Package Transparency for WebAssembly Registries

Kyle Brown, SingleStore

Overview

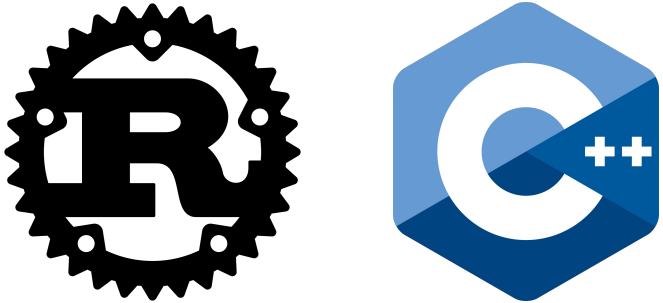
- Introduce **WebAssembly (Wasm)**
- What is a **Package Registry?**
- Applying **Certificate Transparency** to **Package Registries**
- **Package Transparency** & **warg**
- **Package Transparency** vs. **Various Attacks**

WebAssembly (Wasm)

WebAssembly (Wasm) is…

A platform-agnostic **“compile target”** or…

something you can compile programs to.



Well-supported

Work is in progress for many more languages

History

Wasm was created as a web technology

It became a W3C Standard in 2019

supported by major browsers since 2017



Wasm **isn’t** *just* for the web

Wasm has really valuable properties

- **Portability**
- **Speed**
  - Low startup latency
  - Near-native performance
- **Security**
  - Capability safety
  - Sandboxing & memory isolation

People using **Wasm** outside the browser

Database Extensibility

Distributed Apps

Edge Computing

Serverless

BYTECODE
ALLIANCE

Wasm applications and libraries will be **composed**, **shared**, and **deployed**

Wasm needs a native package registry

We need a registry as secure as Wasm itself

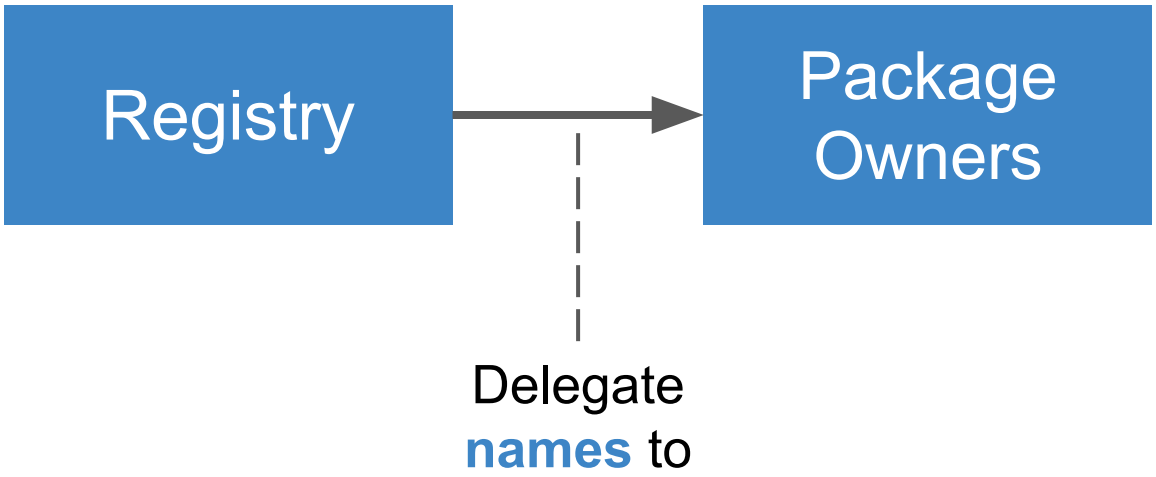
You wouldn’t seal a vault…

with a Cheeto

What is a Package Registry?

Package Registries’ Role

Package Registries' Role



Package Registries' Role

A Registry is an Index

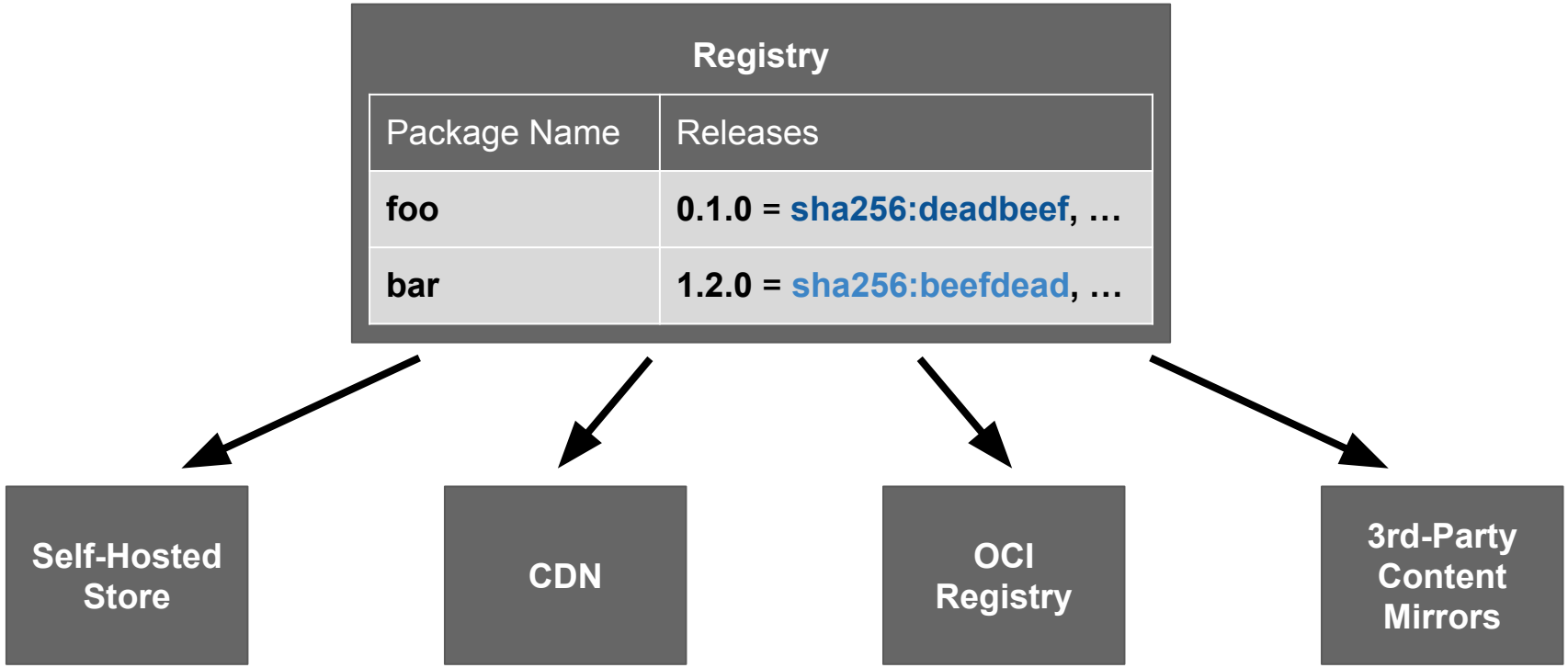
(name, version) ⟶ package digest

Registries must control metadata

Registry

Package Name	Releases
foo	**0.1.0 = sha256:deadbeef, …**
bar	**1.2.0 = sha256:beefdead, …**

Registries may delegate content hosting



How can we apply Certificate Transparency to Package Registries?

People are able to detect when CAs misissue certificates

Clients *should* be able to detect when registries accept invalid package updates

Package Transparency

“Package transparency is

Lann Martin, Fermyon

“Package transparency is publishing cryptographically-verifiable commitments

Lann Martin, **Fermyon**

“Package transparency is publishing cryptographically-verifiable commitments to the state of a package repository

Lann Martin, **Fermyon**

“Package transparency is publishing cryptographically-verifiable commitments to the state of a package repository to allow auditing of the actions of package authors and the registry itself over time.”

Lann Martin, **Fermyon**

Components of Package Transparency

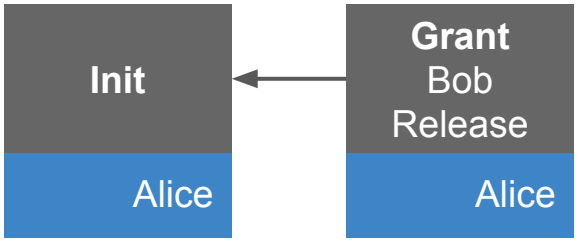
1. Publicly Available Package Registry State
2. Cryptographically-Verifiable Commitments
3. Auditing Package Authors and the Registry

warg is a protocol for
Package Transparency

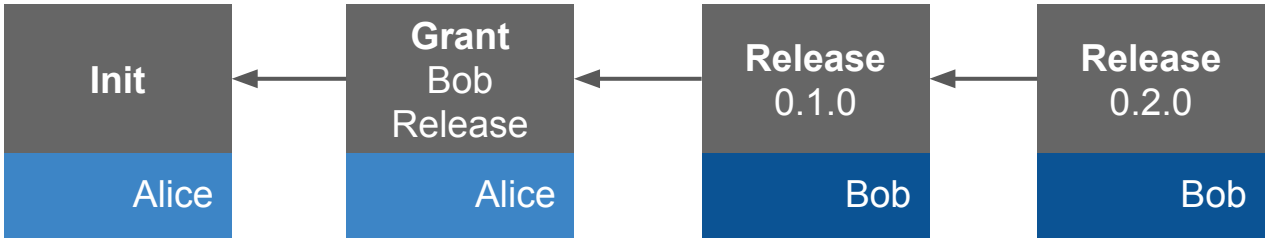
Publicly Available Registry State

Append-only Package Logs

Append-only Package Logs



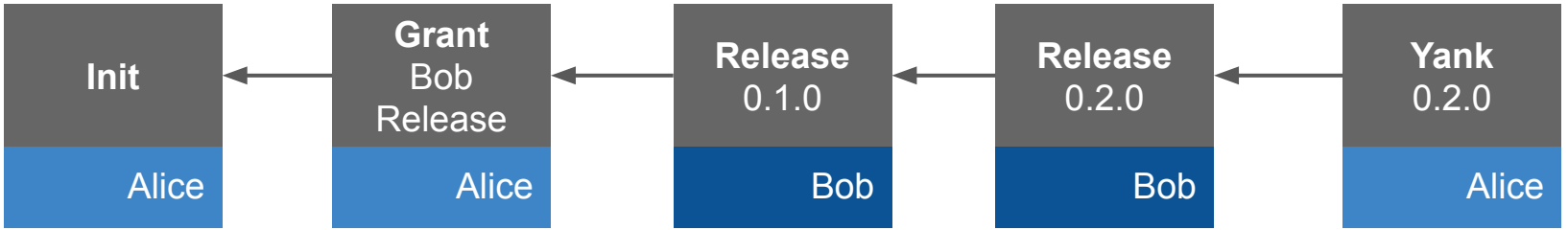
Append-only Package Logs



Releases
- 0.1.0

Releases
- 0.1.0
- 0.2.0

Append-only Package Logs

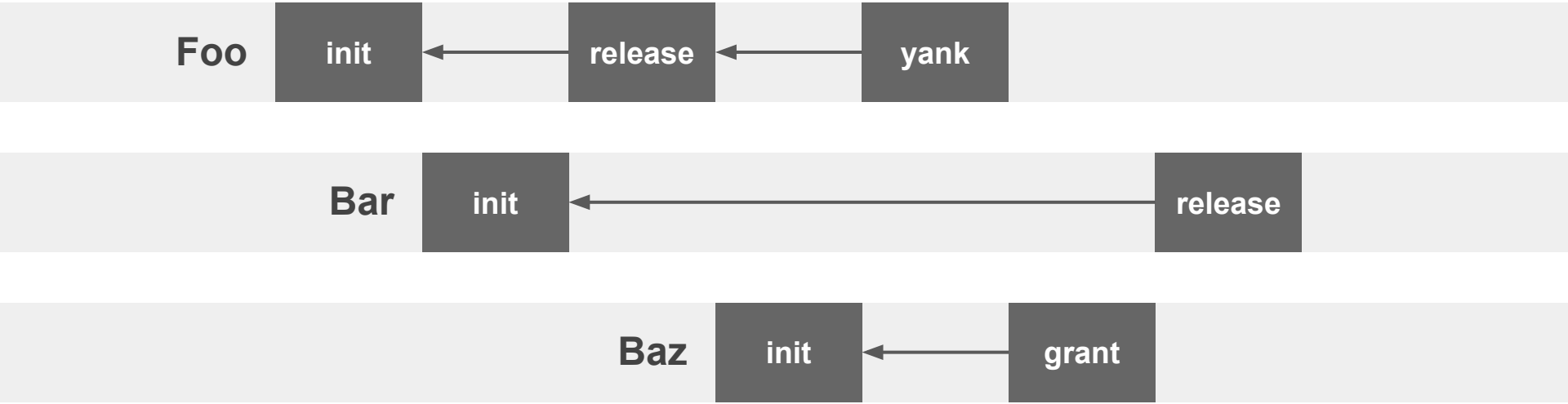


Releases
- 0.1.0

Releases
- 0.1.0
- 0.2.0

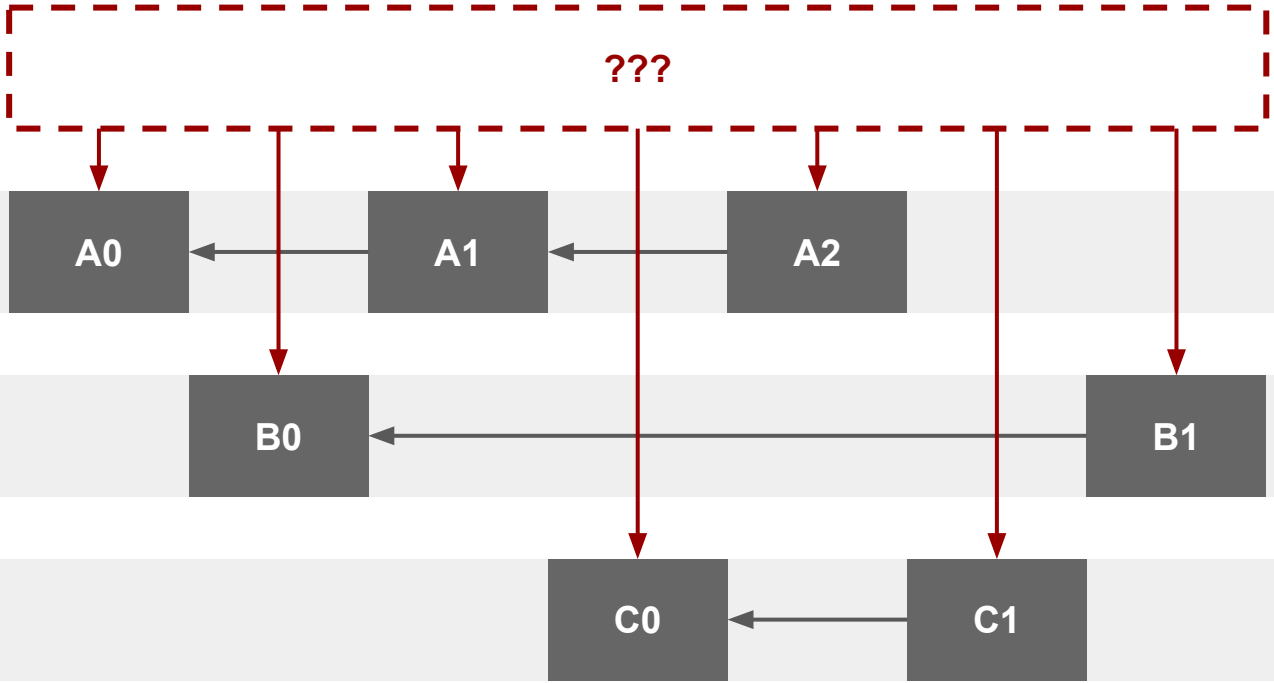
Releases
- 0.1.0
- ~~0.2.0~~

Package Logs



Cryptographically-Verifiable Commitments

What does the registry claim has happened?



