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ABSTRACT

The music industry faces numerous challenges regarding tracking and distributing royalties. This article explores how a decentralized and transparent system for managing music royalties can be created with a smart contract implementation on the Polygon network, utilizing Chainlink oracles. By enhancing the efficiency and transparency of royalty distribution, this groundbreaking smart contract has the potential to revolutionize the music industry and stand as a blueprint for diverse sectors grappling with analogous challenges in intellectual property rights and revenue allocation. At its core, this smart contract, functioning on the bedrock of blockchain, ensures meticulous oversight of financial transactions between consumers and content creators. It streamlines the process and facilitates the collection of user view statistics crucial for strategic fund allocation. With the potential impact of transaction fees on the user experience of blockchain payments, a new solution has been developed that includes a payment channel that reserves significant amounts of funds and enables off-chain payments through specialized messages. By combining these technological advancements, we are taking a transformative step towards a more seamless and fair future in the complex world of royalty management. The application is structured into conventional backend and frontend segments, with the code available on Github.

CCS CONCEPTS

• **Information systems** → **Data management systems**; • **Computer systems organization** → **Peer-to-peer architectures**.

KEYWORDS

Blockchain, Decentralization, Digital Rights, Royalties, Smart Contracts, Web3

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1 INTRODUCTION

Digital Rights Management (DRM) is a systematic approach to safeguard and manage the intellectual property rights of digital content [7]. It can regulate the distribution, access, and use of digital materials such as music, videos, eBooks, and software [18]. DRM mechanisms typically involve encryption, licensing, and access control technologies, which ensure that only authorized users can utilize them in specific ways defined by the copyright owner or publisher [26, 33]. The music industry uses digital rights management due to its complex environment and ongoing issues with tracking and distributing royalties [4, 12, 13]. The digital revolution and shift to streaming services have hit the industry hard, making compensating artists and rights holders reasonably difficult [17]. Thus, DRM can be an essential tool for the music industry to protect its content and ensure that artists are paid fairly.

The music industry stands to streamline its operations, enhance transparency, and optimize royalties management by integrating blockchain technology and smart contracts [25, 30]. Moreover, the application of Web3 digital rights management in the music sector serves as an instructive model for other creative industries grappling with analogous challenges, potentially heralding the expanded adoption of these innovative technologies [15, 28, 29]. The music industry, renowned for its intricate landscape and persistent issues concerning royalty tracking and disbursement, is a quintessential subject for studying Web3 digital rights management. As a central player in the creative economy, the music industry has confronted significant upheaval brought about by the digital revolution and the surge in streaming services, resulting in a complex landscape for justly compensating artists and rights holders. Focusing on the music industry allows us to demonstrate the potential of Web3 technologies in providing practical solutions.

Blockchain technology first emerged with Bitcoin and has since transformed industries beyond digital currencies [27, 37]. Its immutable and transparent nature makes it useful in various sectors, revolutionizing supply chain management, healthcare data security, finance, and more [20–23]. In these industries, it ensures

trust and safety by enabling tamper-proof record-keeping and efficient, transparent transactions. In 2015, Ethereum was introduced, a decentralized, open-source blockchain platform renowned for supporting smart contracts [5]. Smart contracts are self-executing code-based agreements that run on the Ethereum blockchain, enabling decentralized applications with automated and trustless contract enforcement [32]. Blockchain and smart contracts simplify procedures, increase transparency, and improve the efficiency of royalty management. Smart contracts in the blockchain space have evolved with milestones like ERC-20 and NFTs [10, 36]. ERC-20 standardized fungible token contracts on Ethereum, while NFTs introduced indivisible tokens on the blockchain, representing ownership and authenticity of digital assets, especially in digital art and collectibles. Implementing Web3 digital rights management in the music sector can provide valuable insights for other creative domains facing similar challenges, paving the way for broader use of these transformative technologies.

The music industry has faced significant transformations over the past few decades, driven by rapid technological advancements and consumer behavior changes. In the late 20th century, the industry was dominated by physical formats such as vinyl records, cassette tapes, and compact discs. The revenue generated from these formats relied on sales and distribution channels controlled by major record labels. These traditional business models focused primarily on producing, marketing, and selling recorded music, with artists receiving a share of the revenue based on their contracts [3, 24].

Blockchain technology can greatly impact the music industry by addressing challenges in tracking and distributing royalties [31]. Its decentralized structure and automated processes streamline royalty management, reducing intermediaries and manual interventions.

