Alma Mater Studiorum · Università di Bologna

Department of computer science and engineering - DISI

IPFS and Filecoin

Lorello Luca Salvatore Tsiotas Giorgio

Introduction

Definitions (1/4)

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Filecoin Incentive layer which rewards IPFS users with a cryptocurrency (FIL)

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Filecoin Incentive layer which rewards IPFS users with a cryptocurrency (FIL) $\rightsquigarrow$ Aims to compete with traditional file storage businesses by offering extremely low fees

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IPFS (2/4)

- The file is split into blocks, each of which (along with the entire file) is associated with its cryptographic hash
- Each node stores only blocks it's interested in
- A request is resolved by finding which nodes store the blocks composing the file and retrieving them
- IPNS (Interplanetary Naming System) allows to associate filenames with hashes
- IPLD (Interplanetary Linked Data) is an unified namespace for any hash-based data structure

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Filecoin nodes are IPFS nodes as well, therefore IPLD-formatted data can be retrieved seamlessly

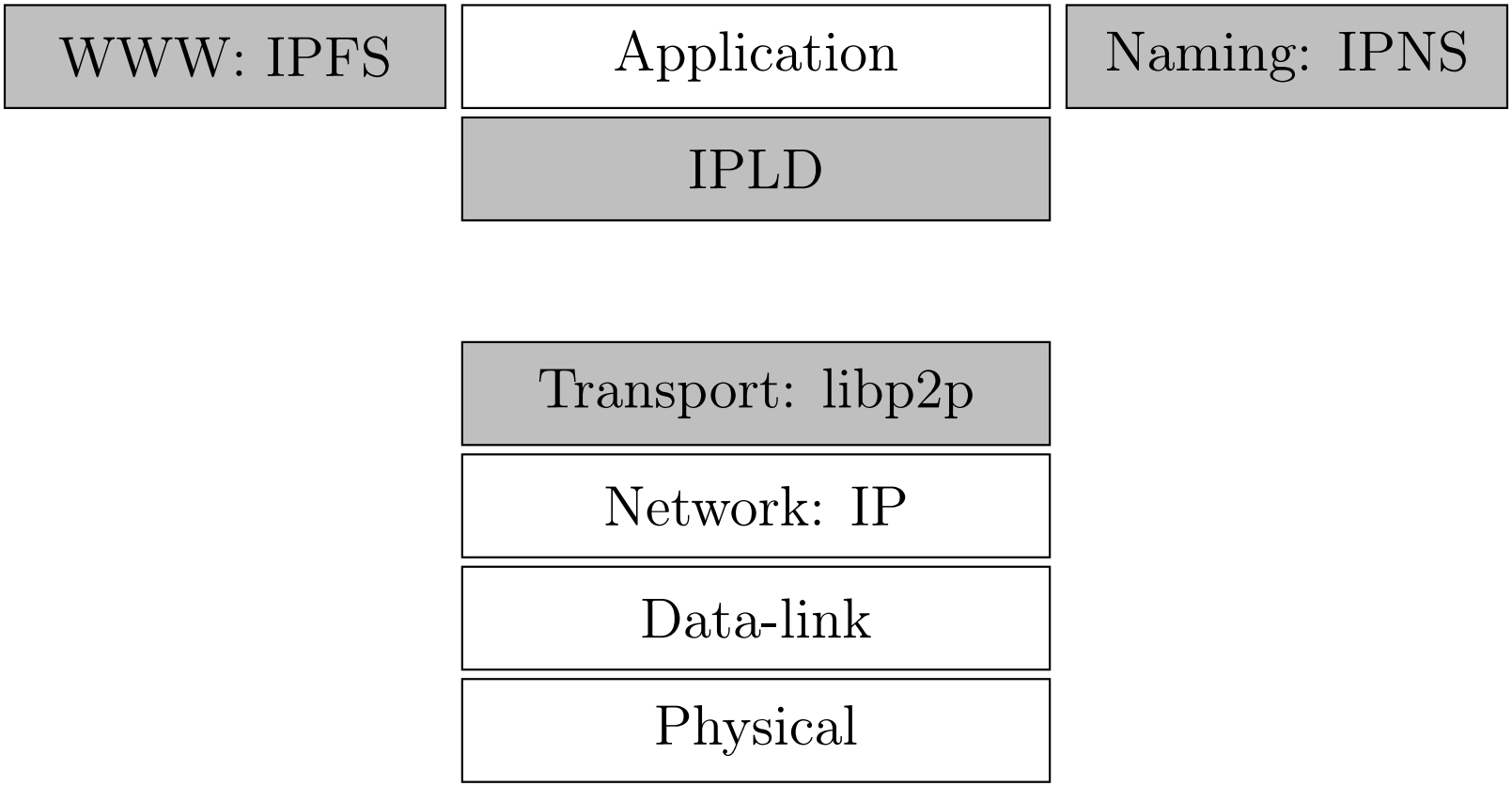
Introduction

IPFS-based Stack (3/4)

WWW: HTTP	Application	Naming: DNS
	Presentation	
	Session	
	Transport: TCP/UDP	
	Network: IP	
	Data-link	
	Physical	

Introduction

IPFS-based Stack (3/4)



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User

- Pays miners to store and retrieve files
- Can auction storage to miners who satisfy its requirements
- Has guarantees thanks to proofs on the blockchain

Storage miner

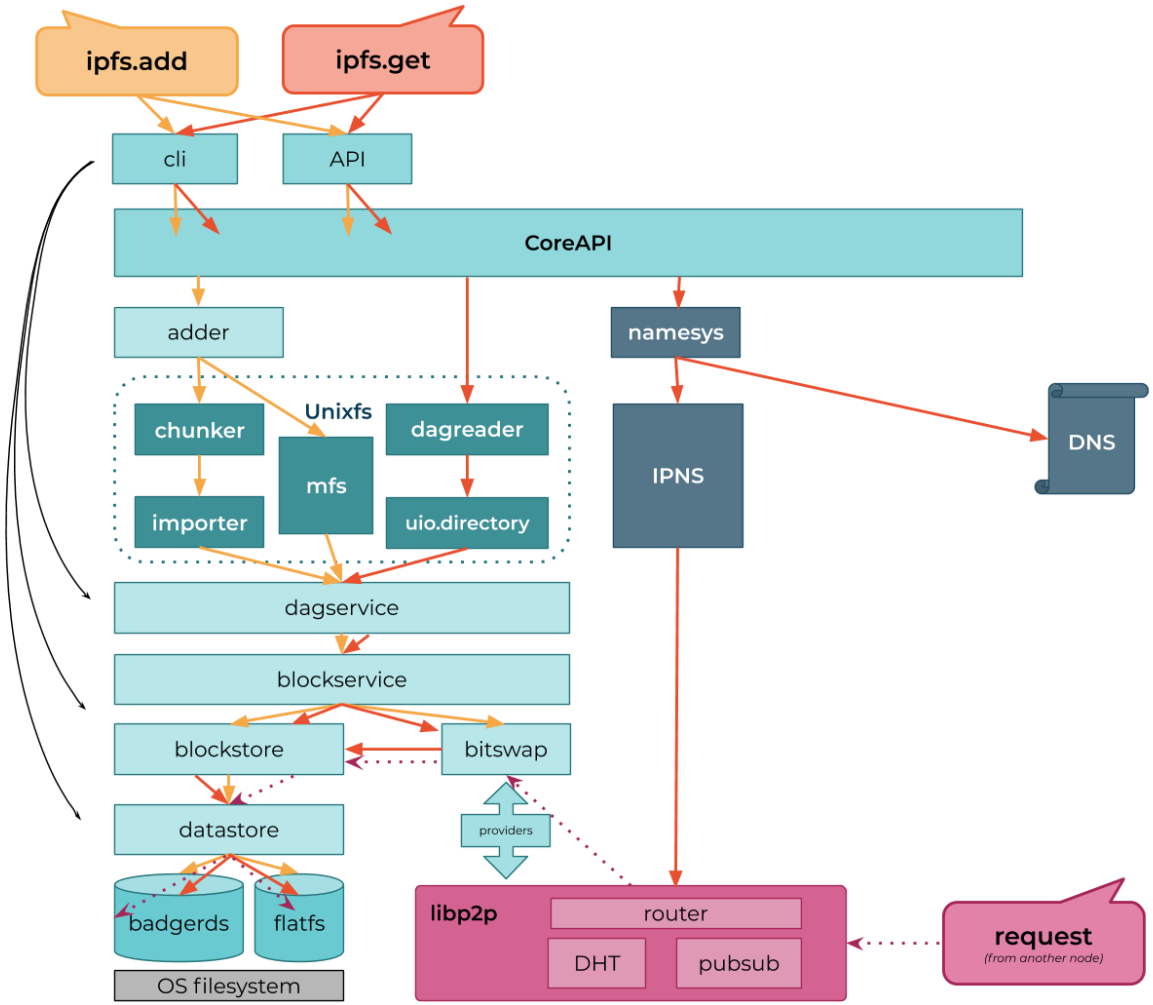
- Stores files for users
- Mines by providing storage
- Mines additional FIL by performing proofs

