Conceptual Decentralized Physical Infrastructure Networks (DePIN) for Shared Storage: A Secure and Incentive-Driven Framework for Decentralized Data Management

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Abstract- The increasing demand for digital storage has created challenges related to storage cost, centralized infrastructure, data availability, privacy, and dependence on large cloud service providers. Decentralized storage systems address some of these limitations by distributing data across multiple independent nodes, while blockchain can provide mechanisms for coordination, verification, identity, and incentives. More recently, Decentralized Physical Infrastructure Networks (DePIN) have introduced a model in which participants contribute physical resources to decentralized networks and receive incentives for useful resource contribution. This paper examines the application of DePIN principles to decentralized shared storage, with particular focus on decentralized storage architectures, peer-to-peer data distribution, blockchain-based coordination, storage verification, incentive mechanisms, and security challenges. Existing technologies and approaches including IPFS, Filecoin, blockchain-based storage, and distributed storage networks are analyzed to identify their architectural characteristics, benefits, and limitations. Based on the literature synthesis, the paper identifies challenges related to storage-provider trust, data integrity, availability, resource verification, malicious nodes, and incentive management. A DePIN-based shared-storage architecture is proposed in which users can contribute unused storage capacity as storage nodes while blockchain-based mechanisms coordinate identity, verification, and incentives, and distributed storage mechanisms handle user data. The proposed approach provides a foundation for developing a secure and resilient peer-to-peer storage marketplace while keeping large data objects off-chain. The paper further defines a methodology, security considerations, evaluation metrics, limitations, and future research directions for validating the proposed system.

Keywords: DePIN, Shared Storage, Blockchain, IPFS, Decentralized Storage, Smart Contracts, Filecoin, Storj, Arweave, Token Economics, Distributed Systems, Web3 Infrastructure.

I. Introduction

The exponential growth of digital data generated by cloud computing, Internet of Things (IoT) devices, artificial intelligence (AI) applications, social media platforms, and enterprise systems has created an unprecedented demand for reliable, scalable, and cost-effective storage solutions. Traditional cloud storage providers, such as centralized data centers and cloud service platforms, have successfully enabled large-scale data storage and management. However, these systems are often associated with challenges including single points of failure, data ownership concerns, vendor lock-in, privacy risks, censorship vulnerability, and dependence on centralized authorities. As data becomes a critical digital asset, ensuring secure, transparent, and user-controlled storage has become an important research and industry objective. Towards Decentralised Cloud Storage with IPFS: Opportunities, Challenges, and Future Directions identifies the concentration of data and traffic in centralized cloud platforms as a major motivation for decentralized alternatives.

Recent advancements in blockchain technology and Web3 ecosystems have introduced decentralized approaches to infrastructure management and resource sharing. One of the most promising developments is the concept of Decentralized Physical Infrastructure Networks (DePINs), which integrate physical resources such as storage devices, computing nodes, networking equipment, and energy infrastructure with blockchain-based governance and incentive mechanisms. DePIN enables individuals and organizations to contribute underutilized physical resources to a shared network while receiving rewards through cryptographic tokens. This approach transforms infrastructure ownership from centralized entities to a community-driven model that promotes openness, transparency, and distributed participation. A Survey of Decentralized Physical Infrastructure Network, Research Directions, and Open Challenges describes DePIN as a paradigm that combines physical infrastructure with decentralized governance and self-incentivized ecosystems to enable collaborative resource sharing and operation.

Among the various application domains of DePIN, decentralized shared storage has emerged as one of the most mature and commercially viable sectors. Storage-focused DePIN platforms create distributed marketplaces where users can rent unused storage capacity to others through blockchain-enabled agreements and cryptographic verification mechanisms. Unlike traditional cloud providers, these systems distribute data across multiple geographically dispersed nodes, improving resilience, fault tolerance, censorship resistance, and data availability. Decentralized storage networks also introduce innovative security mechanisms such as encryption, erasure coding, proof-based verification, and smart-contract-driven agreements to maintain data integrity and trust among participants. Research on blockchain-

based decentralized storage networks identifies platforms such as Filecoin, Storj, and Sia as leading examples of this architecture.

Filecoin utilizes cryptographic mechanisms such as Proof-of-Replication (PoRep) and Proof-of-Spacetime (PoSt) to verify that storage providers maintain client data over time, thereby establishing trust without relying on centralized oversight. Similarly, Storj employs encryption, erasure coding, auditing mechanisms, and reputation systems to deliver decentralized cloud storage services with strong security and reliability guarantees. Meanwhile, Sia introduces blockchain-based storage contracts that automatically enforce agreements between storage providers and users through publicly verifiable proofs. These platforms demonstrate how DePIN can leverage distributed resources to deliver practical storage services while reducing reliance on centralized infrastructure providers.

