Polkadot Native Storage

Summary

Polkadot Native Storage: Overview

A storage solution for Polkadot

1. Introduction

Our main goal is to describe how to implement and maintain a Filecoin-like **system parachain** -- a parachain that uses `DOT` as the native token and is easily usable for all kinds of parachain projects in the ecosystem via XCM.

Part of this vision is to support Polkadot's app-centric future, where resilient data storage and retrieval will be significant components. To name but one example, a Work Package of 5MB in size, could be retrieved from Polkadot Network Storage. This shows some simplified code based on RFC-0031:

```
type WorkClass = u32;
type WorkPayload = Vec<u8>;
struct WorkItem {
  class: WorkClass,
  payload: WorkPayload,
}

struct WorkPackage {
  authorization: Authorization,
  context: Context,
  items: WorkItem[]
}

type MaxWorkPackageSize = ConstU32<5 * 1024 * 1024>;
struct EncodedWorkPackage {
  version: u32,
  encoded: BoundedVec<u8, MaxWorkPackageSize>,
}
```

One can even start to think about replacing certain package blobs with CIDs.

We have updated research previously done -- research reflecting technical changes in Polkadot, Substrate, and Filecoin itself. We have taken a detailed stab at figuring out what it would take to implement an entire solution as a parachain without depending on 3rd party chains. Among the architectural elements we evaluated:

- what can be used as is
- what could be adapted for use
- what could be ported to Rust
- what components would need to be written from scratch

It is often said that **Filecoin is complicated.** The engineers at Protocol Labs have solved a hard problem:

- prove you have replicated a large chunk of data.
- prove that it's unique, not a copy
- prove that you're not cheating by being your own client
- continually prove you are still storing the data

Protocol Labs has built -- and built on -- a great deal of software, which works in the real world. The complex ecosystem is well-documented, used and tested by many users. It is, therefore, logical for us to build on what they have done.

This proposal reflects that perspective. Essentially, we will run the Filecoin system of data storage on a parachain, albeit massively (and thoughtfully) adapted for Polkadot.

2. Methodology

Research, also known as software engineering or computer science research, involves investigating and advancing various aspects of software development, from algorithms and languages to tools and methodologies. It is a process of solving problems, and it is a process of learning. It is also a journey of discovery and invention.

There are several steps to this, including (but not limited to):

- understanding the problem - identify specific conditions, user scenarios and the desired outcome
- gathering information - conduct a comprehensive literature and existing solutions review to understand the current state of knowledge in the area of decentralized storage solutions. Identify gaps, challenges, and opportunities that our research can address.
- formulating questions and hypotheses - define clear and concise research questions or ideas we aim to answer through our document. Our base was also a CGS report, which addressed some problems we would like to solve.
- choose a research approach or methodology that aligns with our research questions - we have decided to do the analysis covered by this document and prototyping by updating the CGS code, including new features and changes in the Substrate ecosystem.
- formulating a solution - based on the research, analysis and experiments with the code, we have prepared a solution that will be a good fit for the Polkadot ecosystem.

The research process is iterative, and we have gone through several rounds of the above steps (such as presenting drafts or checking different code solutions). The next steps should follow:

- implementing the solution - we have already started this process by creating a prototype and will continue it in the further milestones, should the stakeholders collectively decide on such a course of action.
- evaluating the solution - we will assess the solution in the next milestones when there will be more testing code, and we'll be able to run the solution to collect usage data.
- documenting the solution - we will document the solution in the next milestones just as we did in this milestone.

After that, we will go through the following steps with the client:

- communicating the solution - there will be a need to communicate the solution to the community properly.
- maintaining the solution - there will be a need to maintain the solution, and we will need to define the maintenance process.
- improving the solution - there will be a need to improve the solution over time, and we will need to define the improvement process.

The first step from the above methodology we used was to first gain a general understanding of the Filecoin ecosystem, and then to dive into the details of the various components. We had already had some experience with Filecoin's zk-SNARK prover/verifier (`bellperson`), packaging that into a runtime kernel. To gain a more complete view, we gathered information about Filecoin from several sources:

- online specifications
- white papers
- analysis of code repositories
- running `lotus` and `lotus-miner` nodes
- viewing selected videos from some of the key players:
    - general overview, IPFS, IPLD: Juan Benet
    - FVM: Matt Hamilton
    - Saturn: Patrick Woodhead, Ansgar Grunseid

One must bear in mind that the Filecoin ecosystem is quite dynamic; things are changing at a fast clip. For instance, FVM and Saturn both went live in the last year.

The Polkadot ecosystem is equally dynamic, and time was similarly spent getting up to speed with changes there.

3 General Description

The principle idea from which this proposal flows may be simply stated: `Port Filecoin to Polkadot`

It is also not our intention to slavishly follow everything that Filecoin has done, for those parts we eventually do keep. It is merely a model that we know works. And Polkadot is not Filecoin.

3.1 Porting Filecoin to Polkadot

"Never mistake a clear view for a short distance." -- an old Klingon saying

3.1.1 General Strategy

As we want to avoid reinventing the wheel, we have decided to keep the basic methodology of Filecoin. This includes:

- the storage-proof system
- the block transactions (called messages in Filecoin) and their parameter structures
- corresponding actors and methods, porting them to pallets and extrinsics.
- the blockchain state, although with several differences.

See also the section on JSON-RPC, regarding the Filecoin API.

As far as required functionality goes, any storage solution ultimately consists of three main tasks:

- **storage**
- **indexing**
- **retrieval**

3.1.2 Divergence from Filecoin

This is a non-exhaustive list of porting aspects that need to be explicitly observed.

- `DOT`, not `FIL`: This is a MUST have.
- CID vs. hash: CID's are used for both file ID's (for content addressable IPFS) as well as for all Merkle tree hash values.
  - Indeed, they do contain a hash, in addition to
    - multihash fields: type, length, value
    - multicodec identifier, specifying the encoding.
  - We will use simple (and standard) Substrate Merkle tree hashes throughout, and employ CID's only in reference to files, pieces, and sectors. Care must be taken so nothing cryptographic breaks.
  - We note that the XCM message self-description properties were inspired by those aspects of IPFS and IPLD.
- The consensus model will not observe tipsets, being a Filecoin-centric paradigm.

There are also constraints that could be loosened. For example:

- the minimum size of sectors, currently 32G/64G
- the minimum duration of a storage deal, currently 180 days.
- one challenge Proof-of-Spacetime per 6, 12, or 24-hour period, chosen randomly, i.e., a somewhat more optimistic proving. All the proofs eventually go on-chain.

With Coretime, there is a trend towards more agile procurement and utilization. This is a philosophy that could be folded into Polkadot Native Storage, where appropriate.

3.1.3 Consensus

Substrate has undergone many changes during the last two years since the CGS report was published. For example, we may now use AURA consensus in custom chains -- present in Substrate, which was planned when we wrote the CGS report.

There are still many differences in consensus mechanisms between Filecoin and Substrate-based chains. One of the key issues raised in our previous work was collator selection methods. At that time, there did not exist a method to actually choose the collator. According to the Substrate documentation, collator selection can now be done in the user-defined way. During our research, we've ported a simple collator selection pallet, similar to the one from Cumulus, to confirm that we can provide a custom collator set. We've changed the selection method to use the `Power` factor.

Our tests have been successful, and we could register collators of our choice, selecting them with different factors (like storage power, etc.) and choosing subsets with custom algorithms. Registration can be done on demand, and we can change the collator set for each session (pallet-session was used during our research).

