

# ***The Dark Forest***

**A Distributed File System for Secure P2P Applications**

[github.com/wnfs-wg](https://github.com/wnfs-wg)  
[github.com/fission-codes](https://github.com/fission-codes)



**Brooklyn Zelenka**

@expede



# **Brooklyn Zelenka**

**@expede**



- Cofounder & CTO at Fission
  - @FissionCodes
  - <https://fission.codes>
  - Infra & SDK for edge apps
- Standards: UCAN, EIPs, FVM, Multiformats, CAR Pool, WNFS,&c

Meta

**WNFS**

Meta

**WNFS**



# Meta

## WNFS

- ◆ First principles, flipped tradeoffs
- ◆ "Can't be done" → super hard but ***works & scales!***
- ◆ Sharp corners
- ◆ Under explored design space
  - ◆ Databases, blind busses, nym servers, etc
- ◆ Novel ways to recombine a few ideas



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$\frac{2}{3}$

Secret  
Filesystem

$\frac{1}{3}$

Public  
Filesystem



Video Killed the Radio Star

***A New Environment***



A New Environment 🌴

***New Environment, Who Dis?***

A New Environment 🌴

# *New Environment, Who Dis?*

Then 🖨️

Now 🚀

A New Environment 🌴

# *New Environment, Who Dis?*

	Then 🖨️	Now 🚀
Need	Convenient 🙋	Critical 🚨

A New Environment 🌴

# *New Environment, Who Dis?*

	Then 🖨️	Now 🚀
Need	Convenient 🙋	Critical 🚨
Location	Data Centre 🏢	Powerful Clients (M1, IoT) 🕒 🚗 👟



A New Environment 🌴

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	Then 🖨️	Now 🚀
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Access	🖥️	📱

# A New Environment 🌴

# *New Environment, Who Dis?*

	Then 🖨️	Now 🚀
Need	Convenient 🙋	Critical 🚨
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Access		
Bottleneck	Bandwidth 🚚	Latency 🕒

# A New Environment 🌴

# *New Environment, Who Dis?*

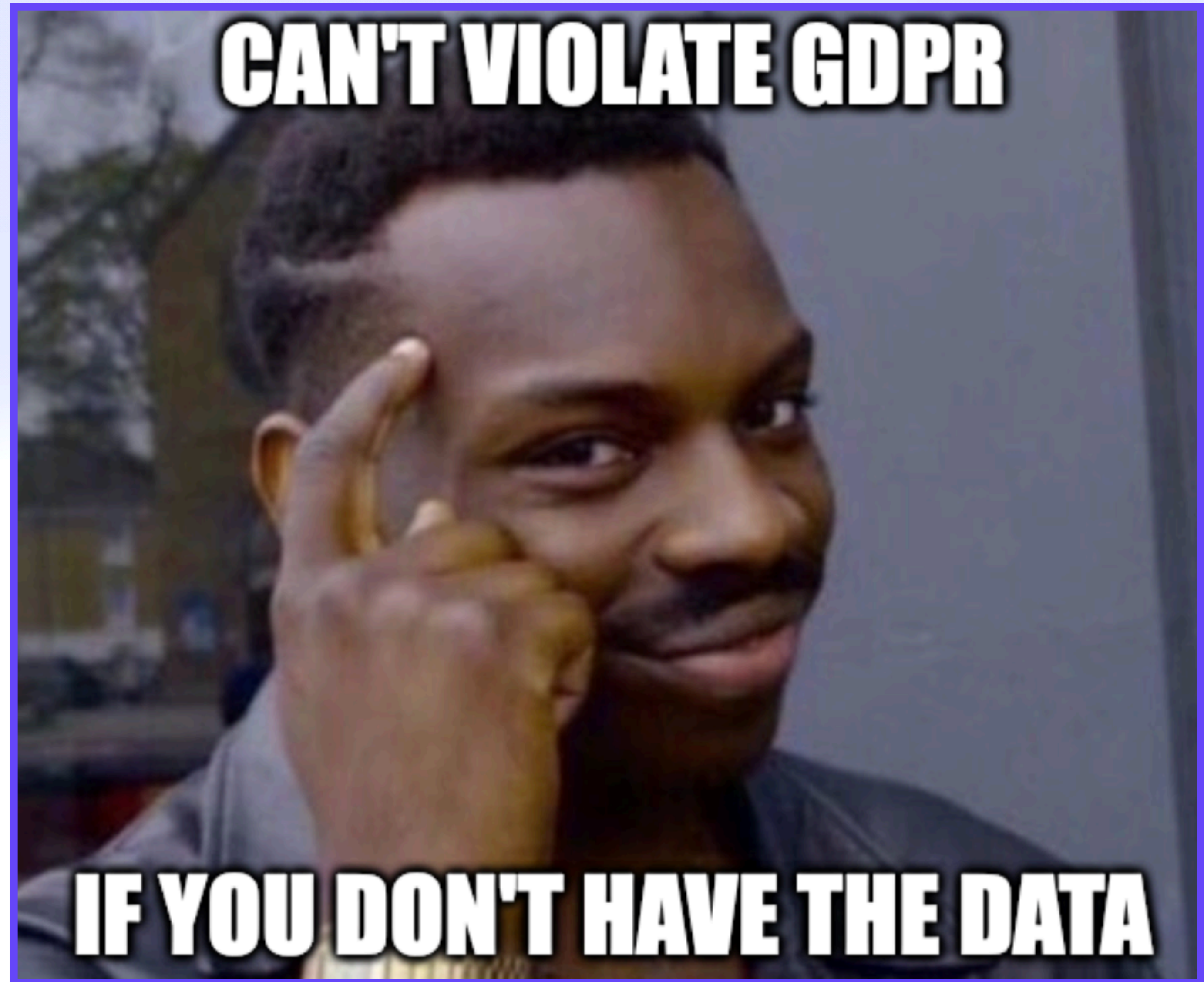
	Then 🖨️	Now 🚀
Need	Convenient 🧑	Critical 🚨
Location	Data Centre 🏢	Powerful Clients (M1, IoT) 🕒 🚗 📖
Access	🖥️	📱
Bottleneck	Bandwidth 🚚	Latency 🕒
Market	🇺🇸 🇪🇺	🌍 🌍 🌍 ... 🌕



A New Environment 🌴

## ***Toxic Data***

- **2005:** Credit card data in DB
- **2015:** Personal info in DB
- **2025:** Nothing in DB



A New Environment 🌴

# ***What LAMP Has Wrought***

A New Environment 🌴

# *What LAMP Has Wrought*

Users 🧑🏿 🧑🏻 🧑🏼 🧑🏽

Developer 🧑🏿💻

A New Environment 🌴

# *What LAMP Has Wrought*

Users 🧑🏿‍💻🧑🏻‍💻🧑🏼‍💻🧑🏭

Browser 🖥️

REST / JSON-RPC / GraphQL ⬆️⬆️

Server ⚙️

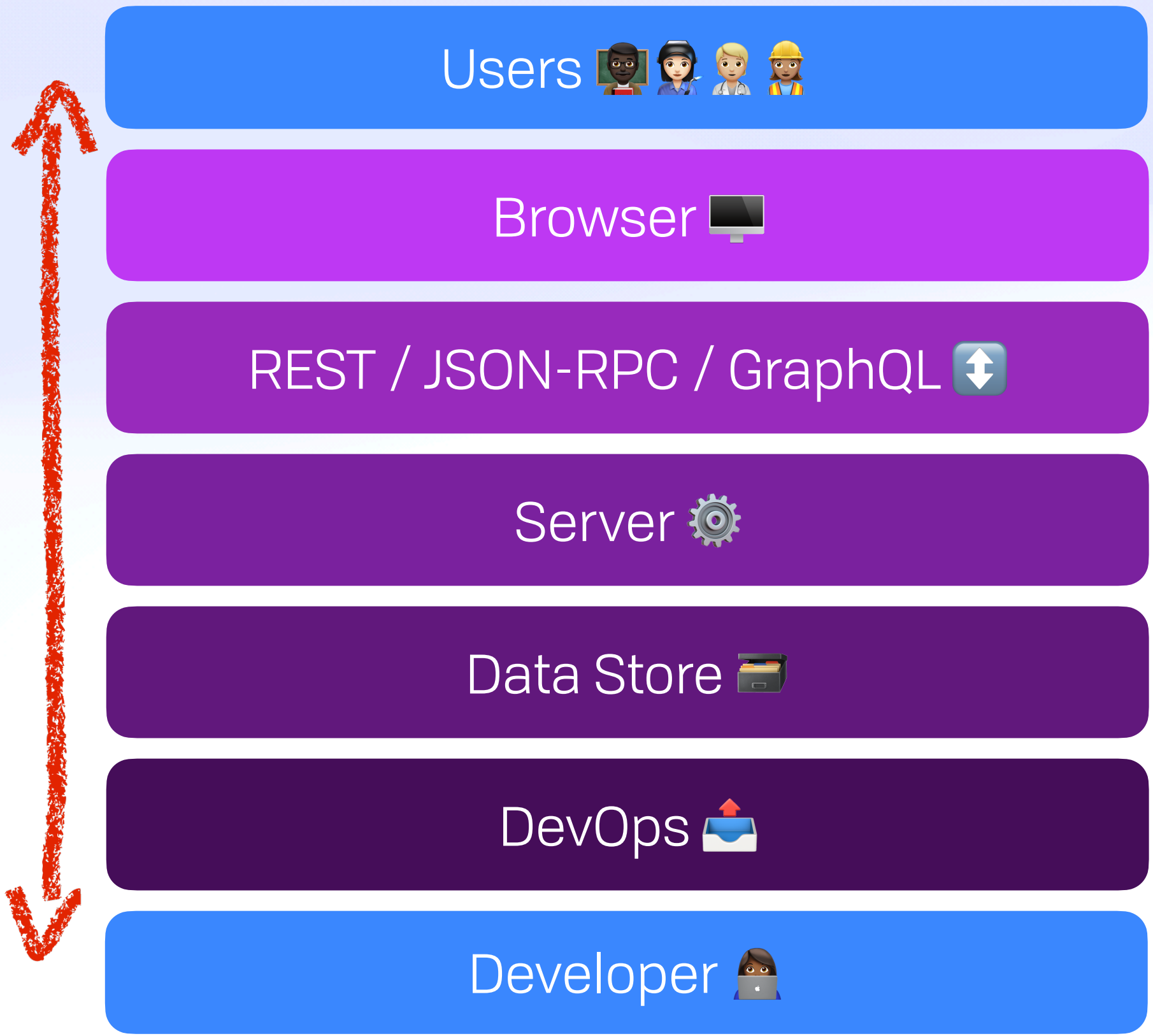
Data Store 🗄️

DevOps 📦

Developer 🧑🏿‍💻

A New Environment 🌴

# *What LAMP Has Wrought*

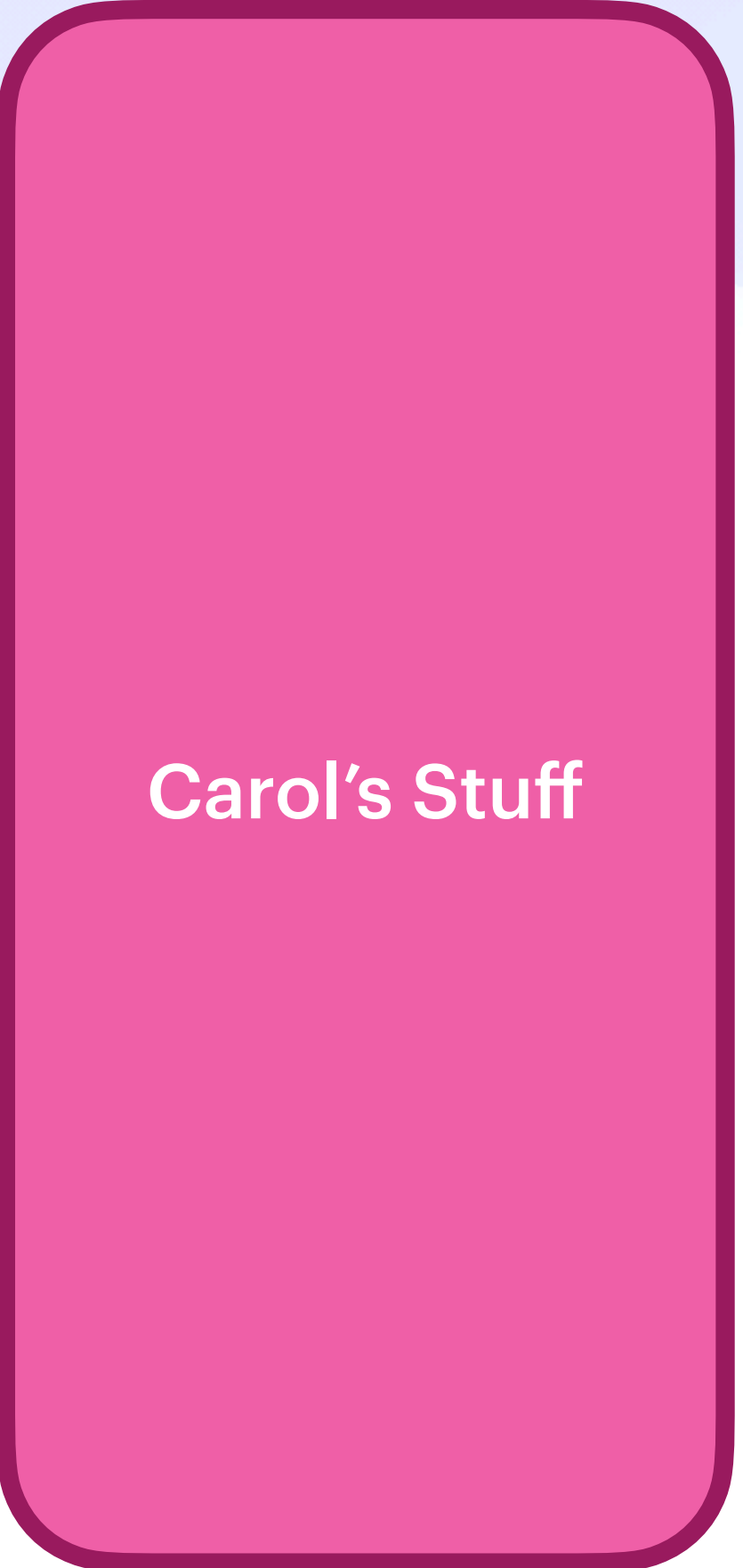
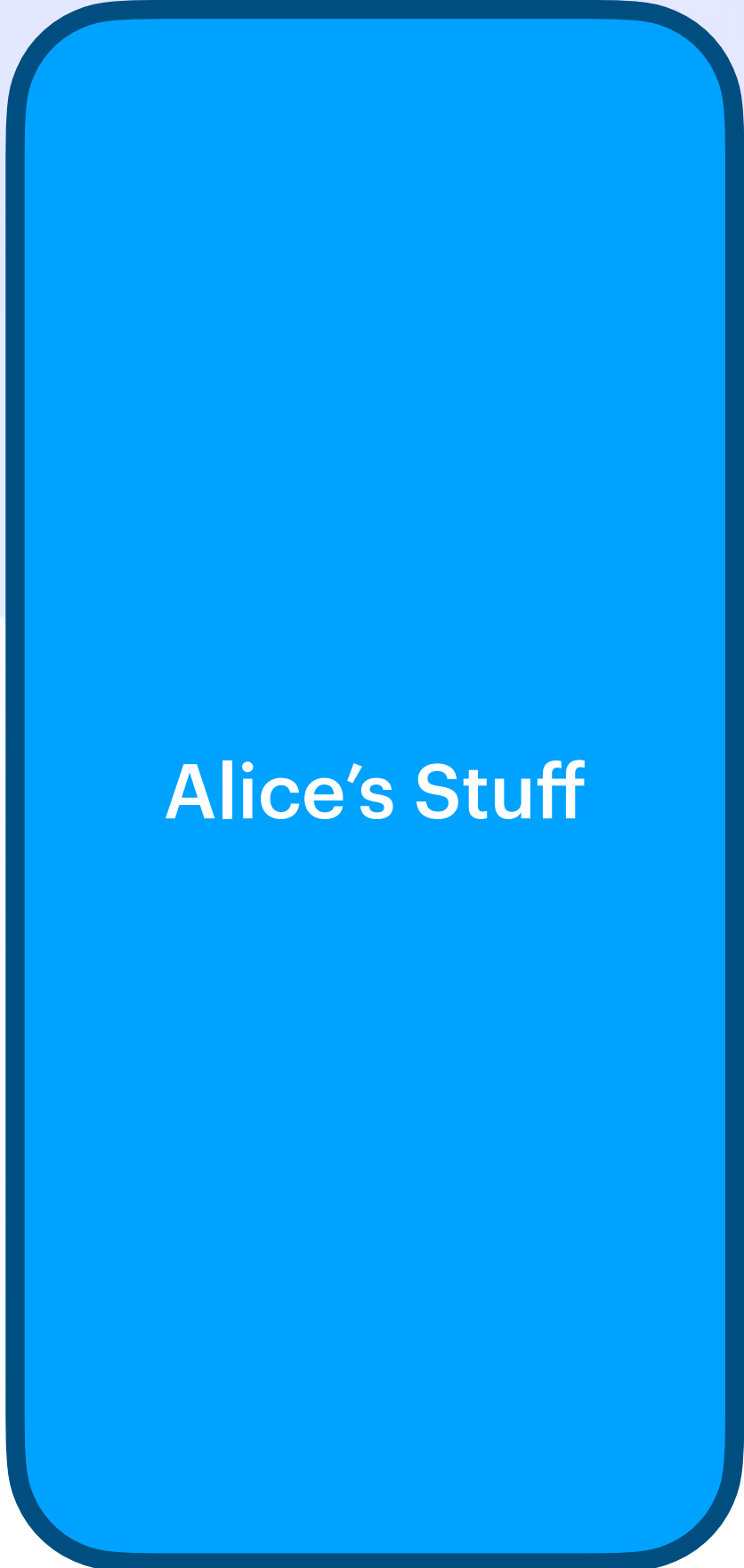


A New Environment 🌴

***Federate Data, Not Apps***

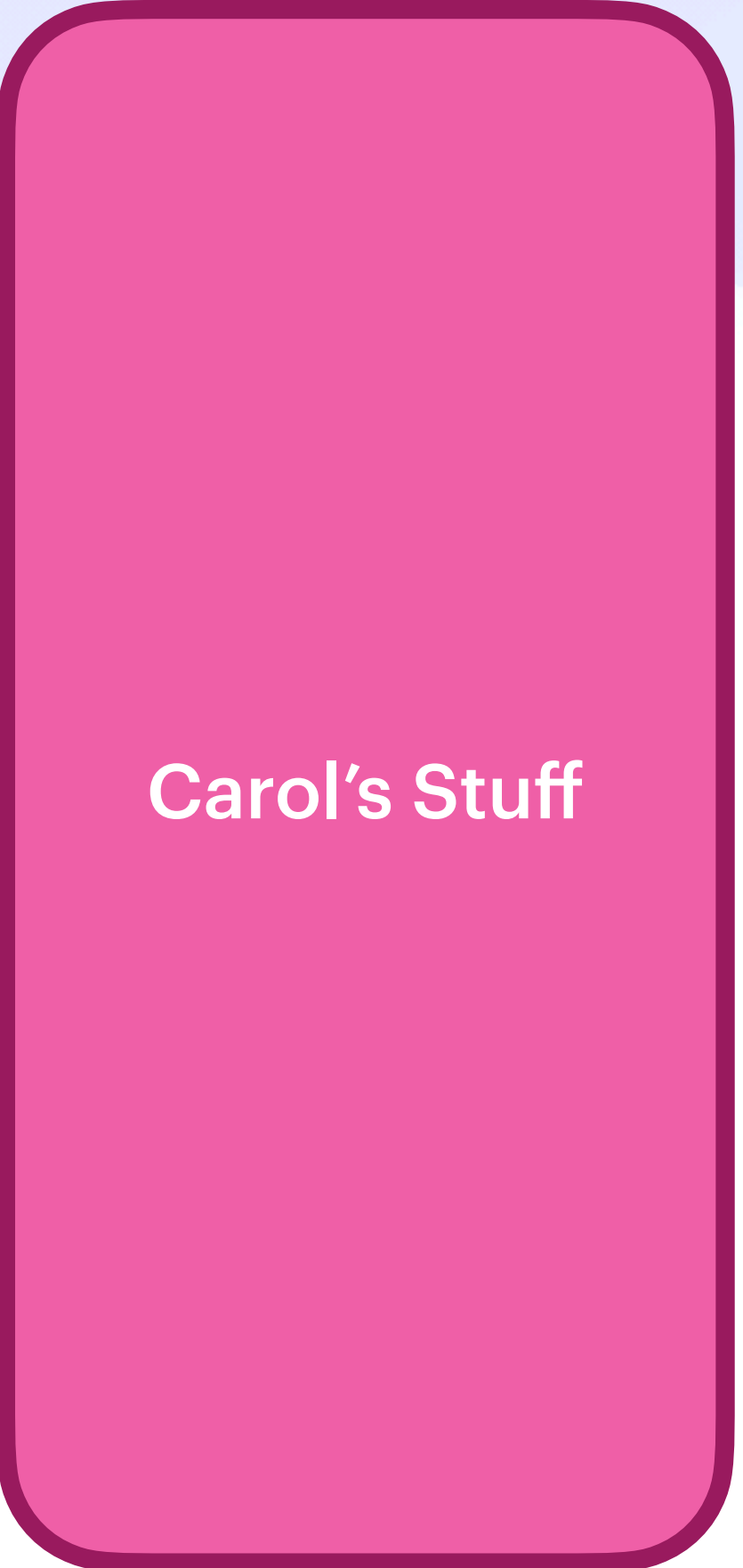
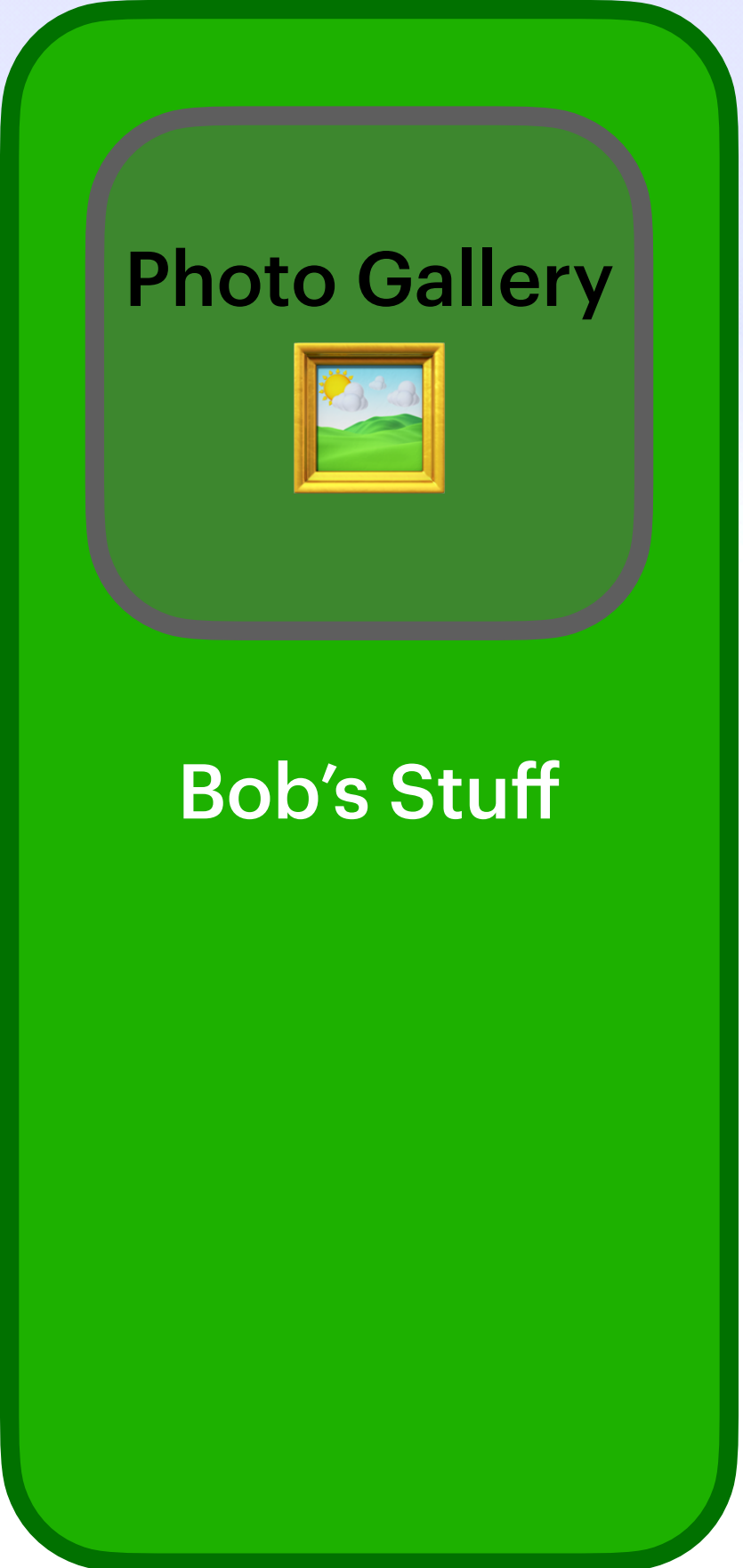
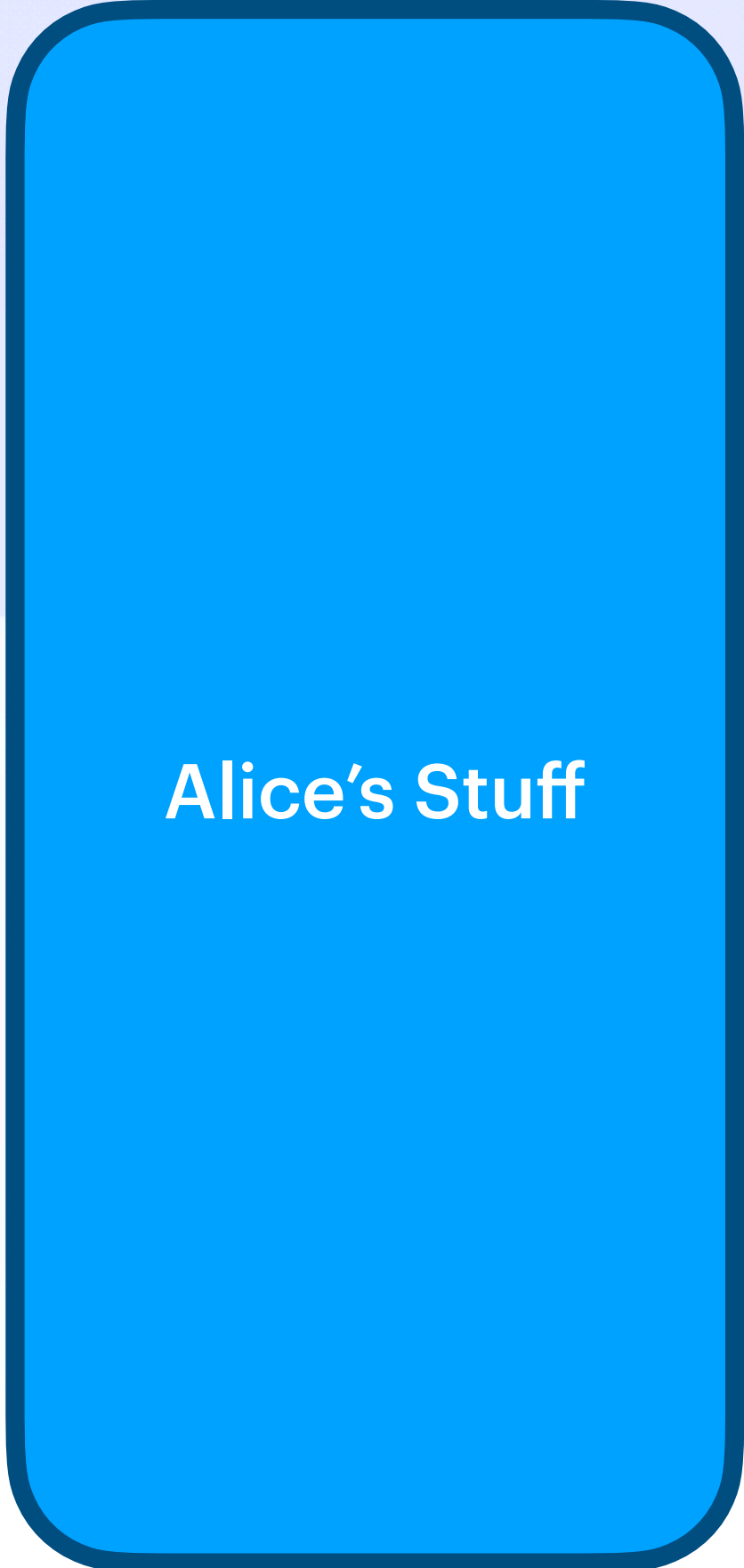
A New Environment 🌴

# ***Federate Data, Not Apps***



A New Environment 🌴

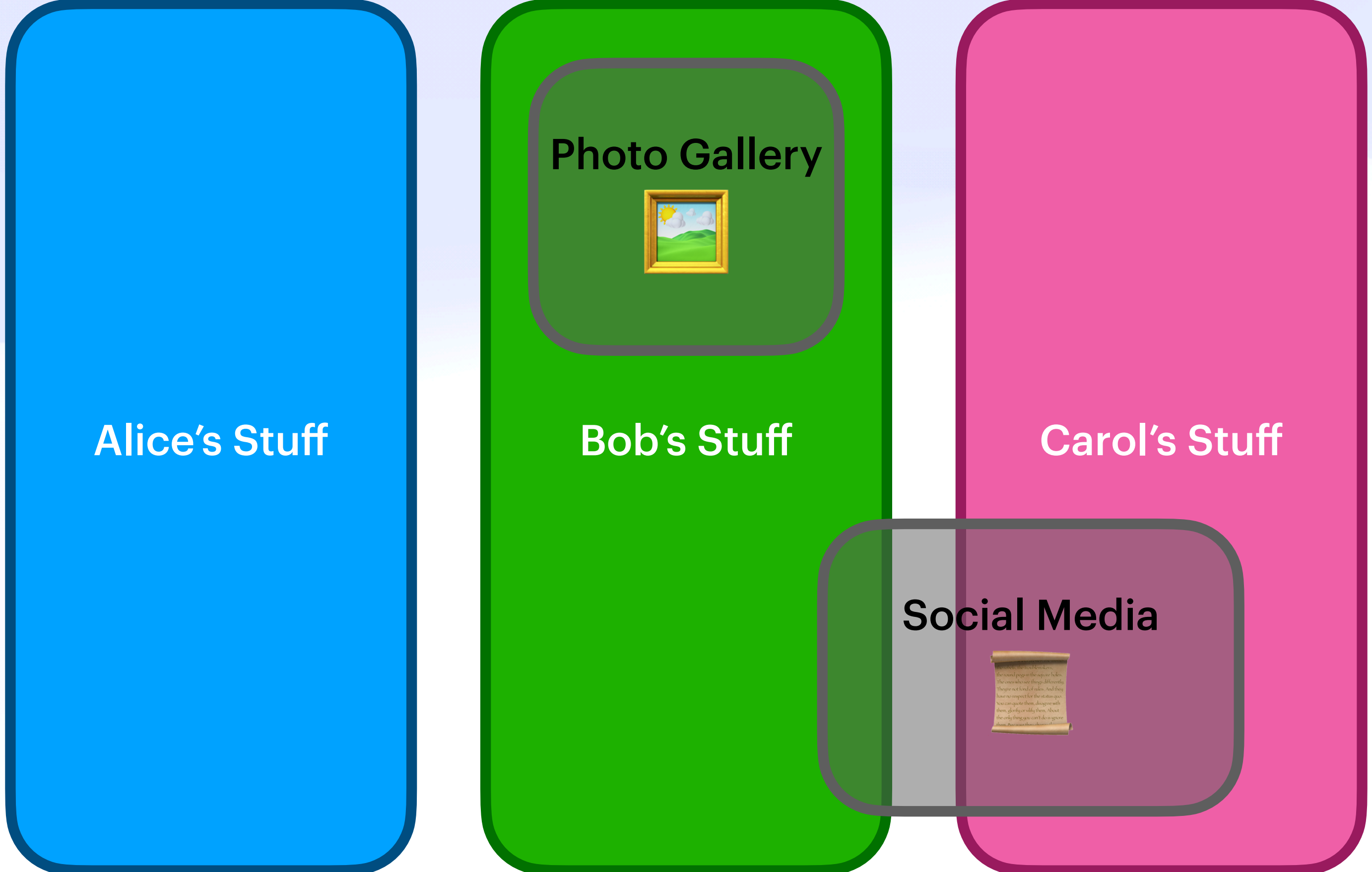
# ***Federate Data, Not Apps***





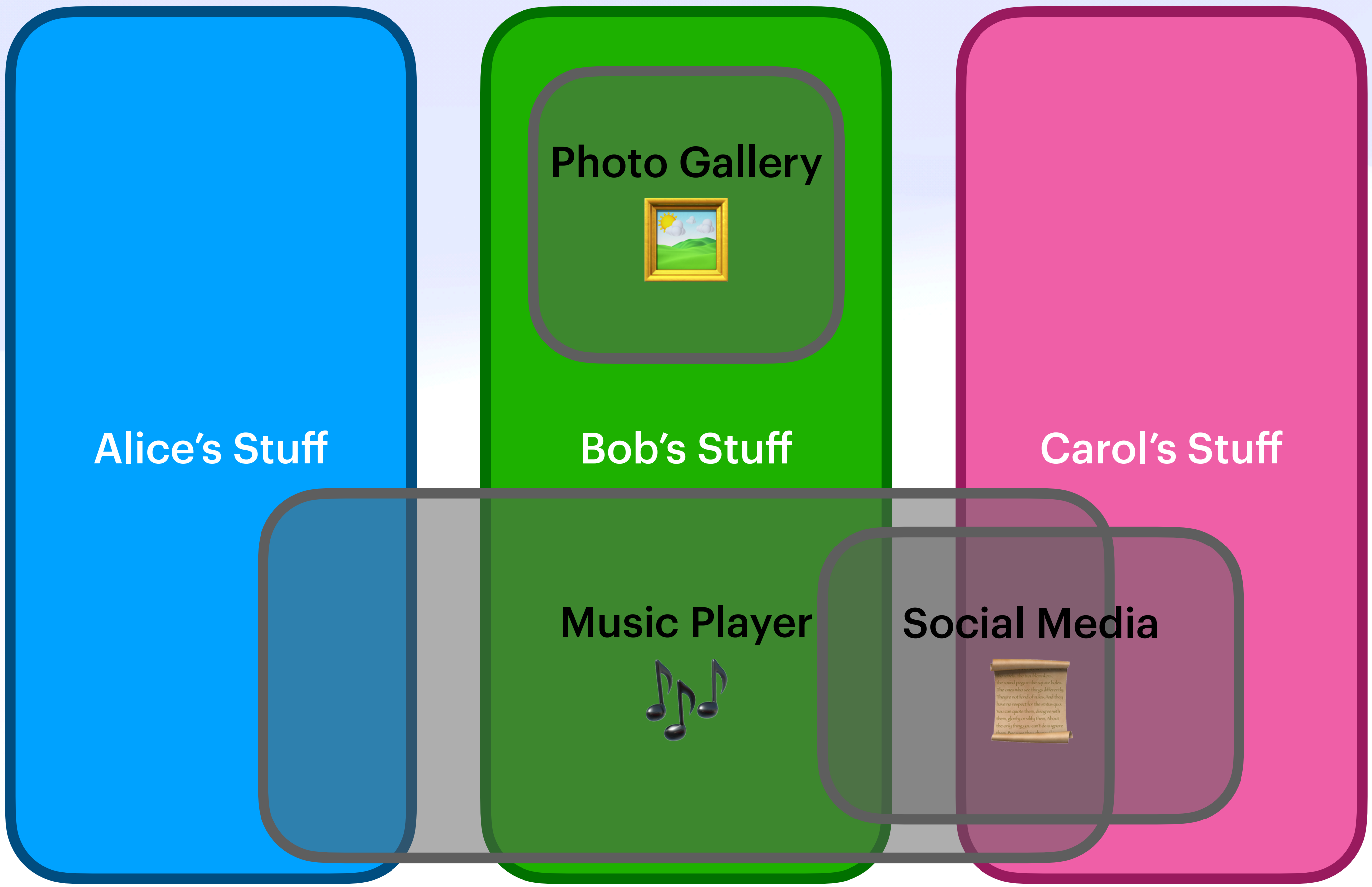
A New Environment 🌴

# *Federate Data, Not Apps*



A New Environment 🌴

# *Federate Data, Not Apps*







A New Environment 🌴

# ***Common Needs***

A New Environment 🌴

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1.  Local-first access control
2.  Arbitrary metadata
3.  Mutability
4.  Versioning (→ concurrency)

A New Environment 🌴

# *Common Needs*

1. 🎫 Local-first access control
2. 🧾 Arbitrary metadata
3. ✨ Mutability
4. 🐣 Versioning (→ concurrency)



A New Environment 🌴

***Ideally Invisible & General***

A New Environment 🌴

# ***Ideally Invisible & General***

**Web Apps**

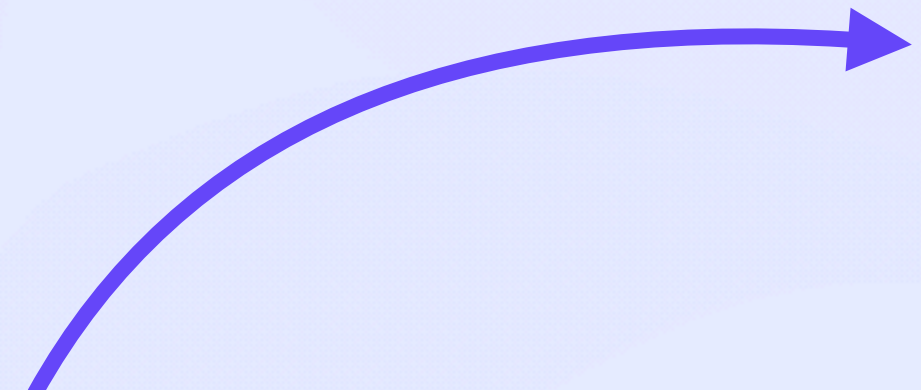
e.g. Fission Drive, Diffuse Music

A New Environment 🌴

# Ideally Invisible & General

## Web Apps

e.g. Fission Drive, Diffuse Music



The screenshot shows a web-based file explorer interface. At the top, the address bar displays 'expede-strange-loop'. Below it, a list of items is shown under the heading 'NAME':

- strange-loop (directory)
- cat (file)
- pwl (file) with a right-pointing arrow
- rs-ucan-mascot (file)

Below the list, it indicates '1 Directory and 3 Files (2.09 KB)'. On the right side of the interface, there is a video thumbnail showing two chalkboards on easels. The left chalkboard has the text 'PAPERS WE LOVE' and a list of names and times: 9:50 - Zeeshan Akhoni, 10:00 - M. Charity, 11:00 - Deirdre Connolly, and 12:00 - LUNCH!. The right chalkboard has a list of names and times: 1:10p - Jason Hockman, 2:10p - Santosh NAGARAKatte, 3:00p - BREAK, 3:20p - Madeline Endres, 4:20p - Zach Tellman, and 5:10p - CLOSING. At the bottom left of the interface is the 'FISSION DRIVE' logo, and at the bottom right are '+ Add / Create' and 'Copy Link' buttons.



A New Environment 🌴

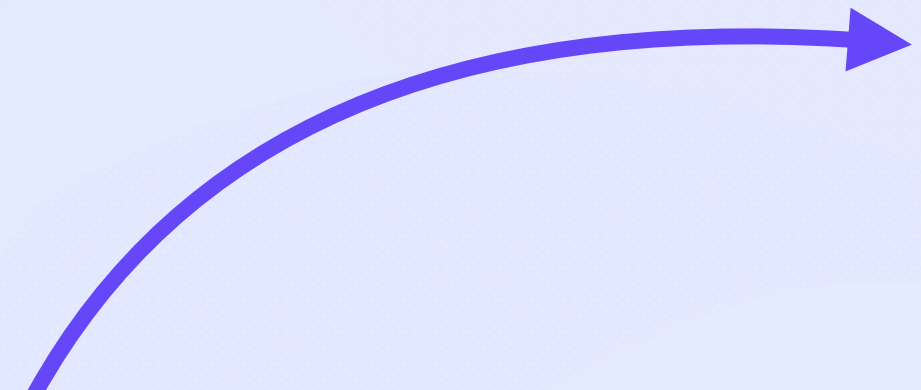
# Ideally Invisible & General

## Web Apps

e.g. Fission Drive, Diffuse Music

## Tools for Thought

e.g. TiddlyWiki



expede-strange-loop /

NAME

- strange-loop
- cat
- pwl →
- rs-ucan-mascot

1 Directory and 3 Files (2.09 KB)

FISSION DRIVE

+ Add / Create Copy Link

A New Environment 🌴

# Ideally Invisible & General

## Web Apps

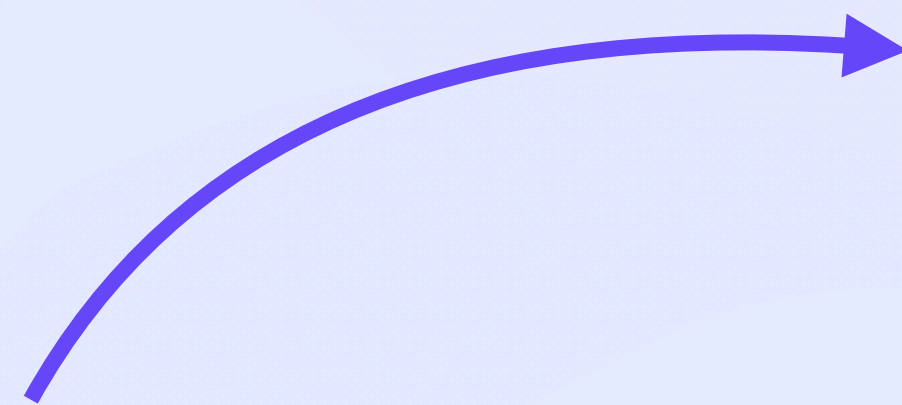
e.g. Fission Drive, Diffuse Music

## Tools for Thought

e.g. TiddlyWiki

## Data Science

e.g. Qri



expede-strange-loop / 🖼️

NAME

- 📁 strange-loop
- 🖼️ cat
- 🖼️ pwl →
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1 Directory and 3 Files (2.09 KB)

FISSION DRIVE

+ Add / Create    🔗 Copy Link

**PAPERS WE LOVE**

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A New Environment 🌴

# Ideally Invisible & General

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e.g. Fission Drive, Diffuse Music

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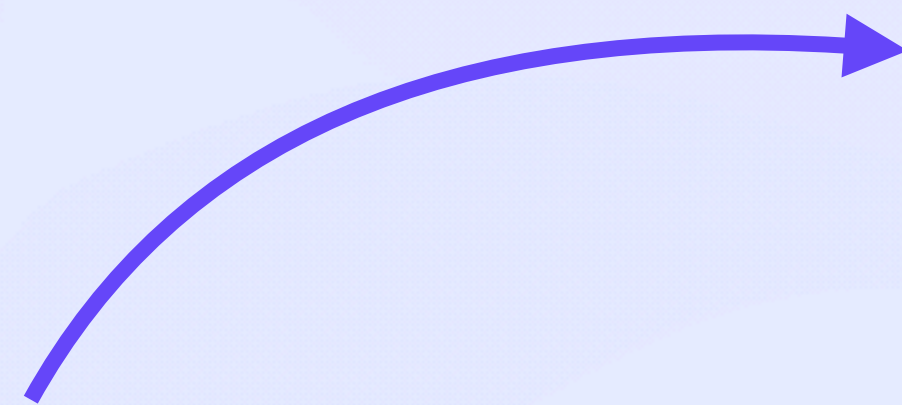
e.g. TiddlyWiki

## Data Science

e.g. Qri

## Storage Networks

WIP



expede-strange-loop / 🖼️

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1 Directory and 3 Files (2.09 KB)

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**PAPERS WE LOVE**

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A New Environment 🌴

***WNFS API***

A New Environment 🌴

# ***WNFS API***

- add
- cat
- ls
- mkdir
- rm
- mv
- write

# A New Environment 🌴

## WNFS API

- add
- cat
- ls
- mkdir
- rm
- mv
- write

```
// After initialising ...
const fs = state.fs

// List the user's private files that belong to this app
await fs.ls(fs.appPath())

// Create a sub directory and add some content
await fs.write(
  fs.appPath(wn.path.file("Sub Directory", "hello.txt")),
  "👋"
)

// Announce the changes
await fs.publish()
```

# A New Environment 🌴

## WNFS API

- add
- cat
- ls
- mkdir
- rm
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- write

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```
file.history.list()
// { delta: -1, timestamp: 1606236743 }
// { delta: -2, timestamp: 1606236532 }