Despite its potential benefits, DePIN-based shared storage faces several technical, economic, and regulatory challenges. Issues such as storage performance variability, scalability constraints, network latency, token-economic sustainability, interoperability, governance complexity, and legal compliance continue to limit widespread adoption. Furthermore, achieving an optimal balance between decentralization, security, efficiency, and user experience remains an active area of research. Recent comparative studies emphasize that different decentralized storage platforms adopt distinct architectural and incentive models, resulting in varying levels of performance, reliability, and economic sustainability.

Therefore, a comprehensive investigation of DePIN-based shared storage systems is necessary to understand their architecture, operational principles, advantages, limitations, and future development opportunities. This paper aims to analyze the role of DePIN in decentralized storage ecosystems, examine major storage-focused platforms, compare their underlying mechanisms, and discuss key research challenges that must be addressed to enable large-scale adoption. By providing a detailed overview of current technologies and emerging trends, this study contributes to a deeper understanding of how decentralized storage infrastructures can support the next generation of Web3 applications and distributed digital services.

II. Review Method and Related Work

A. Review Method

This study adopts a literature review approach to examine the application of Decentralized Physical Infrastructure Networks (DePIN) in shared storage systems. Relevant research papers, survey articles, technical reports, and official documentation published between 2021 and 2026 were collected from IEEE Xplore, Springer, MDPI, arXiv, and official project resources. The review focused on topics including DePIN architecture, decentralized storage, blockchain-based storage systems, IPFS, Filecoin, Storj, and Sia. The selected literature was analyzed to understand the architecture, security mechanisms, incentive models, advantages, and limitations of decentralized storage networks. The findings of these studies provide the basis for identifying research gaps and developing the proposed DePIN-based shared storage framework.

B. Related Work

Decentralized Physical Infrastructure Networks (DePIN) have emerged as a new paradigm for managing and sharing physical infrastructure through blockchain technology and token-based incentives. Recent studies describe DePIN as a decentralized ecosystem where participants contribute storage, computing, and networking resources while receiving rewards for their participation. This approach reduces dependence on centralized infrastructure providers and promotes community-driven resource sharing [1], [2].

Decentralized storage is one of the most significant applications of DePIN. Traditional cloud storage systems offer scalability and accessibility but often suffer from challenges such as privacy concerns, vendor lock-in, limited transparency, and single points of failure. Blockchain-based storage networks address these issues by distributing data across multiple nodes and utilizing cryptographic verification mechanisms to ensure data integrity and availability. Several studies have shown that decentralized storage improves data sovereignty, security, and fault tolerance compared with conventional cloud storage solutions [3], [4].

The InterPlanetary File System (IPFS) plays an important role in decentralized storage ecosystems. IPFS uses content-based addressing and peer-to-peer networking to distribute and retrieve files efficiently across a decentralized network. Research has demonstrated that IPFS improves data accessibility, censorship resistance, and distributed availability while reducing dependence on centralized servers [5].

Several practical platforms demonstrate the feasibility of decentralized shared storage. Filecoin provides a decentralized storage marketplace where users purchase storage services and storage providers earn incentives by contributing storage resources. The platform employs Proof-of-Replication (PoRep) and Proof-of-Spacetime (PoSt) mechanisms to verify that data is stored correctly over time [6], [7]. Storj utilizes end-to-end encryption, erasure coding, and distributed storage nodes to provide secure and reliable cloud storage services [8], [9]. Similarly, Sia uses blockchain-based storage contracts and cryptographic proofs to ensure data integrity and availability within its decentralized storage network [10].

Recent comparative studies indicate that although platforms such as Filecoin, Storj, and Sia successfully implement decentralized storage, they differ considerably in terms of architecture, verification mechanisms, performance, and incentive models. Most existing research focuses on individual storage platforms rather than providing a generalized DePIN-based framework that integrates storage management, verification, governance, and incentive mechanisms within a unified architecture [4], [11]. This limitation motivates the need for further research into comprehensive DePIN-based shared storage systems.

III. Research Gap and Problem Definition

A. Research Gap

Recent research has demonstrated the potential of Decentralized Physical Infrastructure Networks (DePIN) for enabling decentralized storage services through blockchain technology, distributed resource sharing, and token-based incentive mechanisms [1], [2]. Existing platforms such as Filecoin, Storj, and Sia have successfully shown that unused storage resources can be contributed by network participants and transformed into decentralized storage infrastructures [6], [8], [10].

