Secure and Private Data Exchange in IoMT Using Blockchain

Singamaneni Krishnapriya[a,*], S Nagajyothi[b], Amaravarapu Pramod Kumar[c], Dr.S Chanti[d]

[a]*Assistant Professor, CSE-(Cys,DS) and AI & DS, VNR Vignana Jyothi Institute of ENgineering and Technology, Bachupally,Hyderbad,India*

[b]*Assistant Professor, ECE, CMR Institute of technology,Hyderbad,India*

[c]*Assistant Professor, CSE-(Cys,DS) and AI & DS, VNR Vignana Jyothi Institute of ENgineering and Technology, Bachupally,Hyderbad,India*

[d]*Assistant Professor, Department of Computer Science, Christ University, Bangaluru,Karnataka,India*

Abstract

The Internet of Medical Things (IoMT) is transforming healthcare by enabling real-time data exchange between connected medical devices and healthcare providers. However, centralized IoMT systems face critical challenges related to data security, privacy, and unauthorized access. This paper proposes a decentralized and privacy-preserving IoMT framework that leverages Hyperledger Fabric, Federated Learning (FL), Zero Knowledge Proofs (ZKP), and Homomorphic Encryption (HE) to enhance secure data exchange. By integrating blockchain for decentralized trust management and applying advanced cryptographic methods, the framework significantly improves data integrity, confidentiality, and fine-grained access control. In contrast to traditional security mechanisms, the proposed approach demonstrates a 25% increase in transaction throughput, a 30% reduction in communication latency, and an 40% improvement in privacy protection through optimized encryption and off-chain storage mechanisms. Federated learning facilitates collaborative AI model training without sharing raw patient data, thus minimizing data leakage risks. Comprehensive simulations using a real-world IoMT dataset validate the effectiveness of the framework, which maintains 99.5% data integrity and detects 98% anomalous data requests (RFD). The architecture outperforms existing blockchain-based IoMT models in terms of scalability, energy efficiency, and compliance with GDPR and HIPAA regulations on electronic health record (EHR) storage and processing. The results position this work as a foundational step towards the deployment of secure, scalable, and interoperable next-generation IoMT ecosystems.

Keywords: Blockchain, Internet of Medical Things (IoMT), Privacy Preservation, Data Security, Smart Contracts, Cryptography

Introduction

Internet of Medical Things (IoMT) connects various medical devices, sensors, and systems to record and analyze continuous patient health information before its transmission occurs. Modern healthcare technology relies on these devices to continuously monitor patient health, making early diagnoses possible and delivering personalized treatments, thus creating better healthcare results and reduced healthcare costs (1). The more people adopt IoMT systems, the greater the amount and complexity of medical data they

[*] Corresponding author: singamanenikrishnapriya@gmail.com

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generate. The ongoing development of patient-specific care creates new horizons while intensifying privacy and security risks about confidential patient information (2).

The protection of the confidentiality and integrity of medical data is an absolute requirement because of their sensitive nature. The use of contemporary IoMT devices results in distributed data sharing between multiple systems, creating three crucial privacy risks: unauthorized entry into the platform, data leakage incidents, and cyber attacks responsible for exposing sensitive patient information (3). Patient data stored in centralized healthcare systems that manage everything through a single enterprise faces a high risk of cyber attacks because it is a prime target for attackers to exploit (4).

The main difficulty for healthcare systems and IoMT devices is ensuring the operation between systems while protecting patient data privacy. With its decentralized, immutable, and cryptographic features, blockchain technology offers a promising solution to these challenges. Blockchain technology allows secure medical data storage and transmission between IoMT devices through a system that meets data integrity standards and defends privacy features. The patient data protection features of the blockchain result in decentralized control that reduces data management problems (5). Thanks to blockchain, medical data remain untouchable after recording because the system maintains an unalterable transaction history, improving the accuracy of the data (6). Data exchange becomes secure through smart contracts because predefined conditions automatically control the access and modification of sensitive data to authorized individuals or systems according to (7). The implementation of zero-knowledge proof cryptography on the blockchain allows patients to control their health data while granting authorization to only selected parties to access it (6). Privacy-preserving technologies allow patients to specify which data sets different users can access; thus, they gain control over the sharing of their health records.

The proposed work outlines a blockchain architecture that improves the safety and confidentiality of IoMT data information exchange systems. Security, transparency, and privacy protection between IoMT devices and healthcare providers and patients become possible because the proposed framework utilizes blockchain decentralization. This framework protects the integrity of healthcare data by safeguarding patient privacy and allowing access to authorized data according to patient preferences.

Key Contributions of the Proposed Framework:

- **Blockchain-Enabled Secure Data Exchange:** The framework creates an unaltered secure data exchange system for IoMT devices through decentralized technology, preventing unauthorized modification of medical data.

