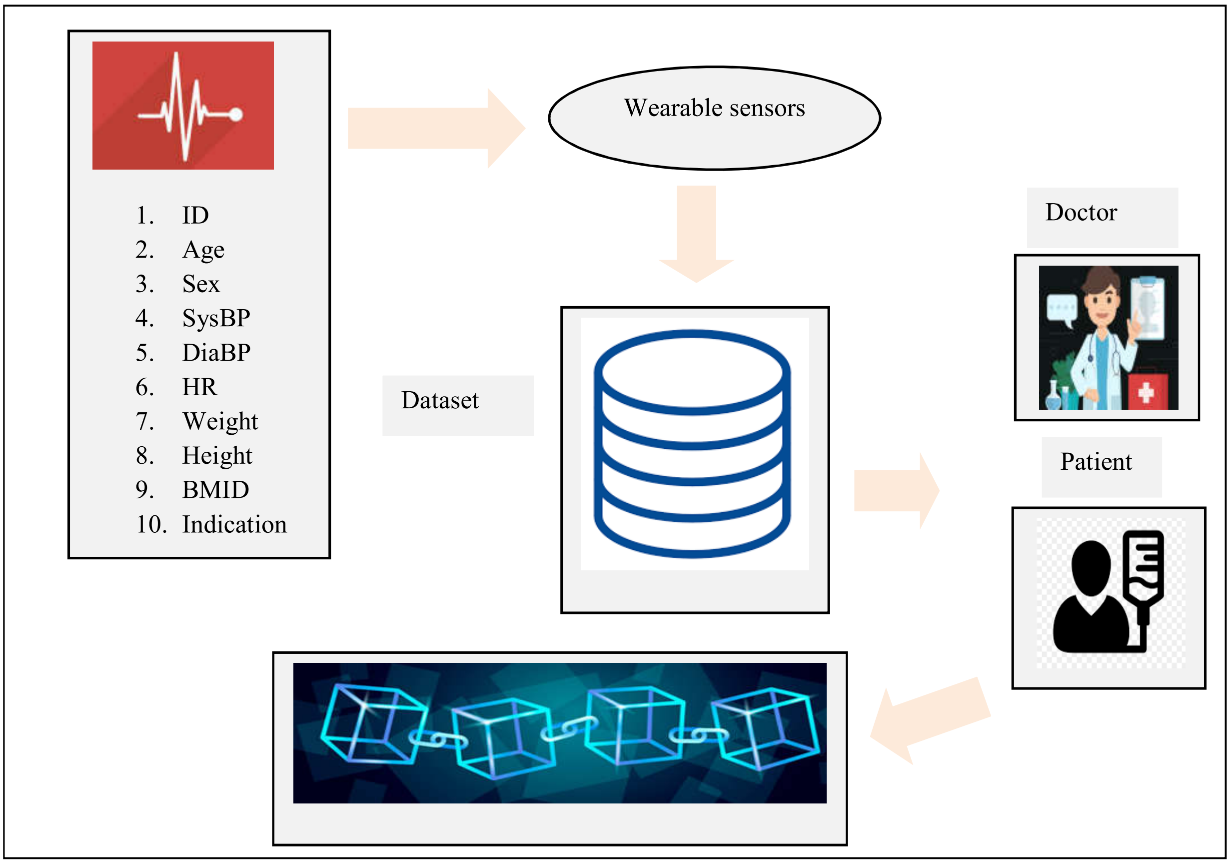

Figure-1 Block diagram of Logarithmic Merkle Quantum-based Legendre Quadratic (LMQ-LQ) IoT generated healthcare extensive data analysis using Blockchain.

The above figure-1 shows that we concentrate on a patient-centric application storing electronic medical records. For this purpose, let us further assume that the patient is utilising a specific wearable sensor's potential of ceaselessly measuring a predefined set of parameters of the heart rate together with blood pressure measurements of the patient (such as age, sex, SysBP, DiaBP, HR, weight, height, BMI).

The data gathered from these wearable sensors load into the decentralised ledger. These IoT-generated data are also stored to retrieve the patient's status in the future, permitting the healthcare personnel to have more delicate clarity of his progression. The interactions between different actors (i.e., between patients, between doctors and patients) handle an enormous amount of personal data, and therefore, it is critical to take them accurately and timely. The proposed LMQ-LQ method design aims to satisfy all these requirements by utilising blockchain technology for IoT-generated health care data. The proposed LMQ-LQ method consists of four parts. They are peer-to-peer network construction using Blockchain Logarithmic Merkle Tree, distributed ledger formation using Post Quantum function, and finally, designing of innovative contract model. The following sections provide a detailed description of the LMQ-LQ method.

3.1 Blockchain Logarithmic Merkle Tree construction

Blockchain is a peer-to-peer network that consists of different types of communication patterns between nodes and node types that participate in the data management process. Each block links to the previous block in the Blockchain. Hence, the hash of each block comprises not only its hash but also the hash of the last block. On the whole, there exist three main classes that are centralised, decentralised, and decentralised unstructured.

