# Unlocking DeFi Literacy: Understanding NFT Market Microstructure in the Decentralized Finance Landscape

***Abstract*—Decentralized finance (DeFi) is an emerging technology that empowers individuals to manage their assets without relying on centralized institutions. This paper examines the nexus between decentralized finance (DeFi) and the NFT market. It clarifies the complexities of DeFi, including liquidity pools, DEXs, and automated market maker algorithms, while clarifying concepts like fungible tokens and stablecoins within NFT ecosystems. Exploring primary and secondary markets, along with NFT royalty structures, it aims to enhance understanding and empower individuals to navigate these landscapes effectively. This paper delves into the intricate relationship between the NFT market and the broader DeFi landscape, offering practical insights for NFT marketplace owners and in-depth analysis for academic researchers.**

***Index Terms*—DeFi literacy, Crypto Investment, NFT market Microstructure, OpenSea**

## 1. Introduction

The rise of decentralized blockchain based systems created the Global Decentralized Finance Market. With the rapid growth of the Global Decentralized Finance (DeFi) market (valued at $20.22 billion in 2023 and with a compound annual growth rate of 45.36% [1] ), DeFi has become a prominent player.

DeFi aims to leverage blockchain technology to build and integrate open-source financial components into sophisticated products, aiming for frictionless experiences and enhanced user value [2]. However, financial literacy is already scarce, even in the case of centralized finance, with only one in three adults worldwide possessing financial literacy [3]. Introducing advanced technologies like blockchain, liquidity pools, decentralized exchanges (DEX), fungible and non-fungible tokens (NFTs) along with their respective standards, stablecoins, and secondary marketplaces, significantly amplifies the complexity.

There has been a significant rise in NFT marketplaces [4][5]. However, due to the NFT marketplace requiring wallet integration, NFT minting and reselling, we require and cannot ignore the DeFi ecospace. Due to the growing interest in opening NFT marketplaces, it is important for individuals to familiarize themselves with certain concepts before entering the complex NFT ecosystems. A solid understanding of these concepts will allow marketplace owners to effectively utilize the available functionalities and establish a more efficient monetization and revenue distribution system. This paper aims to serve as a valuable resource for NFT marketplace owners.

This paper aims to bridge the DeFi literacy gap by providing clarity on various concepts and applications within the DeFi ecosystem. The key contributions of this paper are as follows:

• Explanation of liquidity pools, DEXs, and automated market maker algorithms.

• Clarification of the functioning and purposes of different fungible tokens, including stablecoin, their reserves and fluctuating native coins

• Demonstration of stablecoins and the decimal scaling between stable and non-stable coins.

• Deciphering the process of the primary and secondary marketplaces, and their functioning, including commissions/revenue distribution.

• Royalty Structure for NFT tokens.

The remaining structure of the paper is as follows: Section 2 illustrates user difficulties in DEX and NFT markets. Section 3 elucidates methodology, including key terms, workflow, algorithms, pros, and cons. Section 4 explores relevant research in the domain. Section 5 examines future trajectories in NFT monetization systems.

The paper offers a comprehensive analysis of the NFT market within the broader DeFi landscape, catering to both industry practitioners and academic researchers. Its structured approach and detailed explanations make it a valuable resource for understanding the intricacies of decentralized finance and NFT marketplaces.

## 2. Problem Statement

When opening a new marketplace in DeFi, it is important to have a solid understanding of the market microstructure. To provide a comprehensive exploration of the associated topics, we have chosen to present this information in a narrative format. Our story follows an NFT patron who wishes to acquire a digital asset as a Non Fungible Token (NFT) and sell it. The narrative is shown in Figure-1.

Before the NFT Patron can mint a NFT, they need to acquire some native coins. To commit a transaction on the blockchain, native coins are required. To enter the world of DeFi, the patron (who serves as our user in this case) must purchase cryptocurrency (1). If the user already has cryptocurrency but it is not native to the platform, they will need to exchange it for the relevant currency (2). Section-3.1 details the solution to this problem. In Section-3.1, we also explain the concepts of a DEX and liquidity pools.

