NFTs & Digital Assets: A Quantitative Deep Dive

Standalone Technical Lecture

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University Lecture Series

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Lecture Roadmap

Learning Objectives

- Understand NFT mechanics and token standards
- Analyse marketplace dynamics and pricing
- Explore real-world NFT applications
- Apply quantitative valuation methods
- Evaluate advanced NFT architectures

Prerequisites

- Blockchain fundamentals (Lessons 1–2)
- Smart contract basics (Lessons 3–4)
- Ethereum architecture (Lesson 5)
- Basic programming knowledge

Durat

90 minutes — 5 sections — ˜55 frames — Prerequisite: Lessons 1–5

Table of Contents

Navig

through 5 sections covering NFT fundamentals to advanced topics

Learning Objectives

By the end of this lecture, you will be able to:

1. **Explain** the ERC-721 and ERC-1155 token standards and their metadata architecture
2. **Compare** NFT marketplace mechanisms (auction, fixed price, AMM-based)
3. **Analyze** NFT valuation methods including rarity scoring and floor price analysis
4. **Evaluate** NFT use cases beyond art (gaming, identity, RWA, ticketing)
5. **Assess** advanced NFT concepts (fractional, dynamic, soulbound tokens)

Bloom

taxonomy levels: Remember → Understand → Apply → Analyze → Evaluate → Create

Section 1: NFT Fundamentals & Standards

Building the conceptual and technical foundation for non-fungible tokens

What You Will Learn

- What makes a token non-fungible and why it matters
- The ERC-721 standard: interface, events, and patterns
- ERC-1155 multi-token standard and its advantages
- NFT metadata architecture and storage trade-offs

Frames in This Section

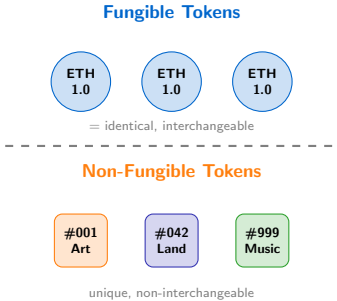
What is a Non-Fungible Token?

Definition

A **Non-Fungible Token (NFT)** is a cryptographic token on a blockchain that represents a *unique* asset. Unlike fungible tokens, each NFT has a distinct identifier and is not interchangeable with any other token.

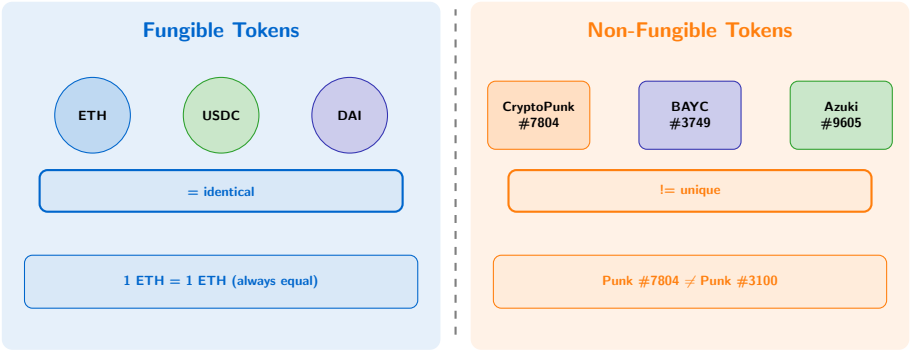
Core Properties

- **Unique** — each token has a distinct `tokenId`
- **Indivisible** — cannot be split into fractions
- **Verifiable** — ownership provable on-chain
- **Transferable** — can be bought, sold, gifted
- **Programmable** — smart contract logic attached



Non-fungible means each token is unique and not interchangeable with any other token

Fungible vs Non-Fungible: A Visual Comparison



Fungi

is about substitutability – fungible tokens are interchangeable, NFTs are not

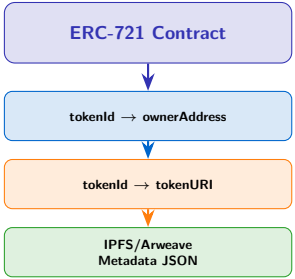
ERC-721: The NFT Standard

Core Interface Functions

- `balanceOf(owner)` — count NFTs owned
- `ownerOf(tokenId)` — get current owner
- `transferFrom(from, to, id)` — transfer token
- `approve(to, tokenId)` — allow one transfer
- `safeTransferFrom(...)` — transfer with safety check
- `tokenURI(tokenId)` — get metadata URI

Key Events

- `Transfer(from, to, tokenId)` — ownership change
- `Approval(owner, approved, tokenId)` — approval set



Ownership & Metadata Architecture

ERC-721 was proposed in January 2018 (EIP-721) and is the foundation for most NFT projects

ERC-721 Interface

Key Functions Explained

- `balanceOf` — returns total NFTs held by an address
- `ownerOf` — resolves tokenId to owner address
- `transferFrom` — moves token between addresses
- `approve` — delegates transfer right for one token
- `tokenURI` — returns off-chain metadata location