Retrieval miner

- Retrieves files for users
- May be a different entity other than a storage miner
- Unlike storage deals, retrieval deals are handled off-chain and their value may depend on retrieval speed

IPFS

Architecture (1/4)



IPFS

Routing and retrieval (2/4)

- A file is identified by its CID (content identifier) and each of its blocks form a Merkle DAG (directed acyclic graph) where nodes store blocks and edges link each block together using their CIDs
- Each block content is stored on a DHT (distributed hash table)

- Peers are assigned a peer ID and possess a public/private key pair for secure communication
- Block retrieval based on bitswap

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- Block retrieval based on bitswap $\rightsquigarrow$ blocks are **exchanged** downloading the rarest first, the probability of sending a block to a specific peer depends on its **share ratio** effectively choking leeches

IPFS

Versioning and IPNS (3/4)

- Hashes in IPFS are immutable **content-based** references to files and are **not human-readable**
- When a file is modified, it's unlikely that its entire content will change, therefore many blocks will remain unchanged

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- A stable **Node ID** is used to find all the versions of the file through routing on DHT:
  1. A public/private key pair is generated to sign the file
  2. The hash of the public key is the node ID associated with that file
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IPFS

Setting up an IPFS node (4/4)

1. Install
2. Initialize the repository
3. Put the node online
4. Configure the node
5. Live demo!

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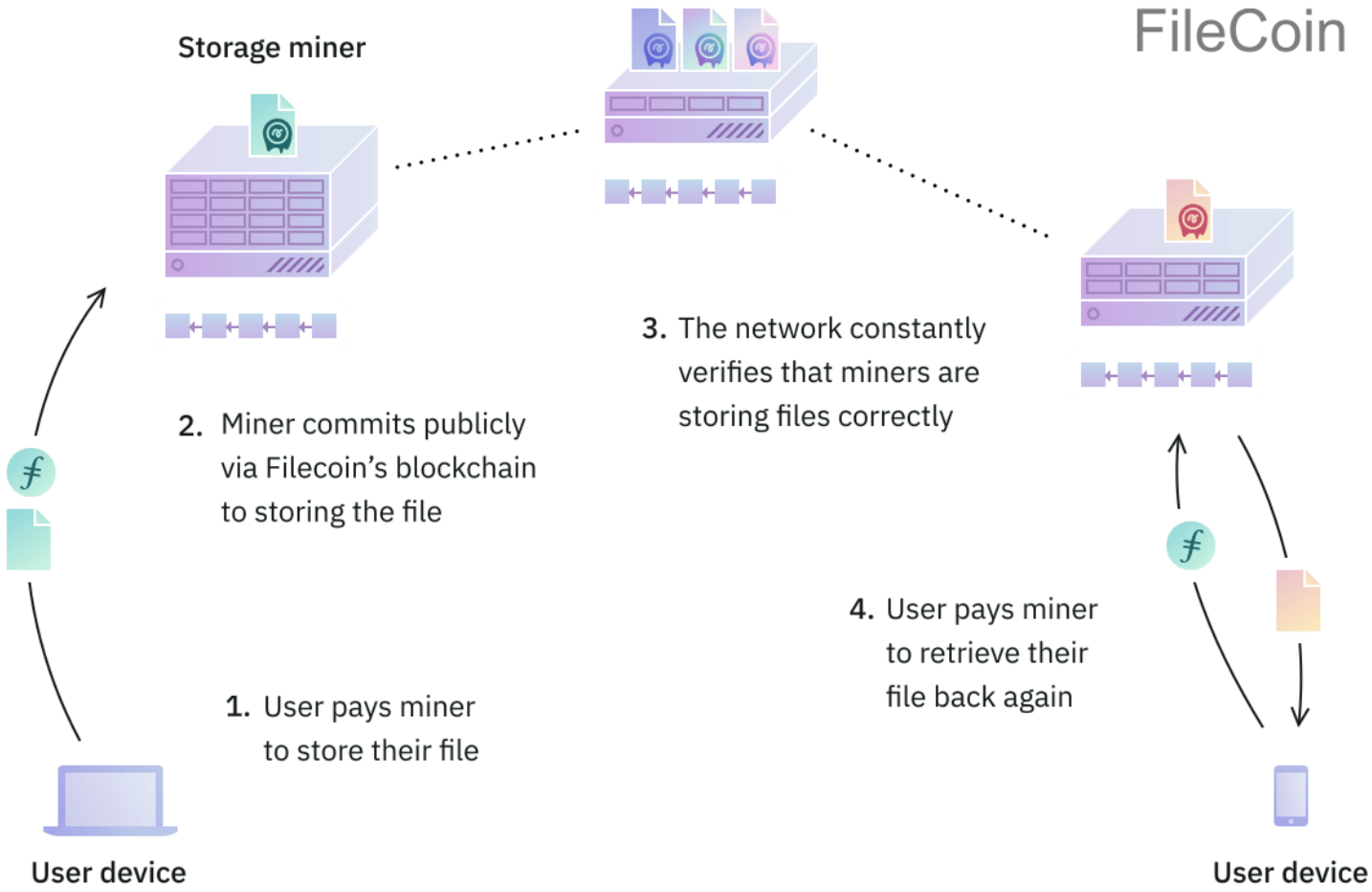
Filecoin

Storage and retrieval (1/7)



Filecoin

Deals (2/7)

Storage deal

Agreement between user and storage miner. The user pays in advance and the miner must periodically prove that it's still storing the file up to the expiration time

Retrieval deal

Agreement between user and retrieval miner. Payment is off-chain, incremental and typically based on retrieval reliability or speed

