

Ethereum Marketplace Creation: Scaling, FT vs NFT in Theory, Cross-Chain and Splitting Experiments

Anastasiya Lavrova[1,2], Vladimir Korkhov[1(✉)], and Albina Lavrova[3]

[1] Saint Petersburg State University, St. Petersburg, Russia
{a.k.lavrova,v.korkhov}@spbu.ru
[2] ITMO University, St. Petersburg, Russia
[3] Lanit-Tercom Italia SRL, Bari, Italy

Abstract. Ethereum is the most popular altcoin today. It is a platform for large decentralized platforms and thousands of DApps. It was this blockchain that gave the crypto community such technologies as NFT and DAO. On September 15, 2022, Ethereum switched to the Proof-Of-Stake consensus algorithm. In this article, we review the existing blockchain architecture and token standards, compare the difference before and after the transition, identify existing problems, and review existing solutions. We evaluate the performance of FT and NFT creation; consider the solution to the Ethereum scaling with ZkSync; evaluate alternative platforms for creating tokens such as Open Sea or switching to other blockchains like Polygon, Fantom or Binance Smart Chain using cross-chain bridges.

Keywords: blockchain · distributed ledger · token · Ethereum · marketplace · solidity · smart-contracts · decentralized finances · cross-chain

1 Introduction

Blockchain technology has revolutionized various industries, offering unparalleled transparency, security, and efficiency. In its essence, the blockchain is a specialized database transforming how we store and manage data. Unlike traditional databases, the blockchain structure consists of a chain of blocks added to this database.

The initial iterations of blockchain, exemplified by Bitcoin, primarily function as decentralized payment systems possessing relatively limited functionalities. However, the advent of the second generation of blockchains, such as Ethereum, has ushered in a new era of possibilities, offering an all-encompassing digital ecosystem rather than merely a cryptocurrency. These advanced blockchains serve as the foundational infrastructure for the creation and execution of decentralized projects. Notably, the key distinguishing feature of this generation is

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024
O. Gervasi et al. (Eds.): ICCSA 2024 Workshops, LNCS 14815, pp. 196–213, 2024.
https://doi.org/10.1007/978-3-031-65154-0_12

the integration of smart contracts and computer protocols designed to facilitate the management of specific entities, such as cryptocurrencies, specialized tokens, and more. Ethereum, for instance, leverages Solidity as its Turing-complete Programming Language for interacting with smart contracts.

One of Ethereum's significant contributions to the crypto community is the invention of crypto tokens. These digital assets exist on specific blockchains and have revolutionized various sectors, including finance, gaming, and art. Crypto tokens can be categorized into fungible and non-fungible tokens (NFTs). Fungible tokens, known as FT, are identical and interchangeable, serving as a form of currency within the blockchain ecosystem. On the other hand, non-fungible tokens, or NFTs, represent unique objects, such as digital art, collectibles, or virtual real estate, bringing scarcity and ownership rights to the digital world.

As we mentioned, blockchain technology's emergence and rapid advancement have transformed various industries. One of the most groundbreaking applications of blockchain is the creation and management of non-fungible tokens (NFTs), which have gained significant attention in recent years. NFTs have revolutionized digital asset ownership by providing a unique identifier and proof of authenticity for digital assets, ranging from artworks and collectibles to music and virtual real estate.

In this article, we have developed a platform Art Space Marketplace [1] for creating and managing fungible and non-fungible tokens. But also, during our work, we delved into the nuances of blockchain technology. We closely studied the second generation of blockchains, theirs scaling and problems and have developed a platform that solves these issues.

Section 2 gives an overview of existing literature and research related to blockchain technology and NFT marketplaces. We highlight the essential findings and insights from previous studies, setting the context for the subsequent sections.

Section 3 delves into the various scaling solutions proposed and implemented to address the challenges faced by the Ethereum network. It explores technologies such as sharding, plasma chains, and state channels, which aim to enhance the throughput and performance of the blockchain.

Section 4 overviews the primary existing ETH token standards, shows the difference between fungible and non-fungible tokens, and emphasizes the importance of choosing the suitable token standard for the proper operation of a decentralized application.

Section 5 discusses the lifecycle of fungible tokens and also covers AMM principle of work.

Section 6 focuses specifically on NFTs. It explores the structure and architecture of NFTs. It also explains the various ways to view NFT assets and introduces the concept of cross-chain bridges and their operation scheme.

Section 7 identifies and describes the main technological challenges and issues present in the current architecture of tokens. It highlights areas that require further improvement and development to enhance the functionality and usability of tokens within the blockchain ecosystem.

The Sect. 8 presents the developed project. We provide a detailed description of the decentralized application, as well as compare it with well-known operating marketplaces such as OpenSea and Rarible.

