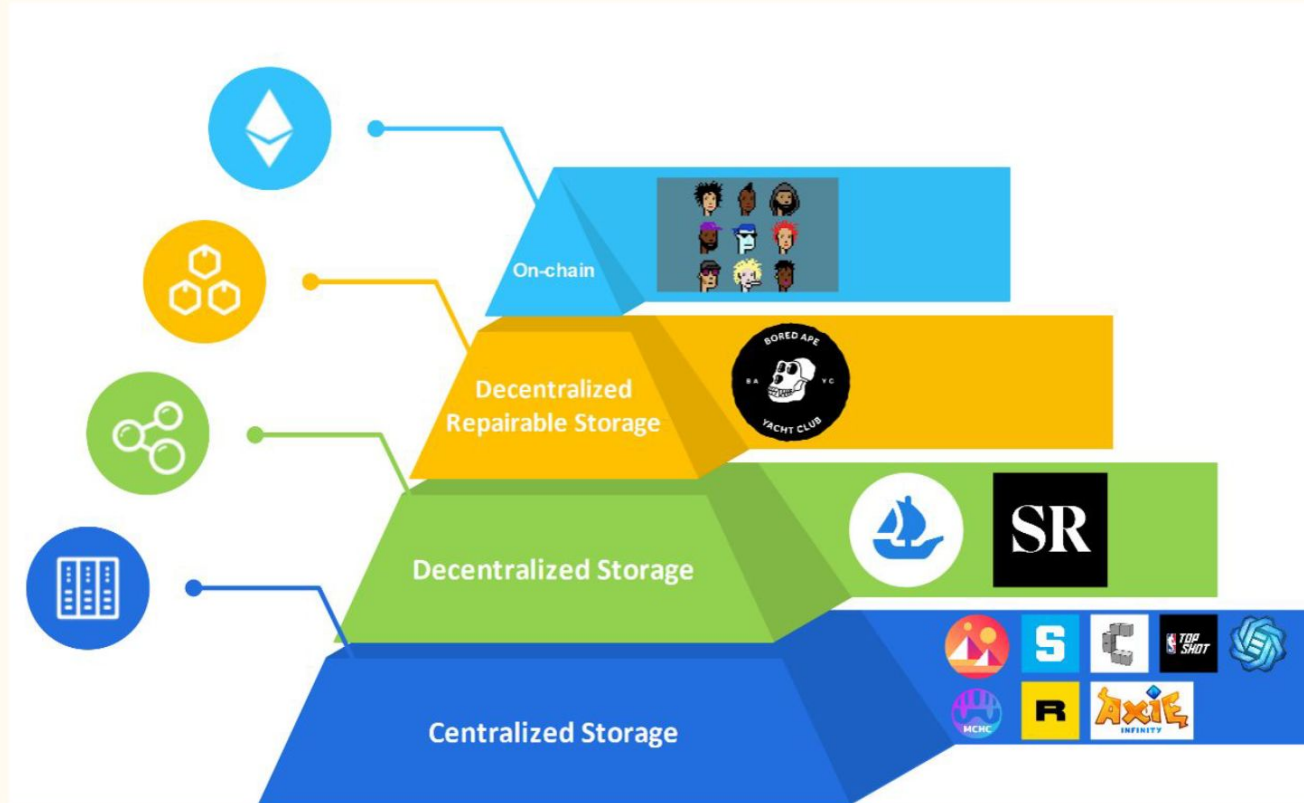
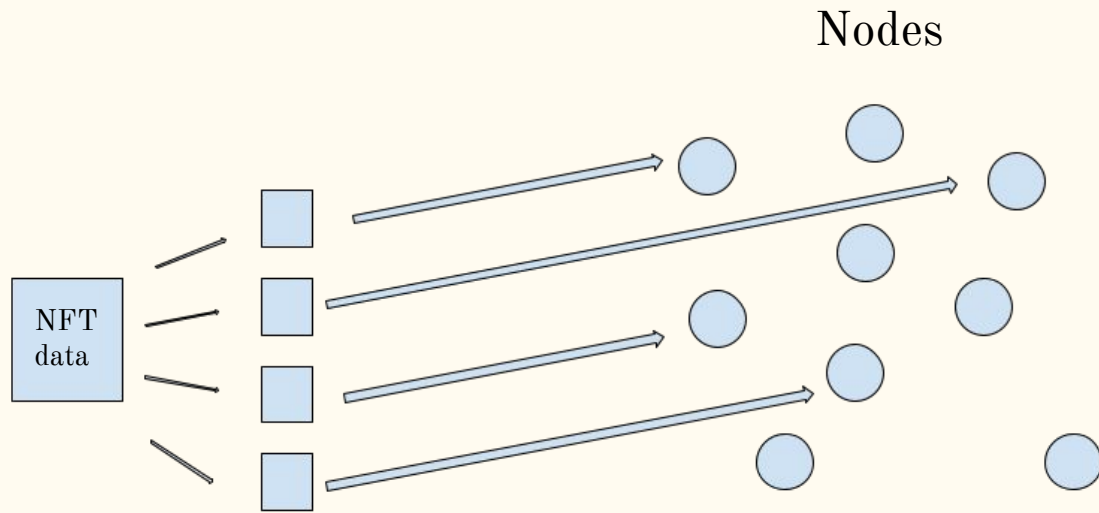


