Engineering Filecoin's Economy

2020-08-27

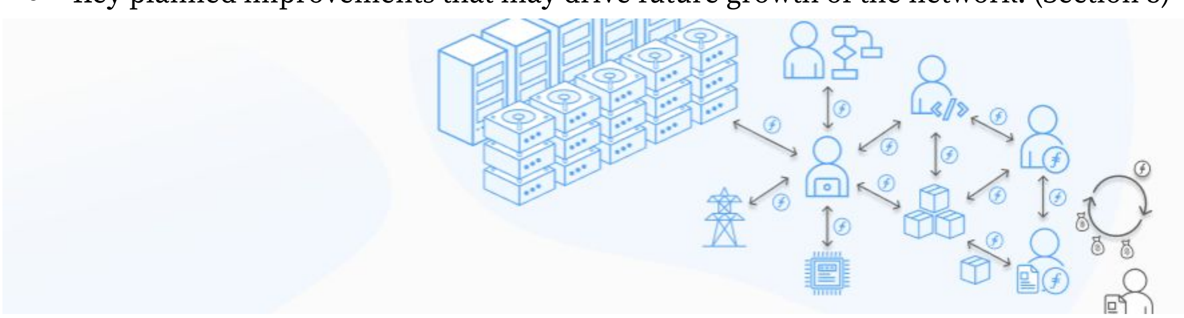
The Filecoin Network and its mission

As a novel data storage and distribution network, the Filecoin Network's mission is to create a decentralized, efficient, and robust foundation for humanity's information. This mission will be advanced by incentivizing consistent growth and development of the Filecoin Network's economy. The goal of the economic design is to align incentives and pragmatically reward useful and reliable storage with as few rules as possible. The action and interaction of each of these mechanisms must be considered during the design process. Other economic structures and product offerings can then emerge from these basic building blocks. This document explains specific incentive mechanisms and economic stimuli provided by the protocol itself. For each fee, reward, or penalty in the protocol, there will be an explanation of how it is intended to contribute to long-term utility of the network.

Additionally, this document explains the importance of long-term cooperation between participants in the Filecoin Network. The protocol's design enables and incentivizes this collaboration and furthers the interests of all participants.

The remainder of this document explains:

- Why the Filecoin Network has a strong value proposition; (Section 1)
- What it means to build an economy and a market from that business model; (Section 2)
- How that market handles data storage; (Section 3)
- The role that storage clients play in that market and the Filecoin Protocol; (Section 4)
- How the protocol retrieves and delivers data; (Section 5)
- The role of the filecoin token as a medium of exchange in the economy; (Section 6)
- The current economic structures and initial parameters of the Filecoin Protocol; (Section 7)
- Key planned improvements that may drive future growth of the network. (Section 8)



1. The future of the data storage and distribution industry

Filecoin is a decentralized data storage and distribution network; it is therefore necessary to describe what it means to be a digital storage network. Cloud storage has evolved into an industry valued at over $46B in 2019, where data is stored in enormous data centers far from end users, where space and utility costs are low. Content delivery networks (CDNs) then acquire space and pack servers in dense population centers to cache content nearer to users, and are, as an industry, valued at over $12B. The rate at which we generate data is growing as video and images supplement text, resolution grows, and the number of internet-accessible devices increases. The growing amount of data stored globally is depicted in Figure 1. And the top five storage providers control 77 percent of the global IaaS market, making it difficult for new market entrants to compete. Any new entrant to the market must compete against the reputation, infrastructure, and potentially network effects possessed by existing providers. Without a single platform for coordination and collaboration, small entities cannot effectively compete with the capacity, scale, and reputation of existing providers.

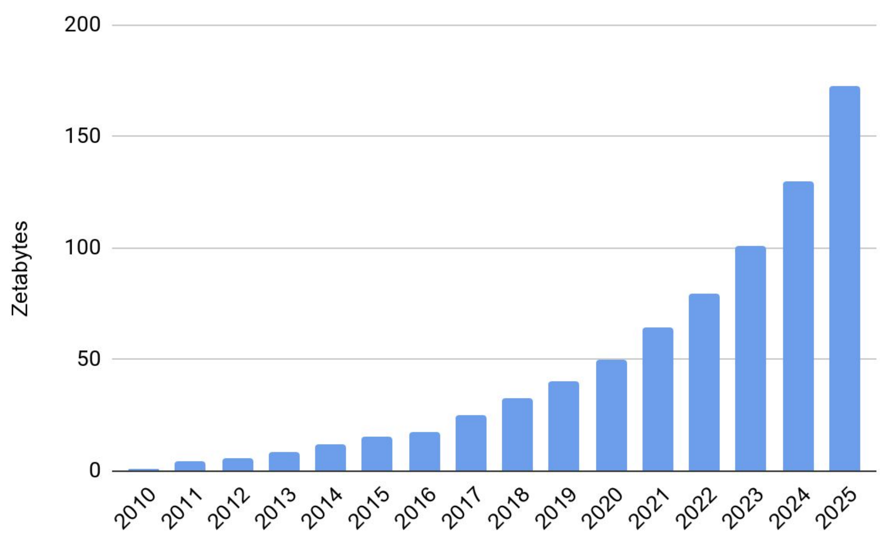


Figure 1. Size of the global datasphere by year [source]

The data itself sits on a spectrum of access. Most data is never read; users simply want to know that they *can* access that document, photograph, record, or footage if the need arises. Alternatively, some data is accessed very frequently, or goes viral, and must be replicated across the internet to be readily available to requesters with low latency.

Just as Airbnb allows homeowners to compete with hotels, the Filecoin Protocol will allow any willing and able storage provider to join a storage network and offer their storage for sale, while offloading auxiliary tasks like tooling, documentation, and branding to the Filecoin

Network itself. At first, the network will be best adapted to infrequently read files, optionally supporting fast retrieval at a client's request; the number of use cases will grow as the network grows, as the protocol evolves, and as tools are built. Even at network launch, however, the Filecoin Network has a unique value proposition:

- **Verifiable storage** – Rather than needing to trust a cloud storage provider or rely on legal recourse, the Filecoin Protocol cryptographically verifies whether or not clients' data are being stored.
- **Open participation** – Anyone with sufficient hardware and an internet connection can participate in the Filecoin Network.
- **Distribution of storage empowers local optimization** – Driven by open participation, market forces in the Filecoin Economy should communicate information more efficiently and the network will be more responsive than centralized storage platforms. The website or video a client requested could be hosted as close as the Filecoin Mining node next door. This will increase the utility of the network by ensuring that data can be stored near the network edge, close to the clients, in a cost effective way.
- **Flexible storage options** – Because the Filecoin Network will be an open platform, the network will support many additional tools and auxiliary services provided by the community of developers improving or building on top of the protocol.
- **The network has been built by a community** – Filecoin will be stronger because it provides participants the opportunity to obtain stake in the network's success. Filecoin participants will benefit by working together to improve the Filecoin Network.

Given the growth of both demand and supply, a decentralized storage network's differentiated approach to cloud storage could unlock significant efficiency improvements and growth.

2. The Filecoin Economy

Filecoin is more than a network; the protocol lays the groundwork for a market economy built around a marketplace for the storage and retrieval of data. Unprecedented growth of the network will require unprecedented collaboration between researchers, engineers, stakeholders, miners, and clients in this market economy, as the network adapts and grows to accommodate additional use cases.

2.1 A Market for Data

In general, markets balance supply and demand, determining the prices at which goods or services trade. In the case of Filecoin, if you have extra storage and computing power, you may be willing to provide it to others for a fee - while those seeking data storage may be willing to pay for storage services. Aligning these two prices would result in a deal (i.e., a market clearing transaction). Creating a marketplace allows consumers and providers to come together and express how much they value commodities. In thriving economies, there are so-called "gains from trade," where trades increase the net utility (or happiness) of both participants.

As a global digital marketplace, it is necessary to choose at least one valid currency for transactions. Because Filecoin is a permissionless market with cryptographically verifiable goods, design constraints could only be satisfied with a native token, the filecoin (FIL). This token acts as a medium of exchange, facilitating transactions and production activities, somewhat similar to the in-game currencies of virtual economies in multiplayer online games. However, as a currency, the token also acts as a store of value; its minting must be tied to adding utility to the network. The interactions underpinning this digital storage market are illustrated in Figure 2.

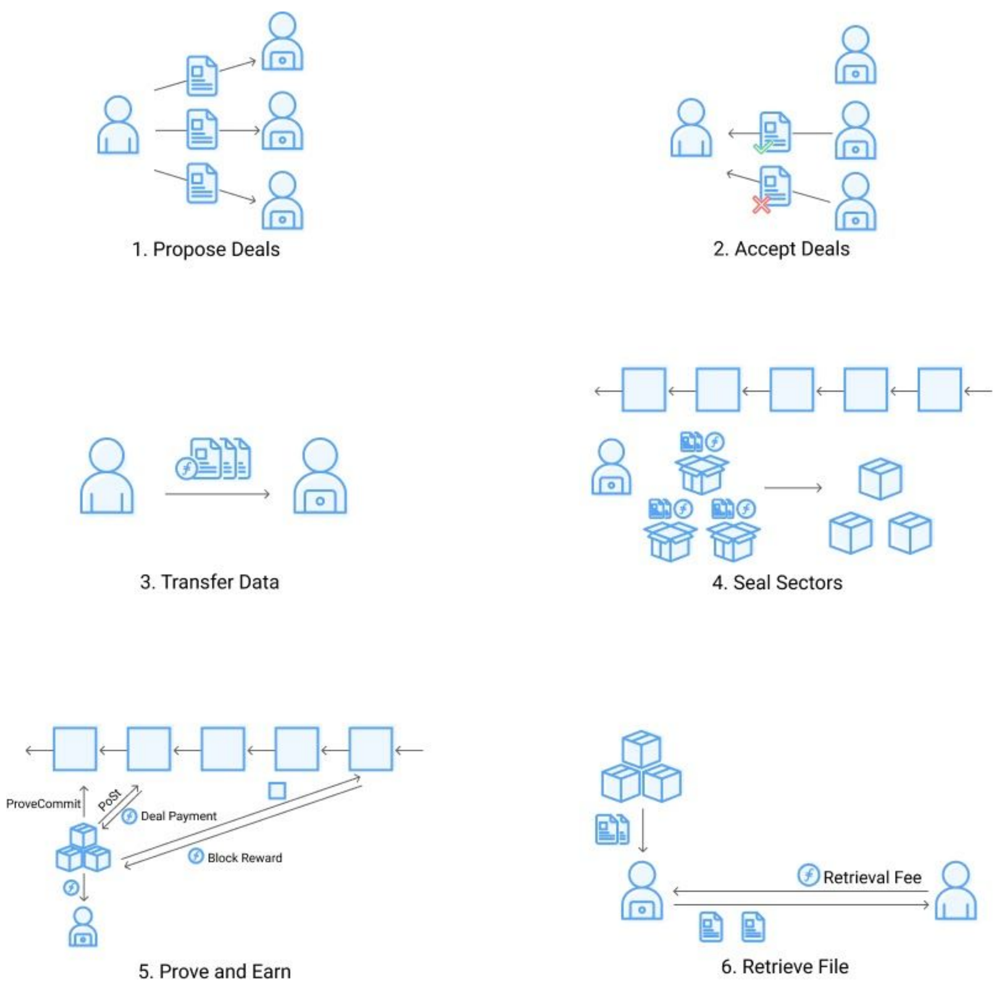


Figure 2: Basic client-miner interaction sequence: clients propose deals to miners, miners accept deals, data transfer occurs, miners seal deal data into sectors, miners prove their sectors and start earning block reward, clients retrieve files from miners.

