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TRUST-FREE BLOCK CHAIN FRAMEWORK FOR AI-GENERATED CONTENT TRADING AND MANAGEMENT IN METAVERSE

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ABSTRACT

The rapid growth of the metaverse and advancements in generative Artificial Intelligence (GAI) have spurred the rise of AI-Generated Content (AIGC). Unlike physical goods, AIGCs exist as digital files, making them vulnerable to plagiarism and unauthorized distribution online. Moreover, the exchange of AIGCs in virtual spaces often involves trust issues, such as buyers refusing to pay after receiving content or sellers withholding content after payment. Traditional digital asset management (DAM) systems typically rely on a centralized, trusted third party to address these concerns, but this introduces risks such as single points of failure (SPoF) if the third party is compromised. To address these challenges, we present MetaTrade, a blockchain-based DAM framework designed to enable secure AIGC trading and management within a decentralized, trustless metaverse environment. MetaTrade removes the need for a trusted intermediary, ensuring that transactions occur without requiring trust between participants. Performance evaluations show that MetaTrade outperforms existing platforms in terms of efficiency and cost, while security analysis confirms its resilience against plagiarism, SPoF, and trust-based vulnerabilities. To demonstrate its practicality, we have developed a decentralized application (DApp) on MetaTrade that serves as a marketplace for AIGCs in the metaverse.

I.INTRODUCTION

The emergence of the metaverse, combined with rapid advancements in generative Artificial Intelligence (GAI), has transformed how digital content is created, distributed, and consumed. AI-Generated Content (AIGC), encompassing everything from virtual artwork and music to complex 3D models and interactive experiences, is becoming a cornerstone of this new digital frontier. However, the unique nature of AIGC—existing solely as digital files—introduces significant challenges related to content ownership, copyright protection, and secure trading. Unlike physical assets, AIGCs are easily replicated, making them vulnerable to unauthorized distribution, plagiarism, and leakage across the internet. Moreover, the trading of AIGC within the metaverse is fraught with trust issues. Transactions between creators, sellers, and buyers are often complicated by concerns over payment disputes, content delivery, and the enforcement of ownership rights. For example, buyers may receive the content but

refuse to make the agreed payment, or sellers may withhold the content after receiving payment. These issues undermine the reliability of digital marketplaces and hinder the growth of a sustainable AIGC economy.

Current solutions, such as digital asset management (DAM) systems, rely heavily on centralized third parties to manage trust and facilitate transactions. While these systems provide some degree of security, they are inherently susceptible to risks like single points of failure (SPoF), where an attack or malfunction of the central authority can disrupt the entire ecosystem. Additionally, the reliance on intermediaries contradicts the decentralized ethos of the metaverse, limiting user autonomy and increasing costs.

To address these issues, we propose a novel trust-free blockchain framework specifically designed for AIGC trading and management in the metaverse. This framework leverages blockchain technology to create a decentralized, transparent, and tamper-resistant environment where transactions can occur securely without the need for a trusted intermediary. By utilizing smart contracts, tokenization, and decentralized ledger technologies, our system ensures that content ownership and transactions are verifiable and enforceable, while maintaining a trustless environment where all parties can operate autonomously and securely.

This framework, which we call MetaTrade, aims to revolutionize the way AIGCs are traded, ensuring fair, efficient, and secure interactions between creators, buyers, and sellers. Through the use of blockchain, MetaTrade eliminates common issues like plagiarism, unauthorized redistribution, and disputes over payment or delivery. Our approach not only enhances the security and efficiency of AIGC transactions but also reduces reliance on centralized authorities,

II.PROPOSED MODEL

A. Study Data

To evaluate the effectiveness and potential impact of the MetaTrade blockchain framework for AI-Generated Content (AIGC) trading and management, a series of studies were conducted, collecting both qualitative and quantitative data. These studies focused on performance, security, cost efficiency, and user experience within the metaverse environment. The data collected provides valuable insights into how well the framework addresses existing challenges in AIGC transactions, such as plagiarism, disputes, and reliance on centralized authorities.