There are known other possibilities to select collators, like pallets for parachain staking, which can also choose the active set of block producers and handle reward mechanisms.

However, if we select more than one collator, each may try to produce a block, but the chain can still accept only one block at a time. The relay chain selects the block from candidates (2/3 validators must accept such a candidate to start backing it). We can use the previously described collator selection mechanisms to control how many collators can produce blocks simultaneously.

In fact, the above problem is deeper when we consider the rewards. We intend to provide a fair and transparent mechanism allowing every collator to receive rewards periodically.

The active collator set can be renewed every round (1200 blocks or approx 4hrs). The mechanism of selecting collators in the active set can be based on the total power of the collator (and associated actors). The more power, the more likely the collator will be selected. Then, to avoid situations where collators with the highest power will be chosen constantly the same, some randomness can be added to the selection process, and the set can be shuffled, including those collators with lower power factor. It will build the sets of collators mostly with high power factor but allow others to participate in the reward system. The exact mechanism of selection collators should be a subject for further discussions with the stakeholders as it can influence the business model of the parachain.

If parachain staking is chosen during implementation, we can use similar mechanisms. It will have an additional impact on the network as it will introduce delegators - who can stake some funds to support collators. Still, it will need to be subject to further changes, as we'd like to create collator sets based on their storage power and promote those with the highest power.

A high priority will be to keep block *finality* to a minimum latency, e.g., so funds show up as quickly as possible when executing a simple transfer (while storage will take longer).

The same problems and solutions can be applied to Sassafras consensus, which will be used in the future.

3.1.4 `lotus` and `lotus-miner`

In the Filecoin ecosystem, these are the main processes that miners run as storage providers.

- `lotus daemon`:
  - runs the blockchain node
  - responsible for maintaining and syncing the blockchain state
  - has Filecoin Virtual Machine, a host for actors
  - handles the JSON-RPC API
  - maintains an indexer
  - `libp2p` market protocols:
    - for proposing storage deals: `/fil/storage/mk/`
    - for querying miners their current StorageAsk: `/fil/storage/ask`
    - querying miners for the deal status: `/fil/storage/status/`
    - for querying information about retrieval: `/fil/retrieval/qry/`
- `lotus-miner`
  - the storage provider
  - a.k.a, miner

    - maintains storage (dagstore)
    - performs storage proofs
    - responds to retrieval requests

The parts of those not belonging to a Substrate collator mode will be moved to another process, and possibly another system.

3.1.5 Storage mining

Storage fees are based on the miner regularly submitting Window Proofs-of-Storage.

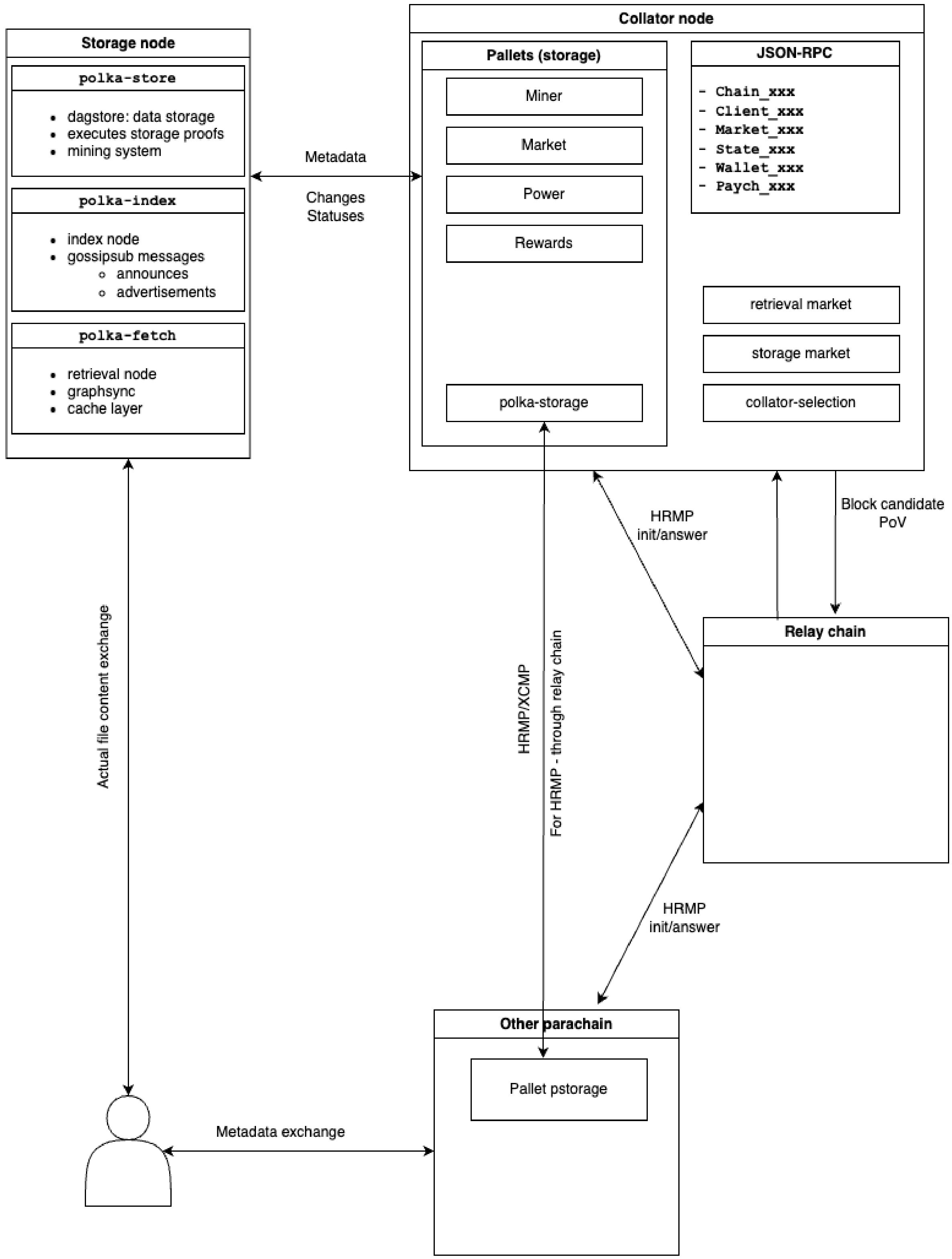
- Deadlines
    - a 24-hour proving period is assigned when a miner is created. The period has a specific starting time
    - in Filecoin, this is broken down into 48 deadlines, one every 30 minutes
- Storage fee payment
    - the client has deposited escrow to pay for the storage
    - fees are automatically deposited to the storage provider regularly for continuously proving the data is being securely stored
- Slashing
    - The storage provider's collateral may be slashed if the storage provider failed to submit timely Proof-of-Spacetime proofs.
    - there are various stages involved in handling this.

If a miner is selected to create a new block, they receive block rewards, dependent upon if they submit a timely (and correct) Winning-Proof-of-Storage.

3.2 Components

This is an outline of the elements required for the parachain under consideration. The collator node will usually be paired with a storage node; both may be running on the same system, although this is not necessary.