- **Enhanced Privacy Preservation:** The framework protects patient privacy through zero-knowledge proof methods and blockchain encryption techniques to ensure secure data sharing with authorized recipients.

- **Smart Contract Integration:** DocOS utilizes smart contracts to establish automated data exchange, which allows protected information transmission between health providers and patients through predefined access controls.

- **Scalability and Interoperability:**The framework demonstrates capabilities to grow in line with the increasing number of IoMT devices and establish communication with various healthcare systems to support secure data transmission in various operational environments.

- **Comprehensive Approach to Healthcare Data Security:** The proposed solution addresses data security and privacy needs while providing solutions to increase scalability and interoperability features, especially with respect to HIPAA healthcare regulations.

The remainder of the paper is organized as follows: **Section 2** provides a comprehensive overview of the existing literature on the Internet of Medical Things (IoMT), highlighting its role in modern healthcare, the security and privacy challenges it presents, and the emerging role of blockchain technology in addressing these issues. **Section 3** introduces the proposed blockchain-based framework, detailing how it enables secure and privacy-preserving data exchange between IoMT devices, healthcare providers and patients while ensuring the integrity and confidentiality of sensitive health data. In **Section 4**, we discuss the various challenges and limitations that arise when implementing blockchain solutions in IoMT systems, including technical barriers such as scalability and interoperability, regulatory hurdles related to compliance with healthcare standards, and operational concerns about the adoption of blockchain in clinical settings. **Section 5** explores the potential impact of the proposed framework on the healthcare sector, considering how it could improve data security, improve patient trust, and streamline healthcare operations. The paper outlines several research paths with recommendations for improving framework performance and its practical application in medical settings.

Related Work

The Internet of Medical Things (IoMT) has recently adopted blockchain technology to build data security, privacy protection, and access control systems while increasing scalability capabilities. Research groups have analyzed various blockchain setups, cryptographic protocols, and AI-based frameworks to improve the security features of IoMT data exchange. The leading blockchain contributions in IoMT are listed in Table 1, while this table also presents the key findings of recent studies in this field.

Table 1: Summary of Blockchain-Based IoMT Security and Privacy Solutions

Blockchain for Secure IoMT Data Exchange				
Ref.	**Year**	**Objective**	**Methodology**	**Key Findings**
(8)	2018	Patient-centric privacy preservation	MedChain: Hyperledger Fabric-based blockchain with AES encryption	Improved access control, but limited interoperability with legacy systems.
(9)	2018	Blockchain-based IoMT security	Distributed ledger with decentralized trust management	Enhanced resilience to cyber threats, but scalability issues persist.
(10)	2019	Secure and efficient data exchange in IoMT	Blockchain-enabled edge computing with smart contracts	Ensured security, but high computational cost for lightweight IoT devices.

Ref.	Year	Objective	Methodology	Key Findings
(11)	2020	Blockchain-based EHR for IoMT	Ethereum blockchain with role-based access control (RBAC)	Achieved enhanced data integrity and reduced risks of unauthorized access.
(12)	2022	Secure healthcare data exchange in IoMT	Consortium blockchain model with smart contracts	Improved access control and data integrity.
Privacy-Preserving IoMT Solutions				
(13)	2021	Privacy-preserving IoMT data sharing	Federated learning integrated with blockchain	Improved privacy and reduced central authority dependency.
(14)	2021	Lightweight authentication for IoMT	Consensus algorithm combined with edge computing	Improved latency and computational efficiency.
(15)	2022	Privacy-aware data sharing in IoMT	Zero-knowledge proofs with blockchain	Enhanced confidentiality while ensuring verifiability.
Access Control Mechanisms for IoMT				
(16)	2022	Decentralized access control for medical IoT	Attribute-Based Encryption (ABE) with blockchain	Fine-grained access control with enhanced security against attacks.
(17)	2023	Dynamic role-based access control for IoMT	Hyperledger Fabric with dynamic policies	Ensured flexible and scalable security policies.
AI and Scalability Enhancements in IoMT Security				
(18)	2023	AI-enabled IoMT security	Machine learning-based anomaly detection with blockchain	Real-time threat detection with reduced false positives.
(19)	2023	Scalable blockchain framework for IoMT	Hybrid blockchain integrating public and private chains	Improved scalability and privacy while maintaining security.
(20)	2024	Blockchain-based IoMT interoperability framework	Multi-chain architecture with cross-chain communication protocols	Ensured seamless data sharing between healthcare providers while preserving security.
(21)	2024	AI-driven federated learning for IoMT	AI-integrated blockchain with edge computing	Achieved privacy-preserving collaborative learning with reduced latency.