Verifiable Log
(Merkle Tree)

What does a Verifiable Log do?

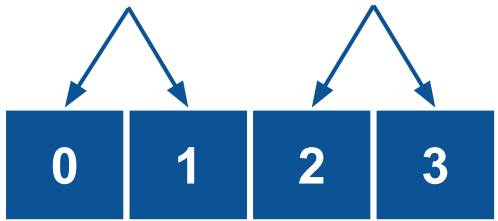
- A **Verifiable Log** is a total ordering of records
- Each **Verifiable Log** is described by a unique hash
- You can cryptographically check if a record is in the log

Verifiable Log (Merkle Tree)

Verifiable Log (Merkle Tree)

Leaf Hash
hash (0b00 || **leaf)**

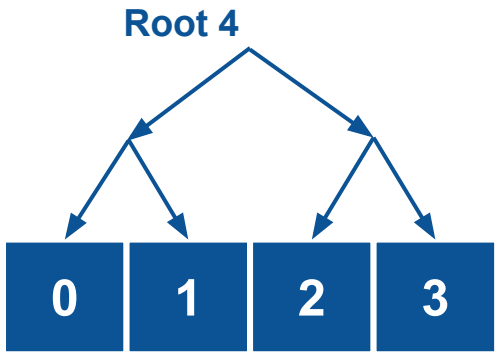
Verifiable Log (Merkle Tree)



Branch Hash
hash (0b01 || left || right)

Leaf Hash
hash (0b00 || leaf)

Verifiable Log (Merkle Tree)



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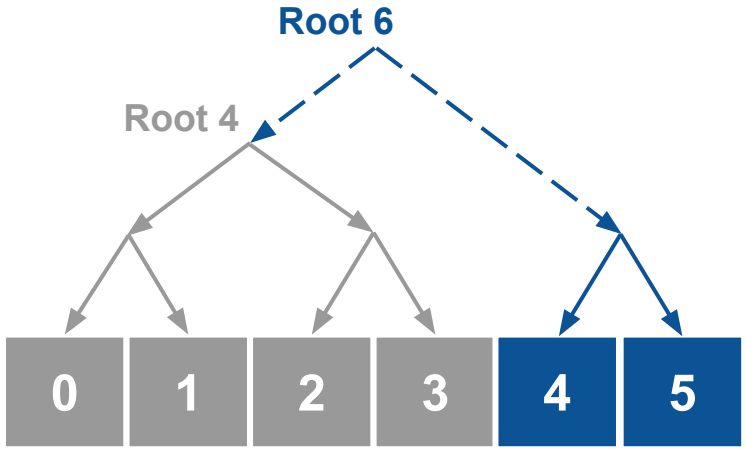
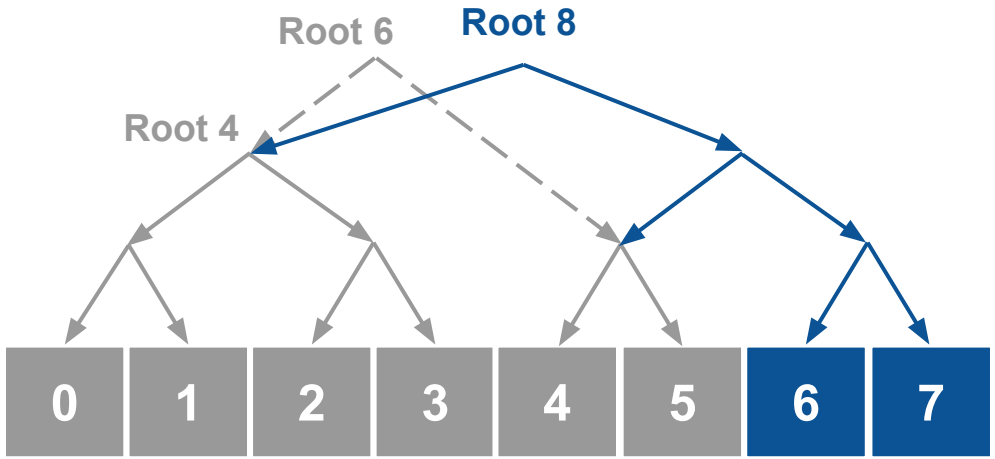
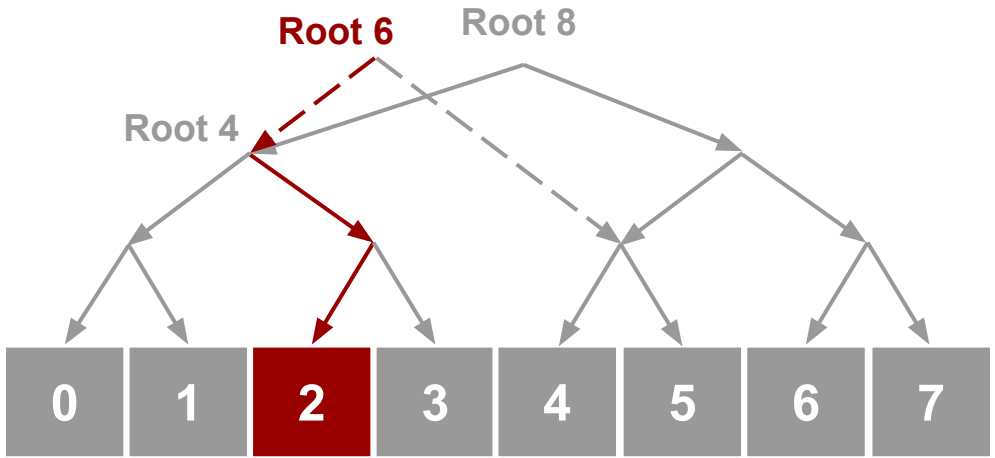
Verifiable Log (Merkle Tree)



Verifiable Log (Merkle Tree)



Verifiable Log (Merkle Tree) - Inclusion Proofs



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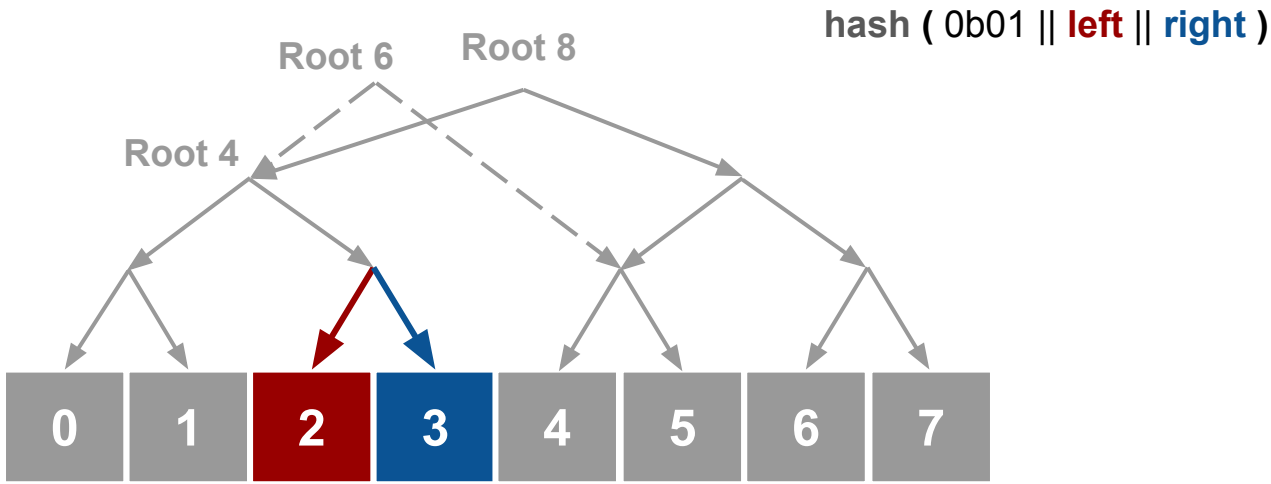

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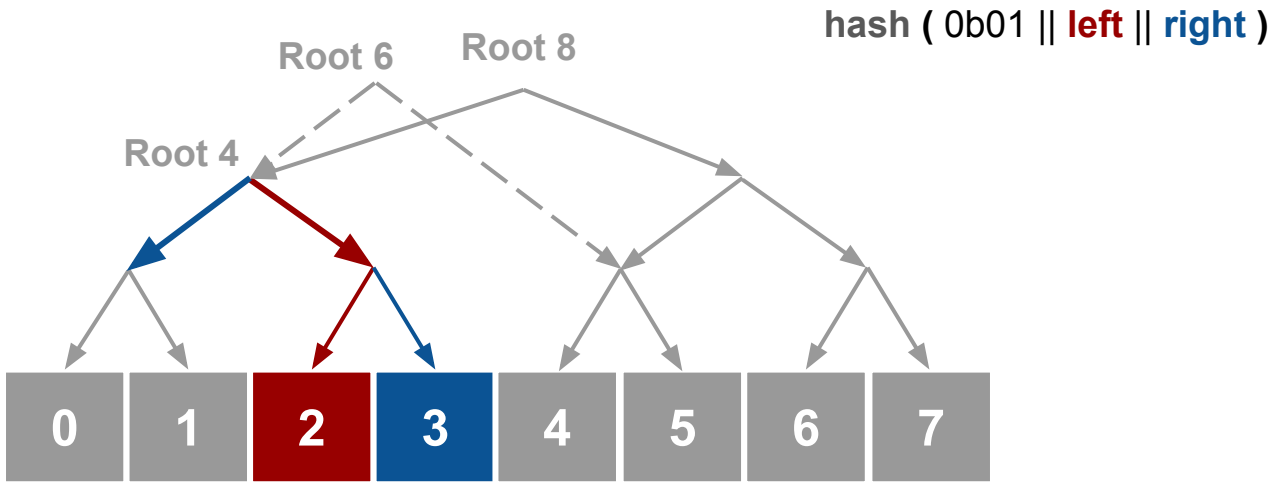

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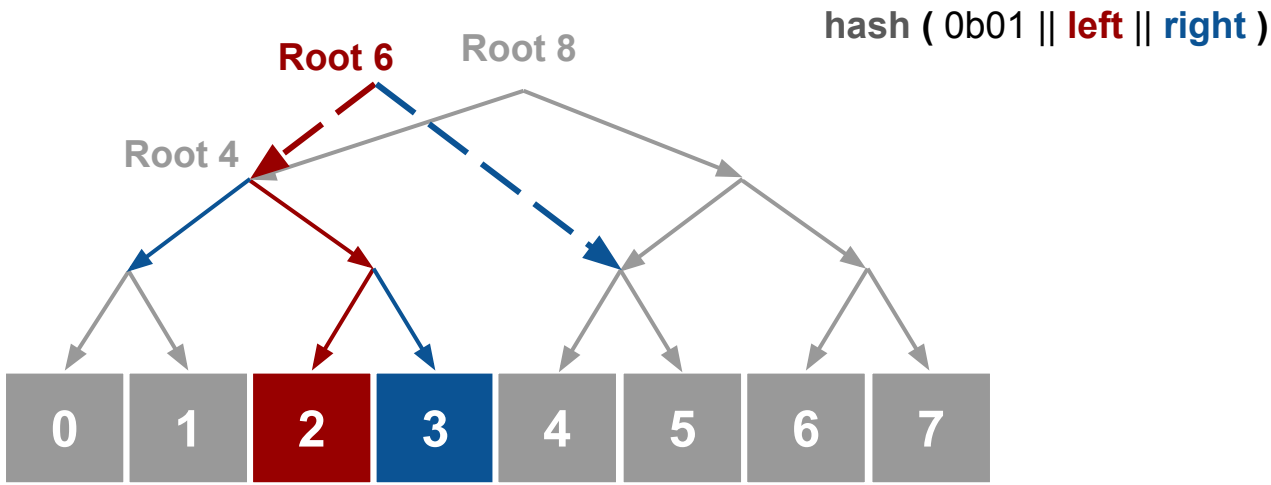
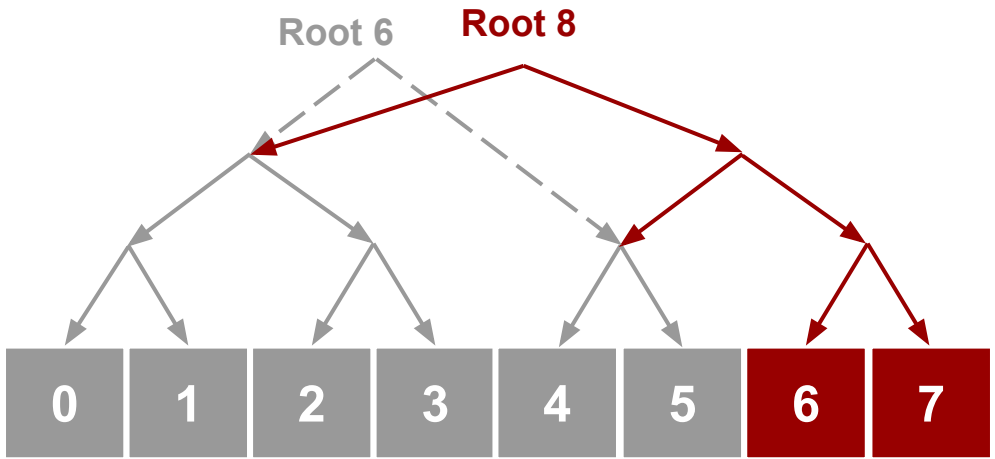
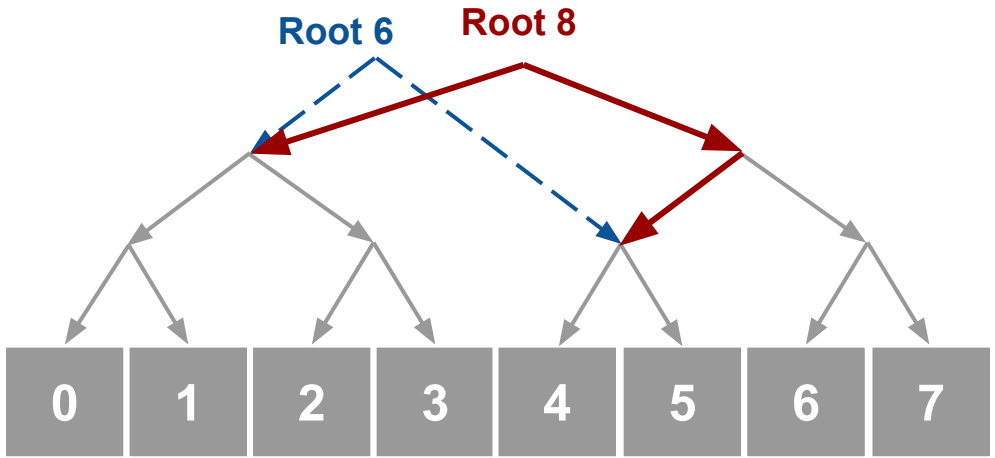


