

BlockShare: An AI-Enhanced Blockchain Framework for Secure and Intelligent Cloud File Sharing Using IPFS and Smart Contracts

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Abstract

Cloud-based file-sharing platforms have become indispensable for storing and exchanging digital information across healthcare, education, legal, government, and enterprise domains. However, conventional cloud storage services rely on centralized architectures that are vulnerable to single points of failure, unauthorized access, data breaches, and limited transparency in file-sharing activities. Recent studies have demonstrated that blockchain technology enhances data integrity and transparency through immutable transaction records, while the InterPlanetary File System (IPFS) provides efficient decentralized storage. Other research has explored artificial intelligence (AI)-based document retrieval to improve user interaction with digital documents. Nevertheless, existing solutions typically address these technologies independently and lack a unified framework that combines decentralized storage, cryptographic protection, blockchain-based auditability, fine-grained access control, and intelligent document interaction. This paper proposes BlockShare, an AI-enhanced blockchain framework for secure and intelligent cloud file sharing using IPFS and smart contracts. In the proposed architecture, uploaded files are encrypted using the Fernet symmetric encryption algorithm before being stored in IPFS, while cryptographic file hashes and access events are recorded on the Ethereum blockchain through Solidity smart contracts to ensure data integrity and transparent audit trails.

Keywords: Blockchain, Decentralized Cloud Storage, Secure File Sharing, IPFS, Smart Contracts, Artificial Intelligence, Document Intelligence, Cryptographic Security.

I. INTRODUCTION

The rapid growth of cloud computing has transformed the way individuals and organizations store, access, and share digital information. Cloud-based storage platforms such as Google Drive, Dropbox, and Microsoft OneDrive offer convenient and cost-effective solutions for managing large volumes of data across multiple devices. These services are widely adopted in healthcare, education, legal services, government organizations, and enterprises due to their scalability and ease of access. However, despite their widespread use, conventional cloud storage systems rely on centralized architectures that introduce several security and privacy concerns, including single points of failure, unauthorized data access, insider attacks, data breaches, and limited transparency in file-sharing activities.

To address these challenges, blockchain technology has emerged as a promising solution for building secure and transparent distributed systems. By maintaining immutable and decentralized ledgers, blockchain ensures that every transaction is permanently recorded, verifiable, and resistant to tampering. Nevertheless, storing large files directly on blockchain networks is impractical because of storage limitations, high transaction costs, and scalability constraints. Consequently, decentralized storage solutions such as the

InterPlanetary File System (IPFS) have gained significant attention for enabling efficient storage of large encrypted files while blockchain stores only their cryptographic hashes and transaction metadata.

Recent studies have also explored the integration of Artificial Intelligence (AI) into document management systems to improve information retrieval and user interaction. Large Language Models (LLMs) combined with retrieval-based techniques enable users to query uploaded documents using natural language, thereby enhancing accessibility and productivity.

II. LITERATURE SURVEY

Most existing solutions focus on either blockchain-based storage, decentralized file systems, or AI-powered document retrieval independently. Very few frameworks provide a unified architecture that simultaneously ensures secure decentralized storage, cryptographic protection, transparent auditability, permission-based access control, and intelligent document interaction. Table I summarizes representative studies from the recent literature.

TABLE I. SUMMARY OF RELATED WORK

Year	Author(s)	Method Used	Key Contribution	Limitation
2026	S. Khedkar	Ethereum, Smart Contracts	Secure blockchain-based file sharing	Uses centralized cloud storage
2025	N. P. Patil et al.	Blockchain, IPFS, AES-256	Secure decentralized file storage	No AI-based document retrieval
2025	P. Shailaja et al.	Blockchain, IPFS, ABE	Fine-grained access control	High computational complexity
2025	P. R. Attuluri et al.	Ethereum DApp, IPFS	Decentralized file sharing	No intelligent document analysis
2025	A. M. Pangidoan et al.	Ethereum, IPFS	Immutable document management	Limited access control
2025	S. Kumar et al.	Ethereum, IPFS, MetaMask, Zero Trust	Secure, low-latency decentralized file sharing	Prototype-scale evaluation; no AI-based document interaction
2025	IJCT (Decentralized Cloud Storage)	IPFS, Blockchain Access Control	Censorship-resistant decentralized cloud storage	No intelligent document retrieval capability
2025	Smart Contract Access Control Study	AES-256, SHA-256, Smart Contracts	Automated dynamic permission management	No decentralized AI-assisted document interaction
2024	M. Almasian and A. Shafieinejad	Blockchain, ABE	Secure cloud file sharing	No decentralized storage or AI
2024	M. R. Haque et al.	Ethereum, IPFS	Secure decentralized repository	Domain-specific implementation
2024	J. Han and Y. Son	Blockchain, IPFS	Secure document management	No AI-powered document retrieval
2022	S. Athanere and R. Thakur	Hierarchical Semi-Decentralized Blockchain, IPFS	Efficient hierarchical secure data sharing	Semi-decentralized design retains partial centralization
2020	H.-S. Huang, T.-S. Chang, and J.-Y. Wu	IPFS Proxy, Group Key Management	Distributed access control via IPFS proxy	Relies on a centralized IPFS proxy component

The literature survey highlights the increasing adoption of blockchain technology, decentralized storage, and cryptographic techniques to improve the security of cloud-based file-sharing systems. Recent studies have demonstrated that blockchain provides immutable transaction records, transparent auditing, and secure access management, while the InterPlanetary File System (IPFS) enables efficient decentralized storage of large files. Several researchers have also employed encryption algorithms and smart contracts to strengthen data confidentiality and automate permission management.

