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NFT Shield: Ensuring the Secure Sharing and Immutable Protection of Engineering Drawings through Blockchain

[1]Shreeya DL, [2]Rakesh R Shastri, [3]Shraddha HP, [4]Parameshwar S,[5]Dr. K. Panimozhi
[1]UG Scholar, [2]UG Scholar,[3]UG Scholar, [4]UG Scholar,[5]Assistant Professor
Department of Computer Science,
B.M.S College of Engineering, Bengaluru, India

Abstract : In the contemporary landscape of manufacturing, Computer-Aided Engineering and Design (CAED) files serve as invaluable assets, containing critical intellectual property and proprietary information. However, the vulnerability of these files to unauthorized access, modification, or theft poses significant risks to companies' competitiveness and innovation. This project proposes a novel solution leveraging blockchain technology to enhance the security and integrity of CAED files. By integrating blockchain into the existing infrastructure, a transparent and immutable ledger is created, providing a secure and tamper-proof environment for storing and managing CAED files. Smart contracts embedded within the blockchain enable automated validation and authorization processes, ensuring that only authorized personnel can access and modify the files, thereby safeguarding against unauthorized tampering or theft. Additionally, the decentralized nature of blockchain enhances resilience against single points of failure and malicious attacks. This innovative approach, will enable the manufacturing companies to fortify the protection of their CAED files, and foster trust among stakeholders.

IndexTerms **- CAD, CAED, NFT, Blockchain, DRM**

INTRODUCTION

As supply chains evolve in an era of globalization, manufacturing companies confront the complex task of sharing proprietary Computer-Aided Design (CAED) files with suppliers and manufacturing partners while balancing the imperative to safeguard intellectual property (IP) against the necessity of collaboration and outsourcing. Historically, CAED design files have been disseminated through conventional methods such as email exchanges, file-sharing platforms, or direct transfers. However, the inherent vulnerabilities of these traditional approaches have increasingly exposed companies to the risks of copyright infringement and unauthorized replication of designs. Despite the implementation of non-disclosure agreements and encryption protocols, these measures often prove insufficient in preventing IP theft once files are shared externally, leaving organizations susceptible to exploitation by malicious actors. Recognizing the limitations of existing practices, this paper proposes a pioneering application of non-fungible token (NFT) technology and blockchain to revolutionize the management and protection of CAED design files within the manufacturing ecosystem.

By leveraging the concept of minting CAED files as Non-Fungible Tokens (NFTs) on a blockchain, each CAED design file transforms a distinctive crypto-asset endowed with inherent scarcity, authentication, and advanced tracking capabilities. Through the utilization of this technology, companies can effectively share NFT design files via secure smart contracts meticulously designed to enforce a range of access controls, expiration parameters, revocation abilities, and even facilitate royalty payments on subsequent transactions. This sophisticated system not only enables authorized suppliers to seamlessly access and collaborate with the designated design files but also serves as a formidable deterrent against unauthorized copying, redistribution, or utilization beyond the predefined boundaries set forth by the token's issuer.

The transparent and immutable ledger inherent in blockchain technology furnishes an indispensable tool for maintaining an auditable trail, crucial for promptly identifying any instances of misuse or unauthorized dissemination of proprietary CAD files. This capability not only enhances accountability but also empowers companies with the means to swiftly address any breaches in security or violations of intellectual property rights. By leveraging this robust mechanism, the proposed NFT solution holds significant promise in mitigating IP risks associated with outsourced manufacturing activities.

OBJECTIVES.

This project aims to develop a revolutionary approach for managing and protecting Computer-Aided Design (CAED) files within the manufacturing ecosystem. This will be achieved by leveraging the transformative power of Non-Fungible Token (NFT) technology and blockchain. Here's a breakdown of the key objectives:

Enhance Security and Prevent IP Theft: The project seeks to replace traditional, insecure methods of sharing CAED files with a secure NFT-based system. By minting CAED files as NFTs, we aim to create unique crypto-assets with inherent scarcity, authentication, and advanced tracking capabilities. This significantly reduces the risk of unauthorized copying, redistribution, or misuse compared to traditional methods.

