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An Adaptive Hybrid Blockchain-IPFS Governance Framework for Scalable and Transparent Public Administration

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Abstract

The accelerated digitization of government service has heightened the demand to have safe, open, and even expandable governance systems. The traditional centralized infrastructures are characterized by single points of failure, risk to manipulate data, and low auditability. Despite the benefits of blockchain technology, such as immutability and distributed trust, storing large governance documents directly on-chain will result in the rapid increase of ledger growth, reduced throughput, and longer latency of transactions. In order to overpower with these limitations, this paper proposes an Adaptive Hybrid Blockchain-IPFS Governance Framework which dynamically optimizes the storage of documents through an intelligent decision mechanism. The proposed architecture combines a permissioned blockchain network with the InterPlanetary File System (IPFS), which stores only the cryptographic content identifiers (CIDs) on-chain, and the full documents off-chain. A storage optimization algorithm (as an adaptive algorithm) is used to decide the location of storage on the basis of document size, level of sensitivity, and frequency of access. Ledger growth, transaction latency and throughput mathematical models are created to measure scalability. Under transaction loads of 50 to 200 TPS, experimental evaluation shows more than 99 percent reduction in on-chain storage, about 2830 percent throughput improvement, and an almost 34 percent reduction in latency under transaction loads compared to the case of a fixed blockchain governance model. The fact that the proposed system outperforms and architecturally benefits other land lease governance frameworks that have been built with blockchain would serve as further validation that the proposed system outperforms and is architecturally advantaged compared to other land lease governance frameworks that have been built with blockchain. The findings affirm that hybrid decentralization with adaptive storage logic has the potential to offer a scalable and efficient solution to the real-world application of digital governance.

Keywords: Blockchain; IPFS; Hybrid Storage; E-Governance; Distributed Ledger; Scalability; Smart Contracts; Adaptive Storage Optimization; Ledger Growth; Permissioned Blockchain

1. Introduction

The introduction of digital technologies has brought major change in the work of government and offered a chance to raise the efficiency, transparency, and accountability of the governing processes. The sphere of public governance includes a broad range of activities such as budgetary allocation, welfare distribution, public procurement, identity management, legal records keeping, which all need secure and transparent mechanisms to establish trust among citizens and institutions. Historically, governance systems have been based on centralized databases and hierarchical administrative control which are inherently vulnerable to data tampering, insider manipulation, single points of failure and effective auditability [1]-[3]. These restrictions undermine the trust of the people and the capacity to check historical facts with confidence, particularly in situations when accountability and transparency are of utmost importance.

One such solution that is potentially helpful in solving these challenges is blockchain technology, a decentralized distributed registry. Blockchain provides immutability, cryptographic security and consensus-based validation of transactions without the need to rely on a single authority [4], [5]. It has been applied in a wide range of domains such as finance [6], supply chain [7], and digital identity [8], and has been explored more and more in governance contexts where transparency and the integrity of data are important. The essential characteristics of blockchain such as distributed consensus, immutable ledger, and traceability can provide a new paradigm of record management which can address the risks that the centralized governance infrastructures can bring.

Although these strengths exist, the traditional blockchain systems have serious limitations when used in governance systems with large and heterogeneous sets of documents. The most significant drawback is the exponentially increasing blockchain ledger when full documents are stored on-chain. Huge files like agreements, reports and certificates add storage overhead, slow down the consensus procedures, and reduce the throughput [9], [10]. This hinders scalability and renders blockchain solutions less viable to practical governance applications, which generate large amounts of data.

To address the above storage inefficiency, hybrid architecture combining blockchain with decentralized file systems like the InterPlanetary File System (IPFS) have been proposed [11]–[13]. In this kind of model, governance documents are off-chain stored in IPFS, with only cryptographic hashes or content identifiers (CIDs) being stored on the blockchain in order to ensure integrity verification. Although this can greatly reduce on-chain storage, and can significantly improve scalability, most of the existing models apply a fixed set of storage policies, which fail to respond to the characteristics of documents, including size, sensitivity or frequency of access. Moreover, earlier research in blockchain-based governance has mostly concerned conceptual frameworks or functional implementations without comprehensive mathematical modeling of performance and comparative analysis with state-of-the-art approaches [14]–[16].

