

# Comprehensive report on Filecoin Virtual Machine (FVM)

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# 1. Introduction

From a technical standpoint, blockchains are decentralized ledgers primarily designed for storing proofs-of-action. Their architecture is not optimized for efficient file storage. Nonetheless, the decentralized storage of files is crucial because it enables secure and censorship-resistant access, eliminates single points of failure, and promotes data integrity.

One of the pioneering efforts to enable decentralized storage of data was the InterPlanetary File System ([IPFS](#)), built by Protocol Labs ([PL](#)) in [2015](#). The same team then iterated over their solution and launched another peer-to-peer file storage protocol called [Filecoin](#) in [2017](#). As of end-of-year 2022, Filecoin's utilized storage is ~32 times more than the closest competitor in the decentralized space, [Storj](#), and this is with just [3% utilization](#) of its total available storage capacity.



The Filecoin team has successfully built the world's largest decentralized storage network and they are running programs like [Filecoin+](#), [ESPA boot camp](#), and [Filecoin Green](#) to onboard more enterprises onto the network. However, most protocols and applications need both storage and compute to execute their solutions. This is where the Filecoin Virtual Machine (FVM) comes in. It delivers on-chain programmability to the network and orchestrates where and how data gets placed, incentivized, and governed.

It was launched in March 2023 through the [Hygge upgrade](#) and the addition of a virtual machine to the Filecoin tech stack is an influential upgrade because it enables:

1. **Native Logic around Data:** The inclusion of a virtual machine allows developers to directly write logic that operates on data stored within the Filecoin network, eliminating the need to

transfer data to external execution environments. This integration reduces computation time, minimizes data transport costs, and enhances security by mitigating potential vulnerabilities associated with data movement. Consequently, developers can build fast, secure applications and explore innovative business models.

- 2. Advancing Filecoin's Mission:** FVM brings Filecoin closer to its fundamental objective of establishing free markets that determine equitable prices for compute and data storage, moving away from pricing models dictated by dominant players. Additionally, FVM enables on-chain storage to be programmable, mirroring the microservices capabilities offered by centralized services such as AWS and Azure. This fosters an environment that is more open and competitive for compute and storage services, driving innovation and choice in the market.

The integration of a Virtual Machine (e.g. smart contract capabilities) into the core Filecoin storage protocol marks a transformative milestone enhancing efficiency and security, and pioneering new possibilities for blockchain applications. It solidifies Filecoin's position as a leading decentralized storage solution and sets the stage for further innovations in this ecosystem.

## Report Overview

This comprehensive report delves deep into the Filecoin Virtual Machine (FVM), providing an in-depth exploration of its ecosystem's evolution, the rationale behind its development, and its purpose within the Filecoin network. We will examine the technical architecture of FVM, offering insights into its execution framework.

The report then transitions into an analysis of the opportunities that FVM presents, focusing on the two prominent solution sectors of data DAOs and decentralized finance (DeFi) primitives. We will showcase the diverse use cases currently being built on FVM, demonstrating its capacity to enable innovative applications within these sectors. Notably, we will provide a network performance summary, shedding light on the efficiency and effectiveness of Filecoin+FVM.

In conclusion, we will address the challenges that lie ahead for Filecoin+FVM and offer insights into the future trajectory of the ecosystem. This section will emphasize how the ecosystem is poised for growth and transformation while acknowledging the hurdles that need to be overcome.

## 2. The Filecoin Virtual Machine

### Definition



The FVM is a runtime environment ([RTE](#)) for smart contracts on the Filecoin network. Smart contracts enable the automated and decentralized execution of predefined actions and conditions related to storage, compute, and data transactions within the Filecoin ecosystem.

### How we identify + retrieve data

#### Location addressing

Location addressing allows us to find data by leading us to a location where data is stored by a specific entry.

*EG: Go to the Boones & Nobel at 223 street in NYC. On the 2nd floor, go to the 3rd bookshelf on the right and get the book that's 16 inches from the left on the top shelf.*

#### Content addressing

Content addressing provides a unique content derived identifier for the data which allows users to find data from a variety of sources.

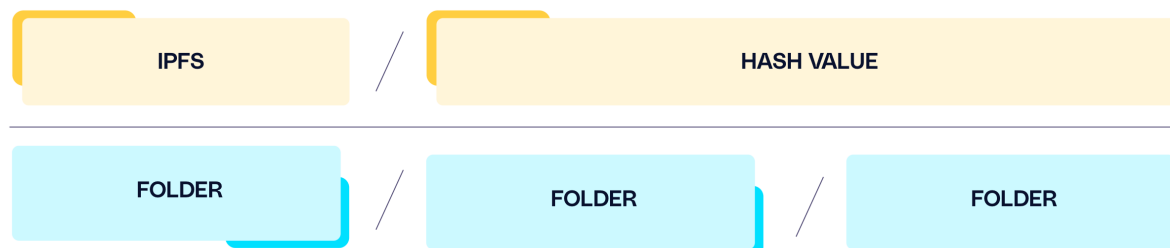
*EG: Go find the Book of Dogs by Alison E. It's ISBN-13 number is 9781168272100*

### Evolution

In [2014](#), during the [Y Combinator](#) program, Juan Benet established Protocol Labs, an open-source research and development company dedicated to pioneering the next generation of internet protocols and projects.

In [2015](#), Protocol Labs introduced the initial version of InterPlanetary File System (IPFS), a peer-to-peer file-sharing network. IPFS revolutionized data storage and transfer by utilizing [content-based addressing](#) rather than traditional [location-based addressing](#), enabling decentralized data exchange among network nodes.

## Content Based Addressing



## Location Based Addressing

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Further reading: [ProtoSchool](#)

Fast forward to 2023, IPFS has amassed an impressive user base of [13 million weekly active users](#) who actively engage with IPFS-based decentralized applications ([dApps](#)) and tools. Remarkably, the IPFS ecosystem has thrived even without a built-in economic incentive layer. Clients seeking data persistence on IPFS currently have three primary user journeys:

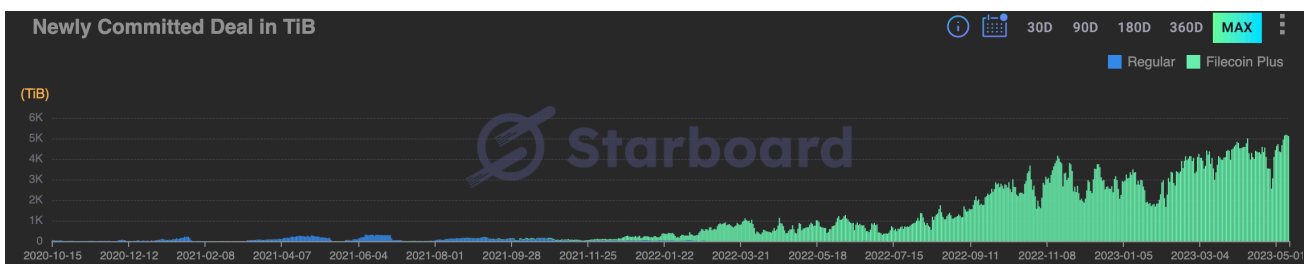
1. Running their own node or network of nodes.
2. Engaging service providers like Pinata, Temporal, Infura, and others to maintain and "pin" their data.
3. Relying on the virality of content, hoping that popular content will be pinned by other nodes.