However, most existing studies focus on individual storage platforms and their specific implementation mechanisms rather than proposing a generalized DePIN-based shared storage architecture. Current storage networks use different approaches for storage verification, node management, governance, incentive distribution, and data storage, resulting in fragmented ecosystems that are difficult to integrate and compare [4], [11]. As a result, there is limited research on a unified framework that combines decentralized storage, governance, verification, and incentive management within a single architecture.

Another limitation is that many decentralized storage solutions focus primarily on data storage and retrieval while giving less attention to provider reputation, governance participation, storage node reliability, and long-term network sustainability. Existing studies discuss storage proofs and security mechanisms but provide limited guidance on how resource contributors, storage consumers, blockchain systems, and governance mechanisms can operate together in a scalable DePIN ecosystem [1], [3].

Furthermore, decentralized storage networks continue to face challenges related to data availability, storage-node failures,

efficient resource allocation, scalability, and fair reward distribution. Although several solutions exist, there is no widely accepted architectural model that integrates storage management, provider verification, reputation tracking, decentralized governance, and incentive allocation in a simple and structured manner [4], [11].

Therefore, a significant research gap exists in the development of a comprehensive DePIN-based shared storage framework that provides secure data storage, decentralized coordination, verifiable resource contribution, reputation-based trust management, governance participation, and incentive-driven sustainability within a unified architecture.

B. Problem Definition

Traditional cloud storage systems rely on centralized service providers to manage data storage, access control, and infrastructure resources. While these systems offer convenience and scalability, they introduce concerns related to data ownership, privacy, vendor lock-in, service dependency, and single points of failure [3], [4]. Users must fully trust centralized providers for the security, availability, and management of their data.

Decentralized storage platforms attempt to address these issues by distributing storage resources across multiple nodes and utilizing blockchain technology for trust and verification. However, existing solutions often operate as isolated ecosystems with platform-specific rules and mechanisms. Differences in governance models, storage verification techniques, node selection methods, and reward systems create barriers to wider adoption and interoperability [6], [8], [10].

The problem addressed in this research is the lack of a unified DePIN-based shared storage architecture that effectively integrates storage providers, storage consumers, distributed storage resources, blockchain-based verification, decentralized governance, reputation management, and incentive distribution. There is a need for a framework that allows users to securely store and retrieve data while enabling storage providers to contribute resources and receive transparent rewards based on verifiable storage performance.

To address this problem, this research proposes a layered DePIN-based shared storage architecture consisting of a User and Application Layer, API and Storage Management Layer, Blockchain and Smart Contract Layer, Governance Layer, Distributed Storage Layer, Verification and Security Layer, and Incentive Layer. The architecture separates large-scale data storage from blockchain coordination, ensuring that data remains off-chain while the blockchain manages storage agreements, verification records, governance activities, reputation information, and reward allocation. This approach aims to improve scalability, security, transparency, fault tolerance, and resource utilization while supporting the long-term sustainability of decentralized storage ecosystems [1], [6], [11].

The ultimate objective of the proposed system is to create a secure, decentralized, and community-driven shared storage infrastructure where participants can contribute unused storage resources, store data reliably, verify resource availability, participate in governance decisions, and receive fair incentives based on actual service contribution. Such a framework can support future Web3 applications, decentralized digital services, and next-generation decentralized infrastructure networks.

IV. Proposed System Architecture

The proposed system is designed as a Decentralized Physical Infrastructure Network (DePIN)-based shared storage architecture that enables participants to act as both storage consumers and storage providers. Storage providers contribute unused storage capacity to the network, while storage consumers utilize the contributed resources to securely store and retrieve files. The architecture separates large-scale data storage from blockchain-based coordination, ensuring that large files are stored off-chain while blockchain technology manages verification, governance, and incentive-related functions [1], [3], [6].