When selecting an ERC20 token to purchase, the patron have to decide between native coins and stable coins (2). This can be a dilemma, as native coins tend to be volatile while stable coins are less prone to fluctuations. Section-3.2 addresses this confusion.

With their chosen ERC20 token, the patron can select the digital asset to mint from a primary marketplace (4). But if the patron wants to use fiat currency only to purchase NFTs, there are various third party on-ramp services to buy cryptocurrency, which will not be discussed as it is out of scope for this paper. This marketplace is owned by our protagonist proprietor. This paper also delves into the

challenges faced by the marketplace owner (4). Section-3.4 explains the concept of a primary marketplace and its connection to real-life asset representation.

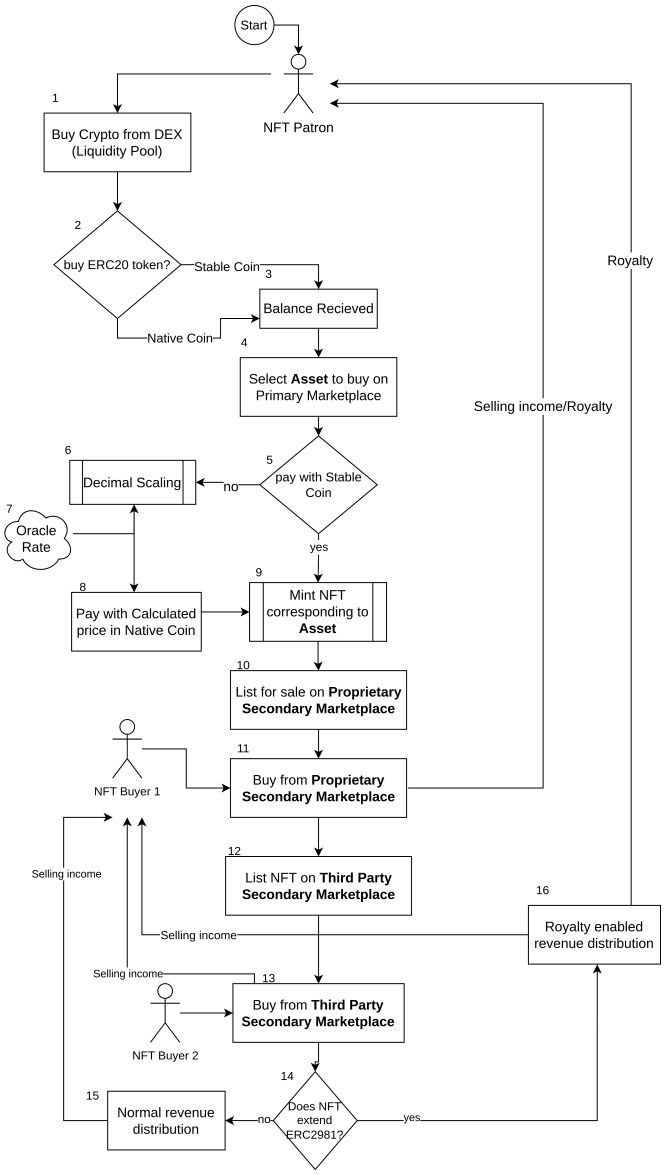


Figure 1. Diagram For Narrative

Minting an NFT incurs a gas fee, which must be paid in the native coin of the blockchain on which the NFT is being minted (5). However, the patron may not have the required native coin. Even if the marketplace owner wishes to list prices in stable coins, they will still need to convert them to the native coin. To accomplish this, real-time price conversion rates are necessary and can be obtained from Oracles (7). Section-3.3 provides more information about Oracles and how they are a potential solution. However, it is worth noting that Oracles may not always provide the expected decimal places, which can create issues with decimal scaling (6). Section-3.3 delves into this challenge.

If the patron chooses to mint the asset with a native coin, they will need to utilize a fixed oracle rate to convert the stable coin rate to the running native coin rate (8). This requires decimal scaling(Section-3.3).