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

interface IERC721 {
    function balanceOf(address owner)
        external view returns (uint256);
    function ownerOf(uint256 tokenId)
        external view returns (address);
    function transferFrom(
        address from, address to,
        uint256 tokenId
    ) external;
    function approve(
        address to, uint256 tokenId
    ) external;
    function tokenURI(uint256 tokenId)
        external view returns (string memory);
}
```

Implementation Note

All transfers must emit the `Transfer` event. Safe transfers check if the receiver implements `IERC721Receiver`.

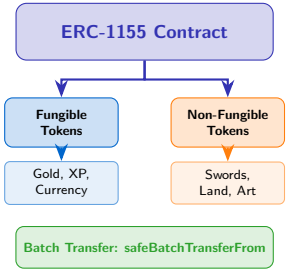
The ERC-721 interface defines the minimal functions every NFT contract must implement

ERC-1155: The Multi-Token Standard

ERC-1155 Advantages

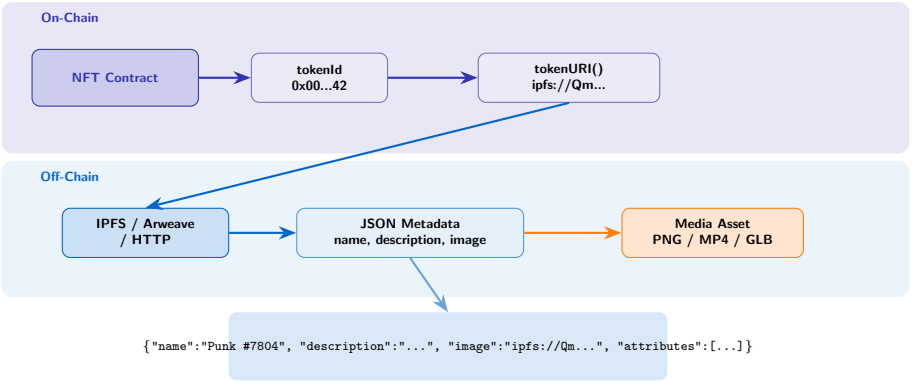
- **Batch transfers** — move many tokens in one call
- **Gas efficiency** — up to 90% savings vs ERC-721
- **Mixed types** — fungible and non-fungible together
- **Single contract** — manages entire token ecosystem
- **Atomic swaps** — safe multi-token exchanges

Standard	Token Types	Batch	Gas
ERC-721	Non-fungible	No	High
ERC-1155	Both	Yes	Low



ERC-1155 supports both fungible and non-fungible tokens in a single contract, reducing gas costs

NFT Metadata Architecture



NFT metadata follows the ERC-721 Metadata JSON Schema – name, description, image, and attributes

On-Chain vs Off-Chain Storage

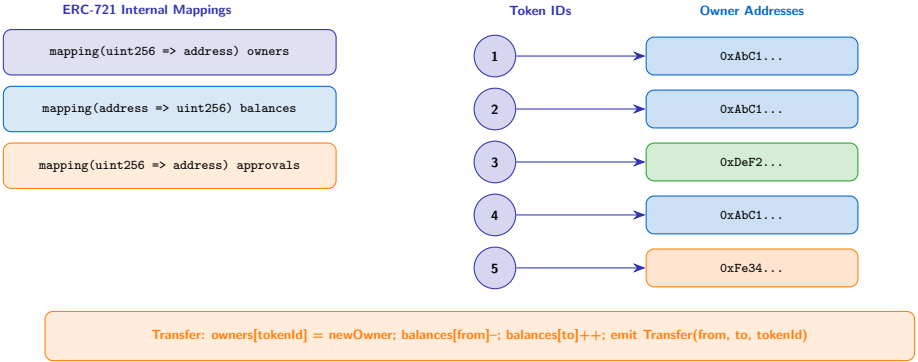
Method	Cost	Permanence	Decentralization	Examples
On-Chain	Highest	Permanent	Fully decentralized	Art Blocks, Nouns
IPFS	Moderate	Depends on pinning	Moderate	Most NFTs
Arweave	Moderate	Permanent	High	Permaweb
HTTP / S3	Cheapest	Fragile	Centralized	Early NFTs

Warning: HTTP/S3 storage creates a single point of failure — the NFT can become inaccessible if the server goes offline

Stora

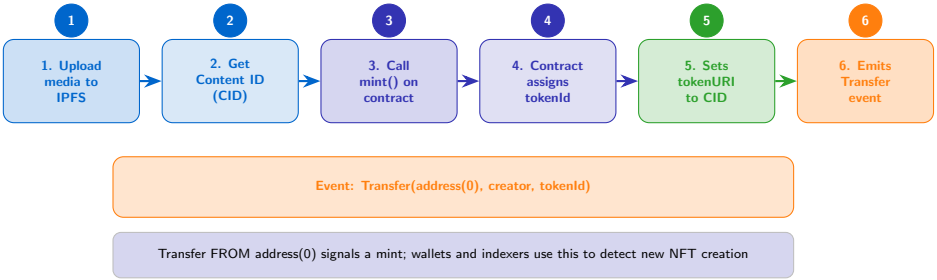
choice is the most critical design decision for NFT longevity

Token ID and Ownership Mapping



An NFT contract is fundamentally a mapping from token IDs to owner addresses

NFT Minting Process



Minti

emits a Transfer event from the zero address – this is how wallets detect new NFTs

Section 1 Summary

1. **NFTs are unique and indivisible — each token has a distinct identity on-chain**
2. **ERC-721 is the core standard; ERC-1155 extends it with multi-token and batch support**
3. **Metadata lives off-chain via `tokenURI()` — pointing to IPFS, Arweave, or HTTP**
4. **Storage permanence varies — on-chain is safest; HTTP is fragile and centralized**
5. **Minting emits `Transfer(address(0), creator, tokenId)` — the zero-address signals creation**

Secti

1 complete – next: NFT Marketplaces & Trading

Section 2: NFT Marketplaces & Trading

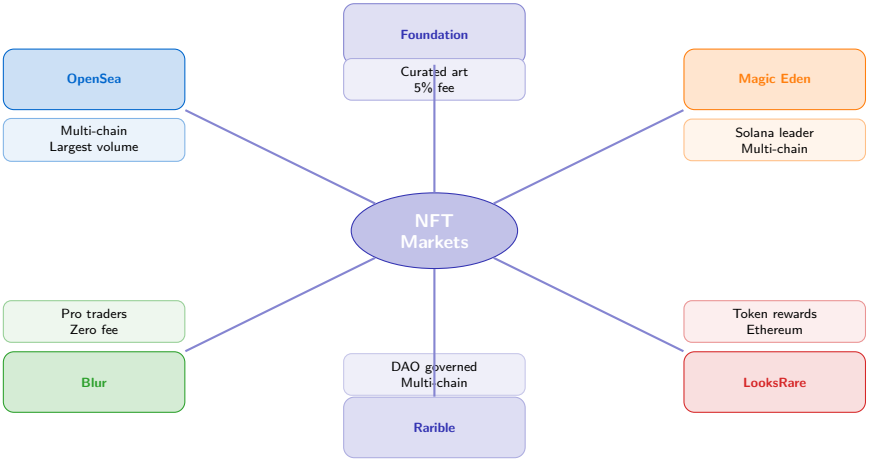
Platforms, pricing mechanics, royalties, and market structure

What You Will Learn

- How NFT marketplace ecosystems are structured
- Mechanics of on-chain NFT trading and settlement
- Pricing models: fixed price, English and Dutch auctions
- Creator royalties and the EIP-2981 standard
- Floor price, wash trading, and market integrity

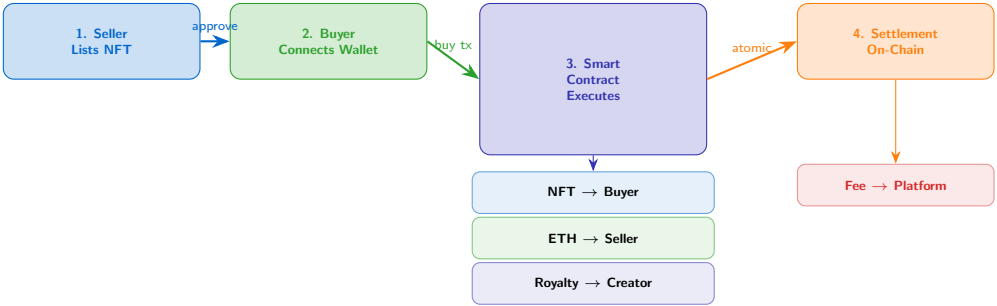
Frames in This Section

NFT Marketplace Landscape



The NFT marketplace landscape has shifted from OpenSea dominance to competitive multi-platform trading

How NFT Trading Works



NFT

trades are atomic on-chain transactions – payment and delivery happen simultaneously

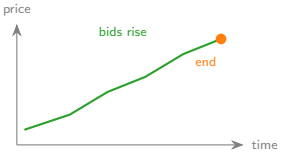
Pricing Mechanisms

Fixed Price

- Seller sets a price
- First buyer pays and receives NFT
- No time pressure
- Simple and predictable

English Auction

- Ascending bid competition
- Highest bid wins at close
- Creates urgency and FOMO
- Price discovery via demand



Dutch Auction

- Price starts high, falls over time
- First buyer to accept wins
- Fair price discovery for mints
- Popular for large collections

Dutch auctions are popular for NFT mints because they help discover fair market price

NFT Royalty Mechanics

Creator Royalties

- Royalties give creators a % of every secondary sale
- Typically 5–10% of sale price
- Paid automatically by marketplace smart contracts
- **EIP-2981** standardizes royalty queries on-chain