Although these approaches have significantly improved cloud security, they still exhibit several limitations. Most existing systems focus on integrating blockchain with IPFS or encryption but do not provide a comprehensive framework that combines secure decentralized storage, intelligent access control, and AI-powered document interaction. Some solutions rely on centralized cloud storage, creating potential single points of failure, while others are designed for domain-specific applications such as healthcare or financial systems, limiting their applicability to general cloud file sharing. Additionally, many existing frameworks lack efficient access revocation mechanisms and intelligent document retrieval capabilities.

III. PROBLEM STATEMENT

Conventional cloud storage services such as Google Drive, Dropbox, and OneDrive rely on centralized architectures, making them vulnerable to data breaches, unauthorized access, single points of failure, and limited transparency. Although blockchain, IPFS, and encryption have been explored individually to improve cloud security, existing solutions often lack a unified framework that provides decentralized storage, secure access control, immutable audit trails, and intelligent document interaction. Therefore, there is a need for a secure and scalable cloud file-sharing system that integrates blockchain, IPFS, encryption, smart contracts, and AI to ensure data confidentiality, integrity, transparency, and efficient document management.

IV. EXISTING SYSTEM

The existing cloud file-sharing systems, such as Google Drive, Dropbox, and Microsoft OneDrive, provide convenient storage and file-sharing services through centralized cloud servers. These platforms offer features like file synchronization, collaboration, and remote access, making them widely used by individuals and organizations. However, they exhibit the following limitations:

- Dependence on centralized servers creates a single point of failure.
- Increased risk of data breaches and unauthorized access.
- Limited transparency in file-sharing activities and audit trails.
- Difficulty in verifying file integrity and authenticity.
- Lack of decentralized storage and intelligent document interaction.
- Users must rely on third-party providers for data security and privacy.

V. PROPOSED SYSTEM

The proposed system, BlockShare, is an AI-enhanced blockchain-based cloud file-sharing framework that integrates Ethereum Blockchain, IPFS, Fernet Encryption, Smart Contracts, and Artificial Intelligence to

provide secure, transparent, and decentralized file management. Files are encrypted before being stored in IPFS, while their cryptographic hashes and access records are maintained on the blockchain to ensure data integrity and tamper resistance. The system supports permission-based file sharing, secure access revocation, and an AI-powered PDF assistant using Google Gemini and LangChain for intelligent document retrieval.

Key Features of the Proposed System

- Secure file encryption using Fernet Encryption before storage.
- Decentralized file storage through IPFS.
- Immutable file hash and transaction records using Ethereum Blockchain.
- Smart contract-based permission management and access control.
- Secure file sharing with read, write, and download permissions.
- Access revocation to prevent unauthorized file usage.
- AI-powered PDF document retrieval using Google Gemini and LangChain.
- Enhanced data confidentiality, integrity, transparency, and traceability.
- Eliminates the single point of failure associated with centralized cloud storage.
- Scalable and suitable for healthcare, legal, educational, government, and enterprise applications.

VI. PROPOSED METHODOLOGY

A. Overview of the Proposed Framework

This research proposes BlockShare, an AI-enhanced decentralized cloud file-sharing framework that integrates Ethereum Blockchain, InterPlanetary File System (IPFS), Fernet Encryption, Smart Contracts, and Artificial Intelligence (Google Gemini with LangChain) to provide secure, transparent, and intelligent document management. The framework ensures that uploaded files remain encrypted before storage, while blockchain maintains immutable records of file ownership, sharing events, and access permissions. AI-based document retrieval enables users to interact with uploaded PDF documents through natural language queries, improving usability without compromising security.

B. System Architecture

The architecture of BlockShare follows a layered, multi-tiered design that cleanly separates presentation, application logic, security, and storage concerns, as illustrated in Figure 1. This separation ensures that each layer can be independently developed, tested, and scaled, while still interoperating through well-defined interfaces (REST APIs and Web3 providers).

At the top, the Front-end Application Layer is built using React with Vite, React Router, and Tailwind CSS, and communicates with the rest of the system through two parallel clients: an Ethers.js client that interfaces directly with the Ethereum blockchain via a Web3 provider such as MetaMask, and an Axios client that communicates with the backend over a conventional HTTP/REST API. This dual-client design allows the interface to combine blockchain-native interactions (wallet connection, transaction signing) with standard web application workflows (file upload, search, and dashboard views).