2 Related Work

Blockchain technology attracts a lot of attention. The article [2] considers the difference between the two most popular blockchains - Bitcoin and Ethereum. The authors compare network architectures and their main characteristics.

Recognizing the distinction between cryptocurrencies and tokens is crucial for researchers, investors, and developers, as it enables a clear understanding of their respective functionalities, use cases, and regulatory considerations. The difference between NFT and cryptocurrency is presented in [3]. In this article, the authors compare NFT, Ethereum cryptocurrency, CryptoCoin, Bitcoin and the relationship between their prices.

The article [5] introduces a comprehensive overview of NFT and its underlying core technologies: blockchain and Ethereum. The authors present an analysis of marketplaces for NFT exchange, NFT dApps in different categories, and challenges that the authors see in NFT technology from the perspective of security, privacy, environmental impact, ownership, governance, and property rights.

Paper [6] overviews state-of-the-art NFT solutions and analyzes their technical components, protocols, standards, and desired proprieties. The authors consider a security evolution, with discussions on the perspectives of their design models, opportunities, and challenges.

Research on measurement of Ethereum-Based ERC20 Token Networks is introduced in [7]. The authors present a descriptive measurement study to characterize token networks quantitatively. Based on the first 6.3 million blocks of the Ethereum blockchain, they provide an overview of more than 64,000 ERC20 token networks and analyze the top 1,000 from a graph perspective.

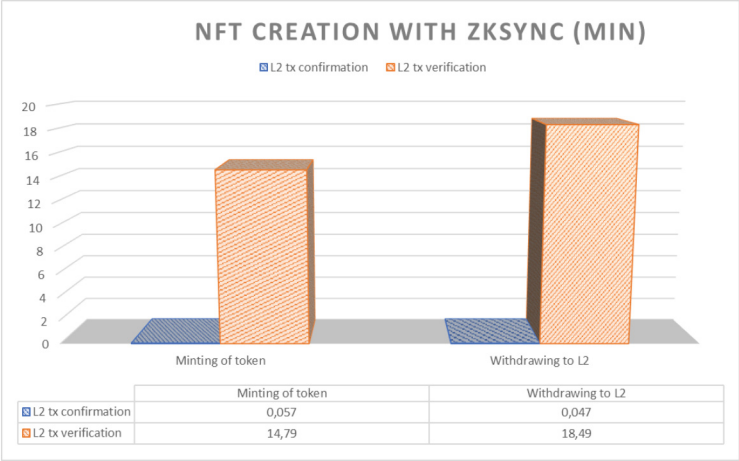
3 Blockchain Scaling

Over a million transactions occur on the Ethereum network every day [8]. So, scaling mechanisms play a key role in modern blockchain architecture, ensuring efficient transaction processing and reducing the load on the main chain. Architectural solutions at the blockchain level may face performance constraints and high fees, which complicates the process of trading and managing NFT. Using L2 solutions when creating a marketplace for NFT can provide more efficient and cost-effective trading, as well as increase the accessibility of the platform for users with different levels of financial capabilities.

On-chain scaling and off-chain scaling are the two categories of scaling for Ethereum.

1. On-Chain Scaling
   This solution entails reconfiguring the main Ethereum network. Scaling is achieved using Sharding technology. Segmenting transactions enables each node of the network to handle just a portion of a block rather than the complete transaction.
2. Off-Chain Scaling
   This solution suggests the creation of a distinct solution from the Mainnet. Depending on the protocol, security is provided directly by the Ethereum Mainnet consensus algorithms (Optimistic Rollups, zkRollups) or independently (sidechains, plasma).
   - **Optimistic Rollups**
     The fundamental premise of the approach is that L2 transactions are valid by default. Calculations will only be made if fraud is suspected.
   - **Zero Knowledge Rollups**
     Such a method combines off-chain transactions and uses zero-disclosure SNARK to produce a specific cryptographic proof. Without having to provide the information, it enables the proving party to verify its accuracy. One of the most popular Ethereum scaling solutions, zkSync, is based on this method. It is with the help of it that further research related to Ethereum L2 will be conducted.
   - **Side-Chains**
     This solution uses a separate blockchain. It is functionally equivalent to the Mainnet Ethereum, allowing the transfer of assets between networks. Assets are frozen in the original blockchain as soon as they are in a different one.
   - **Plasma**
     A separate blockchain connected to the main network serves as the solution. It enables chain creation within the primary networks, enabling scalability. The subsidiary "root contracts," which are Ethereum smart contracts, are linked to the main Ethereum network and contain the fundamental guidelines for running each subsidiary chain.

We conducted a study of scalable Ethereum using ZKSync. And also testing ZkSync, it was found that although the execution of operations on L2 occurs almost instantly, their confirmation and output to L1 takes a lot of time, since these operations are processed through a single L1 blockchain network for all users. Despite the fact that such a solution will significantly reduce gas costs and time to create tokens, it will also significantly complicate the ability of users to log in. An analysis of the creation of tokens in the zkSync Testnet is presented in Fig. 1.