Facilitate Secure Collaboration: The project aims to establish a secure environment for collaboration with authorized suppliers and partners. Through the use of smart contracts, the NFT system will enforce access controls, set usage parameters, and even enable royalty payments. This ensures authorized users can seamlessly access and work with designs while safeguarding them from unauthorized access.

Improve Transparency and Accountability: By leveraging the immutable ledger of blockchain technology, the project aims to create a transparent audit trail for all interactions with the NFT-based CAED files. This provides organizations with the ability to track file use, identify any potential breaches, and take swift action to uphold intellectual property rights.

Mitigate Risks in Outsourced Manufacturing: By implementing a secure NFT-based system, the project aims to significantly reduce the risks associated with outsourcing manufacturing activities. The enhanced security and tracking capabilities will minimize unauthorized access to sensitive design data, fostering trust and collaboration within the manufacturing ecosystem.

LITERATURE SURVEY

References from pertinent works have been used in this literature review to explain the same with regard to the subject of the study. The most pertinent studies that have been done in this field to date are reviewed in this section. This review presents a thorough analysis of the current literature on blockchain technology, NFTs, and smart contracts, with an emphasis on their possible applications and limits.

Core Functions and Potential:

Immutability, transparency, and decentralization: These key functionalities, thoroughly investigated by Taherdoost (2022) [36], Chen et al. (2017) [3], and Alharby et al. (2017) [2], position blockchain technology as a disruptive force in a variety of industries. Its immutability assures tamper-proof records, whereas transparency promotes trust and verifiability. Decentralization eliminates the need for intermediaries, which simplifies processes and lowers costs.

Applications in Various Domains:

Digital Rights Management (DRM): Traditional DRM solutions frequently have issues in content control and user privacy. Finck and Moscon (2018) [10], Altaf et al. (2020) [1], and Garba et al. (2021) [11] recommend using blockchain technology to overcome these challenges. Creators gain more control over their material by preserving ownership and usage rights on an immutable ledger, while users benefit from enhanced transparency and potentially flexible licensing structures.

Patent Management: The process of registering and exchanging patents can be time-consuming and fraudulent. Bamakan et al. (2022) [5] offer a paradigm that uses NFTs to describe patents as distinct digital assets. This solution simplifies the registration procedure, improves security, and allows for secure and transparent ownership transfers.

Medical Device Tracking: Ensuring the authenticity and traceability of medical devices is critical to patient safety and regulatory compliance. Gebreab et al. (2022) [12] and Li et al. (2023) [13] investigate employing NFTs to track medical devices throughout their lives. This enables for more efficient monitoring, targeted recalls in the event of safety problems, and combating counterfeiting.

Traditional library management systems encounter difficulties in keeping accurate records and simplifying procedures. Malik et al. (2022) [14], Coghill (2018) [9], and Verma et al. (2021) [40] all advocate using blockchain technology to improve library operations. This can include creating tamper-proof records of book ownership and borrowing history, automating workflows for borrowing and returning books, and enabling safe access to digital assets.

Specific Applications:

BookChain: Zeng et al. (2019) [37] introduce BookChain, a new system for secure and autonomous book sharing in educational institutions. It uses blockchain technology and smart contracts to automate book trades, increase transparency and traceability, and reduce the risk of loss or damage. This application highlights blockchain's potential to transform peer-to-peer sharing paradigms.

Smart Propertization: Lee et al. (2021) [38] propose "Smart Propertized Digital Content" (SPDC) as a solution for protecting intellectual property rights. SPDC integrates self-decryption capabilities into digital content and stores license conditions on the blockchain. This strategy gives authors granular control over content distribution and revenue, while also providing users with transparent license information.

Ko et al. (2023) [39] investigate the viability of employing NFTs and the InterPlanetary File System (IPFS) to manage digital material. Their testbed experiment shows that NFTs may successfully represent unique digital assets, whereas IPFS is a decentralized storage solution. This method provides the path for the secure and transparent management of digital content ownership and access.