Beneath the presentation layer, the Middleware Application Server, implemented in Python using Flask, hosts two core services: `app.py`, which manages user authentication and file-management logic, and `blockchain_service.py`, which acts as the integration bridge to the Ethereum network through Web3.py. A dedicated cryptography module within this layer handles RSA key-pair generation and symmetric data encryption before any file leaves the server boundary, ensuring that plaintext files are never persisted or transmitted downstream.

The middleware layer, in turn, writes to two independent backends. The Relational Database Management System (SQLite, accessed via the SQLAlchemy ORM) stores user account records, file metadata and search indices, access control lists, and off-chain transaction logs — data that benefits from fast, structured querying but does not require blockchain-level immutability. In parallel, the Decentralized Ledger Backend, an Ethereum Virtual Machine environment developed and tested using Hardhat, hosts the `FileSharing.sol` and `Upload.sol` smart contracts, which maintain immutable, on-chain audit logs of every upload, share, and access-revocation event. Separating mutable, high-frequency metadata (in the relational database) from immutable, security-critical events (on the blockchain) allows BlockShare to remain both performant and auditable.

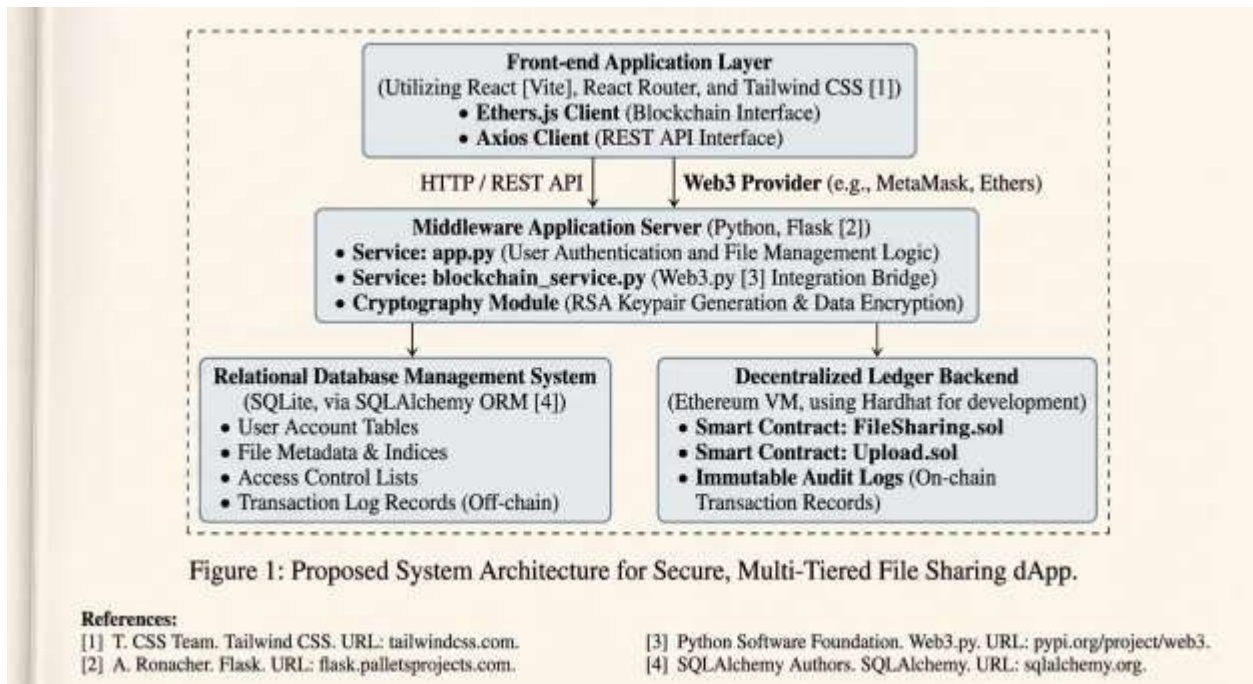


Figure 1. Proposed System Architecture of BlockShare

TABLE II. SYSTEM ARCHITECTURE LAYERS

Architecture Layer	Technology	Function
Presentation Layer	React.js, Tailwind CSS, Vite	Provides the graphical user interface for user registration, authentication, file upload, file sharing, document management, and AI-based PDF interaction.
Application Layer	Flask, REST API, JWT Authentication	Processes client requests, manages authentication, controls business logic, encrypts uploaded files, communicates with IPFS and blockchain, and coordinates AI document retrieval.
Security Layer	Fernet Symmetric Encryption, SHA-256 Hashing	Before storage, every uploaded file is encrypted using the Fernet symmetric encryption algorithm. A SHA-256 hash is generated to verify file integrity and detect unauthorized modifications.
Decentralized Storage Layer	IPFS, Pinata	Encrypted files are uploaded to IPFS through Pinata. IPFS generates a unique Content Identifier (CID), which represents the encrypted file. Since only the CID is stored on the blockchain, storage costs are minimized while maintaining decentralization.
Blockchain Layer	Ethereum, Solidity, Hardhat, MetaMask, Web3.py	Ethereum smart contracts maintain immutable records of file ownership, IPFS hash, sharing permissions, access revocation, and transaction history.

