HYDRAstor: a Scalable Secondary Storage

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C. Ungureanu

9LivesData

NEC Laboratories America
Relentless passion for innovation

Scalable secondary storage

Characteristics	Requirements
Huge amount of data	- Scalability (dynamic) - Low cost per TB
Small backup windows	- Very high write performance
Duplication between backup streams	- Global deduplication
Reliable, on-line retrieval	- Failure tolerance - High restore performance
Varying value of data	- Adjust resilience overhead - Data deletion

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Challenges

- High-performance, decentralized
  global deduplication
  ... in a dynamic, distributed system
  ... with deletion and failures
- Combination introduces complexity
- Tension between:
  - Deduplication and dynamic scalability
  - Deduplication and on-demand deletion
  - Failure tolerance and deletion

HYDRAstor

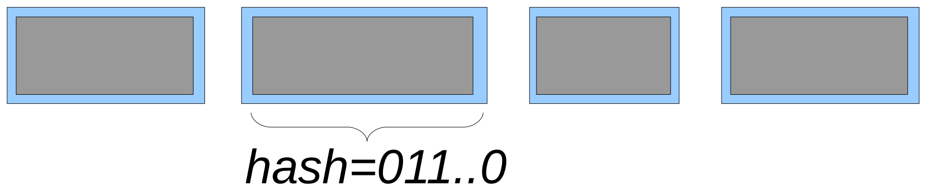
- Satisfies **Scalable secondary storage** requirements
- Started as a research project at *NEC Laboratories America,* in Princeton, NJ
- Successfully commercialized
  - Today: real-world, commercial system
  - Sold by NEC in the US and Japan
- Development of back-end continues at *9LivesData, LLC* in Warsaw, Poland
  - Spinoff from NEC Laboratories

HYDRAstor functionality

- Content addressable storage (CAS)
- Vast data repository
  - Storing and extracting streams of blocks
  - Single system image built of independent nodes
- Support for standard access methods
  - Filesystem, VTL
- Dynamic capacity sharing
- Self-recovery from failures
- On-demand deletion

Programming Model

- Repository of blocks
  - Content-addressed
  - Immutable
  - Variable-sized



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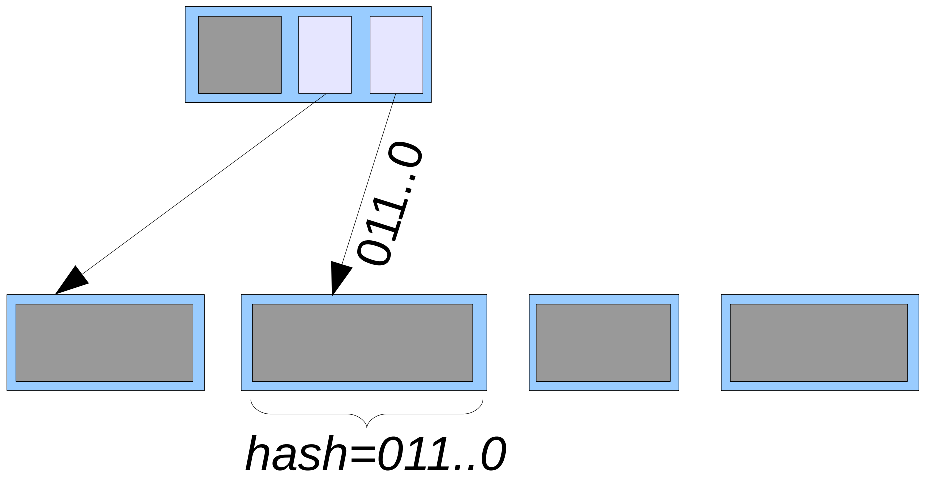