```
// EIP-2981 Royalty Standard
interface IERC2981 {
    function royaltyInfo(
        uint256 tokenId,
        uint256 salePrice
    ) external view returns (
        address receiver,
        uint256 royaltyAmount
    );
}
// Example: 5% royalty
// salePrice = 1 ether
// royaltyAmount = 0.05 ether
```

Enforcement Challenges

- EIP-2981 only *declares* royalties — cannot enforce
- Marketplaces may choose to ignore royalty info
- **Royalty wars (2022–23):** Blur made royalties optional
- Creator revenue fell significantly as a result
- Some projects use transfer restrictions to enforce

EIP-2981 standardizes royalty queries but enforcement depends on marketplace cooperation

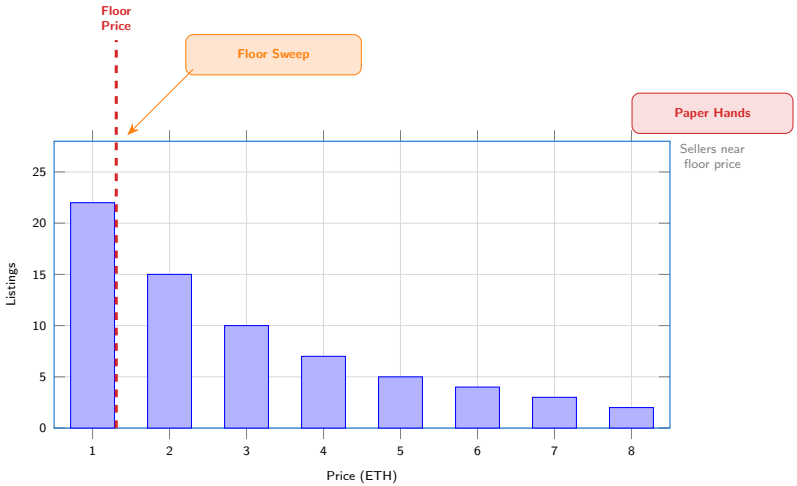
Marketplace Fee Comparison

Platform	Trading Fee	Creator Royalty	Royalty Optional?	Chain
OpenSea	2.5%	Yes	Optional	Ethereum
Blur	0%	Optional	Yes	Ethereum
Magic Eden	2%	Optional	Yes	Solana
LooksRare	2%	Yes	Optional	Ethereum
Foundation	5%	Yes	Enforced	Ethereum

The royalty wars of 2022–23 led most platforms to make creator royalties optional

The royalty wars of 2022–23 led most platforms to make creator royalties optional

Floor Price Mechanics



Floor price is the minimum entry cost for a collection – it is the most-watched metric in NFT trading

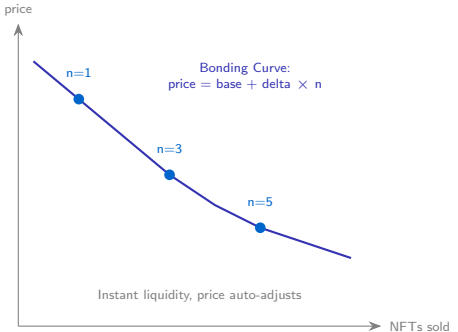
Order Book vs AMM for NFTs

Traditional Order Book (OpenSea)

Bids (Buy)	Asks (Sell)
2.80 ETH	2.90 ETH
2.75 ETH	3.00 ETH
2.70 ETH	3.20 ETH

Spread:
0.10 ETH

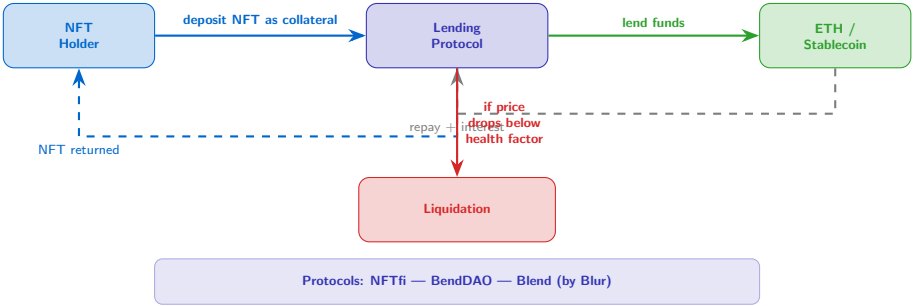
AMM Model (Sudoswap)



NFT

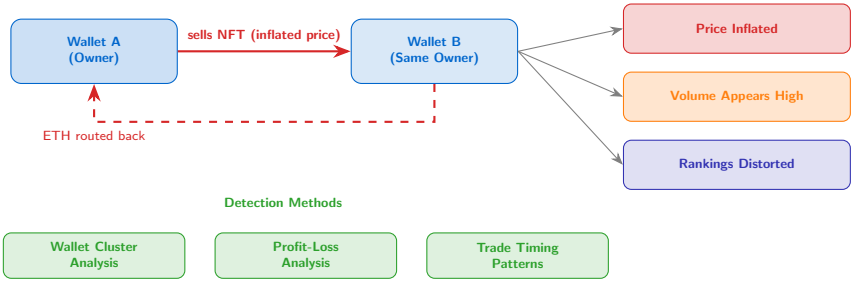
AMMs like Sudoswap bring instant liquidity but work best for floor-priced items

NFT Lending and Collateralization



NFT lending unlocks liquidity for holders without selling – but liquidation risk is significant

Wash Trading Detection

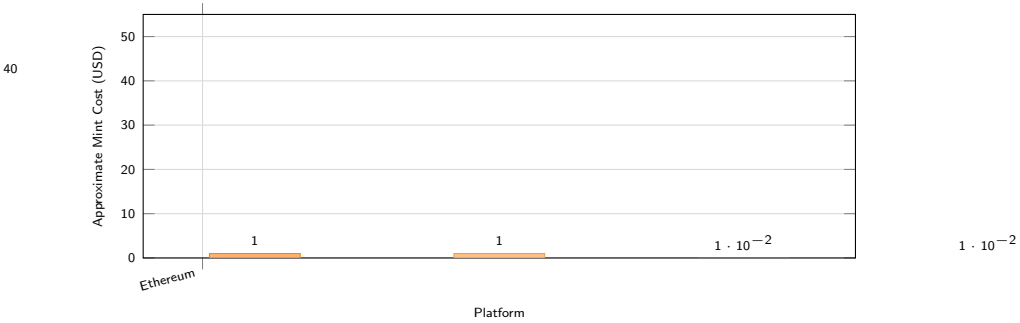


Wash

trading inflates volume metrics – always verify organic trading activity before investing

Gas Costs and Layer-2 NFTs

Layer-2 and alt-chains:
near-zero gas costs



Layer 2 and alternative chains dramatically reduce NFT gas costs, enabling mass-market adoption

Section 2 Summary

1. Marketplaces are shifting — from OpenSea dominance to competitive multi-platform trading
2. NFT trades are atomic on-chain — payment and delivery of the NFT happen simultaneously
3. Pricing mechanisms include fixed price, English auctions, and Dutch auctions for mints
4. Creator royalties face enforcement challenges — EIP-2981 declares but cannot enforce payment
5. Wash trading is significant — estimated 40–70% of 2022 NFT volume was artificial