Challenges and Limitations: Scalability, security, and energy consumption: Studies by Zhao et al. (2023) [17] and Mhatre et al. (2022) [16] identified scalability as a major difficulty for blockchain technology, with existing networks struggling to manage high transaction volumes. Security vulnerabilities are still a worry, as noted by Alharby et al. (2017) [2]. Furthermore, energy consumption connected with certain blockchain technologies creates environmental and sustainability concerns.
NFT downsides: Taherdoost (2022) [36], Chohan (2021) [15], and Abid (2021) [18] all identify potential NFT negatives, such as market instability, environmental effect, and security problems. The value of NFTs might change dramatically, posing financial concerns for consumers. Furthermore, the energy usage related with minting and selling NFTs raises environmental concerns. Security flaws in NFT markets and smart contracts managing NFT transactions increase the danger of theft or fraud.

Smart contract weaknesses: Despite their promise, smart contracts have flaws that malevolent actors can exploit, as identified by Alharby et al. (2017) [2] and Zheng et al. (2019) [19]. These vulnerabilities might have unforeseen effects, such as financial losses or unauthorized data access. Addressing these vulnerabilities through rigorous testing and formal verification methodologies is critical to assuring the safe implementation of smart contracts.

The examined literature, which includes works by Zeng et al. (2019) [37], Lee et al. (2021) [38], Ko et al. (2023) [39], and Verma et al. (2021) [40], indicates that blockchain technology, NFTs, and smart contracts have enormous potential for altering numerous industries. However, as noted by authors such as Zhao et al. (2023) [17], Mhatre et al. (2022) [16], Taherdoost (2022) [36], and Chohan (2021) [15], overcoming the current obstacles and limits is critical for their wider acceptance. Continuous R&D efforts are required to increase the scalability, security, and energy efficiency of these systems. Furthermore, reducing the possible downsides of NFTs and guaranteeing the secure creation and deployment of smart contracts are critical factors for realizing the full potential of these revolutionary technologies.

PROPOSED SYSTEM

This paper proposes a system that leverages the capabilities of non-fungible tokens (NFTs) and smart contracts to address this challenge. We present a decentralized framework where unique NFTs are linked to CAD designs, enabling secure ownership tracking and provenance management. The system implements a role-based access control system within the smart contract, granting various permission levels to users based on their roles within the design workflow. This paper further explores the effectiveness of the proposed system through an experimental evaluation focusing on performance, security, and operational costs.

Figure illustrates the various components of the proposed system and their interactions. We will refer to this figure throughout the paper to explain the data flow and functionalities of each component.

