Decentralized File Storage and Sharing System Using Blockchain: A Proof-of-Work Based Approach

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***Abstract*—This paper presents a decentralized file storage and sharing system leveraging blockchain technology to ensure data integrity, security, and transparency. The proposed system utilizes a blockchain network where files are stored in blocks, each containing metadata such as user information, file size, and content. A Proof-of-Work (PoW) consensus mechanism is employed to validate transactions and add new blocks to the blockchain, ensuring that the system remains secure against tampering and fraudulent activities. The decentralized nature of the network eliminates the need for a central authority, providing users with greater control over their data. This paper explores the architecture, design, and implementation of the system, including its interaction with peers, handling of pending transactions, mining of blocks, and the role of PoW in maintaining the security and consistency of the blockchain. Through performance analysis and comparison of PoW algorithms, the paper highlights the system's efficiency and scalability in real-world applications. The proposed approach offers a promising solution for secure and reliable file sharing in decentralized environments, contributing to the growing field of blockchain-based applications.**

I. Introduction

In the era of increasing data generation, secure and efficient file storage and sharing have become fundamental requirements for individuals and businesses alike. Traditional centralized storage systems often pose security, privacy, and scalability challenges due to reliance on a central authority to manage, store, and transfer data. This creates potential vulnerabilities such as unauthorized access, data tampering, and system downtimes.

Blockchain technology, with its decentralized and immutable nature, offers an innovative solution to these challenges. Originally designed to support cryptocurrencies, blockchain has found applications in diverse fields, including supply chain management, healthcare, and finance. By leveraging cryptographic techniques and consensus protocols, blockchain provides a secure, transparent, and tamper-resistant environment for data storage and transactions.

This paper introduces a decentralized file storage and sharing system built on blockchain technology, designed to enhance the security, integrity, and accessibility of files. In this system, each file is stored within a block that contains not only the file data but also metadata such as the file's size, owner, and a unique identifier. The blocks are linked together in a chain, ensuring that every piece of data is time-stamped and protected against modification or deletion.

To ensure the integrity of the system, a Proof-of-Work (PoW) consensus mechanism is implemented, requiring nodes to solve complex mathematical problems before adding new blocks to the chain. This mechanism ensures that transactions are validated and blocks are appended in a secure and trustless manner, without the need for a centralized authority.

The system is designed to be scalable and efficient, capable of handling multiple transactions concurrently while ensuring that files are securely stored and easily accessible by authorized users. Through this project, we aim to explore how blockchain can be leveraged to address the limitations of traditional file storage systems, paving the way for a more secure and decentralized future of data management.

II. Literature Review

The concept of decentralized file storage has gained significant attention due to the rise of blockchain technology, which offers robust security, immutability, and transparency. Blockchain's ability to provide a decentralized and tamper-resistant record of transactions makes it an attractive solution for managing and sharing files securely. Several studies have explored blockchain's application in file storage systems.

[1] proposed a blockchain-based decentralized storage system where files are divided into smaller pieces, and each piece is distributed across a network of nodes. This approach enhances fault tolerance and data redundancy, making it resistant to data loss. The authors also highlighted the efficiency of blockchain in ensuring data integrity through cryptographic hash functions.

[2] discussed the use of blockchain in cloud storage, where it is used to improve transparency, auditability, and access control. The paper demonstrated how blockchain can address the trust issues associated with traditional cloud service providers, by ensuring that users have full control over their data.

[3] presented a decentralized file-sharing platform built on blockchain and Interplanetary File System (IPFS). The system allows users to securely store and share files, with blockchain

providing the necessary authentication and authorization. The authors emphasized the scalability and security features of the platform.

In [4], a hybrid blockchain approach was proposed for distributed file storage. The study examined the integration of permissioned and permissionless blockchains to achieve scalability and privacy, making the system more suitable for enterprise-level applications.

[5] explored the use of blockchain to prevent data tampering in shared storage systems. The authors implemented a blockchain-based framework to ensure that files, once stored, are immutable and cannot be altered without detection, addressing concerns about data integrity.

[6] investigated the application of blockchain for secure file sharing in the healthcare industry. The paper highlighted how blockchain can improve patient data privacy and facilitate the secure sharing of medical records between healthcare providers while maintaining compliance with regulations such as HIPAA.

[7] proposed a method to store encrypted files on a blockchain, ensuring that only authorized users can decrypt the content. The study highlighted the challenges associated with encryption key management and the performance overhead introduced by encryption and decryption processes.