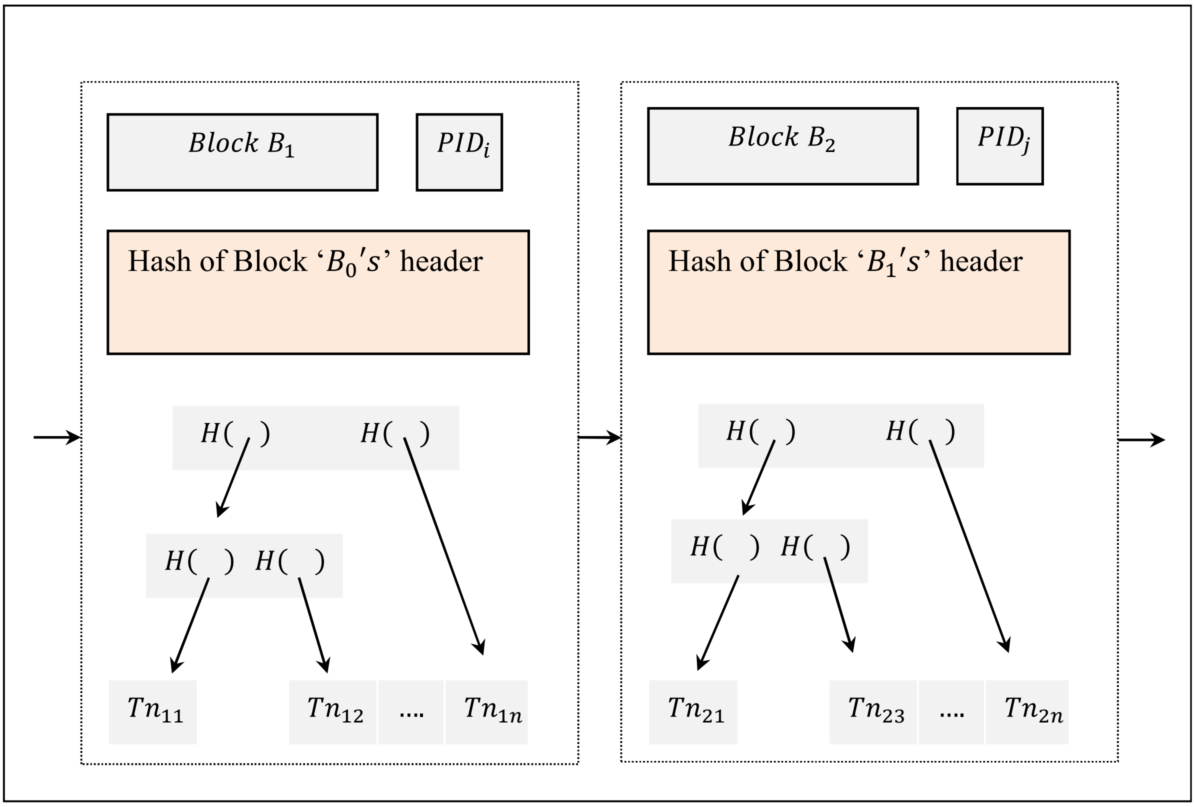

Figure-2 Block diagram of Blockchain Logarithmic Merkle Tree construction model

The conventional Merkle tree stores all the transactions in a block and permits patients or users to validate by ensuring whether a transaction can include in a block and consecutively measuring hashing pair of nodes until there prevails a single hash. Transactions refer to the data exchange (healthcare data) between different users (i.e., between patient and patient, between patient and doctor). A decentralised structure employs the Blockchain Logarithmic Merkle Tree construct in our work. Figure-2 shows the block diagram of the Blockchain Logarithmic Merkle Tree construction model.

The above figure-2 shows that each transaction holds a unique ID (i.e., patient ID 'ID'). Hence, it permits nodes or patients to enter and quit the network free anonymously. For the k-ary Merkle tree, assume the total number of central nodes' CN' for 'B' data blocks. Hence, it indicates the correlation between the total number of leaf nodes and the major nodes. For example, the equations (1) below show the correlation between the leaf nodes and the central nodes.

$$B = (k-1) * CN + 1 \tag{1}$$

Then, from the above equation (1), the total number of central nodes of the k-ary Merkle tree is mathematically stated below.

$$CN = \frac{(B-1)}{(k-1)} \tag{2}$$

The above equation (2) shows that the total number of central nodes' CN' is obtained based on the 'B' blocks of data concerning the 'k' Merkle tree. Therefore, the total number of nodes in the 'k' Merkle tree consists of leaf and central nodes. Thus, the total number of nodes' n' is mathematically stated below.

$$n = B + \frac{(B-1)}{(k-1)} \tag{3}$$

All stacks undergo identical focus in the conventional k-ary Merkle tree; more specifically, they consume the same number of arithmetic calculations for each block. Block is referred to as the record in the Blockchain possessing actual transactions. Therefore, add each transaction to the league. In our proposed Blockchain Logarithmic Merkle Tree, the stack with the smallest index will be selected rather than the highest index.

$$\begin{cases} if\ stack\ is\ empty, Stack_{Height}.low = Height \\ if\ stack\ is\ complete, Stack_{Height}.low = \infty \end{cases} \tag{4}$$

$$Res_{min} = \min(Stack_{Height}.low) \tag{5}$$

3.2 Post-Quantum-based Distributed Ledger formation

Distributed ledger technologies are said to secure means of performing and documenting transfers of IoT-generated healthcare data without the requirement for a central or third-party authority. Distributed ledger in Blockchain is constituted or formed by a group of transactions. The catalogue is distributed as several users or patients participate in healthcare data management and synchronise ledger copies. As a result, new transactions of the corresponding patient's digital healthcare data add in a manner that is visible to all patients or users. Figure-3 shows the sample Post Quantum-based Distributed Ledger for IoT-generated healthcare data.