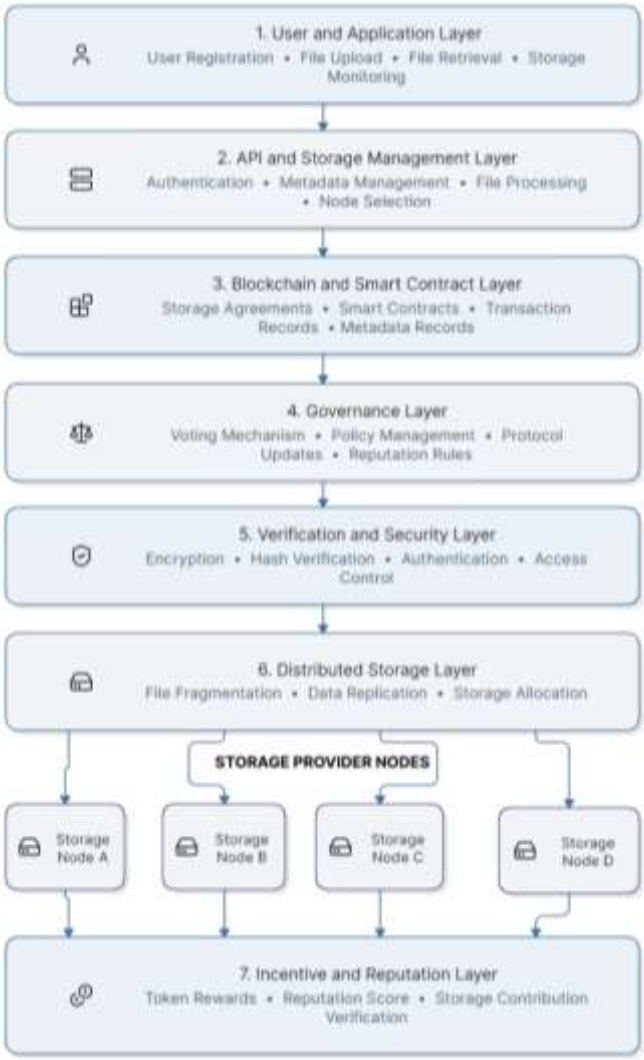


Fig. 1. Layered architecture of the proposed DePIN-based shared storage system.

The architecture consists of seven major layers, each responsible for a specific function within the storage ecosystem.

A. User and Application Layer

The User and Application Layer serves as the interface between users and the decentralized storage network. Through this layer, users can register, upload files, retrieve files, contribute storage resources, monitor storage usage, and manage their accounts. The primary function of this layer is to provide a simple and user-friendly way to interact with the decentralized infrastructure without requiring users to understand the underlying blockchain or storage mechanisms.

B. API and Storage Management Layer

The API and Storage Management Layer acts as the central coordinator of storage operations. It receives user requests, manages authentication, processes file uploads, maintains metadata records, and selects suitable storage nodes for storing data. This layer also handles communication between users, storage nodes, and blockchain services.

Only metadata such as file hashes, ownership details, storage references, and access information are maintained in this layer. Actual file data is never stored directly within the management system.

C. Blockchain and Smart Contract Layer

The Blockchain and Smart Contract Layer maintains decentralized records associated with storage operations. It stores information related to storage agreements, node registration, verification events, transaction history, and reward allocation. Smart contracts automatically execute predefined rules related to storage verification and incentive distribution.

The primary purpose of this layer is to ensure transparency, trust, and tamper-resistant record management without relying on a centralized authority [1], [2].

D. Governance Layer

The Governance Layer enables participants to influence network operations through decentralized decision-making mechanisms. Governance functions may include voting on protocol updates, modifying incentive policies, managing provider reputation parameters, and proposing network improvements.

This layer ensures that the storage ecosystem remains community-driven and follows the fundamental principles of DePIN networks [1].

E. Distributed Storage Layer

The Distributed Storage Layer consists of independent storage nodes contributed by network participants. Files uploaded by users are distributed across multiple storage providers rather than being stored on a single centralized server.

To improve reliability and fault tolerance, files can be fragmented, replicated, or distributed across several storage nodes. If one storage node becomes unavailable, the data can still be recovered from other participating nodes. The distributed nature of this layer significantly enhances system availability and resilience [3], [6], [8].

F. Verification and Security Layer

The Verification and Security Layer is responsible for ensuring that stored data remains secure, available, and unaltered. This layer performs periodic verification of storage providers to ensure that assigned data is continuously maintained.

Security measures such as file encryption, hashing, authentication, authorization, and access control are applied to protect sensitive information from unauthorized access. In addition, the layer maintains reputation scores for storage providers based on their availability, verification history, and service reliability.

The objective of this layer is to establish trust among participants while maintaining the integrity and confidentiality of user data [5], [6], [10].

G. Incentive Layer

The Incentive Layer encourages participation by rewarding storage providers based on their actual contribution to the network. Rewards are allocated according to factors such as storage capacity provided, storage availability, successful verification records, service duration, and reputation score.

This performance-based reward mechanism motivates participants to contribute reliable storage resources and supports the long-term sustainability of the decentralized storage ecosystem [1], [6], [11].