Finally, when the artist confirms the payment, a new NFT corresponding to the asset is minted (9). These NFTs follow the ERC721 token standard and are unique and indivisible, unlike ERC20 tokens. As a result, they are registered on all secondary marketplaces within the Web3 ecospace (10). The concept of NFTs is thoroughly explored in Section-3.4. Many users are interested in creating their own marketplaces. However, when an NFT is distributed in a different marketplace, the control over revenue distribution is lost, which poses a challenge for marketplace owners (11) (12) (13). So, how can marketplace owners address this issue? This is an important topic that will be discussed further in Section-3.4, which explains the concept of listing NFTs on secondary marketplaces and the mechanism of buying and selling them.

When a buyer purchases a token from a secondary marketplace, the distribution of revenue will depend on the NFT's royalty standard (14). There are two options: normal revenue distribution (15), which does not provide the artist with resale royalties, or royalty-enabled revenue distribution (16), which allows the artist to receive royalties for each resale. These options are explained in Section 3.4. We propose our own royalty enabled revenue distribution in Section 3.4 as well.

## 3. Methodology

In our narrative, we've observed that every user must possess crypto-tokens to access the DeFi ecosystem. These tokens are obtained via DEXs, which facilitate the buying and selling of various fungible tokens.

### 3.1. Decentralized Exchange

Decentralized exchanges (DEXs) are peer-to-peer platforms where cryptocurrency traders can directly exchange assets, setting their own prices without intermediaries like banks [6]. Users pay network fees for transactions and trading fees, collected by the protocol, liquidity providers, or token holders. DEXs operate through self-executing smart contracts, establishing prices algorithmically and using liquidity pools. Liquidity pools and liquidity providers are explained in section 3.1.1.

**3.1.1. Liquidity pool.** A liquidity pool is a smart contract that holds a reserve of two or more cryptocurrency tokens in a DEX [7]. The name, liquidity pool comes from creating liquidity for faster transactions. The transaction fee for each trade executed on the platform, is shared by the liquidity providers, who provide liquidity in pools, in proportion to their liquidity contributions [8]

Prices of tokens in liquidity pools, or in a broader aspect, DEXs are based on the supply and demand of the token in the liquidity pools. To calculate the fluctuating price of tokens, an algorithm called automated market maker (AMM), is used.

**3.1.2. Automated Market Maker.** Automated Market Makers (AMMs) employ algorithms to determine the prices of assets based on their quantities in a liquidity pool. The algorithm maintains a constant, denoted as 'k,' ensuring

stability. Initially set at 1 dollar, this constant remains unchanged.

Most AMMs utilize the Constant Product Market Maker (CPMM) algorithm, represented by the equation:

X * Y = K

Where: **X** is Supply of Token A, **Y** is Supply of Token B, and **K** is Constant Product (always remains the same).

Essentially, the product of token quantities in the pool is always constant. This sets the price of one token in relation to the other.

When someone buys Token A from the pool, they remove some amount of A and increase the amount of B (to maintain K constant). This effectively raises the price of A and lowers the price of B. Conversely, selling A decreases its price and increases B's price.

So, in a liquidity pool the price of a token could increase drastically, due to the scarcity of the token in that pool. For which, the DEXs, and liquidity pools accumulate a large amount of tokens for liquidity. However, the price difference of the tokens are easily mitigated by arbitrage traders.

**3.1.3. Arbitrage Trading.** Arbitrage traders engage in the practice of purchasing tokens from pools where prices are lower and selling them to pools where prices are higher, thereby capitalizing on the price differential. This balances token supply between low and high price pools, fostering ecosystem stability. Constraints on arbitrage capital flow can lead to market segmentation, hindering price convergence and liquidity [9]

DEXs transform cryptocurrency trading by facilitating faster transactions and price determination by utilizing liquidity pools and algorithms like AMM . Arbitrage traders help maintain market stability by leveraging price differences in liquidity pools, although constraints on their capital flow can disrupt liquidity and price convergence. Ensuring secure trading practices is crucial for preserving market integrity. DEXs and liquidity pools are essential elements of the DeFi ecosystem, providing efficient and decentralized cryptocurrency trading with ongoing challenges that demand continuous adaptation.

