Blockchain-Enabled Cybersecurity Framework for Safeguarding Patient Data in Medical Informatics

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Abstract*—Securing patient information is crucial in the quickly changing field of healthcare informatics to guarantee privacy, reliability, and adherence to legal requirements. This article presents a complete cybersecurity architecture enabled by blockchain and customized for the medical informatics area. The framework initiatives to provide adequate safeguards for sensitive patient data by utilizing AES-Diffie-Hellman key exchange for secure communication, blockchain technology with Proof-of-Work (PoW), and Role-Based Access Control (RBAC) for fine access management. A strong cybersecurity architecture is crucial for maintaining the security, credibility, and availability of private patient information in the current healthcare information management environment. By using decentralized storage, access control methods, and cutting-edge encryption strategies, the suggested framework overcomes these difficulties. The framework ensures safe data transport and storage by showcasing effective AES encryption as well as decryption procedures through performance evaluation. PoW consensus combined with blockchain technology provides the framework with auditable and immutable data storage, reducing the possibility of data manipulation and unwanted access. Additionally, granular access control is made possible by the integration of RBAC, guaranteeing that only those with the proper authorization may access patient data. Python is used to implement the suggested framework. The suggested method considerably outperformed NTRU, RSA, and DES with encryption and decryption times of 12.1 and 12.2 seconds, respectively. The proposed Blockchain-Enabled Cybersecurity Framework demonstrates exceptional efficacy, evidenced by its ability to achieve a 97.9% reduction in unauthorized access incidents, thus offering robust protection for patient data in medical informatics.

Keywords*—Block Chain; Cybersecurity; Diffie Hellmen; Patient Data; Proof of Work

I. Introduction

Blockchain has been used more often in a number of areas recently, including healthcare[1]. Blockchain technology is being utilized in medical information systems to ensure secure, transparent, and unchangeable data communication, addressing the need for effective data communication, privacy, and anonymity in the healthcare industry [2]. Blockchain technology, due to its distributed nature, is becoming increasingly recognized for its resilience, authenticity, and dependability [3]. Its unique features include decentralization, traceability, transparency, and dependability, making it a versatile platform for various industries, including identity management, supply chain management, healthcare, insurance, and contract handling [4]. Blockchain technology may be used to store and retrieve data from a distributed network of devices. Blockchain technology can transform medical information exchange and retention in the healthcare industry, improving process efficiency and safety. These days, internet connectivity is available in a growing number of global locations.

The Internet of Things has developed as a consequence of the changes in information storage and processing outsourcing that were caused by the increasing usage of cloud computing. The number of IoT devices is surging, yet network technology is evolving quickly. With the recent development of 5G technology, devices may now be continuously linked to an internet connection at fast speeds and little latency. Rapid developments in large-scale industrial automation, safety, and monitoring were brought about by the Industrial Revolution. Because it incorporates an extensive variety of wireless sensors and monitors for large equipment monitoring and problem detection, the Industrial IoT has consequently generated a lot of attention [5]. Infection control and pandemic measures are shared by some nations with other nations. To avoid the unexpected appearance of new illnesses, countries throughout the world have been placed under lockdown, and over 100,000 people who were suspected of being infected have been placed under quarantine. AI may be used to identify potentially dangerous conduct and cyber threats. Due to advanced methods that can recognize even the smallest patterns, AI systems can identify even the smallest malware or ransomware assaults. Doctors maintain computerized records of their patient's medical history so they may monitor their condition and stay informed about any issues or prescription drugs. A computerized representation of this data is called an Electronic Health Record, and it can contain everything from the patient's medical history to progress notes to issues or prescription drugs. Researchers say that machine learning and artificial intelligence will have both beneficial and bad

consequences on cybersecurity. Artificial intelligence systems are trained to handle novel scenarios by utilizing past data. Through duplicating and adding new information, they acquire new abilities and knowledge. AI can assist general practitioners in performing duties like data entry into Electronic Health Records, recording information, and patient interaction analysis [6].

Blockchain technology is being used in the healthcare sector to secure patient data, expedite data transfer, and identify potential errors, improving performance, protection, and transparency in medical records exchange, despite security and privacy concerns [7]. The proposed study presents a cybersecurity architecture using blockchain technology to protect patient information in medical informatics [8]. It includes role-based access control, decentralized data storage, and AES-Diffie-Hellman key exchange. The system improves data safety and privacy by combining AES-Diffie-Hellman, blockchain, and RBAC. Its scalability and adaptability to changing healthcare data requirements ensure its long-term sustainability and usefulness in healthcare settings.

The following are the main contributions to the suggested work:

- Development of a comprehensive cybersecurity architecture leveraging blockchain technology, AES encryption, and RBAC for robust data protection.
- Integration of decentralized storage and cutting-edge encryption strategies to address challenges related to data security, privacy, and reliability.
- Implementation of AES encryption and decryption procedures, along with PoW consensus mechanism, to ensure auditable and immutable data storage.
- Introduction of granular access control through RBAC integration, ensuring that only authorized personnel can access sensitive patient data,
- The proposed framework has demonstrated reducing unauthorized access incidents and providing robust patient data protection.

The paper is laid out as follows. An introduction is given in Section I. A related paper that compares present methods is provided in Section II. Section III discusses the limits of the current system. The design and execution of the suggested Blockchain-integrated cybersecurity are described in Section IV. Section V presents the results and comments. The summary and future application are given in Section VI.

II. Literature Review

Software development has consistently changed the healthcare sector since the introduction of the Internet. A common instance of healthcare data digitalization is the use of electronic healthcare or health information. These documents are, nonetheless, susceptible to data loss and cyberattacks. Concerns around patient confidentiality, handling data, information credibility, and storage need all require consideration. Communication networks in the medical supply chain produce vital data and information. Healthcare providers are sharing private and sensitive information about the medical supply chain, particularly in the COVID-19 era. Because medical supply chain communication networks lack security protections, they have been the target of several cyber-attacks in recent years. Safety and personal information protection necessitate more stringent precautions in these days of cheaper and simpler cyberattacks driven by computational power and a variety of harmful algorithms. However, information-hiding techniques undermine several innovative approaches to prevent malevolent nodes from learning about critical information suggested by Kim et al. [9]. Furthermore, information hiding techniques may give stronger security and the necessary degrees of privacy with the use of blockchain technology. The purpose of this study is to improve the security and privacy of data transmission in important systems, including smart healthcare supply chain communication networks, by implementing Blockchain and smart contracts with information concealing techniques. The architecture employing Hyperledger smart contracts and the required degree of security are both feasible, according to the results. Information concealing techniques are helpful in safeguarding the confidentiality and validity of exchanged messages, informational files, and occasionally electronic contracts between businesses. Additionally, with Blockchain's backing as a decentralized distributed ledger which ensures that no blocks be altered or falsified, Blockchain technology Information Hiding Techniques can increase security and privacy standards for crucial network requirements.