Secti

2 complete – next: NFT Applications & Use Cases

Section 3: NFT Applications & Use Cases

Art, gaming, music, real-world assets, identity, and credentials

What You Will Learn

- How digital art NFTs created verifiable scarcity for creators
- PFP collection mechanics and rarity distribution
- Gaming and play-to-earn ecosystems
- Music, media, and real-world asset tokenization
- Identity, credentials, domain names, and IP licensing

Frames in This Section

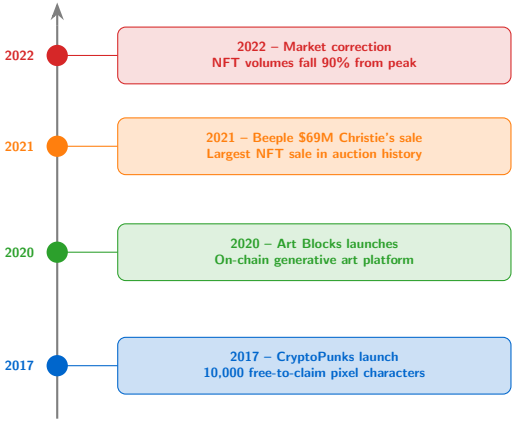
Digital Art NFTs

Key Milestones

- **Beeple $69M at Christie's (2021)** — "Everydays: The First 5000 Days" sold as a single NFT, legitimising digital art in traditional auction houses
- **CryptoPunks (2017)** — 10,000 pixelated characters; first collectible NFT project on Ethereum; free to claim at launch
- **Art Blocks (2020)** — Generative art platform; each piece minted on demand from an algorithm stored on-chain

Why Digital Art NFTs Matter

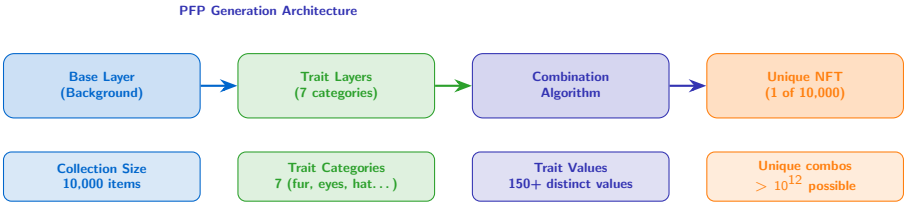
Verifiable scarcity on a public ledger converts infinitely-copyable files into provably unique digital assets with traceable provenance.

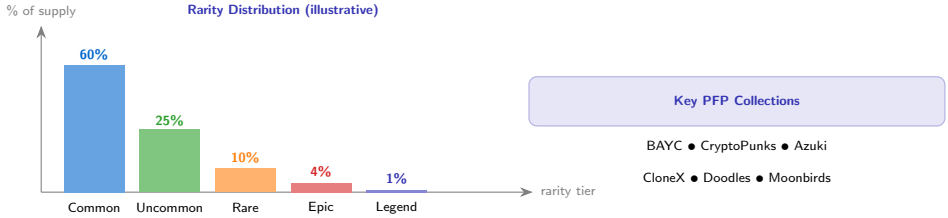


Digit

art NFTs proved that verifiable scarcity can create real value for digital creators

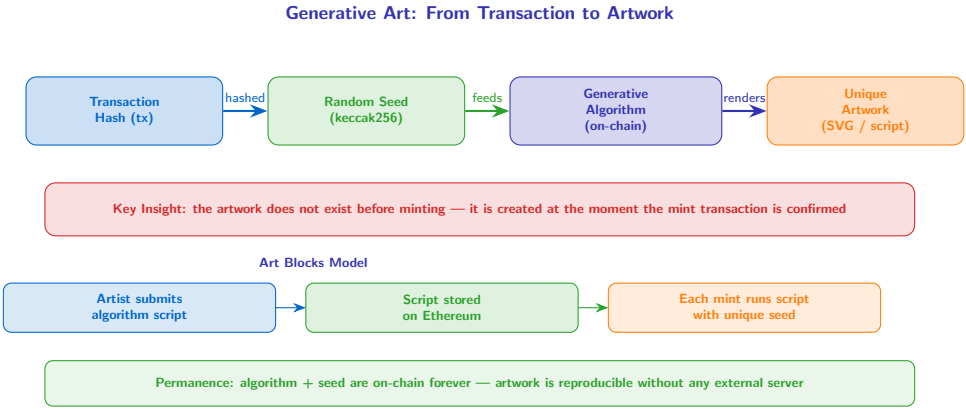
Profile Picture (PFP) Collections





PFP collections use algorithmic generation to create thousands of unique but thematically consistent NFTs

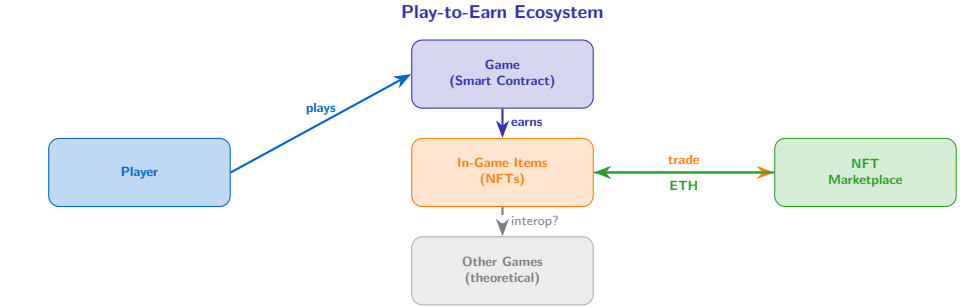
Generative Art NFTs



Gene

art NFTs are unique because the artwork is created on-chain at the moment of minting

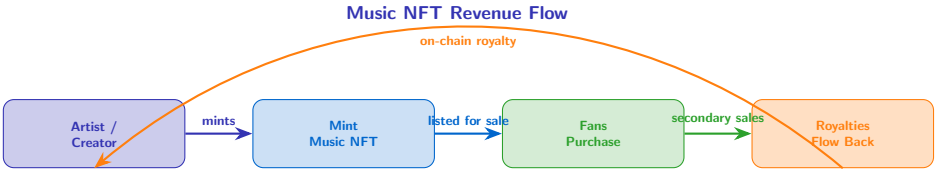
Gaming NFTs



Gami

NFTs give players true ownership of in-game assets – but interoperability remains largely theoretical

Music and Media NFTs



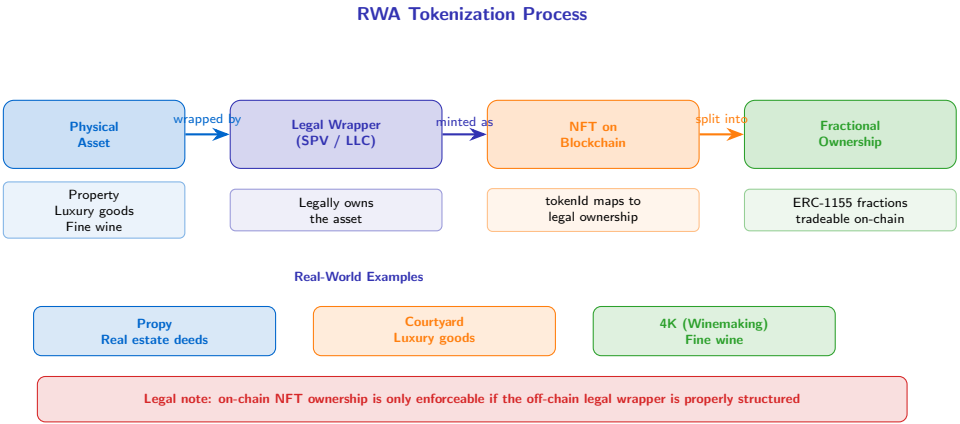
Platforms: Royal • Sound.xyz • Audius • Catalog

Revenue Comparison

Model	Creator Revenue per Play / Sale	Platform Cut
Streaming	$0.003 – $0.005 per stream	70–80%
Music NFT	Direct sale proceeds (e.g. 0.05 ETH)	5–15%

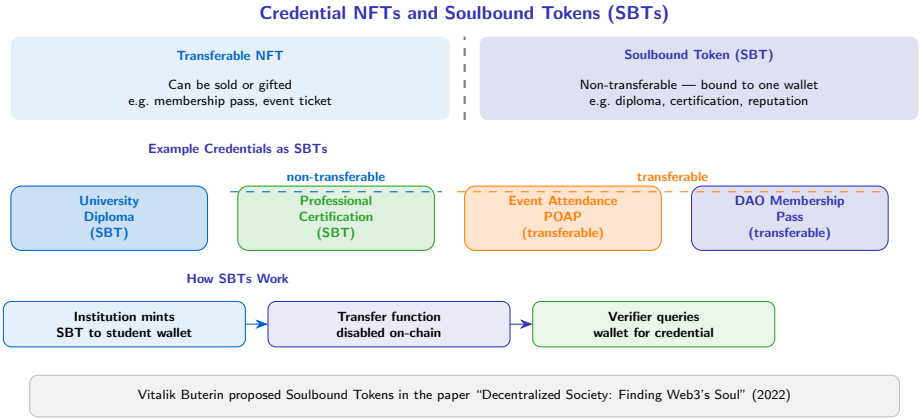
NFTs let artists earn directly from fans without intermediary platforms taking 70–80% of revenue

Real-World Asset (RWA) Tokenization



RWA tokenization bridges physical and digital ownership – legal frameworks are still evolving

Identity and Credential NFTs

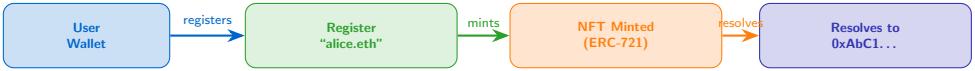


Crede

NFTs and soulbound tokens may replace traditional paper certificates and membership cards

Domain Names as NFTs