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Gas fees

- Gas is spent by a message sender to pay for block mining and the overall network infrastructure
- $BaseFee$ is dynamically determined by the network congestion and burned (sent to an unspendable address, also useful for deflation over time)
- $GasPremium$ priority fee which incentives miners to add the transaction in the block
- $GasLimit$ estimate (made by the sender) of the maximum gas consumable by a single message
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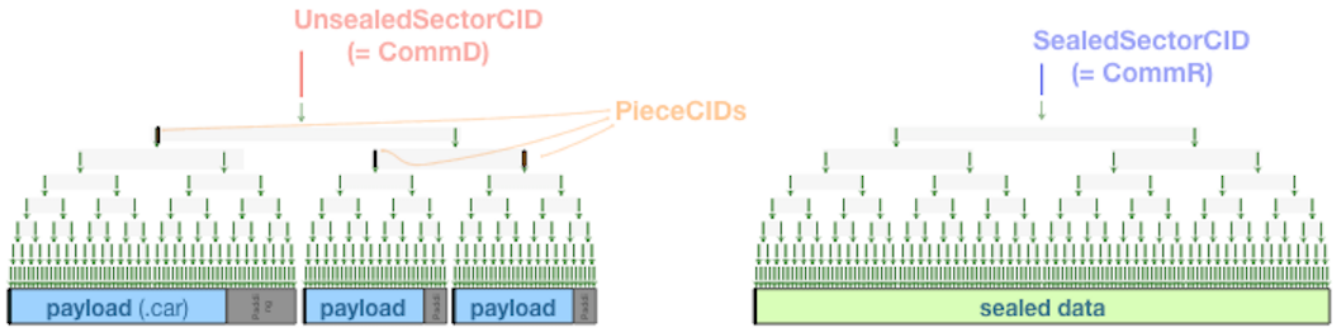
$$\begin{aligned} TotalGas =& (GasUsage + OverEstimation) \cdot BaseFee \\ &+ GasLimit \cdot GasPremium \end{aligned}$$

Filecoin

Sectors (3/7)

Sector

A sector is the basic storage unit on Filecoin. Size and time-increments for commitments are standardized and are chosen as a tradeoff between security and usability, while a sector's lifetime depends on the storage market.



Unsealed Sector

Sealed Sector

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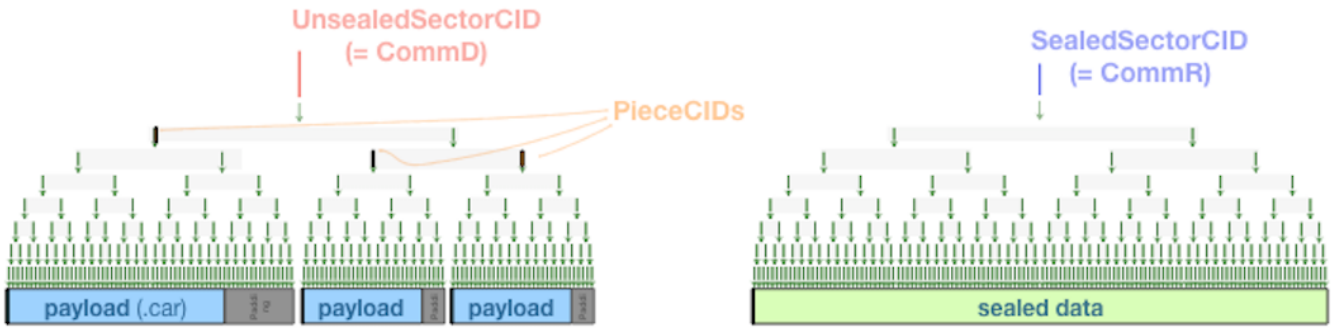

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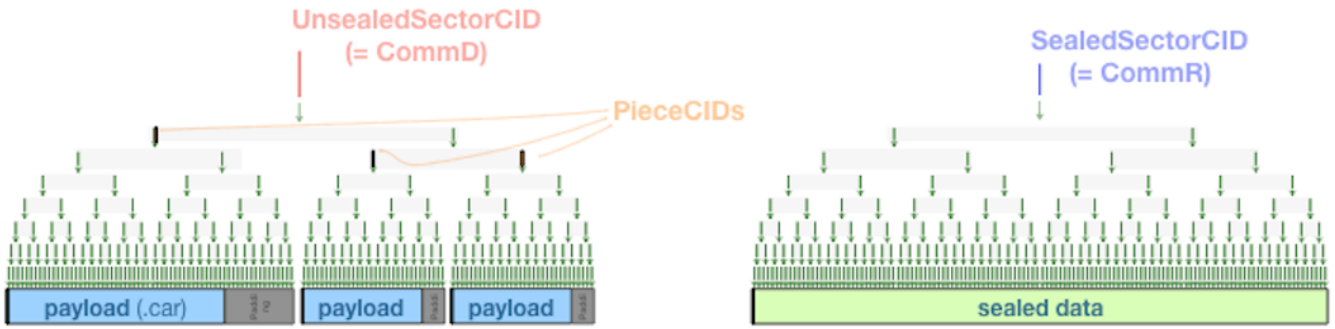