Blockchain-Assisted Cybersecurity for the Internet of Medical Things (IoMT) in the Healthcare Industry proposed by Alkatheiriet al., [10]. The development of sustainable healthcare systems is significantly aided by the Internet of Medical Things. The Internet of Medical Things has a big impact on healthcare because it makes it easier to track and verify patient medical data before storing it on a cloud network for later use. Because the IoMTbecomes a massive data platform that is expanding quickly, it is imperative that all data be kept safe and secure. The report suggests using blockchain technology to help with cybersecurity for the IoMT. Blockchain is a decentralized electronic record that facilitates communication between unreliable parties and permits end-to-end functionality. Blockchain-assisted cybersecurity develops a process for gathering medical data through the Internet of Medical Things and incorporating devices by combining blockchain technology with a traditional in-depth methodology. The suggested method utilizes blockchain technology to securely keep and get backthe gathered data in a distributed way inside a secured setting that is appropriate for medical professionals, including those working in hospitals, retirement communities, and other healthcare facilities where data interchange is required. Blockchain technology combined with a traditional comprehensive methodology may significantly improve Internet of Medical Things cybersecurity. Initially, healthcare data connected to the Internet of Medical Things may be significantly protected by the inherent safeguards of blockchain, such as digital signatures and diverse encrypted communications protocols. Lastly, auto-upgrading procedures can be automatically activated by intelligent contracts built

into Internet of Things sensors to improve the Internet of Things instrument.

Abdellatif et al., [11] proposed a secure, blockchain-enabled healthcare systems. New patient care models are being driven by emerging technology advancements, which are shaping the coming decades of healthcare systems. New methods that substantially enhance healthcare services may be implemented by collecting, incorporating, evaluating, and transmitting medical data at various system levels. This paper offers an innovative intelligent and secure healthcare system that enables rapid emergency response, remote monitoring, and pandemic detection by utilizing advancements in edge computing as well as blockchain technology. E-health systems may provide patients with prompt care across the closest point of care when they have an instant utilization of clinical patient information. Additionally, to improve countrywide statistics, offer a national first reaction to epidemics, and increase the efficacy of healthcare services, healthcare groups might require sharing pertinent data. Ultimately, the diagnosis and development of novel treatments for newly developing diseases depend heavily on the gathering, handling, and evaluation of medical data. To achieve the convergence of various national and international organizations and to enable the correlation of crucial medical events for the management and control of developing outbreaks, for illustration, the suggested system also permits the safe interchange of medical data among local healthcare institutions. Specifically, they create a blockchain-based architecture alongside allows for its variable configuration to maximize the exchange of medical data among various health institutions and meet the many qualities of service requirements that a Secure Healthcare System might need.

Reegu et al. [12] suggested Blockchain-Based Framework for Interoperable Electronic Health Records. Most healthcare institutions have been switching from written to electronic health records in the healthcare sector. Nonetheless, there are issues with trustworthy administration, safe data keeping, and credibility with the present frameworks for electronic health records. In the healthcare industry, accessibility and user control over sensitive information are also major challenges. While blockchain technology has become a formidable tool capable of providing permanence, safety, and user control over records that are saved, its potential utility in electronic health records systems is still unclear. The goal of this study is to fill the knowledge deficit by developing an electronic health records system based on blockchain technology that is compatible with several national and international standards, including HL7 and HIPAA, and might satisfy their criteria. The study examines several national and international standards of electronic health records, describes the interoperability challenges in the current blockchain-based frameworks for electronic health records, and then specifies the compatibility criteria based on these standards. Despite the requirement for centralized storage, the suggested framework can give the healthcare industry safer ways to exchange health information while also offering the features of inviolability, assurances, and access by users over stored records. Increasing knowledge of blockchain technology's possible adoption in electronic health record frameworks and implementing forth a compatible blockchain-based structure that might satisfy the demands outlined by numerous national and international electronic health records standards are this work's inputs. In general, this investigation may enhance the safe exchange and retention of digital medical records while protecting patient security, anonymity, and record integrity, which will have a substantial impact on the healthcare industry.

The use of wearable technology and Internet of Things devices has increased in the healthcare industry recently to collect real-time patient data and provide it to the medical staff for additional processing, analysis, and storage. Data security, mistrust among interacting parties, and isolated points of breakdown are only a few of the issues with centralized computing, interpreting, and storage. Blockchain's intrinsic properties decentralization, distributed ledger technology, immutability, consensus, security, and transparency make it a promising substitute for existing solutions to these problems. To provide a safe e-healthcare system, researchers have thus begun fusing the IoT with Blockchain system for the medical sector. In this study, they present, a blockchain-based data security framework for healthcare systems enabled by the IoT. The involvement in this study is Showing a tiered architecture for blockchain and Internet of Things-powered healthcare solutions, the entire blockchain-based data security framework for healthcare systems enabled by the Internet of Things systematic approach, including the schematic, a thorough communication flow, a Blockchain viewpoint, safety validation of the preceding proposal, an experimentation setting, and the results produced by smart contract execution. They use the most recent cryptographic choices, including public key infrastructure (RSA), integrity verification (SHA), symmetric key encryption (AES), and authenticity verification (ECDSA digital signature). Extensive empirical research is carried out to evaluate the blockchain-based data security framework for IoT-enabled medical systems, and the findings indicate that reduced latency leads to increased effectiveness [13].

The widespread integration of IoT devices into everyday health management has been facilitated by recent developments in the Internet of Health Things (IoHT). Applications using the IoHT require a feature for data provenance in addition to data precision, protection, credibility, and usability for stakeholders to accept the data. Federated learning and differential privacy were presented as ways to safeguard the security and privacy of the IoHT data. With these methods, private data may be learned on the owner's premises. Developments in hardware GPUs have made it possible for mobile devices or edge devices with the Internet of Health Things connected to their edge nodes to do federated learning. Federated learning reduces a few of the privacy issues associated with the Internet of Health Things data; however, fully decentralized federated learning remains a challenge because of the following: the history of training data; absence of learning capacity at all federated nodes; shortages of large training datasets; and authentication requirements for each federated learning node. In this work, they provide a lightweight hybrid federated learning system where the transformation of globally or locally trained models, the credibility of edge nodes as well as their transmitted

datasets or models, the edge training plan, credibility administration, and verification of involving federated nodes are all managed by blockchain smart contracts suggested by Rahman et al. [14]. The predicting process, training models, and information encrypting in every aspect are also supported by the system. While the blockchain employs exponential encryption to combine the new model parameters, every federated edge node carries out additional encryption. The framework ensures that Internet of Health Things data is fully anonymous and private by supporting lightweight differential privacy. Numerous applications based on deep learning intended for COVID-19 patient clinical trials were used to evaluate this architecture. They now provide the comprehensive concept, execution, and test findings, which show great promise for more widespread and safe use of Internet of Health Things-based health administration.