// Get the previous version
file.history.back()
```

# ***Content Addressing Primer***

From a File System Perspective





# Content Addressing

## Content Addressing

The limitation of **local knowledge**  
is the **fundamental fact**  
about the setting in which we work,  
and it is **a very powerful limitation**

– Nancy Lynch, A Hundred Impossibility Proofs for Distributed Computing

Content Addressing 

# ***Addressing Stack***

Content Addressing 

# *Addressing Stack*

Virtual (Machine) Location 

`(42.123.45.6/path)@t0 = content1`

`(42.123.45.6/path)@t1 = content2`

Content Addressing 

# Addressing Stack

Named Location 

{DNS → IP}

Virtual (Machine) Location 

(42.123.45.6/path)@t0 = content1

(42.123.45.6/path)@t1 = content2

Content Addressing 

# Addressing Stack

Universal Content ID

$\{\text{hash}(\text{content}) \rightarrow \text{content}\}$

Named Location 

$\{\text{DNS} \rightarrow \text{IP}\}$

Virtual (Machine) Location 

$(42.123.45.6/\text{path})@t0 = \text{content1}$

$(42.123.45.6/\text{path})@t1 = \text{content2}$

Content Addressing 

***IPLD Node***

Content Addressing 

# ***IPLD Node***

Bytes  
0101000101001001010



Content Addressing 

# *IPLD Node*

Bytes  
0101000101001001010

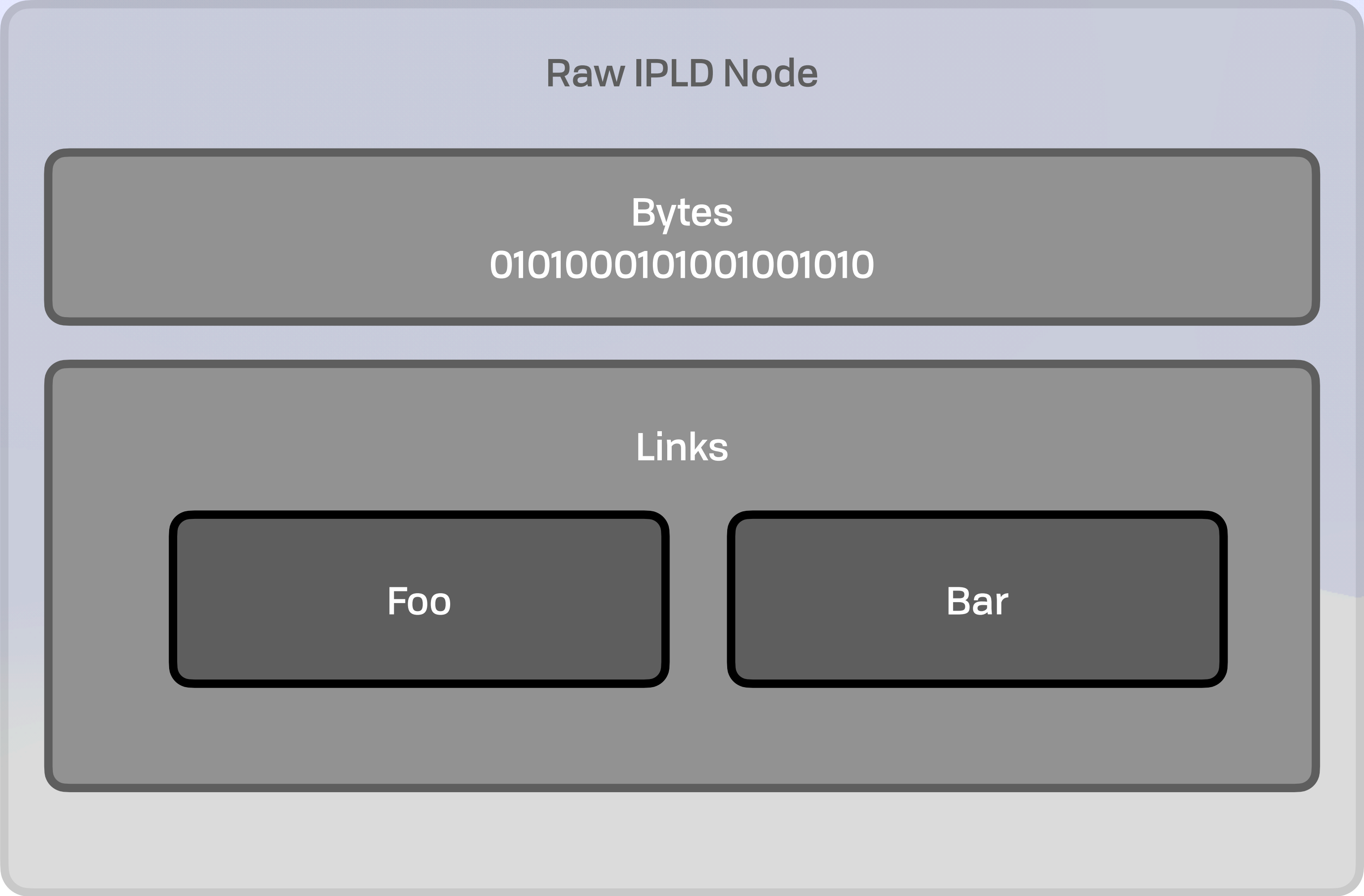
Links

Foo Bar

# Content Addressing

# *IPLD Node*

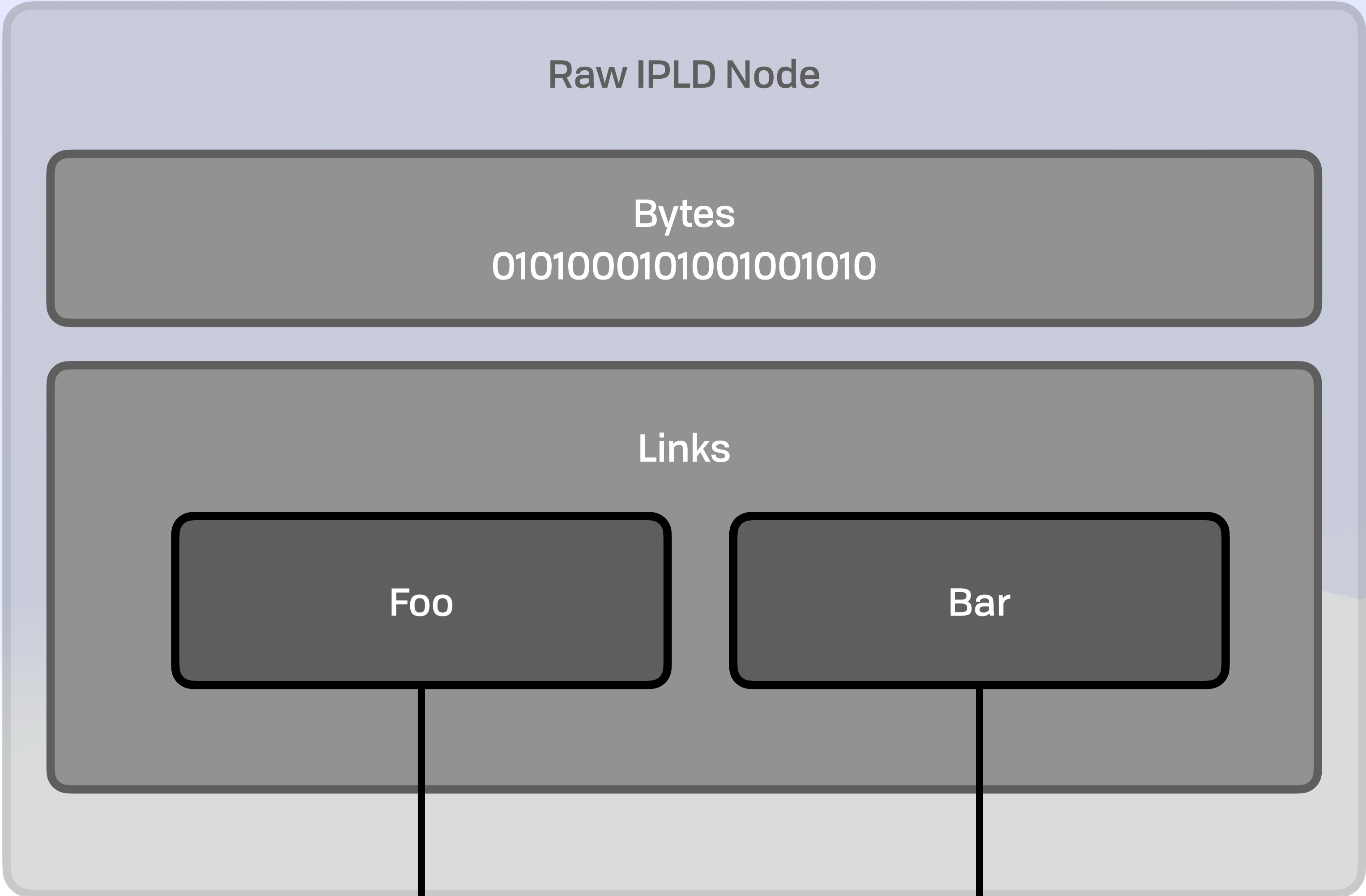
bafy12345



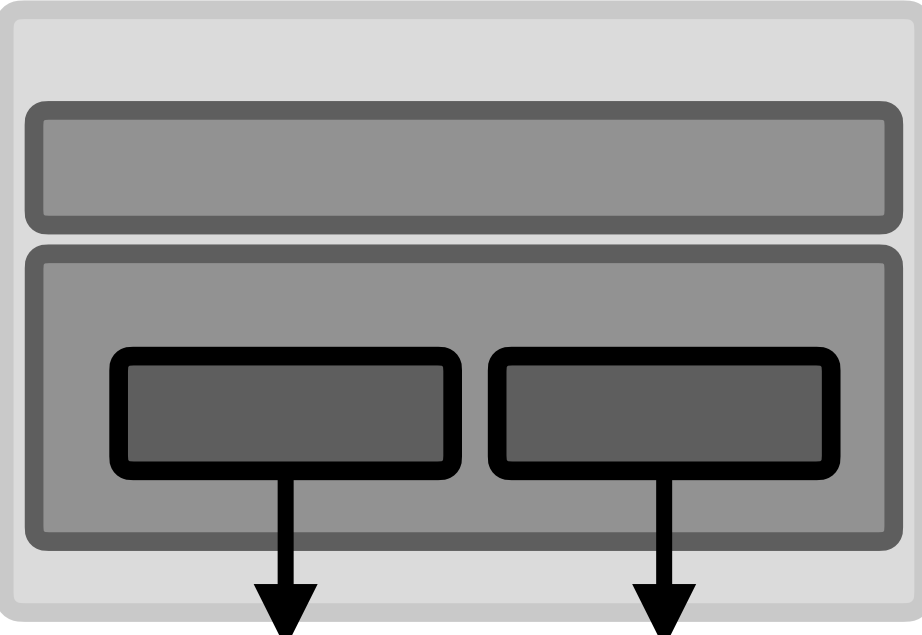
# Content Addressing

# *IPLD Node*

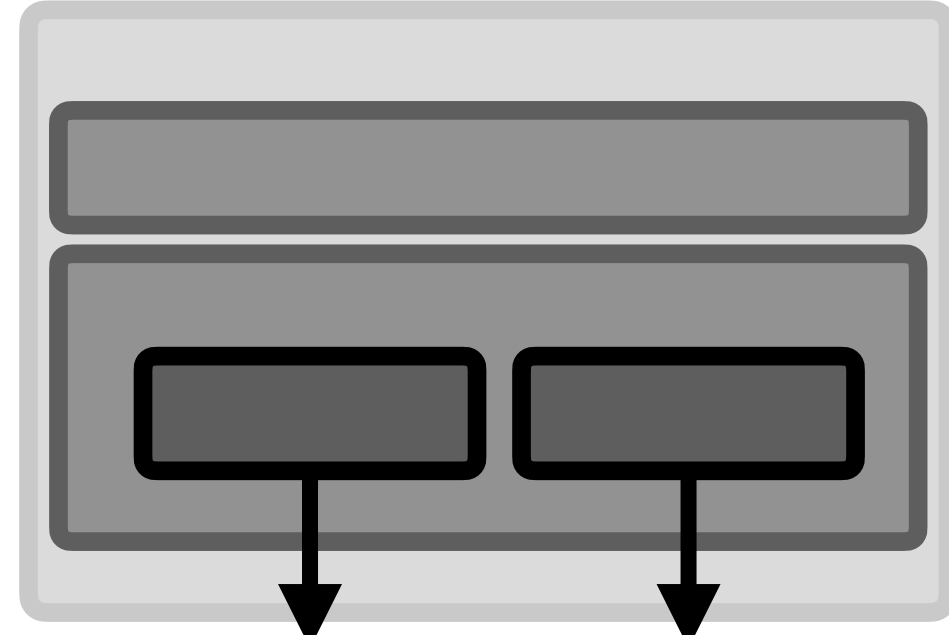
bafy12345



bafyABCDE



bafyVWXYZ



Content Addressing 

***Mutability***

Content Addressing 

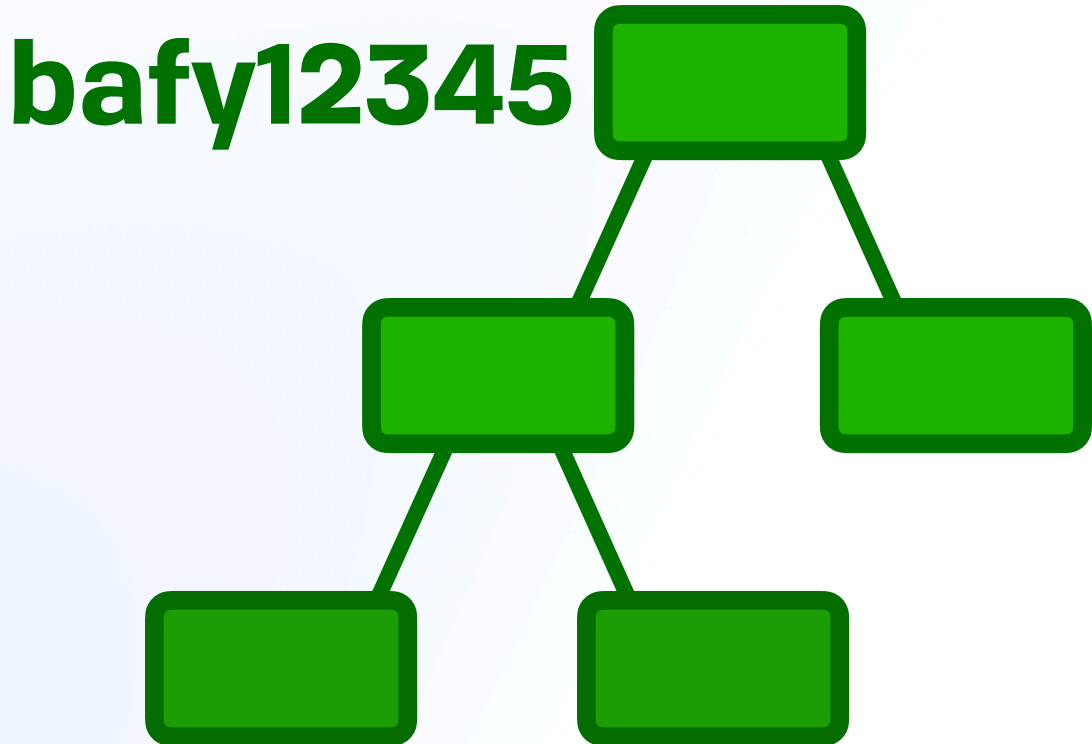
# *Mutability*

TXT \_dnslink.akiko.example.com

Content Addressing 🌐

# *Mutability*

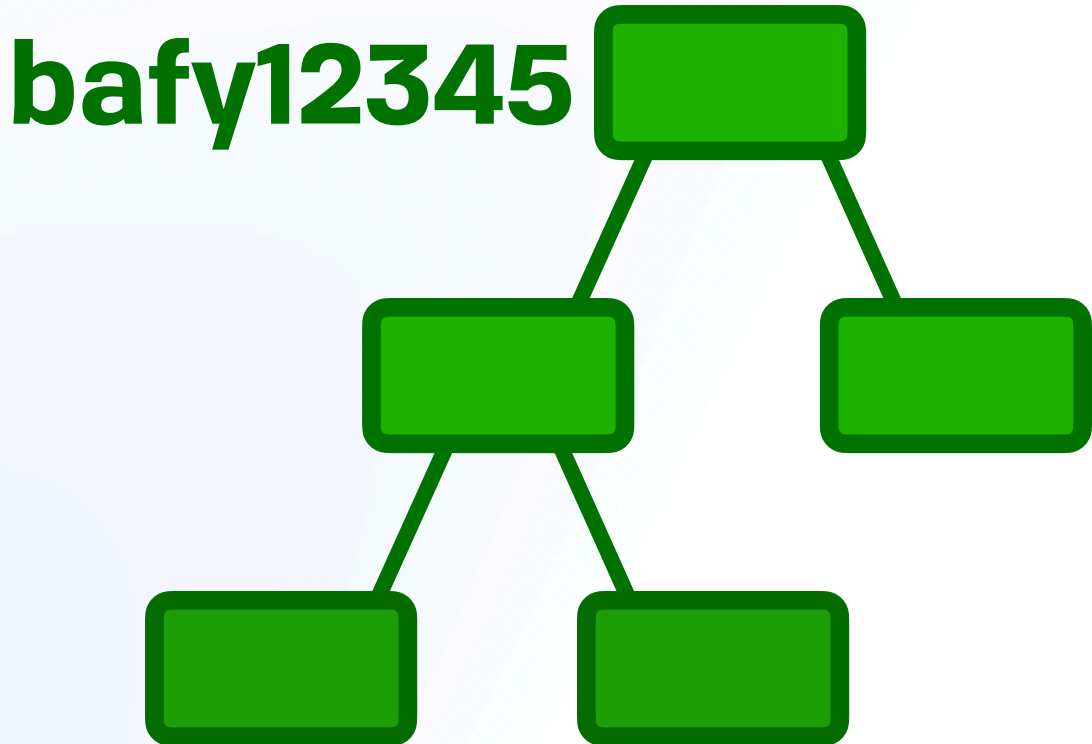
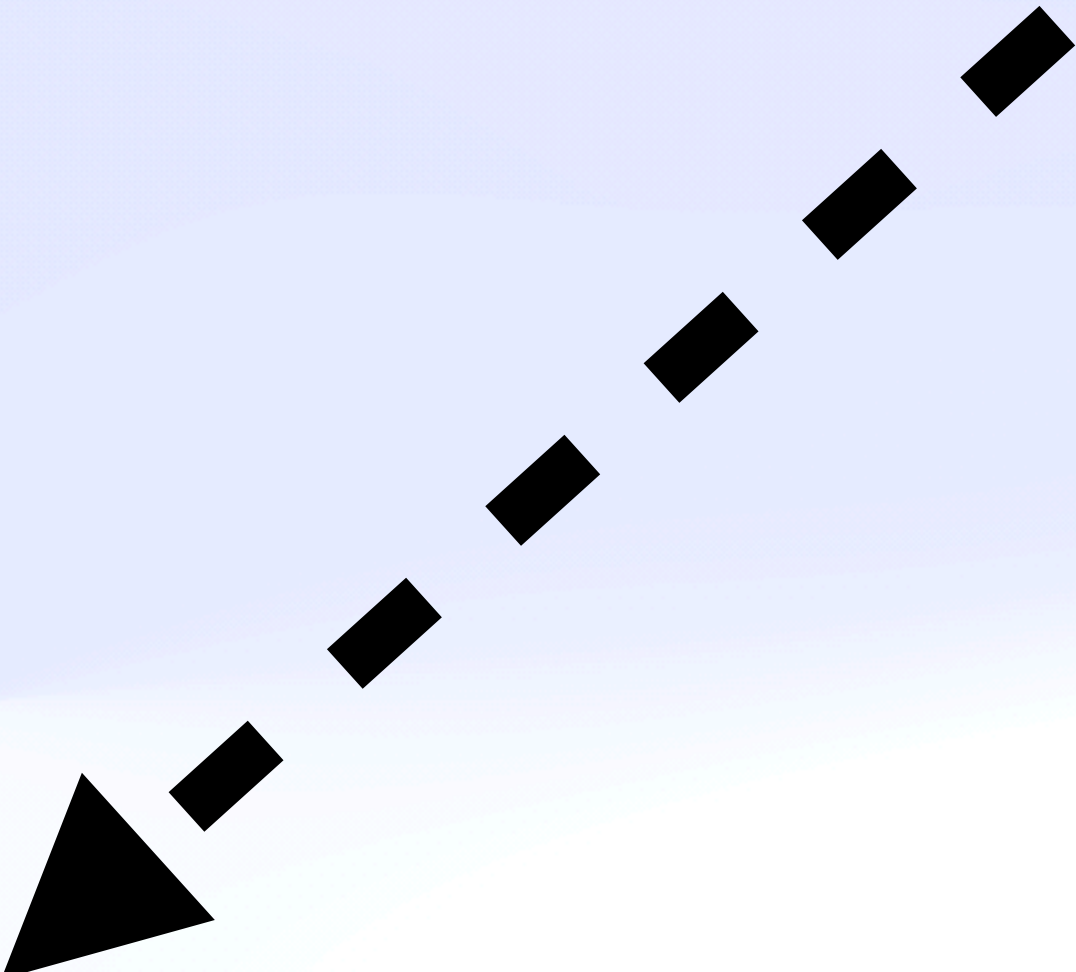
TXT \_dnslink.akiko.example.com



Content Addressing 🌐

# *Mutability*

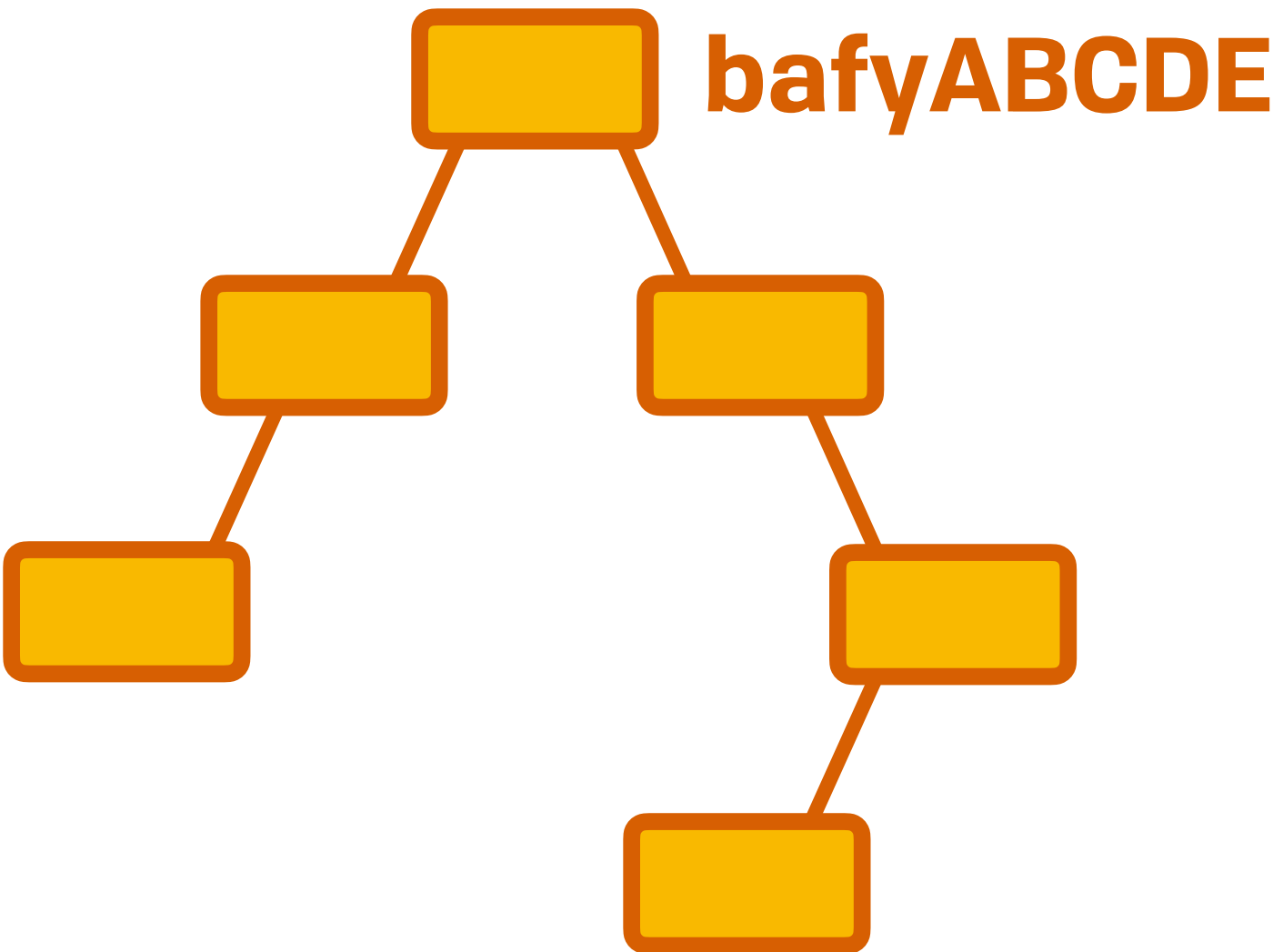
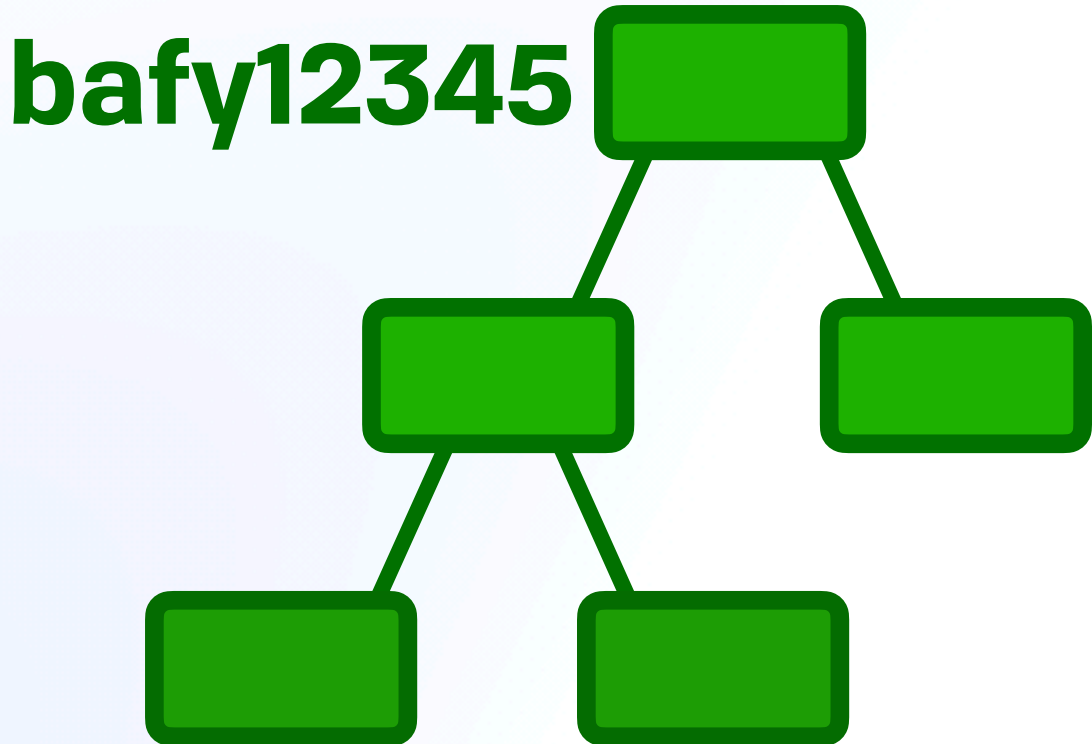
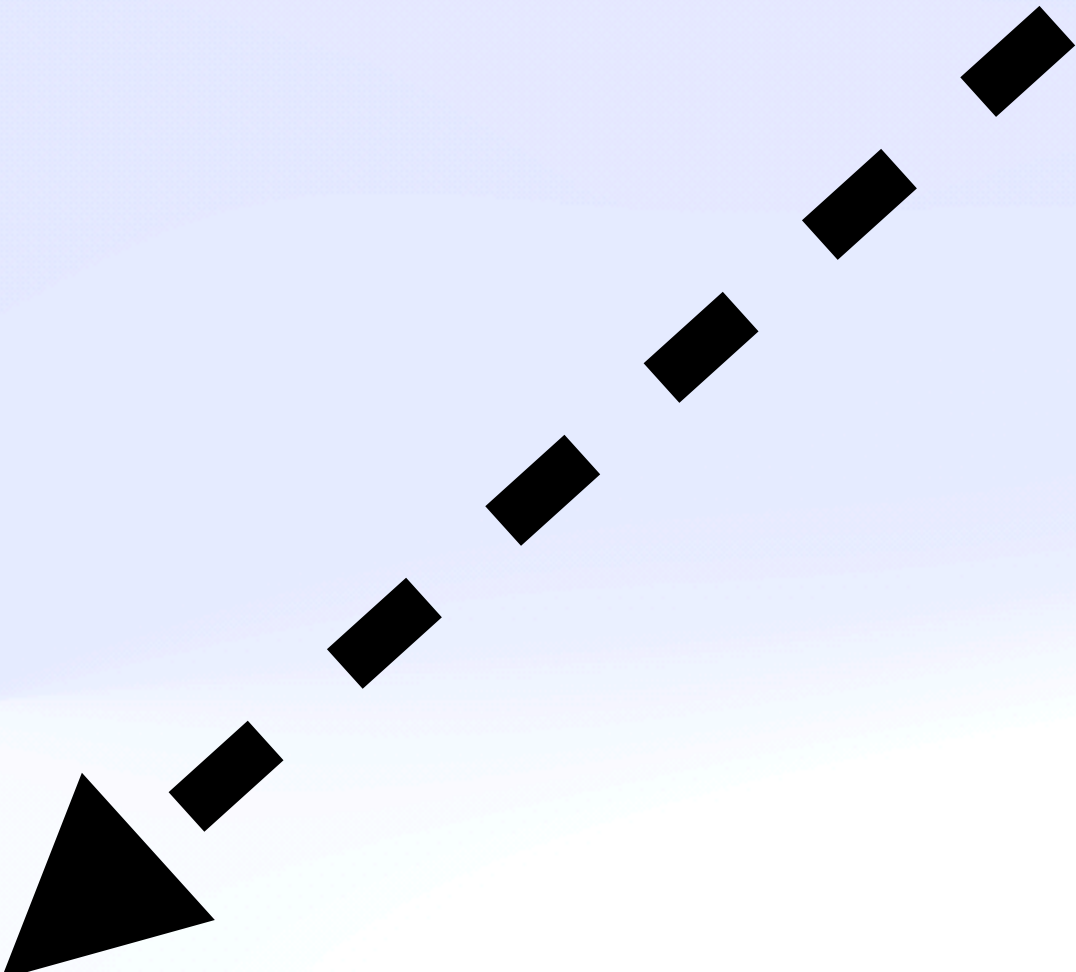
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Content Addressing 

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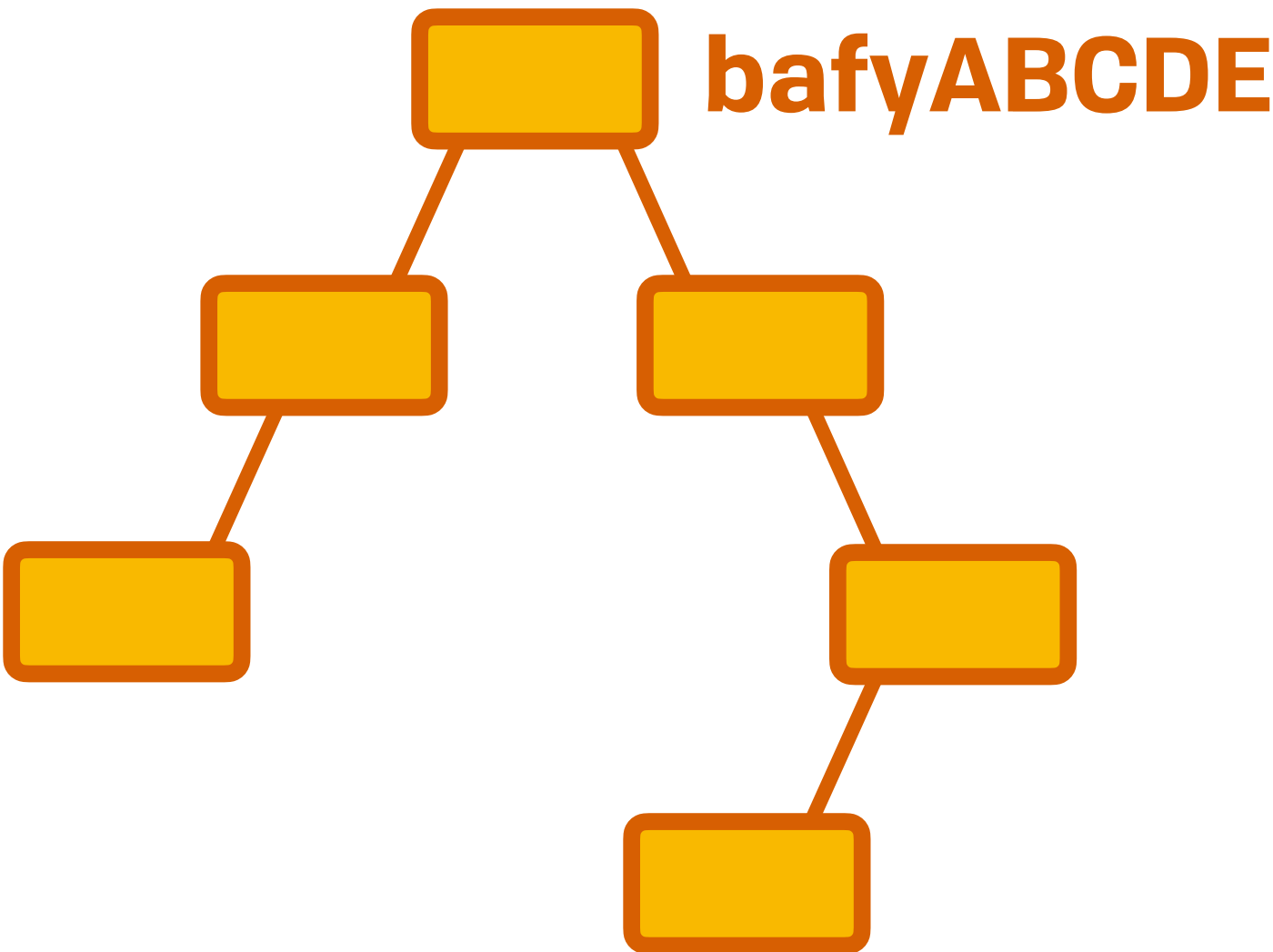
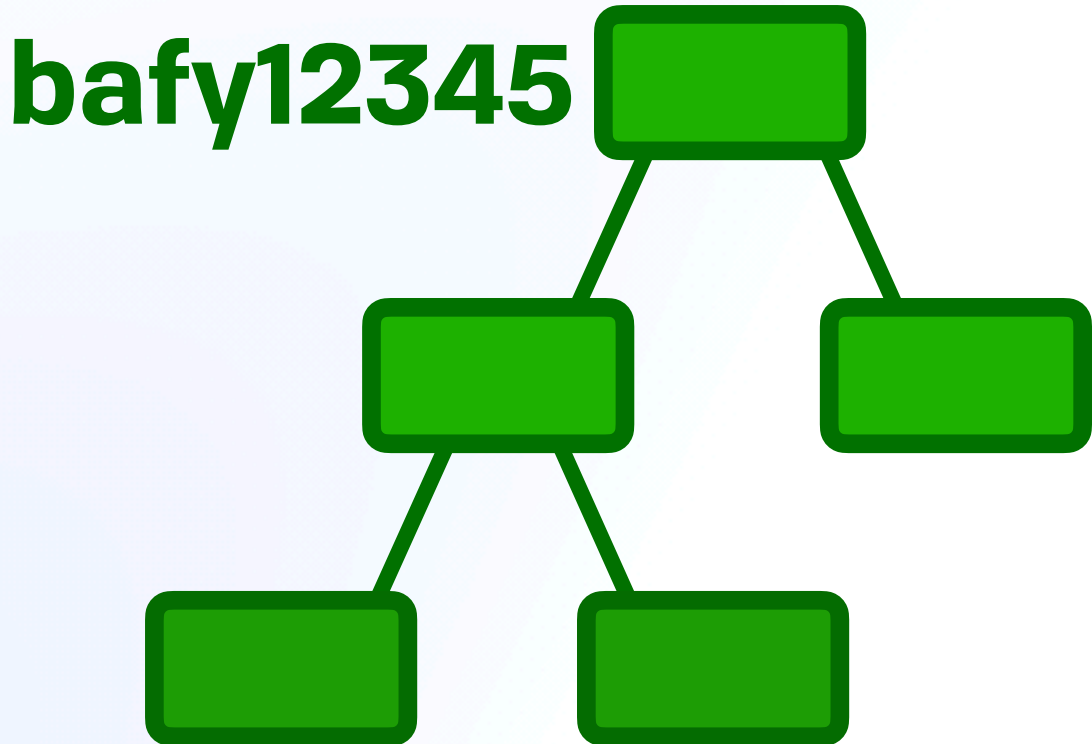
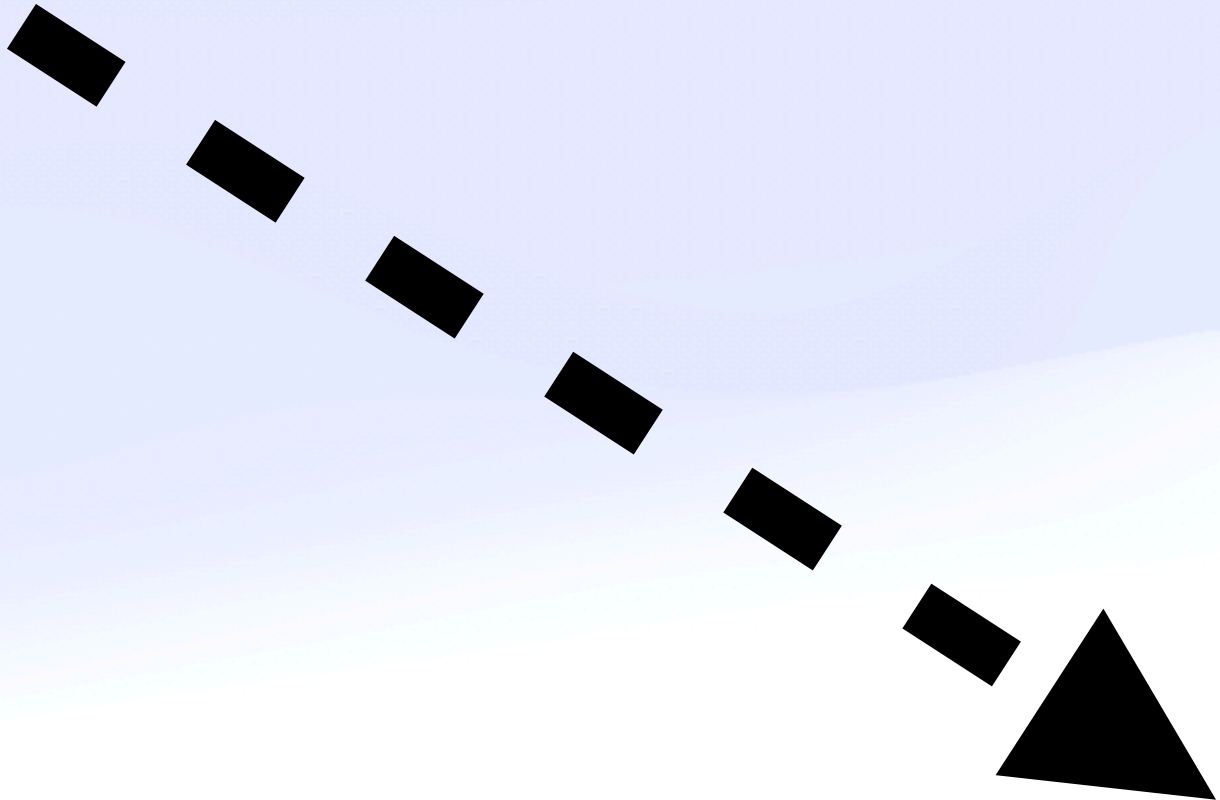




# Content Addressing

# *Mutability*

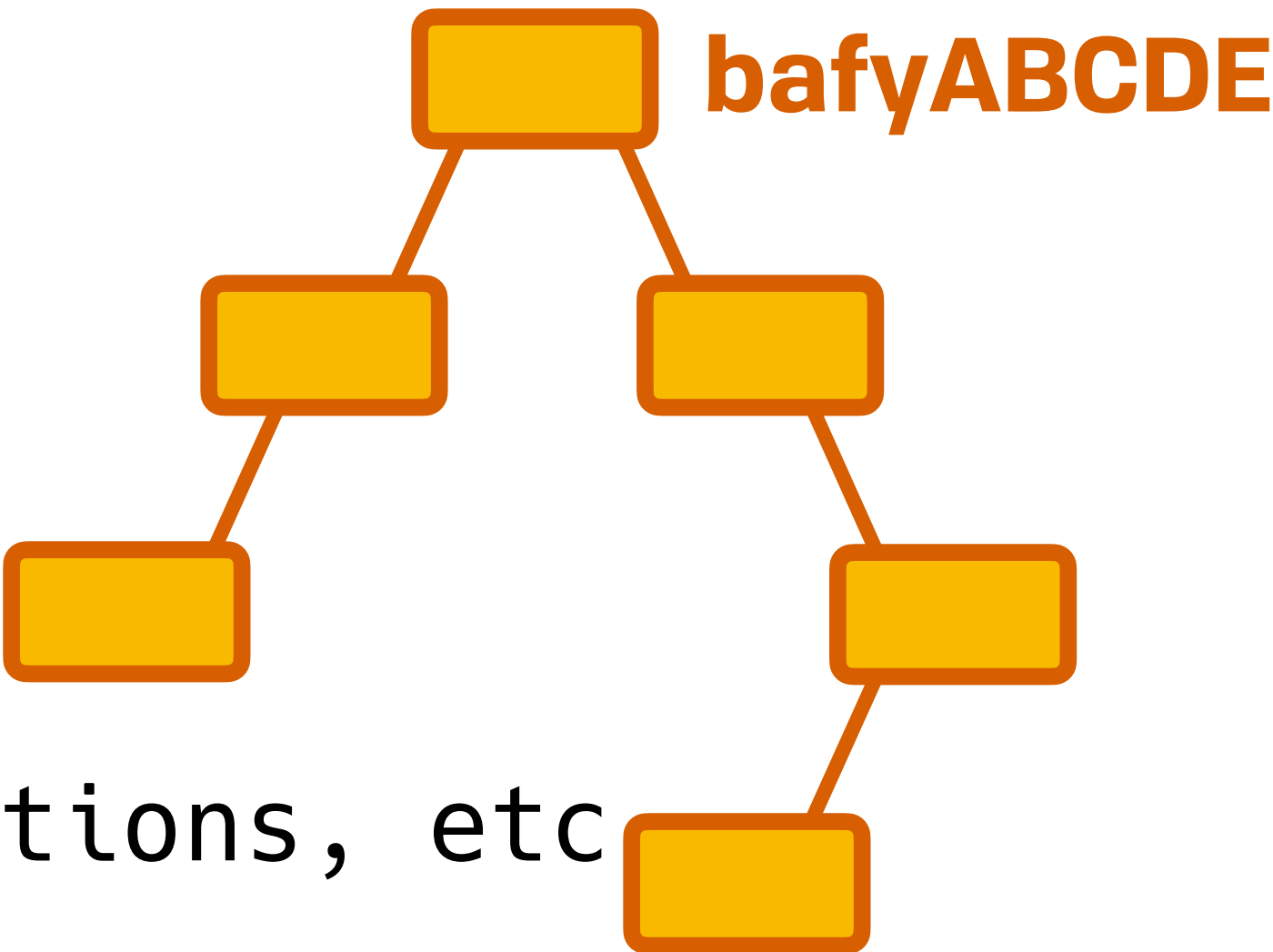
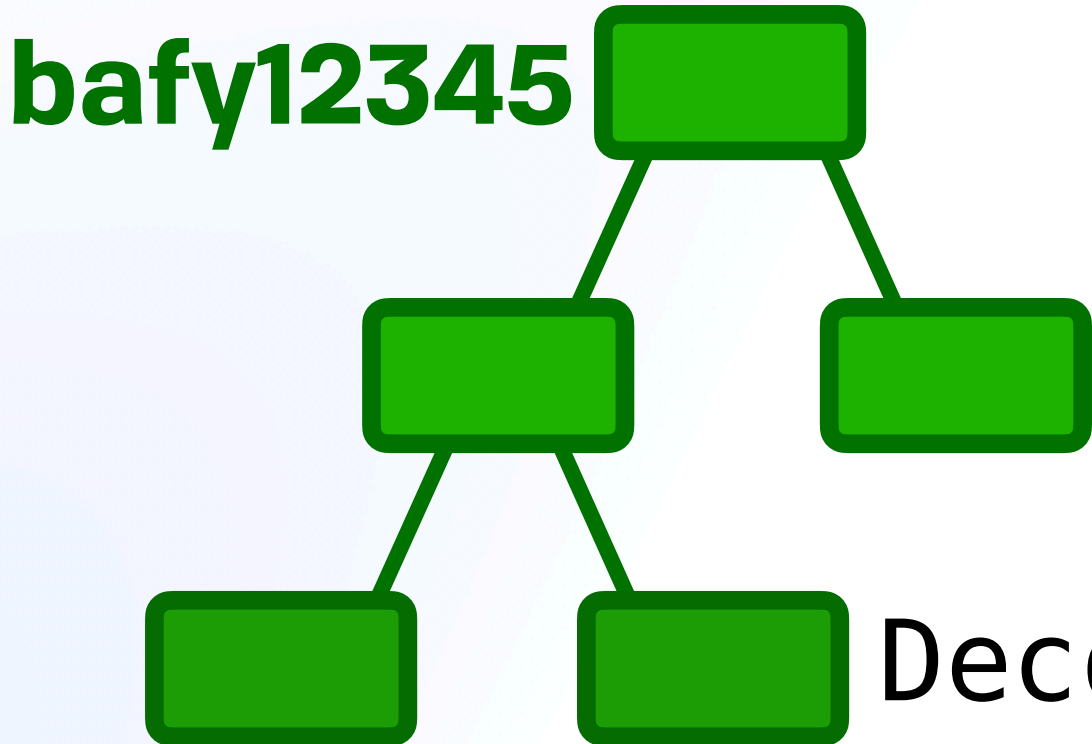
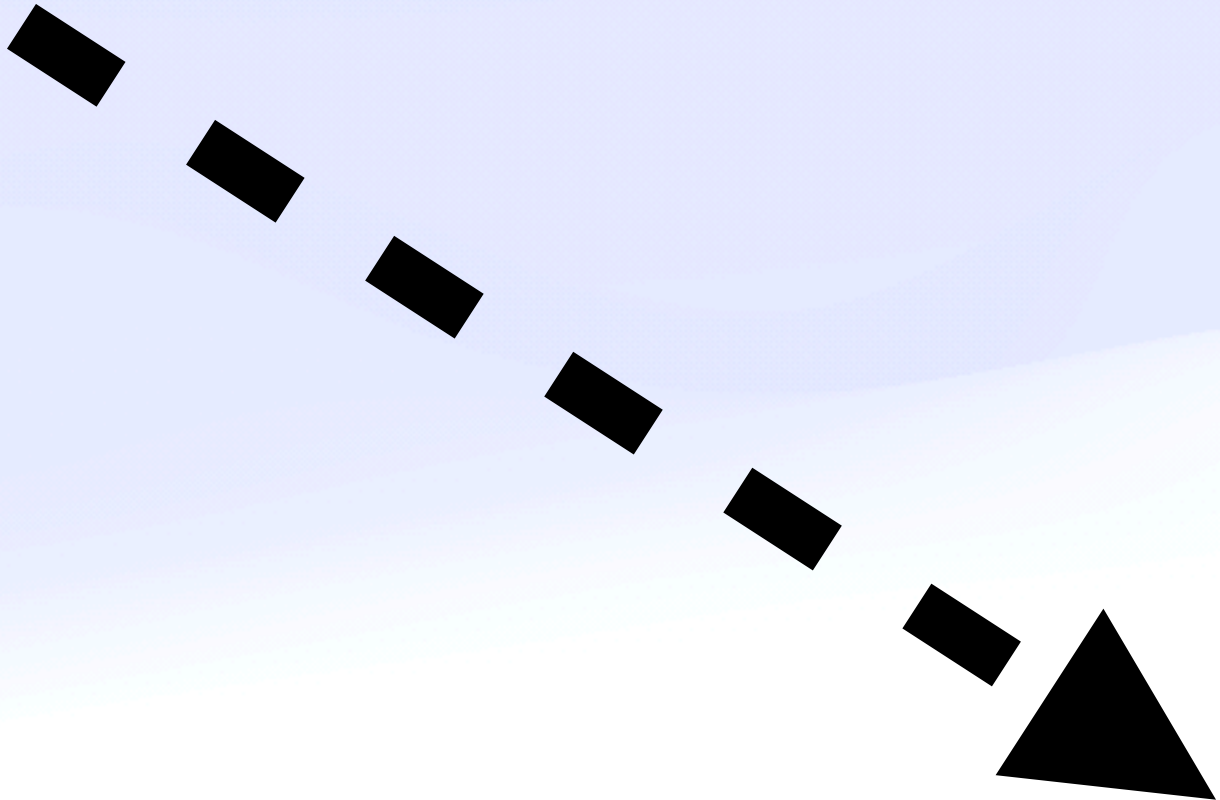
TXT \_dnslink.akiko.example.com



# Content Addressing

# *Mutability*

TXT \_dnslink.akiko.example.com

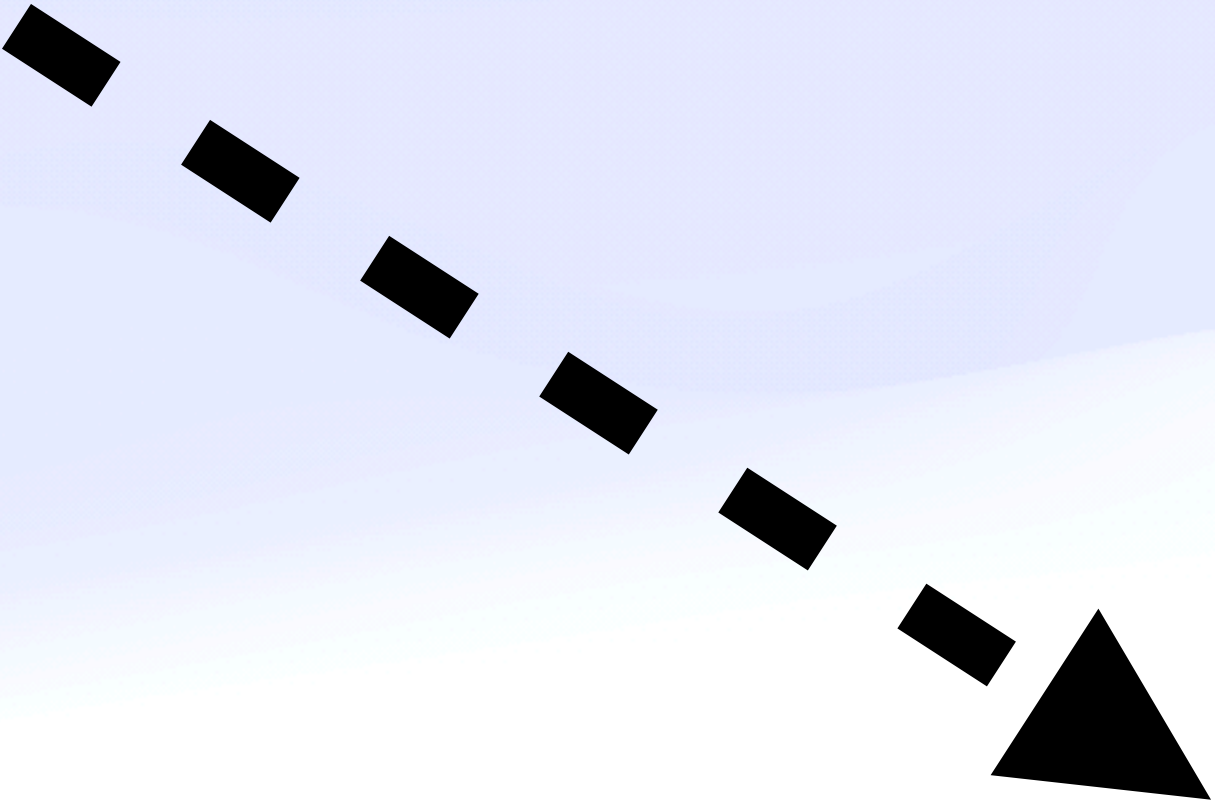


Decoupled: atomic, reductions, etc

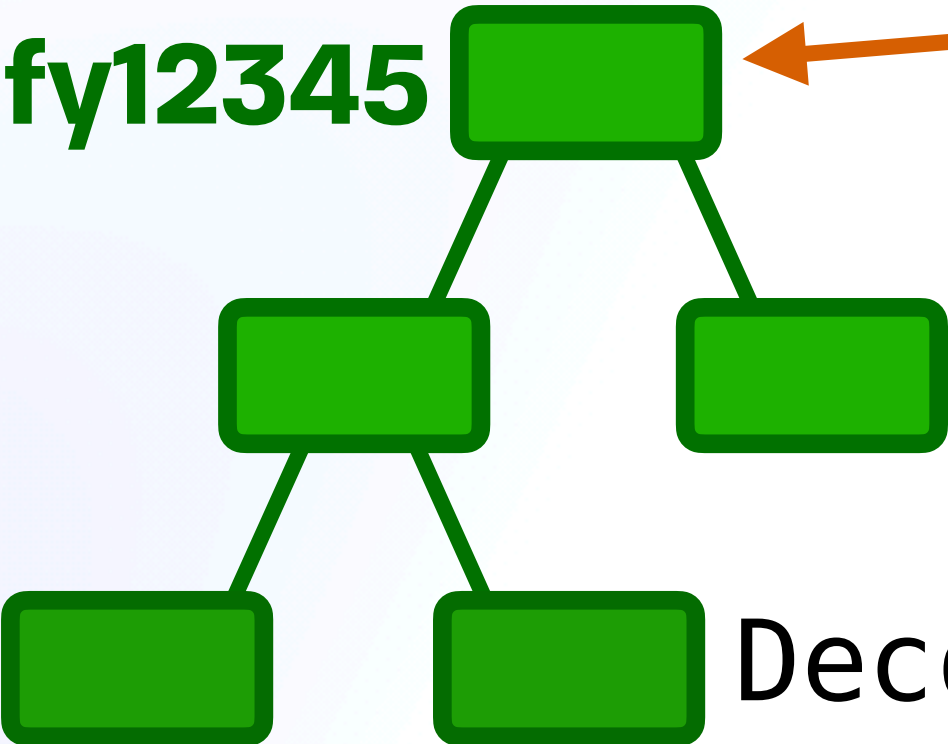
# Content Addressing

# *Mutability*

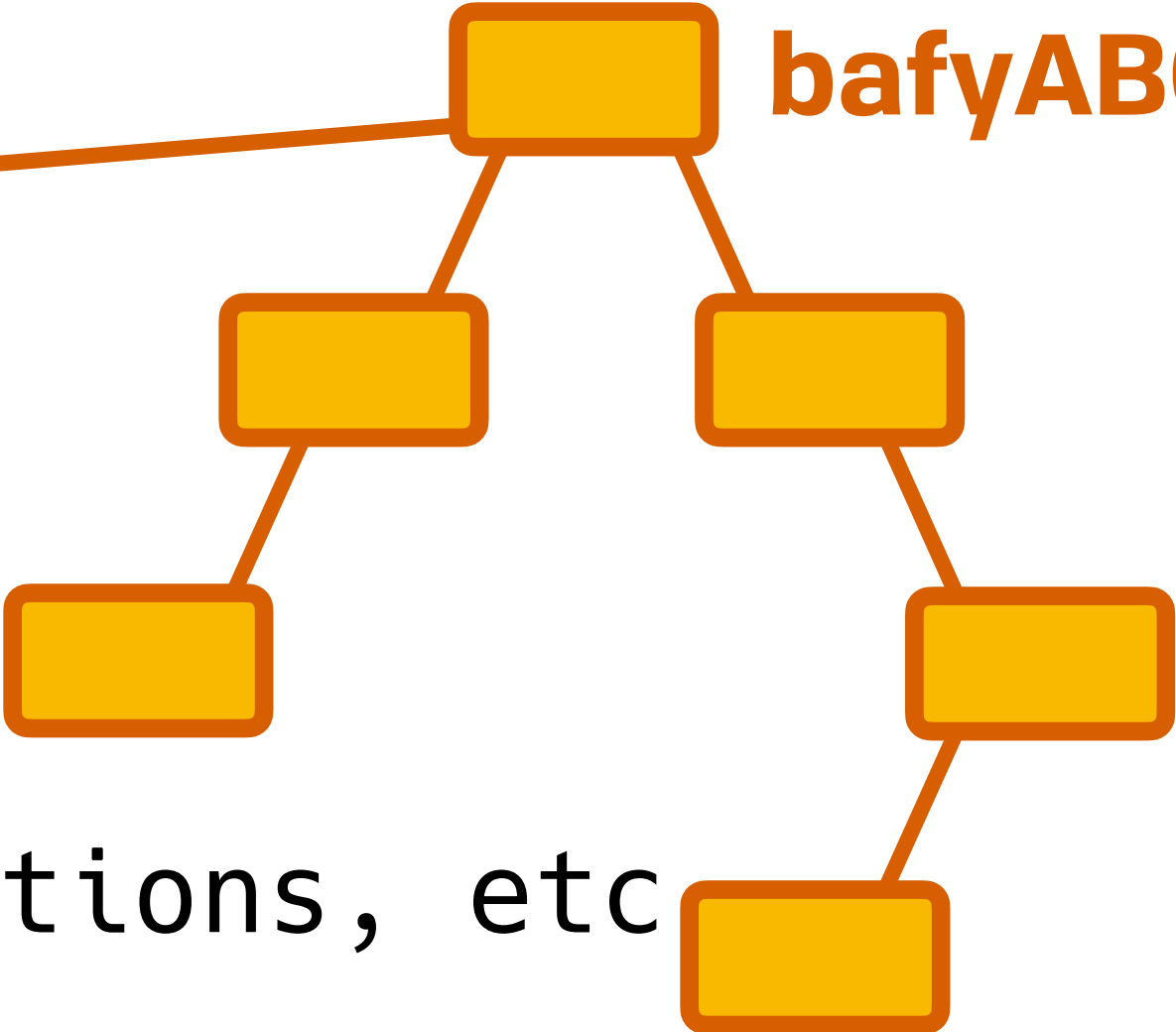
TXT \_dnslink.akiko.example.com



**bafy12345**



**bafyABCDE**



Decoupled: atomic, reductions, etc

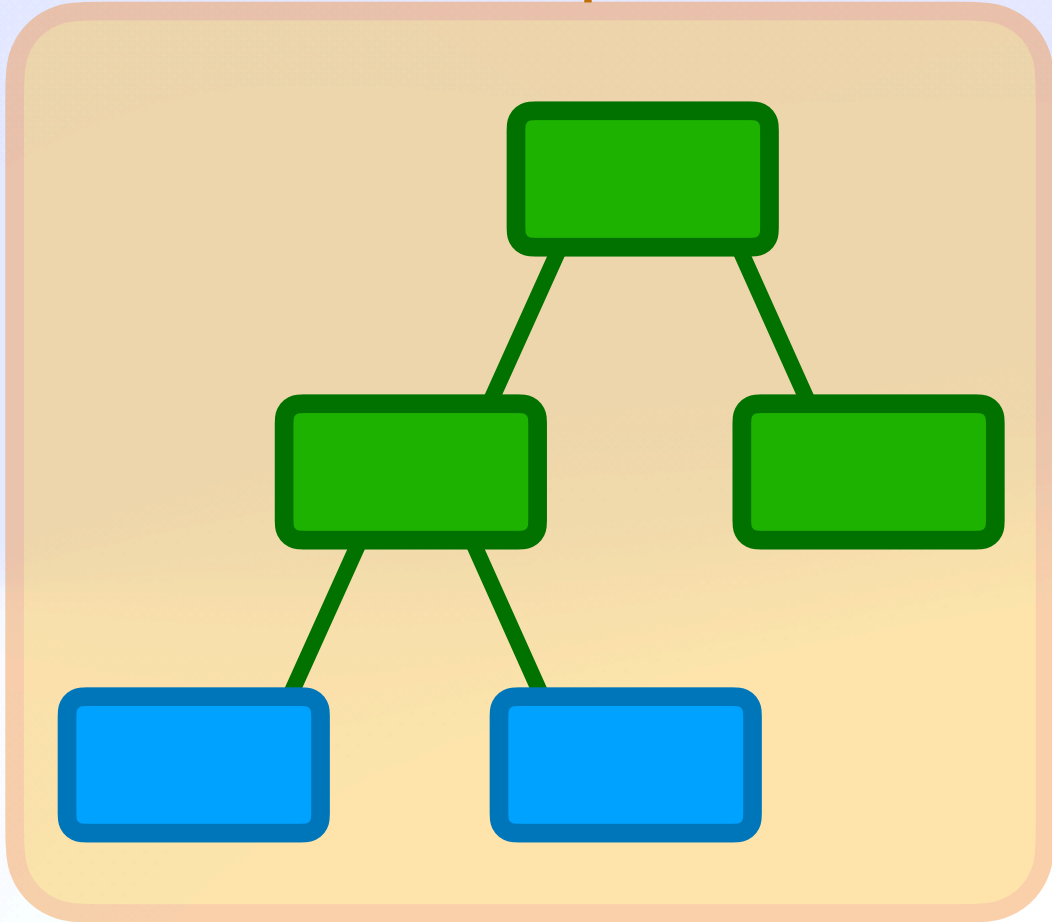
Content Addressing 

# ***Hard & Soft Links***

Content Addressing 🌐

# *Hard & Soft Links*

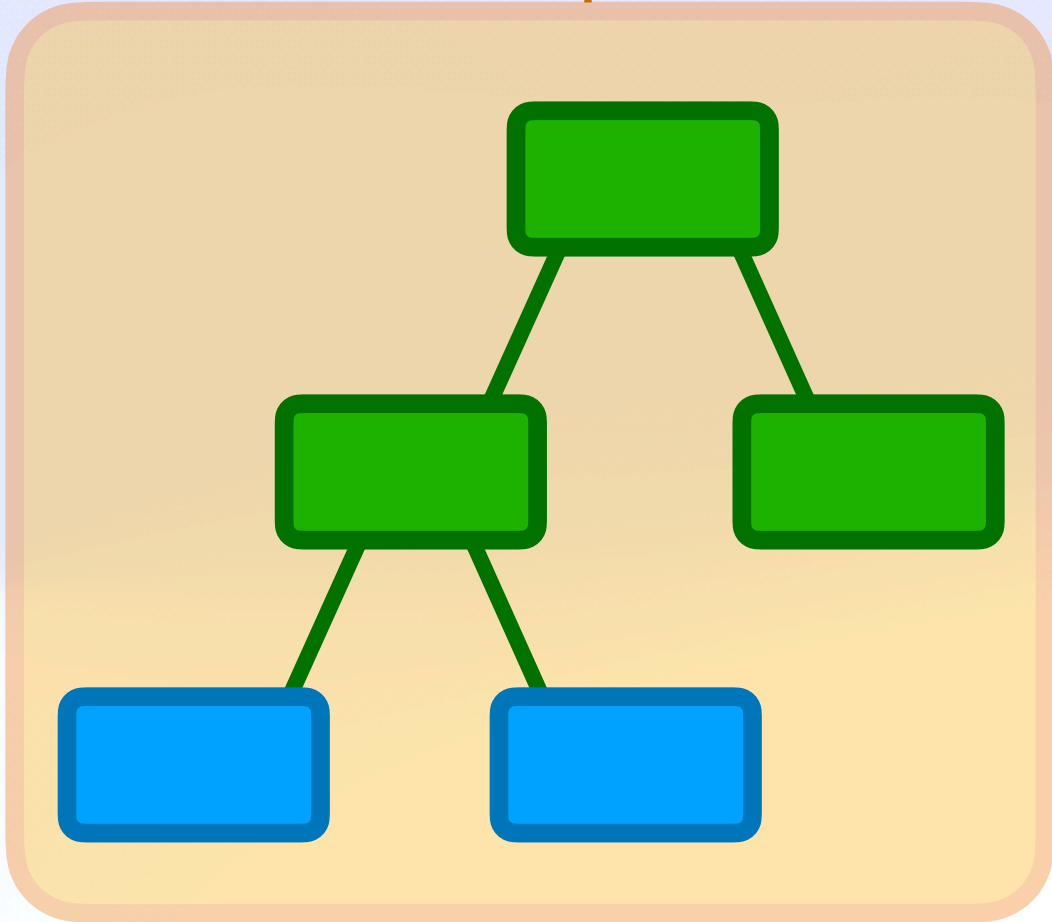
akiko.example.com



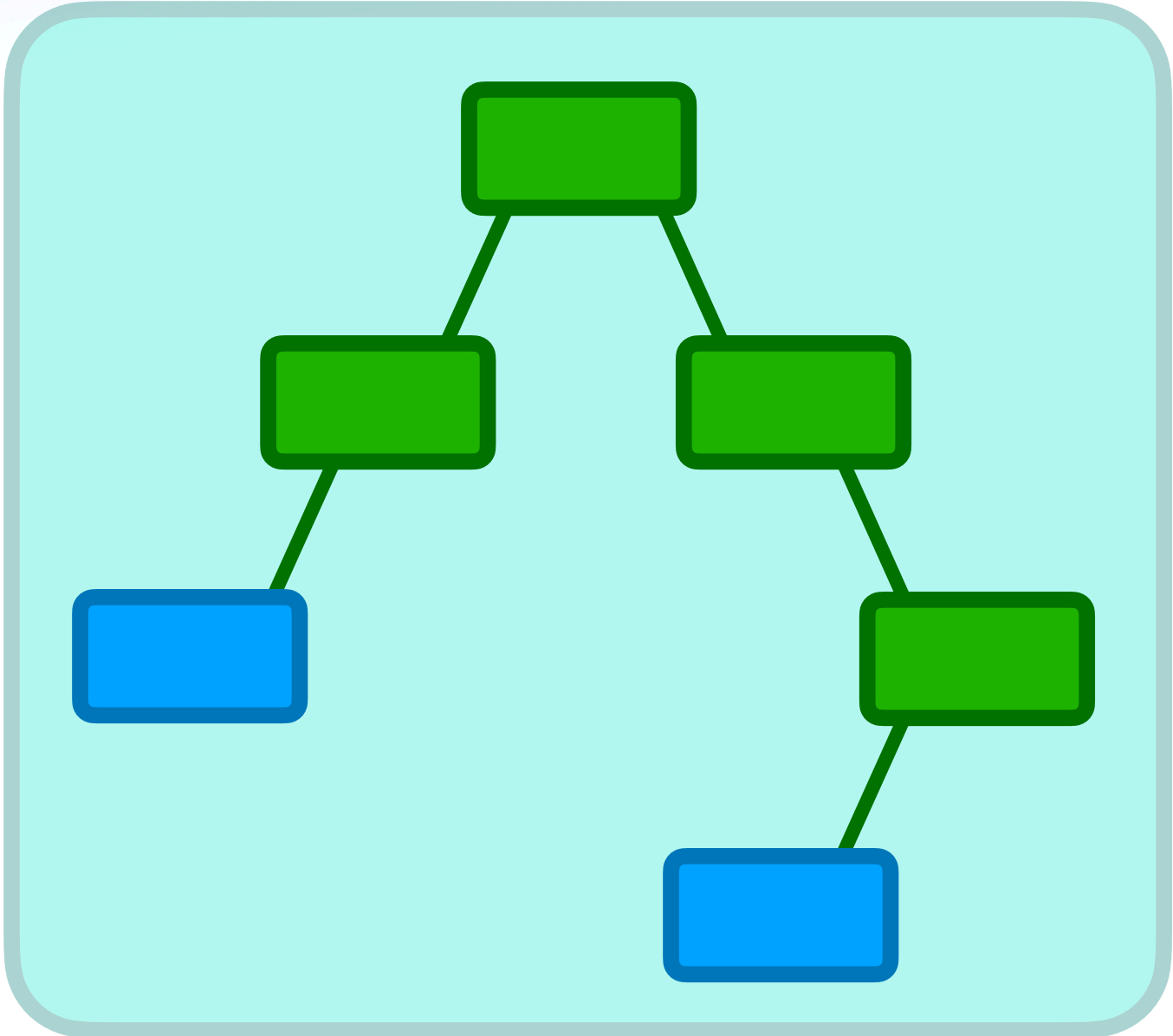
# Content Addressing

# *Hard & Soft Links*

akiko.example.com



boris.example.com

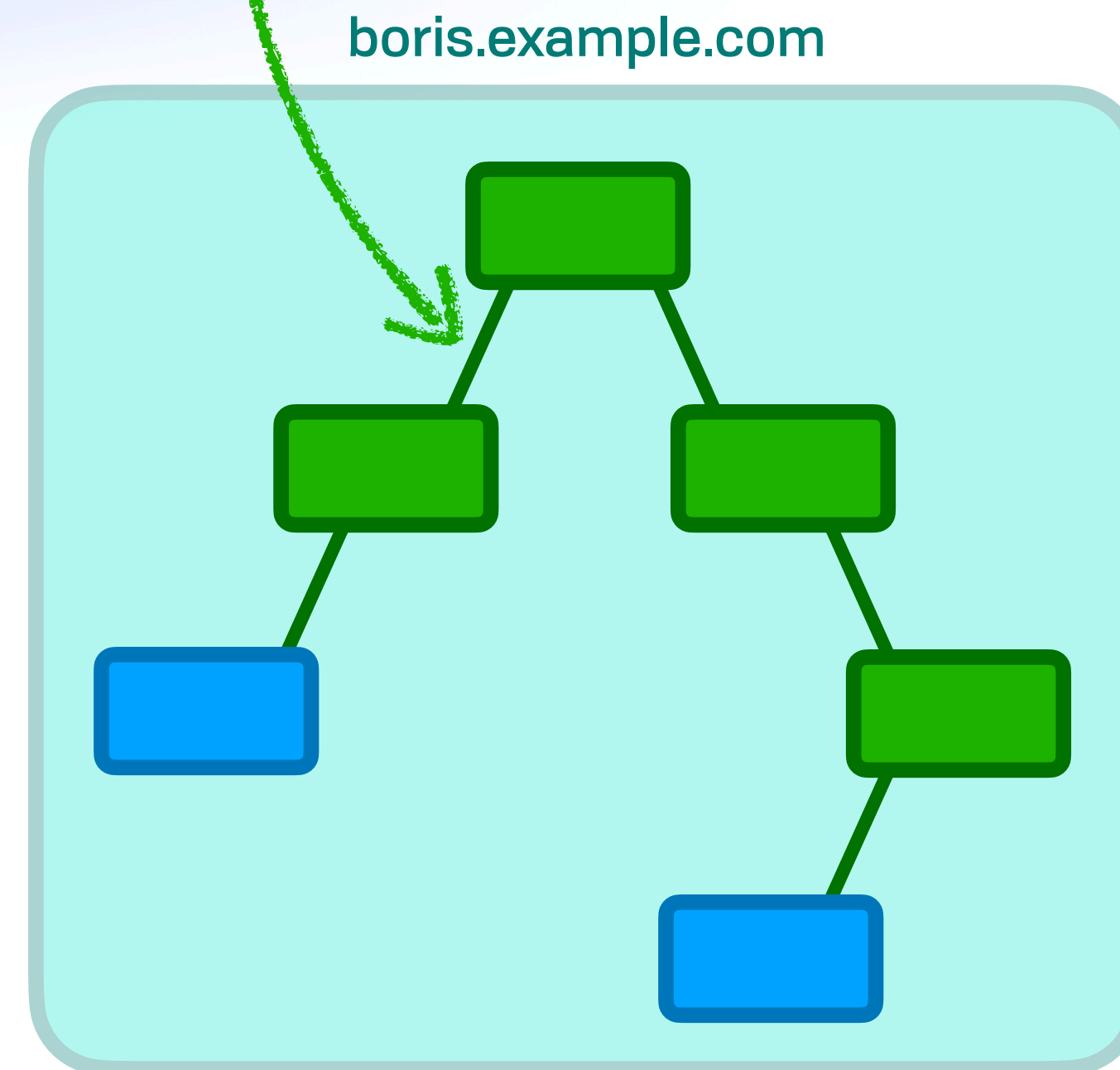
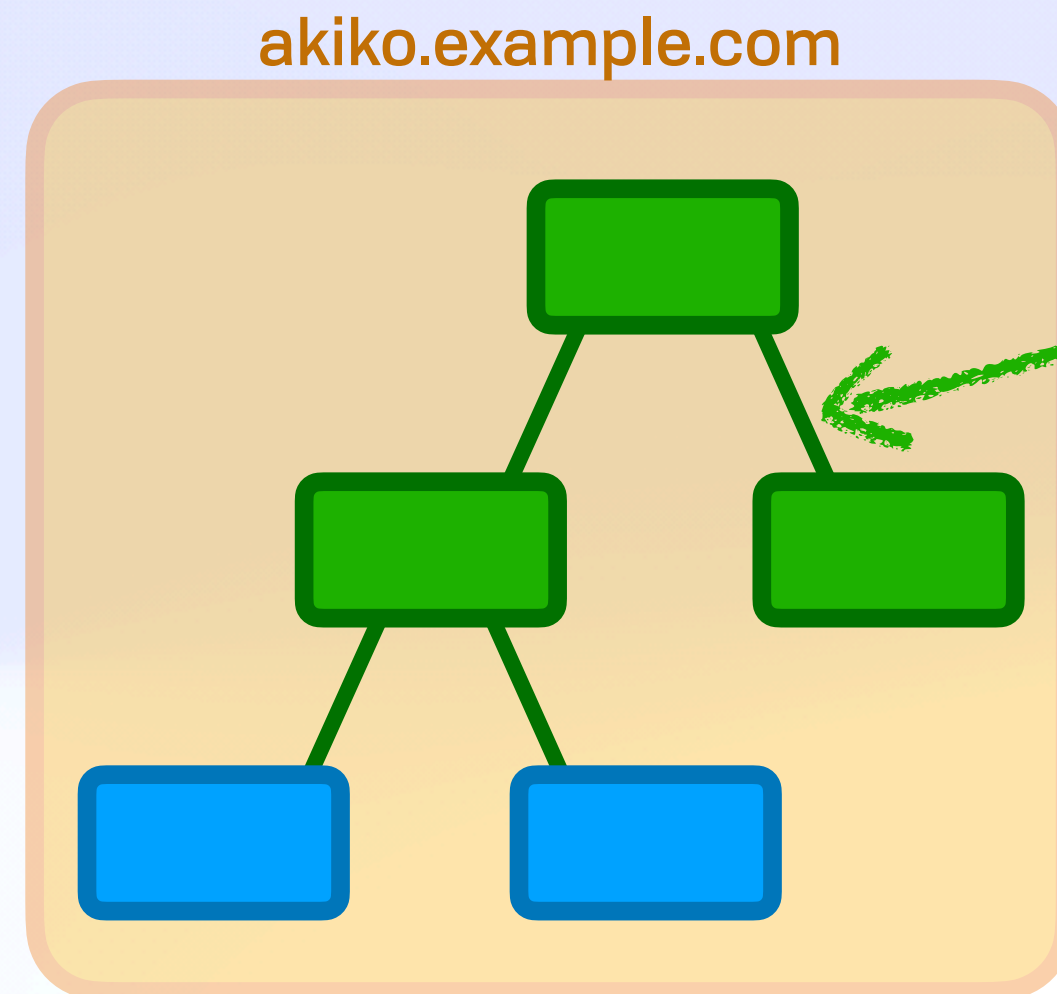


# Content Addressing

## **Hard & Soft Links**

### Hard Links

- ◆ New for the web!
- ◆ Direct reference
- ◆ 2 pointers ~ deduplicate

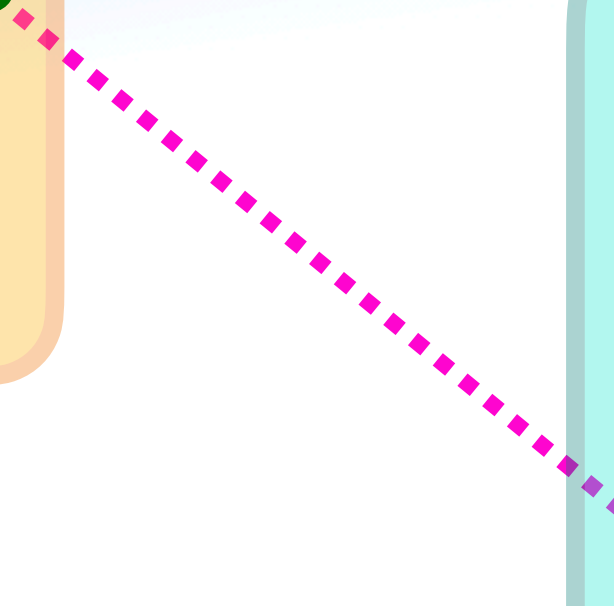
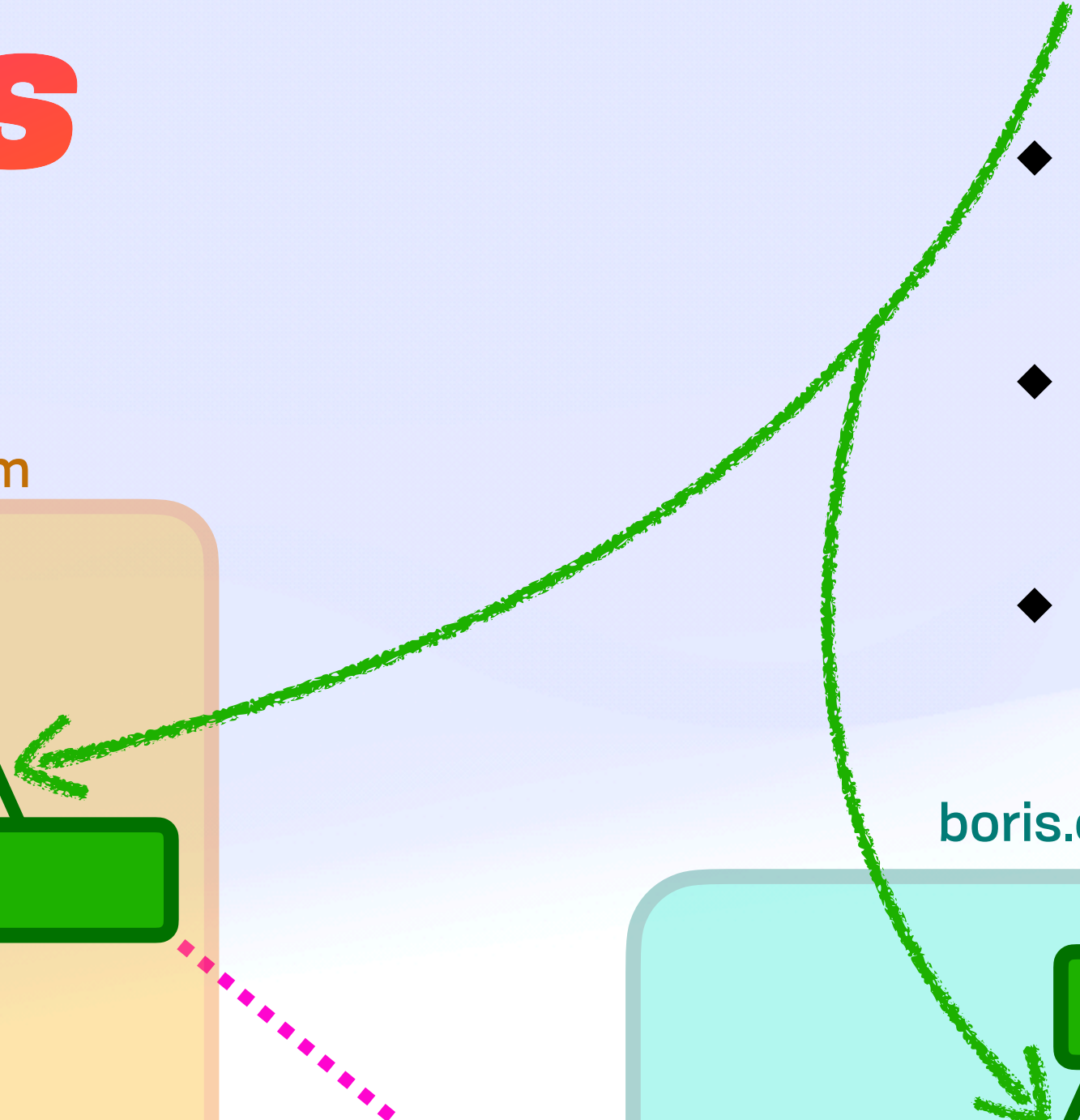
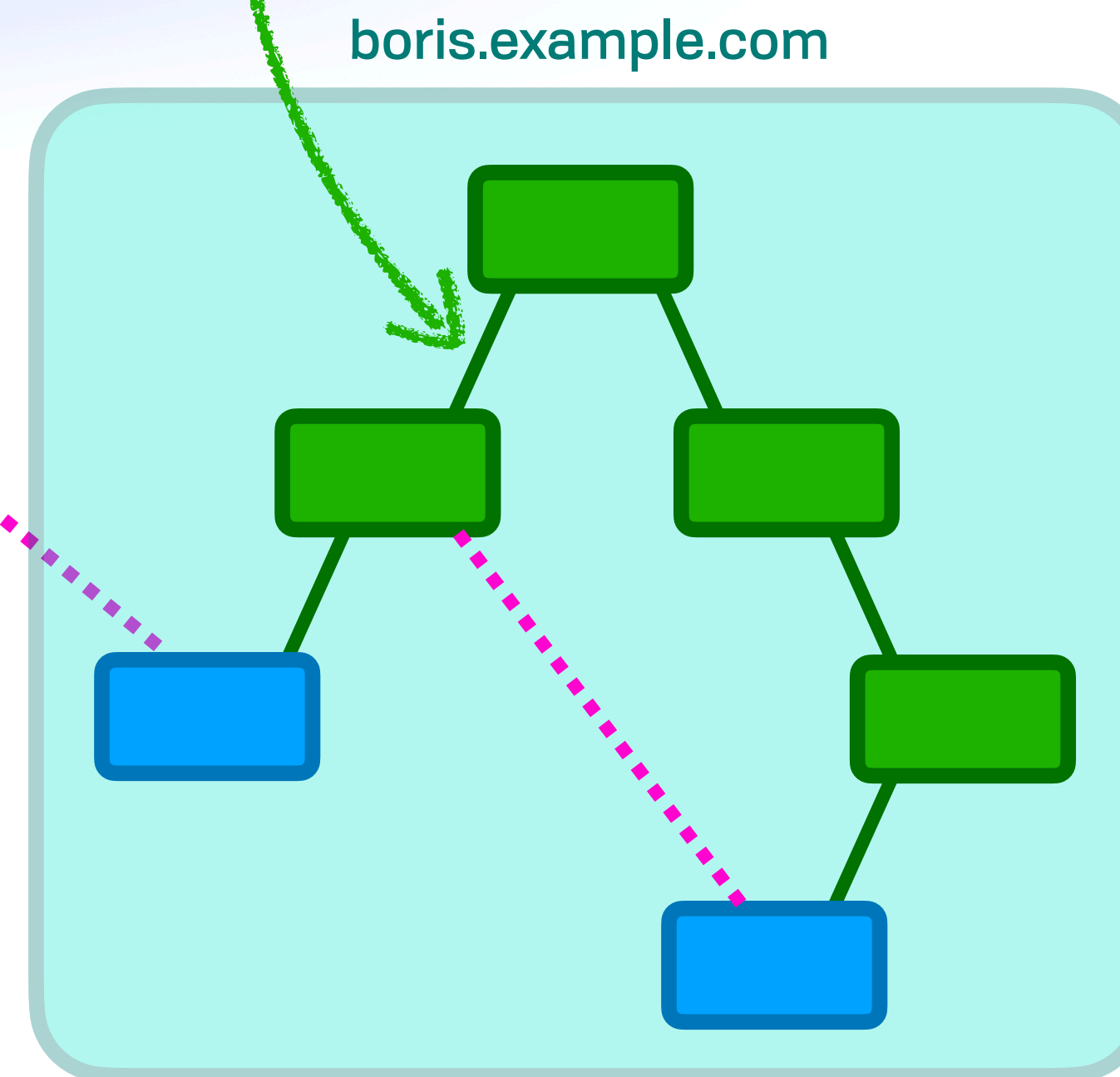
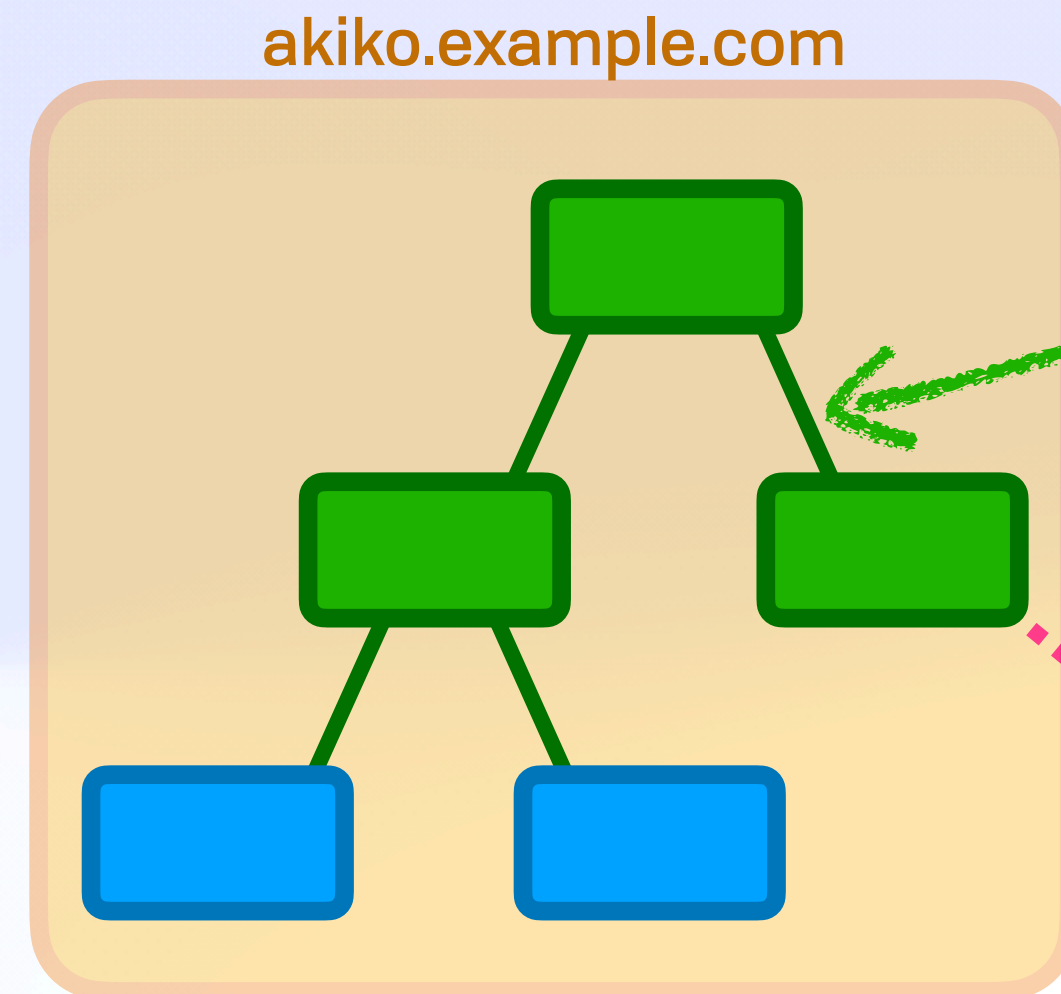


# Content Addressing

## **Hard & Soft Links**

### Hard Links

- ◆ New for the web!
- ◆ Direct reference
- ◆ 2 pointers ~ deduplicate





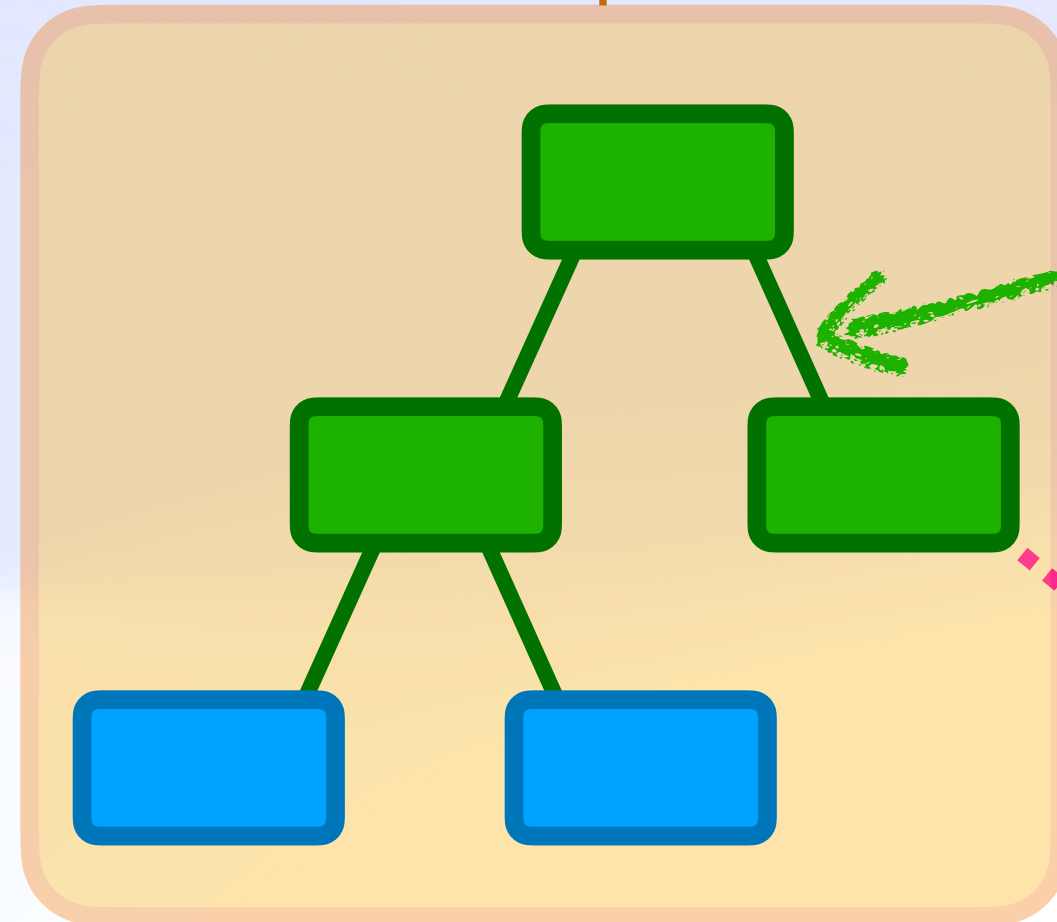
# Content Addressing

## **Hard & Soft Links**

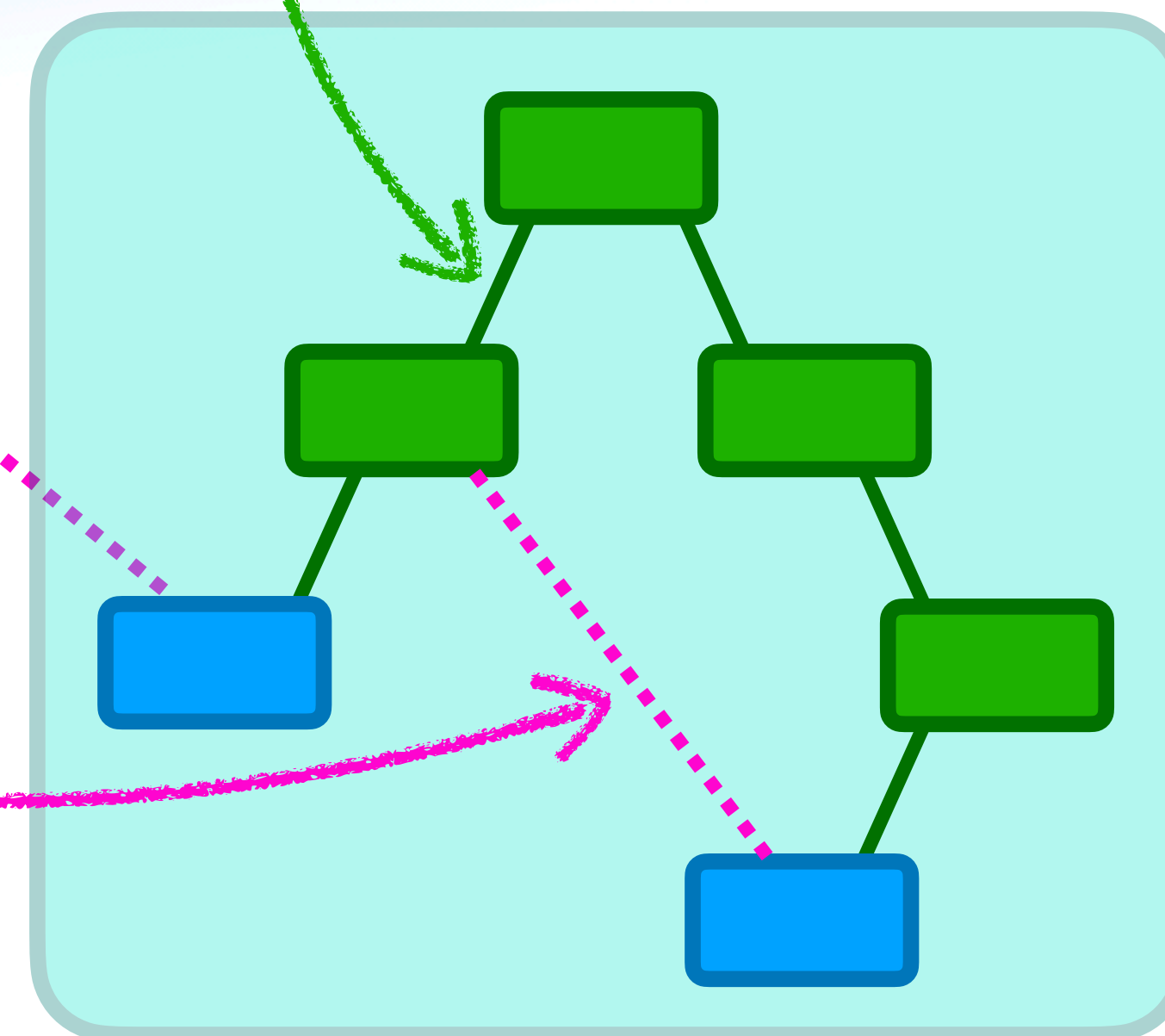
### Hard Links

- ◆ New for the web!
- ◆ Direct reference
- ◆ 2 pointers ~ deduplicate

akiko.example.com

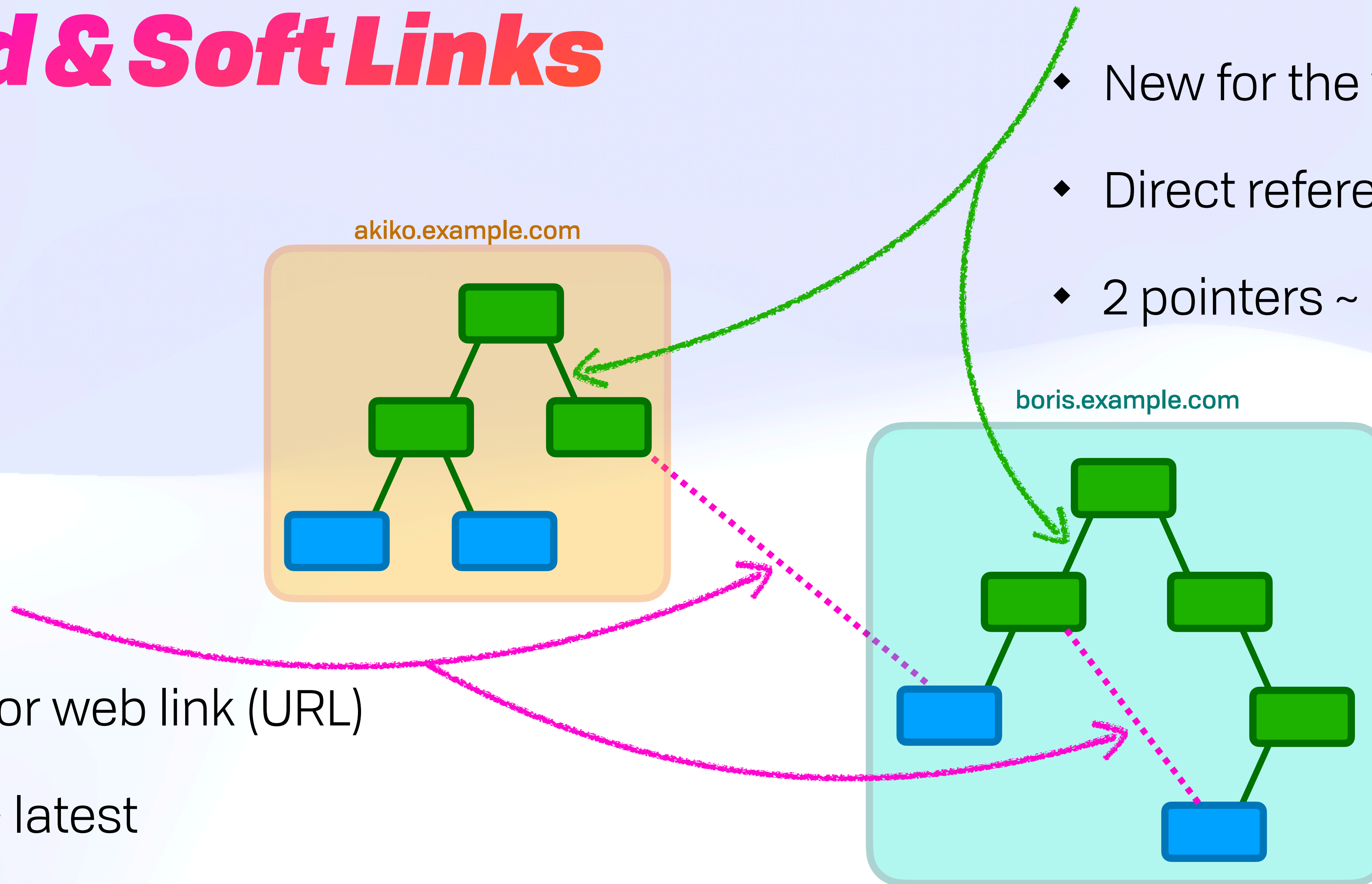


boris.example.com

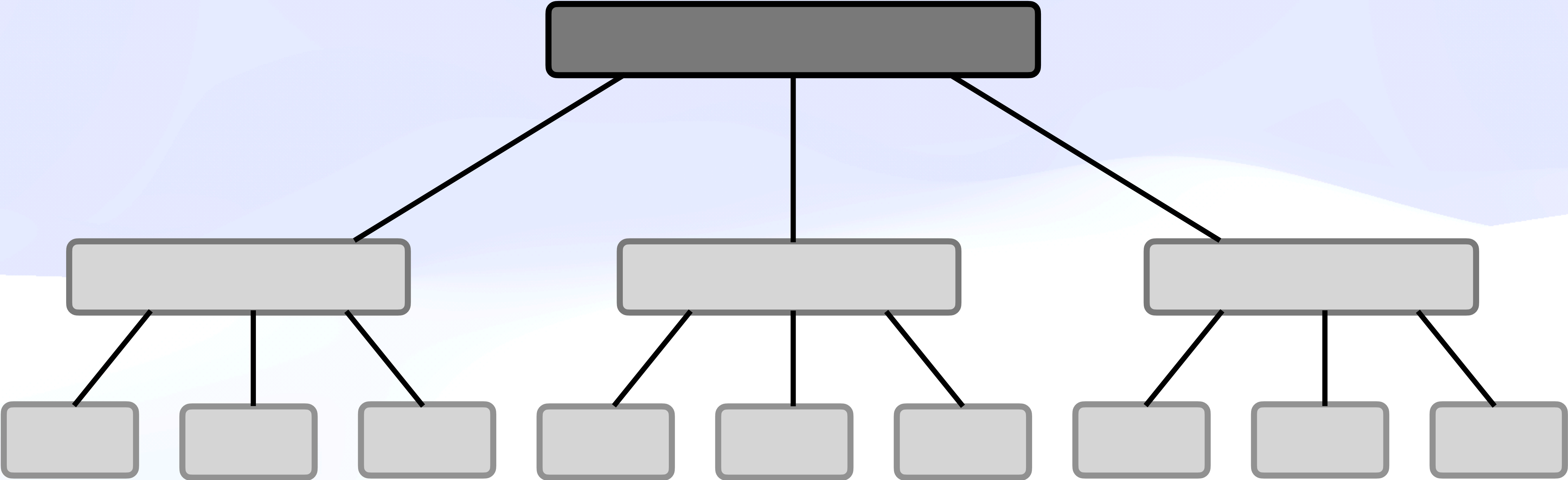


### Soft Links

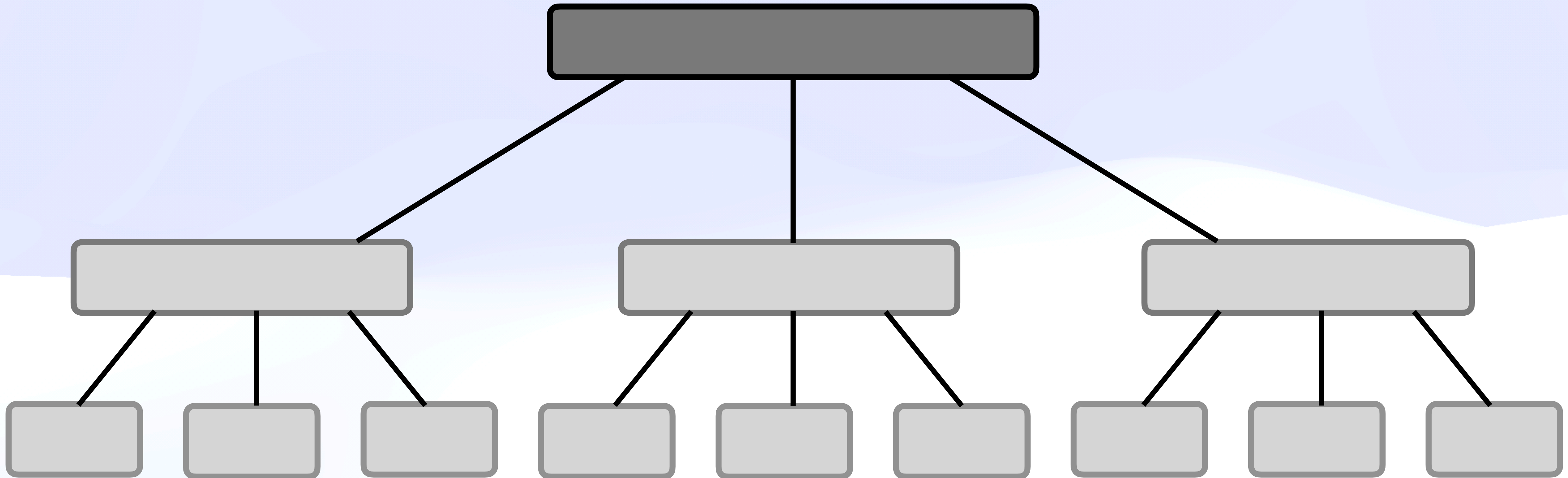
- ◆ Symlink or web link (URL)
- ◆ Pointer ~ latest
- ◆ Latest may break



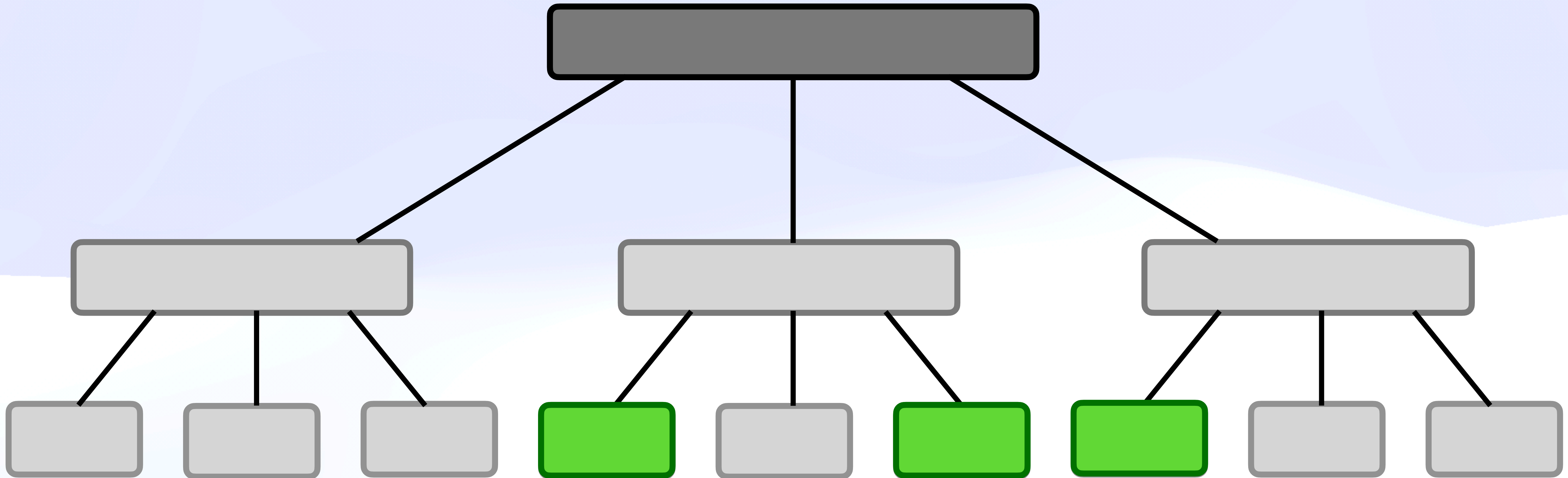