## 3.2. ERC 20 Tokens (Fungible Tokens)

Liquidity pools and DEXs function in ERC20 tokens. Tokens are digital units that operate on the blockchain of another cryptocurrency. They provide access and use within a larger crypto-economic system [10]. Fungible tokens are like fiat currency in that each unit holds the same value and can be swapped for other tokens of the same type. In cryptocurrency transactions, we often deal with ERC20 tokens, which are an example of fungible tokens.

The ERC-20 token, which stands for Ethereum Request for Comment 20, is a technical standard that governs the creation of tokens on the Ethereum blockchain [11]. ERC-20 tokens are created using smart contracts built by OpenZeppelin. They do not possess any special rights or behaviors, making them easy to trade and use in various applications such as a medium of exchange currency, voting rights, staking, and more [12]. Some key features of ERC-20 tokens include standardized functions, security inherited from the Ethereum blockchain, reduced costs compared to traditional finance, and liquidity on exchanges. ERC20 tokens can be defined as native coins and stable coins.

ERC20 tokens are used to buy almost anything in the DeFi ecospace, from minting NFT, staking or investing in liquidity pools, to buying digital assets, cryptonative tokens are a necessity.

**3.2.1. Native Coins.** The term "native token" refers to a fungible ERC 20 token that is created or used on a specific blockchain network [13]. For example, Ether is the default token of the Ethereum network, making it their native token. Similarly, MATIC is the native token of the Polygon network [14]. Native coins are prone to fluctuations, which hinders financial trade and stability, for which stablecoins were introduced.

**3.2.2. Stable Coins.** Stablecoin is a type of ERC 20 token that maintains a stable value by being pegged to another asset, usually a Fiat currency, such as the U.S. dollar [15]. It is an ERC 20 token that requires additional functionalities to limit its supply. Stablecoins aim to provide an alternative to the high volatility of popular cryptocurrencies, which can make cryptocurrency less suitable for common transactions.

The stablecoins that are pegged to fiat currency are called fiat collateralized stablecoin. It operates under a centralized model, thus requiring a centralized entity to hold an equivalent amount of Fiat currency in reserve as the circulating token in the market. An example of a Fiat collateralized stablecoin is Tether, which currently holds the position of the third-largest cryptocurrency by market capitalization, with a value exceeding $96 billion.[16] Nevertheless, while Fiat-backed stablecoins achieve stability through Fiat collateral, they compromise decentralization as a central entity manages the reserves.

There are also two other types of stablecoins:

• Cryptocurrency-collateralized stablecoins use cryptocurrency as collateral, requiring over-collateralization to stay stable despite crypto price fluctuations.

• Algorithmic stablecoins, on the other hand, adjust their supply based on market dynamics to maintain price stability, relying on algorithms for decentralized and efficient operation. However, they face uncertainty regarding long-term stability, as seen with examples like Terra.

Each type of stablecoin possesses its own limitations. The stablecoin trilemma represents the challenge of simultaneously achieving stability, decentralization, and capital efficiency [17]. But the most used stablecoin is fiat collateralized stablecoins.

## 3.3. Decimal scaling from stablecoin to native coin

All cryptocurrencies, whether stable coins or not, have different decimal precision points. For example: Bitcoin (BTC) has up to 8 decimal places of precision point, in contrast, Ether has 18 decimal places. In some cases decimal scaling is necessary during token conversion to maintain the actual price, when the tokens have different precision points from the oracle.

Let's assume a price of an NFT is 143.75 USDC (which is a stablecoin and 1 USD = 1 USDC Stable-Coin) [18].

Though the NFT price is in stablecoin, a consumer may want to pay the price in Native coin (MATIC). As the amount should get validated on-chain, we need price feed oracle support here. For example we can use ChainLink's Price Feed Oracle [19], which offers different price feeds

between different currencies and the contracts are deployed in different blockchain networks. When we can get the conversion rate from the oracle, the smart contract can verify the NFT price in different currencies. Before going to that calculation we must convert the stablecoin to its micro units.

USDC has 6 decimal places [20], so, stablecoin micro unit conversion = n x $10^6$

So, the total NFT price in micro-unit = 143.75 x $10^6$ = 143750000 micro-unit USDC.

