A Scalable Multi-Layered Blockchain Architecture for Enhanced EHR Sharing and Drug Supply Chain Management

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ABSTRACT

In recent years, the healthcare sector's shift to online platforms has spotlighted challenges concerning data security, privacy and scalability. Block chain technology, known for its decentralized, secure and immutable nature, emerges as a viable solution for these pressing issues. This article presents an innovative Electronic Health Records (EHR) sharing and drug supply chain management framework tailored to address scalability, security, data integrity, traceability and secure data sharing. The framework introduces five layers and transactions, prioritizing patient-centric healthcare by granting patients comprehensive access control over their health information. This access facilitates smoother processes, such as insurance claims, while maintaining robust security measures. Notably, our implementation of parallelism significantly bolsters scalability and transaction throughput while minimizing network traffic. Performance evaluations conducted through the caliper benchmark indicate a slight increase in processor consumption during specific transactions, mitigated effectively by parallelization. RAM requirements remain largely stable. Additionally, our approach notably reduces network traffic while tripling transaction throughput. The framework ensures patient privacy, data integrity, access control and interoperability, aligning with traditional healthcare systems. Moreover, it provides transparency and real-time drug supply monitoring, empowering decision-makers with actionable insights. As healthcare evolves, our framework sets a crucial precedent for innovative, scalable and secure systems. Future enhancements could focus on scalability, real-world deployment, standardized data formats, reinforced security protocols, privacy preservation and IoT integration to comply with regulations and meet evolving industry needs.

Keywords: Block-chain; Electronic health system; Privacy; Scalability; Interoperability; Drug supply chain management; Secure EHR sharing

INTRODUCTION

In recent years, block-chain technology has garnered significant attention across various domains, including healthcare. This is primarily due to its potential to enhance data accuracy, security and privacy while enabling trust among disparate stakeholders [1]. Block-chain is characterized by key features such as decentralization, persistency, immutability and security. As healthcare services transition from offline to online modes, new security concerns emerge, including fragmented health data, interoperability challenges, data security, privacy issues and scalability hurdles [2-8].

Consequent, the healthcare community has directed its efforts towards the development of block chain-based systems to address these challenges. Traditional healthcare systems often rely on centralized approaches for the storage and management of Electronic Health Records (EHRs). However, the need for frequent sharing and distribution of these records among various stakeholders, including hospitals, patients and clinics, leads to time and cost-intensive processes. Cloud-based health data management emerged as a solution for real-time data sharing, albeit with memory-intensive data encryption requirements, particularly when transmitting data to the cloud [7]. To address these challenges, lightweight block-chain approaches were introduced, reducing computational and communication overhead [8]. Such approaches, grouped participants into clusters based on demographics, maintaining a single ledger per cluster to address security and privacy issues in sharing medical imaging data [9,10]. Additional efforts have explored data encryption, authorization methods and interoperability solutions to ensure the confidentiality, integrity and accessibility of healthcare data [10]. The contributions of this article, presented in the subsequent sections, align with the broader context of using block-chain technology to enhance healthcare systems. This article specifically introduces a novel framework for data sharing and drug supply chain management, marked by the successful implementation of parallelism. The framework has been meticulously designed to consider essential aspects, including scalability, security, data integrity, deniability, traceability, drug supply chain management and secure data sharing, thereby offering a comprehensive solution for the evolving healthcare landscape, the framework has five layers and five transactions. Notably, this implementation of parallelism has resulted in significantly higher throughput and reduced network traffic, addressing critical challenges in healthcare data management.

