Journal of
**Sports Industry & Blockchain Technology**

https://ndpapublishing.com/index.php/sibt
**e-ISSN:**

# Decentralized Ledger Technologies in the Sports Industry: Applying NFT and Ordinal Theory for Athlete Data Management, Event Management, and Sports Collectibles

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**Keywords**
Blockchain,
Distributed Ledger Technology,
ERC721,
Bitcoin Ordinals

**ABSTRACT**

Since the introduction of the Bitcoin solution, decentralized and distributed solution techniques have significantly evolved. Techniques such as Hirected Acyclic Graphs (DAG), Hashgraph, and Holochain, encompassing blockchain technology, have begun to be evaluated under distributed ledger technologies and applied in nearly every field. One of the extensive application areas of distributed ledger technology is the sports industry, which can benefit from its capabilities in numerous areas, including athlete data management, sports event management, and the financing of sports. In this study we propose methods based on NFT and Ordinal Theory that can be used in athlete data management, sport event management, sports collectibles and products, and sports copyright protection. Sample tests were conducted for both methods, and the results were compared.

## 1. INTRODUCTION

The sports industry generates billions of dollars in added value and is a globally recognized sector. With technological advancements, the effects of technology have also started to manifest in sports, being utilized in various ways such as sports business activities, sports financing, and the technology-supported realization of sports events (like the Video Assistant Referee-VAR system in football). One of the most well-known examples of the intersection of sports and technology is the analysis of athlete data, which can be used to form teams or conduct athlete transfers. Additionally, the sports industry interacts with many different areas, such as betting and gambling processes related to sports, taxation, and copyright issues, where technology is also leveraged. In summary, there is almost no sport where technology is not utilized.

Similar to the impact of internet technology permeating every aspect of life after its introduction, there are almost no areas unaffected by certain technological advancements. One such technological innovation is blockchain technology [1]. Following the success of Bitcoin and Ethereum solutions, the blockchain technology behind these cryptocurrencies now holds a potential impact similar to that of internet technology [2]. The inevitable application of blockchain technology across various fields, particularly finance, has opened the door for its use, or at least experimentation, in the sports industry as well. While many sports clubs have launched tokenization projects to garner fan support, blockchain technology is being tested in several areas that impact both managerial and sports activities in the Sports Industry. In our study, research conducted in this field has been reviewed and shared with readers in the literature review section. Furthermore, it has been observed that blockchain technology can be utilized in sports industry areas such as athlete data management, sport event management, sports collectibles and products, and sports copyright protection. To investigate the feasibility of using NFT and Bitcoin NFT solutions, known as Ordinals, in these areas, two different methods were proposed within the scope of Sport Event Management: one using an NFT developed with smart contract capabilities and the other using the Bitcoin Ordinals solution.

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**How to cite this article**

Takaoğlu, M., and Dursun, T. (2024). Decentralized Ledger Technologies in the Sports Industry: Applying NFT and Ordinal Theory for Athlete Data Management, Event Management, and Sports Collectibles. *J.Sport Industry & Blockchain Tech., 1(1),32-47*

**Research Article/ DOI:** 10.5281/zenodo.12599668

Detailed research was conducted for both methods, and the results are shared in our study.

In our study, the first section initially shares a literature review. Under the Preliminaries section, blockchain technology, tokens and token standards, SegWit and Taproot Soft Forks, and the Bitcoin Ordinals protocol are introduced. In the second Methodology section, methods based on NFTs and Ordinals are presented. The third Results section shares the outcomes obtained from both tested methods. In the Discussion and Conclusion sections, the results of our research are evaluated, and the prominent method is explained with its justifications.

### 1.1. Literature Review

In his study, Fuxing Ma stated that running exercise can increase the basal metabolic rate and extend aerobic exercise duration. Highlighting the public's current need for running training assistance systems, he proposed a solution by integrating wireless sensing and blockchain technology in the design scheme. First, he obtained the user's step information and other relevant parameters through a wireless sensor network and optimized the steps under different conditions using a noise processing algorithm. Then, to protect and analyze the user's personal privacy data, he utilized blockchain technology for data transmission and storage [3].

In their study, Berkani and colleagues systematically reviewed existing research on the application of blockchain technology in the sports industry. The research indicates that there are various blockchain use cases targeting different stakeholders both on and off the field in the sports industry. However, it was noted that there is a lack of sufficient prototype applications to evaluate the effectiveness of these proposed use cases. Additionally, the study focused on the technical details, limitations, and challenges of blockchain-based applications [4].

In his article, Xingbin Du conducted a risk assessment of blockchain technology in the sports industry to improve its application impact. The study summarizes the fundamental application value and cross-border integration of blockchain technology, the challenges of applying it to the sports industry, and analyzes the main technical risks of blockchain in the sports industry. Subsequently, a risk assessment model for blockchain was developed, and ten cities were selected to conduct a blockchain risk assessment in the sports industry. The results obtained were shared [5].

In their study, Wojda and colleagues focused on the health-related applications of distributed ledger technology (DLT) in the sports industry. This review-based study discusses how medical records can be securely stored using DLT solutions, the use of technology in combating doping, the contributions it can make to the pharmaceutical supply chain, and the importance of storing and processing athlete health data [6].

Ning Li and Xiaoyun Zhu focused their study on sports injuries due to the increasing number of Chinese athletes and training intensity, proposing a solution using IoT and blockchain technologies for evaluating this situation. Their proposed system collects injury data from athletes through sensors, analyzes it, and determines risk levels. According to the data they shared in their study, the system can detect injury points in 0.2 seconds and provides accurate monitoring with a 94.39% recovery rate. They highlighted that their proposed system is effective in quickly and accurately identifying sports injuries [7].

Pu and colleagues focused their study on football injuries, noting that injuries are the most significant factor affecting players' performance and that traditional injury management and monitoring systems lack data security and smart analysis. Therefore, in their study, they collected and analyzed comprehensive injury data of footballers using blockchain and machine learning technologies. According to their test results, the self-processing capacity of the blockchain and machine learning-based system was found to be 70%, compared to 50% for traditional systems. They stated that their proposed solution enhances the efficiency of football injury management and monitoring systems [8].

Ante and colleagues focused their study on blockchain-based fan tokens and proposed a framework for blockchain-based fan tokens. They stated that fan tokens encourage fan engagement and decision-making processes within sports organizations. In this context, they analyzed Socios, a platform prominent in the issuance and operation of fan tokens. As a result of their analysis, they developed a framework encompassing Trust and efficiency layer, utility, and financialization features [9].

Pinto and colleagues proposed a blockchain-based approach for athlete doping control applications in their study. They emphasized the need for doping control procedures and related data to be securely generated, stored, accessed, and shared while ensuring immutability and privacy. Due to meeting these requirements, they opted for Hyperledger Fabric, a permissioned layer-1 blockchain solution. They discussed how blockchain can execute processes identified by the World Anti-Doping Agency [10].

Davide Carmelo Calderone explored the potential of Non-Fungible Tokens (NFTs) in sports event management in his study. He investigated how NFTs can enhance scenarios in sports event management and combat ticket speculation. Calderone explained concepts such as ERC1155, ERC4337, Proof of Attendance Protocol (POAP), soulbound token, Decentralized Identifier (DID), and layer-2 techniques like Arbitrum, Optimism, and Polygon zkEvm. The study concluded that NFTs have significant potential in sports event management and can provide substantial benefits to the sports industry [11].

In their study, Baker and colleagues addressed tokens and NFTs, highlighting their use in the sports domain. They discussed the speculative nature of the NFT market and underscored the opportunities NFTs present for sports managers, as well as the promises they hold for sports management. This study is significant for its insights into the potential of NFTs in the field of sports administration [12].