- Collator Node
    - Pallets
        - Miner
        - Market
        - Power
        - Rewards
    - JSON-RPC API modules
        - `Chain`:
        - `Client`:
        - `Market`:
        - `State`:
        - `Sync`:
    - polka-storage: blockchain state
        - blocks, messages, deals, miners, sector info, power table, storage market
    - storage market
    - retrieval market
- Storage Node
    - `polka-store`
        - a Rust executable
        - storage miner
        - maintain file storage, sectors
        - storage proving system
        - paired with collator node, communicating over JSON-RPC
        - publishes new content
    - `polka-index`
        - handles announces and advertisements
        - stores indices: CID-provider mappings + metadata
        - responds to queries
    - `polka-fetch`
        - responds to retrieval requests
        - negotiates with retrieval client
        - sends data via graphsync


Storage node
polka-store
dagstore: data storage
executes storage proofs
mining system
polka-index
index node
gossipsub messages
announces
advertisements
polka-fetch
retrieval node
graphsync
cache layer
Metadata
Changes
Statuses
Collator node
Pallets (storage)
Miner
Market
Power
Rewards
polka-storage
JSON-RPC
- Chain_xxx
- Client_xxx
- Market_xxx
- State_xxx
- Wallet_xxx
- Paych_xxx
retrieval market
storage market
collator-selection
HRMP
init/answer
Block candidate
PoV
Relay chain
Actual file content exchange
HRMP/XCMP
For HRMP - through relay chain
HRMP
init/answer
Other parachain
Pallet pstorage
Metadata exchange

Polkadot Native Storage: Solution

1 Libraries to be forked

Two Rust libraries comprise Filecoin's storage-proof system. We can basically use them as is. Filecoin uses them in their applications written in Go via CGO + FFI. These libraries will be part of `polka-store`, more details here

1.1 `rust-fil-proofs`

From the readme: "The Filecoin Proving Subsystem (or FPS) provides the storage proofs required by the Filecoin protocol. It is implemented entirely in Rust, as a series of partially inter-dependent crates – some of which export C bindings to the supported API."

The proofs produced are 192 bytes in length, which corresponds to 130M constraints. A Proof of Replication contains 10 SNARKs, providing proofs for the 1.3G constraints required for 32GiB sectors.

1.2 `bellperson`

This is a crate for creating zk-SNARK proofs with Groth16. Support for GPU parallel acceleration to the FFT and Multiexponentation algorithms is included out of the box, via compilation to CUDA and OpenCL.

1.3 `storethehash`

This Rust library served as an early iteration of Filecoin's `storetheindex`, an indexer service which we believe could be used as a basis upon which to build `polka-index`, our own indexer (discussed in section 6.2).

Content indexing and discovery is a complex topic, for which there are several possible architectures. It is important to get scalability and performance in balance. Caching also plays a role for content that is often requested.

1.4 `rs-graphsync`

This library is a Rust implementation of the GraphSync protocol. This protocol is used to transfer content between systems, for retrieval.

This is the Go version used by Filecoin.

Another option would be to consider a simpler HTTP protocol.

2 Libraries to be ported

2.1 `dagstore`

This is one of the libraries that we recommend to be ported from Go to Rust. It is a major piece of functionality in the Filecoin ecosystem, being the code that stores Filecoin pieces.

We believe that having the library running in native Rust is a good investment of resources, and would be a boon to the crypto community. The Go code consists of 42 files, 4634 lines-of-code.

3 Actors and Pallets

Filecoin employs actors and their respective methods to run their ecosystem from within the Filecoin Virtual Machine (FVM). These objects essentially map directly to Substrate pallets and extrinsics. Both are Rust libraries compiled to WebAssembly, and both are run in a VM. One strategy we propose, is to bring the Filecoin actors directly into a collator node.

3.1 `builtin-actors`

This is a Rust library used by the Filecoin VM to power their VM. The on-chain built-in actors are compiled to WASM, and run from within the Filecoin Virtual Machine (see their reference implementation)

They will form the basis of the pallets used by Polkadot Native Storage (PNS). Filecoin actors operate very similarly to Substrate pallets. These are Filecoin entities, listed with their Substrate equivalents.

```
Filecoin  ->  Substrate
-------------------------
actor     ->  pallet
method    ->  extrinsic
message   ->  transaction
```

While we will not be porting them *per se*, they will have to be significantly adapted for use in Substrate.

The methods and parameter structures provide a specification of the end result, so the development phase here should be correspondingly shortened.

An additional resource would also be a full enumeration of all structures used in the Filecoin blockchain at the Sentinel site where Lily data dumps are created. Having these as a model could shorten the time of porting Go to Rust.

- Actors: https://lilium.sh/data/actors/
- Chain data: https://lilium.sh/data/chain/

They are used to generate blockchain snapshot, that may be downloaded here: https://lilium.sh/data/dumps/

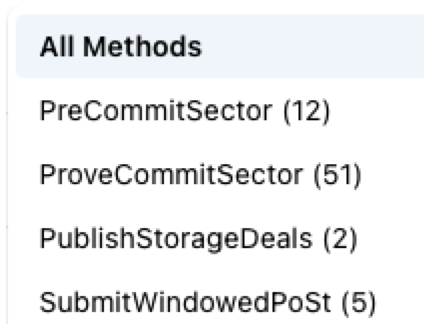
3.2 Pallets

While this is not meant to be a complete listing of all the extrinsics that will eventually be accessible, these are some of the more common methods that are seen in typical blocks on the Filecoin blockchain.

The following four methods account for more than 98% of all messages executing on Filecoin.

- Miner
  - `PreCommitSector`
  - `SubmitWindowedPoSt`
  - `ProveCommitSector`
- Market
  - `PublishStorageDeals`

This is a typical distribution of messages in a block, grabbed from the Filecoin block scanner:



It is important that not every method exposed by the pallet need to be extrinsic. Only actions that produce a state change (transaction) need to be treated as extrinsic and put in the pallet with some weight (fee for executing it). Other pallets can expose some functions that can be called internally by other pallets without the possibility to call them by the parachain user, just to divide the responsibility between pallets.

3.2.1 The miner pallet

These four extrinics have been implemented in our demo pallet:

- `change_worker_address`
- `change_peer_id`
- `change_owner_address`
- `confirm_update_worker_key`

They've been updated from the CGS code, and some of their parameters have been changed to match the Filecoin actor messages. In fact, `pallet-pns-common` contains definitions for some of their parameters, moved from the FVM code as-is, to prove that it's possible to use FVM parts to speed up the development process (like the whole Filecoin `Address` module).

The first three correspond to the following Filecoin actor messages:

```
ChangeWorkerAddress = 3,
ChangePeerID = 4,
ChangeOwnerAddress = 23,
```

3.2.1.1 Methods

These are examples of the data structures used with some of the miner actor messages.