MATERIALS AND METHODS

Related Works

Block-chain technology has the potential to reshape the healthcare industry, offering promising solutions to pressing issues such as security, privacy, scalability and interoperability. A range of block-chain-based frameworks have emerged to address these challenges, particularly within the domains of Electronic Health Record (EHR) sharing and drug supply chain management. In recent years, there has been a growing interest in secure and efficient EHR sharing through block chain technology. Notable examples include "Med Shard", which employs sharing to enhance scalability and "block chain-based framework for interoperable electronic health records for an improved healthcare system" [11,12], known for its fine-grained access control and seamless interoperability with existing EHR systems. Furthermore, scalable electronic health record management systems using a dual-channel block chain hyper-ledger fabric introduces a dual-channel architecture, exemplifying innovative approaches to address scalability and performance challenges [13]. In parallel, the pharmaceutical

supply chain has also garnered attention, with block chain technology playing a pivotal role in enhancing security and transparency. "Healthcare chain network frame-work for monitoring and verifying pharmaceutical supply chain" provides a comprehensive framework for monitoring and verifying the pharmaceutical supply chain [14]. Additionally, "Automating procurement contracts in the health-care supply chain using block chain smart contracts" introduces pioneering solutions for automating procurement contracts within the healthcare supply chain, harnessing the transformative capabilities of smart contracts to optimize procurement processes [15]. As the healthcare industry grapples with the challenge of scalability in block chain applications, research has explored various models to overcome this hurdle. "Scalable block chain model using off-chain IPFS storage for healthcare data security and privacy" introduces a scalable model utilizing off-chain IPFS storage, offering a fresh perspective on data security and privacy in healthcare [16]. Meanwhile, Block chain scalability solved *via* quintessential parallel multiprocessor" presents a parallel processing architecture, emphasizing its potential to enhance block chain network scalability [17]. "Lightweight block chain for healthcare" advances scalability through a refined block-chain architecture tailored for healthcare applications and "A novel blockchain architecture with mutable block and immutable transactions for enhanced scalability" further under-scores scalability through mutable blocks and immutable transactions [18,19]. In addition to these critical areas, other works have contributed significantly to the broader discourse. "Enhancing healthcare system using block chain smart contracts" offers a comprehensive framework focusing on the potential of smart contracts to enhance the healthcare ecosystem, while "performance and scalability analysis of Ethereum and Hyperledger fabric" conducts a comparative analysis of the performance and scalability of two prominent block chain platforms [20]. Building on the foundations laid by these innovative works, our paper introduces a meticulously crafted hyper-ledger fabric framework, dedicated to addressing the intricate challenges associated with secure EHR sharing and efficient drug supply chain management. In the ensuing sections, we delve into our research objectives, methodologies and out-comes, emphasizing the distinct solutions we've developed to usher in a new era of healthcare system optimization.

Proposed System

In this section, we present the proposed system, featuring a meticulously designed layered architecture that enhances flexibility and control. The system's core transactions, driven by patient empowerment and secure data management, form the backbone of our healthcare solution. We delve into the intricacies of information structuring within our controllers, exploring the management of temporary IDs and the benefits of parallelization for scalability.

Layered design: The choice of a layered design for our system is driven by several advantages it offers. This approach enables us to enhance each layer independently, minimizing

the need for significant changes in the overall system structure. Moreover, it effectively manages the responsibilities and access privileges associated with each layer. The system is organized into five distinct layers, each with its unique role:

- **Layer 1-Medical service providers:** This layer is dedicated to medical service providers, including hospitals, doctors and pharmacies. It forms the primary interface for healthcare services.
- **Layer 2-Medical system users:** Layer 2 caters to medical system users, such as patients and their companions. These users are granted different access levels compared to layer 1.
- **Layer 3-Gateway layer:** Acting as a vital intermediary, layer 3 connects layers 1 and 2 with layer 4. It is responsible for receiving requests from layer 1 and layer 2, processing them and subsequently forwarding the information to layer 4. In cases where necessary, it may return data to the patient.
- **Layer 4-Network core layer:** At the heart of the network, layer 4 comprises hyperledger fabric nodes, serving as the central infrastructure of the system.
- **Layer 5-Controller layer:** This layer is tasked with monitoring the correct execution of policies within the system. It encompasses two key components: The health file control unit (c_1) and the medicine supply control unit (c_2).