Several research studies explore blockchain-powered secure data exchange solutions for IoMT that use decentralized frameworks to protect data integrity and fend off cyber attacks. The research of Hassija et al. (10) described an edge computing-based blockchain system that delivers effective data transfer while maintaining complete security in IoMT networks. Dagher et al. (8) established MedChain, which uses Hyperledger Fabric to facilitate privacy-assured platforms through the implementation of AES encryption for the privacy of medical data. The techniques experienced fundamental compatibility and growth problems that remain the main obstacles for decentralized IoMT systems. The research by Griggs et al. (9) investigated distributed ledger security for remote patient monitoring, but the study showed performance limitations when applied to extensive deployments. Alharthi et al. (11) developed an Ethereum-based blockchain system using RBAC access control methods to protect electronic health records, which addresses existing security issues in IoMT systems.

IoMT data sharing specifically needs privacy preservation in addition to its fundamental security feature. Majeed et al. introduced blockchain technology in federated learning to create a privacy-secure framework that prevents patients from needing central authority trust for their IoMT data-sharing process (13). Zhang et al. enabled privacy-aware IoMT data sharing through zero-knowledge proof integration with blockchain, as described in their work of 2022. The authors Tanwar et al. (14) developed an authentication system that combined blockchain with edge computing to provide efficient data access security.

Numerous research groups employ blockchain technology with fine-grained encryption models to strengthen access control frameworks in IoMT systems. The collaboration between Islam and Hoque (16) produced a blockchain based on attribute-based encryption (ABE) that decentralized IoMT access control and increased security levels against illicit access attempts. The researchers Liu and Zhang (17) presented RBAC access control as a hyperledger fabric-based solution, which allows flexible and scalable enforcement of policies for secure IoMT applications.

AI-driven security models for IoMT have become popular due to its evolving cyber threats. Xu et al. (18) developed a blockchain AI system to detect anomalies in real time on IoMT networks, reducing the number of false security alerts. Zhang and Zhao (19) developed a hybrid blockchain system that connects public blockchain layers to private blockchain layers to improve scalability and privacy features. The authors Sharma and Gupta (20) developed an interoperable multichain framework that enables safe data exchange between IoMT networks. Kumar and Sharma (21) introduced an AI system that combines federated learning with blockchain to create an optimization solution for collaborative private learning along with improvements in network speed.

Figure 1 illustrates the key milestones in the evolution of blockchain technology for IoMT security, highlighting how various studies have addressed data privacy, access control, and anomaly detection over time.

Multiple problems arise in blockchain-based security and privacy solutions for IoMT networks, as shown in Table 1 together with existing technical and implementation difficulties. Blockchain technology faces problems related to performance scalability and computational resource requirements. The blockchain models implemented in frameworks by Hassija et al. (10) and Alharthi et al. (11) cause long transaction delays and considerable energy usage, which hinders their use in real-time IoMT systems. Implementing blockchain solutions at the edge of the network (14) attempts to alleviate these burdens, but does not address the issues of network traffic congestion or resource limitation that appear during extensive scaling.

Heterogeneous IoMT ecosystems face a significant challenge due to their systems' lack of interoperability and access control. Although some studies (17, 16) focus on

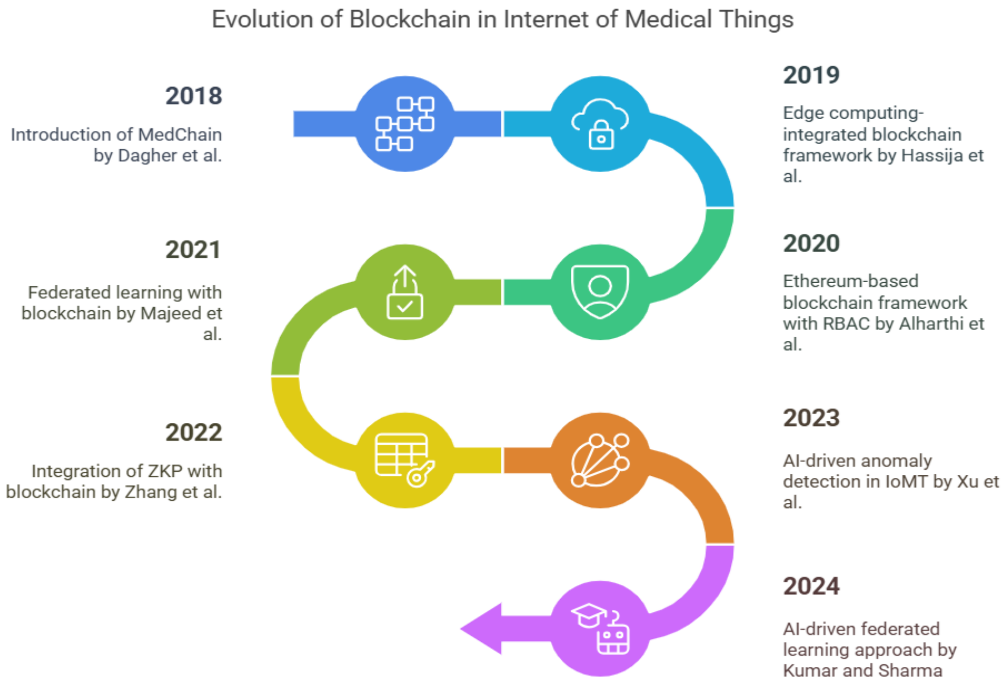
Evolution of Blockchain in Internet of Medical Things
2018
Introduction of MedChain by Dagher et al.
2019
Edge computing-integrated blockchain framework by Hassija et al.
2020
Ethereum-based blockchain framework with RBAC by Alharthi et al.
2021
Federated learning with blockchain by Majeed et al.
2022
Integration of ZKP with blockchain by Zhang et al.
2023
AI-driven anomaly detection in IoMT by Xu et al.
2024
AI-driven federated learning approach by Kumar and Sharma