Overall System Operation

The proposed architecture operates through a coordinated interaction between users, storage providers, blockchain services, and distributed storage nodes. When a user uploads a file, the file is encrypted and processed by the Storage Management Layer before being distributed among selected storage nodes. The Blockchain Layer records storage-related metadata and smart contracts manage verification and reward conditions.

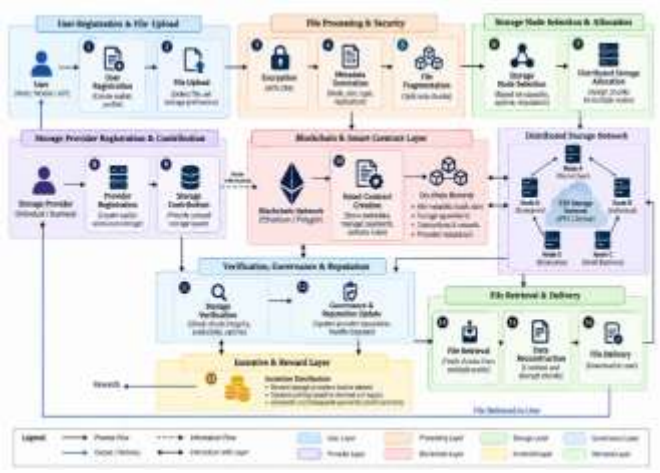


Fig. 2. Workflow of file upload, storage verification, governance, incentive distribution, and file retrieval.

The central principle of the proposed system is to keep large data objects off-chain while using blockchain technology for decentralized coordination, verification, governance, reputation tracking, and incentive management. This separation improves scalability, reduces storage costs, and enables transparent resource sharing within the DePIN ecosystem.

The proposed architecture is expected to provide secure storage, decentralized governance, verifiable resource contribution, node-failure tolerance, reputation-based trust management, and efficient incentive distribution, thereby supporting the future development of Web3 storage applications and decentralized digital services.

V. Detailed Methodology

The detailed methodology describes how the proposed DePIN-based shared storage system operates from storage contribution to file retrieval. The methodology focuses on secure storage, decentralized resource sharing, blockchain-based verification, governance participation, and incentive distribution. The workflow involves interaction among storage providers, storage consumers, distributed storage nodes, smart contracts, and blockchain infrastructure.

The detailed operational workflow of the proposed system is illustrated in Fig. 2. The methodology explains each stage of the workflow from storage provider registration to file retrieval and reward distribution.

A. Storage Provider Registration

The process begins when a participant joins the network as a storage provider. The provider registers its storage node and contributes available storage capacity to the decentralized network. Information such as node identity, storage capacity, availability status, and network details is recorded within the blockchain layer. After successful registration and validation, the storage node becomes available for storage allocation.

To establish trust within the network, each provider is assigned a reputation score that reflects storage reliability and historical performance. This reputation score is continuously updated based on verification results and service quality.

B. User Registration and File Upload

A user registers on the platform and submits a file upload request through the application interface. The system verifies user credentials, access permissions, and storage requirements before initiating the storage process. Once authentication is completed, the uploaded file is forwarded to the Storage Management Layer for processing.

This step ensures secure participation and prevents unauthorized

access to decentralized storage resources.

C. File Encryption and Metadata Generation

Before storing any file, the system performs encryption to protect data confidentiality and privacy. Encryption ensures that storage providers cannot access the original file contents.

After encryption, the system generates metadata containing information such as file ownership, file identifiers, timestamps, cryptographic hash values, and storage references. The metadata serves as a record for future verification and retrieval operations. Only metadata is recorded on the blockchain, while the actual file remains stored within the distributed storage layer.

D. Data Fragmentation and Storage Allocation

To improve fault tolerance and data availability, the encrypted file is fragmented into multiple segments or replicated according to the selected storage strategy. The Storage Management Layer selects suitable storage nodes based on storage capacity, node reputation, availability, and network performance.

The file fragments are distributed across multiple storage nodes rather than being stored at a single location. This decentralized storage model ensures that the data remains accessible even when individual nodes become unavailable or leave the network.

E. Smart Contract Creation

After storage allocation, the system creates a smart contract that defines the storage agreement between the user and storage providers. The contract specifies storage duration, storage commitments, verification requirements, reward conditions, and penalty rules.

The smart contract automates storage operations and transparently manages interactions between participants without requiring centralized supervision. All contract-related records are permanently maintained on the blockchain.