Additionally, within the core network (layer 4), two essential components are present: The block chain of health file (c_3) and the block chain of drug supply (c_4). Our proposed system involves five distinct transactions, with three of them related to managing health records and the remaining two centered on the drug supply chain.

Key System Transactions

In our proposed system, five essential transactions have been designed to facilitate various functions within the network:

Record health file abstract: Storing the raw data of electronic health records directly in the block chain is impractical due to the sheer volume of information and the critical importance of privacy. As illustrated in **Figure 1**, only the abstract of the health record is stored in the block chain. This abstract represents a hash of the health record along with essential information about the record. Each health record generated within the system is assigned a unique ID, meticulously structured with specific segments, each carrying distinct meanings. For instance, the initial ten digits signify the patient's identity within the system. Following these, the subsequent seven digits signify the identity of the information author, which could be the hospital or doctor. The final thirty digits indicate the health file number. The responsibility for maintaining health records is a shared duty, involving both the information author and the patient. They have the option to store records locally or utilize secure cloud-based storage techniques as the need arises. This division of responsibility enhances the system's flexibility and adaptability, aligning it

with traditional healthcare systems. It's worth noting that health records encompass various types, such as Electronic Health Records (EHR), Personal Health Records (PHR), Continuity of Care Records (CCR), and more.
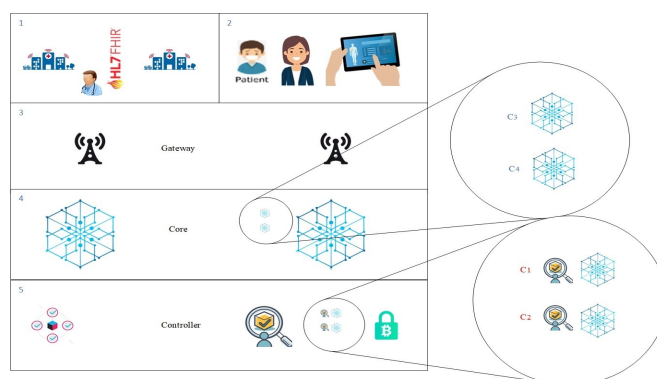

Figure 1: Proposed system layers.

Grant access permissions: As depicted in **Figure 2**, patients have the authority to grant read, write, delete and update permissions to members of the system for specific file IDs and predefined time durations. Furthermore, a unique permission, known as "granting power of attorney," allows patients to delegate the authority to issue permissions on their behalf. This means a system member can act on the patient's behalf to grant these permissions to other members. To initiate this process, the patient first obtains a license from c_1. This license ensures that the permissions granted by the patient align with the system's policies and rules. Once obtained, the patient specifies the scope of authority and the duration of the license, transmitting this information along with permissions to the network as a transaction.

Health record sharing: In the realm of health data sharing, we leverage the Health Level Seven (HL7) standard for seamless and secure transmission. When member B seeks to obtain crucial information from member A, as depicted in **Figure 2c**, member B initiates the process by formally requesting authorization from c_3 nodes through a transaction. Upon the successful registration of this authorization, member A adds an additional layer of security by signing the information hash and transmitting it alongside the relevant file to member B through a secure channel using HL7. Upon receipt of this valuable information from member A, member B further enhances data integrity by signing the hash of the received file, thus confirming its receipt and securely recording this confirmation with c_3. The pivotal role of these signatures is to assure the absolute authenticity of the file transfer from A to B.

Register medicine receipt: Figure 2d outlines the process of registering the receipt of medicine in a pharmacy. When a drug is dispatched to the pharmacy by the drug distributor, the pharmacy initiates a drug registration transaction with c_2. If the request is valid then c_2 signs the transaction and the pharmacy sends the signed transaction to the c_4 to confirm the receipt of the drug. This transaction contains crucial details, including the drug's quick response code and essential information such as its name and expiration date.