Rahardja and colleagues attempted to meet the Indonesian Taekwondo Federation's certification audits using a blockchain-based solution. They utilized the Vexanium public blockchain and opted for the delegated proof of stake consensus algorithm. Their proposed solution enables data to be transparently visible and implemented in accordance with the Federation's established plan, without any manipulation or data loss [13].

Liu and colleagues focused on a reliable player transfer evaluation method supported by all parties involved in player transfer processes. They proposed a trustworthy player transfer evaluation method supported by privacy protection. Named TPTE LSH+B, their method is primarily based on Locality-Sensitive Hashing (LSH) and blockchain technology. The researchers conducted a series of simulated experiments to validate the feasibility of their TPTE LSH+B algorithm and shared that their solutions exhibit good evaluation performance [14].

Chen and colleagues proposed a blockchain-based online digital trading card management system as a solution to fraud encountered in trading cards, especially in the National Basketball Association (NBA). They utilized Hyperledger Fabric, a permissioned layer-1 blockchain, in their proposed solution [15].

Takaoğlu and colleagues highlighted blockchain technology and its potential applications in various fields in Turkey. They emphasized that blockchain technology, widely applicable across different sectors, is also suitable for intellectual property and copyright applications. In this context, it is understood that blockchain technology could be used to protect the copyright of Turkish athletes [16].

## 1.2. Preliminaries

### *1.2.1. Blockchain technology*

The Bitcoin whitepaper, published in 2008, represents a seminal work that surpassed the proposed payment system it introduced [17]. This decentralized solution distinguished itself from previous similar proposals by optimally utilizing techniques from computer science and cryptography, gaining broad acceptance. In the Bitcoin solution, which operates on an open network without restricting access or departure, all transactions are visible, and users remain anonymous within the network [18].

Bitcoin network consists broadly of concepts such as miners and mining, nodes and consensus, transactions, and blocks. While these concepts can vary in other blockchain solutions proposed after Bitcoin, their similar use remains significant [19]. The cryptographic building blocks used in Bitcoin, such as hashing, digital signatures, and elliptic curves, ensure that data produced in the Bitcoin network is immutable and secure. Contrary to common belief, encryption is not used in Bitcoin and many other blockchain solutions; instead, system security is achieved using the cryptographic building blocks mentioned earlier [20]. Initially proposed as a payment system, Bitcoin's distributed, immutable, decentralized, and transparent solution evolved into a versatile solution usable in various fields with the introduction of Ethereum's whitepaper in 2013. Ethereum, proposed as a "world computer," operates similarly to a Java Virtual Machine but in a decentralized manner with the Ethereum Virtual Machine (EVM). It can execute software programs known as smart contracts, expanding the potential applications of the technology introduced by Bitcoin beyond just financial solutions [21].

A smart contract is a self-executing, deterministic digital code segment running on a blockchain, where contract terms are directly written into the code. It automatically applies and enforces the contract when predefined conditions are met. In essence, smart contracts are software programs specifically developed for business purposes. These smart contracts, uploaded to and verified by the Ethereum Virtual Machine (EVM), execute predefined conditions when interacted with by users. Put simply, akin to a doorbell where the smart contract acts as the bell, it operates deterministically-producing the same outcome whenever triggered, much like ringing the bell. The concept of tokens has emerged from the capabilities of smart contracts, facilitating scenarios for digitizing assets. Over time, various tokenization standards and projects have emerged for different purposes, evolving token usage since their inception [22].

Bitcoin and Ethereum's success brought the underlying technology to the forefront, leading to the term "blockchain" being widely adopted starting around 2016. The term blockchain technology aptly describes a collaborative effort between computer science and cryptography, with its roots traceable back to the 1960s. The realization of the Bitcoin solution became possible through technological capabilities such as the creation of initial computer networks, internet technology, service providers, public key cryptography, hash functions, Merkle trees, Byzantine Fault Tolerance, Diffie-Hellman key sharing algorithm, elliptic curves, timestamps, and proof-of-work. Bitcoin was not the first proposed solution in this field. Prior works include David Chaum's paper "Blind Signatures for Untraceable Payments" and the subsequent implementation of DIGICASH, Nick Szabo's Bit Gold, Adam Back's HashCash, and Wei Dai's B-Money. These were all proposed and utilized before Bitcoin in similar contexts. Perhaps the most significant reason for Bitcoin's acceptance and continued use lies in its solution to the problem of **trust**. Of course, the widespread adoption of the internet and technology globally has also greatly contributed to its success [23].

Bitcoin and Ethereum networks have paved the way for numerous blockchain solutions to emerge. Typically open-source, these solutions facilitate the broad application of blockchain technology across various domains. Initially used predominantly in financial projects, blockchain technology is now applicable in nearly every industry. As blockchain technology is applied across different sectors, it naturally gives rise to diverse requirements. For projects that should not operate in a public structure, there are various blockchain solutions available in private architectures such as permissioned and consortium blockchains [24].

In another scenario, scalability is a concern seen in initial blockchain projects like Bitcoin and Ethereum. Bitcoin can process between 3 to 7 transactions per second (TPS), while Ethereum can handle between 15 to 25 TPS. This conundrum, termed the Blockchain Trilemma by Ethereum, illustrates the challenge of achieving decentralization, scalability, and security simultaneously, often requiring trade-offs where enhancing one feature may compromise others. Various solutions have been proposed to overcome this issue, categorized into layers 0, 1, and 2, each offering different technical approaches as solutions to the blockchain trilemma [25]. Figure 1 illustrates the blockchain trilemma.

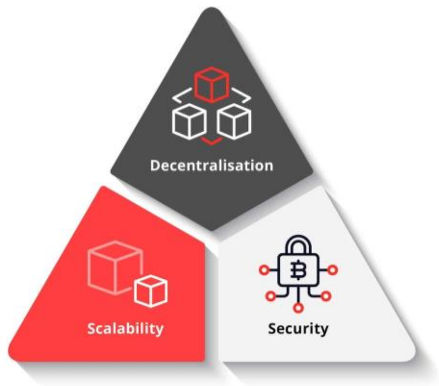


**Figure 1.** Blockchain trilemma

Blockchain networks are closed systems, maintaining a unified structure. In cases where they need to receive data from external sources, they rely on secure cryptographic data sources called oracles. Due to the unified nature of blockchain technology, various solutions are proposed to address its scalability issues. These solutions, including DAG, Holochain, Tempo, Radix, among others, are collectively referred to as Distributed Ledger Technologies (DLT), encompassing all technologies, including blockchain, prominently highlighted by the Bitcoin network, enabling application across diverse domains [26]. Given the diversity of blockchain protocols, blockchain components may vary; however, the following components are common across many blockchain systems [27]:

**Hash Function**

One-way mathematical algorithms that transform data into a fixed-size digest.

**Digital Signature**

Encryption-based electronic signatures that verify the integrity of a message and the identity of the sender.

**Elliptic Curves**

Mathematical structures based on elliptic curves used in cryptography and key management.

**Peer-to-Peer Network**

Network structure enabling direct data exchange among peers without a central server.

**Node**

Independent computer in a blockchain network that stores blocks, validates new transactions, and ensures network security.

**Ledger**

Digital ledger where transactions are recorded and maintained.

**Consensus Mechanism**

Protocols in distributed networks that enable all participants to reach a common agreement.

**Block**

Units in the ledger where data is permanently recorded. Once written, transactions cannot be altered or removed. Each completed consensus creates a new block in the blockchain. The first block is known as the genesis block. Blocks are linked to each other using hash values. The system security primarily relies on hashes and digital signatures. A published block contains a Block Header and Block Body. Figure 2 illustrates the block representation.

**Transaction**

The process of transferring an asset or information from one account to another.

**Mining**

The process of solving complex mathematical problems to create new blocks and add them to the blockchain network, while also verifying transactions in this process.

**Nonce (Number used once)**

A randomly generated or sequentially incremented number used only once in cryptographic operations.