F. Storage Verification Process

To ensure that storage providers continue maintaining assigned data, the system performs periodic verification procedures. Verification mechanisms check data availability, integrity, storage commitment compliance, and node uptime.

The verification results are recorded on the blockchain and used to evaluate provider performance. Successful verification confirms that storage obligations are being fulfilled, while repeated verification failures may reduce node reputation and affect future reward eligibility.

The verification process strengthens trust and accountability within the decentralized storage ecosystem.

G. Governance and Reputation Management

The Governance Layer enables decentralized decision-making and network management. Participants can contribute to governance activities such as protocol updates, storage policies, reward adjustments, and reputation-management rules.

Simultaneously, the system maintains reputation scores for storage providers. Reputation scores are calculated using metrics such as storage availability, verification success rate, uptime, service duration, and overall reliability. Providers with higher reputation scores are considered more trustworthy and may receive greater opportunities within the network.

This mechanism promotes fairness and long-term network sustainability.

H. Incentive Distribution

The Incentive Layer rewards storage providers based on verified resource contribution rather than simple network participation. Incentives are distributed according to measurable performance indicators such as storage capacity provided, successful verification records, service duration, node availability, and reputation score.

This performance-based reward model motivates providers to maintain high-quality storage services and actively contribute resources to the network.

I. File Retrieval Process

When a user requests access to a stored file, the Storage Management Layer retrieves the corresponding metadata from the blockchain and identifies the storage nodes that contain the required file fragments.

The retrieval process includes locating storage fragments, retrieving data from available storage nodes, verifying data integrity using cryptographic hash values, reconstructing the original file, and decrypting the file before delivery to the authorized user.

Because the file is distributed across multiple storage nodes, data can still be recovered even if some nodes are temporarily unavailable, thereby improving system reliability and availability.

J. Methodology Summary

The overall operation of the proposed system follows a structured sequence beginning with provider registration, storage contribution, file upload, encryption, data fragmentation, storage allocation, smart contract creation, verification, governance participation, reputation updates, incentive distribution, and file retrieval.

The proposed methodology combines decentralized storage, blockchain-based verification, governance mechanisms, reputation management, and incentive-driven participation within a single framework. This approach enables secure and scalable shared storage while promoting transparency, reliability, and efficient utilization of distributed storage resources in a DePIN ecosystem.

VI. Evaluation Framework

The proposed DePIN-based shared storage architecture is designed to provide secure, decentralized, and incentive-driven storage services. Since the current study focuses on architectural design rather than practical implementation, this section presents a framework that can be used to evaluate the effectiveness of the proposed system. The evaluation focuses on storage performance, security, reliability, decentralization, governance, and incentive effectiveness.

A. Storage Performance Evaluation

Storage performance measures how efficiently data can be stored and retrieved within the decentralized network. The evaluation should examine file upload time, file download time, data retrieval latency, and overall storage throughput. Lower response times and higher throughput indicate better system efficiency and improved user experience. Additionally, storage utilization should be monitored to determine how effectively available storage resources are being used across the network.

B. Security Evaluation

Security is a critical component of decentralized storage because data is distributed among multiple independent storage providers. The proposed architecture uses encryption, hashing, authentication, and blockchain-based verification mechanisms to protect stored data. The security evaluation should assess whether user data remains confidential, resistant to unauthorized access, and protected against tampering. The effectiveness of smart contracts and verification mechanisms should also be considered to ensure secure system operation.

C. Reliability and Availability Evaluation

The reliability of the system refers to its ability to maintain continuous service even when some storage nodes become unavailable. Since files are distributed across multiple providers, the architecture should be capable of recovering data despite node failures. Evaluation should therefore focus on storage availability, uptime of storage providers, successful recovery of stored files, and resilience against node failures. High availability and recovery success rates indicate a robust storage infrastructure.

D. Decentralization Evaluation

One of the primary objectives of DePIN is decentralization. Therefore, it is important to evaluate how effectively storage resources are distributed throughout the network. The evaluation should consider the number of active storage providers, geographic distribution of storage nodes, storage distribution balance, and participation levels within the governance process. A higher degree of decentralization reduces dependency on individual participants and improves network resilience.

E. Governance Evaluation

The Governance Layer plays an important role in maintaining a community-driven storage ecosystem. Evaluation of governance mechanisms should focus on participant engagement, voting participation, transparency of decision-making, and the effectiveness of protocol updates. A successful governance model should provide fair opportunities for participants to influence network operations while maintaining stability and sustainability.