Verifiable Log (Merkle Tree) - Consistency Proofs



Verifiable Log (Merkle Tree) - Consistency Proofs



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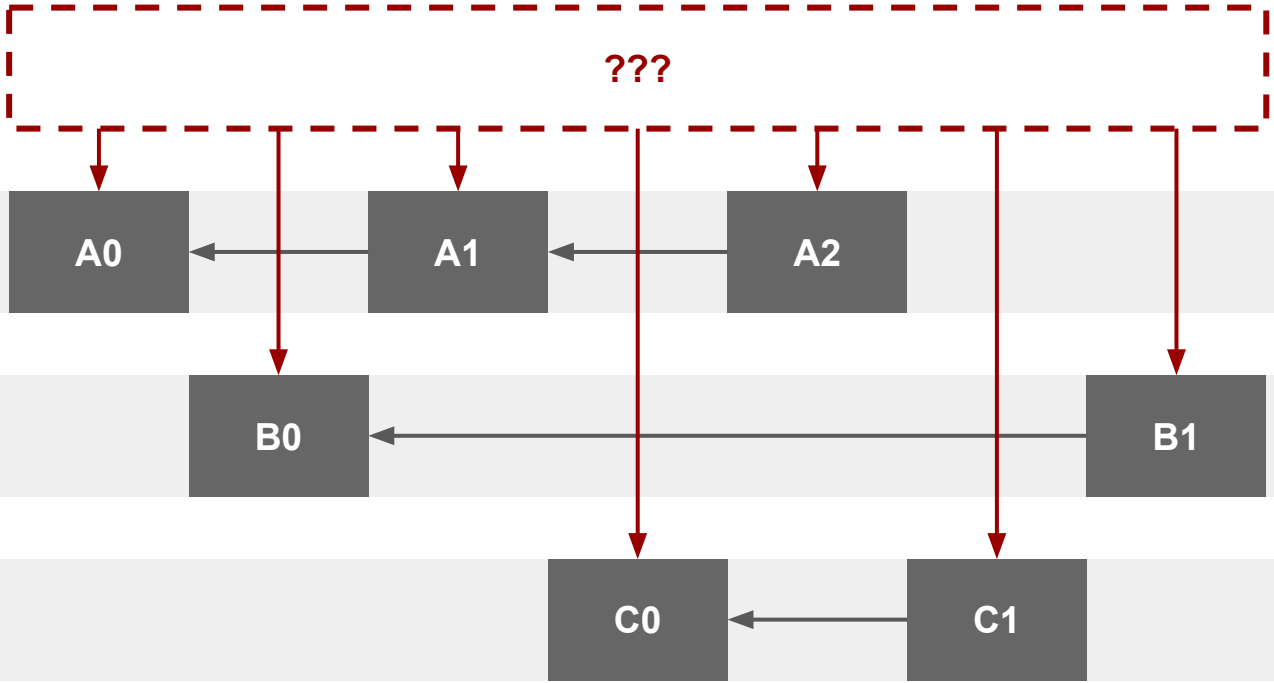
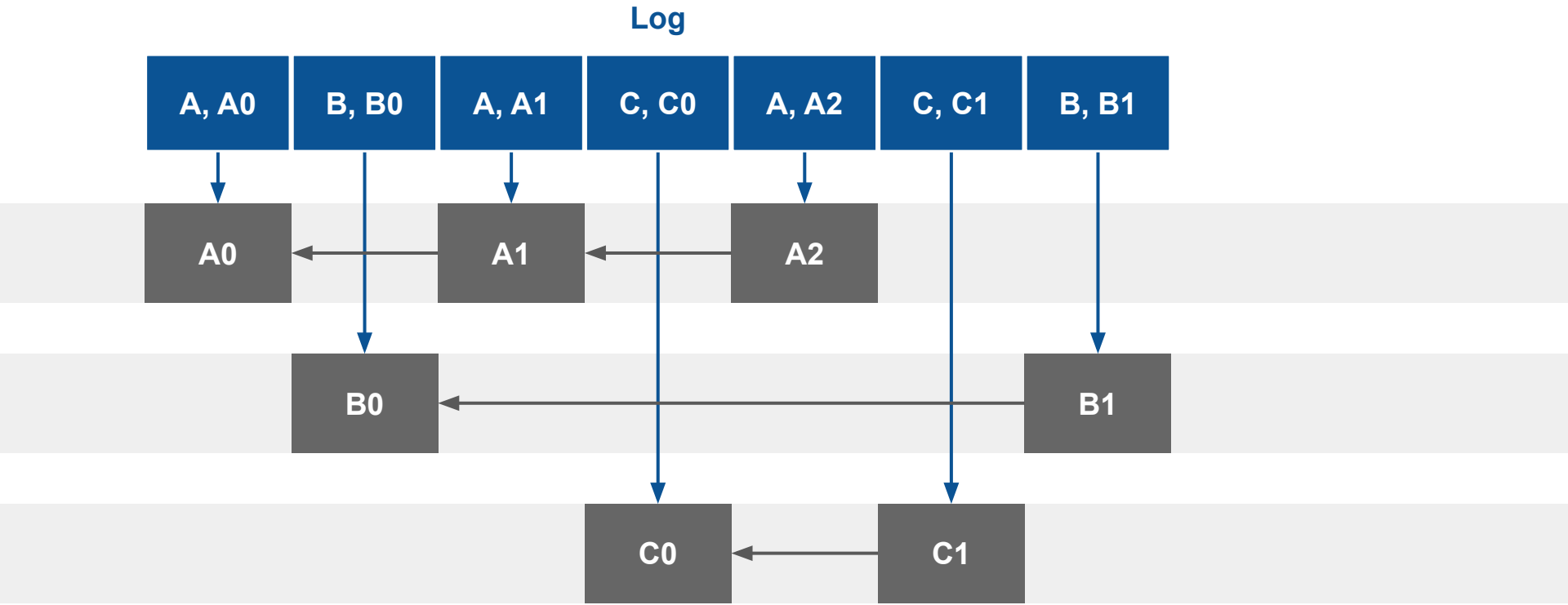
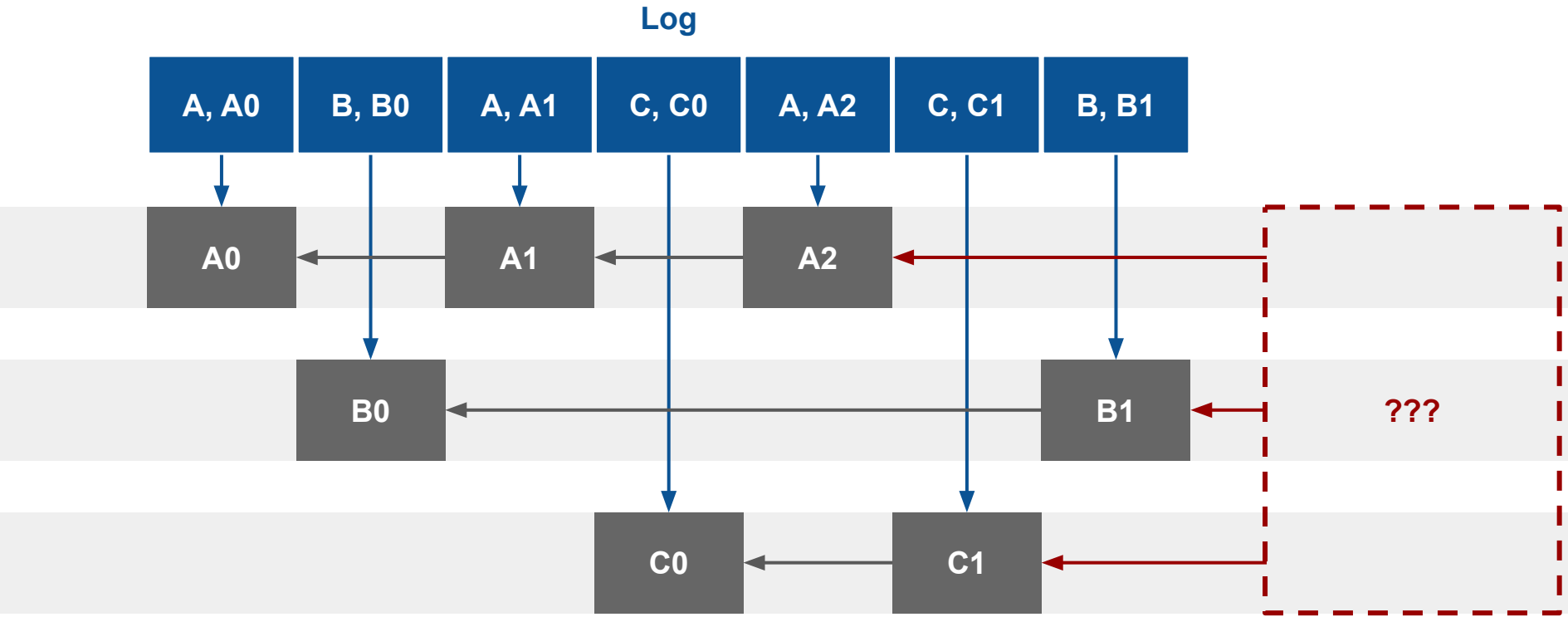


The Package Records in the Verifiable Log



How do clients know what the latest record is?

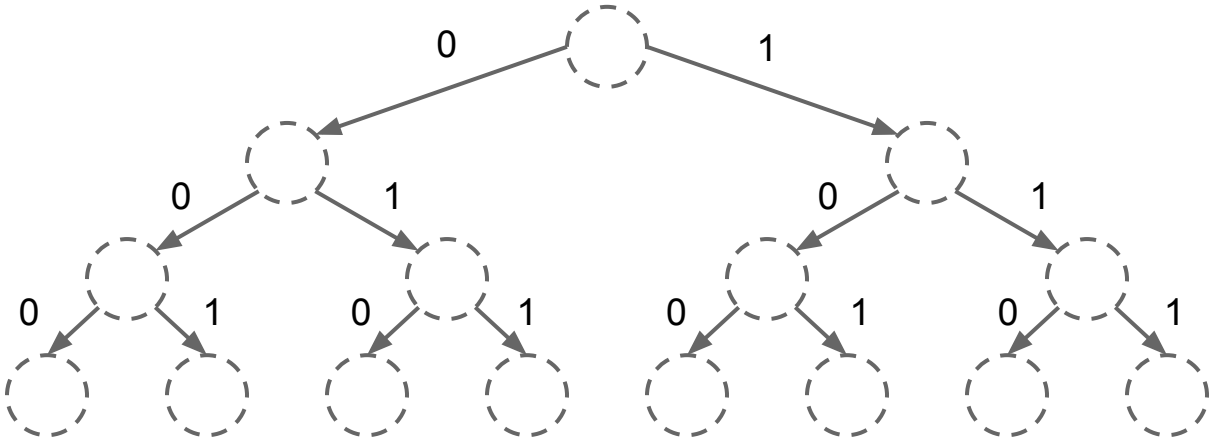


Verifiable Map
(Sparse Merkle Tree)

What does a Verifiable Map do?

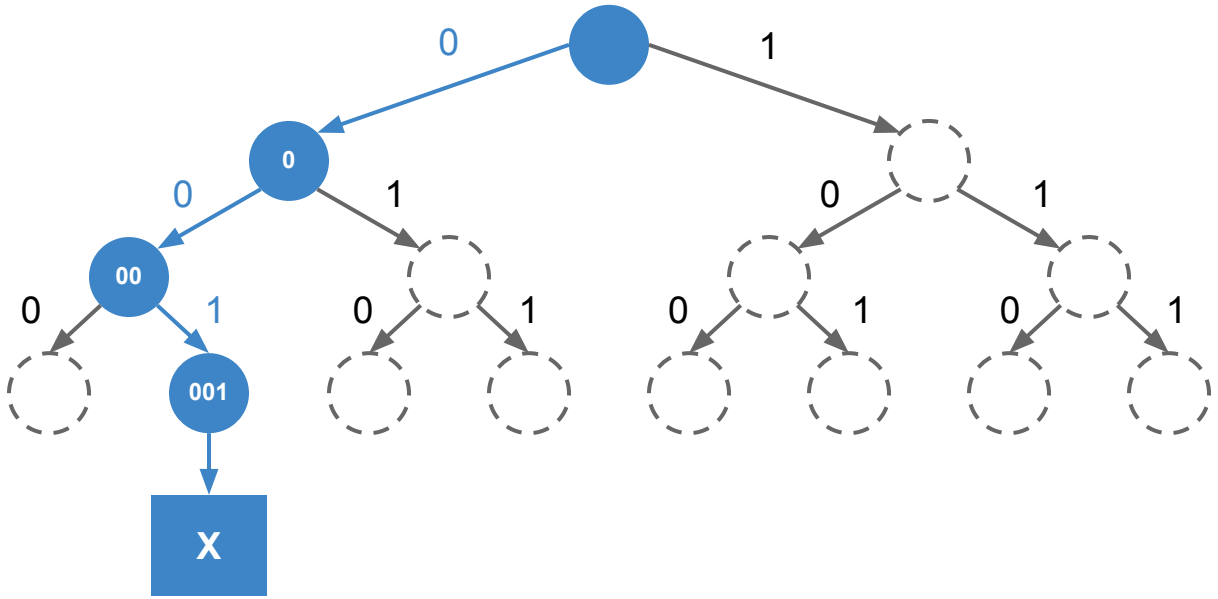
- A **Verifiable Map** is a key-value mapping
- Each **Verifiable Map** is described by a unique hash
- You can cryptographically check if a value is associated with a key

Verifiable Map (Sparse Merkle Tree)



Verifiable Map (Sparse Merkle Tree)

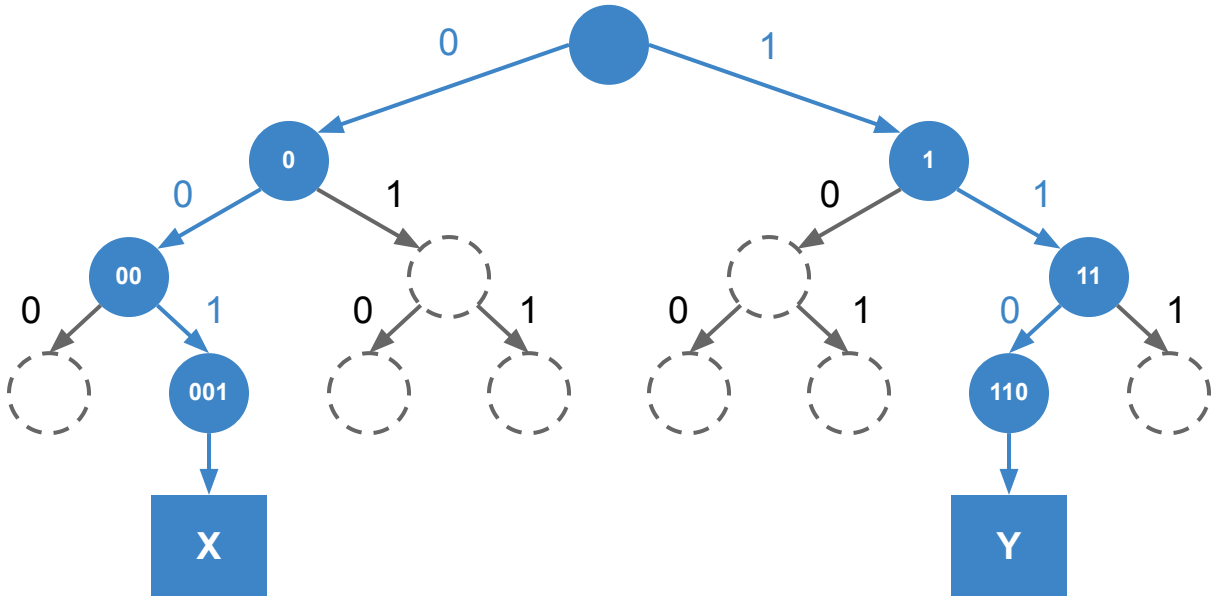
001⟶**X**



Verifiable Map (Sparse Merkle Tree)