2.2 An Export Economy

Filecoin's export economy is most easily understood by considering the metaphor of an island economy producing valuable goods and services from raw materials. Trades are executed in the island's currency, which must be purchased to make trades. Inhabitants of the island participating in trade need to deploy capital in this currency to engage in productive activities; typically this deployment is investment in capital assets, while in the case of Filecoin, this takes the form of mining hardware and collateralized tokens.

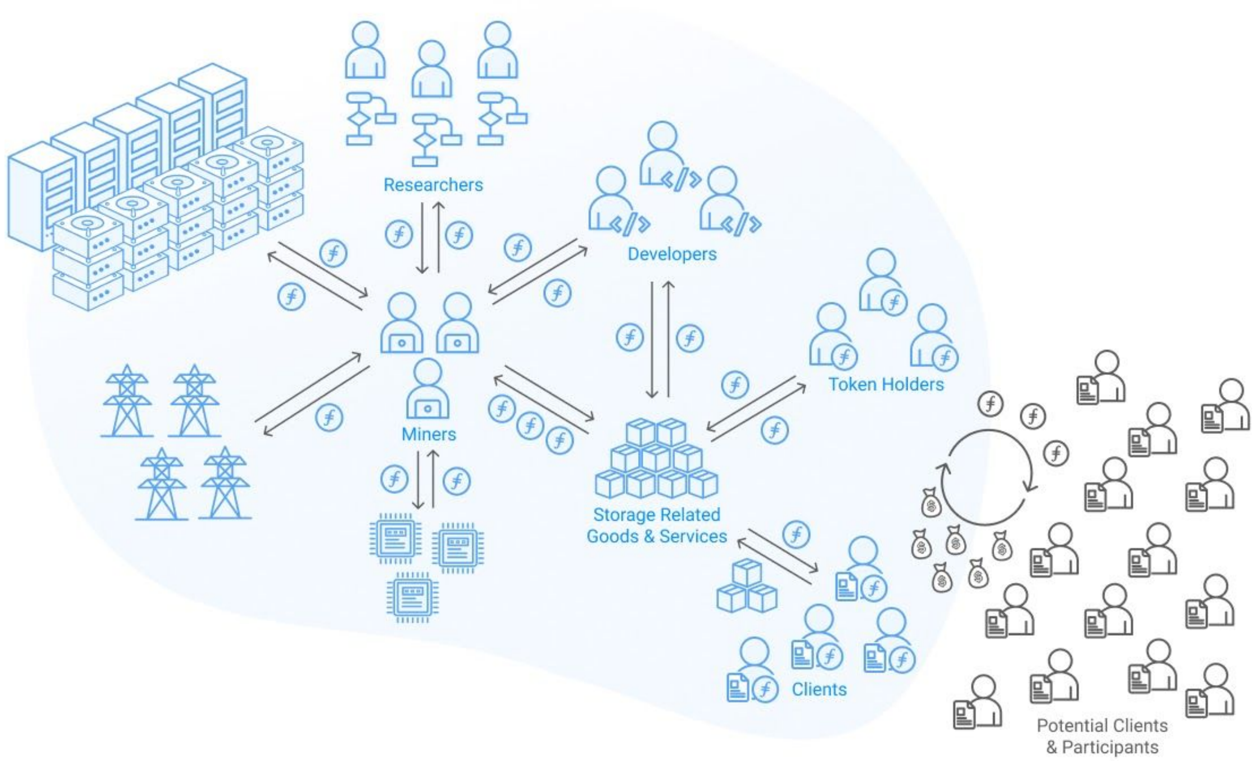


Figure 3: Illustration of the Filecoin Economy where raw materials (electricity, disks, algorithms, data centers, labor, compute resources, software, etc) are converted into valuable storage services to be traded with the outside world.

Given the nature of Filecoin's Economy, the protocol must generate its own currency. The creation of new tokens can facilitate more trades and stimulate the economy, but if supply grows too quickly, it may harm the economy. Ideally, the rate of token minting should approximately match the rate of value creation, which provides a clear mandate for the protocol's token generation rates. Value is created as goods are traded (i.e. supply clears with demand, creating gains from trade). Filecoin's minting function tries to approximate this value, in the absence of a reliable and incentive-compatible measure of economic surplus.

The overarching goal for the whole economy, researchers, miners, developers, clients, is to make the production as efficient as possible and make the network as attractive as it can be to the outside world. An economy producing more valuable goods more efficiently will lead to more demand for the goods and more demand for the network's token. Malicious participants in the Filecoin Economy, who attempt to exploit the protocol, will drive real demand away from the economy and destroy value, harming all members of the economy, like thieves plundering in the island economy. As a result, the goal of all participants should be to get real paying demand for the goods that the network produces - key to a thriving economy that can operate with little or no subsidies. In the long term, the Filecoin Network must be a protocol where demand from clients is so strong that mining is still profitable with little or no block reward. Figure 3 illustrates an example of an export economy where miners amass disks, data centers, compute resources with algorithms developed by researchers and applications and tooling built by developers to produce useful storage goods and services for storage clients.

2.3 Participants in the Filecoin Economy

Within the Filecoin Economy, there are three distinct markets, and participants in the network exchange different goods or services. In the storage market, storage miners offer to rent out digital storage that will be verified by the Filecoin Network. Conversely, storage clients offer filecoin to have their data stored. This storage is priced based on the amount of storage space used and the duration of the contract in time. There is a retrieval market, where clients pay filecoin to retrieval miners to provide them with a copy of the data. Lastly, token exchanges could enable participants to trade to put filecoin in the hands of clients, miners, and other token holders. The five primary stakeholder groups, as well as the common interactions between them, are illustrated in Figure 4.

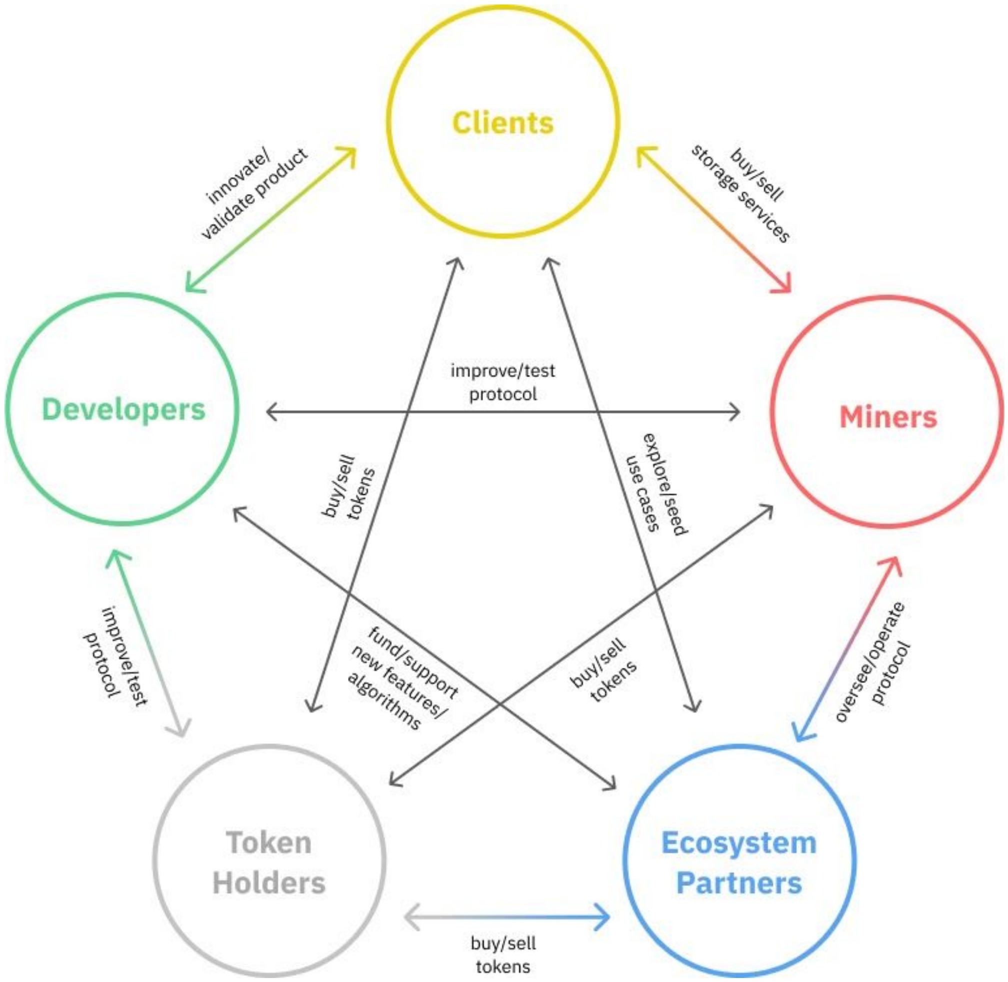


Figure 4: Illustration of different network participants and common sample interactions. Note that an individual or entity can take on multiple roles. For instance, anyone in possession of filecoin would be considered a token holder.

The participants mentioned above must work together to support the growth of the Filecoin Economy. And there's one more major ecosystem partner participating in this economy: the Filecoin Foundation. The Filecoin Foundation is separate from Protocol Labs and is funded with tokens from the genesis block allocation. It will deploy those tokens to guide the network towards its mission of building a robust and growing network for humanity's data.