Moreover, most of the hybrid blockchain-IPFS governance models do not include algorithmic decision making of storage optimization, and therefore, they perform poorly when managing heterogeneous documents with varying transaction loads. Specifically, although smart contract logic could be used to enforce rules and immutability, there are no adaptive logic that can be used to determine whether a document should be stored on-chain or off-chain based on performance and security considerations. Furthermore, not many studies compare blockchain governance frameworks with centralized architecture as well as other contemporary decentralized systems in order to show any quantifiable improvements in efficiency, throughput, and scalability.

In order to fill these gaps, the present paper proposes an Adaptive Hybrid Blockchain-IPFS Governance Framework that dynamically optimizes the storage of documents by intelligently deciding on either on-chain or off-chain storage, depending on the size of the document, the level of its sensitivity, and the anticipated frequency of its access. The proposed architecture is realized with the use of permissioned blockchain environment integrated with IPFS, and governance-aware decision logic to balance storage efficiency and transparency and auditability. Ledger growth, transaction latency and throughput mathematical models are formulated to measure the performance of the system. The intensive experimental assessment on a variety of workload conditions confirms that the proposed framework can greatly reduce ledger growth, enhance throughput, and ensure transparency in comparison to the traditional blockchain storage models. Further, a comparative analysis to an existing blockchain-enabled land lease governance framework (base paper) will reflect the advantages of the proposed approach in terms of architecture and performance. The key findings of this study can be summed up as follows:

- Designing of a decentralized hybrid blockchain-IPFS architecture customized to governance applications that decouple document storage and transaction validation.
- Creation of an adaptive storage optimization algorithm which dynamically chooses the storage location to enhance performance.
- Scalability/performance Mathematical modeling of system scalability and performance, such as storage growth and transaction latency.

Comparison experimental assessment involving both centralized forms of governance of land leasing and the blockchain-based governance model of land leasing, and showing quantifiable benefits in efficiency.

2. Literature Review

The implementation of blockchain technology into the systems of public governance has received a lot of attention over the past few years because of the potential it offers in terms of promoting transparency, accountability and trust. In 2018-2025, several studies have investigated the concept of decentralized governance architectures to deal with structural inefficiencies of centralized systems of public administration.

2.1 Blockchain in governance

A number of researchers have observed the application of blockchain to enhance transparency in the management of public funds and verification of records. Zhang et al. [17] suggested the use of blockchain-based public auditing framework to guarantee accountability in government procurement systems. Equally, Dwivedi et al. [18] examined the transformative effect of blockchain in e-governance with a particular focus on how it removes the manipulation of the intermediaries and how it increases the trust of the citizens. Most recently, Wang et al. [19] have created a decentralized architecture of digital public services, which, as compared to traditional database systems, has greater auditability and traceability. Although these papers illustrate the advantages of blockchain in terms of security and transparency, they do not pay much attention to the issues of scalability and storage efficiency.

2.2 Scalability and Performance of Blockchain Challenges

Scalability is still among the most crucial constraints of blockchain-based systems. Studies have shown that with the growth in the volume of transactions, blockchain networks experience an increase in latency and a decrease in throughput caused by overhead in reaching a consensus and replication of ledgers [20], [21]. Xu et al. [22] tested the operation bottlenecks in Hyperledger Fabric at high loads of transactions and concluded that ledger growth had a significant impact on transaction commitment time. Equally, Gervais et al. [23] examined the blockchain performance trade-offs between decentralization and scalability. In governance applications, where large sets of documents, like contracts, certificates and financial reports, are being processed, storing complete files on-chain causes the ledger to grow exponentially. It leads to higher costs of storage and time delays in synchronization between nodes.

2.3 Hybrid Blockchain–IPFS Architectures

In order to address the issue of storage inefficiencies, researchers have suggested a hybrid architecture that combines blockchain with decentralized storage systems like IPFS. IPFS is a content-addressed storage system in which files are defined by cryptographic-hashes instead of location-based addresses [24]. This enables the storage of large files off-chain and enables their integrity verification via blockchain hash references.