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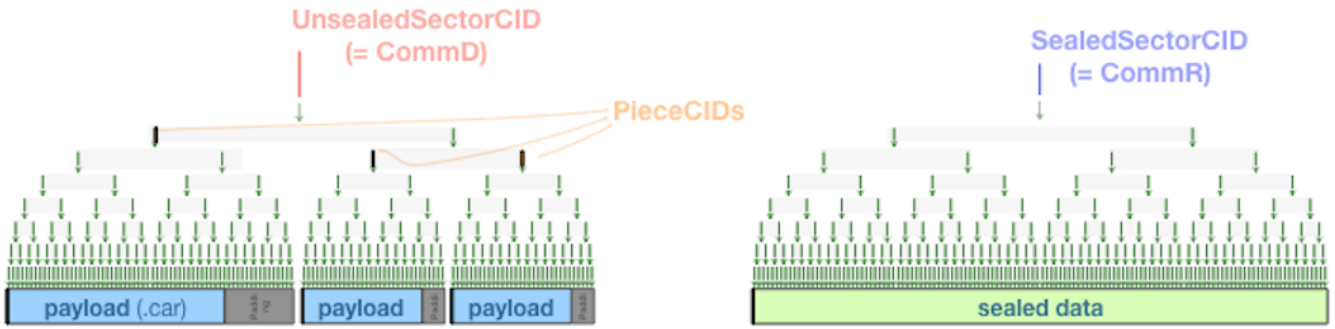

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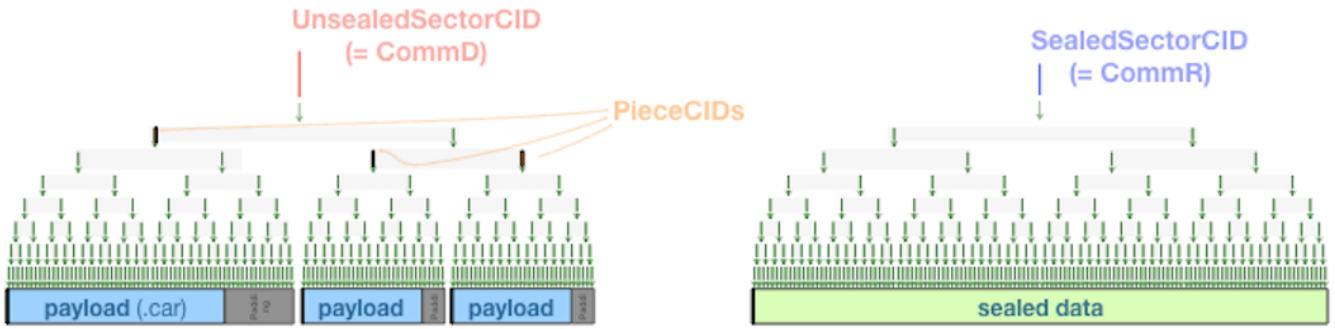

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Mining (4/7)

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- The blockchain acts as a ledger for proofs, deals and FIL transfer
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Proof of Replication (PoRep)