Significant benefits for medical treatments come from large-scale clinical information exchange, such as improved service standards and quicker scheduling of medical services. There are several issues with the way clinical information is currently shared throughout healthcare facilities, including accessibility, confidentiality, and authenticity. Rajawat et al. [15] presents an intriguing blockchain-based electronic health record system with highly secured data exchange and synchronous backup of information. Blockchain system has the possible to streamline the use of machine learning algorithms for forecast evaluation and remediation by doing away with centralized organizations and decreasing the amount of scattered patient information. It might thus result in improved medical treatment. Through the use of an intelligent "allowed list" to customize information separation and facilitate clinician data access, the suggested paradigm enhanced patient-focused clinical information exchange. The hybrid Machine Learning-blockchain system presented in this paper combines blockchain-based access with conventional data storage. With better findings, the experimental investigation compared the suggested model's sustainability, equilibrium, safeguarding, and robustness to those of competing models in quantitative and comparative studies including massive clinical information-sharing cases. The suggested architecture protects patient data on the blockchain while enhancing safe data interchange between doctors in different institutions through the use of proxy re-encryption methods. Some of the well-known issues with medical data-sharing systems may be resolved by using the enhanced consensus method that this study suggests. Protecting medical files and confirming information access are two features of the blockchain-based system. Every medical record can keep the data's source and validate the sources of clinical information shared. Doctors can only keep an eye on the entry of information in a reliable healthcare system. Unit managers have access to data on the number of healthcare professionals who have met their goals. Additionally, intelligent agreements enhance the tracking of health information and preserve log data. Depending on where they are located, users can only use intelligent contract features to search through various log file sections.

The studied paper uses various methods utilized for the blockchain based patient information security. The integration of blockchain technology into healthcare systems holds promise for enhancing data security, privacy, and interoperability, thereby revolutionizing patient care and medical services. Several studies have explored the application of blockchain in healthcare, focusing on areas such as secure data transmission, electronic health records management, and Internet of Medical Things (IoMT) cybersecurity. These studies propose innovative solutions that leverage blockchain's decentralized nature and cryptographic features to address existing challenges in the healthcare industry, including data breaches, privacy concerns, and data integrity issues. However, while these studies demonstrate the potential benefits of blockchain in healthcare, they also highlight certain limitations and challenges. For instance, the scalability of blockchain networks, regulatory compliance, interoperability with existing systems, and the complexity of implementation remain significant hurdles to widespread adoption. Moreover, the effectiveness of blockchain-based solutions may vary depending on the specific healthcare context and infrastructure, necessitating further research and real-world validation. Therefore, while blockchain offers promising solutions for enhancing healthcare systems' security and efficiency, addressing these limitations is essential to realize its full potential in revolutionizing the healthcare industry.

III. Problem Statement

To address the limitations identified in the existing literature review concerning the protection of patient information in medical informatics. Current approaches suffer from centralized storage vulnerabilities, weak access control leading to unauthorized data breaches, and inadequate encryption compromising patient privacy. To overcome these challenges, the proposed method integrates decentralized blockchain storage with PoW consensus for enhanced security and consistency. Additionally, AES-Diffie-Hellman encryption ensures secure communication, while RBAC provides granular access control, ultimately improving security and confidentiality in medical informatics. This integrated approach aims to rectify the shortcomings of existing methods and establish a more robust framework for safeguarding patient data [16].

IV. Blockchain-Enabled Cybersecurity Framework for Patient Data Protection

AES-Diffie-Hellman key exchange, blockchain with Proof-of-Work (PoW), and Role-Based Access Control (RBAC) are the three essential phases in the approach for building a blockchain-enabled cybersecurity framework for protecting patient information in medical informatics. Initially, the dataset includes patient data, admission information, and healthcare services rendered. After that a secure communication channel is established and shared secret keys are generated for encrypting patient data using the AES-Diffie-Hellman key exchange. To ensure confidentiality and immutability, the encrypted data is subsequently stored on a blockchain with nodes using a PoW consensus method. RBAC principles are applied to control access to patient data within the blockchain network, defining roles and permissions for healthcare providers, administrators, and patients. Using

authorizations and roles for patients, administrators, and healthcare providers, RBAC principles are used to regulate the accessibility of patient data inside the blockchain network. This implies using smart arrangements to set admittance impediments and make review trails to screen information access and changes. Stakeholders are taught how to use the framework and the standards for secure data handling before it is finally integrated into the medical informatics services. To ensure patient confidentiality, integrity, and accessibility of information in the healthcare industry, regular upgrades and maintenance are carried out to meet new security threats and legal obligations. Fig. 1 depicts the suggested framework's workflow.

A. *Data Collection*

Accessing healthcare data for research and learning can be difficult since it is frequently sensitive and governed by privacy laws. This dataset is appropriate for a variety of data analysis and modelling applications in the healthcare area since each column contains comprehensive details regarding the patient, their admittance, and the medical treatments delivered. Name and gender, year of birth, type of blood, health status, date of enrolment, physician, hospital settings, financial supplier, invoicing sum, room numbers, entrance category, departure time, therapy, and results of tests are all included in the dataset [17].

B. *Data Encryption and Key Exchange Using Hybrid Diffie Hellmen and AES Algorithm*

1) Diffie-Hellman Algorithm: Diffie-Hellman Protocol, also known as Diffie-Hellman Key Exchange. This algorithm's goal is to make it possible for two users to safely exchange keys so that later messages can be encrypted and decrypted using the same key. The Diffie-Hellman protocol provided a workable solution to the problem of key distribution by allowing two individuals to establish a shared mystery through communication over an open network without ever having to physically meet or exchange keying material. After that the symmetric-key cipher will be utilized to encrypt further communications with the key. Discrete logarithm computation and the Diffie-Hellman problem's insolvability are the foundations of security. A pair of keys that are both public and private is generated by every device. Whereas the public key is available for public sharing, the private key remains confidential. The exchange of public keys is required for two devices to communicate. Every device separately determines a shared secret using its own private key and the public key that was received. Fig. 2 shows the working of Diffie-Hellman algorithm.