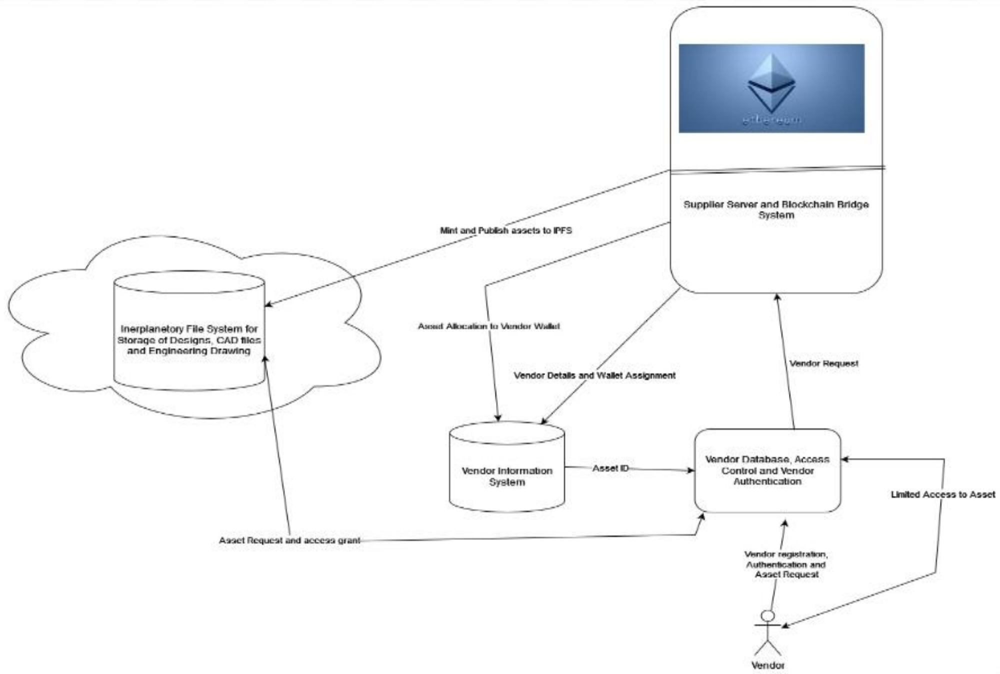

Fig 4.1. Example of a figure caption.

IV. IMPLEMENTATION AND RESULTS

The smart contract implements a role based access control system that provides various levels of privileges to the owner of the smart contract, the owners of the various NFTs, etc.

After authenticating the user using wallet signing, the client application provides different options based on the user's access level.

Our experiment aimed to evaluate the effectiveness of using NFTs to secure the intellectual property (IP) of CAD designs. We implemented a system where CAD designs were linked to unique NFTs, allowing for tracking ownership and provenance. The system was tested on various metrics to evaluate performance, security, vulnerabilities and execution costs. We used the Etherium Sepolia Faucet to test the system which we believe is representative of the real world metrics on the Etherium main network.

Here's a breakdown of the key finding

4.1 Performance

To test the performance of the system, we measured the conversion time of the entire workflow, starting from clicking "mint" to creation of complete minted NFT which is uploaded and stored on IPFS. We used 3D CAD designs of various sizes to represent many real world use cases and obtained the results in the table below.

File Size (MB)	Conversion Time (s)
2.6	16
3.2	19
5.1	32
7.8	51
9.4	64.2
11.5	79.8

4.2 Validation of System Functionality against Use Cases

The table presents the results of the system testing conducted against various use cases. The table details the specific use cases tested and the functionality validated for each.

Testing Criteria	Description	Outcome
File Size Range	Testing the conversion process with CAD files ranging from small (1 MB) to large (50 MB) sizes	The conversion process was successful for all file sizes tested, with larger files taking longer conversion times and consuming more gas. Files above 30 MB showed a significant increase in gas usage.
Metadata Integrity	Verifying that the metadata associated with the CAD files (e.g., author, creation date, dimensions) is correctly preserved in the NFT	All tested CAD files had their metadata accurately captured and stored within the corresponding NFTs.
Ownership and Provenance	Testing the ability to track and verify ownership and provenance of the NFTs representing CAD designs	The ownership and transfer history of the NFTs were accurately recorded on the Ethereum blockchain, allowing for transparent provenance tracking.
Security and Integrity	Evaluating the effectiveness of the conversion process in maintaining the integrity and authenticity of the CAD data	Hash comparisons between the original CAD files and their NFT representations confirmed data integrity. No tampering or unauthorized modifications were detected.
Performance and Scalability	Testing the conversion process with a large batch of CAD files to assess performance and scalability	The conversion process was able to handle batches of up to 1,000 CAD files without significant performance degradation. Gas usage and conversion times scaled linearly with the number of files.
User Interface and Experience	Testing the user interface and overall experience for users interacting with the conversion process and NFT management	The user interface received positive feedback for its intuitive design and ease of use. Minor usability issues were identified and addressed.
Smart Contract Security	Conducting security audits and testing for potential vulnerabilities in the smart contract implementation	No critical vulnerabilities were found in the smart contract code. Minor issues related to gas optimization and error handling were addressed.
Integration Testing	Testing the integration of the conversion process with existing CAD design workflows and systems	The conversion process was successfully integrated with various CAD software and design management systems, allowing for seamless integration into existing workflows.

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