UNIVERSITY of NICOSIA

Non-Fungible Tokens (NFTs)

BLOC 514: Emerging Topics in Blockchain and Digital Currency

About me

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Short bio:

- B.Sc. In Digital Systems
- M.Sc in Network Oriented Systems
- Ph.D in Information Systems from the Department of Digital Systems at the University of Piraeus with the title "Innovative Customer Behavior Forecasting Framework for Subscription-based Organizations"
- Areas of expertise are Information Systems, Blockchain, DLTs, Non-fungible Tokens (NFTs) and the Metaverse where he has authored/co-authored scientific publications

UNIC has always been a global pioneer in crypto

- First university in the world to accept Bitcoin for tuition and launch a crypto course
  - Free MOOC **Introduction to Digital Currencies** (2013), more than 80,000 students to date
- First to offer a full academic degree in the area
  - **MSc in Blockchain and Digital Currency** (2014)
- First to issue blockchain-verifiable certificates (2015 on Bitcoin, 2021 as Ethereum NFTs)
- Largest dedicated crypto team in academia (**Institute for the Future**)
  - Advisors to the European Commission, European Central Bank and many crypto projects
- **First university in the Metaverse**
  - First to launch an on-chain / in-metaverse course, in partnership with Punk 6529 (2022)
  - We aim to launch a full **MSc in Metaverse Systems** in 2023

Outline

- Define Non-Fungible Tokens (NFTs)
- Discuss NFT standards on the Ethereum blockchain (ERC-721, ERC-1155)
- Walkthrough in the history of NFTs
- Explore types of NFTs
- Identify NFT uses
- Discuss examples of NFT collections
- Explore the NFT market size and structure
- Tokenization and Digital Ownership

Bonus Session: Non-Fungible Tokens

1. Technical Primer

A second-generation blockchain, capable of running applications

- **Bitcoin** is the archetypal first-generation blockchain
  - Open, public & permissionless network
  - Single-use: the Bitcoin blockchain secures the Bitcoin cryptocurrency (token) only
- **Ethereum** is a second-generation blockchain network
  - Like Bitcoin, it is also an open, public and permissionless blockchain
  - It also has its own (native) token, called Ether
- However, unlike Bitcoin, **all types of applications can be programmed and deployed on the Ethereum blockchain**
  - Think of Ethereum as **the Internet of decentralized applications (dApps)**: a large global network of computers that **can run any application without the need for third-party service providers & platform owners** (like Google, Amazon, or Facebook/Meta)

Note: *NFTs can be implemented on many blockchains – to avoid unnecessary complexity, we will limit our discussion here on Ethereum, which is currently the largest blockchain supporting NFTs. If you are interested in learning more about blockchains and crypto in general, please follow UNIC's free online course "Introduction to Digital Currencies" (https://www.unic.ac.cy/blockchain/free-mooc/)*

Ethereum runs smart contracts

- Smart contracts are **immutable computer programs** that run deterministically on the Ethereum blockchain.
- **Immutability** is a novel and very powerful characteristic, the importance of which cannot be overstated: **once deployed, the code of a smart contract cannot change or be stopped.**
  - Unlike traditional software, the only way to modify a smart contract is to deploy a new instance.
- **The promise of smart contracts on open blockchains is nothing short of revolutionary**: in theory, every interaction between parties, which can be automated, can be programmed in a smart contract and be trusted to run as programmed, without intermediaries or censorship

Ethereum is a multi-token network

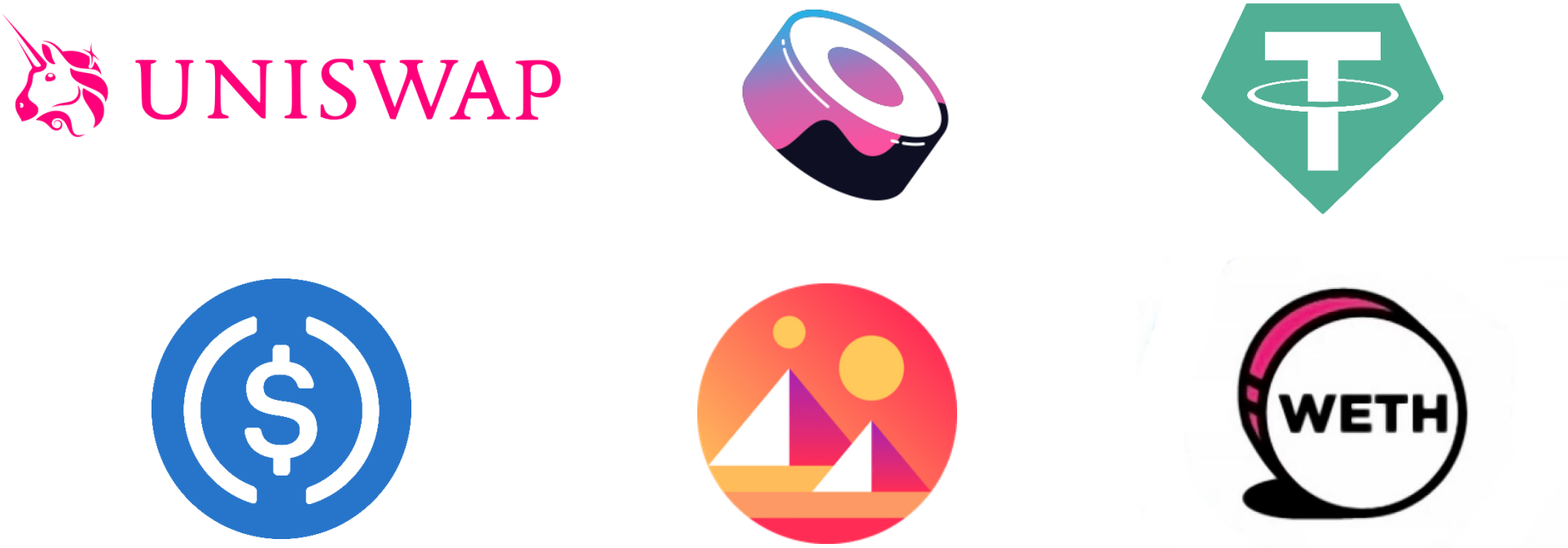
- Like Bitcoin, Ethereum features its own native currency/token, called **Ether**
  - Ether is the second largest cryptocurrency by market capitalization today
- However, unlike Bitcoin, Ethereum can also support the creation of additional tokens
  - Some of these additional tokens are **fungible (ERC-20 tokens)**, while others are not (**ERC-721, ERC-1155 i.e., Non-Fungible Tokens – NFTs**)
  - Fungible tokens (of the same type) are interchangeable. In other words, an ERC-20 token is of equal value to any other ERC20 token.
  - NFTs are not generally interchangeable at the same value. In other words, one Cryptopunk may have significantly different market value from other tokens in the same collection (i.e., other Cryptopunks).
  - You can think of NFTs as unique tokens

