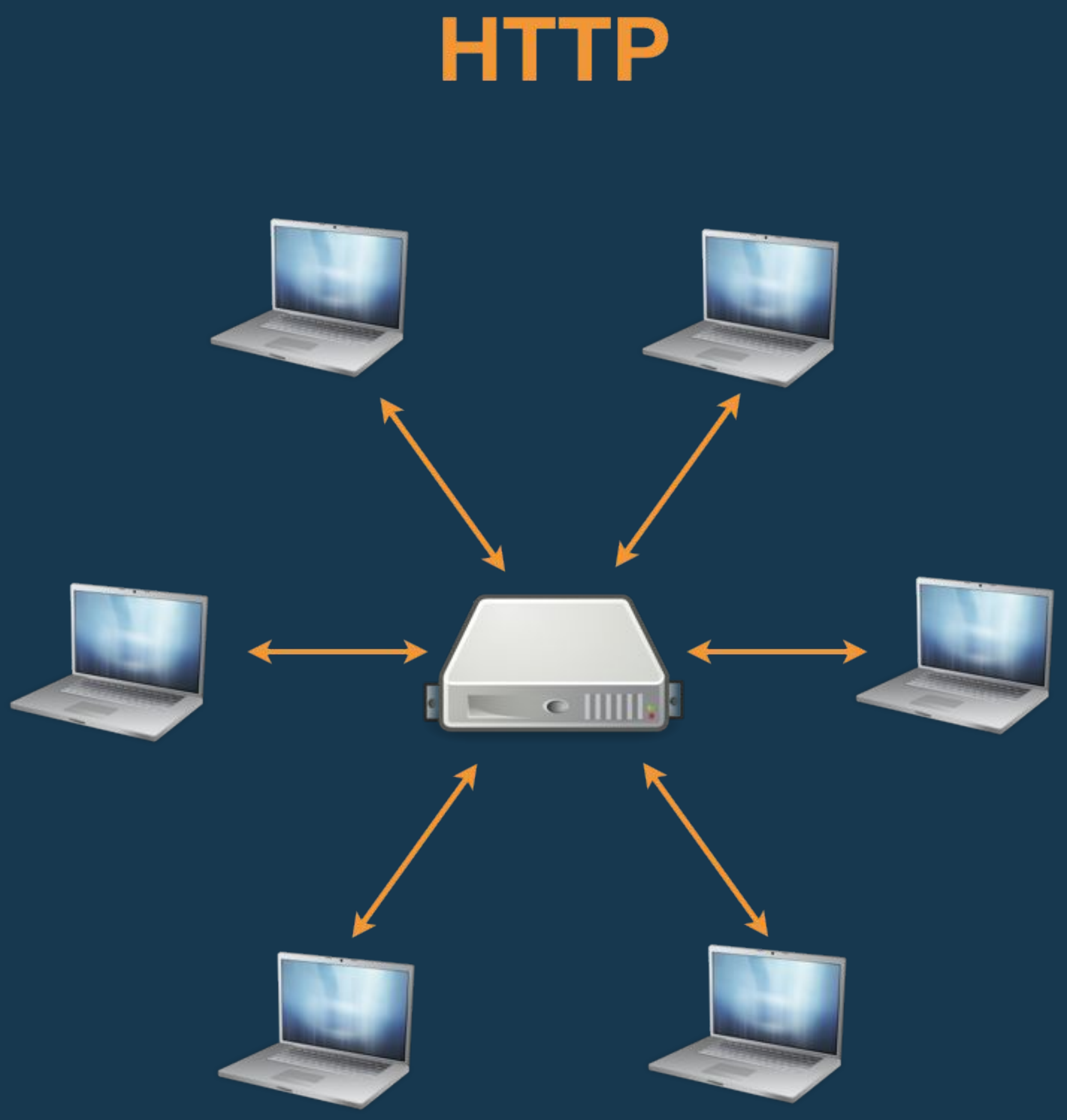
How IPFS Works

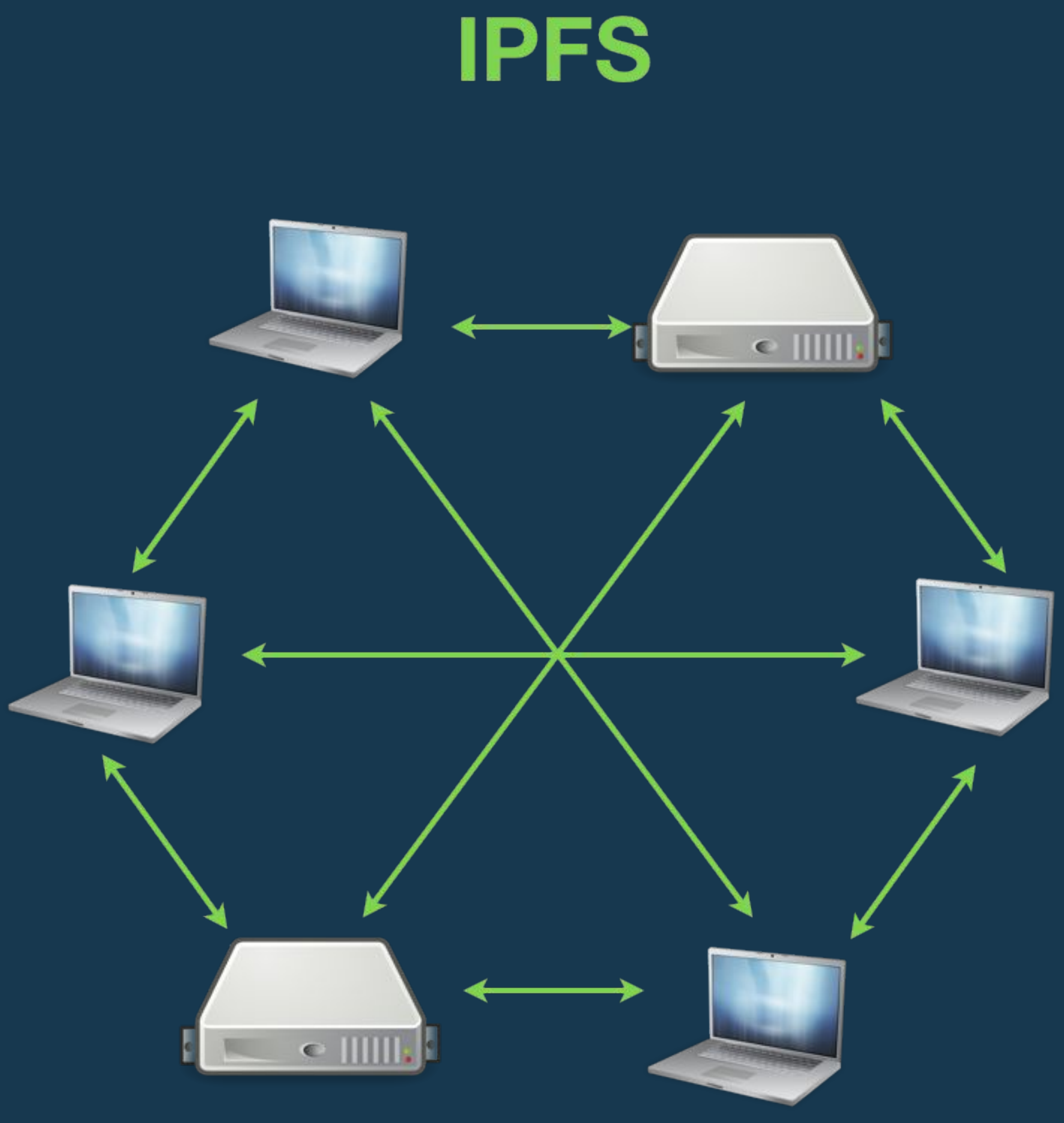
(approximately)

Name (@github)
organization

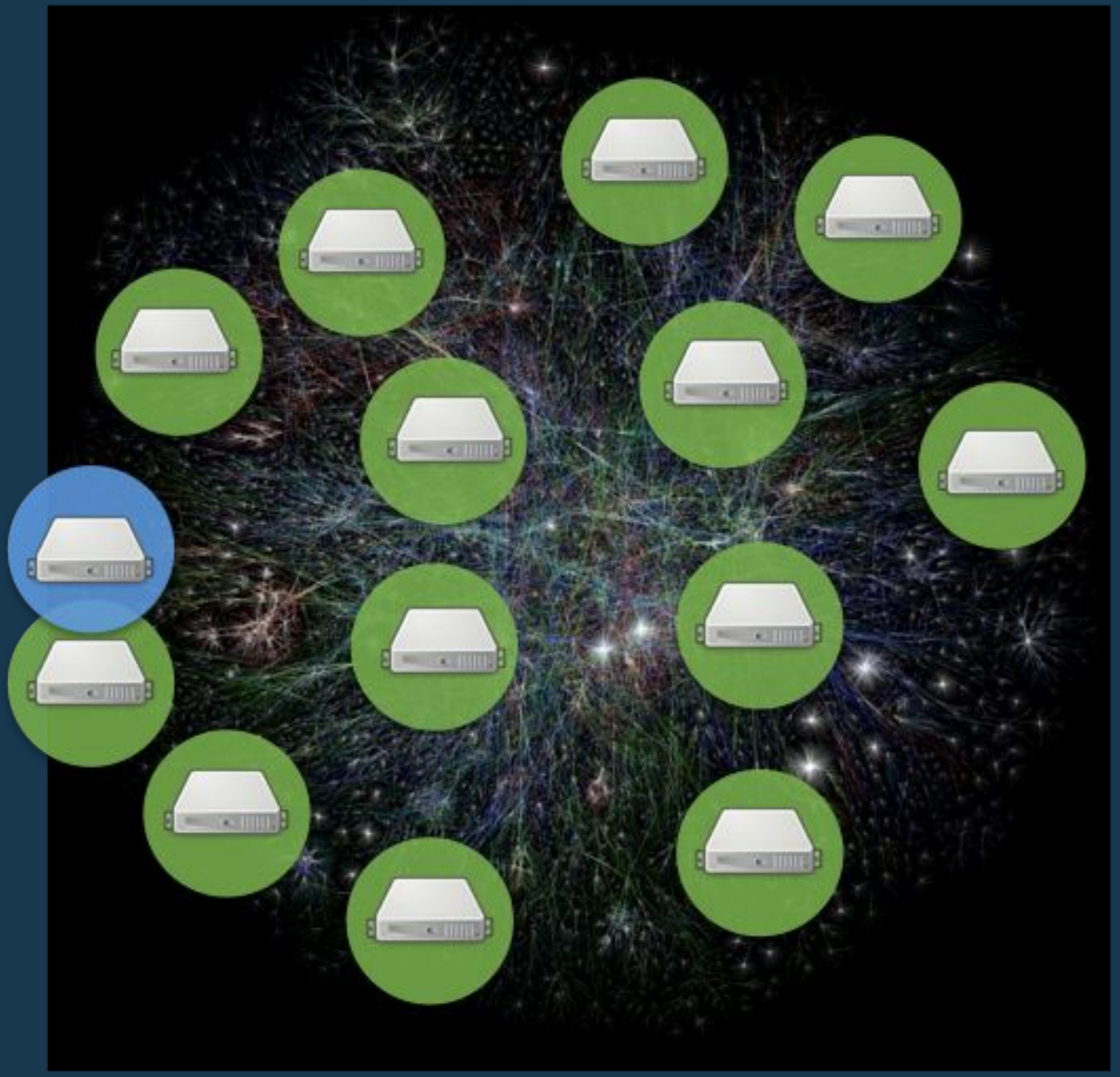
original deck by @stebalien

IPFS makes the web work peer-to-peer





domain name /dns/example.com/foo/bar/baz.png



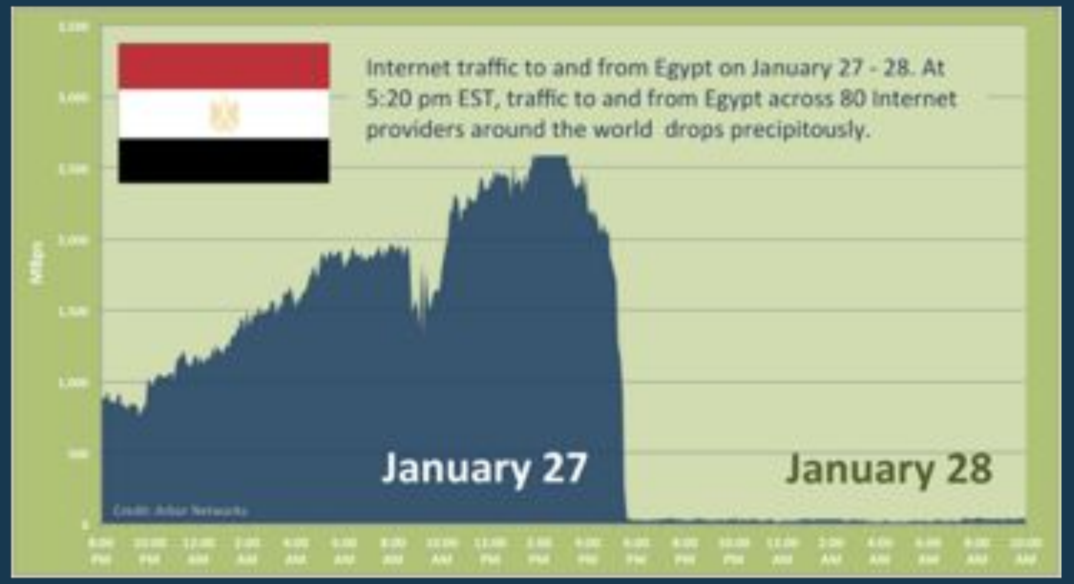
content address /ipfs/QmW98pJrc6FZ6/foo/bar/baz.png