**Smart Contracts**

Deterministic digital code pieces on a blockchain that directly encode contract terms, automatically execute and enforce them when predefined conditions are met.

**Addresses**

Unique identifiers that enable users to send and receive digital assets.

**Wallet**

Crypto wallets store private keys and allow users to store, send, and receive their crypto assets using these private keys. Users manage their crypto assets securely through the wallet by using their private keys to perform transactions.

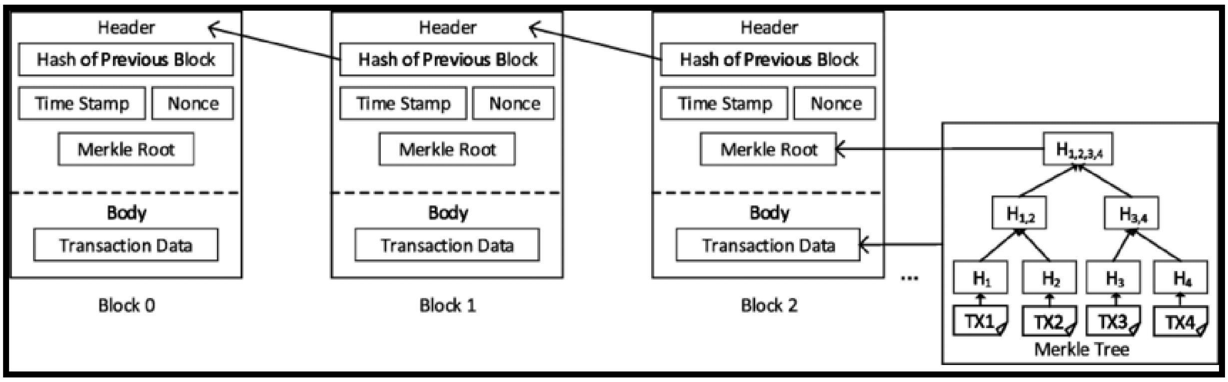


**Figure 2.** Blockchain block structure

In addition to blockchain components, the technology layers of blockchain technology are also crucial. The technology layers of blockchain are illustrated in Figure 3.

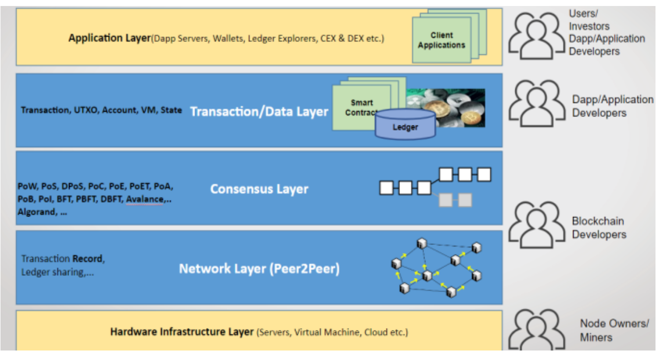


**Figure 3.** Blockchain technology stack

### *1.2.2. Token and token standards*

With Ethereum, the capability to create various types of tokens has become possible using smart contracts. Smart contracts running on the Ethereum Virtual Machine are utilized to create tokens according to established standards. Tokenization has become a crucial process today, enabling the digitization of everything, including real-world assets. Additionally, it is not necessary to use the Ethereum platform exclusively for token creation; tokens can also be produced using different DLT-based solutions. However, Ethereum and platforms like Solana are predominantly used for token creation nowadays. In our study, we opted for the Ethereum test network. Below are some token standards commonly used in creating Ethereum tokens [28].

**ERC-20** is a standard for creating and managing tokens on the Ethereum platform. This standard defines a set of rules and methods that specify how tokens can be transferred, how balances can be queried, and how the total supply is calculated. A Smart Contract that adheres to the transferring tokens from one account to another, querying the balance of an account, determining the total token supply presented to the network, and confirming whether an account can spend a specified amount of tokens by a third party. When a Smart Contract implements these methods and events, it is recognized as an ERC-20 Token Contract and assumes the management of tokens created on the Ethereum network when deployed. This standard ensures interoperability among tokens on the Ethereum network, facilitating developers in using and integrating these tokens effectively.

**ERC-721** is a standard within Smart Contracts that implements an API for tokens, specifically Non-Fungible Tokens (NFTs). This standard provides functionalities such as transferring tokens from one account to another, querying the balance of an account, determining the owner of a specific token, and calculating the total supply of tokens presented to the network. When a Smart Contract implements these methods and events, it is recognized as an ERC-721 Non-Fungible Token Contract and assumes responsibility for tracking tokens created on the Ethereum network when deployed. This standard ensures interoperability among unique tokens on the Ethereum network, making it easier for developers to use and integrate these tokens effectively.

**ERC-777** offers various improvements over the ERC-20 standard. One of these improvements is the introduction of "hooks," which are functions defined in the smart contract code and called when tokens are sent to or received from the contract. This allows the smart contract to react to incoming or outgoing tokens. Hooks are registered and discovered using the ERC-1820 standard. An important advantage of hooks is that they enable a single transaction when sending tokens to a contract and informing the contract, eliminating the need for the two-step process (approve/transferFrom) required in ERC-20. Contracts without registered hooks are not compatible with ERC-777; therefore, if the recipient contract does not have hooks registered, the sender contract halts the transaction, preventing unwanted transfers. Hooks can also reject transactions. ERC-777 addresses the confusion around decimal points present in ERC-20, thereby improving the developer experience. Additionally, ERC-777 contracts can interact with ERC-20 contracts, ensuring backward compatibility. Moreover, ERC-777 allows for additional functionalities to be built on top of tokens. For example, features like a mixer contract ERC-20 standard provides functionalities such as to enhance transaction privacy or an emergency recovery function to retrieve lost private keys can be added. Overall, ERC-777 enhances token standards by offering more flexibility, improved functionality, and better usability compared to ERC-20.

**ERC-1155** provides a standard interface for contracts that manage multiple types of tokens. A single deployed contract can handle combinations of fungible tokens, non-fungible tokens, or other configurations (e.g., semi-fungible tokens). Known as the Multi-Token Standard, this concept aims to create a smart contract interface capable of representing and managing various fungible and non-fungible token types. Consequently, ERC-1155 tokens can perform the functions of ERC-20 and ERC-721 tokens, and even both simultaneously. Key functionalities and features of ERC-1155 include the ability to transfer multiple assets in a single call (Batch Transfer), retrieve balances of multiple assets in a single call (Batch Balance), approve all tokens to an address in one go (Batch Approval), hooks for receiving tokens (Hooks), treating assets with a supply of only 1 as NFTs (NFT Support), and a series of rules for secure transfers (Safe Transfer Rules). ERC-1155 significantly enhances the flexibility and efficiency of managing different types of tokens within a single contract, thereby streamlining token management and interaction across decentralized applications (dApps) on the Ethereum blockchain.

**ERC-4626** is a standard developed to optimize and standardize the technical parameters of yield-bearing vaults. This standard provides a single API for tokenized yield-bearing vaults, facilitating the management of shares representing ERC-20 tokens. In platforms such as credit markets, yield aggregators, and interest-bearing tokens, ERC-4626 enhances development processes by enabling more consistent and error-free implementation of different strategies. Through this standard, ERC-4626 democratizes access to yield in the DeFi ecosystem and offers broader usability across various applications. Its goal is to streamline the management and interaction with yield-bearing assets, thereby fostering innovation and efficiency in decentralized finance.

**ERC-4907** is an extension of EIP-721 that proposes an additional "user" role assignable to specific addresses. This role includes defining a period after which it will automatically expire. The user role signifies permission to "use" an NFT, without the authority to perform operations like transferring the NFT or adjusting its ownership.

This mechanism enables controlled restriction of NFT, essentially facilitating the concept of NFT rental.