Since, MATIC to USDC Oracle rate = 82110000 (0.82 USDC), where the oracle's scientific notation = $10^8$ (8 decimal places )

Here, we can notice the difference in power values (exponent) between Oracle and our on-chain Stable-Coin price. So we have to Scale this difference first before proceeding to the main calculation.

**Decimal Scaling**

Formula = Oracle Rate Decimal Place ÷ Stable Coin Decimal Place = $10^8 \div 10^6 = 10^2$

So, the decimal scaling of Oracle rate = Oracle 8 Decimal Rate $\div 10^2$

Or, 82110000 ÷ $10^2$ = 821100 (Oracle rate in $10^6$)

(We know that MATIC prices are converted into $10^{18}$ Wei for on-chain transactions)

So, NFT price in Wei = (Stable-Coin NFT Price × $10^{18}$) ÷ 6 Decimal Oracle Rate

→ (143750000 × $10^{18}$) ÷ 821100 = 1750700281120448000 Wei

This way, we can calculate the financial crypto calculation at the Smart Contract level in Solidity without losing any precision.

On the user end, we can calculate the Wei into MATIC for better user experience:

→ 1750700281120448000 Wei ÷ $10^{18}$ = 175.0700281120448 MATIC

This way we can convert between different tokens without loosing any value.

## 3.4. NFT market microstructure

**NFT Token standards:** Non fungible tokens are blockchain based assets representing ownership of a single digital or physical item. NFTs have been used for a wide variety of reasons aside from representing just unique indivisible items [21].

• **ERC 721:** ERC 721 is the standard for Non-Fungible tokens. Unlike fungible tokens (where each token is interchangeable with another of equal value), ERC-721 tokens are unique. Each token represents a distinct digital asset. The ERC-721 standard ensures that each token within a smart contract has a globally unique combination of the contract address and a uint256 tokenId.

ERC-721 allows for ownership of the token and transfer, balance inquiry of the Token, ownership lookup for specific token ID, and approval for third party accounts to transfer tokens. The contract can emit three events **Transfer**, **Approval** and **ApprovalForAll**. OpenZeppelin has a standard ERC-721 which can be used to make NFTs [22].

• **ERC 1155:** ERC-1155 is a multi-token standard that acts like a mashup of ERC-20 and ERC-721. It is also known as semi-fungible token. The standard can represent any number of fungible and non-fungible token types. The key features of ERC-1155 are Batch Transfer, Batch Balance, Batch Approval, Hooks, NFT Support and Safe Transfer Rules. Each ERC-1155 token can be unique and have a balance at the same time. If the balance is 1, it becomes an NFT.

**3.4.1. NFT marketplace.** Different token standards like ERC20, ERC721 and ERC1155 are maintained in blockchain ecosystems. Among them ERC721 is used to represent an unique digital asset. For these tokens, there exists marketplaces like OpenSea, Rarible, Magic Eden etc. Whenever a token appears in the blockchain ecosystem, they are immediately displayed on the marketplaces. This adds to the democratization of the blockchain ecosystem, allowing users to create tokens anywhere and sell them anywhere. If a token is sold at a marketplace, the marketplace keeps a royalty fee from the user.

• **Primary Marketplace:** We define NFTs place of origin as the primary marketplace. It is the marketplace from where NFT is minted.

• **Proprietary secondary marketplace:** The marketplace belonging to the NFT proprietor is the proprietary secondary marketplace. The resale value from this site goes to the NFT owner and commission is obtained by the original NFT minter.

• **Third party secondary marketplace:** Platforms like OpenSea, Rarible, Magic Eden etc. are third party secondary marketplaces. They list any tokens minted onchain. The owners of the token can use this marketplace to sell the tokens. In this case, the resale value goes to the owner and commission is owned by the secondary marketplace. The NFT minter doesn't get any royalty unless the token follows ERC 2981 standard. The mechanism followed by OpenSea is shown in Figure - 2 and Figure - 3.

**3.4.2. How Token Transfer works in OpenSea.** When a token is listed for sale in the secondary marketplace by the owner of the token, a **SetApprovalForAllFunction** event is emitted. The event is emitted from the **ApprovalForAll** function.