001⟶X

110⟶Y

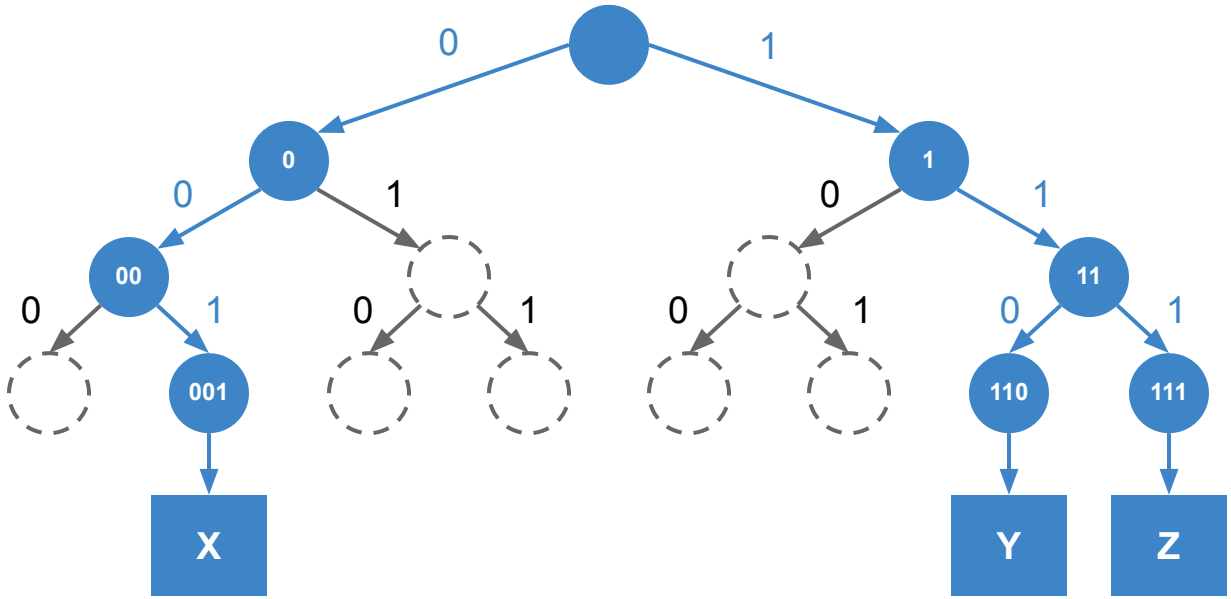


Verifiable Map (Sparse Merkle Tree)

001⟶X

110⟶Y

111⟶Z



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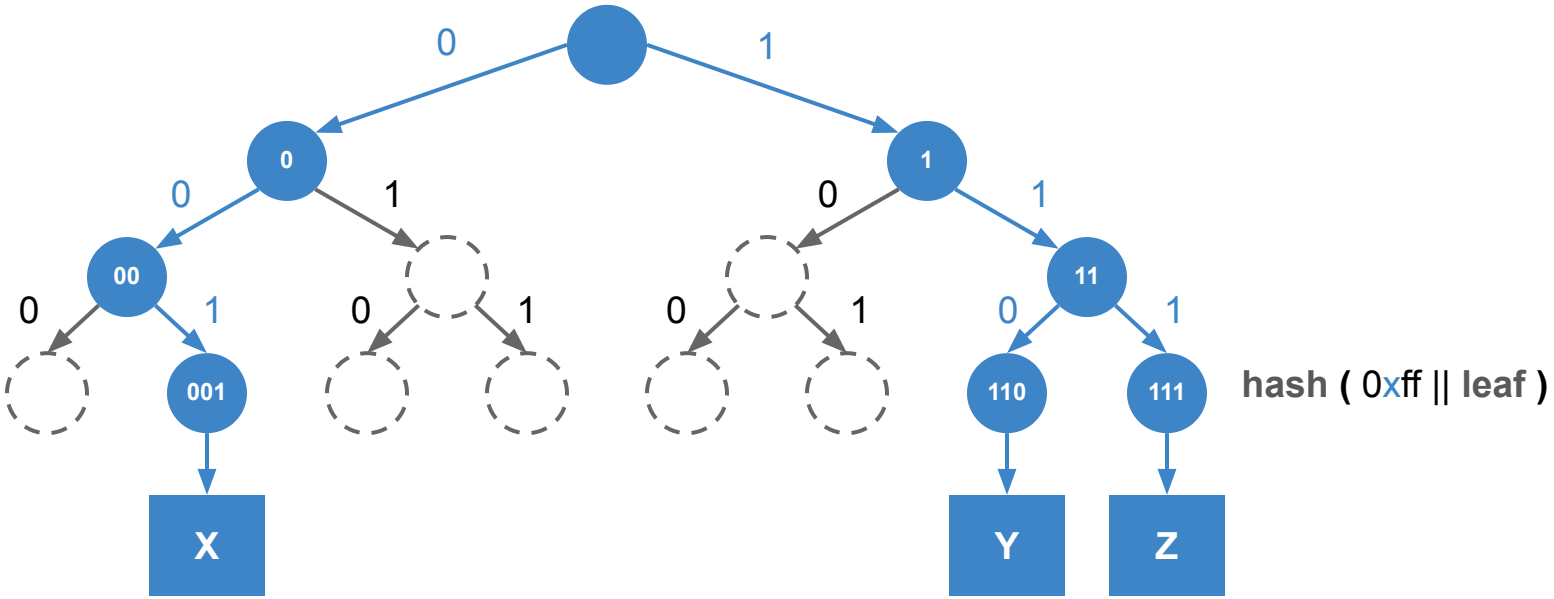

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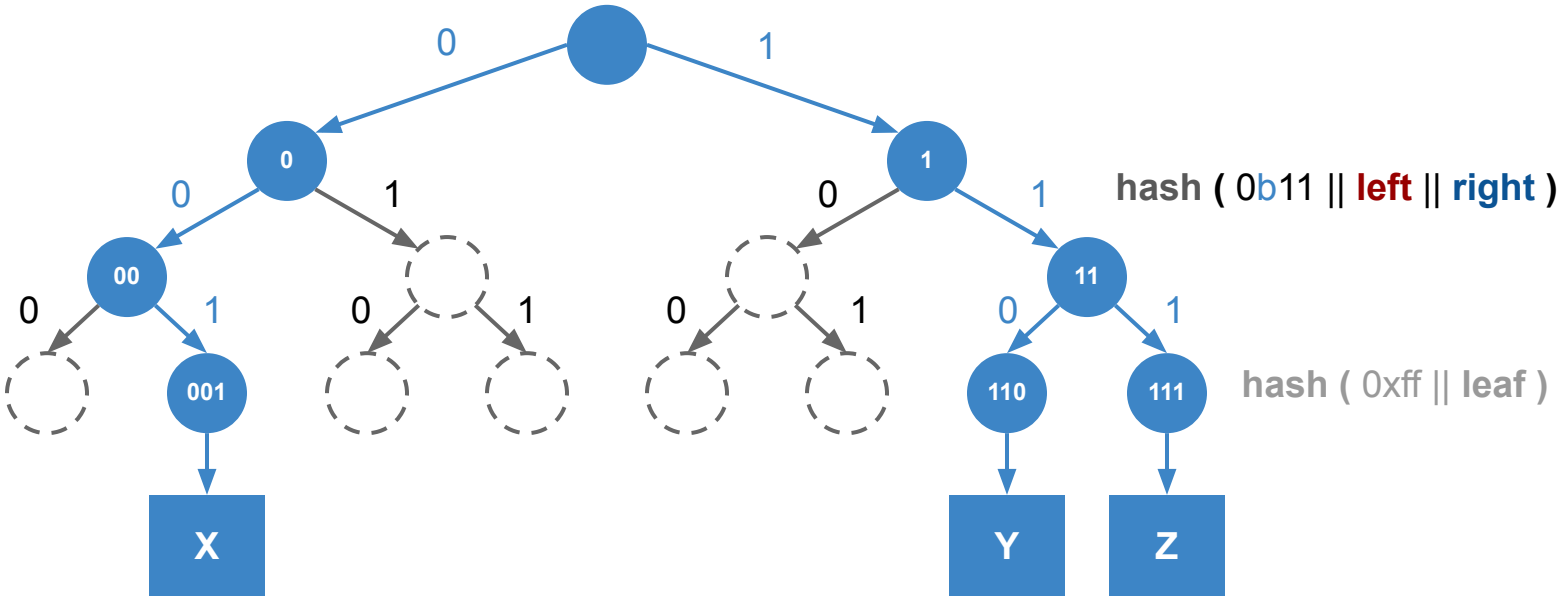

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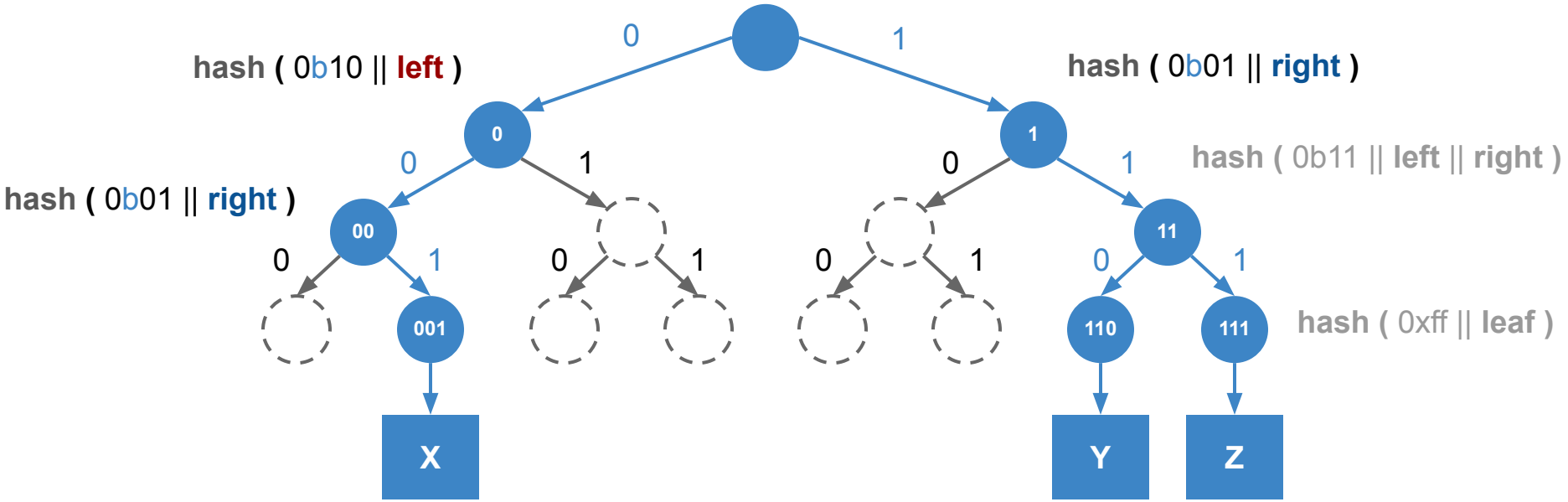

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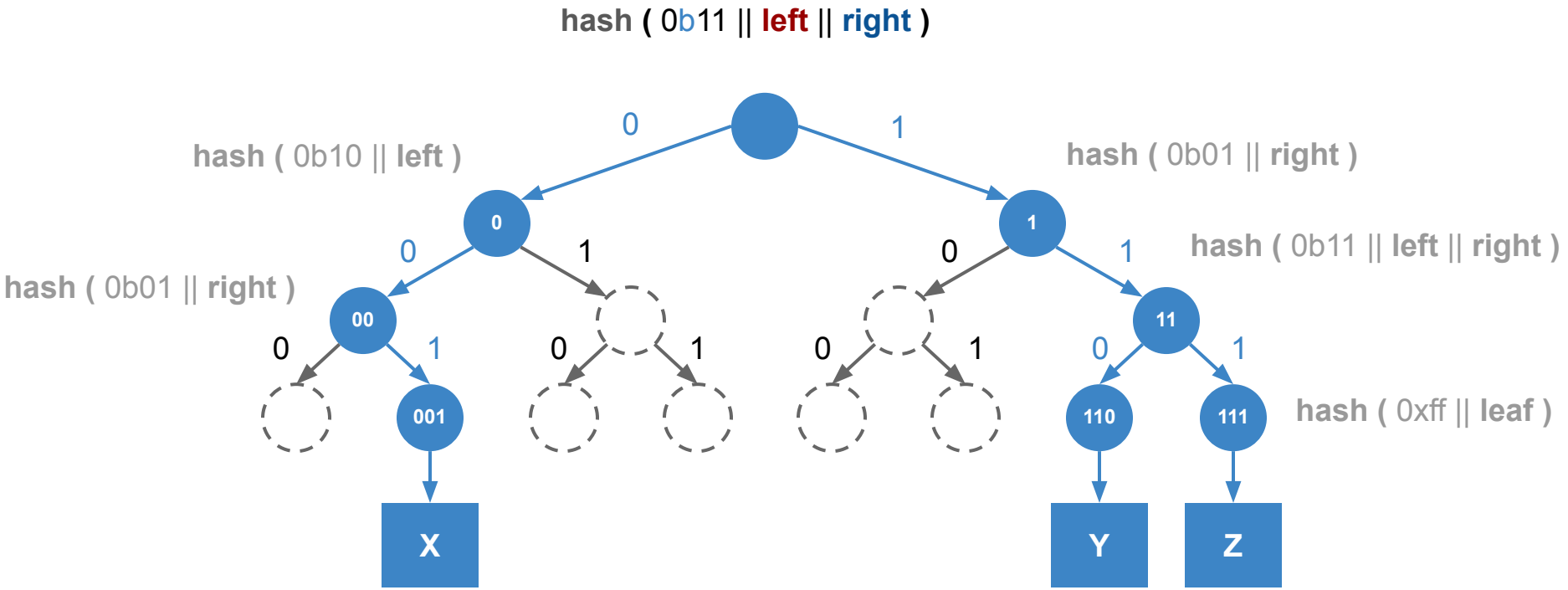
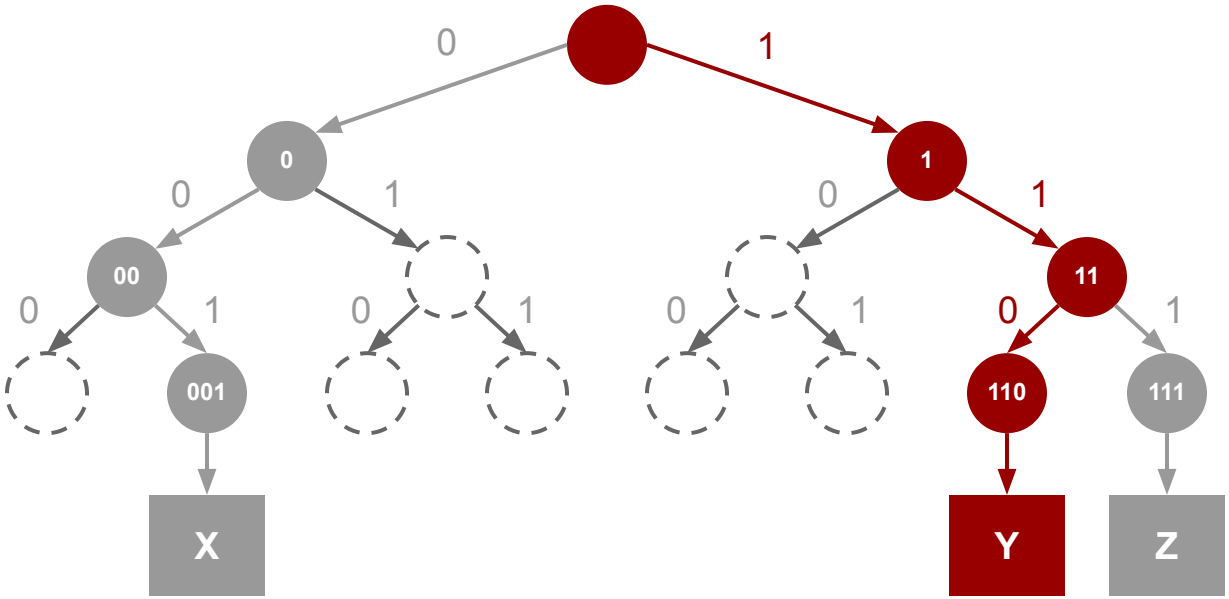