Ethereum tokens are governed by ERC standards

- **ERC-20:** Token Standard (2015)
  - The most widely used standard for fungible tokens on the Ethereum blockchain
- **ERC-721:** Non-Fungible Token Standard (2018)
  - The most widely used standard for NFTs on the Ethereum blockchain
- **ERC-1155:** Multi Token Standard (2018)
  - A standard interface for smart contracts that manage multiple token types.
  - A single deployed contract may include any combination of fungible tokens, non-fungible tokens or other configurations (e.g., semi-fungible tokens)

Note: ERC stands for "Ethereum Request for Comment". You can find a list of all ERC standards at https://eips.ethereum.org/erc.

ERC-20 Tokens Are Fungible Tokens On The Ethereum Network



ERC-20 tokens are used primarily for financial applications and are outside the scope of this course

If you are interested in Decentralized Finance, UNIC offers a dedicated free online course on the subject: https://www.unic.ac.cy/blockchain/free-defi-mooc/

ERC-721 is Ethereum's most popular NFT standard

- ERC-721 allows for the implementation of a standard API for NFTs within Ethereum smart contracts.
- The standard provides basic functionality to track and transfer NFTs.
- ERC-721 tokens are created by writing code in a smart contract programming language, like Solidity.
- In practice, most NFT collections today will be created through service providers and will require little or even no programming to create the token.

APIs (Application Programming Interfaces) define how computer applications communicate with each other, often using requests and responses

ERC-1155 is Ethereum's multi-token standard

- ERC-1155 implements a standard interface for contracts that manage multiple token types.
  - ERC-20 requires deployment of separate contracts per token type.
  - ERC-721 groups a collection of non-fungible tokens in a single contract, with settings for the entire collection.
  - In contrast, ERC-1155 allows for each token ID within a collection to represent a new configurable token type, which may have its own metadata, supply and other attributes.
- In other words, the innovation of ERC-1155 is that **multiple tokens can co-exist in the same smart contract** and can be managed together
  - New functionality is possible, such as transferring multiple token types at once, thus saving on transaction costs.
  - Trading of multiple tokens is also supported, thus removing the need to approve individual token contracts separately.
  - Such functionality is particularly helpful, for example, in gaming applications, which may combine fungible and non-fungible items (e.g., currency and swords).
- Despite its flexibility, ERC-1155 is less popular in art applications than ERC-721, though it is expected to be popular in some gaming and other more complex applications

Different standards for different applications

	ERC-721	ERC-1155
Scope	Tokenize unique individual assets	Combine multiple token types
Fungibility	NFT only	FT, NFT, SFT
Application focus	Collectibles, art, digital assets, tokenized real-world assets	Gaming, complex applications involving multiple assets
Advantages	Standardizes how unique assets are securely stored and managed on the blockchain	Saves on computational burden by reducing the approval steps needed to transfer multiple tokens in a single transaction
Disadvantages	Tokens are indivisible. NFTs cannot be combined with fungible tokens.	The standard is not backward compatible, so it cannot handle ERC-20 or ERC-721 implementations
Gas consumption	Slightly lower, compared to ERC-20	Lower for transaction involving multiple token types in a batch transfer

Source: adapted from https://micobo.medium.com/security-tokens-an-erc-standards-comparison-919e7c379f37