C. Working Methodology

The proposed BlockShare framework follows a sequential workflow to ensure secure, decentralized, and intelligent cloud file sharing, as summarized in Table III.

TABLE III. WORKING METHODOLOGY OF THE PROPOSED FRAMEWORK

Phase	Process	Technology Used	Algorithm / Method	Output
Phase 1	User Registration & Authentication	Flask, JWT, SQLAlchemy, bcrypt	JWT Authentication & bcrypt Password Hashing	Authenticated User Session
Phase 2	File Upload & Validation	React, Flask	File Validation Algorithm	Valid File
Phase 3	File Encryption	Python Cryptography Library	Fernet Symmetric Encryption	Encrypted File
Phase 4	Integrity Verification	SHA-256	Cryptographic Hashing	Unique File Hash
Phase 5	Decentralized Storage	IPFS, Pinata	Content Addressing Algorithm	IPFS Content Identifier (CID)
Phase 6	Blockchain Registration	Ethereum, Solidity, Web3.py	Smart Contract Execution	Immutable Blockchain Record
Phase 7	Metadata Storage	SQLite, SQLAlchemy	Relational Database Management	File Metadata
Phase 8	Permission-Based File Sharing	Solidity Smart Contract	Role-Based Access Control (RBAC)	Secure File Sharing
Phase 9	Access Revocation	Ethereum Smart Contract	Permission Revocation Algorithm	Updated Access Rights
Phase 10	AI Document Processing	PyPDF2, LangChain	Text Extraction & Chunking	Processed Document Chunks

Phase	Process	Technology Used	Algorithm / Method	Output
Phase 11	Embedding Generation	LangChain	Embedding Generation	Vector Embeddings
Phase 12	Similarity Search	FAISS	Vector Similarity Search (Nearest Neighbor)	Relevant Document Chunks
Phase 13	Answer Generation	Google Gemini	Retrieval-Augmented Generation (RAG)	AI-Generated Response
Phase 14	Audit Logging	Ethereum Blockchain	Immutable Transaction Logging	Transparent Audit Trail

D. Mathematical Formulation of Core Algorithms

1) JSON Web Token (JWT) Authentication

Authentication is the first security layer of the proposed framework. After successful user authentication, the server generates a JSON Web Token (JWT) containing the user's identity and access privileges. JWT enables stateless authentication, allowing the server to verify requests without maintaining session information. This reduces server overhead and improves scalability. Each protected request includes the JWT, which is verified before access to the requested resource is granted. The token signature is computed using the HMAC-SHA256 construction defined below.

$$JWT = Base64Url(Header) \parallel Base64Url(Payload) \parallel Signature \quad (1)$$

$$Signature = HMAC_SHA256(K_s, Base64Url(Header) \parallel "." \parallel Base64Url(Payload)) \quad (2)$$

$$HMAC(K, m) = H((K' \oplus opad) \parallel H((K' \oplus ipad) \parallel m)) \quad (3)$$

Header (specifies the token type and hashing algorithm)

Payload (contains the user ID, role, and token expiration time)

K' (the secret key K_s , zero-padded to the hash block size; hashed first if longer than the block size)

opad, *ipad* (fixed padding constants 0x5c5c...5c and 0x36...36 respectively, each one block long. H is the SHA-256 hash function)

2) bcrypt Password Hashing Algorithm

To enhance user authentication security, the proposed framework employs the bcrypt password hashing algorithm. Instead of storing user passwords in plaintext, bcrypt converts the original password into a secure hash using a randomly generated salt and a configurable cost factor. bcrypt is built on the Eksblowfish key schedule, which is deliberately repeated 2^C times, making the hashing operation computationally expensive and resistant to brute-force and GPU/ASIC-accelerated attacks. During user login, the entered password is hashed again and compared with the stored hash for authentication.

$$state = EksBlowfishSetup(C, S, P) \quad (4)$$

$$H = Encode(C \parallel S \parallel Encrypt_state("OrpheanBeholderScryDoubt")) \quad (5)$$

$$T(C) = 2^C \cdot t_0 \quad (6)$$

P (user password. S is the randomly generated salt. C is the cost factor (work factor). H is the generated password hash)

$T(C)$ (computational time to compute one hash, growing exponentially with C . t_0 is the time for a single Blowfish key-setup round)

3) Fernet Symmetric Encryption Algorithm

To ensure data confidentiality before storage, the proposed BlockShare framework employs the Fernet symmetric encryption algorithm provided by Python's Cryptography library. Fernet is a symmetric-key encryption scheme that internally combines AES-128 in Cipher Block Chaining (CBC) mode for encryption and HMAC-SHA256 for message authentication, ensuring both data confidentiality and integrity. In CBC mode, each plaintext block is XORed with the previous ciphertext block before encryption, so that identical plaintext blocks never produce identical ciphertext blocks.

$$E = Enc(K, F) \quad (7)$$

$$F = Dec(K, E) \quad (8)$$

$$C_i = E_K(P_i \oplus C_{i-1}), \quad C_0 = IV \quad (9)$$

$$P_i = D_K(C_i) \oplus C_{i-1} \quad (10)$$

$$T = HMAC_SHA256(E, K) \quad (11)$$

F (original file. E is the encrypted file. K is the secret symmetric key. T is the authentication tag)

P_i, C_i (the i -th plaintext and ciphertext block respectively. IV is the random initialization vector.