The **ApprovalForAll** function sets a contract named **Conduit.sol** as the operator of the token.

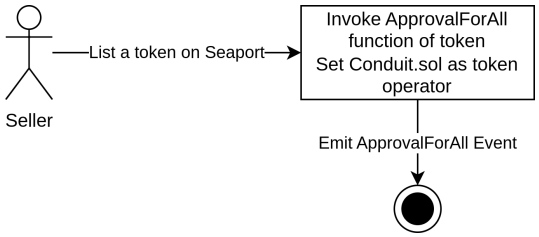


Figure 2. Setting contract address as token operator flow

When the Buyer attempts to buy the token from OpenSea, **fullfillBasicOrder** of **Seaport.sol** function is called. At first the order is validated and after validation conduit data is loaded from the contract. The transfer is then called using Conduit and token transfer takes place. After the token is transferred, fee distribution takes place. The seller receives 99.75% of the transfer amount and OpenSea receives 0.25%. All the contracts and functions shown in figures are designed by OpenSea and are a part of the Seaport market protocol.

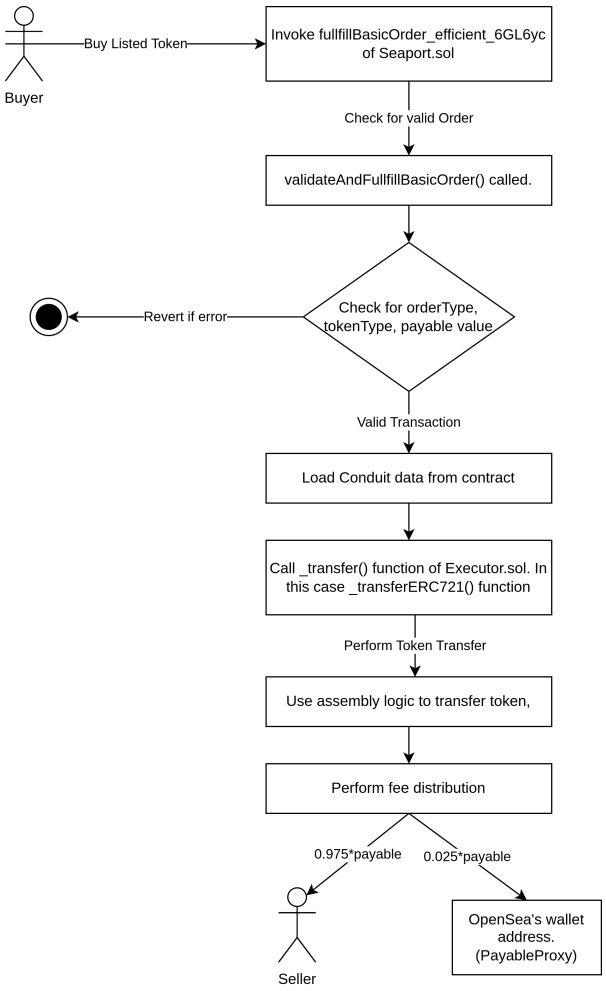


Figure 3. OpenSea token buying flow

**3.4.3. Royalty Standard.** In the Web3 ecospace, new NFTs are created regularly. There should be effective monetization of NFT transfers to ensure rights of creators and owners of NFTs are properly preserved.

The Web3 ecospace has lots of secondary marketplaces where Token transfer can take place. Users can buy or mint tokens from one place and sell it to any secondary marketplaces available on the internet. This can deprive the creator from the royalty fee they should receive when the NFT is sold. So a standardized system has to be put in place to ensure that creators of Tokens are always incentivized for each transfer.

ERC 2981 is the royalty standard that can be implemented to incentivize creators. Whenever a NFT is transferred on a secondary marketplace, creators of the NFT will receive a percentage of the sale. NFT marketplace smart contracts are varied by ecosystem and not standardized. This EIP enables all marketplaces to retrieve royalty payment information for a given NFT. This enables accurate royalty payments regardless of which marketplace the NFT is sold or re-sold at.