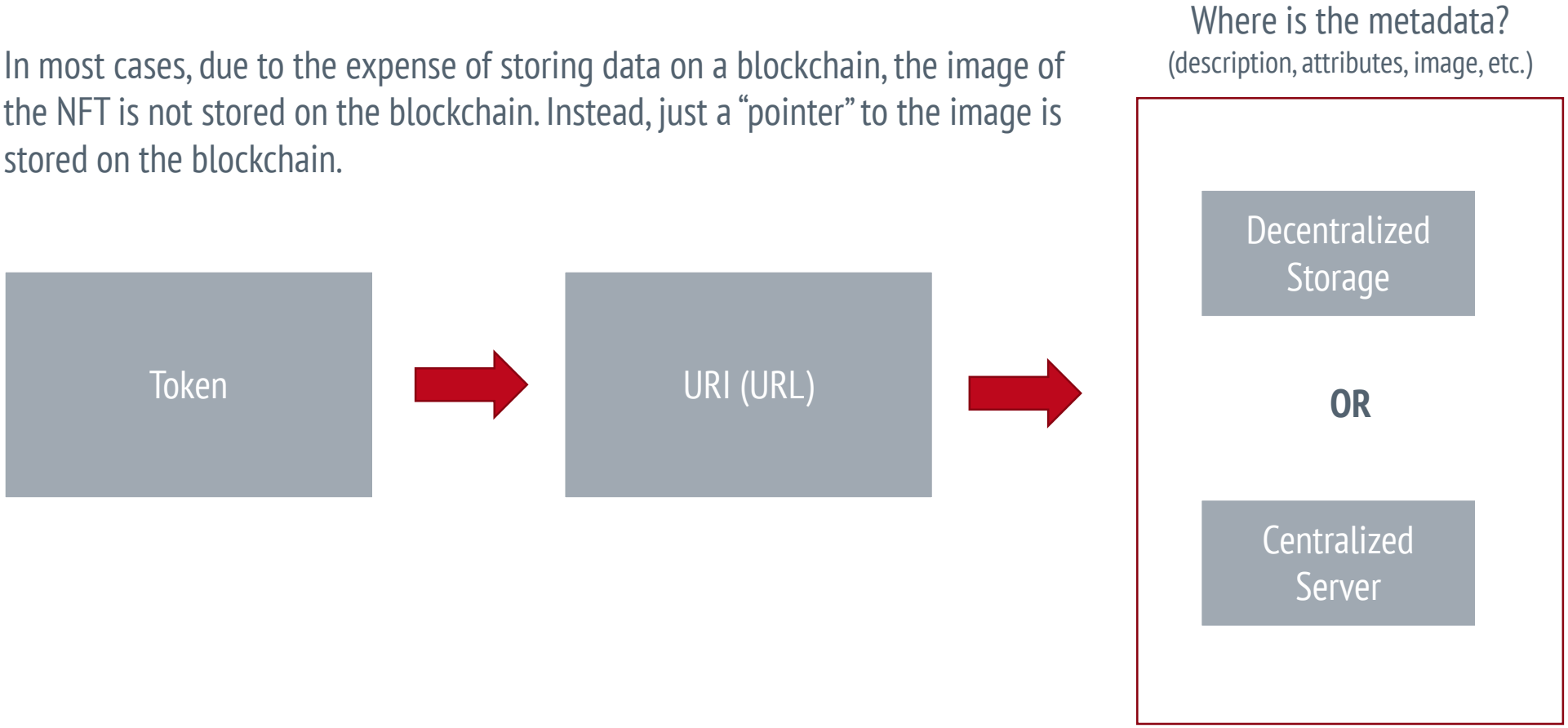
Other L1/L2s that support NFTs

- Avalance
- Near
- Hedera Hashgraph
- Flow

- Efinity
- Polygon
- Binance Smart Chain
- Solana

Each token points to a URL with the information about the NFT

In most cases, due to the expense of storing data on a blockchain, the image of the NFT is not stored on the blockchain. Instead, just a "pointer" to the image is stored on the blockchain.



URI (Uniform Resource Identifier) uniquely identifies a resource by using data like name, location, etc. URL (Uniform Resource Locator) identifies the web address of a unique resource

IPFS and Arweave are the leading decentralized storage networks

- IPFS (InterPlanetary File System)
  - Distributed storage protocol that allows the storage and distribution of uniquely identifiable files as part of a global peer-to-peer network
  - Every computer in the world can choose to "pin" (host) and distribute any files they choose via downloading the IPFS software
- Arweave
  - A distributed storage protocol with a different design philosophy
  - The hosts are paid upfront for permanent storage under the theory that the cost of storage will drop fast enough over time to allow the upfront payment to cover the storage costs forever

In the NFT field, both IPFS and Arweave are considered good solutions for decentralized storage vs a centralized server

Source: 1.IPFS, 2. Arweave

Natively on-chain

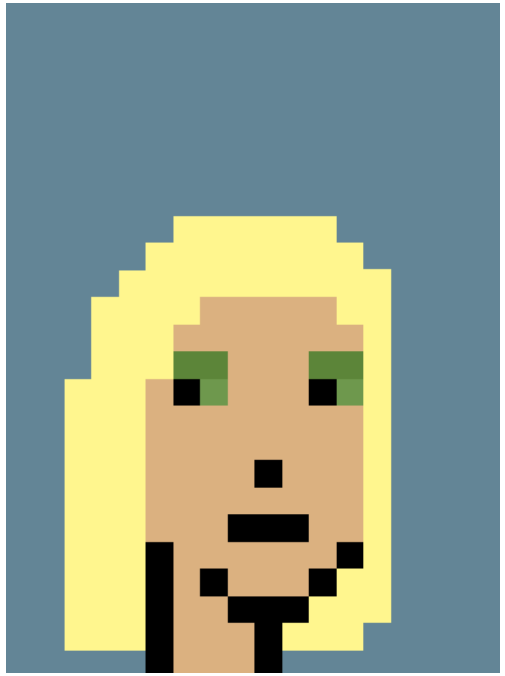
- On-chain storage refers to the actual saving of the asset on the blockchain itself
- Projects that store all asset files on-chain are called "**natively on-chain**", as all the information associated with an NFT is stored on the blockchain (metadata and the actual asset)
- Saving the asset on-chain preserves all the first order features of the blockchain:
  - Immutable
  - Decentralized
  - No single-point of failure, etc.
- This is only feasible / cost-effective for artwork that can be described in code.
- In other words, this is a popular design choice in generative art, but economically / technically infeasible for photography or videography

Source: 1.IPFS, 2. Arweave wiki

Bonus Session: Non-Fungible Tokens

2. What Are NFTs?

NFTs are a trivially simple idea (numbered tokens)...



