International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-12 Issue-2, July 2023

Decentralized Storage for Educational Resources

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Abstract: ***The growth of blockchain over the last ten years has been astounding: from bitcoin to over 2,000 altcoins, and from decentralized electronic payments to programmable transactions, by complicated tokens and smart contracts controlled by autonomous entities. The technological aspects of blockchain are evolving simultaneously with the development of new blockchain applications. This paper considers one such sphere, developing a decentralised solution for accessing educational resources that will alleviate issues due to the single point of failure of centralised systems, democratise access to academic content, and provide a seamless experience for users who are not exposed to web3 technologies. This platform was developed by implementing Smart Contracts using Solidity and deploying them on the Ethereum blockchain to store educational resource metadata and files on the Inter Planetary File System (IPFS). Interfacing of blockchain and the frontend is done using web3.js. The platform is more robust and fault-tolerant than systems using a centralised architecture, and it provides a better user experience by incorporating a search mechanism for the files uploaded to the platform. This paper proposes a decentralised platform that allows users to upload educational resources that can be accessed by others, and implements a file metadata-based search feature to eliminate the need for users to remember the IPFS hash of a file.***

Keywords: Ethereum blockchain, Decentralized Storage, Inter Planetary File System (IPFS), smart contract and Open Educational Resources (OER).

I. INTRODUCTION

As the world around us advances, a new dimension of learning has emerged in the form of digital learning, including digital learning resources. Open Educational Resources [1] have a positive enabling effect in expanding access to such resources and disseminating information among students and academics.

Manuscript received on 07 June 2023 | Revised Manuscript received on 19 June 2023 | Manuscript Accepted on 15 July 2023 | Manuscript published on 30 July 2023.

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As this new form of learning gains traction among enthusiastic learners, especially those who cannot access educational content behind a paywall, specific issues may become a point of concern that needs to be addressed to ensure free access to these resources for everyone. Currently, most of the supporting infrastructure has a centralized architecture and inherently has a single point of failure [2]. Furthermore, because of their centralized nature, they always have the option of limiting access to content hosted on their platform, which does not guarantee open access to aspiring learners. Adding to these issues is the fact that OERs can be subjected to censorship [3]. Keeping these issues in mind, we have explored a decentralized platform that can service our needs while addressing the concerns above. The decentralized application can be developed using Ethereum-based smart contracts. With its inherent immutability and decentralized tendencies [4], blockchain can ensure a trusted and reliable platform and eliminate a single point of failure [2]. Nevertheless, as it will be untenable to store many multimedia documents on the blockchain, IPFS can be used for large amounts of data. Hence, using both of these technologies in conjunction can be employed to create a platform to enable a trusted and reliable solution while addressing the key concerns.

II. LITERATURE REVIEW

The research by Sharma et al. [5] elaborates on the security risks associated with storing data on third-party cloud services. The authors propose a blockchain-based decentralised platform where data owners can maintain access-related details in a distributed manner using blockchain technology, while simultaneously ensuring data integrity without requiring a third-party central authority. Marjit and Kumar, in the paper [2], point out issues such as sustainability and single point of failure of centralized systems and propose a decentralized solution for storing Open Education Resources. The paper by Untung et al. [6] proposes a framework to enhance the teaching and learning experience by improving the performance of decentralized storage systems. They identify blockchain as the core technology of decentralised systems that can bind disparate entities into a cohesive whole. The paper [7] is a survey on solutions using IPFS and blockchain technologies for secure decentralized storage of medical records. The authors discuss the security issues associated with storing sensitive medical records in a centralised manner and conduct a comparative study of relevant proposed models. The paper [8] explores using blockchain technology for applications such as attribution and verifying essential documents in the educational sector. It simplifies the process of verifying the validity of students' records, enabling them to share this information easily with the relevant entities.

Nammari elaborates in [9] on the benefits of OER for learners. He points out the problems posed by copyright issues and a single point of failure associated with centralized systems. He proposes a decentralized solution using blockchain technology to mitigate such issues. In the paper [10], Kumar and Tripathi have discussed the increasing amount of storage in blockchains owing to the growing number of transactions and propose using off-chain solutions such as IPFS to reduce the amount of data stored on blockchains.