**ERC-5114** standard defines a type of token known as a "soulbound badge." These tokens, once minted, are permanently bound to another Non-Fungible Token (NFT) and thereafter cannot be transferred or moved. This feature ensures the immutability of the tokens, guaranteeing that collections of soulbound badges tied to the same NFT remain inseparable and indivisible.

**ERC-1400** provides a standard library for security tokens on Ethereum. These standards enable the issuance, redemption, ownership management, and handling of transfer restrictions of security tokens through standardized interfaces. Additionally, it offers transparency to token holders regarding different subsets of their balances. Key functionalities include querying transfer success, mandatory transfer capability for legal compliance, emitting standard events for issuance and redemption, and supporting features like metadata attachment and data modification during transfers. These standards are ERC-20 compatible and can also be ERC-777 compliant, aiming to cater to a broad range of asset classes.

**ERC-4337** is a standard on Ethereum that allows for account abstraction on the protocol without any changes to the consensus layer. With ERC-4337, user wallets can be transformed into smart contract accounts, simplifying interactions between users and smart contract wallets and preventing the loss of private keys. Together with ERC-4337, a new type of cryptocurrency wallet emerges.

### *1.2.3. SegWit and taproot soft forks*

Segregated Witness (SegWit) is a soft fork update implemented on the Bitcoin network in 2017. Simply put, SegWit involves separating the signature data (witnesses) from the transaction data within Bitcoin blocks. This separation allows for more transactions to be included in each block and reduces the size of transaction data, thereby speeding up the transaction verification process. Specifically, by removing signature data from transaction data, SegWit reduces the overall size of transactions, freeing up more space within blocks. This improvement enhances the scalability of the network by allowing more transactions to be processed per block. Additionally, SegWit facilitates the development of new applications while helping to keep transaction fees under control [29]. Figure 4 illustrates the representation of Bitcoin blocks before and after SegWit implementation allowed functions for specific usage scenarios of an

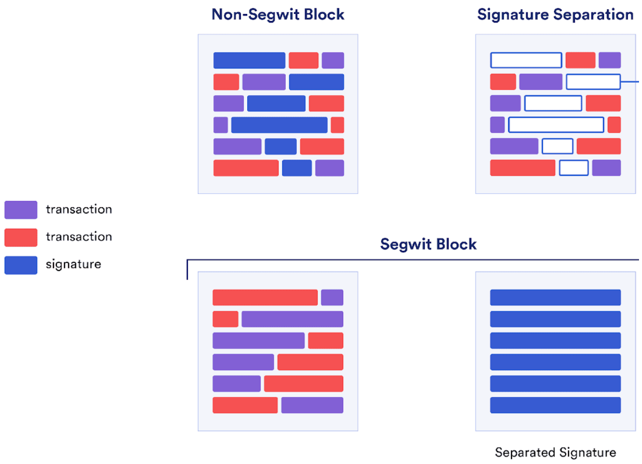


**Figure 4.** Segregated Witness

In 2021, the Taproot upgrade was activated with the production of block number 709,632 on the Bitcoin network. Taproot is a proposed soft fork change for Bitcoin that allows payments to be made to Schnorr public keys with a commitment to a script that can optionally be revealed at spending time. Taproot enables spending of BTC protected by committing to one of the specified scenarios or by providing a signature that verifies against a revealed script (allowing script hiding). Taproot is designed to work alongside Merklized Abstract Syntax Tree (MAST) to simplify multi-party structures using Schnorr signatures (such as MuSig transactions). It allows commitments to multiple scripts at spending time where any one can be used, enhancing privacy and efficiency. As a soft fork, its adoption among full nodes is optional. Currently, there exists an environment where both ECDSA and Schnorr signatures are supported, as illustrated in Figure 5 [30].

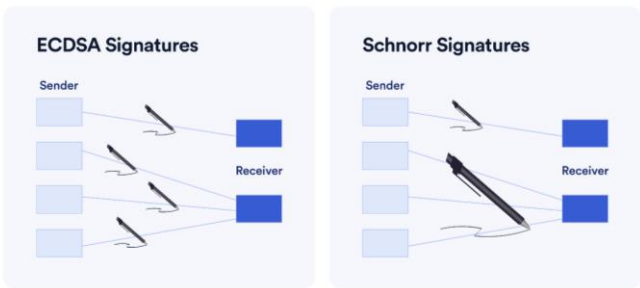


**Figure** 5. ECDSA and Schnorr signatures

Before Taproot, the basic semantics of the signature hash algorithm remained unchanged, but with Taproot, several improvements were introduced. The new signature hash algorithm enhances the verification capability of offline signing devices by adding the amount and scriptPubKey to the signature message.

It reduces unnecessary hashes by using tagged hashes and defines a default Sighash byte. Another improvement involves public keys. Unlike pre-Taproot structures that store a hash of the public key or script in the output, Taproot directly includes the public key in the output. This allows for more efficient space savings at the same transaction cost if key-based spending is preferred by the sender. Overall, Taproot aims to improve efficiency, reduce costs, and enhance privacy by leveraging these enhancements in signature hashing and public key handling within Bitcoin transactions.

The Taproot upgrade aims to enhance scalability, efficiency, and privacy. Its implementation by Bitcoin full nodes contributes to improving scalability, increasing privacy, and enhancing the smart contract capabilities of the Bitcoin blockchain (However, it should not be confused with Ethereum's smart contract capabilities).

### *1.2.4. Bitcoin ordinals*

Casey Rodarmor announced the Ordinals solution in January 2023, focusing on generative art in the NFT space. As a result of the SegWit and Taproot soft forks implemented on Bitcoin, a groundbreaking solution has been proposed that allows for the storage of digital artifacts, akin to NFTs, directly on the Bitcoin mainnet using large, randomly formatted arbitrary data within Bitcoin transactions. This innovative approach opens up the possibility of storing not only image files but also text, audio, video, and game files on the network. A similar proposal was suggested in 2012, but it did not gain practical acceptance due to the limitations of the Bitcoin protocol at that time, which relied on scripts [31].

Currently (theoretically), there is no obstacle to producing an ordinal with a maximum size of 4 MB in a Bitcoin block. However, Ordinal Inscriptions are currently generated not to exceed 0.37 MB (the inscription transaction is carried out to not exceed 400,000 weight units, where each weight unit equals 1 byte. Inscriptions up to 390,000 weight units are considered producible, which roughly equates to a maximum of 0.37 MB on average). Additionally, since the introduction of the ordinals protocol, millions of ordinal transactions have occurred on the Bitcoin network within a limited timeframe. In this context, especially with the enhanced ability to write arbitrary data post-Taproot, facilitated by the Ordinals solution, there is a potential for increased transaction volume on the Bitcoin network [32].

The Bitcoin Ordinals protocol is a solution that enables assigning unique identifiers/serial numbers (ordinals) to satoshis, the smallest unit of BTC on the Bitcoin blockchain. This allows for the numbering and tracking of indistinguishable satoshis. Every satoshi, starting from the first BTC ever created, has a unique number. Given that there are 100 million sats in each BTC, ordinal values are very large numbers. The Bitcoin network uses the UTXO (Unspent Transaction Output) model for data organization. Simply put, each time a transaction occurs, the UTXOs used as inputs are spent and new UTXOs are created. The Ordinals protocol continuously tracks the spending of these sats. Ordinals operate on a first-in, first-out principle [33]. Figure 6 illustrates the general representation of Ordinals.

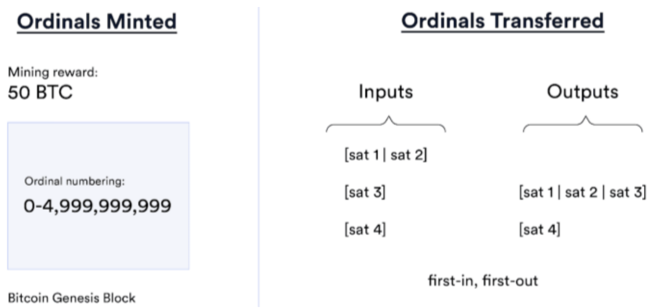


**Figure 6.** Ordinals are numbered according to the order in which they were extracted. Sorting works on a first-in, first-out basis.