CryptoPunk #6528

CryptoPunk #6529

CryptoPunk #6530

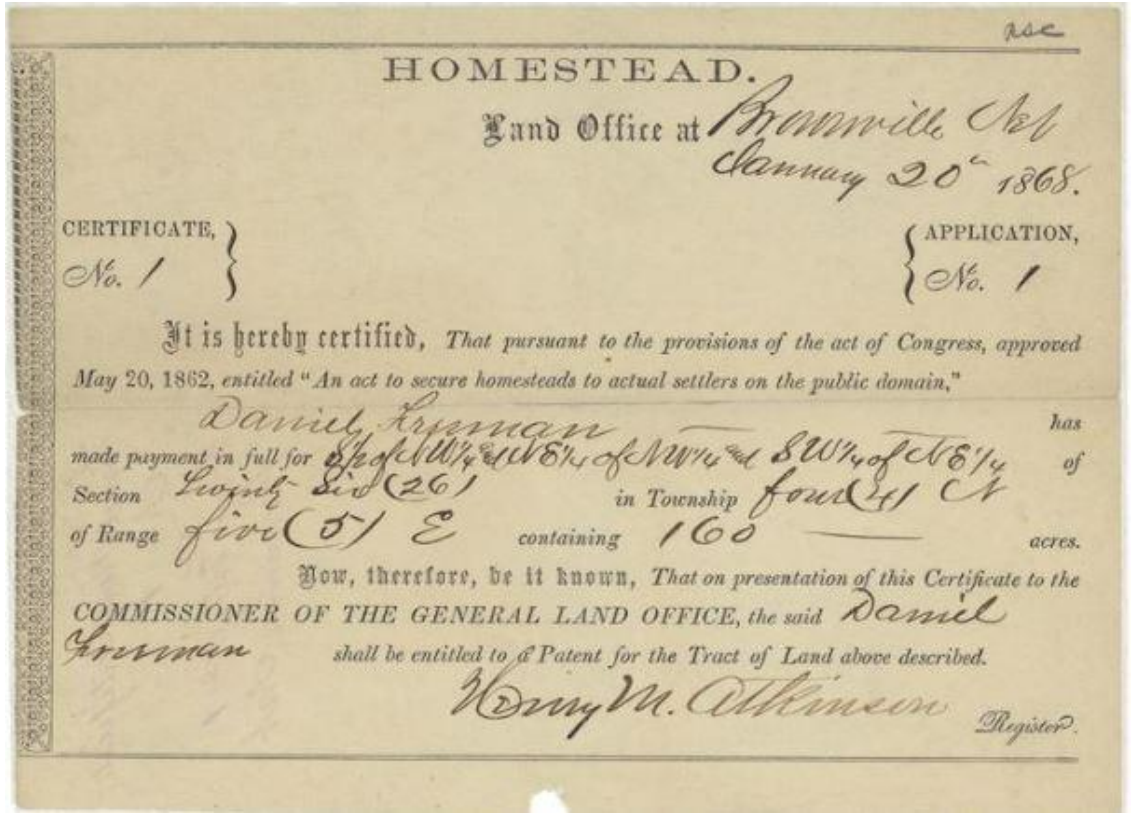
Some Definitions

- A token that represents a unique asset with characteristics that are particular to it: it cannot be interchanged or replaced by another equivalent token
- Digital representation of information or data – proof of ownership
- NFTs and their ownership are recorded on the blockchain
- NFTs can take the form of a digital work, a virtual land, a domain name or even equipment in a video game
  - Mona Lisa - Multiple replicas can be issued based on the original, but nothing could replace the original

- *"Technological medium that allows any digital item to be stored and circulated virtually on a blockchain - Nonfunfible.com"*

Source: Non-fungible.com Yearly Report

...plus a social convention analogous to a title deed...



HOMESTEAD.

Land Office at Brownville Nebr
January 20th 1868.

CERTIFICATE, No. 1

APPLICATION, No. 1

It is hereby certified, That pursuant to the provisions of the act of Congress, approved May 20, 1862, entitled "An act to secure homesteads to actual settlers on the public domain,"

Daniel Freeman has made payment in full for the E½ of NW¼ and SW¼ of NE¼ of Section Twenty Six (26) in Township four (4) North of Range five (5) East containing 160 acres.

Now, therefore, be it known, That on presentation of this Certificate to the COMMISSIONER OF THE GENERAL LAND OFFICE, the said Daniel Freeman shall be entitled to a Patent for the Tract of Land above described.

Henry M. Atkinson Register.

Homestead Entry Number 1, Brownsfield,
Nebraska Land Office, for Daniel Freeman, January 20, 1868.

- This title deed is not a piece of land, but a pointer to a piece of land.
- When we buy and sell land, we do not buy and sell the land itself.
- We buy and sell the pointer to the land.

...in a global, digital, programmable, interoperable environment

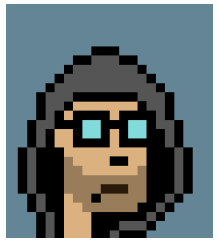
Permissionless, programmable
internet native money

Permissionless, programmable
internet native financial instruments

Permissionless, programmable
internet native **everything else**

NFTs are a standards-based, interoperable technology for direct internet-native ownership of intangible assets

The Adoption Pathway of NFTs by Punk 6529



- >$75 trillion existing stock of intangibles
- The only "public commons" open database for the metaverse

- Physical world assets & services
- Needs regulatory bridges so will take some time

A mental model

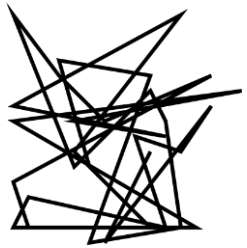
	Tangible	Intangible	
Fungible (this market is huge)	Commodities	Money, Financial Instruments	Fungible Tokens
Non-Fungible (this market is larger)	Real Estate, Products, Humans	Culture/Society, Services, Digital Goods, Intellectual Property	NFTs