Blockchain Domain Name Architecture



Major Blockchain Domain Systems

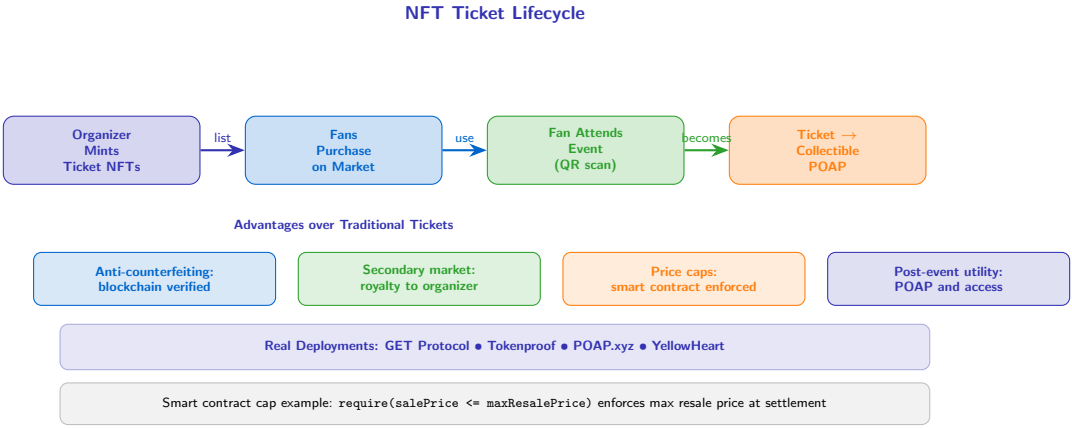
System	Extension	Chain	Standard
ENS	.eth	Ethereum	ERC-721
Unstoppable	.crypto .nft .x	Multi-chain	ERC-721
SNS	.sol	Solana	SPL Token

NFT ownership of a domain means: transferring the NFT transfers full control of the name — no registrar approval needed

Block

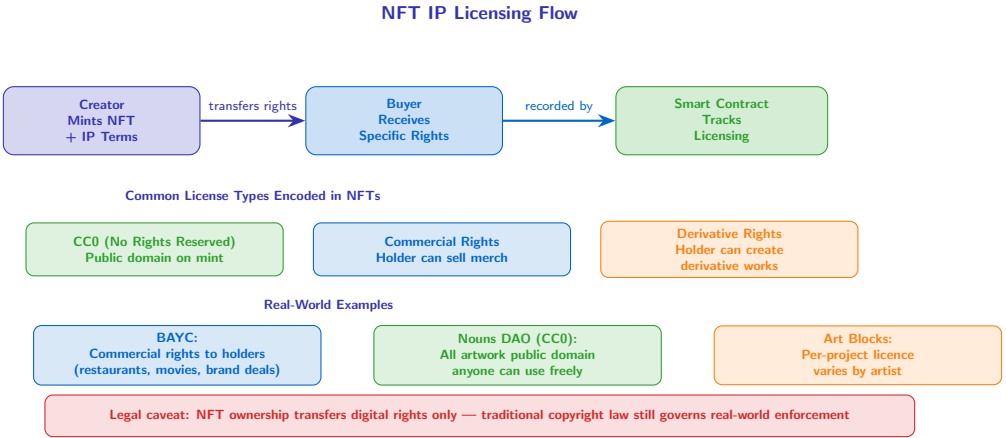
domain names are NFTs that map human-readable names to wallet addresses

NFT Ticketing



NFT tickets solve counterfeiting while giving organizers control over secondary market pricing

Intellectual Property and Licensing



NFTs can encode intellectual property rights – but legal enforcement is still evolving

Section 3 Summary

1. Digital art NFTs (Beeple, CryptoPunks, Art Blocks) proved verifiable scarcity creates real value
2. Gaming NFTs give true asset ownership, but cross-game interoperability remains largely theoretical
3. Music and RWA NFTs let creators and asset holders bypass intermediaries and access new liquidity
4. Identity and credential NFTs (SBTs, POAPs, ENS) offer verifiable, portable digital identity
5. IP and licensing encoded in NFTs (CC0, commercial, derivative) — legal enforcement still evolving

Secti

3 complete – next: NFT Valuation & Analytics

Section 4: NFT Valuation & Analytics

Rarity scoring, floor price analysis, wash trading detection, and market metrics

What You Will Learn

- Why NFT valuation differs fundamentally from traditional finance
- Rarity scoring methods and how to calculate rarity scores
- Floor price trends and support/resistance analysis
- Core market metrics: holders, listings, volume, royalties
- Wash trading detection and index construction

Frames in This Section

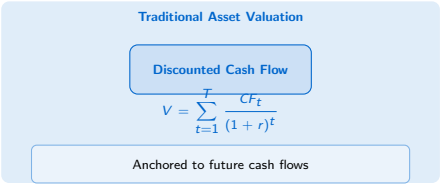
Secti

4 — Frames 39–48 — NFT Valuation & Analytics

NFT Valuation Challenges

Why NFTs Are Hard to Value

- **Illiquidity** — few comparable sales; thin markets
- **Subjectivity** — aesthetic and cultural value is unquantifiable
- **Wash trading distortion** — artificial volume inflates perceived demand
- **No cash flows** — no dividends, no earnings, no DCF anchor
- **Thin markets** — one-sided order books, wide bid-ask spreads



NFT valuation is fundamentally different from traditional finance – there are no discounted cash flow models

Rarity Scoring Methods

Three Methods for Quantifying NFT Rarity

Method 1
Trait Frequency

$$\text{Rarity} = \frac{1}{\text{frequency}}$$

Simple, intuitive

Method 2
Statistical Rarity

$$R = \prod_j p_j$$

Product of probabilities

