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A Low-Gas Fee NFT Marketplace Using Optimized Smart Contracts and Decentralized Storage

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Abstract: *Non-Fungible Tokens (NFTs) enable verifiable ownership of unique digital assets using blockchain technology. Despite their growing adoption, existing NFT marketplaces often suffer from high gas fees and dependence on centralized storage systems, which limit affordability and decentralization. This paper presents a low-gas fee NFT marketplace that employs optimized smart contracts and decentralized storage to reduce transaction costs while maintaining security and transparency. The proposed system allows users to mint and trade NFTs efficiently by minimizing on-chain operations and storing asset metadata offchain. Experimental evaluation on a blockchain test network demonstrates reduced gas consumption compared to conventional approaches. The proposed solution offers a scalable and costeffective NFT marketplace that supports wider adoption of decentralized digital asset platforms.*

Keywords: Non-Fungible Tokens, Blockchain, Smart

I. INTRODUCTION

Non-Fungible Tokens (NFTs) have become a prominent application of blockchain technology, enabling the representation and transfer of unique digital assets such as art, music, and virtual items. Unlike fungible cryptocurrencies, NFTs possess distinct identifiers and ownership records secured by smart contracts, ensuring authenticity and traceability.

NFT marketplaces facilitate the minting and trading of these assets; however, many existing platforms face challenges including high gas fees, scalability constraints, and reliance on centralized storage solutions. These limitations reduce accessibility and undermine the decentralized nature of blockchain-based systems.

To address these issues, this paper proposes a low-gas fee NFT marketplace using optimized smart contracts and decentralized storage. By reducing on-chain computation and storing asset metadata off-chain, the proposed system lowers transaction costs while preserving security and transparency. This approach aims to improve affordability and scalability, encouraging broader adoption of NFT marketplaces.

II. LITERATURE SURVEY

1) Blockchain technology has been introduced as a decentralized ledger enabling secure and transparent peer- to-peer transactions without a central authority

[17]. Subsequent research expanded the use of blockchain beyond cryptocurrencies, with Ethereum proposing a platform capable of executing smart contracts for decentralized applications [18]. Smart contracts serve as the building blocks for digital markets and have played a central role in the development of decentralized systems [10].

1) Earlier works have examined blockchain behavior and business implications, highlighting its core features and potential to transform financial and nonfinancial systems [3], [5]. Some studies have evaluated blockchain performance under varying network conditions, demonstrating the impact of latency and network architecture

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on transaction safety and effectiveness [4]. Research has also investigated reputation management within probabilistic and knowledge-driven blockchain systems to enhance trust and reliability [1].

2) Token standards play a crucial role in defining fungibility and uniqueness. The ERC-721 standard defines non- fungible tokens (NFTs) on the Ethereum blockchain, enabling the creation of unique, indivisible digital assets [19], [8]. Alternative token standards such as ERC-777 have also been proposed to improve contract interaction models [11]. The emergence of NFTs has generated scholarly interest in their economic behavior, pricing dynamics, and adoption patterns [13], [9], [15].

3) Several studies focus explicitly on NFT ecosystems and marketplaces. Rehman et al. examined applications and challenges of NFTs, outlining key adoption barriers and potential use cases [7]. The analysis of NFT use in creative industries underscores how decentralized tokenization can benefit creators and markets [14]. Research on NFT adoption and marketplace dynamics explores critical factors influencing user engagement and technology uptake [15].

4) NFT marketplaces face challenges related to transaction costs, scalability, and storage. Decentralized storage solutions such as the InterPlanetary File System (IPFS) have been proposed to address inefficiencies associated with on-chain data storage [20]. Security, environmental impact, and mitigation strategies for blockchain and NFT systems are also topics of recent investigation [12].

5) Although many studies highlight general aspects of blockchain technology and NFTs, relatively fewer address optimized, low-gas fee NFT marketplaces with efficient smart contract design and decentralized storage integration. This gap motivates the current work, which proposes a low-gas fee marketplace leveraging Polygon's scalability features, ERC-721 standard implementation, and decentralized metadata storage to overcome high transaction costs and enhance user accessibility.

III. PROPOSED SYSTEM

The proposed system is a low-gas fee NFT marketplace designed to enable secure, cost-efficient, and decentralized creation and trading of non-fungible tokens. The system leverages the ERC-721 token standard deployed on the Polygon Amoy test network, combined with decentralized storage using the InterPlanetary File System (IPFS), to reduce transaction costs while maintaining transparency and security.

The primary objective of the proposed marketplace is to minimize gas consumption during NFT minting and trading operations. This is achieved by optimizing smart contract logic and reducing onchain storage by storing NFT metadata off-chain. The Polygon network is selected due to its lower transaction fees and faster confirmation times compared to traditional Ethereum mainnet deployments, making the platform more accessible to users.