- Sectors are sealed (a time consuming process since sectors are 32Gb or 64Gb) using a key which depends on the hardware
- If a user wants its files to be stored as multiple copies on different miners, each copy will have a different seal and a malicious attacker would need to download each block of the file and reseal them
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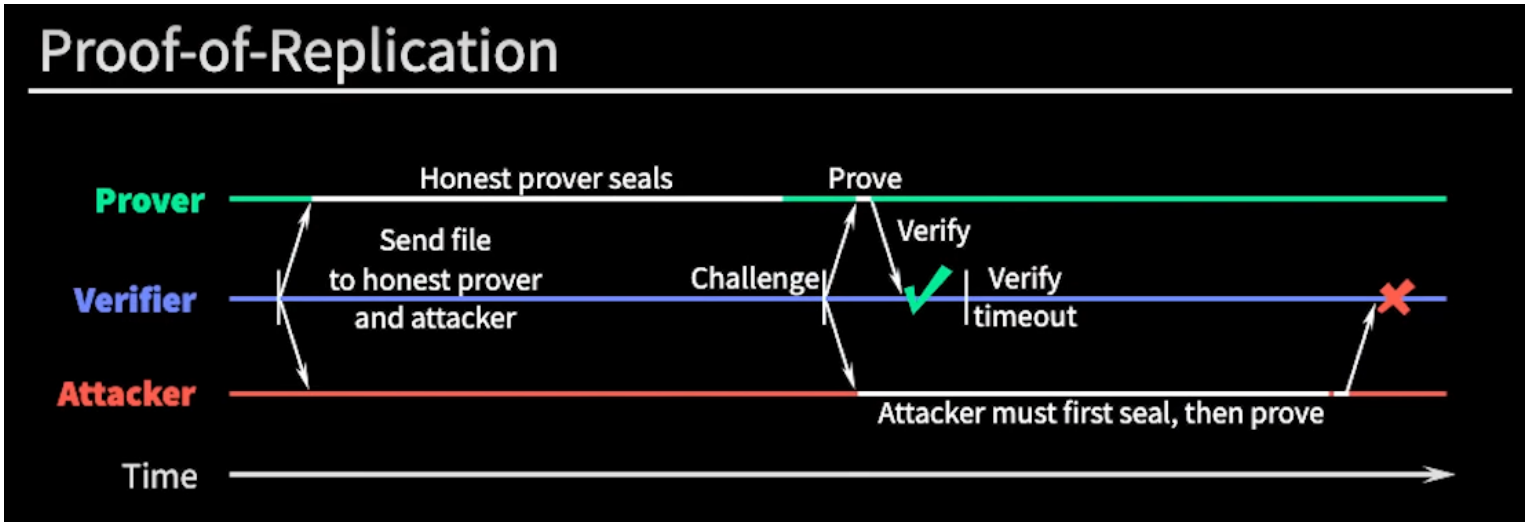
Proof of SpaceTime (PoSt)

- Both users (upon request) and miners (periodically) check that blocks are valid
- Miners are punished if blocks are unavailable before a deal expires
- All miners are asked to perform a PoRep on a random sector of their storage
- Two variants of PoSt:

WinningPoSt	When mining blocks
WindowPoSt	Every day

Filecoin

Proofs (5/7)



Proof of Spacetime

(PoSt)

Over time, randomly selected miners have random sectors challenged, from which data is read for verifications and compressed into a PoSt proof.

random Proofs of Space-time

Miners provide public proof that a given encoding of the data ***existed in physical storage continuously over a period of time.***

Filecoin

Rewards (6/7)

- Storage reward: miners receive payment for their deals with users
- Block reward: at the end of each epoch, a limited number of miners is chosen (with probability dependent on the quantity of storage they provide, ie. their **power**) and the first to complete a proof of spacetime in a given random sector (WinningPoSt) appends a block, winning the reward and a percentage on every deal inside the block
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Verified clients

- Special users certified with respect to their intent to store "useful" data
- They tend to offer better deals
- Miners accepting their deals have a multiplier applied to their power (and therefore their chance of winning a block reward increases)

Filecoin

Slashing (7/7)

WindowPoSt

- A period of 24 hours is split into windows
- All the used sectors of a miner are partitioned randomly into one subset for each window
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Filecoin

Slashing (7/7)

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  - Termination fee: penalty received for every sector which is removed from the network (eg. the miner decides to reduce its storage or an hard drive fails)
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Miner's balance

- In order to make the slashing mechanism work, a miner can enter the Filecoin network only if it has invested some FIL
- If the miner wallet becomes empty, it will be banned from the network because it's no longer capable of covering potential slashing