Recognizing the need to offer an alternative user journey for both storage providers and clients, the Protocol Labs team launched the Filecoin mainnet in [2020](#), integrating built-in economic incentives for various participants. For further insights into Filecoin and IPFS, readers can refer to the introductory video provided by Protocol Labs, which offers a comprehensive overview of these technologies: [Link to Video](#)

By leveraging open market mechanics, Filecoin successfully matches clients seeking data storage with storage providers who have committed their storage capacity to the network. Filecoin ensures reliable and persistent storage of files, facilitating seamless retrieval whenever needed. Filecoin has emerged as the clear market frontrunner in the decentralized storage sector:

	Filecoin	Arweave	Sia	Storj
Mainnet launch	<a href="https://filecoin.io/blog/posts/filecoin-mainnet-is-live/">https://filecoin.io/blog/posts/filecoin-mainnet-is-live/</a>	<a href="https://messari.io/asset/arweave/profile">https://messari.io/asset/arweave/profile</a>	<a href="https://messari.io/report/state-of-sia-q1-2023">https://messari.io/report/state-of-sia-q1-2023</a> (public testnet)	<a href="https://www.storj.io/blog/storj-launches-v3-private-alpha">https://www.storj.io/blog/storj-launches-v3-private-alpha</a> (v3 private alpha)
Used Storage (TB)	514,945	121	1358	16100
Available Capacity (TB)	17,109,355	-	5492	42300
Utilization	3%	-	25%	38%
Annual Revenue (\$M)	13.17	0.69	0.16	0.50
Monthly Storage Cost/TB (\$)	0.19	0.47	0.54	4

Data as of 31st Dec 2022. Source: [Messari's report](#)



Data source: [Starboard](#)

In recent years, the Filecoin team has dedicated its efforts to building the world's largest decentralized storage network and ensuring the security and accessibility of humanity's data.

### 100s of Large Datasets Stored on Filecoin



With Filecoin positioned as a fundamental data layer for computational networks, the Protocol Labs team is now dedicated to advancing compute capabilities specifically designed for data processing. This strategic focus demonstrates their commitment to unlocking the full potential of decentralized storage and computation, propelling the ecosystem forward.

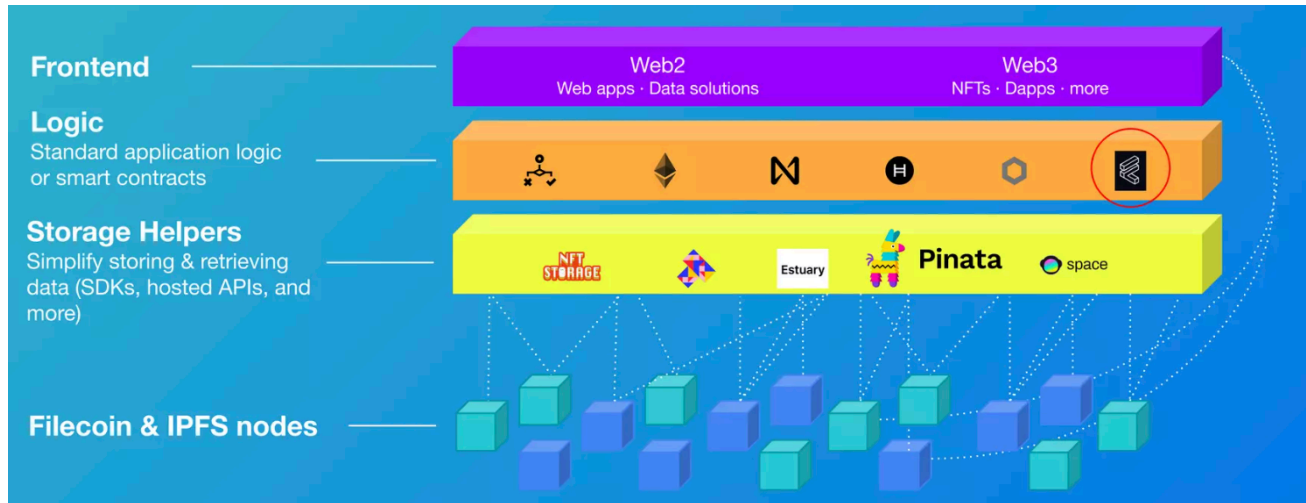


Image credits: [Protocol Labs](#)

## The Purpose and Possibilities of FVM

Introducing the Filecoin Virtual Machine (FVM), the ecosystem enters the next phase of its roadmap focused on "making data useful." The FVM serves as a runtime environment for executing smart contracts on the Filecoin network, empowering developers to create custom applications, perform compute operations on metadata, and access verified proofs of stored data. It establishes a hybrid modular architecture and opens doors to AWS-like functionalities within the decentralized tech stack. FVM promotes integration and interoperability, fostering collaboration across diverse ecosystems. This decentralized approach to building cultivates a vibrant builder community and prevents a single monopolistic entity from controlling the entire architecture. Key innovations and possibilities that FVM brings to the Filecoin ecosystem include:

- **Enabling logic around data:** The core objective of integrating a runtime environment into the Filecoin ecosystem is to empower developers to implement logic around data. This empowers stakeholders to devise innovative solutions and reduces dependence on direct protocol-wide upgrades (FIPs). With the ability to build features using user-defined smart contracts, the FVM opens up new avenues for customization and flexibility within the ecosystem.
- **Compute over metadata:** The FVM serves as the foundation for computing over (meta)data in Filecoin's architecture. It's important to note that FVM enables computation over the state rather than the actual data itself. Here's a closer look at this distinction:
  - Storage providers store the data off-chain and generate verifiable content identifiers and storage proofs that are recorded on the chain and can be utilized in smart contracts.