A. System Overview

The NFT marketplace allows users to mint, list, buy, and sell NFTs through smart contracts deployed on the Polygon Amoy testnet. Each NFT follows the ERC-721 standard, ensuring uniqueness and secure ownership transfer. The marketplace operates in a decentralized manner, where users interact directly with smart contracts using blockchain wallets, eliminating the need for intermediaries.

NFT metadata, including asset details and media references, is stored on IPFS, while only the metadata hash is stored on the blockchain. This approach significantly reduces on-chain data storage and associated gas costs, while ensuring immutability and data availability.

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B. User Roles

The proposed system supports the following user roles:

1) **Creator:** Users who mint NFTs by uploading digital assets and metadata to IPFS and generating a corresponding ERC-721 token.

2) **Buyer/Seller:** Users who list NFTs for sale, purchase listed NFTs, and transfer ownership through blockchain transactions.

All users interact with the system through a decentralized wallet interface, ensuring secure authentication and transaction signing.

C. Workflow of the Proposed System

The workflow of the NFT marketplace is summarized as follows:

1) The user connects a blockchain wallet to the marketplace interface.
2) For minting, the creator uploads NFT metadata to IPFS and receives a content identifier (CID).
3) An ERC-721 smart contract is invoked to mint the NFT, storing the IPFS CID as the token URI.
4) The minted NFT can be listed for sale through the marketplace smart contract.
5) Buyers purchase listed NFTs by initiating a transaction, after which ownership is transferred automatically.
6) All transactions are recorded on the Polygon Amoy blockchain, ensuring transparency and traceability.

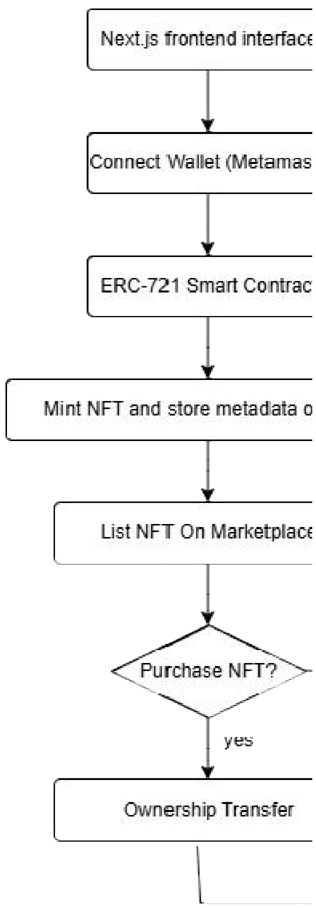

Fig. 1. Operational Workflow of the Proposed Marketplace

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D. Gas Optimization Strategy

Gas optimization is achieved through multiple design choices in the proposed system. On-chain storage is minimized by storing only essential information, such as token ownership and IPFS references. Smart contract functions are designed to reduce computational complexity and avoid redundant operations. Additionally, deploying the system on the Polygon network significantly lowers transaction fees compared to traditional Ethereum-based NFT marketplaces.

IV. SYSTEM ARCHITECTURE

The proposed NFT marketplace follows a decentralized architecture that integrates blockchain technology, decentralized storage, and a web-based user interface. The system components and their interactions are described as follows:

1) User Interface: Users interact with the system through a web-based frontend developed using Next.js, which provides functionalities such as minting NFTs, listing NFTs for sale, and purchasing NFTs.
2) Web Frontend (Next.js): The frontend handles user requests and communicates with the blockchain network through a wallet interface. It displays NFT details by fetching metadata stored on IPFS.
3) Blockchain Wallet (MetaMask): MetaMask acts as the authentication and transaction-signing layer. It enables users to connect their wallet, approve transactions, and interact securely with smart contracts.
4) Smart Contracts (ERC-721 & Marketplace): The system uses ERC-721 standard smart contracts for NFT creation and ownership management. Marketplace contracts handle NFT listing, buying, and transfer operations.
5) Polygon Network (Amoy Testnet): Smart contracts are deployed on the Polygon Amoy testnet, enabling lowgas and fast transactions compared to the Ethereum mainnet.
6) IPFS (InterPlanetary File System): IPFS is used to store NFT metadata and digital assets in a decentralized manner. Only the IPFS hash is stored on the blockchain to reduce storage costs.