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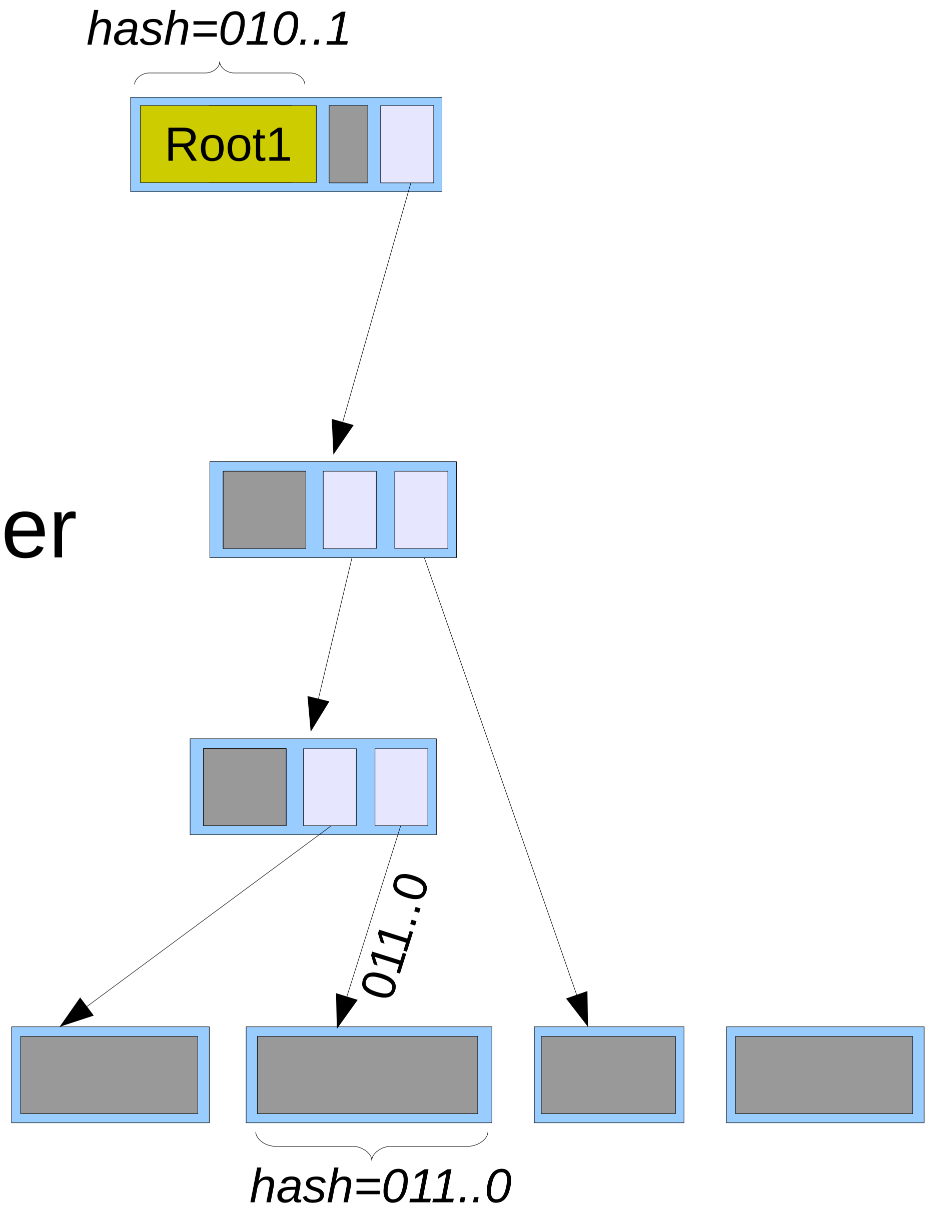

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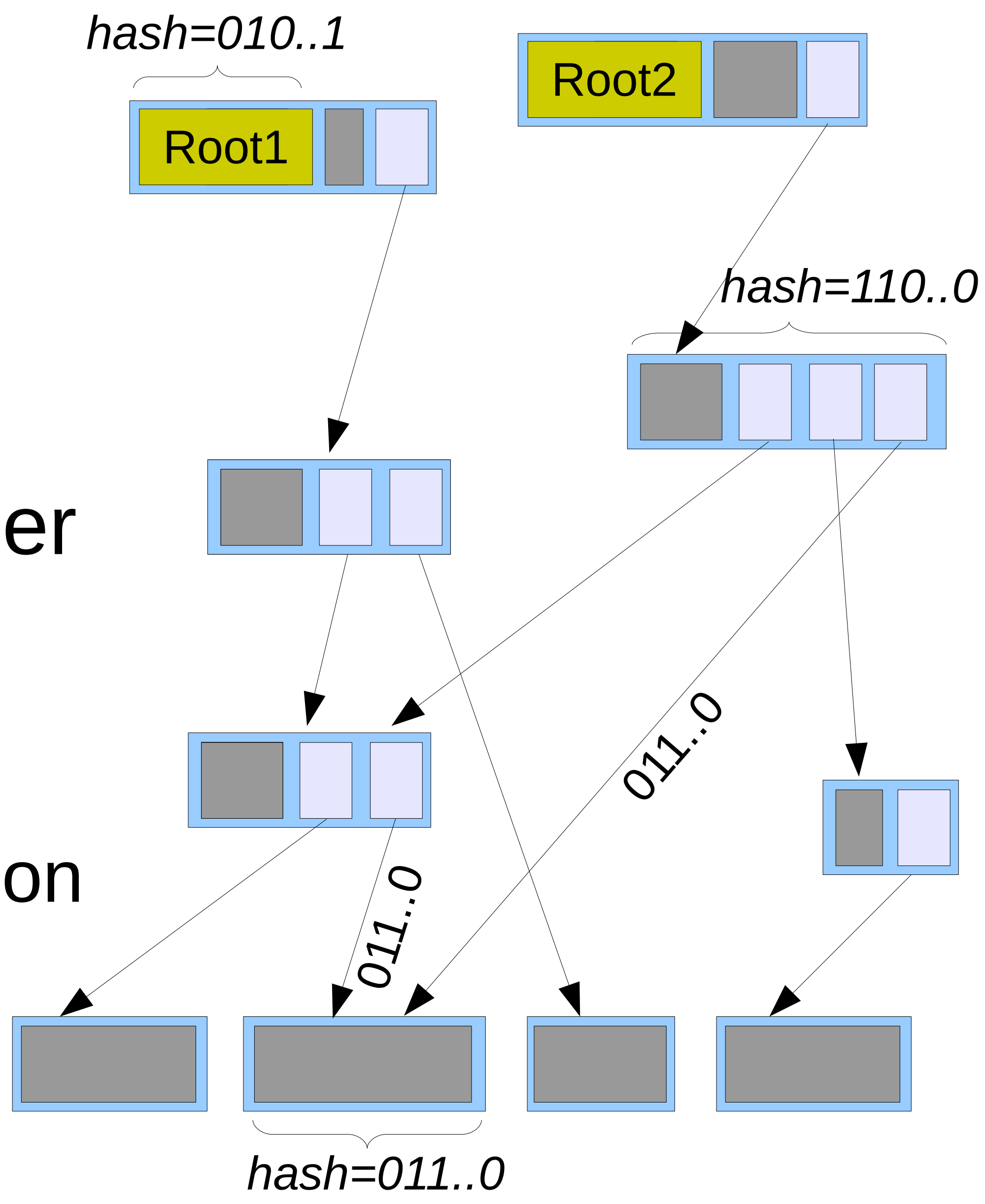