Verifiable Map (Sparse Merkle Tree) - Inclusion Proof



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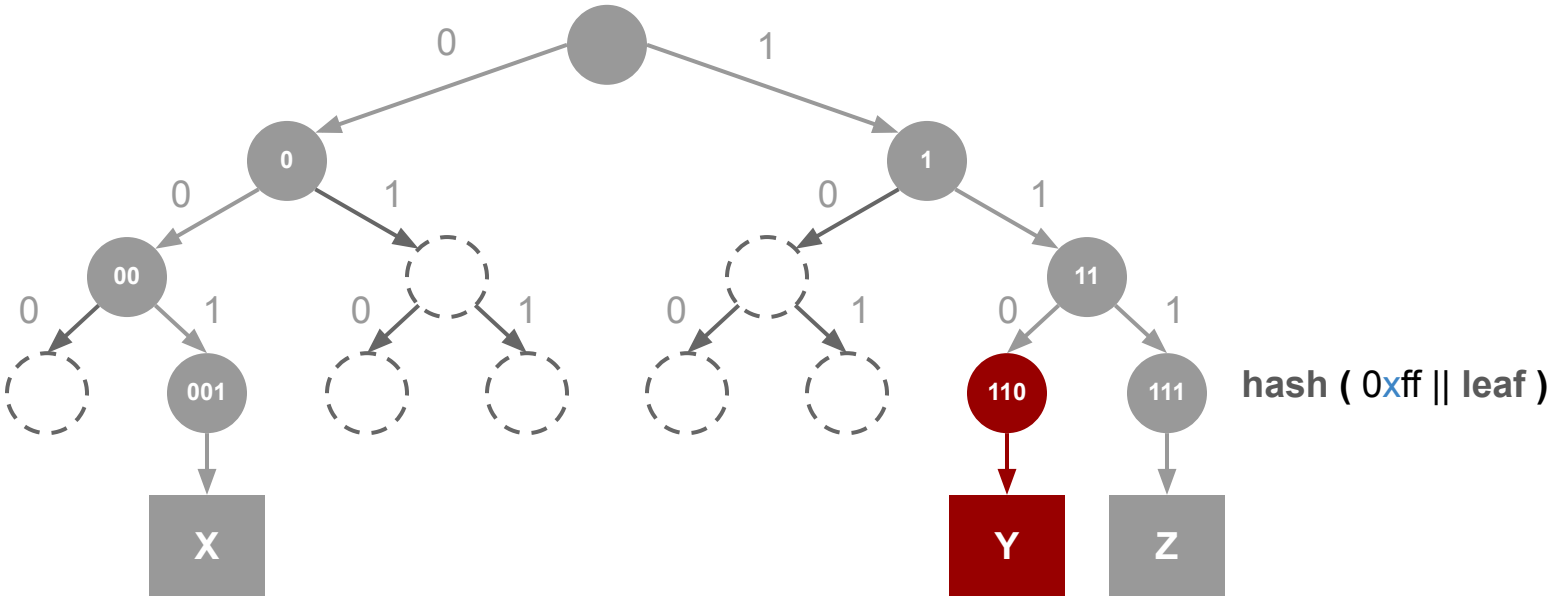

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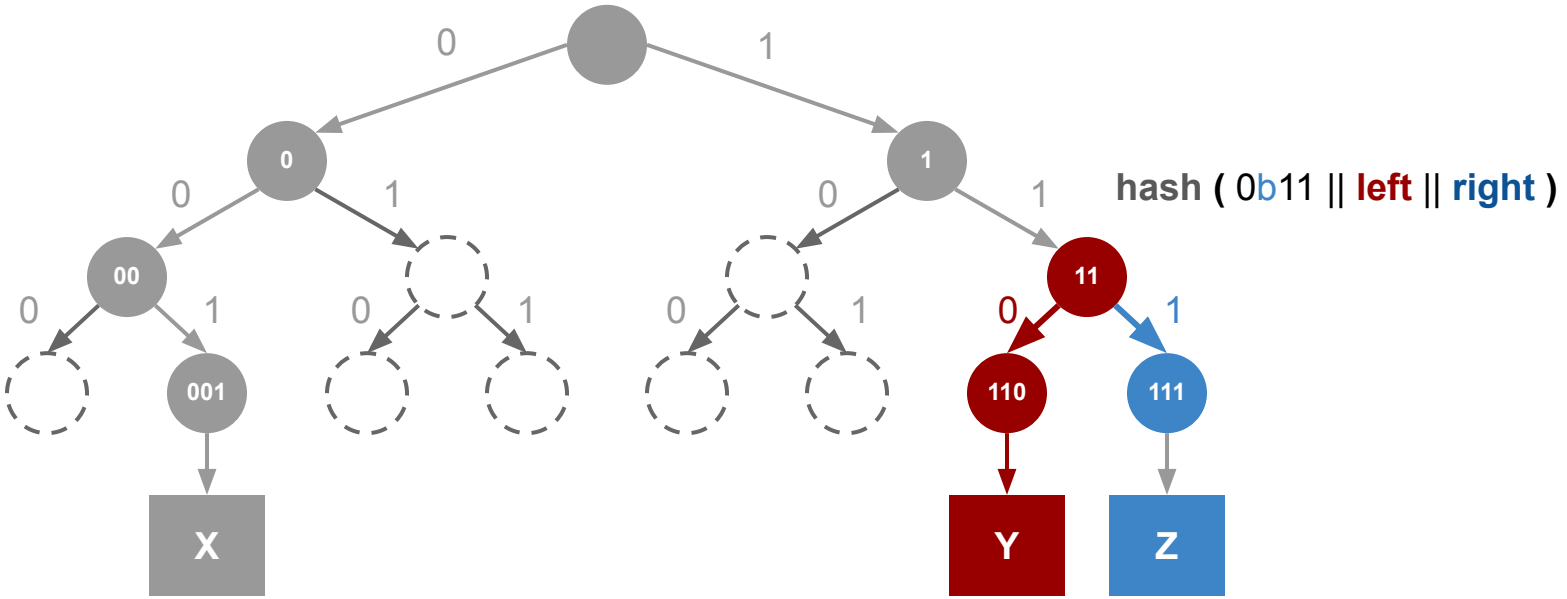

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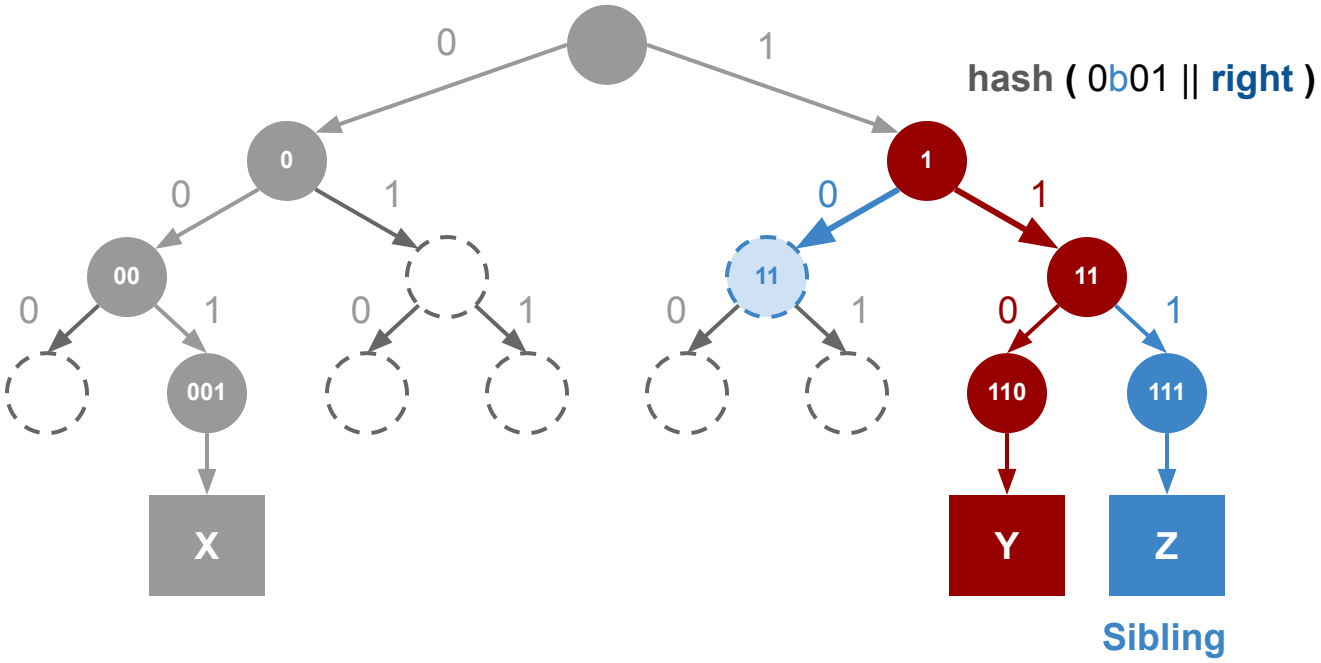

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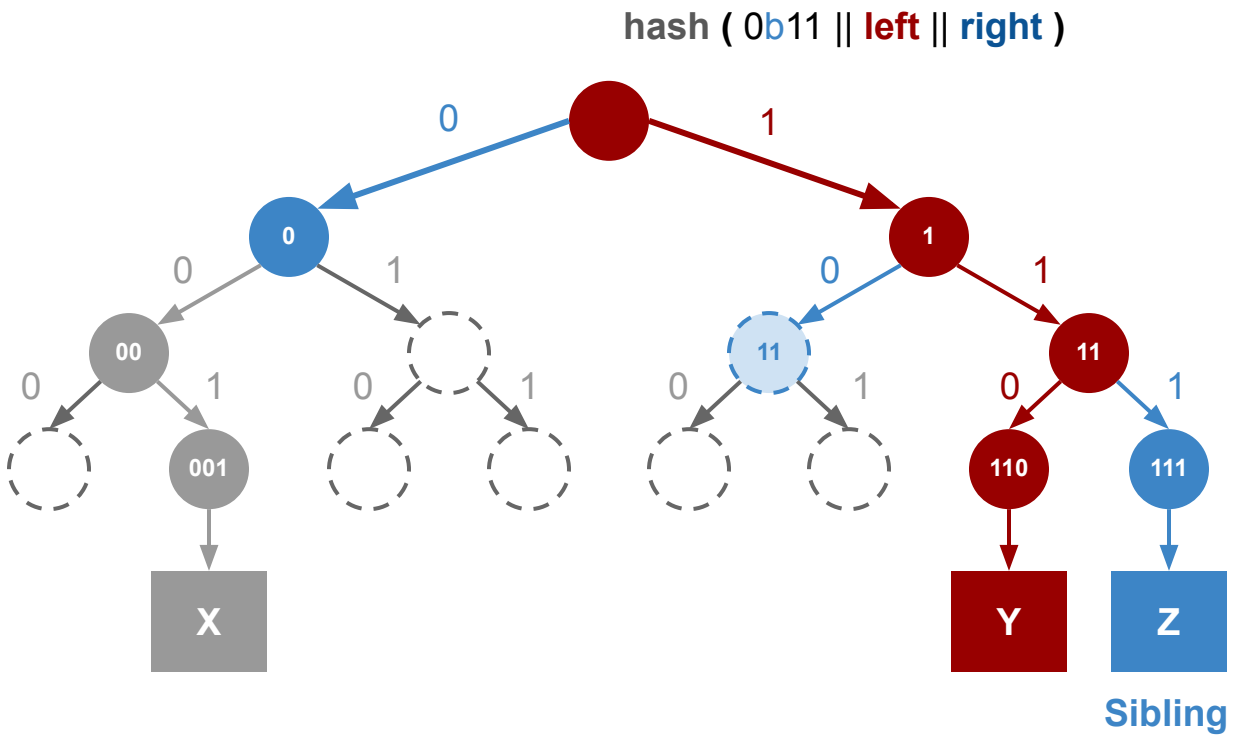