	Minting of token	Withdrawing to L2
L2 tx confirmation	0,057	0,047
L2 tx verification	14,79	18,49

Fig. 1. The time of token generation with ZkSync on 16.10.2023

4 Fungible and Non-fungible Tokens. the Main Ethereum Token Standards

As we have already mentioned, Ethereum is a decentralized platform on the basis of which various decentralized applications can be created. These applications are based on a special script called a smart contract. A large number of smart contracts are based on the same scheme, called the standard. Each standard specifies the minimum set of functions required to regulate tokens in the blockchain.

Ethereum is an open-source project, so any user can propose a new standard. If such a standard turns out to be really useful, then it can become the official Ethereum standard [13].

To create the right smart contract for token management, it is necessary to determine in advance the basic token standard. As was stated before, tokens can be fungible (FT) and non-fungible (NFT). Their main difference is that each NFT token is unique, that is, suitable for identifying something. Therefore, while the NFT encodes a digital object, the FT encodes a digital currency.

There are three main token standards in the Ethereum network: ERC20 ([15]), ERC721 ([16]), and ERC1155 ([17]).

- ERC20 is a protocol integrated into Ethereum in 2017. It is used to manage FT tokens. One smart contract of such a protocol encodes one such FT, which can denote a fiat currency, ounces of gold, or units of experience in a certain gaming platform. That is, 10 different smart contracts are required to work with 10 different types of tokens.
- ERC721 was also introduced in 2017, however, tokens of this standard are NFT. They can encode fragments of digital art, music, unique game objects, domain names ([4]), and even physical objects ([9]). Each such token is

assigned an identifier, so a single smart contract allows you to manage several types of tokens presented in a single instance.
– ERC1155 is a standard released in 2018. It is a mixture of ERC20 and ERC721, which allows managing both FT and NFT on a single smart contract by assigning a unique identifier to each token. An important feature of this protocol is the ability to transfer multiple tokens in a single transaction.

5 Fungible Tokens

As shown above, the FT token can be controlled by the ERC20 and ERC1155 protocols.

Our platform will have to support not only NFT, but also FT. Therefore, it is necessary to give users the opportunity to exchange tokens. The process of exchanging these tokens is usually performed by exchanges called Automated market makers (AMM). AMM is based on a simple mathematical formula that takes various forms. The most common of them is

$$aTokenBalance * bTokenBalance = k, \tag{1}$$

where k characterizes a constant balance of assets that determines the price of tokens in the liquidity pool and multipliers show how many tokens used for exchange are currently in the pool. For example, if AMM has ether (ETH) and bitcoin (BTC), every time ETH is bought, the price of ETH rises because there is less ETH in the pool than before the purchase. Conversely, the price of BTC decreases as there is more BTC in the pool. The pool remains in a constant balance, while the total value of ETH in the pool will always be equal to the total value of BTC in the pool.

6 Non-fungible Tokens

6.1 NFT's Structure

In order to give the user the opportunity to mint NFT using our platform, it is necessary to understand this technology in more detail. NFT allows people to secure the ownership of some digital object in the blockchain. However, data storage in the blockchain is very expensive, so in fact, only a link to JSON with the characteristics of a digital asset is stored in the blockchain. The existing NFT architecture looks like this: a smart contract is stored in the blockchain, in which each NFT has a unique identifier. According to this identifier, the smart contract issues a link to the corresponding JSON, which, in turn, stores links to the corresponding metadata.

A more detailed architecture of all NFT components we present in Fig. 2.

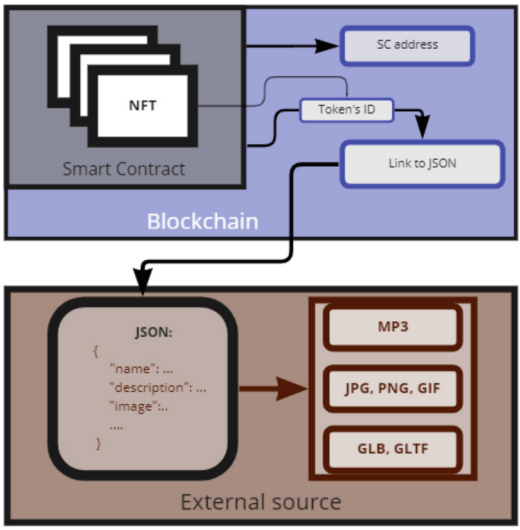


Fig. 2. Architecture of NFT components

NFT Minting. The creation of an NFT is the main operation related to the life of the token. It can be carried out in two ways

- **On-Chain** minting - the most common option. In this case, the creation of the NFT takes place in the blockchain. It meains that each user can see creation transaction, and any third-party service (another market place or crypto wallet) will be able to get information about this token.
- **Off-Chain** minting - the method of creation takes place outside the blockchain. This type of minting is less common, but it can increase the creation speed and reduce the cost. Usually, creating such an NFT directly in the blockchain occurs at the buyer's expense when buying a token on the marketplace.