Sell medicine to patient: Expanding upon the principles elucidated in transaction 1, when a patient requires medication, the system generates a standard medical prescription form. This prescription is then transmitted to the patient for fulfillment. In accordance with the process depicted in **Figure 2e**, the patient forwards the prescription to the chosen pharmacy. Notably, the prescription includes a signed hash to substantiate the patient's ownership of the registered medical prescription abstract within the c_3 block chain. The patient's ID must align across both the c_3 and c_4 block chains, as a segment of the prescription abstract comprises the patient's ID, which is initially recorded in c_3. This requirement ensures validation by c_4, as it cross-references the received prescription with the one stored in c_3 to confirm its authenticity. Subsequently, the quick response codes for the dispensed medications are logged in the c4 block chain. The transaction ID incorporates all essential identity information, including details of the seller, pharmacy, patient and transaction type.

In all the above transactions, if a transaction is rejected, it is stored off-chain, allowing for tracking the reason for the rejection.
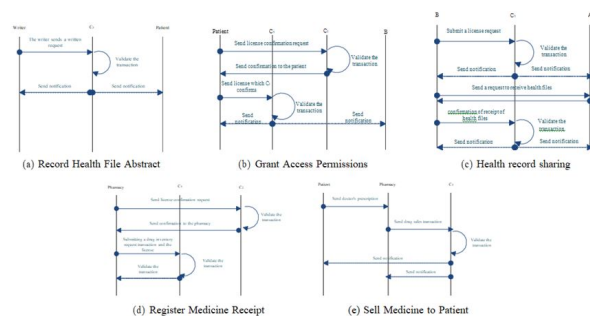
Figure 2: Key system transactions.

Information Structure in System Controllers

Within the controller section, maintaining a comprehensive record of all actors' identities is essential, as it ensures proper monitoring and execution of transactions in adherence to system policies. In our proposed system, when a patient intends to grant authority to the five mentioned operators for example read access, a specific sequence of steps must be followed. Initially, the patient obtains permission from section c_1 and subsequently transmits this authorization to the c_3 (**Figure 2**). The information structure utilized in the current system design is outlined below and can be further expanded as per the designer's requirements.

Patient identity and permanent identity: In our system, each patient has both a temporary identity and a permanent identity. The temporary identity is used for interactions with various network members, while the permanent identity is exclusively employed within the system's controllers, ensuring consistency and serving as a reliable reference for overseeing the patient's activities across the network.

File IDs: All file IDs connected to a patient's permanent identity are synchronized across all c_1 nodes. This ensures

that the department maintains a real-time record of which patient each file ID pertains to.

Authorized and unauthorized members: A comprehensive list of authorized and unauthorized members in the system is stored within the memory of c_1 nodes. Even initially unauthorized members were granted access because their presence was deemed essential. If necessary, they can be reauthorized after a designated period.

Drug supply chain identity: Similarly, the identity of all members in the drug supply chain system must be documented within c_2. Since c_1 and c_2 are interlinked, the duplication of identity information between them is minimized to optimize memory utilization.

Drug entry timestamp: In c_2, critical information such as the time a drug enters the country or is initially produced is meticulously recorded in the chain. This serves as a crucial historical record for the drug supply chain.

By adhering to this structured information model, our system is well-equipped to ensure the integrity and security of transactions, enabling efficient monitoring and adherence to system policies.

Temporary ID Anonymization and Parallelization for Scalability

In our system, two critical aspects deserve attention:

Temporary ID anonymization: A noteworthy challenge in our system is the presence of the patient's registered ID within transactions, which can potentially reveal the health-care centers visited by the patient. To address this concern, a solution has been devised, except for the controllers. In particular, the patient's ID should be anonymized within nodes c_3 and c_4. However, nodes c_1 and c_2 must retain knowledge of the patient's identity and establish the connection between the temporary ID and the patient's permanent identity. An essential consideration when modifying the patient's ID is to ensure that the temporary patient ID remains consistent across c_3 and c_4 as the process of confirming medication purchases by c_4 nodes necessitates matching the patient ID between c_3 and c_4. Importantly, nodes within c_1 maintain awareness of the patient's identity, even when the temporary ID is altered.