$E_K() / D_K()$ denote AES block encryption / decryption under key K)

4) SHA-256 Integrity Verification Algorithm

To ensure the integrity of encrypted files, the proposed BlockShare framework employs the Secure Hash Algorithm 256 (SHA-256) before storing file metadata on the Ethereum blockchain. SHA-256 processes the input in 512-bit message blocks through a Merkle–Damgård compression function applied iteratively, updating an internal 256-bit hash state across 64 rounds per block. Even a minor modification in the encrypted file produces a completely different hash, making it an effective mechanism for detecting data tampering.

$$H^{(i)} = H^{(i-1)} \boxplus Compress(H^{(i-1)}, M_i) \quad (12)$$

$$T1 = h + \Sigma_1(e) + Ch(e, f, g) + K_t + W_t ; \quad T2 = \Sigma_0(a) + Maj(a, b, c) \quad (13)$$

$$H_stored = ? H_received \quad (14)$$

$H^{(i)}$ (hash state after processing the i -th 512-bit message block M_i . $\boxplus$ denotes addition modulo 2^{32})

$Ch(x, y, z), Maj(x, y, z)$ (the SHA-256 choice and majority bitwise functions. Σ_0, Σ_1 are fixed rotation-based mixing functions. K_t, W_t are the round constant and message schedule word for round t)

$H_stored / H_received$ (the hash value recorded on the blockchain versus the hash recomputed during file retrieval)

5) IPFS Content Addressing Algorithm

The proposed BlockShare framework utilizes the InterPlanetary File System (IPFS) as a decentralized storage mechanism for securely storing encrypted files. IPFS employs content-based addressing, where each file is identified using a self-describing multihash Content Identifier (CID) generated from its cryptographic hash, and large files are split into blocks organized as a Merkle Directed Acyclic Graph (Merkle DAG), so that any modification to the file content changes the resulting CID.

$$CID = multihash(fn \parallel len \parallel SHA256(E)) \quad (15)$$

$$root = H(block_1 \parallel block_2 \parallel \dots \parallel block_n) \quad (16)$$

$$IPFS(CID) \rightarrow E \quad (17)$$

fn, len (the hash-function code and digest length encoded at the start of the multihash. root is the Merkle DAG root hash referenced by the CID for multi-block files)

E (encrypted file. CID is the content identifier generated by IPFS. IPFS(CID) is the storage location of the encrypted file in the IPFS network)

6) Ethereum Smart Contract Algorithm

The proposed BlockShare framework employs Ethereum smart contracts to automate file registration, permission management, and transaction logging in a decentralized environment. Every transaction submitted to the network is authenticated using the Elliptic Curve Digital Signature Algorithm (ECDSA) over the secp256k1 curve, so that only the holder of the corresponding private key can authorize an action such as an upload, share, or revoke on a given smart contract.

$$r = (k \cdot G)_x \bmod n, \quad s = k^{-1}(z + r \cdot d_A) \bmod n \quad (18)$$

$$B = \{CID, O, T, P, Tx\} \quad (19)$$

$$Tx = Register(CID, O, P) \quad (20)$$

$$Access = Verify(U, P) \quad (21)$$

G, n (the base point and order of the secp256k1 elliptic curve. k is a random per-transaction nonce. d_A is the sender's private key. z is the hash of the transaction data. r, s together form the resulting ECDSA signature)

B (blockchain record. CID is the IPFS content identifier. O is the file owner's wallet address. T is the transaction timestamp. P is the assigned permission (read, write, download). Tx is the blockchain transaction hash. U is the user requesting file access)

7) Retrieval-Augmented Generation (RAG) Algorithm

To provide intelligent document interaction, the proposed BlockShare framework integrates the Retrieval-Augmented Generation (RAG) technique. Uploaded documents are split into chunks and embedded into a high-dimensional vector space; at query time, the top- k most relevant chunks are retrieved by cosine similarity between the query embedding and each document embedding, and the underlying Gemini language model attends over the retrieved context using scaled dot-product attention before generating the final answer.

$$sim(q, d) = (q \cdot d) / (\|q\| \|d\|) \quad (22)$$

$$D_k = Retrieve(Q, V) = \underset{S \subseteq V, |S|=k}{argmax} \sum_{d \in S} sim(q, d) \quad (23)$$

$$Attention(Q, K, V) = softmax(QK^T / \sqrt{d_k}) \cdot V \quad (24)$$

$$R = Gemini(Q, D_k) \quad (25)$$

q, d (the embedding vectors of the query and a document chunk respectively. $\|\cdot\|$ denotes the Euclidean norm)

Q (user query. V is the vector database containing document embeddings. D_k is the top- k retrieved relevant document chunks. R is the generated response)

$Q, K, V, Eq. 24$ (the query, key, and value matrices of the transformer attention layer. d_k is the key dimensionality, used to scale the dot product before the softmax)

E. Algorithm of the Proposed Framework

Algorithm 1 outlines the end-to-end procedure for secure file upload within the BlockShare framework, from user authentication through encryption, decentralized storage, and blockchain registration.