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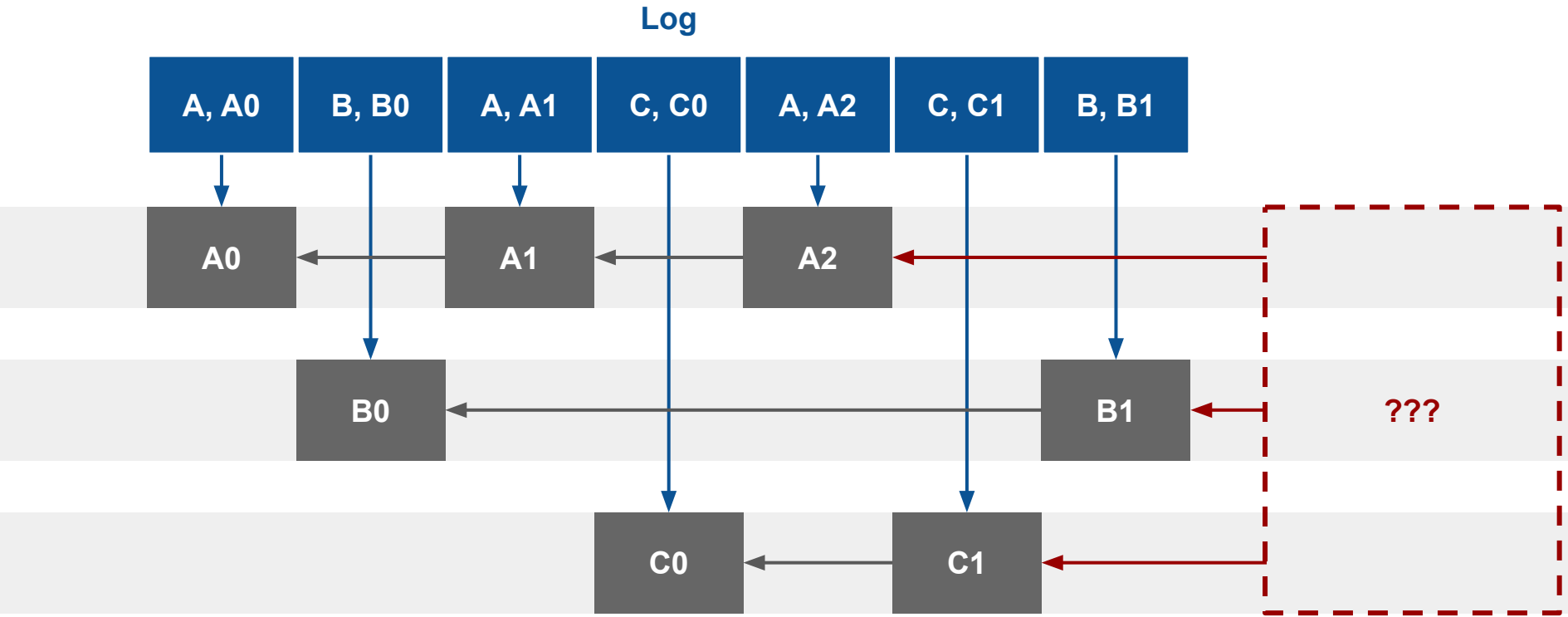
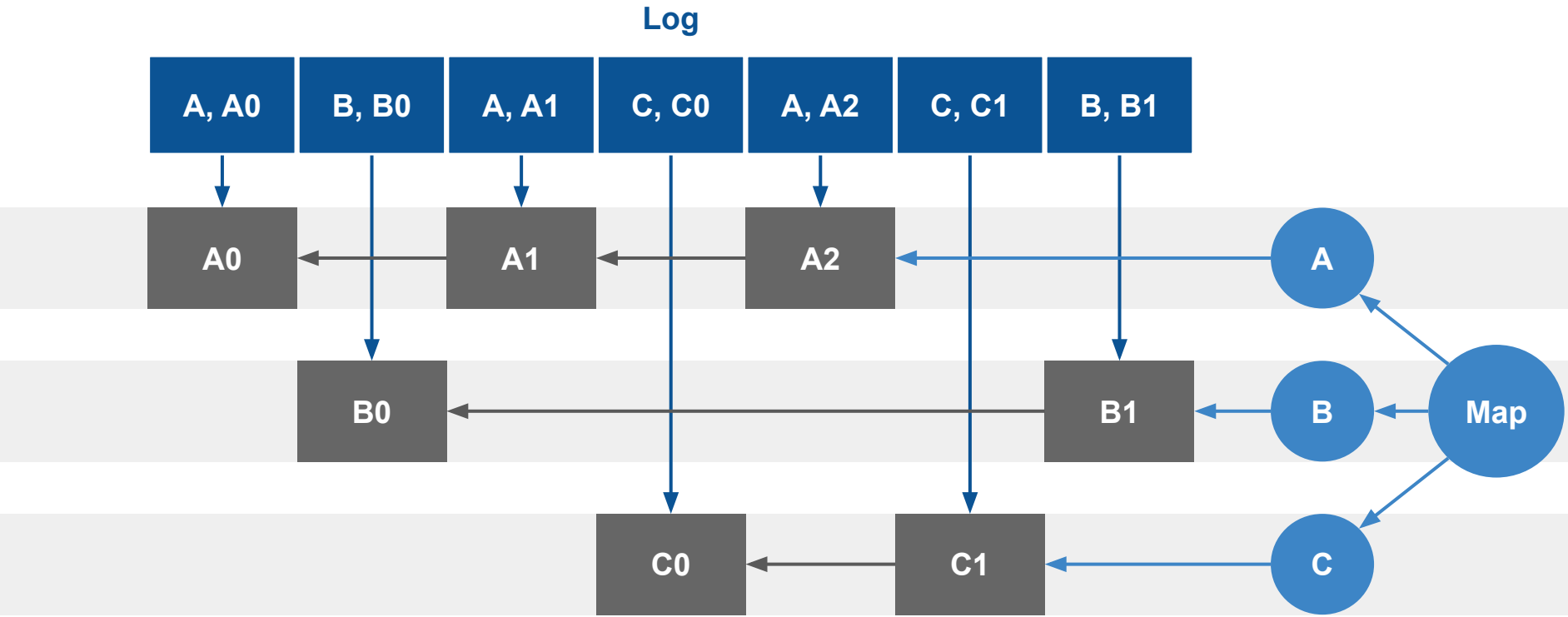
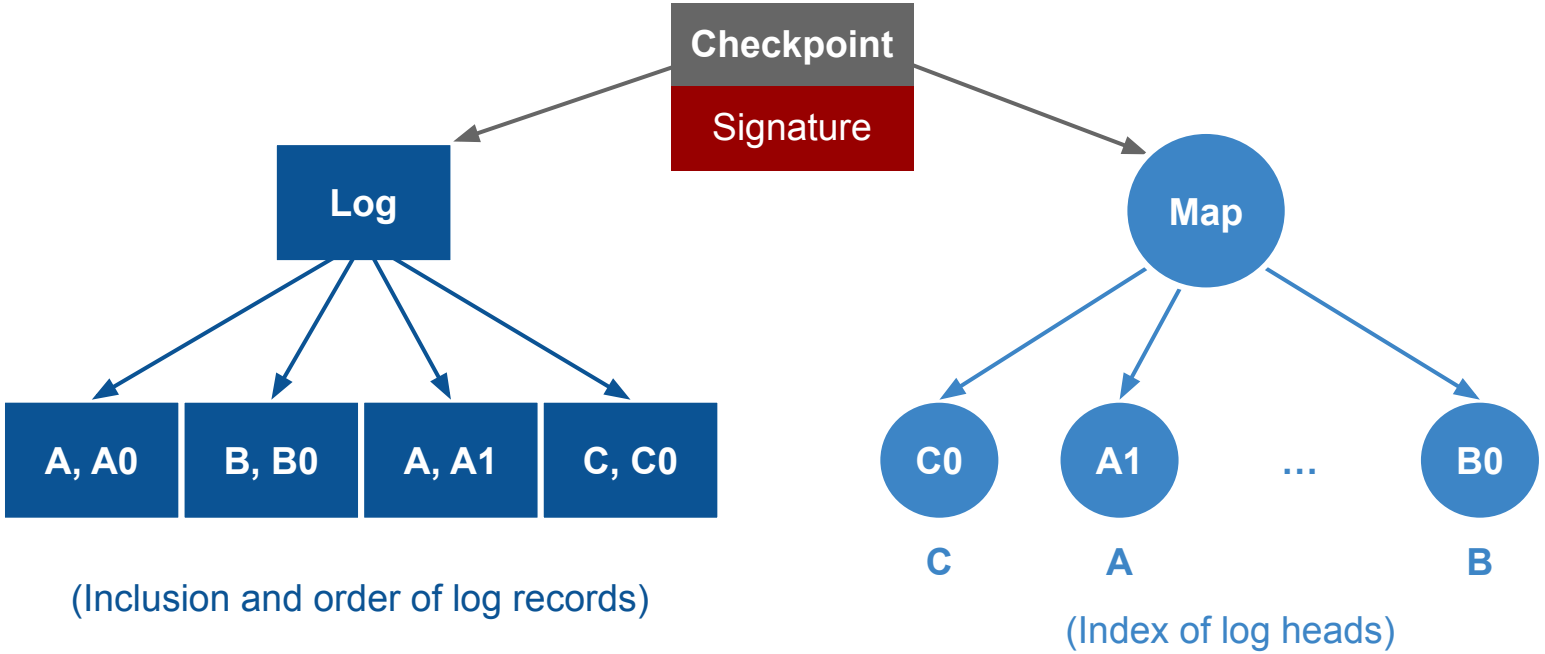


Use a verifiable map of package log heads



Overall Checkpoint / Commitment



Auditing & Verification

Clients

They are

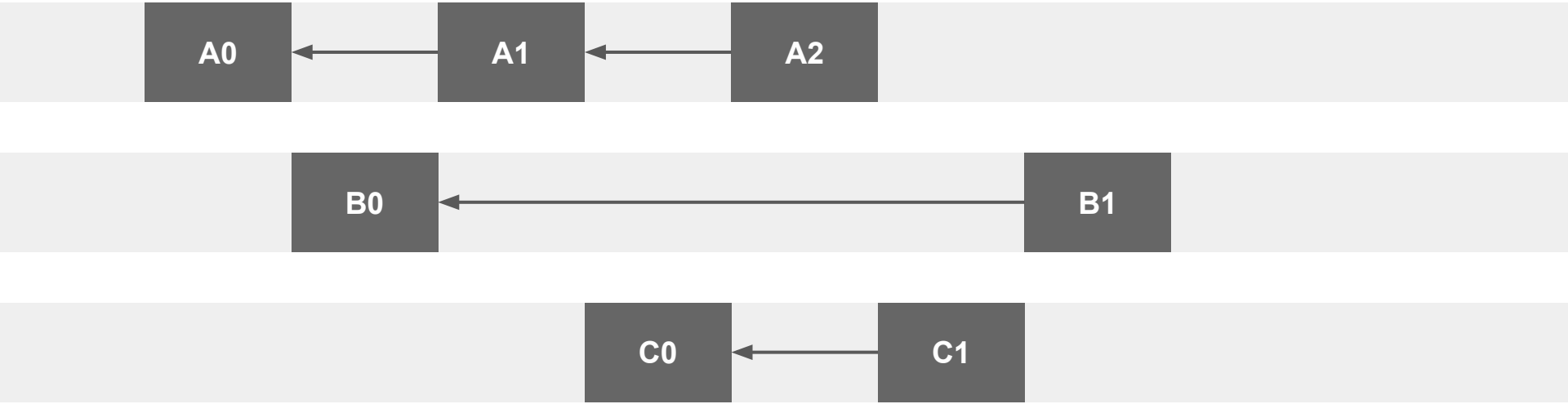
- resource constrained
- only interested in some of the state

So, clients verify

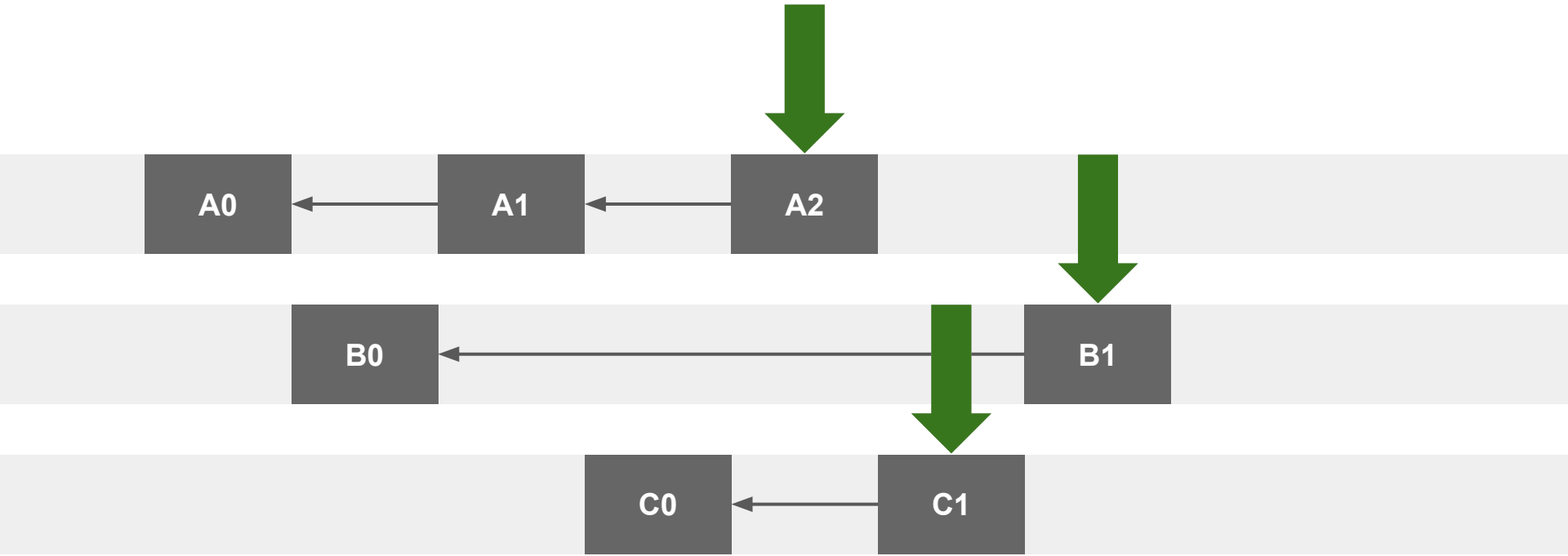
- relevant package state
- that the registry committed to that state
- the commitment is valid / correct