Name: `DeclareFaultsRecovered`
Params:

```
{
  "Recoveries": [
    {
      "Deadline": 1,
      "Partition": 0,
      "Sectors": "66,84,85,92,93,95,102,103, ..."
    }
  ]
}
```

Name: PreCommitSector
Params:


```
{
  "SealProof": 8,
  "SectorNumber": 10266,
  "SealedCID":
"bagboea4b5abcbunob34vedkjyzavz52jmi544t7rmk2xu37qmermgnorol3htoqi",
  "SealRandEpoch": 3212441,
  "DealIDs": [54785735],
  "Expiration": 4757180,
  "ReplaceCapacity": false,
  "ReplaceSectorDeadline": 0,
  "ReplaceSectorPartition": 0,
  "ReplaceSectorNumber": 10266
}
```


Name: `ProveReplicaUpdates`
Params:


```
{
  "Updates": [
    {
      "SectorID": 5970,
      "Deadline": 2,
      "Partition": 0,
      "NewSealedSectorCID":
"bagboea4b5abcapnhm5ixdynkld7dohj6o3klxwdjsgxd4b4wnnkqbed7bio6xgiz",
      "Deals": [54790140],
      "UpdateProofType": 3,
      "ReplicaProof": "0x8b0595b5c5027690b3c2f..."
    }
  ]
}
```


Name: ProveCommitSector
Params:


```
{
  "SectorNumber": "43374",
  "Proof": "0x929b6852f56181a3a..."
}
```

Note: The proof here is 1920 bytes, or `10 * 192`, 192 being the length of a single zk-SNARK proof. Each proof is for a 130M constraint part of the proof, of which ten are required for a 32GB sector

Name: `SubmitWindowedPoSt`
Params:


```
{
  "Deadline": 44,
  "Partitions": [
    {
      "Index": 0,
      "Skipped": ""
    }
  ],
  "Proofs": [
    {
      "PoStProof": 13,
      "ProofBytes":
"0x8cda9442b59777a037c987bc111a6d7db38b7e0ebb24e7c336b995ad2ebd4be9b
06519ec575690078f1e8c860e80294aaff42d9a72712f12ff132c4e4b260211482e1
1e1379c9ca9f986d81957eabbe3e287a1bc8238b7b0107ef248e4d696b10c65e6f3c
9ab92c25ffcfed8602116c4c74a448428266d4424d54ca0b3f082c01aff85e5cf104
7091da55c383d60c571a8f442b029c2859192dfab37966eb3750ed21ab5e5ffacfe6
a5ca0c28f61580643812456b05204736f76ed39a1ea6dce"
    }
  ],
  "ChainCommitEpoch": "3213663",
  "ChainCommitRand":
"0x3a7a835524a317d9e80238709717ee9221addf4e643b26a65665e634af7def3e"
}
```


Note: the proof size is 192 bytes.

3.2.2 The market pallet

This actor is responsible for processing and managing on-chain deals.

- it is the entry point of all storage deals and data into the system.
- maintains a mapping of StorageDealID to StorageDeal
- keeps track of locked balances of storage client and storage provider
- restores collateral to the client if the provider gets slashed

3.2.2.1 Methods

Name: AddBalance
Params: none
Notes: This extrinsic is just an array of from/to transactions

Name: WithdrawBalance
Params:

```
{
    "AmountRequested": "138000000000000000000"
}
```

Name: PublishStorageDeals
Params:

```
{
  "Deals": [
    {
      "Proposal": {
        "PieceCID":
"baga6ea4seaql42omoabvlx3yean24ehj7spyrvsrzmd5r22cxhd6kc3z2pdrsey",
        "PieceSize": 34359738368,
        "VerifiedDeal": true,
        "Client": "f1f5edx6ofn3lf6rk3yfpldbi2pzgq2egoyu6ubpi",
        "Provider": "f01832632",
        "Label":
"mAXCg5AIguGuz88IXudDd62xPn6wLKjWaWhmReXTOaaGSuLU3bVY",
        "StartEpoch": "3228071",
        "EndEpoch": "3746471",
        "StoragePricePerEpoch": "0",
        "ProviderCollateral": "7863774879987970",
        "ClientCollateral": "0"
      },
      "ClientSignature": {
        "Type": 1,
        "Data":
"0xfaa730dd21f0a627064d6603b34cf1b30d88fb29cafa78dc900cf7804aff72b75
f1841b2e0254743bafa581f735ad92d4bd0370f2d3c5919770fb9970d735fc501"
      }
    }
  ]
}
```


Notes: This is transaction typically contains several deals.

3.2.3 The power pallet

Besides maintaining the per-miner power state, this pallet is responsible for creating a miner.

These two extrinics have been implemented in our demo pallet:

- `create_miner`
- `update_claimed_power`

They correspond to the following actor messages:

```
CreateMiner = 2,
UpdateClaimedPower = 3,
```

That pallet also uses `pallet-pns-common` to demonstrate the usage of standard FVM type definition in WASM environment. As the same types are shared between `pallet-miner` and `pallet-power`, it shows not only FVM compatibility but also cooperation between different actors (pallets) in the parachain environment.

3.3 Alternative: bring the entire FVM into a pallet

Instead of creating a pallet for each actor, mirroring the structure of the FVM, an alternative strategy would be to compile the entire FVM into a pallet. This would mirror how the Polkadot Frontier project implemented the EVM for Polkadot.

Setting aside several WASM incompatibilities for a moment, there are a number of points to support this approach

- you get the blockchain state serialization out-of-the-box.
- several complex libraries are already part of the FVM
  - IPLD
  - blockstore

However, other libraries are not compilable to a WebAssembly target. These are mainly the storage proof libraries, which demand multi-core CPU as well as GPU capabilities. For example:

```
[dependencies]
bellperson = { version = "0.26", default-features = false }
bincode = "1.1.2"
blstrs = "0.7"
lazy_static = "1.2"
filecoin-proofs-v1 = { package = "filecoin-proofs", version =
"~16.0.0", default-features = false }
filecoin-hashers = { version = "~11.0.0", default-features = false,
features = ["poseidon", "sha256"] }
fr32 = { version = "~9.0.0", default-features = false }
storage-proofs-core = { version = "~16.0.0", default-features =
false }

[features]
default = ["opencl", "cuda"]
cuda = ["filecoin-proofs-v1/cuda", "filecoin-hashers/cuda",
"storage-proofs-core/cuda", "bellperson/cuda"]
cuda-supraseal = ["filecoin-proofs-v1/cuda-supraseal", "filecoin-
hashers/cuda", "storage-proofs-core/cuda-supraseal",
"bellperson/cuda-supraseal"]
opencl = ["filecoin-proofs-v1/opencl", "filecoin-hashers/opencl",
"storage-proofs-core/opencl", "bellperson/opencl"]
multicore-sdr = ["filecoin-proofs-v1/multicore-sdr"]
```

They would need to be called via the JSON-RPC interface of the `polka-store` process, which does the heavy computation for the miners.

Which approach should be taken will require additional research that is beyond the scope of this proposal. In particular, how the EVM was implemented for Polkadot should be studied in depth, comparing it to the Filecoin VM and its own technical requirements.

3.4 Off-chain workers

One additional Polkadot feature we can take advantage of is off-chain workers. We would avail ourselves of this for longer running and possibly non-deterministic tasks.

They are still WebAssembly modules, so we cannot run multi-threaded or GPU-dependent code. Nevertheless, it would be another tool available to us, given a relevant context.

4 JSON-RPC

Filecoin's JSON-RPC API is a major component of their system. It is the interface to the blockchain state itself, as well as miners, storage market, rewards, etc. Storage clients may directly interact with the blockchain via the `Client` API, for example, to request a quote for a storage deal.

4.1 API

The API calls are implemented in the `lotus` application in Go. Much of this functionality would have to be ported from Go to Rust.

It would require a research task to specify:

- what subset of API calls to keep,
- which calls to eliminate,
- new Polkadot-specific calls.

While there is a lot of freedom here, the Filecoin JSON-RPC API is a useful starting point.