III. DECENTRALIZED ARCHITECTURE

a. Distributed digital ledger

A distributed ledger technology, or DLT, stores data over a network of computers. While a cryptographic signature validates the data recorded, any modifications to the ledger are reflected simultaneously for all holders of the ledger [13]. Because the DLT is decentralized, no central authority or middleman is required to process, validate, or authenticate transactions. DLTs are essentially a set of functions and data structures for recording transactions. Public key cryptography, distributed peer-to-peer networks, and consensus procedures are the three well-known technologies on which all distributed ledger technologies (DLTs) are built. Each DLT distinguishes itself by adopting a different data format and technology. To operate in a distrusted decentralized environment, all three are combined in an exceptional and innovative method [14].

b. Cryptocurrencies

Although there have been numerous attempts over the past 30 years to address the complicated problems associated with digital currencies [17], [18], and [19], this wasn't done until 2009, the year that bitcoin was introduced. In general, the term "cryptocurrency" refers to a decentralised currency based on encryption technology. One of the many potential uses of blockchain is the creation of cryptocurrencies, which are viewed as asset resources or tokens on a blockchain network. It is debatable whether cryptocurrencies are the core value of blockchain technology because a blockchain can function just fine without them [20]. Blockchain frameworks exist already [16] without any integrated cryptocurrency. However, to make transactions easier and more profitable, the majority of public blockchain apps now use cryptocurrencies as their foundation.

c. Blockchains

Even though the concept of blockchain technology was first proposed in 1991 as a way to create a system where document timestamps could not be altered [16], it wasn't until January 2009 that blockchain gained widespread attention when its first practical application, the bitcoin cryptocurrency, was introduced [15]. Even though the terms DLT and blockchain are frequently used synonymously in the literature, they are not the same. For instance, DLTs do not require a chain of blocks, whereas blockchains do. A blockchain is only one type of DLT made up of a chain of blocks that are linked together using hash codes, with each block referencing the block before it. Each block could include a series. In essence, blockchains are distributed, immutable ledgers that store transaction history. However, they offer several features that set them apart from other DLTs, such as smart contracts, which are executable pieces of code that are stored on the blockchain and are executed when specific criteria are met, and miners, who add new transactions to the blockchain and can earn money from this activity [14].

IV. METHODOLOGY

Based on the survey conducted on the above research papers, we have proposed a decentralised application that stores files in IPFS, thereby reducing the amount of data stored on the blockchain, which would have been expensive. After the OER is stored in IPFS, it returns a CID based on the file's contents [6], which will be stored using Smart contracts in the Ethereum blockchain. Users can use the ReactJS frontend to upload an OER to the system or access OERs. In the high-level design illustrated in figure 1, we have a web application that acts as a frontend to the system where the user can perform actions such as accessing an OER, as illustrated in figure 3, and can contribute an OER by uploading the file as shown in figure 4, which will be stored using IPFS. The OER contributed to the platform can be placed and searched using details such as its name, making searching for OERs easier. The IPFS CID, received after uploading a file, is stored in the Ethereum blockchain, which can be used to access that OER later. Furthermore, since