Method 3
Information Content

$$IC = -\log_2(p_j)$$

Sum of trait entropies

Example: Collection of 10,000 NFTs. Trait "Laser Eyes" appears in 500 tokens.

$$\text{Frequency} = \frac{500}{10000} = 5\% \quad \text{Trait Frequency Score} = \frac{1}{0.05} = 20 \quad \text{IC} = -\log_2(0.05) = 4.32 \text{ bits}$$

Tools: Rarity Sniper, Rarity Tools, Trait Sniper — each uses a slightly different scoring formula

Rarity

scores quantify how uncommon an NFT's trait combination is within its collection

Rarity Score: Worked Example

NFT #4271 — Rarity Score Calculation (10,000 item collection)

Trait	Value	Count	Frequency	Score ($1/p$)
Background	Gold	200	2.0%	50.0
Fur	Zombie	88	0.88%	113.6
Eyes	Laser	500	5.0%	20.0
Hat	Crown	120	1.2%	83.3
Mouth	Diamond Grill	350	3.5%	28.6

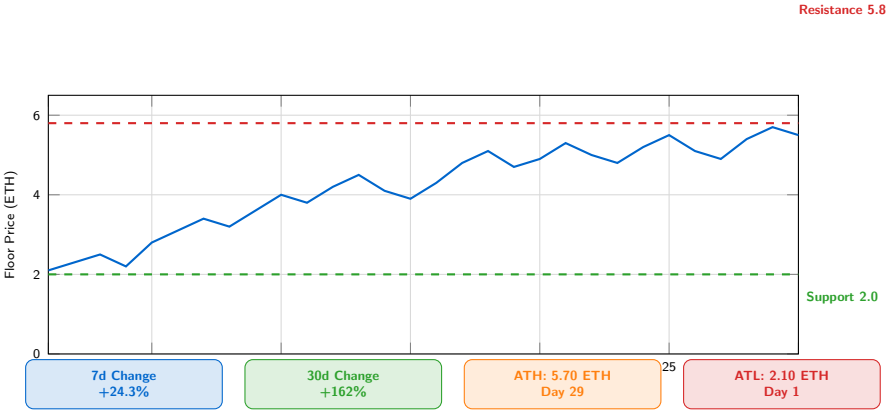
Total Rarity Score $= 50.0 + 113.6 + 20.0 + 83.3 + 28.6 =$ **295.5**

Always verify rarity rankings across multiple tools – different methods produce different rankings

Alway

verify rarity rankings across multiple tools – different methods produce different rankings

Floor Price Analysis



Floor price trends reveal market sentiment – sustained floor above previous lows signals strength

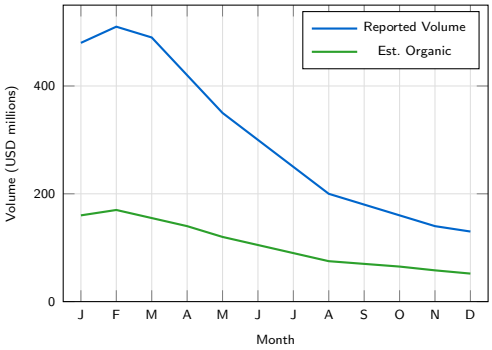
NFT Market Metrics

Metric	Definition	Typical Range	Significance
Floor Price	Lowest listed price	0.01 – 100+ ETH	Market entry cost
Market Cap	Floor × Total Supply	1M – 1B USD	Collection size proxy
Volume (24h/7d)	Total ETH traded	Varies widely	Liquidity signal
Unique Holders	% of supply held by distinct wallets	30 – 80%	Decentralization
Listed Ratio	Listed / Total Supply	5 – 30%	Sell pressure
Royalty Revenue	Creator earnings from secondary sales	0 – 10% per sale	Creator sustainability

Source: OpenSea, Dune Analytics, Nansen – always cross-reference multiple data providers

These six metrics provide a quantitative framework for evaluating any NFT collection

Wash Trading Analytics



Detection Heuristics

- **Self-trading** — same wallet buys back its own NFT
- **Circular patterns** — A sells to B, B sells to C, C sells to A
- **Unprofitable trades** — buyer pays more than seller received (after gas)
- **Funding source analysis** — wallets funded from same exchange withdraw

40–70% of NFT volume in 2022 was estimated to be wash trading

estimates 40-70% of NFT trading volume in 2022 was wash trading

NFT Index Construction

Methods for Constructing NFT Price Indices

Repeat Sales (Case-Shiller style)

Track same NFT sold multiple times; ratio reveals price change

Hedonic Regression (trait-based)