Comparing these two types of minting, it is worth noting that on-chain minting is a more reliable and secure method since transactions occur in a decentralized network. It also allows you to see the entire transaction history, which may be necessary when selling NFT in the future.

Off-chain minting can provide convenience and time savings when creating an NFT. However, this method may need to be more transparent and guarantees that all processes will be carried out correctly and without the possibility of change.

Art Space marketplace strives to achieve the highest level of decentralization, so it will use only on-chain minting.

NFT Trading. The NFT can also be put up for sale in two ways:

1. Storing the order book inside the blockchain. This method ensures transparency of all operations and guarantees the impossibility of substituting information about the lot being sold. However, this approach increases the transaction costs for the user since it forces him to pay for the transaction in a distributed ledger.
2. Storing the order book on a centralized server. This solution saves users money but allows deleting or replacing information about the lot being sold.

Most popular marketplaces, like Opensea [10] or Rarible [11], store order books on centralized servers. But, as mentioned, our goal is to make the platform as decentralized as possible, so we store order book in a special smart-contract.

6.2 Metadata Storage

Since both the JSON file and the corresponding metadata are stored outside the blockchain, 3 options for their placement are considered [12]:

- Personal HTTPS file server.
  The disadvantage of this method is the possibility of changing or deleting data by any user with access to the server.
- A decentralized network for storing files - IPFS.
  This service provides the user with a unique link containing a hash of the data. This makes it impossible to change/replace the file. However, it is necessary to consider that when deleting media data from all network nodes, the user will receive an error when trying to view his NFT. The solution to this problem is to deploy your IPFS network node, which will guarantee the availability of downloaded files.
- Specialized blockchains for storing files.
  In this case, fragments from several old ones will be saved when a new data block appears. Thus, thanks to consensus algorithms and the replication of old files, the data cannot be changed or deleted. However, the problem of the solution under consideration is their low prevalence. For example, a strong reduction in blockchain users can cause uncontrolled data loss.

Table 1 shows the results of the comparison this storage methods.

Table 1. Characteristics of storage methods

	Personal Server	IPFS	Blockchain
Data changing	YES	NO	NO
Data deletion	YES	YES	NO
Distribution	NO	YES	YES

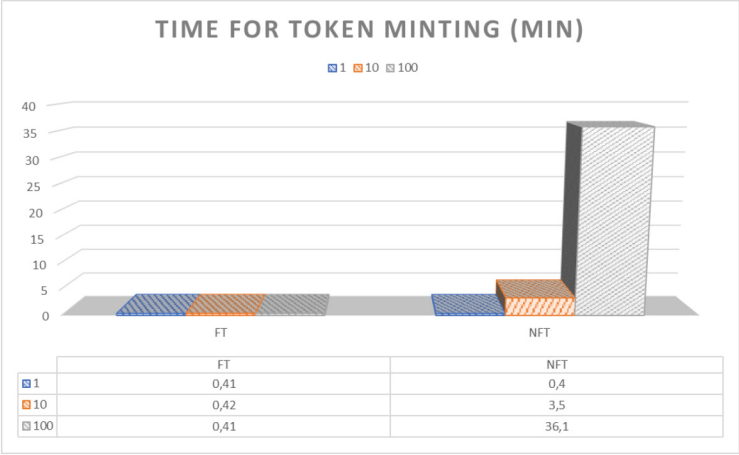
It is also necessary to take into account that links to media files and metadata contain a domain name, which guarantees a loss of access when the corresponding domain is blocked.

7 Main Token Issues

In the context of creating a marketplace, it is important to highlight the main problems of tokens and try to solve them.

7.1 Slow Processing of Operations

Transactions on the Ethereum network take quite a long time, even with high gas prices. For example, we tested the creation rates of FT and NFT in the tightness of Ethereum with Gas Price = 40 Gwei, when the average price was 34 Gwei. The result is shown in Fig. 3.



	FT	NFT
1	0,41	0,4
10	0,42	3,5
100	0,41	36,1

Fig. 3. The time of token generation in Ethereum Sepolia testnet on 16.10.2023

To solve this problem, version 2 plans to transfer the order book to L2, while only purchase transactions will be placed on L1.

7.2 Lack of Tracking of NFT's Creators

One of the ideas underlying NFT technology is to enable the creators of tokens to make a profit by reselling their creations. Since the entire history of transactions related to a certain token is recorded in the distributed ledger, the original creator can be easily found.

The current royalties system implies that the author of the token must manually indicate on the platform selected for sale what amount of commission he would like to receive from resales.