The paper is structured into different sections, each addressing a specific aspect of the research. Section 2 introduces the problem statement that this article aims to address. Section 3 provides an overview of the existing work in this field. The subsequent section, Section 4, demonstrates a proof-of-concept authorization site to showcase the practical application of the developed framework. Finally, the conclusion (Section 5) summarizes the research results and explores potential directions for using the framework in various contexts.

2 PROBLEM STATEMENT

As the music industry continues to evolve, it needs more efficient and transparent systems for tracking and distributing royalties to ensure fair compensation for artists and rights holders. The Association For Electronic Music Research said that about £100m was assigned to the wrong artists annually [9]. This article explores blockchain technology's potential as a solution to these challenges.

The music industry faces several challenges in tracking and distributing royalties that artists, rights holders, and the industry as a whole must contend with [11, 14, 35]:

- **Fragmented Ecosystem:** The music industry comprises numerous stakeholders, including artists, composers, producers, publishers, record labels, and collection societies, each with their interests and rights.
- **Inefficient Systems:** Traditional systems for royalty management are often slow and hard to use, relying on manual processes and intermediaries to collect, process, and distribute payments.
- **Lack of Transparency:** The current royalty allocation process is often not transparent, and information on how royalties are calculated, collected, and distributed is limited.
- **Data Inconsistencies:** Accurate music plays and stream tracking require consistent, standardized metadata across platforms and services. However, song titles, artist names, and other metadata discrepancies may result in misattribution or missed royalty payments.
- **Piracy:** Despite the rise of legal streaming services, piracy continues to be a major problem for the music industry. Illicit downloads and streaming can disrupt artists' income streams.

The music industry faces challenges tracking and distributing royalties, but blockchain technology can offer a solution [31]. Its decentralized structure and automated processes help streamline royalty management, reducing intermediaries and manual interventions. By securing data and minimizing discrepancies in royalty distributions, blockchain technology simplifies licensing rights management and protects against piracy. It also improves accuracy and efficiency in royalty distribution, transparency, and overall industry efficiency. However, before implementing this technology, one must carefully consider the technical specifications and business implications.

The primary goal of this work is to design and implement a Web3 digital rights management system, with a focus on the music industry, to address the challenges outlined above.

3 LITERATURE REVIEW

This section examines the literature review, identifying gaps and evaluating the current state of the field.

Ciriello et al. [6] investigate the challenges of managing digital rights in the music industry and propose design principles for decentralized DRM systems that use blockchain technology. The study examines the complications of music royalty management and identifies necessary design requirements. It presents an optimistic outlook on how blockchain-based solutions can address these challenges. The research suggests developing transparent music licensing structures, keeping comprehensive rights metadata, and implementing efficient and transparent royalty distribution. The proposed architecture stores rights data on a publicly distributed ledger, validates metadata through a consensus mechanism and enforces royalties via smart contracts. Thus providing a more equitable and efficient DRM system. The design principles presented in this study offer guidance for DRM system development and can be applied beyond the music industry. This research aims to inspire future initiatives in the field of decentralized DRM systems, providing an essential foundation for this transformative endeavor.

Zhaofeng Ma et al. [19] suggested an application that addresses digital rights control issues through two distinct parts: an interface for storing metadata about content and a service that uses this information to protect rights. However, the project required the development of two separate blockchain systems - DRMChain and

RightChain - to function properly. This work aims to improve the user experience by working with existing systems, allowing the use of existing payment instruments and infrastructure to interact with the blockchain. Additionally, the authors have created a distributed content storage system, which is a clear advantage and direction for the development of this work.

Kishigami et al. [16] focuses more on the safe content distribution. The authors have constructed a blockchain and an identification system similar to Bitcoin but without the capability to accept payments and generate rewards. The researchers claim that the content itself can be used as a reward to maintain the network, but for the most part, they do not address this issue in their work. However, using a specialized network without proof of its stability may entail risks of successful attacks, discouraging creators from posting content on the platform.

ContentBox [8] is an infrastructure project aimed at creating payment instruments for direct interaction between creators and consumers of content. The project's specifics make it possible to integrate this system only with existing media spaces, which can become a bottleneck in the security and integrity of the entire system.

One of this field's most popular and used products is Theta [34]. It is a separate blockchain compatible with Ethereum, aimed at creating media platforms. Unlike Content Box, it has a separate layer that allows you to store and deliver content. However, again, this service provides infrastructure rather than a full-fledged solution.