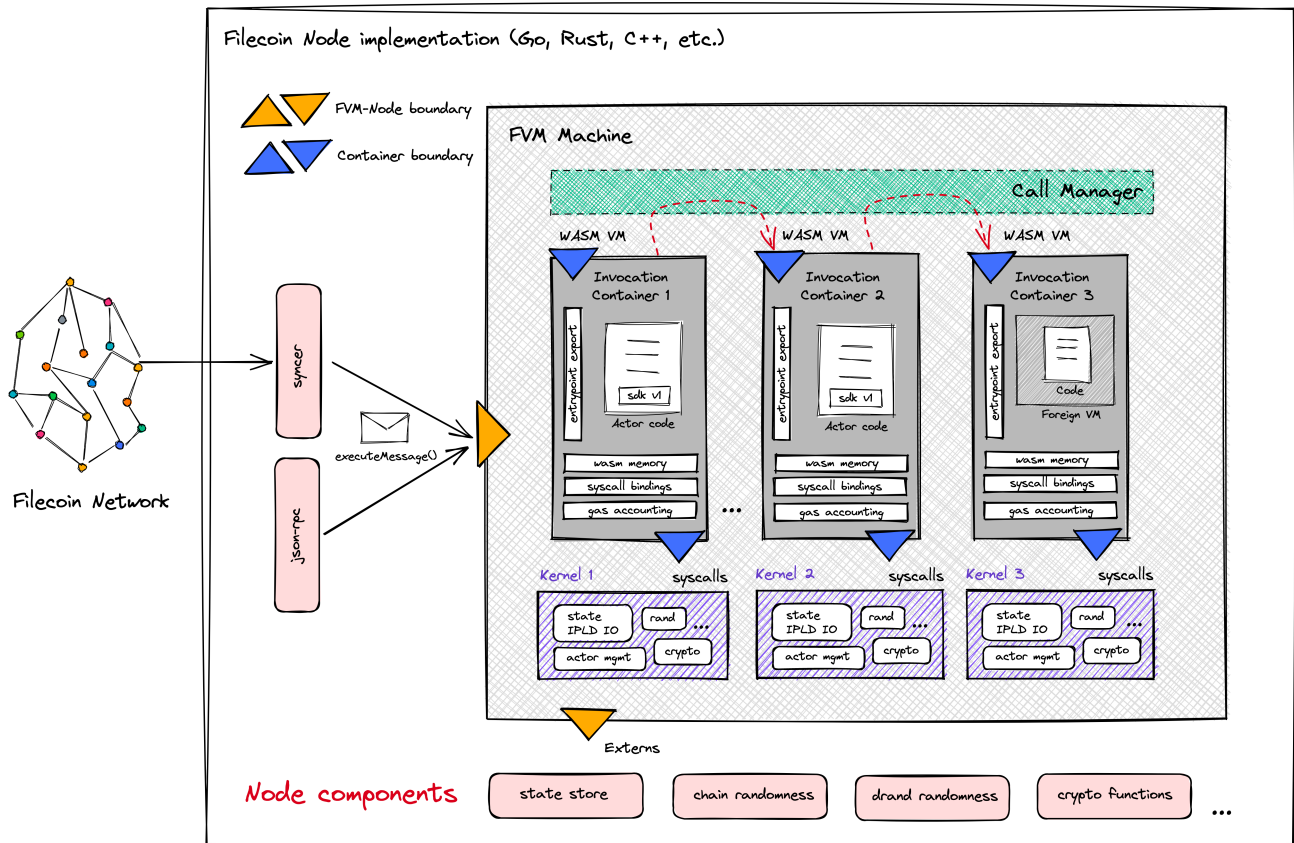
- Smart contracts executed by FVM can manipulate metadata related to stored data deals, such as deal status, replication factor, data CID, and the address of the storage provider. However, they cannot modify the stored data itself.
  - Developers seeking to perform computations on the stored data can leverage FVM to coordinate off-chain computing (for further details, refer to [Bacalhau](#)).
  - Additionally, FVM enables smart contracts to directly access verified proofs of stored data and perform computations at the location where the files are stored, eliminating the need for data movement.
- **Towards AWS-Like Functionalities:** in the long run, this combination of functionalities aims to provide similar capabilities for compute such as AWS' EC2/Lambda coupled with storage and content delivery services like S3/CloudFront/Glacier.
  - **Integration and interoperability:** the long-term vision for FVM is to serve as a system that hosts multiple runtimes, acting as a conductor between them. This concept is similar to a single computer running both Windows and Linux, facilitating seamless integration of contracts from other ecosystems into the Filecoin network. As a significant milestone towards this vision, the Ethereum Virtual Machine (EVM) was deployed as the first VM in the Filecoin ecosystem, known as project FEVM (discussed in section [FEVM](#)).

### 3. Understanding the FVM

Having discussed the purpose and motivations behind FVM's development, let us now delve into its underlying architecture to uncover the transformative potential it holds for the blockchain ecosystem.

#### Execution Architecture

This section focuses on the FVM's execution architecture, which encompasses various components that facilitate the execution of smart contracts on the Filecoin network. By exploring the invocation containers, syscalls, orchestration layer, and IPLD state tree management, we gain a comprehensive understanding of the FVM's execution architecture and its pivotal role in enabling smart contract functionality within the Filecoin ecosystem.



Source: [FIP 0030](#)

**Machine**

The Machine represents the Filecoin Virtual Machine (FVM) operating at a specific time and state. It processes messages for execution.

**Call Manager**

The Call Manager oversees the execution process of a message, including managing the order of operations and tracking gas usage.

**Invocation Container**

The Invocation Container (IC) is like a sandbox where actor code runs for each individual action. It helps prevent issues like reentrancy or recursion.

**Syscalls**

Syscalls are functions that allow actors to interact with the outside world, such as accessing external resources or performing complex operations efficiently.

**Kernel**

The Kernel is an essential part of the FVM that processes syscalls and manages the state for each invocation.

**Externs**

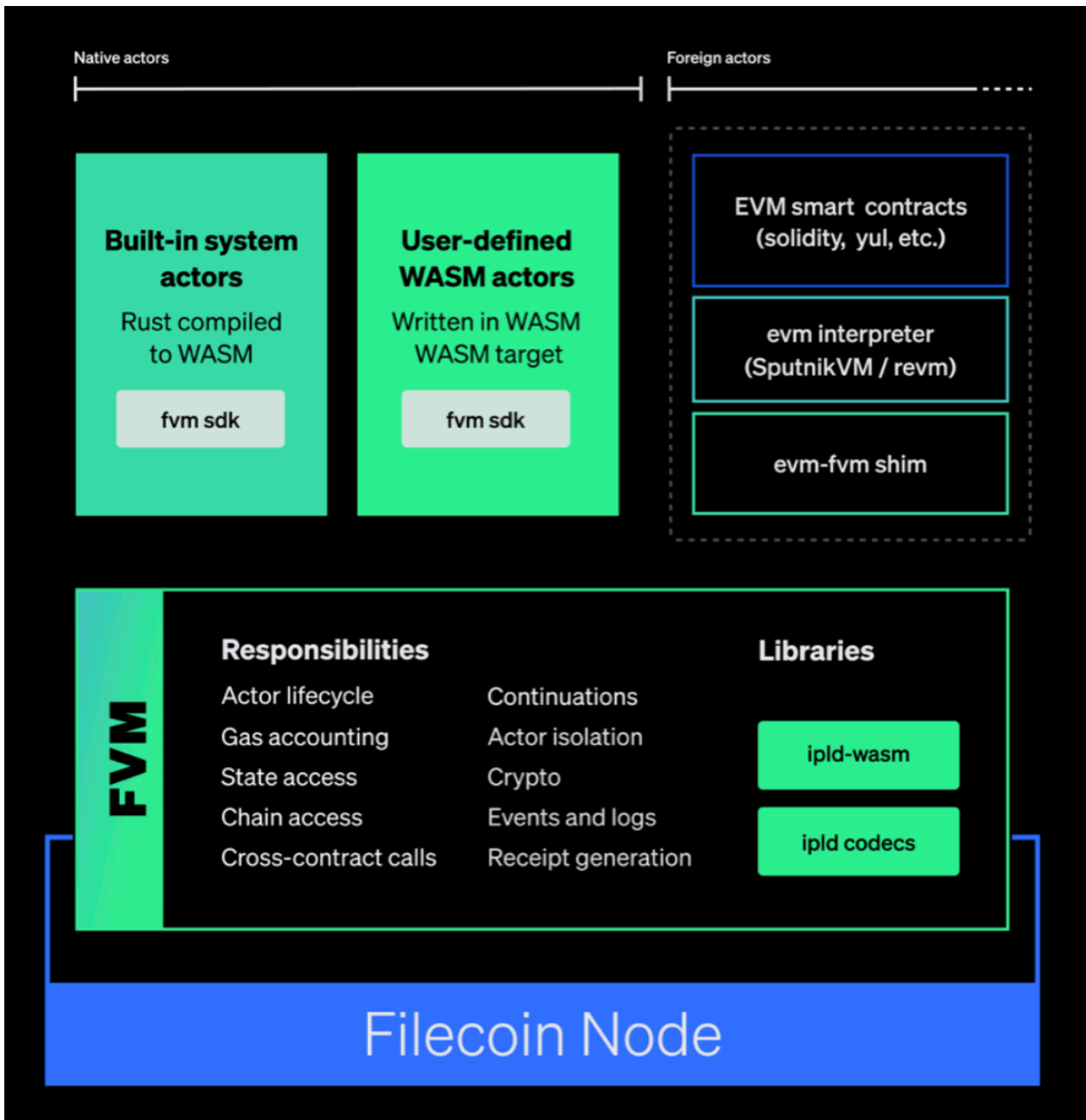
Externs are functions provided by the Filecoin node to the FVM, enabling communication between different programming languages if needed.