Royalty amounts are always a percentage of the sale price. If a marketplace chooses not to implement this ERC, then no funds will be paid for secondary sales. It is believed that the NFT marketplace ecosystem will voluntarily implement this royalty payment standard; in a bid to provide ongoing funding for artists/creators. NFT buyers will assess the royalty payment as a factor when making NFT purchasing decisions.

Openzeppline has the royalty standardized using ERC-2981 standard. If a smart contract inherits it, it will have access to setting royalty. Figure - 4, 5 and 6 show the process of generating royalty.

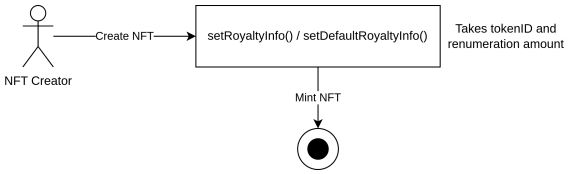


Figure 4. Setting Royalty Amount During Minting

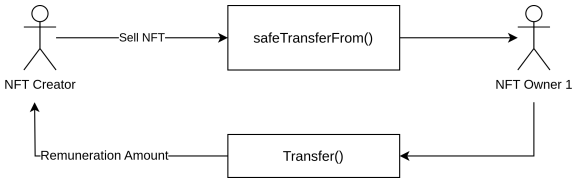


Figure 5. First Token Transfer after setting Royalty

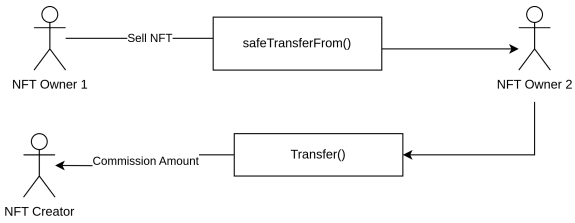


Figure 6. Consecutive Token Transfers after setting Royalty

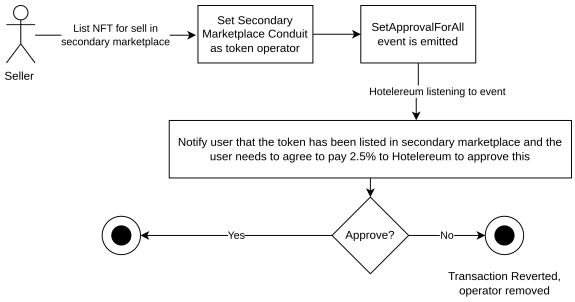


Figure 7. Approving Royalty Fee Transfer During Selling

**Royalty Calculation:** The default royalty rate is set to 10%, equivalent to 1000. This percentage must remain constant regardless of the sale price. In other words, whether the sale price is 10, 10000, or 1234567890, the royalty calculation should consistently apply the specified percentage. If the calculation results in a remainder, implementers have

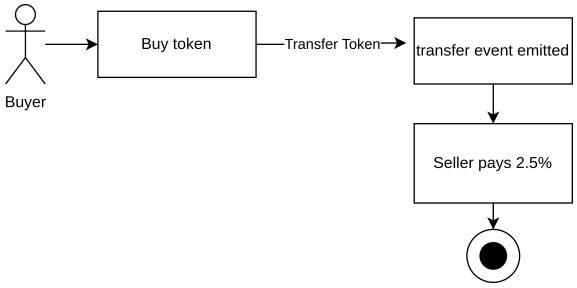


Figure 8. Royalty Transfer During Selling Token at any marketplaces

the flexibility to round up or down to the nearest integer. For instance, if the sale price is 999 and the royalty fee is 10%, implementers can return either 99 or 100 for the royalty amount, both being acceptable outcomes.

**Our proposed Royalty Distribution Mechanism:** We propose another royalty standard which can be used instead of the ERC2981 royalty standard. It will give the origin marketplace more control over the tokens minted using that platform. In our case, the origin marketplace will listen to the SetApprovalForAll event. Whenever it is emitted, it means that any third party contract or address has been set as the token operator. So our platform will ask the owner to confirm that indeed the owner has listed the token on another platform and they need to pay 2.5% to the host platform as well. The 2.5% transfer occurs when the token transfer occurs. Figure - 7 and Figure - 8 narrates this procedure.