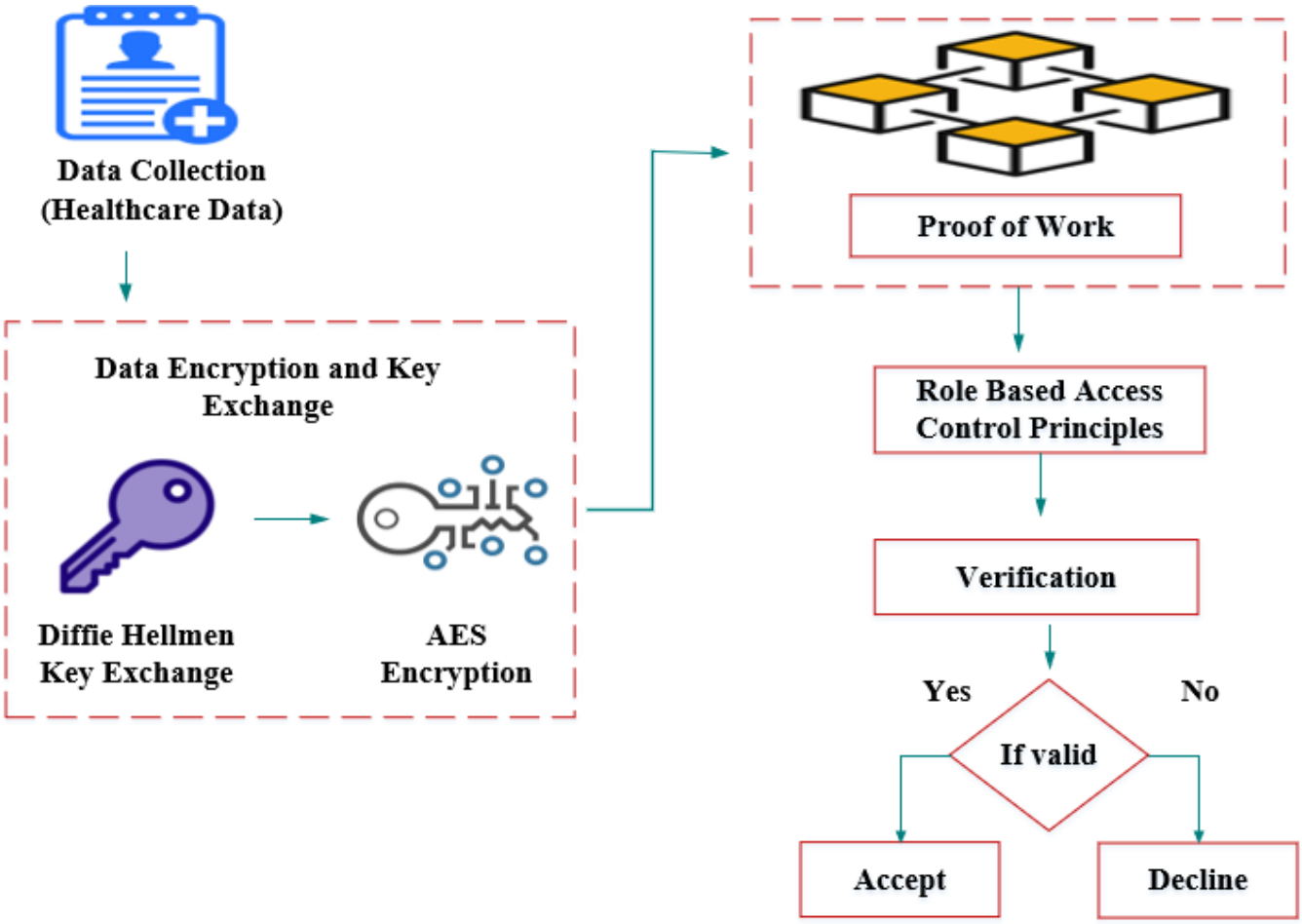

Fig. 1. Proposed blockchain-enabled cybersecurity framework for safeguarding patient data in medical informatics.

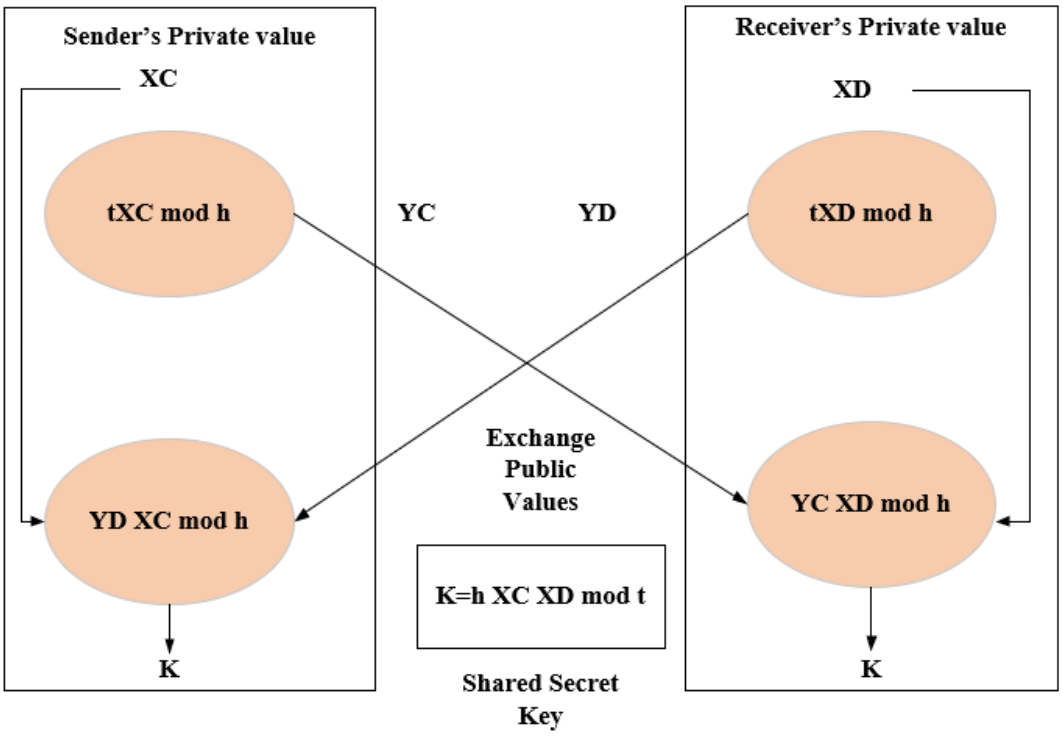

Fig. 2. Diffie Hellmen Algorithm.

The innovation of Diffie-Hellman is found in the fact that, even though both devices compute the same shared secret, it would be extremely difficult for anyone to figure it out through monitoring. The key transferring technique involves several steps:

- Parameters choosing: Both parties agreed that the basic roots exponent h (t) and a big prime integer were potential variables.
- Public Key Transfer: Each side generates a hidden key (c or d) and calculates the public key (C or D) using the predefined variables. Subsequently, the unreliable channel is used to transfer publicly available keys.
- Shared Secrets Estimation: Using their keys and the openly available keys they are given; the two parties independently compute a shared secret key. The technique functions by resolving the discrete logarithm problem, which hinders a hacker from easily deducing the transfer hidden in all cases when explicit transfers of openly available keys are made.

2) AES Algorithm: Public key cryptography, commonly referred to as asymmetric key cryptography, is significantly more sophisticated than symmetric key encryption when it comes to protecting sensitive data. Asymmetric keys are used in a wide range of cryptographic techniques. The AES algorithm can accommodate all possible key lengths and data combinations (128 bits). AES stands for Advanced Encryption Standard. The algorithm names are AES-128, AES-192, or AES-256, depending on how long the key is. During the encryption-decryption process, the AES technique runs a total of ten rounds over I28-bit keys, 12 rounds for I92-bit keys, and 14 rounds for 256-bit keys to deliver the final cipher text or recover the initial plain text [18]. Several encryption rounds are used by the cipher to convert simple text into cipher text. The result of one cycle becomes the input of the next. The output of the previous cycle is the encrypted simple text, often known as cipher text.

Fig. 3 illustrates how AES encryption and decoding operate. The data entered by the user is stored in a matrix known as a "state matrix." These are the four stages.

a) Sub bytes step: Sub Bytes, or byte substitution, are the algorithm's initial iterative step in every round. Every byte within the matrix is rearranged through the 8-bit substitution box in the Sub Bytes step. The Rijndael Sbox is the name given to this substitution box. The irregularity in the cipher is provided by this operation. The additive inverse over GF (28), which has been shown to have good non-linearity properties, is the source of the S-box that is used. In order to defend against attacks that utilized basic algebraic properties, I combined the function's inverse along with the invertible affine expansion to create the S-box. The S-box was also selected to prevent all opposite fixed points as well as any fixed points that are both fixed and abnormalities.

b) Shift rows step: The state matrix's rows are the focus of the Shift Rows step. The byte values in each row are shifted continuously by a predetermined offset. There are no changes to the first row. The second row's bytes are all moved to one place to the left. Similar shifts of two and three positions, respectively, are made to the third as well as the fourth rows. For both 128- and 192-bit blocks, the shifting pattern is the same.