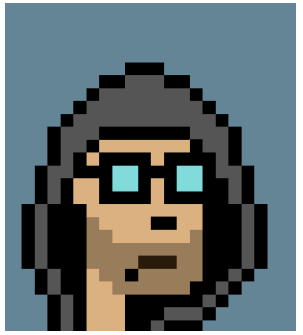
History of NFTs at a glance

- Colored Coins (c. 2012) – An attempt to represent real world assets on the Bitcoin blockchain, using bitcoin denominations (i.e., satoshis)
  - They exemplified a leap in the usage of Bitcoin blockchain
  - Not efficient as projected as Bitcoin network was not initially designed with NFTs in mind
- Artworld Ethereum (July 2014) by Rhea Myers – Oldest Ethereum art market one year before Ethereum mainnet launch (July 2015)
  - Myers explains that Ethereum is blockchain for smart contracts and how smart contracts could be used to create smart property
- Pepereum Project (March 2017) – NFT project focused on Pepe memes similar Rare Pepes collectibles
  - Created a decentralized meme marketplace and trading card game
- John Watkinson and Matt Hall (Larva Labs) (June 23,2017 – Developed the famously known NFT project CryptoPunks
  - 10,000 unique CryptoPunk avatars on Ethereum Blockchain

Founder Cryptokitty
28
(November 2017)

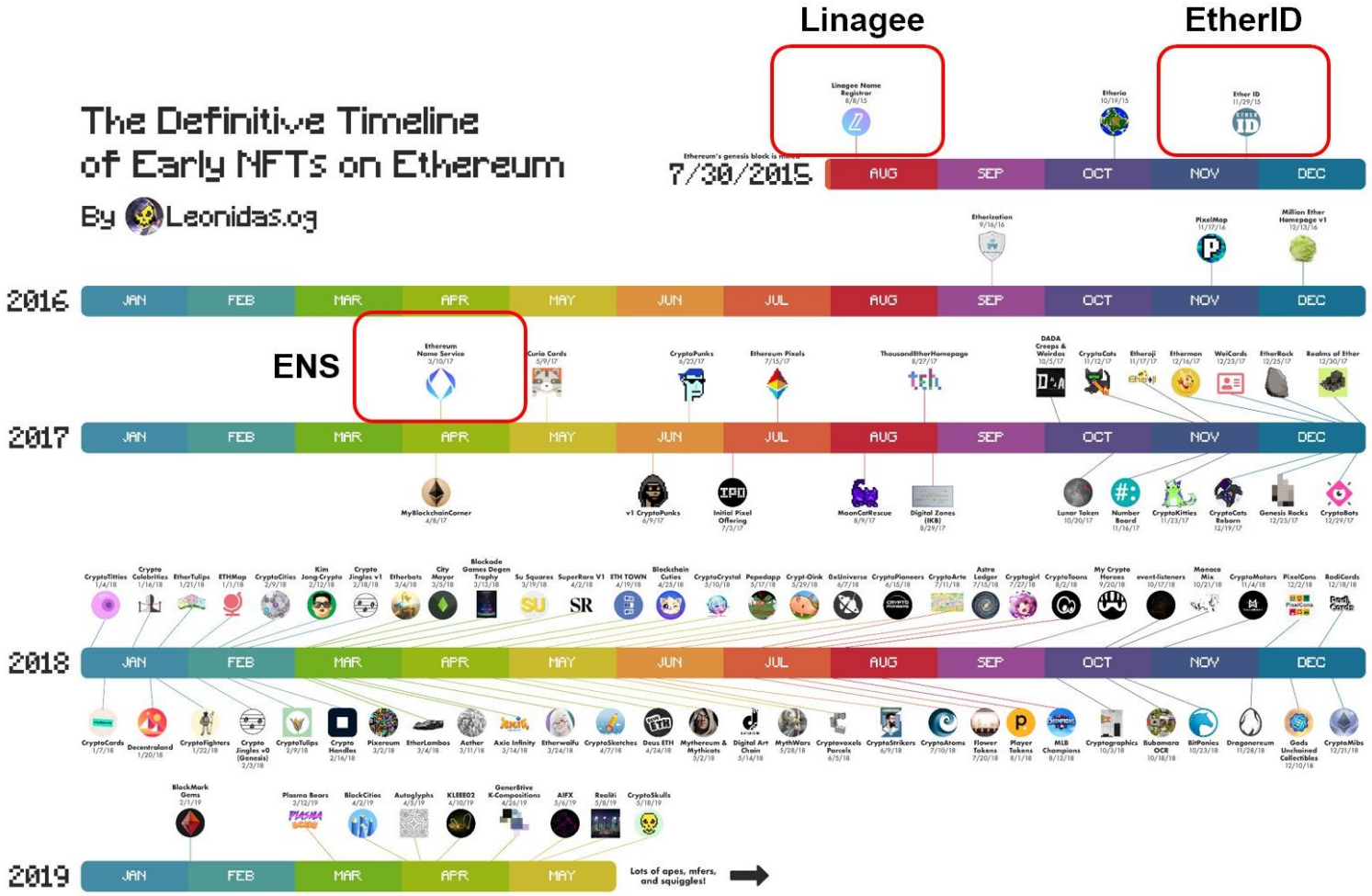
Nakamoto
Rare Pepe
(Sept 2016)





CryptoPunk
6529
(June 2017)