$$P(t) = \alpha + \sum_j \beta_j \cdot \text{trait}_j + \varepsilon$$

regress price on traits

Machine Learning (non-parametric)

Random forest / XGBoost on trait features; handles non-linearity

Key Challenges

Sparse data thin trading

Selection bias only sales observed

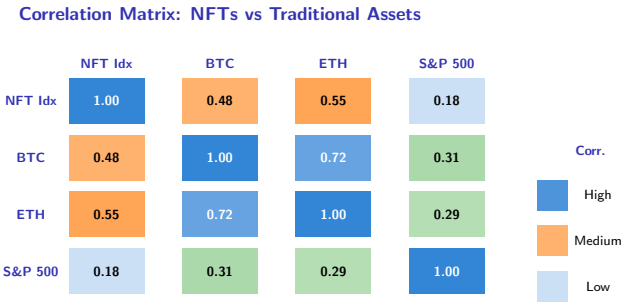
Wash trading distorts signals

Existing indices: NFT Blue Chip Index (Nansen) — OpenSea Collection Floor Index — Artsy NFT Index

All suffer from selection bias and wash trading contamination

NFT indices are essential for portfolio analysis but face sparse data and selection bias

Portfolio Analysis with NFTs



NFTs show low correlation with S&P 500 (0.18) — potential diversification benefit

Caveat: high illiquidity risk and wide bid-ask spreads severely limit practical portfolio utility

NFTs show low correlation with traditional assets but high illiquidity risk limits portfolio utility

Section 4 Summary

1 NFT valuation lacks cash flow anchors — price is driven by rarity, community, and sentiment

2 Rarity scoring (trait frequency, statistical, IC) quantifies uniqueness within a collection

3 Floor price support/resistance levels reveal sentiment — sustained floor above lows signals strength

4 Wash trading (40–70% in 2022) distorts all volume metrics — use organic volume estimates

5 NFT indices face sparse data and selection bias — repeat-sales and hedonic methods are used

Secti

4 complete – next: Advanced Topics & Future

Section 5: Advanced Topics & Future

Fractional NFTs, dynamic NFTs, soulbound tokens, composability, and regulation

What You Will Learn

- Fractional NFTs: splitting high-value assets via ERC-20 tokens
- Dynamic NFTs: metadata that changes in response to real-world events
- Soulbound tokens: non-transferable identity and reputation
- ERC-6551: token-bound accounts and NFT composability
- The evolving global regulatory landscape for NFTs

Frames in This Section

- Frame 49 — Section overview
- Frame 50 — Fractional NFTs
- Frame 51 — Dynamic NFTs (dNFTs)
- Frame 52 — Soulbound tokens
- Frame 53 — NFT composability
- Frame 54 — Regulatory landscape
- Frame 55 — Key takeaways

Secti

5 — Frames 49–55 — Advanced Topics & Future

What is Fractionalization?

- A high-value NFT (e.g. CryptoPunk $10M) is locked in a **vault contract**
- The vault mints a fixed supply of **ERC-20 tokens** representing fractional ownership
- Fractions are tradeable on any DEX — lowering entry barrier
- Governance vote required to unlock and sell the underlying NFT
- Examples: Fractional.art (now Tessera), NFTX, PartyDAO