The Ordinals protocol enables adding arbitrary content to individual satoshis and transforms them into Bitcoin-specific digital artifacts known as inscriptions. In brief, the Ordinals solution consists of two layers:

- Protocol Layer (base layer)
- Inscription Layer (Digital Artifacts, NFTs) (layer above the Protocol Layer)

Inscription differs from traditional Bitcoin Op-Return script transactions by leveraging the ability to load 4 MB of witness data post SegWit and Taproot. It stores arbitrary content within the transaction witness as arbitrary content. When creating an Inscription, arbitrary content such as images, audio, video, text, etc., is added to the first satoshi of the output. An ordinal number assigned to each satoshi is used to link and identify the Inscription to a specific satoshi. Once added to the blockchain/distributed ledger and confirmed, it becomes immutable.

The Ordinal protocol enables tracking of all digital artifacts created and/or transferred on the Bitcoin network. Using a Bitcoin node and the Ord wallet (where "ord" refers to an index, block explorer, and command-line wallet), marked ordinals can be viewed and transferred.

It's important to note that there are different versions, and careful migration from older to newer versions is required. Additionally, using the Ord wallet with a compatible Bitcoin node, you can fund your wallet with enough satoshis to cover transaction fees and create/write ordinals (digital artifacts). An important consideration is that without ORD, Satoshis carrying Inscription cannot be distinguished from others and may inadvertently be sent as "fee". There is also an experimental fungible token standard for Bitcoin known as BRC-20, which is under ongoing development [31][34].

## 2. METHODOLOGY

In the sports industry, blockchain technology is predominantly used in areas such as athlete's data management, sport event management, sports collectibles and products, and sports copyright protection. Each of these areas essentially involves representing data on the blockchain using different token standards tailored to the purpose of token creation. The necessary tokenization processes should be prepared and defined during the system engineering phase before token production begins. To illustrate the process through sport event management, consider the example of ticket sales for any sports event using blockchain. It's possible to create NFTs equivalent to the number of tickets to be sold, storing them in users' wallets even after they are used, and serving as memorabilia. For clarity, imagine selling NFT tickets for a historical match, such as the Muhammad Ali vs. Joe Frazier bout. These NFT tickets would remain accessible over time and could potentially increase in value. In our work, we propose two different methods utilizing NFTs and Ordinals techniques to ensure that data generated in the sports industry is stored on the blockchain.

### 2.1. NFT Based Method

Ethereum network has been chosen for NFT production, and it has been decided to create a token using the ERC-721 standard. NFTs will be generated on the Sepolia Testnet using REMIX IDE, an integrated web-based development environment for developing and testing smart contracts on the Ethereum platform. OpenZeppelin provides reliable and security-focused smart contract libraries, which have undergone smart contract audits. Therefore, the OpenZeppelin ERC721 contract template has been used. Additionally, the Metamask wallet, a widely preferred wallet application on the Ethereum network, will be used throughout this process. Figure 7 shares an example of an OpenZeppelin ERC-721 smart contract for 1000 NFTs.

In an NFT-based approach, the process extends beyond just developing the smart contract. Although our study does not cover the entire process, here's how an NFT-based sport event management process would work: Firstly, a smart contract for ticket production is developed based on the chosen DLT platform and deployed to the selected blockchain platform. Optionally, promotional activities such as advertisements where information like whitepapers, roadmaps, and tokenomics are shared, may follow. A web page or mobile application platform is set up where the developed smart contract interacts with users. This platform facilitates user registration and provides user-friendly interfaces for ticket purchases. Once users pay the specified ticket fees, ticket sales are processed. Figure 8 outlines the flowchart of the proposed NFT Based Method methodology in ourstudy.

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.0;

import "@openzeppelin/contracts/token/ERC721/extensions/ERC721URIStorage.sol";
import "@openzeppelin/contracts/utils/Counters.sol";

contract GameItem is ERC721URIStorage {
    using Counters for Counters.Counter;
    Counters.Counter private _tokenIds;
    uint256 public constant MAX_TOKENS = 1000;

    constructor() ERC721("GameItem", "ITM") {}

    function awardItem(address player, string memory tokenURI)
        public
        returns (uint256)
    {
        require(_tokenIds.current() < MAX_TOKENS, "Max token limit reached");

        uint256 newItemId = _tokenIds.current();
        _mint(player, newItemId);
        _setTokenURI(newItemId, tokenURI);