## FVM's Responsibilities

These components collaborate to carry out the following functions:

- 1. Setting up Invocation Containers (ICs):** each IC represents an isolated environment for executing distinct smart contracts.
  1. The FVM manages their lifetime and stacking.
  2. The FVM also sets up the WASM runtime and managed memory for every IC so that the smart contract can execute commands.
  3. Every IC has system calls (syscalls) as host-provided functions. These syscalls enable the IC to talk to other ICs or the outer Filecoin network as well.
  4. It can (potentially) access dynamically linked libraries. This means that the code in the container can access and use the functionality provided by these libraries, just as if they were compiled directly into the program - instead of being loaded at runtime.
- 2. Serving as the Orchestration Layer:** the FVM acts as the orchestrator, effectively coordinating and managing interactions among different actors within the network.
  1. For instance, when an actor seeks to retrieve data from another actor, the FVM facilitates this interaction, ensuring proper communication between the actors and accurate data transfer.
- 3. Relaying Syscalls:** the FVM handles the resolution of syscalls between the FVM-Node boundary (yellow arrow in the above diagram) or the container boundary (blue arrow). These system calls (syscalls) are made by actors to access resources and services provided by the host environment, such as the Filecoin network.
  1. When a smart contract within an invocation container needs to read or write data to the Filecoin network, it makes a syscall to the FVM, which acts as an intermediary, interacting with the network on behalf of the container.
  2. It is important to note that gas costs are incurred for these calls, contributing to the overall computational expenses.
- 4. Managing IPLD State Tree:** the FVM effectively manages the Interplanetary Linked Data (IPLD) state tree - the data format behind IPFS and Filecoin. FVM is responsible for buffering writes from actors running within ICs until successful execution occurs. Additionally, it maintains memory caches and optimizes access patterns, employing techniques such as optimistic fetches to enhance efficiency and performance. (reference read for [IPLD](#))

In summary, the Filecoin Virtual Machine operates as a software layer that runs on top of Filecoin nodes, facilitating the execution of smart contracts within isolated invocation containers (ICs). Its responsibilities encompass setting up ICs, serving as an orchestration layer, relaying syscalls, and managing the IPLD state tree. Together, these functions enable the functionality of smart contracts, drive the growth of the Filecoin ecosystem, and foster innovative applications.



## FVM Primitives

Virtual machines provide a standardized set of instructions and rules for contract execution, enabling developers to write and deploy dApps on different blockchains. While there are many EVM adaptations such as Moonbeam, Solana's Neon, Near's Aurora, Scroll, Optimism, etc the FVM incorporates new system actors specifically tailored to the Filecoin ecosystem into its version of the EVM.

There are 11 built-in System Actors in total:

- Init Actor: initializes new actors and records the network name.
- Cron Actor: scheduler actor that runs critical functions at every epoch.
- Account Actor: responsible for user accounts.

- Reward Actor: responsible for block reward and token vesting.
- Storage Market Actor: responsible for managing storage and retrieval deals.
- Storage Miner Actor: responsible to deal with storage mining operations and collect proofs.
- Multisig Actor: responsible for dealing with operations involving the Filecoin wallet.
- Payment Channel Actor: responsible for setting up and settling funds related to payment channels.
- Storage Power Actor: responsible for keeping track of the storage power allocated at each storage miner.
- Verified Registry Actor: responsible for managing verified clients.
- System Actor: general system actor.

These actors play vital roles in managing storage and retrieval deals, storage mining operations, multi-signature wallets, payment channels, storage power allocation, verified client management, and general system operations. By integrating these actors into the FVM, Filecoin introduces a comprehensive set of tools and functionalities that cater to the decentralized storage and compute needs of the network.

Now, to truly understand FVM primitives and how they set FVM apart from other EVM adaptations, let's delve into the role and functionality of the Storage Market Actor using the example of a data DAO. This will help us appreciate the unique capabilities and possibilities that FVM brings to the design space.

## 4. Business Case Study: Leveraging FVM for Data DAOs

To illustrate the practical application of the FVM, we will discuss a business case study revolving around Data DAOs, a prominent solution facilitated by the FVM's launch.

### Solution Description

Data DAOs provide a mechanism for creating economies around collectively owned datasets. This solution empowers communities to collaboratively curate, monetize, and govern valuable datasets in sectors such as:

- Healthcare (e.g. genome sequences)
- Consumer financial data (e.g. credit cards, endowment management, loan repayment histories)
- Knowledge management (e.g. encyclopedias, research data), etc.