The problem arises when the buyer of the token resells it on another platform. In this case, if the author of the token did not register his contract there, he will

not be able to receive any commission. This arises due to the fact that smart contracts of marketplaces use only a universal transfer function in the token smart contract.

Let's denote through A - the smart contract of the marketplace, through B - the smart contract of the token and consider the approximate algorithm of the purchase function is shown on Fig. 4.

1. Receipt of token value in the contract A
2. Calling the token transfer function in Contract B
3. Receiving the specified royalties in contract A
4. Calculation of commissions and transfer of funds taking into account the received data

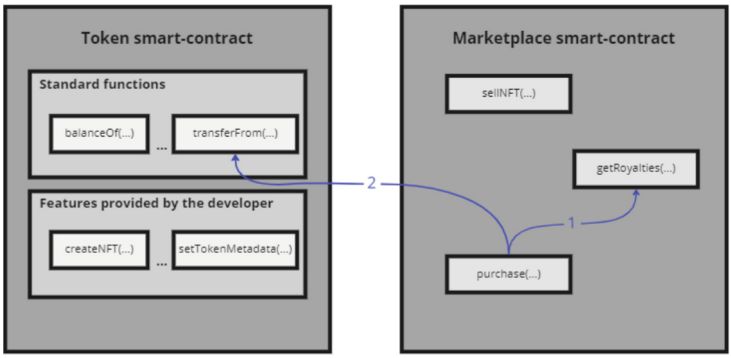


Fig. 4. Approximate algorithm of the purchase function

To solve this problem, a new standard EIP2981 [14] was introduced. It provides a function that takes the token ID and the sale price as input and returns the recipient and the desired commission. In this case, the algorithm will look like this:

1. Receipt of A token value in the contract A
2. Receiving the specified royalties in a contract B
3. Calling the token transfer function in Contract B
4. Calculation of commissions and transfer of funds taking into account the received data

This scheme is presented in Fig. 5.

However, this solution also has drawbacks. The standard assumes that the marketplace will voluntarily turn to this function and transfer part of its profits. Currently, only one of the popular marketplaces adheres to this policy - Rarible.

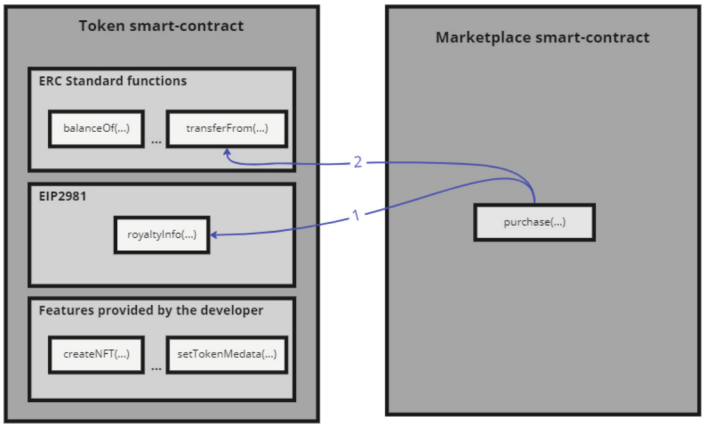


Fig. 5. Approximate algorithm of the purchase function with EIP2981

8 Art Space

Currently, there are several marketplaces designed to work with NFT. The most popular of these are OpenSea and Raible. However, each of these marketplaces has some unresolved issues for both users and NFT developers. Such problems may include the high cost of operations with tokens, the lack of support for test networks or certain blockchains, and the insufficiency of submitted operations to work with tokens.

Cross-Chain Bridges. Since users were given an opportunity to mint the NFT on various blockchains, it was decided to implement cross-chain NFT bridge for transferring assets. This can be useful, for example, when a user created his/her NFT based on Ethereum, but was tired of paying for expensive transactions, then he could transfer his NFT, for example, to Polygon, where the cost of transactions is much lower. (Comparison of transaction prices will be presented below). Currently there are many ready-made solutions for transferring FT between the blockchains, but the transfer of NFT has not been implemented, as there are some difficulties with transferring of metadata and burning of tokens.

To understand NFT problem, let's go a little bit deeper into the smart contracts theory. As we discussed above, there are special standards for smart contracts. They represent a list of functions with a predetermined name and argument. It is this predestination that tells the developer for transferring certain token, for example, of ERC-1155 standard it will be needed to call a function, named *SafeTransferFrom()* and pass in it 4 parameters - the address of the sender, the address of the recipient, the token and the number of

1. From whom token will be transferred
2. Address of recipient
3. ID of that token

4. Amount of transferring tokens

However, in the development process, the creator of the smart contract extends the list of functions predefined by the standard. The most common such extension is the function of token minting. This is where we are faced with a problem. The developer can give such a function the name "mintNFT" or "mint" or "createTokens" or some other. Thus, if we want to create a token on a pre-existing contract, we don't know if there is a function like this, how it is called and what arguments it takes.