In [8], the authors introduced a decentralized file storage and sharing system using blockchain and smart contracts. The system automatically executes storage agreements between users, reducing the need for intermediaries and enhancing efficiency. The study demonstrated the potential of smart contracts in automating file transactions.

[9] provided an in-depth analysis of blockchain's role in data privacy and security for file sharing applications. The authors discussed various consensus algorithms, including Proof-of-Work (PoW), and their applicability in maintaining data integrity while balancing system performance.

[10] explored the challenges and solutions for scaling decentralized file storage systems based on blockchain. The paper focused on addressing issues such as network latency, storage efficiency, and transaction throughput, which are critical for the widespread adoption of blockchain-based file storage solutions.

[11] presented a comparative analysis of different blockchain-based file storage platforms. The study evaluated performance, scalability, and security aspects of various systems, providing valuable insights for designing efficient decentralized storage networks.

[12] proposed a lightweight blockchain protocol for storing metadata of files, which reduces the computational overhead typically associated with storing large files directly on the blockchain. The system ensures that file integrity is verified using hash functions stored on the blockchain.

[13] focused on the integration of blockchain with Distributed Hash Tables (DHT) for decentralized file storage. The study demonstrated how combining DHT and blockchain can improve both the retrieval speed and the security of files in distributed storage systems.

In [14], the authors discussed the potential of blockchain to address the problems of trust and transparency in the Internet of Things (IoT)-enabled file storage systems. The paper presented a framework that combines blockchain with IoT devices for secure and automated file sharing.

[15] explored the application of blockchain in decentralized video streaming platforms, where users contribute to both storing and streaming videos. The study examined how blockchain ensures content integrity and provides transparent access control for video files.

These studies demonstrate the wide-ranging applications of blockchain technology in file storage and sharing, highlighting the various ways blockchain can improve security, privacy, scalability, and efficiency in decentralized systems.

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III. PROPOSED WORK

The proposed work aims to design and implement a decentralized file storage and sharing system using blockchain technology. The system leverages blockchain's decentralized and immutable nature to ensure data integrity, transparency, and security while facilitating efficient and reliable file sharing among users. The blockchain will serve as the backbone of

the file storage system, maintaining a tamper-resistant ledger of transactions and file metadata.

The key objectives of the proposed work are:

A. File Storage and Management

The system will break down files into smaller data chunks and store them across multiple nodes within the network. These nodes are responsible for ensuring the availability and redundancy of files. To enhance the reliability of the file storage, the system will integrate encryption techniques to protect user data both at rest and in transit. Blockchain will store the metadata of files, ensuring that users can verify the integrity of the data by hashing each piece of the file before and after storage.

B. Transaction and File Validation using Blockchain

The proposed system will implement two major Proof-of-Work (PoW) algorithms to validate file transactions and ensure the authenticity of the file data shared across the network. The first algorithm generates a nonce using a random function, while the second algorithm increments the nonce iteratively. These algorithms will be compared in terms of computational efficiency and their ability to meet the security and scalability requirements of the system.

C. Decentralized File Sharing

Once the file is uploaded to the system and validated, the user can share it with other participants in the network. Blockchain's decentralized nature ensures that there is no single point of failure, and users can access the files from multiple nodes in the network. The use of smart contracts will automate the process of file access, allowing users to share files securely without the need for intermediaries.

D. Security and Privacy Considerations

Security and privacy will be central to the design of the proposed file storage system. Blockchain's inherent properties of immutability and transparency ensure that once a file is uploaded to the network, it cannot be tampered with or altered. Moreover, the system will integrate encryption techniques for both file data and transaction data to protect user privacy. The use of cryptographic hashing will ensure that any modifications to the file or its metadata are detectable by other participants in the network.

E. Performance and Scalability

To assess the performance and scalability of the proposed system, various metrics, such as transaction throughput, file retrieval time, and latency, will be evaluated. The system will be tested under different levels of network load, file sizes, and transaction volumes to determine its efficiency in real-world scenarios. The impact of different Proof-of-Work algorithms on system performance will also be analyzed.

F. Comparison of Proof-of-Work Algorithms

The proposed work will include a comparative analysis of two different Proof-of-Work algorithms used for validating file transactions. The first algorithm employs a random nonce generation approach, and the second algorithm uses an iterative nonce increment approach. These algorithms will be evaluated based on their computational efficiency, security, and scalability. The analysis will help determine the most suitable PoW algorithm for a decentralized file storage system, considering factors such as energy consumption and time complexity.