Collaboration across participants is required to make Filecoin a robust and efficient economy in producing valuable storage-related goods and services. Some participants may join temporarily to exploit subsidies from the protocol. However, the protocol is designed so that rational decisions are aligned with the creation of value for the network; therefore their profits are increased if they join the network and participate on long time horizons. The permissionless nature of the protocol should thus result in a virtuous cycle, drawing in new participants, incentivizing continued participation, and making future growth self-sustaining. Existing and mechanisms are described in the remainder of the document. With enough entrepreneurs and engineers that see the potential of a decentralized storage network, the subsidies will empower participants and accelerate the rate at which the community can build a thriving economy that can operate with little or no subsidies.

Given the permissionless nature of the network, the rules and parameters must incentivize participant alignment with the long-term goals and mission of the network. It is possible to rely on trust in a small community. But in order to support permissionless, pseudonymous interactions, rules must be enforceable with cryptography and aligned with incentives. As a distributed storage network, the Filecoin Network's value is fundamentally determined by its ability to deliver long-term, reliable, and useful storage. As a result, a community of rational actors will lead to a network where real value is created, as clients are drawn to the functionality of the network, and they purchase and use Filecoin for most, if not all, of their online storage needs.

3. Storage Services on Filecoin

Because Filecoin's economy is centered around data storage, storage miners play a central role in the network, in both securing consensus and providing storage services. The Filecoin blockchain uses its block reward to subsidize both consensus participation and useful storage services. This section describes how storage services are provided on the Filecoin Network, explaining the abstractions and frameworks used to take storage that exists on different devices in different machines and turn it into a fungible and tradable commodity in a distributed storage network. An overview of the process of providing storage services is shown in Figure 5.

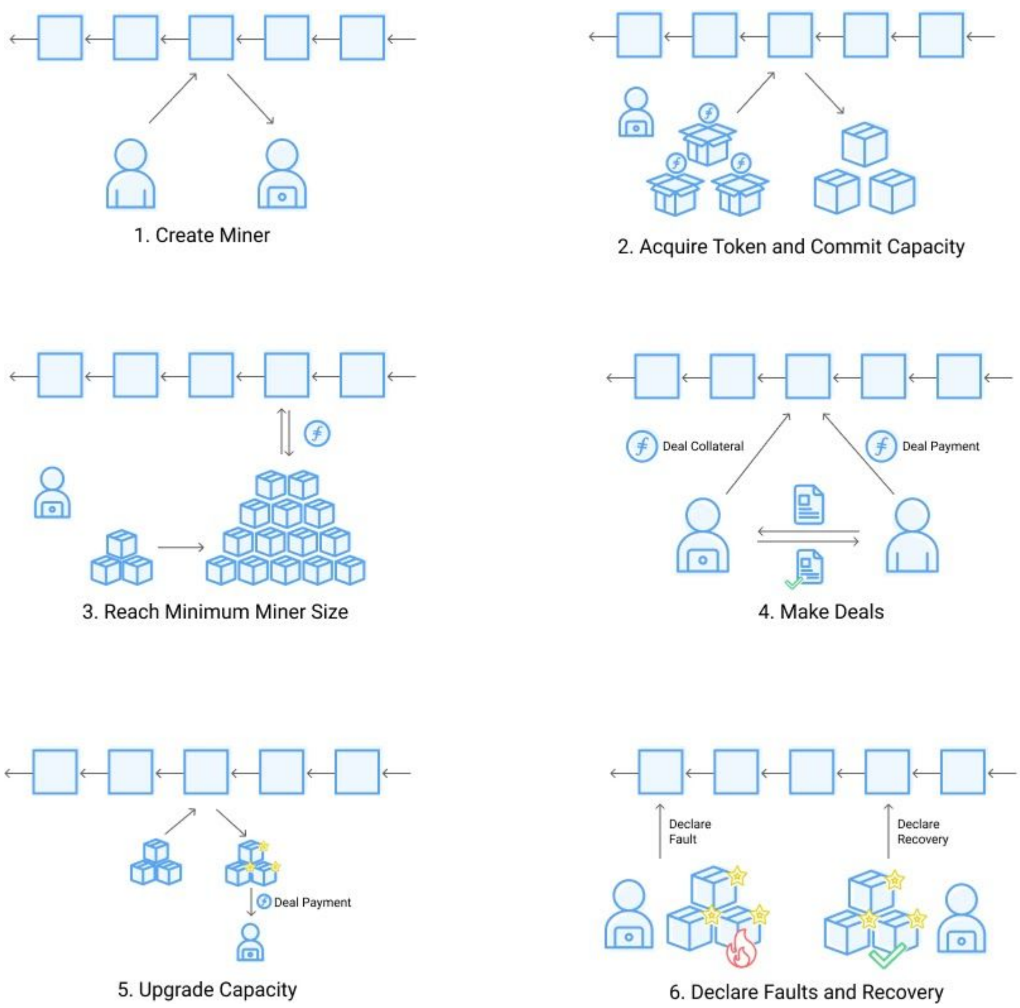


Figure 5: Life cycle of a miner, create miners on chain, acquire tokens and commit capacity to the network, start producing blocks when minimum miner size is reached, make deals with clients, upgrade committed capacity sectors to sectors with deals and earn additional deal revenue, declare and recover faults.

3.1 What is a sector?

Sectors are the basic units of storage on Filecoin. They have standard sizes, as well as well-defined time-increments for commitments, and serve as the digital storage analog to the intermodal containers in global freight shipping. The size of a sector balances security concerns against usability. A sector's lifetime is determined in the storage market, and sets the promised duration of the sector.

Individual deals are formed when a storage miner and client are matched on Filecoin's storage market. The protocol does not distinguish miners matching with real clients from miners generating self-deals.[1] However, committed capacity is a construction that is introduced to make self-dealing unnecessary and economically irrational.

If a sector is only partially full of deals, the network considers the remainder to be committed capacity. Similarly, sectors with no deals are called committed capacity sectors; miners are rewarded for proving to the network that they are pledging storage capacity and are encouraged to find clients who need storage. When a miner finds storage demand, they can upgrade their committed capacity sectors to earn additional revenue in the form of a deal fee from paying clients. Upgrading capacity currently involves resealing, creating a unique representation of the data through a computationally intensive process. Looking ahead, committed capacity upgrades should eventually be possible without a reseal.[2]

Committed capacity sectors improve miners' incentives to store client data, but they don't solve the problem entirely. Storing real client files adds some operational overhead for storage miners. In certain circumstances – for example, if a miner values block rewards far more than deal fees – miners might still choose to ignore client data entirely and simply store committed capacity to increase their storage power as rapidly as possible in pursuit of block rewards. This would make Filecoin less useful and limit clients' ability to store data on the network. Filecoin addresses this issue by introducing the concept of verified clients. Verified clients are certified by a decentralized network of verifiers. Once verified, they can post a predetermined amount of verified client deal data to the storage market, set by the size of their DataCap. Sectors with verified client deals are awarded more storage power – and therefore more block rewards – than sectors without. This provides storage miners with an additional incentive to store client data.

Verification is not intended to be scarce – it will be very easy to acquire for anyone with real data to store on Filecoin. Even though verifiers may allocate verified client DataCaps liberally (yet responsibly and transparently) to make onboarding easier, the overall effect should be a dramatic increase in the proportion of useful data stored on Filecoin. Verified client deals are described in further detail in Section 4.

[1] In earlier designs of the network, only sectors filled with deals increased the miner's likelihood of winning the block reward. This led to the expectation that miners would attack and exploit the network by playing the role of both storage provider and client, creating a malicious self-deal.
[2] A succinct and publicly verifiable proof that the committed capacity has been correctly replaced with replicated data should achieve this goal. However, this mechanism must be fully specified to preserve the security and incentives of the network before it can be implemented.

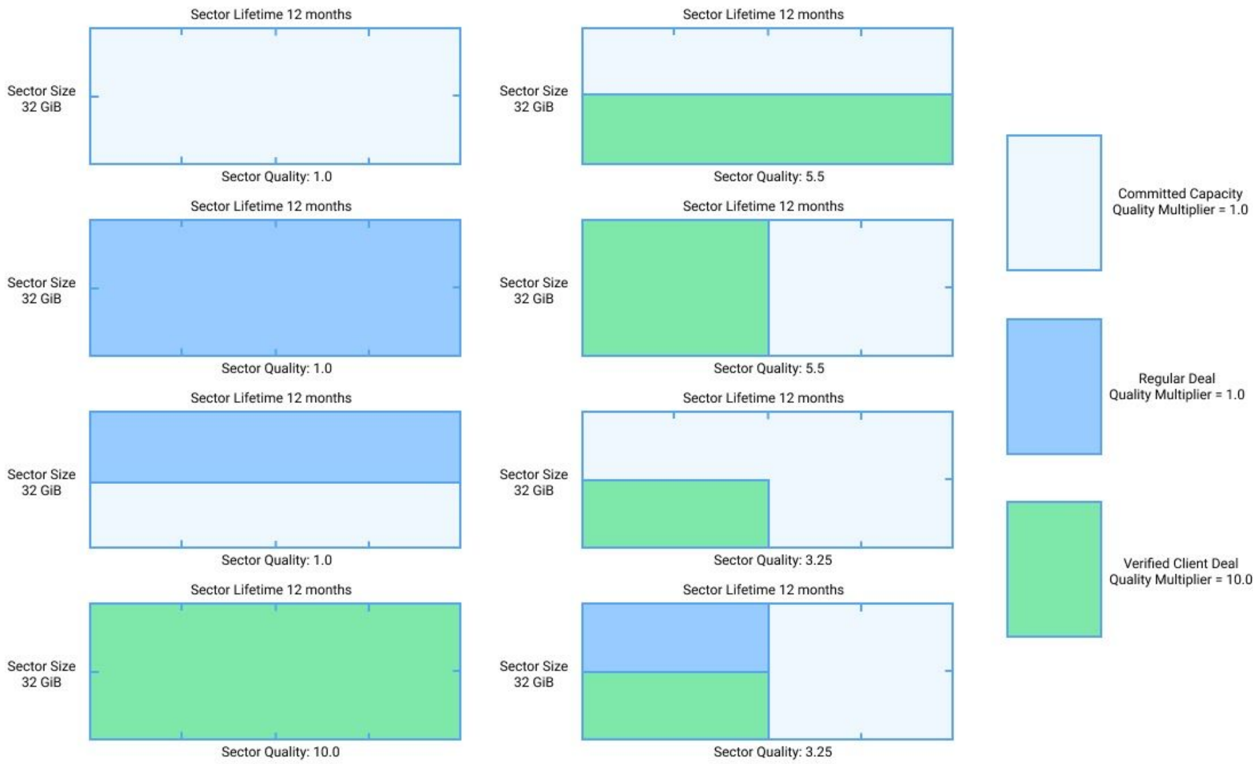


Figure 6: Illustration of deal types and their impact on sector quality. Note that the sector quality does not change during the lifetime of the sector. The sector quality is a weighted average of deal quality multipliers of different deal types in a sector, weighted by the spacetime that they occupy.