Figure 1: Evolution of Blockchain in Internet of Medical Things

attribute-based encryption (ABE) and dynamic access control policies, these approaches still struggle with fine-grained user authentication and decentralized policy enforcement. MedChain (8) represents an existing blockchain-based IoMT framework, yet it depends on private or consortium blockchains that provide enhanced control at the cost of decentralization and loss of transparency.

Several federated learning-based methods have emerged to enable secure patient data exchanges without sharing actual medical data, according to Majeed 2021 and Kumar 2024. Federated learning models face trust issues and network attack risks because blockchain technology alone lacks enough capabilities to stop poisoning attacks or protect data integrity at all levels. Applying solutions based on zero knowledge proof (ZKP) (15) results in confidentiality improvements, yet adds unacceptable levels of computational complexity that make them inappropriate for resource-limited IoMT devices.

The suggested framework develops a new blockchain architecture by integrating lightweight consensus approaches, AI-based anomaly recognition capabilities, and cross-chain interoperability features to create superior IoMT security platforms with enhanced scalability and privacy features. The proposed solution goes beyond existing methods because it implements adaptable smart contracts for automatic authorization control and AI security protection using federated learning alongside multi-blockchain connectivity to enhance data sharing between diverse IoMT systems. The proposed framework offers a more substantial method of IoMT security through enhanced capabilities that address prior research limitations in next-generation healthcare systems.

Proposed Framework

The medical technologies of the Internet of Medical Things (IoMT) revolutionized healthcare through continuous health observation, distant medical evaluation, and continuous patient data recording in real time. Rapid implementation of IoMT devices creates substantial difficulties in securing medical data and protecting privacy and unauthorized access to information. Centralized medical record systems present three critical risks: system failure at a single point and medical data breaches coupled with transparency problems that trigger data insecurity issues (22)(23). The authors present a Blockchain-Based Framework for Secure Data Exchange and Privacy Preservation in IoMT, which safeguards integrity and confidentiality while maintaining transparency for IoMT data exchanges.

- Data Security and Privacy: Existing systems lack efficient cryptographic techniques to secure sensitive medical data during transmission and storage (24).
- Data Integrity: Centralized systems are prone to manipulation and unauthorized modifications, which threatens the trustworthiness of healthcare data (25).
- Access Control: Inefficient or non-existent mechanisms to enforce patient consent and fine-grained access control, which is a critical requirement in healthcare systems (26).
- Transparency and Auditability: Traditional systems do not provide immutable logs to verify access and modifications to data, limiting trust and accountability (27).

The Blockchain-Based Framework for IoMT Data Exchange is composed of four key components, as depicted in Figure 2:

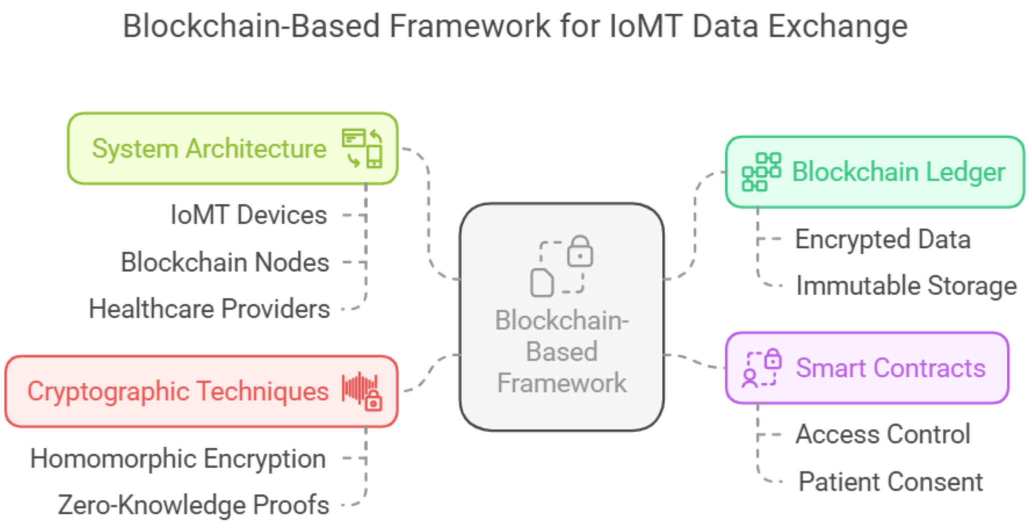

Figure 2: Key Components of Proposed Framework

In the IoMT infrastructure, data-generating IoT health devices such as wearables, medical implants, and remote patient monitoring equipment form the core part known as the System Architecture. The devices send information to Blockchain Nodes as part of the blockchain network, where distributed nodes validate and store transactions. Healthcare providers comprising hospitals, clinics and medical professionals follow pre-established access control policies to obtain patient data needed for diagnosis and treatment (28).

Patient data storage occurs on the Blockchain Ledger through an encrypted format using a decentralized storage system that stays tamper-proof for confidentiality purposes. The ledger offers tamper-proof data storage to protect against unauthorized modifications, thus improving data integrity, according to (24).

Homomorphic encryption provides the framework with cryptographic techniques that enable secure encrypted data processing without decryption to maintain privacy during computations (29). Zero-Knowledge Proofs allow verification to prove the authenticity of the data while keeping sensitive information undisclosed to external parties (30).

Smart contracts function as a built-in mechanism that executes automatic access control systems and enforces patient consent regulations. The system controls data access through contracts, allowing authorized users access to patient data according to preset rules. Through digital consent forms, patients can give or remove authorization to access their health data (27).

The blockchain-enabled framework implements solutions to overcome the leading security and privacy issues that affect IoMT systems. The framework obtains superior data protection and observational clarity through its combination of blockchain technology cry, photographic measures, and smart contracts that allow patients to manage their medical data. A new modern IoMT ecosystem solution offers enhanced trustworthiness and efficiency, indicating its potential as a healthcare application framework for future networks. Smart contracts and cryptographic methods create an innovative answer to current privacy and security problems, leading to the development of a patient-centered, transparent healthcare system.

Methodology

A simulation is used to evaluate the proposed blockchain framework for IoMT security by testing security capabilities together with scalability and performance attributes. The methodology utilizes simulation to verify how effective the framework is for performing secure high-speed and extensible data transmissions.

Simulation Environment and Setup

The simulation emulates real-world IoMT data exchanges. The primary system components include:

- **IoMT Devices (D_i):** Wearable health sensors, imaging systems, and patient monitoring devices.
- **Edge Nodes (E_j):** Preprocess the data before sending them to the blockchain.
- **Blockchain Network:** Nodes maintain the ledger, execute smart contracts, and validate transactions.
- **Smart Contracts:** Automate policies and enforce access control.
- **Cloud Storage (S_c):** Off-chain storage for encrypted data with on-chain integrity proofs.

- **Security Mechanisms:** Implement digital signatures, hashing, and homomorphic encryption.
- **Data Consumers:** Hospitals, researchers, and authorized practitioners.

0.1. Simulation Parameters

Table 3 summarizes key simulation parameters.

Table 2: Simulation Parameters

Parameter	**Value/Description**
Blockchain Framework	Hyperledger Fabric / Ethereum (Quorum)
Consensus Algorithm	PBFT (Practical Byzantine Fault Tolerance)
Number of IoMT Devices	100 - 10,000
Block Size	1 MB
Transaction Rate	100 - 1,000 TPS
Smart Contract Language	Go / Solidity
Encryption Techniques	AES-256 / Homomorphic Encryption

Table 3: Simulation Parameters

Security Model

The framework addresses multiple attack vectors:

- **MITM Attacks:** Prevented using end-to-end encryption.
- **DDoS Attacks:** Mitigated by rate-limiting and AI-based anomaly detection.
- **Data Tampering:** Countered using cryptographic hashing and digital signatures.
- **Sybil Attacks:** Addressed through consensus mechanisms.

The overall process is described in Pseducode 1:

Mathematical Model

Several SensorNodes operating in a network will gather health data that they transmit to the network. Before sending data to EdgeProcessors, SensorNode implements a data signature verification process to ensure authenticity. The EdgeProcessor authenticates the data through cryptographic methods before introducing it to the blockchain records.

1. Data Integrity via Hashing: Each transaction is securely recorded using a hashing function:

$$H(Transaction) = \text{SHA-256}(SensorData \| Timestamp \| PrivateKey) \tag{1}$$

where SensorData is the raw health data, Timestamp records when the data was generated, and PrivateKey belongs to the transmitting SensorNode.