Problems

IPFS

Addresses

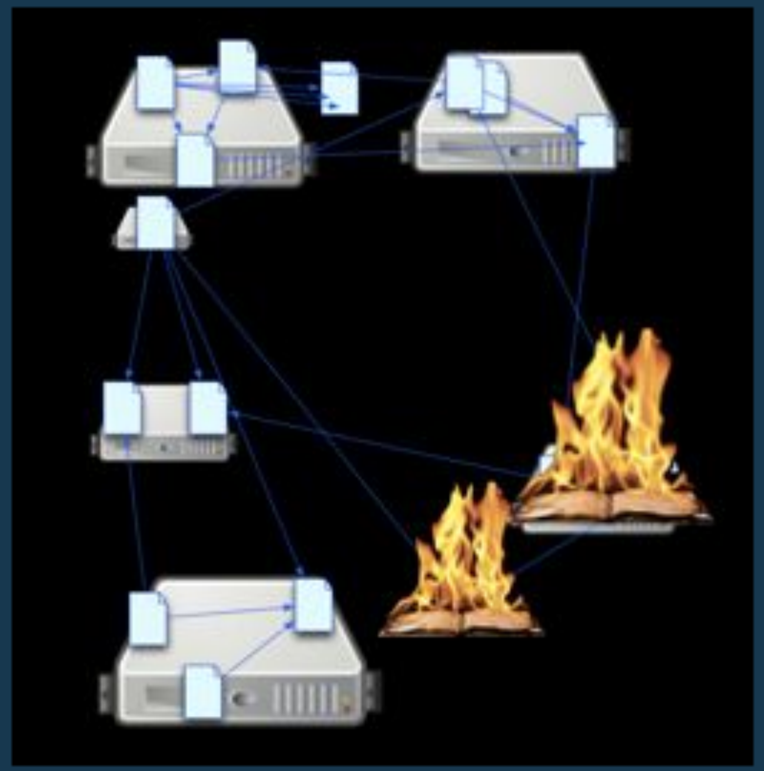
emerging networks

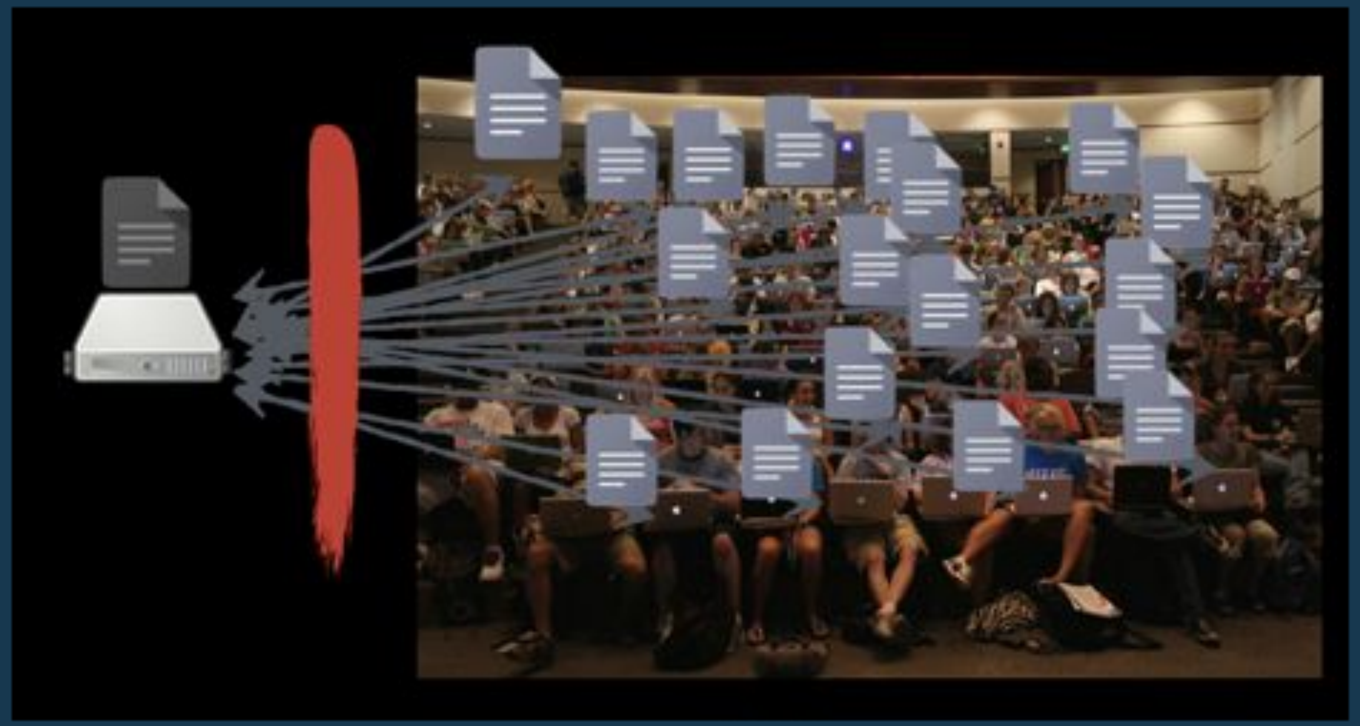


censorship

200 MB x 30 x 8 = 48 GB
huge inefficiency

bad security model


links break


no offline use

IPFS: Distributed Web Protocol

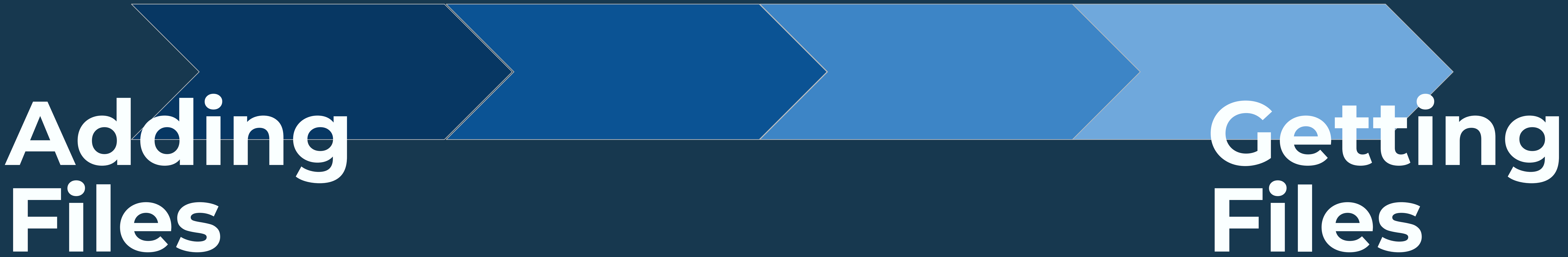
IPLD: authenticated data model & formats

libp2p: modular p2p networking library

Multiformats: future-proofing & upgradability

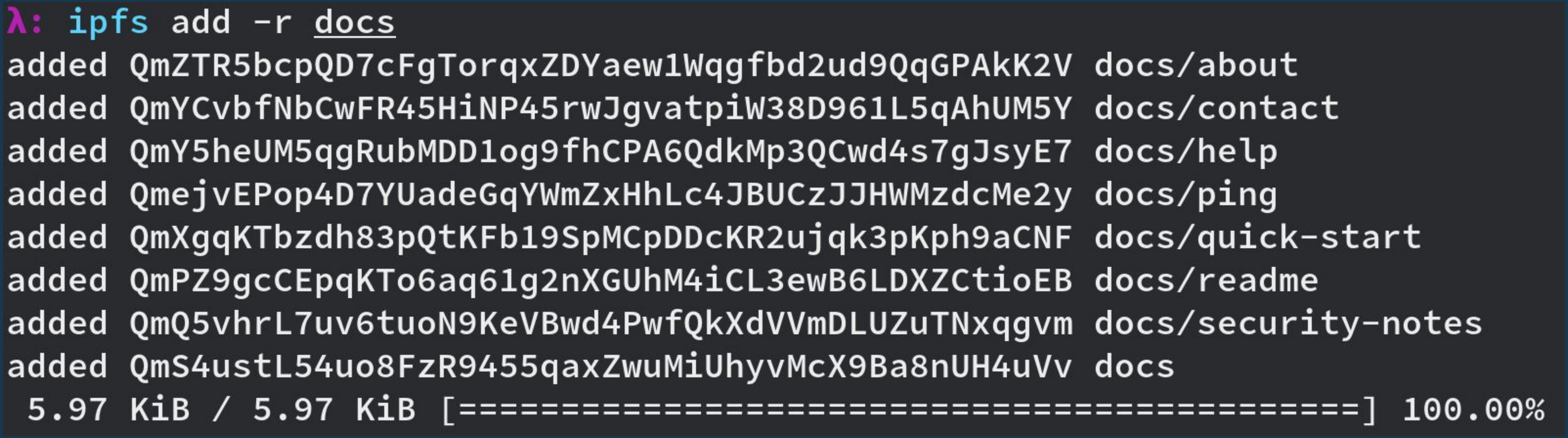
IPFS:

Lifecycle



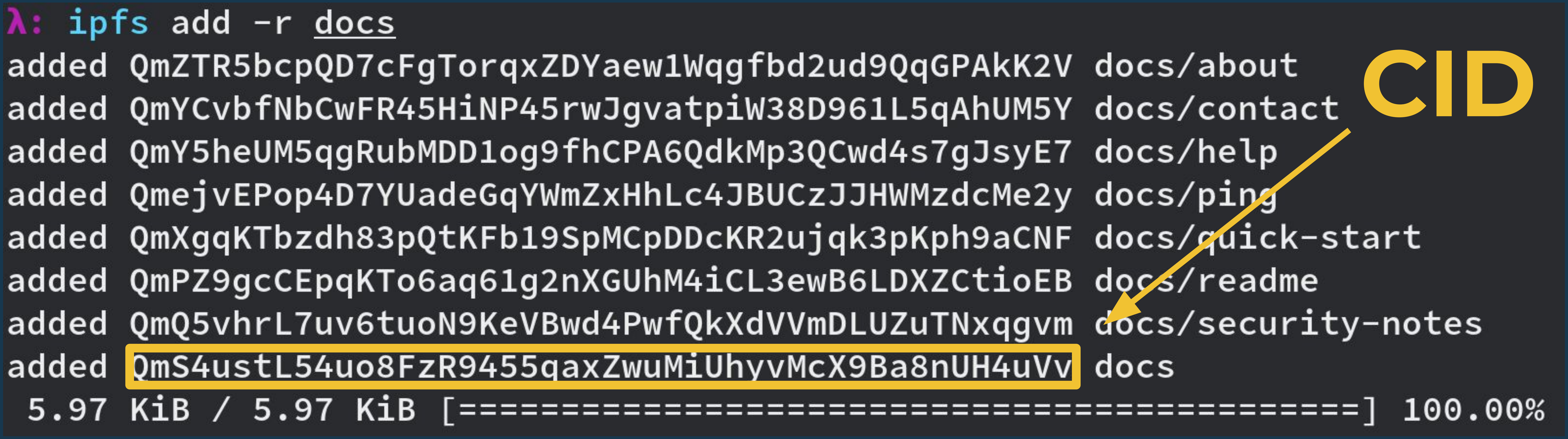
IPFS:

Adding Files



```
λ: ipfs add -r docs
added QmZTR5bcpQD7cFgTorqxZDYaew1Wqgfbd2ud9QqGPAkK2V docs/about
added QmYCvbfNbCwFR45HiNP45rwJgvatpiW38D961L5qAhUM5Y docs/contact
added QmY5heUM5qgRubMDD1og9fhCPA6QdkMp3QCwd4s7gJsyE7 docs/help
added QmejvEPop4D7YUadeGqYWmZxHhLc4JBUCzJJHWMzdcMe2y docs/ping
added QmXgqKTbzdh83pQtKFb19SpMCpDDcKR2ujqk3pKph9aCNF docs/quick-start
added QmPZ9gcCEpqKTo6aq61g2nXGUhM4iCL3ewB6LDXZCtioEB docs/readme
added QmQ5vhrL7uv6tuoN9KeVBwd4PwfQkXdVVmDLUZuTNxqgvm docs/security-notes
added QmS4ustL54uo8FzR9455qaxZwuMiUhyvMcX9Ba8nUH4uVv docs
 5.97 KiB / 5.97 KiB [============================================] 100.00%
```

IPFS:
Adding Files



```
λ: ipfs add -r docs
added QmZTR5bcpQD7cFgTorqxZDYaew1Wqgfbd2ud9QqGPAkK2V docs/about
added QmYCvbfNbCwFR45HiNP45rwJgvatpiW38D961L5qAhUM5Y docs/contact
added QmY5heUM5qgRubMDD1og9fhCPA6QdkMp3QCwd4s7gJsyE7 docs/help
added QmejvEPop4D7YUadeGqYWmZxHhLc4JBUCzJJHWMzdcMe2y docs/ping
added QmXgqKTbzdh83pQtKFb19SpMCpDDcKR2ujqk3pKph9aCNF docs/quick-start
added QmPZ9gcCEpqKTo6aq61g2nXGUhM4iCL3ewB6LDXZCtioEB docs/readme
added QmQ5vhrL7uv6tuoN9KeVBwd4PwfQkXdVVmDLUZuTNxqgvm docs/security-notes
added QmS4ustL54uo8FzR9455qaxZwuMiUhyvMcX9Ba8nUH4uVv docs
 5.97 KiB / 5.97 KiB [==========================] 100.00%
```

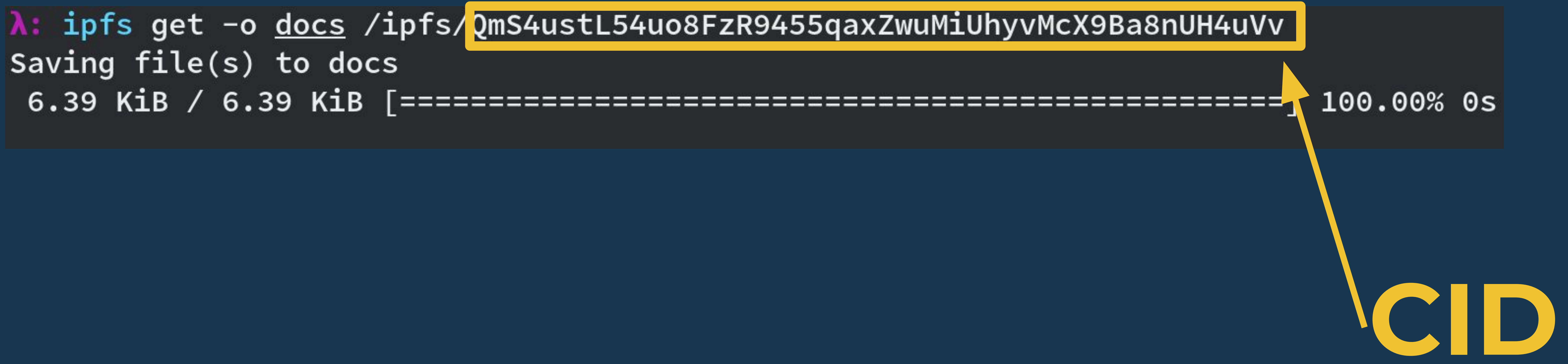
-> **CID: Content Identifier**

-> **IPFS Path: /ipfs/QmS4ustL54uo8FzR9455qaxZwuMiUhyvMcX9Ba8nUH4uVv**

-> **Gateway URL: https://ipfs.io/ipfs/QmS4ustL54uo8FzR9455qaxZwuMiUhyvMcX9Ba8nUH4uVv**

IPFS:

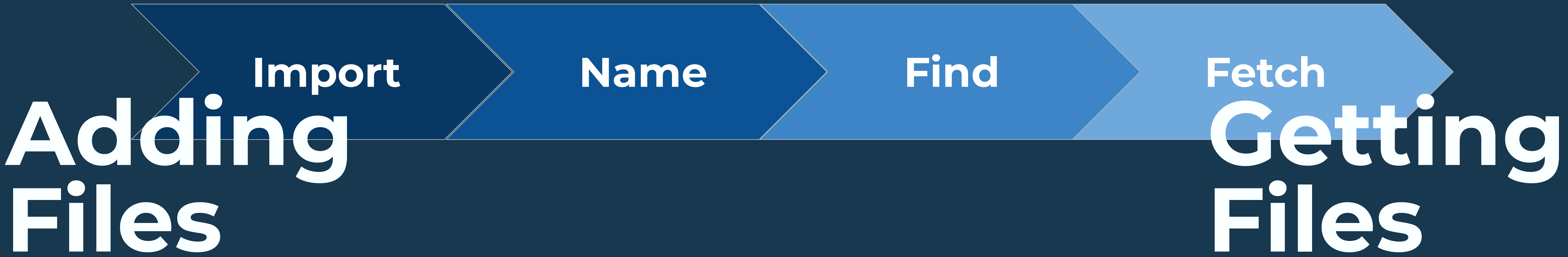
Getting Files



```
λ: ipfs get -o docs /ipfs/QmS4ustL54uo8FzR9455qaxZwuMiUhyvMcX9Ba8nUH4uVv
Saving file(s) to docs
 6.39 KiB / 6.39 KiB [=================================================] 100.00% 0s
```

IPFS:

Lifecycle



IPFS

Import → **Name** → **Find** → **Fetch**

Import	Name	Find	Fetch
Chunking	CID	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	

Import → Name → Find → Fetch

Import	Name	Find	Fetch
Chunking	CID	Routing	Bitswap
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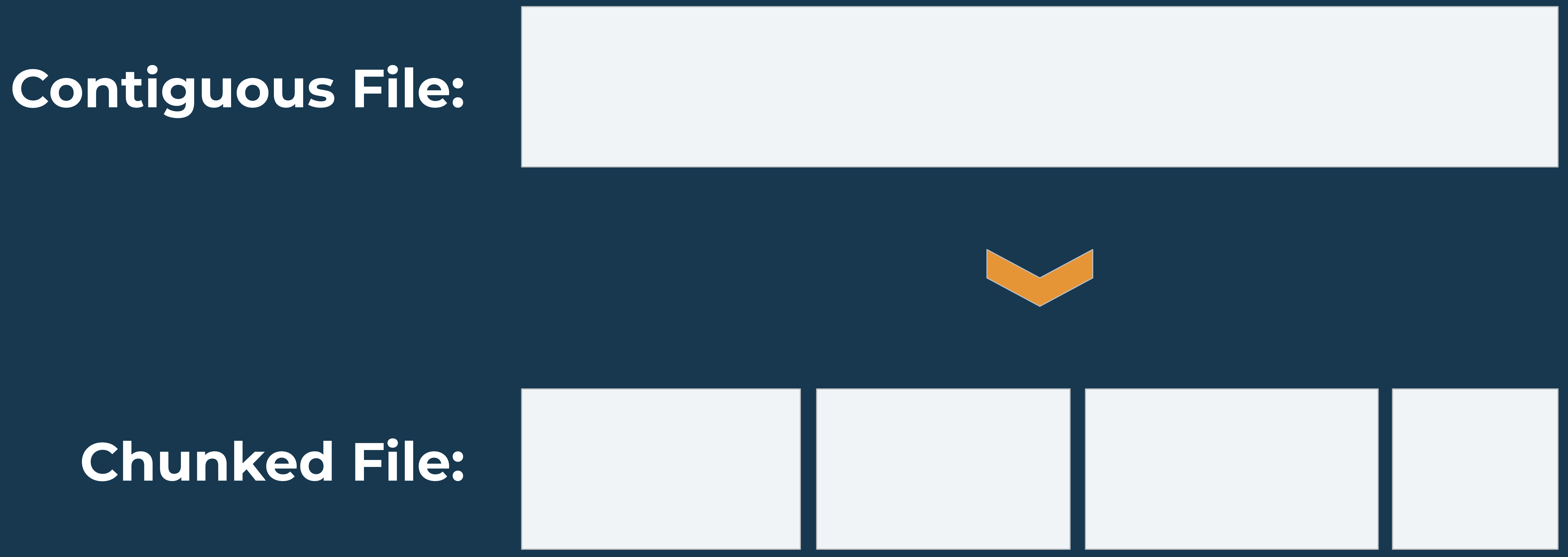
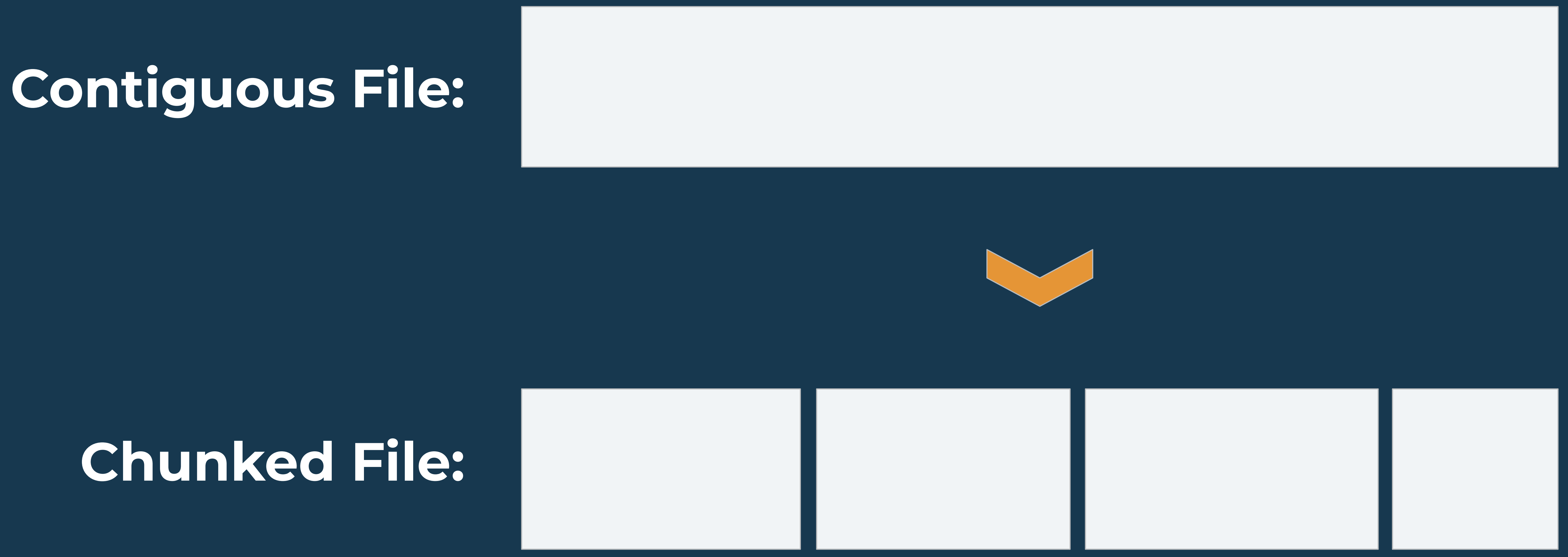


(each chunk is hashed)

- Deduplication
- Piecewise Transfer
- Seeking

Import → Name → Find → Fetch

Import	Name	Find	Fetch
Chunking	CID	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	