Parallelization for scalability: The proposed system lever-ages parallelization to enhance scalability, as the components of each block chain or the sub-block chain, exhibit minimal interdependence. Unlike financial systems such as Bitcoin and Ethereum, there is no requirement to record all block on all nodes. Consider a scenario where the entire network comprises several sub-block chain, each corresponding to a specific state. Medical transactions within a state have limited interaction with those in other states. Should the need arise to transfer information between two states; it can be achieved by establishing a bridge between sub-block chains. Therefore, not all nodes within the country must record and store all transactions.

To optimize the system's scalability, parallelization of the blockchain has been implemented.

RESULTS AND DISCUSSION

Implementation and Testing

In this section, we provide an in-depth exploration of the meticulous implementation of our block chain network, along with the comprehensive testing scenarios that we executed to evaluate its performance and functionality.

Enhancing healthcare blockchain with parallelism:

- **Problem statement:** Healthcare systems, characterized by their intricate data requirements, demand robust solutions to handle ever-increasing transactions efficiently. However, traditional healthcare block chains often encounter performance bottlenecks and scalability limitations. Our work addresses this pressing issue and opens the door to enhanced healthcare blockchain capabilities.

- **Why parallelism:** Parallelism presents a dual advantage within our healthcare block chain system. Firstly, it enables the same peer nodes to process transactions concurrently, substantially increasing the system's throughput. This means that more transactions can be handled in the same timeframe, enhancing the overall operational capacity of the network. Secondly, parallelism plays a pivotal role in reducing network traffic. With transactions processed in parallel, the cumulative network traffic is significantly lowered. This not only optimizes the efficiency of data transfer but also minimizes the strain on the network, resulting in a more streamlined and responsive healthcare data management system.

- **Technical challenges:** Implementing parallelism in healthcare chain code posed unique technical challenges. Adapting this approach to the intricacies of healthcare data management required meticulous planning, code development and rigorous testing. Our research addresses these challenges head-on, paving the way for healthcare systems to benefit from this novel solution.

- **Pioneering implementation:** Our work signifies a notable step in the realm of implementing parallelism within Hyperledger Fabric for healthcare chaincode, demonstrating a novel approach that contributes to the ongoing development of healthcare blockchain solutions. This implementation paves the way for valuable insights, potentially inspiring further research and system improvements in the future.

Implemented network: The implemented network comprises two organizations, an ordering node, licensing nodes and several member nodes responsible for signing and recording transactions. We initially kick started the network by obtaining the relevant files from reference. Subsequently, utilizing code we developed, we expanded the initial network and integrated new nodes into the system. The network is constructed using Docker, featuring configuration files written in JavaScript and YAML. We've created a smart contract using the Go programming language to register drug sales and retrieve information about registered drugs. Additionally, we've established a smart contract to record new drugs in the blocks. All code and network configurations are implemented on an Ubuntu desktop running the 2022 version. The hardware utilized boasts a Core i7 CPU with 12 GB of RAM. You can access all of the provided codes in reference.

Implemented scenarios: We have conducted five unique scenarios in our network, utilizing two network structures as illustrated in **Figure 3**. The initial two scenarios involve drug sales registration, while the subsequent three scenarios focus on retrieving information from the ledgers. In each scenario, we consistently involve 20 clients. Notably, **Figure 3a** represents a parallelism network idea, featuring two organizations with 8 peer nodes in each organization. Each organization operates independently. In contrast, **Figure 3b** depicts a formal network where the two organizations work interdependently. The parallelism concept is embodied in **Figure 3a** whereas **Figure 3b** does not follow a parallel structure

- **Drug sales scenarios:** Imagine a network with sixteen members. In the first scenario, we've established two parallel block chains, as illustrated in **Figure 3a** each block chain comprises eight members, collectively processing 10,000 drug sales transactions, with 5,000 transactions executed in each block chain. These transactions entail selling and recording medicines within the ledger. The second scenario mirrors the first but adopts the network structure presented in **Figure 3b**. The key distinction is that the two block chains collaborate through a channel in the Hyperledger Fabric, enabling the execution and recording of 10,000 drug sales transactions jointly.