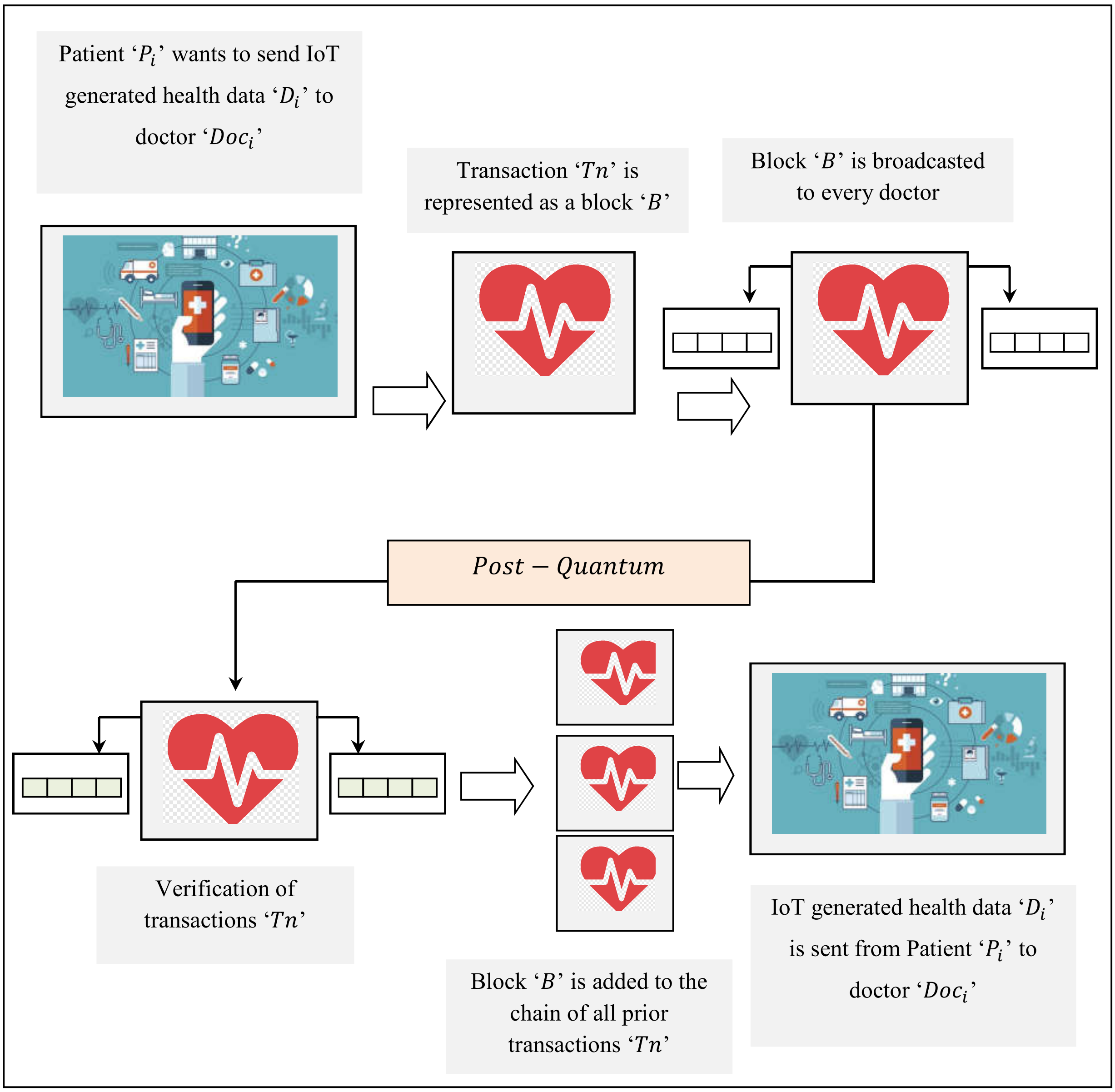

Figure-3 Block diagram of Post Quantum-based Distributed Ledger for IoT generated healthcare data.

As shown in the above figure-3, let us represent the patient as an order coordinate set '$P = (F_1, F_2, \dots, F_m)$', with '$F$' representing the feature set and its values modelled as '$V = (V_1, V_2, \dots, V_m)$'. Similarly, let us consider another ordered coordinate set '$D = (F_1, F_2, \dots, F_n)$'(i.e., server templates) with 'F' representing the feature set in the server template and its values modelled as '$V = (V_1, V_2, \ldots, V_n)$'. Then, the two ordered a coordinate set for IoT-generated health data mathematically stated as given below.

$$P = \sum_{i=1}^{m} F_i V_i \ [Tn_i] \tag{6}$$

$$Doc = \sum_{j=1}^{n} F_j V_j \left[Tn_j\right] \tag{7}$$

From the above equations (6) and (7),'$F_i V_i$'and'$F_j V_j$'denote the features and corresponding values of the patient coordinate set' P,' and the database templates Doc' for each transactions'$[Tn_i]$'respectively. Then, employing the multiplication of two vectors is formulated as given below.

$$PDoc = \sum_{i,j=1}^{m,n} F_i V_i [Tn_i] F_j V_j \left[Tn_j\right] \tag{8}$$

From the above equation (8), the coordinate.'F_i'and'F_j'represents the finite field elements and each of the values'V_i'and'V_j'is said to be substituted by one component vector. The mathematical stated is, given below.

$$V_i[Tn_i] V_j [Tn_i] = \begin{cases} V_{i+jmod\ 4}, if\ i\ mod\ 2 = 0, not\ equal \\ V_{i-jmod\ 4}, if\ i\ mod\ 2 = 1, equal \end{cases} \tag{9}$$

The above formulation ensures the distributed ledger validation. The distributed ledger stores the IoT-generated transaction data at the end of the warranty.