- **Deduplication**
- Piecewise Transfer
- Seeking

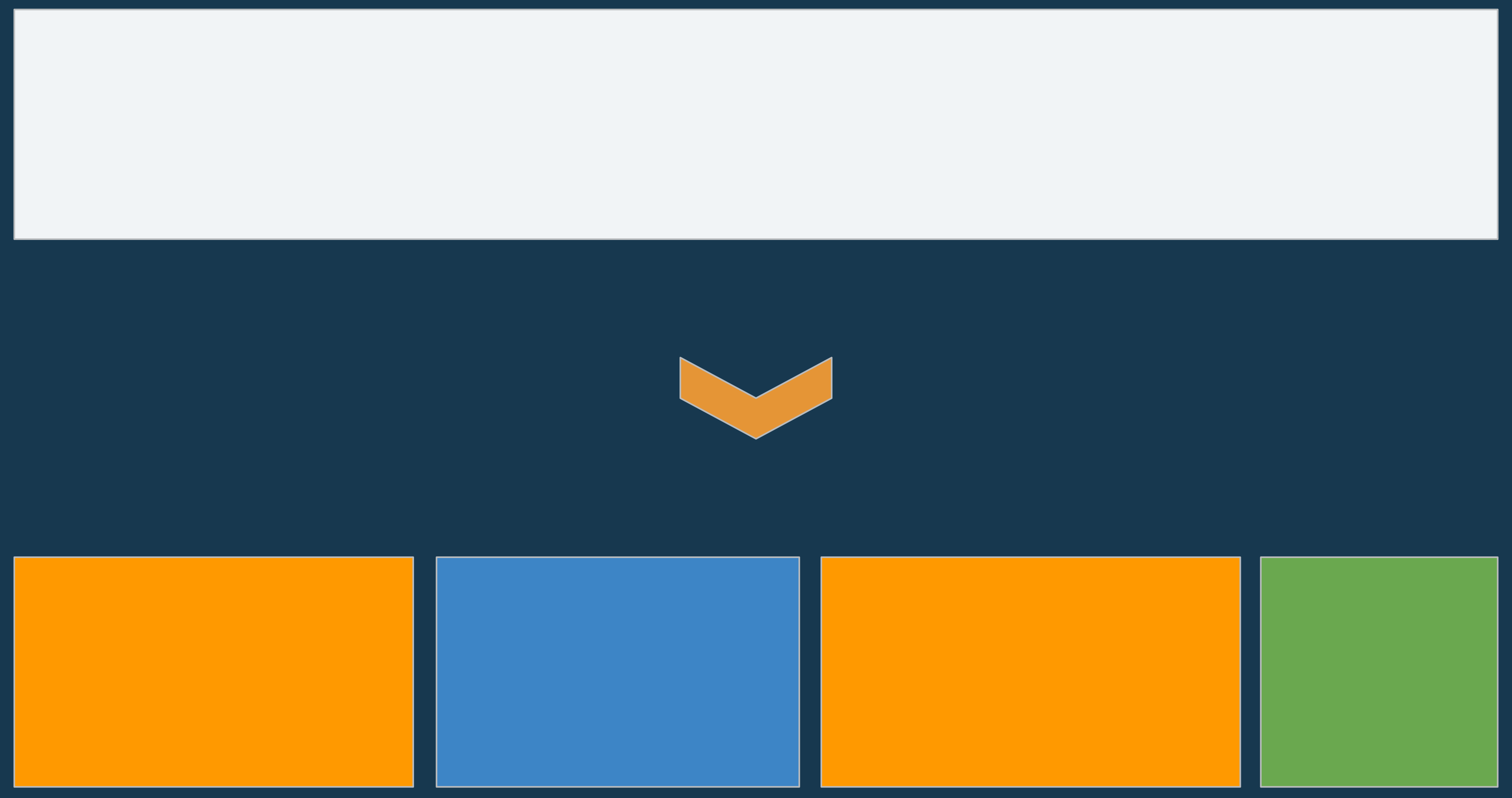
Import | Name | Find | Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap



- **Deduplication**
- Piecewise Transfer
- Seeking

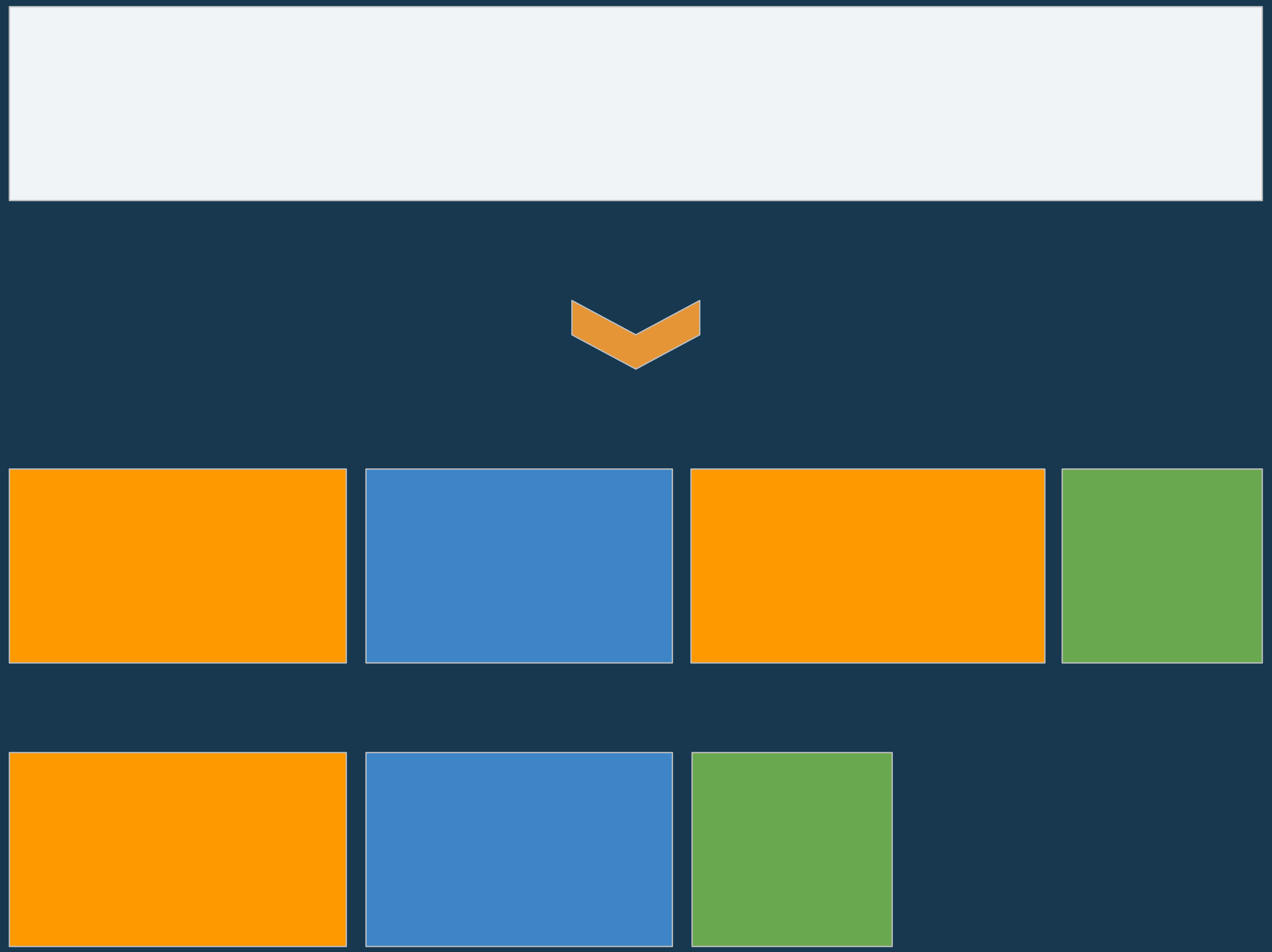
Import | Name | Find | Fetch

Chunking
UnixFS
IPLD

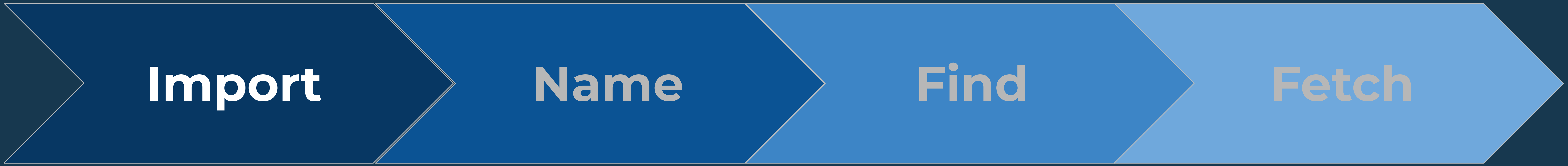
CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap



- **Deduplication**
- Piecewise Transfer
- Seeking

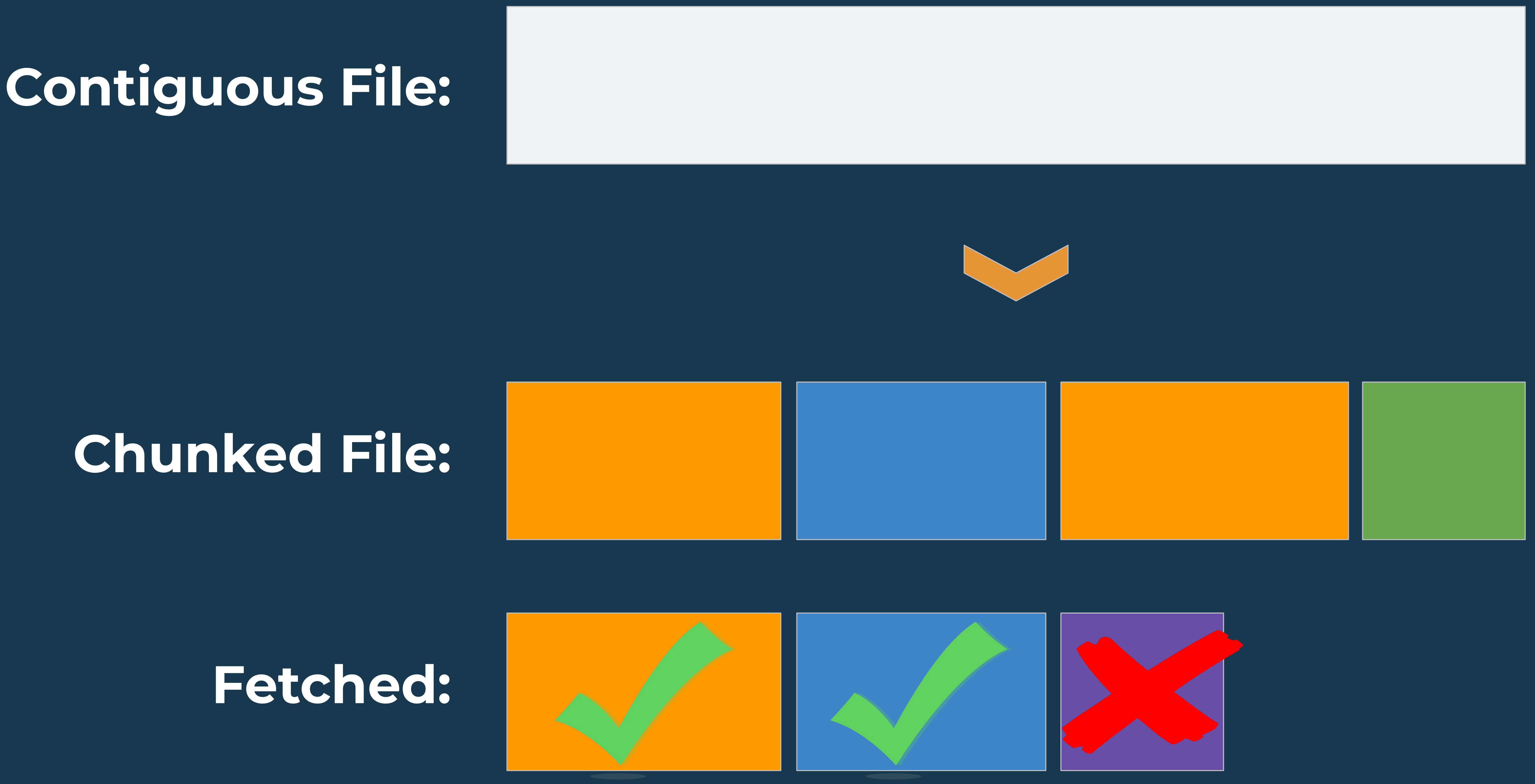


Chunking
UnixFS
IPLD

CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap



- Deduplication
- **Piecewise Transfer**
- Seeking

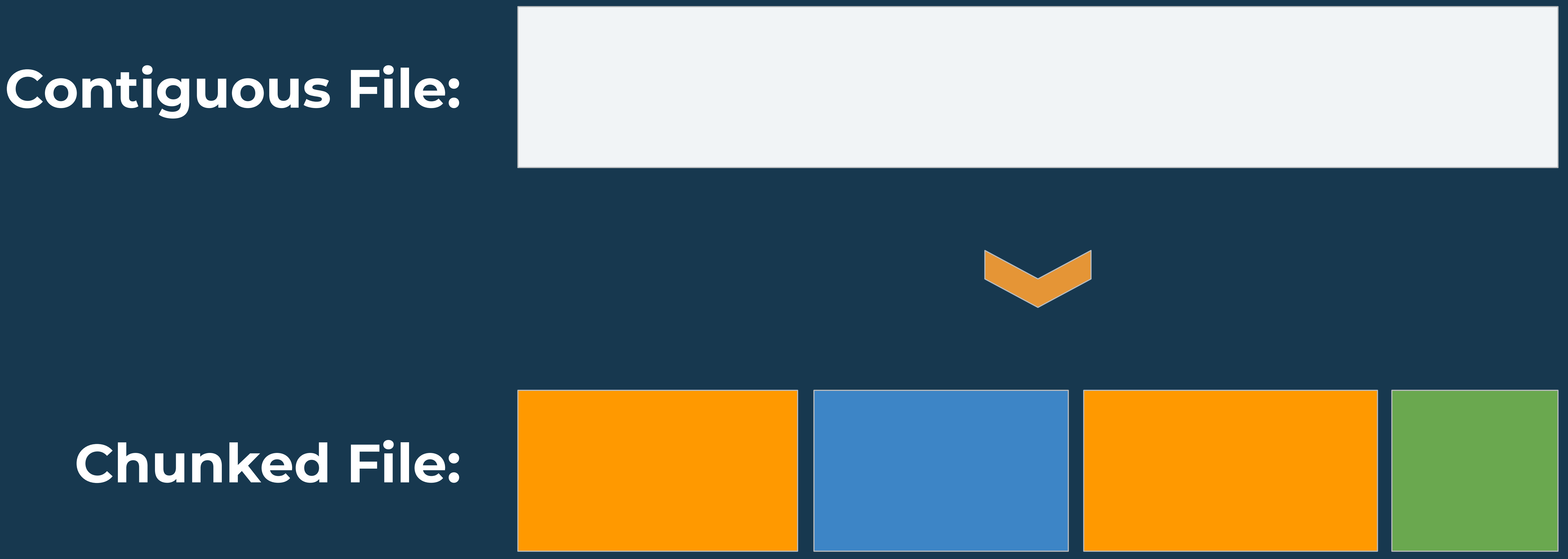
Import | Name | Find | Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap



- Deduplication
- Piecewise Transfer
- **Seeking**

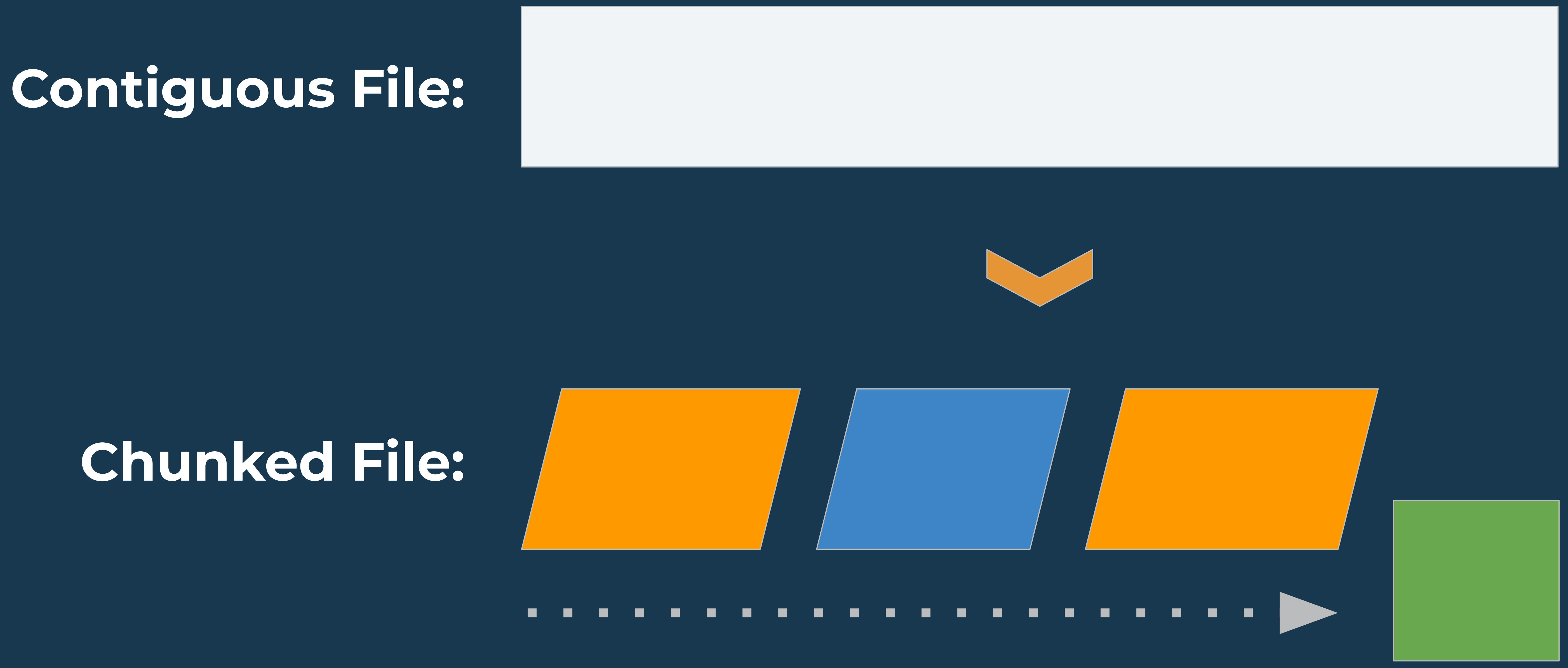
Import | Name | Find | Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap



- Deduplication
- Piecewise Transfer
- **Seeking**

Import Name Find Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap

File Chunks:

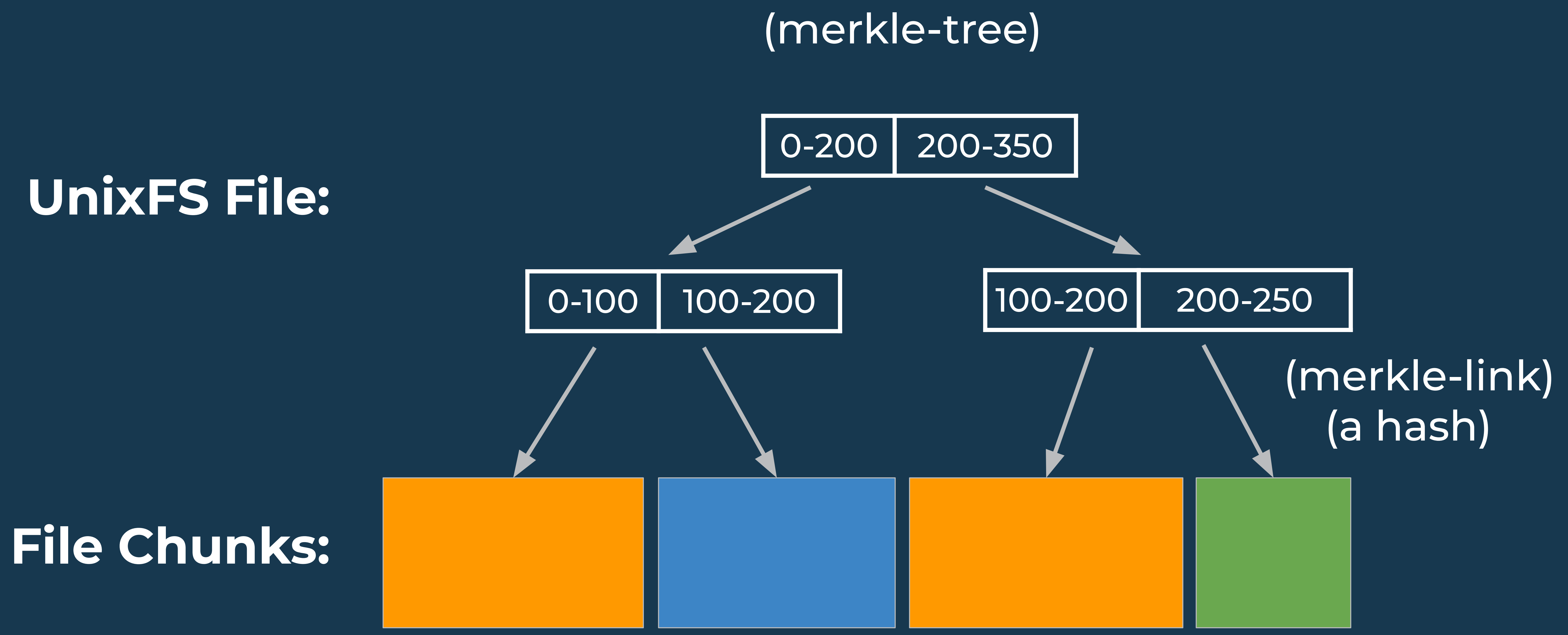
Import | Name | Find | Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap



Import Name Find Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

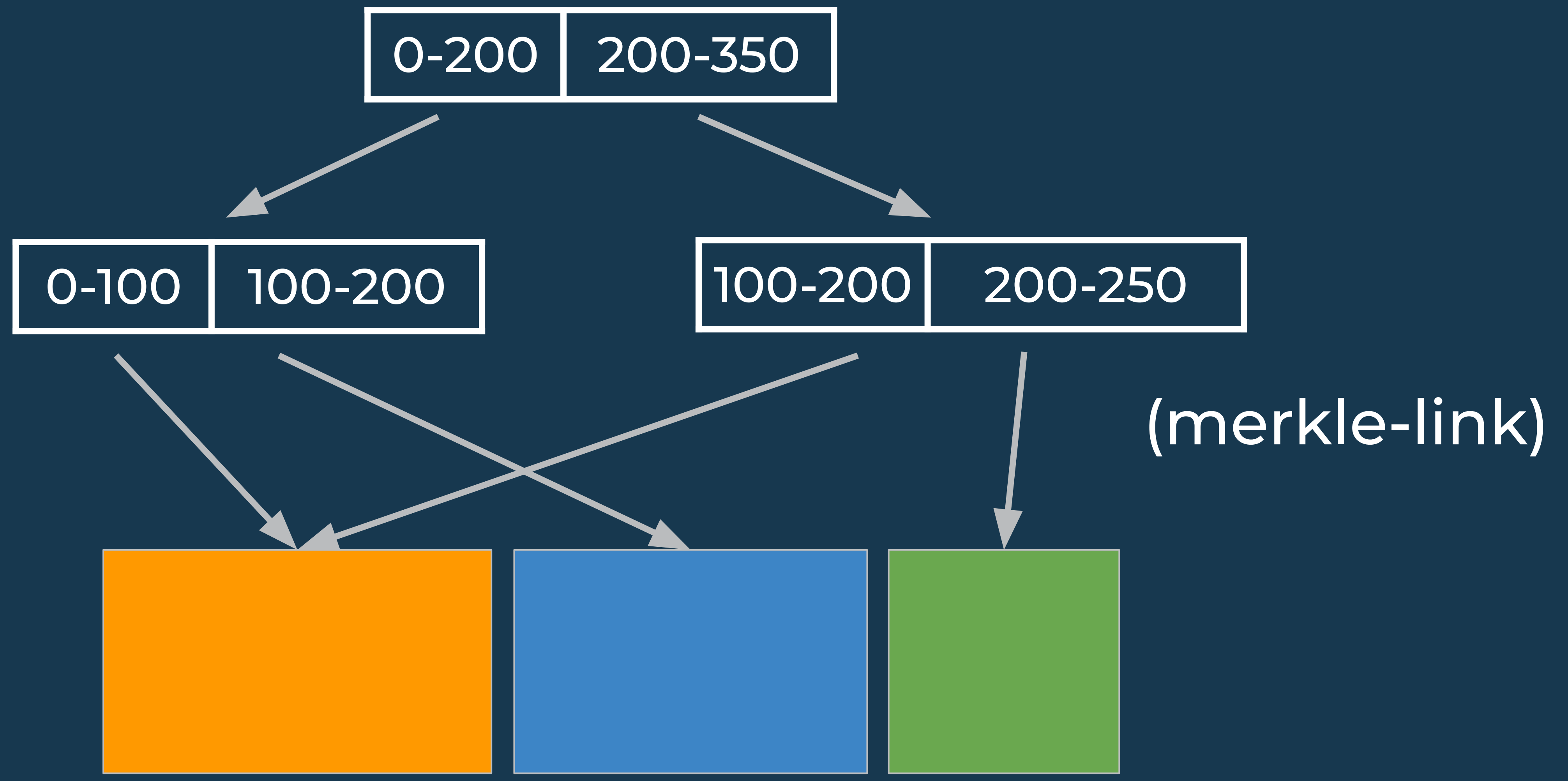
Routing
DHT
Kademlia

Bitswap

(merkle-~~tree~~-***dag***) - directed acyclic graph

UnixFS File:

File Chunks:



Import → Name → Find → Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

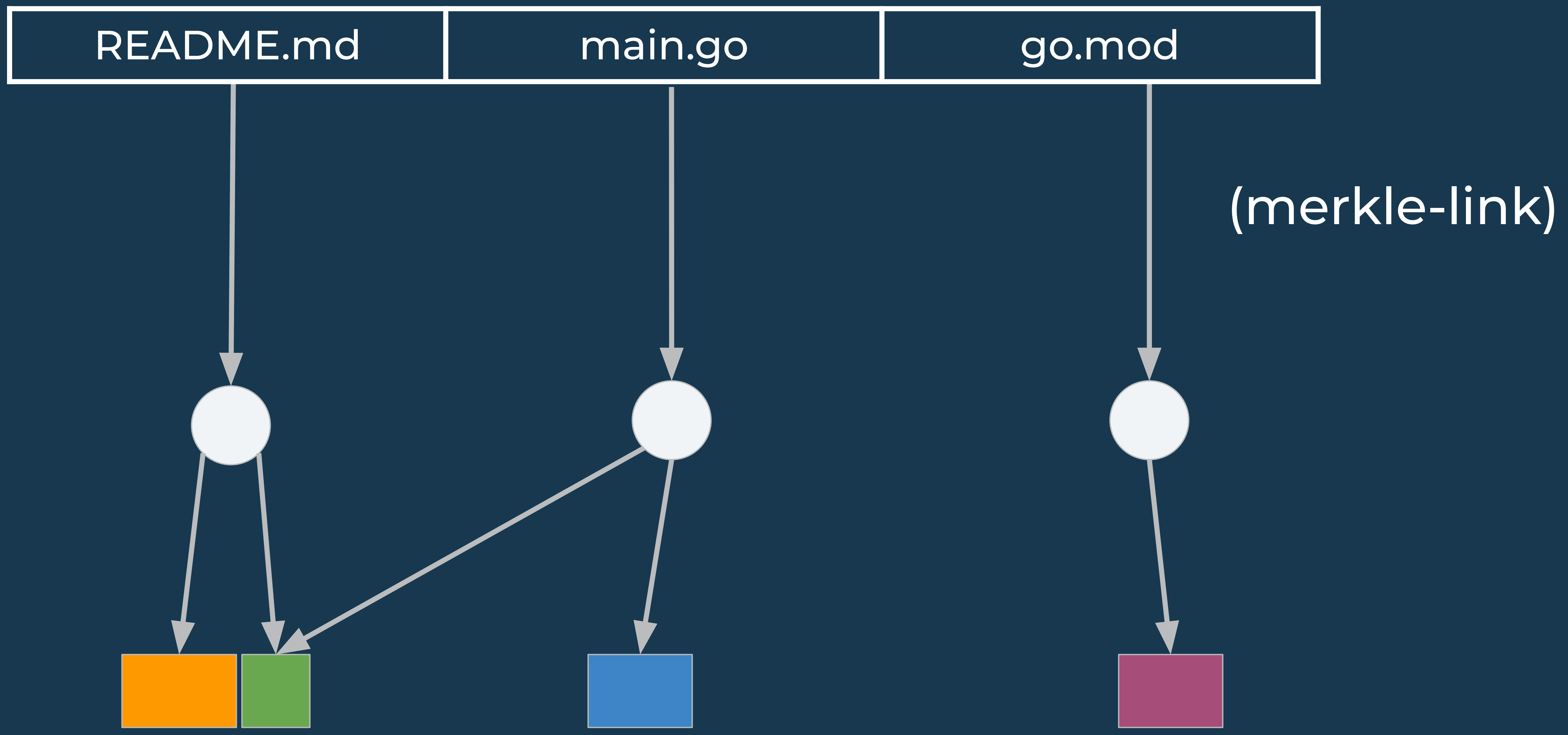
Routing
DHT
Kademlia

Bitswap

UnixFS Directory:

UnixFS File(s):

File Chunks:



Import	Name	Find	Fetch
Chunking	CID	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	

Meta-format for understanding, encoding, and decoding merkle-linked data.

IPFS

Import	Name	Find	Fetch
Chunking	CID	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	

Linked Data

```
http://b.com/Bar.json -> {
    "foo": http://a.com/Foo.json
}
http://a.com/Foo.json -> {
    "content": "I am foo"
}
```

Import | Name | Find | Fetch

Import	Name	Find	Fetch
Chunking	CID	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	

Linked Data

```
http://b.com/Bar.json -> {
    "foo": http://a.com/Foo.json
}
http://a.com/Foo.json -> {
    "content": "I am foo"
}
```

Authority

Import | Name | Find | Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap

Merkle-Linked Data

```
QmBar -> {
    "foo": QmFoo
}
QmFoo -> {
    "content": "I am foo"
}
```

- Immutable
- Authority Less

Import | **Name** | Find | Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap

Content Identifier

QmS4ustL54uo8FzR9455qaxZwuMiUhyvMcX9Ba8nUH4uVv

bafybeibxm2nsadl3fnxv2sxcxmxaco2jl53wpeorjdzidjwf5aqdg7wa6u

- Used for **content addressing**
- Are **self describing**
- Used to name every piece of data in IPFS/IPLD
- Are basically a **hash** with some **metadata**

Import → **Name** → Find → Fetch

Import	Name	Find	Fetch
Chunking	**CID**	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	

Digression:

Content Addressing / Location Addressing

Import | **Name** | Find | Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap

Digression: Content Addressing

Location Addressing

"My cat, Ozzy, is here."

Import → **Name** → Find → Fetch

Import	Name	Find	Fetch
Chunking	**CID**	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	

Content Addressing

"This is my cat, Ozzy."

Import | Name | Find | Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap

Digression: Content Addressing

Location Addressing

Import | Name | Find | Fetch

Chunking
UnixFS
IPLD

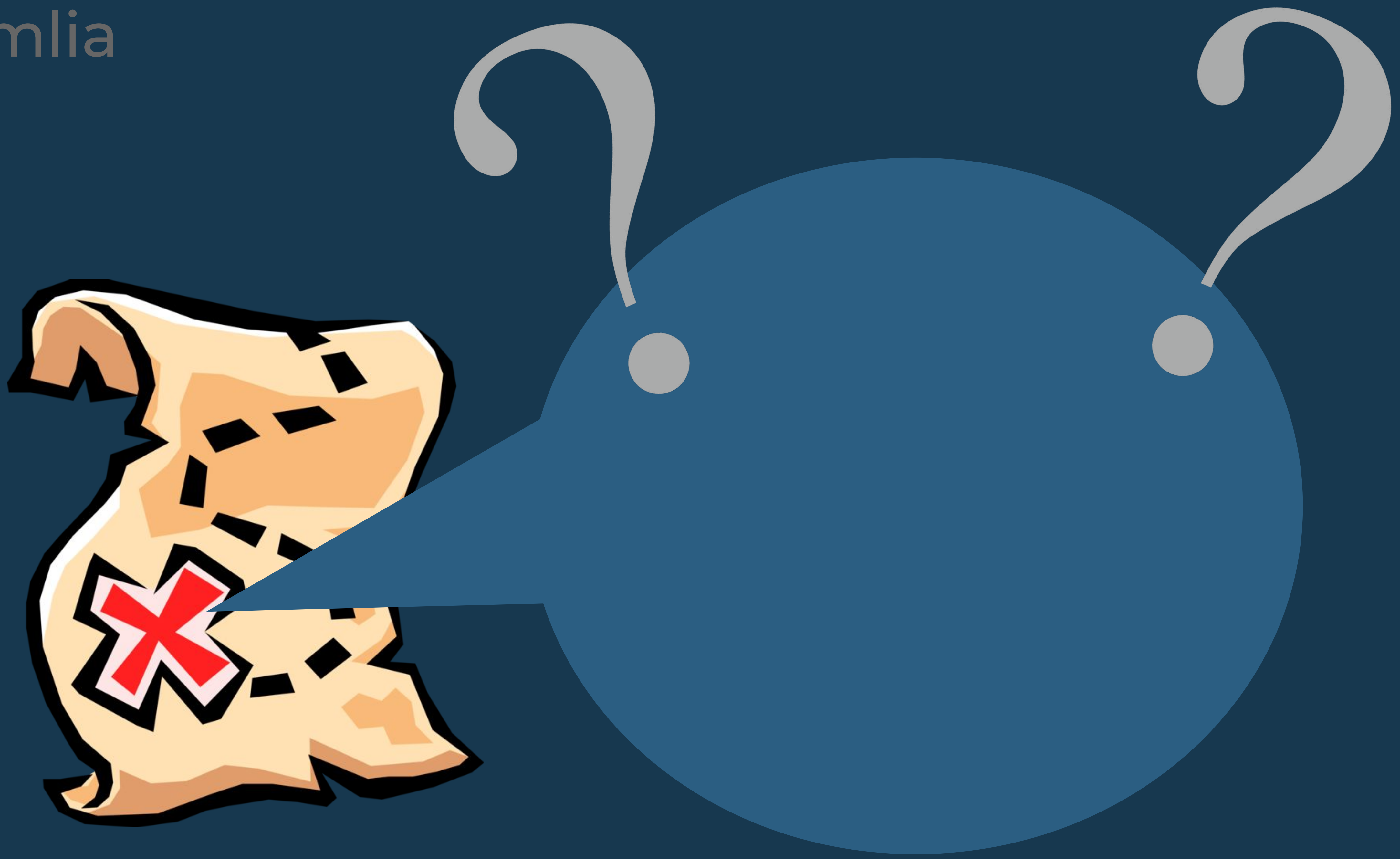
CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap

Digression: Content Addressing

Location Addressing



Import Name Find Fetch

Import	Name	Find	Fetch
Chunking	**CID**	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	

Digression: Content Addressing

Location Addressing

Import → Name → Find → Fetch

Import	Name	Find	Fetch
Chunking	**CID**	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	

Digression: Content Addressing

Location Addressing

"That's the wrong cat!"

Import | Name | Find | Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap

Digression: Content Addressing

Location Addressing

"That's the wrong cat!"

(But you can't know that!)

Import | **Name** | Find | Fetch

Chunking
UnixFS
IPLD

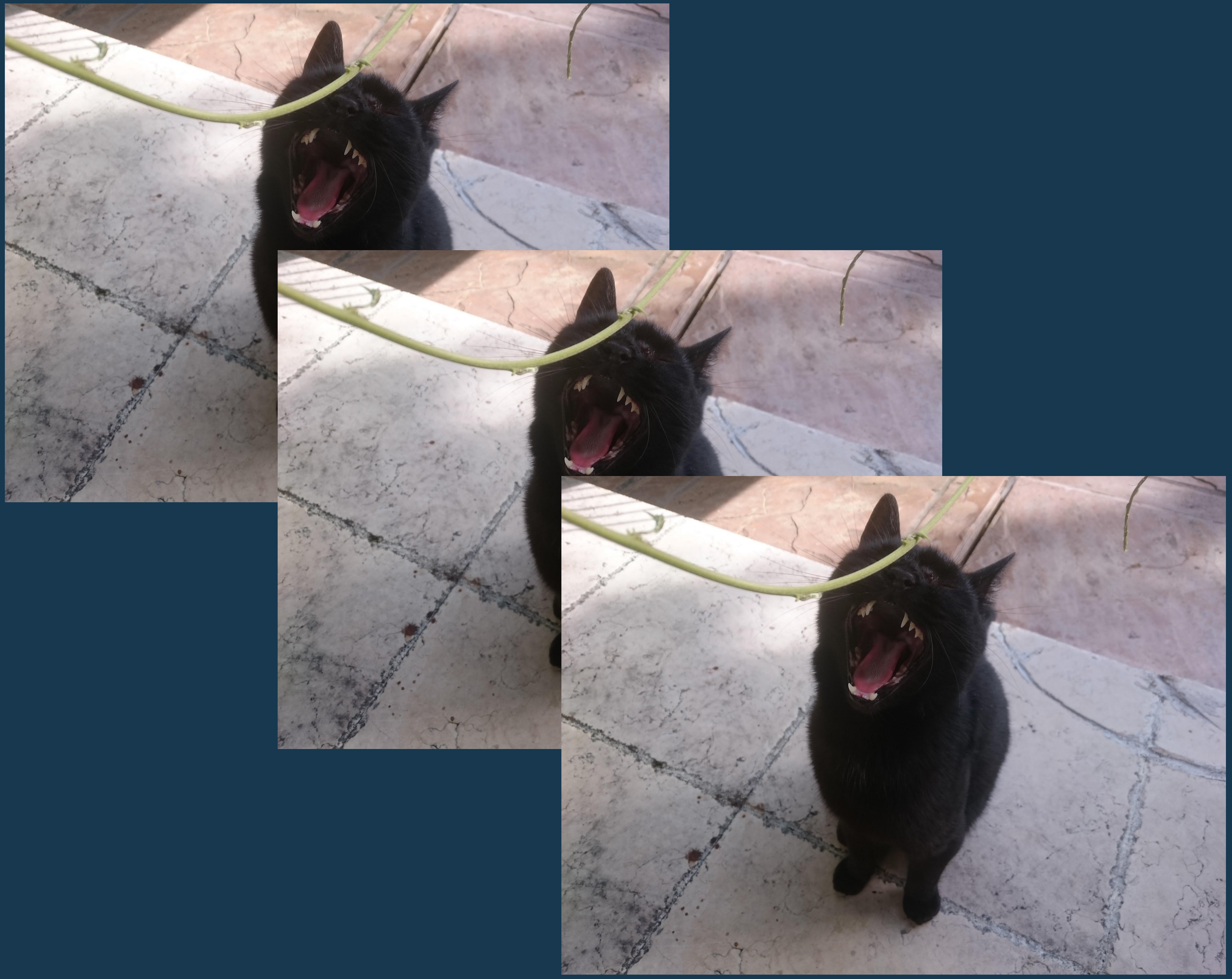
CID
Path
IPNS

Routing
DHT

Bitswap

Verifiable, Immutable, **Trustless**

Permanent



Import	**Name**	Find	Fetch
Chunking	**CID**	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	

Digression:

Multiformats: Self Describing Data

Import	**Name**	Find	Fetch
Chunking	**CID**	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	

Digression: Multiformats

- Multicodec: a non-magic number to uniquely identify a format, protocol, etc.
- Multihash: a self describing hash digest.
- Multibase: a self describing base-encoded string.