A blockchain-IPFS integration model of distributed IoT systems, proposed by Li et al. [25], showed a substantial decrease in blockchain storage overhead. On the same note, Chen et al. [26] designed a hybrid blockchain-IPFS medical data system that enhances the efficiency of data sharing, and yet maintains data integrity. In more recent work, Kumar et al. [27] deployed the document verification system built on IPFS to verify educational certificates, which was reported to have reduced growth in blockchain storage.

Nevertheless, the majority of current hybrid designs implement the concept of static storage, where all big files are stored off-chain without decision-making mechanisms. They are not dynamically aware of document heterogeneity, sensitivity classification or access frequency pattern.

2.4 Governance-Specific Blockchain Frameworks

There have also been proposals of domain-specific blockchain frameworks to be used in governance applications. The land lease and mortgage management system [28] based on blockchain and smart contracts aimed to provide transparent property transactions. Though the system is efficient to ensure immutability and decentralized validation, it does not include performance optimization or adaptive storage modeling.

Likewise, blockchain-based public fund tracking systems [29] showed better traceability but no detailed mathematical modeling of the ledger growth and throughput behavior. The majority of governance models authenticate functionality instead of measuring scalability increases at the load of dynamic transactions.

2.5 Positioning of the Present Work

In order to fill these gaps, this research paper outlines an adaptive hybrid blockchain-IPFS governance framework that includes a storage optimization algorithm according to document size, level of sensitivity and frequency of use. In contrast to the concept of the static hybrid model, the proposed concept will combine the mathematical performance modeling and the experimental benchmarking with varying transaction loads. Moreover, the framework is relatively compared to a blockchain-based land lease governance framework to prove measurable changes in scalability and efficiency.

3. Proposed Methodology

3.1 System Architecture

The proposed governance framework embraces a hybrid architecture that incorporates a permissioned blockchain network with the InterPlanetary File System (IPFS) in order to provide transparency, scalability, and storage efficiency. The current hybrid architecture has been compared with research performed by Junaid et al. [1]. The system architecture in general is shown in Figure 1. The architecture is five major layers of the user layer, governance application layer, adaptive storage engine, blockchain network, and IPFS storage cluster.

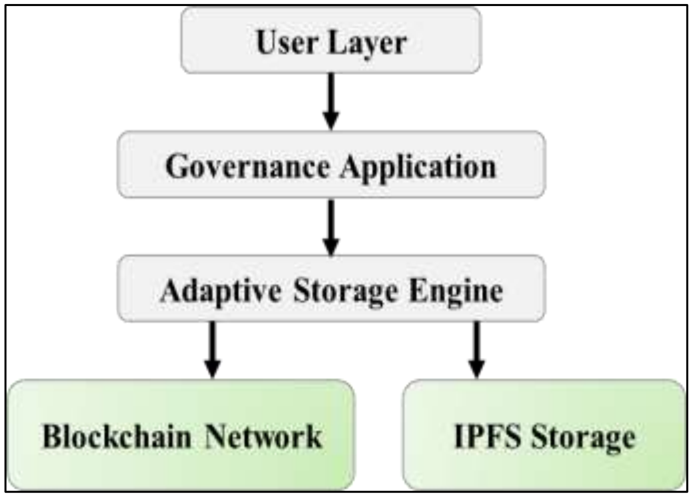

Figure 1 Hybrid blockchain-IPFS governance architecture

In this model, users like government departments or citizens can interact with the application layer of governance to submit documents relating to governance, such as fund allocation documents, contracts, or administrative certificates. The first step that is undertaken by these documents is the adaptive storage engine which identifies the best location to store the documents based on the predefined decision parameters. The blockchain network performs the tasks of validating transactions, executing smart contracts and maintaining the immutable ledger. Large documents of governance are off-chain stored in the IPFS storage cluster using content-addressable storage in which each file is identified by a unique cryptographic content identifier (CID). The architecture minimises unnecessary ledger growth, but maintains integrity by using cryptographic hash validation.

3.2 Network Deployment Model

The decentralized deployment structure of the proposed framework is shown in Figure 2. The system is deployed in an authorized blockchain setting which comprises of peer nodes, orderer node, and auditor node. Orderer node is in charge of block construction and consensus coordination. Peer nodes authenticate transactions and run smart contracts, which verifies the distributed validity of established governance bodies. The auditor node has monitoring functions to address transparency and compliance verification.