Given different sector contents, not all sectors have the same usefulness to the network. The notion of Sector Quality distinguishes between sectors with heuristics indicating the presence of valuable data. That distinction is used to allocate more subsidies to higher-quality sectors. To quantify the contribution of a sector to the consensus power of the network, some relevant parameters are described here.

- **Sector Spacetime:** This measurement is the sector size multiplied by its promised duration in byte-epochs.
- **Deal Weight:** This weight converts spacetime occupied by deals into consensus power. Deal weight of verified client deals in a sector is called Verified Deal Weight and will be greater than the regular deal weight. More details in Section 6.
- **Deal Quality Multiplier**: This factor is assigned to different deal types (committed capacity, regular deals, and verified client deals) to reward different content.
- **Sector Quality Multiplier:** Sector quality is assigned on Activation (the epoch when the miner starts proving they're storing the file). The sector quality multiplier is computed

as an average of deal quality multipliers (committed capacity, regular deals, and verified client deals), weighted by the amount of spacetime each type of deal occupies in the sector. Expressed algebraically,

$$SectorQualityMultiplier := \frac{\sum_{deals} DealWeight * DealQualityMultiplier}{SectorSpacetime}$$

- **Raw Byte Power:** This measurement is the size of a sector in bytes.
- **Quality-Adjusted Power:** This parameter measures the consensus power of stored data on the network, and is equal to Raw Byte Power multiplied by Sector Quality Multiplier.

The multipliers for committed capacity and regular deals are equal to make self dealing irrational in the current configuration of the protocol. In the future, it may make sense to pick different values, depending on other ways of preventing attacks becoming available.

The high quality multiplier and easy verification process for verified client deals facilitates decentralization of miner power. Unlike other proof-of-work-based protocols, like Bitcoin, central control of the network is not simply decided based on the resources that a new participant can bring. In Filecoin, accumulating control either requires significantly more resources or some amount of consent from verified clients, who must make deals with the centralizing miners for them to increase their influence. Verified client mechanisms add a layer of social trust to a purely resource driven network. As long as the process is fair and transparent with accountability and bounded trust, abuse can be contained and minimized. A high sector quality multiplier is a very powerful leverage for clients to push storage providers to build features that will be useful to the network as a whole and increase the network's long-term value. The verification process and DataCap allocation are meant to evolve over time as the community learns to automate and improve this process. An illustration of sectors with various contents and their respective sector qualities are shown in Figure 6.

3.2 Sealing Sectors

Sealing a sector through Proof-of-Replication (PoRep) is a computation-intensive process that results in a unique encoding of the sector. Once data is sealed, storage miners: generate a proof; run a SNARK on the proof to compress it; and finally, submit the result of the compression to the blockchain as a certification of the storage commitment. Depending on the PoRep algorithm and protocol security parameters, cost profiles and performance characteristics vary and tradeoffs have to be made among sealing cost, security, onchain footprint, retrieval latency and so on. However, sectors can be sealed with commercial hardware and sealing cost is expected to decrease over time. The Filecoin Protocol will launch with Stacked Depth Robust (SDR) PoRep with a planned upgrade to Narrow Stacked Expander (NSE) PoRep with improvement in both cost and retrieval latency. Figure 7 illustrates a slice of the tradeoff and characteristics of the two PoRep algorithms and future research direction.

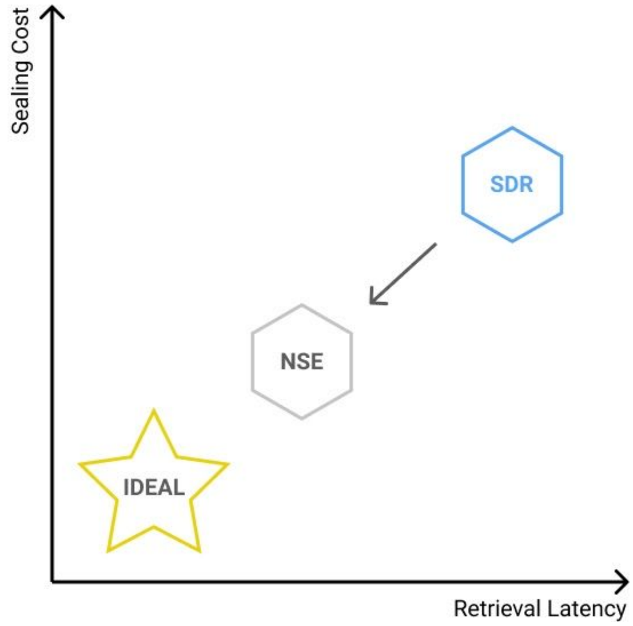


Figure 7: Illustration of cost and performance characteristics of different Proofs-of-Replication (PoReps), comparing the Stacked Depth Robust (SDR) PoReps to Narrow Stacked Expander (NSE) PoReps

3.3 Lifecycle of a Sector

Once the sector has been generated and the deal has been incorporated into the Filecoin blockchain, the storage miner begins generating Proofs-of-Spacetime (PoSt) on the sector, starting to potentially win block rewards and also earn storage fees. Parameters are set so that miners generate and capture more value if they guarantee that their sectors will be around for the duration of the original contract. However, some bounds are placed on a sector's lifetime to improve the network performance. As sectors of shorter lifetime are added, the network's capacity can be bottlenecked. The reason is that the chain's bandwidth is consumed with new sectors only replacing expiring ones. As a result, a minimum sector lifetime of six months was introduced to more effectively utilize chain bandwidth and miners have the incentive to commit to sectors of longer lifetime. The maximum sector lifetime is limited by the security of the present proofs construction. For a given set of proofs and parameters, the security of Filecoin's Proof-of-Replication (PoRep) is expected to decrease as sector lifetimes increase. The network plans to update the algorithm on a regular basis to improve longevity and efficiency of the network. Future improvements to the network will include secure proofs where sectors have no maximum lifetime but this will not be the case for the first iteration of the protocol.

In the first iteration of the protocol, 32GiB and 64GiB sectors are supported. Maximum sector lifetime is determined by the proof algorithm. Maximum sector lifetime is initially 18 months. These numbers can be adjusted with new proofs or new deal functionalities.

A sector naturally expires when it reaches the end of its lifetime. Additionally, the miner can extend the lifetime of their sectors. Rewards are earned and collaterals recovered when the miner fulfils their commitment.

Operational risks and failures are common in storage businesses. However, it is important for storage providers to have a strong incentive to both report the failure to the chain and attempt recovery from the fault in order to uphold the storage guarantee for the network's clients. Without this incentive, there's no way to distinguish an honest miner's hardware failure from malicious behavior, which is necessary to treat miners fairly. The size of the fault fees depend on the severity of the failure and the rewards that the miner is expected to earn from the sector to make sure incentives are aligned. The three types of sector storage fault fees are:

- **Sector fault fee:** This fee is paid per sector per day while the sector is in a faulty state. The size of the fee is slightly more than the amount the sector is expected to earn per day in block rewards. If a sector remains faulty for more than 2 consecutive weeks, the sector will pay a termination fee and be removed from the chain state. The initial value for this fee is 2.14 days worth of block reward for the faulty sector. As storage miner reliability increases above a reasonable threshold, the risk posed by these fees decreases rapidly.
- **Sector fault detection fee:** This is a one-time fee paid in the event of a failure if the miner does not report it honestly and instead the unreported failure is caught by the chain. Given the probabilistic nature of our PoSt checks, this will be 5 days' worth of block reward that would be expected to be earned by a particular sector.
- **Sector termination fee:** A sector can be terminated before its expiration through automatic faults or miner decisions. A termination fee is charged that is, in principle, equivalent to how much a sector has earned so far, up to a limit to not discourage long sector lifetimes. In an *active termination*, the miner decides to stop mining and they pay a fee to leave. In a fault termination, a sector is in a faulty state for too long (14 days), and the chain terminates the deal, returns unpaid deal fees to the client and penalizes the miner. Termination fee is currently capped at 90 days worth of block reward that a sector will earn. Miners are responsible for deciding to comply with local regulations, and may sometimes need to accept a termination fee for complying with content laws.

Many of the concepts and parameters above make use of the notion of "how much a sector would have earned in a day" in order to understand and align incentives for participants. This concept is robustly tracked and extrapolated on chain.

Figure 8 presents a simplified view of a sector's lifecycle.

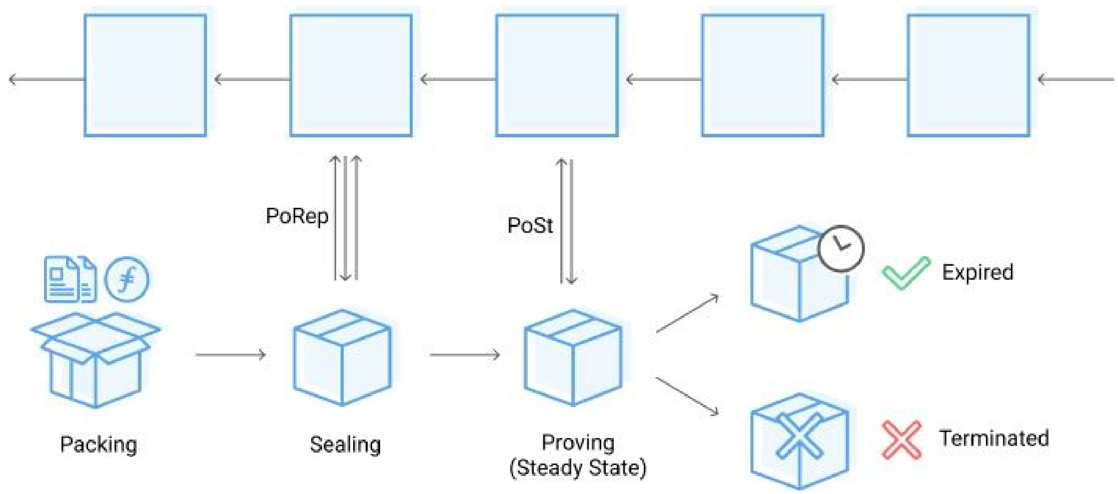


Figure 8: Illustration of a sector's lifecycle including the packing of the sector with deals, the proof-of-replication (PoRep) as part of initializing the sector, the proofs-of-spacetime (PoSts) generated to demonstrate continued storage, and the two possible end states.