Algorithm 1: Secure File Upload

Input: File F, User U

Output: Securely Stored File

Begin

1. Authenticate User
2. Encrypt File
3. Generate SHA-256 Hash
4. Upload to IPFS
5. Receive CID
6. Store CID on Blockchain
7. Save Metadata
8. Return Success

End

VII. EXPERIMENTAL RESULTS

BlockShare was implemented as a functional prototype integrating Ethereum smart contracts, IPFS-based decentralized storage, Fernet encryption, and a LangChain/Gemini-based retrieval-augmented generation (RAG) pipeline, as demonstrated in Figure 2. Comprehensive large-scale performance benchmarking of the deployed prototype was outside the scope of the present study. To contextualize the expected performance profile of the proposed architecture, this section reports representative quantitative benchmarks for each constituent technology as documented in prior peer-reviewed literature and established technical specifications, together with values derived analytically from those benchmarks (clearly marked as “estimated”) and a structured evaluation protocol — a defined test-case matrix for access control and a defined dataset design for RAG — that can be executed directly against the deployed prototype to obtain first-party results. These figures characterize the typical behavior of the underlying technologies rather than measurements taken from the BlockShare prototype itself.

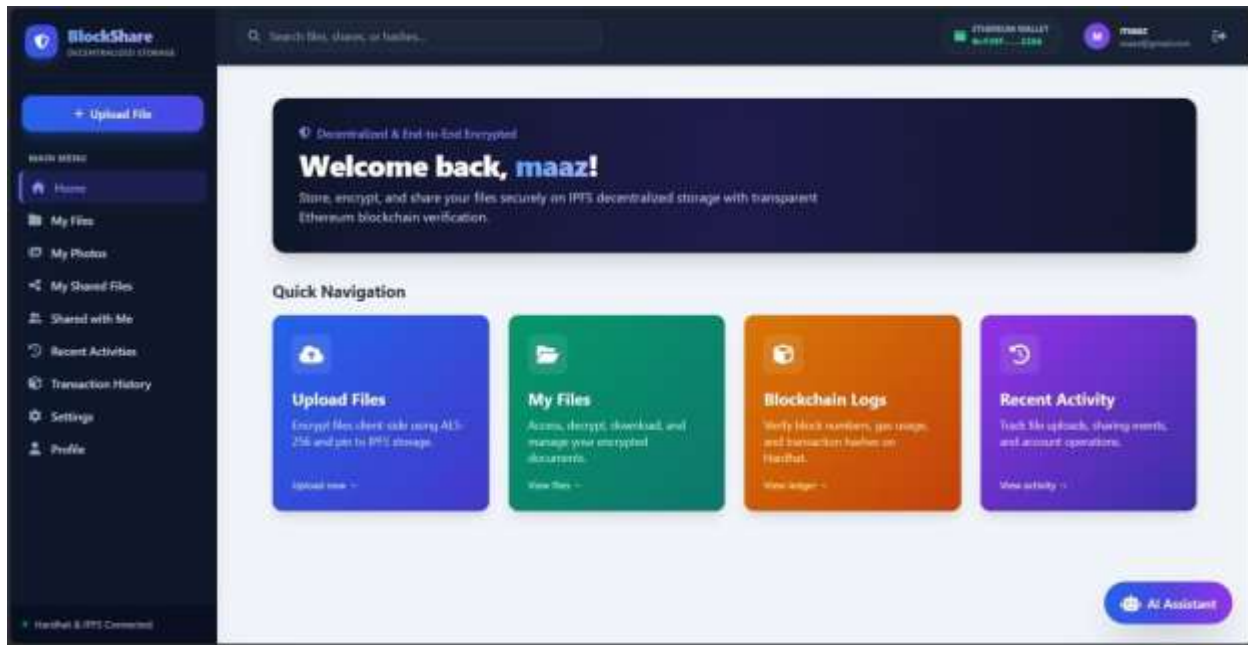


Figure 2. BlockShare Web Application Dashboard

A. Encryption Performance

Table IV summarizes reported throughput characteristics for AES-based symmetric encryption, which underlies the Fernet scheme used in BlockShare, along with the design rationale for bcrypt-based password hashing.