G. Future Enhancements

The proposed work will provide a foundation for further improvements in the area of blockchain-based file storage and sharing systems. Future work could explore the integration of more advanced consensus algorithms such as Proof-of-Stake (PoS) or Delegated Proof-of-Stake (DPoS) to improve the scalability and energy efficiency of the system. Additionally, the system can be enhanced to support larger files and higher transaction volumes by implementing advanced data storage techniques, such as sharding.

Overall, the proposed decentralized file storage system aims to offer a secure, transparent, and scalable solution for file management and sharing, with blockchain technology ensuring the immutability and integrity of the stored data.

IV. System Architecture

The proposed decentralized file storage and sharing system uses blockchain to ensure the integrity, security, and transparency of file transactions. The architecture is designed to enable efficient file storage, management, and sharing in a distributed environment. The following section describes the key components of the system and their interactions.

A. Overview of System Components

The architecture consists of the following key components:

- **User Interface (UI)**: The front-end of the system that allows users to upload, download, and manage their files. It interacts with the backend through API calls.
- **Blockchain Network (Peers)**: A network of nodes that stores the blockchain ledger, validates transactions, and maintains a copy of the file metadata and transaction history. Each peer runs the blockchain software and can mine new blocks, process transactions, and validate file uploads.
- **File Storage System**: A distributed storage system where files are stored across multiple nodes. The storage is decentralized, ensuring redundancy and availability. The metadata of each file is stored on the blockchain, and the file content is stored in encrypted chunks across the network.
- **Transaction Validator (Proof-of-Work)**: The blockchain system uses a Proof-of-Work (PoW) mechanism to validate file transactions. This ensures

that transactions are processed securely and added to the blockchain ledger after mining a valid block.

- **Smart Contracts**: A mechanism to automate the process of file sharing and access control. These contracts define the rules for sharing files and enforce security policies without the need for intermediaries.

B. File Upload and Storage Flow

1. **File Upload**: The user uploads a file through the UI, which is saved to the local storage of the node.
2. **Transaction Creation**: The system generates a transaction containing metadata about the uploaded file, such as the file name, user, file size, and a unique hash of the file content.
3. **Transaction Submission**: The transaction is submitted to the blockchain network, where it is validated and added to the list of pending transactions.
4. **Mining and Validation**: Nodes in the network mine new blocks by solving Proof-of-Work puzzles. When a block containing the new transaction is mined, it is added to the blockchain.
5. **File Storage**: While the blockchain holds the metadata of the file, the actual file content is distributed across different nodes in the network, encrypted for security. Nodes maintain a backup of the file, ensuring redundancy.

C. File Retrieval Flow

1. **File Request**: A user requests to download a file through the UI.
2. **Transaction Lookup**: The system queries the blockchain to retrieve the metadata of the requested file, including its hash, file name, and owner.
3. **File Retrieval**: Based on the metadata, the file content is fetched from the appropriate nodes in the network. Since the file is stored in encrypted chunks across multiple nodes, the system ensures that the file is reassembled securely for the user.
4. **Decryption and Access**: Once retrieved, the file is decrypted using the private key of the user, and the file is presented to the user for download.

D. Blockchain Integration

The blockchain serves as a decentralized ledger that records all file transactions, ensuring that each file upload or download is traceable and transparent. The blockchain is maintained across multiple nodes in the network, and each transaction is secured using a cryptographic hash function. The Proof-of-Work mechanism ensures that only valid transactions are added to the blockchain, making it resistant to fraud and tampering.

E. Security Features

Security is a primary concern in the design of this system. The blockchain ensures that the transaction history is immutable, preventing unauthorized modifications. The file data is stored in an encrypted format across multiple nodes, ensuring confidentiality. Additionally, the system uses public-key cryptography to allow users to securely upload and retrieve files. Smart contracts are employed to automate access control and enforce sharing policies, ensuring that only authorized users can access specific files.

F. Scalability Considerations

The system architecture is designed to scale as the number of users and files increases. By distributing file storage across multiple nodes and using blockchain to manage metadata, the system can handle large amounts of data efficiently. The modularity of the architecture allows for easy addition of new nodes, increasing storage capacity and improving the overall system's performance.

G. Conclusion

The system architecture of the decentralized file storage and sharing system ensures security, transparency, and efficiency. By leveraging blockchain technology, the system can provide a reliable and tamper-proof method for file storage, while decentralizing the management of files to enhance redundancy and availability. The use of Proof-of-Work and smart contracts adds additional layers of security and automation, making the system scalable and secure for a variety of use cases.