3.4 Miner Collaterals

In most permissionless blockchain networks, resources are required to participate in the consensus. The more power an entity has on the network, the greater the share of total resources it needs to own, both in terms of physical resources and/or staked tokens (collateral). This ensures a capital investment at stake in the process of mining. Bitcoin and other proof-of-work blockchains tend to pick ASICs that are hard to resell, to ensure the capital investment is specific to the network and hard to recoup after an attack. Proof-of-stake networks use large quantities of token stake collaterals to achieve the same function, with the added benefit that an attacker purchasing large quantities of the token would consume token supply, driving the price higher and thus making the attack extremely expensive.

Filecoin must also achieve security via the dedication of resources. Note that by design Filecoin mining involves commercial hardware that is cheap in amortized cost and easy to repurpose, which means the protocol cannot solely rely on the hardware as the capital investment at stake for attackers. Filecoin also uses upfront token collaterals, as in proof-of-stake protocols, proportional to the storage hardware committed. This gets the best of both worlds: attacking the network requires both acquiring and running the hardware, but it also requires acquiring large quantities of the token.

To satisfy the multiple needs for collateral in a way that is minimally burdensome to miners, Filecoin includes three different collateral mechanisms: initial pledge collateral, block reward as collateral, and storage deal provider collateral. The first is an initial commitment of filecoin that a miner must provide with each sector. The second is a mechanism to reduce the initial token commitment by vesting block rewards over time. The third aligns incentives between miner and client, and can allow miners to differentiate themselves in the market. The remainder of this subsection describes each in more detail.

3.4.1 Initial Pledge Collateral

Filecoin Miners must commit resources in order to participate in the economy; the protocol can use the miners' stake in the network to ensure that rational behavior benefits the network, rewarding the creation of value and penalizing malicious behavior via slashing. The pledge size is meant to adequately incentivize the fulfillment of a sector's promised lifetime and provide sufficient consensus security.

Hence, the initial pledge function consists of two components: a storage pledge and a consensus pledge. The storage pledge protects the network's quality-of-service for clients by providing starting collateral for the sector in the event of slashing. The storage pledge must be small enough to be feasible for miners joining the network, and large enough to collateralize storage against early faults, penalties, and fees. The vesting of block rewards and the use of unvested rewards as additional collateral reduces initial storage pledge without compromising the incentive alignment of the network. This is discussed in more depth in the following subsection. A balance is achieved by using an initial storage pledge amount approximately sufficient to cover 7 days worth of Sector fault fee and 1 Sector fault detection fee. This is denominated in the number of days of future rewards that a sector is expected to earn.

Since the storage pledge per sector is based on the expected block reward that sector will win, the storage pledge is independent of the network's total storage. As a result, the total network storage pledge depends solely on future block reward. Thus, while the storage pledge provides a clean way to reason about the rationality of adding a sector, it does not provide sufficient long-term security guarantees to the network, making consensus takeovers less costly as the block reward decreases. As such, the second half of the initial pledge function, the consensus pledge, depends on both the amount of quality-adjusted power (QAP) added by the sector and the network circulating supply, which will be defined in section 6. The network targets approximately 30% of the network's circulating supply locked up in initial consensus pledge when it is at or above the baseline. This is achieved with a small pledge share allocated to sectors based on their share of the network's quality-adjusted power. Given an exponentially growing baseline, initial pledge per unit QAP should decrease over time, as should other mining costs.

3.4.2 Block Reward as Collateral

Clients need reliable storage. Under certain circumstances, miners might agree to a storage deal, then want to abandon it later as a result of increased costs or other market dynamics. A system where storage miners can freely or cheaply abandon files would drive clients away from Filecoin as a result of serious data loss and low quality of service. To make sure all the incentives are correctly aligned, Filecoin penalizes miners that fail to store files for the promised duration. As such, high collateral could be used to incentivize good behavior and improve the network's quality of service. However, high collateral creates barriers to miners joining the network. Filecoin must launch with a construction that satisfies both needs.

To reduce the upfront collateral that a miner needs to provide, the block reward is used as collateral. This allows the protocol to require a smaller but still meaningful initial pledge. Block rewards earned by a sector are subject to slashing if a sector is terminated before its expiration. However, due to chain state limitations, the protocol is unable to do accounting on a per sector level, which would be the most fair and accurate. Instead, the chain performs a per-miner level approximation. Sublinear vesting provides a strong guarantee that miners will always have the incentive to complete their deals. An extreme vesting schedule would release all tokens that a sector earns only when the sector promise is fulfilled.

However, the protocol should provide liquidity for miners to support their mining operations, and releasing rewards all at once creates supply impulses to the network. Moreover, there should not be a disincentive for longer sector lifetime if the vesting duration also depends on lifetime of the sector. As a result, a fixed duration linear vesting for the rewards that a miner earns after a short delay creates the necessary sub-linearity. Initial parameter recommendation puts the vesting delay at 20 days and the linear vesting duration after that for a period of 180 days.

In general, fault fees are slashed first from the soonest-to-vest unvested block rewards followed by the miner's account balance. When a miner's balance is insufficient to cover their minimum requirements, their ability to participate in consensus, win block rewards, and grow storage power will be restricted until their balance is restored. Overall, this reduces the initial pledge requirement and creates a sufficient economic deterrent for faults without slashing the miner's balance for every penalty.

3.4.3 Storage Provider Deal Collateral

The third form of collateral is provided by the storage provider to collateralize deals. There is a minimum amount required by the protocol to provide a minimum level of guarantee, and it is slashed if the deal is terminated. However, miners can offer a higher deal collateral to imply a higher level of service and reliability to potential clients. Given the increased stakes, clients may associate additional provider deal collateral beyond the minimum with an increased likelihood that their data will be reliably stored. This collateral is returned to the storage provider when all deals in the sector successfully conclude.

3.5 Redundancy

To enhance reliability of the storage network, the Filecoin Protocol offers storage clients unlimited flexibility to store redundant copies of files with different miners, and to verify that unique copies are actually being stored. Unlike centralized cloud storage services, which back up data in ways clients can't change or verify, Filecoin allows clients to easily express their own preferences for reliability and cost.

Verified clients can also request that bidding miners store multiple copies of their data. This has the effect of the network further subsidizing redundant and reliable storage of data that are likely to be of interest, again supporting activities that bring value to the network.

3.6 Fast retrieval

Because of the bidirectionally slow encoding currently required for a secure PoRep, the Filecoin Network can support miners additionally storing an unsealed copy of the data to support fast retrieval of client data. Retrieval will be faster and cheaper in future PoRep constructions. However, the early network will offer the capability for verified clients to request that miners store an unsealed copy. The increased costs of additional storage should be compensated by the additional block reward subsidy from the increased sector quality. Reputation systems that will account for miners' adherence to these requests are under development.

3.7 Offline data transfer

Sometimes when dealing with huge troves of data, it's difficult (expensive and time-consuming) to transfer those files over the internet for safekeeping. For petabyte-scale datasets and larger, the most sensible solutions often involve shipping data on hard drives. The Filecoin Protocol and project has tools and structures to support what's known as offline data transfers.

The two factors to consider when making the decision whether to transfer data online or off are expense and time.

> ***Expense:*** Using the internet to stream data, transfer costs can build very quickly. Transferring petabytes of data in today's cloud services requires sending the data through multiple regions, incurring interconnection fees, and regional bandwidth fees, as well as additional costs if you choose to rent a dedicated line or account for the

inevitable retries. For a rough sense of cost, the bandwidth alone to transfer 2.5 petabytes of data would cost about $140,000 – and more if you're moving this data across regions. Then, consider the cost of a hard drive itself – a physical medium to store and ship the data. A server-grade 8 TiB drive costs about $200. To transfer 2.5 petabytes of data, for example, you would need roughly 315 hard drives, totaling approximately $63,000. While you might have slight additional per-unit costs for shipping, import fees, and currency exchange – you're well below the cost of streaming the data over the internet!

Time: It's also time consuming to stream data. Transferring 500 TB of data at 100 Mbps would take more than a year. On the other hand, transferring the same data offline using hard drives would take just the amount of time to download and ship – likely you'd be done within a week.

Filecoin's offline data transfer feature allows users with very large datasets to complete the data transfer step offline (e.g. by shipping hard drives from the client to the storage miner), and have the deal work as intended on-chain. It is implemented via a flag that tells the client *not* to transfer the data over the network. Instead, the client passes a piece CID (a unique identifier describing the data), which a miner must then match for the deal to go through. This gives the client node flexibility in how it can set up the deal – for example, passing miners a specific location on a hard drive for the data they can use to generate the piece CID.

4. Power of a storage client

Having discussed the ways in which the Filecoin Protocol and its economy commoditize and manage storage, it's important to provide additional clarity on the role of the storage clients. They play an important role in the ecosystem, not just using the storage services, but also shaping the storage network offering: because storage clients bring demand to an export-oriented economy, anyone with filecoin tokens to spend on storage can push the network to better meet consumer demand.

4.1 Client lifecycle

Equipped with data and filecoin tokens, likely obtained at an exchange, a storage client is ready to store data on the Filecoin Network. Before engaging miners, a storage client might choose to become verified, which will be elaborated on later in this section. The client begins participation in the storage market by preparing data into a piece, finding a miner, and proposing a deal to the miner. Once terms like price and duration are agreed upon, the miner and client enter into a deal and the client can later pay for the miner to retrieve it. Figure 9 presents an overview of clients lifecycle.