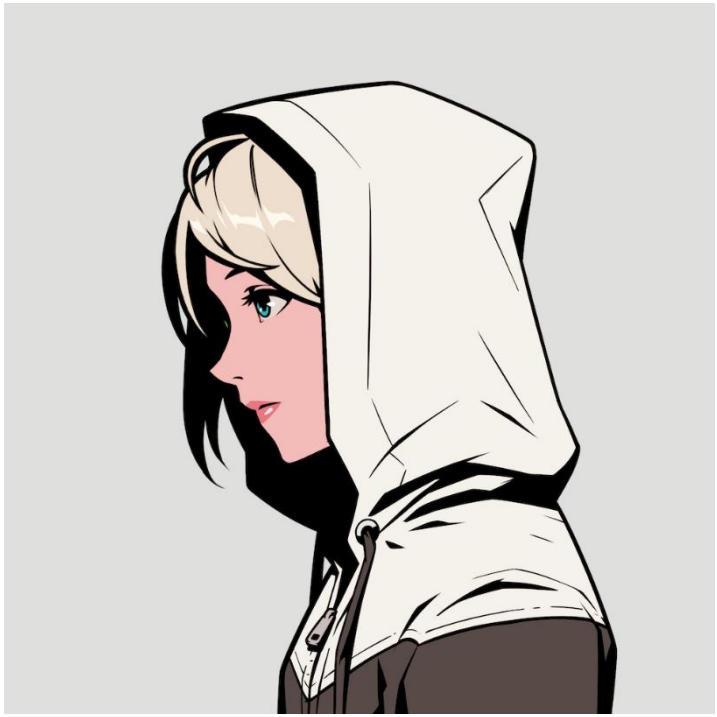
The Definitive Timeline of Early NFTs on Ethereum by Leonidas.og