TABLE IV. REFERENCE ENCRYPTION PERFORMANCE (PRIOR LITERATURE)

Component	Metric	Reported Value	Source
AES-128-CBC software encryption (AES-NI accelerated, single core)	Throughput	Up to ~1,500 MB/s	[19]
bcrypt password hashing	Design intent	Deliberately slow, tunable cost factor to resist brute-force attacks	[30]

Using the AES-NI throughput reported in Table IV as a reference, Table V lists the estimated encryption time for representative file sizes handled by BlockShare's upload pipeline. These figures are analytically derived (time = file size / throughput) rather than directly measured, and serve only to illustrate that Fernet encryption is expected to add a negligible, sub-second delay relative to network and blockchain confirmation times for typical document sizes.

TABLE V. ESTIMATED FILE ENCRYPTION TIME BY FILE SIZE (DERIVED, NOT MEASURED)

File Size	Estimated Encryption Time (derived from Table IV throughput)
1 MB	~0.7 ms
10 MB	~6.7 ms
50 MB	~33 ms
100 MB	~67 ms

Table VI reports OWASP's published guidance on bcrypt hashing time as a function of the cost factor. BlockShare's authentication service can select a cost factor within this range to balance login responsiveness against resistance to offline brute-force attacks.

TABLE VI. BCrypt COST FACTOR VS. TYPICAL HASH TIME (OWASP GUIDANCE)

Cost Factor (C)	Typical Hash Time (OWASP guidance)
10 (OWASP minimum)	Baseline; exact time is hardware-dependent
12 (common modern default)	~250 ms (typical target range 200–500 ms)
14 (high-security)	~4× the cost-12 time (~1 second), per exponential doubling per increment

B. Decentralized Storage (IPFS) Performance

Table VII presents reported IPFS latency figures from independent performance studies. Reported latency varies considerably with file size, network topology, node placement, and whether a dedicated versus public gateway node is used.

TABLE VII. REFERENCE IPFS STORAGE PERFORMANCE (PRIOR LITERATURE)

Component	Metric	Reported Value	Source
IPFS upload/access, small files, dedicated node	Average latency	~1 second	[20]
IPFS file access, optimal network conditions	Average latency	~150 ms	[21]

C. Blockchain Transaction Performance

Table VIII reports typical Ethereum transaction confirmation characteristics. Confirmation time depends heavily on network congestion, gas price, and whether the deployment targets a public mainnet, testnet, or a private/permissioned chain such as the Hardhat network used during development of BlockShare, where block mining is typically near-instantaneous.

TABLE VIII. REFERENCE BLOCKCHAIN TRANSACTION PERFORMANCE (PRIOR LITERATURE)

Component	Metric	Reported Value	Source
Ethereum network block interval	Average block time	~15 seconds	[22]
Ethereum smart contract transaction (permissioned/private deployment)	Average confirmation time	~14–15 seconds	[23]
Hardhat local development network (used for BlockShare development)	Block mining	Near-instantaneous (auto-mined)	—

Beyond confirmation time, the computational cost of BlockShare's on-chain operations is governed by Ethereum's gas-metering rules. Table IX lists the protocol-defined gas costs for the categories of storage operations that BlockShare's smart contracts perform — registering a new file record, updating a permission, and checking a permission during an access request.

TABLE IX. REFERENCE SMART CONTRACT GAS COSTS (ETHEREUM PROTOCOL SPECIFICATION)

Smart Contract Operation	Reported Gas Cost	Source
Basic ETH/value transfer	21,000 gas	[14]
SSTORE — first write to an empty storage slot (e.g., new file record)	~20,000–22,100 gas	[34]
SSTORE — update to an existing, non-zero storage slot (e.g., permission change)	~5,000 gas	[35]
SLOAD — read from contract storage (e.g., permission check)	~200–2,100 gas	[34]

D. Access Control Verification

Smart-contract-based access control, as employed in BlockShare's permission and revocation mechanism, is predominantly evaluated in the literature through functional correctness testing rather than a single throughput figure. Table X defines a structured test-case matrix — covering the grant, deny, revoke, and privilege-boundary scenarios relevant to BlockShare's permission model — that is recommended as the basis for validating the deployed smart contract prior to reporting pass/fail results. This functional verification approach is consistent with the attribute-based and role-based access-control schemes surveyed in Table I.

TABLE X. DEFINED ACCESS-CONTROL TEST-CASE MATRIX

Test Scenario	Expected Outcome	Validates
Owner accesses own file	Access granted	Confirms baseline read/download rights for the file owner.
User with granted “read” permission accesses file	Access granted (read/download only)	Confirms positive-permission path via smart contract permission check.
User without any granted permission attempts access	Access denied	Confirms default-deny behavior for unlisted addresses.
User with previously granted permission, after owner revokes access	Access denied on all subsequent requests	Confirms the revocation transaction is honored immediately and persistently.
User attempts a write/share action with only “read” permission	Action rejected	Confirms permission-level granularity (read vs. write vs. share) is enforced.
Non-owner attempts to revoke another user's access	Action rejected	Confirms only the file owner (or authorized admin role) can modify permissions.