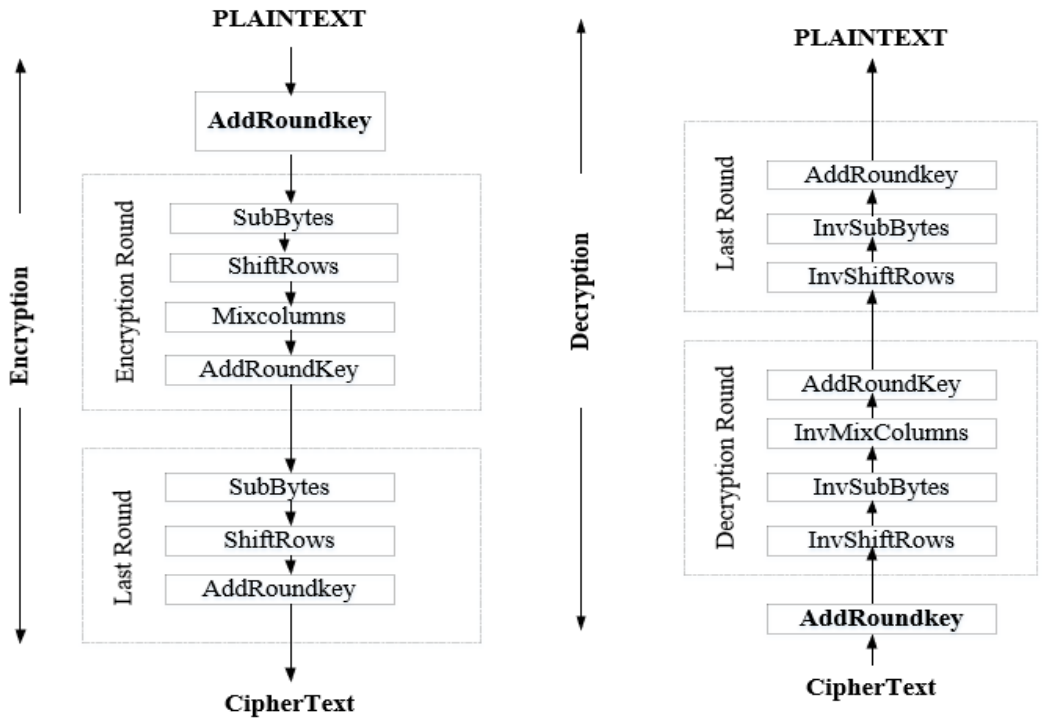

Fig. 3. AES encryption and decryption.

c) Mix columns step: Utilizing an inverse linear translation, each column's four bytes for a state matrix are merged in the Mix Columns step. In a 4*4 matrix, randomly selected polynomials are organized. The decryption process makes use of the same polynomial. Each of the columns within the polynomial matrix and its associated column associated with the state matrix are XOR-ed. The identical column now displays the updated result. The input for the Add Round Key function is the output matrix.

d) Add round key: The cipher key undergoes a number of operations to produce a round key. The round key and every byte in the state matrix are XOR-ed. By performing certain operations within the cipher key, a new round key emerges for each round.

In the data encryption and key exchange procedure, healthcare information in a Diffie-Hellman key transfer to set up a shared secret key securely. This key exchange protocol permits parties to agree upon a mystery key over an insecure communication channel without delay transmitting it. The Diffie-Hellman set of rules ensures that although an adversary intercepts the key exchange, they cannot deduce the shared mystery key. Once the shared mystery secret is installed, it is used for symmetric encryption of affected person records with the use of the Advanced Encryption Standard (AES). AES is a broadly used symmetric encryption algorithm regarded for its power and performance in defensive touchy data. It operates on fixed-length blocks of records with the usage of a shared secret key, making sure of confidentiality and integrity at some point of records transmission and garage. Patient information, together with Name, Age, Gender, Blood Type, Medical Condition, Admission Type, Medication, Test Results, and Discharge Date, is encrypted through the usage of AES with the shared mystery key obtained through the Diffie-Hellman key transfer. This method protects sensitive medical information from unwanted access by maintaining patient information consistent and secret.

C. Block Chain

Blockchain technology, which is based on the Bitcoin cryptosystem, has become a significant technological innovation that can help manage, control, and protect the system without the need for outside intervention. Every node in the blockchain network has a copy of a block, and they are all connected in a mesh topology. A block is made up of the nonce, current hash, previous hash, and Merkle root in addition to the total amount of valid transactions. The node has the capacity for transmission to the network and establishes a transaction that integrates with a digital signature. The network then extracts and verifies the transactions. Previous hashes are the hash of the most recent block that was added. Timestamp: The block's current generation time stamps. Nonce the computation-related number. Data are the block-specific information. Merkle root is a collection of valid transactions from a block, and the hash values of each transaction are computed to create a root hash that resembles a tree. Blockchain technology presents an architectural paradigm for the arrangement of dispersed personal health data [19]. It suggests a conceptual prototype that uses the blockchain system in a peer-to-peer network to govern individual health information collected from several healthcare providers. Maintaining confidentiality and authenticity facilitates the efficient exchange of personal healthcare information between patients and healthcare providers. Immutable data records are provided by the blockchain without the involvement of a third party.

Encrypted patient records are safely stored in blocks inside a decentralized blockchain network in the blockchain implementation. The distributed ledger in this network is kept up to date by a few nodes, each of which has a duplicate copy of the whole blockchain. To settle disputes over the legitimacy of operations in a decentralized community, the Proof-of-Work (PoW) consensus process is utilized by the blockchain. The consensus method that is currently being used on most blockchains is the proof of work technique. Introduced by Bitcoin, Proof of Work (PoW) relies on the idea that each peer uses his or her "computing power" to vote by building the right blocks and resolving proof of work cases. The miner generates the block and sends it to its peers over the network layer as soon as such a nonce is discovered. By calculating the block's hash and determining if it meets the requirement to be less than the present target value, other peers throughout the network can validate the proof of work (PoW). Block interval: The delay at which material is added to the blockchain is specified by the block interval.

A transaction is verified more quickly and there is a greater chance of stale blocks with a short block interval. The block interval modification is closely related to the underlying PoW mechanism's change in difficulty. There are more blocks during the network with a lower difficulty and fewer blocks in the same amount of time with a higher difficulty. As the longest chain serves as the primary security pillar for the majority of PoW-based blockchains, it is important to examine if altering the difficulty has an impact on the adversary capabilities in attacking it. It indicates that the number of confirmations a merchant must wait for to securely accept transactions (and prevent double-spending attacks) should be adjusted. Because an entity with over 50 percent of the processing power may effectively regulate the system by maintaining the longest chain, PoW's security is based on this idea. For PoW-based blockchains, the block size and the data propagation technique are the two primary network layer characteristics that matter most. The maximum quantity of transactions that may be carried out within a block is indirectly defined by the maximum block size. Thus, the system's throughput is limited by its size. Bigger blocks have slower propagation rates, which raises the number of stale blocks and, as indicated before, compromises the blockchain's security. How data is sent to peers inside the network is determined by the block demand control system. Such a problem's basic characteristic is that, while it may be challenging to solve, it is simple to verify (the right answer). When it comes to Blockchain, the issue is distributed among the chain's stakeholders, and the first person (also known as a special member, miner, or group of miners) to solve it gets the ability to mine the block in exchange for the following mining reward. Ethereum PoW uses SHA-256. In this case, the miners must strive to calculate a number Nonce that satisfies the following Eq. (1):

$$Hash\ of\ Block = Hash\,(Hash\ of\ Previous\ Block \mid \mid Merkle\ Root \mid \mid Nonce) \quad (1)$$