# *Data Partitioning & Selective Replication*



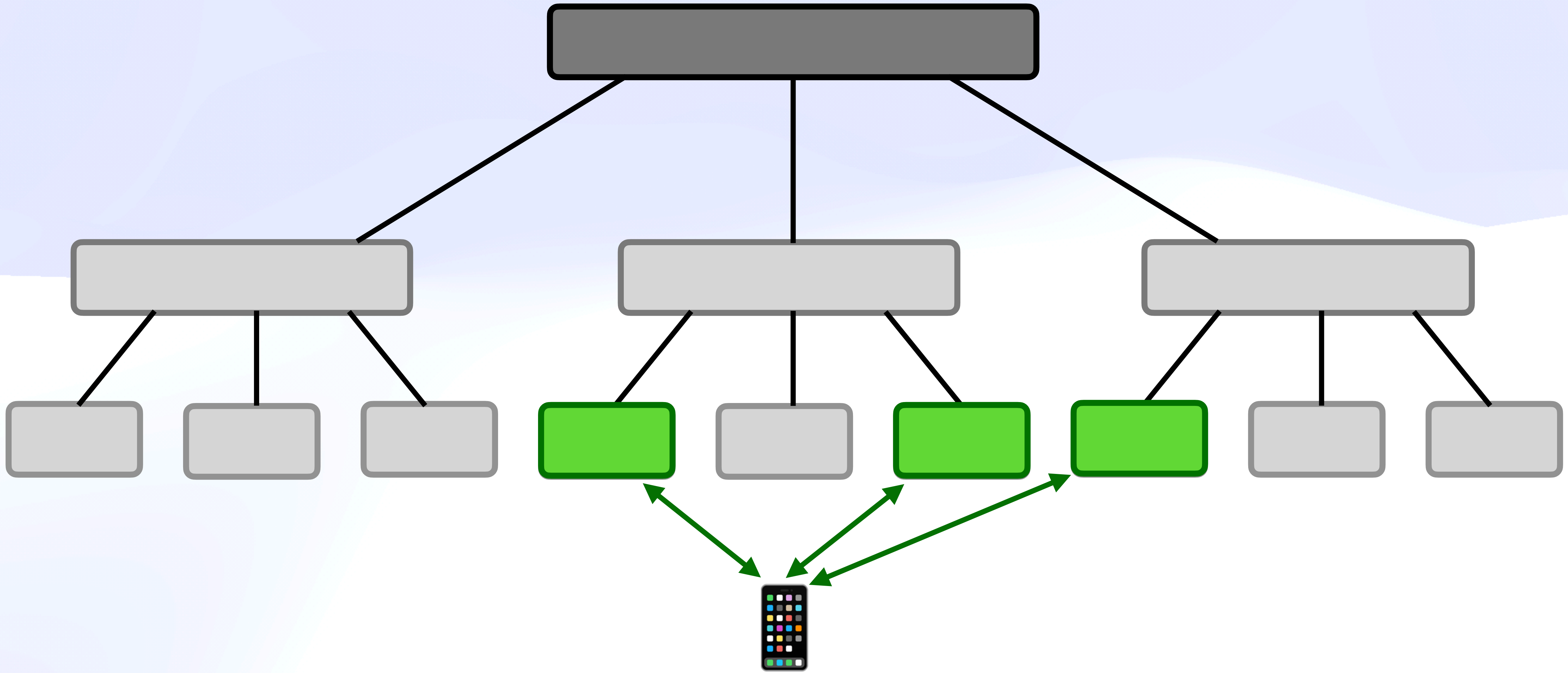
# *Data Partitioning & Selective Replication*



# *Data Partitioning & Selective Replication*



# *Data Partitioning & Selective Replication*



Content Addressing 

***Layout***

Content Addressing 

# *Layout*

WNFS Root

Content Addressing 

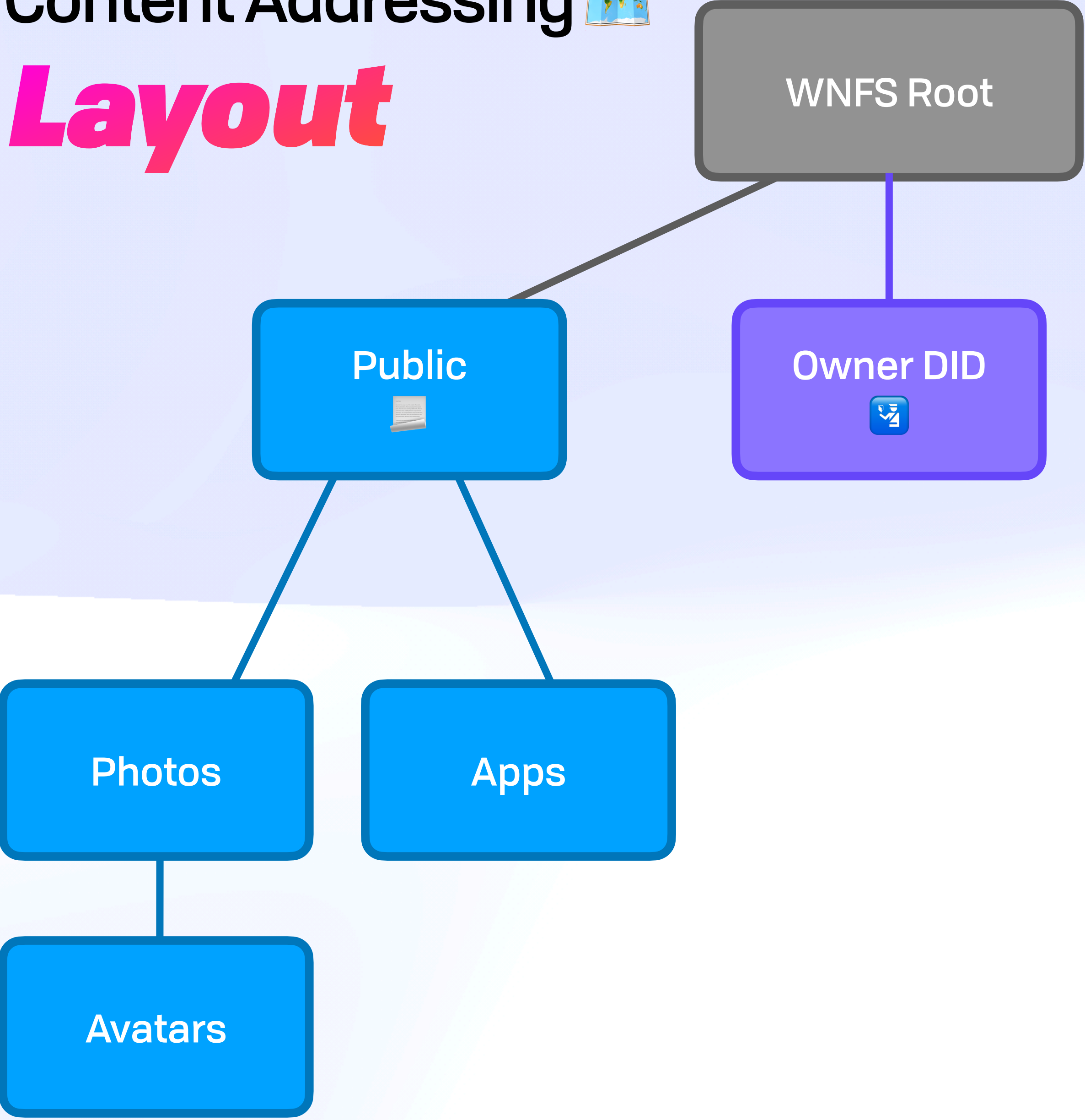
# *Layout*





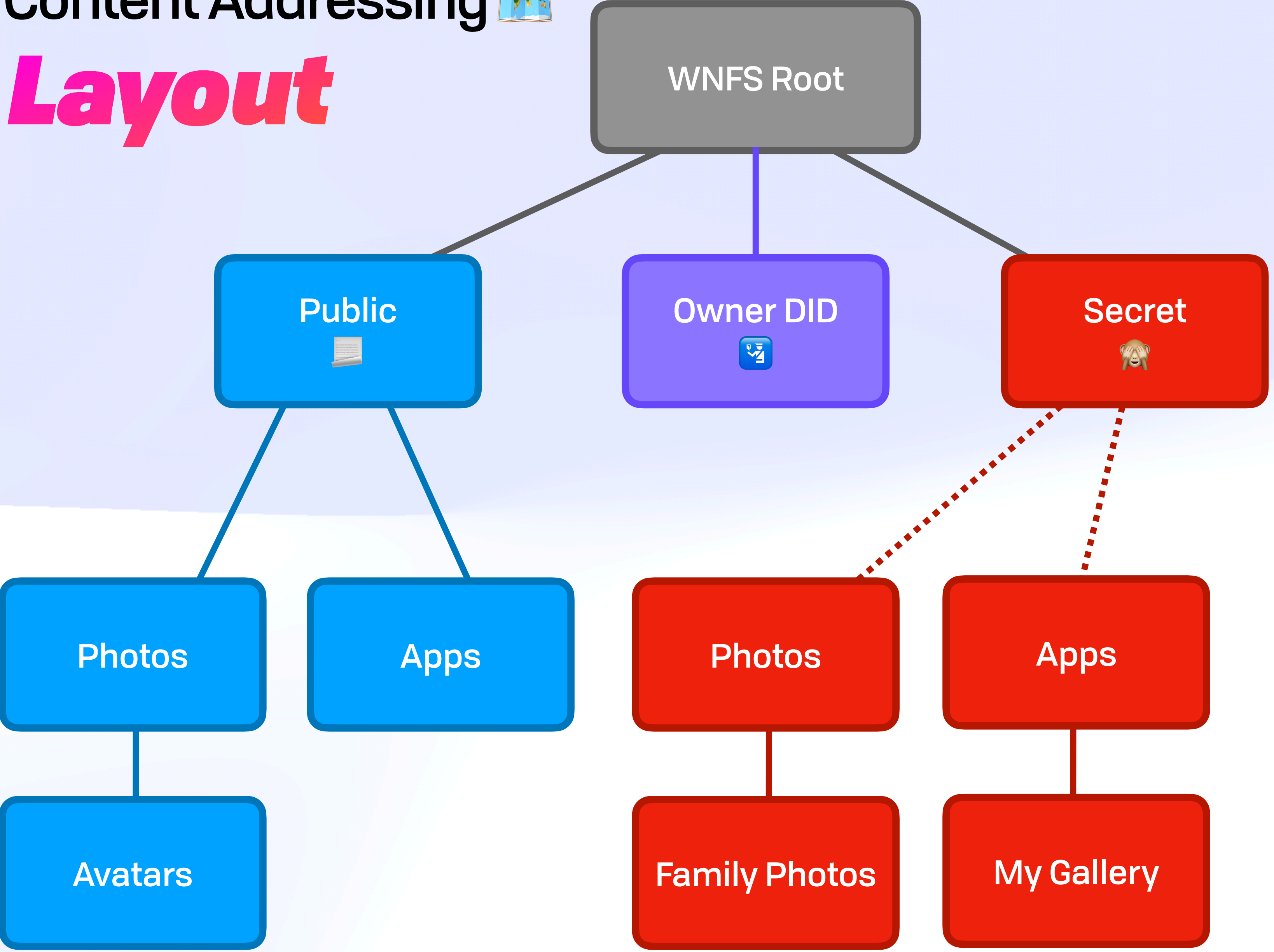
# Content Addressing

## *Layout*



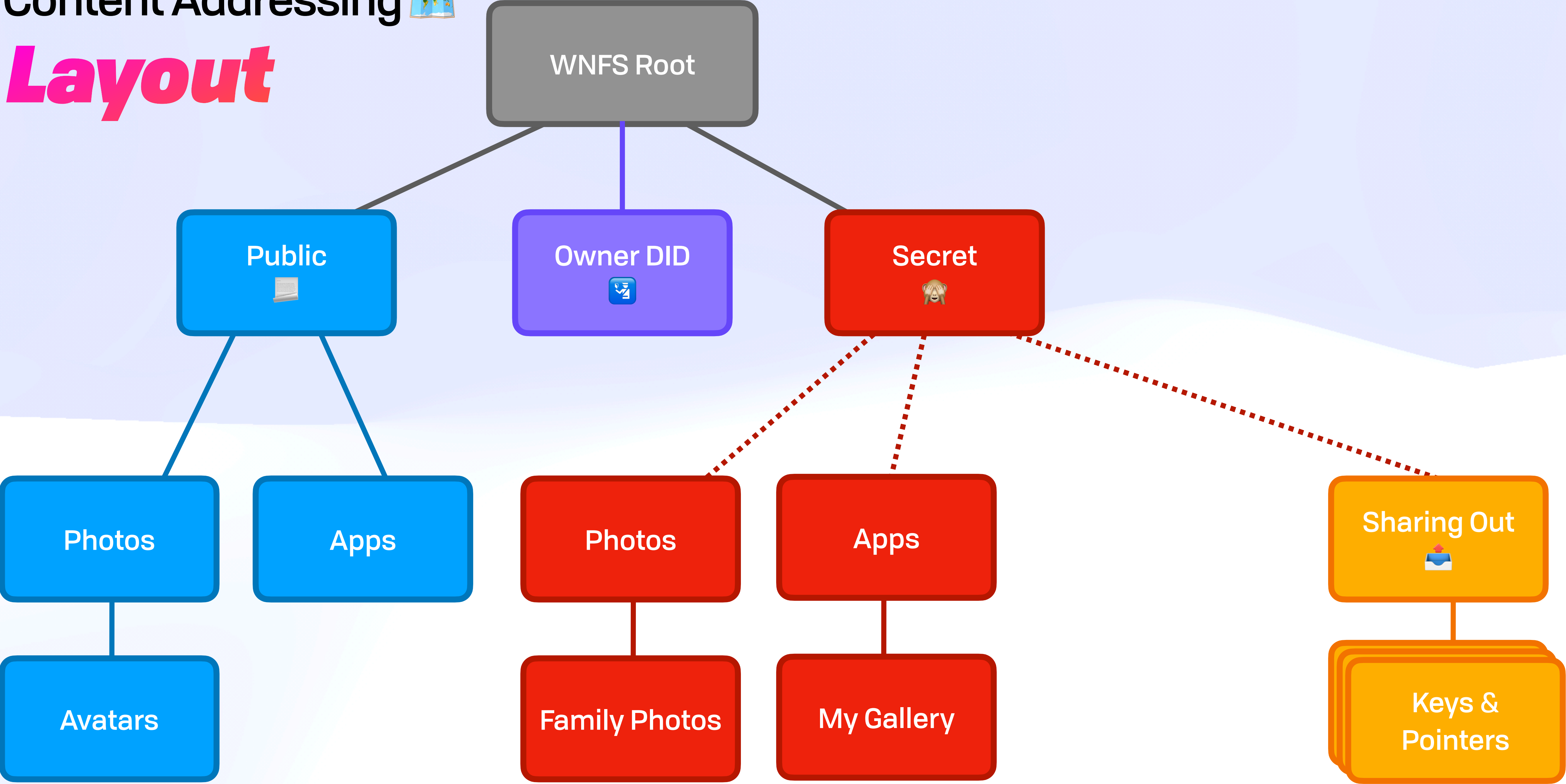
# Content Addressing

## *Layout*



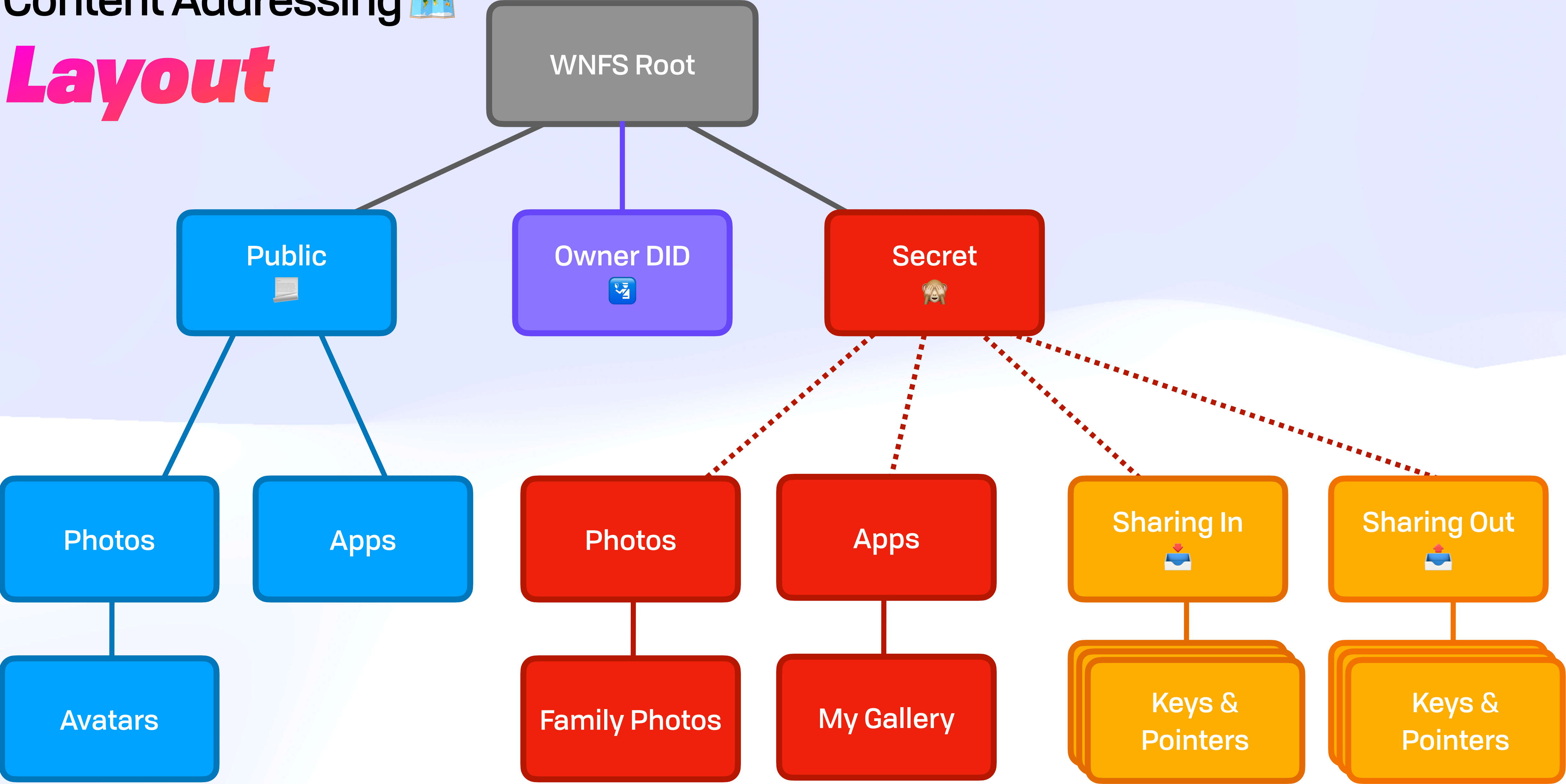
# Content Addressing

## *Layout*



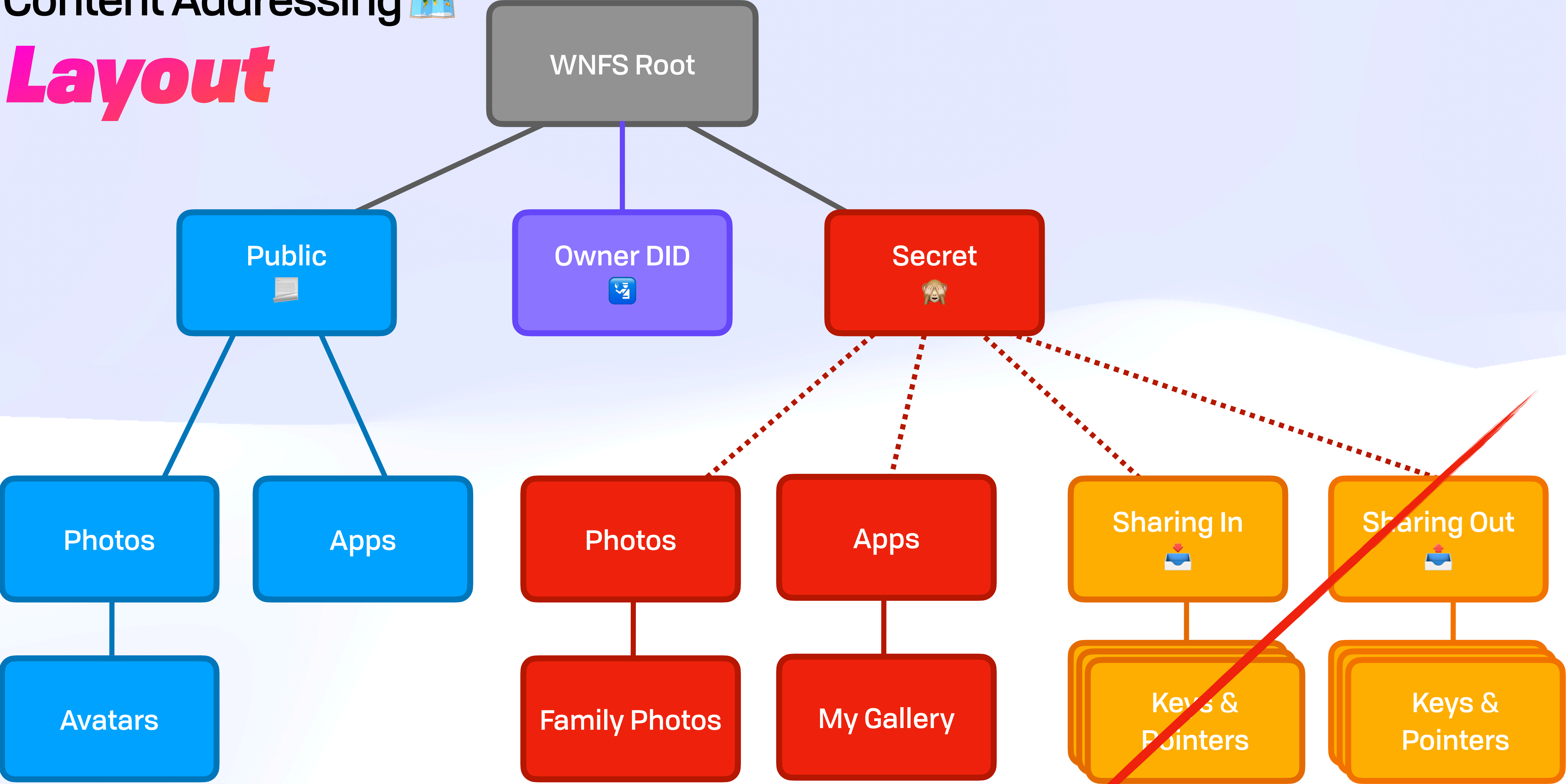
# Content Addressing

## *Layout*



# Content Addressing

## *Layout*

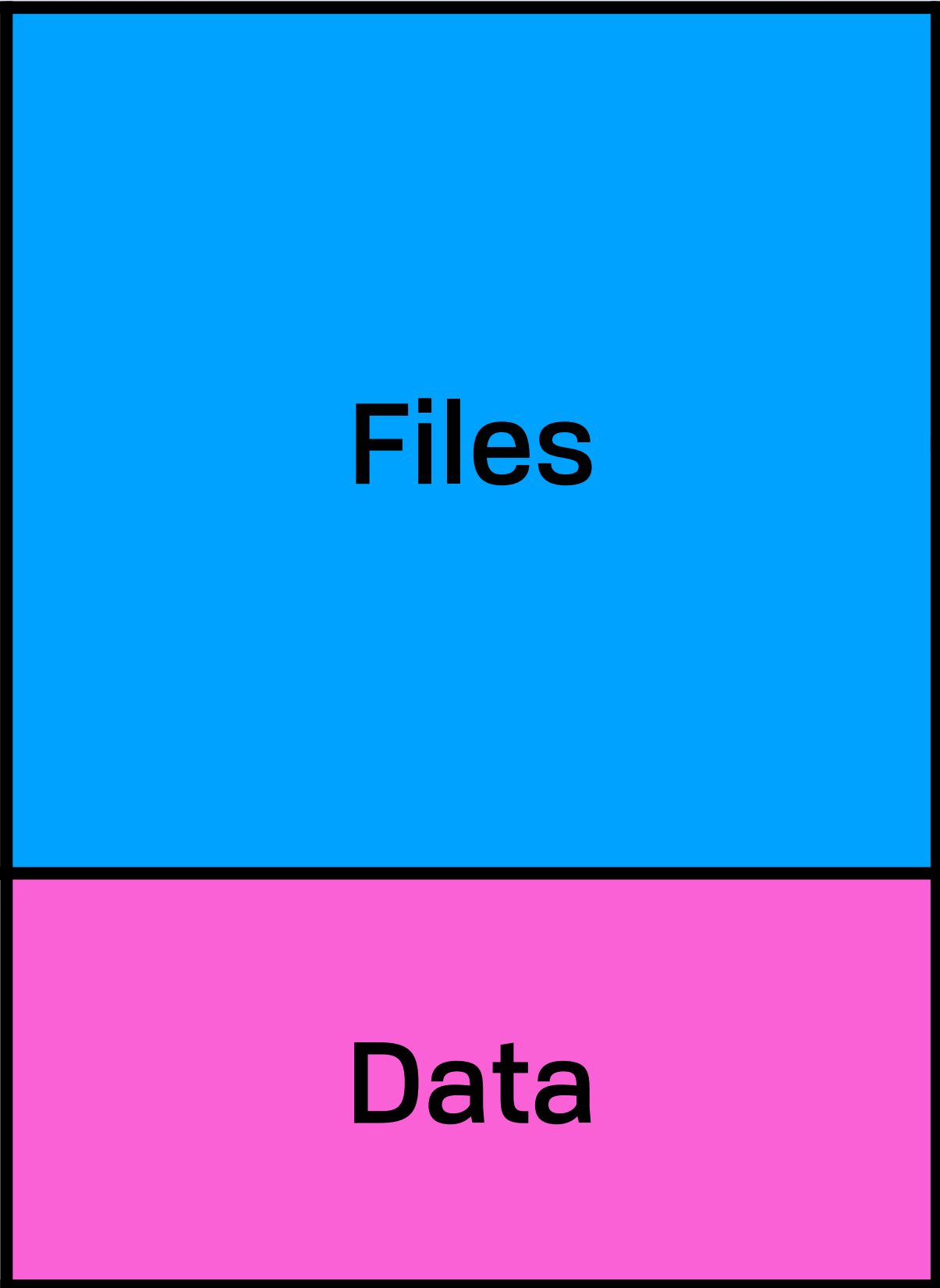


Content Addressing Primer 

# ***Semantic Layers***

# *Semantic Layers*

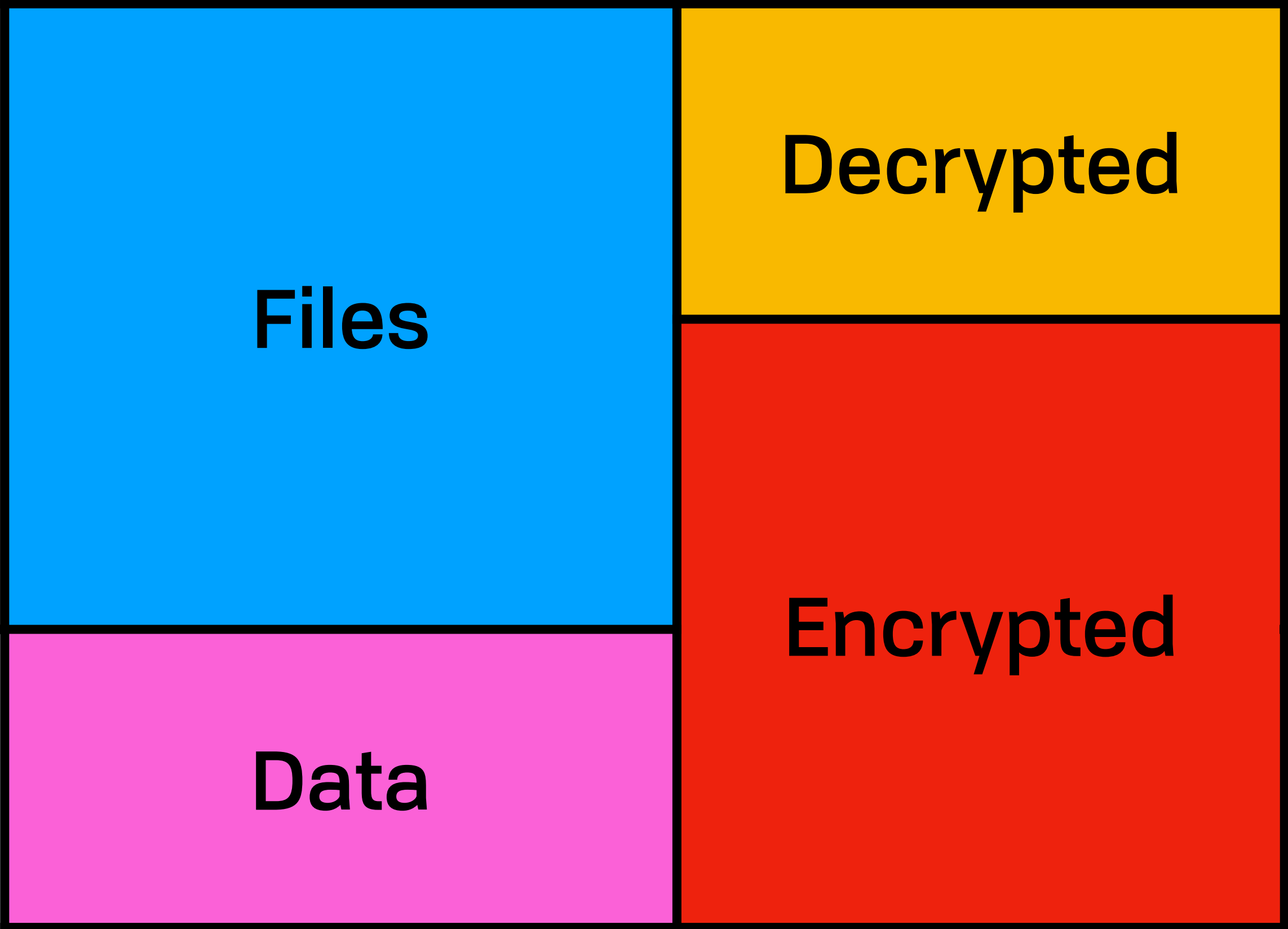
Noun



# *Semantic Layers*

Noun

Visibility

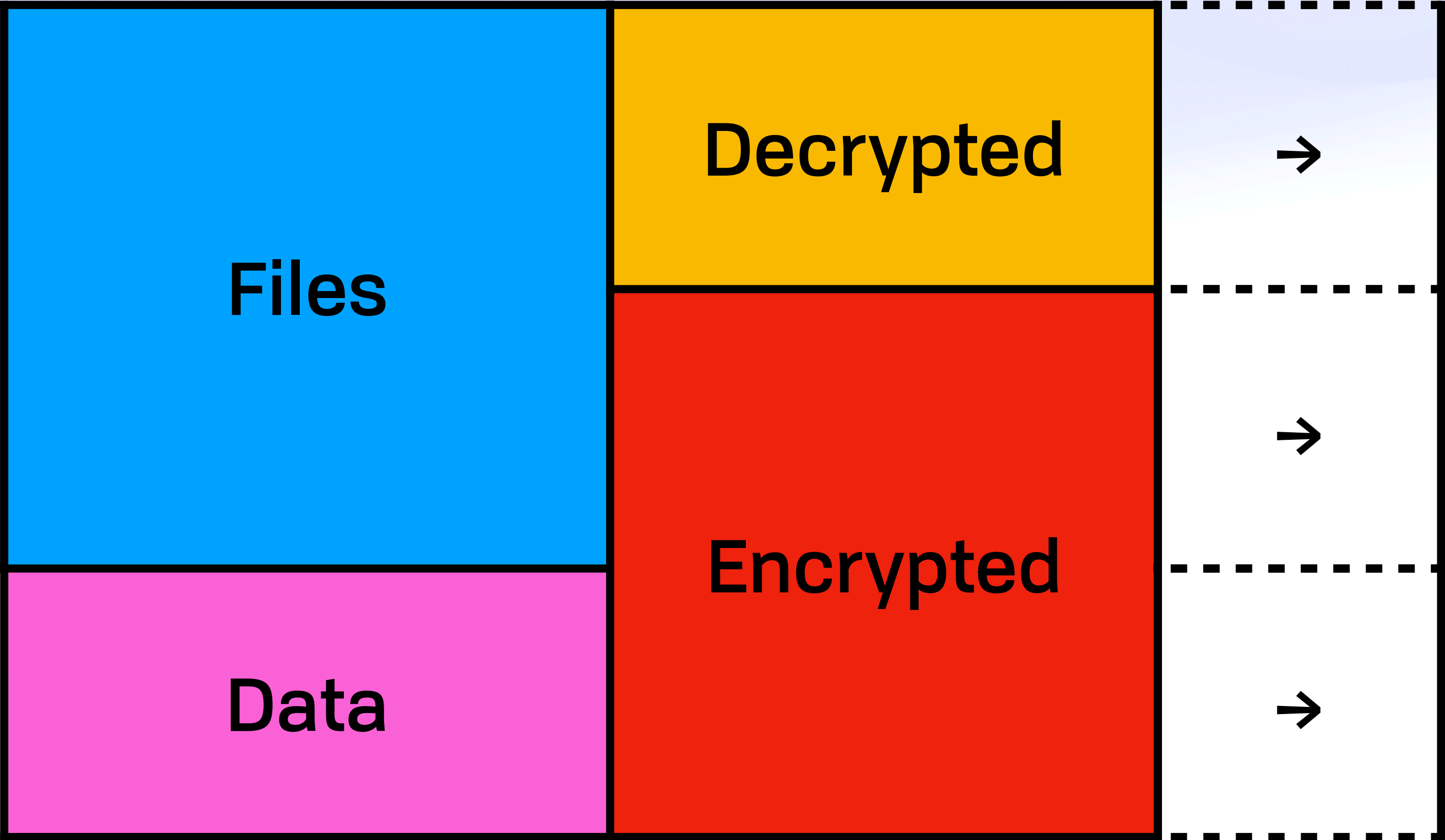




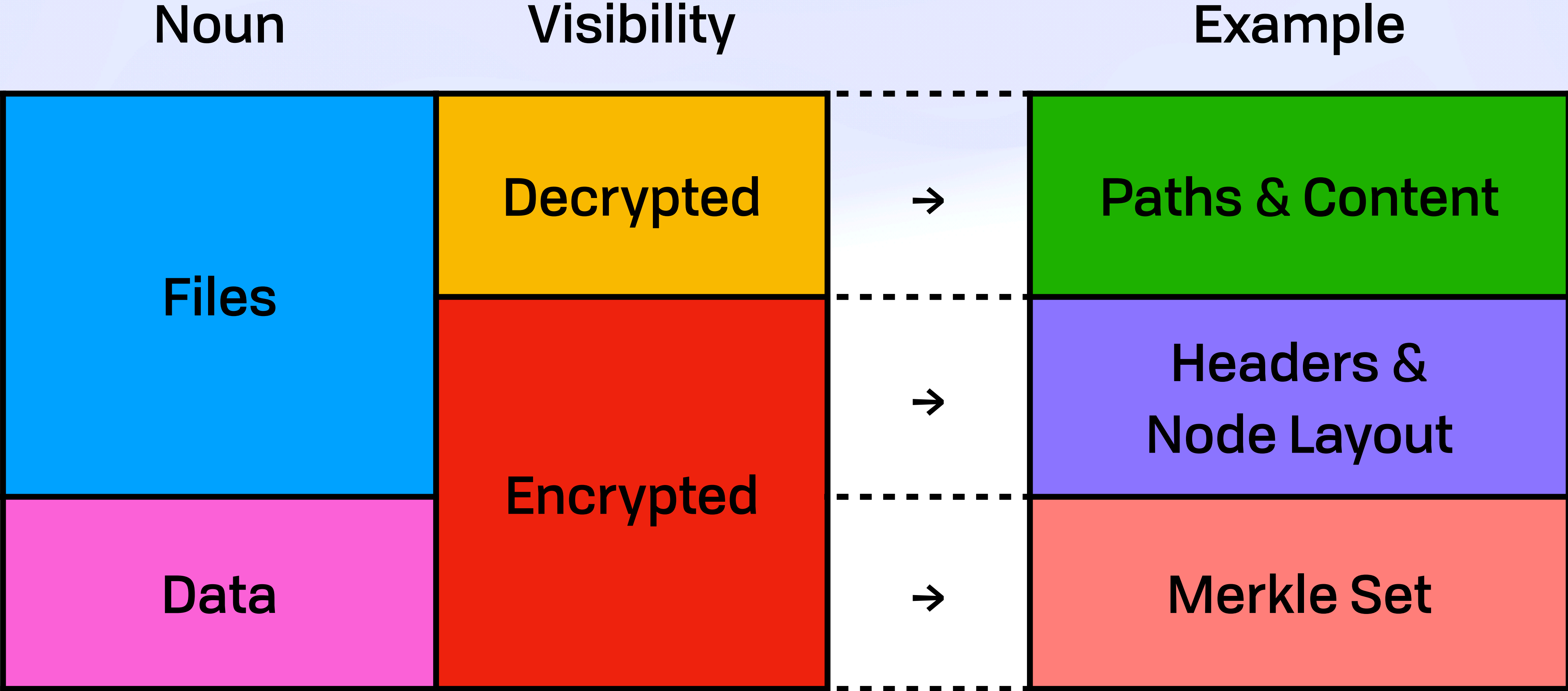
# *Semantic Layers*

Noun

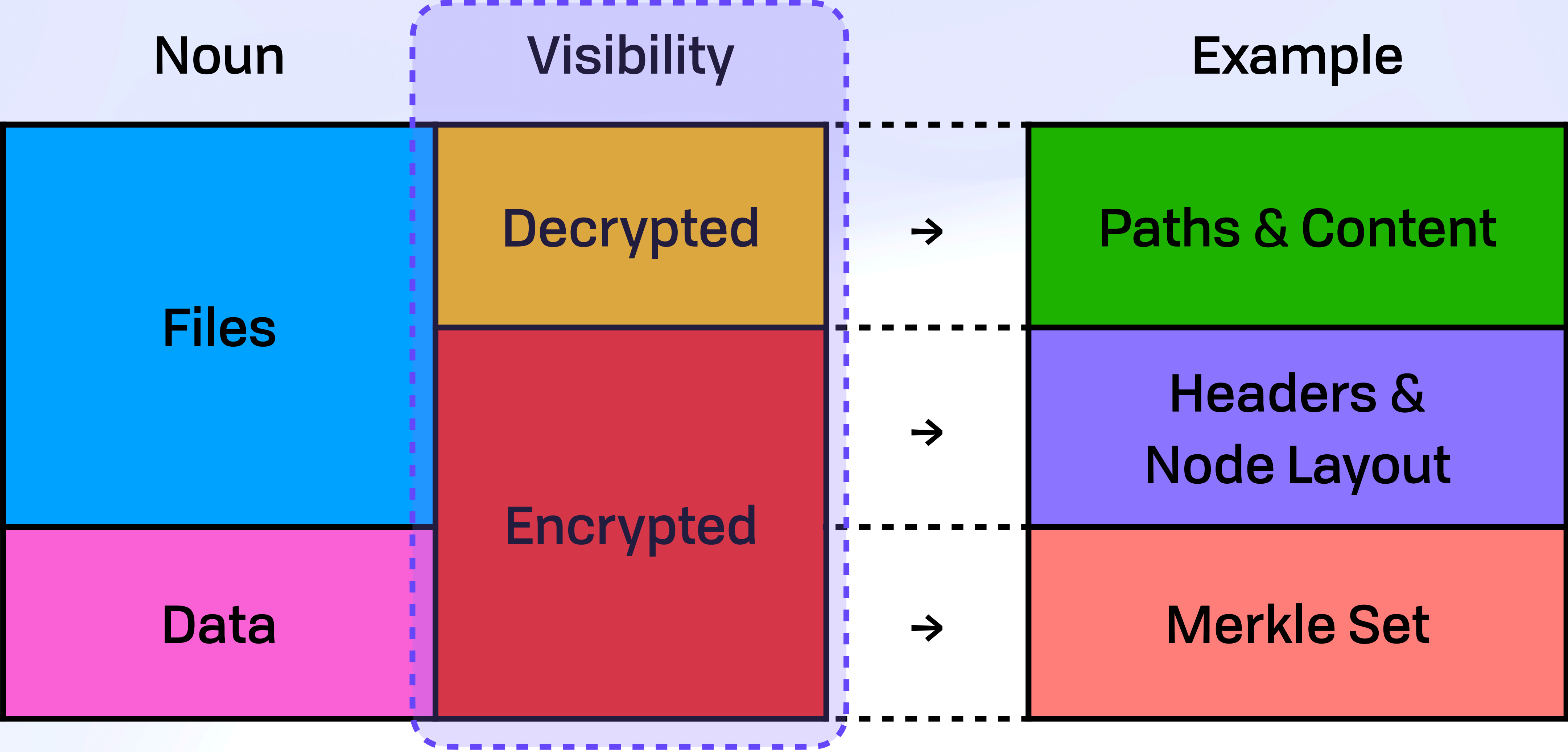
Visibility



# *Semantic Layers*

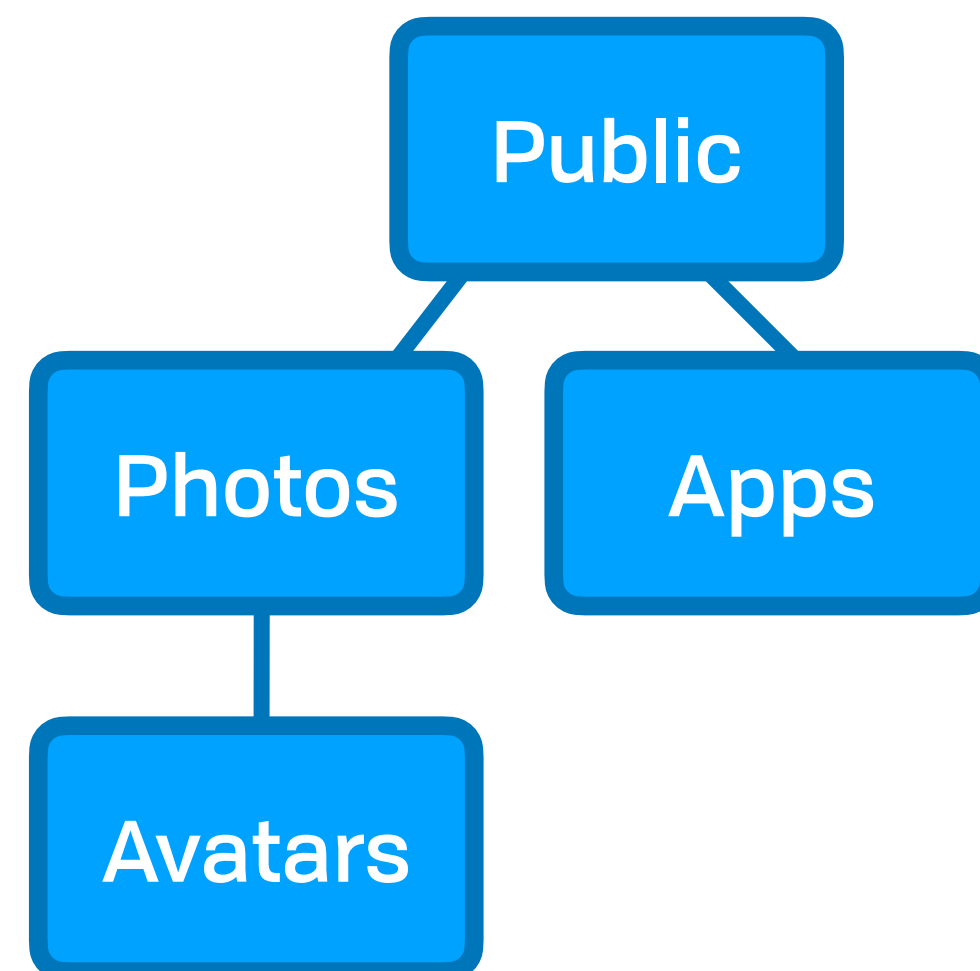


# *Semantic Layers*



# *Public Files*

## WNFS Data Model



Public Files 

# ***Virtual Nodes***

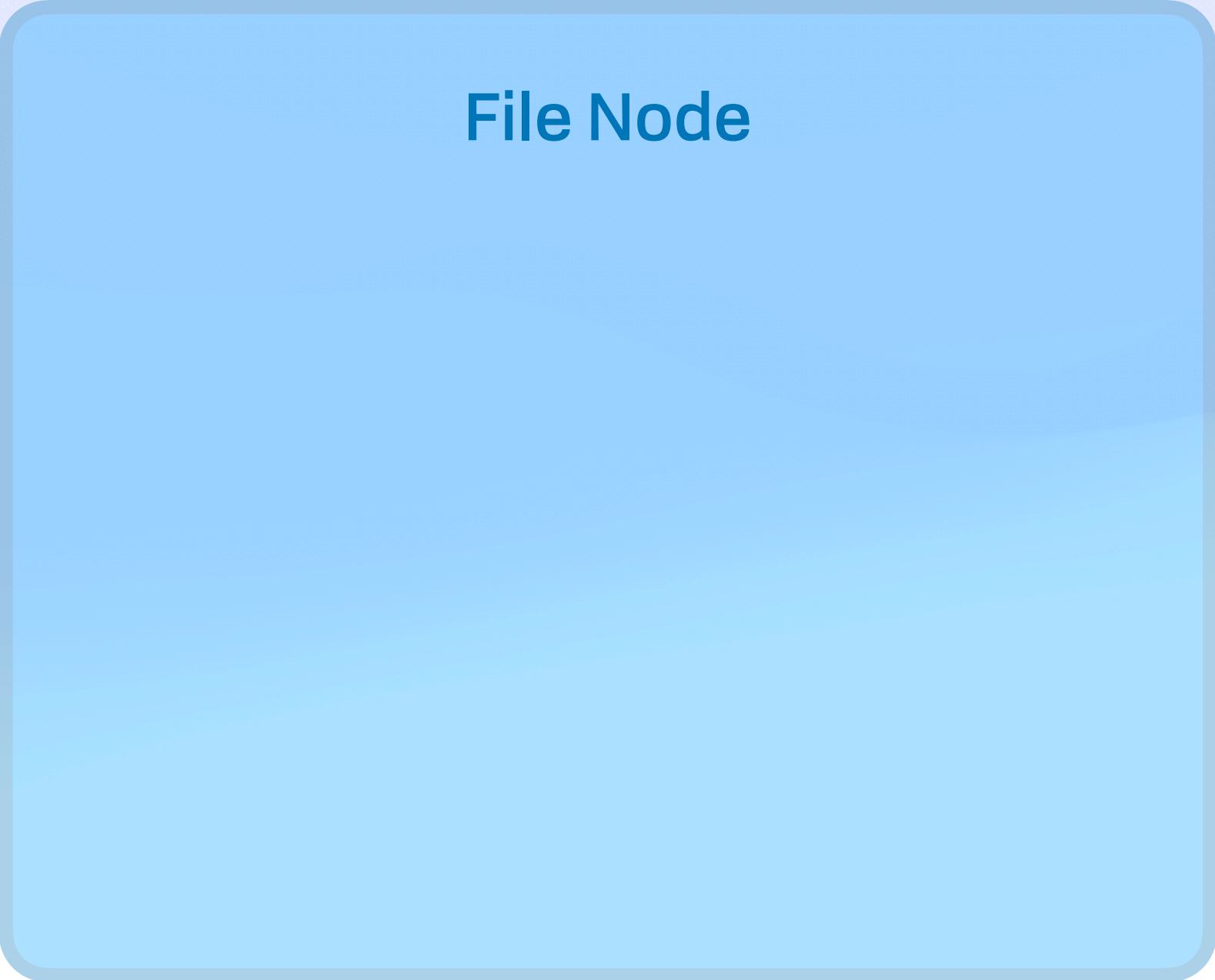
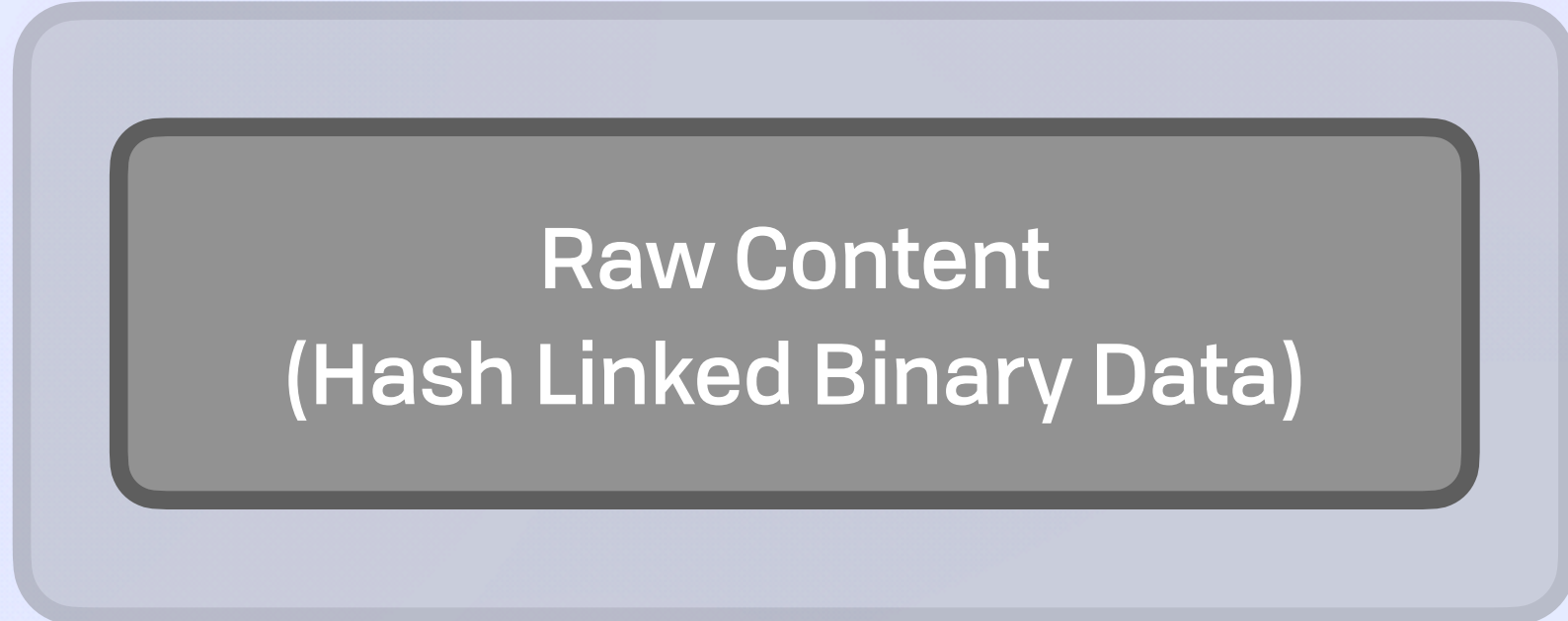
Public Files 

# *Virtual Nodes*

Raw Content  
(Hash Linked Binary Data)

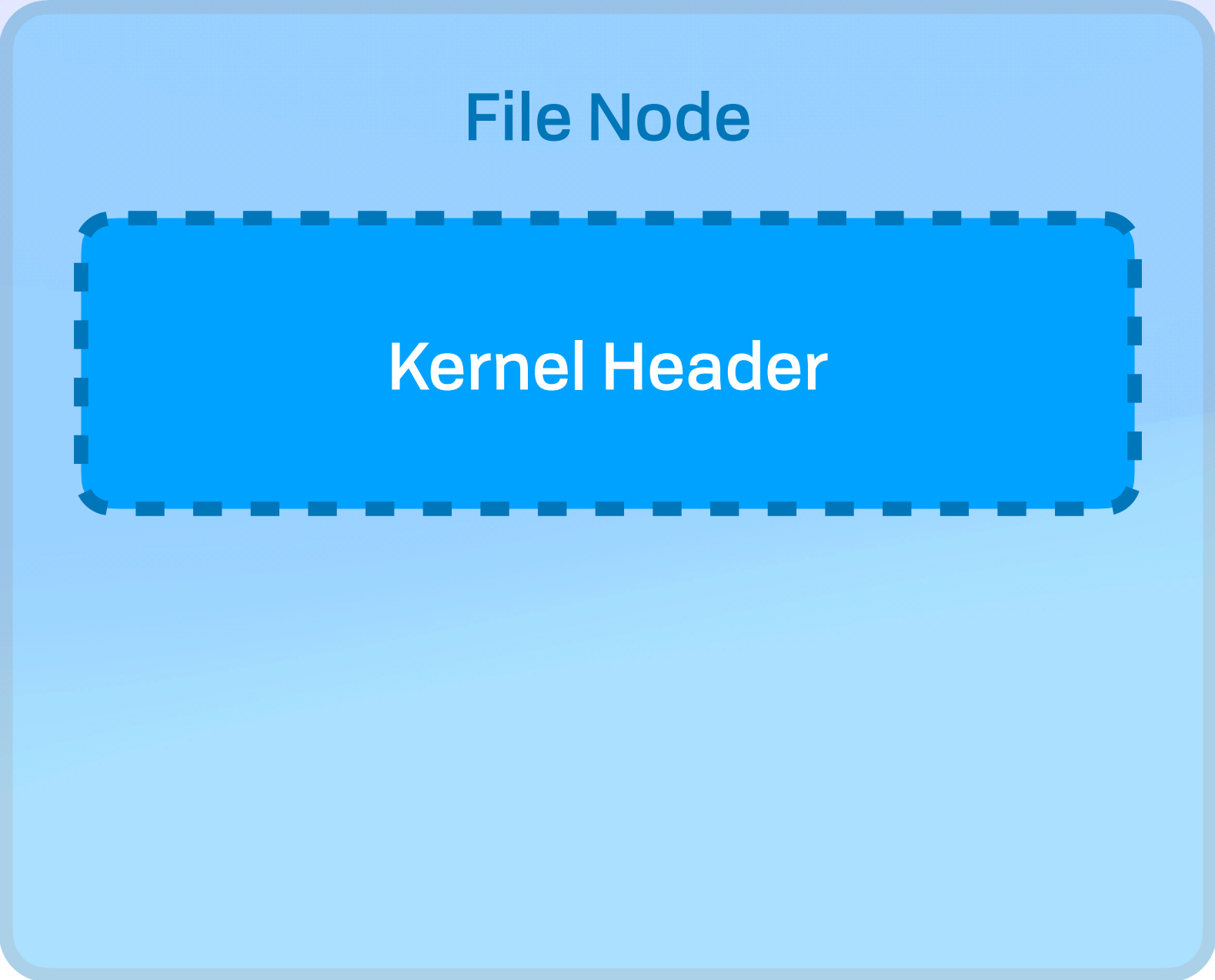
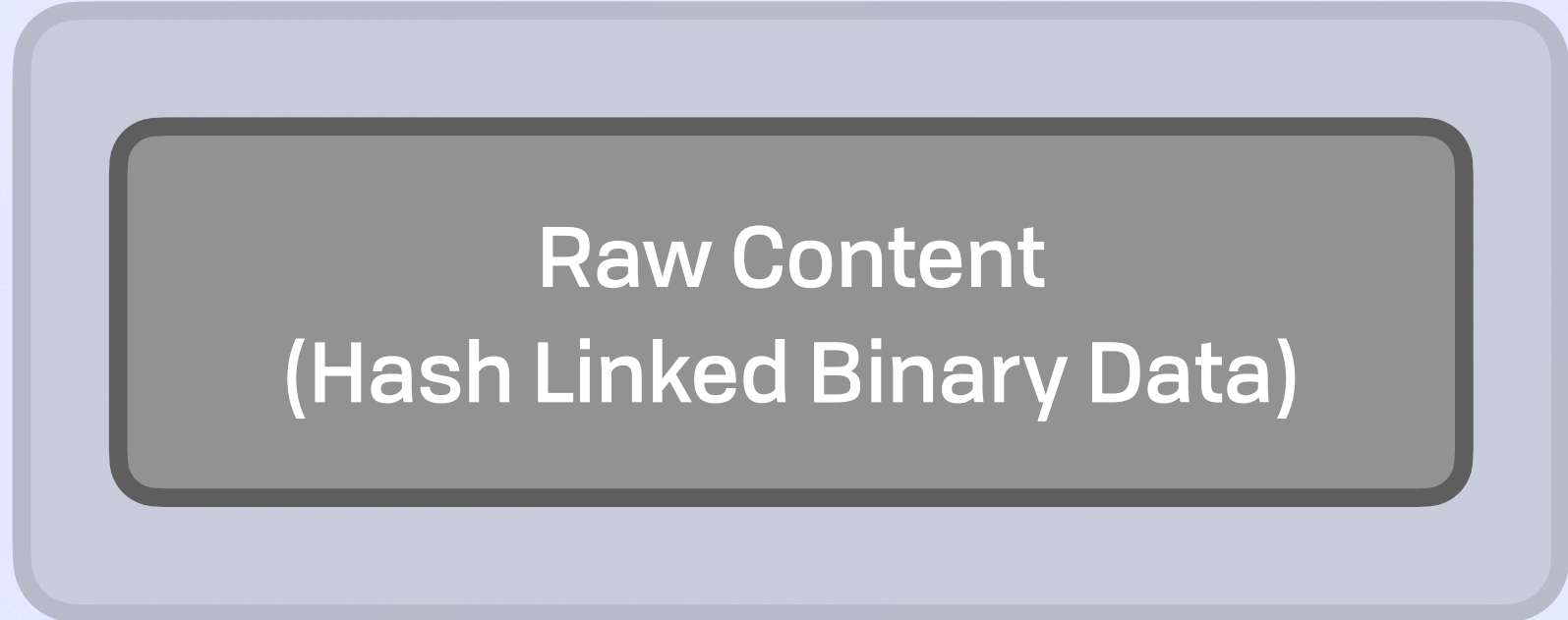
Public Files 

# *Virtual Nodes*



Public Files 

# *Virtual Nodes*





Public Files 

# *Virtual Nodes*

Raw Content  
(Hash Linked Binary Data)

File Node

Kernel Header

Userland  
Raw Data

Public Files 

# *Virtual Nodes*

Raw Content  
(Hash Linked Binary Data)

File Node

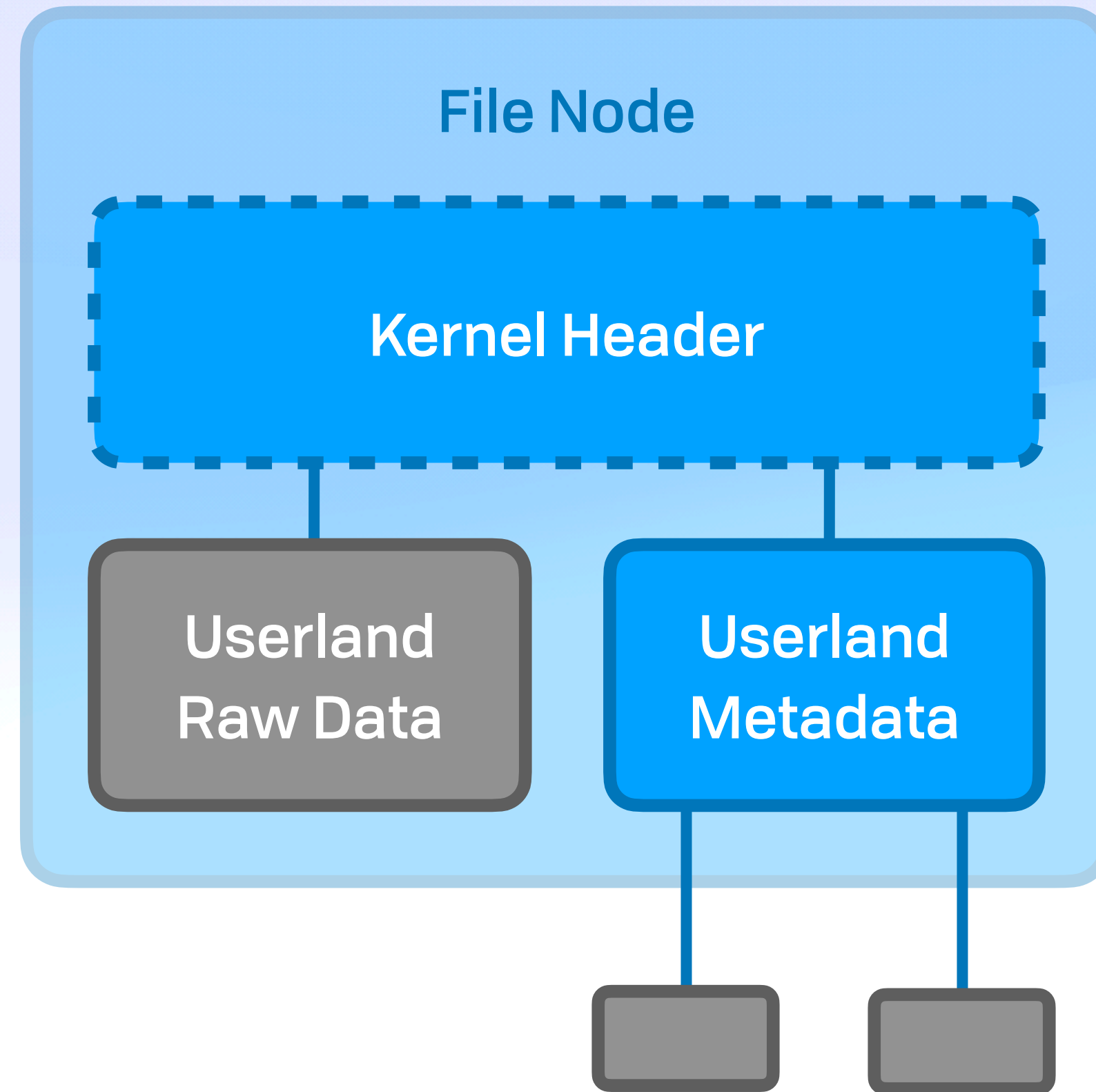
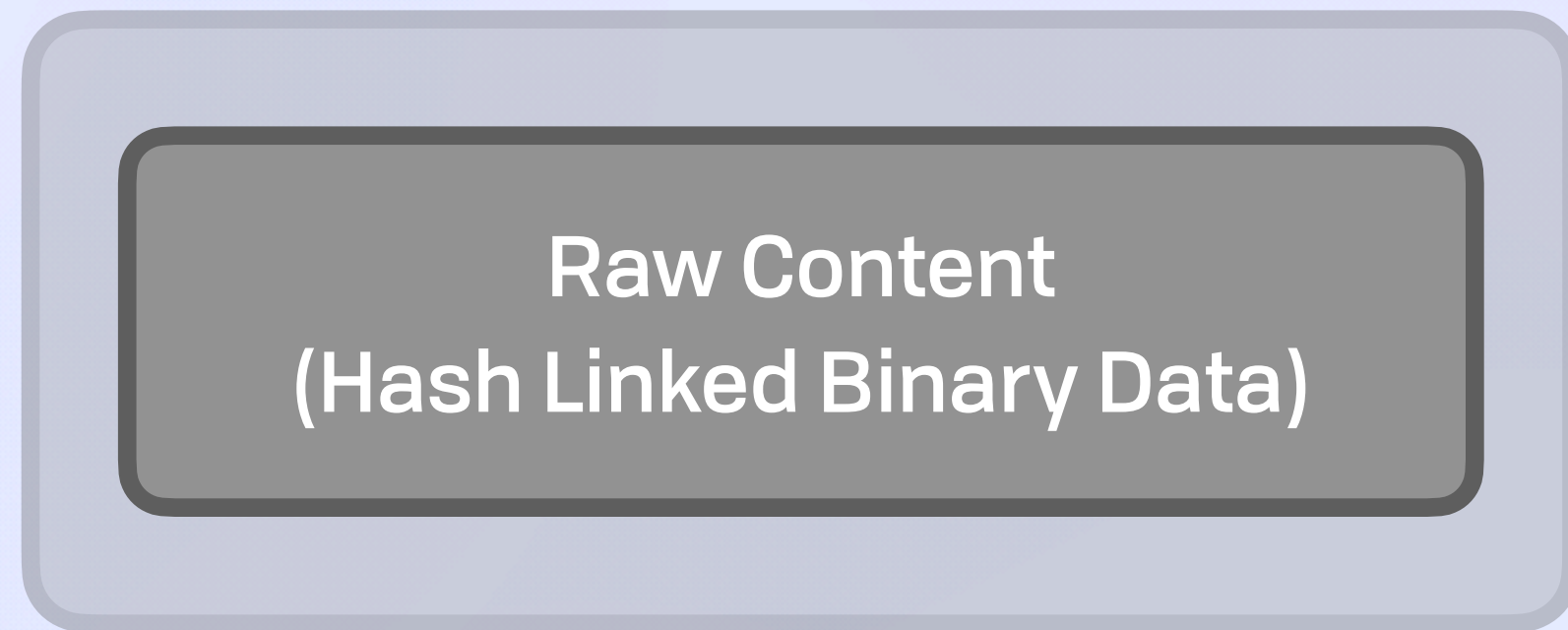
Kernel Header

Userland  
Raw Data

Userland  
Metadata

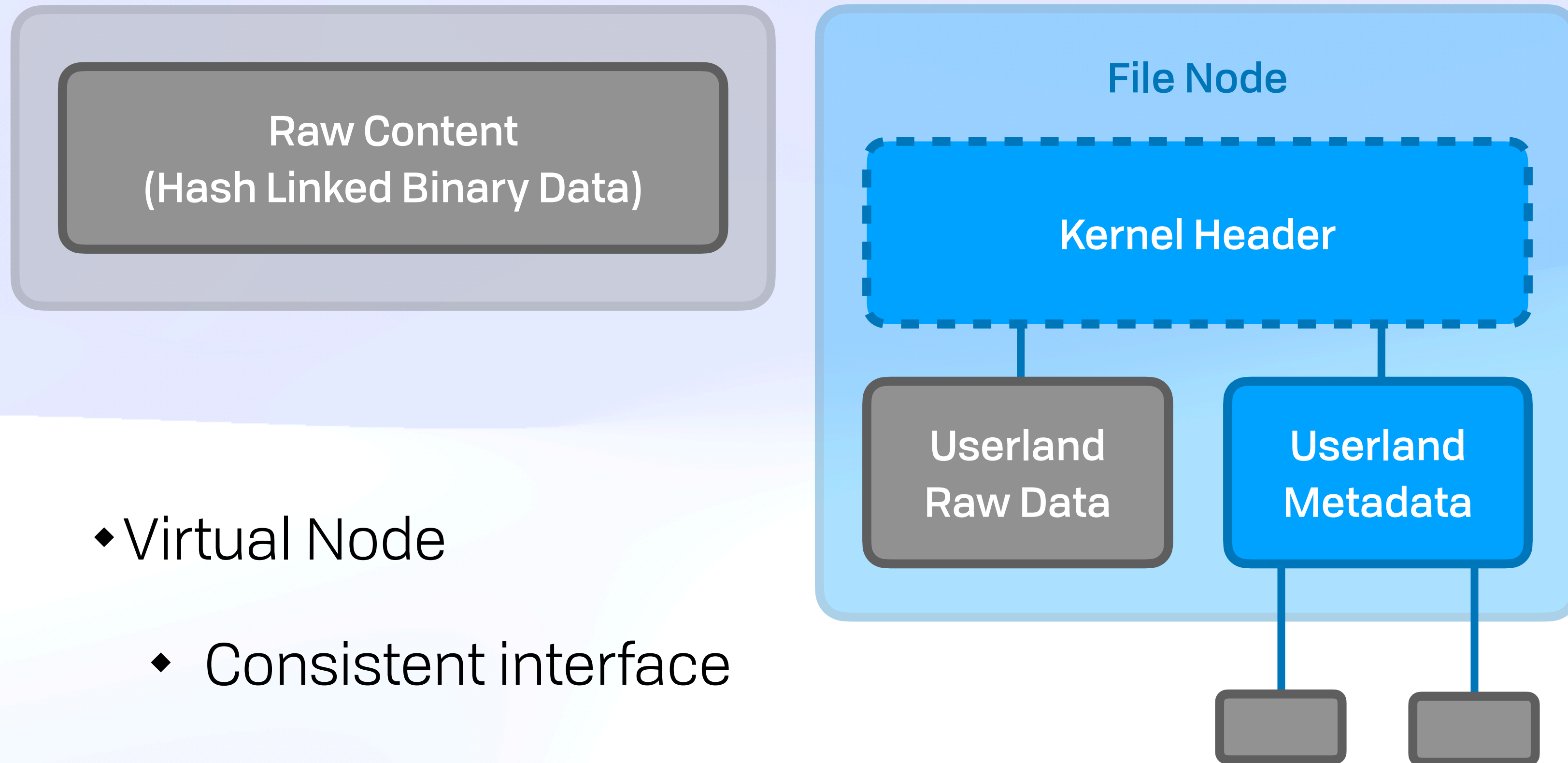
Public Files 

# Virtual Nodes



Public Files 

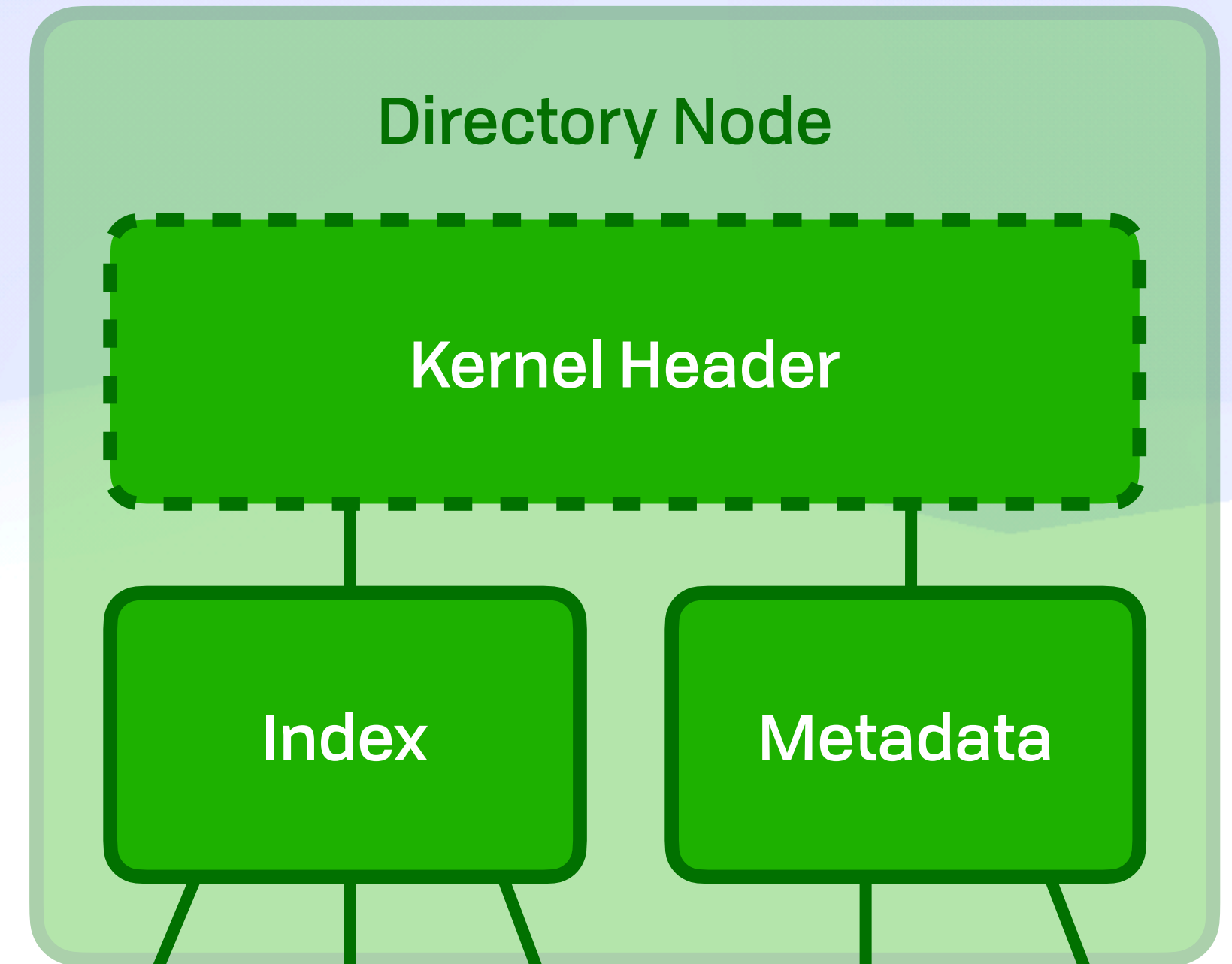
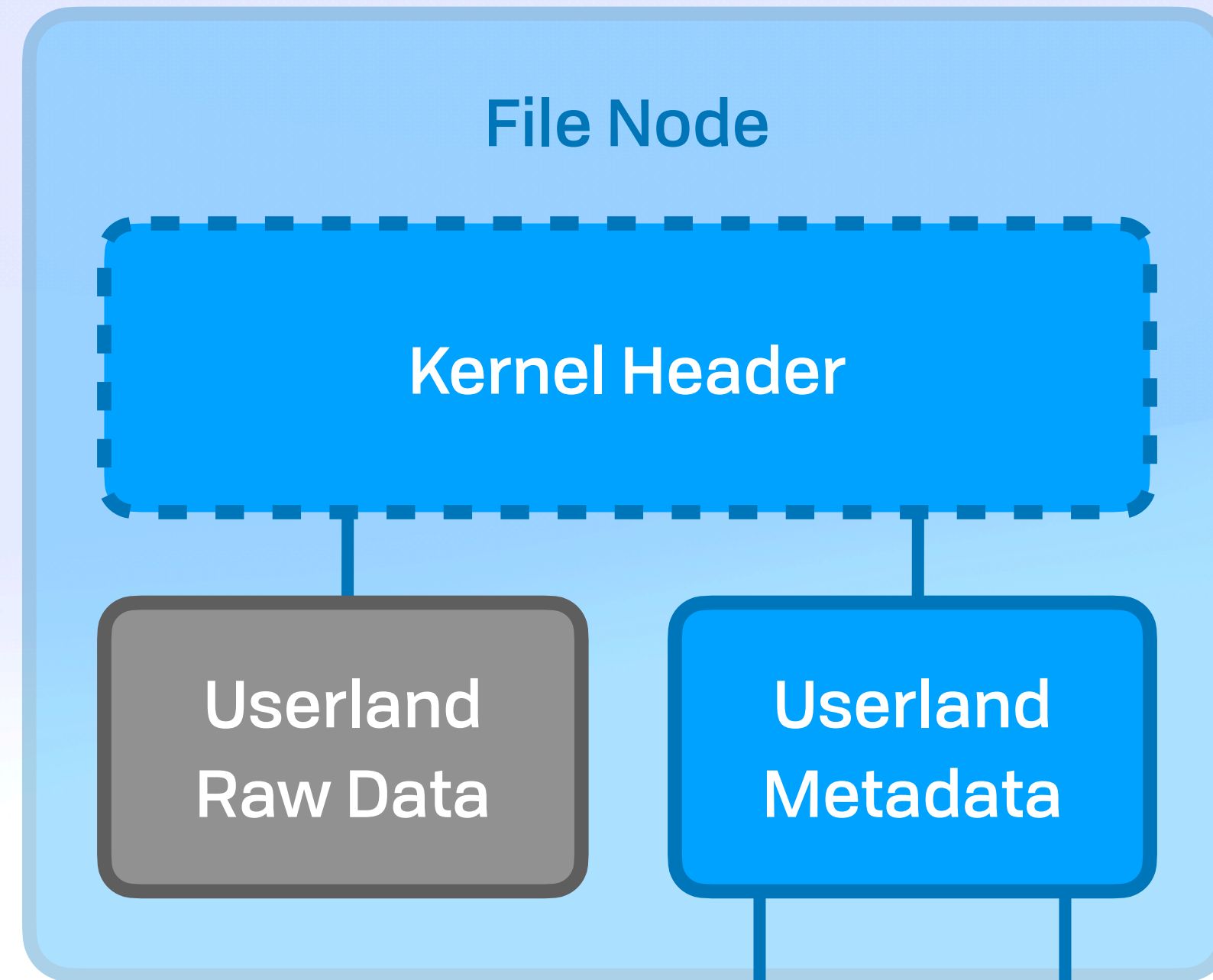
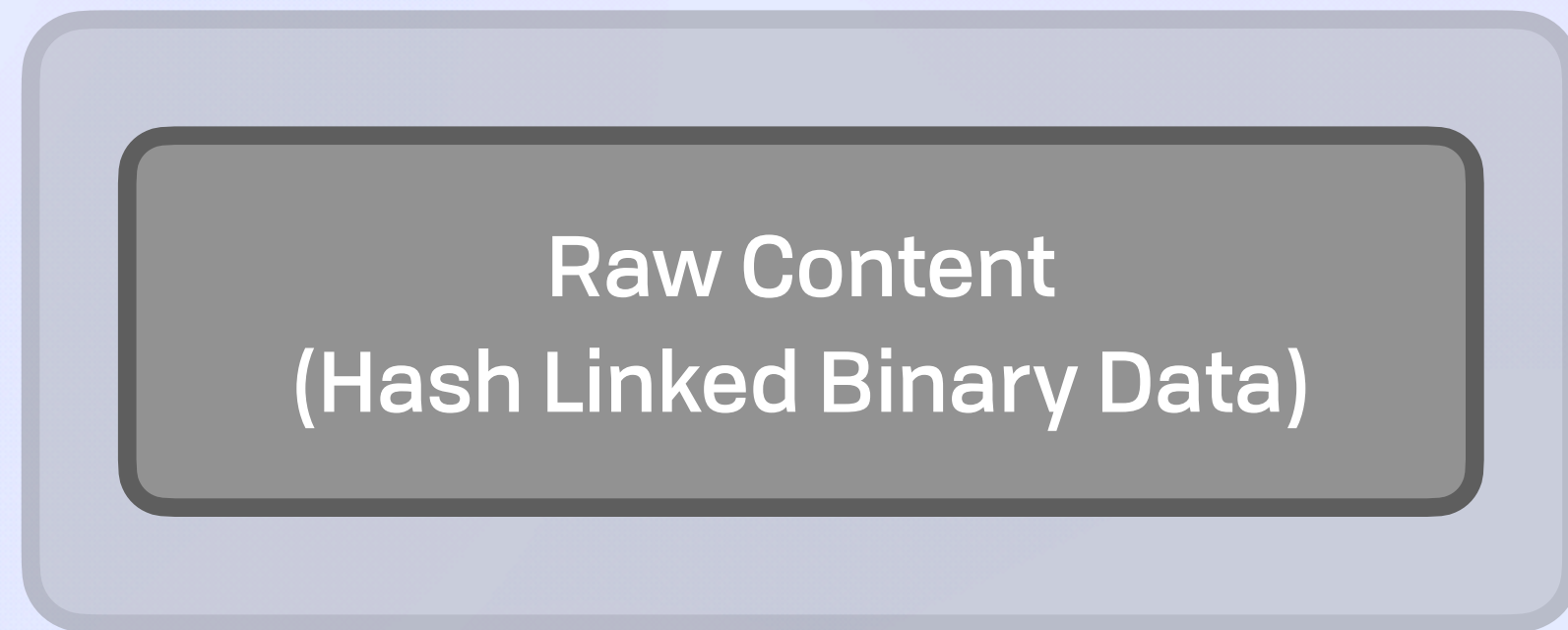
# Virtual Nodes



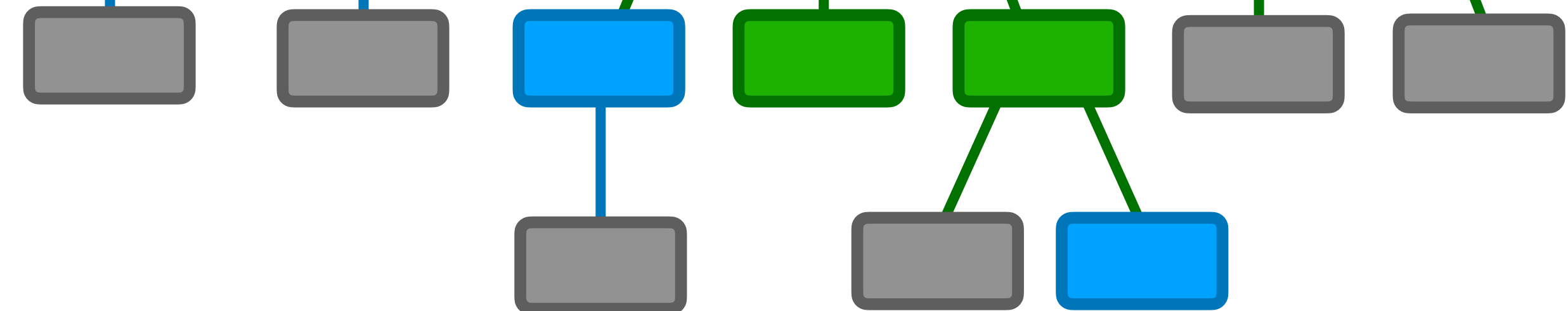
- ◆ Virtual Node
  - ◆ Consistent interface
- ◆ Arbitrary metadata
  - ◆ Tags, creators, MIME, sources, &c

# Public Files

## *Virtual Nodes*



- ◆ Virtual Node
  - ◆ Consistent interface
- ◆ Arbitrary metadata
  - ◆ Tags, creators, MIME, sources, &c



Public Files 

# ***Hash-Linked Layout***

Public Files 

# *Hash-Linked Layout*

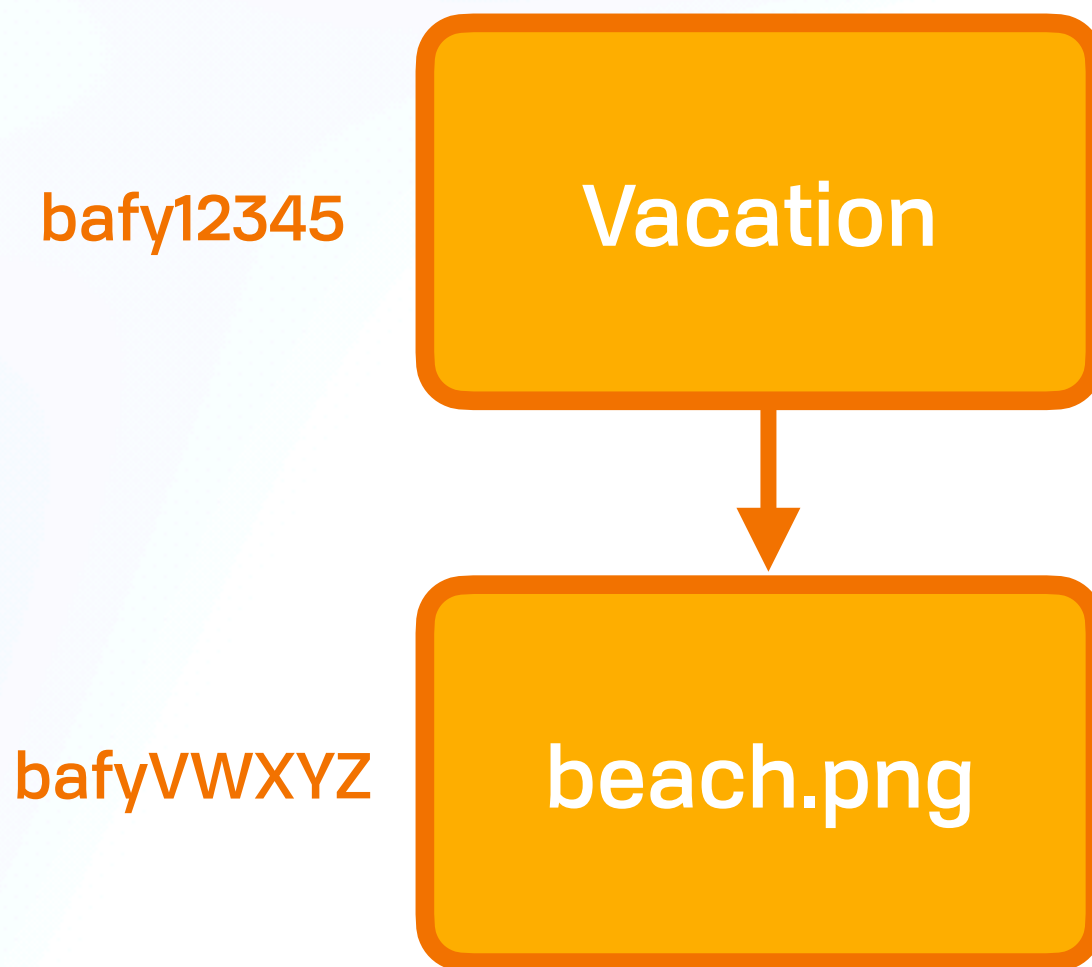
bafyVWXYZ



beach.png

Public Files 

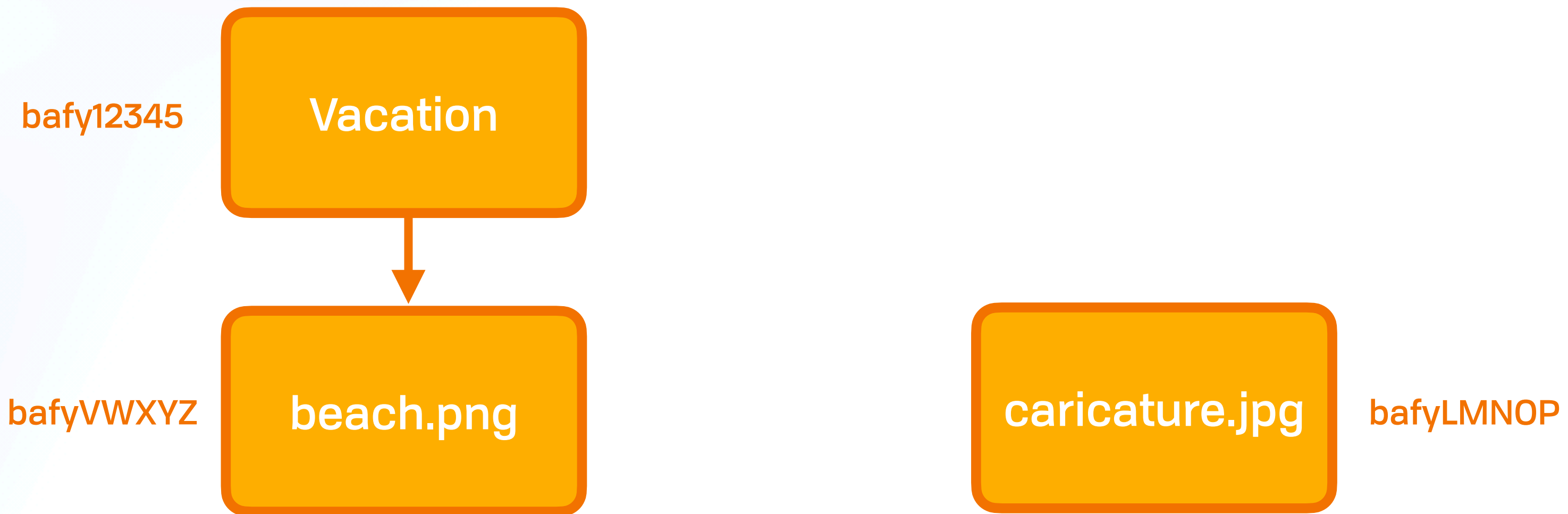
# *Hash-Linked Layout*





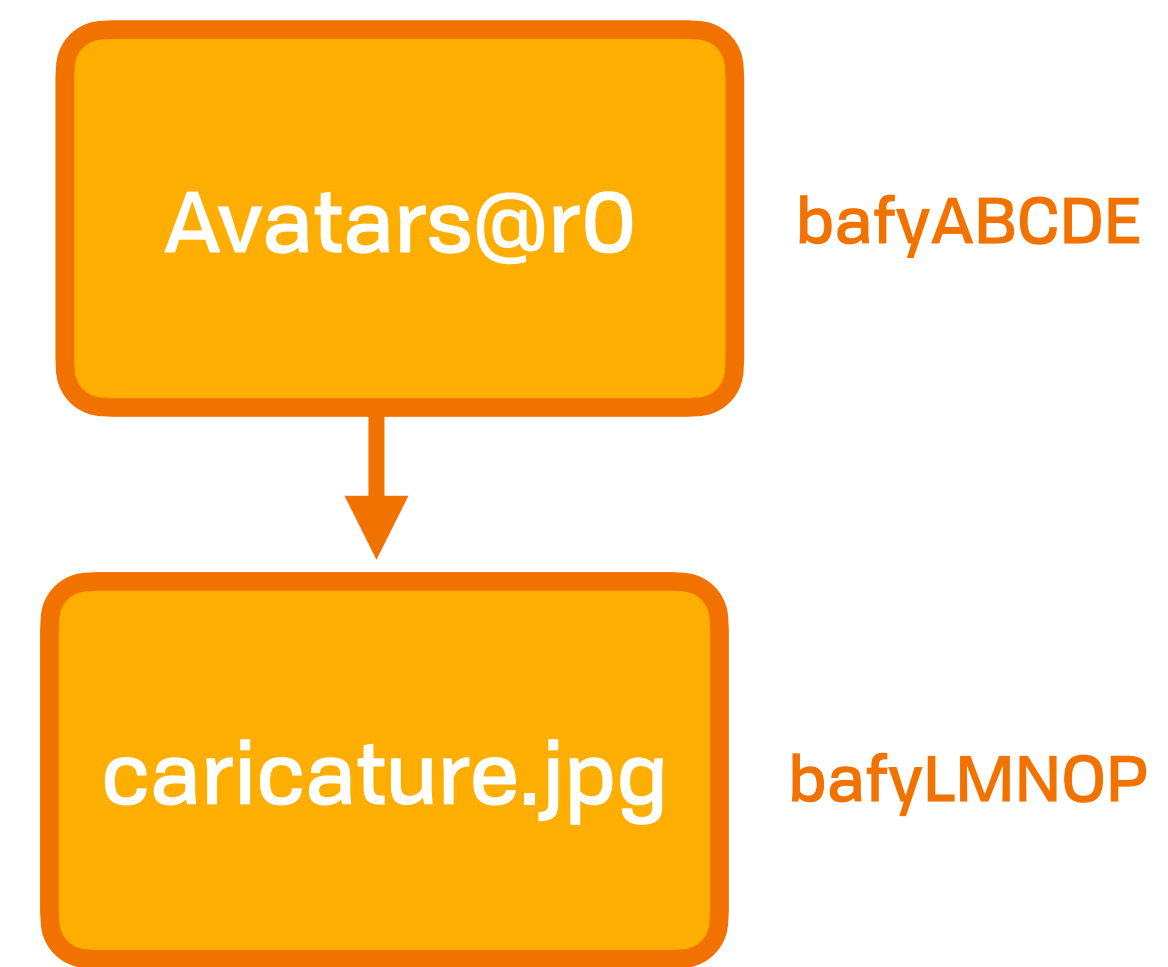
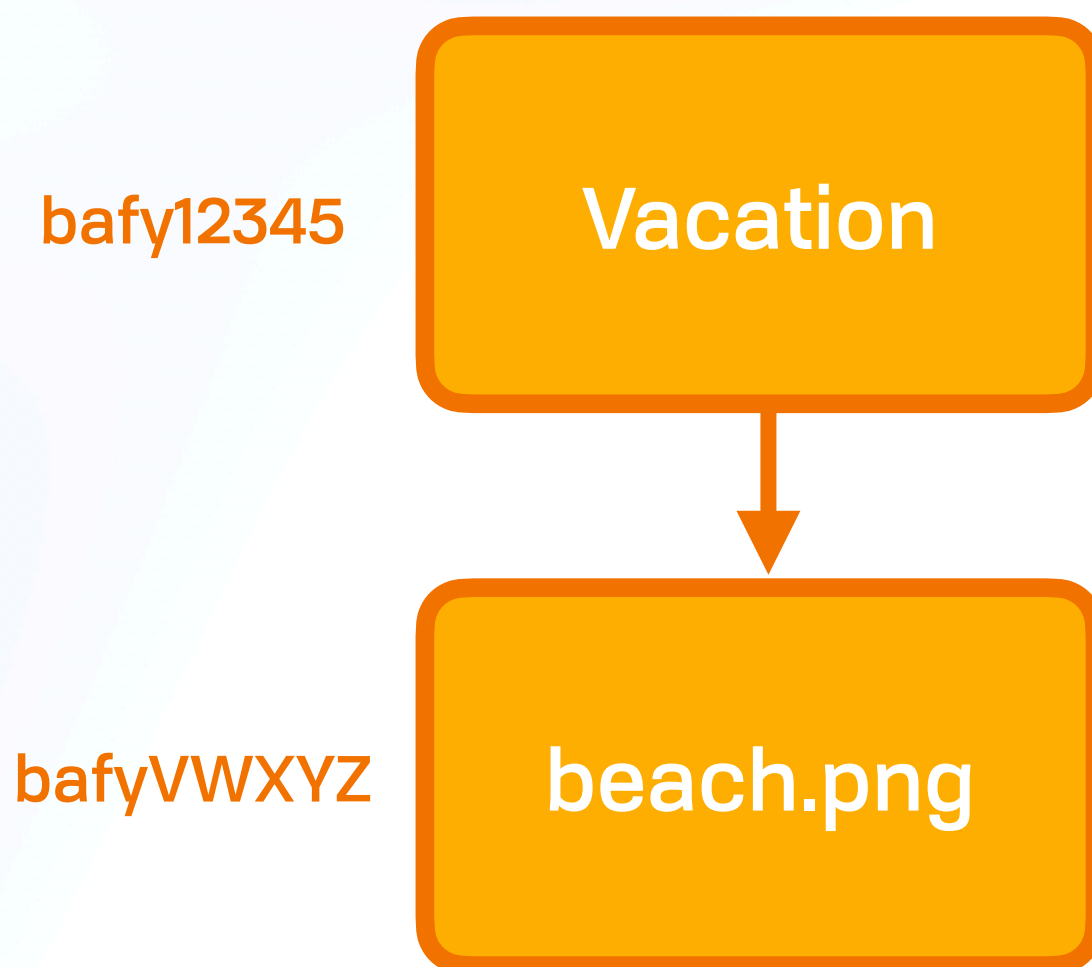
Public Files 

# Hash-Linked Layout



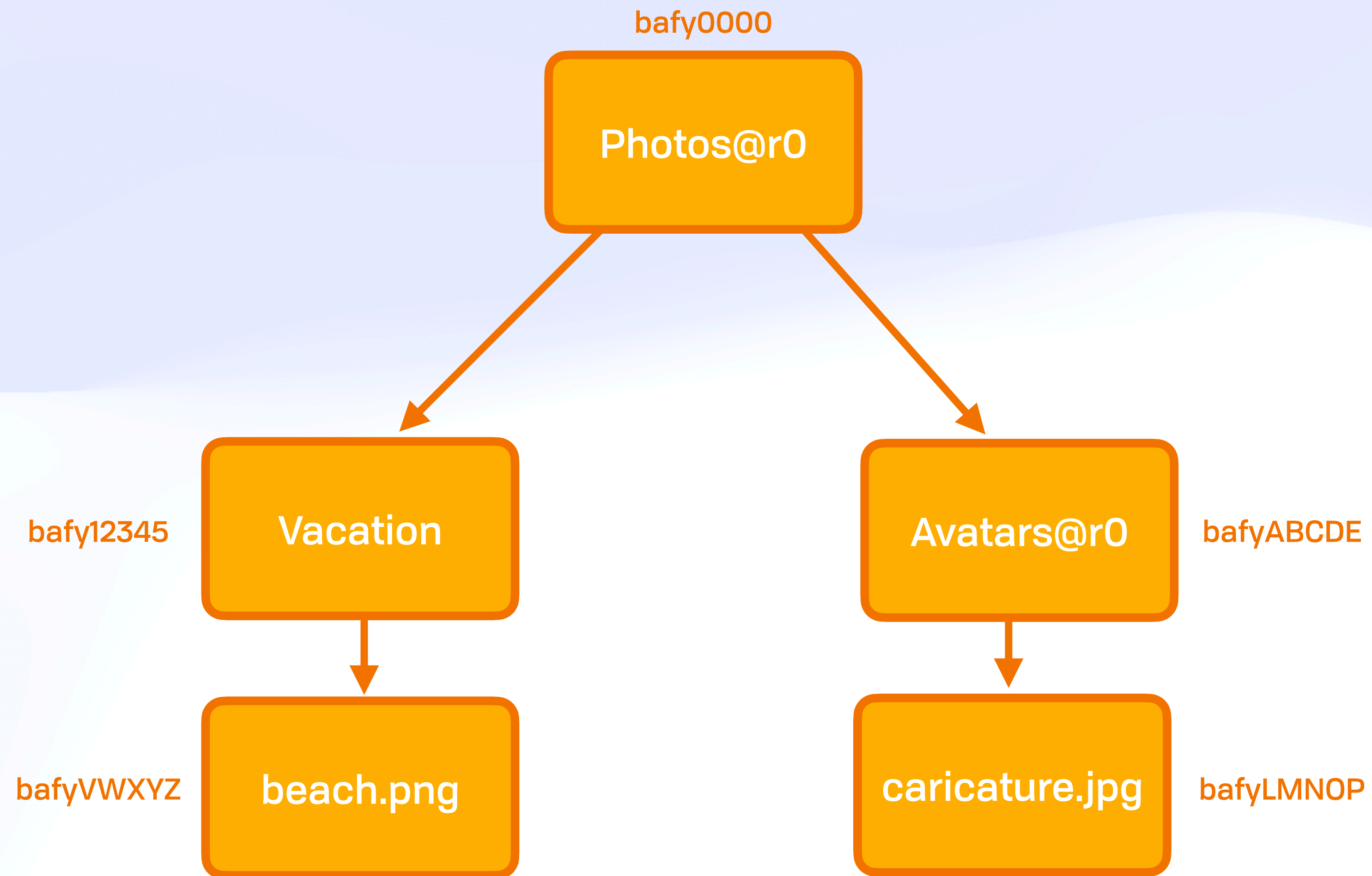
Public Files 

# Hash-Linked Layout



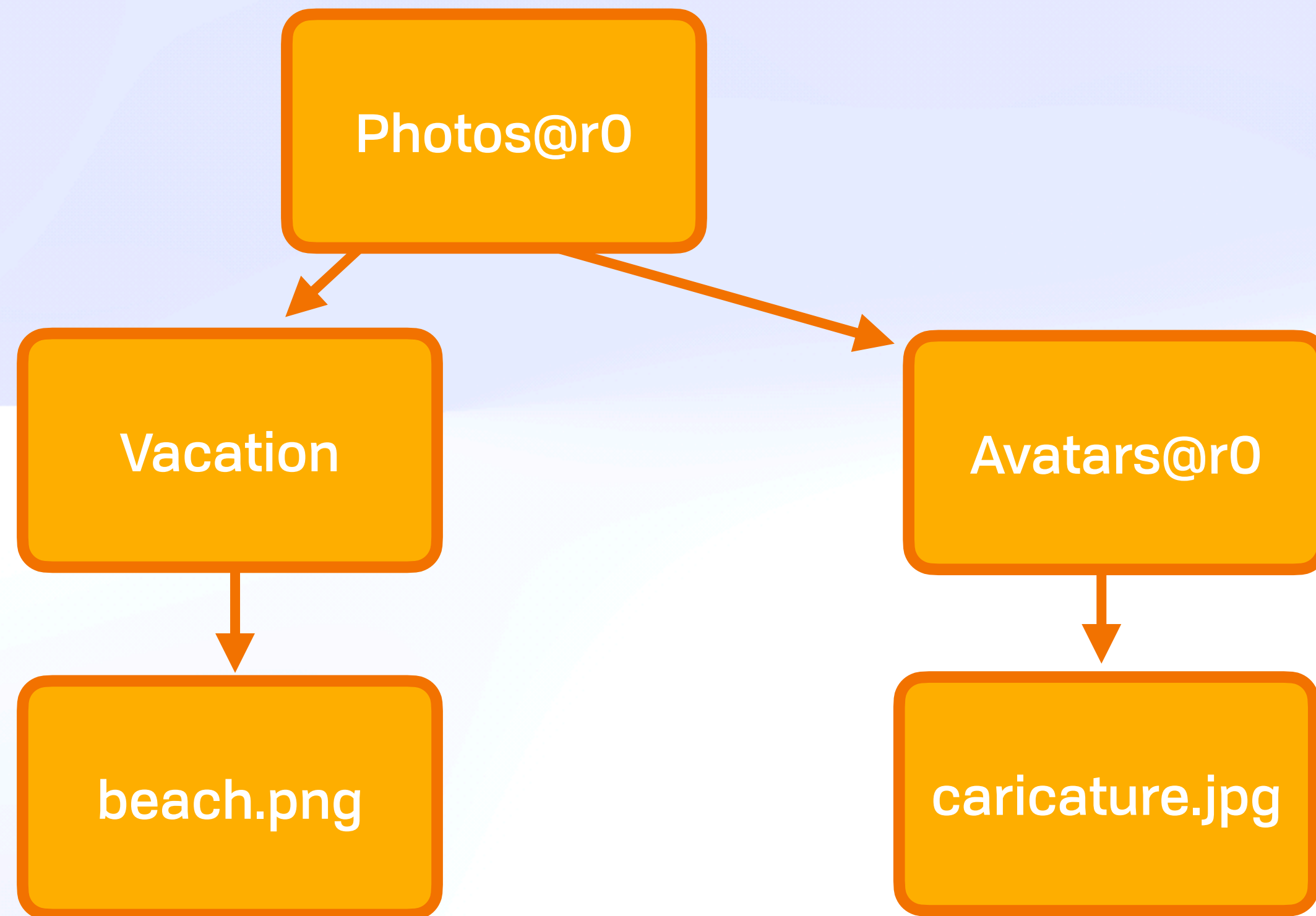
Public Files 

# Hash-Linked Layout



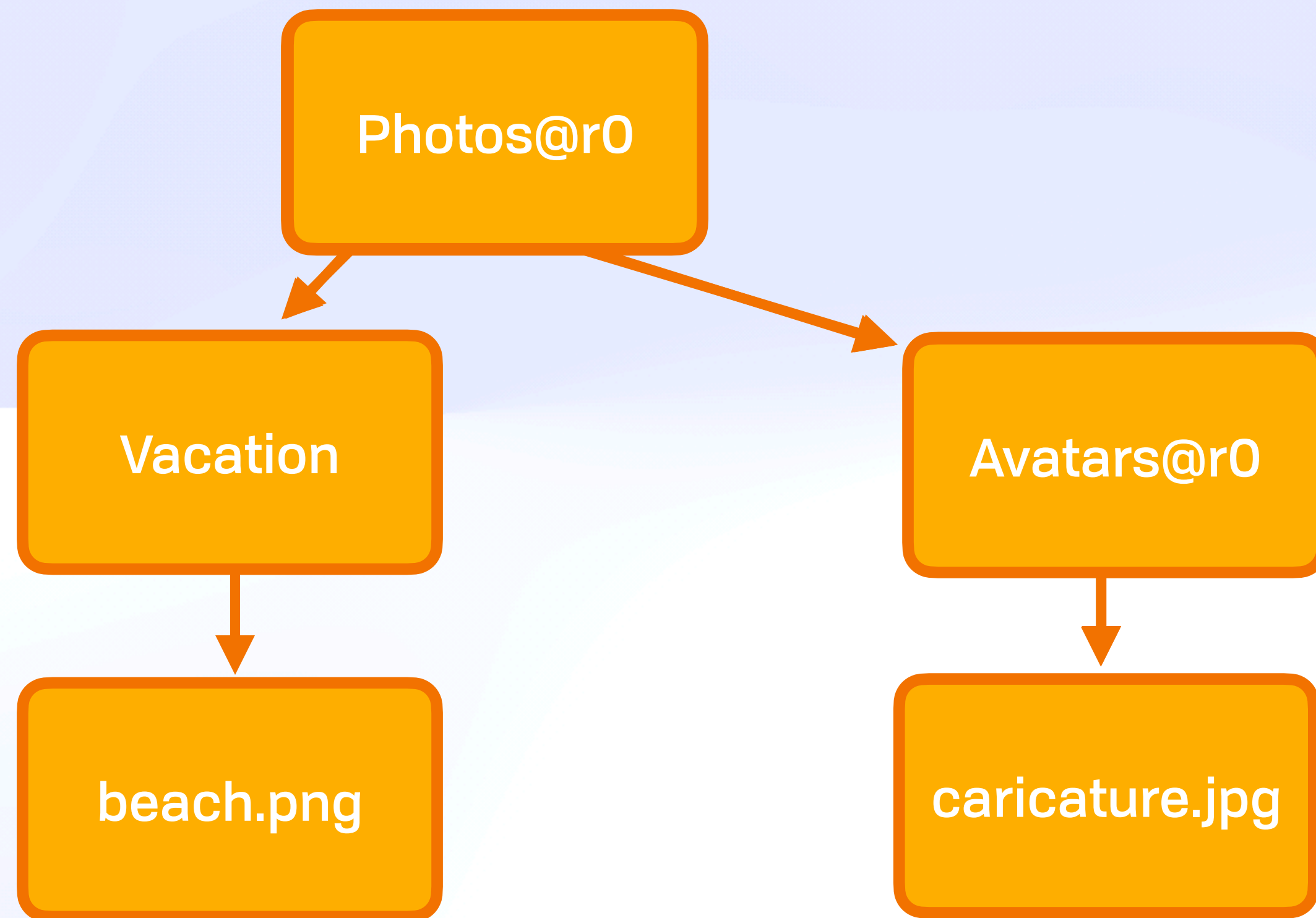
Public Files 

# *Hash-Linked Layout*



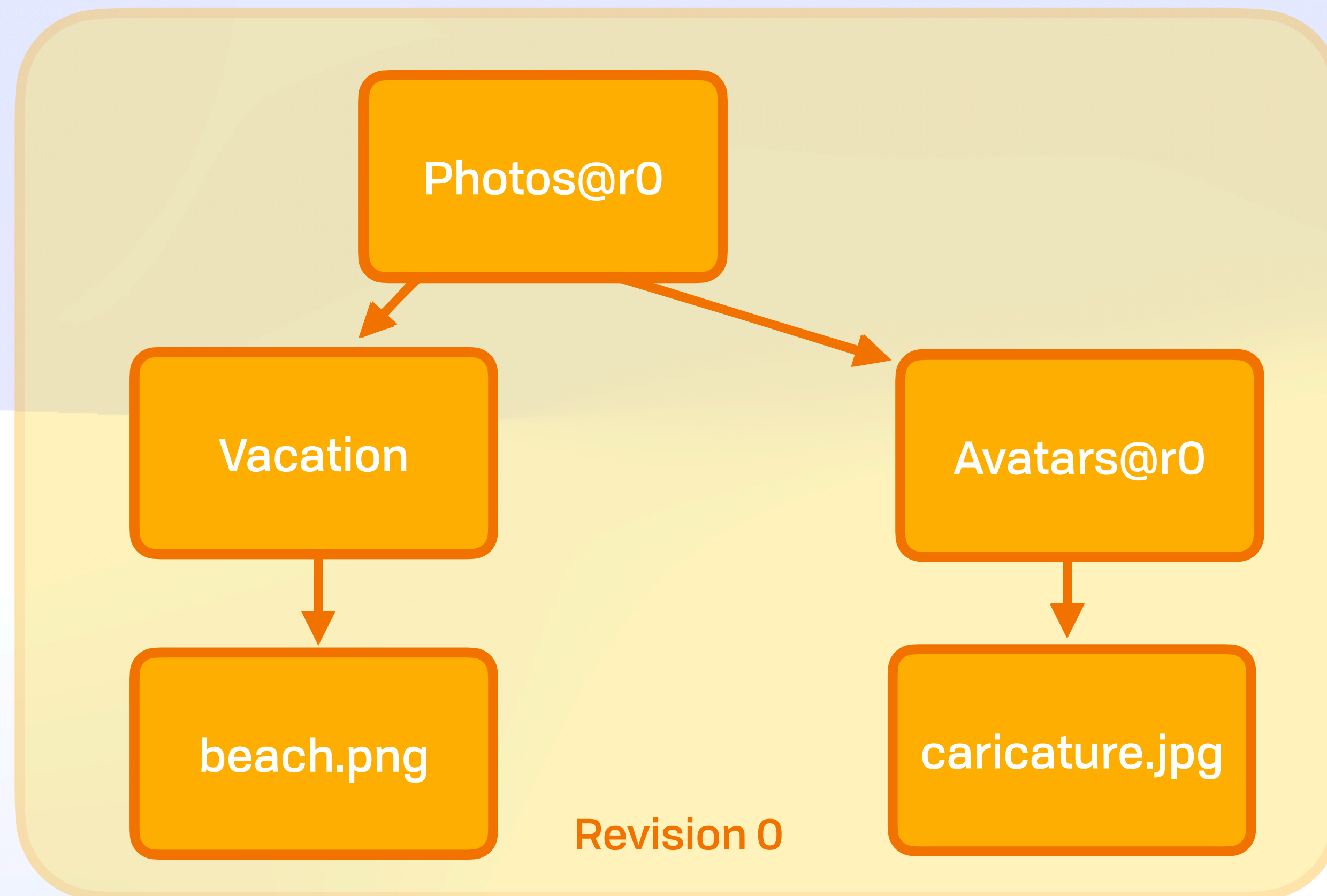
Public Files 

# *Persistent Versioning*



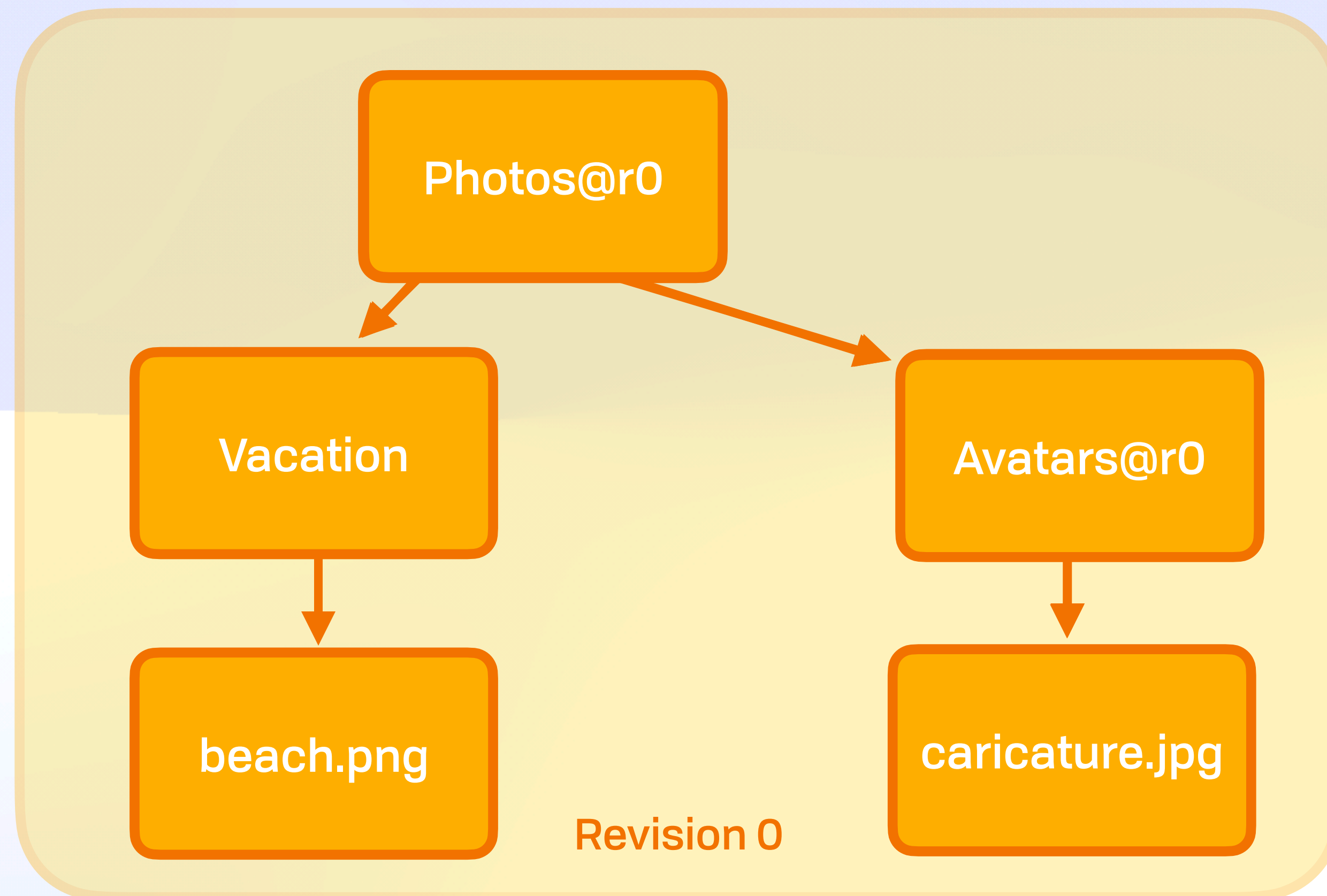
Public Files 

# *Persistent Versioning*

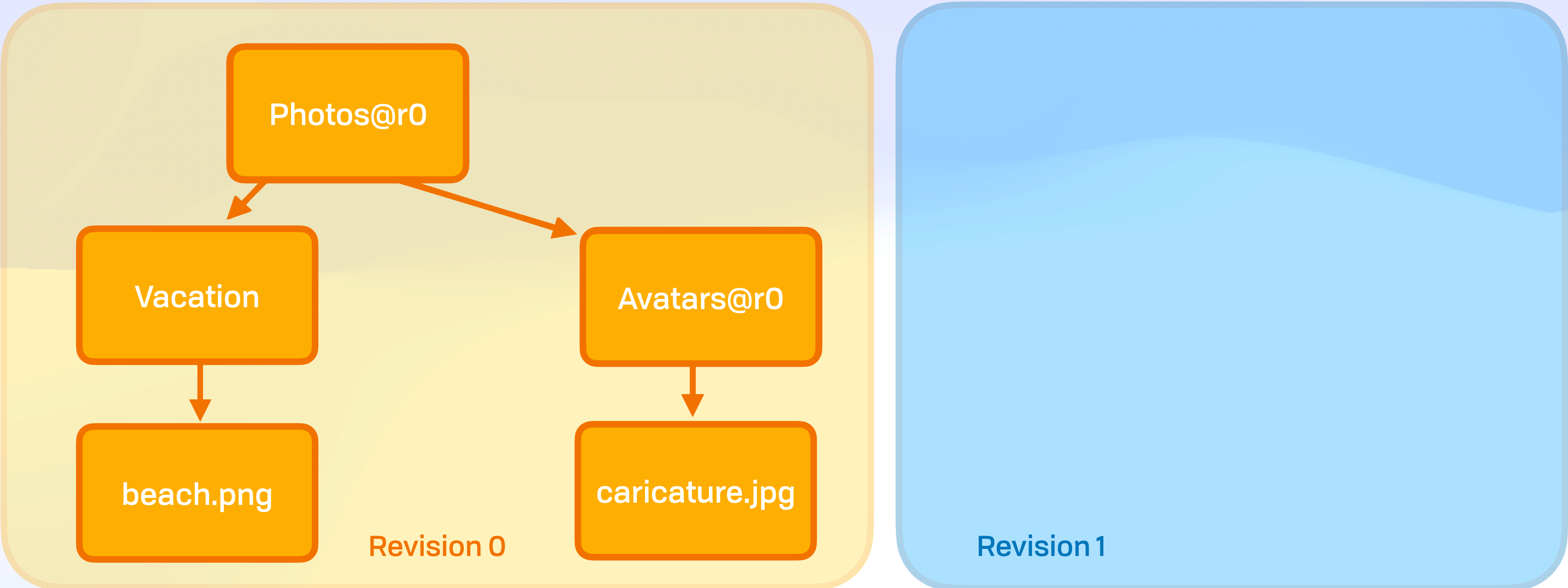


Public Files 

# Persistent Versioning



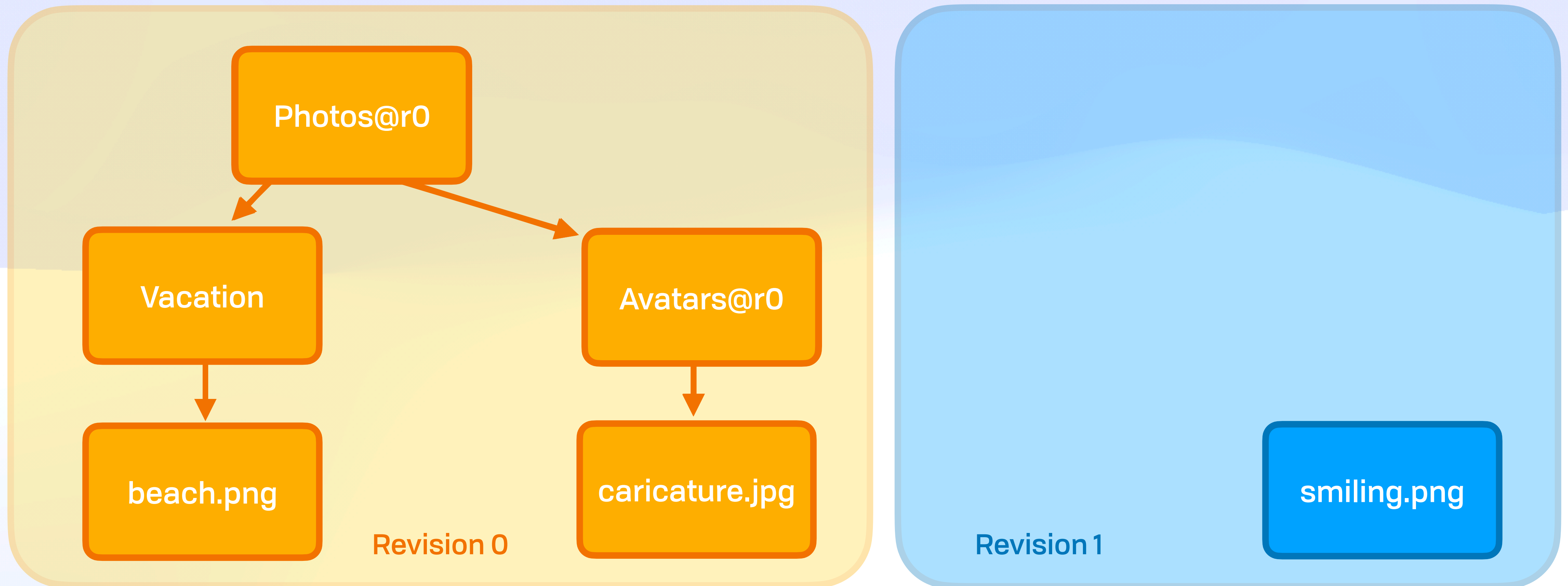
# Persistent Versioning





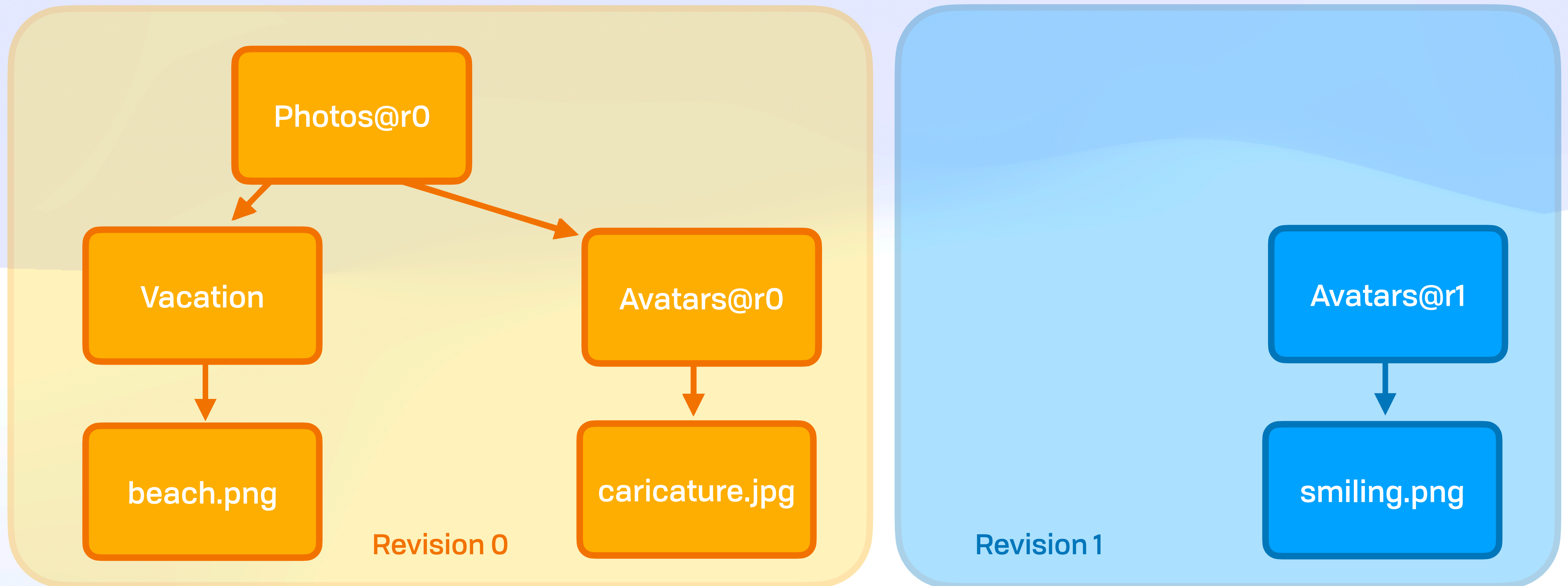
Public Files 

# Persistent Versioning



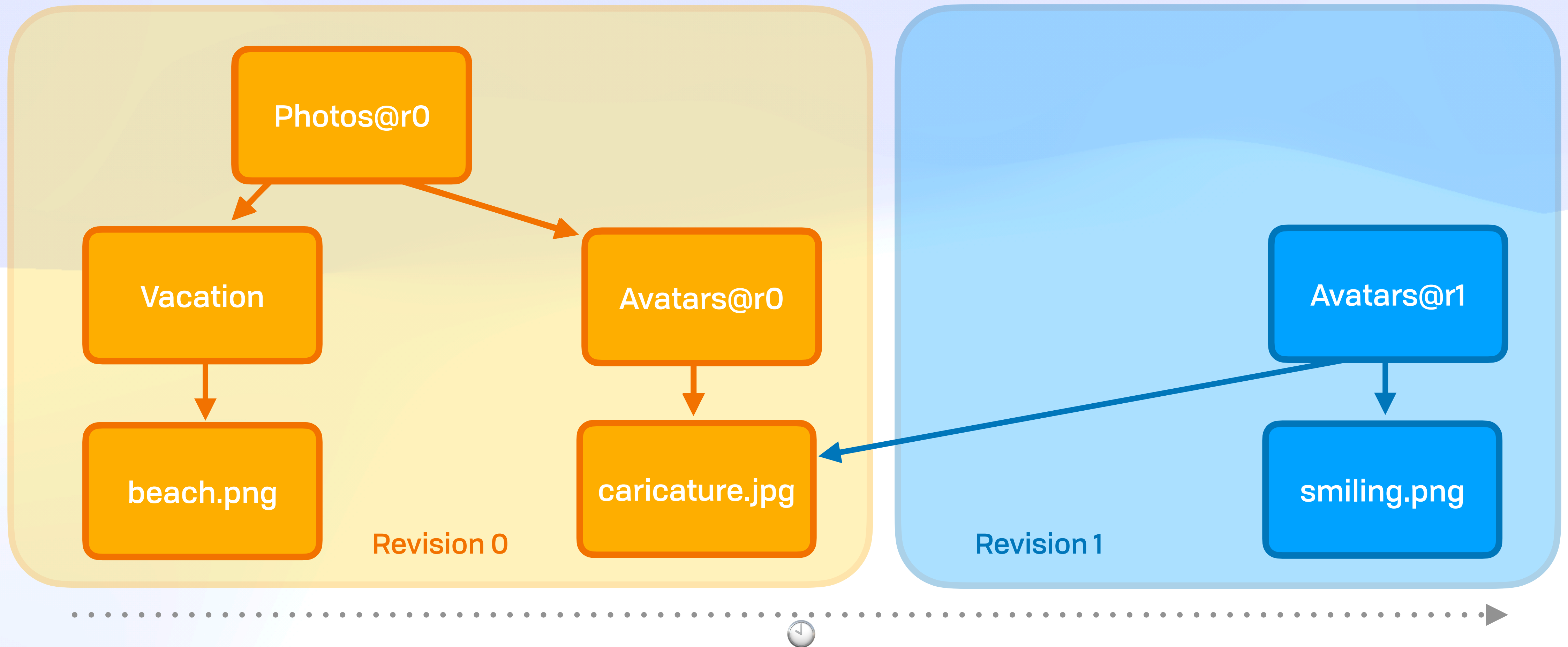
Public Files 

# Persistent Versioning

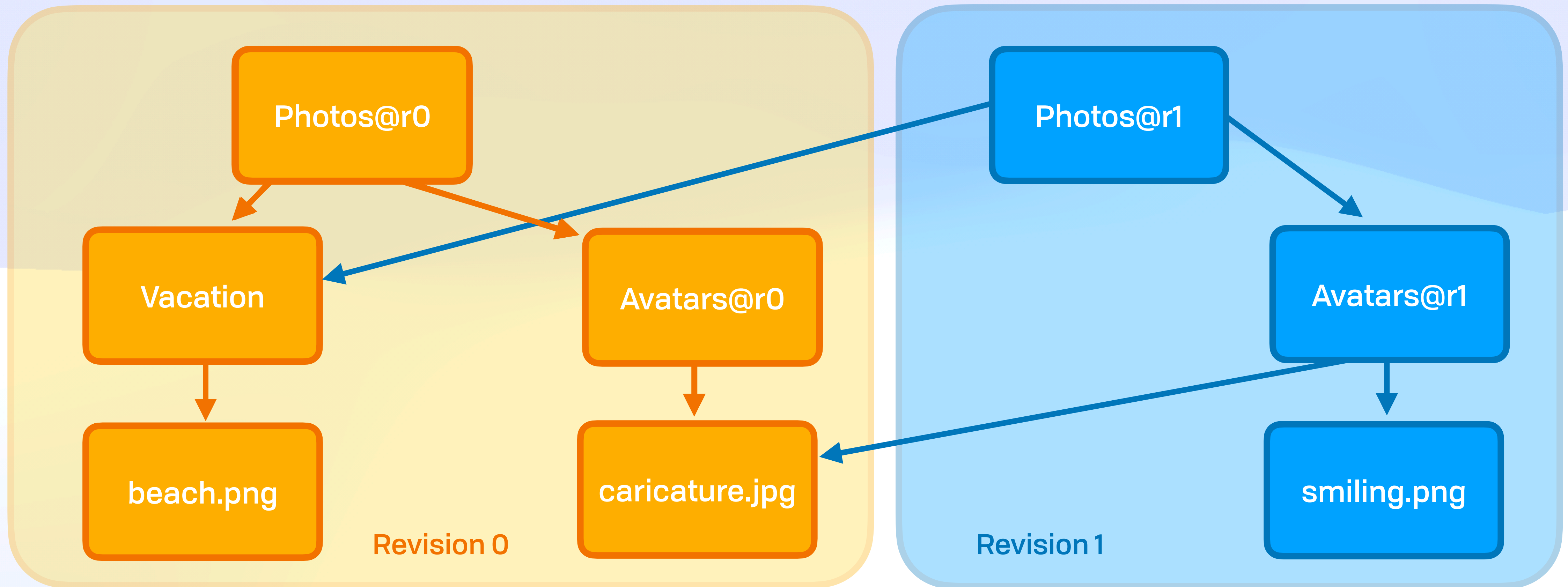


Public Files 

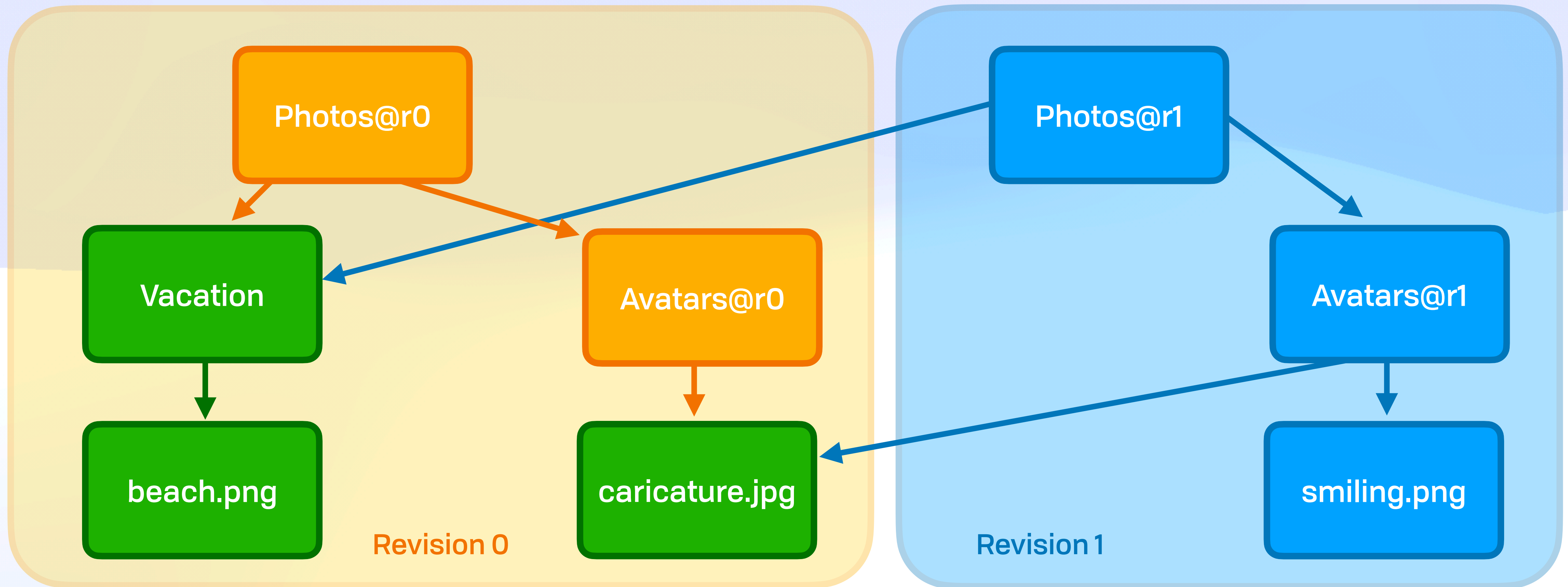
# Persistent Versioning



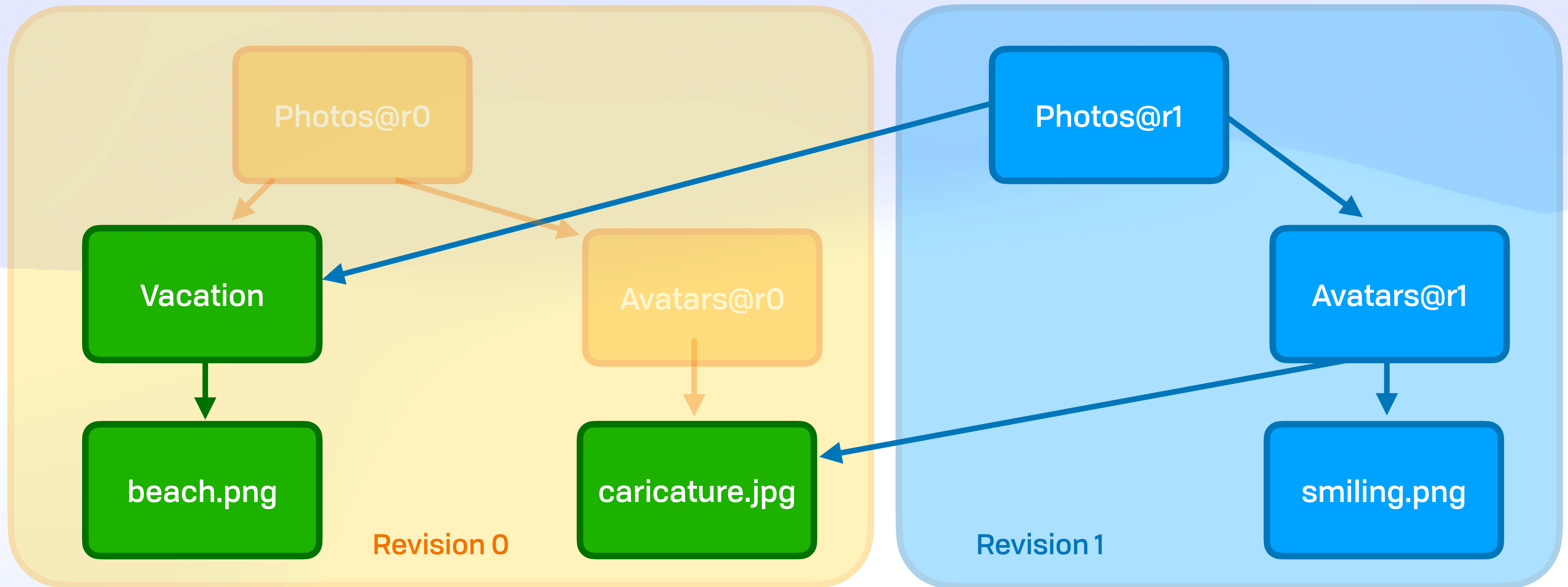
# Persistent Versioning



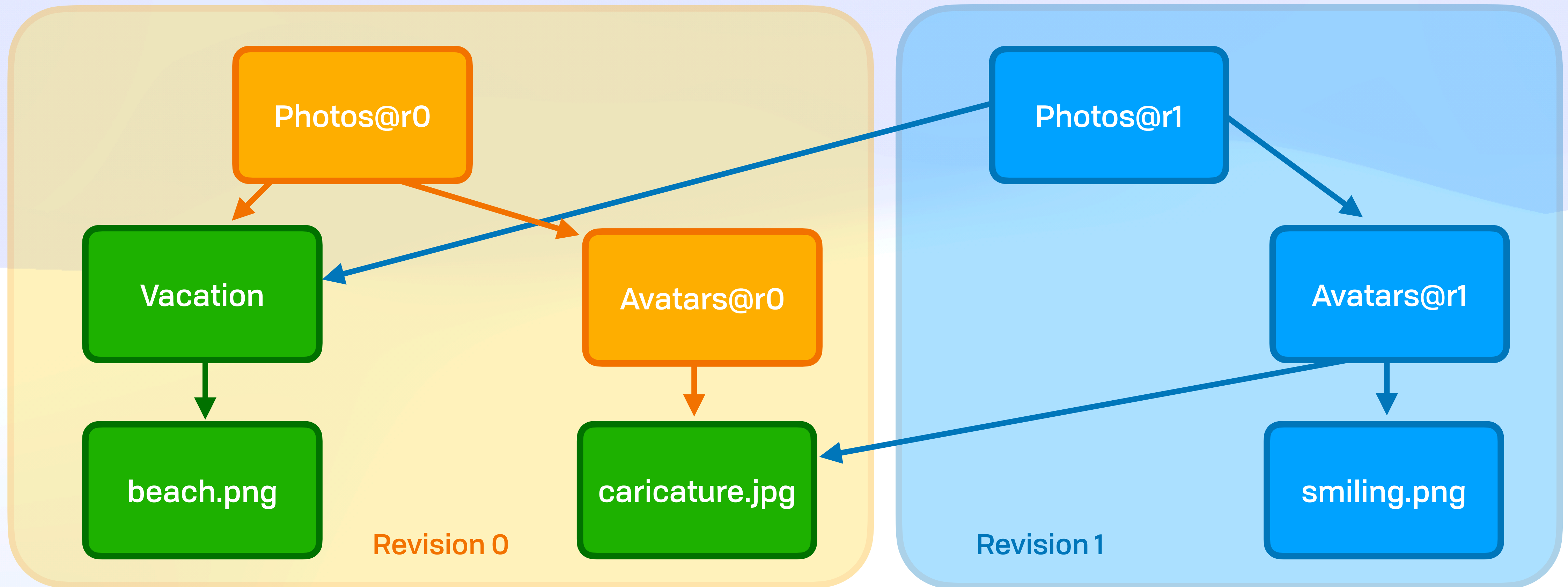
# Persistent Versioning



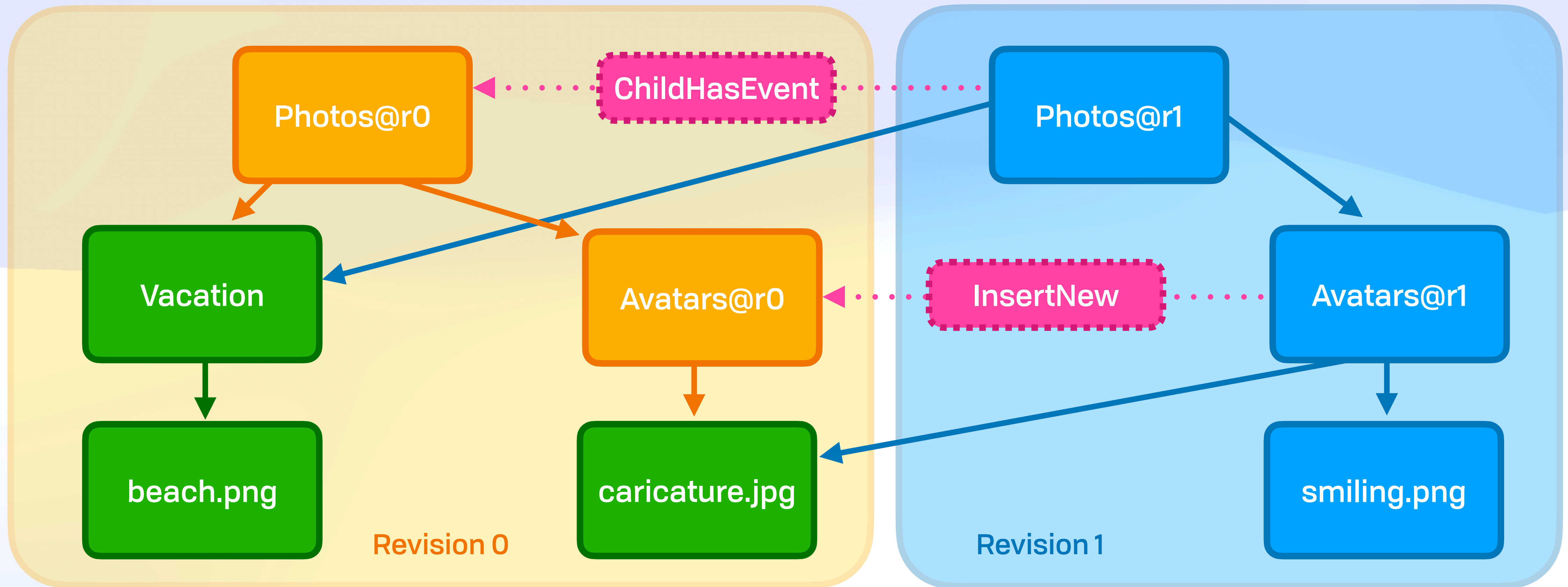
# Persistent Versioning



# Persistent Versioning

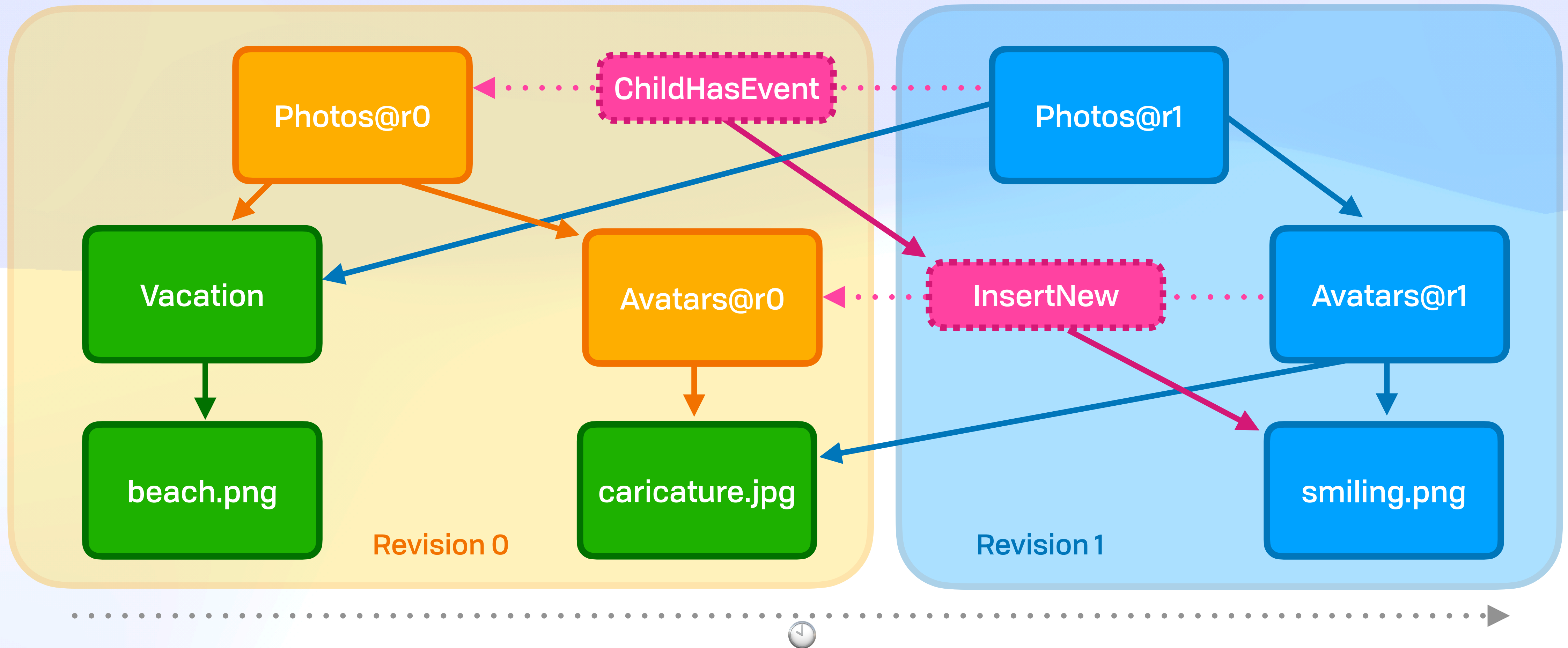


# Persistent Versioning



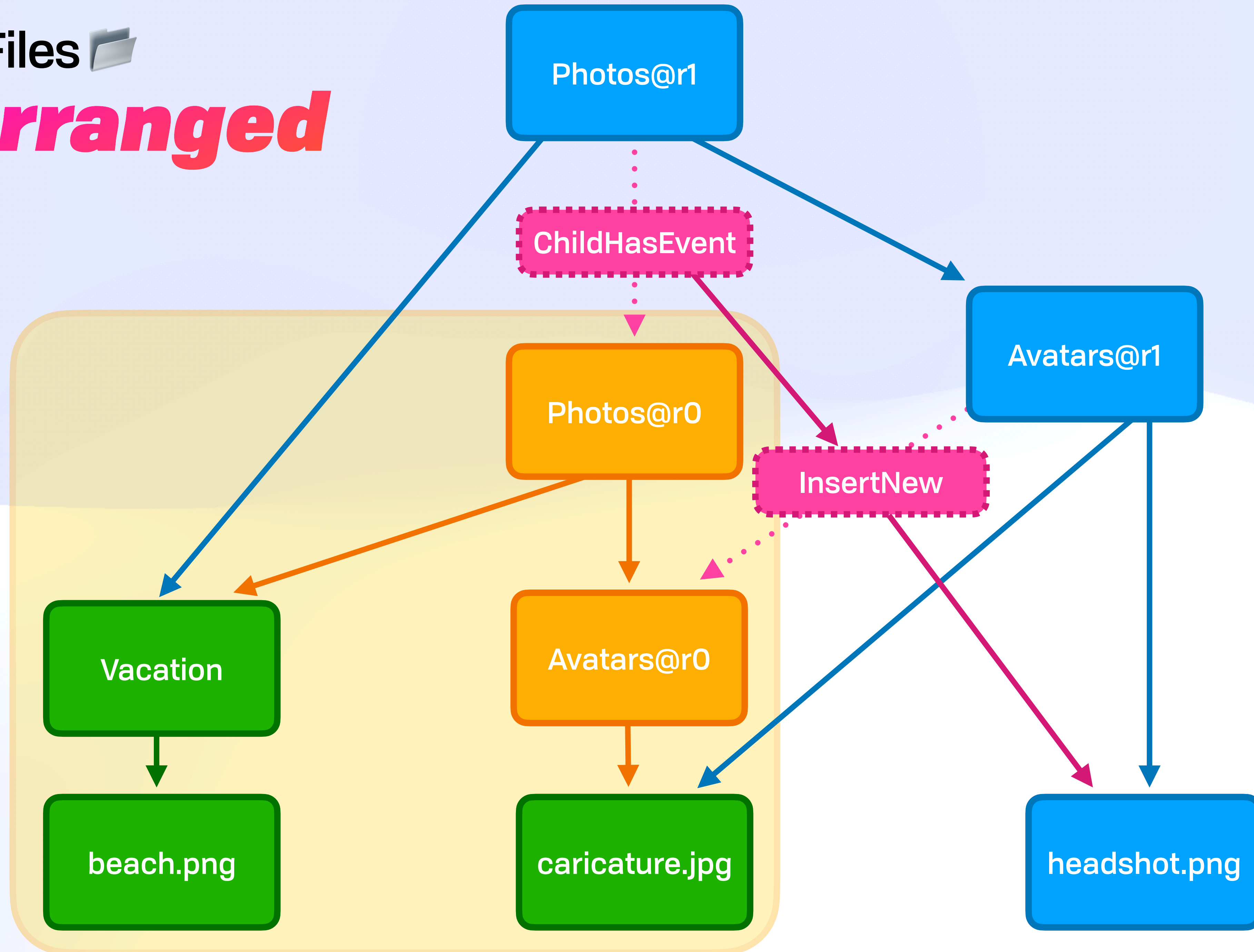


# Persistent Versioning



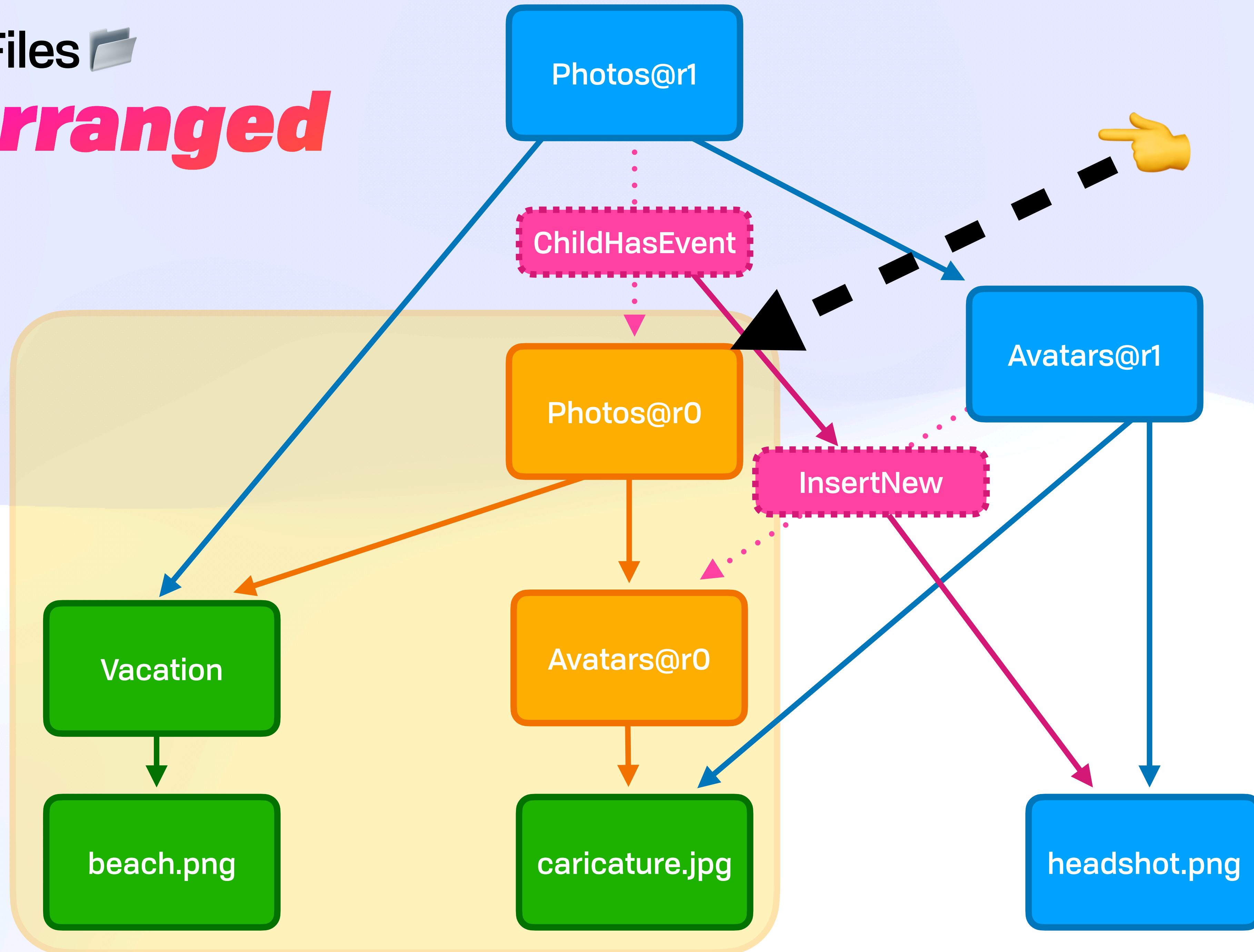
Public Files 

**Rearranged**



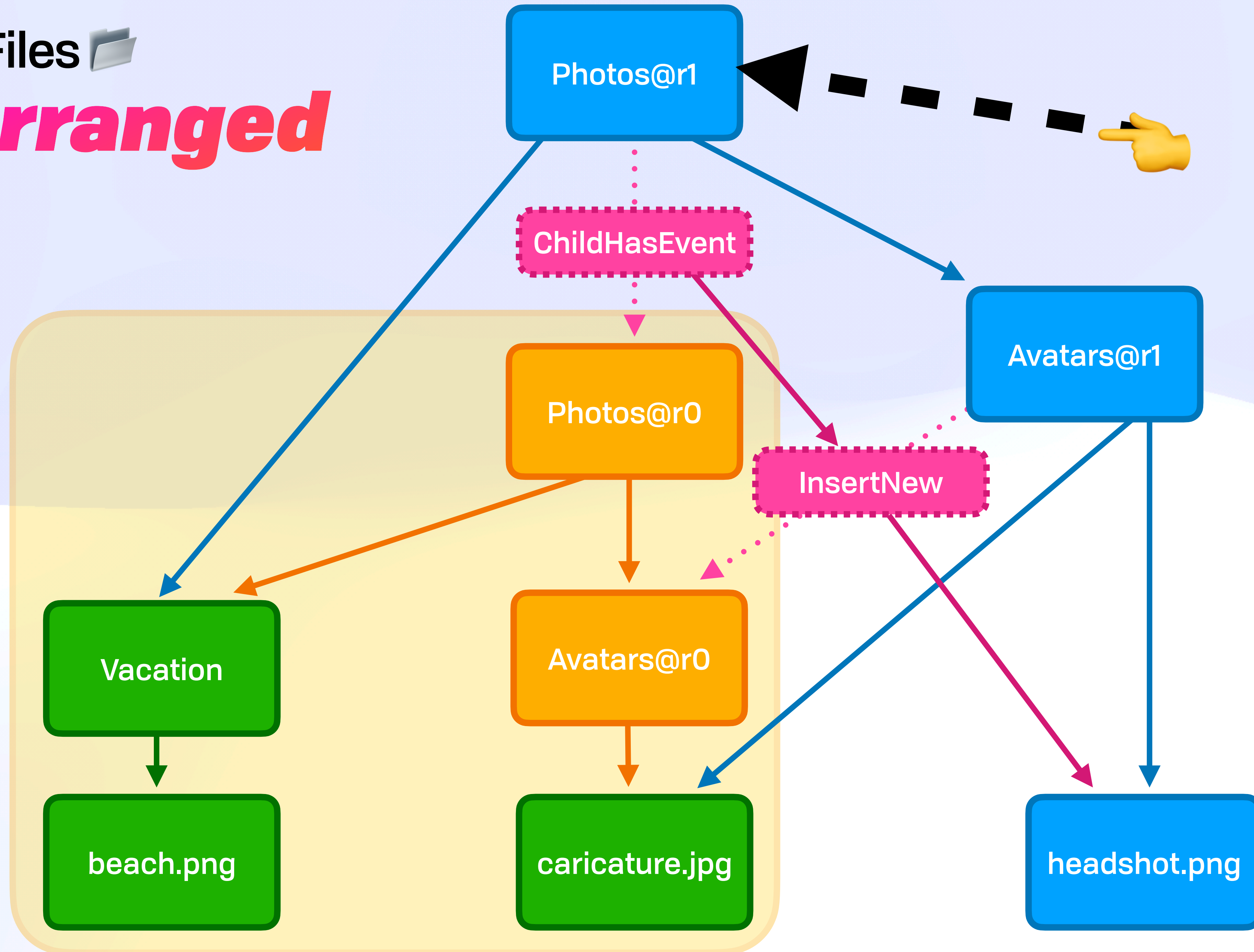
Public Files 

**Rearranged**



Public Files 

**Rearranged**



Public Files 

# *It's All Just Maps*