Decentralized NFT Storage: IPFS

Exploring IPFS, Commercial Storage Solutions,
Data&Security Challenges

Storage Types





IPFS: Decentralized Distributed Storage

IPFS (InterPlanetary File System) is a decentralized storage protocol designed for secure and efficient data sharing.

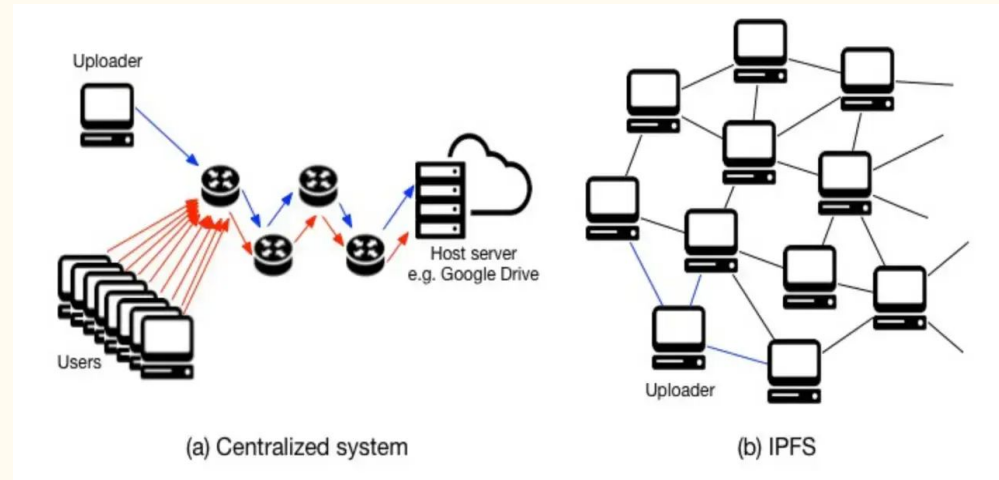
- Content addressing with unique Content Identifier (CID)
- Network Agnostic

Why is this important?

Integrity: The CID remains the same as long as the content is unchanged.

Security: Content is tamper-proof

Availability: Data remains accessible even if the original server is offline.