```
// Simplified NFT Fractionalization
contract FractionalVault {
    IERC721 public nft;
    uint256 public tokenId;
    ERC20 public fractions;

    function fractionalize(
        address _nft, uint256 _id,
        uint256 totalFractions
    ) external {
        IERC721(_nft).transferFrom(
            msg.sender, address(this), _id
        );
        fractions.mint(
            msg.sender, totalFractions
        );
    }
}
```

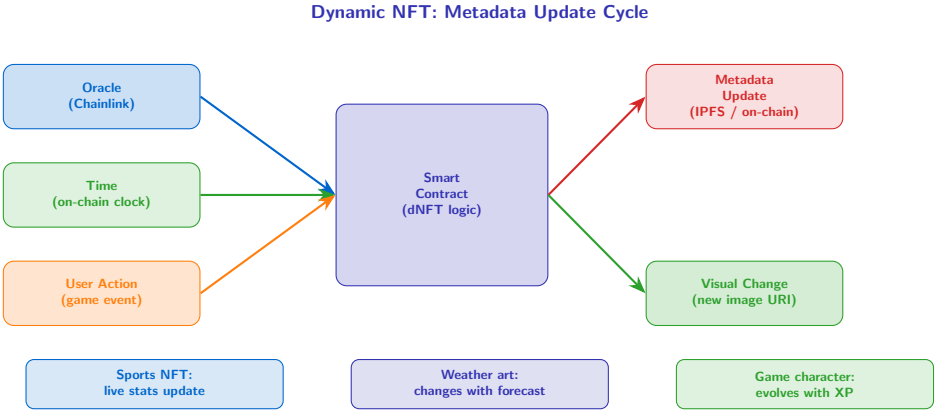
Economic Benefit

Fractionalization enables price discovery and liquidity for illiquid, high-value NFTs — analogous to REITs for real estate.

Fract

NFTs lower the barrier to entry by splitting ownership into ERC-20 tokens

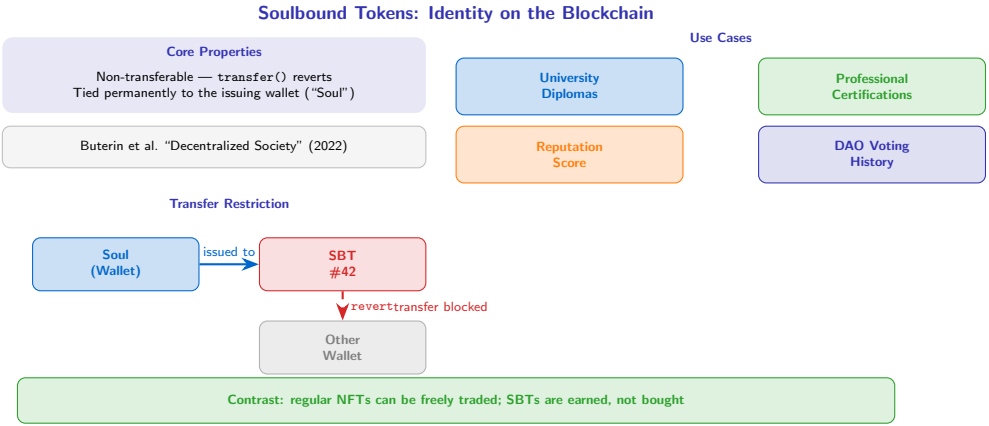
Dynamic NFTs (dNFTs)



Dyna

NFTs can change their metadata based on external data

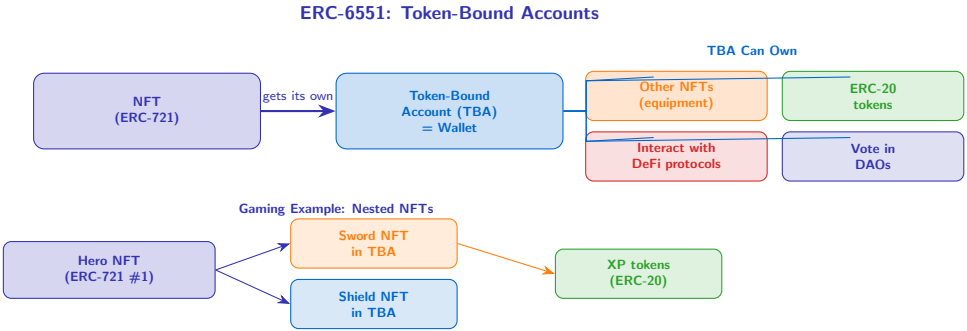
Soulbound Tokens (SBTs)



Soulb

tokens represent identity and reputation – they cannot be bought or sold, only earned

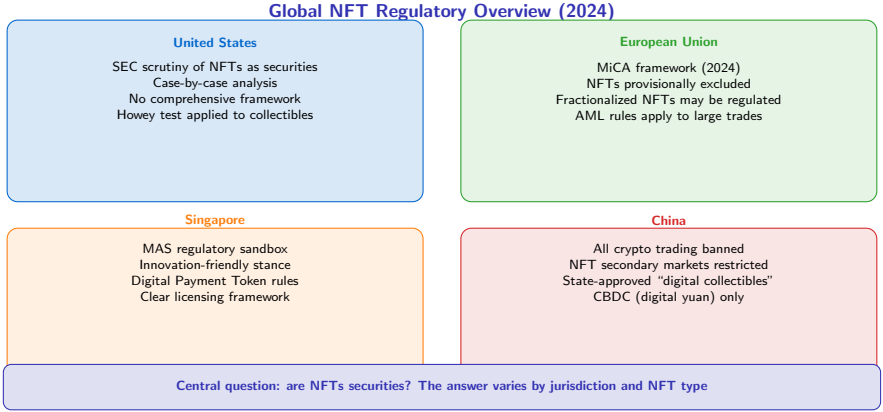
NFT Composability and Nesting



ERC-6551 passed as Ethereum standard in May 2023 — enables NFTs to hold assets and sign transactions

ERC-6551 gives every NFT its own wallet, enabling NFTs to own assets and interact with protocols

NFT Regulation Landscape



NFT regulation is evolving rapidly – the classification of NFTs as securities remains a central debate

Key Takeaways and Course Summary

1. NFTs create verifiable digital ownership via ERC-721 / ERC-1155 and on-chain provenance
2. Marketplace dynamics: floor price, royalties, and wash trading dominate NFT market structure
3. Applications span art, gaming, music, real-world assets, identity, ticketing, and IP licensing
4. Valuation requires rarity analysis, wash trading detection, and index construction methods
5. Future: dynamic NFTs, soulbound tokens (SBTs), ERC-6551 composability, and evolving regulation

Next Lecture: DeFi Protocols and Automated Market Makers

End of lecture – 55 frames covering NFT fundamentals to advanced topics.