The rest of the solutions on the market are either tailored to a separate area (original movies, music) or are separate blockchains with a poorly described scheme of operation and maintaining consensus in the system. Also, there is a reward scheme for network creators and investors in many such projects. This work is planned to reward only content creators and node owners who ensure data delivery to the client.

4 IMPLEMENTATION

This section outlines the development of an application to facilitate DRM through blockchain technology.

4.1 Song Registration

Registering songs on the blockchain is crucial in creating a transparent, efficient, decentralized music royalty distribution system. Here are three approaches that can be followed to implement this:

4.1.1 Approach 1: Decentralized File Storage. One approach involves storing the song metadata and ownership information on decentralized file storage systems like IPFS [1]. This method ensures data permanence and reduces the risk of data loss or tampering. However, it requires additional integration with the blockchain platform to ensure the proper functioning of the royalty distribution system. The core principle of IPFS is shown in Figure 1.

4.1.2 Approach 2: On-Chain Metadata Storage. Another approach is to store song metadata and ownership information directly on the blockchain using smart contracts. This method offers a high level of security and transparency, but it may lead to higher transaction costs and reduced scalability due to the increased amount of data stored on-chain.

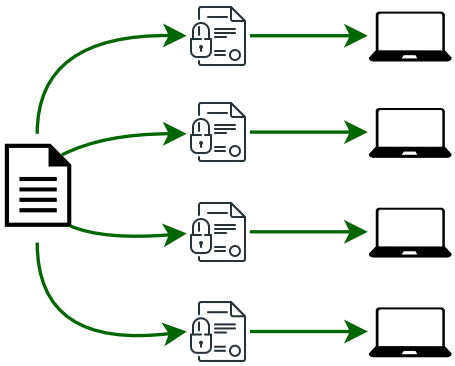

Figure 1: IPFS for Registering Songs on the Blockchain. File uploaded on decentralized storage, File split into parts and encrypted, and File stored on multiple nodes in different locations

4.1.3 Approach 3: Off-Chain Metadata Storage with On-Chain Hashes. A hybrid approach involves storing the song metadata and ownership information off-chain while storing a cryptographic hash of the data on the blockchain. This method combines the benefits of off-chain storage (reduced costs and improved scalability) with the security and immutability provided by the on-chain hash.

The third approach balances security, transparency, and efficiency, ensuring the royalty distribution system remains cost-effective and scalable without compromising the integrity and authenticity of the song metadata and ownership information. By implementing Off-Chain Metadata Storage with On-Chain Hashes using Polygon, we can leverage its compatibility with Ethereum's ecosystem and benefit from its improved performance and lower fees.

The next steps involve developing a comprehensive solution for off-chain storage and integration with the on-chain hashes and designing a user-friendly interface for artists and rights holders to register their songs and manage their royalties.

4.2 Monitoring Song Plays

Accurate monitoring of song plays is essential for ensuring that artists and rights holders receive their fair share of royalties from streaming services. This section explores different approaches for monitoring song plays and chooses the best approach for the use case.

4.2.1 Approach 1: On-Chain Play Count Storage. We can store the play count of each song directly on the blockchain through smart contracts. This method provides high transparency and security, as the play count is updated in real-time and tamper-resistant. However, this approach may lead to increased transaction costs and reduced scalability due to the frequency of updates required for each song play.

4.2.2 Approach 2: Off-Chain Play Count Storage with Periodic On-Chain Updates. Another approach is to store the play count off-chain on a centralized or decentralized database, with periodic updates to the blockchain through smart contracts. This method can reduce transaction costs and improve scalability by minimizing

the frequency of on-chain updates. However, it may introduce the risk of data manipulation or inaccuracies in the off-chain database.

4.2.3 Approach 3: Oracle-Based Play Count Monitoring. The third approach is to use oracles, trusted third-party services that provide real-world data to the blockchain (Figure 2). In this case, the oracles would monitor song plays from various streaming services and securely transmit the data to the smart contracts on the blockchain. This method balances transparency and efficiency, as the oracles can aggregate and verify play counts before submitting them to the blockchain.

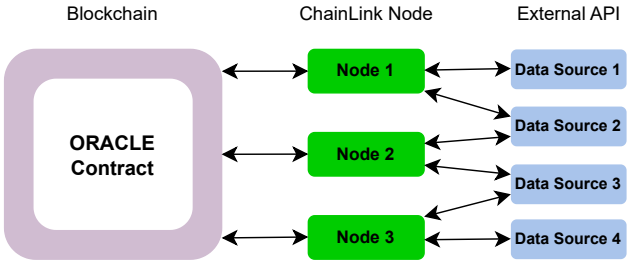

Figure 2: Chainlink Oracle solution for Monitoring Song Plays.