3.3 Legendre Quadratic Residue-based Consensus algorithm

A consensus algorithm is a procedure with which all the nodes or patients of the Blockchain attain coarse-grained concerning the existent circumstances of the distributed ledger. In our work, the Proof of Work (PoW) consensus mechanism is adopted that presumes every peer vote with its Legendre Quadratic Residue function by deciphering proof of work puzzles and constructing the pertinent blocks. Let us consider two integers' x' and 'q,' then, we say that 'x' is a quadratic residue modulo with 'q'if there exists some integer r'so that. '$r^2 - x$' is divisible by 'q.'

$$\left(\frac{x}{q}\right) = \begin{cases} 0, if\ PD_i(q) |\ PD_j(x) \\ 1, if\ PD_i(q) |\ PD_j(x)\ \ and\ PD_j(x)\ is\ a\ quadratic\ residue\ modulo\ x \\ -1, if\ PD_i(q) |\ PD_j(x)\ \ and\ PD_j(x)\ is\ quadratic\ non-residue\ modulo\ x \end{cases} \tag{10}$$

Because the Blockchain or patient nodes are anonymous, none of the IoT-generated data can be compromised, ensuring the secure mining of blocks and data storage accuracy. Therefore, the proposed method provides guaranteed data ledger storage and ensures data storage accuracy to a greater extent.

3.4 Smart contracts

Finally, an intelligent contract is said to invoke in an automated fashion upon the execution of a transaction. The smart contract is an uncoerced agreement placed in computer code managed by a blockchain with rules under which the users (i.e., patients and doctors) of that intelligent contract consent to link. Upon accomplishing the pre-established rules, the agreement has implemented in an automated fashion. The figure shows the sample IoT generated augmented health heart rate for brilliant contract execution.

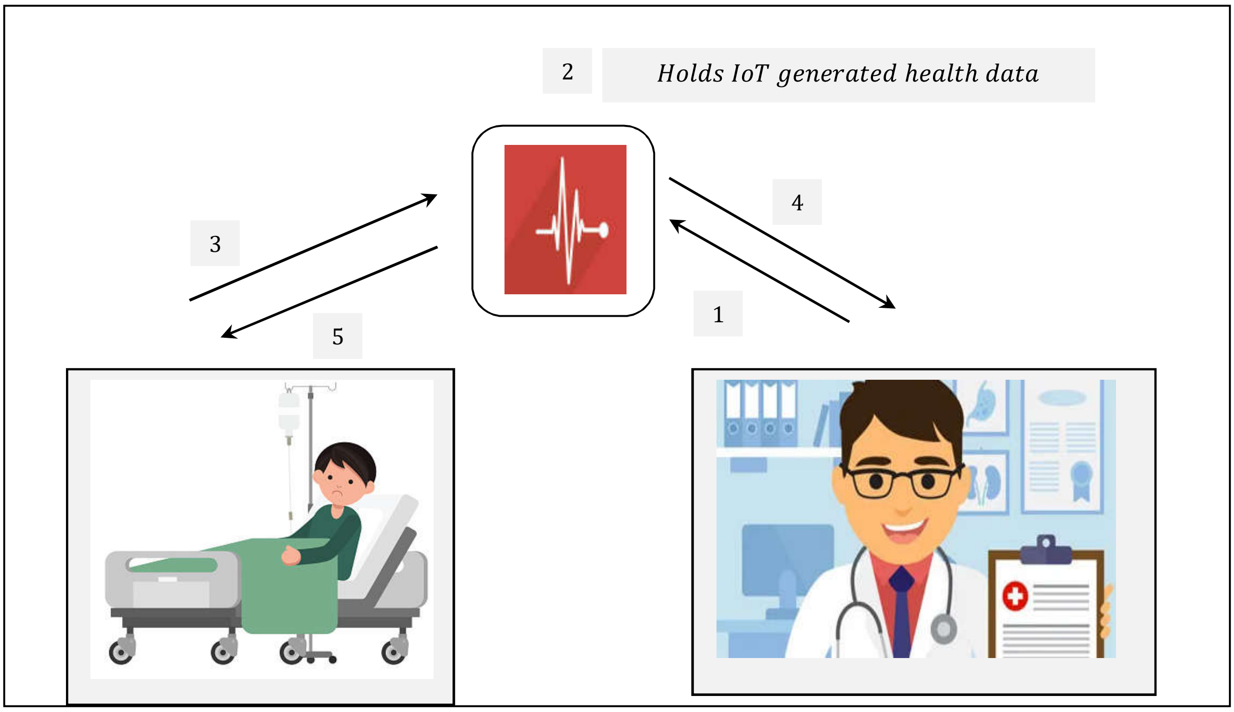

Figure-4 Example for IoT generated Healthcare Smart Contract Execution.