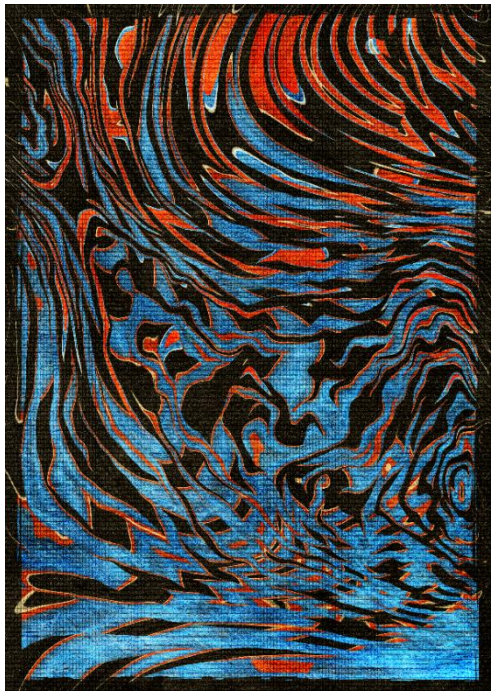
Source: Adopted from Leonidas.og

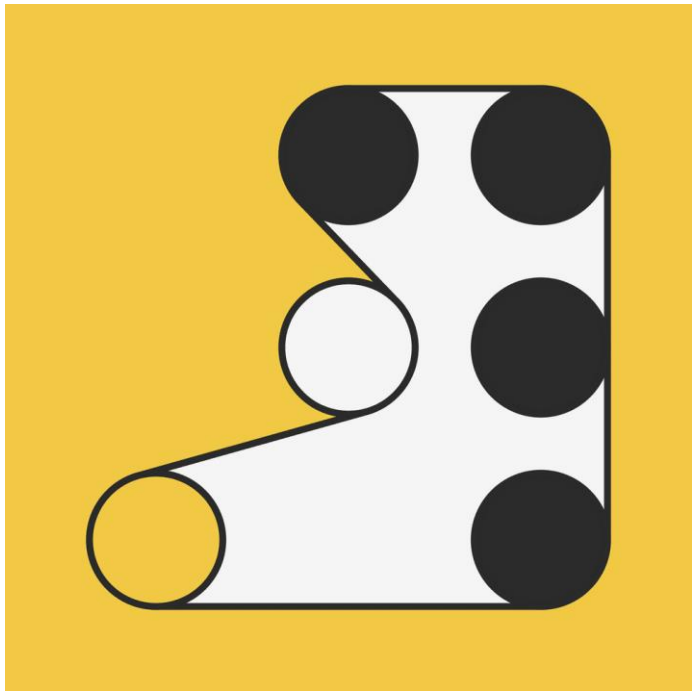
@LeonidasNFT

PFPs (Profile Pictures) are the largest market category today

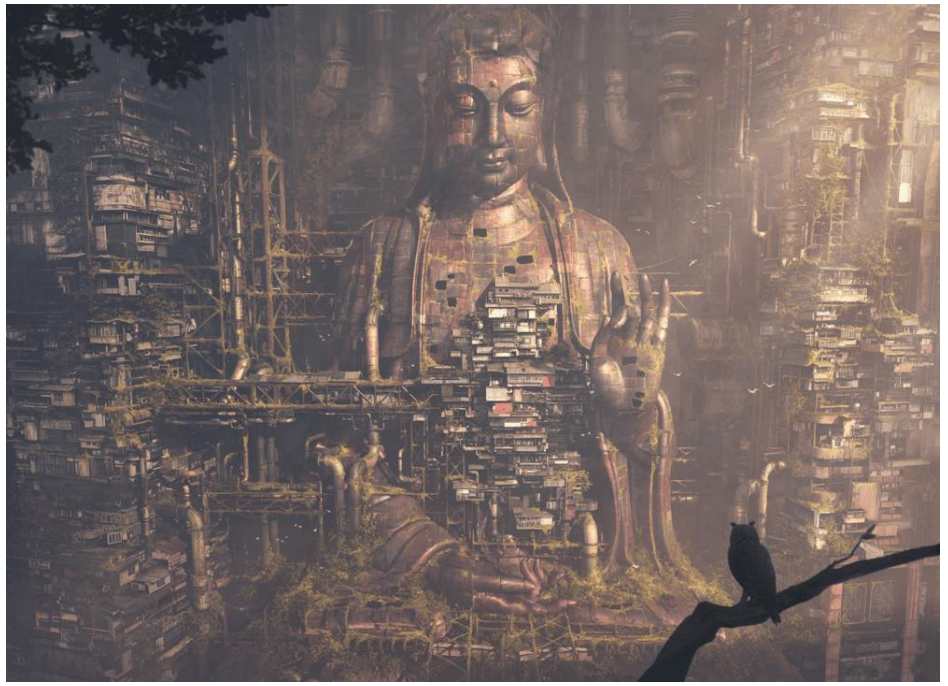


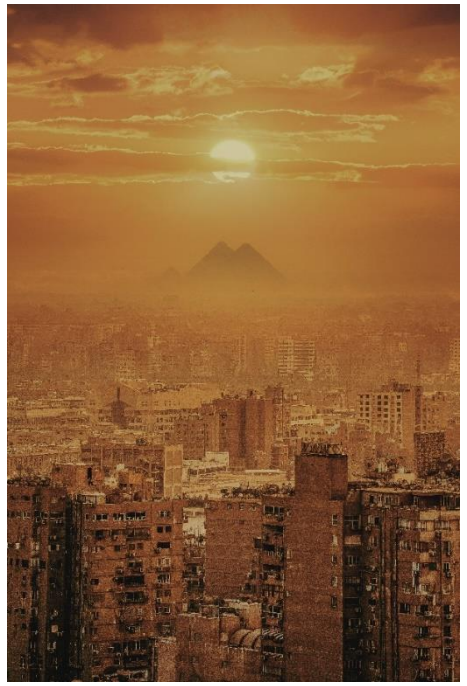
On-chain generative art is the largest art category in NFTs



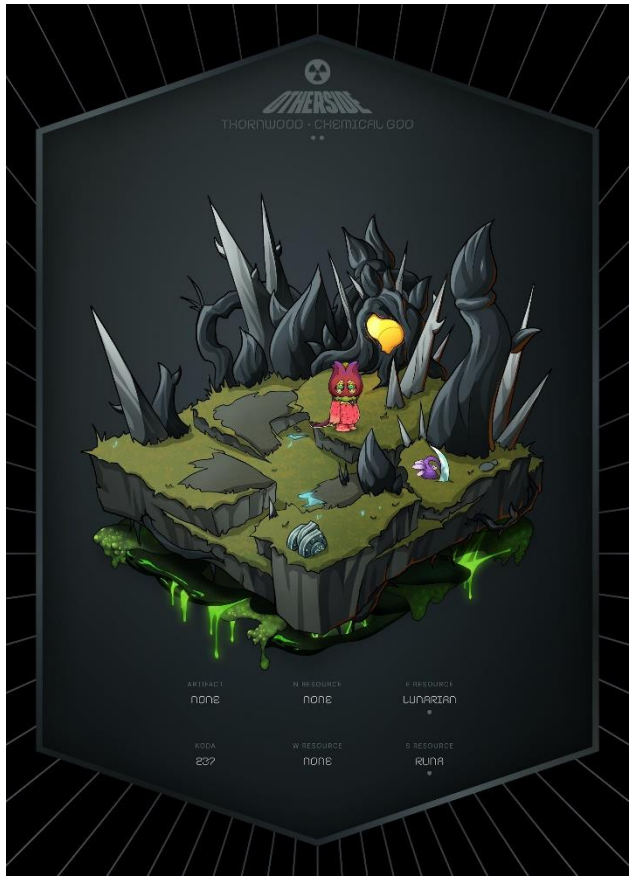


1 of 1 art is an NFT category that most people would think of as “art”

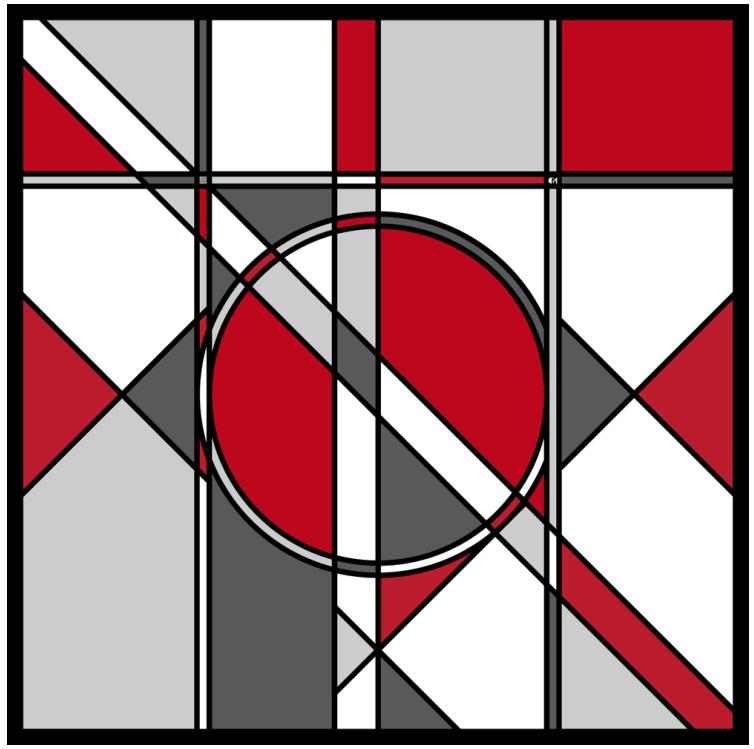




Gaming NFTs and metaverse land are expected to grow in impact



Utility based NFTs, like domain names and access passes are mostly unexplored



This area is almost completely unexplored

9DCC Tokenized T-Shirts

- Unlike purely digital objects, tokenized physical objects, whether t-shirts or houses have counterparty risk
- In other words, there must be a mechanism, private or public, to enforce the delivery of the physical good along with the NFT
- These "bridges" to the physical world will take time to evolve. I expect them to be more active in the second half of the 2020s