        _tokenIds.increment();
        return newItemId;
    }
}
```

**Figure 7.** OpenZeppelin ERC-721 smart contract

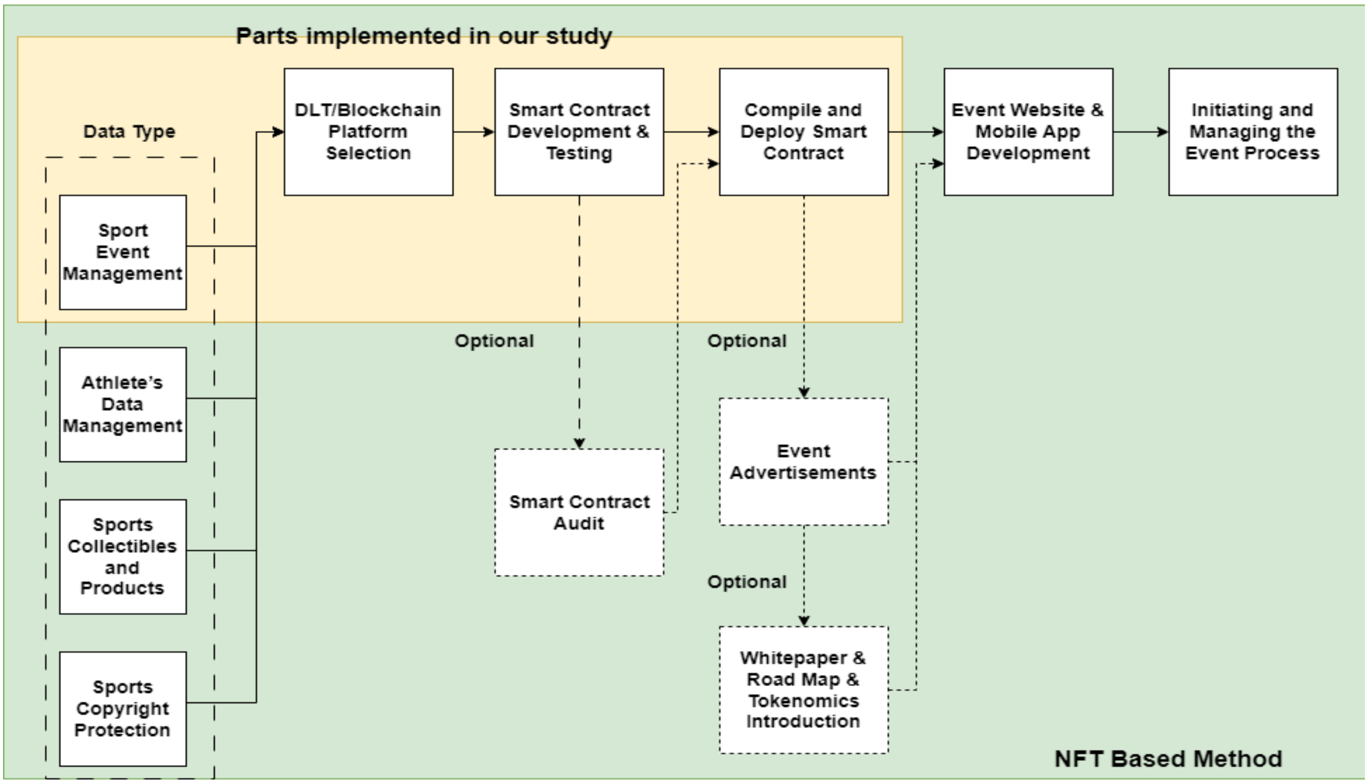


**Figure 8.** NFT based method

### 2.2. Ordinals Based Method

Bitcoin Ordinals is a new system that allows adding digital content such as images, text, audio, etc., to each satoshi (SAT) on the Bitcoin network without requiring any changes to the underlying protocol. Introduced as recently as 2022, it represents an area of study where established best practices for application development have yet to fully mature. However, it distinguishes itself from alternative solutions both conceptually and in practice due to Bitcoin's permission to append data on-chain in its distributed ledger. Producing Ordinals Inscriptions, which involves adding metadata to every satoshi with a sequence number on the Bitcoin blockchain, is not a cost-effective process. Therefore, in our study, Ordinals were generated in a test environment.

One of the most crucial aspects to consider in the Ordinals Based Method is the use of a Bitcoin wallet that is taproot-enabled and supports coin control features (such as Xverse, UniSat, Ordinals Wallet, Earth Wallet, Sparrow Wallet, etc.).

This is essential because the wallet's ability to support coin control is crucial in selecting the specific satoshi containing the Ordinal inscription that will be sent.

There are two preferred methods for generating Ordinals. If you are proficient in programming, you can create Ordinals using tools like Ord tool and Bitcoin Core. You can integrate this process with web/mobile applications you develop, designing and implementing a system that users can easily utilize. However, if you are not strong in programming, you can easily generate Ordinals and even create collections using third-party tools such as UniSat, Gamma, Ordinalsbot, and Ordswap. It's important to note that Bitcoin Ordinals are not like Ethereum NFTs in terms of a pre-set limit on the number of tokens that can be produced. Therefore, event organizers should first generate the Bitcoin Ordinals they intend to sell and then transfer them to buyers' wallets. Both the production and transfer processes incur transaction fees, which, compared to Ethereum, are technically more challenging to execute.

Generating Ordinals involves transaction fees similar to those in regular Bitcoin transactions. These fees must be paid in Ordinals-compatible wallets. Transaction fees vary based on the transaction size. Ordinals up to 400 KB can be generated without needing support from a Bitcoin miner. However, for Ordinals larger than 400 KB, collaboration with a miner is required to complete the production process. Figure 9 illustrates the flowchart of the Ordinals based method methodology.

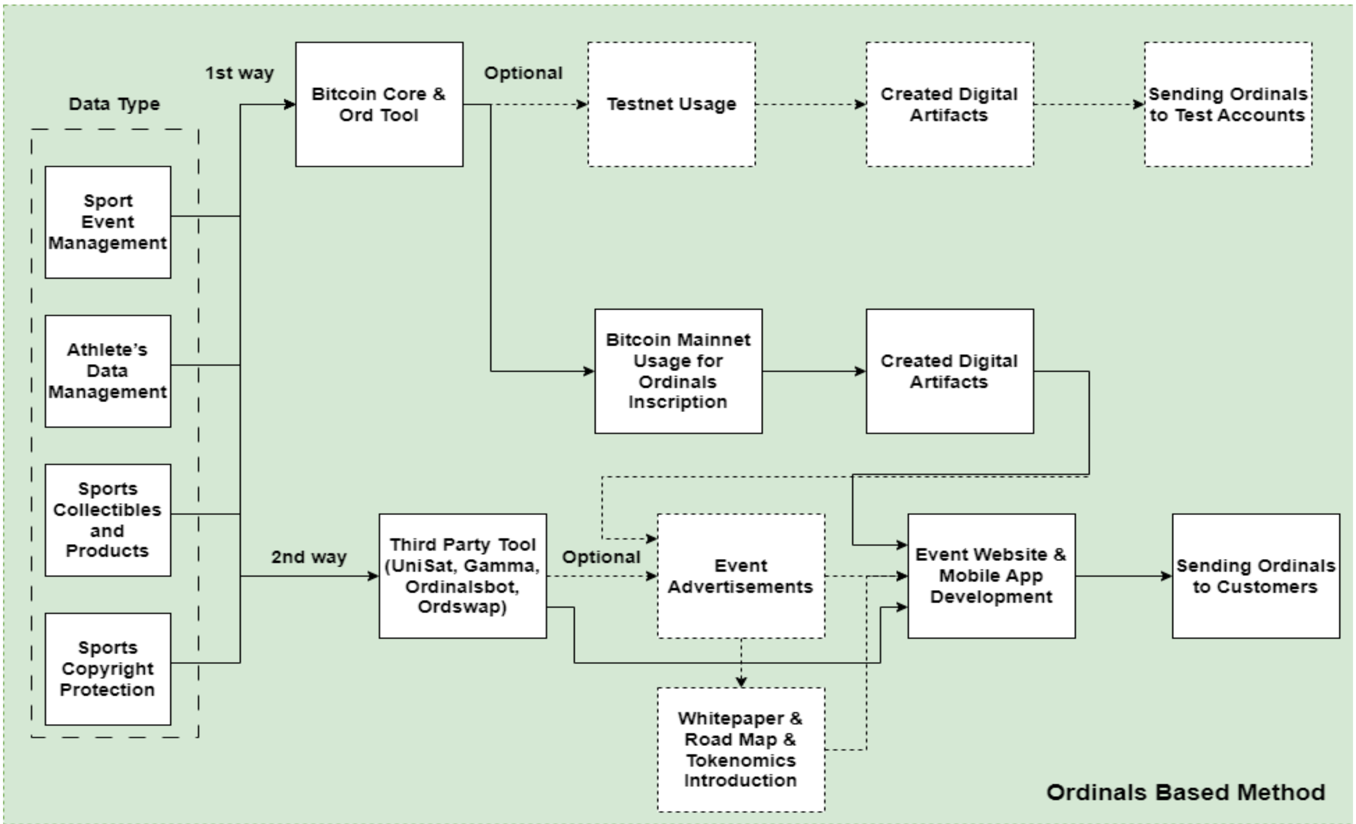


**Figure 9.** Ordinals based method

In the Ordinals Based Method, similar to the NFT based method, the process extends beyond just producing Ordinal Digital Artifacts. Depending on the type of sports data being worked on, a project process should be initiated and system engineering should be conducted accordingly. Various aspects such as event promotion, designing and developing event environments, creating simple interfaces to guide users, and other necessary steps for the project's success must be identified and implemented. It has been noted that there are two alternatives in the Ordinals Based Method. Unlike running a process similar to NFTs, Ordinals Inscriptions can be stored in organizers' wallets after they are created. Upon completing specific procedures, such as registering on event websites or mobile applications, users can then complete their transactions. This demonstrates that individuals without extensive software development experience can also digitize and sell data related to many aspects of the sports industry using third-party tools, especially for sport event management.

## 3. RESULTS

### 3.1. NFT Based Method's Results

The NFT Based Method was initially tested following these steps in sequence:

- Metamask wallet is created and connected to the Sepolia testnet.
- Test ETH is obtained from the Sepolia faucet.
- The created Metamask wallet is connected to REMIX IDE.
- An account is opened on Pinata.
- The match ticket shown in Figure 10 is uploaded to IPFS.

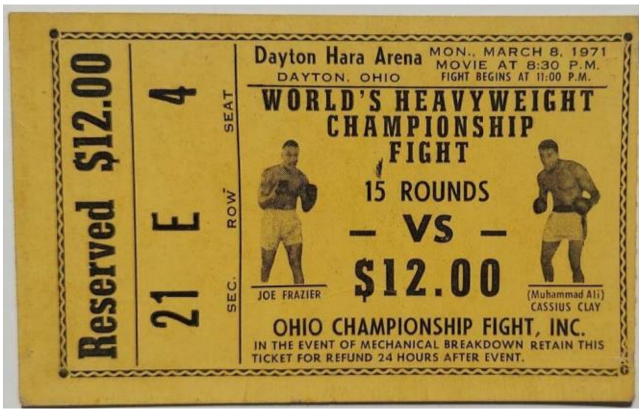


**Figure 10.** Example match ticket

- A JSON file is created. The following information is added into this file: The IPFS link of the created image is included here. This JSON file is then uploaded to

IPFS via Pinata. Figure 11 shows the content of the JSON file.