As shown in figure-4, two users (a patient and a doctor) proceed with IoT healthcare-generated data analytics with a smart contract. The whole process completes in five steps. In step 1, the doctor sends the required IoT-generated augmented health heart rate data to the smart contract's address to hold the other or remaining data in escrow. In step 2, the intelligent contract notifies the patient by triggering an event indicating the recipient ID of the doctor's request. In step 3, the patient checks and validates the doctor's recommendation; upon validation of the request, the patient will ship the data and inform the smart contract with the shipment message. In step 4, after the patient acquires the requested data, the intelligent agreement updates the delivery status. Finally, in step 5, the intelligent contract releases the requested data to the doctor's account. The pseudo-code representation of Blockchain Logarithmic Merkle Post Quantum Legendre Quadratic Residue algorithm for IoT-generated healthcare data is below.

Input: Dataset' DS', Sensors' $S = S_1, S_2, \dots, S_n$', Transactions' $Tn = Tn_1, Tn_2, \dots, Tn_n$'
Output: Robust and accurate IoT-generated health data analysis.
Step 1: **Initialise** central nodes' CN', '$n = 10\ sensors$', two integers' x' and 'q' Step 2: **Begin** Step 3: **For** each Dataset' DS' with Sensors' S' and samples **//Construct a peer-to-peer structure for** Step 4: **Evaluate** the correlation between the leaf nodes and the central nodes as in equation (1) Step 5: **Evaluate** the total number of central nodes as in equation (2) Step 6: **Evaluate** the total number of nodes as in equation (3) Step 7: **Evaluate** Logarithmic Merkle Tree as in equations (4) and (5) Step 8: **End for** **//Distributed ledger validation** Step 9: **For** each Dataset' DS' with Sensors' S'and two ordered coordinate set Step 10: Formulate the vector as in equations (6) and (7) Step 11: Model multiplication of two vectors as in equation (8) Step 12: **If**'$V_i[Tn_i] = V_{i+j mod\ 4} = 0$' Step 13: Validation is unsuccessful Step 14: Proceed with other transactions Step 15: **End if** Step 16: **If**'$V_i[Tn_i] = V_{i+j mod\ 4} = 1$' Step 17: Validation is successful Step 18: IoT generated health data 'D_i' is sent from a Patient 'P_i' to a doctor 'Doc_i' Step 19: **End if** Step 20: **End for** **// Proof of Work (PoW) consensus mechanism** Step 21: **For** each Dataset' DS' with Sensors' S' and validated distributed ledgers Step 22: Perform quadratic residue modulo-based validation as in equation (10)

Step 23: **Return** validated results

Step 24: **End for**

Step 25: **End**

Algorithm 1 Blockchain Logarithmic Merkle Post Quantum Legendre Quadratic Residue algorithm for IoT generated healthcare data.

As given in the above Blockchain Logarithmic Merkle Post Quantum Legendre Quadratic Residue algorithm for IoT generated healthcare data to ensure accurate and timely data analytics or management with minimum energy consumption, three different functions are employed. First, the corresponding sensors acquire the IoT-generated data with the Augmented Health Heart Rate Dataset provided as input. Second, in the form of a Blockchain Logarithamic Merkle tree constructed the IoT-generated data. The complexity involved in building the network (i.e., for healthcare data) is optimal. Third, the data acquired are stored in a distributed ledger using the Post Quantum function. Finally, by employing Legendre Quadratic Residue, the energy consumed by the Blockchain is said to be improved.

4. Experimental setup

In this section, the experimental evaluation of the proposed Logarithmic Merkle Quantum-based Legendre Quadratic (LMQ-LQ) and the existing Deep Learning-based IoT-enabled Health Monitoring [1], blockchain-enabled large-scale IoT [2] for IoT generated healthcare extensive data analysis using Blockchain is implemented in the Python high-level, general-purpose programming language.

To perform the experimental setup, the augmented health heart rate dataset (https://www.kaggle.com/datasets/shaukathussain/augmented-health-heart-rate) applies for robust and accurate data management or analysis. The dataset consists of ten types of input features with 71761 patient records—table 1 given below lists the dataset details.

Table 1 Dataset Details: Augmented Health Heart Rate Dataset

S. No	Attribute or feature name	Description
1	ID	Patient ID
2	age	Patient Age
3	sex	Patient Sex
4	Sys BP	Systolic Blood Pressure

5	Dia BP	Diastolic Blood Pressure
6	HR	Heart Rate
7	Weigh kg	Patient weight
8	Height cm	Patient height
9	BMI	Body Mass Index
10	Indication	Indication results

Among multiple features, Blockchain Logarithmic Merkle Tree construction generates a peer-to-peer network to establish robust communication patterns between nodes (i.e., patients and doctors) and node types that participate in the data management process. Following this, Post Quantum-based Distributed Ledger for IoT generated healthcare data modelled to ensure accurate data management. Furthermore, the Legendre Quadratic Residue function provided consensus between nodes by utilising the Blockchain Logarithmic Merkle Post Quantum Legendre Quadratic Residue algorithm. Finally, experimental evaluation is carried out for data storage time, accuracy, and energy consumption for different patient data numbers.