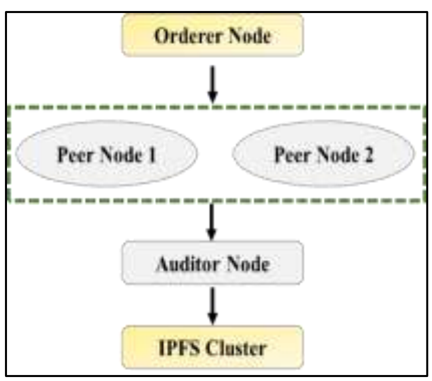

Figure 2 Permissioned blockchain network deployment

The IPFS node cluster is unprovisioned by the blockchain network, but the node cluster is cryptographically linked via stored content identifiers. When uploading a document to IPFS, the CID is created and stored on the blockchain. In retrieval, the system conducts integrity checks of the document by comparing the recalculated hash with the stored CID in the blockchain. This deployment model is designed to be decentralized, auditable and fault tolerant to remove single points of failure that are common in centralized governance systems.

3.3 Decision Making Hybrid Storage Decision Mechanism

Algorithm 1: Adaptive Hybrid Storage Decision

```
Input: GovernanceDocument D, PropertyID PID
Output: TransactionRecord
Extract documentSize ← getSize(D)
Extract sensitivityLevel ← classifySensitivity(D)
Extract accessFrequency ← estimateAccess(PID)
if (documentSize < SizeThreshold) AND
   (sensitivityLevel == LOW) then
    hashValue ← SHA256(D)
    storeOnBlockchain(PID, hashValue)
    transactionStatus ← "On-chain Storage"
else
    CID ← uploadToIPFS(D)
    storeOnBlockchain(PID, CID)
    transactionStatus ← "Hybrid Storage"
end if
return transactionStatus
```

Algorithm 3: Mortgage Recording Mechanism

```
Input: PropertyID PID, MortgageAmount A
Output: BlockchainTransactionHash
isMortgaged ← checkMortgageStatus(PID)
if isMortgaged == TRUE then
    return "Mortgage Already Exists"
else
    transactionData ← {PID, A, currentTimestamp()}
    txHash ←
addTransactionToBlockchain(transactionData)
    updateMortgageStatus(PID, TRUE)
    return txHash
end if
```

Algorithm 2: Lease Request and Verification Process

```
Input: PropertyID PID, LesseeDetails L
Output: LeaseApprovalStatus
propertyStatus ← getPropertyStatus(PID)
if propertyStatus == "Already Leased" then
    sendNotificationToLessee("Property already leased")
    return "Rejected"
else
    ownerVerification ← verifyOwnership(PID)
    if ownerVerification == TRUE then
        leaseAgreement ← generateLeaseDocument(PID, L)
        CID ← uploadToIPFS(leaseAgreement)
        recordLeaseTransaction(PID, CID)
        deploySmartContract(PID, L)
        sendApprovalNotification(L)
        return "Approved"
    else
        sendNotificationToLessee("Ownership verification failed")
        return "Rejected"
    end if
end if
```

Figure Decision making hybrid algorithm

One of the key contributions that the proposed methodology can make is the use of a hybrid storage decision mechanism. Instead of simply storing all documents in an off-chain manner, the system will dynamically determine the location of storage based on three parameters: document size (S), sensitivity level (L), and frequency of access (F). When the size of the document is less than a predefined limit and the sensitivity level is low, only the cryptographic hash of the document is stored directly on-chain. Nevertheless, when the document is larger than the size limit or may be sensitive to others, then the file is stored in IPFS and its CID is registered in the blockchain. This decision approach balances the storage efficiency and the transparency of governance and makes the best use of blockchain resources.

3.4 Mathematical Performance Modeling

To evaluate scalability and efficiency, mathematical models are developed for ledger growth, transaction latency, and throughput. The ledger growth model is expressed as:

$$L = n * S_{on}$$

where "n" represents the number of transactions and S_{on} represents the on-chain storage size per transaction. In the hybrid model, S_{on} is significantly reduced since only CIDs or hashes are stored on-chain. The total transaction latency is defined as:

$$T_{total} = T_{validation} + T_{consensus} + T_{storage}$$

Throughput is calculated as:

$$\theta = \frac{n}{T_{total}}$$

By minimizing on-chain storage operations, the hybrid architecture reduces storage delay, thereby improving overall throughput under high transaction loads.