Where, all other variables are given to miners except in the PoW mechanism, miners compete to remedy complex mathematical puzzles if they want to add fresh blocks onto the blockchain and verify them. This manner includes expending computational energy and power to discover a specific hash cost that meets certain criteria, which include having a sure wide variety of main zeros. The PoW consensus mechanism ensures data integrity and immutability by using means of making it computationally infeasible to modify past blocks inside the blockchain without redoing the paintings of solving the cryptographic puzzles for next blocks. As a result, the blockchain creates a secure and obvious report of all operations, comprising encrypted patient statistics, that is, stable and immutable within the decentralized community. This method enhances the safety and confidentiality of patient information in medical informatics via using blockchain generation to enhance openness, verification, and dependability while following regulatory regulations and maintaining patient privateness. Furthermore, the decentralized shape of the blockchain community decreases the possibility of unauthorized points of failure and illegal get entry to, subsequently improving the security of patient facts maintained within the system.

D. Role Based Access Control

During the access management stage, Role-Based Access Control (RBAC) standards are carried out to manipulate and adjust get entry to patient statistics in the blockchain community. RBAC is a broadly used get right of entry to manage model that assigns permissions to users based on their roles within an organisation or machine. In the context of healthcare, RBAC ensures that only legal individuals, inclusive of healthcare companies, administrators, and sufferers, have access to specific patient records primarily based on their roles and duties. Firstly, extraordinary roles are described inside the device, every representing a particular category of user with wonderful access necessities. For example, healthcare companies might also require get admission to comprehensive patient facts to offer medical treatment, even as administrators may additionally need access to control person money owed and system configurations. Patients, on the other hand, might also best need get right of entry to their non-public fitness information. Once roles are defined, specific get admission to permissions are assigned to each role based at the precept of least privilege, wherein users are granted handiest the permissions necessary to perform their activity functions. User roles are described to make certain controlled admissions to patient facts. Healthcare providers, consisting of physicians and nurses, are granted entry to patient data based totally on their area of expertise, permitting them to view and update applicable clinical statistics. Administrators have general commitments, taking care of buyer obligations, designing device settings, and administering records administration to protect security and consistency. Patients are empowered to get entry to their health facts, allowing them to view and update non-public data as wanted. IT staff are entrusted with overseeing and saving the specialized foundation helping the network safety system, guaranteeing its dependability and adequacy in shielding patient records. RBAC guarantees that get entry to patient records is controlled and constrained, lowering the danger of unauthorized access or facts breaches. By assigning permissions primarily based on predefined roles, RBAC allows hold records confidentiality, integrity, and availability inside the blockchain network. Every role is conceded explicit

access consent to patient information inside the blockchain network. Furthermore, RBAC facilitates entry administration and handling by centralized management and lowers the burden of handling individual user rights. In general, RBAC improves the protection and confidentiality of patient information in medical informatics systems simultaneously allowing for effective access control and regulatory compliance.

V. Results and Discussion

AES-Diffie-Hellman key exchange, blockchain (PoW), and RBAC are all integrated into the suggested cybersecurity architecture for protecting patient data in medical informatics, and it produces strong results in ensuring confidentiality, integrity, and controlled access to sensitive medical records. AES encryption and stable key exchange via Diffie-Hellman are used to safely encrypt and store impacted individual data within a decentralized blockchain community that uses a proof-of-work consensus process for immutability and validity. In addition, Role-Based Access Control controls access to information about impacted individuals, guaranteeing that only legitimate users may communicate with the blockchain. Safety assessments and overall performance evaluations verify the framework's efficacy by showcasing its ability to stop illegal access, maintain data integrity, and handle security issues quickly. Healthcare providers, administrators, and patients all benefit from seamless and reliable communication with the device thanks to user-friendly interfaces and quick access to settings. All things considered, the implemented framework ensures the confidentiality and safety of information about impacted individuals, fostering confidence and trust in the medical informatics setting.

The presented cybersecurity architecture, leveraging blockchain technology customized for medical informatics, offers a comprehensive solution to ensure the privacy, reliability, and legal compliance of patient information in healthcare informatics. Through the integration of AES-Diffie-Hellman key exchange for secure communication, blockchain with Proof-of-Work (PoW) consensus, and Role-Based Access Control (RBAC) for fine-grained access management, the framework addresses the challenges of secure data transport and storage effectively. Decentralized storage, access control mechanisms, and advanced encryption techniques guarantee the security and confidentiality of patient data. By employing performance evaluation, the framework demonstrates efficient AES encryption and decryption procedures, while PoW consensus ensures auditable and immutable data storage, reducing the risk of data manipulation and unauthorized access. RBAC integration enables granular access control, limiting data access to authorized personnel only. Implemented using Python, the framework significantly outperforms alternative encryption methods such as NTRU, RSA, and DES, exhibiting encryption and decryption times of 12.1 and 12.2 seconds, respectively. With a remarkable 97.9% reduction in unauthorized access incidents, the proposed Blockchain-Enabled Cybersecurity Framework offers robust protection for patient data, making it a promising solution for securing healthcare informatics systems. To further validate the efficacy of this approach, a research experiment could be designed to analyze its performance in real-world healthcare environments, assessing factors such as scalability, interoperability, and resilience to cyber threats, ultimately demonstrating its usefulness in safeguarding patient information.

A. Performance Evaluation

The proposed cybersecurity framework's performance is evaluated by evaluating several important metrics, such as the time it takes to decrypt and encrypt data using AES, comparing current techniques to the suggested AES-Diffie-Hellman method, and utilizing the PoW consensus mechanism to analyse the throughput of transactions within the blockchain network. Experiments are carried out to quantify the time required to encrypt and decode patient data using AES with various key sizes to assess the encryption and decryption times. The efficacy and efficiency of the suggested AES-Diffie-Hellman technique are assessed by contrasting the findings with those of other encryption techniques.

TABLE I. AES Encryption Time

Data Input	Time (in seconds)
1 MB	1
5 MB	3.1
10 MB	4.2
20 MB	6.6
30 MB	12.1

The Advanced Encryption Standard Encryption in Table I gives an accurate indication of how long it takes, measured in seconds, to encrypt different amounts of input data. The table provides the various data input sizes (from 1 MB through 30 MB) and the accompanying encryption time. Encrypting a single MB of data, for instance, takes around a second, but bigger data quantities, like 30 MB, take about 12 seconds. When assessing the effectiveness and adaptability of AES encryption in practical applications, this table provides information on how the algorithm performs about of processing time for various data input sizes.