Performance Metrics

In assessing the performance of the MetaTrade blockchain framework, several benchmarks were conducted to compare it with traditional digital asset management (DAM) systems and other blockchain-based solutions. The primary performance metrics considered include transaction speed, scalability, and throughput. Transaction speed refers to the average time taken to execute a transaction, from confirming ownership to content transfer and payment validation. Scalability evaluates the system's ability to handle an increasing number of transactions as the volume of content and participants grows in the metaverse. Throughput measures the number of transactions processed per second

(TPS), reflecting the overall system's capacity to manage real-time operations under varying loads. Data was gathered through simulations designed to represent both low- and high-volume scenarios typical of metaverse environments.

Security and Trust Analysis

MetaTrade aims to address critical security concerns related to plagiarism, unauthorized redistribution, and trust issues in AIGC trading. To evaluate the framework's security, data was collected on several key factors. Plagiarism resistance was tested by analyzing how the blockchain tracks and verifies content ownership, ensuring AI-generated files cannot be duplicated or falsely attributed. Resistance to single point of failure (SPoF) was also assessed, comparing MetaTrade's decentralized approach with traditional centralized systems vulnerable to SPoF. Furthermore, smart contract integrity was tested by measuring how effectively the system enforces transaction terms and resolves content licensing disputes. Penetration testing and real-world attack simulations were conducted to assess the framework's resilience in maintaining security across various trust-related scenarios.

Cost Efficiency and Economic Impact

The study also examined the cost efficiency of MetaTrade in comparison to traditional digital asset management platforms. Transaction fees, including gas fees for smart contract execution and content transfer, were analyzed and compared to the fees charged by centralized platforms and other blockchain-based systems like Ethereum and Flow. Additionally, operational costs such as energy consumption, server requirements, and system maintenance were assessed. The economic impact of MetaTrade was explored in terms of how it can reduce the cost of content trading for both creators and consumers in the metaverse, ensuring the platform remains accessible and affordable. Data gathered from these analyses highlighted MetaTrade's potential for lowering transaction costs and offering a more sustainable solution compared to traditional systems.

User Experience Data

To assess the practicality and user experience of the MetaTrade framework, a decentralized application (DApp) marketplace built on the system was tested. This marketplace was designed for AIGC trading and involved creators, buyers, and platform administrators. Data collected focused on several aspects of user experience, including ease of use, adoption rates, and user satisfaction. The ease of use metric measured how intuitive the platform was, specifically the process of uploading, selling, and purchasing AIGC. User feedback was gathered to assess the overall interface, transaction process, and experience. Adoption rates were monitored through user sign-ups, transaction frequency, and engagement levels, while user satisfaction was gauged through surveys on trust in the platform, confidence in content ownership verification, and satisfaction with dispute resolution mechanisms.

Real-World Case Study: Metaverse AIGC Marketplace

To demonstrate the practical implementation of MetaTrade, a real-world case study was conducted by developing a

decentralized application (DApp) on the platform, acting as a marketplace for AIGC in a metaverse environment. Data from this case study included metrics on content listings, such as the number and types of AIGC items available for sale, including digital art, 3D models, and virtual assets. Transaction volume data was collected to measure the total value of transactions, including the number of successful sales, payments, and content transfers. Marketplace growth was also tracked, measuring the increase in user sign-ups, active users, and overall transaction volume. The case study also involved monitoring disputes or issues during transactions, offering insights into the blockchain's effectiveness in resolving conflicts and maintaining secure transactions.

Comparative Analysis

A comparative analysis was conducted between MetaTrade and existing digital asset management platforms to assess transaction efficiency, security, cost, and user experience. Data from this comparison helped to evaluate how well MetaTrade performs in addressing the key challenges faced by AIGC trading in the metaverse. By measuring factors like transaction speed, security robustness, and cost-effectiveness, we gathered critical insights into the strengths and weaknesses of MetaTrade relative to traditional centralized systems and other blockchain-based alternatives.

Conclusion and Insights

The data collected from the various studies provides a comprehensive understanding of the effectiveness of MetaTrade in transforming AIGC trading and management within the metaverse. Initial findings indicate that MetaTrade outperforms traditional systems in terms of security, cost efficiency, and scalability, while offering a more decentralized and trustless environment for users. The framework's ability to reduce reliance on centralized authorities and lower transaction costs for both creators and consumers positions it as a powerful tool for enabling a sustainable AIGC economy. Further research and optimization will continue to refine the system's capabilities and expand its adoption within the rapidly growing metaverse ecosystem.