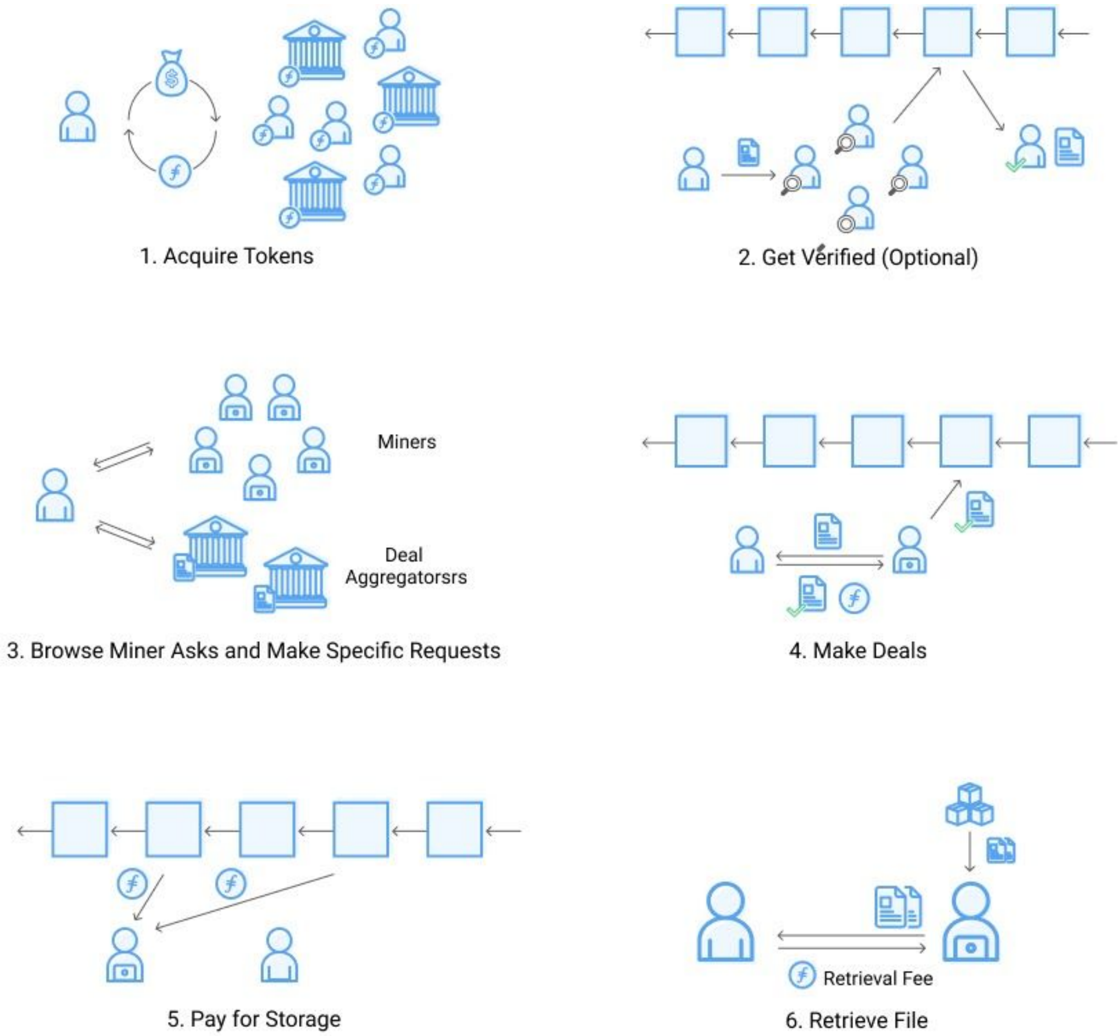


Figure 9: Lifecycle of clients, acquire tokens, optionally become a verified client, browse miner asks and make specific requests, make deals with miners once agreements are reached, chain verifies storage for clients and pays miners for storage, retrieves files from miners.

4.2 Deal proposals

Deals are communicated using a gossip network, where proposals are offered by clients and miners. This free exchange of prices acts as a decentralized storage market. Many third party entities operating on this platform can enhance the deal proposal and matching process, including participation from exchanges or the creation of novel aggregators of deal bids and asks. These communications are not even limited to one protocol or platform; storage deals could be proposed over digital spaces like Twitter or email (especially for storing large amounts of data), for example.

4.3 Deals

The deals themselves are formed when storage demand and supply are met on Filecoin. In addition to stating the storage amount, price, and duration, deals can also specify the amount of collateral that both storage miners and clients pledge during deal creation. A storage miner would offer a provider deal collateral above the minimum amount as a differentiating factor, allowing them to signal their commitment and level of service. Additionally, a miner could select for deals where clients also provide collateral. This mechanism exists but is left optional for market participants.

However, there is a minimum provider deal collateral set by the protocol, needed because the chain state and bandwidth are limited resources and providers should guarantee a minimum level of service to clients. Minimum deal collateral requirement per unit quality adjusted power is set such that if the network baseline is filled with deals, the sum of deal collateral targets 5% of the circulating supply of Filecoin.

In addition to collateral commitments from both parties, there's also a deal payment from client to miner. This payment is initially locked by the client when the deal is incorporated into the blockchain; as a result, the client's exposure to Filecoin price volatility ends the moment they enter into a storage deal. Payment is released to the miner as some fraction of the total deal fee per payment period. Deal payments begin to pay out immediately to provide a greater incentive for miners to seek paid client deals. If a miner terminates before a deal expires, the miner will pay a termination fee and the provider deal collateral will be burned. Additionally, the remaining deal payments will be returned to the client.

There is clear utility to the network from developing some additional features. To this end, the following improvements are prioritized for future releases:

- **Deal Extension:** A client and miner could easily agree to renew a deal.
- **Deal Migration:** Instead of implicitly bounding the maximum deal duration by the sector lifetime, a deal could be capable of outliving the sectors that contains it, permitting it to be migrated to a new sector.
- **Deal Substitution:** A client could replace one of their deals in a sector with another file of the same size.
- **Deal Transfer** - A miner could pass on deals to other miners with client consent.

4.4 Verified clients

As described in Section 3, verified clients as a construction make the Filecoin Economy more robust and valuable. While a storage miner may choose to forgo deal payments and self-deal to fill their storage and earn block rewards, this is not as valuable to the economy and should not be heavily subsidized. However, it's impossible in practice to tell useful data apart from encrypted zeros. Introducing verified clients pragmatically solves this problem through social trust and validation. There will be a simple and open verification process to become a verified client; this process should attract clients who will bring real storage demand to the Filecoin Economy.

Verifiers should eventually form a decentralized, globally distributed network of entities that confirms the useful storage demand of verified clients. If a verifier evaluates and affirms a client's demand to have real data stored, that client will be able to add up to a certain amount of data to the network as verified client deals; this limit is called a DataCap allocation. Verified clients can request an increased DataCap once they have used their full allocation and Verifiers should perform some due diligence to ensure that the clients are not maliciously exploiting verification. The verification process will evolve over time to become more efficient, decentralized, and robust.

Storage demand on the network will shape the storage offering provided by miners. With the ability to deploy data with a greater sector quality multiplier, verified clients play an even more important role in shaping the quality of service, geographic distribution, degree of decentralization, and consensus security of the network. Verifiers and verified clients must be cognizant of the value and responsibility that come with their role. Additionally, it is conceivable for miners to have a business development team to source valuable and useful dataset in the world, growing demand for the storage they provide. Teams would be incentivized to help their clients through the verification process and start storing data on the Filecoin Network, in addition to providing their clients with strong SLAs.

5. Content delivery on Filecoin

The storage market alone is not sufficient for a functioning decentralized storage network that can serve as a foundation for humanity's information. The network must additionally provide a mechanism by which content can be efficiently delivered to locations where it is requested.

At present, the internet achieves this distribution using a quasi-hierarchical architecture with efficient communication along the so-called backbone. Latency generally increases as the content and the client move farther from these high-speed connections and each other. To facilitate efficient distribution of data, content delivery networks (CDNs) use a geographically distributed network of servers and data centers to route requests toward the nearest copy of the data. Moving physical copies of data is increasingly cheaper and faster than increasing bandwidth and connectivity between servers and clients, as exemplified by Netflix's Open Connect program, wherein content is physically delivered to ISPs as appliances, or AWS's Snow

Family, which addresses the inverse problem of getting large datasets from individuals to datacenters.

Filecoin aims to provide infrastructure for a permissionless data-retrieval market. This will allow retrieval miners to bring data to the clients. Marketplace can form in different regions with local retrieval miners serving content to local clients as illustrated in Figure 10. Market forces inform not only how capabilities should be allocated to meet demand, but also what characteristics and features are best-suited to the users needs and interests. As a result, the role this retrieval market plays is clearly distinct from the storage market, where miners provide long term durable storage. It is also likely for storage miners to provide direct retrieval services in the early days of the network.

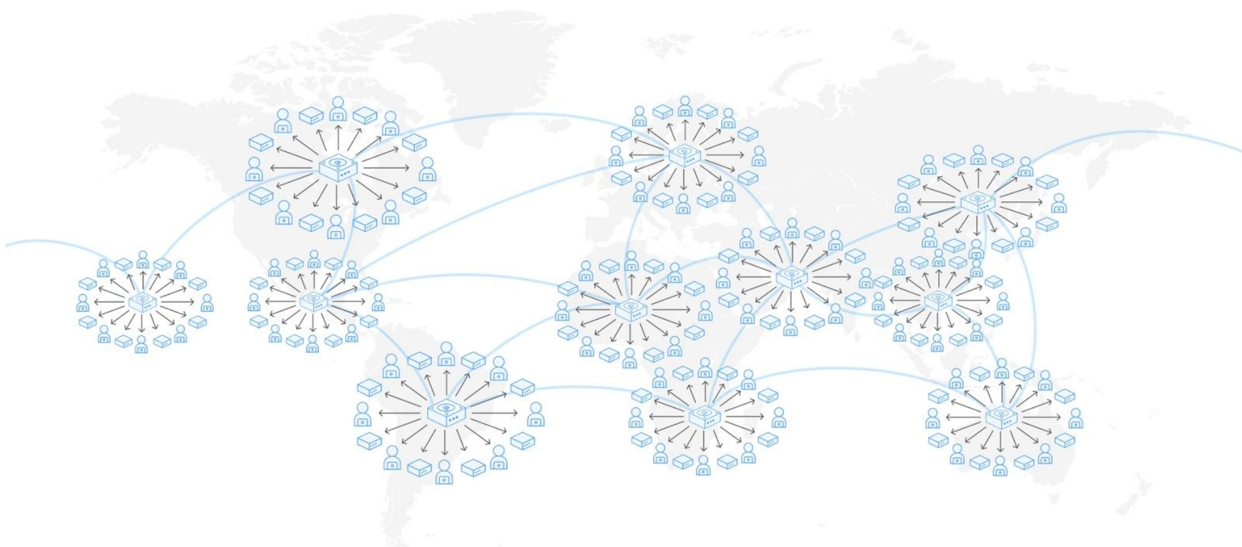


Figure 10: Illustration of retrieval market on Filecoin.