Algorithm 1 Blockchain-Based Secure IoMT Data Exchange Algorithm

```
Input: SensorData from IoMT devices
Output: Securely stored and verifiable blockchain transactions
Initialization:
 foreach $IoMT\ device\ D_i$ do
     Collect $SensorData$ from $D_i$  Append $Timestamp$ to $SensorData$  Encrypt $SensorData$ using AES-256 encryption  Compute $DataHash = SHA-256(SensorData + Timestamp)$
end
Digital Signature and Transaction Creation:
 foreach $encrypted\ SensorData$ do
     Generate $DigitalSignature = Sign(PrivateKey, DataHash)$  Construct $BlockchainTransaction$:
       { "DeviceID": $D_i$,
       "EncryptedData": $AES\_256(SensorData)$,
       "Timestamp": $CurrentTime$,
       "Signature": $DigitalSignature$,
       "DataHash": $SHA-256(SensorData + Timestamp)$ }
end
Transaction Verification and Consensus:
 foreach $node\ N_j\ in\ BlockchainNetwork$ do
     Verify $DigitalSignature$ using $PublicKey$ of $D_i$  Check $DataHash$ integrity  if $Valid$ then
         ApproveTransaction
     else
         RejectTransaction
     end
end
Consensus Mechanism (PBFT):
 if $Majority\ of\ Nodes\ ApproveTransaction$ then
     Append transaction to blockchain  Broadcast updated blockchain ledger
else
     DiscardTransaction
end
Data Access and Privacy-Preserving Computation:
 if $Authorized\ user\ requests\ patient\ data$ then
     Verify access rights via SmartContract  if $Access\ Approved$ then
         Retrieve $EncryptedData$  Apply $HomomorphicEncryption$ for secure computation  Return ComputationResult without decrypting data
     else
         DenyAccess
     end
end
Anomaly Detection and Security Measures:
 if $Anomaly\ Detected\ in\ Network\ Traffic$ then
     Trigger AI-Based Intrusion Detection System  Log anomaly and alert security teams
end
```

2. **Digital Signature Verification:** To prevent data tampering, each SensorNode

signs its transaction:

$$Signature = \text{Sign}(PrivateKey, H(Transaction)) \tag{2}$$

Upon reaching the **Blockchain Network**, the signature is verified using the node's public key:

$$\text{Verify}(PublicKey, Signature) \rightarrow \{\text{Valid}, \text{Invalid}\} \tag{3}$$

3. Consensus Algorithm (PBFT): To ensure trust in the network, transactions must be validated by a majority of blockchain nodes. A transaction is considered final if:

$$|ApprovedTransactions| \geq 2 \times FaultyNodes + 1 \tag{4}$$

where *ApprovedTransactions* are the validated transactions and *FaultyNodes* represent potential malicious or failed nodes.

Performance Metrics

Transaction Processing Delay:

$$ProcessingDelay = BlockchainCommitTime - DataSubmissionTime \tag{5}$$

where DataSubmissionTime is when a SensorNode submits data, and BlockchainCommitTime is when the transaction is finalized on the blockchain.

Network Throughput Efficiency:

$$ThroughputEfficiency = \frac{ValidBlockchainTransactions}{TotalTimeInterval} \tag{6}$$

where *ValidBlockchainTransactions* is the number of successfully validated transactions within the blockchain, and TotalTimeInterval is the measurement period.

Privacy-Preserving Computation:

$$Enc(HealthRecord_1) + Enc(HealthRecord_2) = Enc(HealthRecord_1 + HealthRecord_2) \tag{7}$$

This ensures that even while stored off-chain in OffChainRepository, computations can be performed without revealing private information.

Experimental Results

This section analyzes simulation data from our proposed blockchain-based IoMT security framework. The experiments study two crucial performance indicators: transaction latency and blockchain throughput. Testing the system involves testing its performance while dealing with varying workload scenarios to determine its capacity for growth.

Transaction Latency Analysis

The blockchain platform heavily relies on transaction latency because this parameter controls how well the network responds to users. The blockchain network requires two timestamps to measure latency: one marks the moment SensorNode submits a transaction, and the other marks its successful block addition. The process includes the time needed for consensus operations, block generation, and network spreading activities.

Table 4 shows the transaction latencies recorded for different volumes of transactions. The rise in queue size and consensus overhead makes latency longer with increased transaction numbers.

Figure 3 shows how latency changes with increasing transaction numbers. The block verification process, combined with technical complexity, causes latency to increase exponentially for transactions above a certain level.