4.1 Comparison between different methods based on data storage time

The first and foremost significant parameter for IoT-based extensive data healthcare analysis is the data storage time. Data are acquired from the respective sensors and stored in some form of structure. Therefore, a significant amount of time is said to take place. The mathematically stated as given below.

$$DS_{time} = \sum_{i=1}^{n} Samples_i * time\ (DS) \tag{11}$$

The above equation (11) shows the data storage time.'DS_{time}'is evaluated based on the samples or patients' ID involved in the simulation process.'$Samples_i$'and the actual time consumed in storing the respective augmented health heart rate data' $time.'$ It measures in terms of milliseconds (ms). Table 2 given below shows the data storage time obtained for three different methods, Logarithmic Merkle Quantum-based Legendre Quadratic (LMQ-LQ) and the existing Deep Learning-based IoT-enabled Health Monitoring [1], Blockchain-enabled large-scale IoT [2] respectively.

Table 2 Tabulation for data storage time

Samples	Data storage time (ms)		
	LMQ-LQ	Deep Learning-based IoT-enabled Health Monitoring	blockchain-enabled large-scale IoT
7000	1505	1575	1715
14000	1625	1735	1845
21000	1685	1925	2015
28000	1735	2015	2325
35000	1785	2135	2815
42000	1815	2325	3145
49000	1935	2415	3325
56000	2045	2635	3845
63000	2235	2925	4015
70000	2845	3135	4135

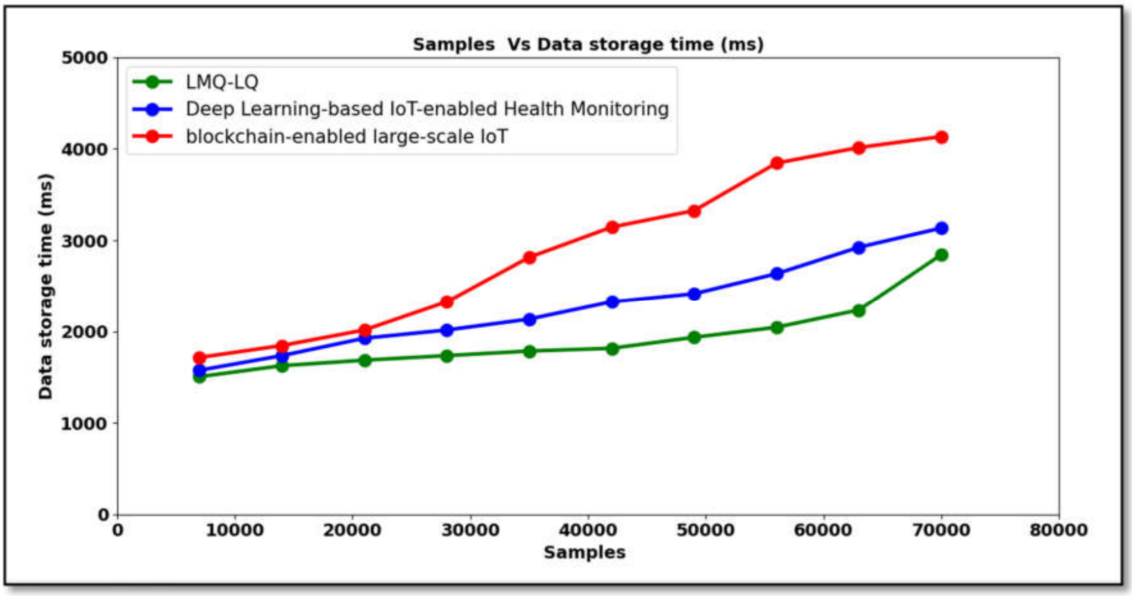

Figure-5 Graphical representation of data storage time

Figure-5 given above illustrates the graphical representation of data storage time using the proposed Logarithmic Merkle Quantum-based Legendre Quadratic (LMQ-LQ) method and two state-of-the-art methods, Deep Learning-based IoT-enabled Health Monitoring [1], Blockchain-enabled large-scale IoT [2]. All three methods found a steep increase in prediction time and proposed the LMQ-LQ method to infer minimum data storage time. As a result, the data storage time for IoT-based extensive data healthcare analysis using the proposed LMQ-LQ method is significantly reduced compared to [1] and [2]. Furthermore, it is owing to the application of Blockchain Logarithmic Merkle Tree construction that, in turn, ensures non-linear data structure and hence does not follow any system for storing IoT-generated healthcare data. As a result, the data storage time using the LMQ-LQ method is reduced by 15% compared to [1] and 31% compared to [2].

4.2 Comparison between different methods based on data storage accuracy

The second factor of significance for IoT-based extensive data healthcare analysis is the data storage accuracy. Data storage accuracy refers to the rate at which the data storage performs accurately. The mathematically stated as given below.

$$DS_{accuracy} = \sum_{i=1}^{n} \frac{Samples_{accstored}}{Samples_i} * 100 \quad (12)$$

In the above equation (12), the data storage accuracy.'$DS_{accuracy}$'is measured based on the samples or patients' ID involved in the simulation process.'$Samples_i$'and accurate samples or patients data stored in the distributed ledger.'.$'$ It measures in terms of percentage (%). Table-3, given below, provides the data storage accuracy results obtained from equation (12) for all the three methods, Logarithmic Merkle Quantum-based Legendre Quadratic (LMQ-LQ) and the existing Deep Learning-based IoT-enabled Health Monitoring [1], Blockchain-enabled large-scale IoT [2] respectively.