A transaction on the retrieval market is outlined in Figure 11. First, a client broadcasts a query for a specific piece of data. Retrieval miner nodes use gossipsub to spread these queries in the network of miners. Then retrieval miners with the content return retrieval proposals, which include price information. Clients exchange payment for data with a chosen retrieval miner using a payment channel. To reduce the risk of malicious behavior, small amounts of data and filecoin are exchanged incrementally. The profitability of retrieval will depend on pricing, popularity, locality and latency

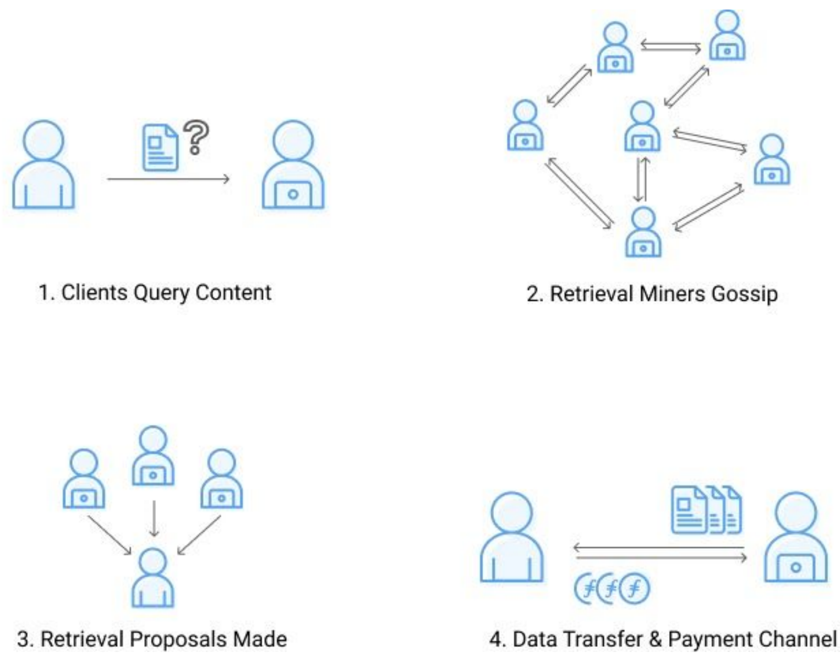


Figure 11: Content delivery flow on Filecoin

Filecoin will launch its main network with capabilities to retrieve files, as well as the capability for layer 2 applications to provide nascent retrieval markets and content delivery features. Early use cases will focus on long-term storage where clients hold deals with a variety of storage miners. Verified clients, and the ability to request storage of a plaintext copy of the data should improve retrieval properties.

On the day the network launches, it will include the capabilities to perform the following actions

- Address data by content hash,
- Find the miner that has a specific piece of content,
- Negotiate request of data by one node from another node,
- Payment from client to retrieval miner in payment channel for the data retrieved.

Through improvements to the protocol, the network will support fast retrieval and short-term access storage in the near future. More work will seed the emergence and growth of the content delivery market, where miners are incentivized to provide a wide range of content delivery services. The filecoin reserve will incentivize this in the future.

6. Demand and supply of the filecoin token

6.1 Network Baseline

Many blockchains mint tokens based on a simple exponential decay model. Under this model, block rewards are highest in the beginning, and miner participation is often the lowest, so mining generates many tokens per unit of work early in the network's life, then rapidly decreases.

Over many cryptoeconomic simulations, it became clear that the simple exponential decay model would encourage short-term behavior around network launch with an unhealthy effect on the Filecoin Economy. Specifically, it would incentivize storage miners to over-invest in hardware for the sealing stage of mining to onboard storage as quickly as possible. It would be profitable to exit the network after exhausting these early rewards, even if it resulted in losing client data. This would harm the network: clients would lose data and have less access to long-term storage, and miners would have few incentives to contribute to improving the network. Additionally, this would result in the majority of network subsidies being paid based wholly on timing, rather than actual storage (and hence value) provided to the network.

To encourage consistent storage onboarding and investment in long-term storage, not just rapid sealing, Filecoin introduces the concept of a network baseline. Instead of minting tokens based purely on elapsed time, block rewards instead scale up as total storage power on the network increases. This preserves the shape of the original exponential decay model, but softens it in the earliest days of the network. Once the network reaches the baseline, the cumulative block reward issued is identical to a simple exponential decay model, but if the network does not pass the pre-established threshold, a portion of block rewards are deferred. The overall result is that Filecoin rewards to miners more closely match the utility they, and the network as a whole, provide to clients.

Specifically, a hybrid exponential minting mechanism is introduced with a proportion of the reward coming from simple exponential decay, "Simple Minting" and the other proportion from network baseline, "Baseline Minting". The total reward per epoch will be the sum of the two rewards. Mining Filecoin should be even more profitable with this mechanism. Simple minting allocation disproportionately rewards early miners and provides counter pressure to shocks. Baseline minting allocation mints more tokens when more value for the network has been created. More tokens are minted to facilitate greater trade when the network can unlock a greater potential. This should lead to increased creation of value for the network and lower risk of minting filecoin too quickly.

The protocol allocates 30% of Storage Mining Allocation in Simple Minting and the remaining 70% in Baseline Minting. 30% of Simple Minting can provide counter forces in the event of shocks. Baseline capacity can start from a smaller percentage of world's storage today, grow at a rapid rate, and catch up to a higher but still reasonable percentage of world's storage in the future. As such, the network baseline will start from 1EiB (which is less than 0.01% of the world's storage today) and grow at an annual rate of 200% (higher than the usual world storage annual growth rate at 40%). The community can come together to slow down the rate of growth when the network is providing 1-10% of the world's storage.

There are many features that will make passing the baseline more efficient and economical and unleash a greater share of baseline minting. The community can come together to collectively achieve these goals:

- More performant Proof of Replication algorithms, with lower on chain footprint, faster verification time, cheaper hardware requirement, different security assumptions, resulting in sectors with longer lifetime and enabling sector upgrades without reseal.
- A more scalable consensus algorithm that can provide greater throughput and handle larger volume with shorter finality.
- More deal functionalities that allow sectors to last for longer.

Lastly, it is important to note that while the block reward incentivizes participation, it cannot be treated as a resource to be exploited. It is a common pool of subsidies that seeds and grows the network to benefit the economy and participants. An example of different stages of the economy and different sources of subsidies is illustrated in Figure 12.

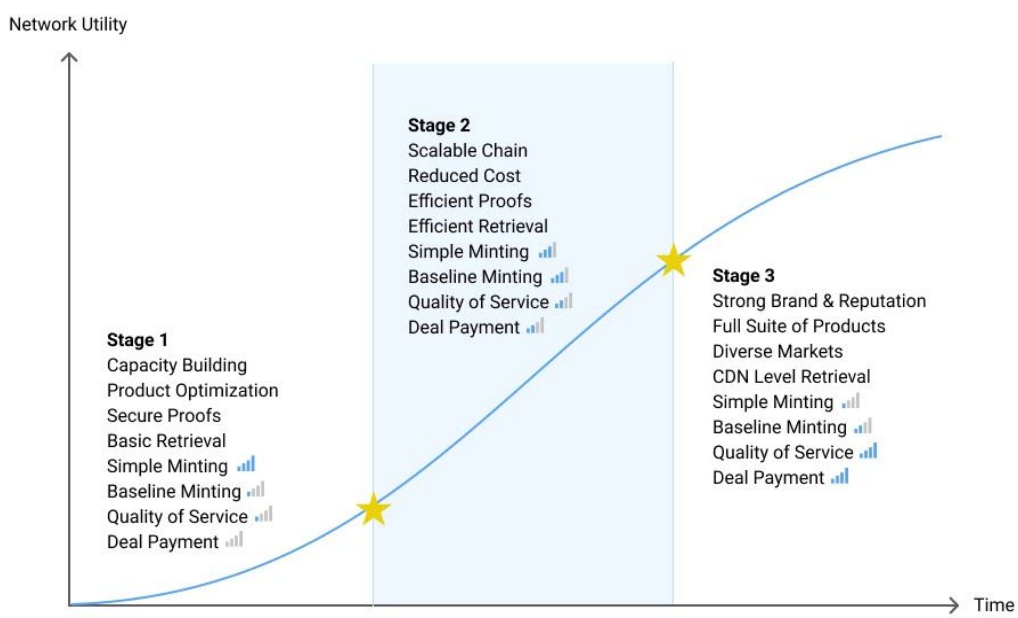


Figure 12: Different stages of the economy with different emphases and revenue drivers.

6.2 Token Allocation

Filecoin's token distribution is broken down as follows. A maximum of 2,000,000,000 filecoin will ever be created, referred to as FIL_BASE. Of the Filecoin genesis block allocation, 10% of FIL_BASE were allocated for fundraising, of which 7.5% were sold in the 2017 token sale, and the 2.5% remaining were allocated for ecosystem development, future fundraising, and/or other uses described in 2017. 15% of FIL_BASE were allocated to Protocol Labs (including 4.5% for the PL team & contributors), and 5% were allocated to the Filecoin Foundation. The other 70% of all tokens were allocated to miners, as mining rewards, "for providing data storage service, maintaining the blockchain, distributing data, running contracts, and more." There are multiple types of mining that these rewards will support over time; therefore, this allocation has been subdivided to cover different mining activities. A pie chart reflecting the allocations is shown in Figure 13.

Storage Mining allocation. At network launch, the only mining group with allocated incentives will be storage miners. This is the earliest group of miners, and the one responsible for maintaining the core functionality of the protocol. Therefore, this group has been allocated the largest amount of mining rewards. 55% of FIL_BASE (78.6% of mining rewards) is allocated to storage mining. This will cover primarily block rewards, which reward maintaining the blockchain, running actor code, and subsidizing reliable and useful storage. This amount will also cover early storage mining rewards, such as rewards in the SpaceRace competition and other potential types of storage miner initialization, such as faucets.

Mining Reserve. The Filecoin ecosystem must ensure incentives exist for all types of miners (e.g. retrieval miners, repair miners, and including future unknown types of miners) to support a robust economy. In order to ensure the network can provide incentives for these other types of miners, 15% of FIL_BASE (21.4% of mining rewards) have been set aside as a Mining Reserve. It will be up to the community to determine in the future how to distribute those tokens, through Filecoin improvement proposals (FIPs) or similar decentralized decision making processes. For example, the community might decide to create rewards for retrieval mining or other types of mining-related activities. The Filecoin Network, like all blockchain networks and open source projects, will continue to evolve, adapt, and overcome challenges for many years. Reserving these tokens provides future flexibility for miners and the ecosystem as a whole. Other types of mining, like retrieval mining, are not yet subsidized and yet are very important to the Filecoin Economy; Arguably, those uses may need a larger percentage of mining rewards. As years pass and the network evolves, it will be up to the community to decide whether this reserve is enough, or whether to make adjustments with unmined tokens.