To create a mechanism that would transfer a token belonging to a smart contract in blockchain A on smart contract in blockchain B, you need:

1. Burn a token in blockchain A.
   But the combustion function is not a standard and is added to the contract developer as an extension. It follows that if a user comes to our platform to transfer his or her token to another blockchain, it may be that parent smart contract does not provide a burning feature. Even in case it exists, we still don't know exactly what it's called.
2. Create a pair smart contract, token ID in smart contract B.

Thus, if developers need to create cross-chain bridge for tokens, they will have to develop an individual solution based on the characteristics of a written certain smart-contract. We have made such a bridge built on the basis of our smart-contracts, in which we added the possibility of burning tokens. This solution will allow users to move between the supported blockchains all the tokens minting on our platform. However, the user who created NFT somewhere outside will not be able to transfer it's asset.

Also, the main value of NFT is the number of transactions carried out with it. Accordingly, with the transition to a new blockchain, it is impossible to transfer the entire history of operations. This problem is solved by storing each NFT in the database its pair address of the smart contract, token ID for each blockchain and displaying the complete transaction history of one token on all distributed registries.

The algorithm of the bridge presented by the Art Space team is as follows:

1. ERC-1155 contracts are created on each selected blockchain.
2. The user selects the token to transfer and the blockchain to which the token will be transferred. Then, it starts the transfer process on the oracle (in this case, a web page).
3. Oracle receives the NFT metadata reference.
4. The user signs a transfer transaction in blockchain A. This transaction unlocks metadata from the original token and transfers it to a temporary storage wallet.
5. The Oracle checks whether there is a "twin" in the database for chosen token on the selected blockchain.
6. The user signs the creation transaction if there is no "twin" for the token in blockchain B. As a result of this transaction, a new token is created in

blockchain B, linked to the metadata obtained in step 3. If the "double" is detected, the unfreezing transaction will be signed, which will fix the metadata of the token in the blockchain and transfer it from the storage wallet to the user's wallet.

7. In the database, if the "twin" of the token has not been found, then a new bundle smart contract address, token ID is added for the NFT on the blockchain B. Then the bundle of the "twin" is marked active.

Thus, NFT retains information about previous transactions on all blockchains supported by the marketplace, and, in the case of transferring the token to the original blockchain, the original token with its entire history will be returned to the user. Unpinning metadata at the transfer stage to the repository ensures that tokens with the same parameters cannot be found on third-party marketplaces.

NFT Splitting. Imagine a situation where the NFT is a large expanse of land, for example, a park in virtual reality. The owner of this park wants to place a kiosk with the sale of certain digital objects on it. However, in order to transfer NFT of certain part to the seller's ownership, it is necessary to transfer the NFT of the entire park and lose ownership of another territory.

In this case, the owner of the NFT will be able to turn to our platform to cut the token into two parts. Then the NFT part for the kiosk will be transferred to the ownership of the tenant, and the rest of the NFT part of the park will remain with the original owner. Parent NFT of the ownership of the entire park in this case will be frozen. With this tool, we provide an opportunity for the landlord to significantly increase the potential income. This feature also helps to provide more flexible conditions for tenants and simplifies the process of managing virtual real estate.

A unique feature of our token division is also the ability to combine child elements into the original token. So, after the lease ends, the owner of the park will be able to burn the issued child NFTs and unfreeze his original asset.

8.1 Infrastructure Design

For the client, the Art Space ecosystem will be presented in two forms:

- Mobile Unity application;
- website.

Thus, the platform becomes universal for the user: it can be used from desktop or mobile devices.

However, it is crucial to have a well-planned ecosystem of servers, in addition to smart contracts, to ensure correct functionality. They face the following class of tasks:

1. Getting information from the selected distributed ledger:
   - Getting the current gas price of the selected blockchain;

- Getting a list of wallet transactions in the selected blockchain;
- Getting the transaction execution status;
- Getting the owner of the selected token;
- Getting the metadata of the token when importing it in the application.

2. Token maintenance:
   - Uploading image/video files to IPFS;
   - Generating token metadata in a JSON file and uploading it to IPFS;
   - Maintaining an IPFS node.