Some example categories and some representative calls are listed here:

```
Chain
  ChainGetBlockMessages
  ChainGetBlock
  ChainGetMessage

Client
  ClientQueryAsk
  ClientStartDeal
  ClientListDeals
  ClientGetDealStatus

Market
  MarketAddBalance
  MarketWithdraw

State
  StateMinerSectors
  StateMinerProvingDeadline
  StateMinerInfo
  StateMinerDeadlines
  StateMinerPartitions
  StateMinerAvailableBalance
  StateSectorGetInfo
  StateMarketDeals
  StateListMiners

Sync
  SyncSubmitBlock
  SyncIncomingBlocks
  SyncValidateTipset
```

There are several other modules

- `Eth` : ethereum calls
- `Gas`
- `Mpool` : message pool
- `Msig` : multisig wallets
- `Paych` : payment channels for off-chain transactions
- `Wallet`

4.2 Storage and Retrieval Markets

Much of the code for the storage and retrieval markets are in separate Go libraries:

- retrieval market
- storage market

This functionality must be folded into both the RPC handlers and relevant actors. See also Section 5 that follows for a more in-depth discussion.

There are generally two ways of moving forward with RPC implementation:

1. allow each actor (pallet) to handle his own RPC calls and expose the RPC endpoint to the `node`
2. put every call to one pallet (`pallet-pns`), which will handle all RPC calls and will be exposed to the `node` and forward calls to the right actors

We've left the decision for the future, as it's not a priority at the moment. The first option is more flexible and seems to be right from the architectural point of view, as each actor is fully handling everything about its functionality. It introduces simple responsibility and simplifies updating because, in case of any changes, only one actor (pallet) must be updated. On the other hand, keeping all RPC calls in the main pallet allows handling them in one place and presenting them to the user consistently. It also introduces some level of abstraction, where we can make some additional tasks before redirecting the call to the destination pallet.

For the demo, we've implemented the RPC endpoint in the `pallet-pns` with some simple calls returning hardcoded values. It just presents how the RPC endpoint works and how it can be plugged into the runtime from the pallet level. Calls can be easily moved to the actors and be handled from the other pallet - as well as adding new RPC endpoints to the other pallets by analogy.

5 Markets

Filecoin has two markets on its platform: one for storage and one for retrieval.

- In the case of storage, deals are recorded on-chain.
- In the case of retrieval, deals are set up off-chain, between a client and a retrieval market provider. The payments are also executed off-chain, via a payment channel.
- the protocols execute over `libp2p`

5.1 Storage Market

5.1.1 How to store a file with Filecoin

There are four basic steps to setting up a storage deal: discovery, negotiation, publish, and handoff.

- Discovery: The client identifies miners and determines their current asks, i.e. the price per GiB per epoch that miners want to receive in order to accept a deal. Currently a deal in Filecoin has a minimum duration of 180 days.

    - A client queries the chain to retrieve a list of Storage Miner Actors who have registered as miners with the StoragePowerActor.
    - A client may perform additional queries to each Storage Miner Actor to determine their properties. Among others, these properties can include worker address, sector size, libp2p Multiaddress etc
    - Once the client identifies potentially suitable providers, it sends a direct libp2p message using the `Storage Query Protocol` to get each potential provider's current `StorageAsk`.
    - Miners respond on the `AskProtocol` with a signed version of their current `StorageAsk`.

- Negotiation and data transfer: During this out-of-band phase, both parties come to an agreement about the terms of the deal, ending with the deal being published on the chain

    - The client calculates the piece commitment (`CommP`) of the data to be stored

  - Before sending the proposal, the client deposits fund in the storage market actor
  - The client creates a `StorageDealProposal` and sends the CID to the storage provider using the `Storage Deal Protocol` , one of the markets libp2p protocols.
  - the storage provider inspects the deal, verifying the parameters against his own internal criteria, rejecting it if mismatch
  - provider queries the market actor, verifying the client has enough funds to cover the price of the deal (or reject)
  - provider then signals the client (using the protocol) an intent to accept
  - the storage client opens a push request for the payload data using the `Data Transfer Module`
  - the provider checks the CID, and then accepts the data transfer request
  - the `Data Transfer Module` now transfers the payload data to the storage provider using GraphSync
  - at completion, the DTM notifies the storage provider.
  - the storage provider recalculates the `CommP` , and verifies it matches the corresponding field of the `StorageDealProposal`

- Publish: The deal is published on-chain, via the `PublishStorageDeals` message, making the storage provider publicly accountable for the deal. A deal is only valid when it is posted on chain with signatures from both parties and at the time of posting, there are sufficient balances for both parties locked up to honor the deal in terms of deal price and deal collateral.

  - storage provider adds collateral for the deal as needed to the market actor (using `AddBalance`).
  - storage provider prepares and signs the on-chain `StorageDeal` message with the `StorageDealProposal` signed by the client and its own signature. It can now either send this message back to the client or call `PublishStorageDeals` on the market actor to publish the deal. It is recommended for the provider to send back the signed message before `PublishStorageDeals` is called.

    - After calling `PublishStorageDeals`, the storage provider sends a message to the client on the `Storage Deal Protocol` with the CID of the message that it is putting on chain for convenience.
    - if all goes well, the market actor responds with an on-chain `DealID` for the published deal.
    - finally, the client verifies the deal. They query the node for the CID of the message published on chain (sent by the provider). It then inspects the message parameters to make sure they match the previously agreed deal
    - generally, a confirmation that the deal is published is not sent immediately, as the storage provider may be waiting for other deals in order to fill an entire sector.

- Handoff: Now that a deal is published, it needs to be stored, sealed, and proven in order for the provider to be paid.

    - The storage provider writes the serialized, padded piece to a shared Filestore.
    - The provider then calls `HandleStorageDeal` on the miner actor with the published `StorageDeal` and filestore path (in Go this is the io.Reader).

A deal is only valid when it is posted on chain with signatures from both parties and at the time of posting, there are sufficient balances for both parties locked up to honor the deal in terms of deal price and deal collateral.

While this can all happen from the command line, using curl and some cleverly crafted `jsonrpc` calls, it would be better for deals to be executed at a higher level.

We posit the creation of two tools, Delia and Gregor. At minimum, these could be web applications or electron executable. This is just one possibility -- there are many ways to Rome. Simplicity and ease-of-use should be high priorities.

Filecoin has an entire ecosystem dedicated to file onboarding: [Filecoin Data Tools]().

We believe that a relatively simple solution could be viable, and not only for an MVP.

5.1.2 Delia

This is where an entire piece is uploaded and encoded. The data size here would be on the order of 4GB.

The idea of Delia, is that it hides the low-level details of:

- finding a miner
- proposing a deal
- executing a deal

Data on-ramping tools like this work primarily off-chain. We would need some input from stakeholders to form a working solution.

5.1.3 Gregor

This is a storage *aggregator* web service. This is specifically for smaller amounts of data to be stored.

A match is made between a client and a storage aggregator. When an aggregator has enough files to fill a sector, it seals the sector, and returns confirmation to the various constituent clients.

This would be an instance to use a payment channel, rather than an on-chain transaction.

How file aggregation should work will necessitate discussions with stakeholders.