```
{
  kernel: {
    ty: FILE,
    history: [
      {cid: "bafkreidrgwjljxy6s7o5uvrifxnwefggi7chmye3pn6wyisv2n4b3uordi", event: UPDATE},
      {cid: "bafkreicushgsax35ihrwo6smk4qmjuwzbf7qzqg6o1qxyaisuxtgpvxrim", event: REPLACE}
    ]
  },
  metadata: {
    utime: 1661837091,
    author: "did:key:StEZpzSMtTt9k2vszgvCwF4fLQQSyA15W5AQ4z3AR6Bx4eFJ5crJFbuGxKmbma4"
  },
  content: "HwRZys6pMUjvyS4pYKSS4Et33jDB+kwvCuMJu4GeNCan1eAmhPykHFR+gc2D+Qa/..."
}
```

Public Files 

# *It's All Just Maps*

```
{
  kernel: {
    ty: FILE,
    history: [
      {cid: "bafkreidrgwj\ljxy6s7o5uvrifxnwefggi7chmye3pn6wyisv2n4b3uordi", event: UPDATE},
      {cid: "bafkreicushgsax35ihrwo6smk4qmjuwzbf7qzqg6o\qxyaisuxtgpvxrim", event: REPLACE}
    ]
  },
  metadata: {
    utime: 1661837091,
    author: "did:key:StEZpzSMtTt9k2vszgvCwF4fLQQSyA15W5AQ4z3AR6Bx4eFJ5crJFbuGxKmbma4"
  },
  content: "HwRZys6pMUjvyS4pYKSS4Et33jDB+kwvCuMJu4GeNCan1eAmhPykHFR+gc2D+Qa/..."
}
```

Public Files 

# *It's All Just Maps*

```
{
  kernel: {
    ty: FILE,
    history: [
      {cid: "bafkreidrgwjljxy6s7o5uvrifxnwefggi7chmye3pn6wyisv2n4b3uordi", event: UPDATE},
      {cid: "bafkreicushgsax35ihrwo6smk4qmjuwzbf7qzqg6o1qxyaisuxtgpvxrim", event: REPLACE}
    ]
  },
  metadata: {
    utime: 1661837091,
    author: "did:key:StEZpzSMtTt9k2vszgvCwF4fLQQSyA15W5AQ4z3AR6Bx4eFJ5crJFbuGxKmbma4"
  },
  content: "HwRZys6pMUjvyS4pYKSS4Et33jDB+kwvCuMJu4GeNCan1eAmhPykHFR+gc2D+Qa/..."
}
```

Public Files 

# *It's All Just Maps*

```
{
  kernel: {
    ty: FILE,
    history: [
      {cid: "bafkreidrgwj\ljxy6s7o5uvrifxnwefggi7chmye3pn6wyisv2n4b3uordi", event: UPDATE},
      {cid: "bafkreicushgsax35ihrwo6smk4qmjuwzbf7qzqg6o\lqxyaisuxtgpvxrim", event: REPLACE}
    ]
  },
  metadata: {
    utime: 1661837091,
    author: "did:key:StEZpzSMtTt9k2vszgvCwF4fLQQSyA15W5AQ4z3AR6Bx4eFJ5crJFbuGxKmbma4"
  },
  content: "HwRZys6pMUjvyS4pYKSS4Et33jDB+kwvCuMJu4GeNCan1eAmhPykHFR+gc2D+Qa/..."
}
```

Multiple?! (More on this later)



Public Files 

# *It's All Just Maps*

```
{
  kernel: {
    ty: FILE,
    history: [
      {cid: "bafkreidrgwj\jxy6s7o5uvrifxnwefggi7chmye3pn6wyisv2n4b3uordi", event: UPDATE},
      {cid: "bafkreicushgsax35ihrwo6smk4qmjuwzbf7qzqg6o\qxyaisuxtgpixrim", event: REPLACE}
    ]
  },
  metadata: {
    utime: 1661837091,
    author: "did:key:StEZpzSMtTt9k2vszgvCwF4fLQQSyA15W5AQ4z3AR6Bx4eFJ5crJFbuGxKmbma4"
  },
  content: "HwRZys6pMUjvyS4pYKSS4Et33jDB+kvvCuMJu4GeNCan1eAmhPykHFR+gc2D+Qa/..."
}
```

Public Files 

# *It's All Just Maps*