F. Incentive and Economic Evaluation

The long-term sustainability of the proposed architecture depends on its ability to motivate participants to contribute storage resources. The incentive model should be evaluated based on reward fairness, provider participation rates, storage contribution growth, and retention of active storage providers. The relationship between storage contribution and reward allocation should be analyzed to ensure that incentives are distributed according to measurable and verifiable contributions.

G. Comparative Evaluation

To assess the effectiveness of the proposed architecture, it can be compared with existing decentralized storage platforms such as Filecoin, Storj, and Sia [6], [8], [10]. The comparison should focus on storage verification methods, governance support, decentralization level, security mechanisms, scalability, reputation management, and incentive structures. Such a comparison helps identify the strengths and limitations of the proposed framework relative to existing storage ecosystems.

H. Evaluation Summary

The proposed evaluation framework provides a structured approach for assessing the performance and effectiveness of the DePIN-based shared storage architecture. By evaluating storage efficiency, security, reliability, decentralization, governance, and incentive mechanisms, researchers can determine whether the proposed framework can support sustainable and scalable decentralized storage services. The framework also establishes a foundation for future implementation, testing, and experimental validation of the proposed system.

VII. Expected Outcomes, Benefits, and Limitations

The proposed DePIN-based shared storage architecture is expected to create a secure, decentralized, and scalable storage ecosystem where users can store and retrieve data without relying on centralized cloud providers. By utilizing distributed storage resources, blockchain-based verification, governance mechanisms, and incentive models, the system aims to improve data availability, transparency, and resource utilization while enabling participants to earn rewards for contributing unused storage capacity. The architecture offers several benefits, including enhanced data security through encryption and verification mechanisms, improved fault tolerance through distributed storage, reduced dependence on centralized infrastructure, transparent storage management, and community-driven governance. In addition, the incentive mechanism encourages active participation and supports the long-term sustainability of the storage network. However, the proposed framework also has certain limitations. Since the study presents a conceptual architecture, its performance, scalability, and efficiency have not been validated through real-world implementation. The effectiveness of the system may depend on the number of active storage providers, network conditions, and the incentive model adopted. Furthermore, issues related to blockchain overhead, smart contract complexity, regulatory compliance, and storage verification costs could affect deployment in large-scale environments. Therefore, further implementation, testing, and optimization are required to evaluate the practical feasibility and long-term sustainability of the proposed DePIN-based shared storage framework. [1], [3], [6], [8], [10], [11]

VIII. Future Scope

The proposed DePIN-based shared storage architecture provides a foundation for the development of future decentralized storage ecosystems. Future work can focus on implementing and testing the proposed framework in real-world environments to evaluate its performance, scalability, and reliability. The architecture can be extended by integrating advanced storage verification mechanisms, AI-based storage management, and automated resource allocation techniques to improve efficiency and decision-making. Future research may also explore interoperability between multiple blockchain networks, allowing storage resources to be shared across different Web3 ecosystems.

Another important direction is the development of more sophisticated governance and reputation-management models that improve trust and encourage long-term participation. The incentive mechanism can be further optimized to ensure fair reward distribution and economic sustainability. In addition, future implementations may incorporate edge computing, Internet of Things (IoT) devices, and decentralized applications (dApps) to support a wider range of use cases. Research on regulatory compliance, data privacy requirements, and cross-border data management can also improve the practical adoption of decentralized storage systems. Overall, the proposed architecture offers significant opportunities for further enhancement and can serve as a foundation for future secure, scalable, and community-driven storage infrastructures within the DePIN ecosystem [1], [3], [6], [8], [10], [11].

IX. Conclusion

This paper presented a Decentralized Physical Infrastructure Network (DePIN)-based shared storage architecture that enables secure and decentralized storage resource sharing through blockchain technology, distributed storage nodes, governance mechanisms, and incentive-driven participation. The study reviewed existing decentralized storage solutions and identified the need for a unified framework that integrates storage management, verification, governance, reputation management, and reward distribution within a single ecosystem [1], [3], [4].

To address this challenge, a layered architecture consisting of a User and Application Layer, API and Storage Management Layer, Blockchain and Smart Contract Layer, Governance Layer, Distributed Storage Layer, Verification and Security Layer, and Incentive Layer was proposed. The architecture separates large-scale data storage from blockchain coordination, allowing files to remain off-chain while blockchain technology manages storage agreements, verification records, governance activities, and

incentive allocation. This approach improves scalability, transparency, security, and fault tolerance while maintaining decentralized accountability [1], [6], [8], [10].