### Solution Architecture

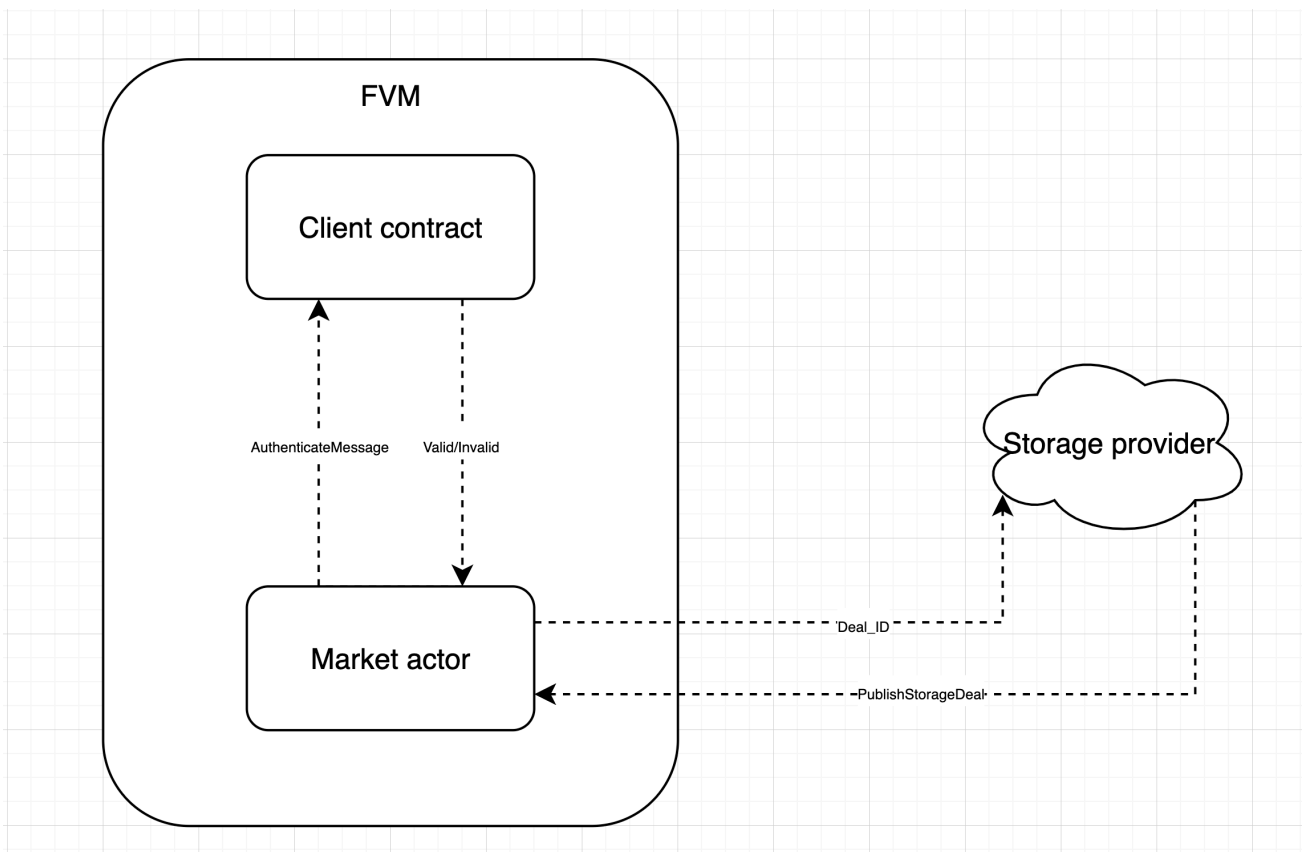
The storage deal lifecycle in a Data DAO encompasses four phases: discovery, negotiation, publishing, and storage.

- In the discovery phase, the client finds a suitable storage provider for the deal.

- The negotiation phase has four sub-phases of deal proposal and verification, transferring of data, and ensuring that the storage provider has posted the collateral for the deal.
- During publishing the deal is put on chain by the storage provider and the published deal is verified by the client.
- Finally, the data is sealed and stored for the duration of the deal.

Zooming in on the publishing phase, we explore how a Data DAO (client contract) leverages the FVM environment to publish a deal:

1. The storage provider, operating within the Filecoin network, utilizes the FVM's "publish storage deal" function to publish the deal to the market actor.
  1. The market actor serves as a built-in system actor responsible for managing deals, accessible to smart contracts within the FVM.
2. The market actor leverages the FVM's "authenticate" message function to verify the deal with the client contract, ensuring compliance with the Data DAO's business logic.
3. The Data DAO, represented by the client contract, responds with a valid or invalid designation, reflecting whether the deal aligns with its predefined criteria.
4. If the deal is deemed valid, the market actor provides the storage provider with a unique deal ID, signifying the completion of the deal publication phase.



An illustrative explanation of the deal publishing phase

## 5. The FVM Opportunity

The FVM empowers individuals and entities to create and harness value from data, revolutionizing the data economy and enabling widespread participation in data generation, transformation, analytics, interpretation, and monetization.

One of the key advantages of FVM is the introduction of programmable storage markets. These markets facilitate a wide range of innovative offerings, including storage bounties, managed access to datasets, full sector auctions, notifications, repair work on deals, and brokerage services. These composable new products and services can be combined to create higher-level, value-added services. In the initial wave of FVM-enabled products, we observe them being categorized into the following five distinct areas:

S.No	Name	Description	Purpose	Potential opportunities
1	General-purpose storage tools	Tools automating storage deal-making	Seamless deal-making will increase the rate of client data onboarding	Repair and replication workers, discounting tools, perpetual storage, data onboarding tools like sealing-aaS, access control solutions
2	Discovery and analytics	Tools that create differentiation opportunities for storage providers	Enhance reliability for clients	Trustless reputation systems, quality of service portals, block explorers, retrievability oracles, naming services
3	DeFi	Tools to provide access to collateral for storage providers	Higher capital efficiency for operations and more utilities for the FIL token	AMMs, lending markets, staking services, undercollateralized lending, data derivatives
4	Management of specialized datasets	Tools to facilitate data DAOs (discussed above)	Enable opening of the data economy	Healthcare data, financial data, research data, consumer data, etc.
5	Integration and other services	Tools to facilitate transactions between Filecoin and other ecosystems	Easily import and export services in/out of the Filecoin ecosystem	Cross-chain token bridges, NFT standards with built-in storage guarantees, voting tools, trustless Filecoin+ notaries

### Powerful Effects of FVM on the Filecoin Network

With the introduction of the Filecoin Virtual Machine (FVM), the Filecoin network can transform into a protocol that offers both storage and compute services. While third-party vendors previously facilitated data storage with the blockchain abstracted away, FVM improves the composability of these services by enabling the creation of compute services that can be bundled with storage. This comprehensive offering enhances efficiency and functionality, making it more appealing to a broader user base and fostering the overall growth of the Filecoin ecosystem.