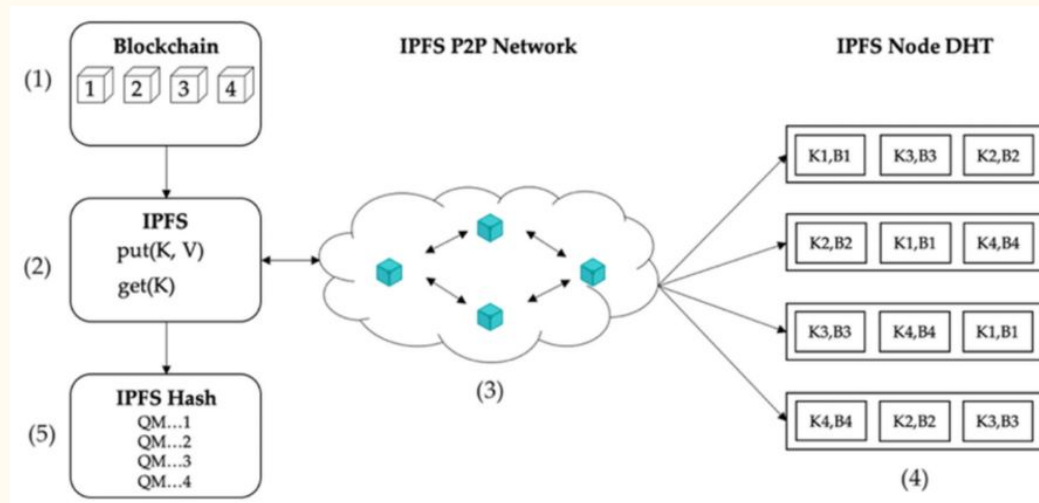


IPFS Data Storage: Chunking & Merkle DAG

Instead of storing entire files in a single location, IPFS splits files into multiple chunks. Each chunk is assigned its own cryptographic hash and stored across multiple nodes in a P2P network.

When a file is added to IPFS:

1. It is **broken into smaller chunks** (if large).
2. Each chunk is **hashed** (assigned a unique identifier).
3. A **Merkle DAG (Directed Acyclic Graph)** links the chunks together, forming a structure that allows efficient data retrieval.
4. The entire file is referenced by a **root CID**, which acts as the file's permanent identifier in the network.

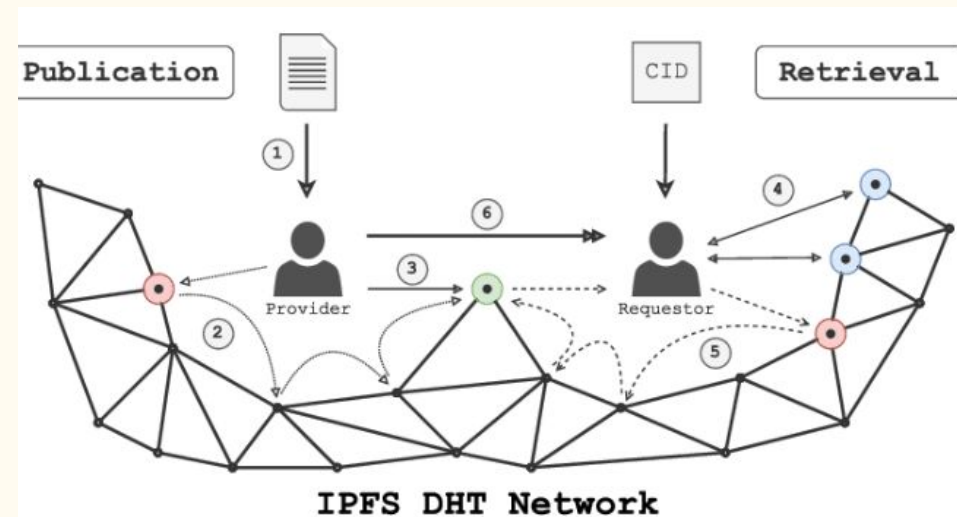


IPFS Data Retrieval

When a user wants to access a file on IPFS, they request it using the CID instead of a URL. IPFS then searches the network to locate nodes storing the requested data.