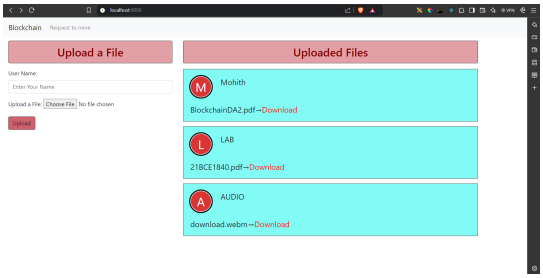

Fig. 1. UI of FileStore.

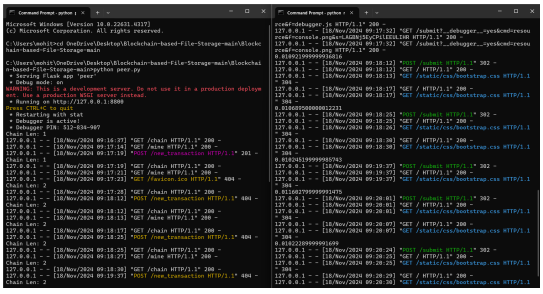

Fig. 2. Server-Client command prompt.

V. Implementation

A. Blockchain Class

The 'Blockchain' class is the core of the system, managing the chain of blocks, validating transactions, and ensuring the integrity of the entire blockchain. It begins by initializing the blockchain with a genesis block, which serves as the starting point of the chain.

```
class Blockchain:
    difficulty = 3  # Difficulty level for
    proof of work

    def __init__(self):
        self.pending = []  # List of pending
        transactions to be added to the chain
        self.chain = []  # The blockchain itself
        genesis_block = Block(0, [], "0")
        # Create the genesis block
        genesis_block.hash =
        genesis_block.generate_hash()
        # Generate hash for genesis block
        self.chain.append(genesis_block)
        # Append the genesis block to the chain
```

The ‘Blockchain‘ class manages the list of pending transactions and the blockchain itself. The genesis block is created with an index of 0 and no transactions, and its hash is generated.

B. Block Class

Each block contains essential data such as the index, list of transactions, previous block’s hash, nonce for Proof of Work, and its own hash. The ‘Block‘ class is responsible for generating a block’s hash and validating its integrity.

```
class Block:
    def __init__(self, index, transactions,
    prev_hash):
        self.index = index
        self.transactions = transactions
        self.prev_hash = prev_hash
        self.nonce = 0  # Proof of work nonce
        self.hash = self.generate_hash()
        # Generate the hash of the block

    def generate_hash(self):
        block_data = f{self.index}
        {self.transactions}{self.prev_hash}
        {self.nonce}
        return hashlib.sha256
        (block_data.encode()).hexdigest()
```

The ‘generate hash‘ method generates the hash using the SHA-256 algorithm, ensuring the integrity and immutability of each block.

C. Proof of Work (PoW)

To secure the blockchain, we use Proof of Work (PoW), which requires computational work to mine new blocks. Two PoW methods are implemented: one using a random nonce and the other using an incremental nonce.

```
def p_o_w(self, block):
    block.nonce = 0
    get_hash = block.generate_hash()
    while not get_hash.startswith("0"
    * Blockchain.difficulty):  # Difficulty check
        block.nonce = random.randint(0, 99999999)
        # Random nonce
        get_hash = block.generate_hash()
        # Recompute the hash
    return get_hash
```

In the ‘pow‘ method, a random nonce is used to generate a valid hash. The process continues until the hash meets the required difficulty, represented by the number of leading zeros.

```
def p_o_w_2(self, block):
    block.nonce = 0
    get_hash = block.generate_hash()
    while not get_hash.startswith("0"
    * Blockchain.difficulty):  # Difficulty check
        block.nonce += 1  # Incremental nonce
        get_hash = block.generate_hash()
        # Recompute the hash
    return get_hash
```

The ‘pow-2‘ method increments the nonce and continues until the hash meets the difficulty level.

D. Transaction Handling

Transactions are submitted by users and temporarily stored in the ‘pending‘ list. When a new block is mined, the transactions are included in the block.

```
def add_pending(self, transaction):
    self.pending.append(transaction)
    # Add the transaction to the pending list
```

This method adds transactions to the pending list, which will later be included in the next mined block.