- **Information retrieval scenarios:** In these scenarios, our focus shifts to the retrieval of information regarding all drugs. The third scenario features two parallel block chains, each housing eight members and storing data for 500 drugs. The fourth scenario closely resembles the third, with the exception that it records data for 1,000 drugs in each information member. This is conducted to explore the impact of non-parallelism in information handling. The fifth scenario wit-nesses the union of two block chains into a single channel, with each information member containing data for 1,000 drugs. By comparing the third and fifth scenarios, we aim to gauge the impact of parallelization. Meanwhile, the fourth scenario probes the consequences of non-parallel information handling on system performance. The network structure for the third and fourth scenarios aligns with **Figure 3a**, whereas **Figure 3b** characterizes the fifth scenario. In all scenarios, we subjected the network to the maximum load, meaning that the benchmark caliper operated at its peak capacity.
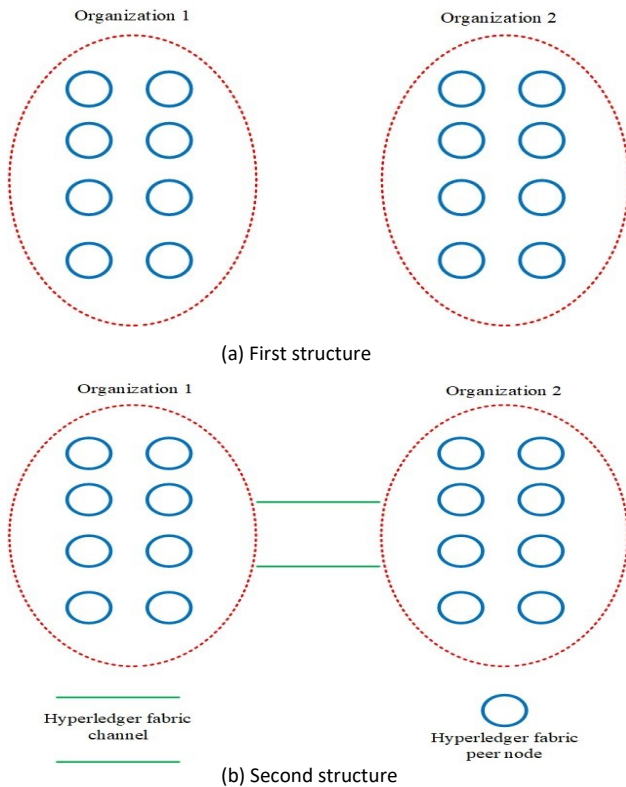
(a) First structure

Hyperledger fabric channel

Hyperledger fabric peer node

(b) Second structure

Figure 3: Test structures.

Performance Evaluation and Key Features

In this section, we delve into the comprehensive evaluation of our implemented network. We explore the networks performance across a range of critical metrics, providing insights into its efficiency and scalability. We present the results of our performance assessment, comparing the impact of parallelization on various parameters. Following this analysis, we detail the standout features of our proposed system in the second subsection, highlighting its capabilities and advantages.

Performance metrics evaluation: Following the implementation of the proposed network, a comprehensive evaluation was conducted using the Caliper benchmark, encompassing the five scenarios previously out-lined. The assessment encompassed various key performance metrics, including processor utilization, RAM requirements, input and output traffic of nodes, and network throughput. To gauge the impact of parallelization on scalability, we considered the two organizations equal since it is assumed that two parallel block chains yield analogous results.