## 4. Related work

A variety of research studies have delved into the potentials of DEXs and NFT marketplaces. Advances in economics, business and management research [23] examined the effect of financial literacy, risk perception, and overconfidence on cryptocurrency investment decisions while taking investment experience as a moderating variable and found that investment experience has a significant moderating effect between financial literacy and risk perception toward cryptocurrency investment decision. Jean-Michel Chabot (2023) [24] discussed the current landscape for digital asset investing and the many operational risks facing cryptocurrency investors and discussed the ongoing progress in the institutionalization of digital asset investment and the risks inherent when investing in cryptocurrencies and blockchain opportunities. Lehar (2021) [25]furnishes evidence regarding the stability of equilibrium liquidity pools in major DEXs like Uniswap. Additionally, Krishnamachari (2021) [26] propose innovative approaches such as dynamic curves and dynamic AMM to maintain liquidity and eliminate arbitrage opportunities in decentralized cryptocurrency exchanges. These studies collectively enrich our comprehension and refinement of liquidity dynamics in DEXs, particularly concerning ERC tokens.

The landscape of NFT market microstructure presents a complex and rapidly evolving domain, bearing significant ramifications for investors and regulatory bodies. Mukhopadhyay (2021) [27] illuminates the challenges associated with distinguishing authentic NFTs from fraudulent schemes, emphasizing the necessity for due diligence. White (2022) [28] conducts a meticulous examination of the OpenSea NFT marketplace, shedding light on the impact of a select group of users on price fluctuations and the emergence of user communities. Their study considered 5.25 million sales that occurred between January 1, 2019, and December 31, 2021. Their findings shed light on areas of the NFT marketplace that have been relatively unexamined and provide a multi-level analysis of a multi-billion dollar market. Furthermore, Madhavan (2000) [29] delivers an extensive survey of market microstructure, highlighting the pivotal role of information in price determination, market configuration, and its intersection with other financial realms. Collectively, these studies underscore the critical importance of comprehending the intricacies of NFT market microstructure and its implications for stakeholders in the market. S. Karim et al. (2022) [30] discussed significant risk spillovers among blockchain markets with strong disconnection of NFTs. Overall, NFTs offer greater diversification avenues with substantial risk-bearing potential among other blockchain markets to shelter the investments and minimize extreme risks.

## 5. Future work

While this study has provided a comprehensive analysis of DeFi literacy and the microstructure of NFT markets within the DeFi landscape, further research into flash loans is warranted.

Flash loans, a type of uncollateralized loan in the DeFi ecosystem, are only valid within a blockchain transaction and must be repaid with fees by the end of that transaction [31]. These loans have been used to exploit vulnerabilities in deployed protocols, resulting in substantial profits for attackers [32]. The popularity of flash loan services is increasing, with a growing number of transactions being identified.

Future research should investigate the mechanics of flash loans, including their utilization by traders and developers for market exploitation and complex trading strategies. Moreover, assessing the risks associated with flash loans, such as market manipulation, liquidity shocks, and systemic risks, is crucial for understanding their broader impact on the DeFi landscape. Furthermore, exploring the regulatory challenges and implications of flash loans within decentralized finance is essential.

## 6. Conclusion

This paper comprehensively explores of decentralized finance (DeFi) literacy and the microstructure of non-fungible token (NFT) markets within the DeFi landscape. It emphasizes the importance of understanding key concepts such as liquidity pools, DEXs, ERC-20 tokens, stablecoins, and NFT token standards for both industry practitioners and academic researchers. Additionally, it underscores the necessity for further research into flash loans and their implications for market exploitation, complex trading strategies, risks, and regulatory challenges within decentralized finance. Overall, this paper serves as a valuable resource for understanding the complexities of decentralized finance and NFT marketplaces, offering insights and guidance for both practitioners and researchers in the field. As the DeFi landscape continues to evolve, it is crucial to stay informed and adapt to emerging trends and challenges, and we hope that this paper contributes to that ongoing exploration.

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