The retrieval process follows these steps:

1. The Distributed Hash Table (DHT) helps locate which nodes store the chunks of the requested CID.
2. Chunks are retrieved from multiple nodes in parallel, making downloads faster and ensuring redundancy.
3. The original file is reconstructed by combining the retrieved chunks, following the structure stored in the Merkle DAG.



Advantages Compared to Current Solutions

Compared to Centralized Storage

- **Higher Availability:** Data remains accessible even if a server goes down.
- **Improved Security:** Eliminates Single Point of Failure (SPOF).
- **Censorship Resistance:** Unlike centralized storage, IPFS prevents third-party takedowns.

Compared to On-Chain Storage

- **Lower Costs:** Storing only the CID on-chain avoids high gas fees.
- **More Flexibility:** Supports large files, unlike blockchain's size constraints.
- **Scalability:** Keeps essential hashes on-chain while storing bulk data off-chain.

Compared to Decentralized Repairable Storage

- **No Repair Needed:** Unlike repairable storage, IPFS doesn't require constant re-pinning.
- **Better Availability:** Distributed P2P storage ensures reliability despite node failures.

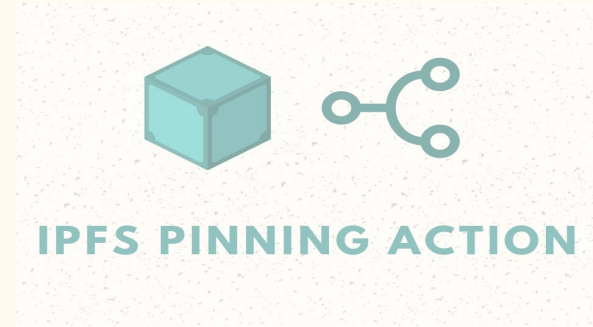
Compared to Other Peer-to-Peer Storage Networks

- **Mature Ecosystem:** Adopted by NFT platforms like OpenSea, integrated with Filecoin.
- **Faster Retrieval:** Uses Distributed Hash Tables (DHT) for efficient content discovery.

Commercial NFT Storage Offerings

Pinning Services for IPFS

- Pinata – Popular pinning service for long term availability.
- NFT.Storage – Free IPFS storage for NFT metadata
- Infura IPFS – Enterprise-grade IPFS gateway.



Filecoin & Permanent Storage

- IPFS needs pinning – Otherwise, files may become unavailable.
- Filecoin guarantees long-term storage – Users pay for decentralized data preservation.
- Filecoin Plus (Fil+) – Verified deals for NFT metadata storage.

Commercial NFT Storage Offerings

Alternative Storage Solutions

Decentralized Alternatives

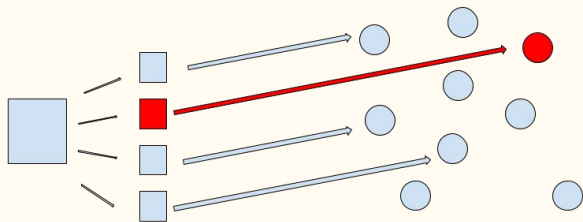
- Arweave – On-chain permanent storage, widely used in Solana NFTs.
- Storj – Decentralized cloud storage, different incentive models from IPFS.

Centralized Storage

- Amazon S3, Google Cloud, Azure – Still used by some NFT projects.
- Pros: High speed, reliable access.
- Cons: Not decentralized, data loss if provider shuts down.

Challenges

Long term availability



Ownership verification



Future of IPFS

- **IPFS v2 for Faster Data Retrieval:** Optimized DHT and GraphSync reduce latency.
- **Decentralized Pinning Marketplaces:** Token-based networks for long-term storage incentives.
- **Metaverse & Gaming Asset Storage:** IPFS stores 3D assets for virtual worlds.
- **Cross-Chain NFT Storage:** Seamless metadata access across multiple blockchains.



Thank you!