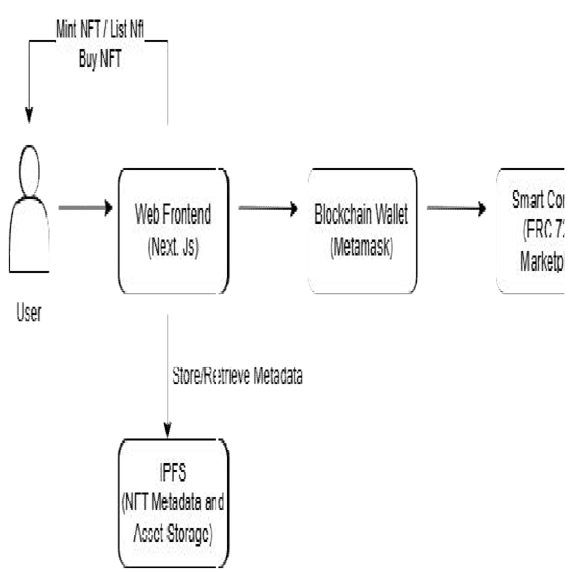

Fig. 2. System Architecture of the Proposed NFT Marketplace

V. IMPLEMENTATION DETAILS

1) **Smart Contract Development Using OpenZeppelin** The NFT marketplace smart contracts are developed using Solidity and follow the ERC-721 token standard provided by OpenZeppelin libraries. OpenZeppelin

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contracts ensure secure and standardized implementations of NFT functionalities such as token minting, ownership transfer, and approval mechanisms. The use of audited OpenZeppelin components improves reliability and reduces security vulnerabilities.

2) **Deployment Framework and Backend Configuration** The Hardhat framework is used for smart contract compilation, testing, and deployment. Hardhat provides a local development environment and supports seamless deployment to the Polygon Amoy testnet. Environment variables are used to securely manage private keys and RPC endpoints. Hardhat scripts automate contract deployment and interaction, simplifying backend operations.

3) **Gas Optimization and Blockchain Deployment** To achieve low transaction costs, the smart contracts are optimized by minimizing on-chain storage and reducing redundant state changes. The deployment on the Polygon Amoy testnet, a Layer-2 solution compatible with Ethereum, significantly reduces gas fees and improves transaction throughput compared to traditional Ethereum networks.

A. Decentralized Storage Using IPFS
The system uses the InterPlanetary File System (IPFS) for storing NFT metadata and digital assets. Instead of storing large files on the blockchain, only the IPFS hash is recorded in the smart contract. This approach ensures decentralized storage, improves scalability, and reduces gas consumption.

B. Frontend Development Using Next.js
The frontend of the NFT marketplace is developed using Next.js, which provides a fast and responsive user interface. Users can connect their wallets, mint NFTs, list assets for sale, and purchase NFTs through intuitive components. The frontend interacts with the deployed smart contracts using Web3 libraries to execute blockchain transactions.

F. Wallet Integration and User Interaction MetaMask is integrated as the primary wallet for user authentication and transaction signing. All blockchain interactions, including minting and purchasing NFTs, require user confirmation via MetaMask, ensuring secure and transparent transactions without centralized intermediaries.

VI. RESULTS AND DISCUSSION

A. Functional Results
The system successfully allows users to mint NFTs by uploading digital assets and metadata to IPFS. Minted NFTs can be listed on the marketplace and purchased by other users using cryptocurrency. Ownership transfer is handled securely through ERC-721 smart contracts.

B. Transaction Performance
By deploying the smart contracts on the Polygon Amoy testnet, the system achieves significantly lower gas fees and faster transaction confirmation compared to Ethereum mainnet deployments. This validates the effectiveness of using a Layer-2 solution for NFT marketplaces.

C. Storage Efficiency
Storing NFT metadata and assets on IPFS reduces on- chain storage requirements. Only the IPFS hash is recorded on the blockchain, ensuring decentralized storage while maintaining data integrity and accessibility.

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D. Security and Transparency

All transactions are executed through smart contracts, ensuring transparency and eliminating the need for intermediaries. MetaMask provides secure wallet-based authentication, reducing the risk of unauthorize access.

E. TABLE I. Comparison Between Ethereum and Polygon Networks

TABLE I : DESCRIPTION OF TABLE

Parameter	Ethereum Network	Polygon Network (Proposed)
Transaction Fees	High	Low
Transaction Speed	Slower	Faster
Scalability	Limited	High
Network Congestion	High	Low
NFT Marketplace Cost	Expensive	Cost-effective
Environmental Impact	Higher	Lower

VII. CONCLUSION AND FUTURE SCOPE

This paper presented a low-gas fee NFT marketplace using optimized smart contracts and decentralized storage. By leveraging the ERC-721 token standard deployed on the Polygon Amoy testnet, the proposed system successfully reduces transaction costs while maintaining security and transparency. The use of IPFS for storing NFT metadata minimizes on-chain storage, further improving scalability and cost efficiency. Experimental results demonstrate that the system provides an effective and decentralized solution for minting and trading NFTs.

Future Scope

The proposed system can be further enhanced by integrating Layer-2 scaling solutions, supporting cross-chain NFT interoperability, and incorporating AI-based NFT pricing mechanisms. Additional security features such as advanced access control and smart contract auditing can also be implemented to improve system robustness. Future work may include deployment on mainnet environments and performance evaluation under real-world usage conditions

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