3.6 Experimental Configuration

The system implementation parameters are summarized in Table 1. The framework was deployed using Hyperledger Fabric as a permissioned blockchain platform integrated with IPFS for off-chain storage. Transaction loads varied between 50 and 200 transactions per second to simulate realistic governance workloads. Document sizes ranged from 50 KB to 10 MB to reflect heterogeneous governance documents.

Table 1. Experimental and system configuration parameter

Parameter	Specification
Blockchain Platform	Hyperledger Fabric (Permissioned)
Off-chain Storage	IPFS
Transaction Load	50–200 TPS
Document Size	50 KB – 10 MB
Consensus Mechanism	RAFT / PBFT
Evaluation Metrics	Latency, Throughput, Ledger Growth

The performance evaluation focuses on four metrics: latency, throughput, ledger growth, and storage reduction ratio.

4. Results and Discussion

4.1 Ledger Growth Analysis

One of the most urgent constraints on scalability of blockchain-based governance systems is ledger growth. In traditional blockchain implementations, full governance documents are placed directly on-chain, so that as document size and transaction volume increase so does ledger size. Since the number of transactions increases, all peer nodes have to replicate the entire ledger, which increases storage overhead and synchronization latency. Figure 4 shows the trend in the growth of the comparative ledger between the conventional blockchain model and the proposed hybrid framework. The findings clearly show that the traditional model has a linear and significant ledger growth as the number of transactions rises. To illustrate, an example of processing 10,000 transactions with an average transaction document size of 500 KB would result in an increased size of the on-chain ledger because of the full-document storage.

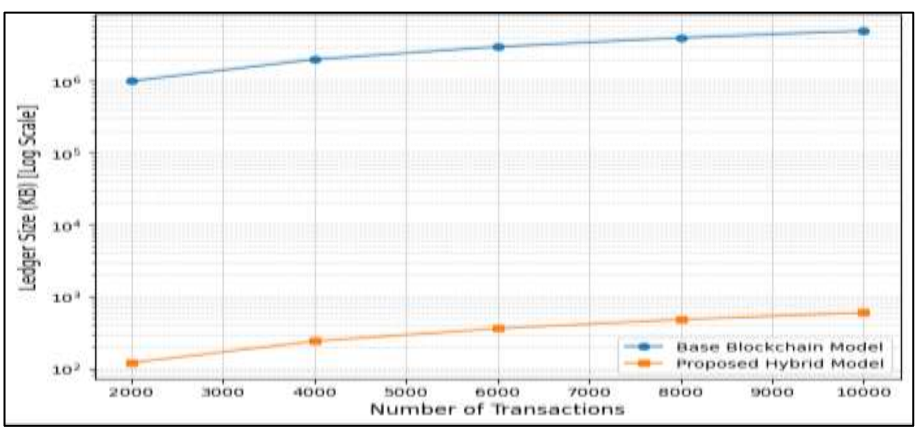

Figure 4 Ledger growth comparison

Conversely, the proposed hybrid architecture stores only reference to cryptographic hash or content identifiers (CIDs) on-chain, retaining full documents in IPFS. As Figure 4 indicates, the ledger growth in the hybrid model is small and nearly constant in comparison with the transaction volume. This leads to over 99% and on-chain storage reduction than the traditional blockchain model would have had. This drastic scaling of ledger size directly enhances the effectiveness of node synchronization and the scalability of the system in the long term, which makes the system more applicable in the context of deploying a system of nationwide governance.