```
{
  kernel: {
    ty: FILE,
    history: [
      {cid: "bafkreidrgwjljxy6s7o5uvrifxnwefggi7chmye3pn6wyisv2n4b3uordi", event: UPDATE},
      {cid: "bafkreicushgsax35ihrwo6smk4qmjuwzbf7qzqg6o1qxyaisuxtgpymrim", event: REPLACE}
    ]
  },
  metadata: {
    utime: 1661837091,
    author: "did:key:StEZpzSMtTt9k2vszgvCwF4fLQQSyA15W5AQ4z3AR6Bx4eFJ5crJFbuGxKmbma4"
  },
  content: "HwRZys6pMUjvyS4pYKSS4Et33jDB+kwvCuMJu4GeNCan1eAmhPykHFR+gc2D+Qa/..."
}
```

Public Files 

# ***Single Public File History***

Public Files 

# *Single Public File History*

Single File History / "Causal Shadow"

Public Files 

# *Single Public File History*

A

Single File History / "Causal Shadow"

Public Files 

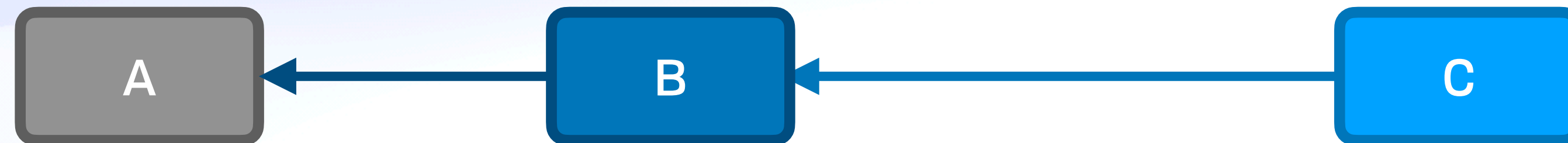
# *Single Public File History*



Single File History / "Causal Shadow"

Public Files 

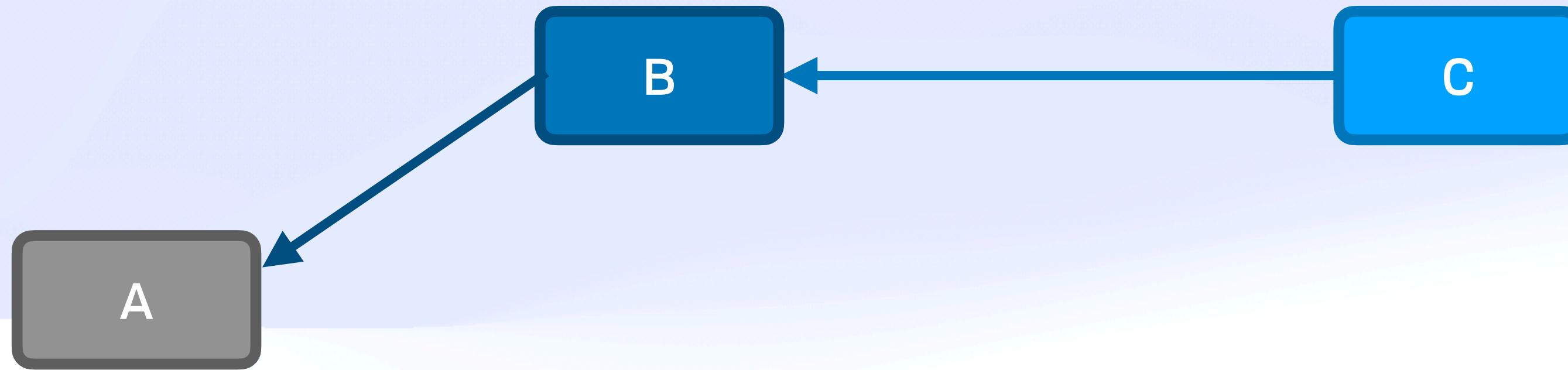
# *Single Public File History*



Single File History / "Causal Shadow"

Public Files 

# *Single Public File Confluence*

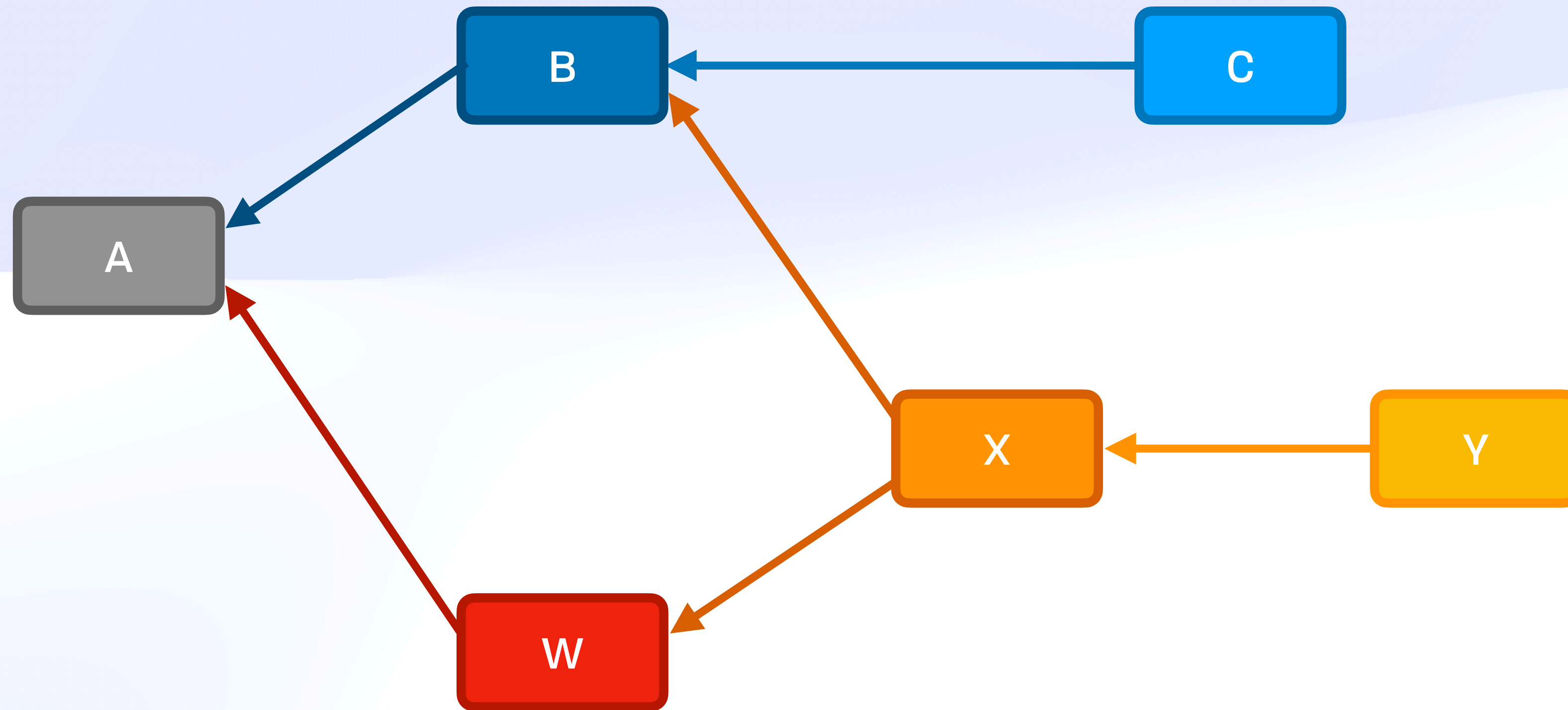


Single File History / "Causal Shadow"



Public Files 

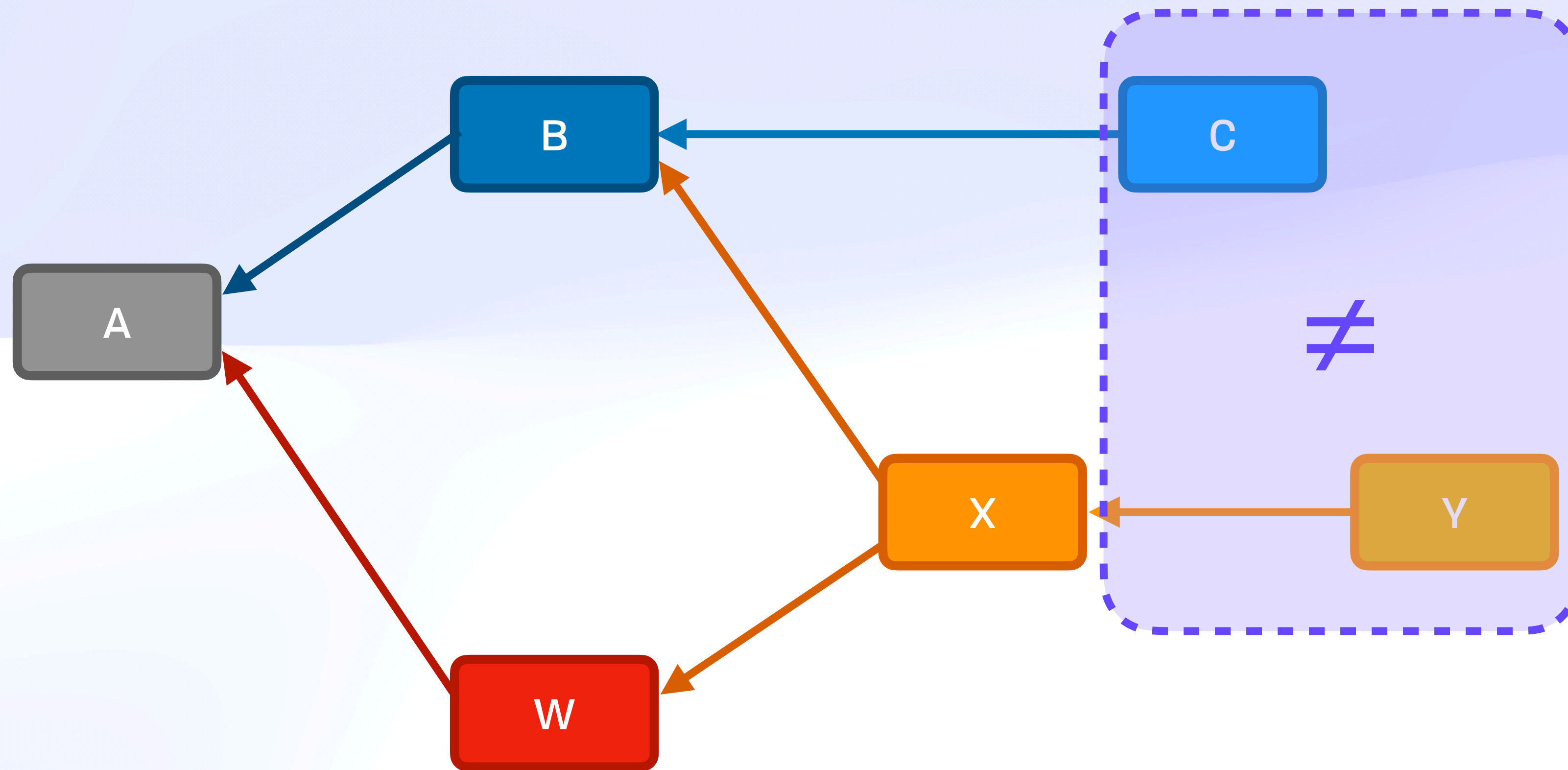
# Single Public File Confluence



Single File History / "Causal Shadow"

Public Files 

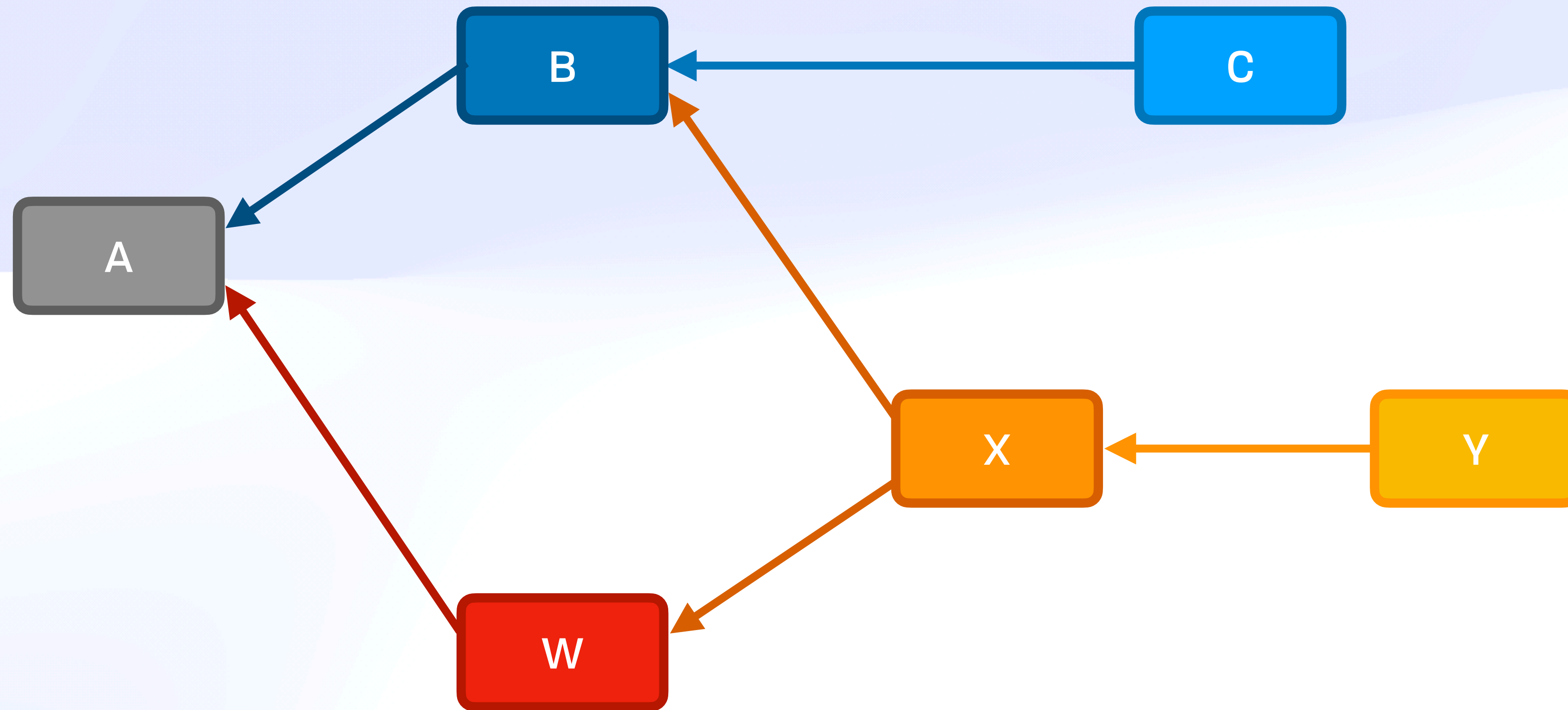
# Single Public File Confluence



Single File History / "Causal Shadow"

Public Files 

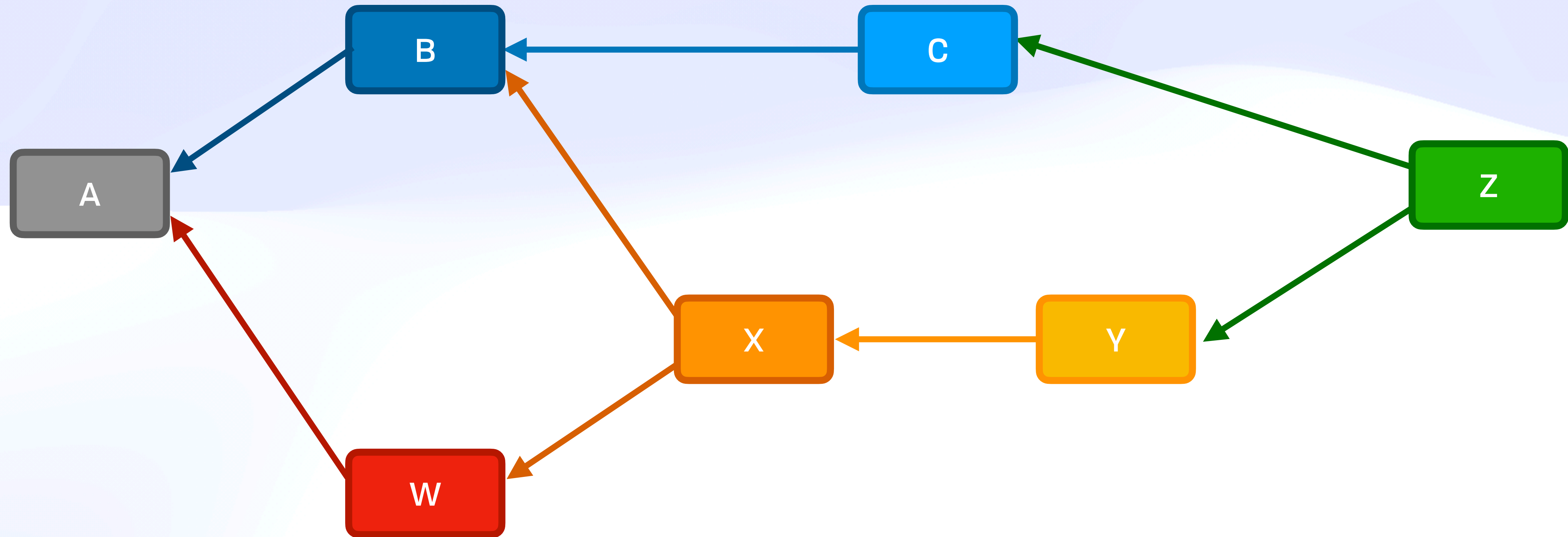
# Single Public File Confluence



Single File History / "Causal Shadow"

Public Files 

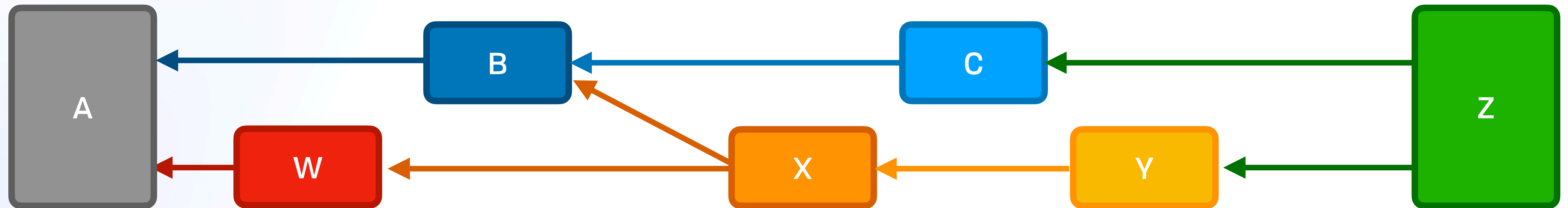
# Single Public File Confluence



Single File History / "Causal Shadow"

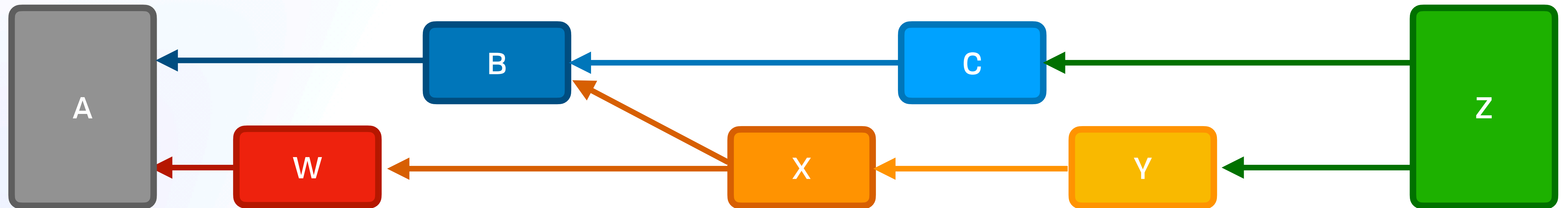
Public Files 

# *Single Public File Confluence*



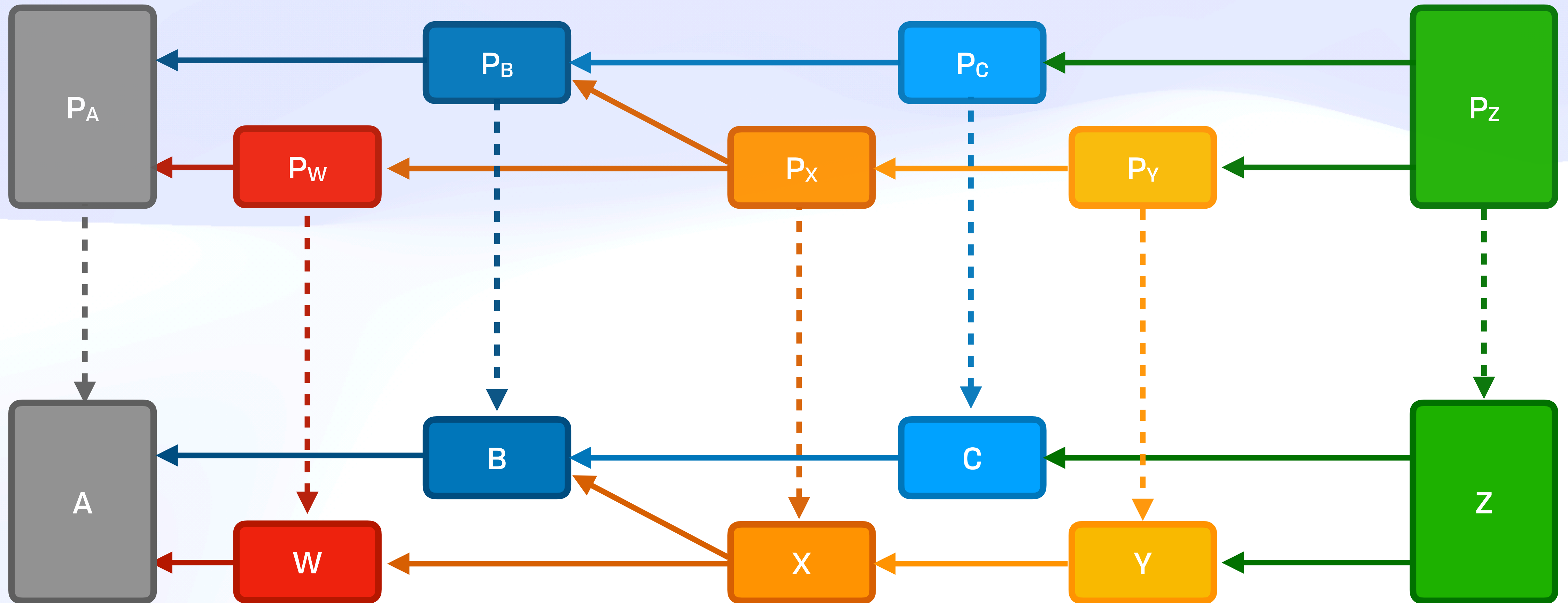
Public Files 

# Directory History

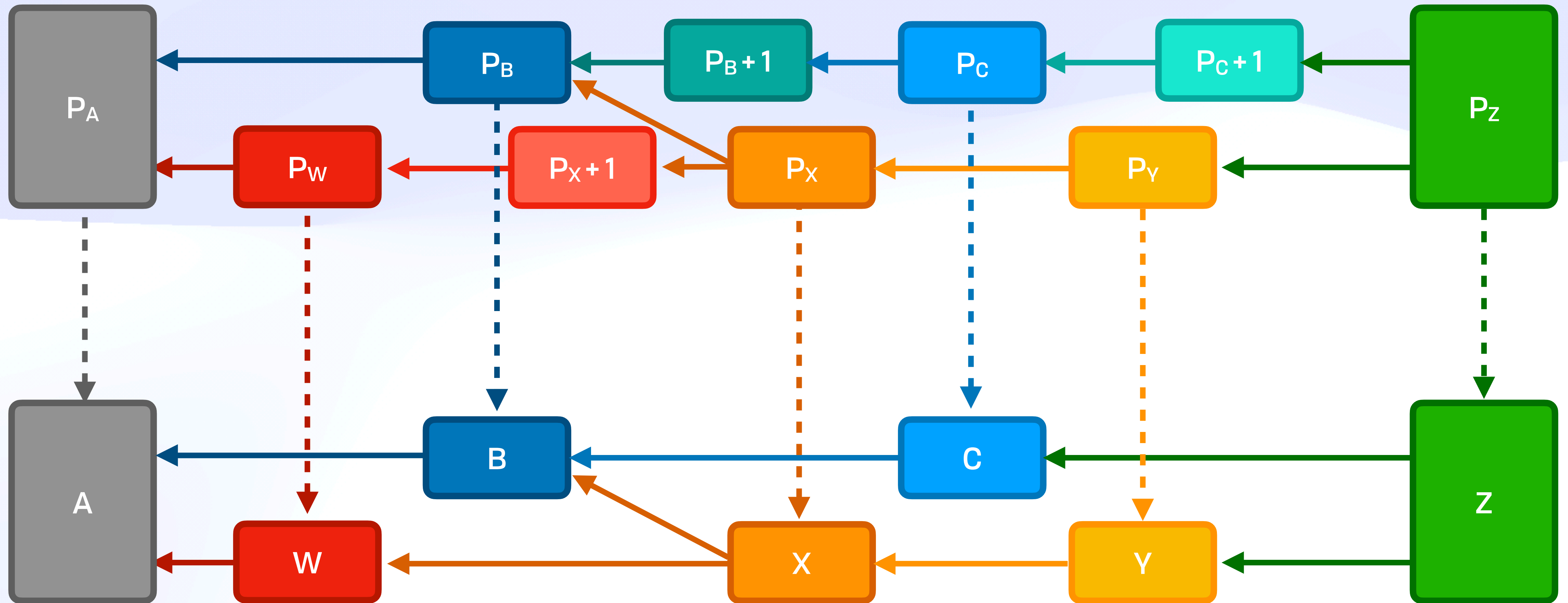


Public Files 

# Directory History

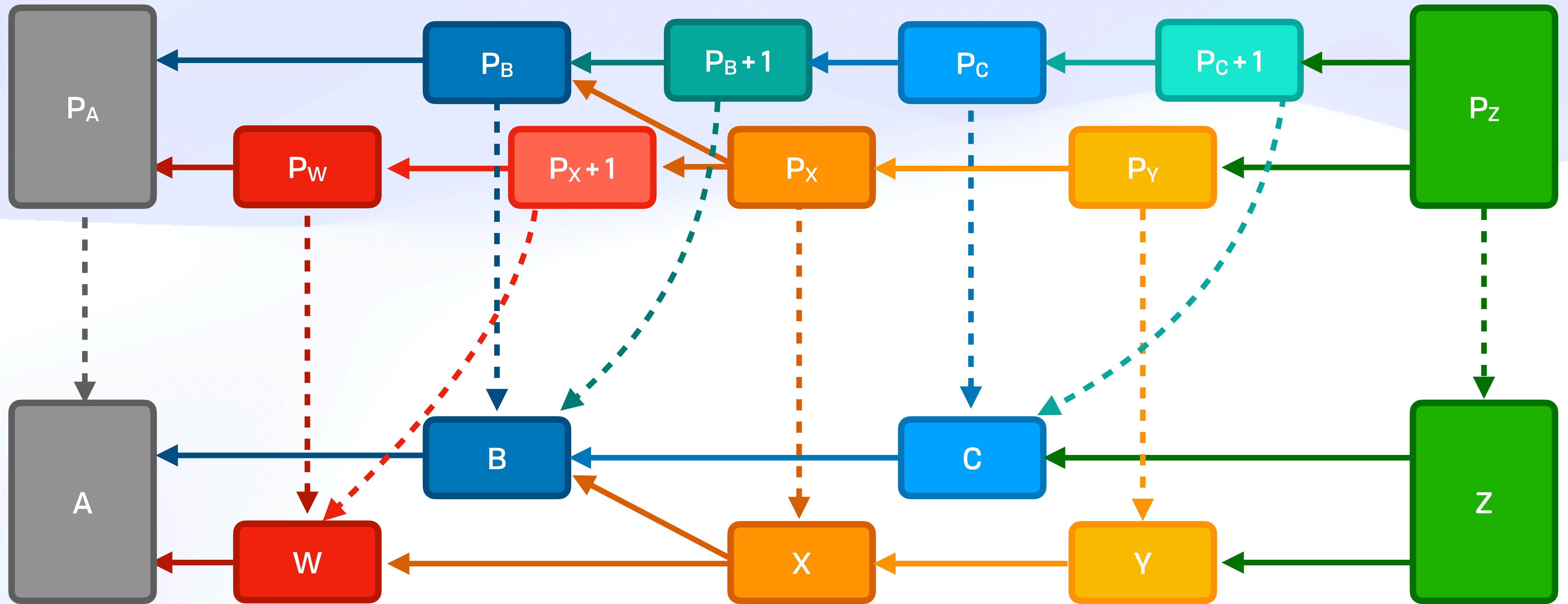


# Directory History + Extra Updates

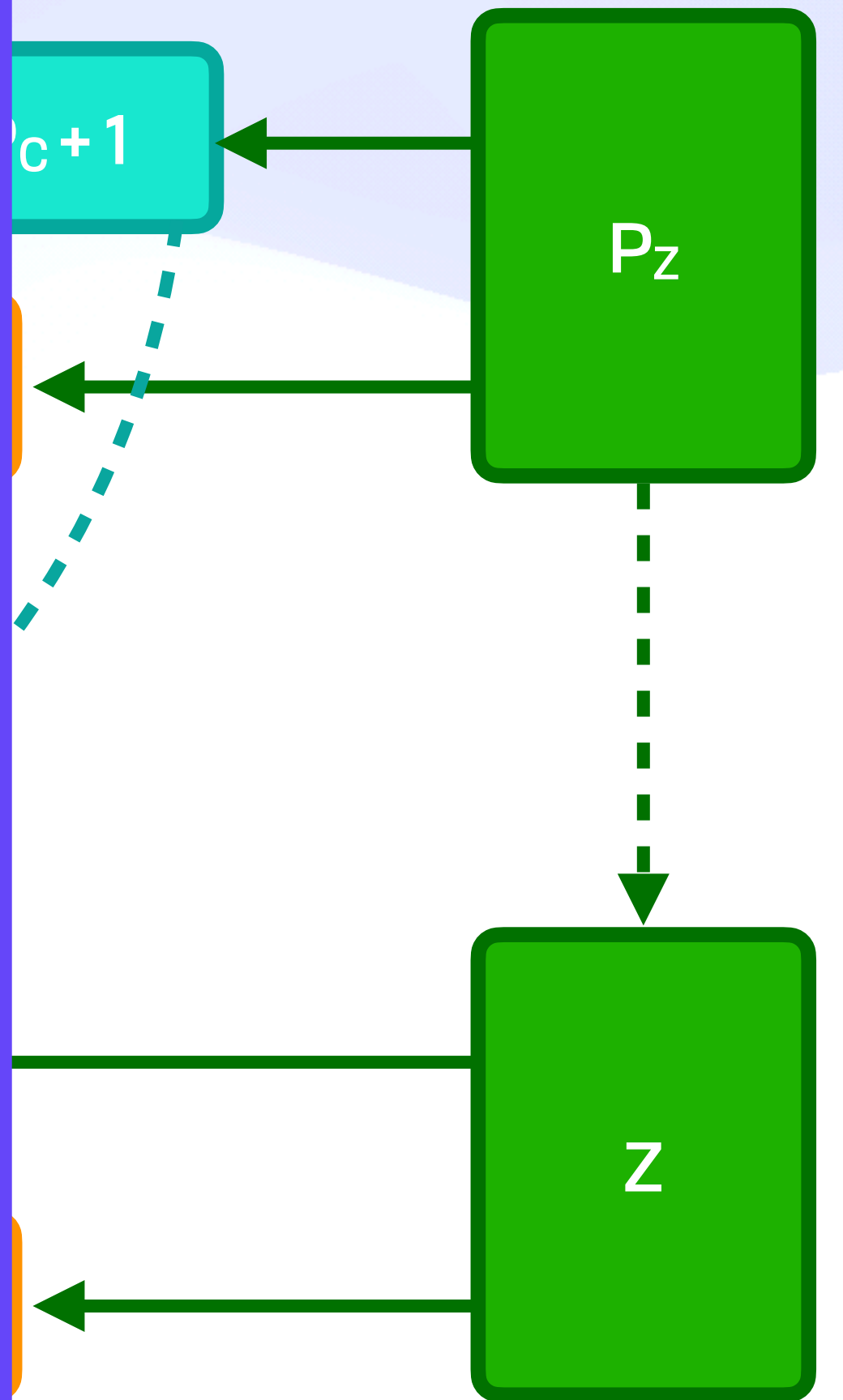
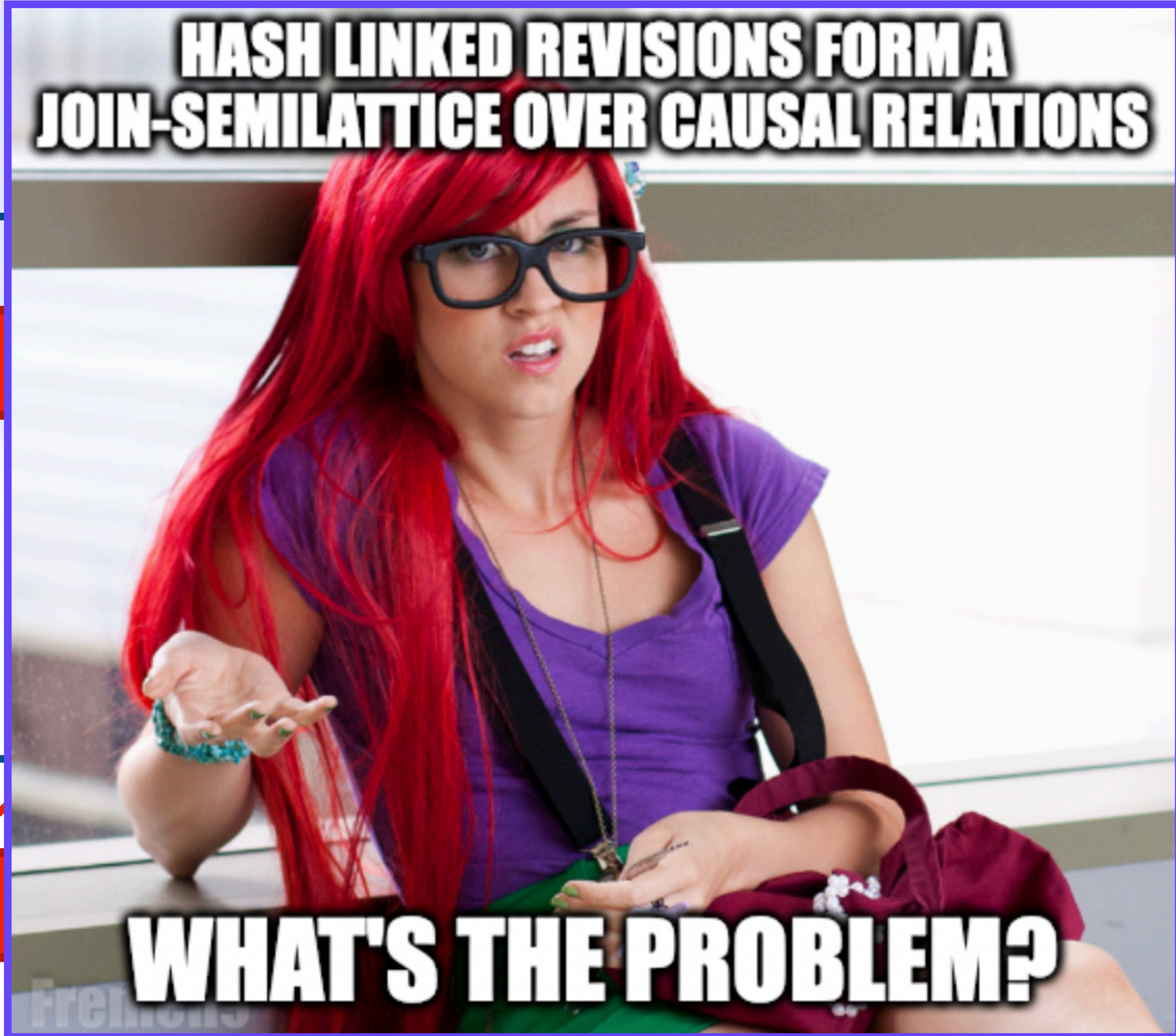
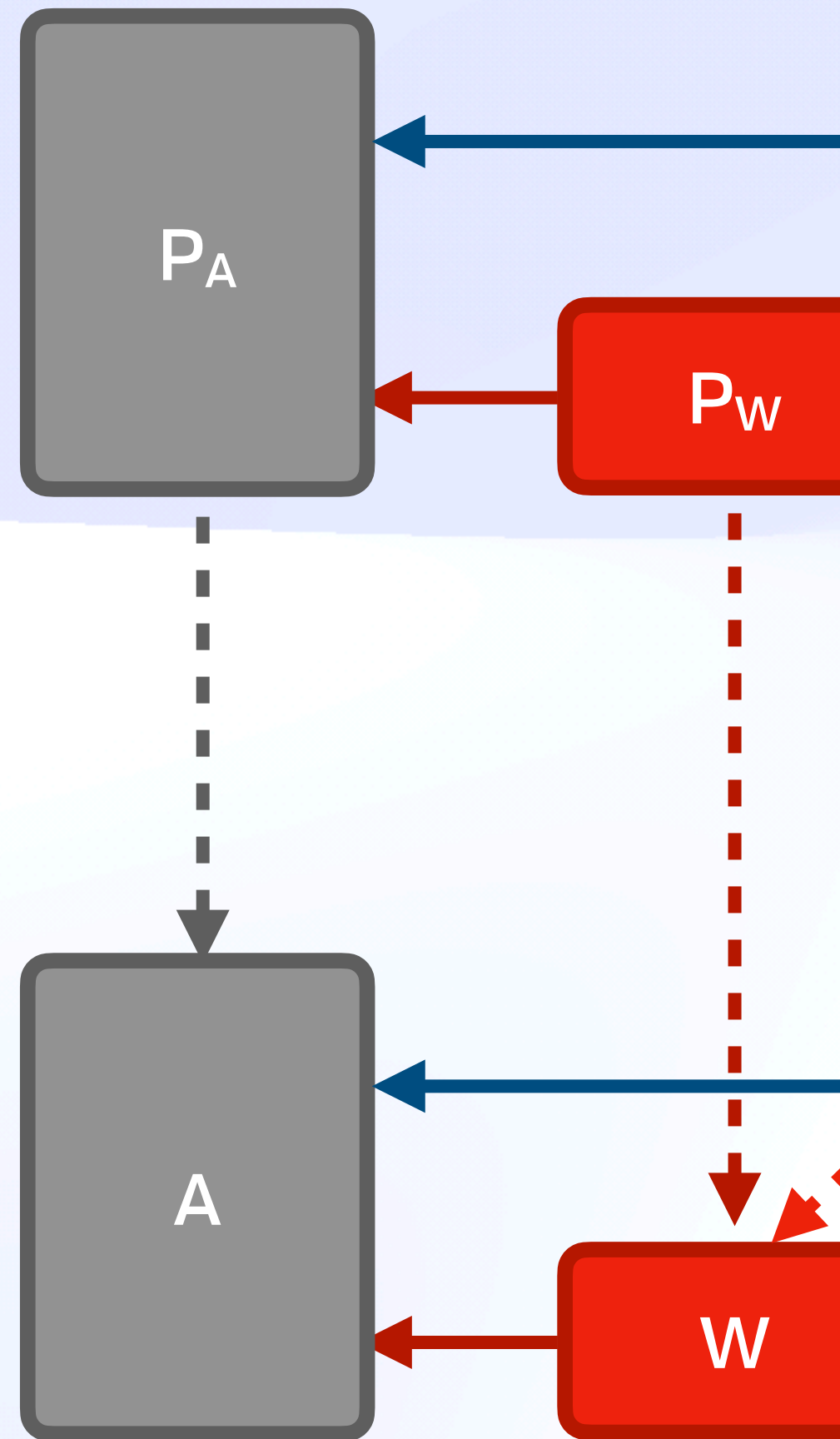




# Directory History + Extra Updates



# Directory History + Extra Updates

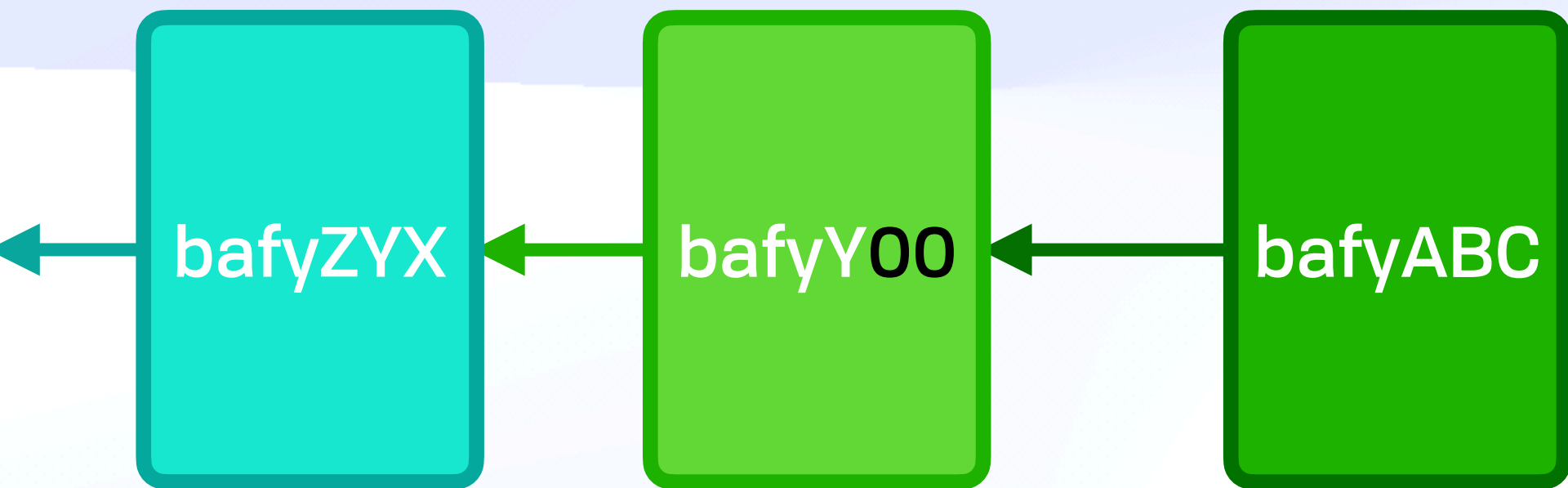


Public Files 

# ***Diff Checkpointing***

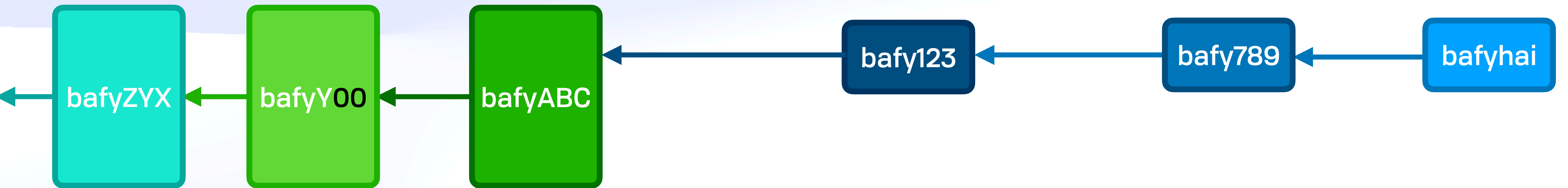
Public Files 

# *Diff Checkpointing*



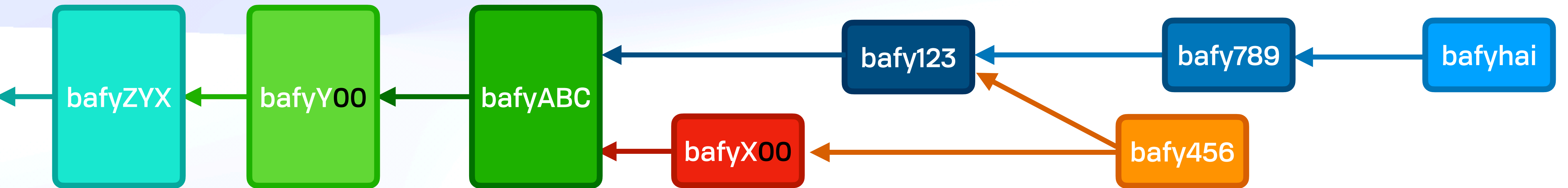
Public Files 

# *Diff Checkpointing*



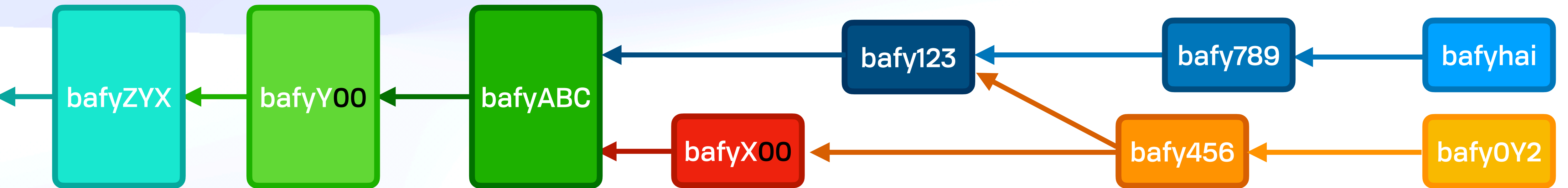
Public Files 

# *Diff Checkpointing*



Public Files 

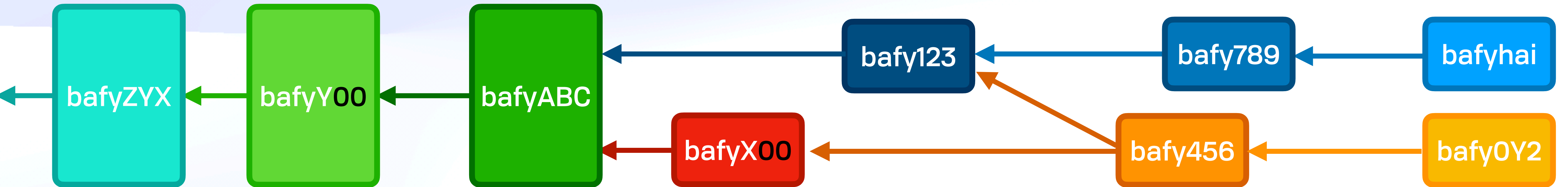
# Diff Checkpointing



Public Files 

# Diff Checkpointing

Skip to nodes ending in "00"

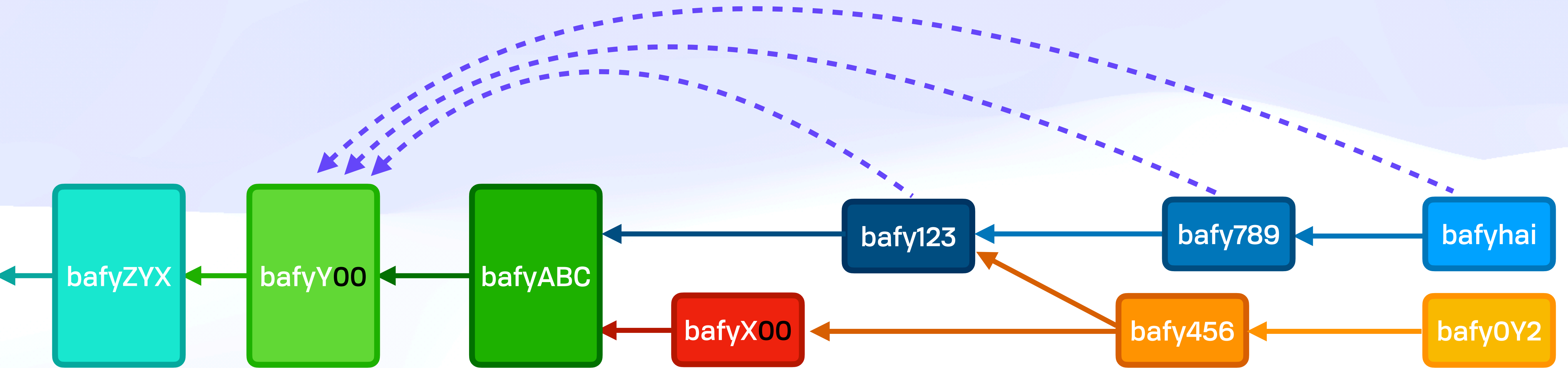




Public Files 

# Diff Checkpointing

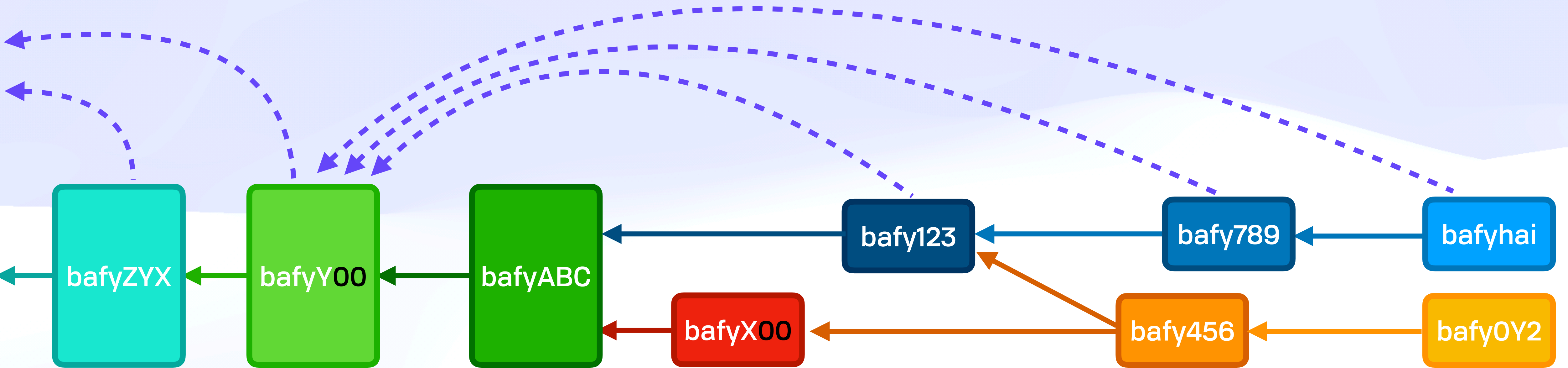
Skip to nodes ending in "00"



Public Files 

# Diff Checkpointing

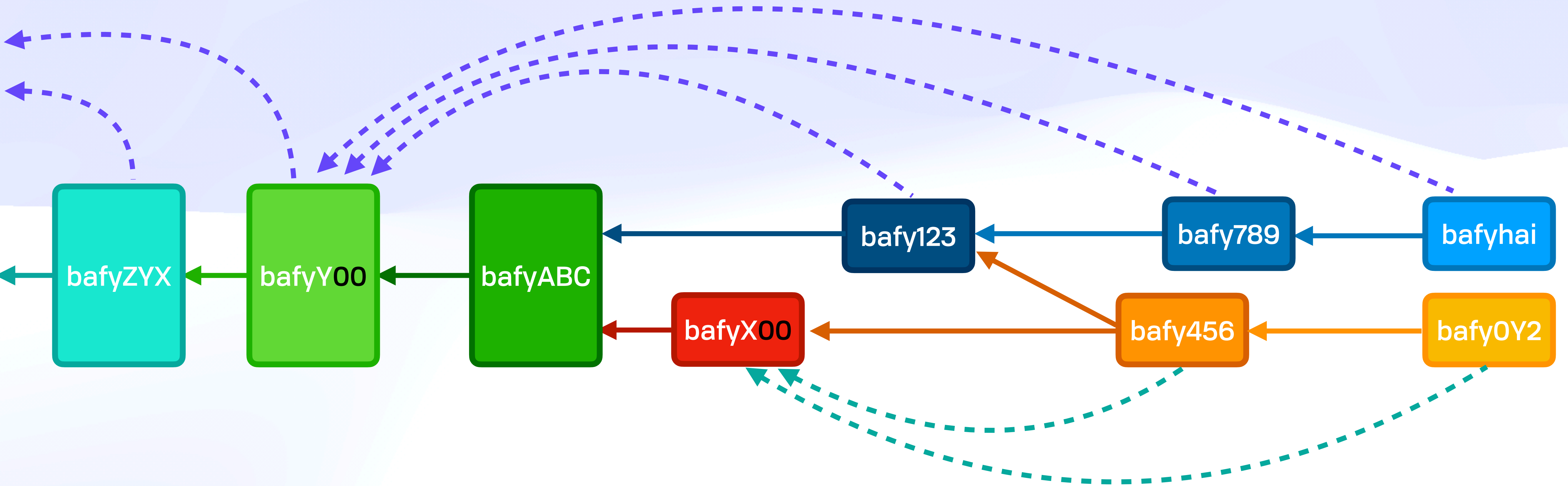
Skip to nodes ending in "00"



Public Files 

# Diff Checkpointing

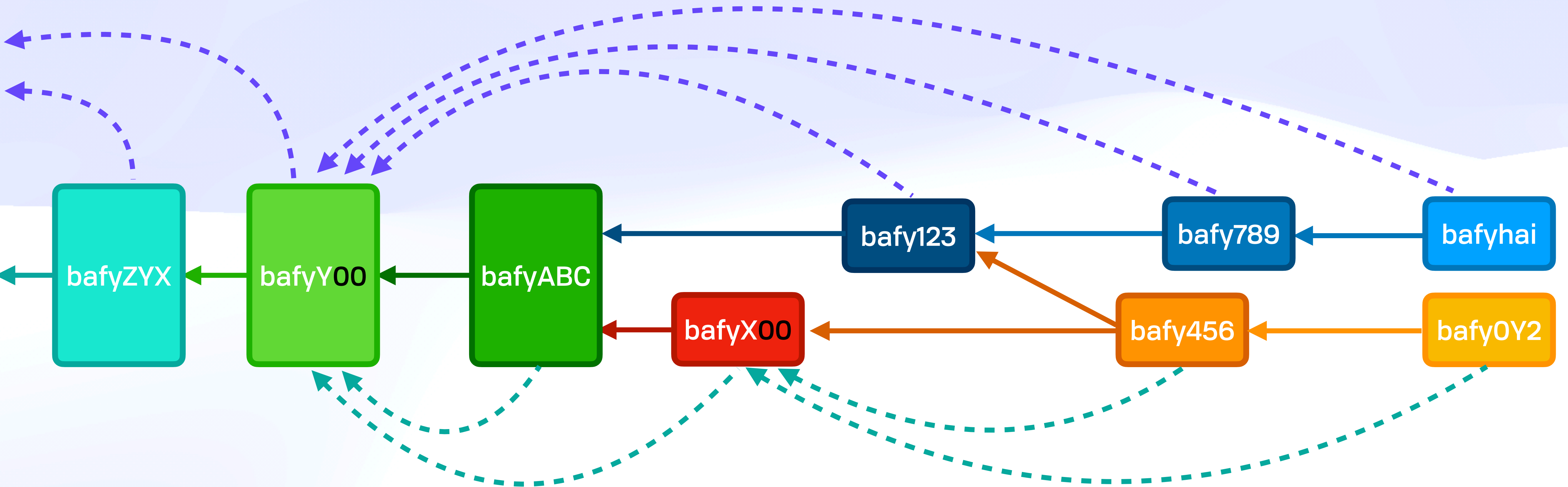
Skip to nodes ending in "00"



Public Files 

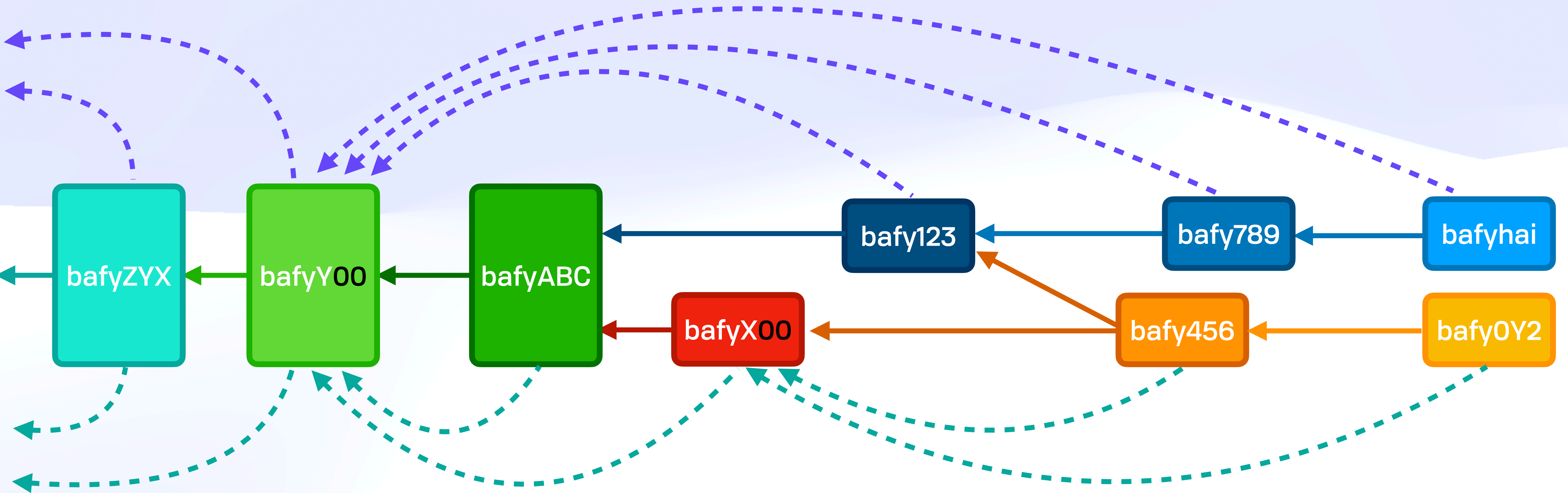
# Diff Checkpointing

Skip to nodes ending in "00"



# Diff Checkpointing

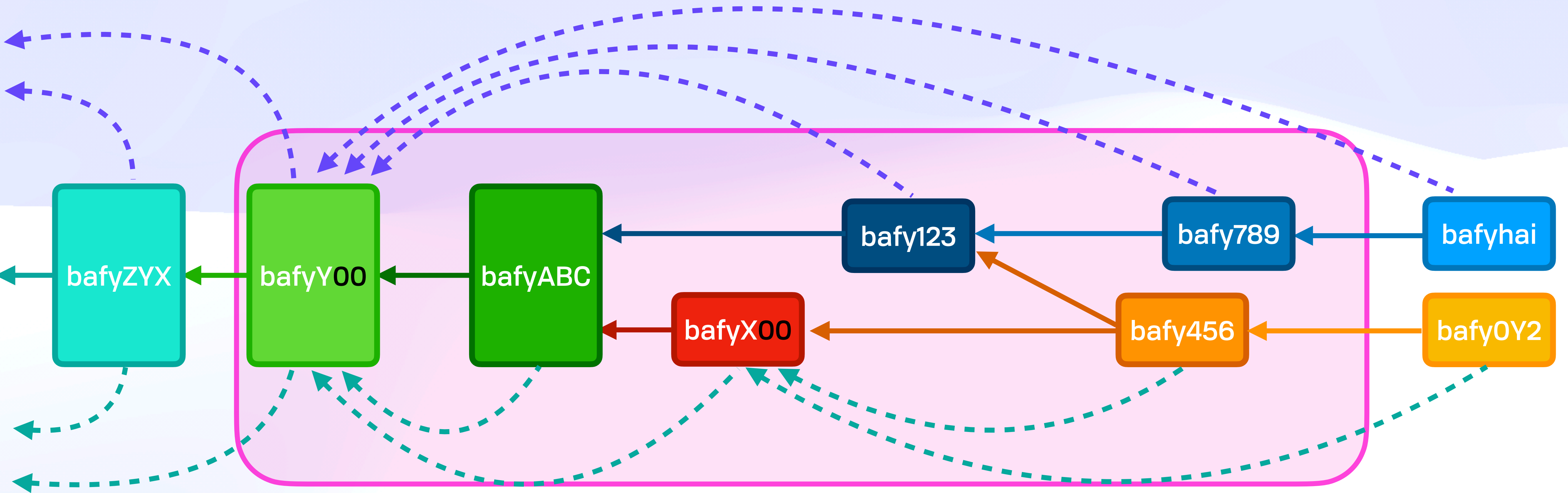
Skip to nodes ending in "00"



Public Files 

# Diff Checkpointing

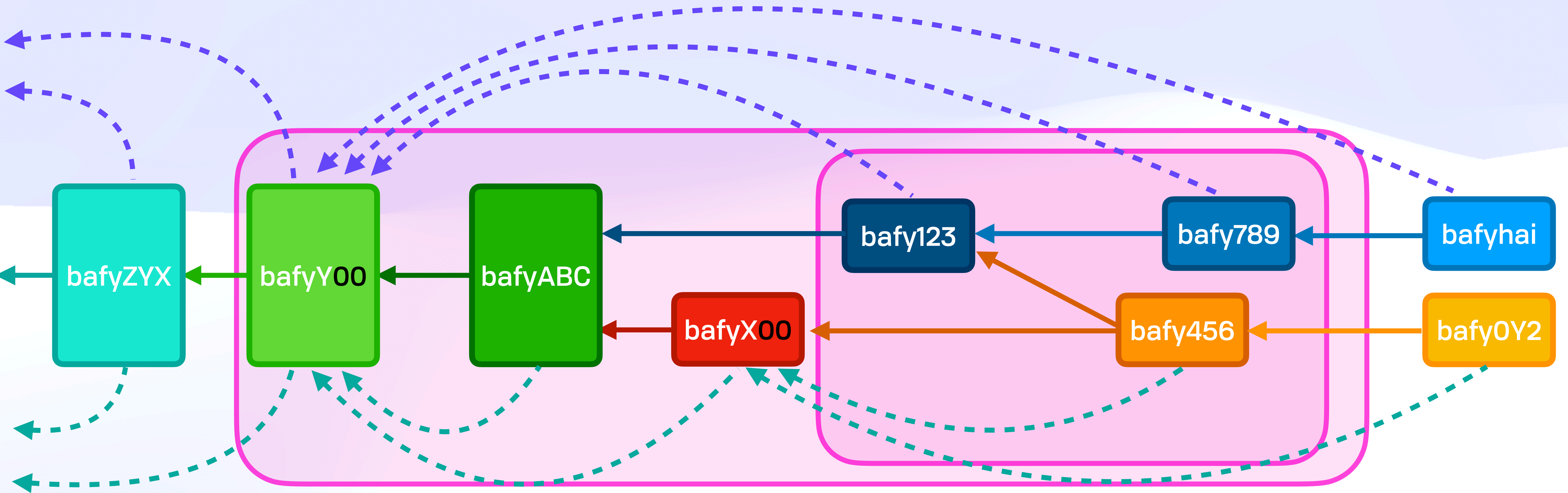
Skip to nodes ending in "00"



Public Files 

# Diff Checkpointing

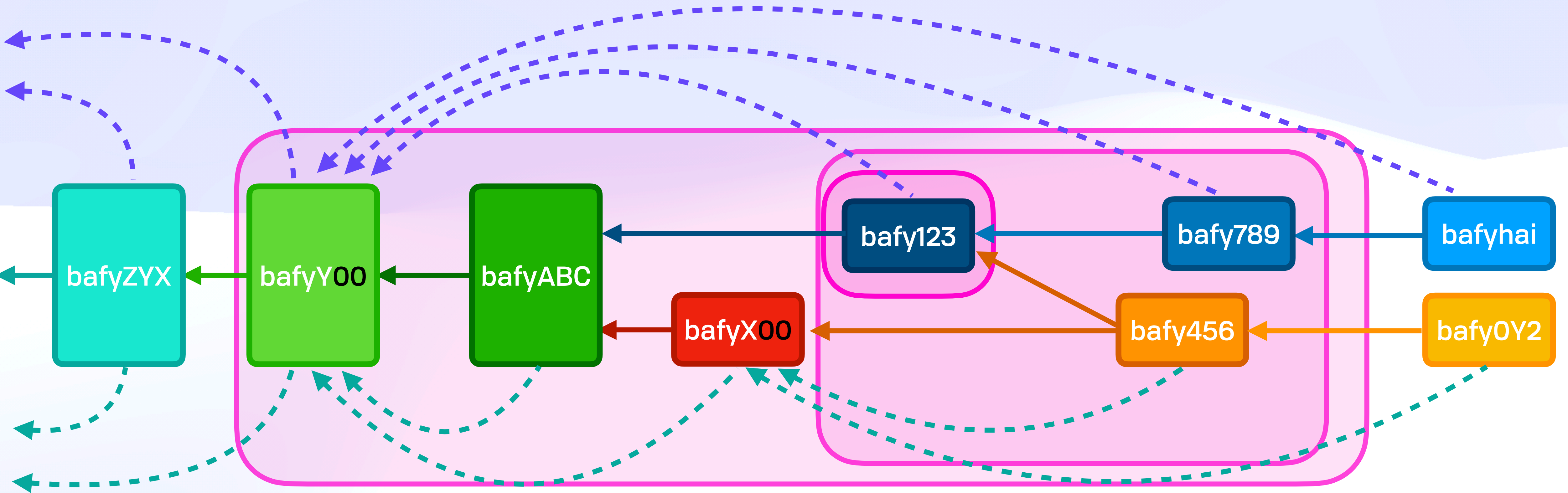
Skip to nodes ending in "00"



Public Files 

# Diff Checkpointing

Skip to nodes ending in "00"



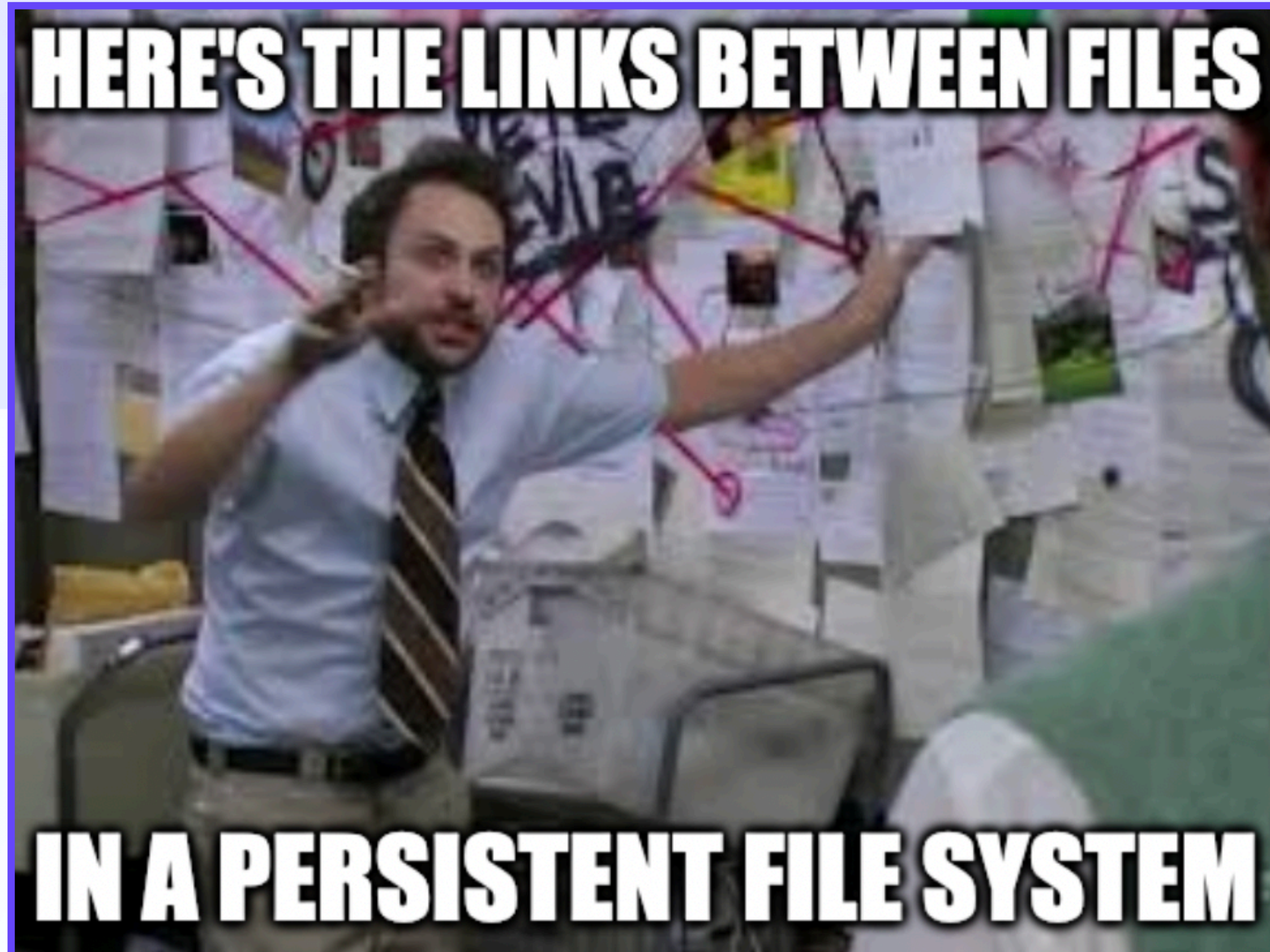


Public Files 

***...Moving On...***

Public Files 📁

*...Moving On...*



# 秘 *Secret Files* 🥷

Distributed Storage When The Pipes Are Broken





***Cryptography*** is a tool for turning  
lots of different problems into  
***key management problems***

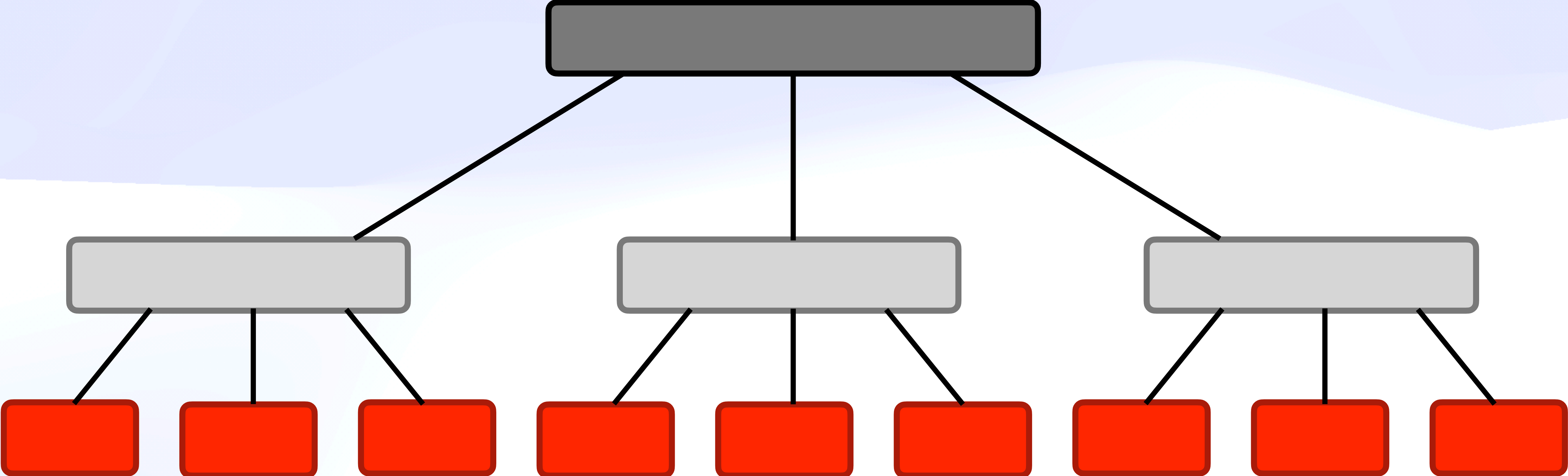
Dr. Lea Kissner, Google's Global Lead of Privacy Technologies

Secret Files 

# ***Dark Forest***

Secret Files 