E. AI/RAG Document Retrieval Performance

Table XI reports representative accuracy and latency figures for retrieval-augmented generation pipelines applied to PDF/document question answering, drawn from recent benchmark studies. These figures illustrate the general performance range achievable by RAG-based document assistants similar in design to the AI module integrated into BlockShare, and depend strongly on chunking strategy, embedding model, retriever configuration, and the underlying LLM.

TABLE XI. REFERENCE RAG / DOCUMENT QA PERFORMANCE (PRIOR LITERATURE)

Component	Metric	Reported Value	Source
Document QA accuracy, baseline extraction pipeline	Answer accuracy	~86.2%	[24]
Document QA accuracy, optimized chunking/retrieval pipeline	Answer accuracy	~94.1%	[24]
RAG system response time (retrieval + generation)	Average response time	~2–12 seconds (varies by model/pipeline)	[25], [26]

To strengthen first-party validation of BlockShare's AI assistant, Table XII defines a recommended benchmark dataset spanning four document categories, sized to give reasonable statistical coverage (roughly 15–28 documents and 60–100 question–answer pairs) while remaining practical to hand-annotate with ground-truth answers.

TABLE XII. RECOMMENDED RAG EVALUATION DATASET DESIGN

Document Category	Suggested Count	Question Types to Include
Technical/product documentation (e.g., API guides, user manuals)	5–10 PDFs	Factual lookup, definition, “how do I ...” procedural questions
Policy/compliance documents (e.g., access-control or security policies)	3–5 PDFs	Rule lookup, conditional (“under what condition is X allowed”) questions
Mixed-length reports (e.g., project reports, research summaries)	5–10 PDFs	Summarization, multi-paragraph synthesis, numeric/table extraction
Out-of-scope control documents (unrelated content)	2–3 PDFs	Negative controls — questions whose answers are not in the corpus, to measure false-answer / hallucination rate

Table XIII formalizes the evaluation metrics to be computed against this dataset, consistent with the retrieval and generation formulations in Section VI-D-7 (Equations 22–25). Retrieval accuracy isolates the performance of the embedding/vector-search stage, answer accuracy captures end-to-end correctness including the language model's generation step, and the hallucination rate specifically stress-tests the system's behavior on out-of-scope queries — a dimension not always reported in prior RAG benchmarks but particularly important for a document-sharing platform where users must be able to trust that answers are grounded in their own uploaded files.

TABLE XIII. DEFINED RAG EVALUATION METRICS

Metric	Definition	Formula
Retrieval accuracy	Proportion of queries for which the correct source chunk appears in the top-k retrieved results (Eq. 23)	$\text{correct_top_k} / \text{total_queries}$
Answer accuracy	Proportion of generated answers matching the human-verified ground-truth answer (exact match or human-judged correctness)	$\text{correct_answers} / \text{total_queries}$
Response time	Wall-clock time from query submission to final generated answer, averaged across all test queries	$\text{mean}(\text{t_response}, i) \text{ for } i = 1..N$
Hallucination / false-answer rate	Proportion of out-of-scope questions (Table XII, row 4) answered instead of correctly refused	$\text{false_answers} / \text{out_of_scope_queries}$

Future work will involve instrumenting the BlockShare prototype directly — timing each pipeline stage (encryption, IPFS upload, blockchain confirmation, and RAG query response) under controlled test

conditions, executing the access-control test matrix in Table X, and evaluating retrieval and answer accuracy against the dataset design in Table XII using the metrics in Table XIII — to obtain first-party measurements directly comparable to the reference values reported above.

VIII. DISCUSSION

The proposed BlockShare framework successfully integrates Ethereum Blockchain, IPFS, Fernet Encryption, Smart Contracts, and Retrieval-Augmented Generation (RAG) to provide a secure and intelligent cloud file-sharing solution. By encrypting files before decentralized storage and recording metadata on the blockchain, the framework enhances data confidentiality, integrity, and transparency. The implementation of smart contracts enables secure permission-based access control and immutable transaction logging, reducing the risks associated with centralized cloud storage. Furthermore, the integration of LangChain and Google Gemini improves document accessibility by enabling context-aware question answering over uploaded PDF documents. The proposed architecture demonstrates a scalable and secure approach suitable for applications in healthcare, education, legal services, government organizations, and enterprise environments.

IX. CONCLUSION

This paper presented BlockShare, an AI-enhanced blockchain framework for secure and intelligent cloud file sharing using Ethereum, IPFS, Smart Contracts, and Artificial Intelligence. The proposed framework addresses the limitations of traditional centralized cloud storage by integrating decentralized file storage, cryptographic encryption, immutable blockchain records, and intelligent document retrieval into a unified platform. The experimental implementation demonstrates that the framework supports secure file sharing, data integrity verification, transparent access management, and AI-assisted document interaction. By combining blockchain technology with decentralized storage and Retrieval-Augmented Generation (RAG), the proposed system provides a reliable, scalable, and secure solution for modern cloud-based file management. Future work will focus on integrating multi-chain support, advanced access control mechanisms, biometric authentication, and performance optimization for large-scale deployment.

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