- **Processor consumption: Figure 4** illustrates resource consumption for each node across all five scenarios. As portrayed in **Figure 5a**, when comparing T1 (Test result scenario 1) and T2, it becomes apparent that our approach incurs an increase in CPU consumption during drug sales registration, which can be considered a drawback. A similar trend is observed when comparing T3 and T5, where the same effect on processor consumption is observed during drug retrieval transactions (query transaction). However, when comparing T3 and T4, it is evident that processor consumption can be reduced through parallelization of information. This suggests that while maintaining nodes in a non-parallel state, information parallelization can optimize processor consumption.

- **RAM requirements:** As indicated in **Figure 5b**, our approach does not significantly affect the required RAM, as comparisons between T1 and T2, T3 and T4 and T3 and T5 reveal no substantial deviations in RAM utilization. Input, output and total traffic: **Figure 5c-e** showcase the analysis of traffic consumption. In this context, "Input traffic" refers to data being received by block chain members, "output traffic" refers to data being transmitted by them and "total traffic" represents the cumulative traffic, which is the sum of both input and output data. By comparing T1 and T2 with our approach, it is evident that our method can reduce input, output and total traffic consumption by half at the node. This signifies a significant decrease in telecommunication traffic.

- **Transaction throughput:** The term Throughput refers to the network's operational capacity to process Transactions Per Second (TPS) within Hyperledger Fabric. **Figure 5f** illustrates that with our approach, throughput can increase up to threefold. In other words, the network's ability to handle transactions is significantly enhanced. With our approach, the network can serve up to three times more users with the same number of peer's nodes (**Table 1**).

(a) Test result scenario 1   (b) Test result scenario 2   (c) Test result scenario 3

(d) Test result scenario 4   (e) Test result scenario 5

Figure 4: Detail of nodes for five scenarios.

(a) CPU   (b) RAM   (c) input traffic

(d) Output traffic   (e) Total traffic   (f) Throughput

Figure 5: Performance metrics evaluation of five scenarios.

Table 1: Performance metrics evaluation of five scenario.

CPU %	Test result scenario 1	Test result scenario 2	Test result scenario 3	Test result scenario 4	Test result scenario 5
	42%	32%	34%	44%	24%
Memory (Mib)	2429 Mib	2558 Mib	1756 Mib	1812 Mib	1482 Mib
Input traffic (MB)	1935 MB	3013 MB	681 MB	1298 MB	1428 MB
Output traffic (MB)	1859 MB	3070 MB	1868 MB	3267 MB	3651 MB
Overall traffic (MB)	3794 MB	6083 MB	2549 MB	4565 MB	5133 MB
Throughput (Tps)	129 Tps	37 Tps	118 Tps	78 Tps	36 Tps

In summary, our method leads to an increase in processor consumption. However, with no changes to the number of member nodes, transaction throughput can be enhanced by at least threefold and traffic consumption is reduced by at least half. Notably, our approach has a limited impact on the required RAM, which remains largely unchanged.

Key features of the proposed system

- **Patient privacy:** The system safeguards patient privacy by introducing them with a temporary ID, which undergoes periodic changes. The use of temporary IDs enhances patient privacy, while the controllers within the health system retain knowledge of the patient's identity, which is essential for the system's operation.

- **Data integrity:** The information abstract stored in the block chain includes a timestamp. System members with access to a file can compare the information abstract of their accessible file with the one recorded in the block chain. This verification ensures the integrity of the data and confirms the accuracy of the information.

- **Non-repudiation:** Transactions in the Hyperledger Fabric blockchain are based on a public-private key infrastructure. Each transaction is signed before being sent to the block chain, ensuring non-repudiation, a crucial feature in preventing transaction denial.