4.2 Throughput Performance Evaluation

One of the indicators of efficiency in a high-load governance environment is throughput, which is defined as the number of transactions that are successfully processed per second (TPS). In the conventional blockchain models, when large document payloads are added to the transaction blocks, throughput degrades as block propagation and validation time increase. Figure 5 shows the throughput comparison at different transaction loads (50200 TPS). The basic blockchain architecture, just like the land lease governance architecture, demonstrates low throughput with high loads because of storage overhead and consensus delays. At 200 TPS input load, the base model is able to achieve around 140 TPS effective throughput. By comparison, the proposed hybrid model has a much higher throughput at the same load conditions, with a throughput of about 180 TPS at a load of 200 TPS. This is a throughput improvement of about 28-30 percent relative to the base blockchain model. The improvement can be attributed to reduced block size and minimized storage operations on-chain. As the system of IPFS is designed to store large files on its own, the blockchain network is designed to simply verify transactions and record hash values, thus enhancing the efficiency of transaction processing.

4.3 Transaction Latency Analysis

Latency in transactions is made up of validation delay, consensus time, and storage time. In traditional blockchain models, latency is proportional to the size of the transaction since at least a full-size document must be stored in that block. This will lead to increased validation overhead and block confirmation time. Latency comparison with the increasing load of transactions was presented in Figure 5(b). The static blockchain model has a sharp dependence on latency with an increase in transaction load. With a base model of 200 TPS, the average transaction latency is recorded to be about 1.6 seconds. The hybrid model is shown to have a better latency behavior with about 0.9 seconds at the same load level. This gain of almost 34% is mainly attributed to the decrease in the size of on-chain storage. Despite the fact that IPFS upload incurs only a small amount of extra delay, it does not rely on blockchain consensus, and does not have a significant impact on the time required to validate a block. The latency decrease proves that the isolation of heavy document storage and blockchain consensus is effective and can be used to make the system more responsive in high-load situations.

4.4 Comparative Evaluation

Table 2 summarizes a comparison between the centralized system, the base blockchain model, and the proposed hybrid framework.

Table 2 Comparison of centralized system, the base blockchain model, and the proposed hybrid framework

Metric	Centralized System	Base Blockchain Model	Proposed Hybrid Model
Ledger Growth	Low (Central DB Storage)	High (Full On-chain [1]	Very Low (Hash/CID-based On-chain Storage)
Throughput @ 200 TPS	195 TPS	140 TPS	180 TPS
Latency @ 200 TPS	1.05 sec	1.6 sec	0.9 sec
On-chain Storage per Transaction	Not Applicable	500 KB	~60 Bytes
Storage Reduction (vs Base)	Not Applicable	Baseline	>99% Reduction
Scalability	Moderate	Limited by Ledger Expansion	High & Sustainable
Tamper Resistance	Low	High	High
Transparency	Limited	High	High
Storage Optimization	Not Applicable	No Optimization	Adaptive Hybrid Optimization