E. Block Mining

The ‘mine‘ method is responsible for mining a new block. It processes the pending transactions, creates a new block, and applies Proof of Work to secure the block.

```
def mine(self):
    if len(self.pending) > 0:
    # Check if there are pending transactions
        last_block = self.last_block()
        # Get the last block
        new_block = Block(last_block.index + 1,
        self.pending, last_block.hash)
        # Create a new block
        hashl = self.p_o_w(new_block)
        # Run PoW to get the valid hash
        self.add_block(new_block, hashl)
        # Add the block to the chain
        self.pending = []
        # Clear the pending transactions
        return new_block.index
        # Return the index of the new block
    return False
```

The method generates a new block, applies Proof of Work, and appends the block to the blockchain.

F. Chain Validation

To maintain blockchain integrity, the ‘check chain validity‘ method ensures that all blocks are valid and conform to the Proof of Work and hash integrity requirements.

```
def check_chain_validity(self, chain):
    prev_hash = "0"
    # The hash of the previous block
    for block in chain:
        block_hash = block.hash
        # Get the current block’s hash
```

```
        if self.is_valid(block, block_hash) and
        prev_hash == block.prev_hash:
            block.hash = block_hash
            # Update the hash
            prev_hash = block_hash
            # Update the previous hash
        else:
            return False
    return True
```

This method checks if each block in the chain is valid by verifying the hash and the previous block's hash.

G. Web Interface for File Upload and Blockchain Interaction

The web interface allows users to submit files and associate them with transactions that are added to the blockchain. Files are uploaded to the server, and a transaction is created with the file's metadata.

```
@app.route("/submit", methods=["POST"])
def submit():
    user = request.form["user"]
    up_file = request.files["v_file"]

    # Save the uploaded file in the destination
    up_file.save(os.path.join
    ("app/static/Uploads/", secure_filename
    (up_file.filename)))
    files[up_file.filename] =
    os.path.join(app.root_path,
    "static", "Uploads", up_file.filename)

    # Create a transaction object
    post_object = {
        "user": user,
        "v_file": up_file.filename,
        "file_data": str(up_file.stream.read()),
        "file_size": os.stat(files
        [up_file.filename]).st_size
    }

    # Submit the transaction to the blockchain
    address = "{0}/new_transaction".format(ADDR)
    requests.post(address, json=post_object)

    return redirect("/")
```

This route handles file uploads, saves the files to the server, and submits the file information as a transaction to the blockchain.

VI. Importance of Blockchain

Blockchain is a secure, decentralized data structure used to store various types of digital information such as transactions, files, and messages. As an open ledger, blockchain allows multiple parties to access and verify information simultaneously. Key functionalities include consensus algorithms, block mining, and block validation.

In this project, we implemented a blockchain for secure file storage and sharing. Users can upload and download files via a publicly available website. The blockchain uses the SHA-256 cryptographic algorithm to ensure data integrity and security. To reach consensus, a Proof of Work (PoW) mechanism is implemented, requiring miners to solve cryptographic puzzles. In our case, miners must find a hash with three leading zeros to append a block to the chain.

VII. Proof of Work Algorithm

Blockchain-based systems aim to maximize decentralization by enabling any peer to add new blocks. PoW algorithms support this by requiring peers (miners) to solve cryptographic puzzles. The first to solve the puzzle earns the right to add a block. In our implementation, two PoW approaches were compared:

A. Algorithm 1: Random Nonce PoW

This algorithm generates a random nonce in each iteration to find a valid hash.

Listing 1. Random Nonce PoW Algorithm

```
def p_o_w(self, block):
    block.nonce = 0
    get_hash = block.generate_hash()
    while not get_hash.startswith("0" *
    Blockchain.difficulty):
        block.nonce = random.randint(0, 99999999)
        get_hash = block.generate_hash()
    return get_hash
```

B. Algorithm 2: Incremental Nonce PoW

Here, the nonce is incremented sequentially until a valid hash is found.

Listing 2. Incremental Nonce PoW Algorithm

```
def p_o_w_2(self, block):
    block.nonce = 0
    get_hash = block.generate_hash()
    while not get_hash.startswith("0" *
    Blockchain.difficulty):
        block.nonce += 1
        get_hash = block.generate_hash()
    return get_hash
```

C. Performance Comparison

The two algorithms were tested under varying difficulty levels. Table I summarizes the running times for each method.