The oracle-based approach combines the benefits of transparency and security provided by the blockchain with the efficiency of off-chain data aggregation and verification by trusted oracles, which is the best option for our case. The most used Oracle solution is Chainlink; therefore, we adapt it to monitor song plays across various streaming services and integrate it with the smart contracts responsible for royalty distribution.

4.3 Calculation and Distribution Royalties

Calculating and distributing royalties are essential in ensuring that artists and rights holders receive their fair share of revenue from streaming services.

4.3.1 Method 1: Static Royalty Distribution Model. We can implement a static royalty distribution model in the smart contract, where predefined percentages are allocated to various stakeholders (e.g., artists, producers, and record labels) based on the revenue generated from song plays. This method offers simplicity and predictability but lacks flexibility and may not accurately reflect the agreements between the involved parties.

4.3.2 Method 2: Dynamic Royalty Distribution Model. Another method is to implement a dynamic royalty distribution model in the smart contract, where the rights holders can update the royalty distribution percentages based on their agreements. This method offers more flexibility and can better represent the actual agreements. Still, it may introduce the smart contract's complexities and require additional security measures to prevent unauthorized updates.

4.3.3 Method 3: Tokenized Royalty Distribution Model. The last method involves tokenizing the royalty distribution process, where rights holders receive tokens representing their share of the song's revenue. These tokens can be traded, sold, or redeemed for the corresponding share of the revenue generated from song plays. This method offers flexibility, transparency, and the potential for secondary market opportunities, but it may introduce additional complexities in token management and regulatory compliance, especially if the tokens are considered securities by regulatory bodies. It also has some security concerns–introducing could create additional security risks, such as the potential for hacking or theft of tokens.

The second method (Dynamic Royalty Distribution Model) balances simplicity, flexibility, and accuracy, ensuring that royalty distributions reflect the actual agreements between artists, producers, and record labels while remaining manageable and efficient so that it will be the preferable one.

4.4 Smart Contract Specification

In this section, we will outline the specifications for the proposed smart contract. These specifications provide a detailed view of the functional and non-functional requirements for the smart contract, giving us a roadmap for its development. The aim is to design a contract that ensures secure registration of songs, accurately monitors song plays, and handles the calculation and distribution of royalties efficiently and transparently.

The outlined specifications delineate the features, functionalities, and considerations for our Music Royalties Smart Contract. We have detailed necessary features such as song registration, royalty calculation, distribution, and licensing management. The smart contract design has been systematically structured around the notions of songs and licenses, with every pertinent detail captured, including stakeholder shares, license duration, and more. The functions encapsulate essential operations, from registering songs to distributing royalties and handling licenses.

Particular attention has been paid to the secure execution of transactions, with checks incorporated for parameter validation and the existence of songs and licenses. Furthermore, the issue of gas cost optimization has been addressed with a batch distribution functionality that significantly reduces transaction costs.

The dependencies have been judiciously chosen to facilitate Oracle-based play count monitoring and ERC20 token support. All these aspects collectively embody a detailed and comprehensive specification for a smart contract that serves the complex requirements of music royalty management. With this blueprint, we are now equipped to develop the solidity code for the Smart Contract.

The application code is available in Github [2].

4.5 Result and Discussion

During the testing phase, we conducted a series of tests using Hardhat, a blockchain framework, to measure the gas consumption and transaction costs of various functions and for registering a song with different metadata sizes and numbers of stakeholders. The results of these tests are outlined in Figures 3 and 4.

From the data above, we can see that the gas consumption and transaction costs increase with the length of metadata and the number of stakeholders. Registering a song with more metadata or stakeholders leads to higher transaction costs, as more data needs to be stored on the blockchain. It's also obvious why storing lyrics on-chain is inefficient and why we need to use the Oracle-based