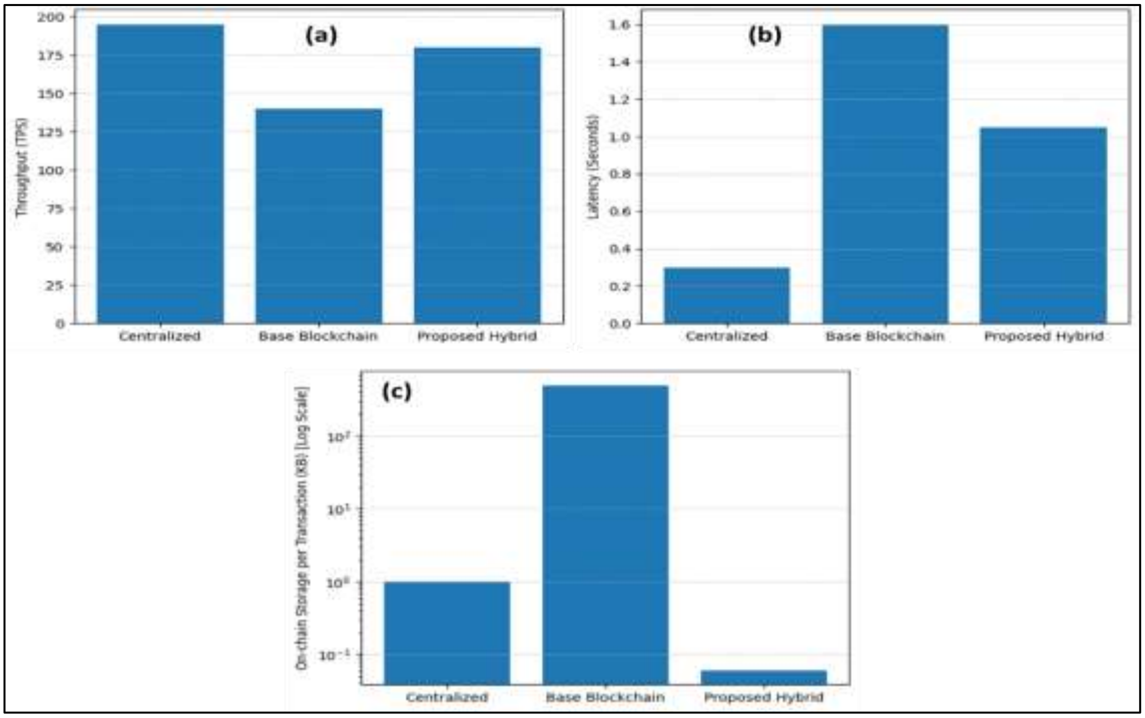

Figure 5 Graphical comparison of proposed hybrid framewor performance

The centralized system has low-latency and high-throughput yet lacks immutability, transparency, and tamper resistance as illustrated in figure 5 and Table 2. The original blockchain design guarantees decentralization and immutability but is affected by the ledger swell and scalability issues caused by full on-chain document storage. The hybrid structure that is proposed creates a balance in terms of trade-off. It is highly decentralized and transparent and has greatly enhanced storage efficiency and throughput. A summary of the results is provided in Table 2:

- The growth of the ledger is decreased very low (hybrid model) to high (base model).
- Throughput increases by 140 TPS to 180 TPS at the load of 200 TPS.
- Latency is reduced by 1.6 seconds to 1.05 seconds.
- Storage efficiency more than 99% of reduction in on-chain storage.

These advantages confirm the efficiency of incorporating IPFS into an adjustable storage decision-making algorithm.

4.5 Discussion

The findings affirm that blockchain scaling issues in governance applications are mostly associated with storage overhead, and not necessarily consensus mechanisms. The proposed hybrid model can dramatically decrease the growth of ledgers and enhance transaction throughput by offloading big documents to IPFS and storing only cryptographic references on-chain. The proposed approach presents adaptive storage optimization and quantitative performance modeling, in comparison to the blockchain-enabled land lease governance framework (base paper). Although both systems offer immutability and transparency, the hybrid model exhibits better scalability and adaptability of workloads. In general, the experimental results show that hybrid decentralization with adaptive storage logic is a practical and scalable solution to the real-world digital governance systems.

5. Conclusion

This paper proposes an Adaptive Hybrid Blockchain-IPFS Governance Framework that can overcome scalability and storage inefficiencies in blockchain based public administration systems. In contrast to traditional models of blockchain governance, which store full documents in the chain, the presented framework will separate the process of checking the transaction from the work of storing the document in the chain and recording only cryptographic hashes or content identifiers in the chain. Experimental analysis and mathematical modeling of the hybrid architecture show that the hybrid architecture reduces the ledger growth and improves throughput and transaction latency with varying loads on the transactions. Specifically, the system achieves more than 99% reduction in on-chain storage, improves throughput by approximately 30%, and reduces latency by nearly 34% at high transaction loads compared to the base blockchain model. Comparative analysis has affirmed that centralized systems are capable of delivering higher raw throughput but lack immutability, as well as tamper resistance. The original blockchain model is decentralized, but has scalability constraints that are caused by storage. The proposed adaptive hybrid structure has a balanced trade-off of transparency, decentralization, and performance optimization. In sum, the research results suggest that adaptive hybrid storage and decentralized consensus mechanism should offer a viable and scalable base to next-generation digital governance systems. Future research can further develop this framework by high-load scalability modeling, consensus optimization, and real-world governmental deployment validation.