Table 3 Tabulation for data storage accuracy

Samples	**Data storage accuracy (%)**		
	LMQ-LQ	Deep Learning-based IoT-enabled Health Monitoring	Blockchain-enabled large-scale IoT
7000	98.57	97.35	96.21
14000	97	96	94.35

21000	96.25	95.35	94
28000	96	94	93.15
35000	95.85	93.85	93
42000	94.25	93.25	92
49000	93.15	92	90.25
56000	93	91.35	89
63000	92.55	91	87.35
70000	92	90	86

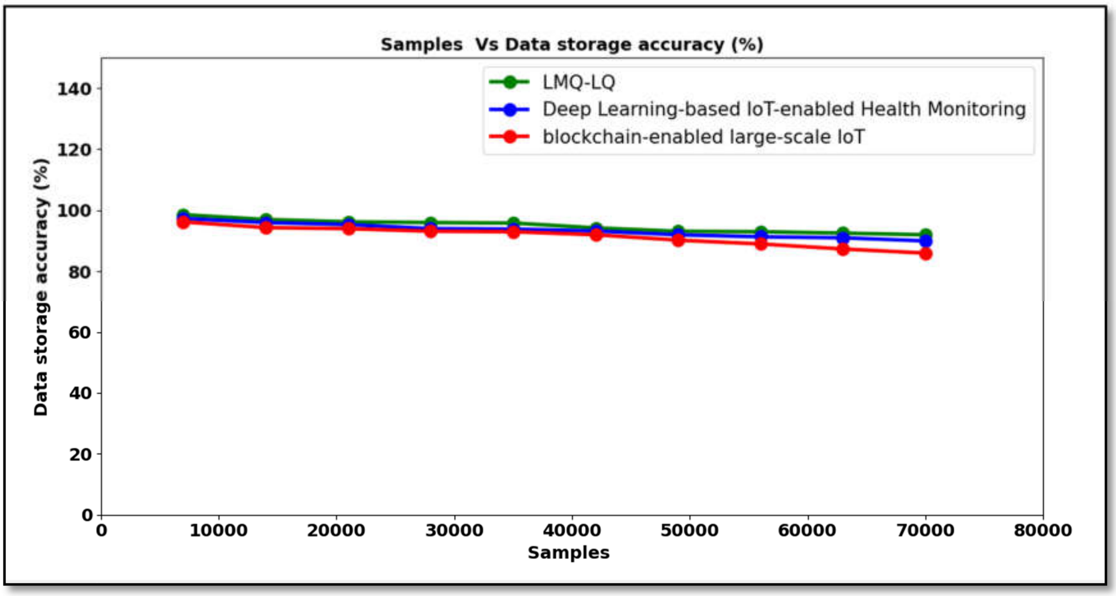

Figure-6 Graphical representation of data storage accuracy

The above figure-6 shows the graphical representation of data storage accuracy concerning 70000 different patient data. The above figure improves the accuracy of LMQ-LQ compared with Deep Learning-based IoT-enabled Health Monitoring [1] and Blockchain-enabled large-scale IoT [2]. The significant improvement in accuracy is due to the deciphering proof of work puzzles and construction of the pertinent blocks by employing the Legendre Quadratic Residue function. Furthermore, by applying this function, Blockchain nodes or the patient IoT-generated data were anonymous, and none of the IoT-generated data implied to be compromised. Finally, data ledger storage ensured IoT-generated data via quadratic residue modulo operation, ensuring significant data analysis or management. As a result, the data storage accuracy using LMQ-LQ is improved by 2% compared to Deep Learning-based IoT-enabled Health Monitoring [1] and 4% compared to Blockchain-enabled large-scale IoT [2], respectively.

4.3 Comparison between different methods of energy consumption

Finally, energy consumption refers to the amount of energy consumed by a Blockchain, determining what IoT-generated healthcare data add to the distributed ledger. The mathematically stated as given below.

$$EC = \sum_{i=1}^{n} Samples_i * EC[Blockchain] \quad (13)$$

From the above equation (13), the energy consumption 'EC' is measured based on the samples involved in the simulation.' $Samples_i$ 'and the energy consumed by a Blockchain for the corresponding operation $EC[Blockchain]$.' Joules has measured in terms of 'J.' Table 4 shows the energy consumption rate using three different methods, Logarithmic Merkle Quantum-based Legendre Quadratic (LMQ-LQ) and the existing Deep Learning-based IoT-enabled Health Monitoring [1] Blockchain-enabled large-scale IoT [2], respectively.