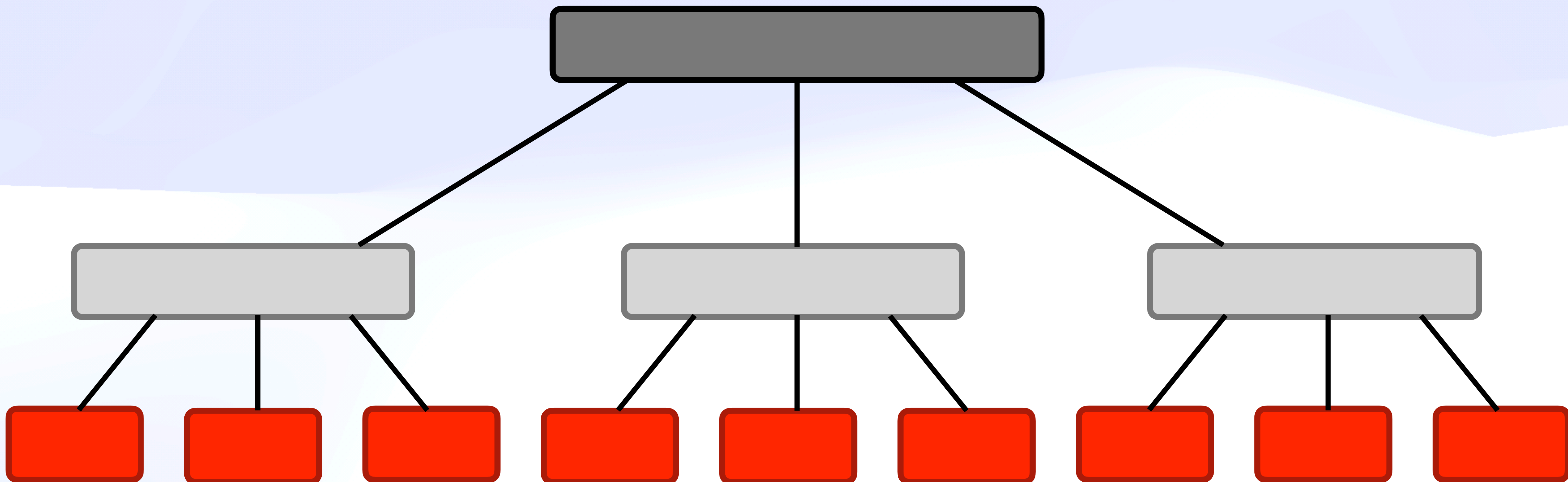
# Dark Forest



Secret Files 

# Dark Forest

CHAMP  
(weight 16)





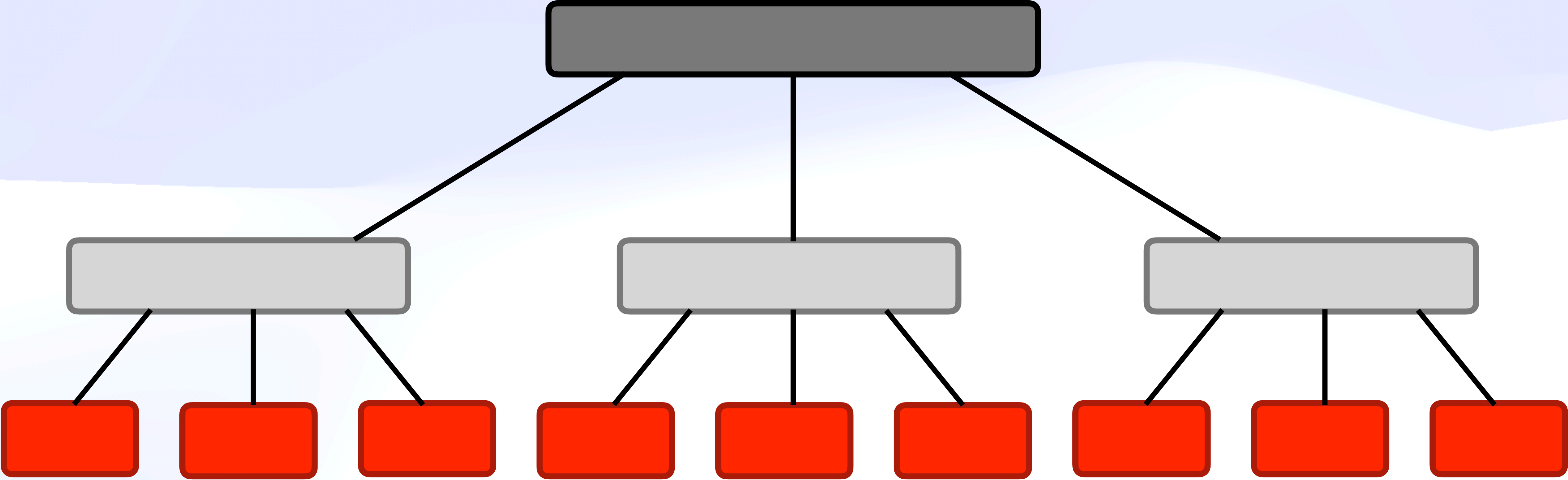
# Dark Forest

**CHAMP**  
(weight 16)

$16^3 > 4k$  buckets

$16^4 > 65k$  buckets

$16^5 > 1M$  buckets



# Dark Forest

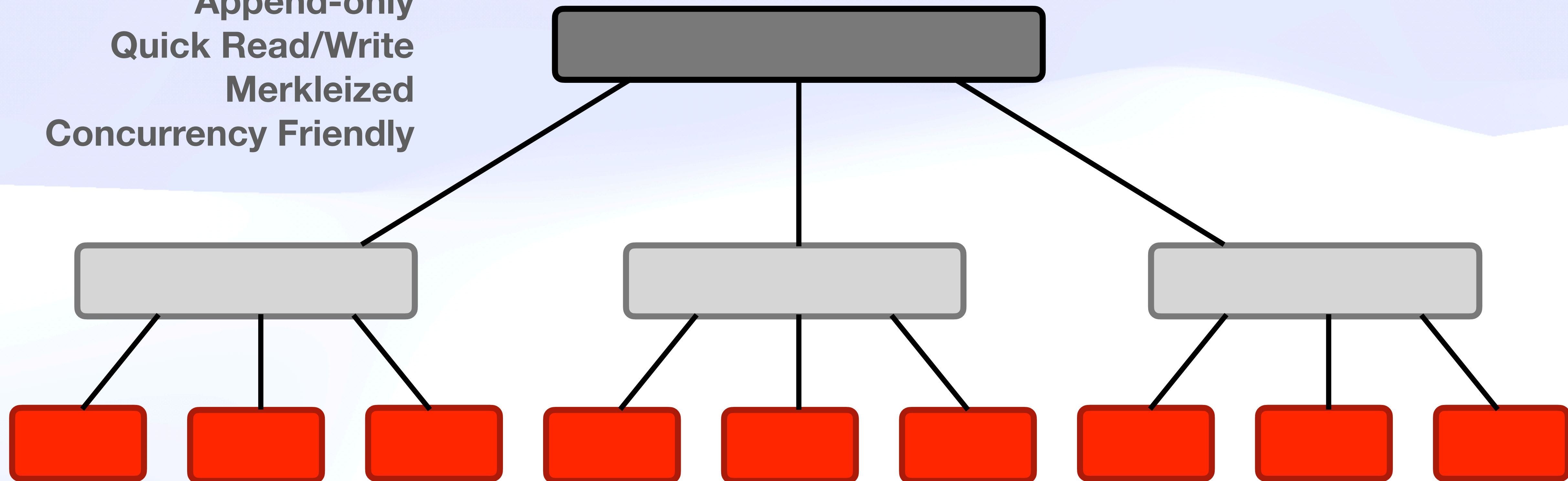
**CHAMP**  
(weight 16)

$16^3 > 4k$  buckets

$16^4 > 65k$  buckets

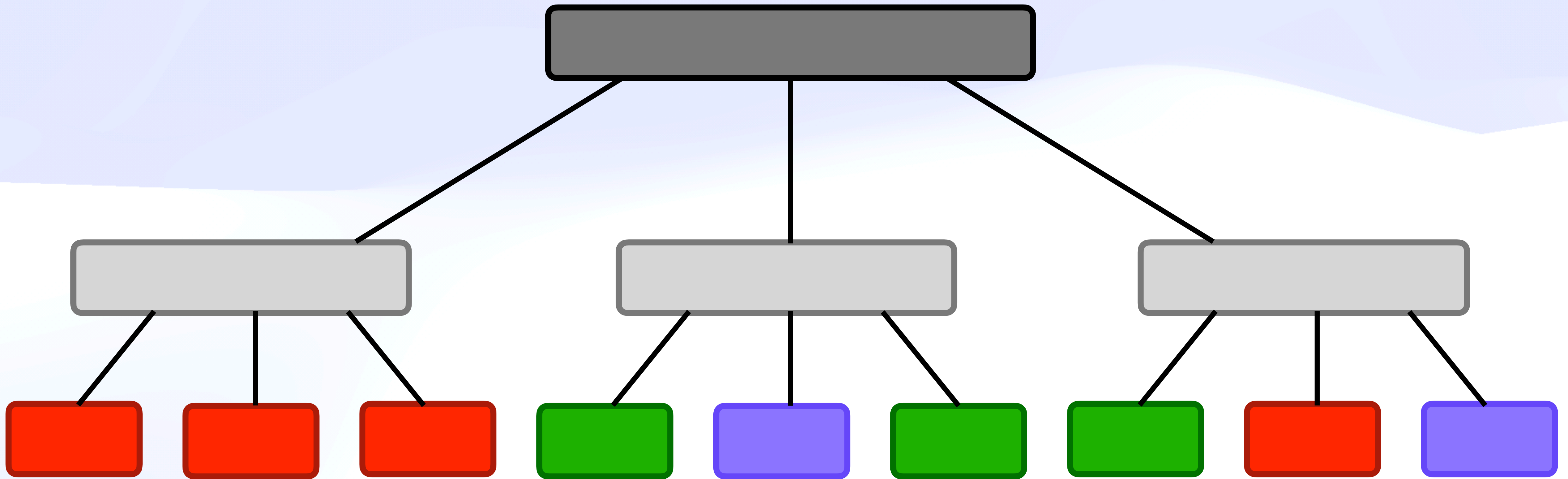
$16^5 > 1M$  buckets

Append-only  
Quick Read/Write  
Merkleized  
Concurrency Friendly



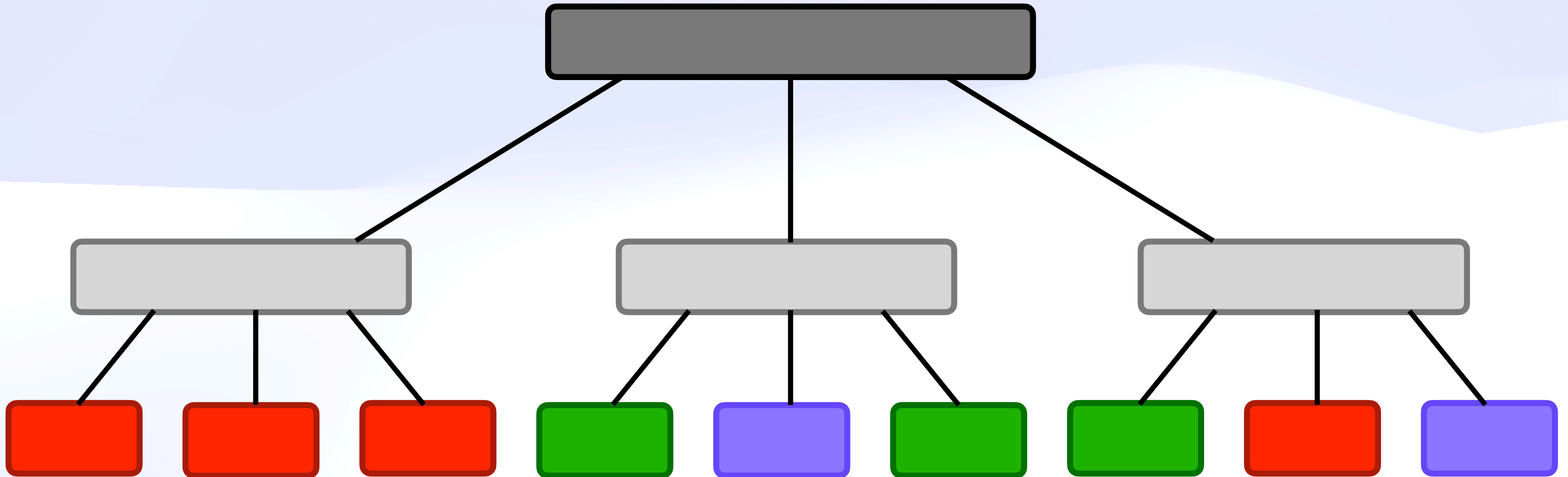
Secret Files 

# Dark Forest



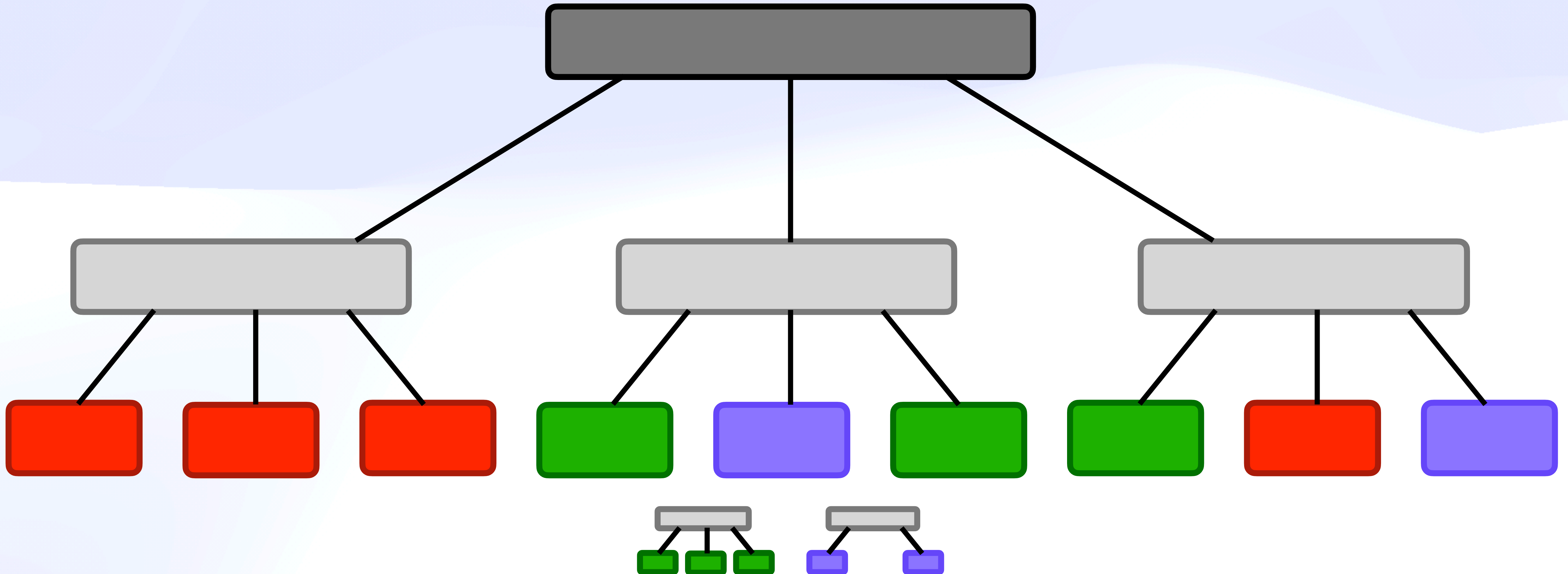
# Dark Forest

One Pointer Machine  
Many (Secret) Roots



# Dark Forest

One Pointer Machine  
Many (Secret) Roots

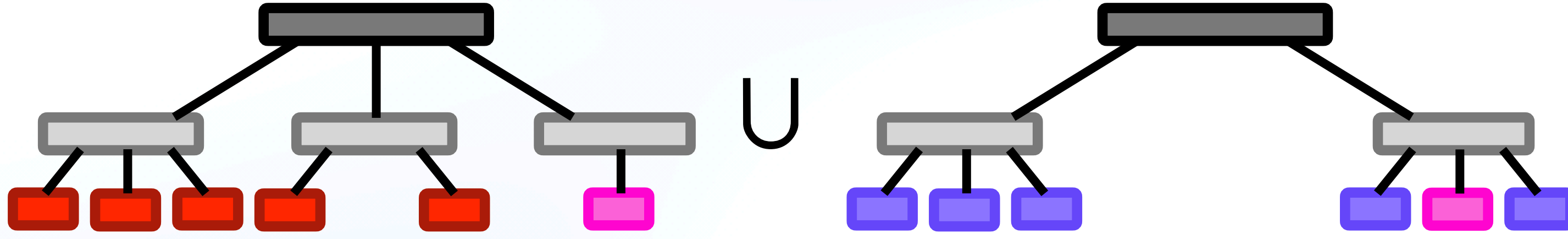


Secret Files 

***Useful: Arbitrary Merge***

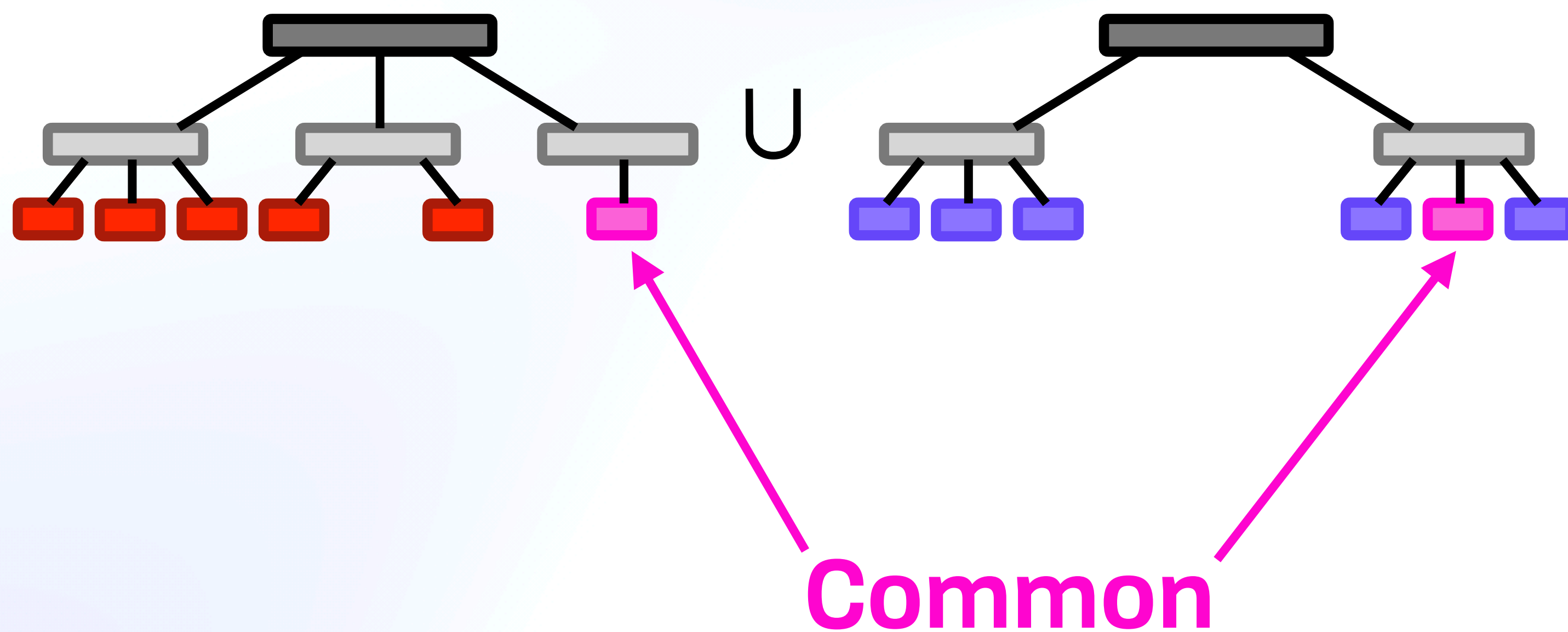
Secret Files 🥷

# *Useful: Arbitrary Merge*



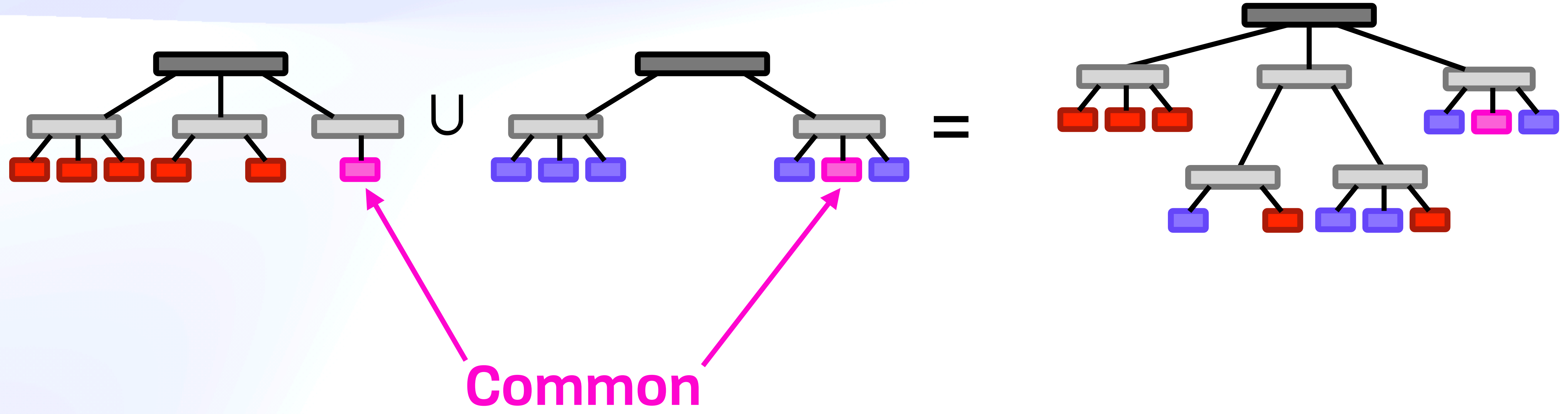
Secret Files 🥷

# Useful: Arbitrary Merge



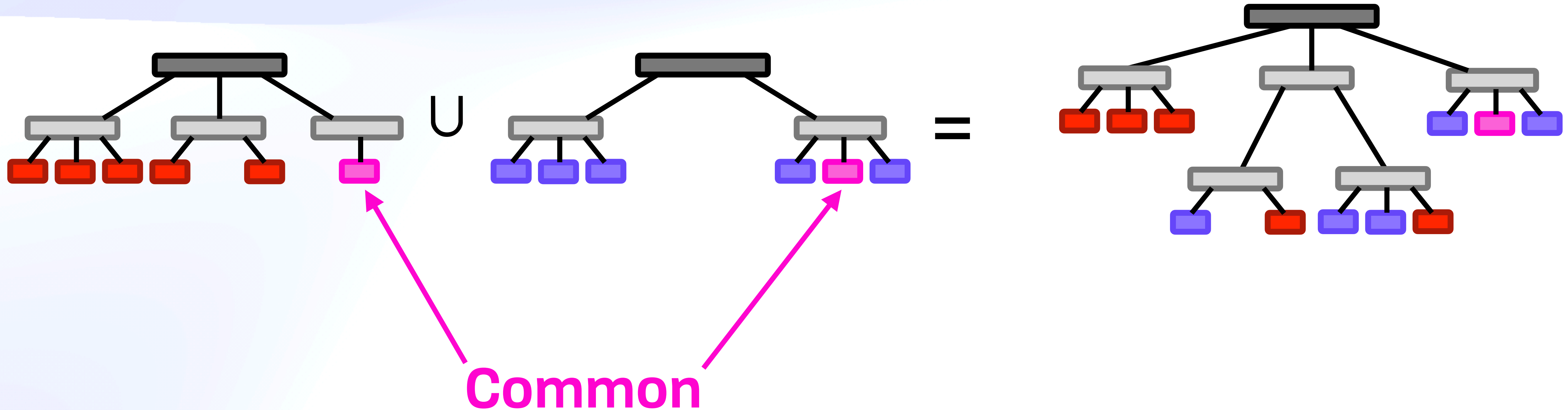


# Useful: Arbitrary Merge



# Useful: Arbitrary Merge

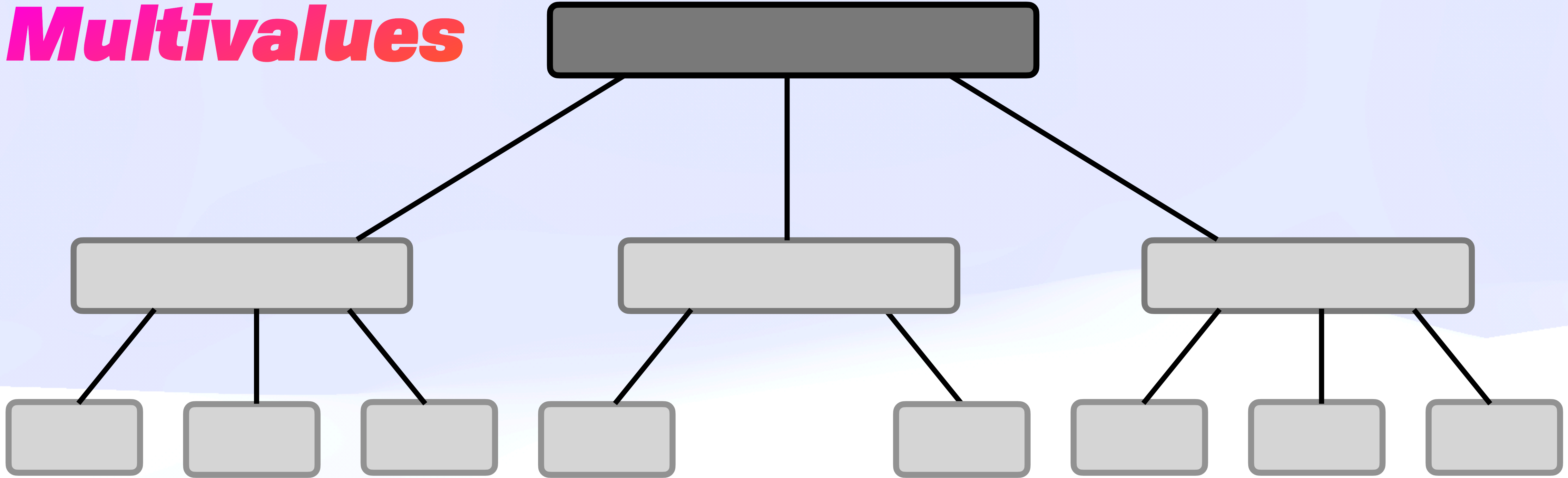
Visibility	Noun		Example
Decrypted	Files	→	Paths & Content
Encrypted		→	Headers & Node Layout
	Data	→	Merkle Set



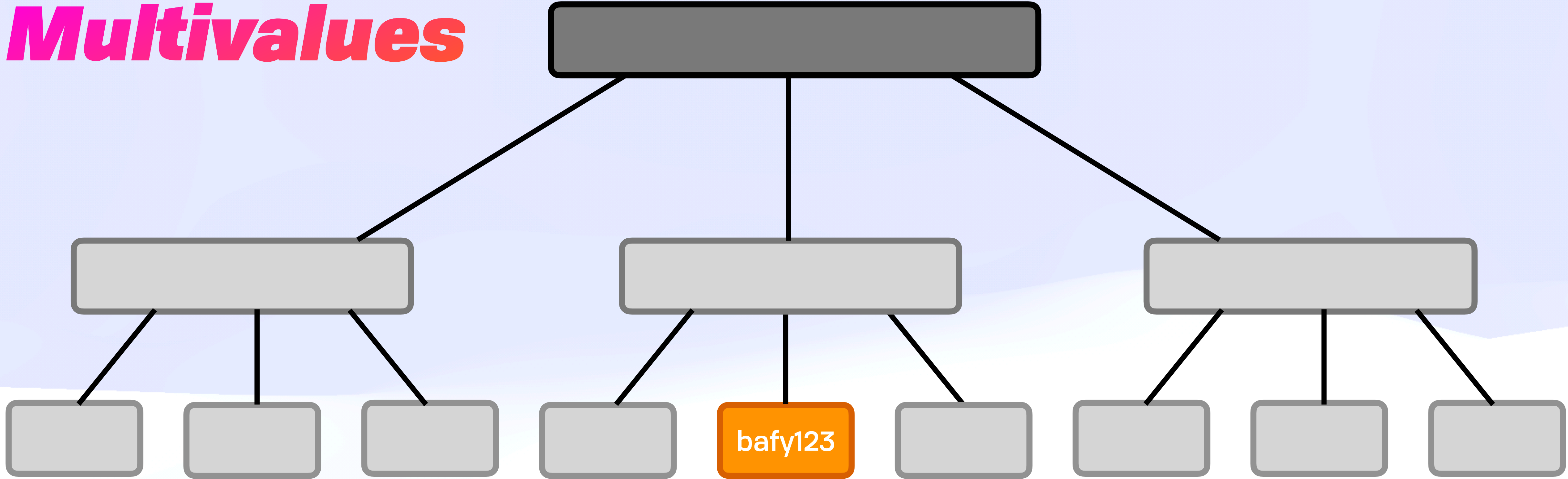
Secret Files 

# ***Multivalues***

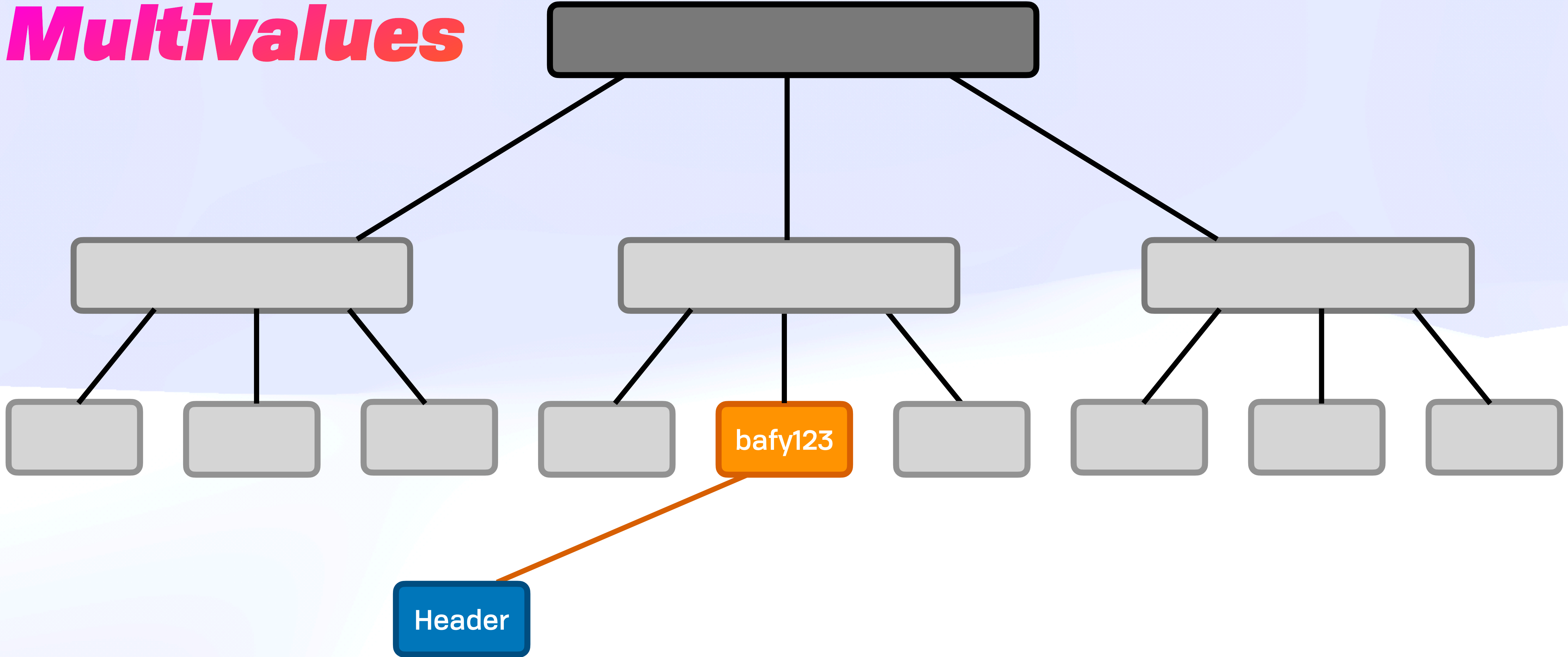
# *Multivalues*



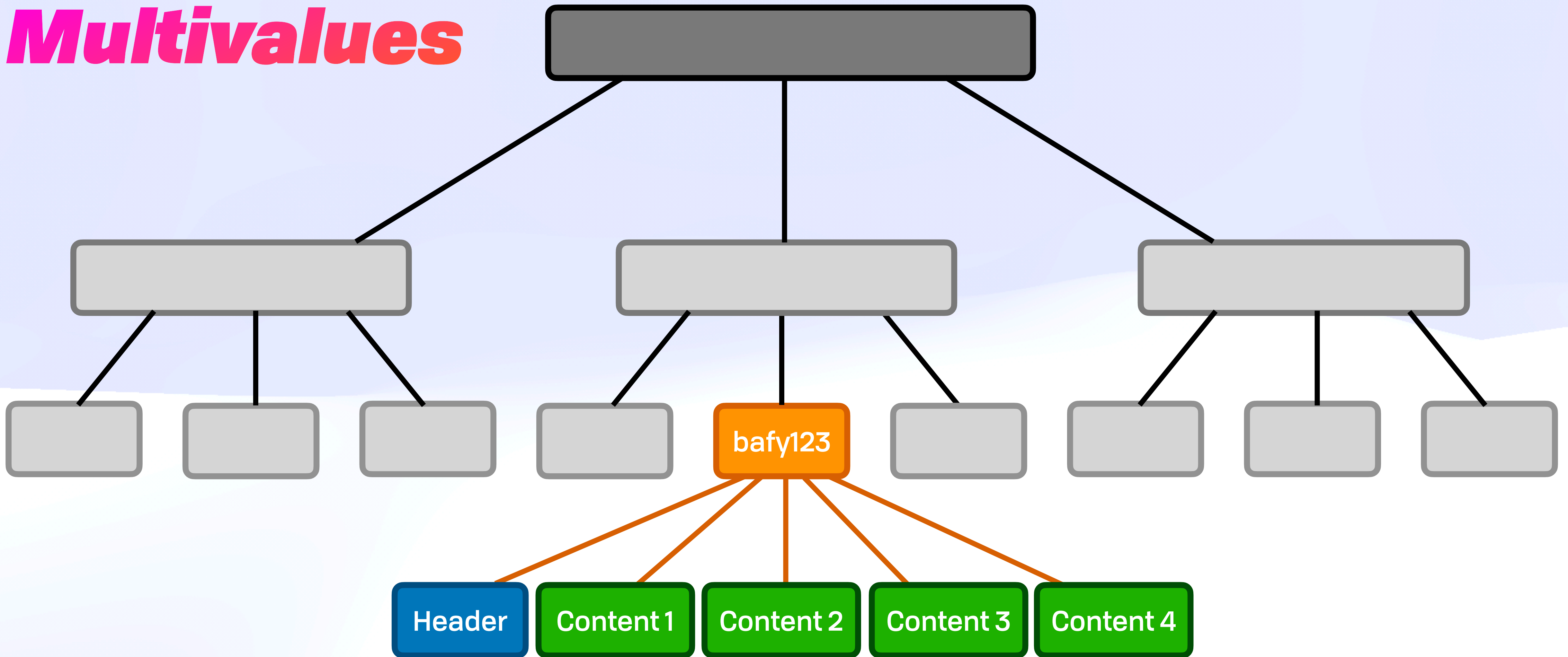
# Multivalues



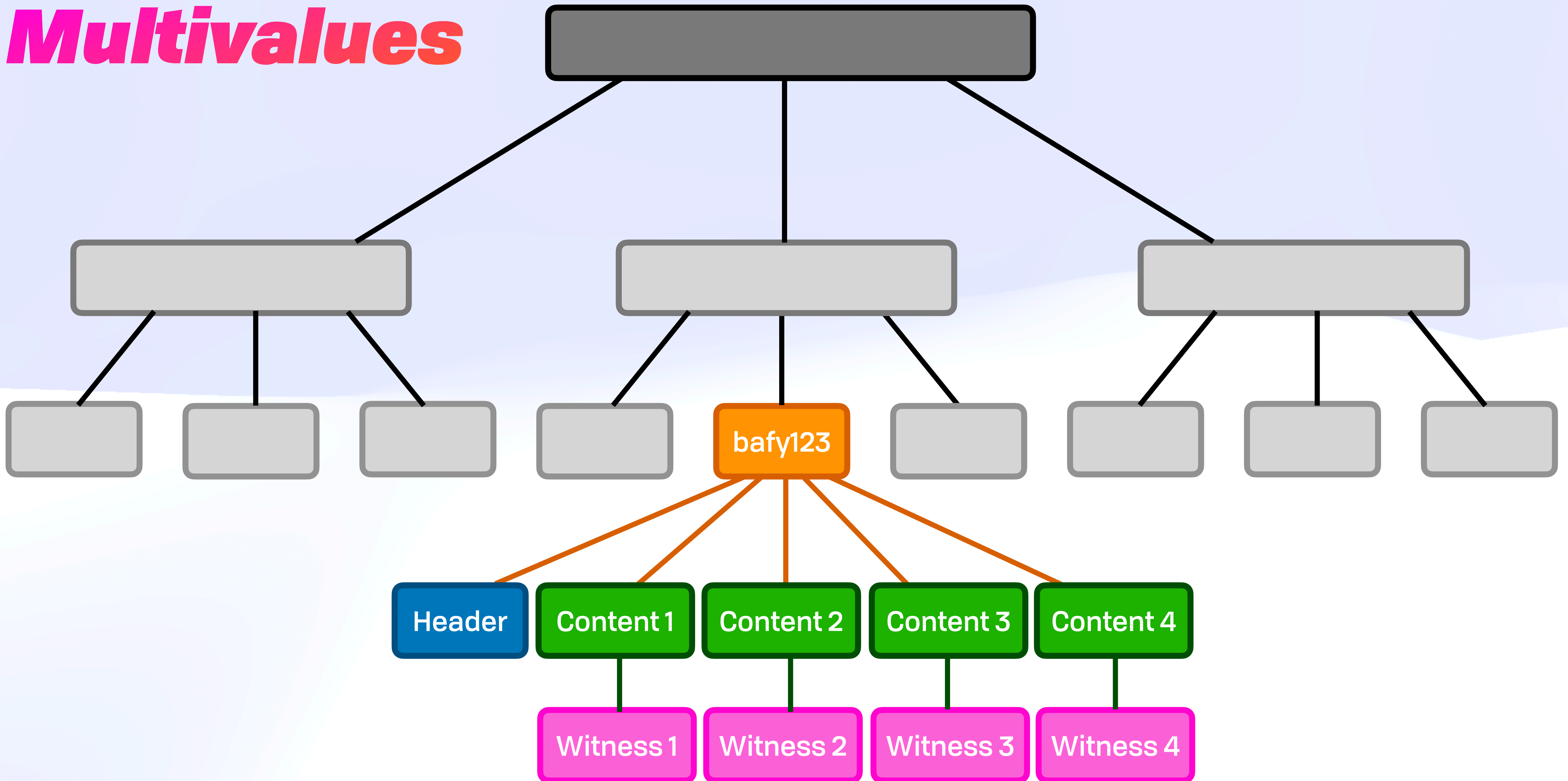
# Multivalues



# Multivalues



# Multivalues





Secret Files 

# *Single Private Node*

Secret Files 

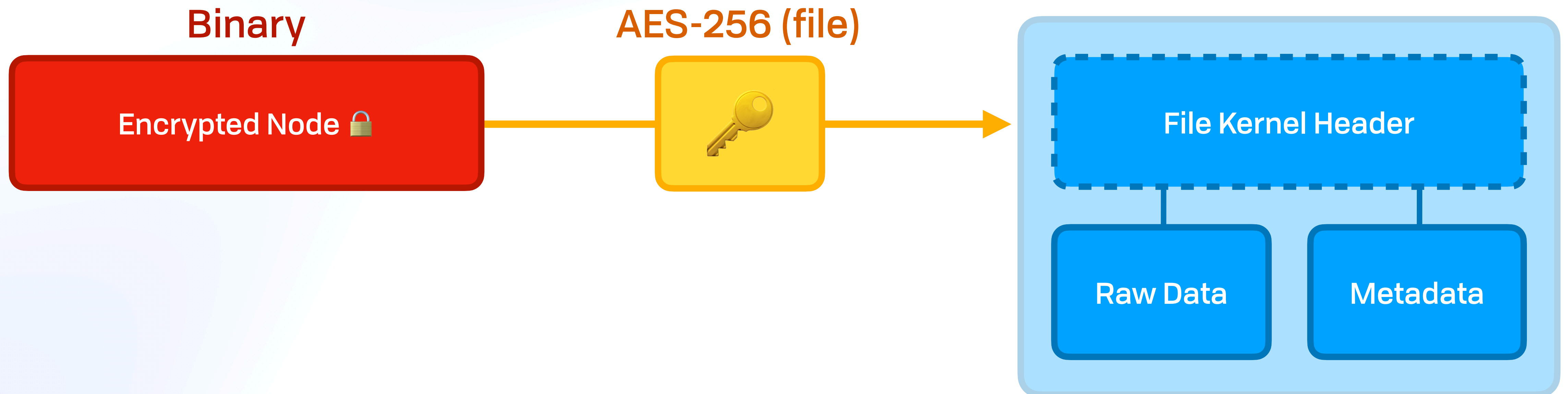
# *Single Private Node*

Binary

Encrypted Node 

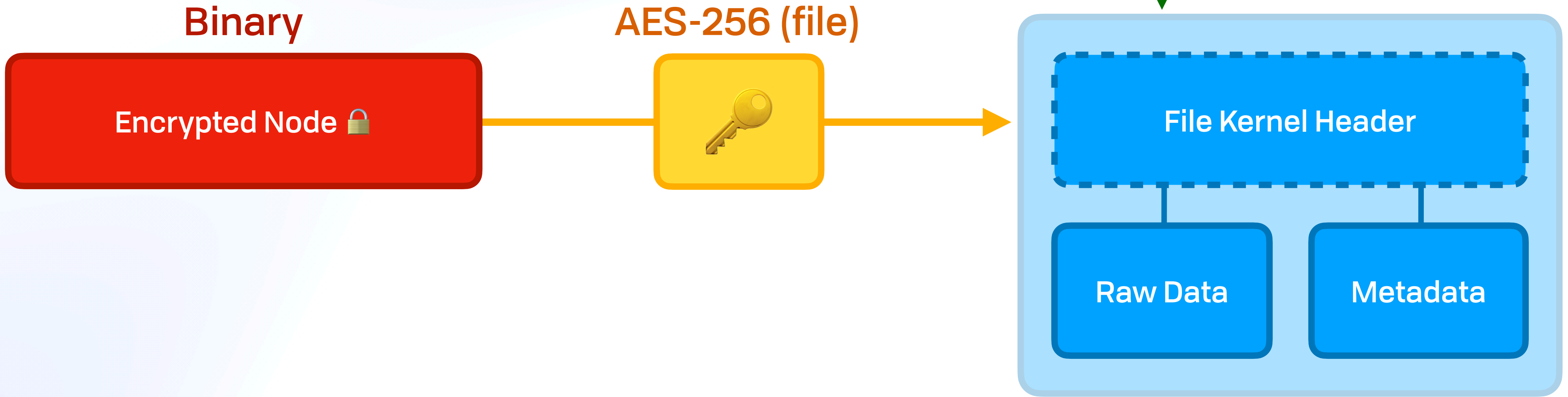
Secret Files 

# Single Private Node

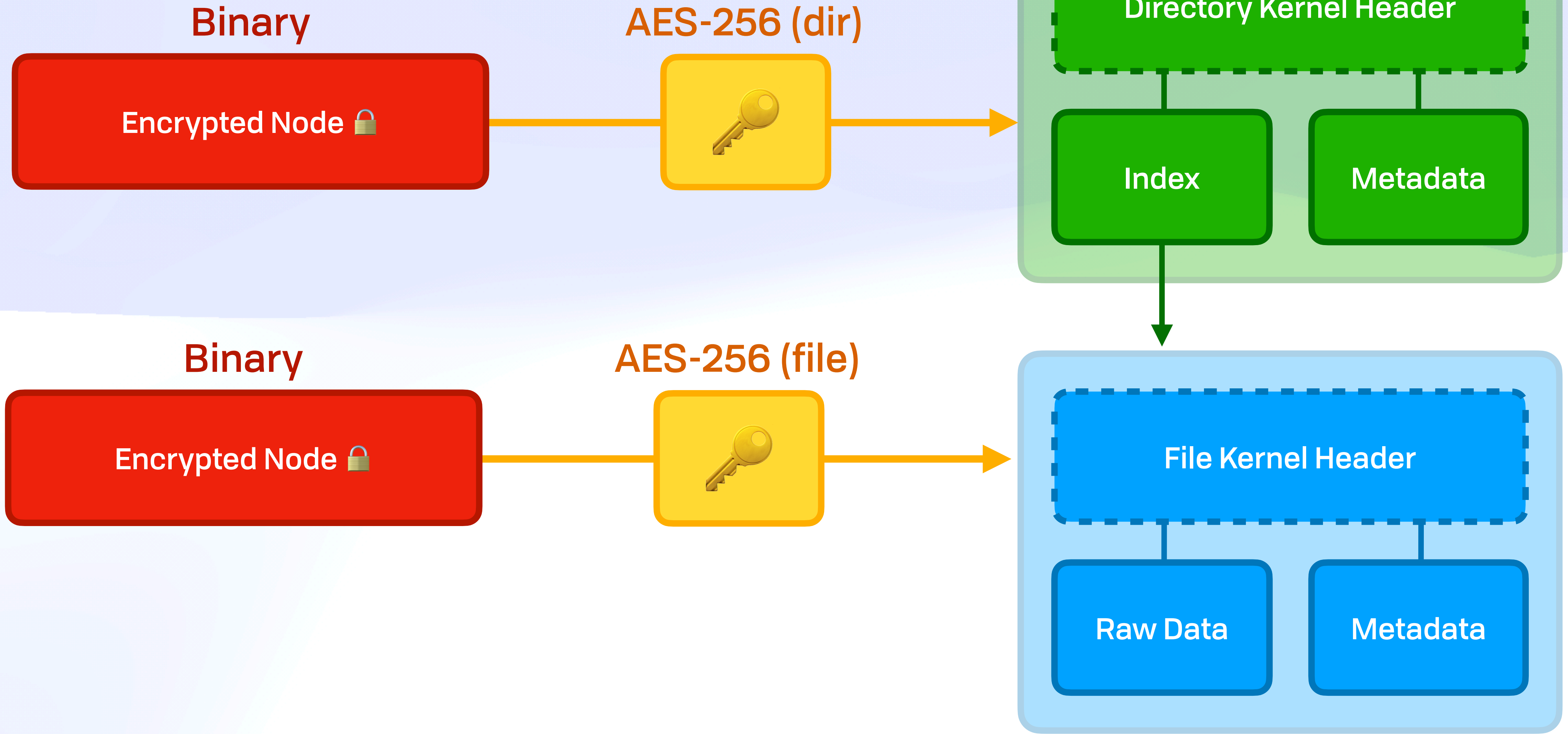


Secret Files 

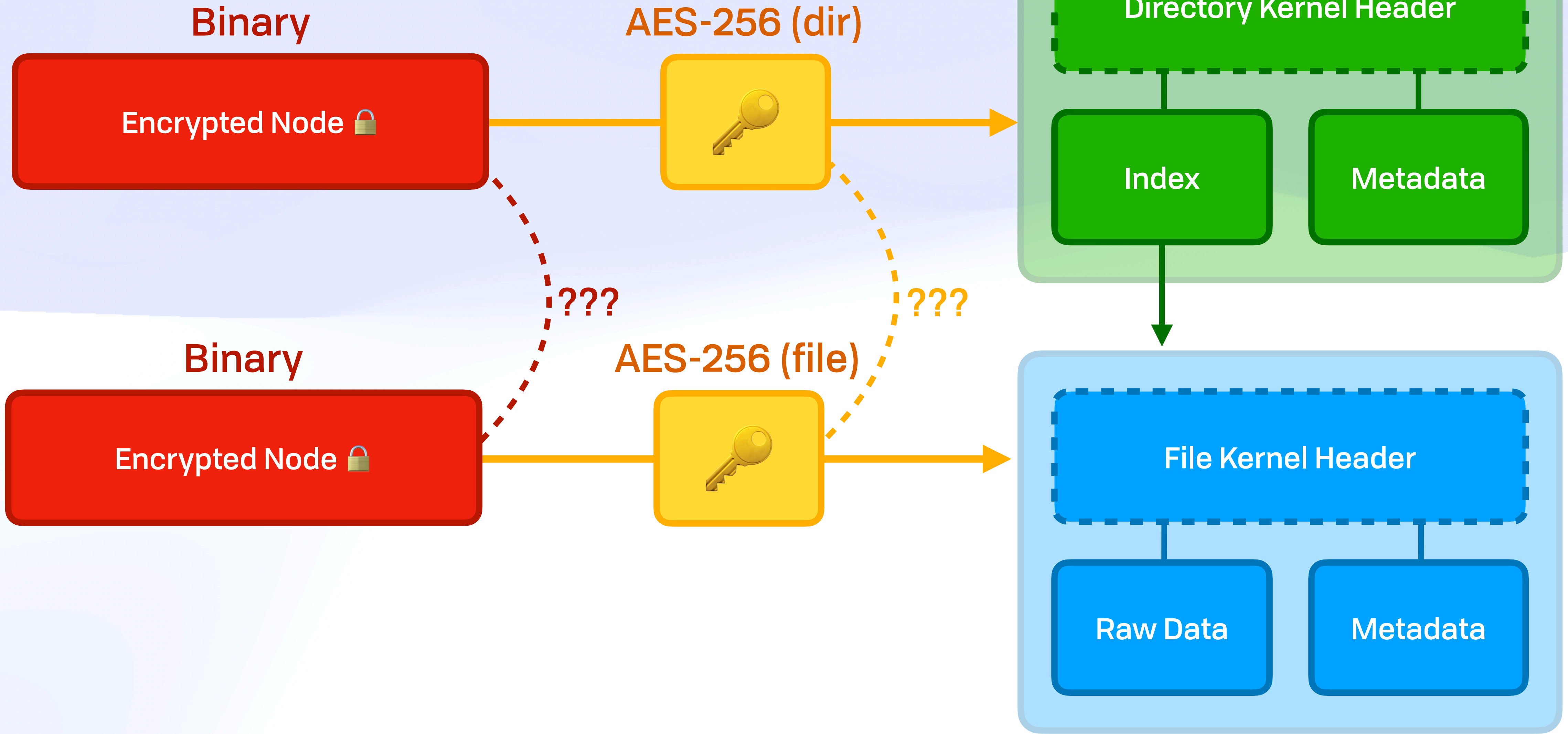
# Single Private Node



# Single Private Node



# Single Private Node



Secret Files 


# Keys... Lots of Keys

Encrypted Node 



Encrypted Node 



Encrypted Node 



Encrypted Node 



Secret Files 

# Keys... Lots of Keys

Encrypted Node 




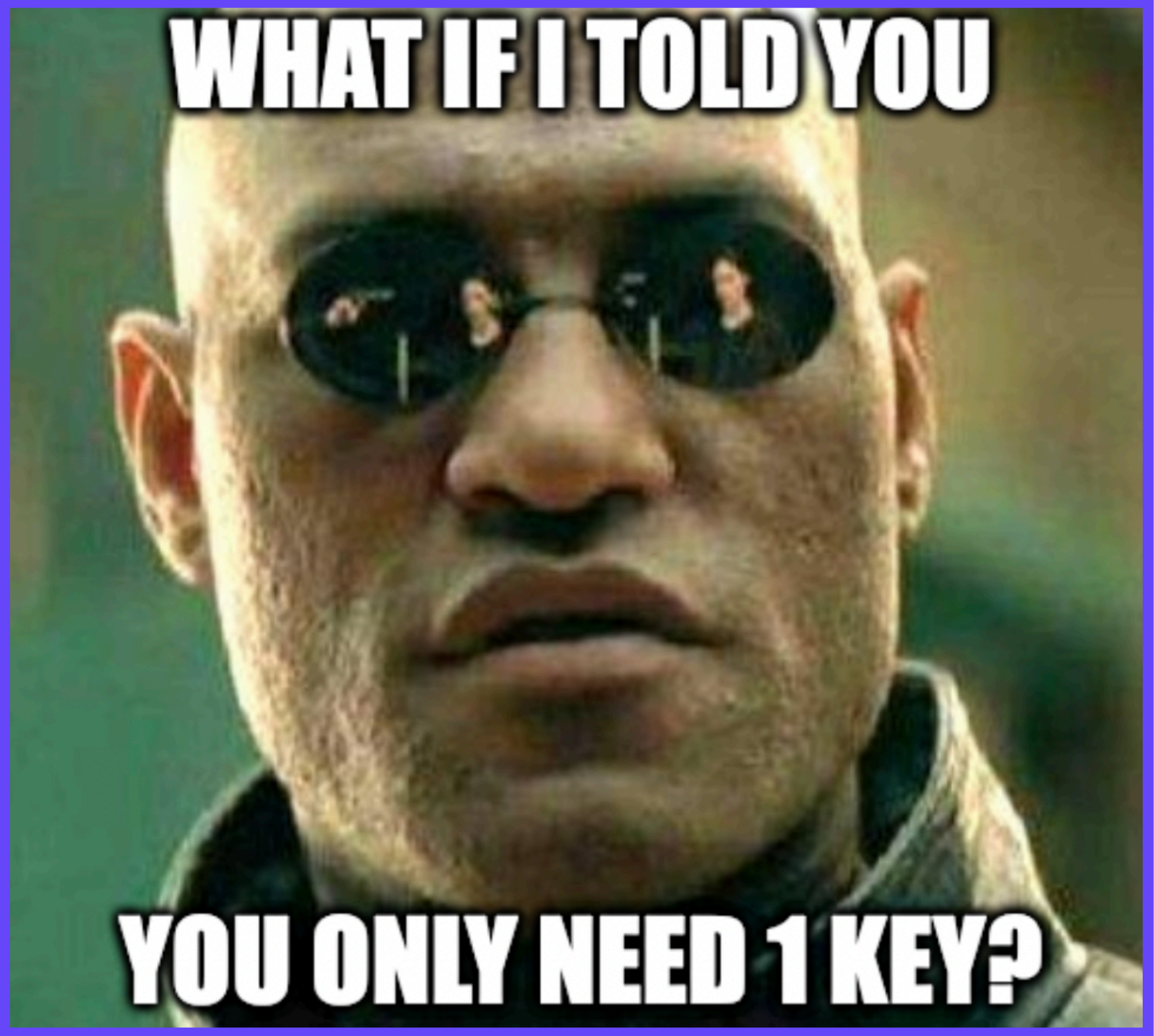
Encrypted Node 



Encrypted Node 



Encrypted Node 





Secret Files 

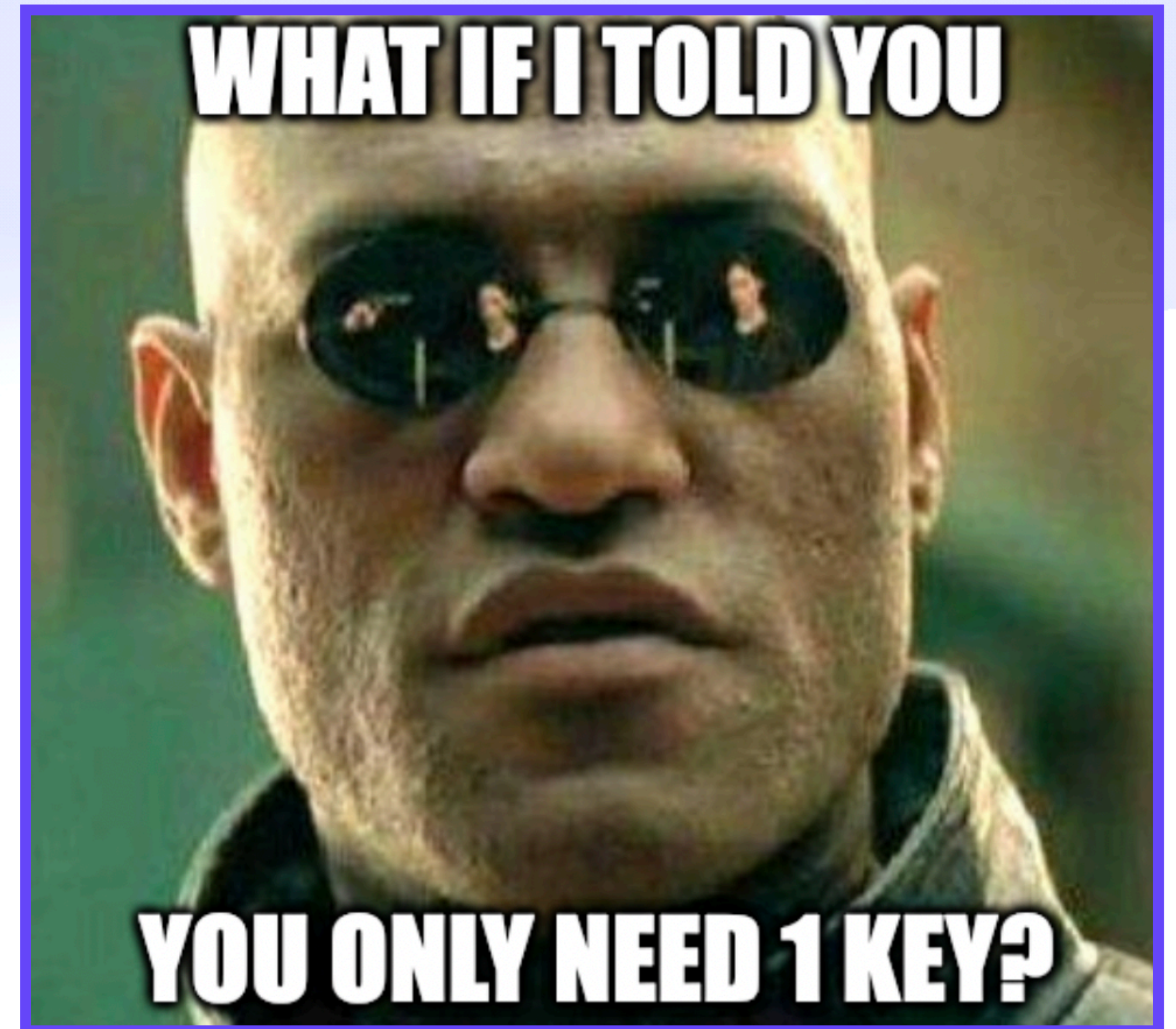
# Keys... Lots of Keys

Encrypted Node 

Encrypted Node 

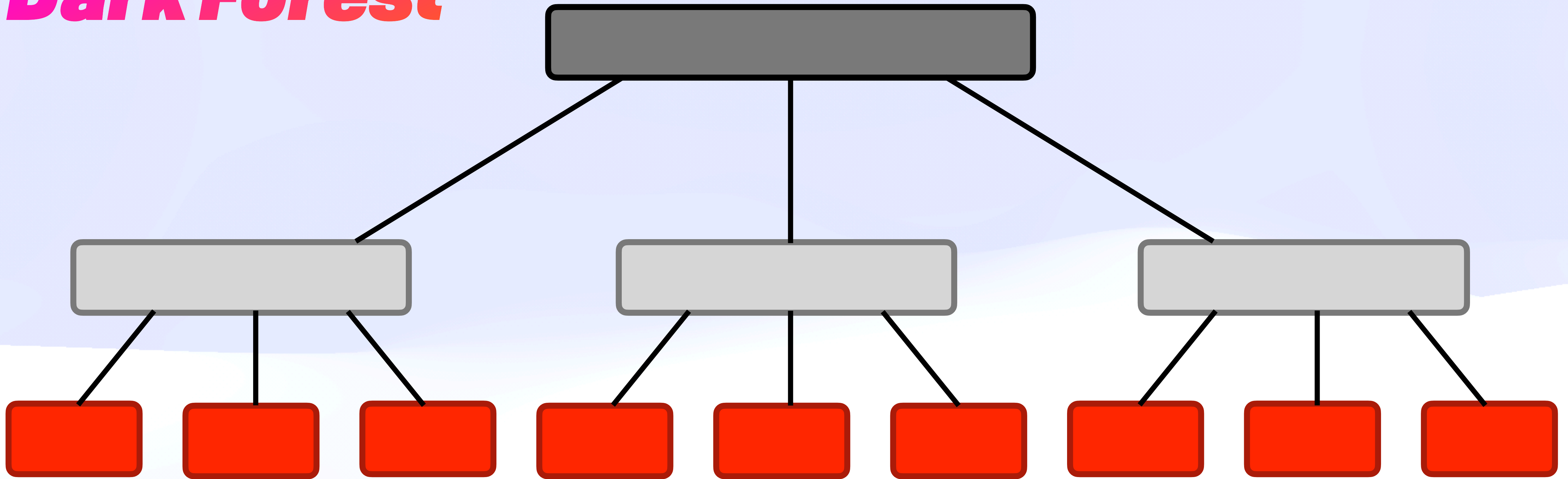
Encrypted Node 

Encrypted Node 



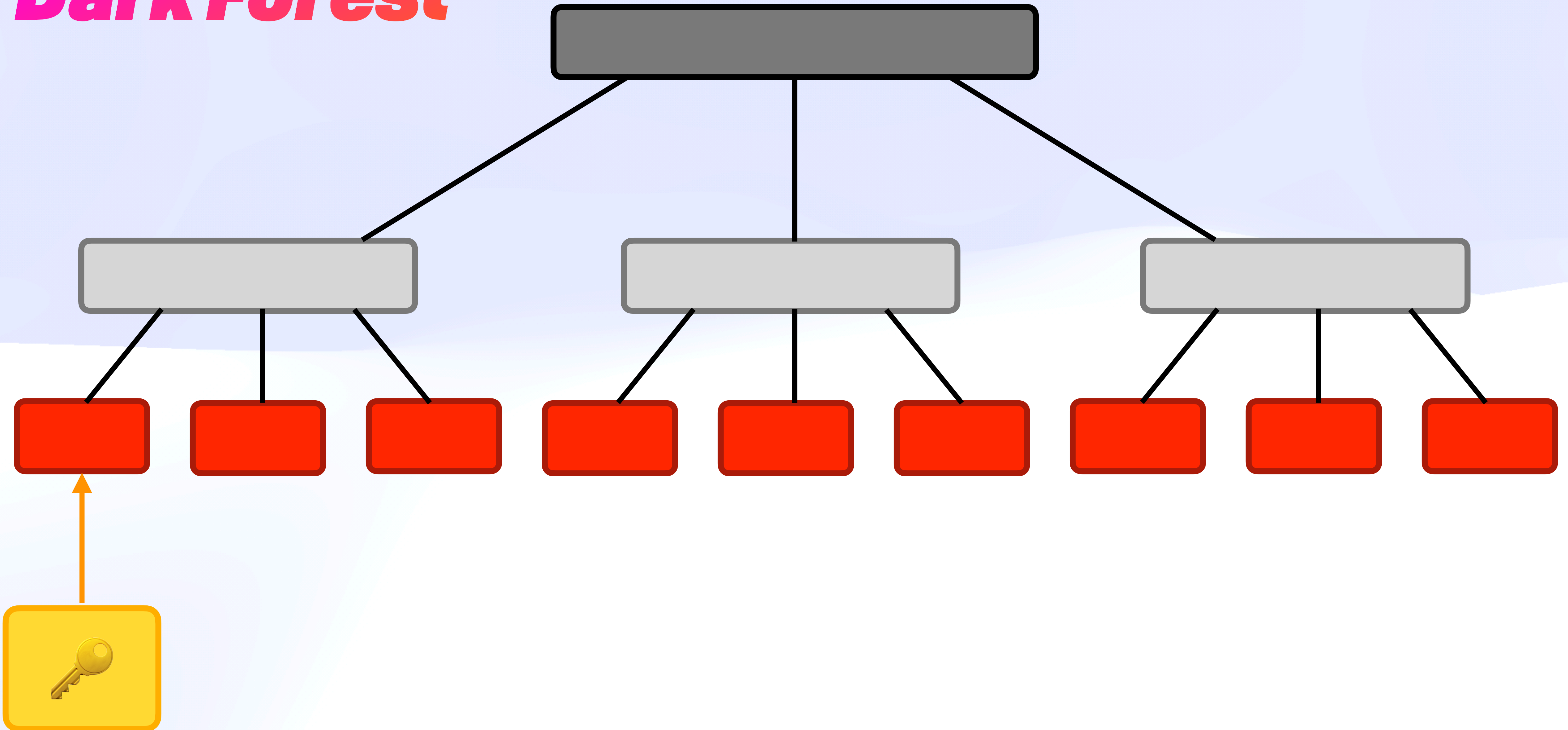
Secret Files 

# *Dark Forest*



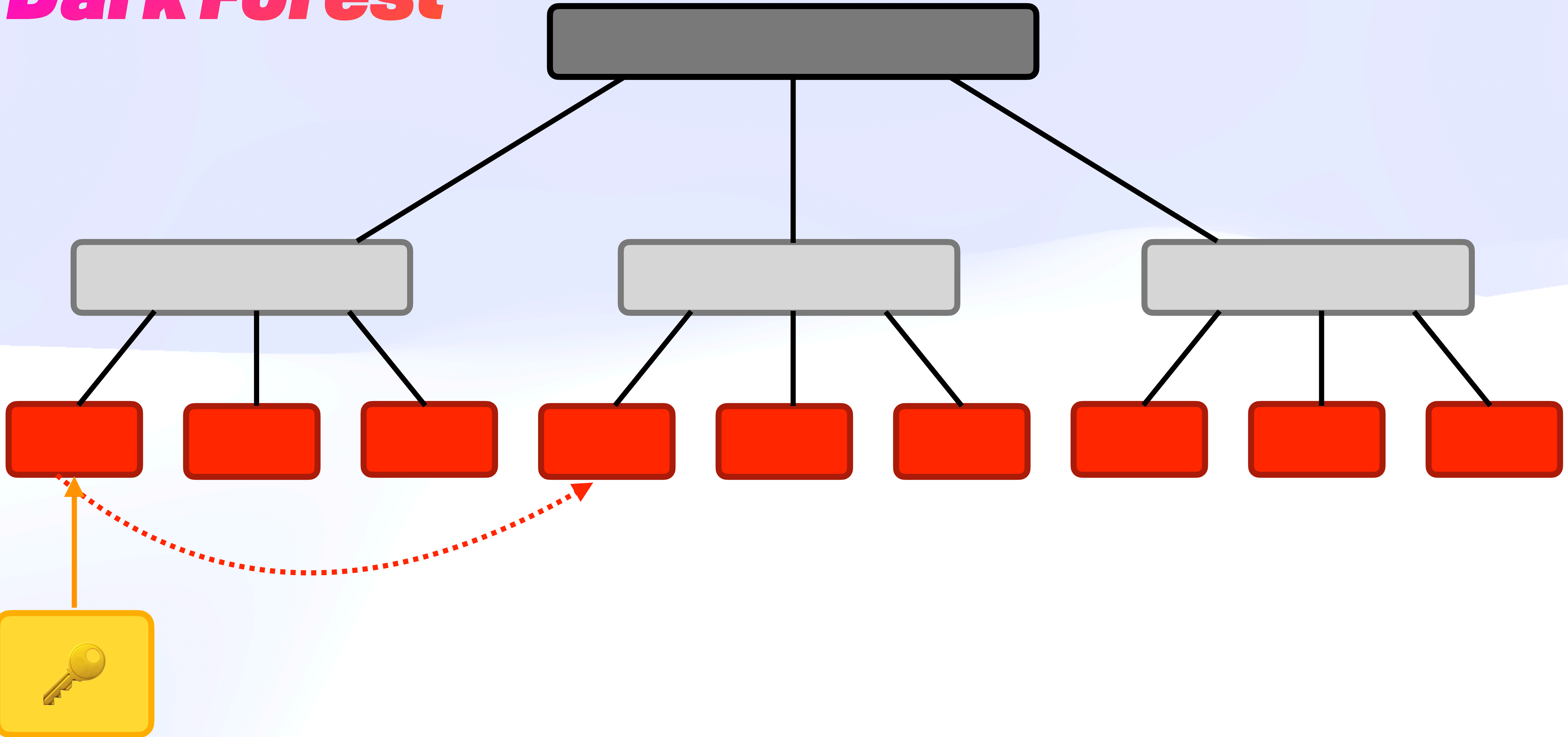
Secret Files 

# Dark Forest



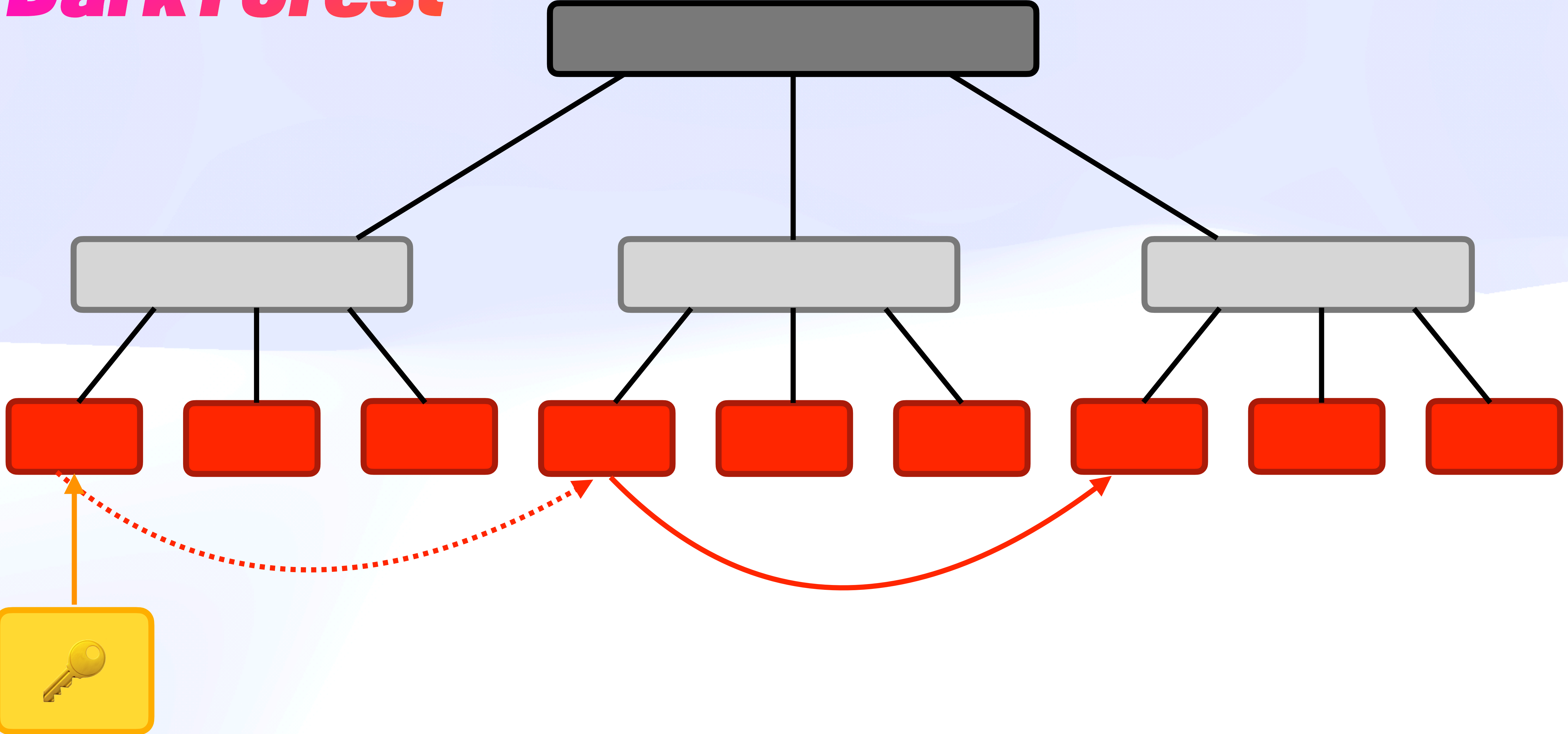
Secret Files 🥷

# Dark Forest



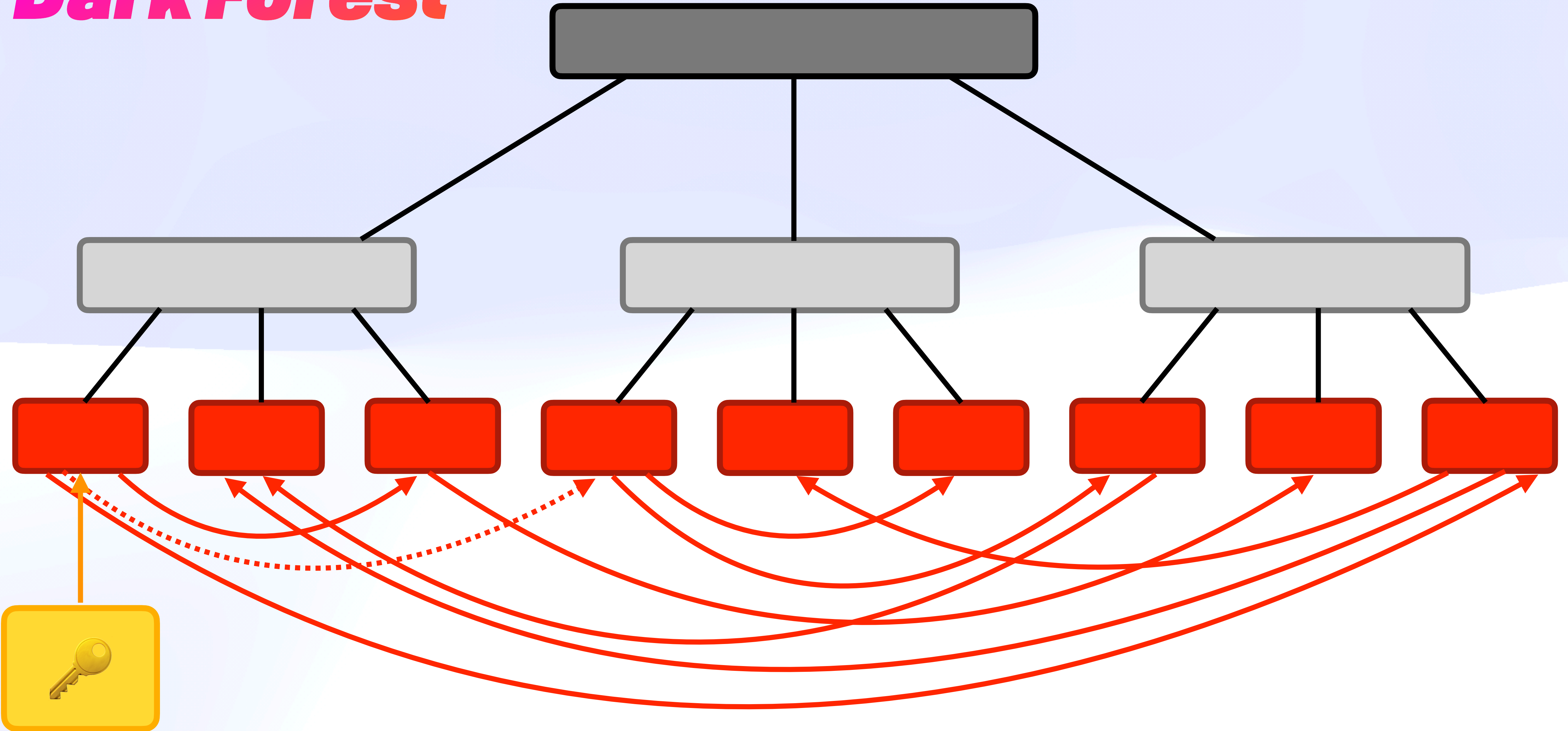
Secret Files 🥷

# Dark Forest



Secret Files 

# Dark Forest



Secret Files 

***Cryptree***

Secret Files 

# *Cryptree*

Binary

Encrypted Node 

Encrypted Node 

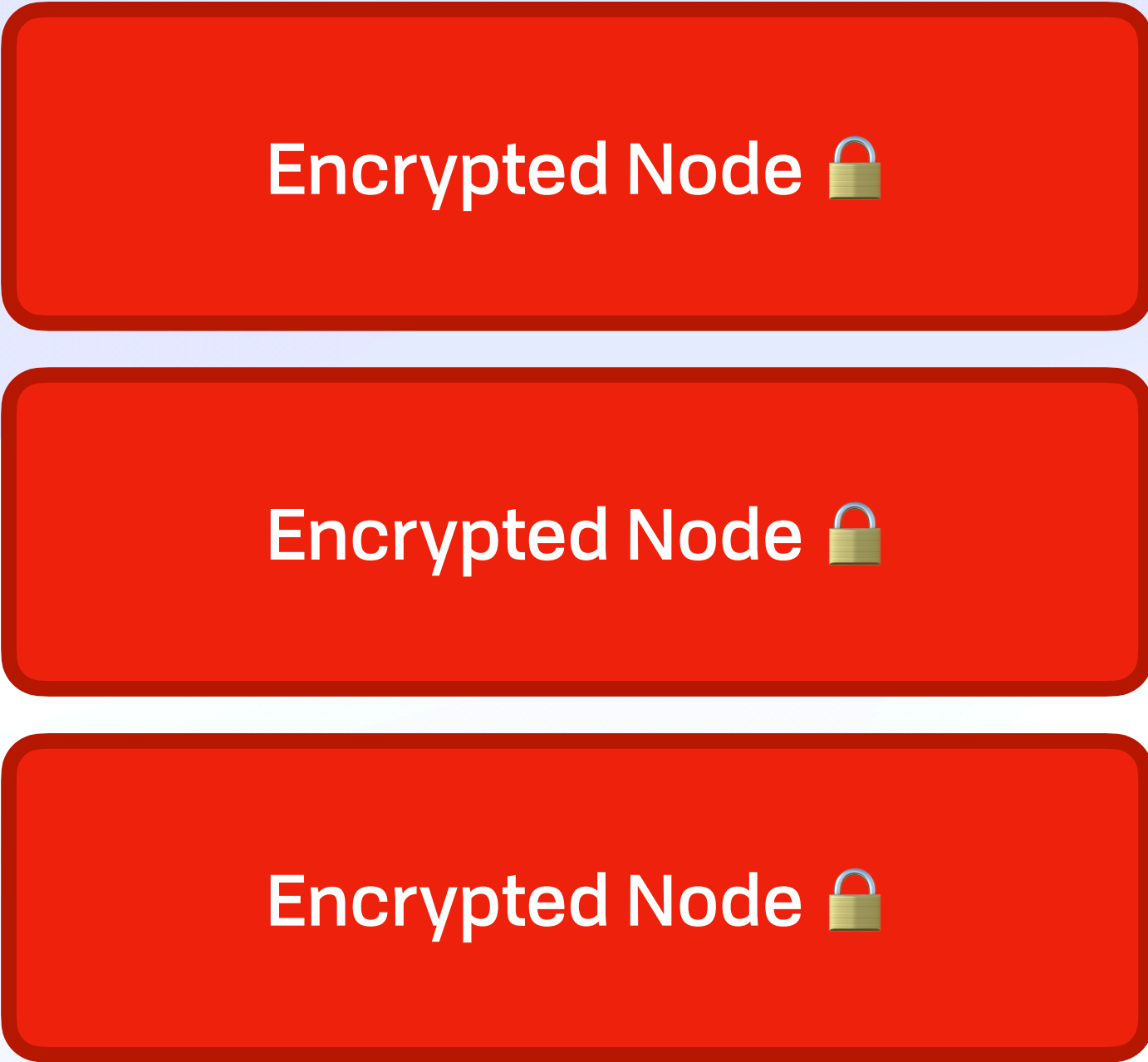
Encrypted Node 



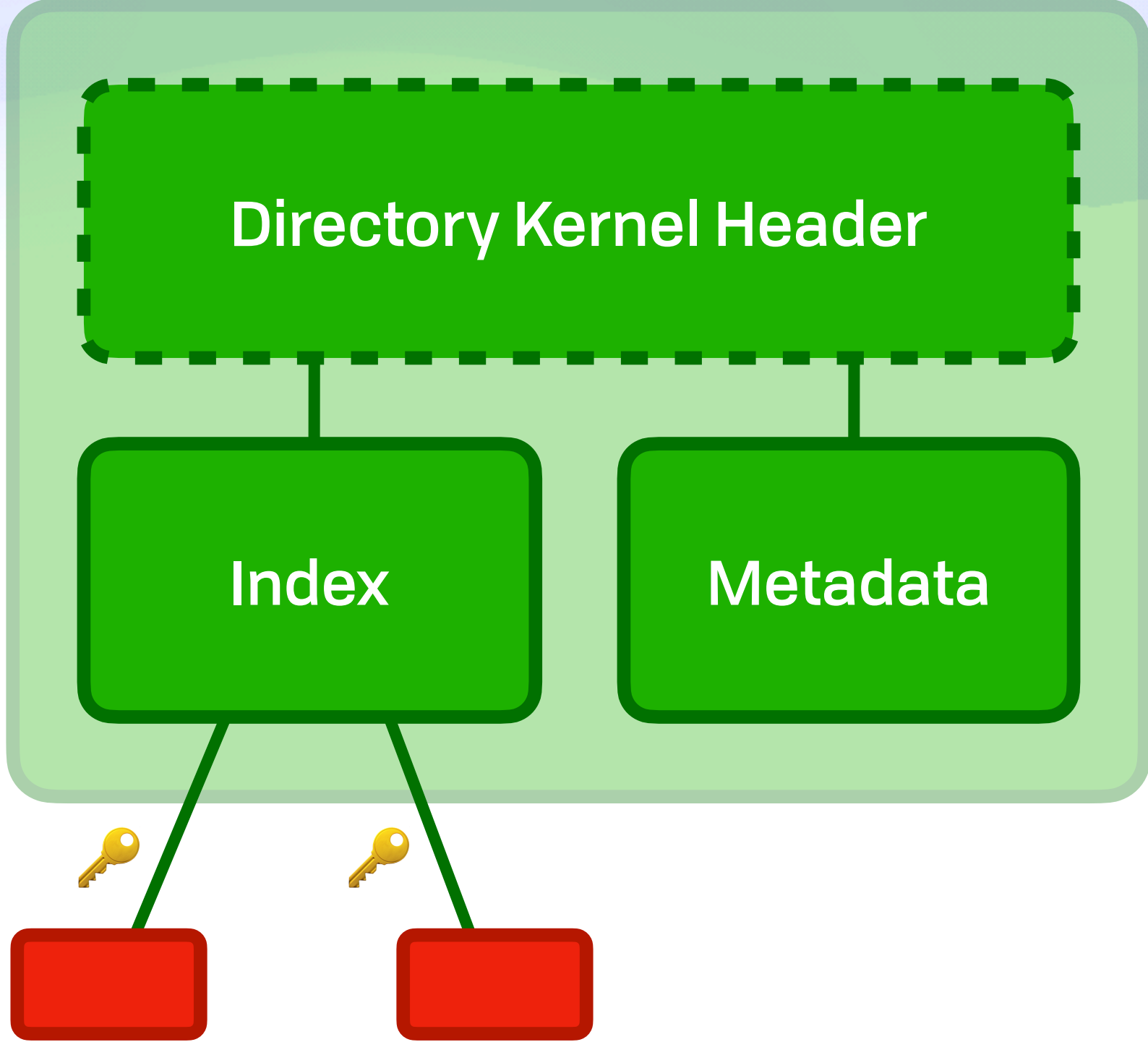
# Secret Files

# *Cryptree*

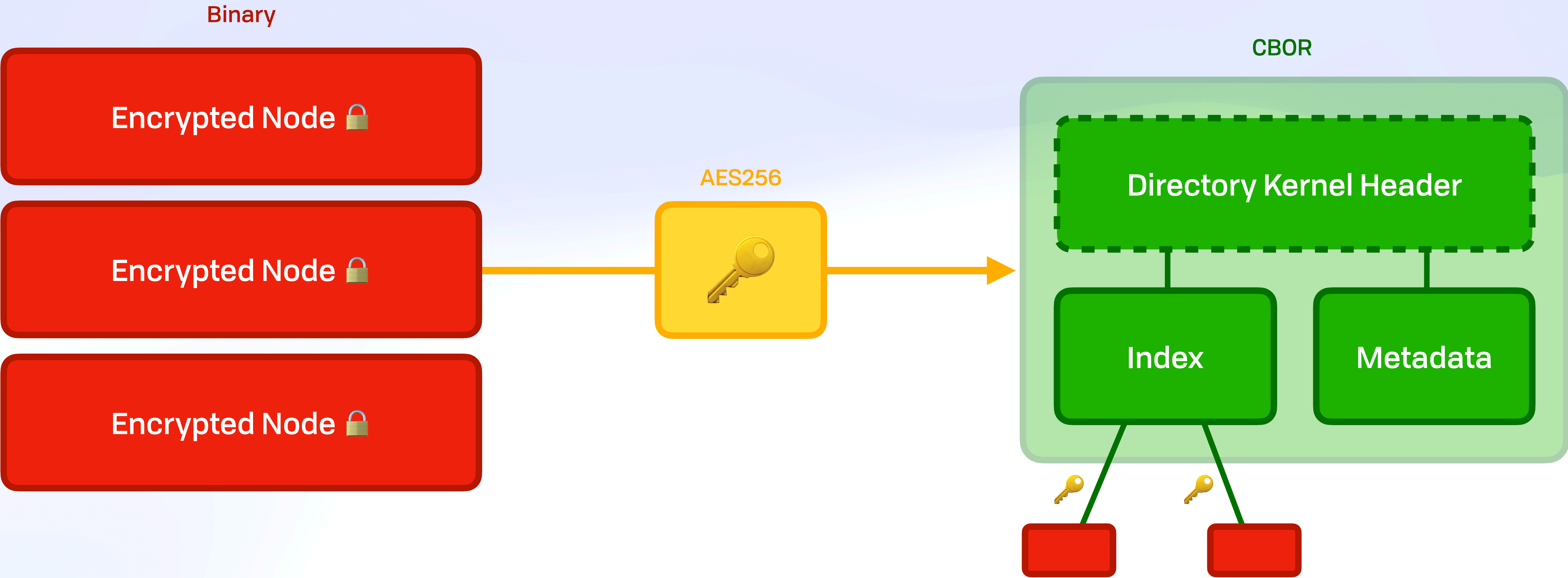
Binary



CBOR

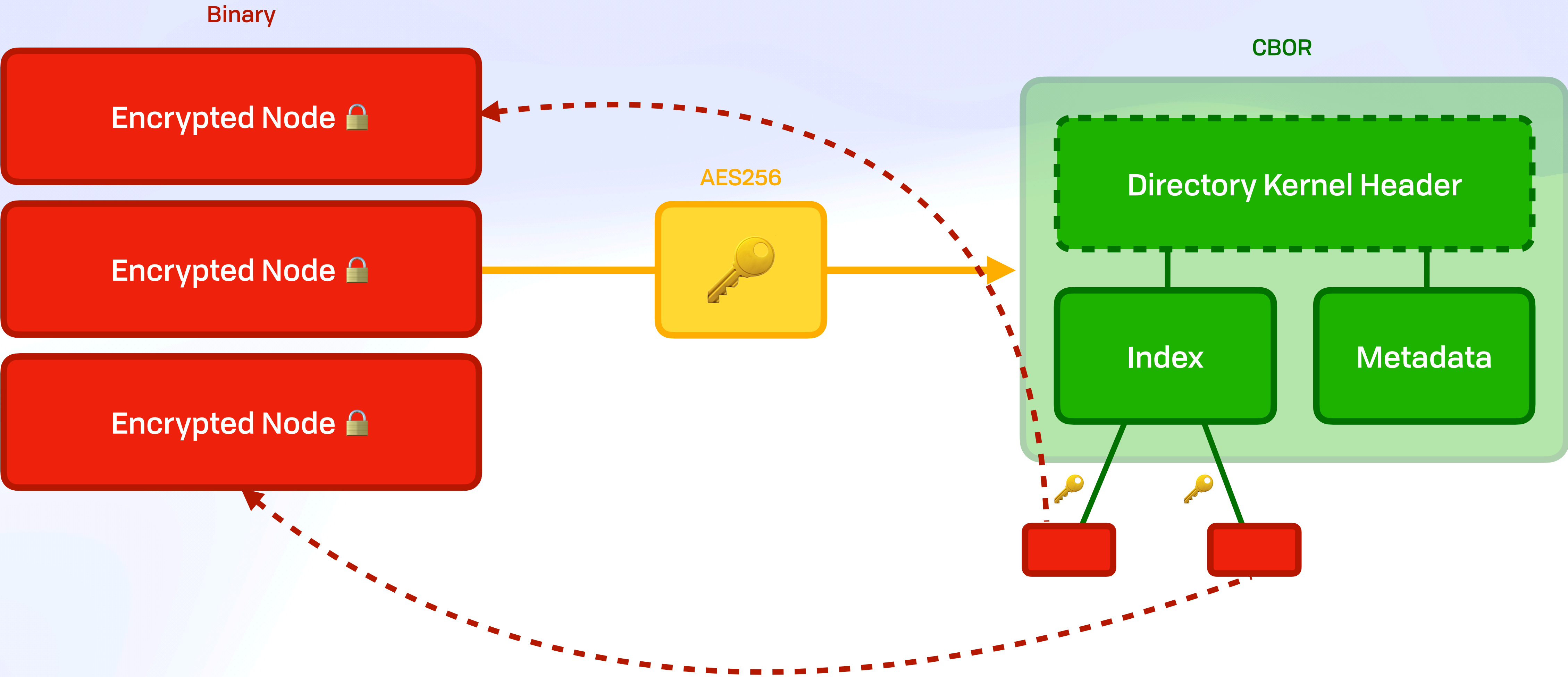


# Secret Files *Cryptree*

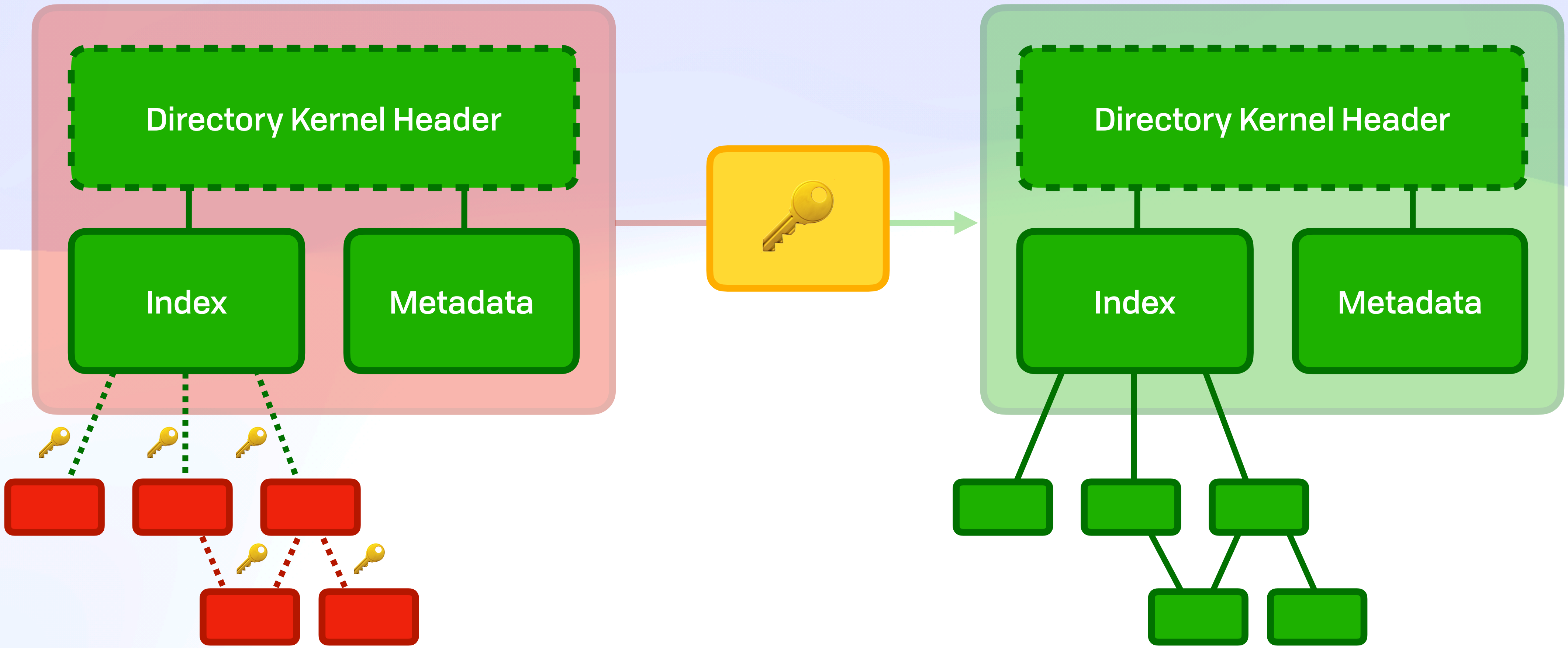


# Secret Files

# Cryptree

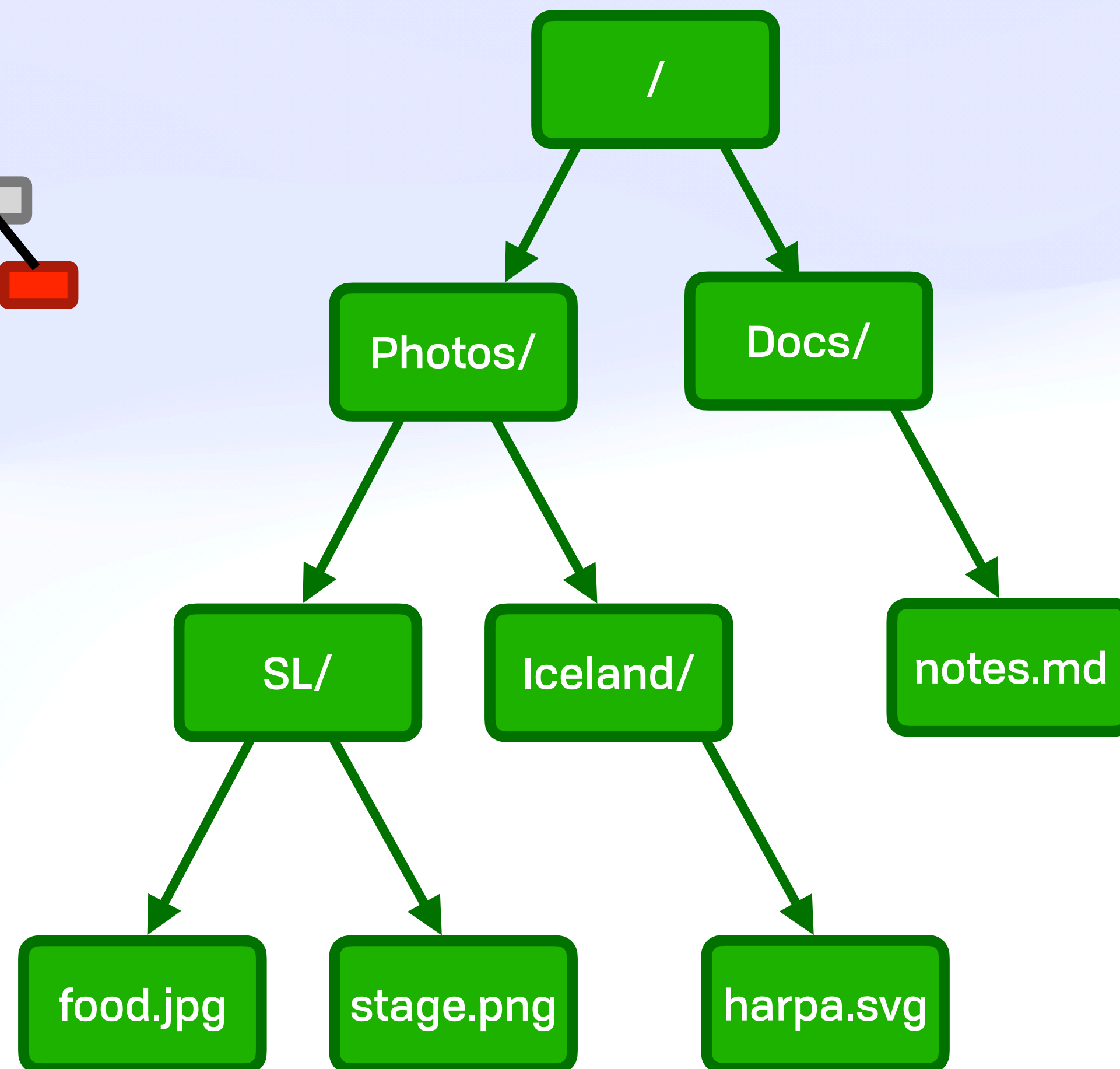
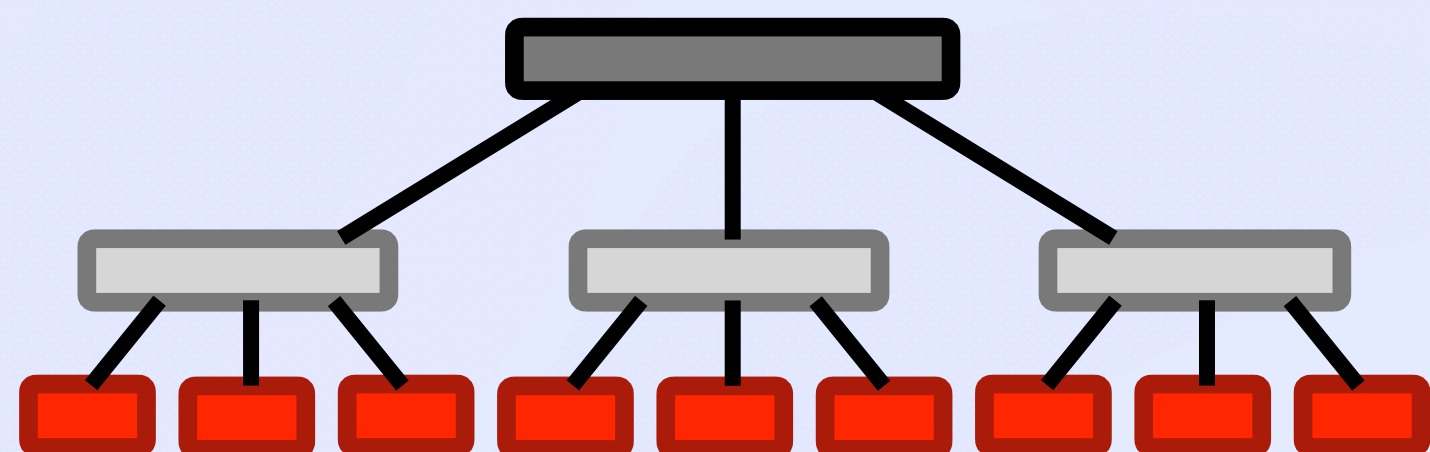


# Read Window



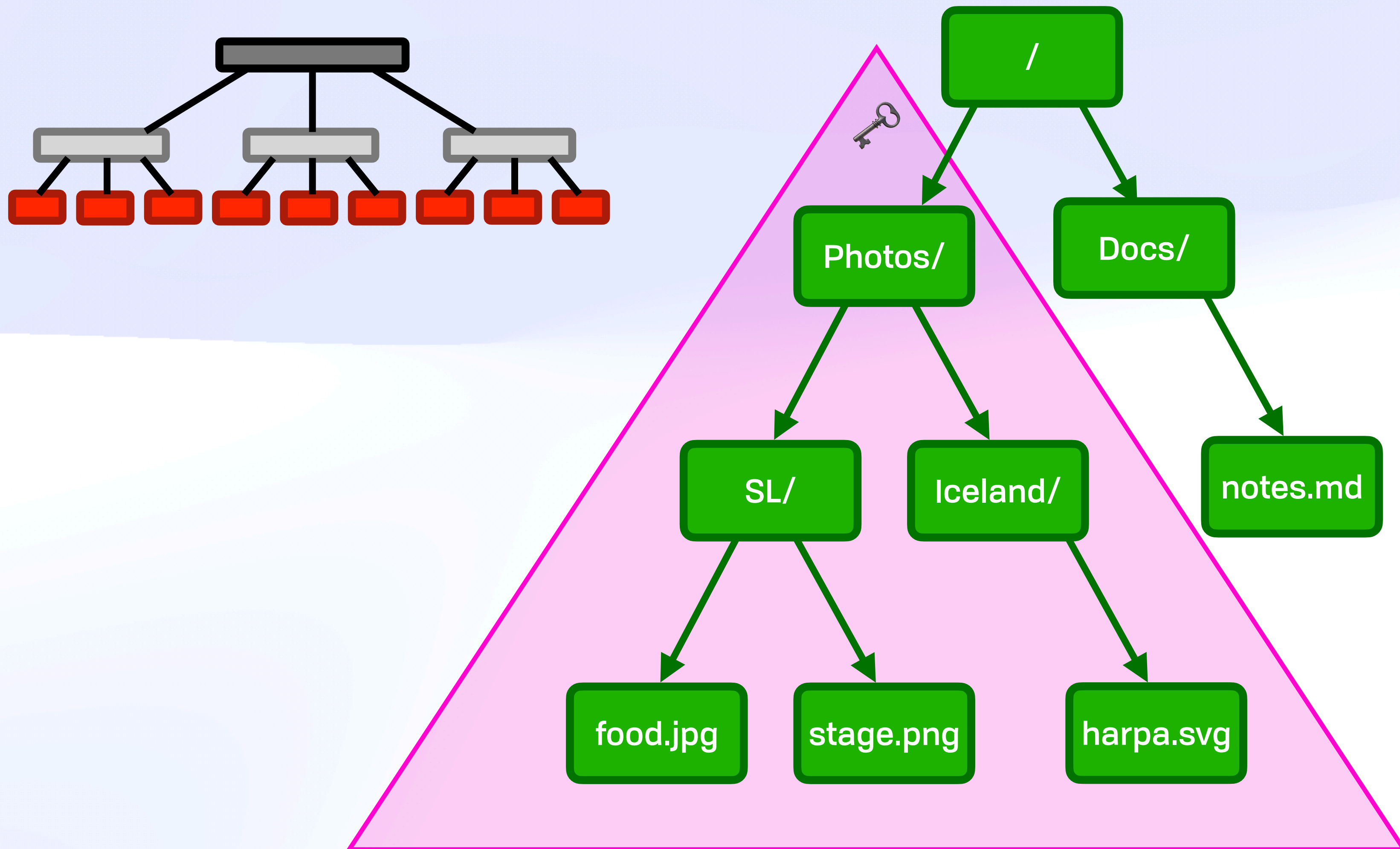
Secret Files 🥷

# Offline Access Control



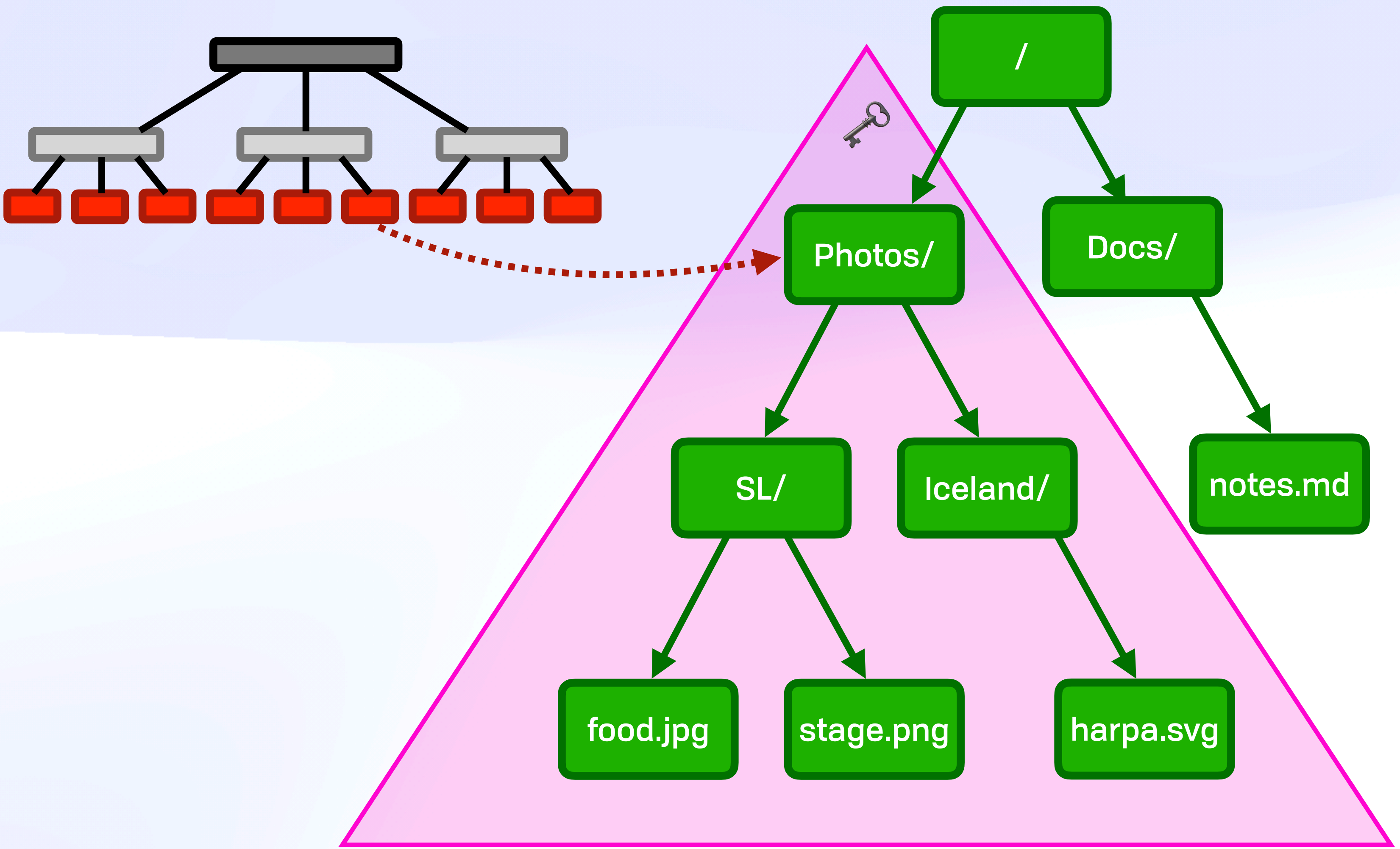
Secret Files 🕵️

# Offline Access Control



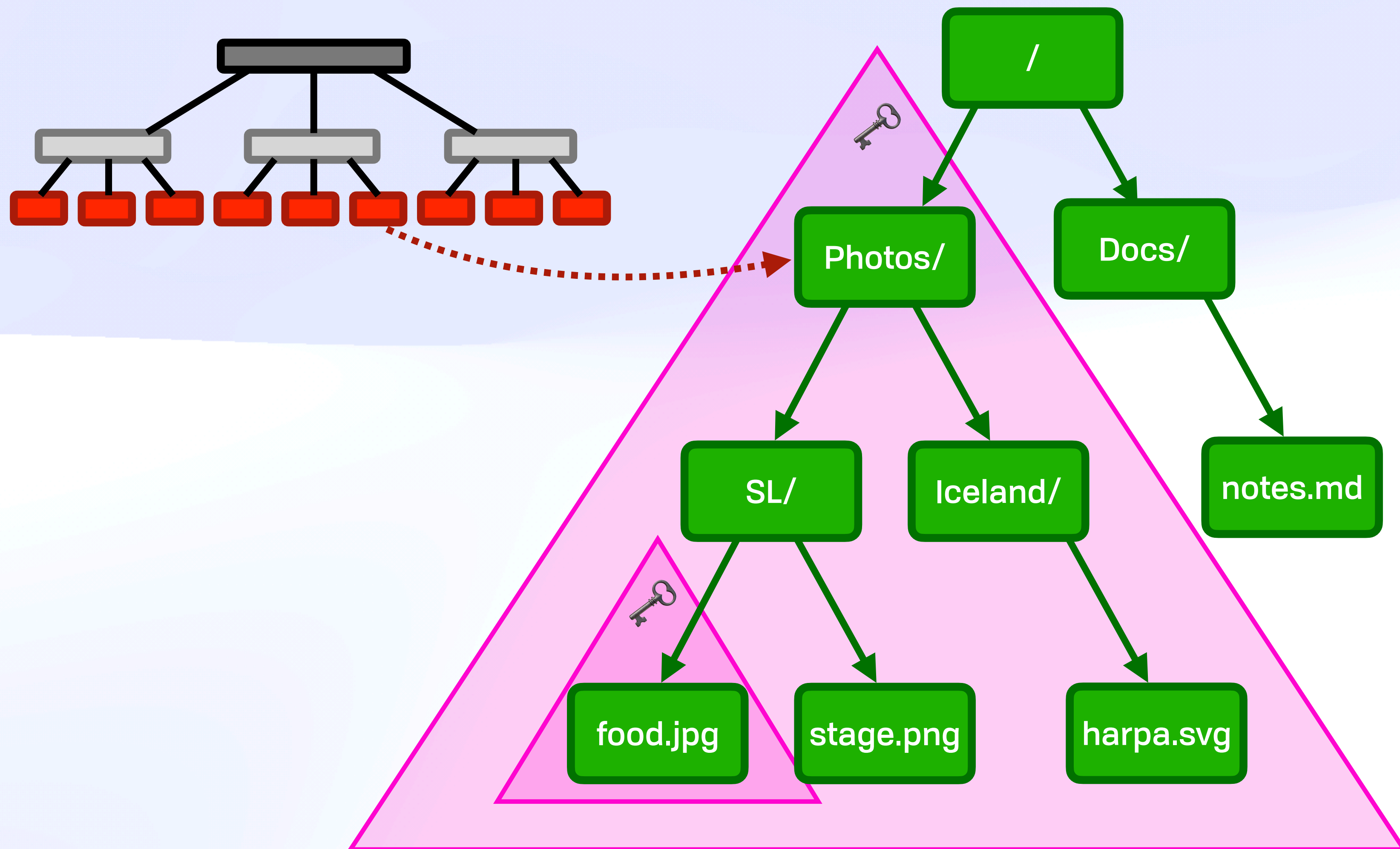
Secret Files 🕵️

# Offline Access Control



Secret Files 🕵️

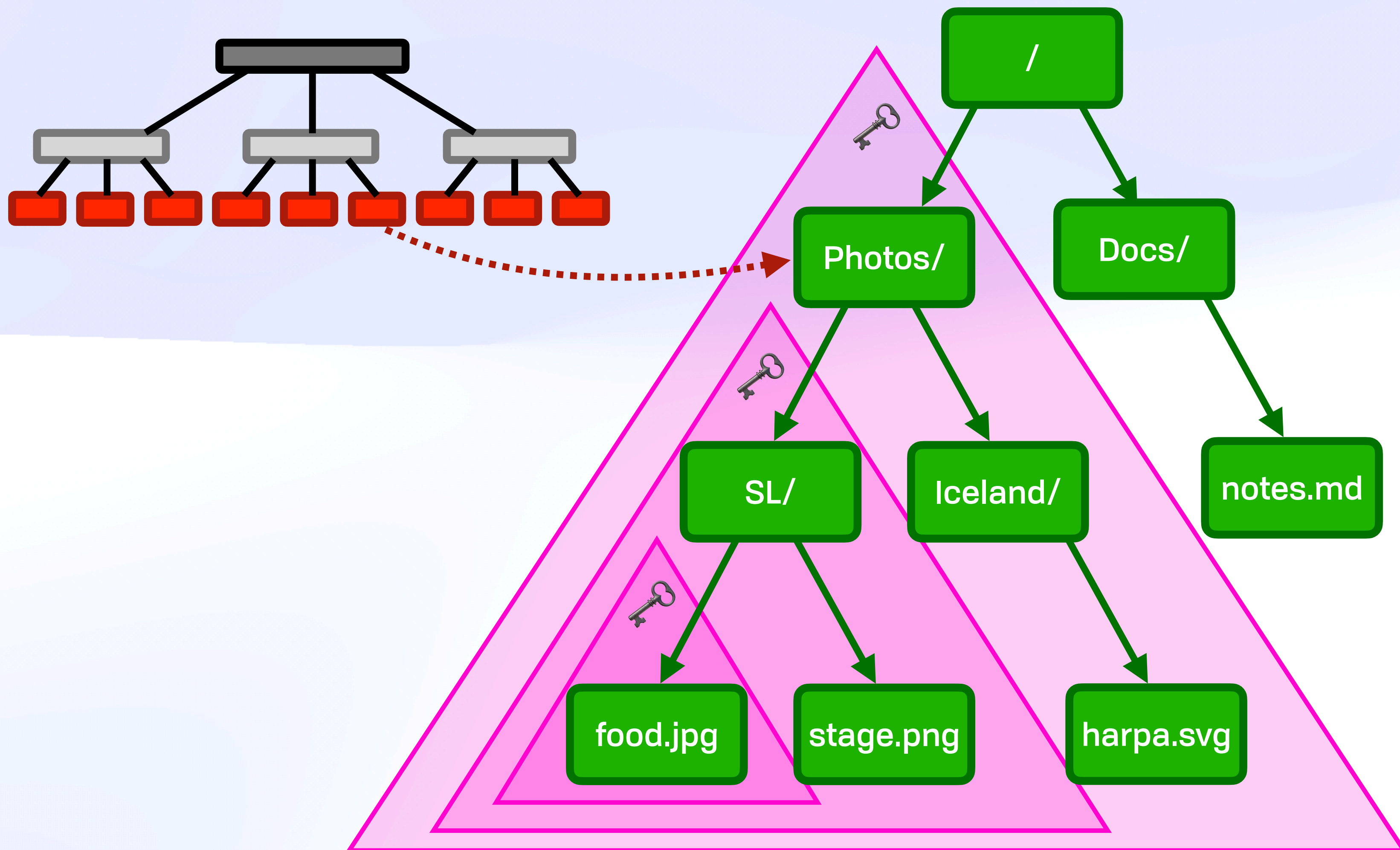
# Offline Access Control





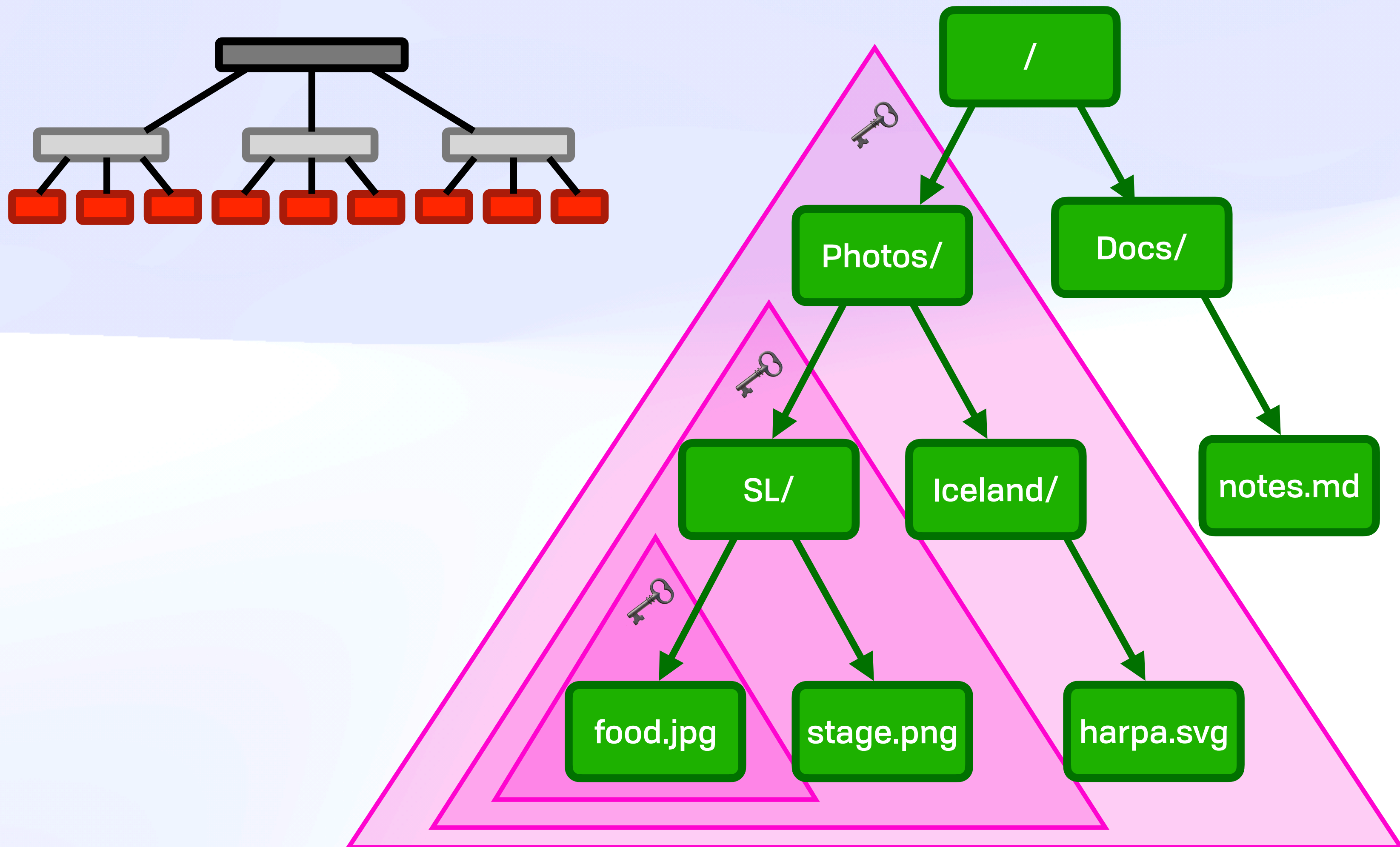
Secret Files 🕵️

# Offline Access Control



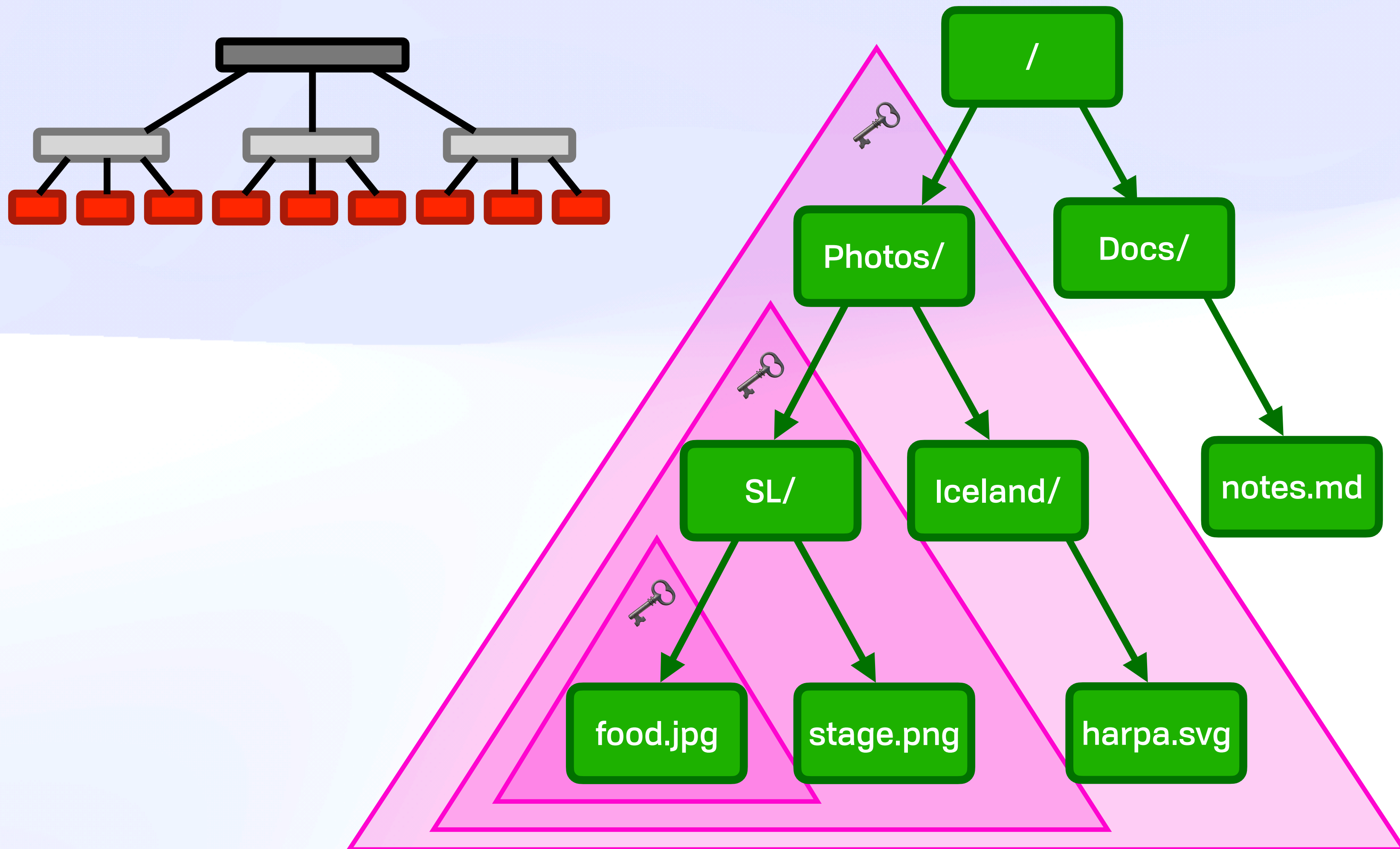
Secret Files 🕵️

# Offline Access Control



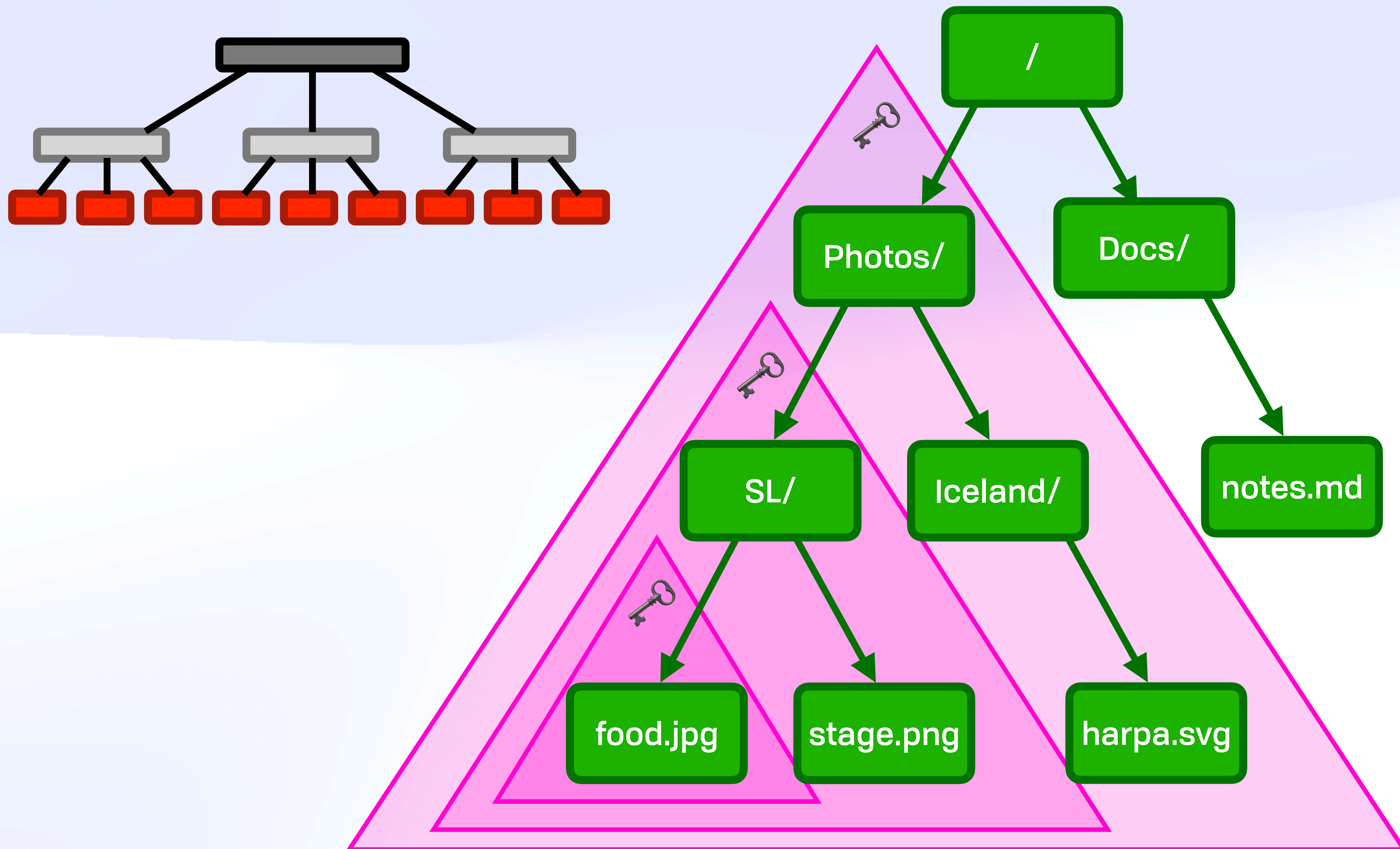
Secret Files 🕵️

# Offline Access Control



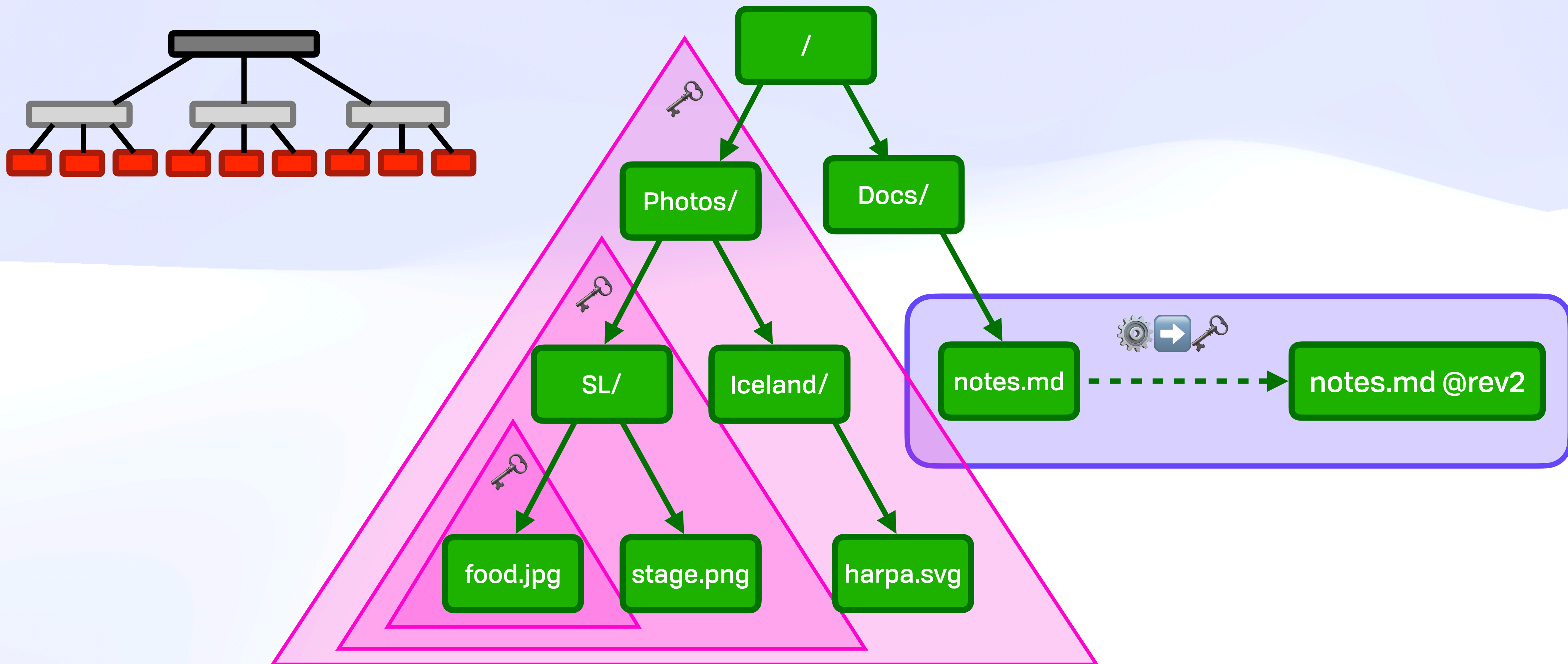