```
{ "name": "Boxing Match Ticket #1",
 "description": "This is a limited edition ticket for the boxing match event.",
 "image": "ipfs://QmdnNsEogARbx9UwwVS6iSMAPTDjoB3rL4y8fZ4ZCfSBiy",
 "attributes": [   {     "trait_type": "Event",     "value": "Boxing Match"   },   {     "trait_type": "Seat",     "value": "VIP"   } ]}
```

**Figure 11.** JSON file content

- The smart contract code based on the ERC721 standard is written in Remix IDE. The smart contract is shared in Figure 12 below.

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.20;
import
"@openzeppelin/contracts/token/ERC721/extensions/ERC721URIStorage.sol";
import "@openzeppelin/contracts/access/Ownable.sol";
contract BoxingMatchTicket is ERC721URIStorage, Ownable {
   uint256 public constant MAX_SUPPLY = 10;
   uint256 public tokenCounter;
   uint256 public constant TICKET_PRICE = 0.00001 ether;
   constructor() ERC721("BoxingMatchTicket", "BMT")
Ownable(msg.sender) {
      tokenCounter = 0;   }
   function mintTicket() public payable {
      require(tokenCounter < MAX_SUPPLY, "All tickets have been minted");
      require(msg.value >= TICKET_PRICE, "Insufficient ETH sent");
      uint256 newTokenId = tokenCounter;
      _safeMint(msg.sender, newTokenId);
      _setTokenURI(newTokenId,
"ipfs://QmeEdQxRCqsVzCobC6yNavwuKT7UCvX7ABo14hi26b9L6J");
      tokenCounter += 1;   }
   function withdraw() public onlyOwner {
      uint256 balance = address(this).balance;
      payable(owner()).transfer(balance);   }
   function setTokenURI(uint256 tokenId, string memory
tokenURI) public onlyOwner {
      _setTokenURI(tokenId, tokenURI);
   }}
```

**Figure 12.** Developed smart contract

- The shared code performs the following tasks sequentially:
  - Imports statements include necessary libraries for the contract. These include ERC721URIStorage (for NFT functionality) and Ownable (for access control).
  - MAX_SUPPLY and TICKET_PRICE are set as constant variables, with values 10 and 0.00001 ether respectively. This determines the maximum number of tickets that can be minted and the price of each ticket.
  - Constructor initializes the contract, setting tokenCounter to 0 and assigning ownership to the deploying address.
  - mintTicket is a public function allowing users to purchase a boxing match ticket. It checks if there are any tickets left and if enough Ether has been sent to cover the ticket price. If conditions are met, it mints a new token with the current value of tokenCounter, sets its URI to "ipfs://QmeEdQxRCqsVzCobC6yNavwuKT7UCvX7ABo14hi26b9L6J", and increments tokenCounter.
  - withdraw function allows the contract owner to withdraw all Ether from the contract, transferring the entire current balance to the owner.
  - Lastly, setTokenURI function is a public function callable only by the contract owner, allowing them to change the URI of any token in the contract. This can be useful for updating metadata information about individual tokens.
- The compiled smart contract is deployed.
- The Metamask wallet is connected to Remix IDE, and then the smart contract is deployed. After this stage, our smart contract is loaded on the Sepolia testnet.
- The address of the deployed contract in this work is: 0x0F77083a76c27e5354079d1b3338435BBef70270.
- Using Remix IDE, the mintTicket function is called by paying a transaction fee of 10000000000000 wei, and NFTs are minted.
- The generated NFTs can be viewed on Etherscan. It is shown in Figure 13.

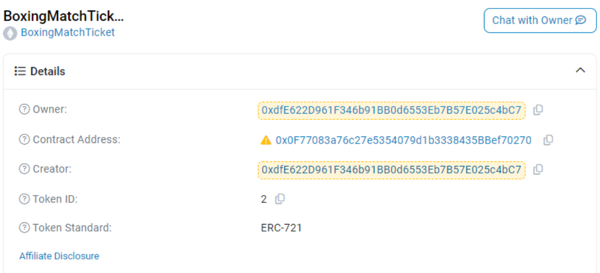

**Figure 13.** Generated NFTs on etherscan

By manually entering the contract address and token ID into your Metamask wallet, previously generated NFTs associated with your wallet are added and can then be viewed. The wallet representation of the 3 tickets generated is shown in Figure 14.

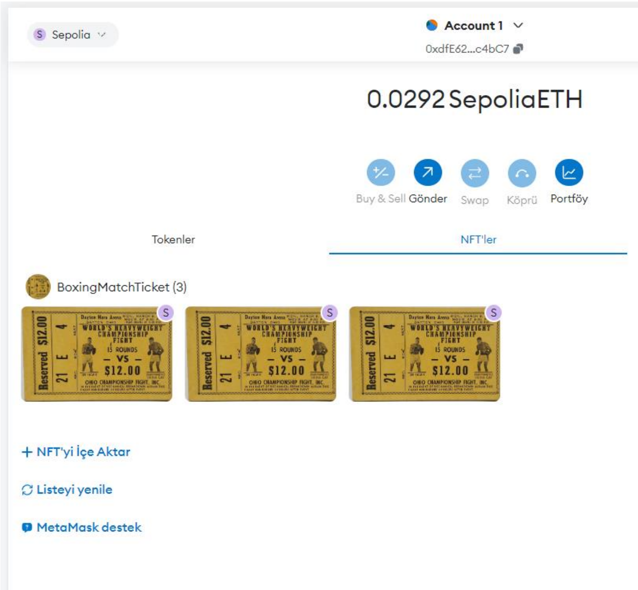


**Figure 14.** Generated NFTs on metamask

The entire process described above typically takes about 15 minutes for a developer experienced in this field. The Ethereum ecosystem is highly advanced, offering numerous free tools and resources. Production and transfers of NFTs are quite fast but may vary based on the congestion of the Ethereum network.

Using an NFT-based method, the blockchain side of an event management system can be easily implemented. However, there are many tasks required to realize any event-specific activities, such as advertising, promotion, whitepaper creation, tokenomics, and development of web and mobile applications, which were out of scope for our study. Therefore, our focus was primarily on producing a limited number of NFTs and distributing them, which was accomplished quite easily.

### 3.2. Ordinal Based Method's Results

Digital Artifact production can follow two methods. The first method is suitable for developers with stronger programming skills and involves setting up Bitcoin Core and Ord Wallet. The process works as follows:

- Download Bitcoin Core to your computer and synchronize it with the Bitcoin network. This process takes approximately 8 hours and requires a fast 1 TB SSD and high-speed internet.
- Download and install the latest Ord Wallet from doc.ordinals.com.
- Run Ord Wallet from the command prompt and create a Bitcoin account. Accounts created are Taproot compatible.
- Transfer real BTC to the created account.
- After completing Bitcoin Core installation and synchronization and setting up Ord Wallet with account creation and sufficient BTC transfer, you can proceed to perform Ordinals Inscription.
- As intended in our study, using the file path of the image shared in Figure GT, determine the transaction fee required based on the transaction size from mempool. space. Then, perform Ordinals Inscription via Ord Wallet. Transaction confirmations can take as little as 10 minutes in the best scenario, or hours to days in unfavorable scenarios, depending on network congestion and the fee paid.
- In an event management process, the desired amount of Digital Artifacts can be produced and subsequently distributed to users' accounts through a developed event website or mobile application.