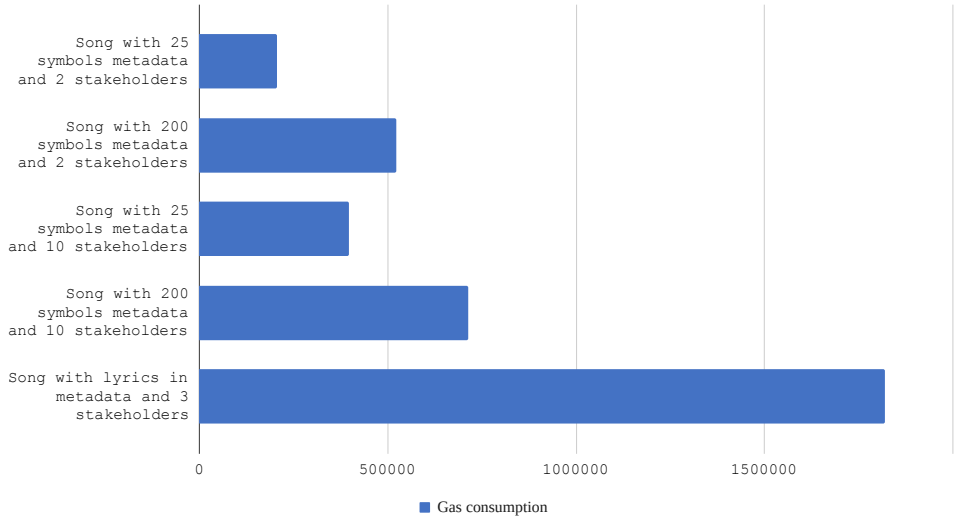

Figure 3: Gas consumption for registering songs with various sizes of metadata.

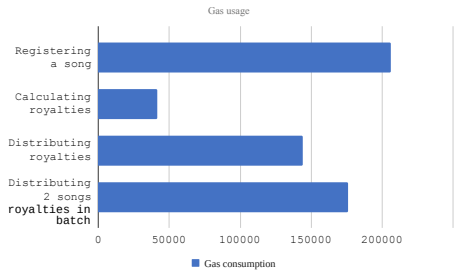

Figure 4: Function gas consumption comparison.

solution. As for the other functions, calculating royalties has the lowest gas consumption and transaction cost since it is a view function that does not modify the blockchain state. Distributing royalties has a higher gas consumption due to token transfers and updating the song's state. It's worth noting that using the batch distribution function for multiple songs results in a lower total gas consumption compared to distributing royalties for each song individually. This highlights the advantage of using batch distribution for multiple songs, as it can lead to cost savings when distributing royalties to stakeholders.

Gas measuring also gives us information to estimate if blockchain has 'enough space' to make this system work. Based on the test results, the gas usage for registering a song is approximately 300,000, meaning 100 songs can be registered in a single block. Considering the overall number of blocks generated, it means that there already could be stored 17 billion songs. The blockchain provides ample space to store many songs using the smart contract, making it a viable solution for managing music registration and royalty distribution. As the number of blocks grows over time, the storage capacity of the blockchain will continue to increase, further enhancing the system's feasibility.

5 CONCLUSION

This article analyzes the music industry's challenges in tracking and distributing royalties and the potential of Web3 and blockchain technology to address these issues. Addressing the challenges facing the music industry requires a concerted effort to streamline royalty management systems, enhance transparency, standardize metadata, and combat piracy. By implementing efficient and transparent royalty allocation processes, leveraging standardized metadata, and actively combating piracy, the industry can overcome fragmentation, inefficiencies, and data inconsistencies. Achieving these objectives will not only benefit artists and stakeholders but also foster a more sustainable and equitable music ecosystem for all involved parties.

We have presented a smart contract implementation that leverages the capabilities of the Polygon network and Chainlink oracles to create a decentralized and transparent system for managing music royalties. This smart contract enables the registration of songs, monitoring of song plays, and automatic calculation and distribution of royalties among stakeholders. Throughout the development process, extensive testing was performed using the Hardhat framework to ensure the functionality and efficiency of the smart contract. These tests measured the gas consumption for various functions, such as registering songs, calculating royalties, and distributing royalties. The results indicate that the implemented smart contract is efficient and cost-effective, making it suitable for widespread use in the music industry. The implementation of this smart contract has the potential to improve the efficiency and transparency of royalty distribution, allowing artists and other stakeholders to receive their fair share of revenues. Furthermore, the application of blockchain

technology in the music industry can serve as a powerful example for other industries that face similar challenges in managing intellectual property rights and revenue distribution. As the Web3 ecosystem continues to develop and mature, we can expect to see an increasing number of innovative solutions leveraging blockchain technology to address the challenges faced by various industries, ultimately transforming the way we interact with digital assets and creating a more equitable and transparent digital economy.

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