- **ID management:** The public-private key infrastructure in the Hyperledger Fabric block chain ensures secure management of IDs, enhancing the overall system's security and integrity. Access control: Patients can control access levels for individuals or organizations through the execution of smart contracts. Transaction 2, initiated by the patient, is recorded only after confirmation from the controller, ensuring that permissions align with health system policies. Access control in the proposed system offers robust control while maintaining policy compliance.

- **Compatibility with traditional health system:** The system is designed to incorporate health organizations as users, with investors and supervisory organizations creating nodes and controllers. Health organizations and patients join the system through distinct channels. The use of HL7 for information exchange ensures compatibility with the traditional health system.

- **Interoperability:** The utilization of HL7 for communication between organizations and information exchange establishes a foundation for seamless interoperability, making it a fundamental system feature. Furthermore, our five proposed transactions contribute to achieving interoperability among organizations, enabling key operations like data sharing between organizations.

- **Transparency for patients:** In the proposed system, the issuance of licenses by the block chain is required for the transfer and registration of information. This mechanism ensures that the relevant patient is informed of changes and information transfers, thereby enhancing transparency.

- **Real-time drug supply monitoring:** The system allows controllers to have real-time visibility into the drug supply chain. They can track the availability of drugs, their locations in various pharmacies, and record sales. Data analysis tools empower controllers to extract valuable insights from this information.

- **Counterfeit drug prevention:** Counterfeit drugs are a significant concern, particularly in regions with weaker economies. The proposed system addresses this issue by registering drugs from the manufacturer to the pharmacy. Patients can verify the authenticity of a drug by scanning a QR code, reducing the likelihood of counterfeit drug usage.

- **Scalability enhancement:** One of the distinctive contributions of our research lies in the implementation of scalability enhancement techniques within the context of healthcare transactions on the Hyperledger fabric block chain. Our study marks a pioneering endeavor in adapting and applying this concept to the intricacies of healthcare data management, what sets our research apart is its unique application within the healthcare domain. We've harnessed the potential of parallelization to optimize the performance of our proposed system for healthcare transactions. This groundbreaking approach is a response to the specific demands of healthcare systems, where data integrity, security and real-time processing are paramount. By implementing parallelization, we've not only addressed these critical aspects but have also introduced a new dimension to the field of healthcare data management. Our research demonstrates that scalability enhancement, when tailored to healthcare transactions in Hyperledger Fabric, can significantly impact the system's ability to handle a growing number of transactions and users. It's

worth noting that our work is among the first to implement parallelization in this context, making it a pioneering step towards ensuring the scalability and efficiency of healthcare block chain systems. In summary, our system offers advanced patient privacy, data integrity and non-repudiation. It ensures compatibility, interoperability and transparency while pioneering scalability enhancement through parallelization, a groundbreaking contribution to healthcare block chain systems.

CONCLUSION

In this research, we have presented a novel framework for data sharing and drug supply chain management in the health-care domain. Our meticulously designed system successfully addresses critical challenges in modern healthcare systems, providing an innovative solution for data security, scalability, data integrity, traceability, deniability and secure data sharing. The implementation of parallelism is a key feature of our framework, enhancing scalability, throughput and network efficiency. Our performance evaluation, conducted through the Caliper benchmark, has demonstrated the significant benefits of our approach. We have witnessed an increase in processor consumption, mainly during drug sales registration and query transactions. However, the use of parallelization effectively optimized processor consumption. Remarkably, our approach had limited impact on RAM requirements, ensuring efficient resource utilization. In terms of traffic, our system has significantly reduced input, output and total traffic consumption at the nodes. This reduction translates to a decrease in telecommunication traffic, a crucial improvement for healthcare data management. Moreover, we observed a substantial increase in transaction throughput, with our approach enhancing the network's capacity to process transactions by up to threefold. Our system consists of five distinct layers and it encompasses five unique transactions. These features contribute to a patient-centric healthcare system, enabling easy access to essential documents and streamlining processes like insurance claims, ultimately enhancing the patient experience.

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