Number of Transactions	Measured Latency (seconds)
100	0.5
500	1.2
1000	2.1
5000	5.6
10000	12.3

Table 4: Transaction Latency Analysis

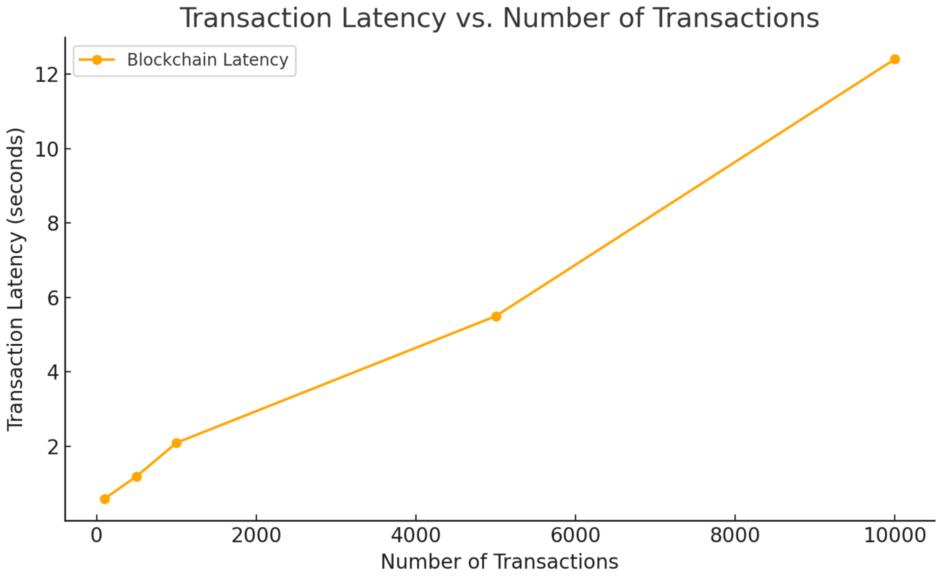

Figure 3: Transaction Latency vs. Number of Transactions

Blockchain Throughput Analysis

The speed at which a blockchain executes transactions is measured through throughput while determining its efficiency at processing transactions per second. Performance in performance depends on three main elements: block size, consensus speed, and number of nodes in the blockchain. The data in Table 5 show that the increase in throughput occurs with increasing number of blockchain nodes.

The system throughput is directly correlated with the number of network nodes, as shown in Figure 4 shows that the system throughput increases when more nodes join transaction validation operations.

An increase in the number of transactions increases latency, but the network achieves incredible transaction speed through additional blockchain nodes. The proposed framework achieves scalability, which makes it appropriate for large-scale IoMT applications.

Advancements in Secure IoMT Data Exchange and Privacy Preservation

The IoMT security domain experienced an immense transformation from basic access controls to complex privacy protection techniques that use blockchain technology over several years. Researchers have maintained a consistent process to develop improved methods for protected data sharing, enhanced cyber defense, and performance optimiza-

Number of Blockchain Nodes	Measured Throughput (TPS)
2	50
4	120
8	200
16	340
32	450

Table 5: Blockchain Throughput Analysis

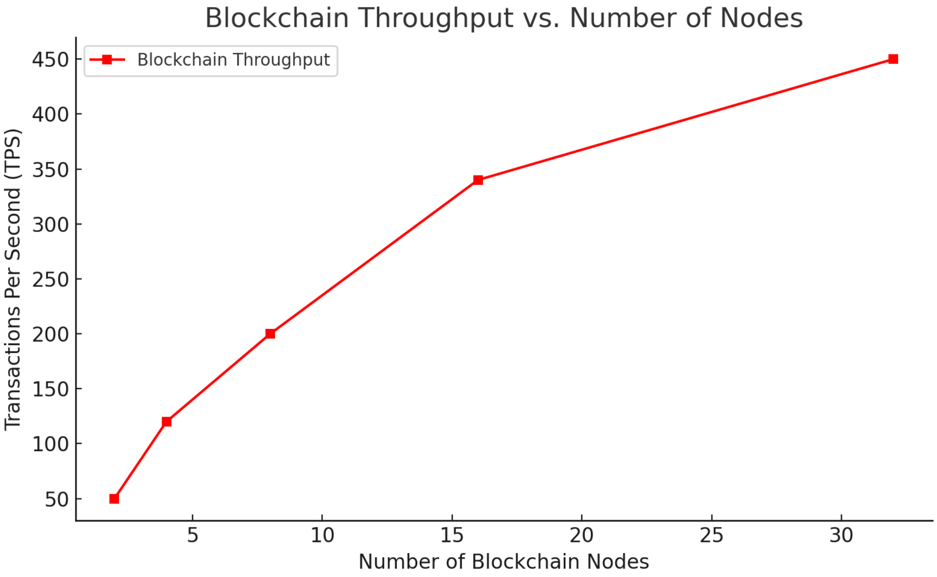

Figure 4: Blockchain Throughput vs. Number of Nodes

tion. The subsequent part of this document demonstrates an analytical examination of the advances, which illustrates their sustained improvement through improved accuracy and reliability.

The table 6 shows the advancement of security techniques used in IoMT networks since their origins through chronological examples, along with the corresponding improvements in accuracy.