Import | **Name** | Find | Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap

Digression: Multiformats

Multicodec: a non-magic number.

```
name,           tag,            code,   description
identity,       multihash,      0x00,   raw binary
ip4,            multiaddr,      0x04,
dccp,           multiaddr,      0x21,
dnsaddr,        multiaddr,      0x38,
protobuf,       serialization,  0x50,   Protocol Buffers
cbor,           serialization,  0x51,   CBOR
raw,            ipld,           0x55,   raw binary
...
```

github.com/multiformats/multicodec

Import	**Name**	Find	Fetch
Chunking	**CID**	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	

Digression: Multiformats

Multihash: a self-describing hash digest:

- Hash Function (*multicodec*)
- Hash Digest Length
- Hash Digest

github.com/multiformats/multihash

Import | Name | Find | Fetch

Import	Name	Find	Fetch
Chunking	**CID**	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	

Digression: A bit of metadata

Multibase: a self-describing base encoding.

- A multibase prefix.
  - b - base32
  - z - base58
  - f - base16
- Followed by the base encoded data.

*b*afybeibxm2...

Import | **Name** | Find | Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap

Self Describing

- CIDv0: **Qm**S4u...
  - Base58 encoded sha256 multihash
- CIDv1: **bafy**bei...
  - Multibase encoded (ipld format multicodec, multihash) tuple.
- Why CIDv1?
  - Can be encoded in arbitrary bases (base32, base58, etc.).
  - Can link *between* merkle-dag formats using the *ipld format* multicodec.

Import → **Name** → Find → Fetch

Import	Name	Find	Fetch
Chunking	CID	Routing	Bitswap
UnixFS	**Path**	DHT	
IPLD	IPNS	Kademlia	

IPFS uses **paths**, not **URIs/URLs**:

Like URLs, paths are **namespaced**:

/ipfs/QmFoo/welcome.txt
/ipns/QmBar/index.html

Unlike URLs, paths are ***recursive***:

/dns/github.com/tcp/22/ssh/git

Versus:

git+ssh://github.com:22

Not Composable!

Import → **Name** → Find → Fetch

Import	Name	Find	Fetch
Chunking	CID	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	**IPNS**	Kademlia	

IPNS maps **Public Keys** to *paths*

/ipns/QmMyKey -> /ipfs/QmFoo (signed)

IPNS is *mutable*

/ipns/QmMyKey -> /ipfs/Qm**SomethingNew**

IPNS can point to arbitrary paths

/ipns/QmMyKey -> /ipns/Qm**YourKey**

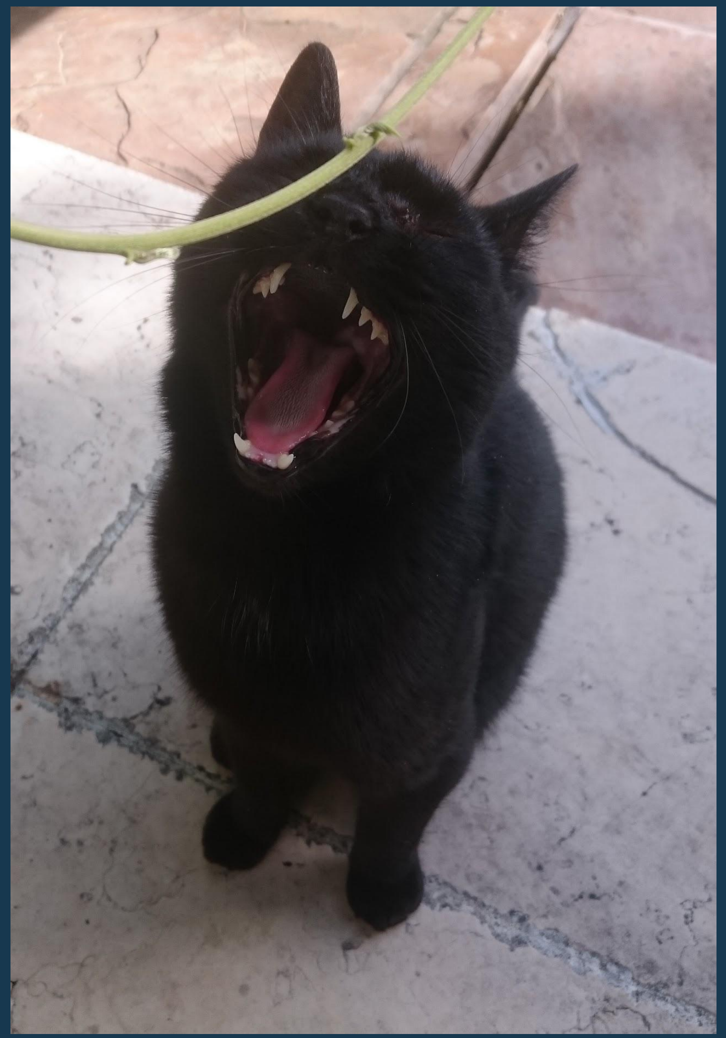
Import | Name | **Find** | Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap



Content Address (CID) → Location Address (Peer)

Import	Name	Find	Fetch
Chunking	CID	**Routing**	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	

Solution: Keep a "routing table"

What	**Who**
QmFoo	Ozzy
QmBar	Izzy

Import | Name | Find | Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap

But the table is too *BIG!*

What	Who
QmFoo	Ozzy
QmBar	Izzy
… *millions of lines later* …	
QmXXXXXXXXXXXXXXXX	Seth (not a cat!)

Import | Name | Find | Fetch

Import	Name	Find	Fetch
Chunking	CID	Routing	Bitswap
UnixFS	Path	**DHT**	
IPLD	IPNS	Kademlia	

Solution: *Distribute* the routing table and give a little bit to each peer.

Ozzy Knows

What	**Who**
QmBar	Izzy
...	

Izzy Knows

What	**Who**
QmFoo	Ozzy
...	

Import	Name	Find	Fetch
Chunking	CID	Routing	Bitswap
UnixFS	Path	**DHT**	
IPLD	IPNS	Kademlia	

How do we know who has what piece of the routing table?

Import	Name	Find	**Fetch**
Chunking	CID	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	**Kademlia**	

How do we know who has what piece of the routing table?

Solution: *Deterministically* distribute the routing table.

Import → Name → Find → **Fetch**

Import	Name	Find	Fetch
Chunking	CID	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	**Kademlia**	

Distance Metric: Is peer X closer to content C than peer Y?

Query Algorithm: Given the distance metric, how do we find the peers *closest* to C.

Import → Name → Find → Fetch

Import	Name	Find	Fetch
Chunking	CID	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	**Kademlia**	

Distance Metric: `XOR(HASH(C), HASH(Peer))`

Query Algorithm:

1. Ask the closest peers you know for closer peers.
2. Remember the closest peers.

Import → Name → Find → **Fetch**

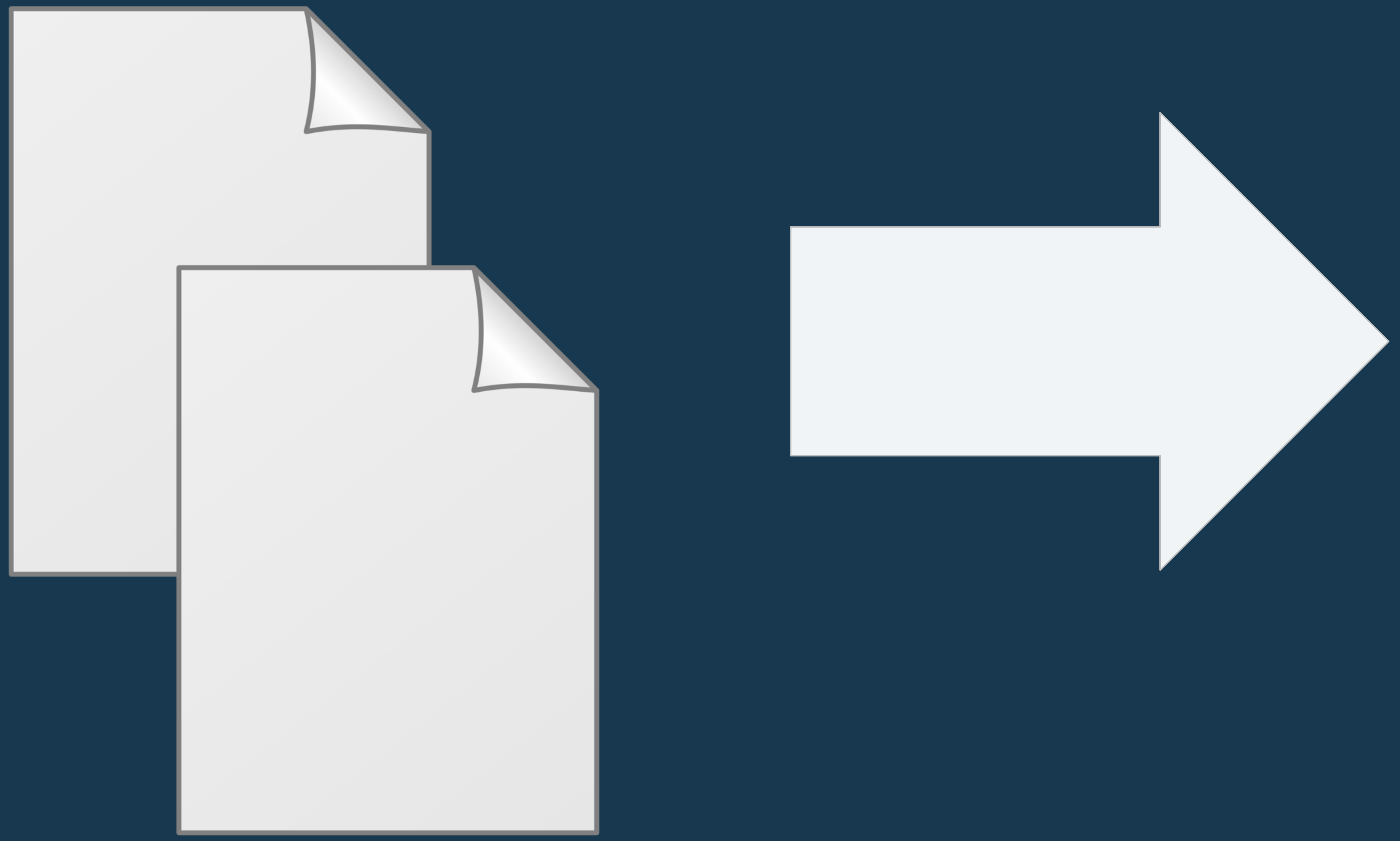
Import	Name	Find	Fetch
Chunking	CID	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	**Kademlia**	

Distance Metric: "Is this closer?"

Query Algorithm: "How do I get closer?"