TABLE I
Running Time Comparison of PoW Algorithms

Difficulty	Attempt 1	Attempt 2	Attempt 3	Attempt 4
Random Nonce PoW				
2	0.00018	0.00281	0.00102	0.00039
3	0.00069	0.03207	0.00485	0.00356
4	0.13479	0.22688	0.34565	0.19841
5	4.06034	2.08288	0.58391	0.2094
Incremental Nonce PoW				
2	0.00035	0.00080	0.00062	0.00108
3	0.02190	0.02463	0.02104	0.01625
4	0.00366	0.03813	0.32095	0.02145
5	0.04403	3.10820	1.53688	1.50288

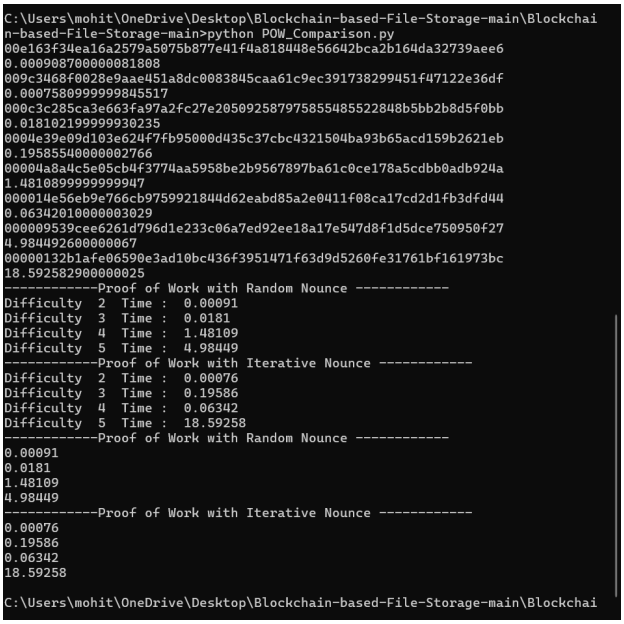

Fig. 3. Performance Data of PoW Methods

D. Discussion

Algorithm 1: Random Nonce PoW shows better performance at higher difficulty levels due to its probabilistic nature. It provides a higher likelihood of finding a valid nonce quickly, as each nonce is equally probable.

Algorithm 2: Incremental Nonce PoW, while simpler, faces a deterministic limitation. If new transactions are added during the mining process, previously tested nonces won't be revisited, reducing efficiency.

E. Security Analysis

Algorithm 2 poses security risks as its running time can reveal nonce value ranges. If an attacker estimates the nonce, they could potentially disrupt the blockchain's integrity. Conversely, Algorithm 1 mitigates this by using a random nonce, making it more secure.

VIII. On-Chain vs Off-Chain Blockchain

Blockchain can be categorized into On-Chain and Off-Chain systems:

- **On-Chain:** Stores complete data within blocks. It offers high security and ease of recovery.
- **Off-Chain:** Stores metadata in blocks while actual data resides externally. It reduces block size and improves efficiency.

For this project, we adopted the On-Chain approach, storing entire file data within blocks to prioritize security and reliability.

IX. Conclusion

In this research, we presented the design and implementation of a decentralized file storage and sharing system using blockchain technology. The system leverages an on-chain blockchain architecture to store file data, ensuring security, transparency, and immutability. By incorporating the SHA256 cryptographic algorithm, we provide a robust mechanism for securing data and maintaining the integrity of the blockchain.

A critical component of our implementation was the use of Proof of Work (PoW) as the consensus algorithm. Two PoW strategies were explored: one with random nonce generation and another with incremental nonce values. Through extensive testing and performance analysis, we demonstrated that the random nonce generation approach (`p_o_w`) performs better at higher difficulty levels, offering both improved efficiency and enhanced security. The incremental nonce algorithm, while simpler, showed vulnerabilities due to predictable nonce values, which could compromise system security.

Our results highlight the importance of selecting an appropriate PoW strategy based on the specific requirements of blockchain applications. For systems requiring high security and faster block validation, random nonce generation offers clear advantages. However, the computational cost of PoW remains a significant challenge.

Future enhancements to the system could include exploring alternative consensus mechanisms such as Proof of Stake (PoS) or Delegated Proof of Stake (DPoS), which offer more energy-efficient solutions. Additionally, the scalability of the blockchain could be improved by adopting off-chain storage for large files, while retaining essential metadata on-chain.

Overall, this project demonstrates the potential of blockchain technology to provide secure, decentralized, and tamper-proof solutions for file storage and sharing, laying the groundwork for further innovations in this domain.

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