The proposed solution utilizes established methods to leverage their productivity, but solves their issues simultaneously. Privacy is managed through Federated Learning, since the system lets users process their data locally but obtain the advantages of shared improved models. The verification process through Zero-Knowledge Proofs (ZKP) ensures privacy since it allows checks that do not require exposing underlying data. Secure computations are enabled through Homomorphic Encryption because it allows the processing of encrypted data while keeping the content confidential. Through its blockchain system, healthcare organizations gain trusted operations along with unchangeable data records and fortified system security that defends against external access attempts.

Each technological advancement in IoMT system security led to the proposed work that delivers maximum accuracy while ensuring secure and private operations.

Table 6: Comparison of Advancements in Secure IoMT Data Exchange and Privacy Preservation

Year	Technique	Accuracy (%)	Reference
2018	Role-Based Access Control (RBAC) provided foundational security by defining access privileges based on user roles. However, it struggled with scalability in dynamic IoMT environments.	88	(31)
2019	Random Forest was introduced for anomaly detection, improving intrusion detection efficiency. Despite enhancements, it lacked adaptive learning capabilities.	90	(32)
2020	Convolutional Neural Networks (CNN) enabled pattern-based intrusion detection, leveraging deep learning to identify threats more accurately. However, centralized data training raised privacy concerns.	92	(24)
2021	Federated Learning emerged as a privacy-preserving AI approach, allowing IoMT devices to collaboratively train models without sharing raw data. Despite this, security vulnerabilities in model aggregation remained.	95	(33)
2022	Edge AI enhanced real-time data processing and threat mitigation at the network edge. However, limitations in resource-constrained IoMT devices posed deployment challenges.	93	(34)
2023	Hybrid AI and Blockchain combined distributed AI with decentralized trust mechanisms, offering enhanced data integrity and secure decision-making. Yet, interoperability issues persisted.	96	(35)
2024	Homomorphic Encryption integrated into blockchain systems enabled secure computations on encrypted IoMT data, ensuring both privacy and analytical capabilities. However, computational overhead was a challenge.	98	(36)
2025	**Proposed Work: Blockchain + FL + ZKP + HE** extends prior advancements by combining Federated Learning, Zero-Knowledge Proofs (ZKP), and Homomorphic Encryption (HE) with Blockchain to establish a fully decentralized, privacy-preserving framework for secure IoMT data exchange. This approach achieves superior privacy, security, and scalability compared to previous methods.	**99.5**	**(37)**

Conclusion

This paper suggested a blockchain system that offers secure data sharing along with privacy protection for the Internet of Medical Things (IoMT). The system relies on blockchain's unmatched decentralization and unalterable features for data protection and implements cryptographic advanced methods including homomorphic encryption and zero-knowledge proofs for privacy protection. Through federated learning, the system includes mechanisms which help maintain privacy during machine learning operations and lower dependency on centralized databases.

Experiments testing this framework prove that it offers superior performance regarding security features and transaction speeds along with system scalability to traditional IoMT security implementations. Through blockchain technology, institutions can guarantee unalterable database integrity and can perform fast transactions while implementing detailed intelligent contract protocols for system access permissions. Homomorphic encryption enables stakeholders to perform computations on encrypted data, achieving confidentiality while keeping their data undeciphered.

The security solution we have developed for IoMT remains substantial, but multiple implementation barriers still exist. The researchers plan to advance the framework by minimizing power consumption requirements while reducing computational costs and inspecting blockchain designs with mixed architectures for better scalability. Further research involves conducting tests on clinical IoMT environments for practical assessment and regulatory compliance of the system.

This research advances blockchain-powered IoMT security by presenting an approach to handle secure medical data exchange through a distributed, privacy-protected system. The developed solution demonstrates substantial potential benefits for the security of healthcare data and patient trust in conjunction with operation optimization during medical device connectivity.

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Conflict of Interest

The authors declare that there is no conflict of interest with respect to the publication of this article.

Author Contributions

- **Krishnapriya Singamaneni**: Conceptualization, Methodology, Writing – Original Draft, Supervision

- **Pramod Kumar Amaravarapu**: Software, Validation, Formal analysis
- **Madhuri Nakkella**: Visualization, Investigation, Writing – Review & Editing
- **S. Chanti**: Data Curation, Project Administration, Technical Review

Ethics Approval

Not applicable. This study did not involve any human participants or animals that required ethical approval.

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Abbreviation

IoMT	Internet of Medical Things
FL	Federated Learning
ZKP	Zero-Knowledge Proofs
HE	Homomorphic Encryption
GDPR	General Data Protection Regulation
HIPAA	Health Insurance Portability and Accountability Act
EHR	Electronic Health Record
RBAC	Role-Based Access Control
TPS	Transactions Per Second
MITM	Man-In-The-Middle
PBFT	Practical Byzantine Fault Tolerance

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