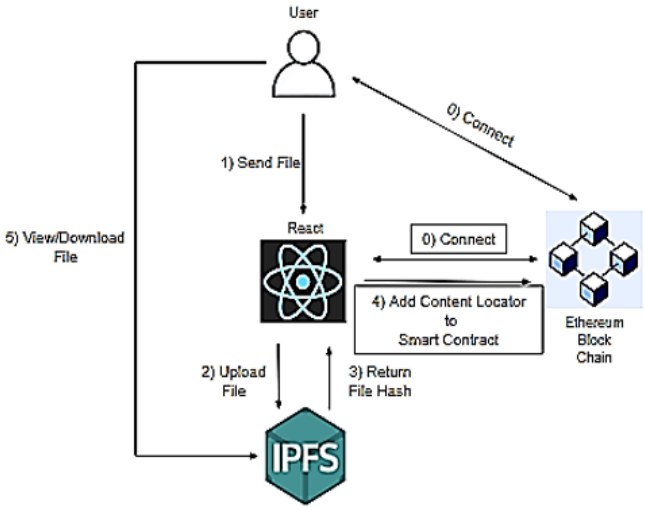

Figure 1. High Level Diagram of decentralized platform

The IPFS CID for a particular file will vary with changes to the file's content in IPFS. Storing the IPFS CID of a file will verify whether the user is accessing an authentic resource. This system features a dynamic search function that caches data from the blockchain on the client side using the web3.js API, enabling users to search for files based on OER metadata rather than their IPFS CID. The pseudocode detailing the interactions between IPFS and Ethereum is presented in Figure 2. Based on the survey conducted on the above research papers, we have proposed a decentralised application that stores files in IPFS, thereby reducing the amount of data stored on the blockchain, which would have been expensive.

Retrieval Number: 100.1/ijrte.B78070712223
DOI: 10.35940/ijrte.B7807.0712223
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

After the OER is stored in IPFS, it returns a CID based on the file's contents [6], which will be stored using Smart contracts in the Ethereum blockchain. Users can use the ReactJS frontend to upload an OER to the system or access OERs.

```
Step 1 : Start
Step 2 : connect to Blockchain
Step 3 : connect To IPFS
Step 4 : uploadFileToIPFS(file_attributes)
Step 5 : storeFileHashToBlockchain(file_hash, file_attributes)
Step 6 : listFiles()
Step 7 : stop

uploadFileToIPFS(fileDescription, file)
    Add file to IPFS
end

storeFileHashToBlockchain(fileCount, _fileHash, _fileSize, _fileType, _fileName, _fileDescription, time,    uploader)
    If  fileName length > 0 and fileDescription length > 0
    Add file to the contract
    Emit file upload
end

listFiles()
    Retrieve accountID
    Get networkID
    If networkID exists then
        Assign contract
        Load files into the state variable and sort by newest
        fileCount ← count total number of files
        for i ← fileCount to i >= 1
            file = files[i]
        Add file to the state
End
```

Figure 2. Pseudocode displaying interaction between IPFS and Ethereum

As a part of the solution, we have proposed:

- A Smart contract that stores the IPFS CID in the blockchain, which enables verifying the OER's authenticity.
- A mechanism to access and download files from IPFS by providing the IPFS CID of a file.
- Dynamic searching of OERs based on the name and other metadata of an OER, which eliminates the predicament for learners to remember the IPFS CID of the resource they want to access.

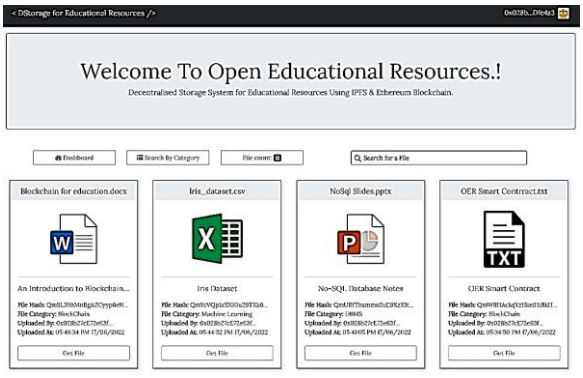

Figure 3. Users can choose an OER using the web interface

The user and system interactions are shown in the sequence diagram in Figure 5. The user can authenticate on the platform using crypto-wallets such as MetaMask [11]. Subsequently, they can upload an educational document, such as an article, to IPFS and will receive a unique IPFS CID for that document.