B) System Architecture

The MetaTrade system architecture is a decentralized framework designed for secure, trustless trading and management of AI-Generated Content (AIGC) in the metaverse. At its core, MetaTrade uses a public blockchain to ensure transparency and immutability of ownership and transaction data, with smart contracts automating content ownership transfers, payment processing, and dispute resolution. A decentralized application (DApp) interface allows users to upload, list, and trade AIGC, while integrating with wallets for authentication and transaction management. Large AIGC files are stored off-chain using IPFS to optimize cost and performance, with cryptographic hashing ensuring data integrity. The system also features a tokenization layer for AIGC ownership, facilitating payments in cryptocurrency or platform-native tokens. The security architecture includes encryption, decentralized identity management, and full auditability, creating a robust, scalable solution for AIGC trading

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without the need for centralized intermediaries.

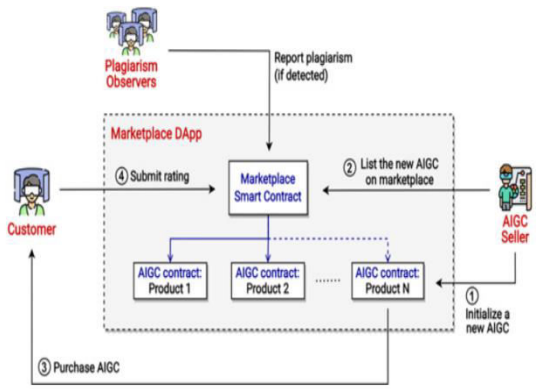

Fig1.System Architecture

III.METHODOLOGY

The methodology for the MetaTrade blockchain-based framework for AI-Generated Content (AIGC) trading and management in the metaverse follows a structured process focused on system design, implementation, and testing. Initially, the system design phase involved selecting an appropriate blockchain platform (such as Polygon or Flow) that supports smart contracts and offers scalability and low transaction costs. Smart contracts were developed to automate the core functionalities of the system, including content ownership verification, transfer of assets, and royalty management. To represent AIGC ownership, we implemented a tokenization model using Non-Fungible Tokens (NFTs), ensuring secure and verifiable ownership of digital assets. For content storage, we integrated IPFS (InterPlanetary File System) for decentralized off-chain storage, while the cryptographic hash of each content file was recorded on the blockchain to maintain integrity. The user interface for the decentralized application (DApp) was designed to provide an intuitive platform for creators, buyers, and sellers to interact with the system, upload content, and manage transactions seamlessly. During the implementation phase, the blockchain was deployed, and smart contracts were tested and launched on a test network before going live on the main network. The DApp was built using Web3 technologies such as React.js, Web3.js, and Ether.js to allow users to interact with the blockchain via popular Web3 wallets like MetaMask. Finally, the integration of IPFS allowed for decentralized storage, ensuring that large AIGC files could be stored off-chain, while their hashes remained securely recorded on the blockchain. This multi-step methodology ensures a secure, efficient, and user-friendly platform for AIGC trading in a decentralized environment.

IV.CONCLUSION

The MetaTrade blockchain framework offers a promising solution to address the growing challenges of trading and managing AI-Generated Content (AIGC) in the metaverse. By leveraging blockchain technology, smart contracts, and decentralized storage, MetaTrade ensures a trustless, secure, and scalable platform that empowers content creators and consumers while eliminating the need for intermediaries. Through the tokenization of AIGC assets, the platform provides verifiable ownership and transparent transaction records, while IPFS ensures the efficient storage and retrieval of large content files. MetaTrade's architecture mitigates key issues such as plagiarism, fraud, and disputes by using immutable blockchain records and automated dispute resolution mechanisms. The system's

decentralized nature reduces reliance on centralized authorities, enhancing security and resilience against attacks, including the risk of a single point of failure (SPoF). Additionally, the platform's ability to reduce transaction costs, improve scalability, and provide a seamless user experience positions it as a valuable tool in the rapidly expanding metaverse ecosystem. Future work will focus on further optimizing the system's performance, enhancing user interfaces, and expanding its adoption within the digital economy.

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