Table 4 Tabulation for energy consumption

Samples	**Energy consumption (J)**		
	LMQ-LQ	Deep Learning-based IoT-enabled Health Monitoring	Blockchain-enabled large-scale IoT
7000	1750	2100	2800
14000	1785	2355	3015
21000	1835	2455	3135
28000	1925	2815	3245
35000	2015	3035	3395
42000	2135	3135	4015
49000	2245	3325	4135
5600	2385	3455	4255
6300	2415	3535	4735
7000	2535	3725	4925

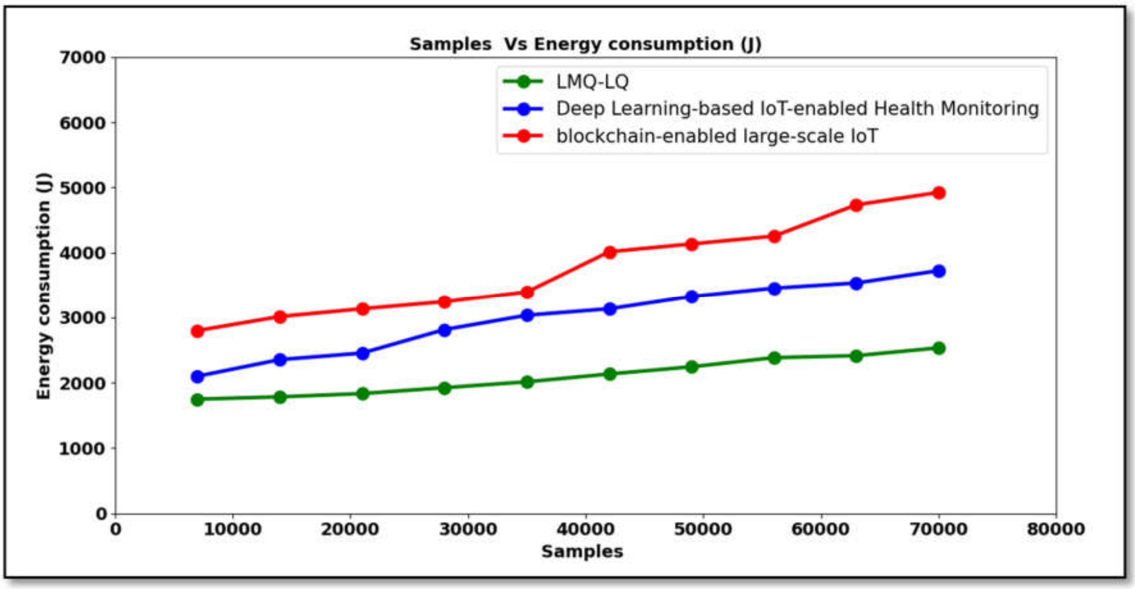

Figure-7 Graphical representation of energy consumption

Finally, Figure-7 shows the graphical plot of energy consumption concerning 70000 different samples of IoT-generated healthcare data obtained from augmented heart rate data. The figure shows that increasing the samples procured from the patient causes an increase in the number of blocks to create in the Blockchain for IoT-generated healthcare data. In turn, it causes an increase in the energy consumption consumed by a Blockchain to either make a new block or exit from the existing block. However, simulations performed with 7000 instances observed the energy consumption rate using LMQ-LQ to be 1750J, 2100J using [1], and 2800J using [2], respectively. These results show that Compared to [1] and [2], reduced the energy consumption using the LMQ-LQ method. The improvement was due to the application of Blockchain Logarithmic Merkle Post Quantum Legendre Quadratic Residue algorithm for IoT-generated healthcare data. By applying this algorithm, the Proof of Work (PoW) consensus mechanism is adopted with the aid of the Legendre Quadratic Residue function to construct the pertinent blocks. Here, two transactions, the patient and the doctor, are provided separately at the start of the transaction. As a result, every transaction is updated only upon the whole transaction is found to be completed. As a result, it reduces the energy consumption using the LMQ-LQ method by 29% compared to [1] and 44% to [2].

Two parties are provided with a wallet differently (displaying the amount of bitcoin) at the start of the transaction. First, save the wallet's address, and then the virtual channel is stored in Blockchain. Every transaction is updated only when the whole transaction is done or completed [12]. This has minimised the energy consumption per transaction and hence consumes much less energy. Although faster transactions using the lightning network method reduce through a bit of power, it could not minimise the massive energy consumption for mining.

5. Conclusion

In this paper, a Logarithmic Merkle Quantum-based Legendre Quadratic (LMQ-LQ) IoT generated healthcare extensive data analysis using Blockchain for data analytics is designed. The primary purpose of this work is to receive a large set of monitored parameters from the augmented health heart rate dataset and performs data analysis using the proposed LMQ-LQ method. In the initial phase, the proposed LMQ-LQ method obtains distinct types of parameters comprising both heart rate and blood pressure measurements for training and evaluating the dataset. First, Blockchain Logarithmic Merkle Tree is employed to construct a peer-to-peer network with IoT-generated heart rate data. Second, with the IoT-generated data built in the tree, Post Quantum-based Distributed Ledger is modelled according to the tree construction for IoT-generated healthcare data. Finally, the Legendre Quadratic Residue function applies to the IoT generated data from distributed ledger to formulate consensus with wise contract policy using Blockchain Logarithmic Merkle Post Quantum Legendre Quadratic Residue algorithm. A ten features benchmark augmented health heart rate dataset validates The proposed method's accuracy, time, and energy consumption. Further, the simulation results show that the proposed LMQ-LQ method outperforms conventional deep learning methods in numerous performance matrices.

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Declaration of Competing Interest:

A self-serving stake in the research result will be a promotion in my career.

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Two authors prepared this article. Manikandan Sivaprakasam performed materials preparation, data collection, coding and analysis. The first draft of the manuscript was written and evaluated by Dr Pushpa Vinu Amalraj. Both the two authors read and approved the final manuscript.