5.2 Filecoin's Retrieval Market

5.2.1 Classic Filecoin Retrieval

The Filecoin Retrieval Market protocol for proposing and accepting a deal works as follows

- Discovery
    - The client finds a provider of a given piece with FindProviders().
    - The client queries a provider to see if it meets its retrieval criteria (via Query Protocol)
- Deal Negotiation
    - the client schedules a Data Transfer Pull Request passing the RetrievalDealProposal as a voucher.
    - the provider validates the proposal and rejects it if it is invalid.
    - If the proposal is valid, the provider responds with an accept message and begins monitoring the data transfer process.
- Payment Channel
    - the client creates a payment channel as necessary and a "lane" and ensures there are enough funds in the channel.
    - Data Transfer and payment
    - the provider unseals the sector as necessary.
    - the provider monitors data transfer as it sends blocks over the protocol, until it requires payment.
    - when the provider requires payment, it pauses the data transfer and sends a request for payment as an intermediate voucher.
    - the client receives the request for payment.
    - the client creates and stores a payment voucher off-chain.
    - the client responds to the provider with a reference to the payment voucher, sent as an intermediate voucher (i.e., acknowledging receipt of a part of the data and channel or lane value).
    - the provider validates the voucher sent by the client and saves it to be redeemed on-chain later
    - the provider resumes sending data and requesting intermediate payments.
    - the process continues until the end of the data transfer.

This may be sufficient for an MVP.

How this eventually works is something that should be discussed with the stakeholders. There will definitely be a need for caching files that are often used. Crypto incentivization will probably also need to be a part of a solution. Something that would also need to be figured out is what is on-chain and what is off-chain. We want to verify everything that is necessary, but not overwhelm the blockchain with verbose traffic.

5.2.2 Saturn

Filecoin's Saturn project deserves some mention here. It is:

- an open source CDN
- community run
- incentivized
- has L1/L2 nodes for caching.
- On-boarding looks to be fairly painless
- payments occur once per month, based on submitted logs showing file transfers (to & from)

They have 5000+ nodes currently connected

In addition, they recognize it is a large problem, as well as a business opportunity. 15 teams are participating in further work in file retrieval.

Of course, Polkadot's mission is not the same as Filecoin. A CDN edge server for streaming media is not a use-case that is a high priority for this parachain.

5.2.3 `lassie`

https://github.com/filecoin-project/lassie

A minimal universal retrieval client library for IPFS and Filecoin. Written in Go, also with the intent as *reference implementation*.

When the CLI version is used, lassie is straight forward: you can just `fetch` a CID, receiving back a `.car` file. One way to unpack that is to use ipfs-car.

It queries a network indexer for the supplied CID, finds a storage provider who has it, and then proceeds to download the CAR file.

```
temp$ lassie fetch -o fetch-example.car -p
bafybeic56z3yccnla3cutmvqsn5zy3g24muupcsjtoyp3pu5pm5amurjx4
Fetching bafybeic56z3yccnla3cutmvqsn5zy3g24muupcsjtoyp3pu5pm5amurjx4
Querying indexer for
bafybeic56z3yccnla3cutmvqsn5zy3g24muupcsjtoyp3pu5pm5amurjx4...
Found 6 storage provider candidate(s) in the indexer:
        12D3KooWSQ1Qg74oMQ7uAHh8gtME2HdENJMiaoyLnjDQn3drvagg,
Protocols: [transport-ipfs-gateway-http]
        12D3KooWKGCcFVSAUXxe7YP62wiwsBvpCmMomnNauJCA67XbmHYj,
Protocols: [transport-graphsync-filecoinv1]
        QmQzqxhK82kAmKvARFZSkUVS6fo9sySaiogAnx5EnZ6ZmC, Protocols:
[transport-bitswap]
        QmUA9D3H7HeCYsirB3KmPSvZh3dNXMZas6Lwgr4fv1HTTp, Protocols:
[transport-ipfs-gateway-http]
        QmQzqxhK82kAmKvARFZSkUVS6fo9sySaiogAnx5EnZ6ZmC, Protocols:
[transport-bitswap]
        QmUA9D3H7HeCYsirB3KmPSvZh3dNXMZas6Lwgr4fv1HTTp, Protocols:
[transport-ipfs-gateway-http]
Retrieving from [QmUA9D3H7HeCYsirB3KmPSvZh3dNXMZas6Lwgr4fv1HTTp]
(started-retrieval)...
Retrieving from [QmUA9D3H7HeCYsirB3KmPSvZh3dNXMZas6Lwgr4fv1HTTp]
(connected-to-provider)...
Retrieving from [Bitswap] (started-retrieval)...
Retrieving from
[12D3KooWSQ1Qg74oMQ7uAHh8gtME2HdENJMiaoyLnjDQn3drvagg] (started-
retrieval)...
Retrieving from
[12D3KooWSQ1Qg74oMQ7uAHh8gtME2HdENJMiaoyLnjDQn3drvagg] (connected-
to-provider)...
Retrieving from
[12D3KooWKGCcFVSAUXxe7YP62wiwsBvpCmMomnNauJCA67XbmHYj] (started-
retrieval)...
Retrieving from
[12D3KooWKGCcFVSAUXxe7YP62wiwsBvpCmMomnNauJCA67XbmHYj] (connected-
to-provider)...
Retrieving from
[12D3KooWKGCcFVSAUXxe7YP62wiwsBvpCmMomnNauJCA67XbmHYj] (proposed)...
Retrieving from
[12D3KooWSQ1Qg74oMQ7uAHh8gtME2HdENJMiaoyLnjDQn3drvagg] (first-byte-
received)...
Retrieving from [Bitswap] (first-byte-received)...
Received 19 blocks / 15 MiB....
Fetched
[bafybeic56z3yccnla3cutmvqsn5zy3g24muupcsjtoyp3pu5pm5amurjx4] from
[Bitswap]:
        Duration: 3.205753114s
          Blocks: 19
```

```
           Bytes: 15 MiB
temp$ npx ipfs-car unpack fetch-example.car --output .
temp$ ls -l
total 31472
-rw-rw-r-- 1  16110964 Sep 29 10:11 birb.mp4
-rw-r--r-- 1  16112590 Sep 29 10:10 fetch-example.car
```

5.3 `store@polkadot` / `fetch@polkadot`

This section is not part of the solution per se. But to emphasize the community aspect of storage and retrieval -- and with a nod to `SETI@home`, the distributed computing project -- it might be worth considering both markets as co-dependent or symbiotic entities. There is a great deal of symmetry there.

We can achieve something fairly democratic, if there is :

- ease of use
- low entry requirements, both technical and hardware

The names `store@polkadot` and `fetch@polkadot` might eventually justify themselves, by virtue of what the parachain is accomplishing. It could be the public face of PNS.

6 Implement from scratch

6.1 `polka-store`

This is an executable that will handle all the heavy lifting associated with a storage provider, communicating with the collator node via JSON-RPC.

- it is the mining system, a Rust executable
- maintains the sector storage
- performs proofs as required
- hefty hardware requirements.

- communicates via JSON-RPC with the collator node.

In short, it is the one major piece of software that has to be basically built from scratch.
It is (usually) paired with a collator node. While it may often be running on the same server, that is not strictly necessary.

Unlike `lotus`, there is no:

- FVM
- `libp2p`
- publish/subscribe, `gossipsub`
- transactions
- block production
- handling of miner cash flow

`polka-store` is conceived of as having a subset of the `lotus`'s functionality. Although the latter is written in Go, its source code could nevertheless prove useful as a model, since it has to respond to (and send) the same actor-messages. Many of the tests would also be similar.

6.2 `polka-index`

This is the indexer process. It handles indexes, which are namely a key-value mapping of CID's to storage provider, including other metadata such as supported protocols.
`polka-index` has three purposes:

- store indices
- ingest indices
- respond to query requests.