In essence, FVM enables process automation within the Filecoin ecosystem. Previously, business logic, such as selecting a green vendor, would reside in an external execution environment. However, with FVM, this logic can be encapsulated within a smart contract directly within the Filecoin network itself. This has several advantages, including reduced execution time and cost, mitigate

risks of data leaks, and the potential for greater automation within the storage market. By bringing automation to different parts of the ecosystem, FVM enhances efficiency and streamlines operations, ultimately driving the evolution and expansion of Filecoin. Here are a few solution spaces we are excited about:

- **Easier Onboarding:** FVM enables clients to transition away from vendor lock-in and embrace more affordable and resilient storage solutions. This provides greater flexibility and choice for clients, allowing them to access storage services that best suit their needs.
- **Catering to Specific Storage Requirements:** FVM empowers decentralized storage networks to cater to specific storage requirements, such as compliance with green regulations or storage in specific jurisdictions. This expands the addressable markets for decentralized storage, attracting users with specialized needs and preferences.
- **DeFi Solutions:** FVM unlocks the potential for decentralized finance (DeFi) solutions within the Filecoin ecosystem. By leveraging FVM, DeFi applications can be built on top of Filecoin, expanding the staking pool for FIL tokens and introducing new opportunities for users to earn yield or access storage deals.
- **Better Value Attribution in the Data Economy:** The current data economy often favors aggregators over data creators, limiting value capture opportunities. FVM, in conjunction with web3 technologies, enables better value attribution throughout the data value chain. It allows transparent tracking of how datasets are generated, transformed, and utilized, ensuring fairer distribution of value among participants.
- **Bridging Assets and Commands from Other Ecosystems:** FVM will enable bridges to be built on top of Filecoin, facilitating the integration of assets and commands from other ecosystems into the Filecoin network's smart contract environment. This interoperability opens up new avenues for collaboration, allowing for the seamless transfer of assets and the execution of commands across different blockchain ecosystems.

## FEVM

The Filecoin Virtual Machine (FVM) embraces the Ethereum Virtual Machine (FEVM) as its initial VM deployment. In the short term, the FVM ecosystem is expected to witness similar DeFi and NFT activities as observed in other EVMs such as Binance Smart Chain (BSC), Moonbeam, Arbitrum, Optimism, and Polygon.

Deploying the EVM in a new ecosystem remains a wise strategy for several reasons:

- **Developer Familiarity:** The EVM has gained widespread adoption and is renowned as one of the most popular virtual machines in the blockchain space. By deploying the EVM in the new ecosystem, developers already familiar with Ethereum and its smart contract ecosystem can leverage their existing knowledge and skills. This reduces the learning curve and accelerates development on the new platform.

- **Smart Contract Interoperability:** The EVM's compatibility with Ethereum's programming languages, like Solidity, and its tooling enables easy migration and interoperability of smart contracts. Developers can seamlessly port their existing Ethereum smart contracts to the new ecosystem, benefiting from the vast collection of open-source projects, libraries, and code snippets available in the Ethereum ecosystem.
- **Ecosystem Growth and Network Effects:** Leveraging the EVM's established ecosystem, including a vibrant developer community, robust tooling, libraries, and frameworks, jumpstarts the growth of the new ecosystem. Developers are attracted to platforms that offer compatibility with existing Ethereum-based applications and infrastructure, fostering network effects and driving increased adoption.
- **Security and Audited Standards:** The EVM has undergone extensive security audits, and its smart contract standards, such as ERC-20 and ERC-721, have been thoroughly reviewed and proven reliable. By deploying the EVM, the new ecosystem can benefit from the security practices established within the Ethereum community, reducing the risk of vulnerabilities and enhancing overall security.
- **Ecosystem Compatibility:** Many decentralized finance (DeFi) protocols, decentralized exchanges, and other blockchain applications are built on Ethereum, designed to interact specifically with EVM-compatible networks. Deploying the EVM allows seamless integration with existing DeFi protocols, tapping into the liquidity and user base of the Ethereum ecosystem.

By adopting the EVM, the FVM ecosystem can rapidly develop, benefit from developer familiarity, promote smart contract interoperability, leverage network effects, enhance security, and seamlessly integrate with existing Ethereum-based applications. These advantages contribute to the rapid growth, adoption, and innovation within the new ecosystem while capitalizing on the strengths and resources of the Ethereum community.

## 6. Emerging Use Cases

### Hackathon Review

The Filecoin ecosystem is witnessing the development of various systems, applications, and primitives, harnessing the capabilities of FVM. To foster innovation and attract more builders, Protocol Labs and the Filecoin Foundation have hosted several hackathons, providing a platform for developers to explore different use cases. The recent FVM hackathon, named "[Space Warp](#)," took place from January 20th to February 10th, 2023. It attracted participation from 1,040 hackers representing 82 countries, resulting in the submission of 279 projects. Among these [projects](#), winners were selected across different tracks, showcasing the diversity and creativity of solutions being built on the FVM platform.

General Track	DeFi	Tooling	Cross-chain
<u>Eigen</u> : a DAO around AI models	<u>Cosmic Chicken</u> : undercollateralized lending to Storage Providers.	<u>FVM Explore</u> : deploy, interact, verify smart contracts in a user-friendly interface	<u>Tau</u> : multi-chain DEX
<u>CollectifDAO</u> : non-custodial liquid staking protocol on Filecoin	<u>Spacetime</u> : storage derivatives	<u>HonestFIL</u> : real-time reserve tracking dashboard	<u>FogMeta Data Rebuilder</u> : guarantees N replicas stored on filecoin network
<u>Dora the tipset explorer</u> : event indexer, for the FEVM	<u>FILL</u> : liquidity pool	<u>Creds Protocol</u> : Zero-Knowledge identity layer	<u>FNS Lookup</u> : integrate FNS on Filfox explorer

Given the fact that FVM's launch in March 2023, most projects are currently in the hackathon or pre-seed stage. Nonetheless, two sectors have garnered significant builder interest and show promise for future development: data DAOs and DeFi primitives.

“As long-term builders in the Filecoin ecosystem, we had been keenly waiting for the launch of FVM and the possibilities it opens up for the open data economy. At Spheron our aim is to aid the FVM ecosystem through the Spheron Universal Storage SDK that allows developers to seamlessly integrate Filecoin's storage infrastructure.”

-Prashanth M, Founder of Spheron

## Data DAOs

Data is undoubtedly one of the most valuable assets in today's world, with organizations across various industries seeking to capture and derive insights from the data flowing through their systems. However, the current data monetization model often involves intermediaries, raising concerns about data ownership and privacy.

While it may take time for a robust business model to emerge for different Data DAOs, we are closely monitoring the initial experiments in the decentralized scientific (deSci) space. Notably, there are already important large datasets such as New York City's public data, GenRAIT's genomic data, and Genocide testimonies (preserved by Stanford University and USC), etc. These datasets stored on Filecoin, demonstrate the potential for secure and decentralized data storage.

## The FVM Effect on Data DAOs

The introduction of FVM unlocks novel capabilities for Data DAOs, revolutionizing their operations and value proposition. Leveraging FVM, Data DAOs can now:

- **Incorporate additional content** into deals through on-chain governance processes.
- **Ensure perpetual data storage** through endowments, allowing storage providers to recycle content IDs from expiring deals.

- Partner with **quality-controlled providers** by querying the built-in power actor and exclusively accepting deals from providers surpassing a predefined quality threshold.
- **Temporarily freeze datasets** by disabling authorization for further content additions, enabling auditing before additional funding from the Data DAO.
- **Accept donations** as incentives for data storage.
- Engage in **data swaps** with other DAOs, enabling the handling of mismatched values and access to data.

These enhancements, made possible by FVM, empower Data DAOs to optimize their operations, govern datasets more effectively, and foster collaborative innovation within the Filecoin ecosystem.