Secret Files 🕵️

# Offline Access Control



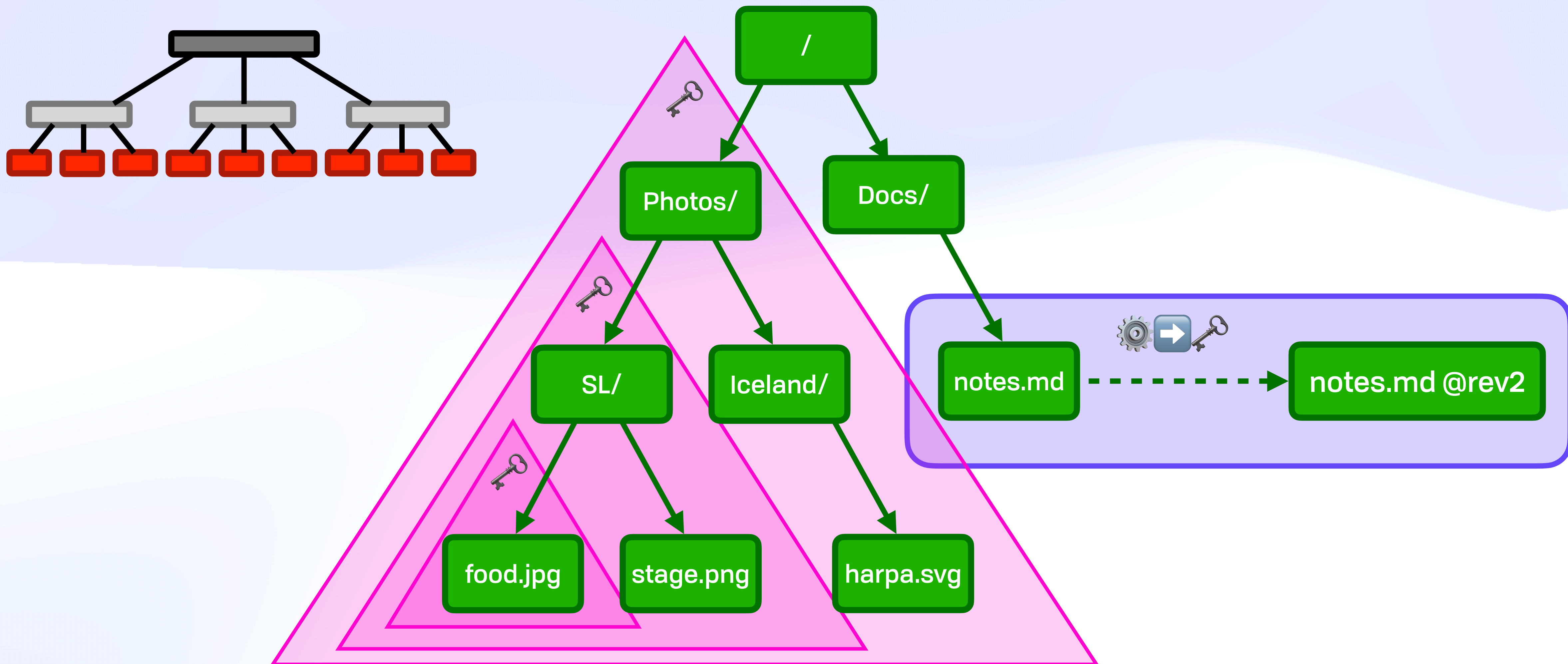
Secret Files 🕵️

# Offline Access Control



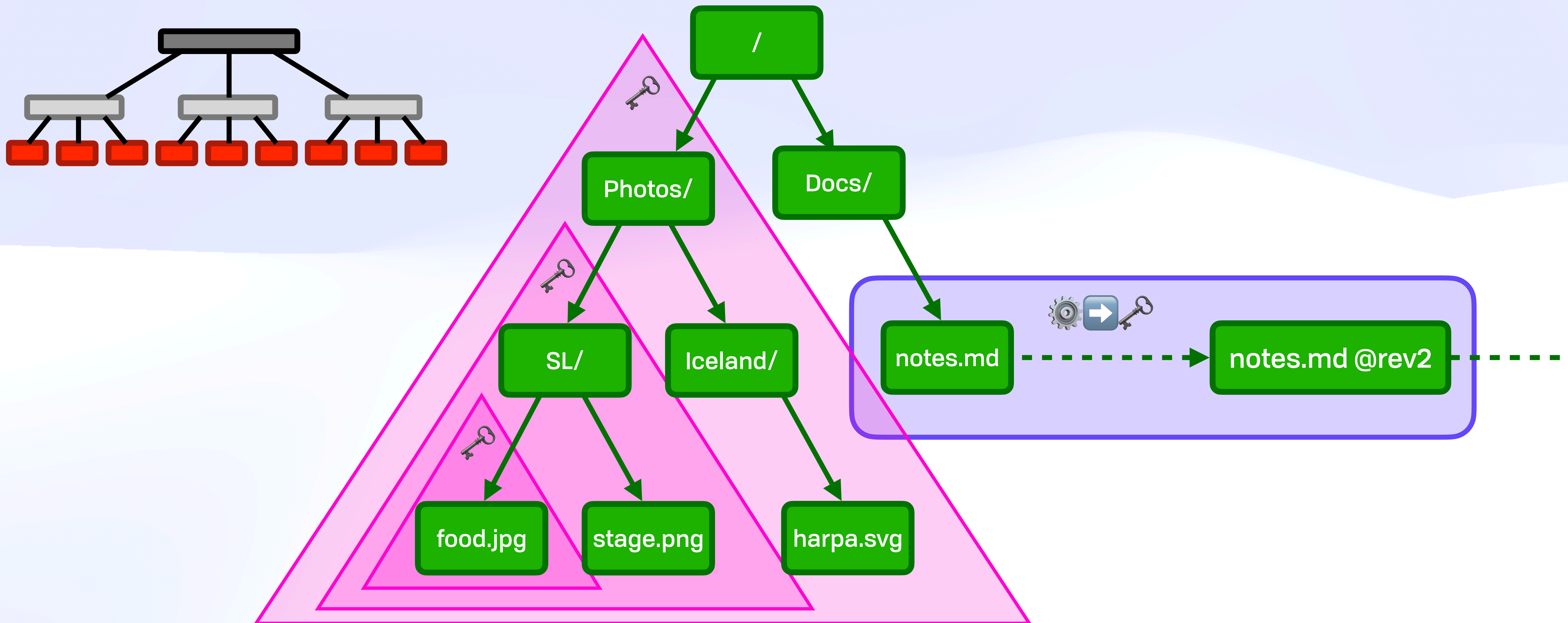
Secret Files 🕵️

# Offline Access Control



Secret Files 🕵️

# Offline Access Control



# *Temporal Cryptree*



Secrets in Space & Time 🚀



Temporal Cryptree 

# ***Access Control in Space & Time***

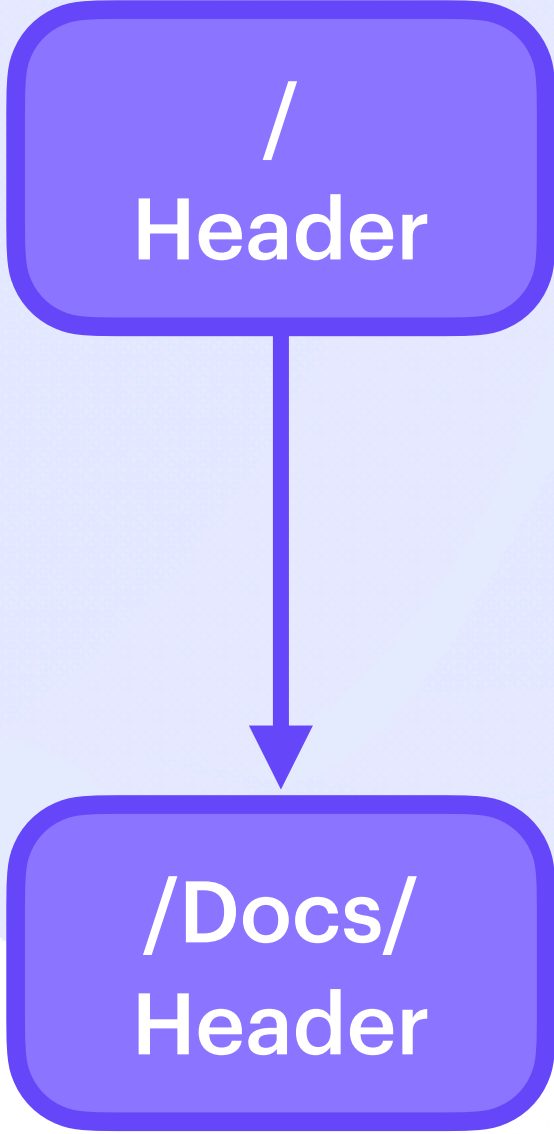
Temporal Cryptree 

# ***Access Control in Space & Time***

/  
Header

Temporal Cryptree 🕒

# Access Control in Space & Time 🛸



Temporal Cryptree 🕒

# Access Control in Space & Time 🛸

/  
Header



/Docs/  
Header

/  
Header



/Docs/  
Header

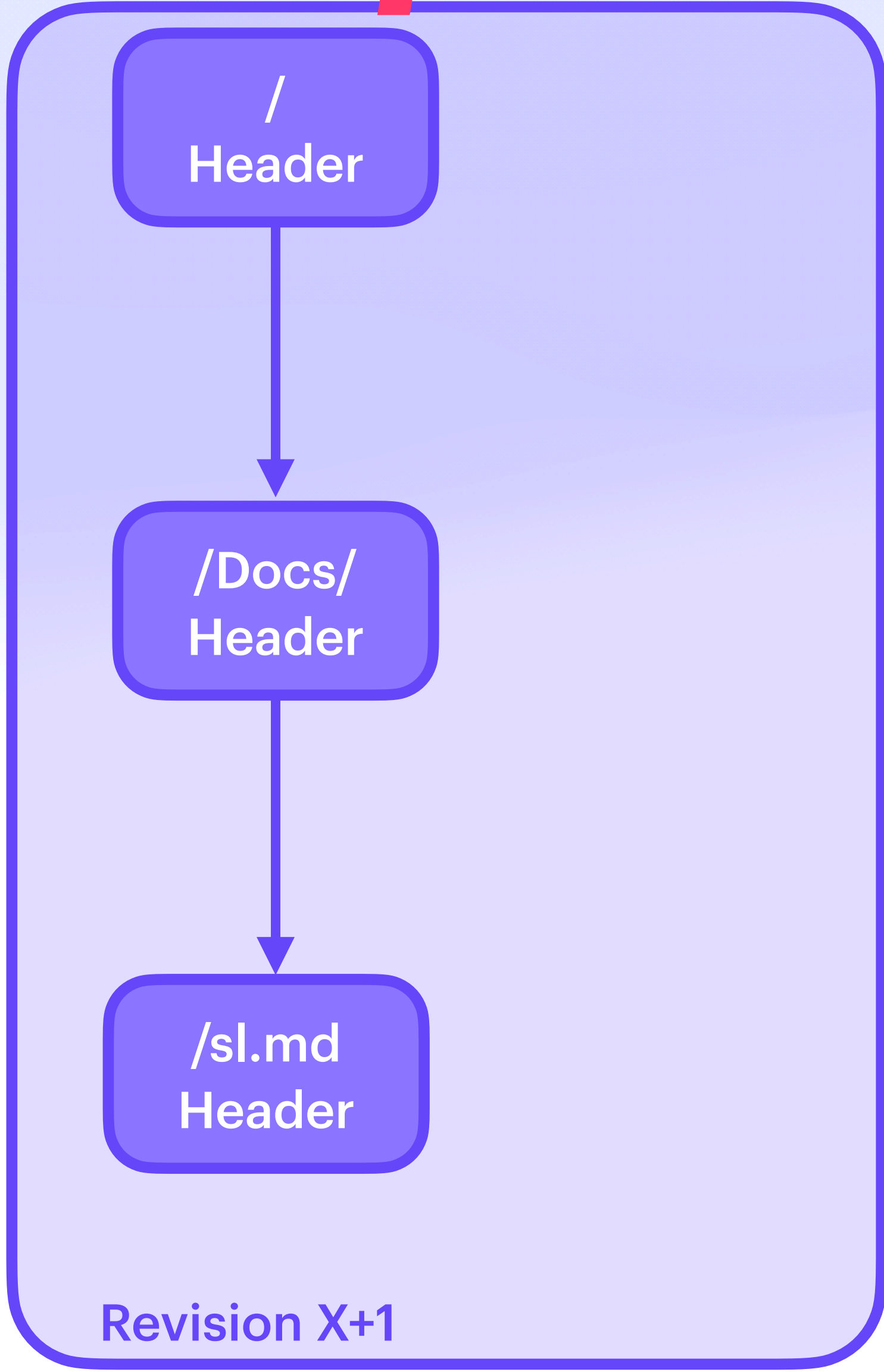
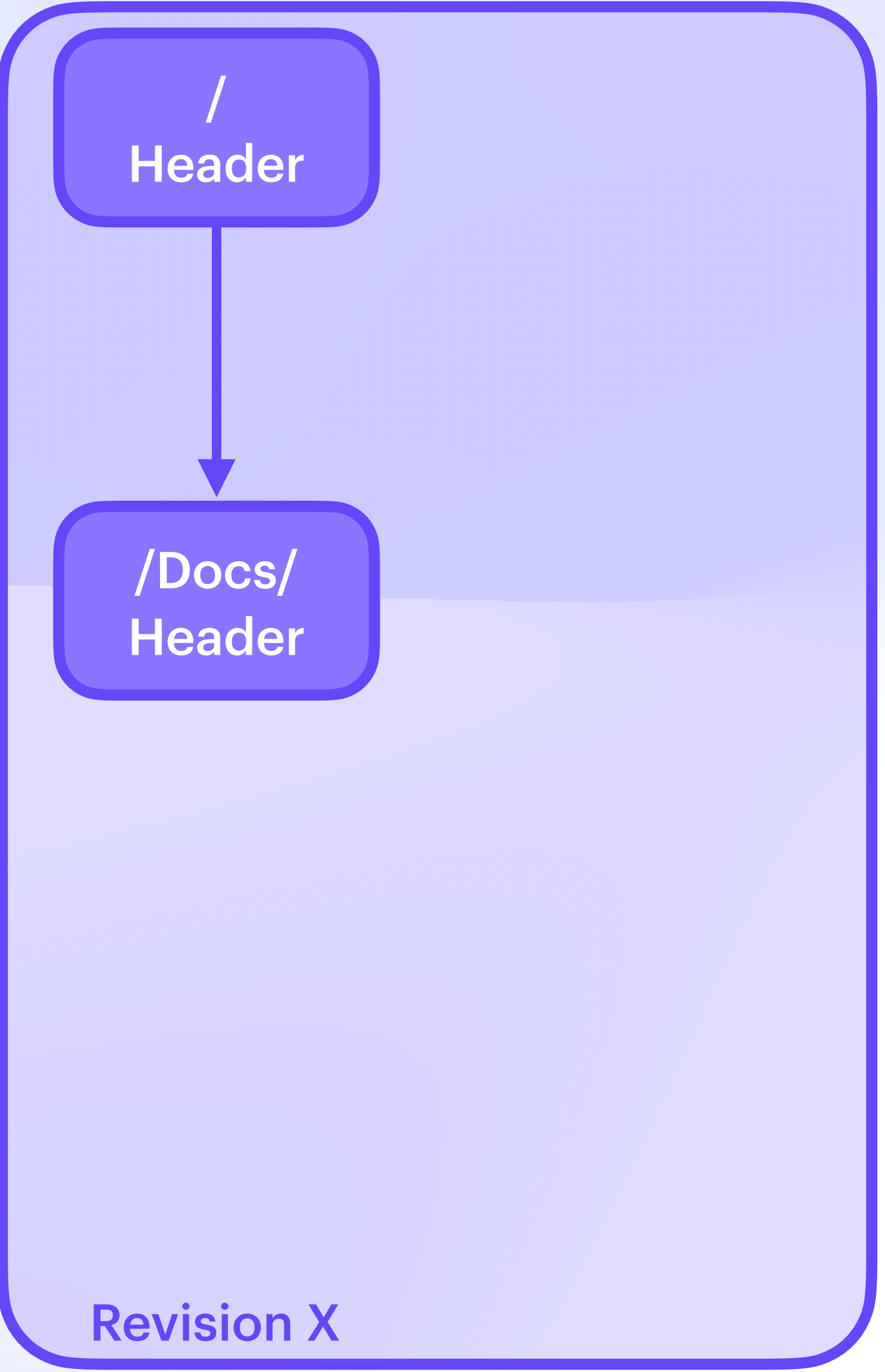
Temporal Cryptree 🕒

# Access Control in Space & Time 🛸



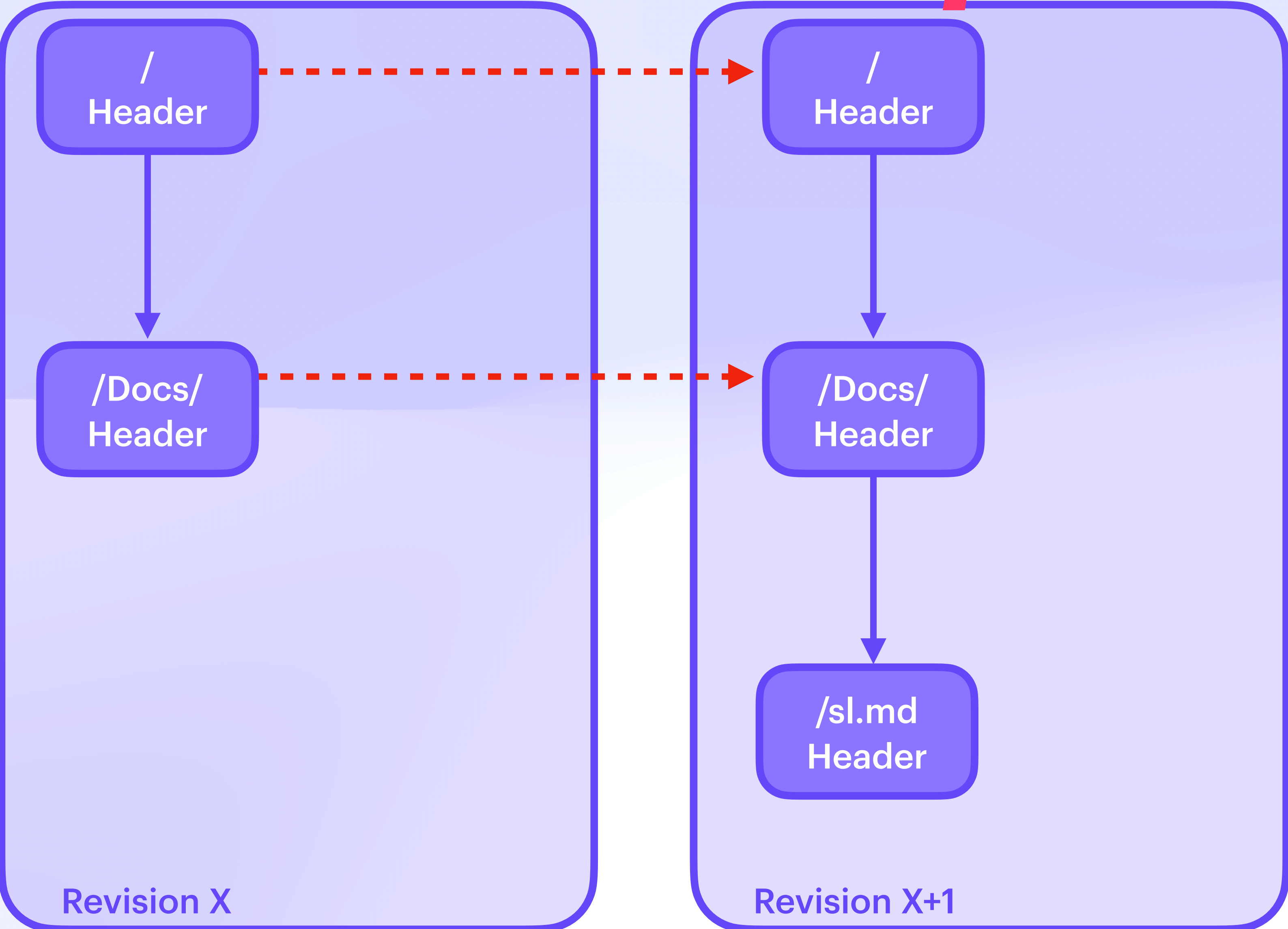
# Temporal Cryptree

# Access Control in Space & Time



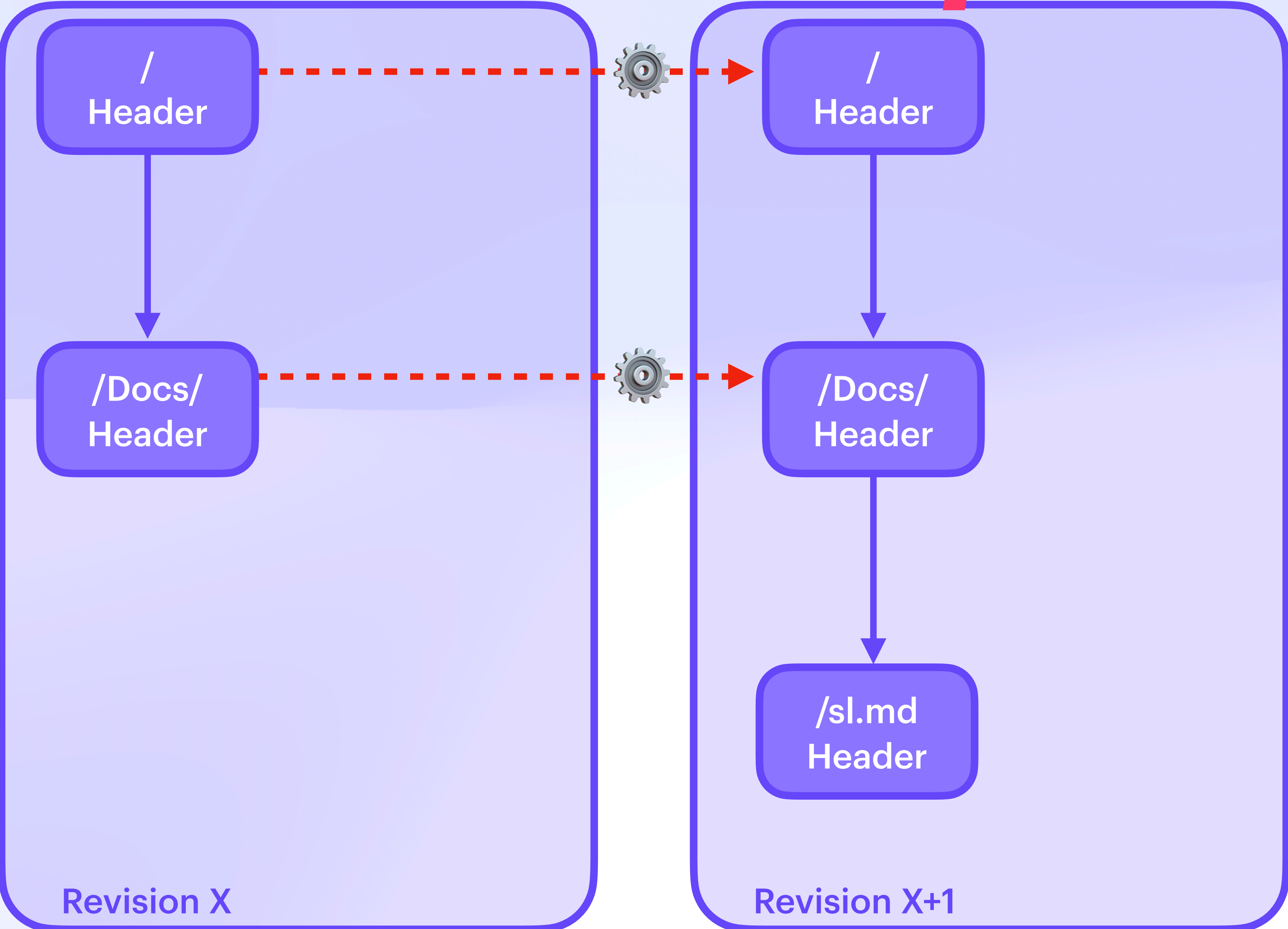
# Temporal Cryptree

# Access Control in Space & Time



# Temporal Cryptree

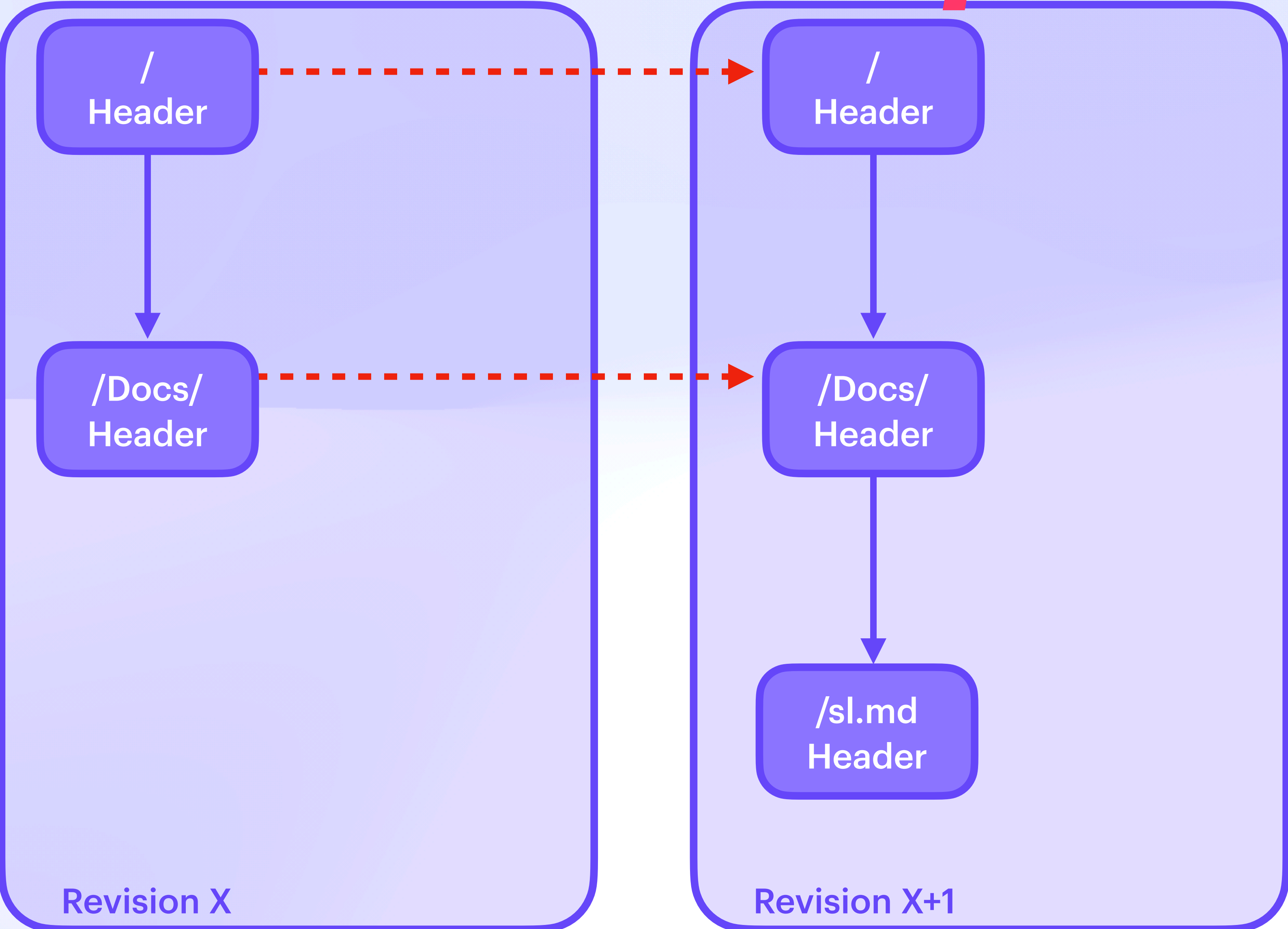
# Access Control in Space & Time





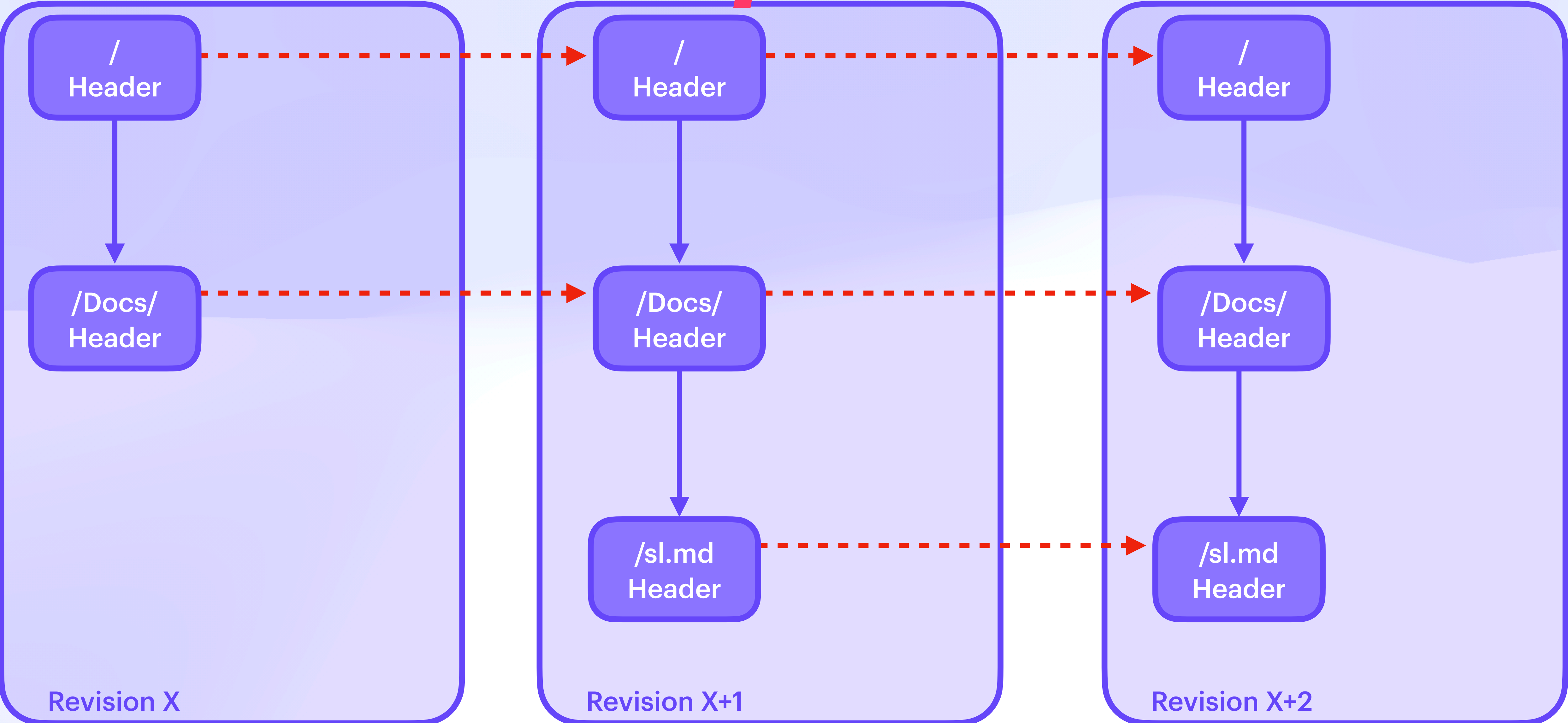
# Temporal Cryptree

# Access Control in Space & Time



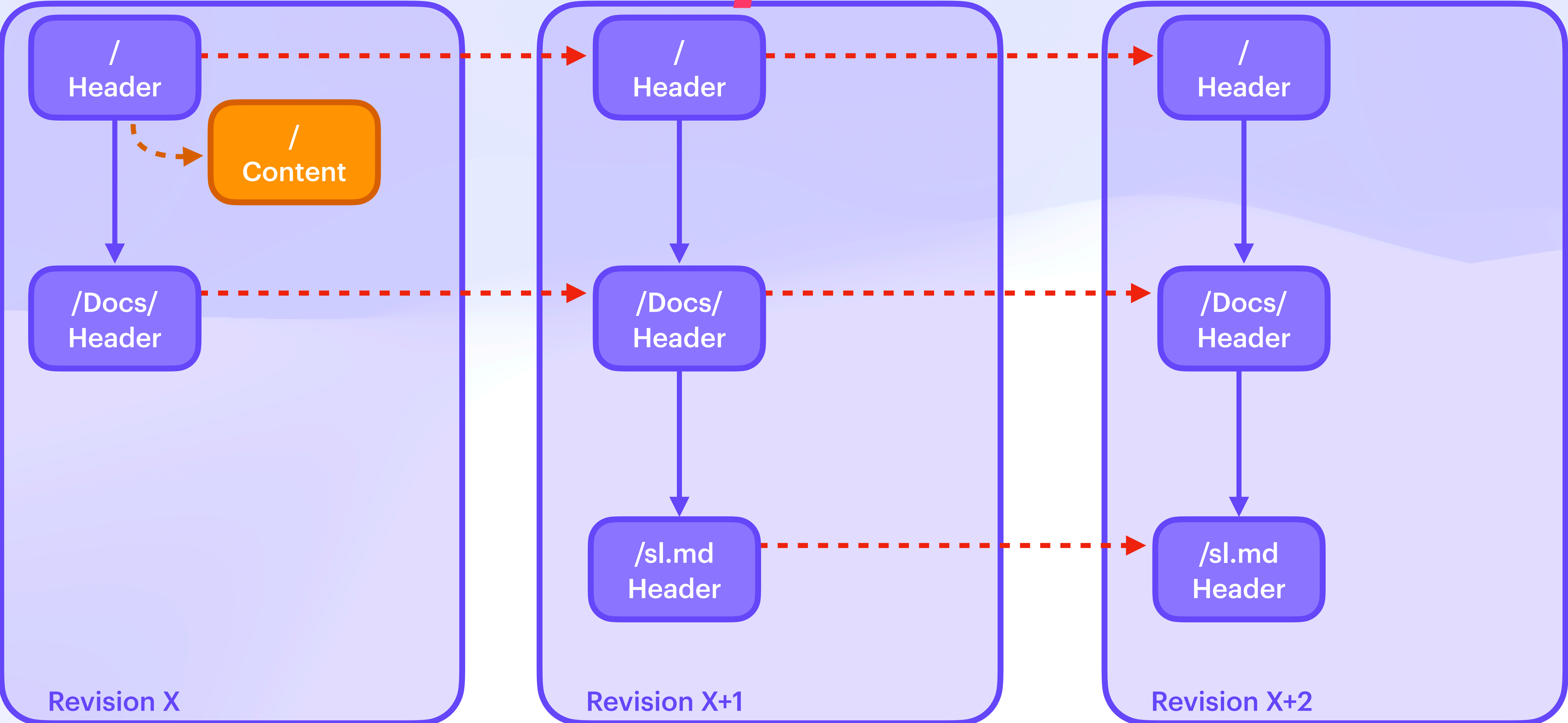
# Temporal Cryptree

# Access Control in Space & Time

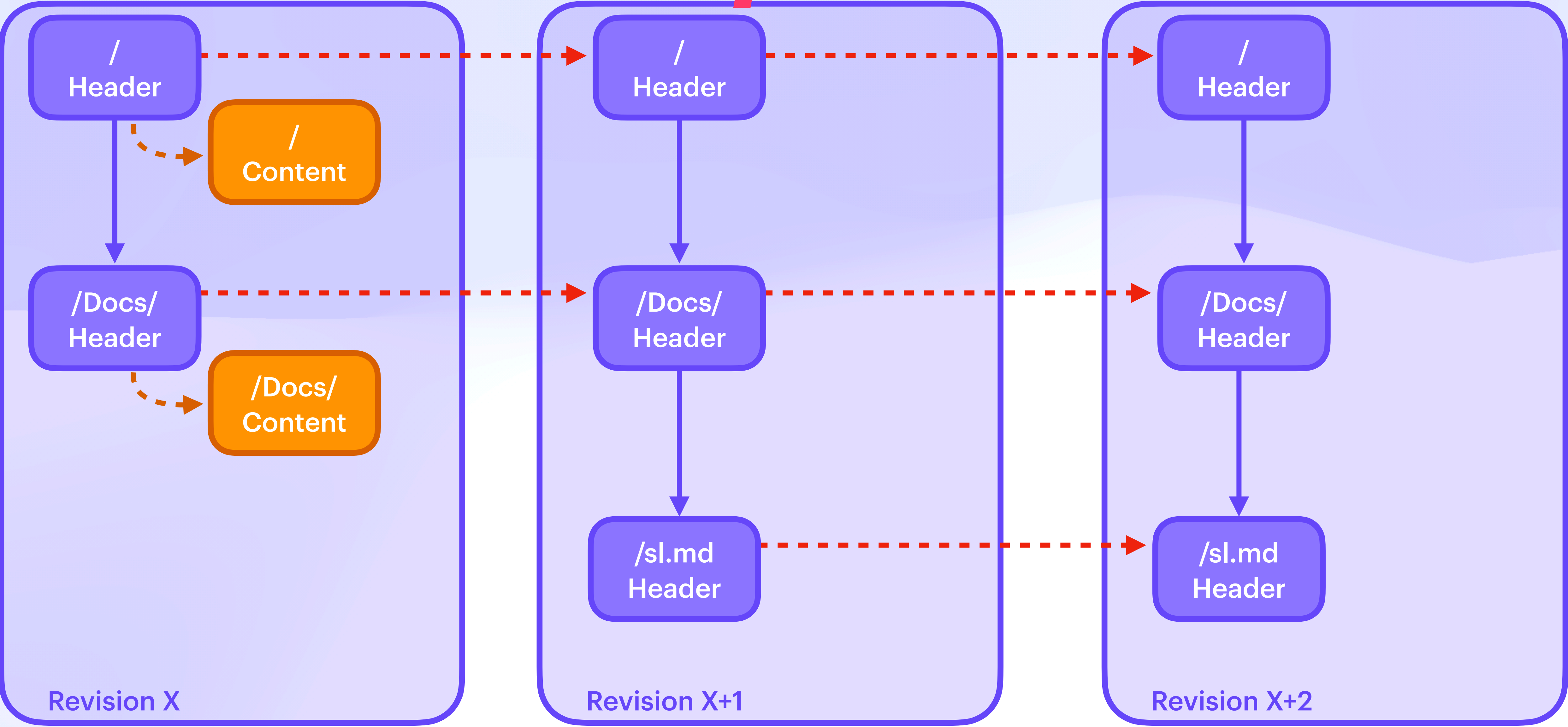


# Temporal Cryptree

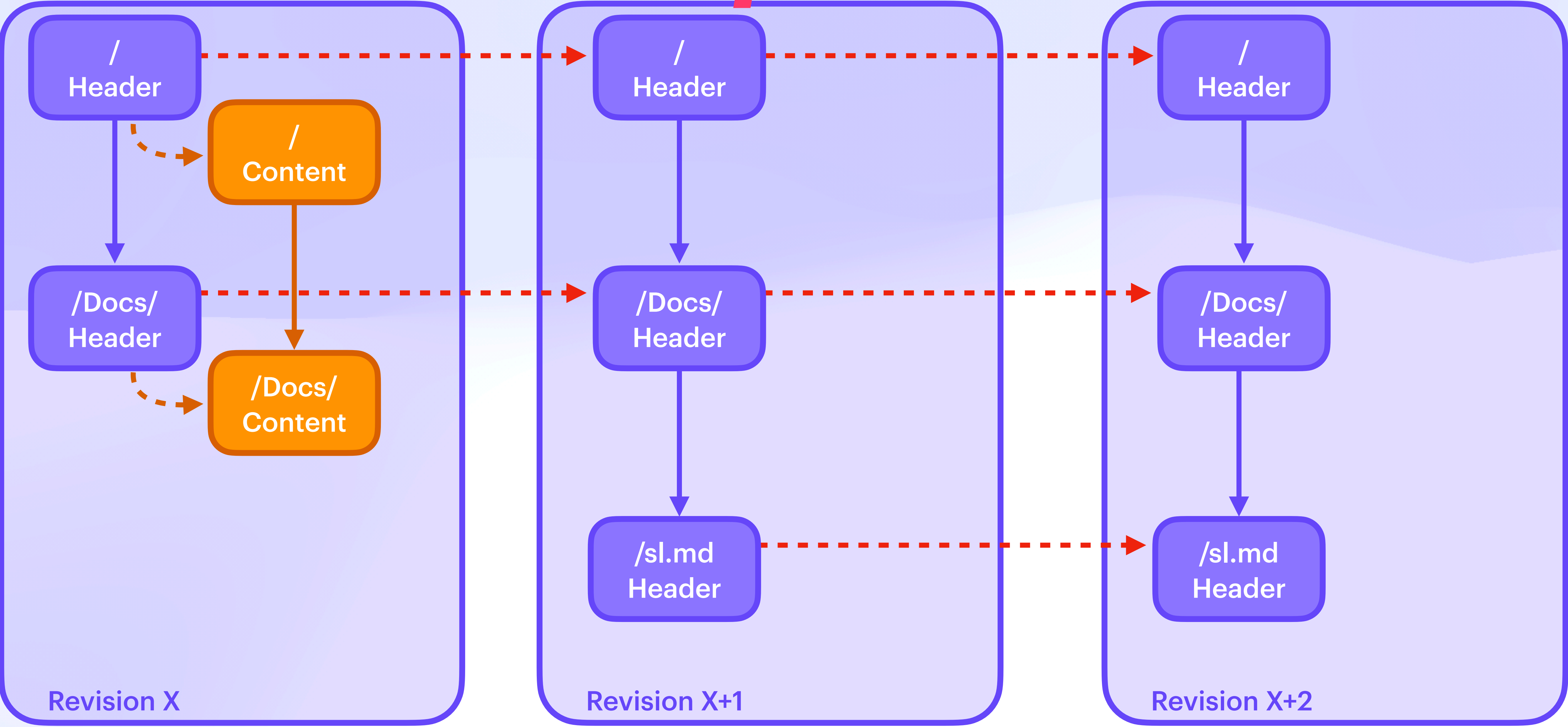
# Access Control in Space & Time



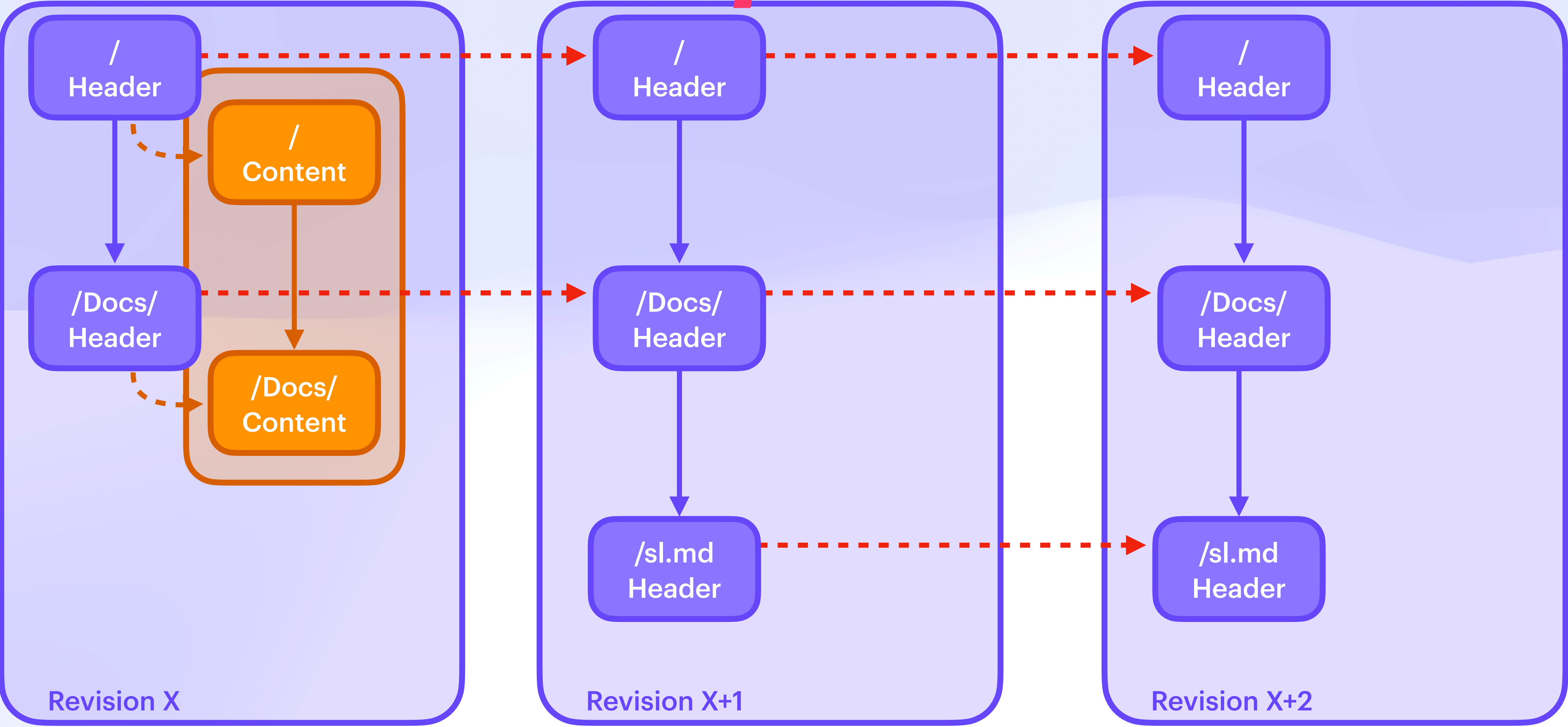
# Access Control in Space & Time



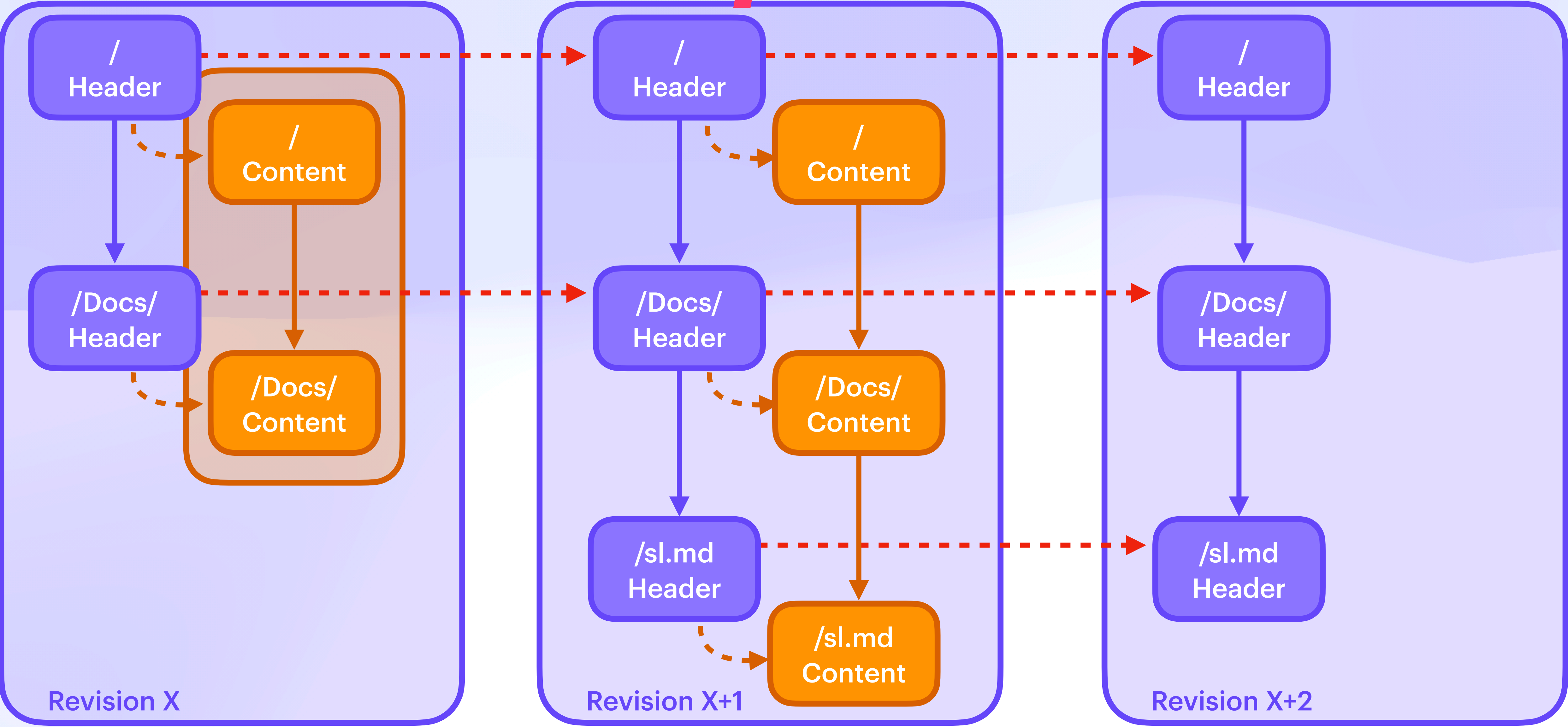
# Access Control in Space & Time



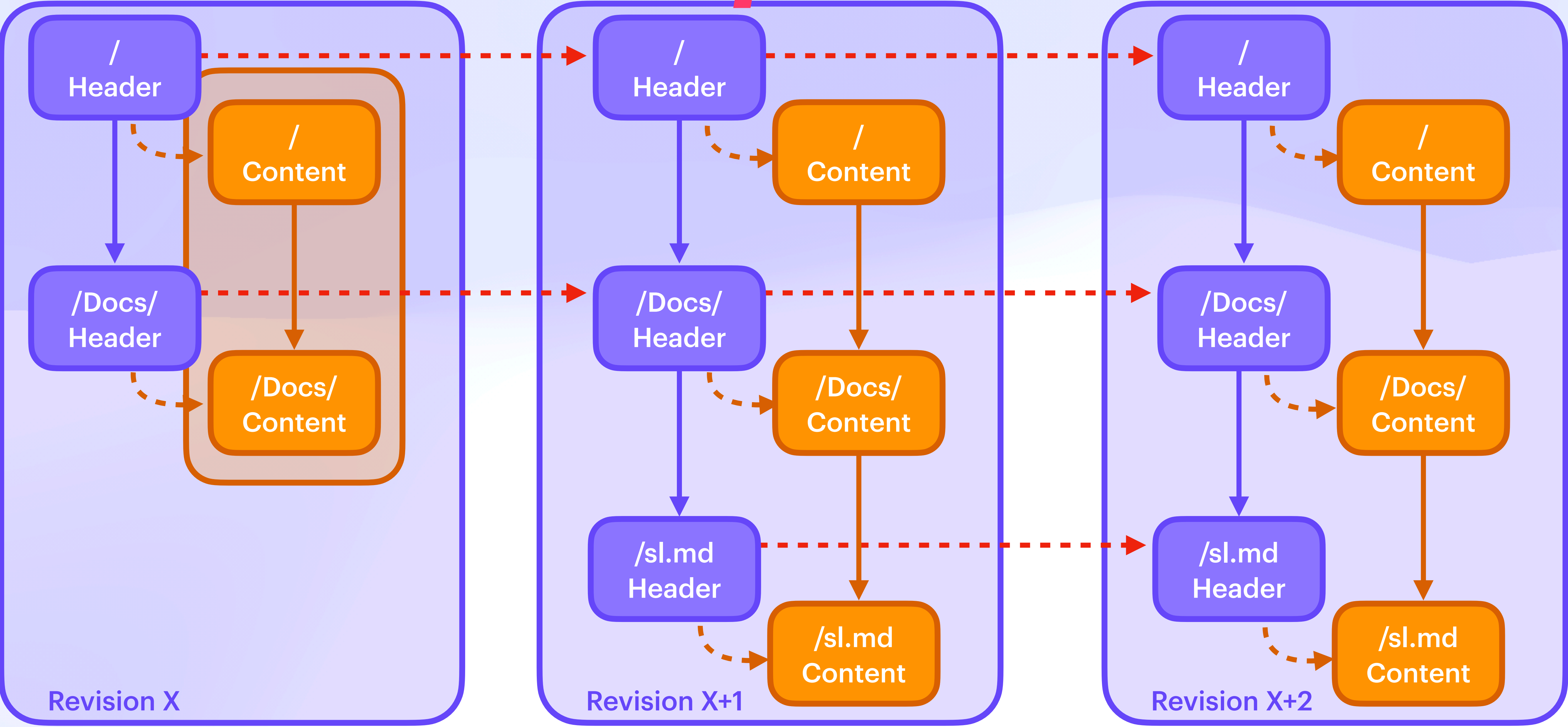
# Access Control in Space & Time



# Access Control in Space & Time

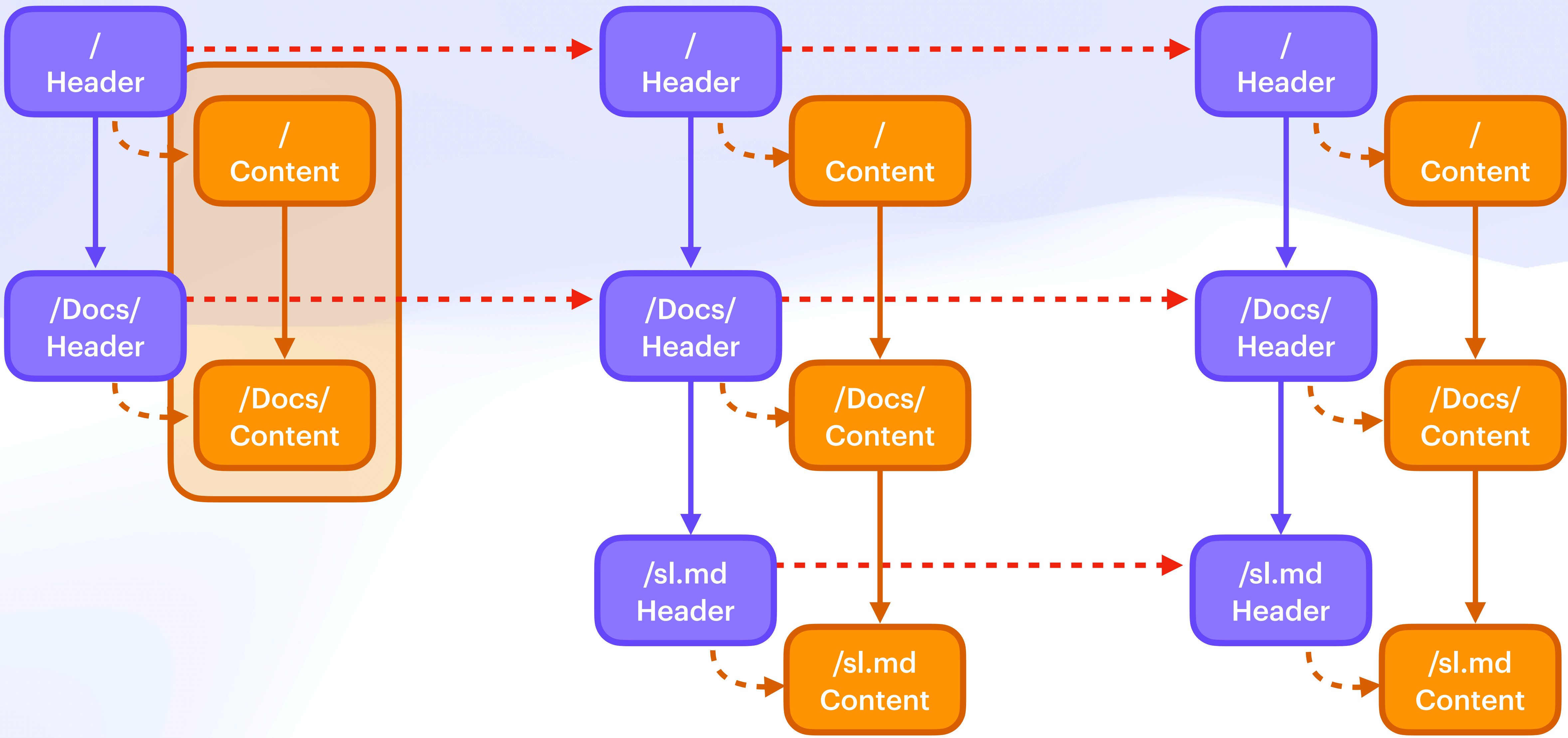


# Access Control in Space & Time

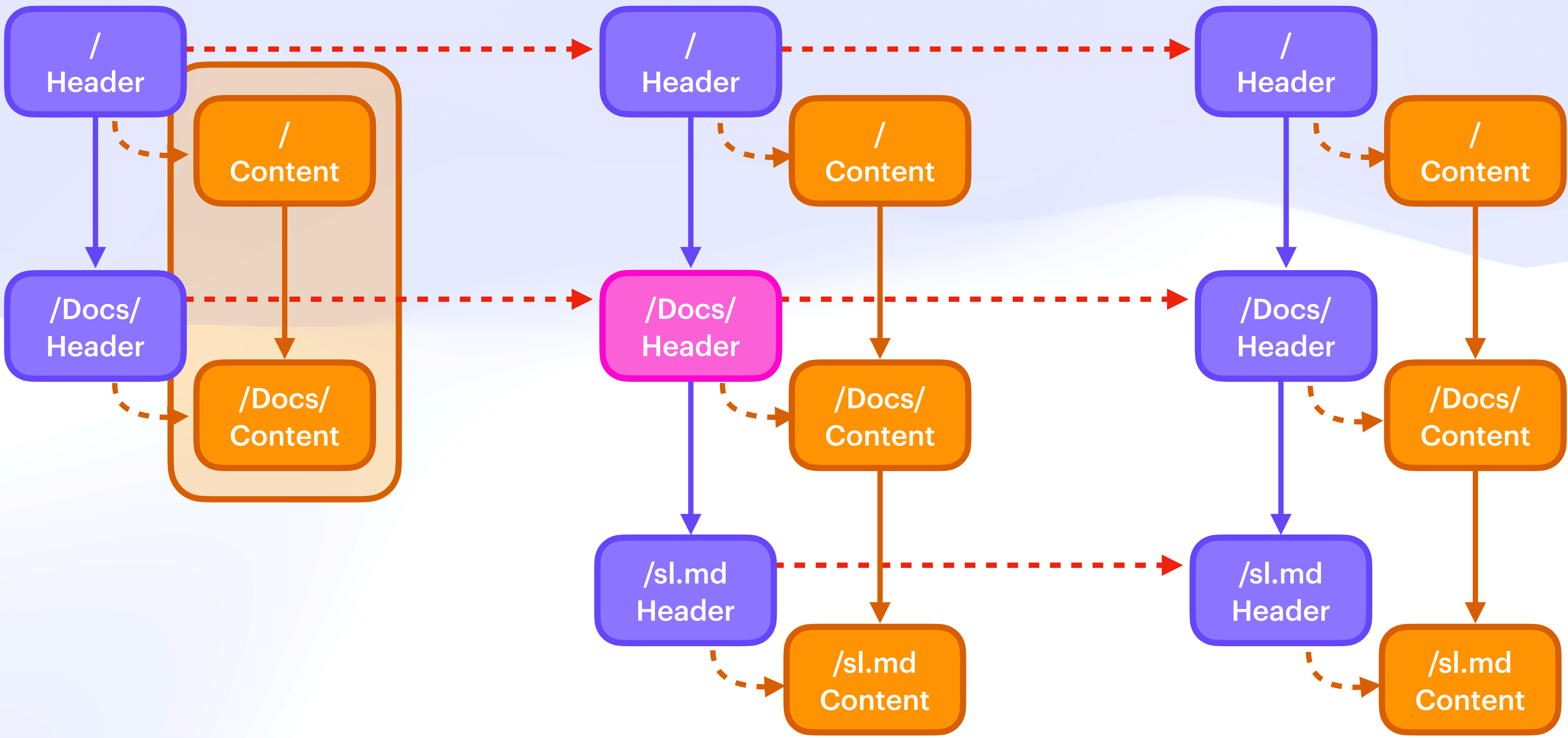




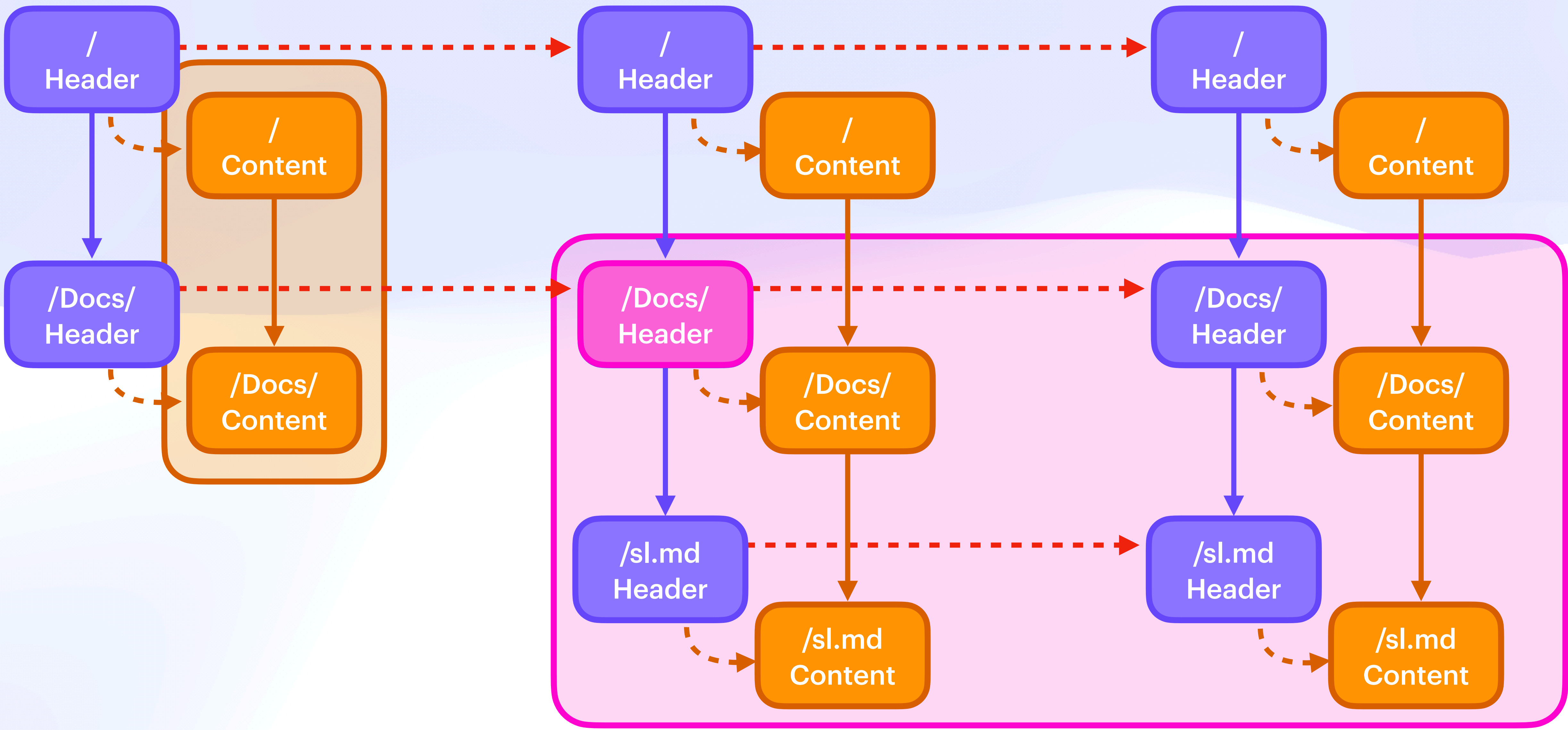
# Access Control in Space & Time



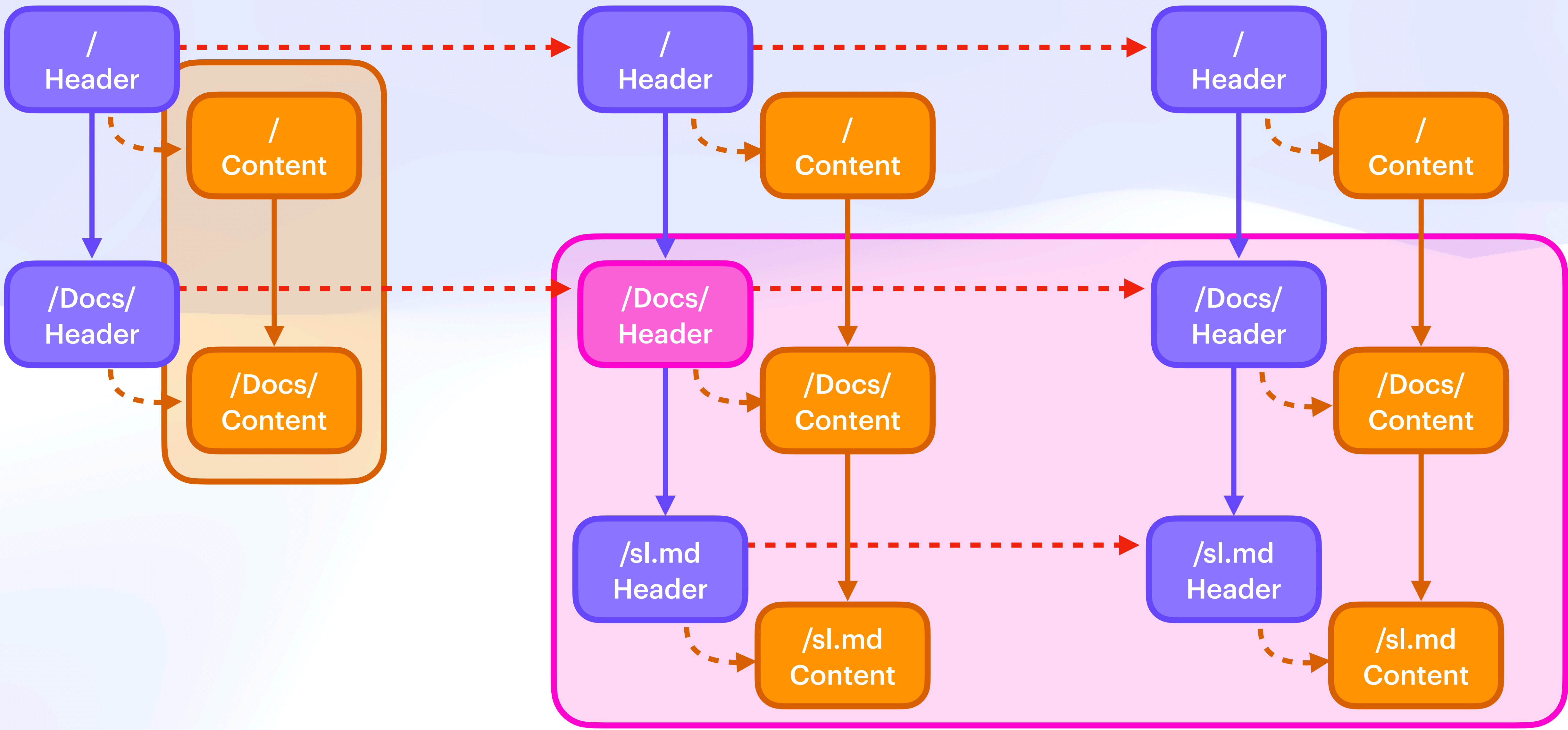
# Access Control in Space & Time



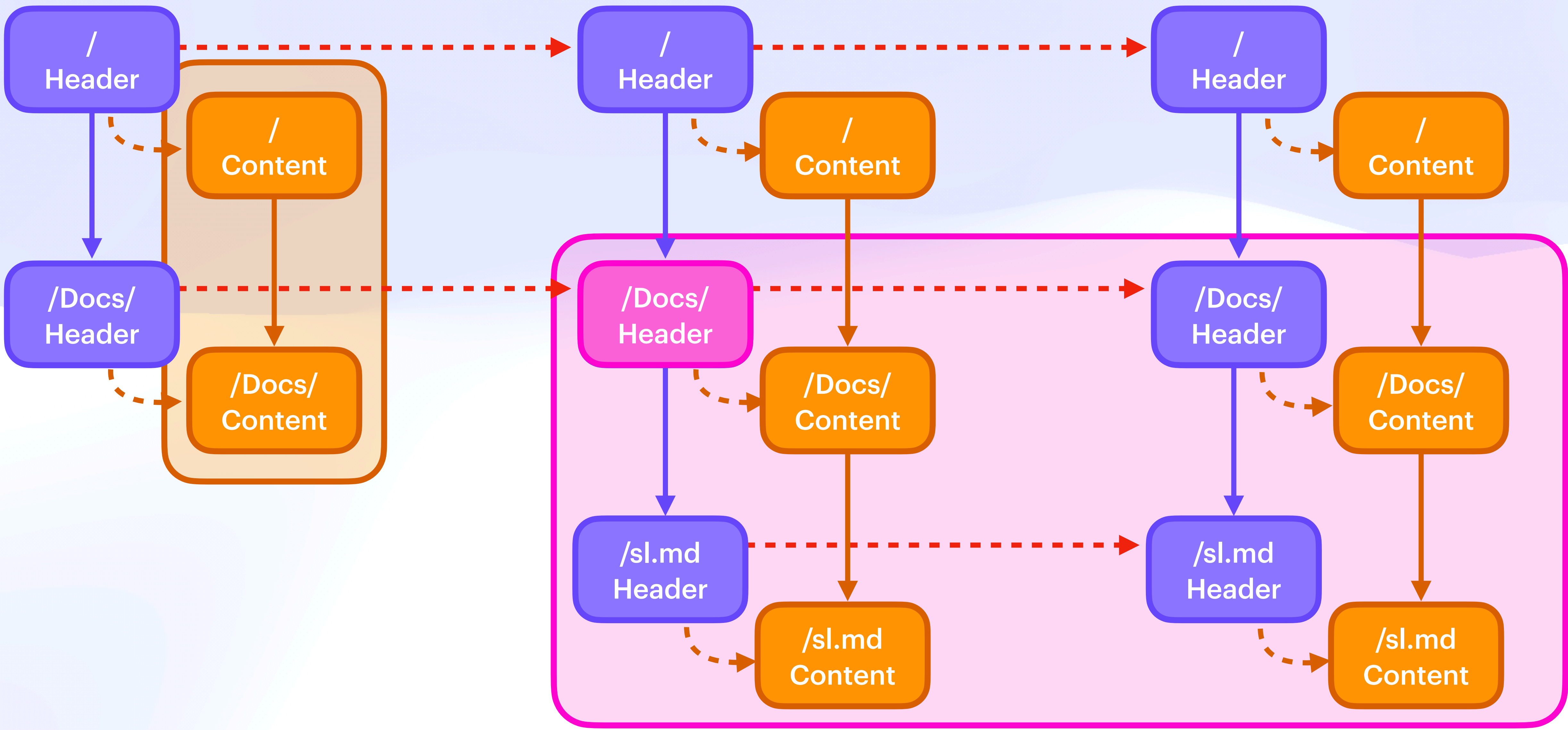
# Access Control in Space & Time



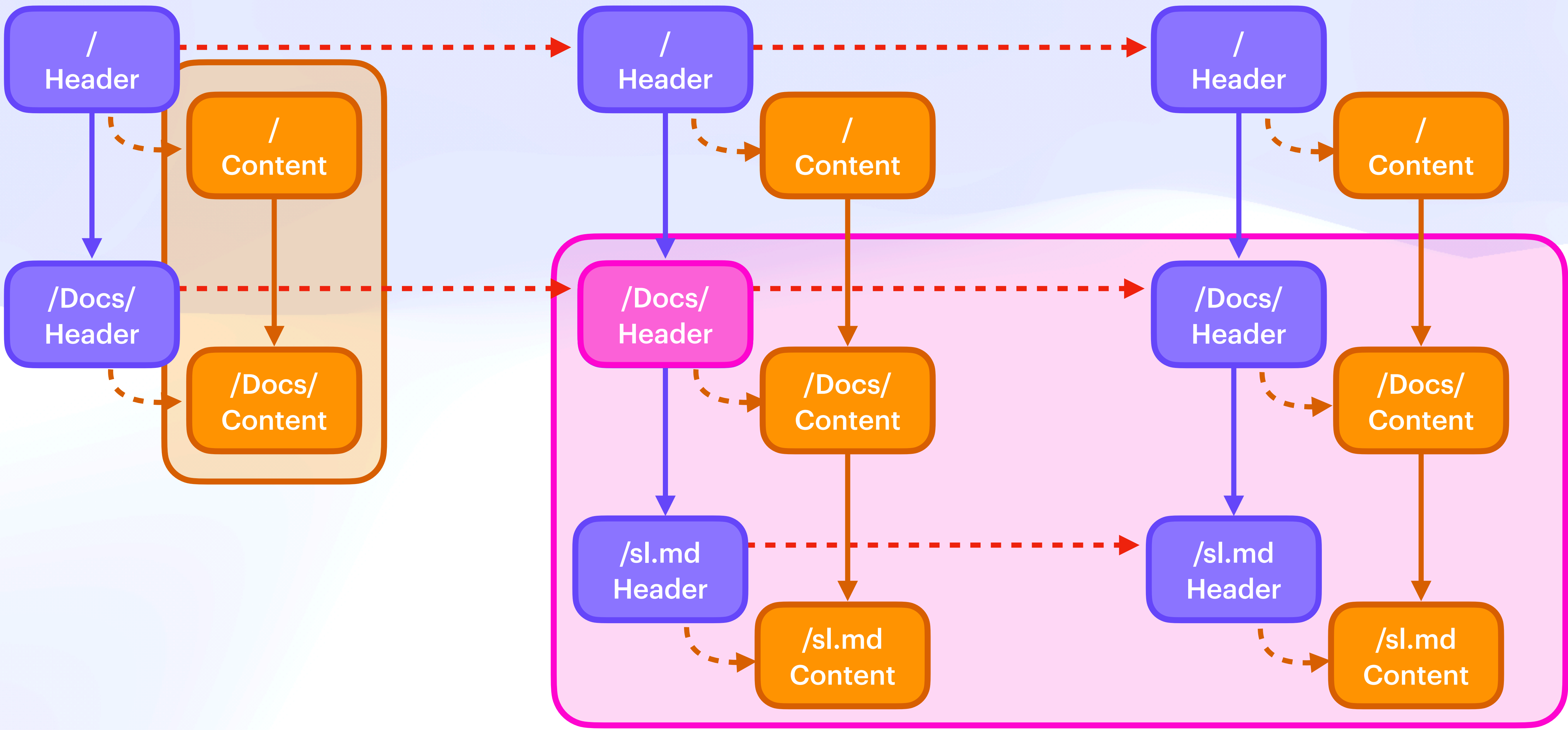
# Access Control in Space & Time



# Access Control in Space & Time



# Access Control in Space & Time

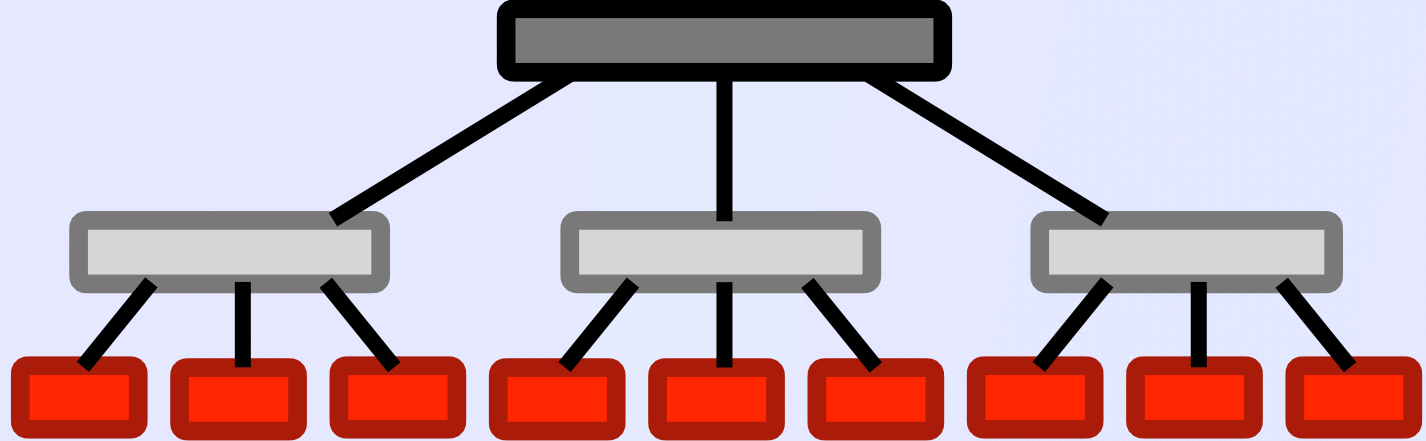


Temporal Cryptree 

***Lazy Rooting***

Temporal Cryptree 🕒

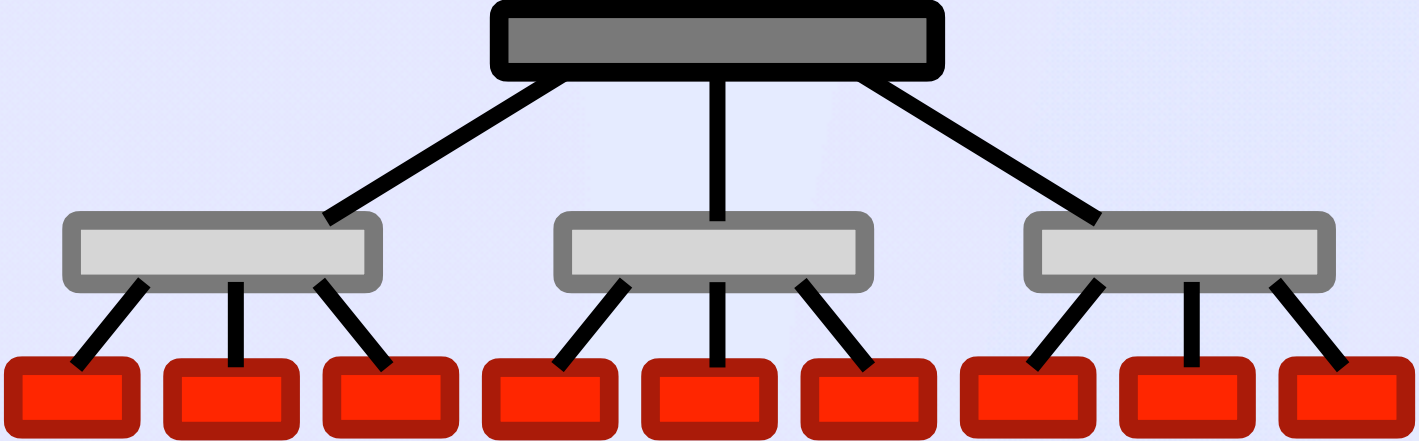
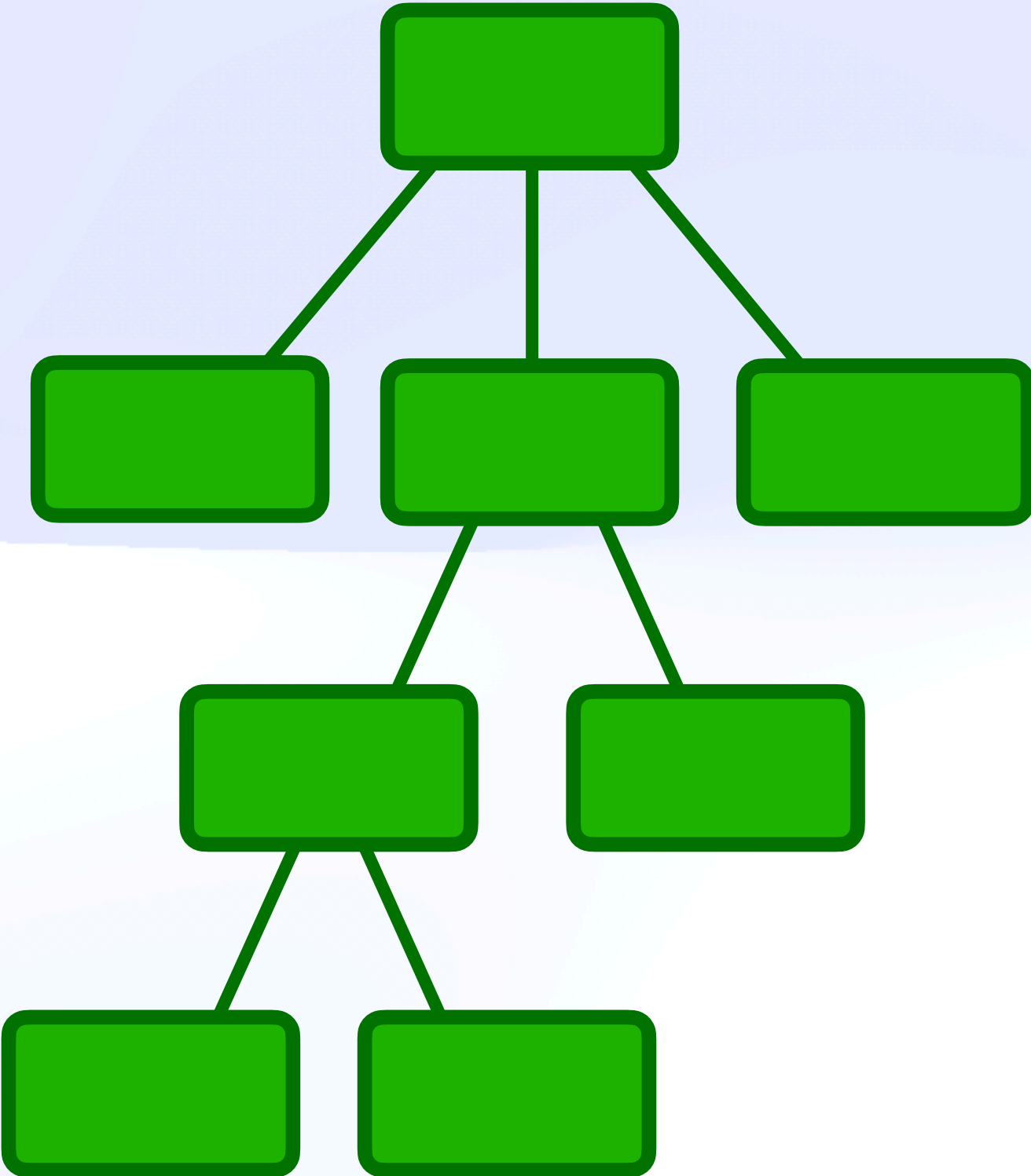
# *Lazy Rooting*





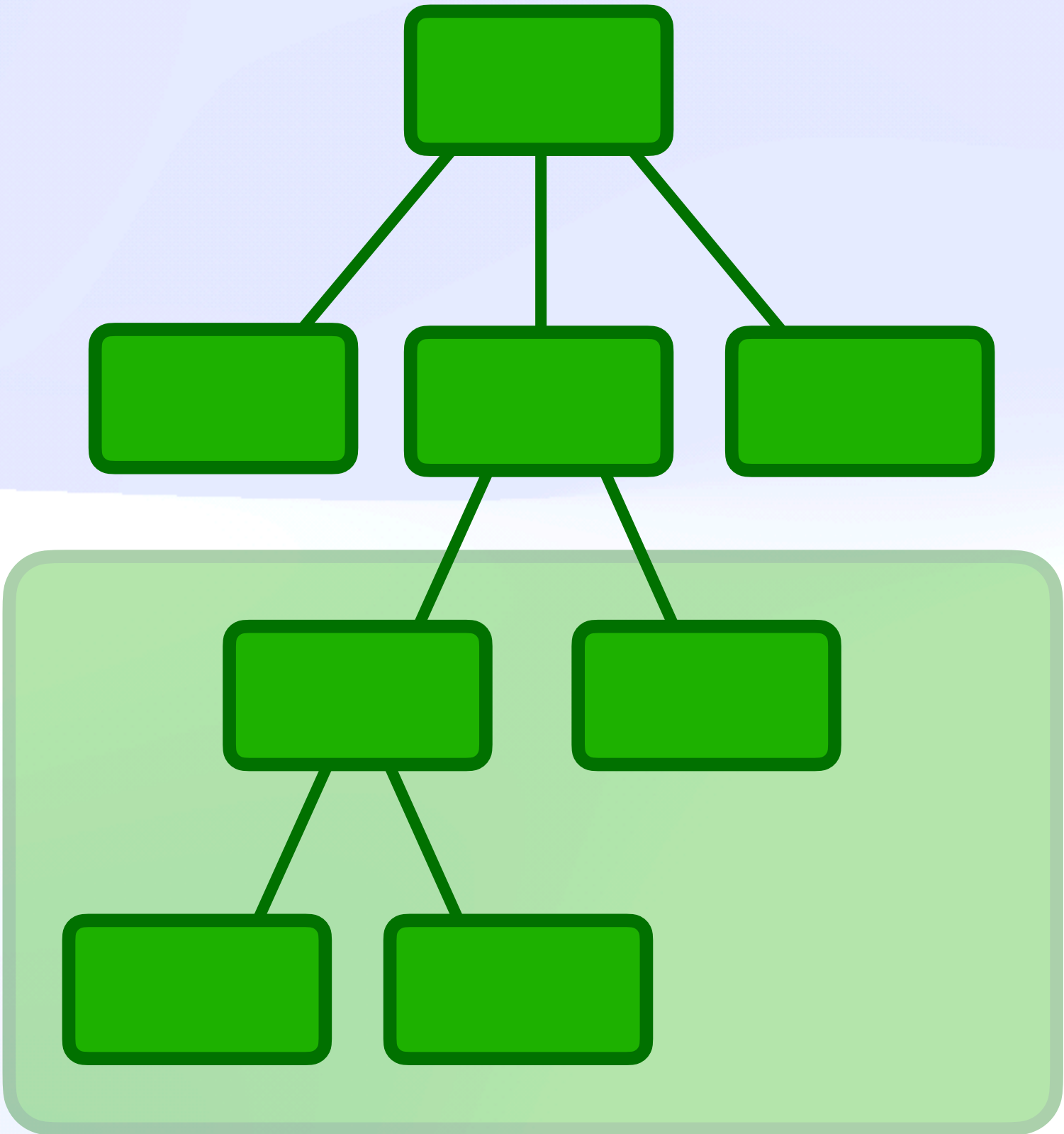
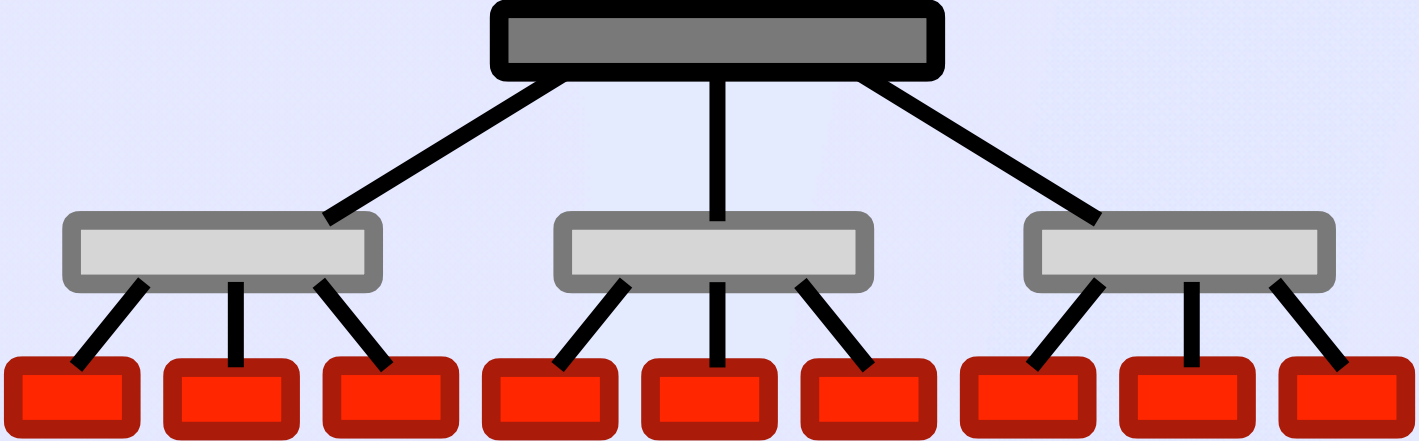
Temporal Cryptree 

# *Lazy Rooting*



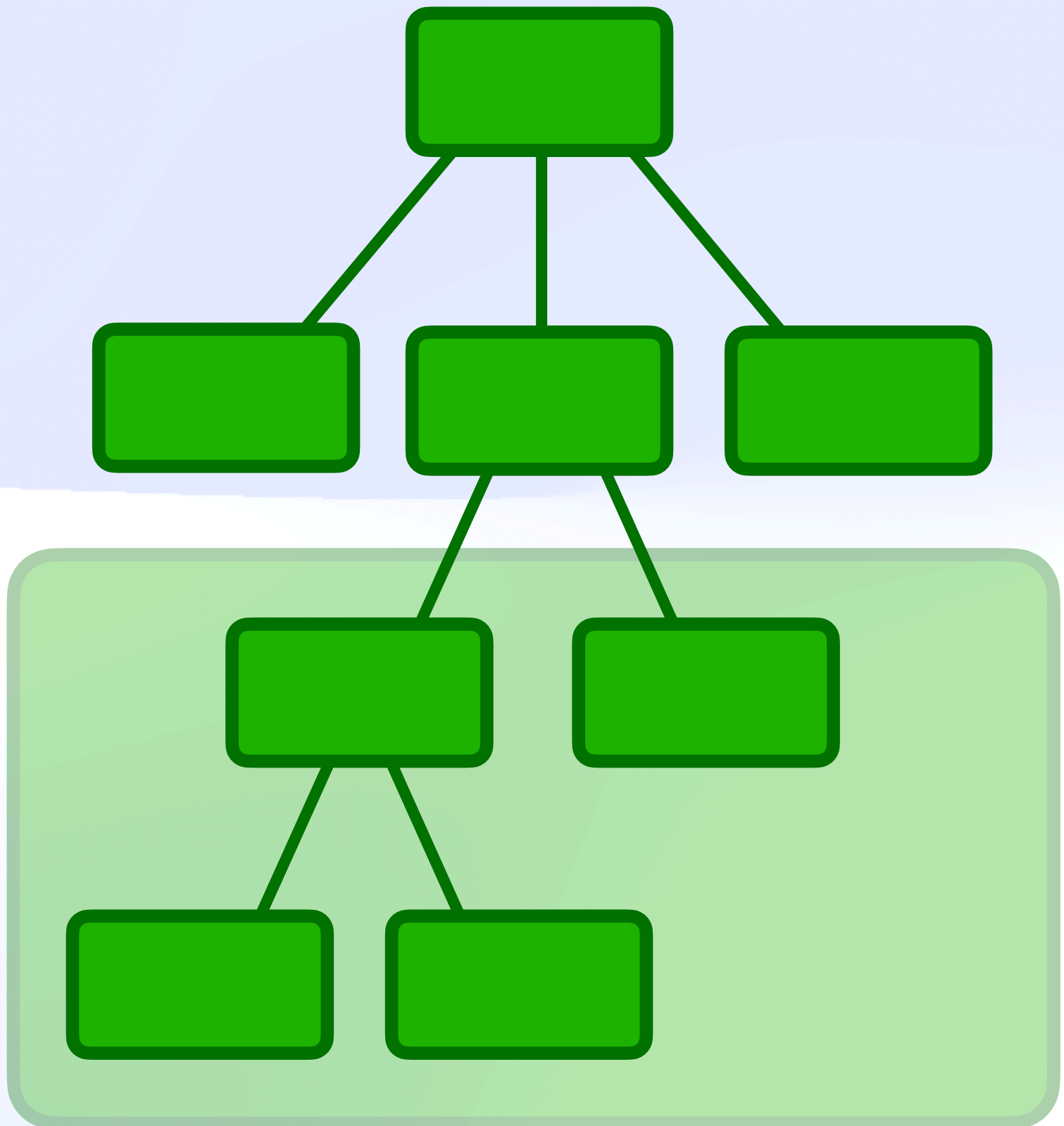
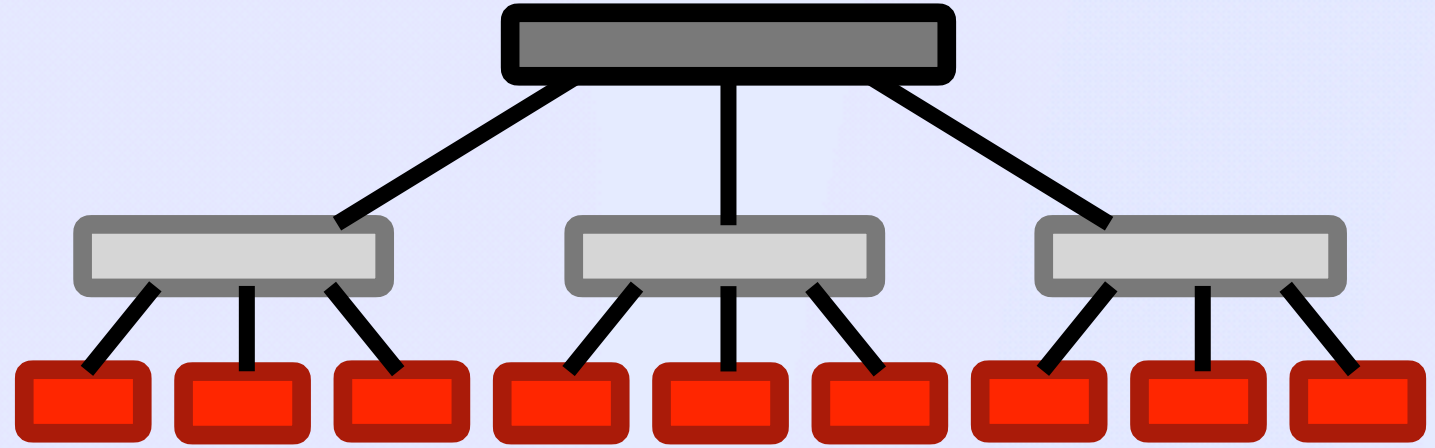
Temporal Cryptree 

# *Lazy Rooting*



# Temporal Cryptree

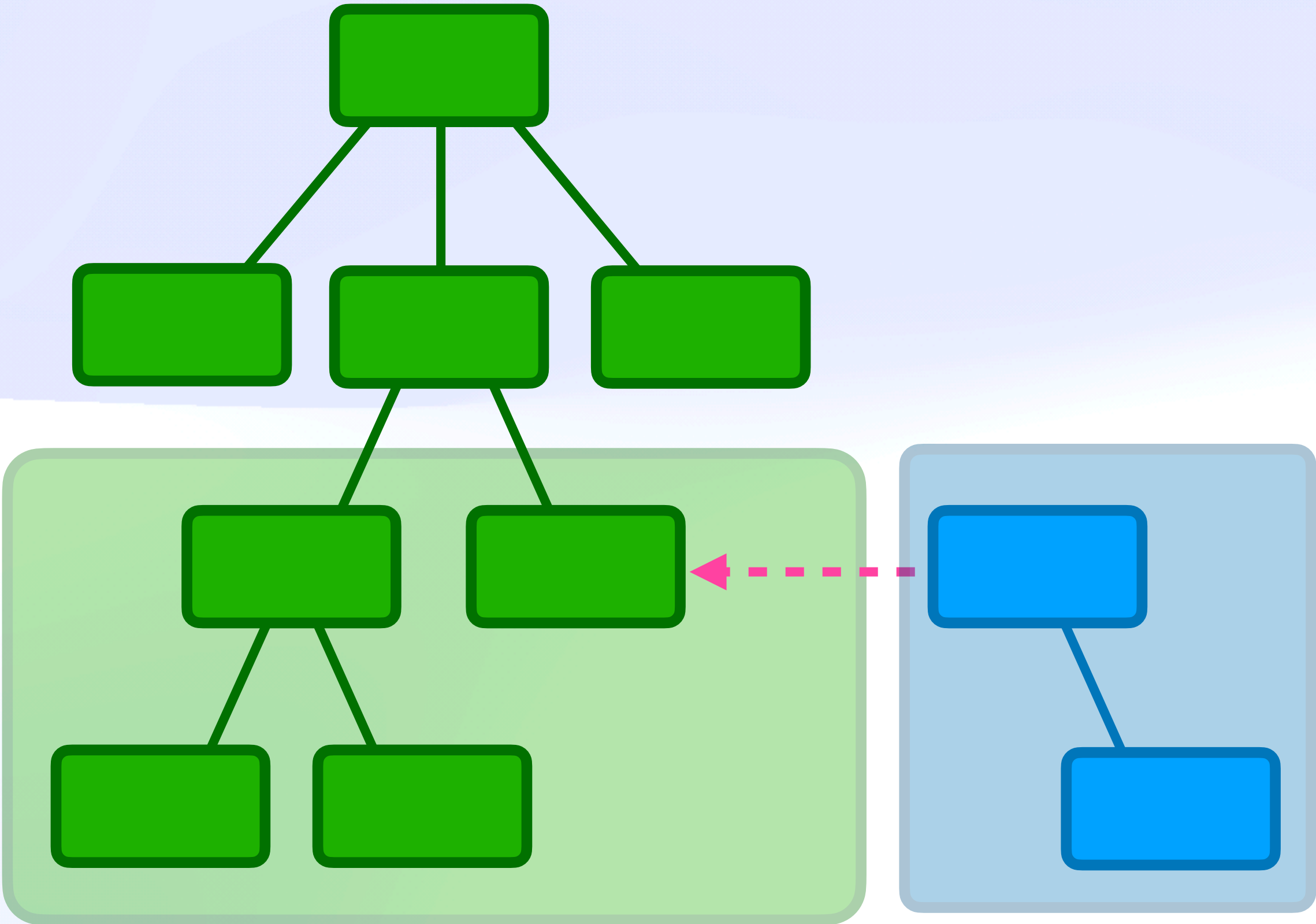
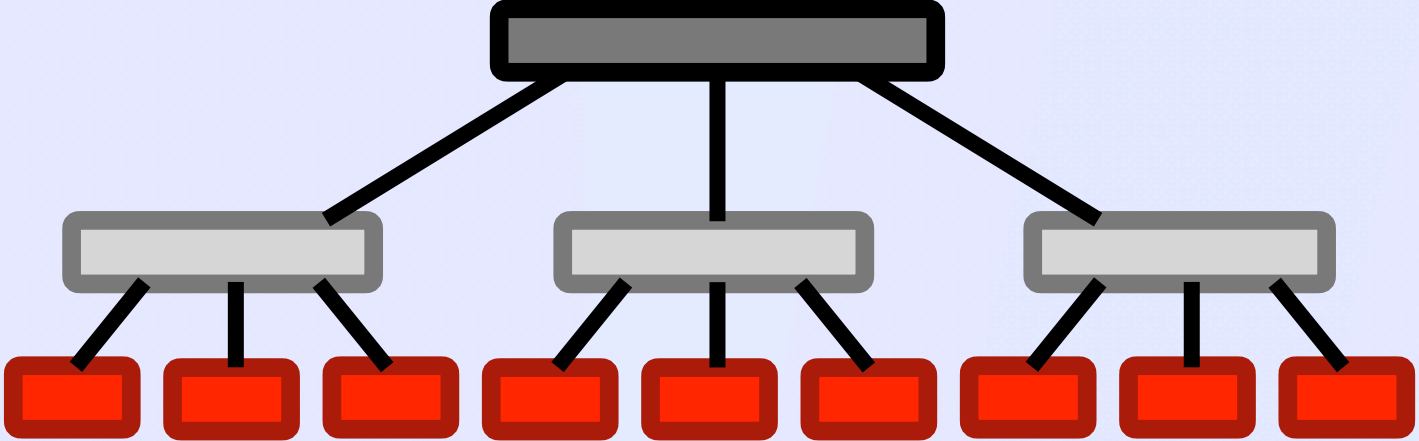
## *Lazy Rooting*



Rev 0

# Temporal Cryptree 🕒

# *Lazy Rooting*

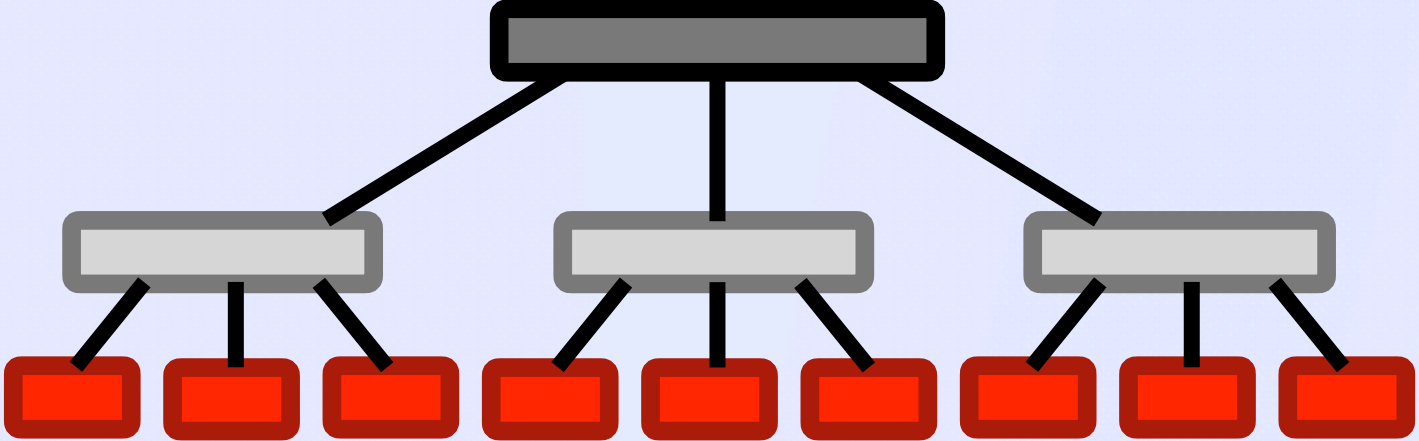


Rev 0

Rev 1  
(Partial)

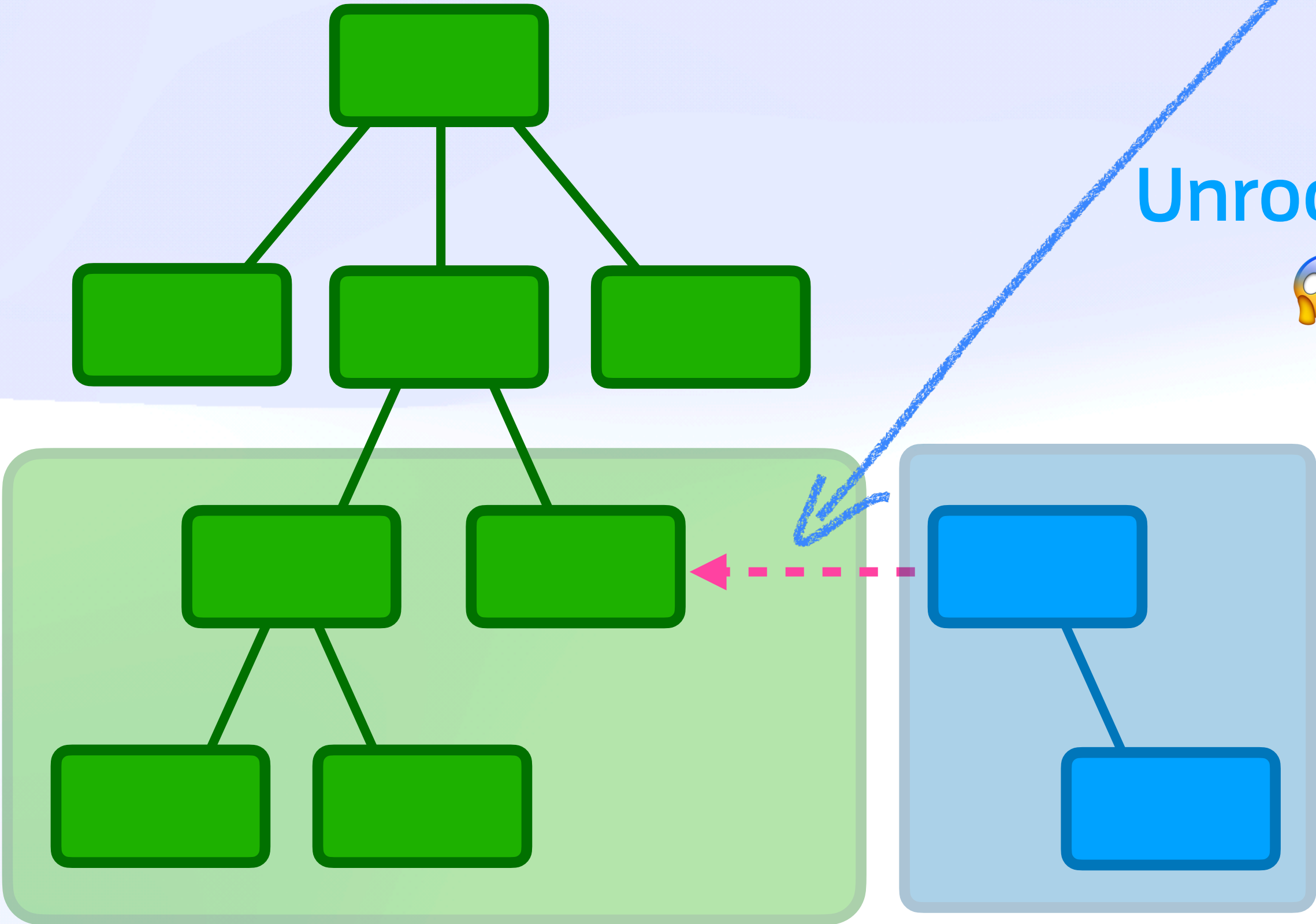
# Temporal Cryptree 🕒

# *Lazy Rooting*



Attachment progress

Unrooted?! 🤪

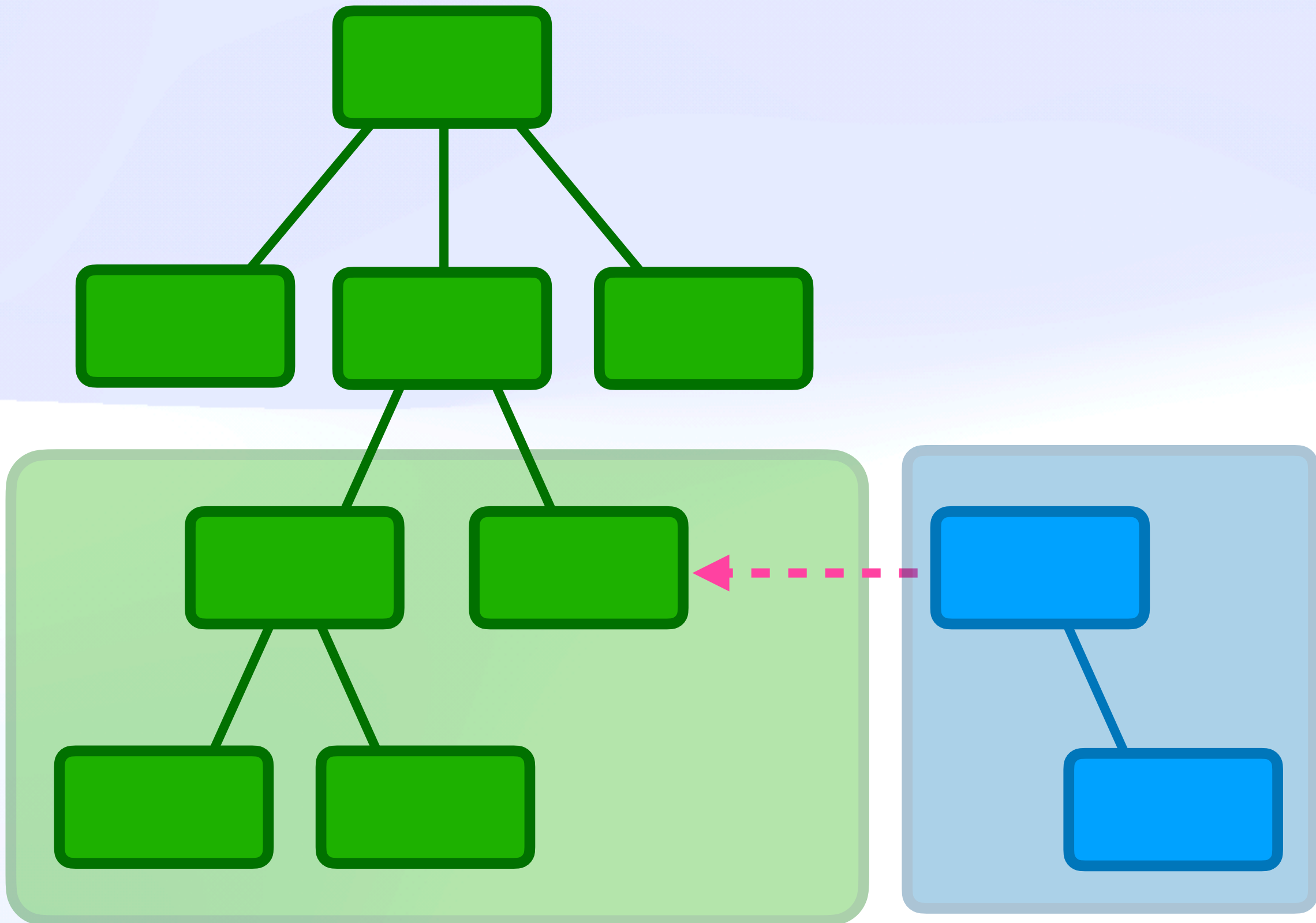
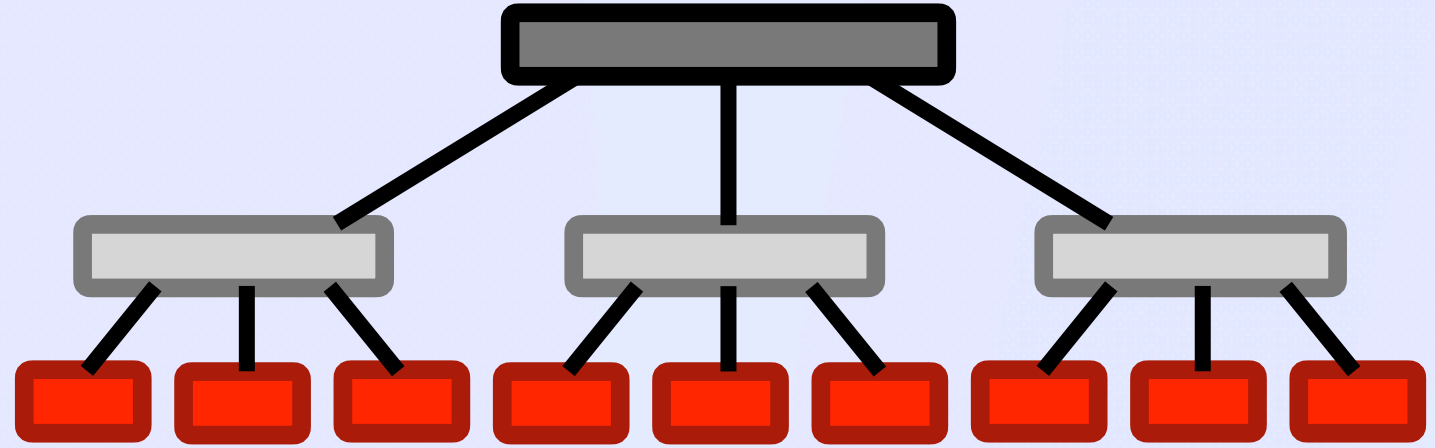


Rev 0

Rev 1  
(Partial)

# Temporal Cryptree

## *Lazy Rooting*

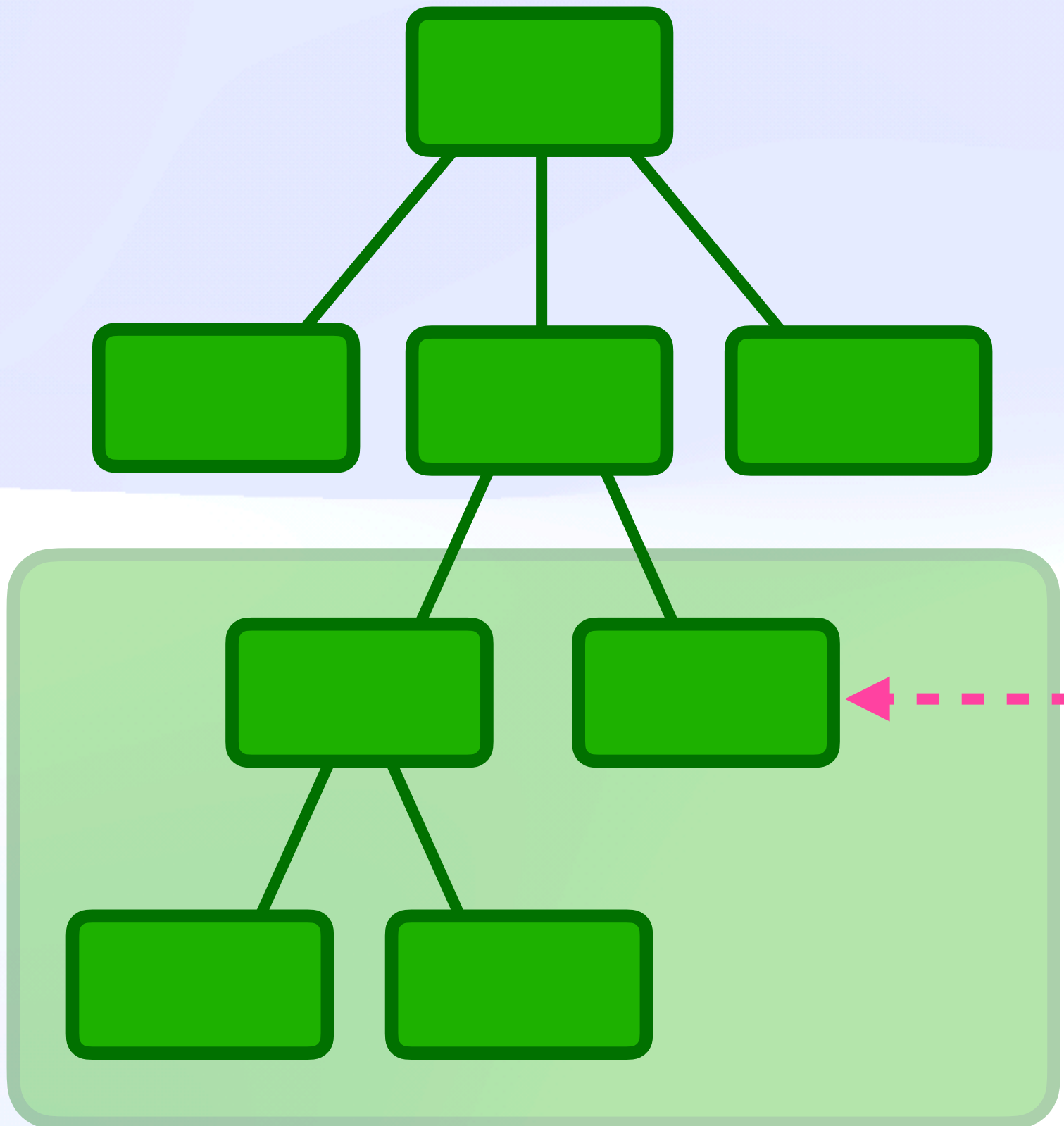
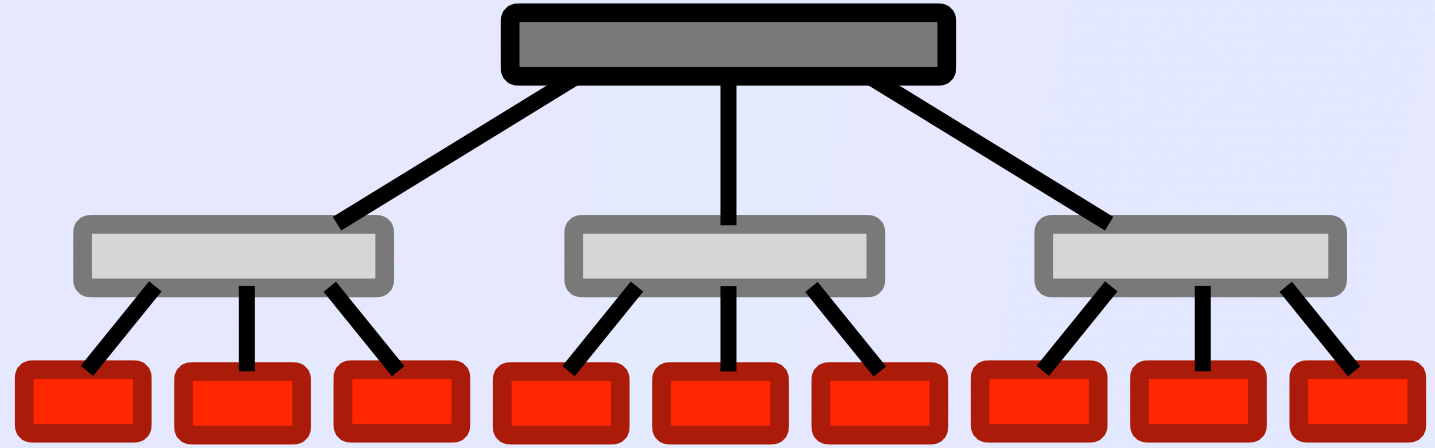


Rev 0

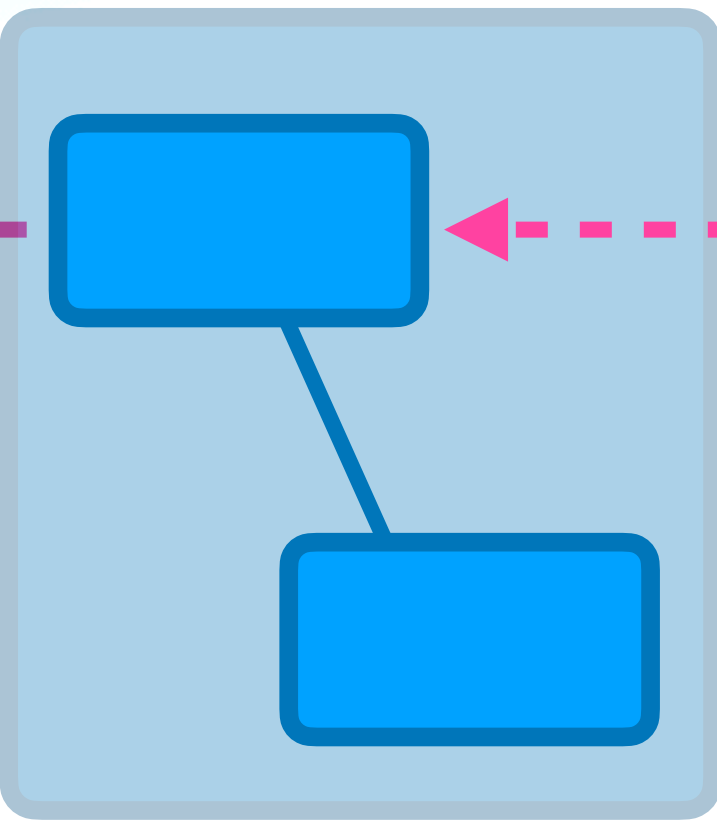
Rev 1  
(Partial)

# Temporal Cryptree

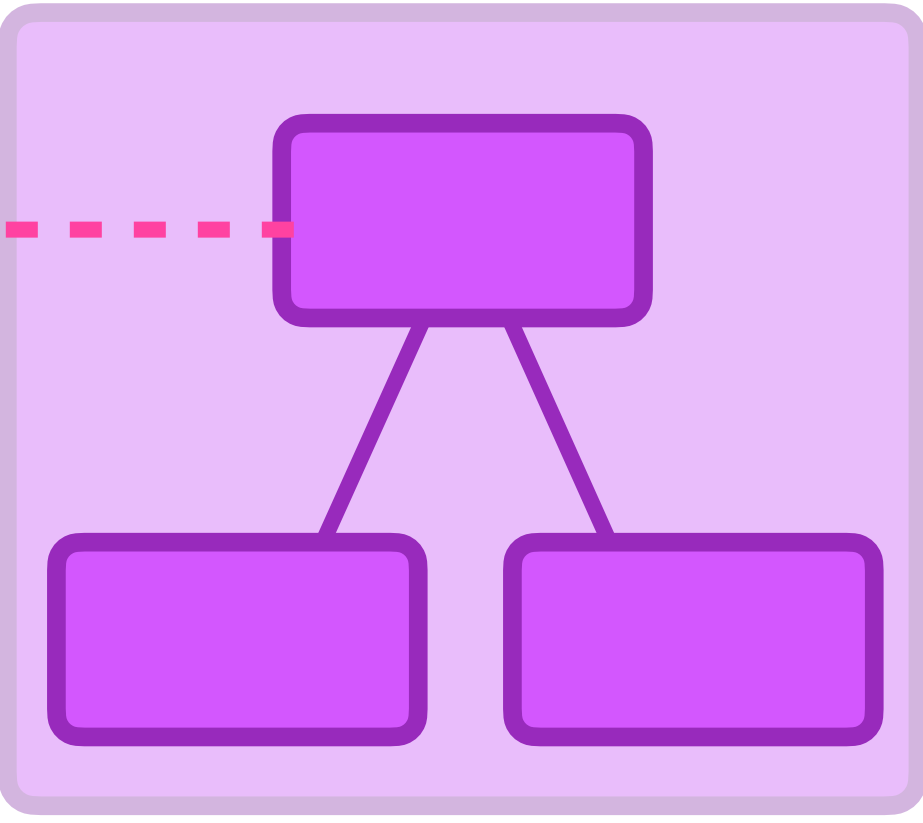
## *Lazy Rooting*



Rev 0



Rev 1  
(Partial)

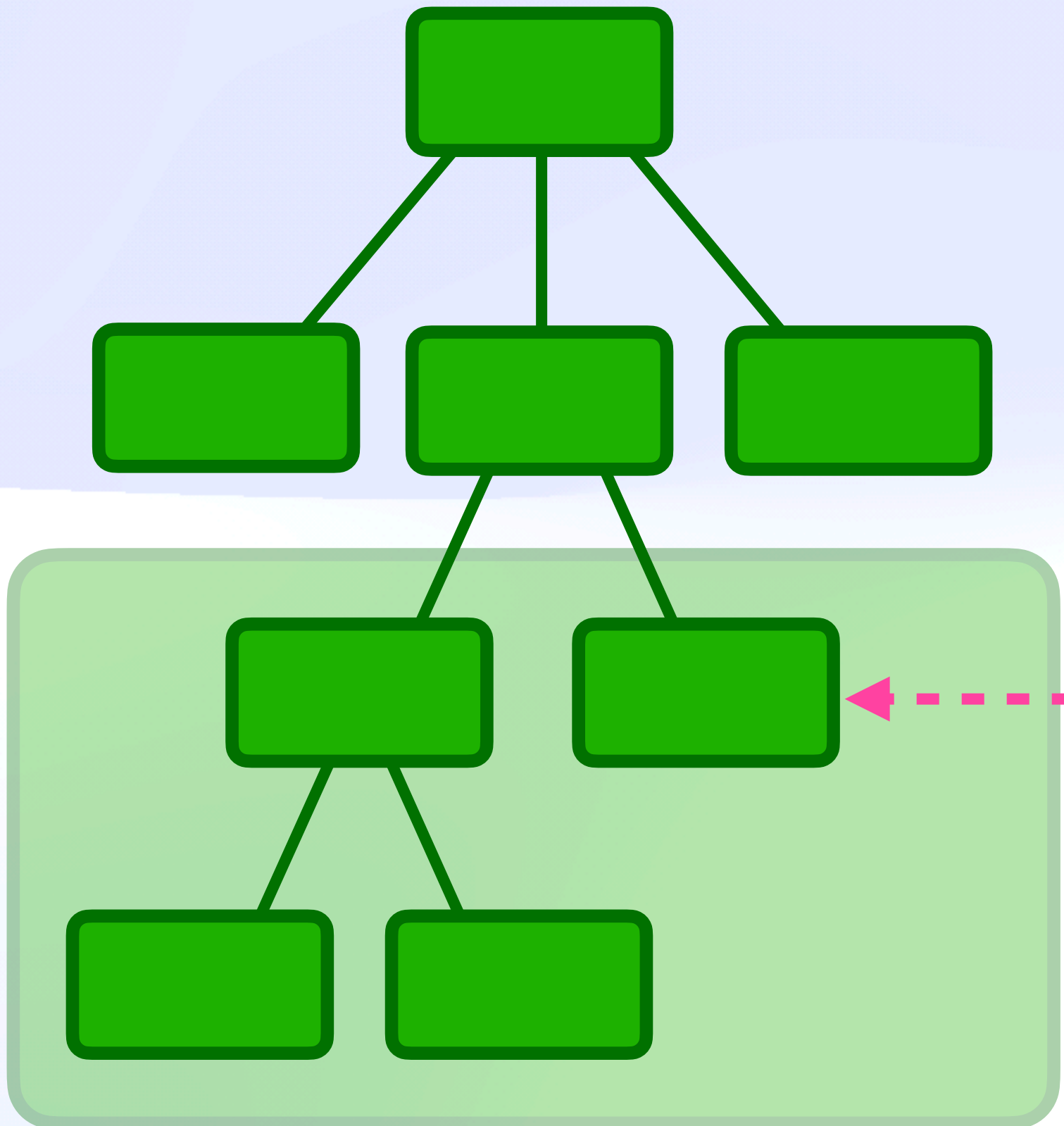
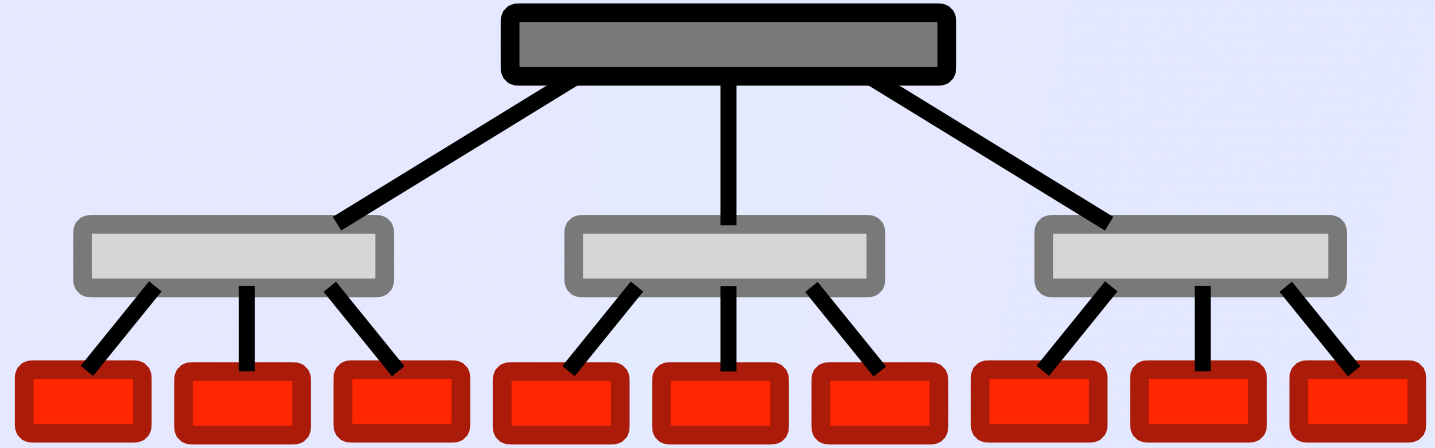


Rev 2  
(Partial)

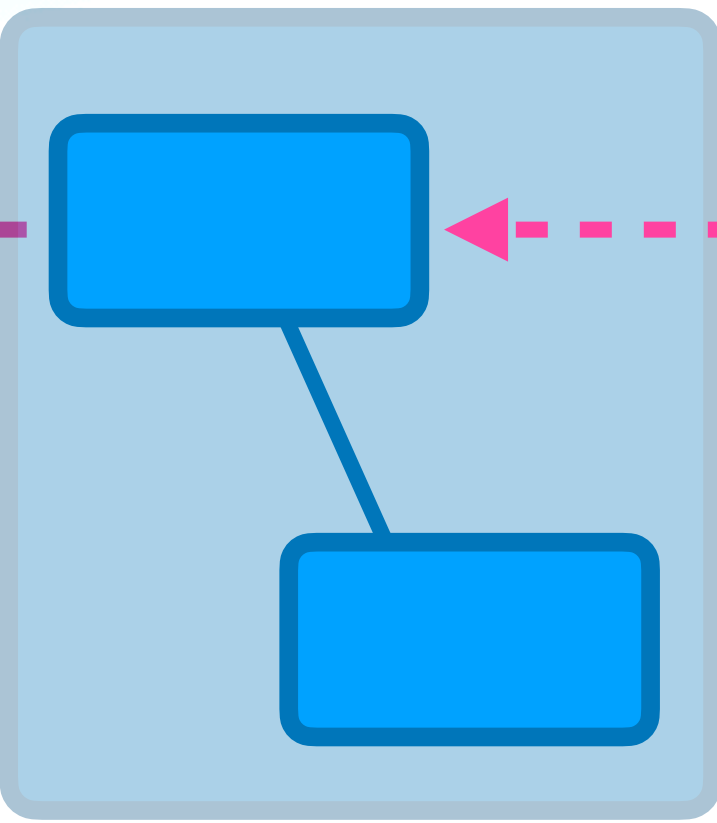


# Temporal Cryptree

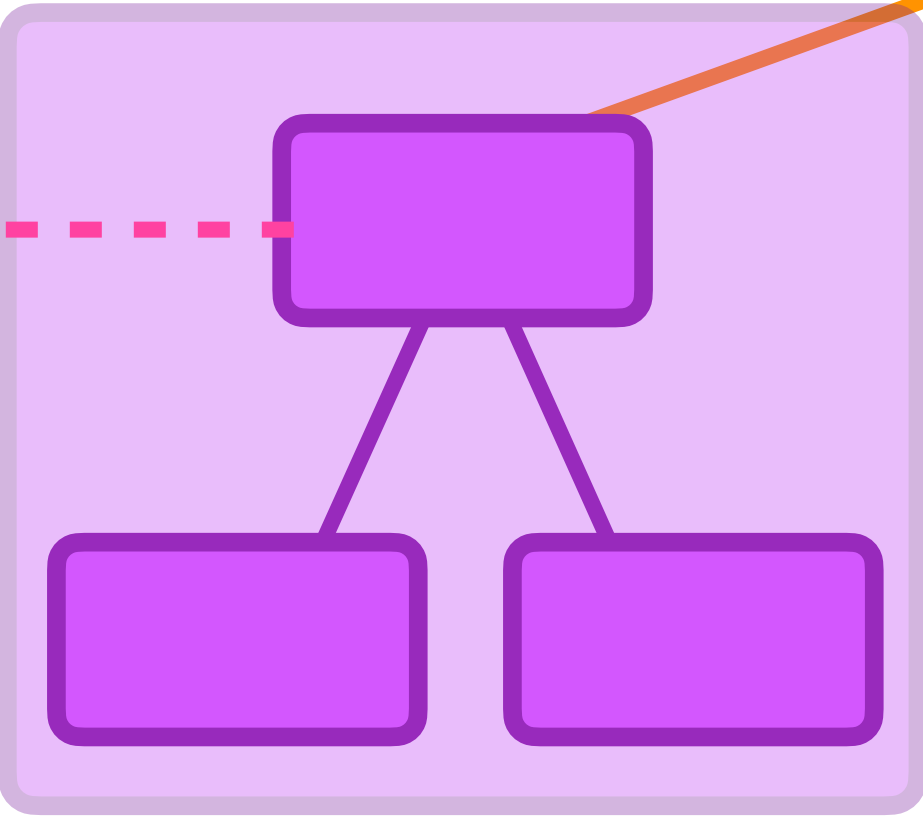
## *Lazy Rooting*



Rev 0



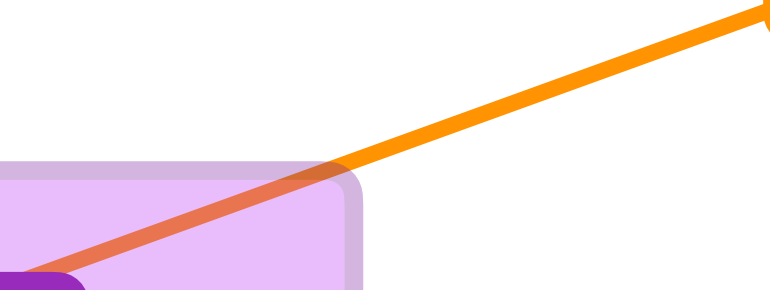
Rev 1  
(Partial)



Rev 2  
(Partial)



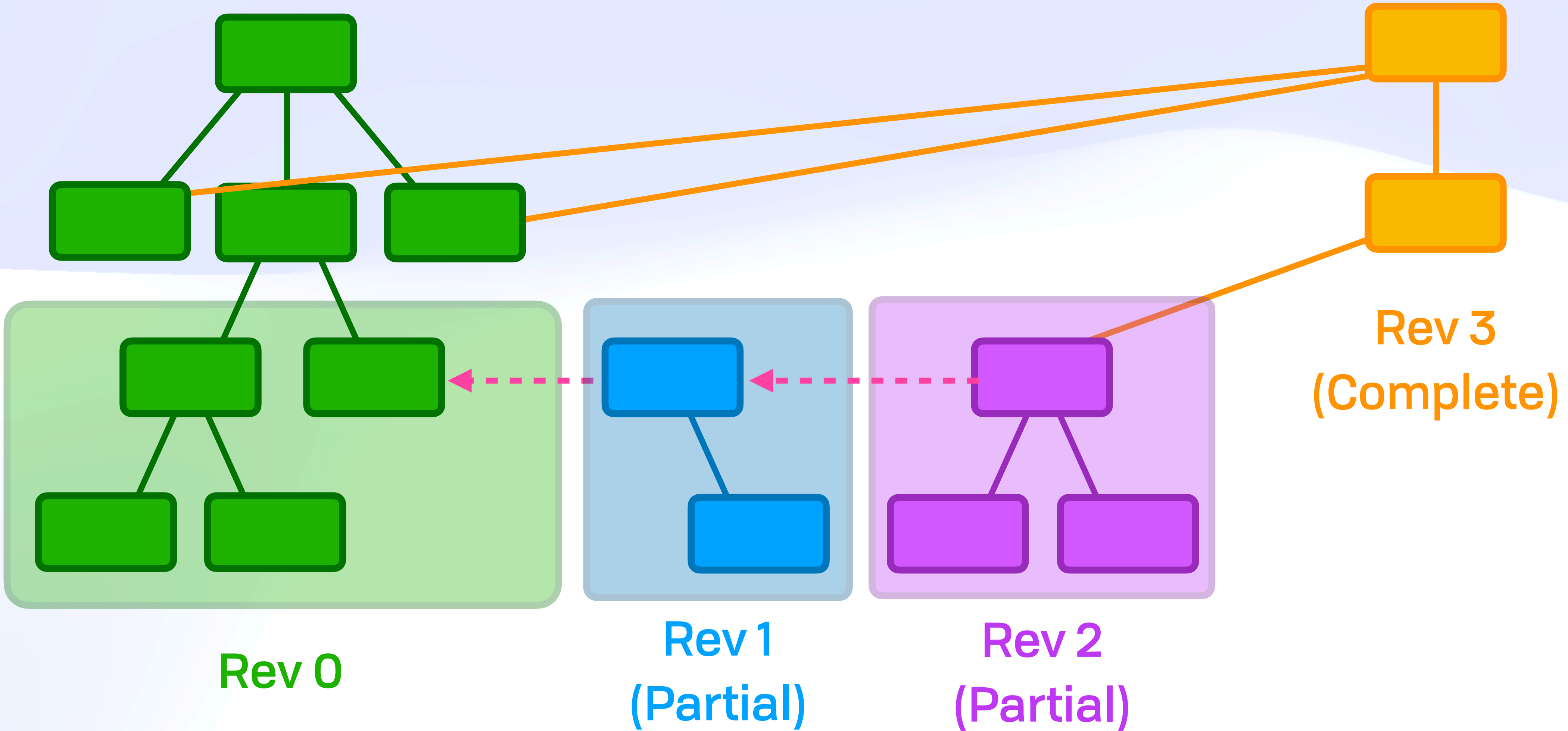
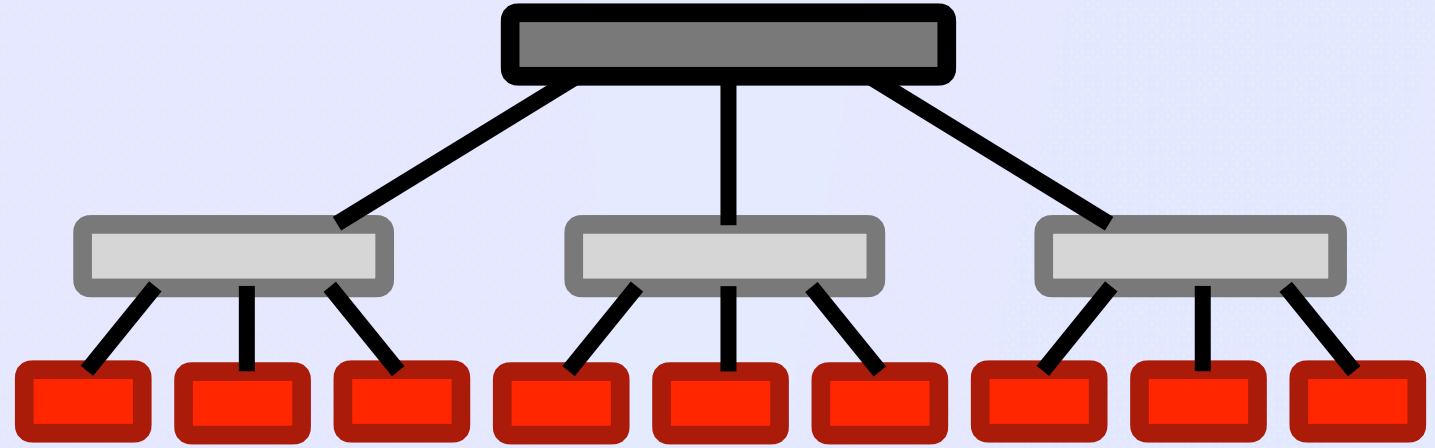
Rev 3  
(Complete)





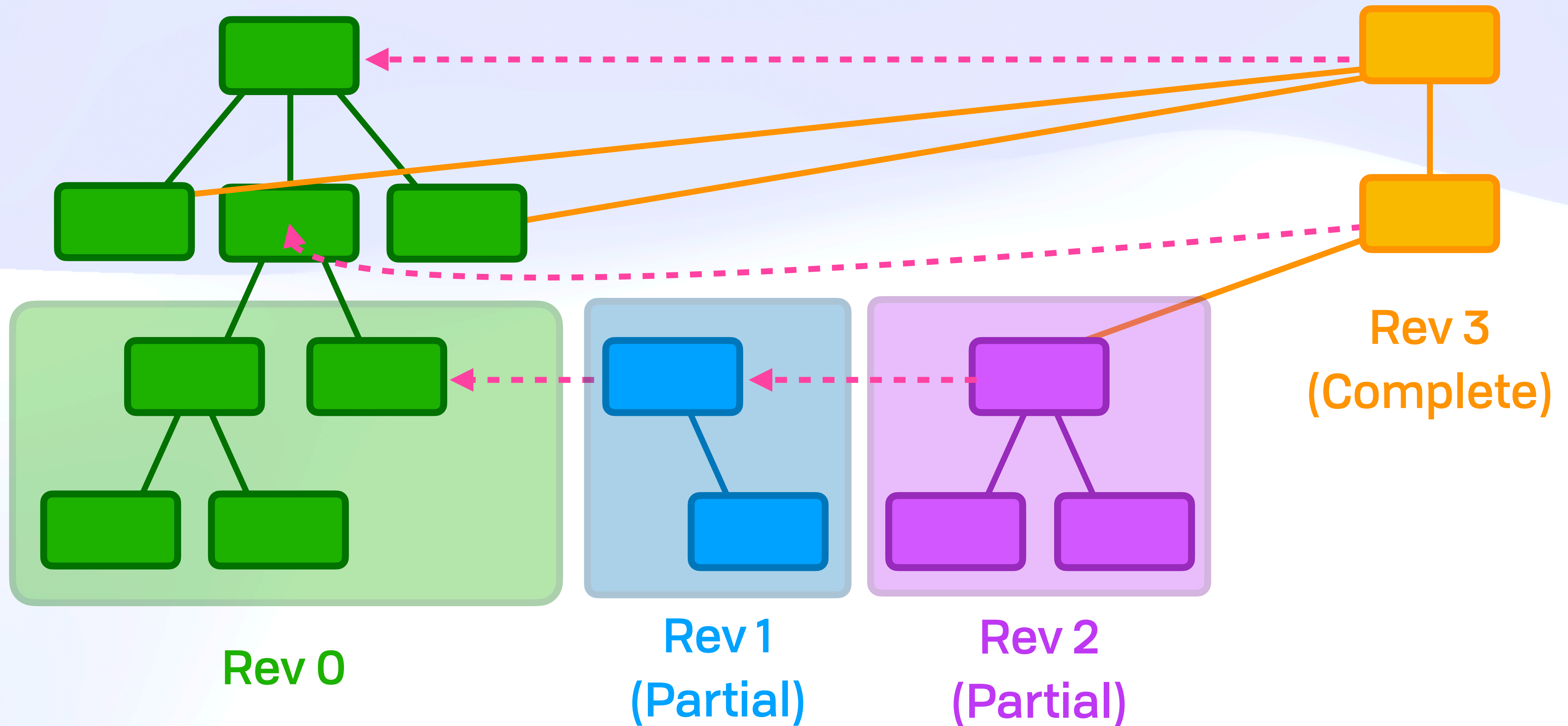