The second method involves using third-party tools, which simplify the entire process for users in a straightforward manner. Similar to the first method, real BTC is used, and there may be additional costs for the services provided, which are passed on to the user. Here's an example process:

- Set up Xverse wallet.
- Load a certain amount of BTC into the Xverse wallet.
- Use a third-party tool like Gamma io to perform the following steps: Create -> Create Individual Inscription -> Select your inscription type -> Decide Transaction Settings such as which satoshi you want to inscript, add metadata, and set your transaction fee (Between $90 to $96) -> Enter wallet address -> Complete the payment process to finalize the transaction.

During our project, we encountered challenges finding a stable Ordinals Testnet, which led to testing being halted at the transaction creation stage. High transaction fees (around $100), the 9-hour synchronization time for Bitcoin

Core, and delays in transaction processing were noted as significant drawbacks. Utilizing Bitcoin Core and Ord Wallet for Ordinals Inscriptions allowed for transactions without requiring deep software expertise. Additionally, 3rd party tools enable Ordinal inscription processes without the need for any software knowledge. Apart from Ordinal Protocol, Ordinal Inscriptions, and Ordinal Digital Artifacts, there is also a token standard called BRC20, which was developed by Casey Rodarmor to create fungible tokens using the BRC-20 standard, known as the Runes Protocol. However, neither BRC-20 nor the Runes Protocol were utilized in our study.

## 4. DISCUSSION

In our study, we focused on blockchain applications in the sports industry, particularly in athlete's data management, sport event management, sports collectibles and products, and sports copyright protection. While exploring each of these areas, we specifically emphasized two different methods, with a detailed focus on sport event management.

In the first method, the use of NFTs was targeted, and Ethereum was chosen among several DLT (Distributed Ledger Technology) and blockchain solutions capable of producing NFTs. Ethereum's widespread adoption, high-quality documentation, active community engagement, and easy access to educational resources were key factors that influenced this decision.

Using the OpenZeppelin library on the Ethereum network, a smart contract was developed by leveraging audited template codes with minor modifications to generate 10 tickets. Both the smart contract development process and the uploading of images for use in NFTs to IPFS took a very short time. Through applications on the Sepolia test network, the produced NFTs have demonstrated how easily a blockchain-based solution can be implemented in a sport event management process.

Throughout the testing processes, entirely open-source tools were utilized, allowing the completion of the test process without the need for any transaction fees. Since the developed smart contract was not actively used, a meaningful dataset for analyzing the transactions was not generated. Our study, which focused solely on the blockchain aspect without developing any frontend software, fully achieved its intended result. It demonstrated how easy and feasible blockchain usage is in the sports industry, particularly for sport event management.

The implementation of the sport event management process using the Bitcoin Ordinals protocol began with the installation of Bitcoin Core and Ord Wallet. Despite both being open source, they garnered attention due to the high internet connection speed required and hardware specifications like a 1 TB SSD drive. After installing Bitcoin Core, the synchronization with the Bitcoin network took approximately 9 hours. Using Ord Wallet, Bitcoin accounts were easily created, and basic tests as shared in the Ordinal Theory Handbook were conducted in the test environment.

For Ordinals Inscriptions to be performed, BTC needs to be sent to the Bitcoin Accounts created in Ord Wallet for transaction fees and for use during the ordinal creation process. Initially, real BTC must be sent to these wallets from any exchange or wallet. With these BTC, the Bitcoin Inscription process can be executed, and after the Bitcoin Artifact is created, it needs to be transferred to another account (in our example, a customer/user). This process involves a total of 3 Bitcoin transactions. While it's feasible to produce multiple Ordinals Artifacts, there is a significant transaction cost associated with transferring these artifacts to users afterward. In the current scenario, the use of Bitcoin Ordinals in the sports industry doesn't appear to be highly efficient. However, under different scenarios and depending on the sizes of visuals or metadata used, it may be possible to produce them at lower costs.

Using 3rd party tools is not more cost-effective. The difference lies in the fact that these tools do not handle the Bitcoin Core installation and Ord Wallet usage processes, and they typically have more intuitive and user-friendly UIs, making them easier to use.

Bitcoin Ordinals and NFTs share a common ground in representing the uniqueness and ownership of digital assets using distributed ledger technology. However, there are some key differences that distinguish these two technologies. One fundamental difference lies in the storage mechanism of ordinals-digital artifacts. Bitcoin Ordinals directly store digital content on the Bitcoin network (on-chain). In contrast, traditional NFTs like ERC-721 are based on various standards, and the related information is stored in smart contracts while the content itself is often stored in off-chain storage environments. In essence, Ordinals (Bitcoin Ordinal Artifact) are completely immutable, preserving the digital asset against any changes, whereas standard NFTs can be updated over time with additional information or modified features (there is a risk of data becoming inaccessible over time on IPFS). Another difference is that creating a digital artifact through the Ordinals protocol does not lead to the creation of a separate token. Instead, a Bitcoin digital artifact is linked to a numbered specific satoshi and becomes uniquely and immutably associated with the underlying Bitcoin blockchain network.

There is currently no standard for Ordinal Inscriptions, also referred to as Bitcoin NFTs. The Bitcoin solution is not currently compatible with advanced smart contract capabilities. Ethereum, on the other hand, offers various token standards and the ability to develop complex applications. Running a full node is required to perform Bitcoin Ordinals Inscription, whereas Ethereum does not have such a requirement. In Bitcoin Ordinals, file sizes are limited to 4 MB, with not all of this space being usable in a single Ordinal. Ethereum, however, has a 100 MB file size limit and utilizes off-chain techniques like IPFS to prevent excessive increase in transaction sizes. Nevertheless, transaction fees increase as transaction sizes grow in both solutions. Currently, the cost of performing Bitcoin Ordinals Inscription is higher compared to Ethereum due to these factors.

## 5. CONCLUSION

In conclusion, our study indicates that the use of blockchain technology in the sports industry will continue to increase. Between the Ethereum and Bitcoin Ordinals methods we examined, the Ethereum method stands out as easier, faster, and cheaper compared to Bitcoin Ordinals. It is fair to state that Bitcoin Ordinals Artifacts, produced according to the Bitcoin Ordinals protocol, are true NFTs due to their on-chain nature. However, without using a coin control and Taproot-supported wallet, there is a risk of spending the satoshi to which the data is linked. It is understood that using the Bitcoin Ordinals method for a sport event management process would be very costly. In contrast, transaction costs are more affordable with the Ethereum method, and they can be further reduced by using Ethereum layer-2 techniques.

Another important point is that the Bitcoin Ordinals Protocol requires much more development compared to Ethereum. Issues such as the lack of testnet facilities, interoperability problems encountered when existing tools work together, tools that are no longer being supported, the absence of standards, and high transaction fees demonstrate that the Ordinals solution is not the best alternative for meeting the needs of the sports industry.

As future work, it is suggested to research the most suitable DLT solution for various areas of the sports industry such as athlete's data management, sport event management, sports collectibles and products, and sports copyright protection. Besides Ethereum and Bitcoin Ordinals, there are many different DLT solutions, each with distinct features. Conducting such a study and comparing the results would have scientific value.

**Acknowledgement**

We would like to extend our sincere gratitude to the editors of Journal of Sport Industry & Blockchain Technology, for their invaluable guidance and constructive feedback throughout the review process.

### Conflict of Interest

No conflict of interest is declared by the authors. In addition, no financial support was received.

### Ethics Committee

No need for Ethics Committee approval for this study.

### Author Contributions

Study Design, MT, TD; Data Collection, MT, TD; Statistical Analysis, MT, TD; Data Interpretation, MT, TD; Manuscript Preparation, MT, TD; Literature Search, MT, TD. All authors have read and agreed to the published version of the manuscript.

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