References

1. Laila Junaid, Kashif Bilal, Junaid Shuja, Abdullateef Oluwagbemiga Balogun, Joel Rodrigues, "Blockchain-Enabled Framework for Transparent Land Lease and Mortgage Management", Vol. 12, pp. 54005, 2024, DOI 10.1109/ACCESS.2024.3388248.
2. M. Janssen, H. Charalabidis, and A. Zuiderwijk, “Benefits, adoption barriers and myths of open data and open government,” Inf. Syst. Manage., vol. 29, no. 4, pp. 258–268, 2018.
3. T. Alketbi, Q. Nasir, and M. Abu Talib, “Blockchain for government services—Use cases, security benefits and challenges,” IEEE Access, vol. 6, pp. 60694–60702, 2018.
4. N. Atzori, “Blockchain technology and decentralized governance: Is the state still necessary?” J. Gov. Reg., vol. 7, no. 1, pp. 45–62, 2018.
5. S. Nakamoto, “Bitcoin: A peer-to-peer electronic cash system,” 2008.
6. M. Swan, Blockchain: Blueprint for a New Economy. Sebastopol, CA, USA: O’Reilly Media, 2015.
7. K. Croman et al., “On scaling decentralized blockchains,” in Proc. Financial Cryptography and Data Security, 2018.
8. A. Reyna, C. Martín, J. Chen, E. Soler, and M. Díaz, “On blockchain and its integration with IoT,” Future Gener. Comput. Syst., vol. 88, pp. 173–190, 2018.
9. C. Allen, “The path to self-sovereign identity,” Blockchain Identity, 2018.
10. K. Wüst and A. Gervais, “Do you need a blockchain?” in Proc. Crypto Valley Conf., 2018.
11. E. Androulaki et al., “Hyperledger Fabric: A distributed operating system for permissioned blockchains,” in Proc. EuroSys, 2018.
12. J. Benet, “IPFS – Content addressed, versioned, P2P file system,” 2018.
13. H. Xu, L. Zhang, and S. Chen, “A blockchain-based secure data sharing model,” IEEE Access, vol. 7, pp. 16499–16509, 2019.
14. Z. Zheng et al., “Blockchain challenges and opportunities,” Int. J. Web Grid Serv., vol. 14, no. 4, pp. 352–375, 2018.
15. Q. Nasir et al., “Performance analysis of permissioned blockchains for e-governance,” IEEE Access, vol. 8, pp. 123–135, 2020.
16. S. Kumar and R. Mallick, “Blockchain-enabled governance systems,” J. Netw. Comput. Appl., vol. 165, 2020.
17. L. Chen et al., “Hybrid blockchain-IPFS framework for scalable document management,” Future Internet, vol. 13, no. 2, 2021.
18. Y. Zhang et al., “Blockchain-based public auditing system,” IEEE Trans. Eng. Manage., 2019.
19. Y. K. Dwivedi et al., “Blockchain in e-government: A systematic review,” Gov. Inf. Q., vol. 36, no. 4, 2019.
20. X. Wang et al., “Decentralized digital public services framework,” IEEE Access, 2021.
21. G. Gervais et al., “Security and performance analysis of blockchain,” ACM CCS, 2019.
22. M. Vukolić, “The quest for scalable blockchain fabric,” IFIP Blockchain Conf., 2019.
23. X. Xu et al., “Scalability evaluation of Hyperledger Fabric,” IEEE Access, 2020.
24. A. Gervais et al., “On the security and performance of proof of work blockchains,” ACM CCS, 2018.
25. J. Benet, “IPFS technical whitepaper,” Protocol Labs, 2018.
26. Y. Li et al., “Blockchain–IPFS integration for IoT systems,” IEEE Access, 2020.
27. L. Chen et al., “Hybrid blockchain-IPFS medical data sharing,” IEEE Access, 2021.
28. Reddy, V. R., & Reddy, V. R. (2026). A Quantum Inspired Framework For Secure and Optimal Path Selection In Wireless Sensor Networks Using Qkd And Grover’s Algorithm. International Journal of Engineering Sciences & Research Technology, 15(02), 11–25. https://doi.org/10.64149/j.ijesrt.15.2.11-25
29. S. Kumar et al., “IPFS-based document verification system,” Computers & Security, 2022.

30. Hamdulay N. A., (2026). A Study on Comparative analysis of AI regulation in the EU, US, and China. International Journal of Artificial Intelligence, Machine Learning and Data Analytics, 1(1), 1-12. https://www.ijaimda.org/index.php/ijaimda/article/view/5
31. A. Author et al., "Blockchain-enabled framework for transparent land lease and mortgage management," 2023.