Clients know nothing at the start

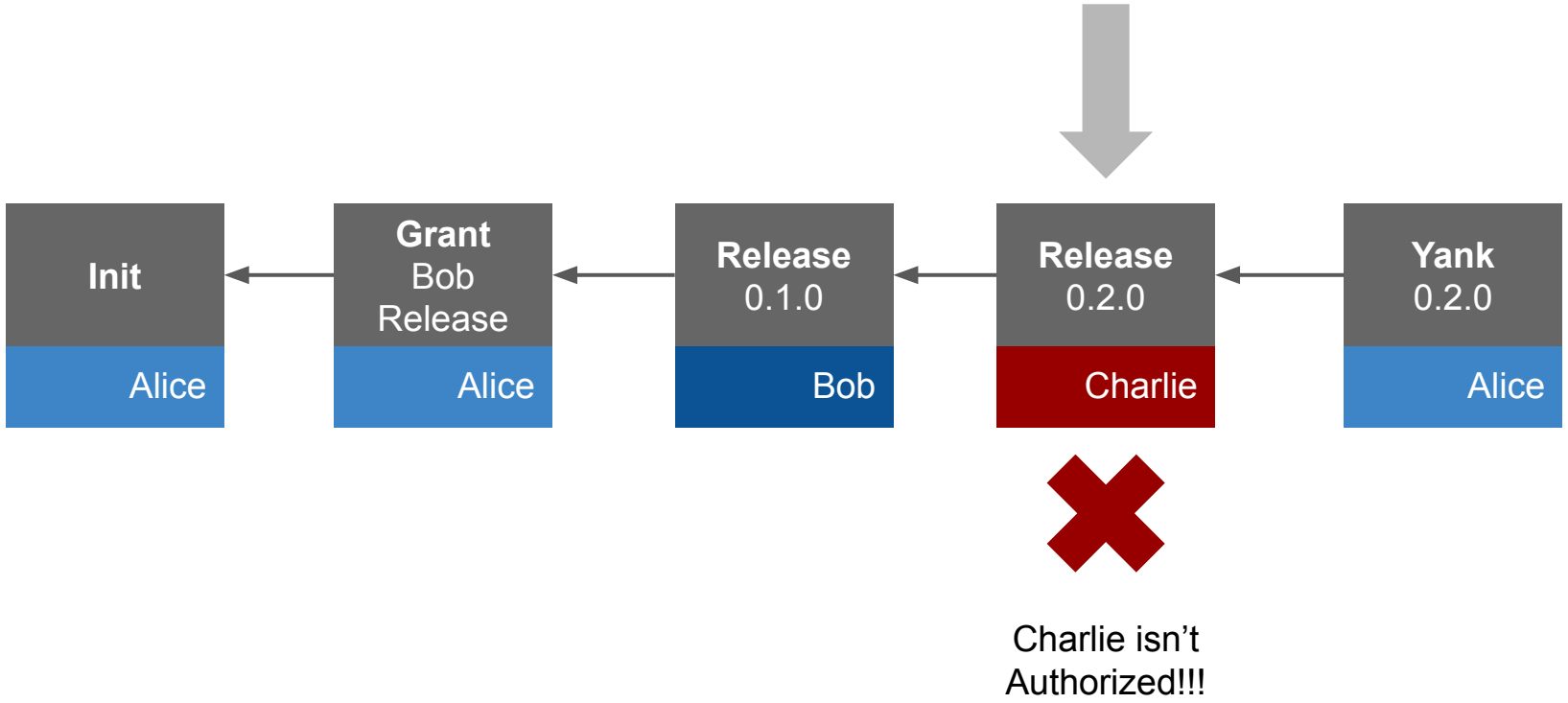
Clients **download** the Package Logs



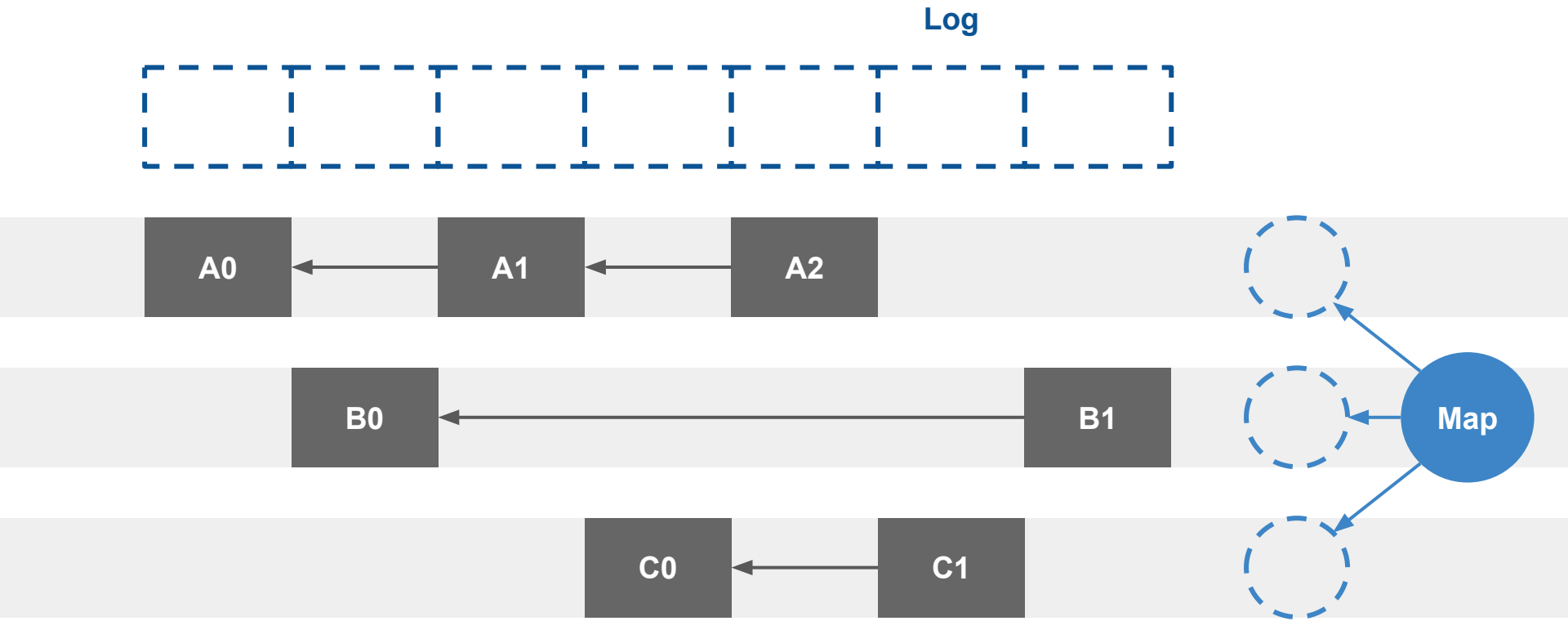
Clients **verify** Package Logs



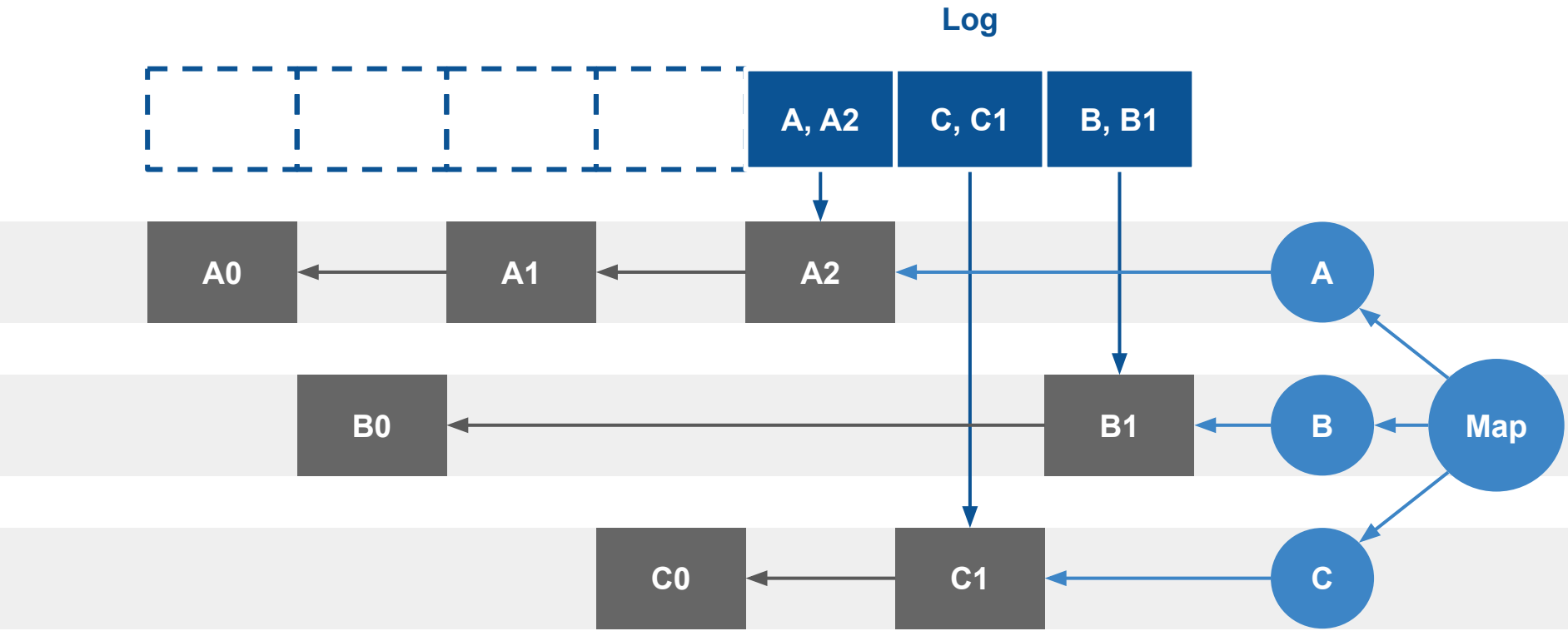
Clients **verify** Package Logs



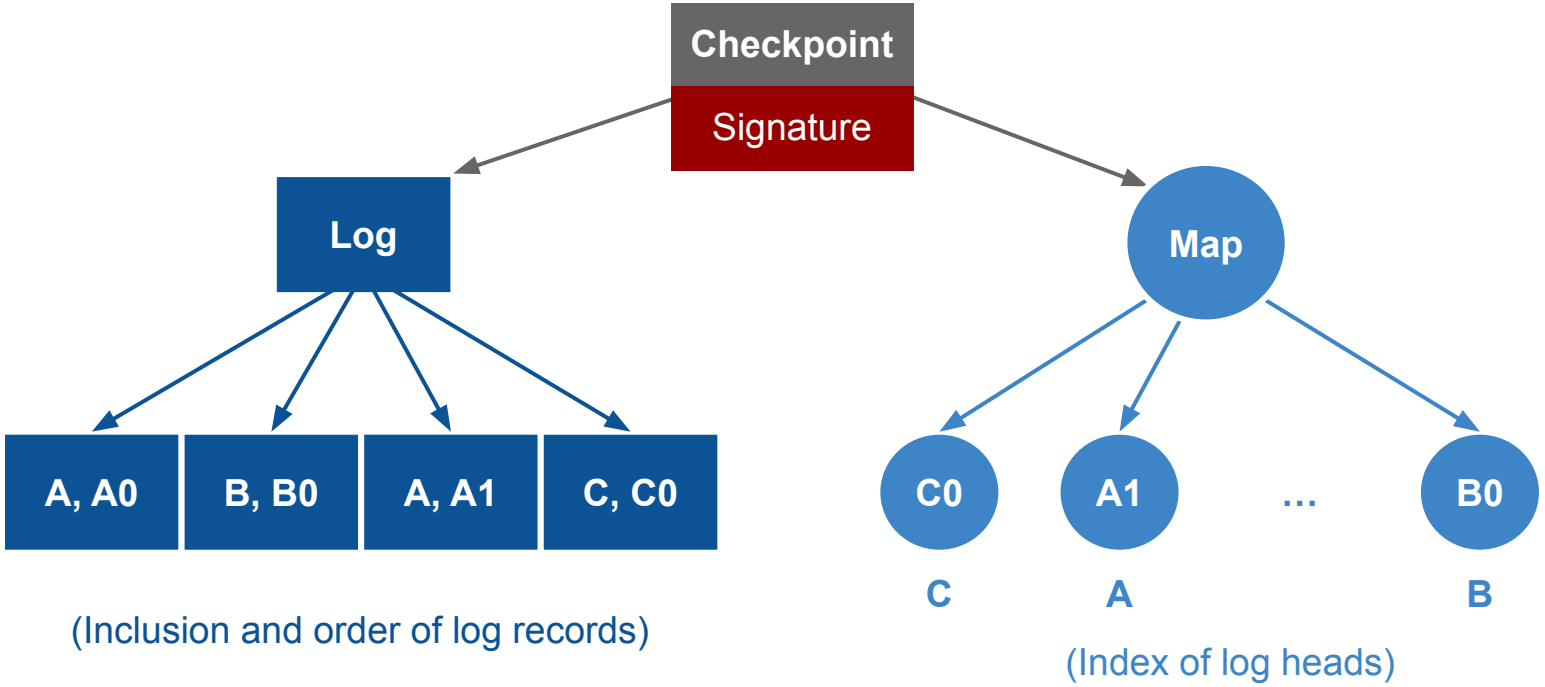
Clients **get** checkpoints for the map and log



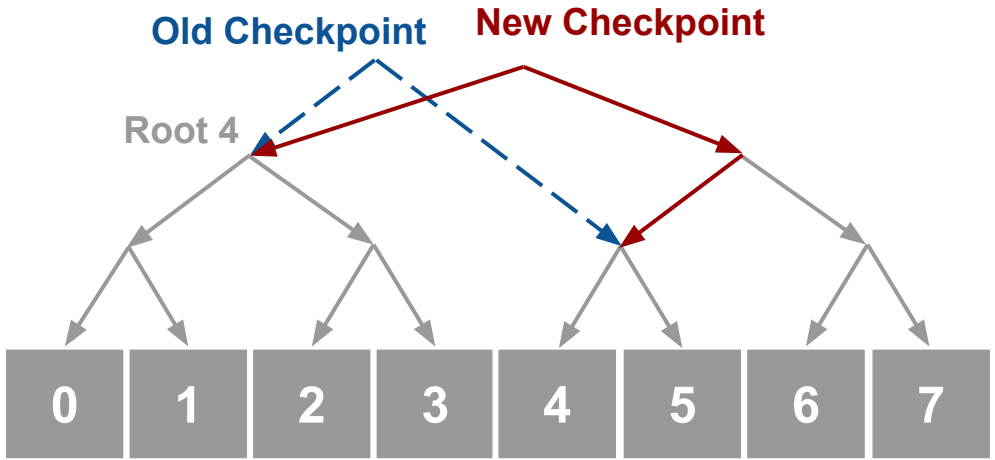
Clients **get** & **verify** proofs for map and log inclusion



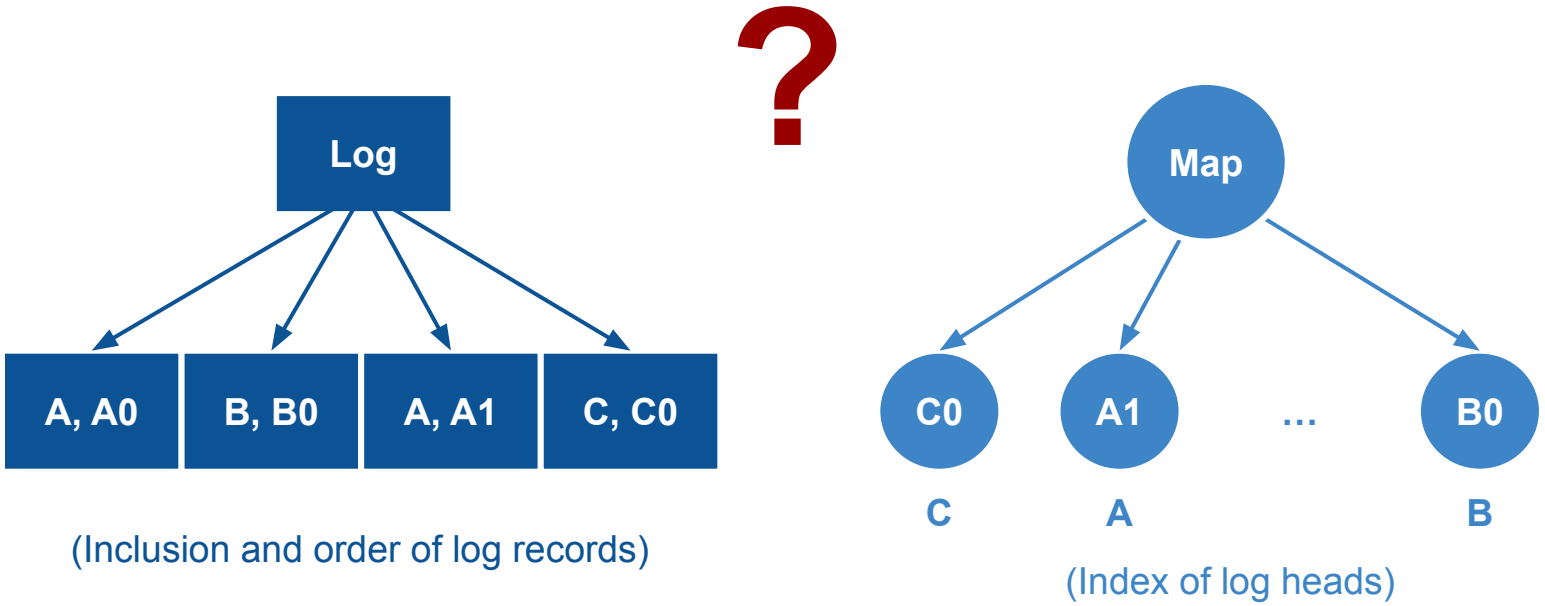
Client **validate** Checkpoint Signature



Client Validation - Log Checkpoint Consistency



Client can’t validate consistency of the **Log** & **Map**



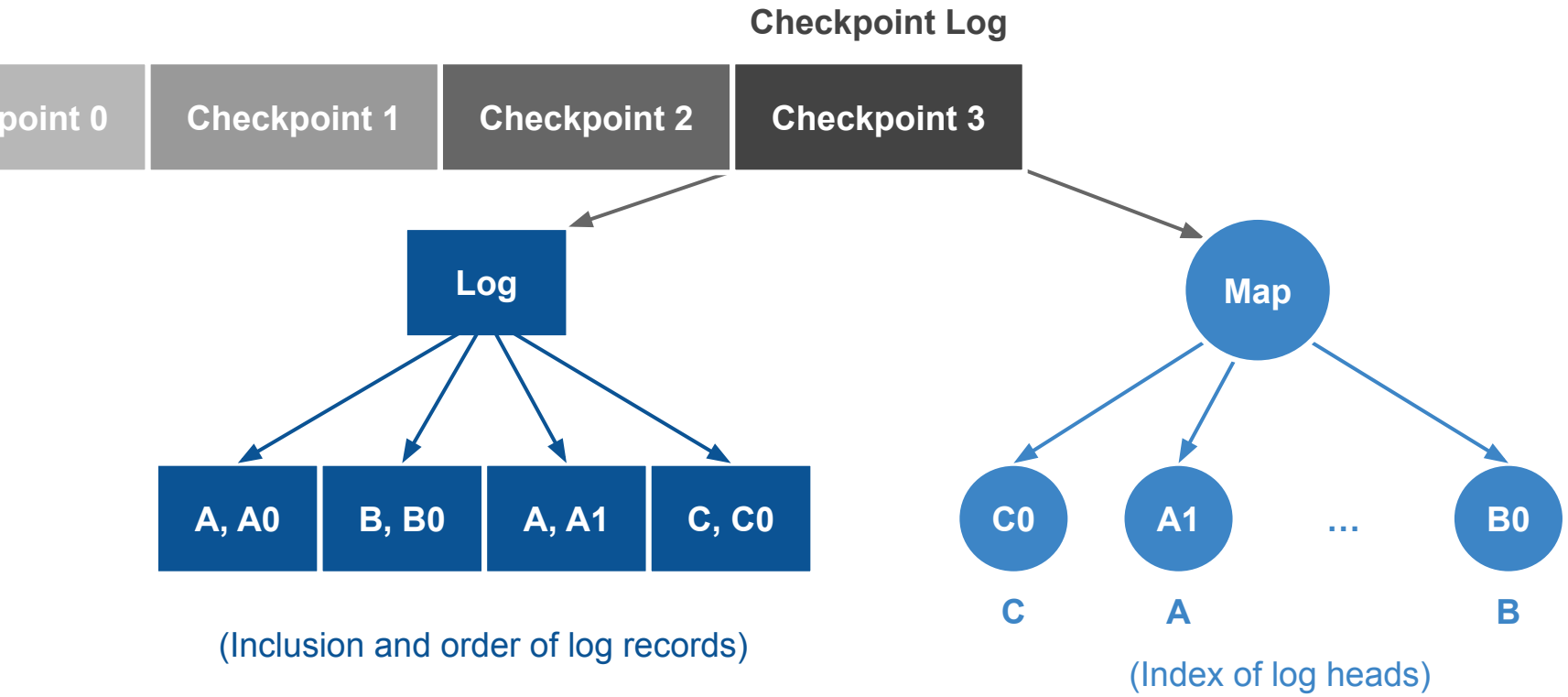
(Inclusion and order of log records)

(Index of log heads)

Who are clients gonna call?