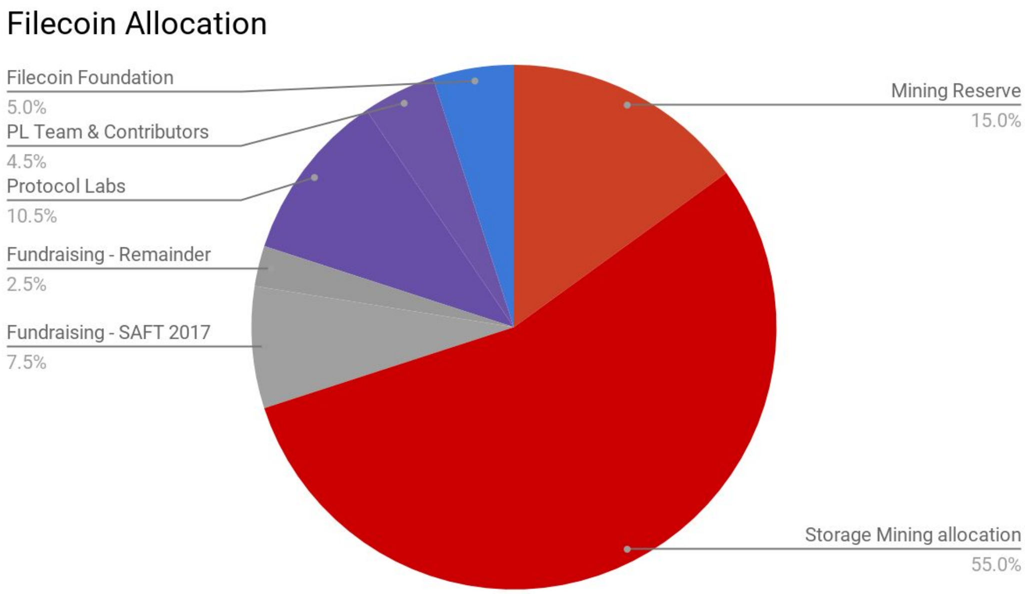


Figure 13: Filecoin token allocation.

Parameter	**Value**	**Description**
FIL_BASE	2,000,000,000 FIL	The maximum amount of FIL that will ever be created.
FIL_MiningReserveAlloc	300,000,000 FIL	Tokens reserved for funding mining to support growth of the Filecoin Economy, whose future usage will be decided by the Filecoin community.
FIL_StorageMiningAlloc	1,100,000,000 FIL	The amount of FIL allocated to storage miners through block rewards, network initialization, etc.
FIL_Vested	Sum of genesis MultisigActors .AmountUnlocked	Total amount of FIL that is vested from genesis allocation.
FIL_StorageMined	RewardActor .TotalStoragePowerReward	The amount of FIL that has been mined by storage miners.
FIL_Locked	TotalPledgeCollateral + TotalProviderDealCollateral + TotalClientDealCollateral + TotalPendingDealPayment	The amount of FIL locked as part of mining, deals, and other mechanisms.

	+ OtherFutureLockedFunds	
FIL_CirculatingSupply	FIL_Vested + FIL_Mined - TotalBurntFunds - FIL_Locked	The amount of FIL circulating and tradeable in the economy. The basis for Market Cap calculations.
TotalBurntFunds	BurntFundsActor.Balance	Total FIL burned as part of penalties and on-chain computations.
TotalPledgeCollateral	StoragePowerActor .TotalPledgeCollateral	Total FIL locked as collateral in all miners.
TotalProviderDealCollateral	StorageMarketActor .TotalProviderDealCollateral	Total FIL locked as provider deal collateral.
TotalClientDealCollateral	StorageMarketActor .TotalClientDealCollateral	Total FIL locked as client deal collateral.
TotalPendingDealPayment	StorageMarketActor .TotalPendingDealPayment	Total FIL locked as pending client deal payment.

Note that exact values of parameters above are subject to changes and readers could find the most up-to-date value in the codebase.

Market Cap. Various communities estimate the size of cryptocurrency and token networks using different analogous measures of market capitalization. The most sensible token supply for such calculations is *FIL_CirculatingSupply,* because unmined, unvested, locked, and burnt funds are not circulating or tradeable in the economy. Any calculations using larger measures such as FIL_BASE are likely to be erroneously inflated and not to be believed.

TotalBurntFunds. Some filecoin are burned to fund on-chain computations and bandwidth as network transaction fees, in addition to those burned in penalties for storage faults and consensus faults, creating long-term deflationary pressure on the token. Accompanying the network transaction fees is the priority fee that is not burned, but goes to the block-producing miners for including a transaction.

7. Initial parameter recommendation

Economic analyses and models were developed to design, validate, and parameterize the mechanisms described in the previous sections. Cryptoeconomics is a young field, where global expertise is both sparse and shallow. As such, designing mechanisms like this requires a level of intellectual depth typical of scientific research, in conjunction with a scale of "engineering in the large" typical of aerospace. Developing these recommendations is advancing the state of the art, not only of decentralized storage networks, but also of cryptoeconomic mechanism design as a whole discipline. A lot of advances have been made but this work continues. The following table summarizes initial parameter recommendations. These will continue to evolve and adapt through testing and validation during incentivized testnet, leading up to Mainnet launch and beyond.

Parameter	**Value**
Baseline initial value	1 EiB
Baseline annual growth rate	200%
Percent simple minting vs baseline minting	30%/70%
Reward delay and linear vesting period	20 days and 180 days
Sector quality multipliers	Committed Capacity: 1x Regular Deals: 1x Verified Client Deals: 10x
Initial pledge function	20 days worth of block reward + share of 30% FIL circulating supply target
Minimum sector lifetime	180 days
Maximum sector lifetime	540 days
Minimum deal duration	180 days
Maximum deal duration	540 days
Sector fault fee	2.14 days worth of estimated block reward
Sector fault detection fee	5.00 days worth of estimated block reward
Sector termination fee	Estimated number of days of block reward that a sector has earned; capped at 90 days
Network transaction fee	Dynamic fee structure based on network congestion

Why have baseline minting? Filecoin tokens are a limited resource. The rate at which tokens are deployed into the network should be controlled to maximize their net benefit to the community, just like the consumption of any exhaustible common-pool resource. The purposes of baseline minting are (a) to reward participants more proportionately for the storage they provide rather than exponentially more based on the time when they join the network, (b) and to adjust minting rate based on approximated network utility to maintain a relatively steady flow of block rewards for longer.

Why have an initial pledge? First, an initial pledge gives storage miners something to lose if they renege on their sector commitments, even before they have earned any block rewards. Second, requiring a pledge of stake in the network supports the security of the consensus mechanism.

Why have block-reward vesting? To reduce the initial pledge requirement of a sector, the network considers all vesting block rewards as collateral. However, tracking block rewards on a per-sector level is not scalable. Instead, the protocol tracks rewards at a per-miner level and linearly vests block rewards over a fixed duration.

Why have a minimum sector lifetime? Committing a sector to the Filecoin Network currently requires a moderately computationally-expensive “sealing” operation up-front, whose amortized cost is lower if the sector’s lifetime is longer. In addition, a sector commitment will involve on-chain transactions, for which gas fees will be paid. The net effect of these transaction costs will be subsidized by the block reward, but only for sectors that will contribute to the network and earn rewards for a sufficiently long duration. Under current constraints, short-lived sectors would reduce the overall capacity of the network to deliver useful storage over time.

Why have a sector fault fee? If stored sectors are withdrawn from the network only temporarily, a substantial fraction of those sectors’ value may be recovered in case the data storage is quickly restored to normal operation—so the network need not levy a termination fee immediately. However, even temporary interruptions can be disruptive, and also damage confidence about whether the sector is recoverable or permanently lost. So the network charges a much smaller fee per day that a sector is not being proven as promised (until enough days have passed that the network writes off that sector as terminated).

Why have a sector fault detection fee? If a sector is temporarily damaged, storage miners are expected to proactively detect, report, and repair the fault. An unannounced interruption in service is both more disruptive for clients and more of a signal that the fault may not have been caught early enough to fully recover. Finally, dishonest storage miners may have some chance of briefly evading detection and earning rewards despite being out of service. For all these reasons, a higher penalty is assessed when the network detects an undeclared fault.

Why have a sector termination fee? The ultimate goal of the Filecoin Network is to provide useful data storage. Use-cases for *unreliable* data storage, which may vanish without warning, are much rarer than use-cases for *reliable* data storage, which is guaranteed in advance to be maintained for a given duration. So to the extent that committed sectors disappear from the network, most of the value provided by those sectors is canceled out, in most cases. If storage miners had little to lose by terminating active sectors compared to their realized gains, then this would be a negative externality that fails to be effectively managed by the storage market; termination fees internalize this cost.

8. Growth and governance of the Filecoin Network

8.1 Upcoming features

The functionality and performance of the Filecoin Network will evolve over time. The following are examples of such growth.

- **Repair Miners:** Currently, if a miner stops storing a sector, they pay a termination fee as described above. However, if another miner is storing the data, there should be an actor, referred to as a repair miner, who retrieves the data and sets up a new deal on behalf of the original client, integrating the data into a new sector and ensuring that a stable number of replicas are stored.
- **App Miners:** A significant fraction of the value of storage services comes from applications, improved user experience, and differentiated use cases that are developed on the service itself. Hence, it is important for a future version of Filecoin to incentivize the development of high-quality applications that utilize the market.
- **Filecoin Loans:** Token holders should be able to use their tokens as deployed capital for miners as third party collateral, sharing the volatility risks and earning a yield in partnership with the miners.
- **Fast Retrieval PoRep:** Future proofs-of-replication will provide natively secure, fast, and efficient retrieval.
- **Scalable Consensus:** Improved consensus mechanisms will lead to improved throughput and security.
- **Generalized Smart Contracts:** Future improvements to the Filecoin blockchain will allow the use of generalized smart contracts and an on-chain state machine.

These improvements will make Filecoin's economy significantly more productive. This increased productivity may lead to demand and the largest long-term growth and robustness, increasing the network's utility.

8.2 Governance and improvement

It's important to have a process and mechanism to collectively decide on the future of the network after Mainnet launch. The Filecoin Network will use a Filecoin improvement proposal (FIP) practice similar to Bitcoin's BIPs and Ethereum's EIPs. The FIP process details have not yet been finalized, but all updating of parameters and mechanisms after the Filecoin Mainnet launch will be determined using FIPs.

In closing, it's important to reiterate that Filecoin will be a collaboratively constructed economy that will evolve over time. However, improvements will be clearly explained as proposals that further the long-term interests of Filecoin's Economy and each category of its participants. As the network grows, using limited tools and subsidies to build a robust economy that can function independently and without subsidies is of paramount importance.