Import Name Find **Fetch**

Import	Name	Find	Fetch
Chunking	CID	Routing	**Bitswap**
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	



Import → Name → Find → **Fetch**

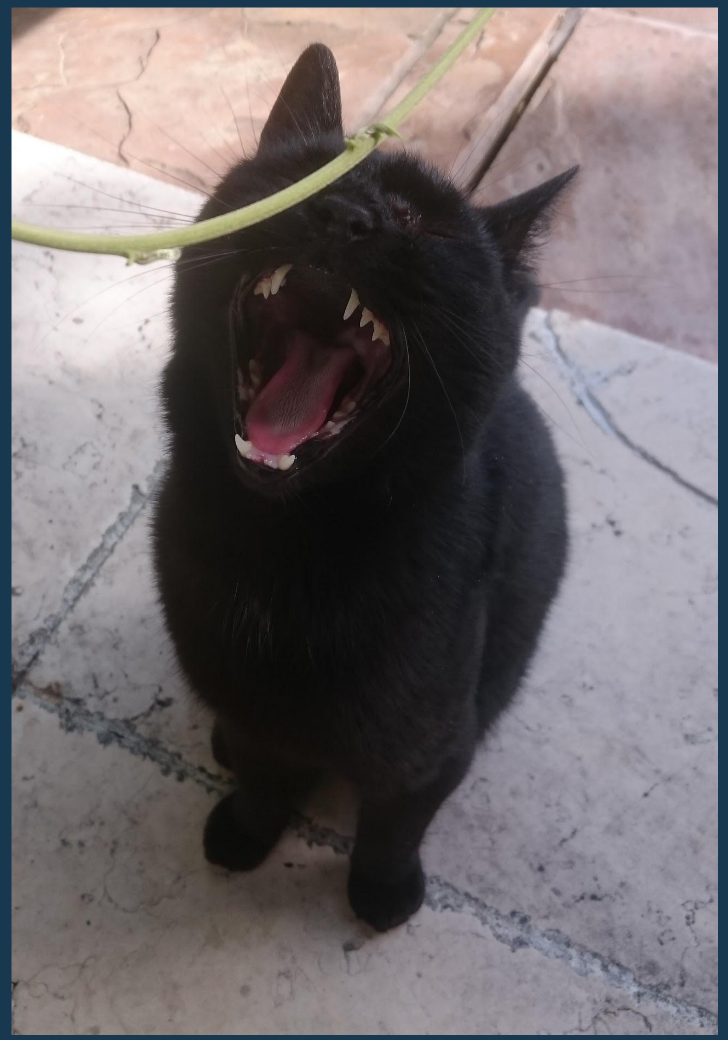
Import	Name	Find	Fetch
Chunking	CID	Routing	**Bitswap**
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	

Izzy Wants

- **QmTreats**
- **QmToy**

Ozzy Wants

- **QmCuddles**
- **QmFood**
- **QmAttention**



Izzy

↔

Ozzy

Import | Name | Find | Fetch

Chunking
UnixFS
IPLD

CID
Path
IPNS

Routing
DHT
Kademlia

Bitswap

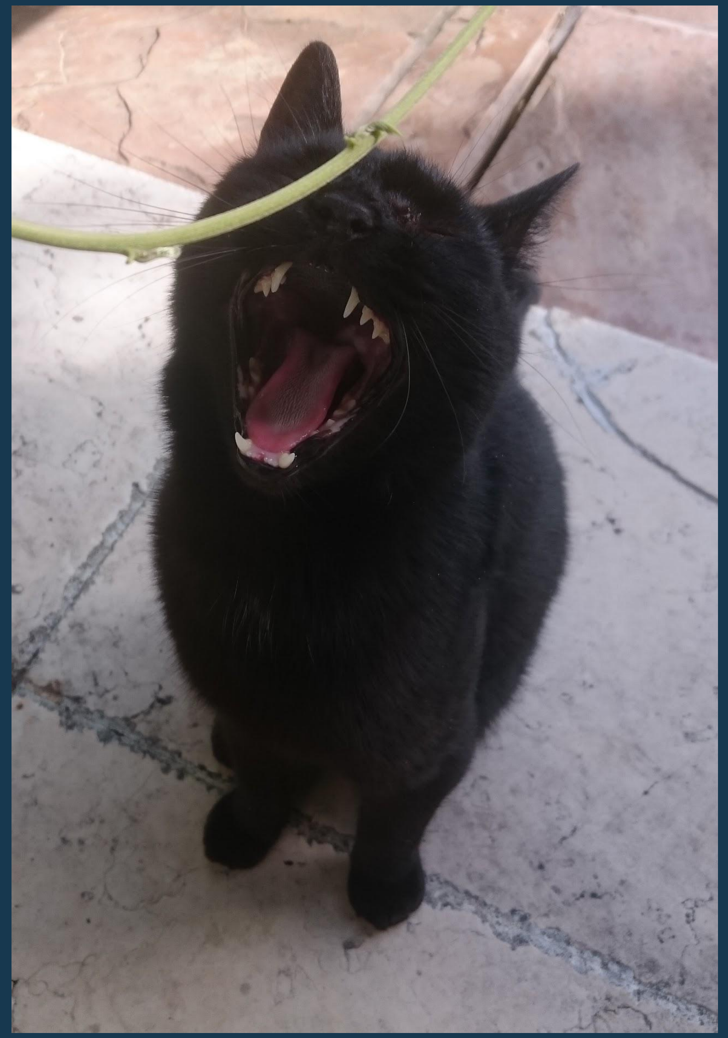
Izzy Wants

- QmTreats
- QmToy

Izzy

Ozzy Wants

- QmCuddles
- QmFood
- QmAttention



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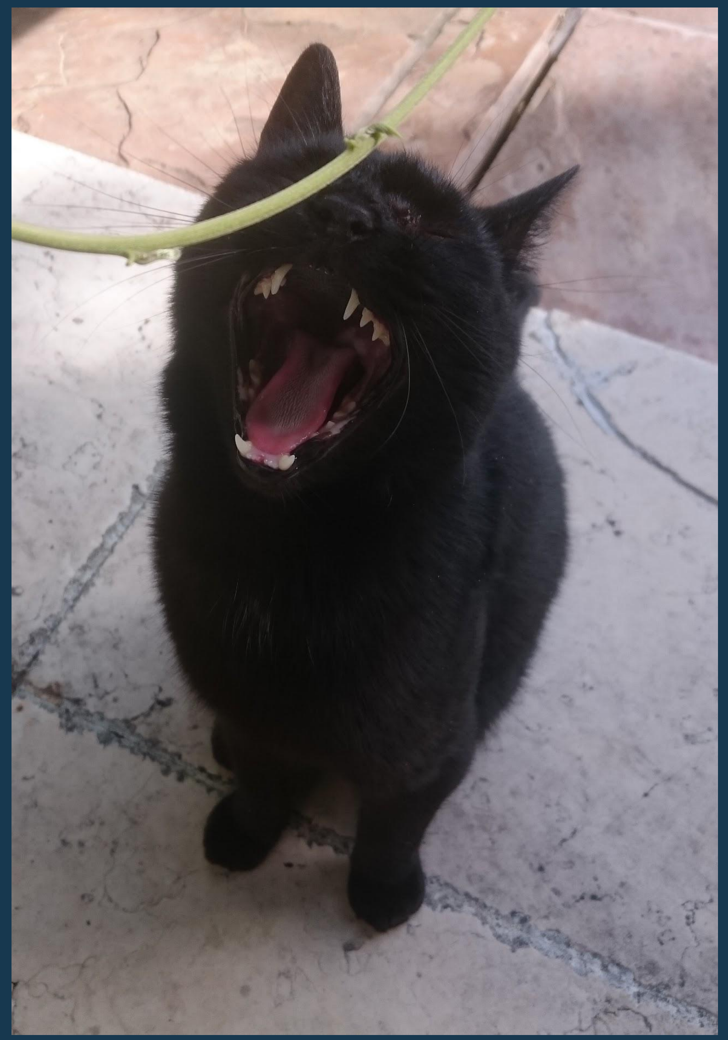

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QmToy

outing
HT
demlia

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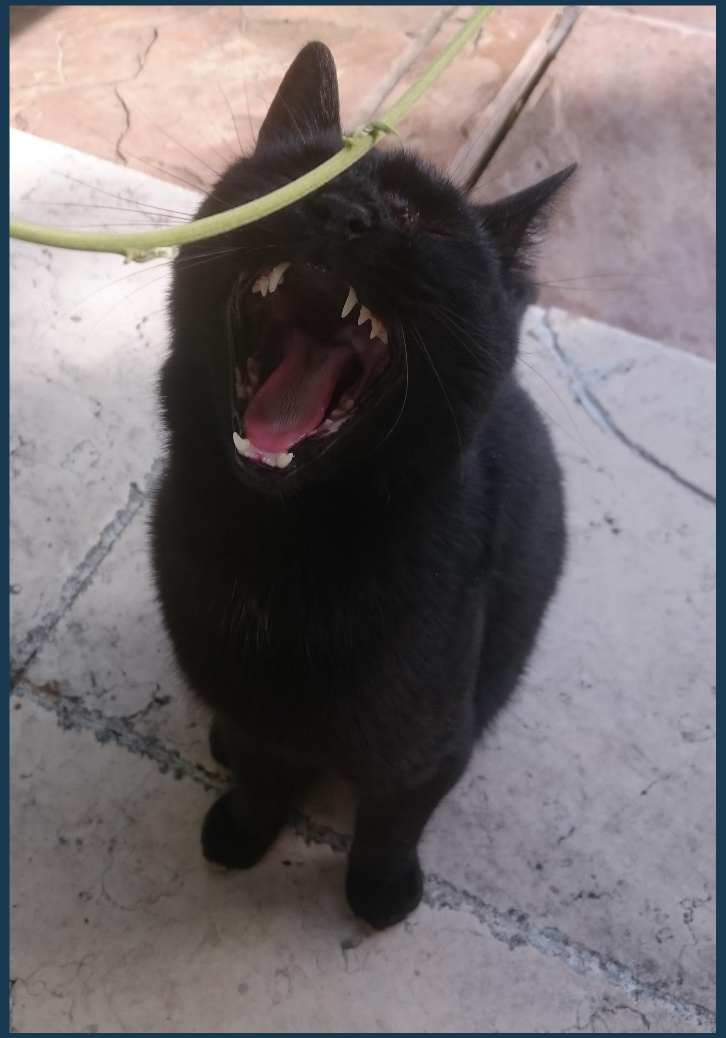
QmFood

QmAttention



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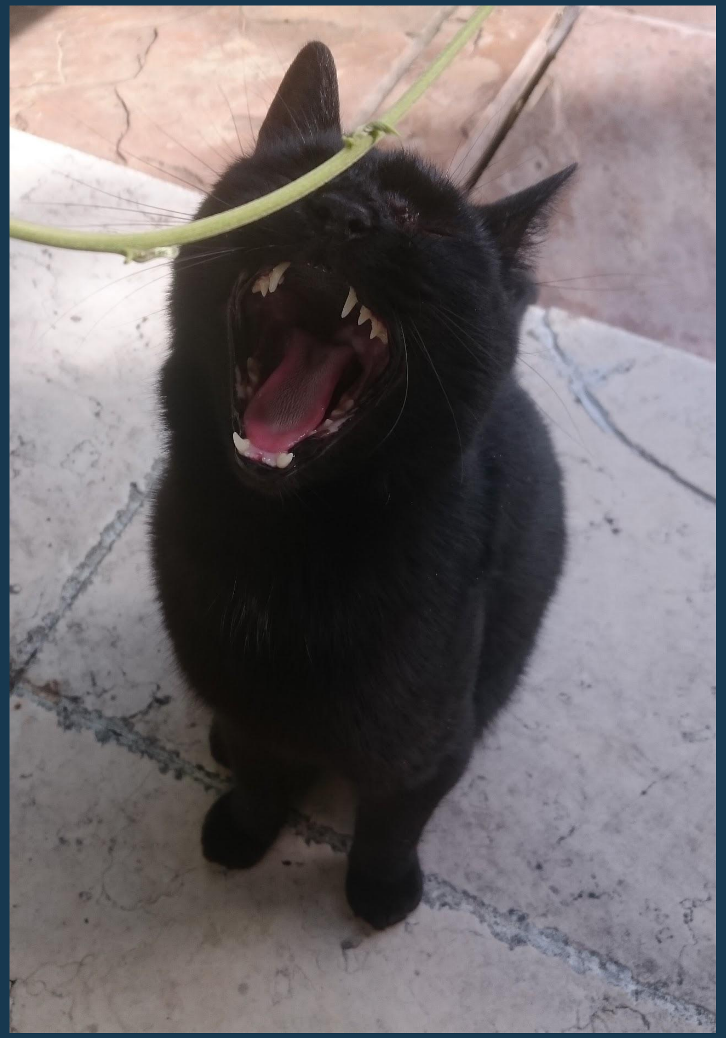

Ozzy

Import	Name	Find	Fetch
Chunking	CID	Routing	Bitswap
UnixFS	Path	DHT	
IPLD	IPNS	Kademlia	

How IPFS Works

(approximately)

Name (@github)
organization