Monitors

Monitors Audit Log/Map Consistency Over Time

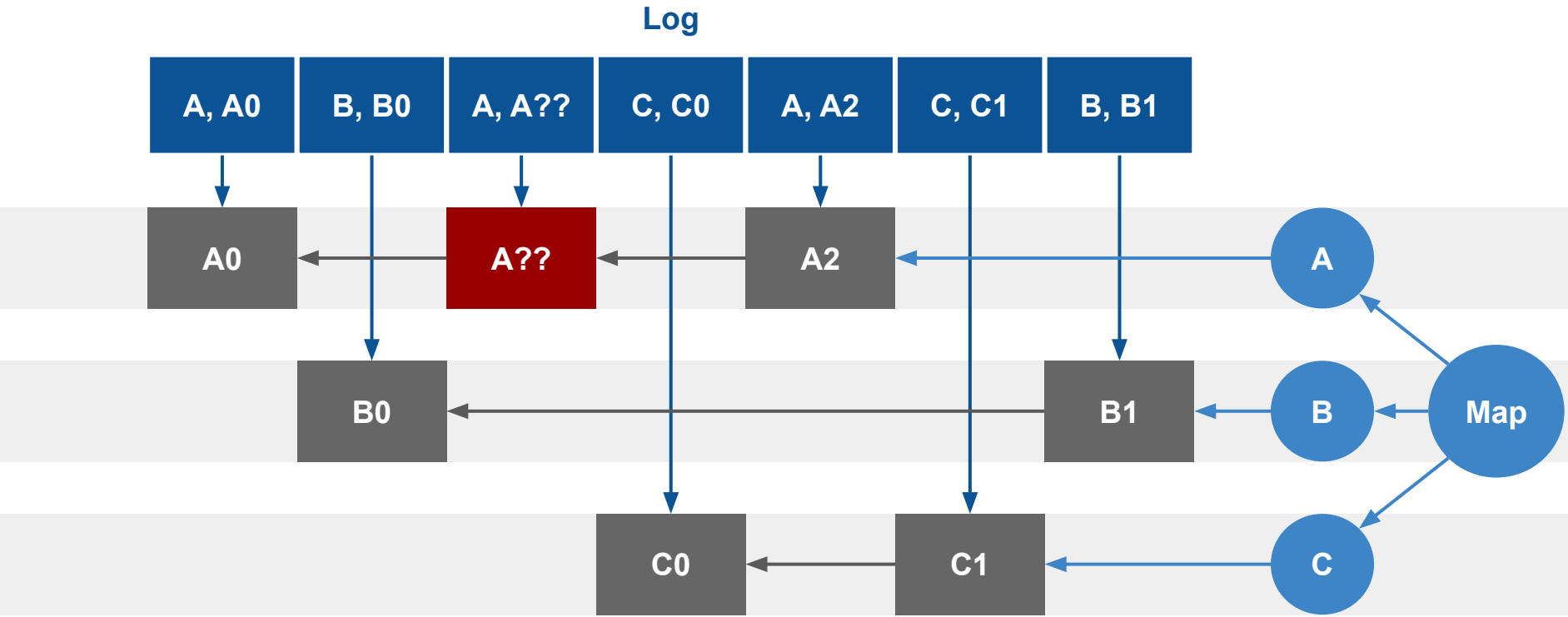


Components of Package Transparency (Revisited)

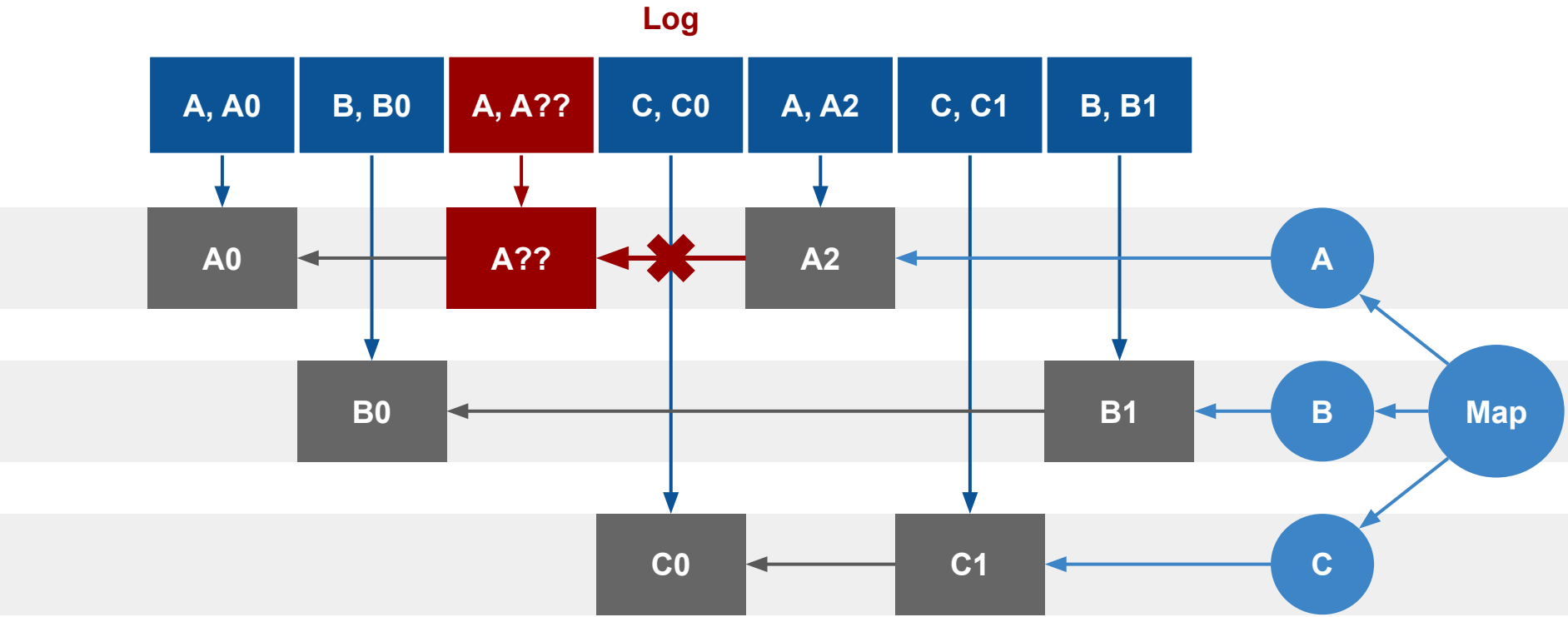
1. **Publicly Available Package Registry State**
    - **A collection of package logs**
2. **Cryptographically-Verifiable Commitments**
    - **Signed log + map checkpoints**
3. **Auditing Package Authors and the Registry**
    - **Client and monitor validation**

Package Transparency vs. Various Attacks

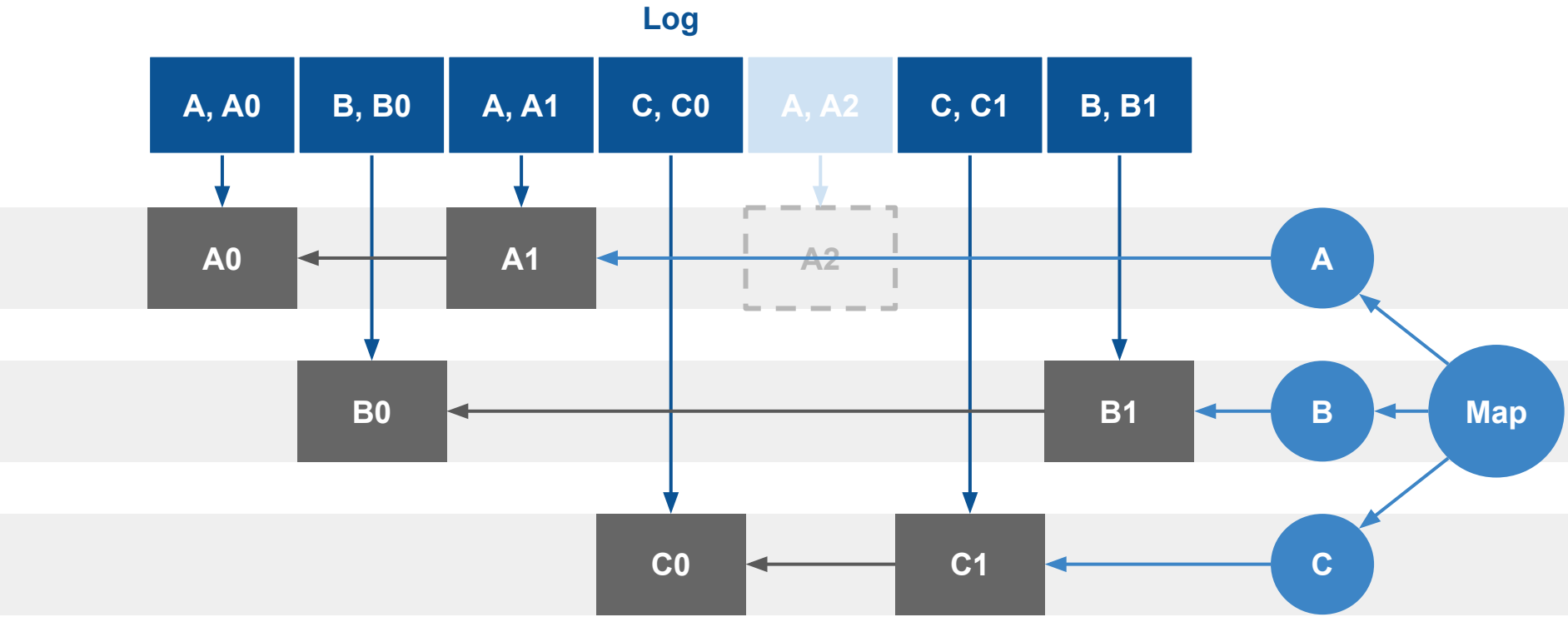
What if an attacker changes a record?



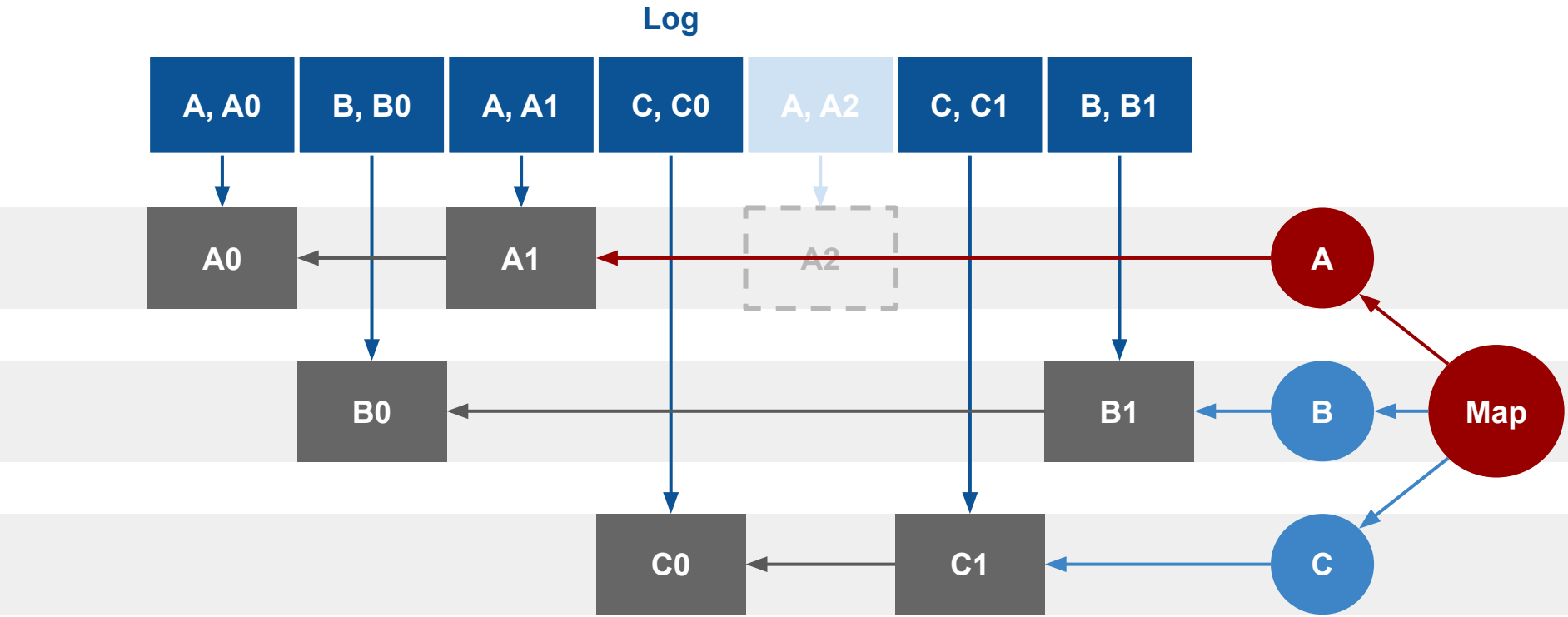
Internal hash linking will fail! (and log inclusion too)



What if an attacker hides new record(s)?



The map checkpoint will no longer match!



Summary

- **WebAssembly (Wasm)** is a promising way to make ***portable and secure*** software
- **Package Registries** are ***indexes of content***, not necessarily content stores or providers
- **Package Transparency** builds on the the ideas of ***Certificate Transparency*** to offer registries valuable properties
- **Package Transparency** provides ***defenses*** against a variety of ***attacks***

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