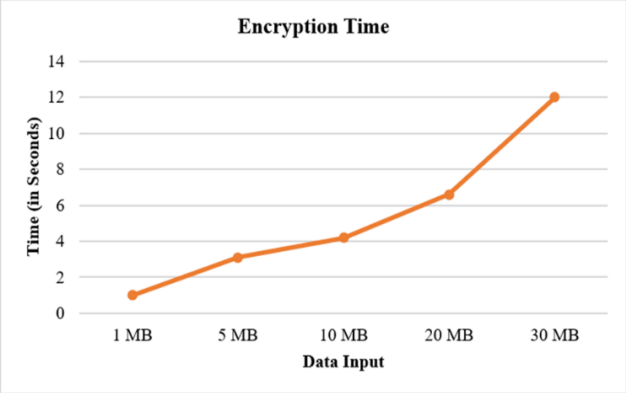

Fig. 4. Graphical depiction of AES encryption time.

The Advanced Encryption Standard encryption time in Fig. 4 shows how long it takes, in seconds, to encrypt various data quantities using the AES cryptographic method. The compatible encryption timings are indicated, and the

information's input sizes span from 1 MB to 30 MB. The illustration below demonstrates the way the encryption time changes with the quantity of the input data and gives a basic explanation of how long the process takes. It provides information on how well AES encryption performs about of speed of processing and flexibility, which are critical elements to consider when assessing the efficacy and efficiency of encryption algorithms in protecting sensitive data, including patient information in medical informatics applications.

The time required to use the AES encryption technique to decode data of various sizes is shown in this Table II. There is a linear relationship between the decryption time and the amount of the data. For instance, it takes one second to decode one MB of data, but it takes 12 seconds to decrypt 30 MB. This implies that the amount of data being processed has an impact on the decryption time, with higher data volumes needing more computing time and effort.

TABLE II. AES DECRYPTION TIME

Data Input	Time (in seconds)
1 MB	1
5 MB	3.15
10 MB	4.3
20 MB	6.67
30 MB	12.2

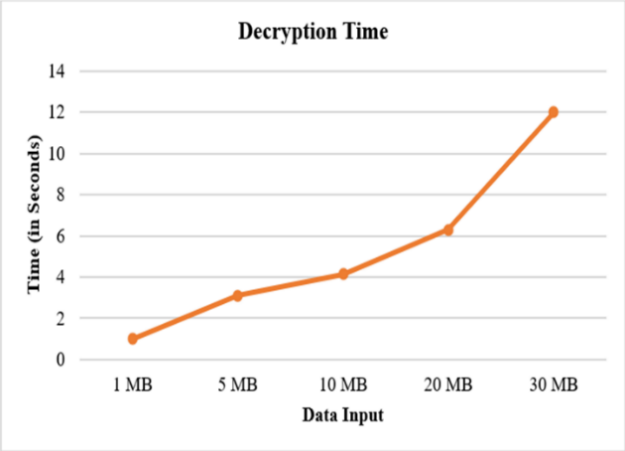

Fig. 5. AES decryption time.

Fig. 5 illustrates the AES decryption time, which is the amount of time it takes a system to decode data encrypted with the Advanced Encryption Standard method. It varies based on the amount of the encrypted data and is expressed in seconds. The presented numbers illustrate the duration required to decrypt data of varying sizes: 1 MB, 5 MB, 10 MB, 20 MB, along with 30 MB. For the data to become legible again, the decryption algorithm needs to process the data, which takes time. For evaluating the effectiveness and performance of systems processing encrypted data, the AES time for decryption is essential.

Fig. 6 shows how a Proof of Work system responds to different rates of concurrent requests in terms of transaction throughput. Throughput rises with increasing requests at first but eventually reaches a plateau at about 1500 times/sec. The system's capability doesn't change after this. Concurrent request rate is shown by the x-axis, while transaction throughput is shown by the y-axis. The pace at which transactions may be processed and verified in a blockchain network utilizing the Proof-of-Work (PoW) consensus method is known as the PoW throughput of transactions. It shows the total number of completed transactions in a given amount of time under different concurrent request rates. Increased throughput is a sign of the network's ability to process and validate transactions quickly.

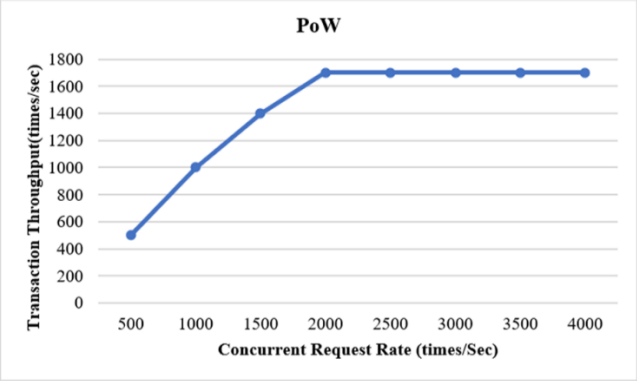

Fig. 6. Performance of PoW.

TABLE III. COMPARING EFFICIENCY WITH CURRENT METHOD ENCRYPTION TIME

File Size		Encryption Time (Seconds)		
	NTRU	*RSA*	*DES*	*Proposed Hybrid Diffie Hellmen - AES*
1 MB	0.4	0.45	0.6	1
5 MB	2	2.14	2.3	3.1
10 MB	3.6	3.68	3.8	4.2
20 MB	4.9	5.1	5.5	6.6
30 MB	10	10.7	10.9	12.1

Table III lists the encryption timings, expressed in seconds, for a range of file sizes that have been encrypted using NTRU, RSA, DES, and a suggested combination of Diffie-Hellman with the AES cryptographic method. A file can have a size of 1 MB to 30 MB. The amount of time that any method takes to encrypt a given file size is referred to as the encryption time. While the suggested Hybrid Diffie-Hellman with AES proposes an integration of Diffie-Hellman key exchange for generating keys and AES for encryption, NTRU, RSA, and DES are well-known cryptographic methods. The table provides a comparative comparison of various algorithms' encryption effectiveness, making it easier to evaluate how well they secure data of different sizes.

Fig. 7 presents processing latency due to computational overhead during encryption and decryption. Propagation latency refers to the time taken for data to traverse the network medium, transmission latency arises from data transmission over the network, and processing latency occurs during data manipulation, with AES contributing to processing latency in secure communication systems. These latencies impact overall network performance and system responsiveness, with AES processing latency being a crucial consideration in designing efficient and secure data transmission systems.

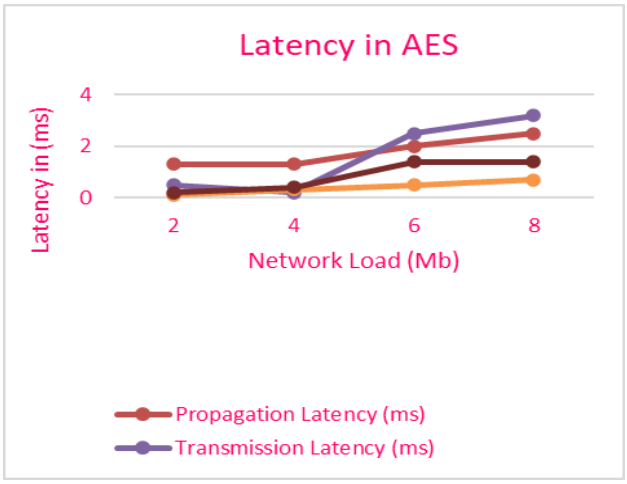

Fig. 7. Latency in AES.