Efficient indexing is of prime importance in order for clients to perform fast retrieval. To improve content discoverability, indexer nodes are instantiated to store mappings of CIDs to content providers for content lookup upon retrieval request.

In IPFS, this is handled through a Kademlia DHT (Distributed Hash Table). However, this method does not scale well and is not terribly performant.

Filecoin has a network indexer instance running at cid.contact. When one inserts a CID into the query field, an array of storage providers is returned. If we use the CID from the `lassie` example, `bafybeic56z3yccnla3cutmvqsn5zy3g24muupcsjtoyp3pu5pm5amurjx4`, a returned provider will look something like this:

```
Peer Id:      12D3KooWSQ1Qg74oMQ7uAHh8gtME2HdENJMiaoyLnjDQn3drvagg
Multiaddress: /dns/ipfs.va.gg/tcp/3747/http
Protocol:     2336
```

That tool is an instance of their indexer at `storetheindex`.

We recommend implementing `polka-index` starting from the earlier Rust project, which Filecoin ported to Go (in the above library).

6.3 polka-fetch

This process is responsible for delivering content to client requesting it. The simple idea is that a user requests some content (namely, a CID). The content is found, and then retrieved.

At minimum (e.g., for an MVP), the classic methods of doing content retrieval would work. However, one problem is the lack of caching, depending on the use case.

It is a deep conversation how to implement something like this. Filecoin has 15 teams working just on retrieval.

On the other hand, there may be simpler solutions that could be imagined, where some limited caching is implemented here, where the storage is. Much depends on the mix of file sizes, and frequency of access.

7 XCM: Integration with Polkadot

PNS utilises routes of communication together with various protocols and technologies in order to expose its functionality to other parachains

The main idea is to provide a set of XCM messages, allowing other parachains to interact with PNS. Those messages will be sent to the PNS parachain and processed by the collator node. Everything that we plan to use is already implemented in Polkadot and Substrate.

7.1 XCM messages

XCM is a message format used to communicate between the parachains. XCM messages are just a set of instructions executed by the recipient parachain.

We've identified that existing messages will be sufficient to provide all functionalities of Polka Native Storage. All fees will be paid in DOTs, and it applies to fees for executing actions on the Polkadot chain.

A typical message would contain:

1. `WithdrawAsset` - to withdraw DOTs from the parachain sovereign account;
2. `BuyExecution` - pay for execution of the message; buy weight using fees;
3. `Transact` - execute call from `polka-storage` pallet.

The `Transact` message was chosen intentionally to provide more flexibility during pallet-storage development and usage. Thanks to it, we can perform any operation in the future, not only those predicted and implemented.

To provide a better user experience, we propose to use the `pstorage` pallet (described in the next section) to map the calls with some human-friendly format. It enables the user to call some `pstorage` extrinsics, which can establish a real connection to the other part of the system.

7.2 Communication

XCM is only a message format and doesn't provide any communication protocol. We will use HRMP (XCMP if available) to send messages between parachains. HRMP needs to be implemented in both parachains (sender and receiver) and demands opening a communication channel. Channel could be opened by sending HRMP init message from one parachain to PNS - our parachain can answer then with the opening confirmation. Then, parachains can communicate and exchange XCM messages between them.

The communication schema would be as follows:

1. parachain sends `HrmpNewChannelOpenRequest` to the relay chain, which sends it to PNS;
2. PNS sends `HrmpChannelAccepted` to the relay chain, which sends it to parachain;
3. communication until parachain sends `HrmpChannelClosed` .

Notice: HRMP messages are always routed through the relay chain.

To make communication easy for other parachains, we will provide a pallet (`pstorage`), which can be used in other parachains to provide calls which construct appropriate XCM message and sends them through HRMP protocol. It could also use the SPREE execution engine to perform certain operations in the future.

Polkadot Native Storage: Scenarios

1 General

We've identified the following scenarios for the storage solution. All of them are written from the user's perspective.

1. Parachain (or Polkadot ecosystem) users shall be able to:
   - store a file which is on their hard drives;
   - store a file that is placed somewhere in the network (URL);
   - retrieve a file from the PNS, transferring it to their computer;
   - get file metadata;
   - delete a file from the storage.
2. All the above use cases, but with a user employing an external client, not using a parachain directly (optional scenario).
3. All of the above use cases, but with the user using our PNS directly.
4. Administrative actions:
   - retrieve information about storage nodes;
   - add/remove a storage node;
   - add/remove the collator from the pool;
   - retrieve information about the system as a whole (free space, etc.).
   - receive alerts (free space shortage).

Besides the above scenarios, we've identified internal scenarios which map the high-level behavior of the system to the low-level implementation details. Mainly, those scenarios are connected with the user stories and are a part of them but are too complicated to describe in the user story form. Those scenarios are:

1. Publishing a deal in the market.
2. Slashing - in case of missed Window-PoSt.

2 User scenarios

2.1 Store a large CAR file

- Client discovers miners
  - `jsonsrpc::StateListMiners`
- Iteratively queries miner properties
  - `jsonrpc::StateMinerInfo`
- Get a deal quote; Returns price (per GB-epoch), and range of piece sizes
  - `jsonrpc::ClientQueryAsk`
- Add funds to the market actor, which serve as an escrow
  - `market-actor::AddBalance`
- Propose a deal
  - `market-actor::AddBalance`
- Uploads data to a web server (TBD)
- When the storage provider has collected data to fill a sector, he is then ready to publish the deal. This happens on-chain.
  - `market-actor::PublishStorageDeals`

3 Onboarding Storage Providers and Collators

One of the most important administrative tasks is the management of collators and storage providers. Even the best network will be dead when there will be no one who would like to participate in it.

Our vision is to create an easy and intuitive onboarding process, to make it as simple as possible for the user to become a storage provider or collator. We believe it will make the network more attractive for users.

Onboarding should be a process, not a single action, which should lead a new storage provider or collator right from the zero point to complete setup from the technical and business perspectives. We're convinced that anyone can join the network and start providing some storage services for others (and earn money).

To achieve this goal, we need to provide tools and documentation to guide the user through the whole process. We can divide the process into the following steps:

1. The user decides to become a storage provider or collator based on the information about the network (e.g. how much money can be earned, how much time is needed to be spent, etc.).
2. The user decides to join the network and starts the onboarding process - the user is redirected to the onboarding page with the first step.
3. The user is asked to provide basic information about himself (name, email, etc.).
4. The user is asked to provide technical information (e.g. storage capabilities, network link params, etc.).
5. The pre-verification process - automatically checks if the user can be a storage provider or collator (e.g. if the user has enough free space if the network link is fast enough, etc.).
6. The user is asked to provide some business information (e.g. how much money he would like to earn, etc.) and the potential earnings based on the given information.
7. The user is redirected to the documentation page, where he can find information about the next steps.
8. The user is redirected to the technical setup page, where he can find information about the technical preparation, node setup, etc.
9. The user ends the onboarding process and starts providing storage services for the others.

Polkadot Native Storage: Conclusion

1 Our Previous Proposal

This is a link to the proposal we submitted two years ago.

https://github.com/common-good-storage/report/blob/master/src/SUMMARY.md

2 Other Storage Solutions

We've considered other storage solutions found over the network during our research.