The proposed methodology describes how storage providers contribute resources, how users store and retrieve files, how verification mechanisms ensure data availability, and how governance and incentive models support sustainable network participation. In addition, the evaluation framework provides a basis for assessing the performance, security, reliability, and economic viability of the proposed system.

Overall, the proposed DePIN-based shared storage framework demonstrates the potential of decentralized infrastructure networks to provide secure, transparent, and community-driven storage services. As Web3 technologies continue to evolve, DePIN-based storage systems can play an important role in supporting future decentralized applications and digital services while reducing dependence on traditional centralized cloud infrastructures[1],[2],[11].

References

[1] M. Jiang, E. Liu, X. Qu, W. Ni, Z. Wei, and E. Hossain, "A survey of decentralized physical infrastructure network, research directions, and open challenges," IEEE Communications Surveys & Tutorials, Early Access, 2026.

[2] "Decentralized physical infrastructure networks: Backgrounds, architectures, open issues, and case studies," in Proc. IEEE Int. Conf. Blockchain, 2025.

[3] M. I. Khalid, I. Ehsan, A. K. Al-Ani, J. Iqbal, S. Hussain, S. S. Ullah, and N. Khan, "A comprehensive survey on blockchain-based decentralized storage networks," IEEE Access, vol. 11, pp. 10995–11015, 2023.

[4] M. M. Merlec and H. P. In, "Blockchain-based decentralized storage systems for sustainable data self-sovereignty: A comparative study," Sustainability, vol. 16, no. 17, 2024.

[5] T. V. Doan, Y. Psaras, J. Ott, and V. Bajpai, "Towards decentralised cloud storage with IPFS: Opportunities, challenges, and future directions," 2022.

[6] J. Benet and N. Greco, Filecoin: A Decentralized Storage Network. Protocol Labs, 2017.

[7] Protocol Labs, "Filecoin and IPFS documentation." [Online]. Available: https://docs.filecoin.io

[8] Storj Labs Inc., Storj: A Decentralized Cloud Storage Network Framework, ver. 3.1, 2024.

[9] Storj Labs Inc., V3 White Paper Executive Summary, 2024.

[10] D. Vorick and L. Champine, Sia: Simple Decentralized Storage. Nebulous Inc., 2014.

[11] Z. Wu, B. Lin, N. Nikiforakis, and A. Balasubramanian, "Degrees of decentralized freedom: Comparing modern decentralized storage platforms," in Proc. IFIP TMA Conf., 2025.

[12] D. Bane and S. Gala, State of DePIN 2024. Messari Research, 2025.

[13] D. Bane and S. Gala, State of DePIN 2025. Messari Research, 2026.

[14] N. D. H. Son, S. Mathivanan, and H. N. P. Bao, "A blockchain-based autonomous data storage system: Revolutionizing data storage and comparative analysis with centralized system," International Journal of Computer Applications, vol. 185, no. 35, pp. 15–34, 2023.

[15] S. Sarkar, "Demystifying decentralized storage: A critical building block of future internet or Web3," Telecom Business Review, vol. 17, no. 1, pp. 18–32, 2024.

[16] S. K. Dwivedi, R. Amin, and S. Vollala, "Blockchain-based secured IPFS-enable event storage technique with authentication protocol in VANET," IEEE/CAA Journal of Automatica Sinica, vol. 8, no. 12, pp. 1913–1922, 2021.

[17] S. K. Aman, A. K. Bharti, and R. Amin, "Decentralized secure storage of medical records using blockchain and IPFS: A comparative analysis with future directions," Security and Privacy, 2021.

[18] B. Shetty, "Secure file sharing over blockchain and IPFS," World Journal of Advanced Research and Reviews, vol. 12, no. 3, pp. 697–704, 2021.

[19] "Efficient decentralized data storage based on public blockchain and IPFS," in Proc. IEEE Conf., 2021.

[20] "An innovative IPFS-based storage model for blockchain," IEEE Access, 2021.

[21] M. R. Haque, S. I. Munna, S. Ahmed, M. T. Islam, M. M. H. Onik, and A. A. Rahman, "An integrated blockchain and IPFS-based solution for secure and efficient source code repository hosting using middleman approach," PLOS ONE, vol. 20, no. 9, 2025.

[22] Hashed Emergent, India Web3 Landscape Report 2024, 2024.

[23] Consensys Research, Web3 and Crypto Global Survey 2024, 2024.

[24] Protocol Labs, "IPFS documentation." [Online]. Available: https://docs.ipfs.tech

[25] "A study and analysis of decentralized cloud-based platform," in Proc. IEEE Conf., 2022.