Bonus Session: Non-Fungible Tokens

3. Market Structure

NFTs are primarily traded on on-chain marketplaces

OpenSea
Dominates in overall volume

SuperRare & Foundation
Focus on Fine Art

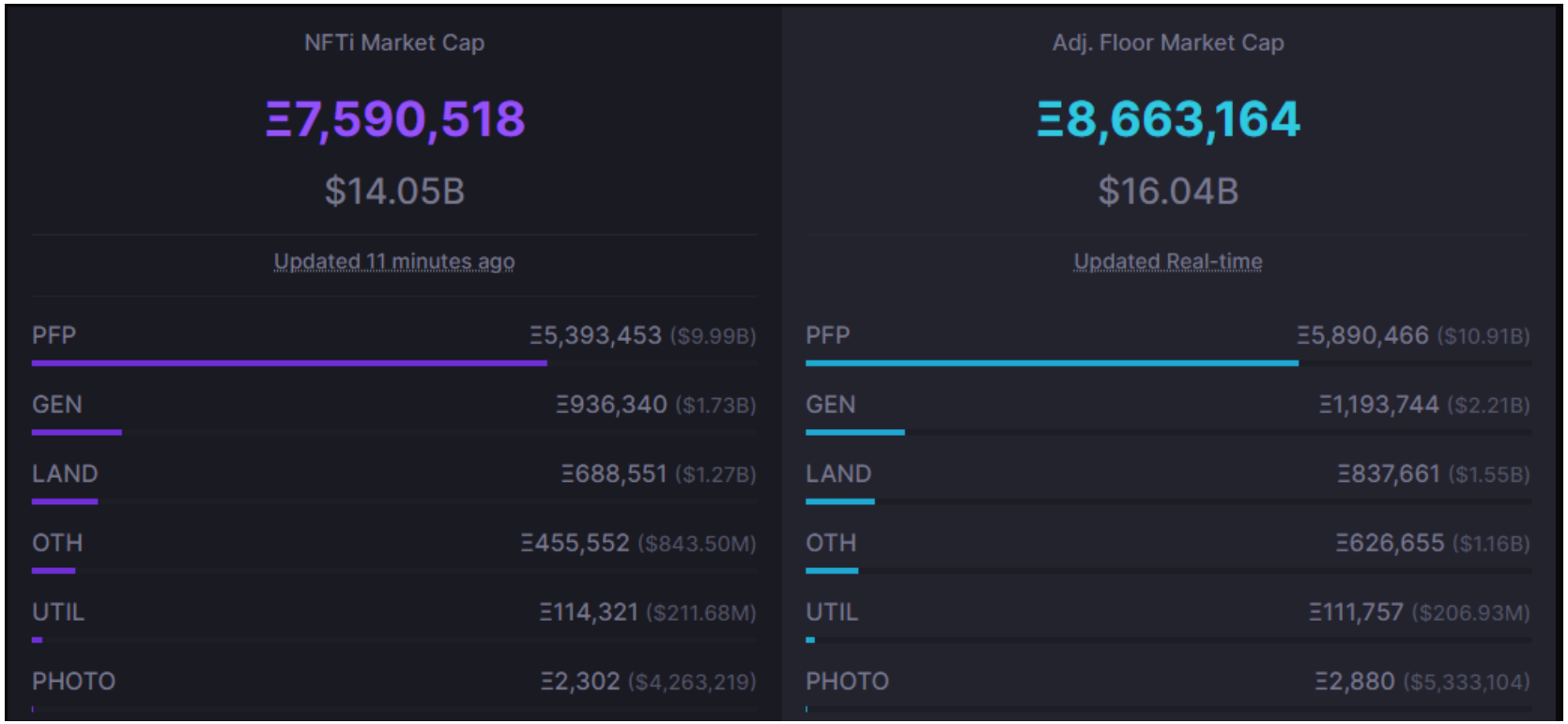
LooksRare
Tokenized Exchange

This is an illustrative set – there are other exchanges as well. Unlike fungible tokens, the vast majority of NFTs trade on-chain

PFP and Generative Art Market Cap is about $12B (peaked close to $30B)

Source: NFTValuations.com

PFP collections are the majority of the market cap (no good estimates yet for 1 of 1 art and other categories but data is improving)



Source: NFTValuations.com

Bonus Session: Non-Fungible Tokens

4. Conclusions

Main takeaways from this session

- NFTs are unique tokens stored on smart contract blockchains, like the Ethereum blockchain.
- NFTs can represent an extraordinary range of intangible objects and, with appropriate bridges, tangible objects, too.
- The potential addressable market for NFTs is very large, but this is contingent on successful development and adoption.
- The NFT market is still immature and experimental. Initial progress has been made in collectibles and art, but most other categories are mostly unexplored.

Further reading

- Technical Specifications
  - https://ethereum.org/en/nft/#build-with-nfts
  - https://ethereum.org/en/developers/docs/standards/tokens/erc-721/
  - https://blog.enjincoin.io/erc-1155-the-crypto-item-standard-ac9cf1c5a226
  - https://eips.ethereum.org/EIPS/eip-2309
- Punk 6529 Tweetstorms:
  - https://twitter.com/punk6529/status/1429399888786333697
  - Coming soon in easier-to-read format
- NFT markets
  - The NFT Valuations Market Report: https://static.nftvaluations.com/reports/20221005%20-%20NFT%20Market%20Report%20Teaser.pdf

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Questions?

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