## DeFi Primitives

The Filecoin network has established itself as a market leader in decentralized storage, offering a solid foundation for exploring the development of financial primitives. Developers can leverage the physical infrastructure provided by Filecoin to build innovative DeFi solutions. Some notable areas of exploration include:

- **Borrowing against Future Revenue:** Smart contracts can enable storage providers to access liquidity by borrowing against their anticipated future revenues. This financial innovation allows providers to unlock value from their stored data assets.
- **Addressing Information Asymmetry in Lending Markets:** Traditional lending markets face challenges in efficiently serving small borrowers due to a lack of transparent and comprehensive business activity data. FVM's money markets offer an opportunity to explore how on-chain capture and utilization of business activity data can bridge the information gap and facilitate more inclusive lending practices.
- **Segmented Pools:** To mitigate default risks, it is crucial to establish segmented pools catering to different risk appetites. By creating pools with varying risk profiles, the FVM ecosystem can provide investors with diversified investment opportunities and align risk-reward dynamics to suit their preferences.

Pool	Borrowers	Lenders	Risk/Yield	Remark
<b>Permissioned</b>	Only from a pre-defined list	Only from a pre-defined list	Low	Manual SP and lender onboarding
<b>Semi-permissioned</b>	Only from a pre-defined list	Open	Low	Like Maple finance
<b>One-sided permissionless</b>	Borrowers can join if they match a defined criteria	Open	Med	Automated SP onboarding
<b>Permissionless</b>	Open	Open	High	Good for newer actors

- **Liquid Staking:** Inspired by successful projects in the Lido and Rocket Pool ecosystems, teams are actively exploring the concept of liquid staking in the Filecoin ecosystem. Liquid staking allows users to stake their FIL tokens and receive a liquid representation of their

stake in return, enabling them to participate in other DeFi protocols or gain additional utility from their staked assets.

- **Reputation Tools:** Building trust and establishing a reputation within the Filecoin network is crucial for efficient and reliable storage services.
  - To address this, developers are creating verifiable credentials on-chain to store sustainability claim metadata about storage providers (SPs). These credentials enable transparency and allow clients to make informed decisions when selecting SPs.
  - The tokenization of renewable energy certificates provides an opportunity to incentivize sustainable energy practices within the network.
  - Insurance policies are being explored to cover SPs from active faults, providing an additional layer of protection and risk management for the ecosystem

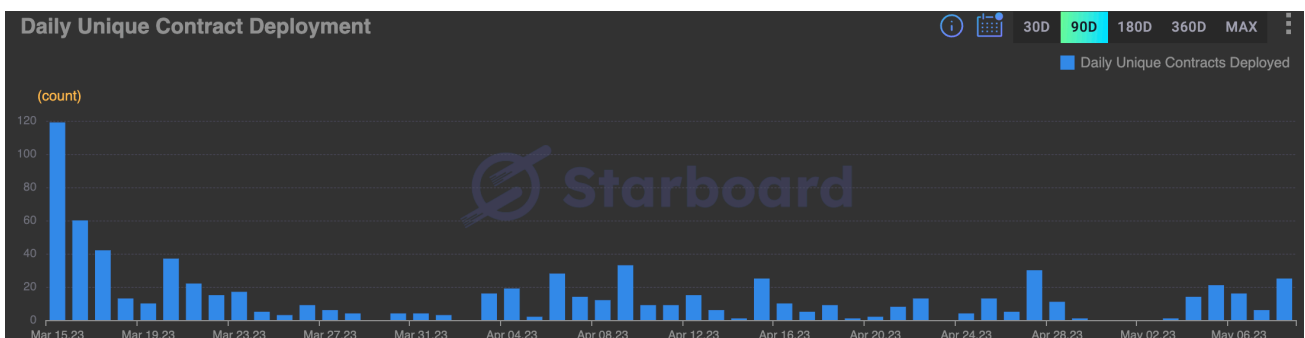
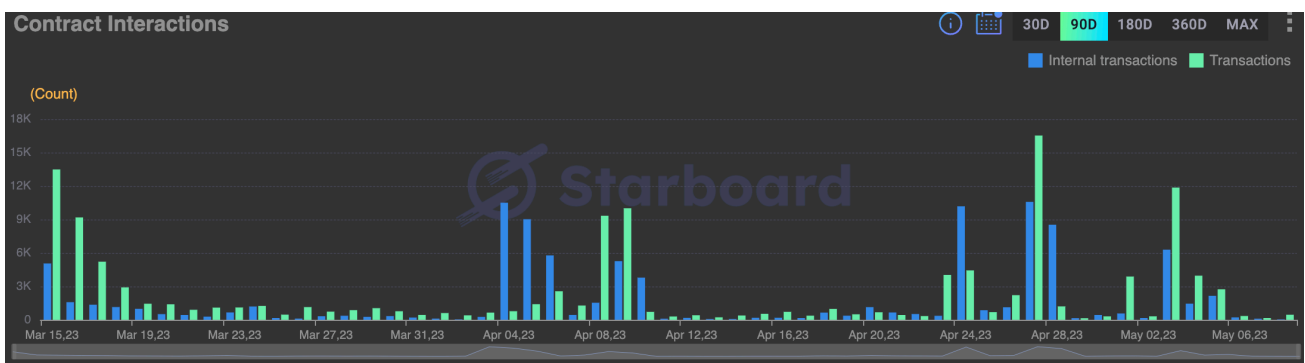
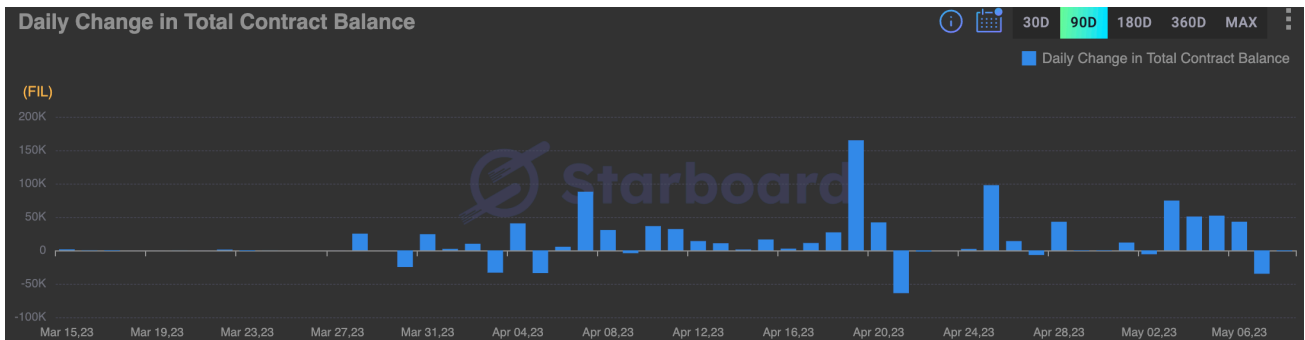
As the FVM ecosystem evolves, we anticipate further exploration of these sectors and the emergence of additional innovative use cases. The intersection of data DAOs and DeFi primitives on the Filecoin network presents compelling opportunities for value creation, economic growth, and decentralized innovation.