We've evaluated only solutions which:

1. are open source and have a public repository along with a friendly license (or their ideas are described in a public document);
2. have a working implementation;
3. are mature enough to be used in production.

We've found and analyzed the following solutions:

Name	Description	Language	License	Status
Akash	Akash is a decentralized cloud computing marketplace and	Go	Apache 2.0	Productior

Name	Description	Language	License	Status
	deployment platform.			
Arweave	Arweave is a new type of storage that backs data with sustainable and perpetual endowments, allowing users and developers to truly store data forever – for the very first time.	Rust	Apache 2.0	Productior
Filecoin	Filecoin is a decentralized storage network that turns cloud storage into an algorithmic market.	Go	MIT	Productior
IPFS	IPFS is a protocol and peer-to-peer network for storing and sharing data in a distributed file system.	Go	MIT/Apache	Productior

Name	Description	Language	License	Status
Sia	Sia is a decentralized storage platform secured by blockchain technology. The Sia Storage Platform leverages underutilized hard drive capacity around the world to create a data storage marketplace that is more reliable and lower cost than traditional cloud storage providers.	Go	MIT	Productior
Storj	Storj is an open-source platform that leverages the blockchain to provide end-to-end encrypted cloud storage services	Go	GNU	Productior

After analyzing the above solutions, we've concluded that they cannot be integrated out-of-the-box with Polkadot. The main reasons are very similar to those described in the case of Filecoin, which we've described now and previously. That makes us believe that the best way to implement a storage solution for Polkadot is to port Filecoin to Polkadot and continue the ideas described in the CGS report.

3 Conclusion

3.1 Implementation

This is a structured listing of tasks and subtasks, 28 in all. The end result would be the MVP of the Polkadot Native Storage. Several of the individual subtasks may be implemented in parallel to others. For instance, #1 and #2 could largely be implemented simultaneously, by two engineers or engineering groups.

1. Collator node
    - `[1.1]` Research FVM: See section 3.3 in the solution page for more detail here. The result of this research is a clear plan forward.
    - `[1.2]` Research JSON-RPC: Decide what parts of the API to keep, what to cut, and what needs to be added
    - Implementation Milestones
        - `[1.3.1]` JSON-RPC
        - `[1.3.2]` Running actors in pallets or FVM
        - `[1.3.3]` Serialize blockchain state to disk
        - `[1.3.4]` Block production
        - `[1.3.5]` Common consensus
        - `[1.3.6]` Parachain integration
2. `polka-store` : this is a Rust executable, corresponding to a Filecoin storage provider.
    - `[2.1]` Port `dagstore` to Rust
    - `[2.2]` add JSON-RPC listener.

- link in forked proof libraries
    - `[2.3.1]` `rust-fil-proofs`
    - `[2.3.2 ]` `bellperson`
- Implementation Milestones
    - `[2.4.1]` perform a sector store, ending with PoRep returned
    - `[2.4.2]` perform a Winning PoSt
    - `[2.4.3]` perform a Window PoSt

3. `polka-index`

    - `[3.1]` Research phase:
        - determine the processing that this executable should do.
        - define how publish/subscribe will work, and implications for `polka-store` and possibly the runtime.
        - define how `gossipsub` will work.
    - `[3.2]` Fork `storethehash`
    - `[3.3]` Implementation

4. `polka-fetch`

    - `[4.1]` fork `rs-graphsync`
    - `[4.2]` return a stored file via CID.
    - `[4.3]` Research phase: figure out caching: technical details, incentivization.
    - `[4.4]` Implement file caching

5. Deployment

    - `[5.1]` Create necesary scripts and instructions to bootstrap a new collator node
    - `[5.2]` Create necesary scripts and instructions to bootstrap a new mining system. Docker may play a role here.

6. `Delia` : This is a Web-based onramp to creating and executing storage deals. This handles larger amounts of data, e.g., 4G and up.

    - `[6.1]` Research phase
    - `[6.2]` Implementation

7. `Gregor` : This is a file aggregator. For smaller sized file content, e.g., a 5MB Work Package.
    - `[7.1]` Research phase
    - `[7.2]` Implementation

3.2 Our Team

We have an experienced team ready to work on such an endeavor -- including, but not limited to:

- Mark Henderson - is the VP of Engineering at Equilibrium. He has led the team starting with the original Rust IPFS grant in late 2019, through engagements with many of the largest names in Web3, and is now circling back to finish the critical work the team started with the original Ziggurat proposal. Core contributor to OrbitDB, Rust IPFS, and Ziggurat.
- Piotr Olszewski - is a Software Engineer at Eiger, and has over 13 years of professional experience, with a strong academic background in distributed computing. He has a large bag of experiences, ranging from military appliances, cryptographic projects, telecommunication software to embedded platforms. During his career, Piotr took different roles, from developer to team and tech leader. His main tools are C/C++ and Rust. One of the last works is a port of Move Virtual Machine to Substrate ecosystem.
- Karlo Mardesic - is a Software Engineer at Eiger and has experience with telecommunications and low-level drivers in C/C++. These days his expertise has shifted to blockchain technology and P2P protocols, where he primarily uses Rust to tackle exciting problems. One of the last works is a port of Move Virtual Machine to Substrate ecosystem.
- Kyle Granger - is a Software Engineer at Eiger. He has wide experience in 3D graphics, audio, video, WebRTC. A lifelong interest in cryptography led to creating a block cipher interoperable between C++ and GPU shaders. At Eiger, he participated in the early development of Gevulot (https://www.gevulot.com), integrating proof systems for Filecoin, Marlin, and Groth16, both for WASM and Rust. Kyle has researched GPU

applications for cryptography and applied 3D visualization to p2p networks
- Tomek Piotrowski - is a Software Engineer at Eiger with extensive Rust experience. Since joining Eiger he has worked exclusively with Zcashd and Zebra codebases and supported Eiger’s efforts in the Zcash ecosystem.

3.3 Risks

1. Implementation details can affect architecture and design decisions. Although we've made a PoC modelling some of the design decisions, there is a chance that some of the technical constraints may still be unknown. We will need to be flexible and adapt to the situation.
2. The project is complex and requires a lot of work (and still, some research). We will need to be careful with the time estimations and make sure that we can deliver the project on time.
3. Technology changes - we must be aware of the changes in the Polkadot ecosystem and adapt to them.
4. Easy onboarding - we must provide an easy onboarding process for storage providers and collators. It may not be easy to achieve, and it may occur it will be iterative process which can take a longer time to be polished.
5. Storage providers and collators may not be interested in joining the network for other than technical reasons. We should also provide a good business (reward) model for them to make it attractive.
6. Task complexity (storing and retrieving) may be too high for some users. We will need to provide a simple and intuitive interface for them to make it easy to use to be attractive for the vast majority of users.

3.4 Future Plans

This project is a part of a bigger vision. We believe that the storage solution is a crucial component of the Polkadot ecosystem. We would like to continue our work and provide a full-featured storage solution for Polkadot. To achieve that we need to divide our future work into three areas: remaining research to be done, implementation, and support.

Implementation is the most important part in short term. It aims to deliver a fully functional solution for Polkadot in the form of a parachain. While fully functional, it does not mean the end of our work. The first working version is needed to verify all of the requirements and absorb initial feedback from users and testers. That can signal the start of the support phase, where we will react to feedback, delivering improvements to the parachain.

Research is a long term task. It aims to deepen the knowledge of areas that may be done better as well as providing new features that can be implemented. It may be done in parallel with the storage implementation.