These functions were implemented in JavaScript. Their representation in the form of an API is performed using the AXIOS library [19]. To reduce the cost of implementing functions, we utilized two pre-built solutions:

1. It is important for the marketplace to have the current state of the blockchain at the time of the user's request. Deploying a local block browser requires high costs for sorting and storing all transactions related to tokens in a distributed ledger. Therefore, to obtain up-to-date data from a distributed ledger the Moralis NFT API is used [20], which supports such popular blockchains such as Ethereum, Polygon, Binance SC, Solana, Fantom et al.
2. To ensure the safety of data on the IPFS network, a data pinning process is required on a specific network node. This prevents important data from being deleted from the node during the cleanup process. However, data control and consolidation are possible only on own nodes: it is impossible to force other network nodes to consolidate personal data. Thus, to ensure the safety of metadata in IPFS, it is necessary to start own node of this system. Tracking pinned content and managing large amounts of pinned data requires investing in the creation of additional tools to work with the local IPFS node. In addition, accessing content through a shared gateway *https://ipfs.io/ipfs/${CID}* sets a limit on the number of requests per hour. For these reasons, the Infura pinning service is used IPFS, which allocates its gateway for receiving data, as well as tools for working with uploaded files.

During the development of application, one of the tasks is to develop database that stores information about tokens, smart contracts, users, and user exhibitions. The Django framework (Python) was used for this task.

The general scheme of the developed solution is shown on Fig. 6.

At the moment, Art Space mobile application is available to users in the Play Market [21] and App Store [22]. The website is in the final stages of development.

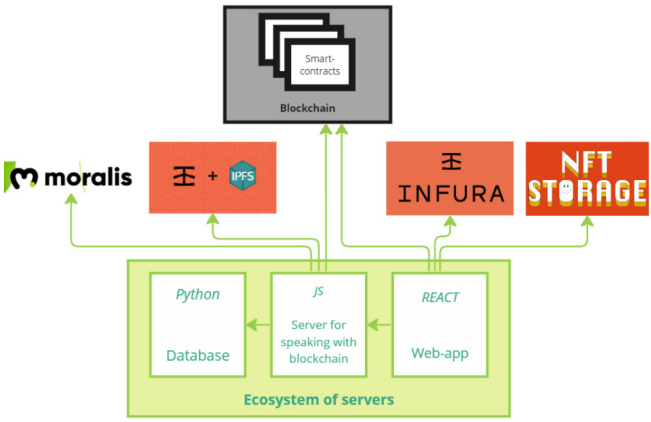
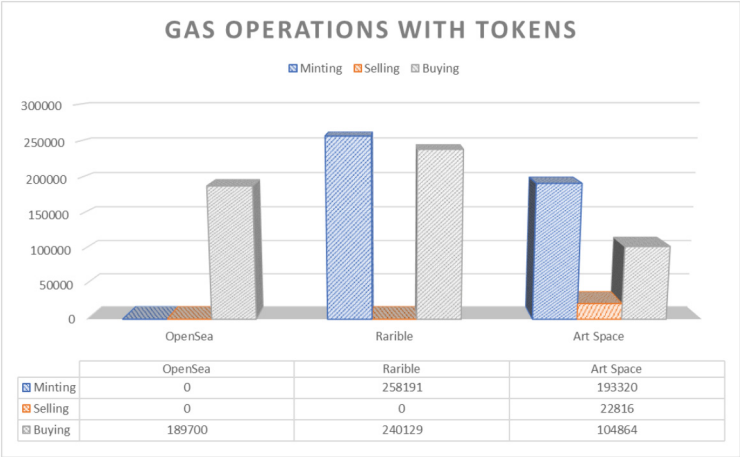


Fig. 6. Approximate algorithm of the purchase function with EIP2981

8.2 Comparison with Existing Solutions

One of the important steps in this process is to compare the resulting solution with analogs on the market. This approach allows you to evaluate the advantages and disadvantages of a new product and determine its competitiveness. In this part, the Art Space Marketplace will be compared with the most popular analogs, namely OpenSea and Raible. We will compare basic operations with NFT: minting, selling, and buying. Since the cost of transactions may differ at different times due to changes in the price of gas, the comparison of the cost of transactions will be carried out in units of gas. This will help you accurately compare the amount of computing resources needed to interact with smart contracts, without reference to a time interval. The results of comparison are presented in Table 2.

The first thing worth noting is that ArtSpace Marketplace smart contracts require less gas to function, but they need to be paid for creating an NFT and putting it up for sale. This payment ensures transparency and security of transactions. Figure 7 shows a comparison of basic operations in gas units on 3 platforms.



	OpenSea	Rarible	Art Space
Minting	0	258191	193320
Selling	0	0	22816
Buying	189700	240129	104864

Fig. 7. Comparison of the labor costs of operations for working with NFT on the marketplaces selected for the study.