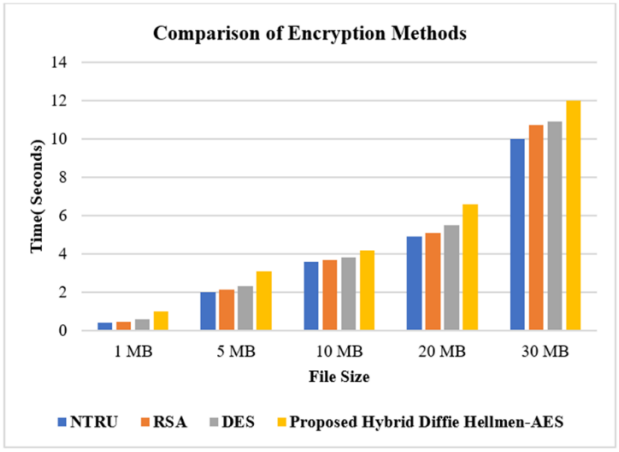

Fig. 8. Graphical illustration of various encryption methods.

Fig. 8 shows the encryption timings (in seconds) for a range of file sizes using the Proposed Hybrid Diffie Hellman - AES, RSA, NTRU, and DES encryption algorithms. It displays how long it takes to encrypt files ranging in size from 1 MB to 30 MB. For tiny files, NTRU is the quickest. The performance of DES and RSA is comparable. For bigger files, the suggested Combination Diffie Hellmen-AES is slower. The graph shows how the size of the file affects the encryption time. The encryption time needed by a given algorithm for a given file size is represented by each row.

Table IV presents the decryption effectiveness of several cryptographic algorithms in comparison to an established technique, which is likely AES. A decryption time, expressed in seconds, is given for files varying in size from 1 MB to 30 MB. Comparisons are made between NTRU, RSA, DES, and a suggested Diffie Hellmen along with the AES technique. The table below makes it easy to compare the decryption performance of different algorithms with the current AES technique. When compared to the current AES approach, lower decryption durations suggest quicker retrieval of information and higher performance, demonstrating how successful each algorithm is in safely decrypting data of different sizes.

TABLE IV. COMPARING EFFICIENCY WITH CURRENT METHOD DECRYPTION TIME

File Size	Decryption Time (Seconds)			
	NTRU	*RSA*	*DES*	*Proposed Hybrid Diffie Hellmen-AES*
1 MB	0.5	0.52	0.8	1
5 MB	2.1	2.2	2.4	3.15
10 MB	3.5	3.57	3.72	4.3
20 MB	5.1	5.2	5.8	6.67
30 MB	10	10.3	11	12.2

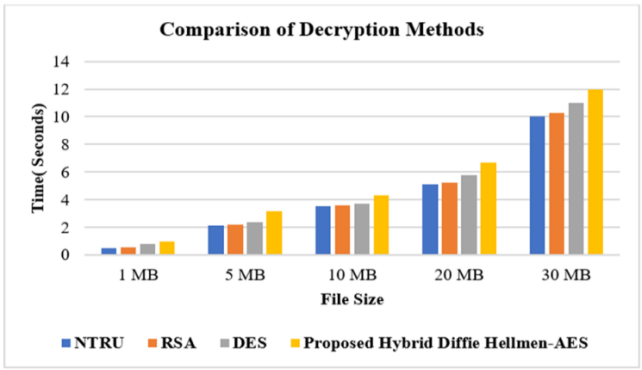

Fig. 9. Graphical illustration of various decryption methods.

Fig. 9 compares decryption speeds (in seconds) using several decryption algorithms (NTRU, RSA, DES, and Suggested Hybrid Diffie Hellmen-AES) for varying file sizes (1 MB, 5 MB, 10 MB, 20 MB, and 30 MB). The decryption time needed by a certain algorithm for a given file size is shown by each row. For instance, the proposed AES method takes 1 second to decode a file weighing one megabyte, while RSA takes 5.2 seconds, DES takes 0.8 seconds, and NTRU takes 5.1 seconds. The information helps choose the most effective decryption method for decryption jobs by comparing the performance of these algorithms for varying file sizes. Comparing Efficiency with current decryption time is given in Table V.

TABLE V. COMPARING EFFICIENCY WITH CURRENT METHOD DECRYPTION TIME

Test	Unauthorized Access Incidents
Diffie Hellmen-AES	1000 incidents
With Blockchain-Enabled Framework	21 incidents
Reduction	97.9%

A. Discussion

The integration of blockchain technology, RBAC, and the AES-Diffie-Hellman key exchange in healthcare cybersecurity architecture presents a promising solution to safeguard patient data in medical informatics. This approach offers significant advantages, including consistent encryption and decryption durations, enhanced data security through secure key setup, regulated access to confidential healthcare data, and improved data consistency and integrity. Despite these benefits, challenges such as scalability issues with proof-of-work consensus and the complexity of the architecture may impact its practical implementation, particularly in busy hospital settings with limited computational resources. However,

future research endeavors, as suggested by existing literature, could explore alternative blockchain consensus mechanisms like Proof-of-Stake to enhance sustainability and energy efficiency. Additionally, integrating AI-driven anomaly detection and cutting-edge encryption methods could further bolster the safety features of the framework. While blockchain holds promise for revolutionizing healthcare data security, addressing scalability, regulatory compliance, interoperability, and implementation complexities will be crucial for its widespread adoption and realization of its full potential in improving patient care and medical services [20].

VI. Conclusion and Future Work

The suggested cybersecurity framework, which combines blockchain, RBAC, and AES-Diffie-Hellman key exchange, shows notable benefits and accomplishments in protecting patient data in medical informatics systems. The architecture makes use of the Diffie-Hellman exchange of keys for secure key formation, blockchain with proof-of-work for decentralized and permanent data storage, RBAC for restricted access management, and AES encryption for safe information transport. It was discovered during performance assessment that the framework offers effective encryption and decryption procedures, guaranteeing patient data integrity and confidentiality. By integrating blockchain-based technologies, the framework solves important issues in handling health care data and provides improved data security, resistance against manipulation, and auditability. Furthermore, granular access control is made possible by the integration of RBAC, guaranteeing that only authorized individuals may deal with critical patient data. The innovative approach of the suggested framework offers a substantial improvement over current practices by offering a complete and safe solution designed especially for the protection of healthcare data. Future research might concentrate on several areas to improve the suggested framework even more. Examining different block chain consensus techniques, like Proof-of-Stake, is one way to make improvements to solve scalability issues and boost energy efficiency. Furthermore, including innovative cryptography methods and artificial intelligence (AI)-powered anomaly detection systems might improve the security posture of the framework and quickly identify any attacks. To assure the framework's viability in resource-constrained healthcare situations, further study might focus on lowering computing overhead and maximizing resource efficiency. Furthermore, examining data exchange methods and interoperability standards may help promote interoperability between various healthcare providers as well as seamless integration with current healthcare systems. The suggested framework may develop further and continue to be a strong and dependable solution for protecting patient information in medical informatics by tackling those fields of future research, which will eventually enhance the quality of patient care and the effectiveness of healthcare delivery.

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