## 7. Network Performance Summary

Metric	Value	Explanation	Significance
<b>Total Contract Balance</b>	751.8k FIL (\$ 3.6M)	Represents the cumulative balance of FIL tokens held within the smart contracts deployed on FVM.	Indicates the total value locked within the ecosystem and reflects the level of economic activity and value exchange happening through smart contracts.
<b>Transactions</b>	131,350	Represents the total number of transactions recorded on the FVM network.	It captures the activity and engagement within the ecosystem, as users interact with smart contracts to perform various operations such as storage, data access, financial transactions, and more.
<b>Internal Transactions</b>	99,120	Represents the transactions that occur between smart contracts within the FVM ecosystem.	The number of internal transactions indicates a network of interconnected smart contracts, working together to provide advanced services and functionalities within the FVM ecosystem.
<b>Unique Contracts Deployed</b>	852	Represents the number of distinct smart contracts that have been deployed on the FVM network.	A higher count of unique contracts deployed signifies a diverse range of applications and use cases being developed and deployed on FVM, showcasing the versatility and potential of the ecosystem.
<b>Unique Deployer Addresses</b>	173	Represents the number of unique addresses that have deployed smart contracts on the FVM network.	Each deployer address represents an individual or entity responsible for deploying and managing smart contracts within the ecosystem.

Data source: [Starboard](#), as of 9th May 2023

- 75% of all transactions have been internal transactions, which means that most contract calls are generated as a contract's own code, rather than being initiated by an external user or contract.
- A granular breakdown of metrics shows that there was maximum activity in the network around the launch, post which the hackathons have been great catalysts for increasing network activity, albeit temporarily.



## 8. The Road Ahead

### Opportunities

We have covered the [FVM Opportunity](#) in detail above and it is important to point out that over the next quarters, a **WebAssembly FVM runtime** will also be added, with more VMs possible in the future. Developers will then be able to also write custom smart contracts in Rust, AssemblyScript, Go and compile them to Wasm bytecode, and potentially other privacy-preserving programming languages for zk-SNARKs like [Lurk](#).

The FVM is just the first in a series of significant updates coming to Filecoin in 2023.

### Growth in the Filecoin Ecosystem

The Filecoin Network is laying the groundwork for a decentralized internet that revolves around open services, incorporating open source principles and incentivizing the production of high-quality services directly into the protocol.

Having established a strong foundation for a storage market, with an impressive 15 EiB of available storage capacity, 2023 promises to be an exciting year as Filecoin introduces new releases in the Retrieval Market, Computer Over Data, and Interplanetary Consensus.

We are particularly interested in observing how these open service capabilities and markets will interact with the Filecoin Virtual Machine (FVM), further enhancing the ecosystem and fostering innovative applications and solutions.

### Challenges

The success and continued growth of the Filecoin Virtual Machine (FVM) ecosystem hinge upon effectively addressing various challenges. Some key challenges that need to be tackled include:

- 1. Competition for Developer Talent:** The smart contract layer is a highly competitive space, making it essential to attract top developer talent. When assessing the competitiveness of FVM compared to other young ecosystems (less than 3 years old), several factors should be considered. These include the number of total developers, full-time developers (as reported by Electric Capital's [developer report](#)), initiatives utilizing community treasuries to attract builders, and the overall token market capitalization.

Chain	Age (in yrs)	Total Developers	Full-time developers	Community tokens	Token FDV (\$ B)
Sui	1	175	67	50%	11.7
Starknet	1	347	117	50% of the initial supply	-
Aptos	1	213	60	51%	8.5
BNB	2	480	121	\$1B ecosystem fund	48.7
Osmosis	2	357	87	-	0.6
Filecoin (superset for FVM)	5*	230	80	-	1.9

FVM will need to compete with younger ecosystems that have well-capitalized foundations and heavily marketed projects, as well as established players with established and engaged developer communities. Building a strong developer community will be crucial for the long-term success of FVM.

- 2. Metrics and Event-Driven Activity:** Currently, the metrics for FVM may not reflect the full potential of the ecosystem as the launch is still relatively recent. While high transaction counts can indicate engagement, it is crucial to ensure sustained and diverse activity within the ecosystem. Fostering a thriving ecosystem requires a broader range of meaningful and sustainable use cases beyond event-driven activities.

Furthermore, it's worth mentioning that the [most popular contract](#) on FVM, accounting for 105,500 transactions (80% of the total transactions on FVM), belongs to [FilaDoge](#). This contract, perceived as a memecoin by most members of the community, highlights the importance of encouraging a diverse set of meaningful use cases on the platform.

- 3. Adoption and Net Capital Flow:** DeFi initiatives can sometimes be extractive to an ecosystem, and it will be important to monitor whether there is a net capital inflow or outflow from the Filecoin ecosystem as FVM promotes on-chain activity.

Understanding the dynamics of capital flow and the implementation of other primitives like Miner Extractable Value (MEV) will be essential in evaluating the overall health and sustainability of the ecosystem. Navigating these challenges will require a strategic approach, including targeted efforts to attract and retain developer talent, fostering diverse and impactful use cases, and ensuring a balanced and sustainable DeFi ecosystem.

By addressing these challenges, the Filecoin Virtual Machine has the potential to overcome obstacles and position itself as a leading platform for decentralized applications and services in the future.

## 9. Conclusion

In conclusion, the Filecoin Virtual Machine (FVM) represents a major milestone in the Filecoin ecosystem, enabling the execution of smart contracts and unlocking new possibilities for innovative applications and services. By allowing developers to write logic around data, the FVM enhances the value and utility of the Filecoin network.

The FVM brings numerous advantages to the Filecoin ecosystem. It introduces programmable storage markets, enabling the creation of diverse offerings such as storage bounties, managed data access, DeFi solutions, and specialized data management tools. These advancements empower data DAOs, improve value attribution in the data economy, and facilitate integration with other blockchain ecosystems.

The network performance summary demonstrates the growth and engagement within the FVM ecosystem. With a substantial total contract balance, a significant number of transactions, internal transactions, unique deployed contracts, and deployer addresses, the FVM showcases promising economic activity and a diverse range of applications and use cases.

The report also recognizes the challenges that need to be addressed for the continued success of the FVM. These challenges include attracting and retaining developer talent, ensuring sustained and diverse activity, and fostering a balanced and sustainable DeFi ecosystem.

Despite these challenges, the Filecoin Virtual Machine holds immense potential. By addressing these challenges and monitoring net capital flow, the FVM can position itself as a leading platform for decentralized applications and services. It has the capacity to revolutionize the data economy, empower data DAOs, and establish itself as a key player in the decentralized application landscape.

Overall, the Filecoin Virtual Machine is a significant leap forward in the evolution of the Filecoin ecosystem, enabling greater functionality, automation, and innovation. As it continues to evolve and overcome challenges, the FVM has the potential to reshape the data economy and solidify its position as a vital component of the decentralized application ecosystem.

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