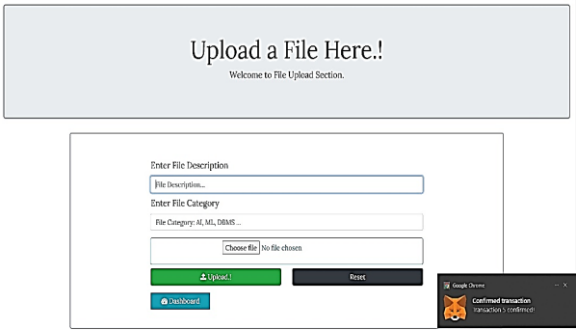

Figure 4. Users can upload an OER to the platform

After that, they could use an IPFS CID of a previously uploaded file that can be accessed without hindrance. Furthermore, due to the distributed nature of IPFS, as long as a single IPFS node contains a copy of the requested resource, it will be accessible to the user, which resolves sustainability issues to a great extent.

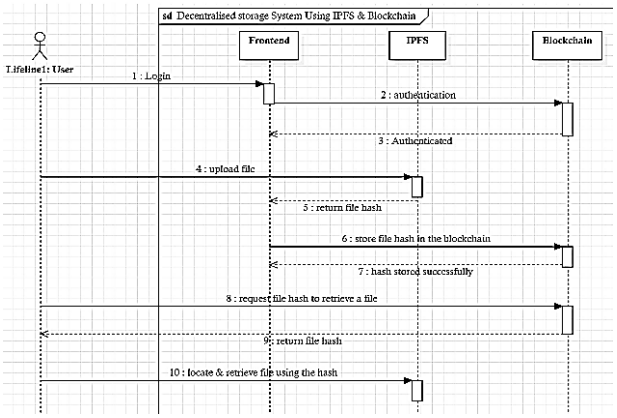

Figure 5. Sequence diagram indicating interactions between users and the system

V. EXPERIMENTAL OUTPUT

The paper proposes a decentralised platform that utilises the Ethereum Blockchain as its core and leverages the distributed storage provided by IPFS. The cost for deploying gas in the smart contract and uploading a file is as follows in Table 1:

Table 1: Cost- Cost-Function Table

Functions	Gas Fees
Contract Deployment	0.01953772 ETH
Uploading File	0.00855 ETH

The platform is a highly fault-tolerant system with minimal downtime. As long as a single IPFS node with the required data is online, it will continue to service its clients. Additionally, users have a straightforward web interface that abstracts the complexities of interacting with blockchain to retrieve metadata of files stored on the platform, eliminating the need for users to remember a 46-character-long CID to access files stored using IPFS.

VI. CONCLUSION

This paper presents a reliable, tamper-proof decentralised platform for storing and accessing educational resources using Smart contracts deployed on the Ethereum Blockchain, which provides exceptional fault tolerance. Leveraging IPFS, a distributed and scalable storage system, this platform addresses the issues associated with centralised systems and benefits learners. A dynamic search feature based on meta-details of OERs is implemented, which will remove the need for learners to painstakingly remember the IPFS CID of the resource they want to access. Although we will utilise decentralised storage for OERs, the user interface will be hosted on a centralised platform. In the future, we plan to deploy the website using services such as Fleek [12], which allows developers to host websites on IPFS, to make it a comprehensively decentralized platform.

DECLARATION

Funding/ Grants/ Financial Support	No, I did not receive.
Conflicts of Interest/ Competing Interests	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval or consent to participate, as it presents evidence that is not subject to interpretation.
Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	Implementation and idea of suggestion by Harsha R and K. Panimozhi. Indra E and Thirugnana Sambandham guided the review of the implementation and writing of the related study.

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AUTHORS PROFILE

Harsha R. I pursued my academic journey in Computer Science and Engineering at BMS College of Engineering. I completed my Bachelor's degree in Engineering with a specialisation in Computer Science. Throughout my studies, I displayed dedication and a passion for learning. With a keen interest in Web3, Machine Learning, and Systems, I actively sought opportunities to expand my knowledge and skills in these areas. I engaged in research projects, internships, and extracurricular activities that allowed me to explore and apply concepts related to these fields. Moving forward, I am excited to contribute to the cutting-edge developments in Web3, Machine Learning, and Systems, utilizing my academic background and practical experience.

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