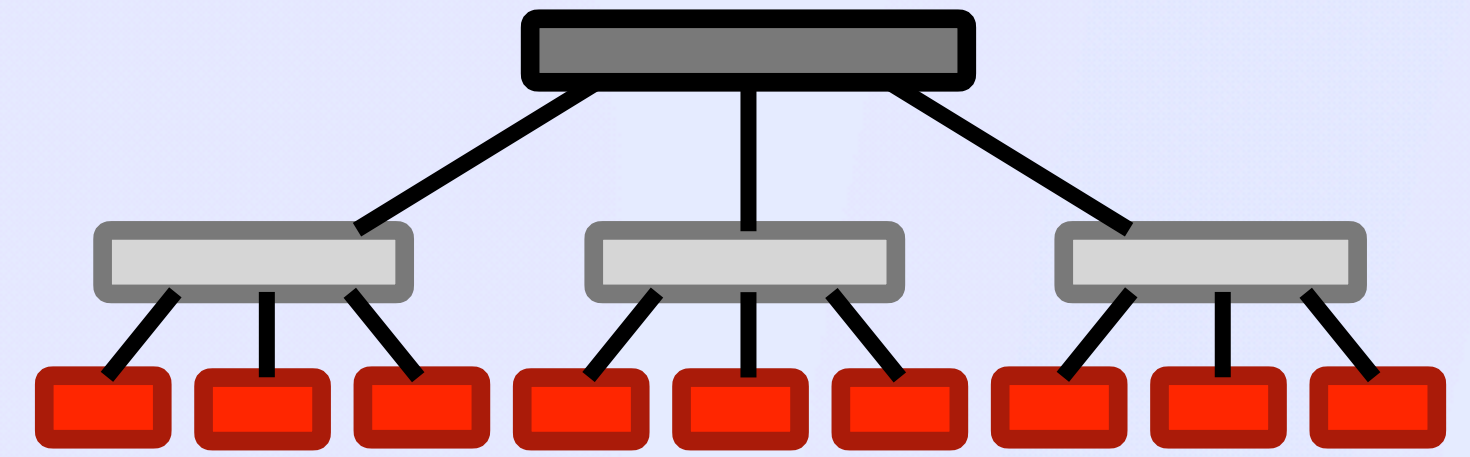
# Temporal Cryptree

## *Lazy Rooting*



# Temporal Cryptree

## *Lazy Rooting*



# ***What's In a Name?***

 Hiding Paths In Plain Sight 

What's In a Name? 🙈

# ***Why Hidden Paths?***

- TL;DR correlation is bad
- File hierarchy (space)
- File history (time)

What's In a Name? 🙈

# *Quasi-Commutative Hash*

What's In a Name? 🙈

# *Quasi-Commutative Hash*

X

What's In a Name? 🙈

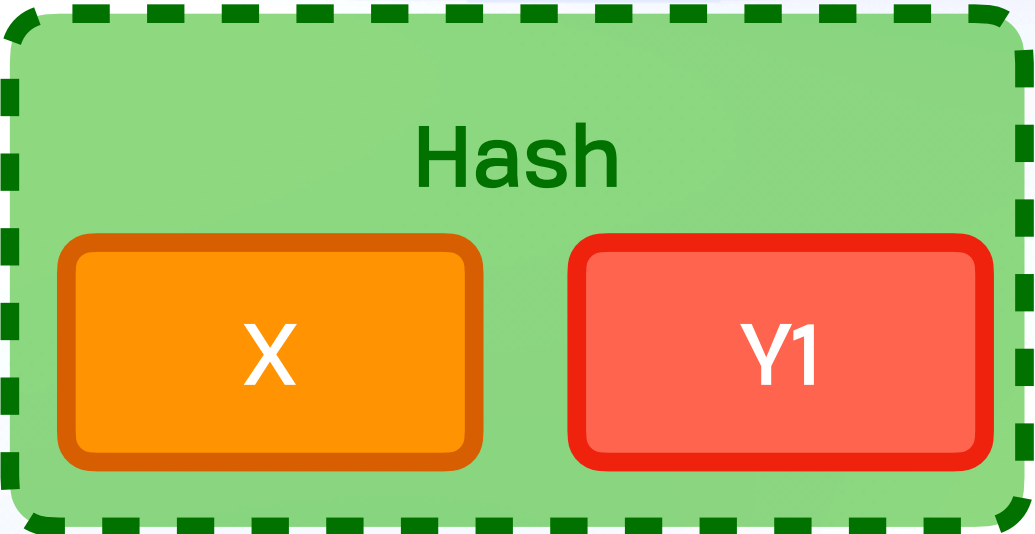
# *Quasi-Commutative Hash*

X

Y1

What's In a Name? 🙈

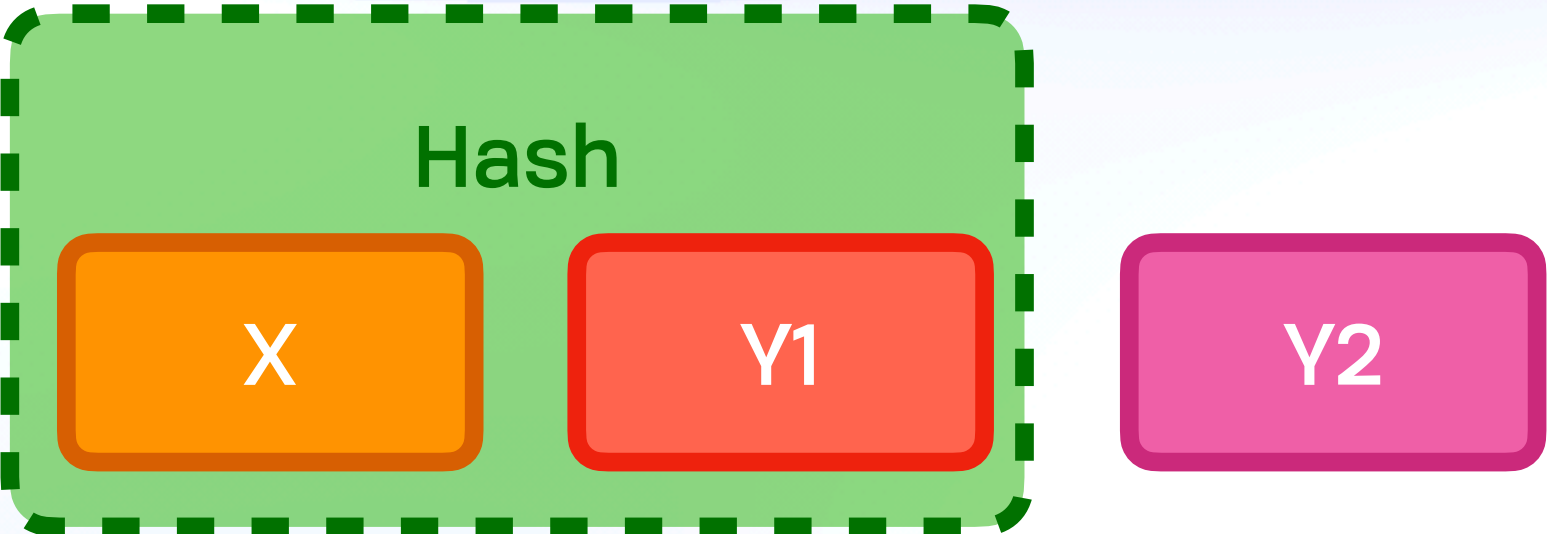
# *Quasi-Commutative Hash*





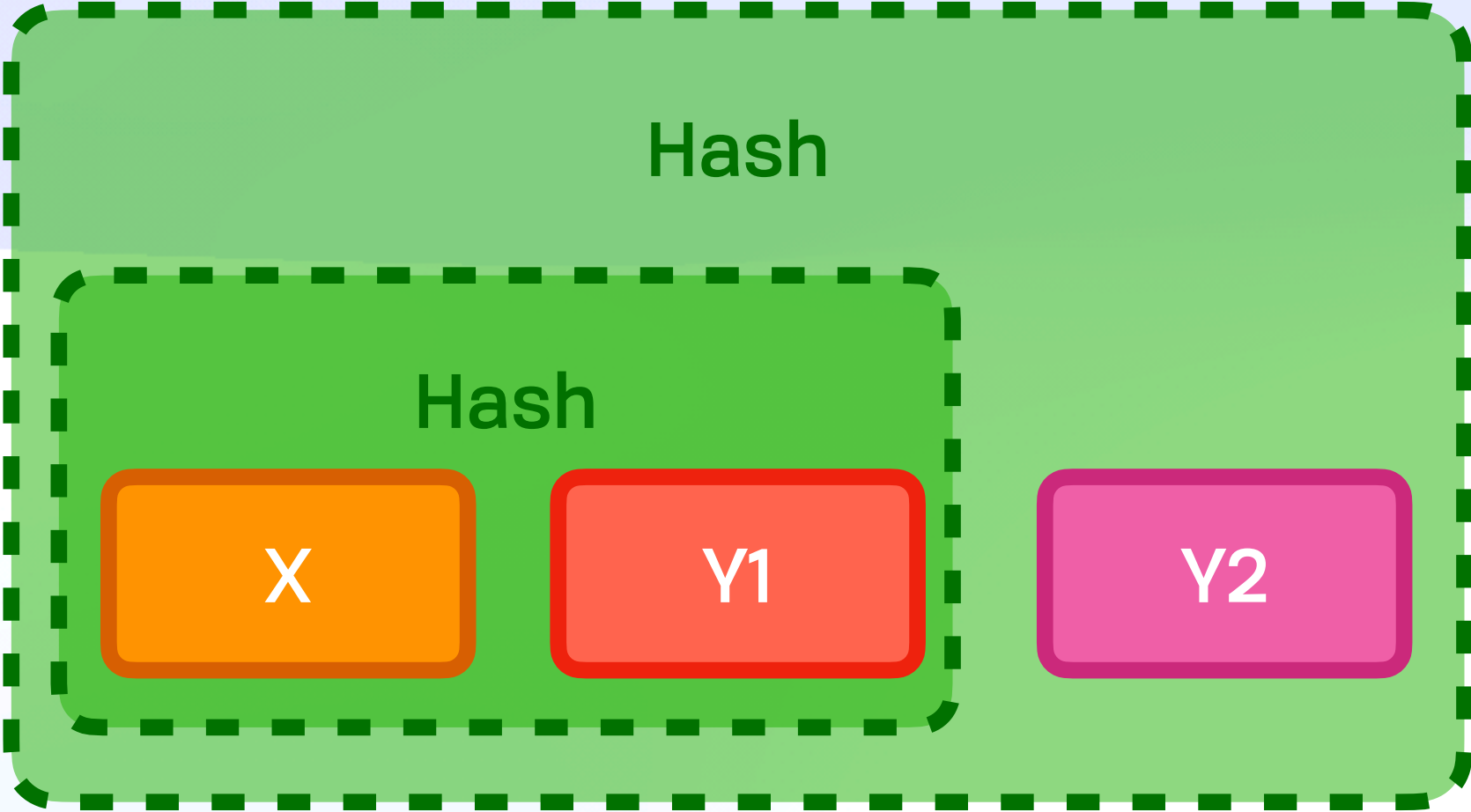
What's In a Name? 🙈

# *Quasi-Commutative Hash*



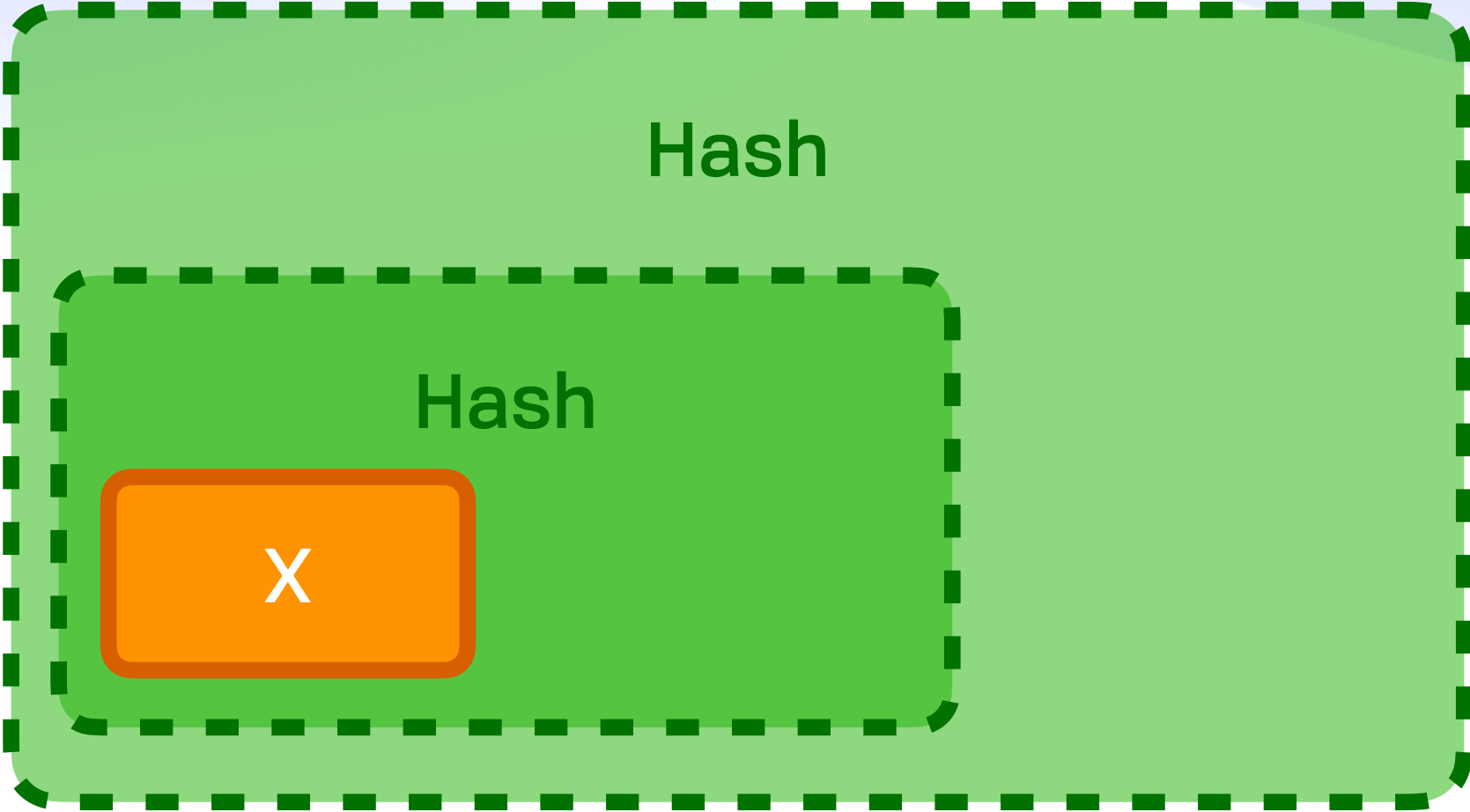
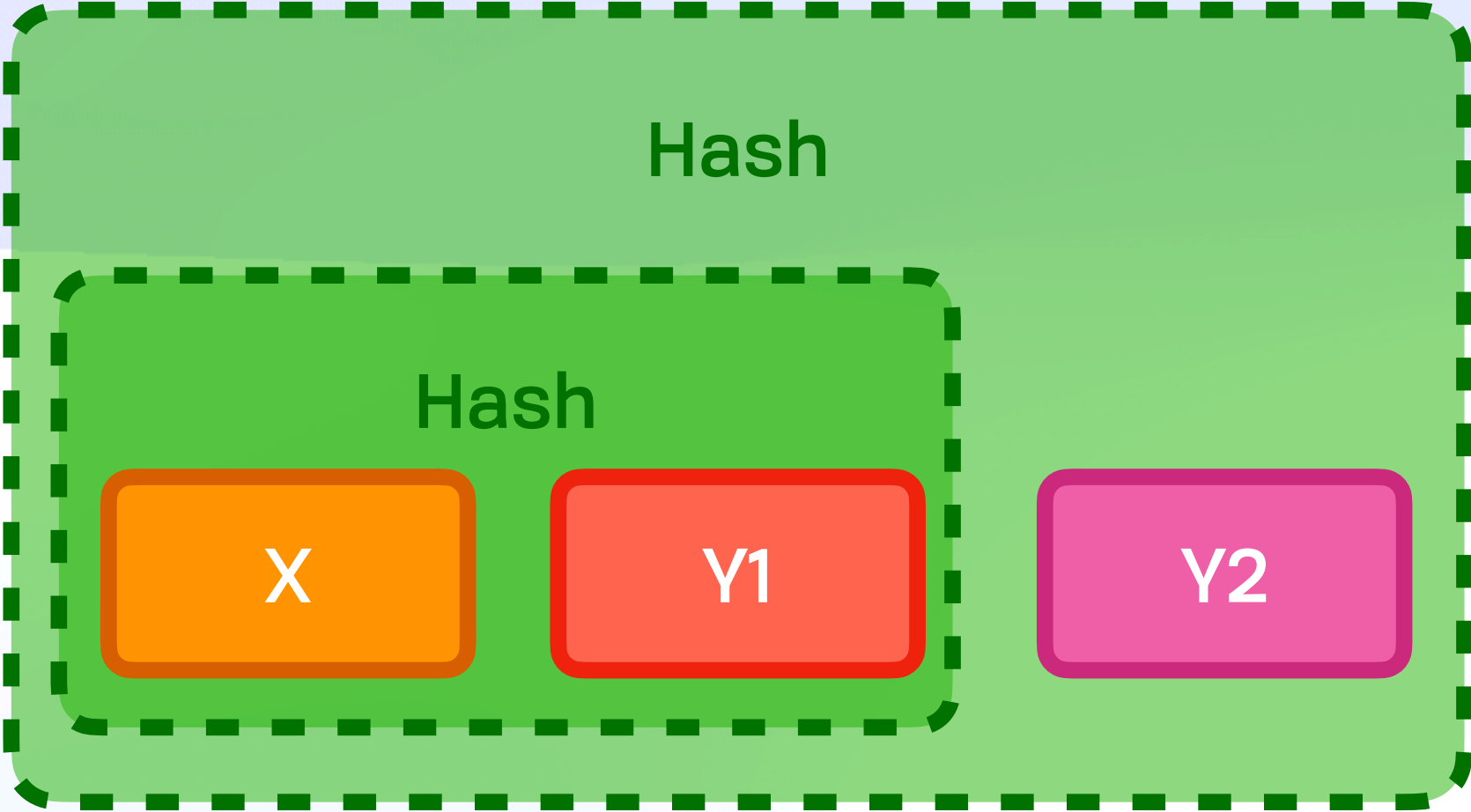
What's In a Name? 🙈

# *Quasi-Commutative Hash*



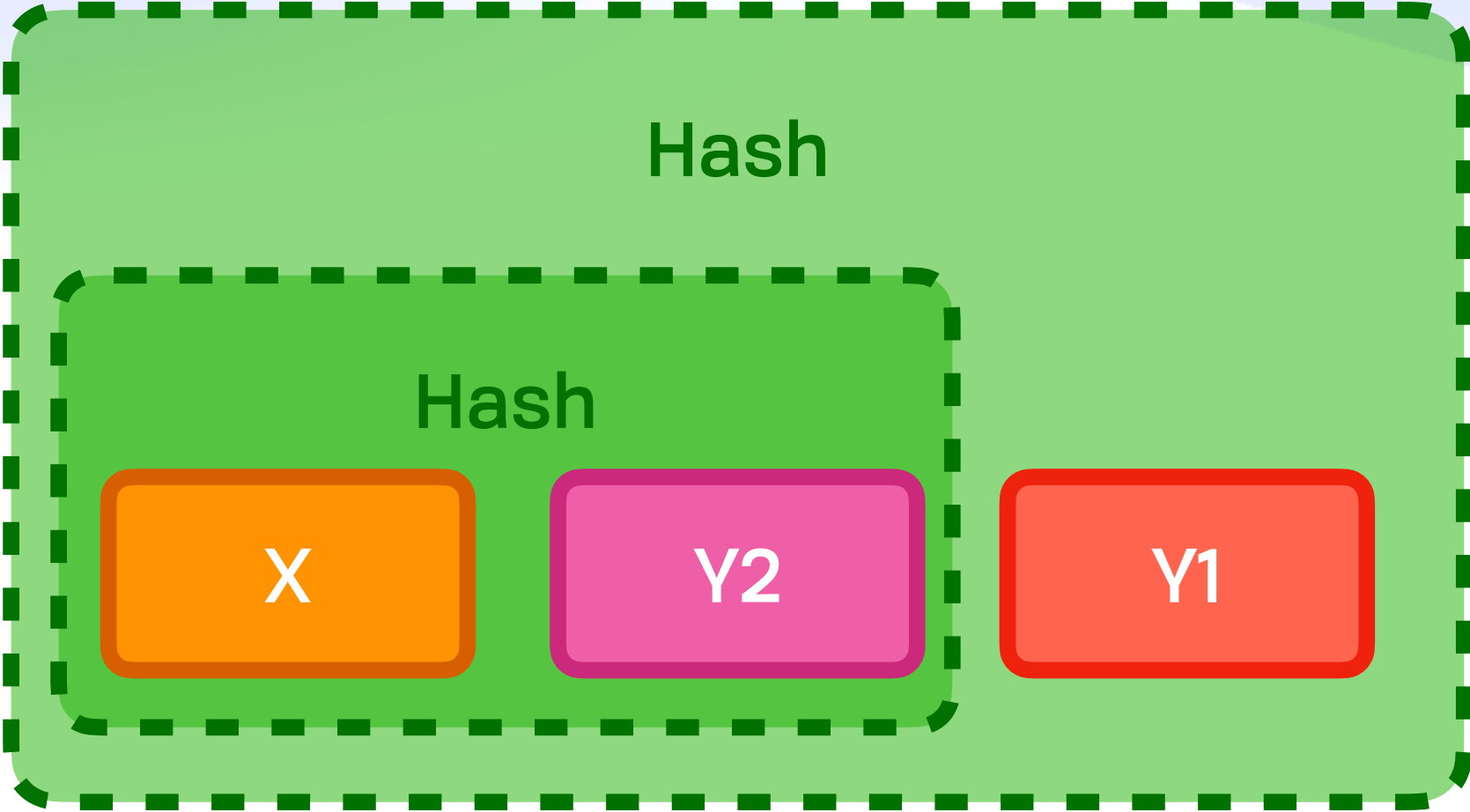
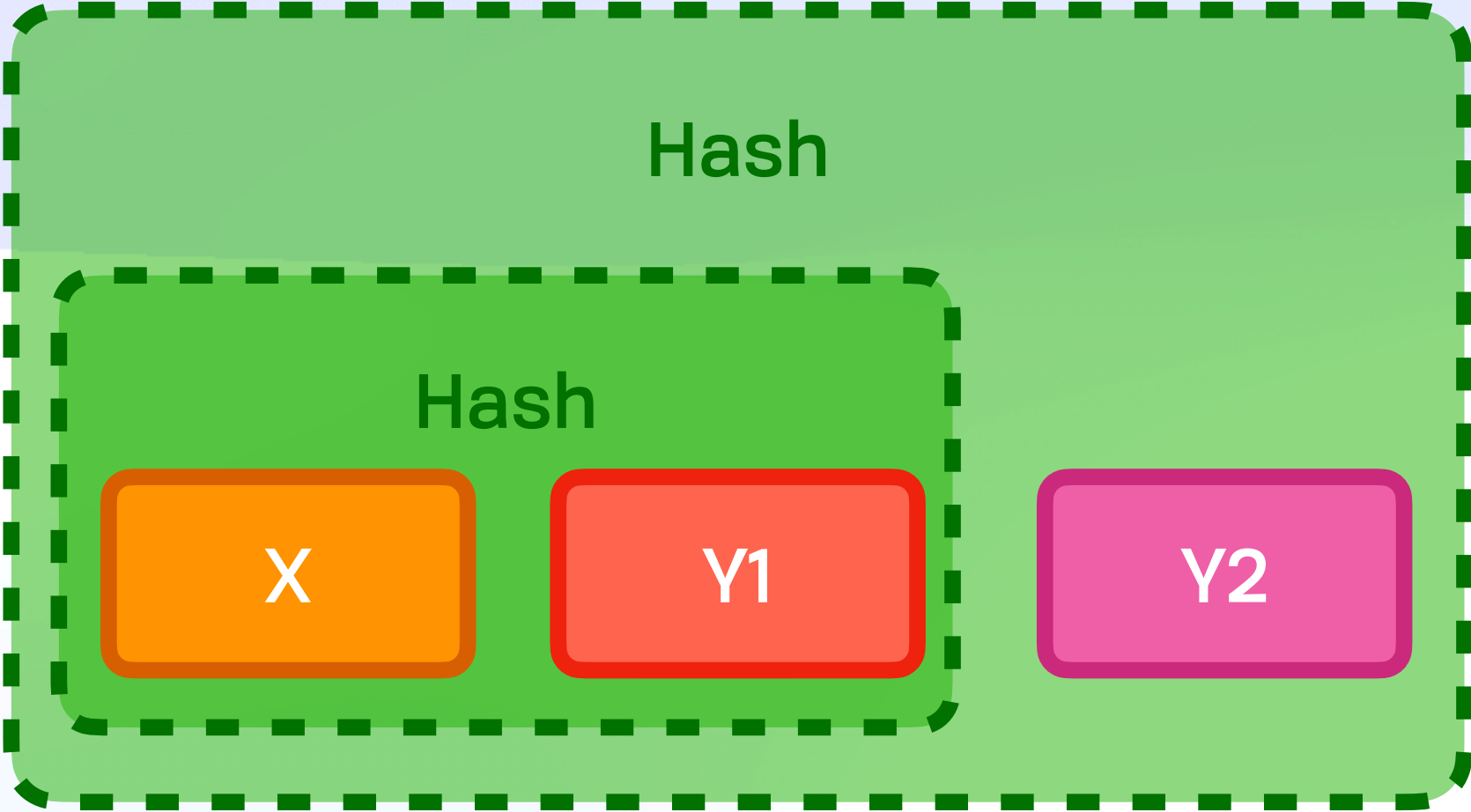
What's In a Name? 🙈

# Quasi-Commutative Hash



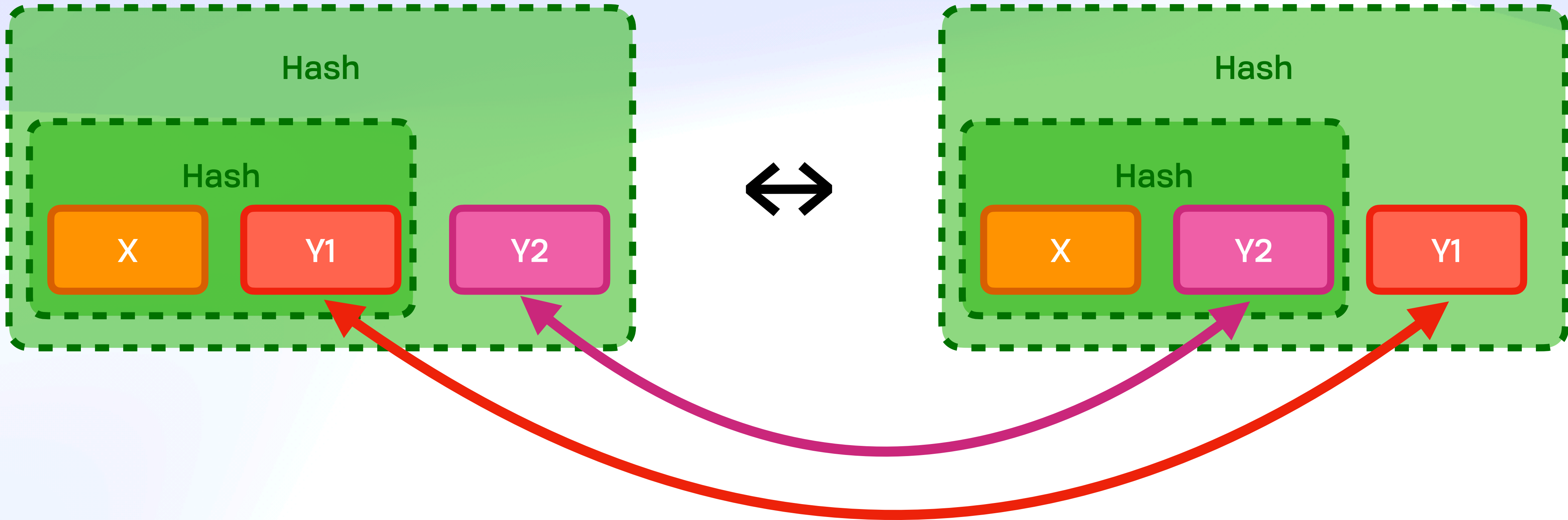
What's In a Name? 🙈

# *Quasi-Commutative Hash*



What's In a Name? 🙈

# Quasi-Commutative Hash



What's In a Name? 🙈

# ***Cryptographic Accumulator***

What's In a Name? 🙈

# *Cryptographic Accumulator*

/  
root i-number

/Strange Loop/  
SL i-number

/Photos/  
Photos i-number

/stage.png  
stage.png i-number

stage.png@42  
hash(AES Key)

What's In a Name? 🙈

# *Cryptographic Accumulator*

/  
root i-number

/Strange Loop/  
SL i-number

/Photos/  
Photos i-number

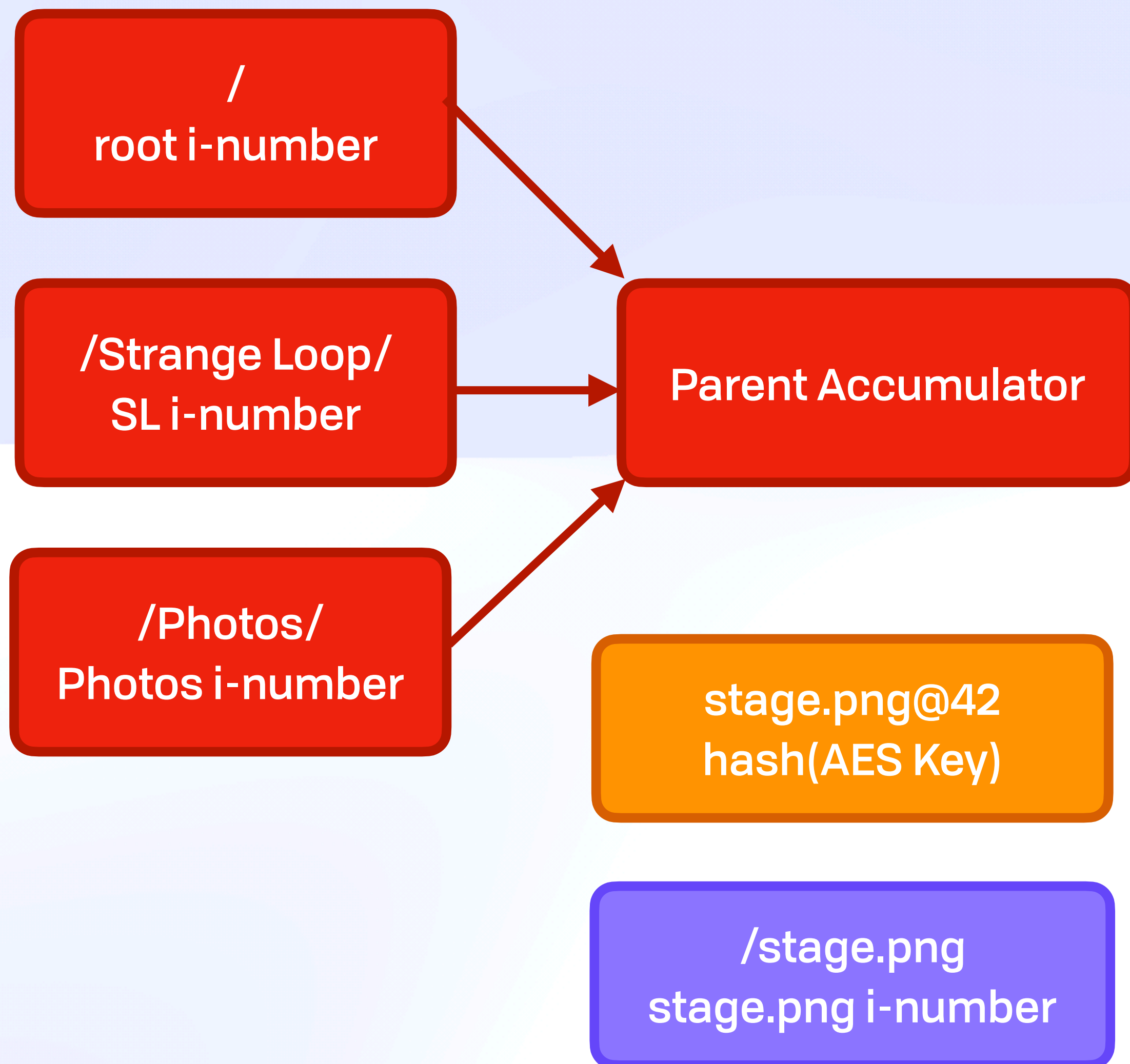
stage.png@42  
hash(AES Key)

/stage.png  
stage.png i-number



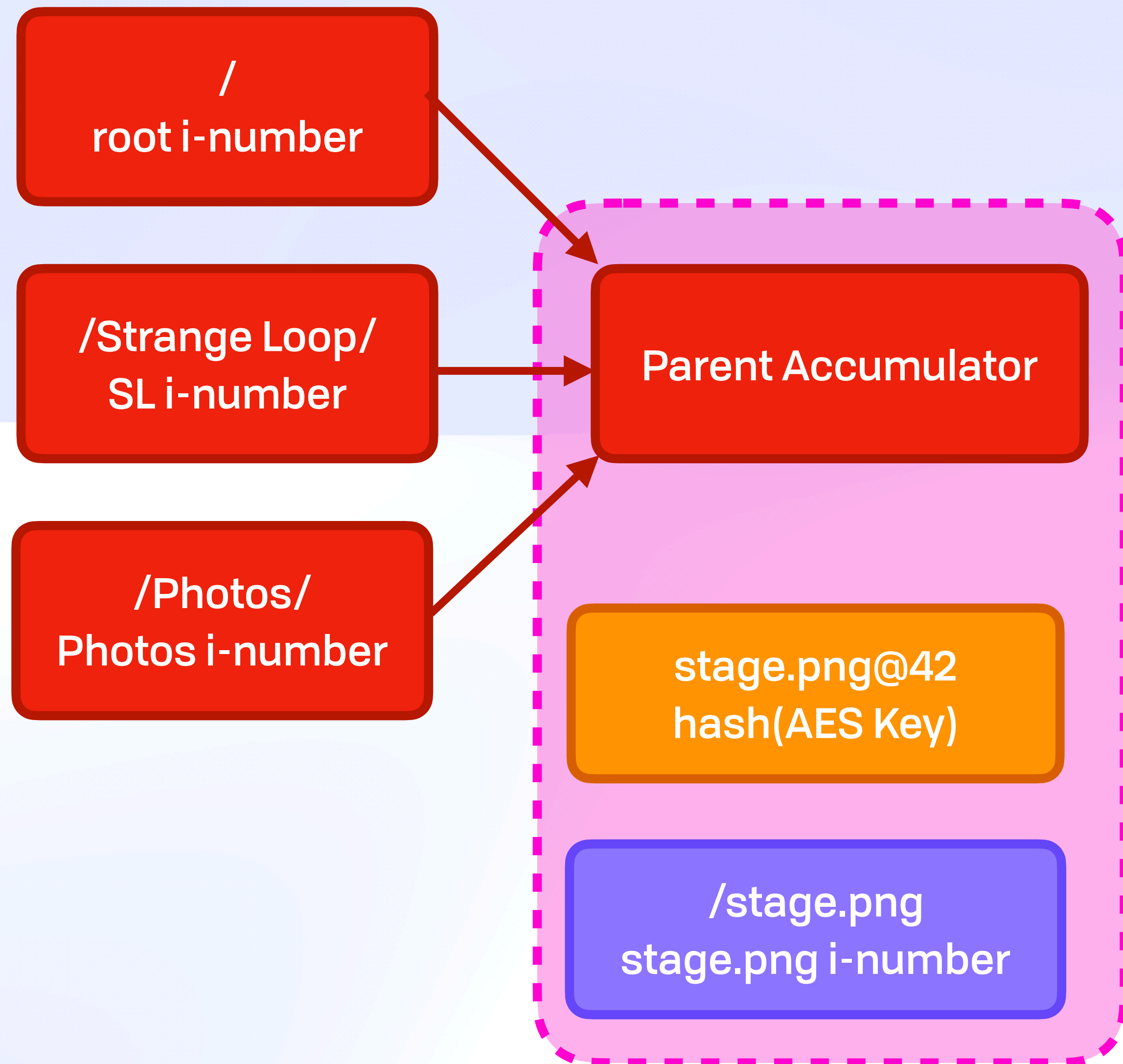
What's In a Name? 🙈

# *Cryptographic Accumulator*



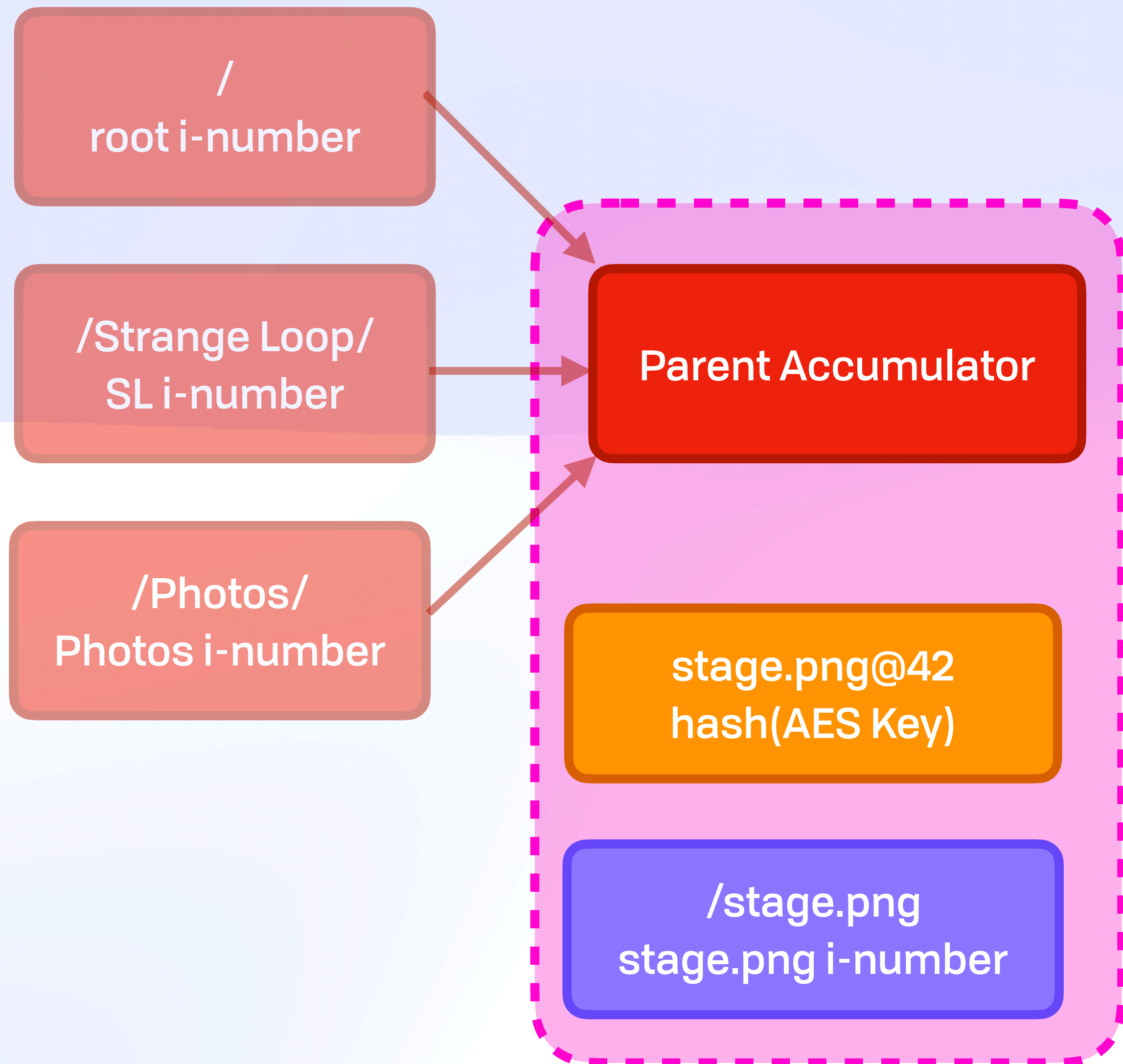
What's In a Name? 🙈

# *Cryptographic Accumulator*



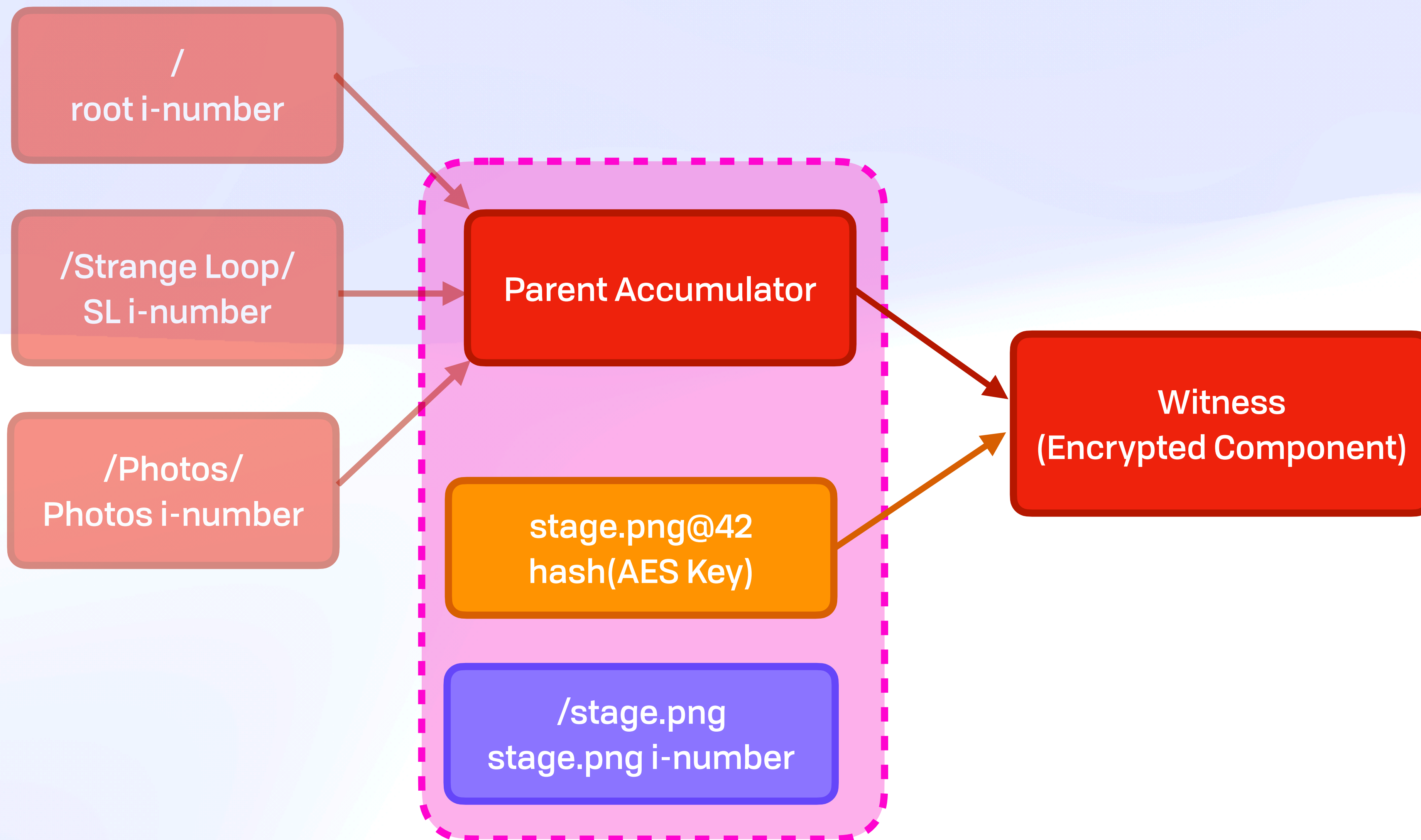
What's In a Name? 🙈

# *Cryptographic Accumulator*



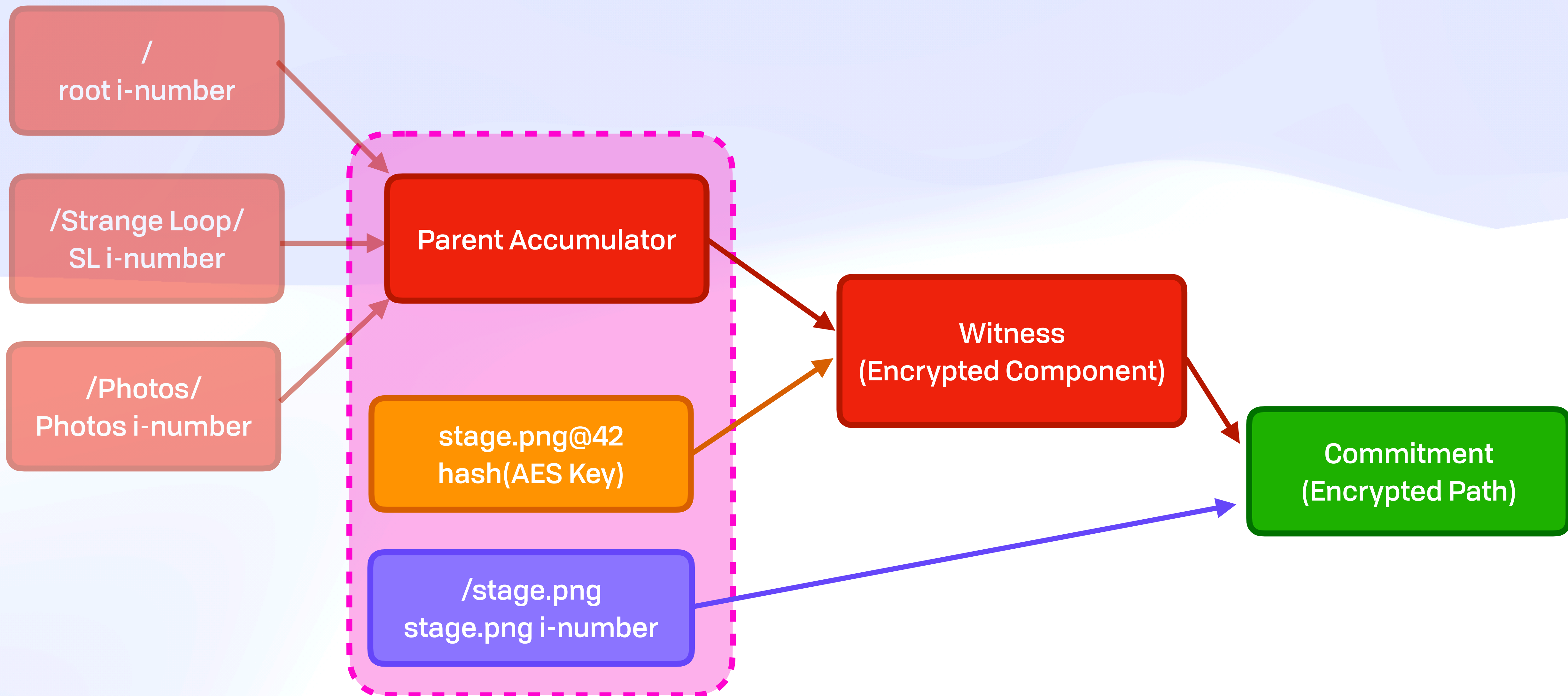
What's In a Name? 🙈

# Cryptographic Accumulator



What's In a Name? 🙈

# Cryptographic Accumulator



What's In a Name? 🙈

# *Cryptographic Accumulator*

/  
root i-number

/Photos/  
Photos i-number

/Strange Loop/  
SL i-number

stage.png@42  
hash(AES Key)

/stage.png  
stage.png i-number

What's In a Name? 🙈

# *Cryptographic Accumulator*

/  
root i-number

stage.png@42  
hash(AES Key)

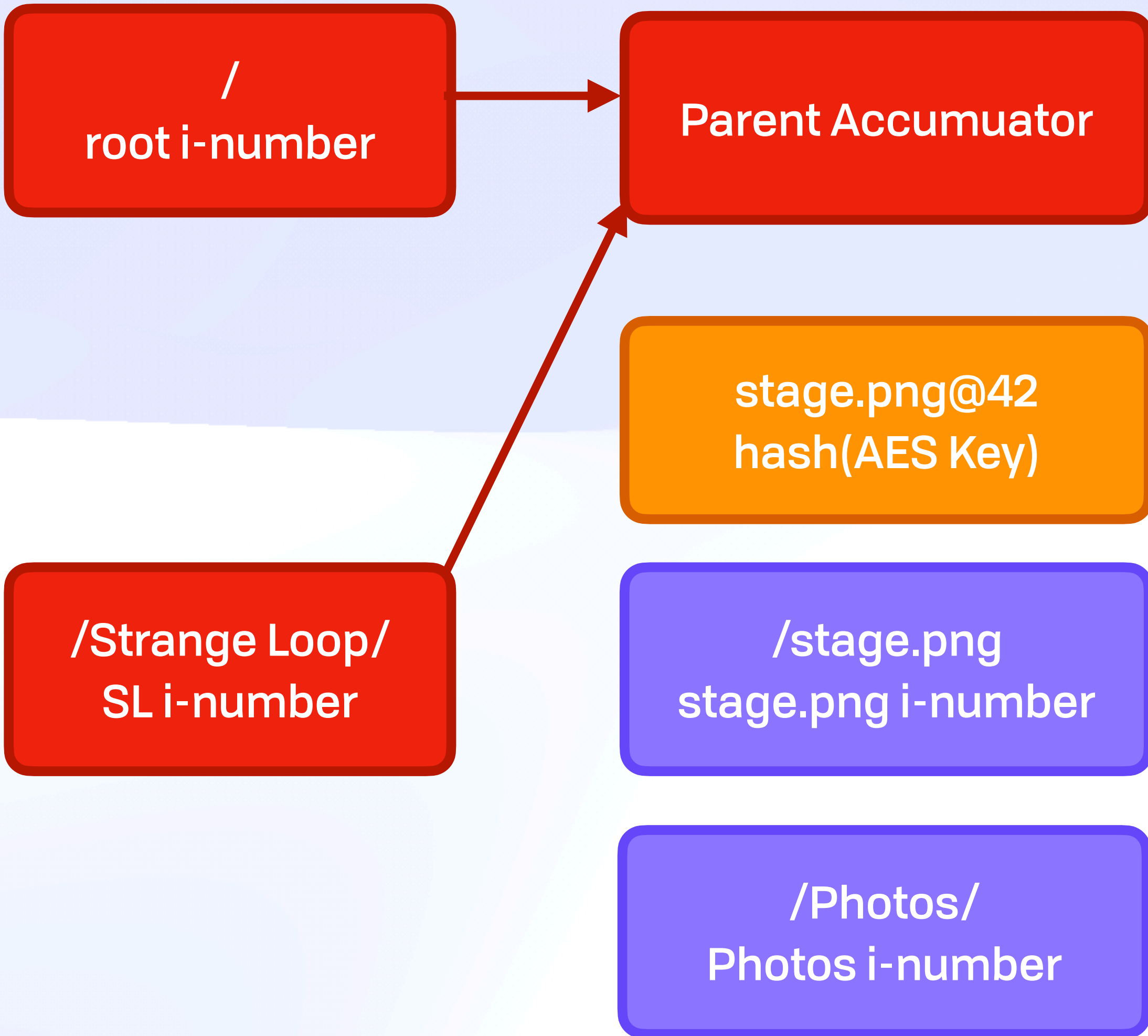
/Strange Loop/  
SL i-number

/stage.png  
stage.png i-number

/Photos/  
Photos i-number

What's In a Name? 🙈

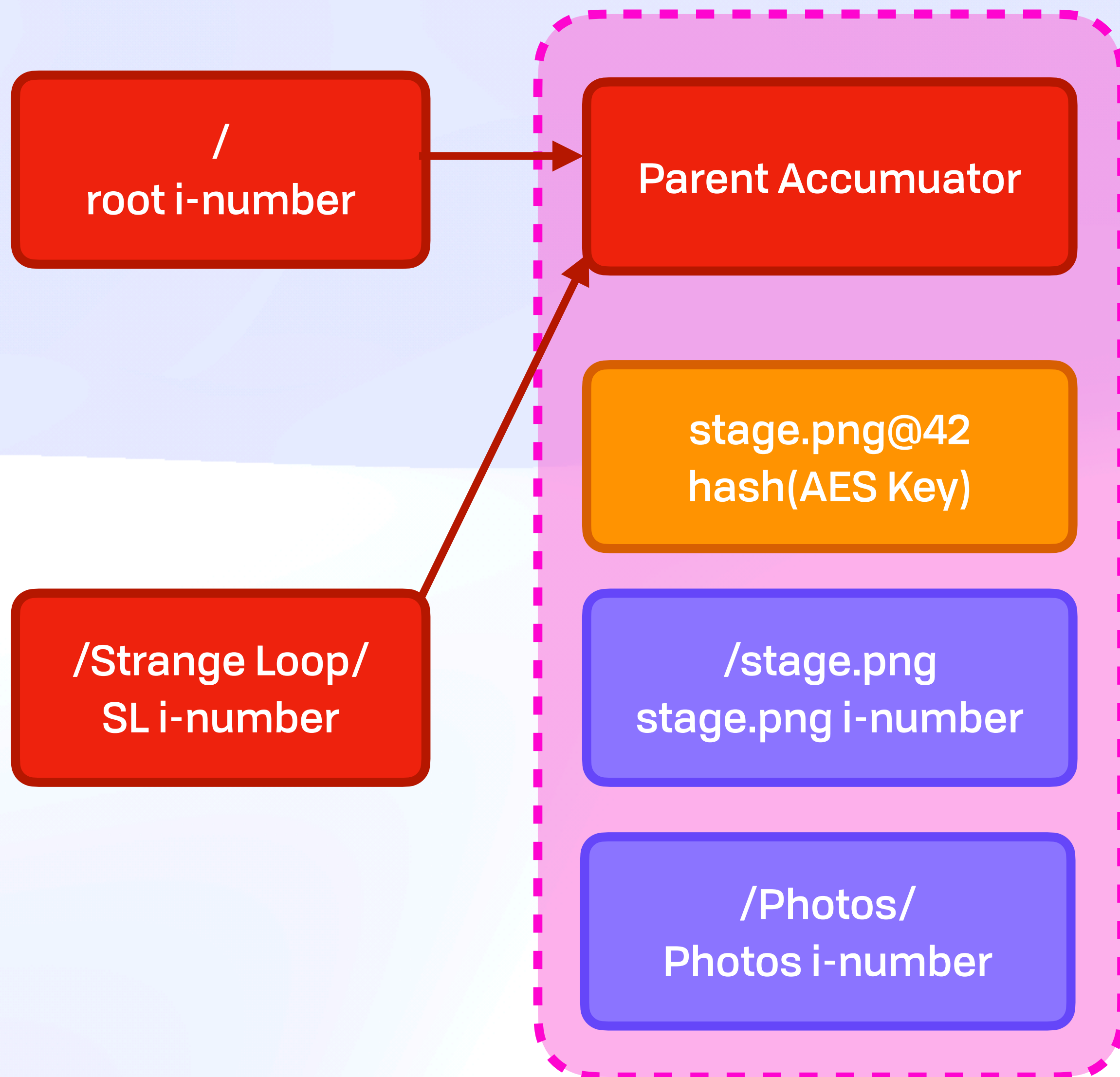
# Cryptographic Accumulator





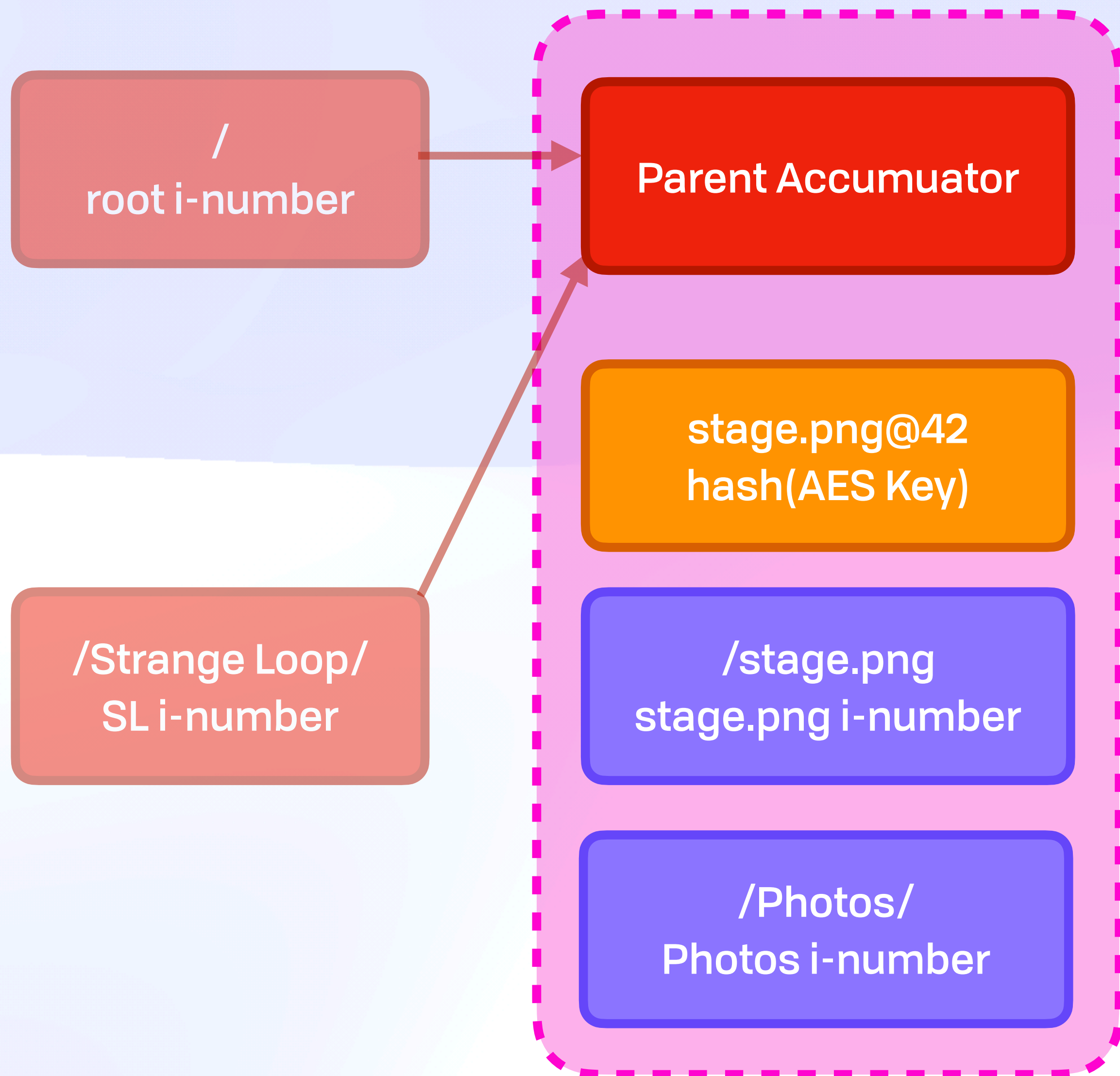
What's In a Name? 🙈

# *Cryptographic Accumulator*



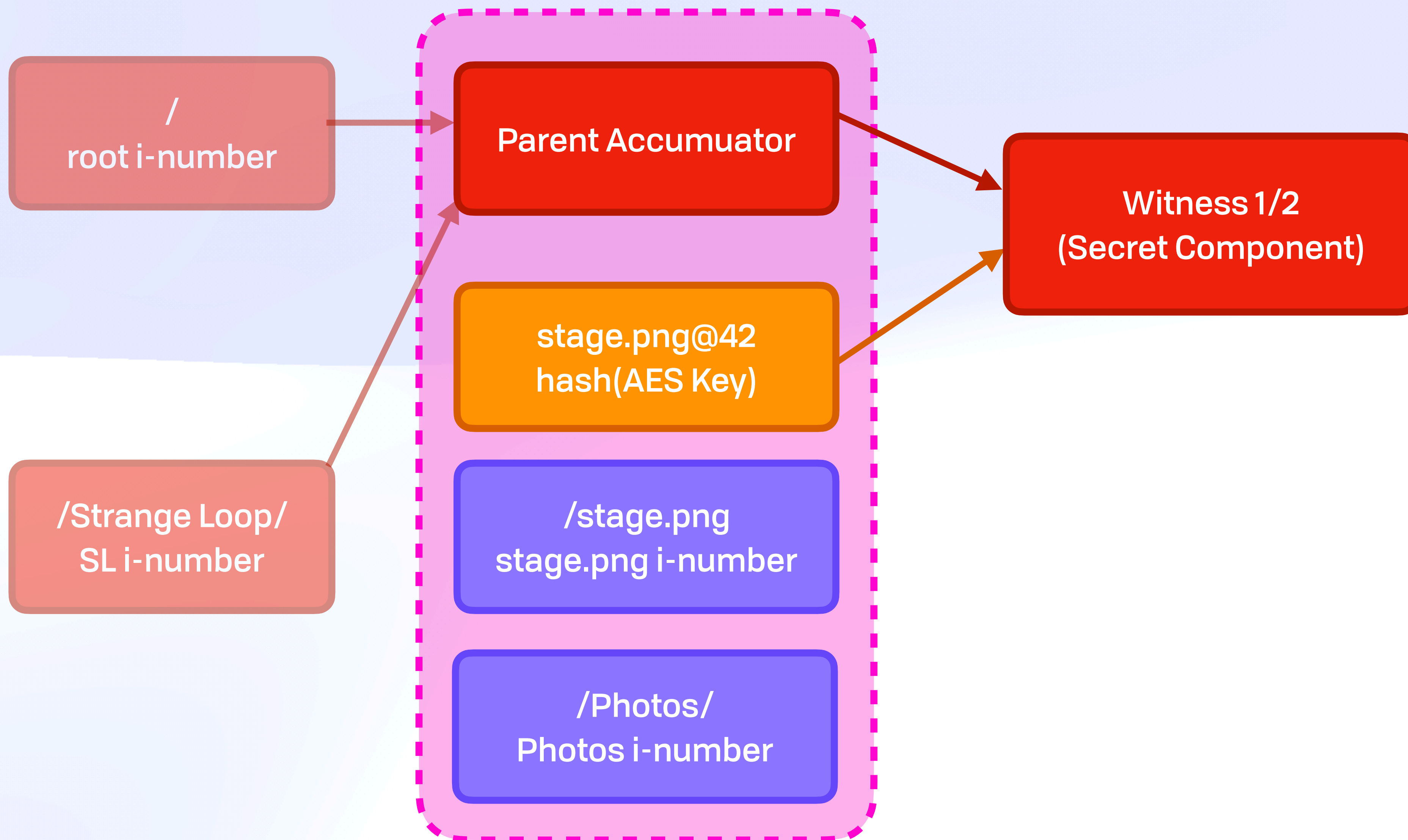
What's In a Name? 🙈

# *Cryptographic Accumulator*



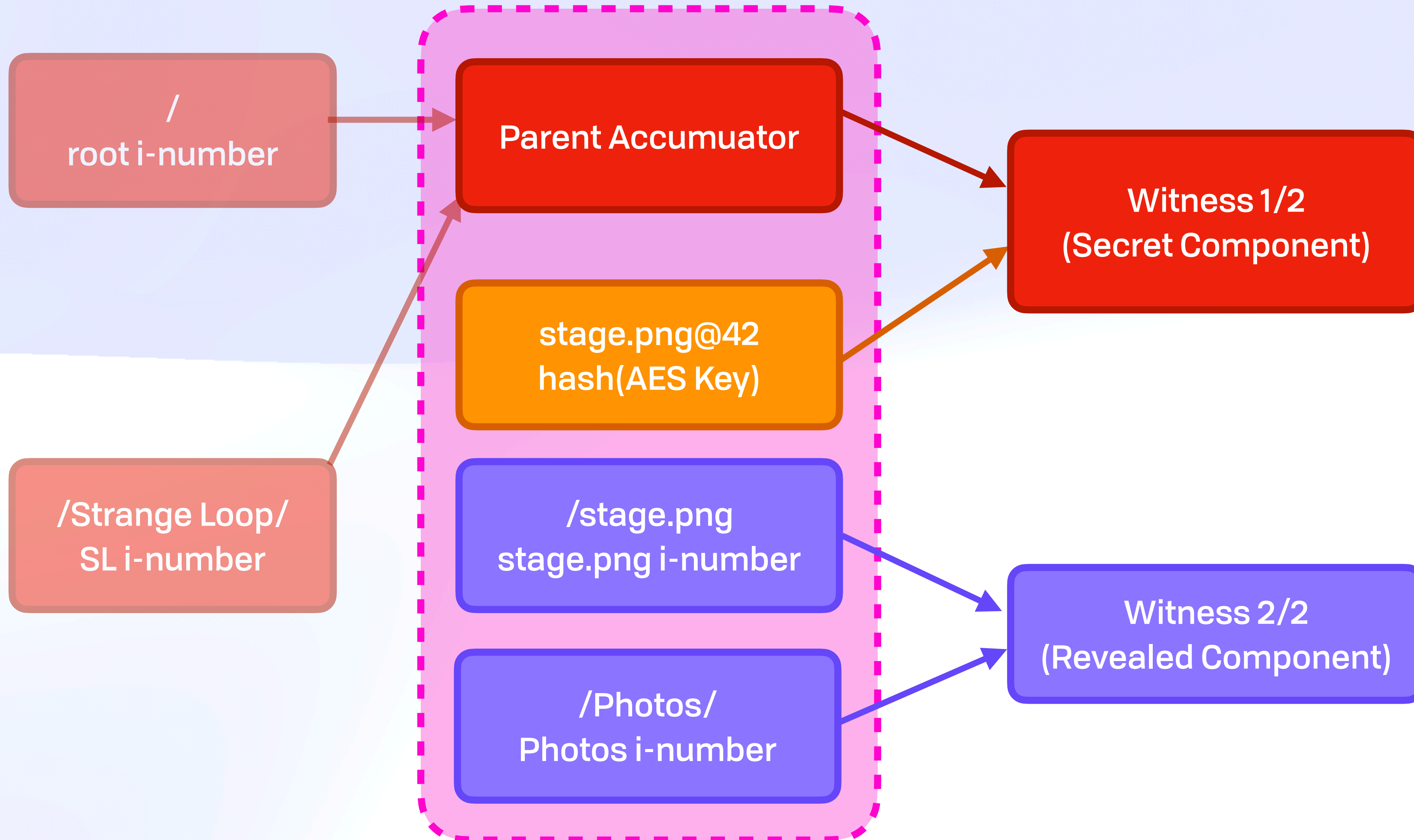
What's In a Name? 🙈

# Cryptographic Accumulator



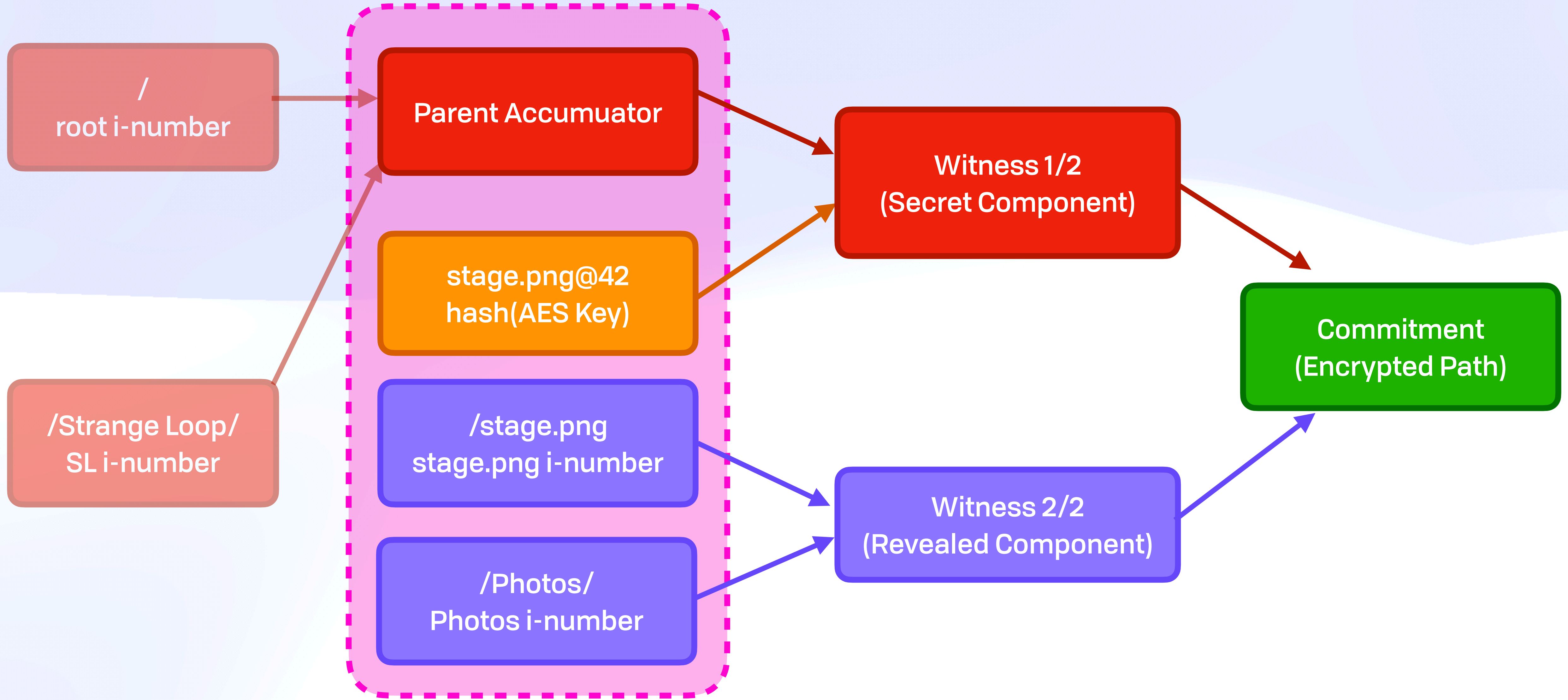
What's In a Name? 🙈

# Cryptographic Accumulator



What's In a Name? 🙈

# Cryptographic Accumulator



# *Wrap Up*



Wrap Up 

## *Is That All?*

- Hash linked files
- Privacy-preserving paths
- Cryptrees: one key per entrypoint
- Temporal access control
- History & fork/merge on public and private data

Wrap Up 📦

## ***Future Work***

- Wasm & native SDKs based on rs-wnfs — soon!
- Local-first, encrypted-at-rest, collaborative datalog
- Faster, more reliable networking
- ZK-ify private tree certificates
- FUSE support



Wrap Up 📦

# *Where To Get Started*

`guide.fission.codes`

`github.com/wnfs-wg/spec`

`github.com/wnfs-wg/rs-wnfs`



The Difficult is that which can be done immediately;  
***the Impossible that which takes a little longer.***

— George Santayana



 **Thank You, Strange Loop** 

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**brooklyn@fission.codes**

**<https://fission.codes>**

**[discord.gg/fissioncodes](https://discord.gg/fissioncodes)**

**[github.com/wnfs-wg\(/spec\)](https://github.com/wnfs-wg/spec)**