Table 2. Characteristics of storage methods

	OpenSea	Rarible	Art Space
Way of minting	off-chain	off-chain and on-chain	on-chain
Token standards	ERC1155	ERC721	ERC1155 and ERC721
Support of EIP2981	NO	NO	YES
Supported blockchains	1 Ethereum, Polygon, Klaytn, Solana, Arbitrum, Optimism, Avalanche, and BNB	Ethereum, Polygon, Tezos	1 stage: Polygon, Ethereum; 2 stage: zkSync, BSC, Fantom, Harmony, Polka dot, Avalanche
Storing the order book	centralized	centralized	decentralized

9 Conclusion

In this article, we have extensively examined the creation of a decentralized application tailored for second-generation blockchains. Throughout the development process, we have thoroughly investigated the intricate architecture of blockchains and their distinctions. Also, our focus of study in this article revolves around exploring tokens. This examination encompasses their diverse types, the stages

they undergo throughout their lifecycle, the encoding standards, the methodologies for observing them, and finally, the techniques employed for storing their metadata.

As a direct outcome of our meticulous research and articulation throughout this article, we have successfully conceived and established an ecosystem of two innovative applications. The first application is an online platform, currently undergoing its final stages of development, poised to provide useful services in alignment with our research findings. The second application complements the initial platform and has been meticulously crafted to cater to mobile users. It is available for download on popular mobile application stores.

Acknowledgements. Partially supported by Saint Petersburg State University, project ID: 95438429.

References

1. Art Space Marketplace Info page. https://lanit-tercom.ru/art-space. Accessed 01 Dec 2023
2. Vujičić, D., Jagodić, D., Ranđić, S.: Blockchain technology, bitcoin, and Ethereum: a brief overview. In: 17th International Symposium INFOTEH-JAHORINA, East Sarajevo, Bosnia and Herzegovina, March 2018. IEEE (2018). https://doi.org/10.1109/INFOTEH.2018.8345547
3. Apostu, S.A., Panait, M., Vasa, L., Mihaescu, C., Dobrowolski, Z.: NFTs and cryptocurrencies-the metamorphosis of the economy under the sign of blockchain: a time series approach. Mathematics **10**(17), 3218 (2022). https://doi.org/10.3390/math10173218
4. Unstoppable domains. https://unstoppabledomains.com/. Accessed 1 Dec 2023
5. Rehman, W., Zainab, H.; Imran, J., Bawany, N.Z.: NFTs: applications and challenges. In: 22nd International Arab Conference on Information Technology (ACIT), December 2021. IEEE (2021). http://dx.doi.org/10.1109/ACIT53391.2021.9677260
6. Wang, Q., Li, R., Wang, Q., Chen, S.: Non-Fungible Token (NFT): overview, evaluation, opportunities and challenges. Cryptography and Security (cs.CR), FOS: Computer and Information Sciences, FOS: Computer and information sciences (2021). https://doi.org/10.48550/ARXIV.2105.07447
7. Victor, F., Lüders, B.K.: Measuring Ethereum-based ERC20 token networks. In: Goldberg, I., Moore, T. (eds.) FC 2019. LNCS, vol. 11598, pp. 113–129. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-32101-7_8
8. Ethereum Daily Transactions Chart. https://etherscan.io/chart/tx. Accessed 01 Dec 2023
9. Patent NIKE CryptoKickss. https://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=/netahtml/PTO/search-bool.html&r=1&f=G&l=50&co1=AND&d=PTXT&s1=Nike&s2=Crypto&OS=Nike+AND+Crypto&RS=Nike+AND+Crypto. Accessed 01 Dec 2023
10. OpenSea marketplace web. https://opensea.io/. Accessed 01 Dec 2023
11. Rarible marketplace web. https://rarible.com/. Accessed 01 Dec 2023
12. Lavrova, A., Iakushkin, O.: NFT performance and security review. In: Gervasi, O., Murgante, B., Misra, S., Rocha, A.M.A.C., Garau, C. (eds.) ICCSA 2022.

LNCS, pp. 217–228. Springer, Cham (2022). https://doi.org/10.1007/978-3-031-10536-4_15
13. Official Ethereum standards. https://eips.ethereum.org/erc. Accessed 01 Dec 2023
14. EIP2981 standard description. https://eips.ethereum.org/EIPS/eip-2981. Accessed 01 Dec 2023
15. EIP20 standard description. https://eips.ethereum.org/EIPS/eip-20. Accessed 01 Dec 2023
16. EIP721 standard description. https://eips.ethereum.org/EIPS/eip-721. Accessed 01 Dec 2023
17. EIP1155 standard description. https://eips.ethereum.org/EIPS/eip-1155. Accessed 01 Dec 2023
18. Mohan, V.: Automated market makers and decentralized exchanges: a DeFi primer. Financ. Innov. **8**, 20 (2022)
19. Link to axios web. https://axios-http.com/. Accessed 01 Dec 2023
20. Link to Moralis web. https://moralis.io/. Accessed 01 Dec 2023
21. Link to mobile app Art Space in Google Play. https://play.google.com/store/apps/details?id=com.lanittercom.artspace. Accessed 01 Jun 2023
22. Link to mobile app Art Space in App Store. https://apps.apple.com/us/app/art-space/id6444775365/. Accessed 01 Dec 2023