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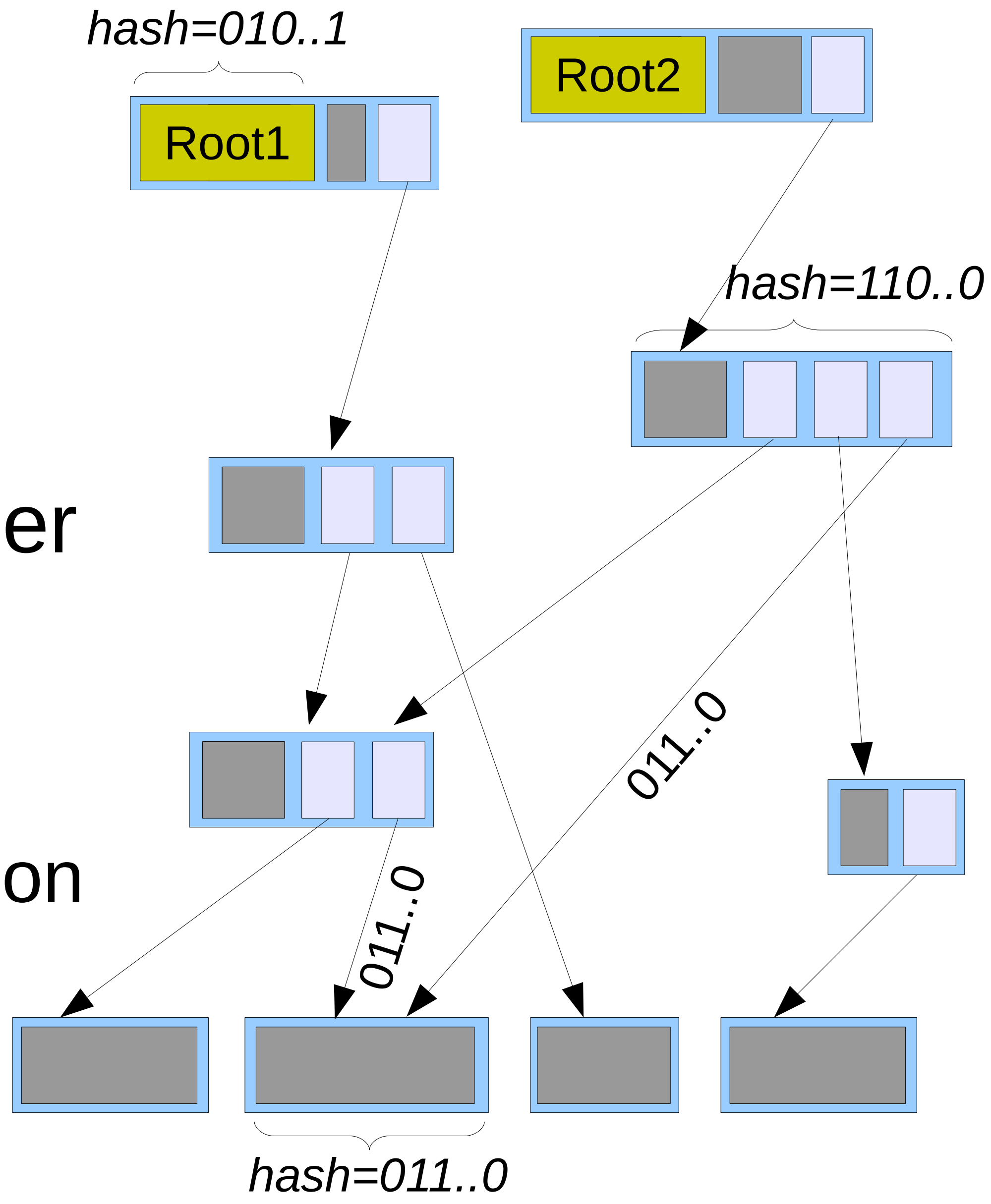

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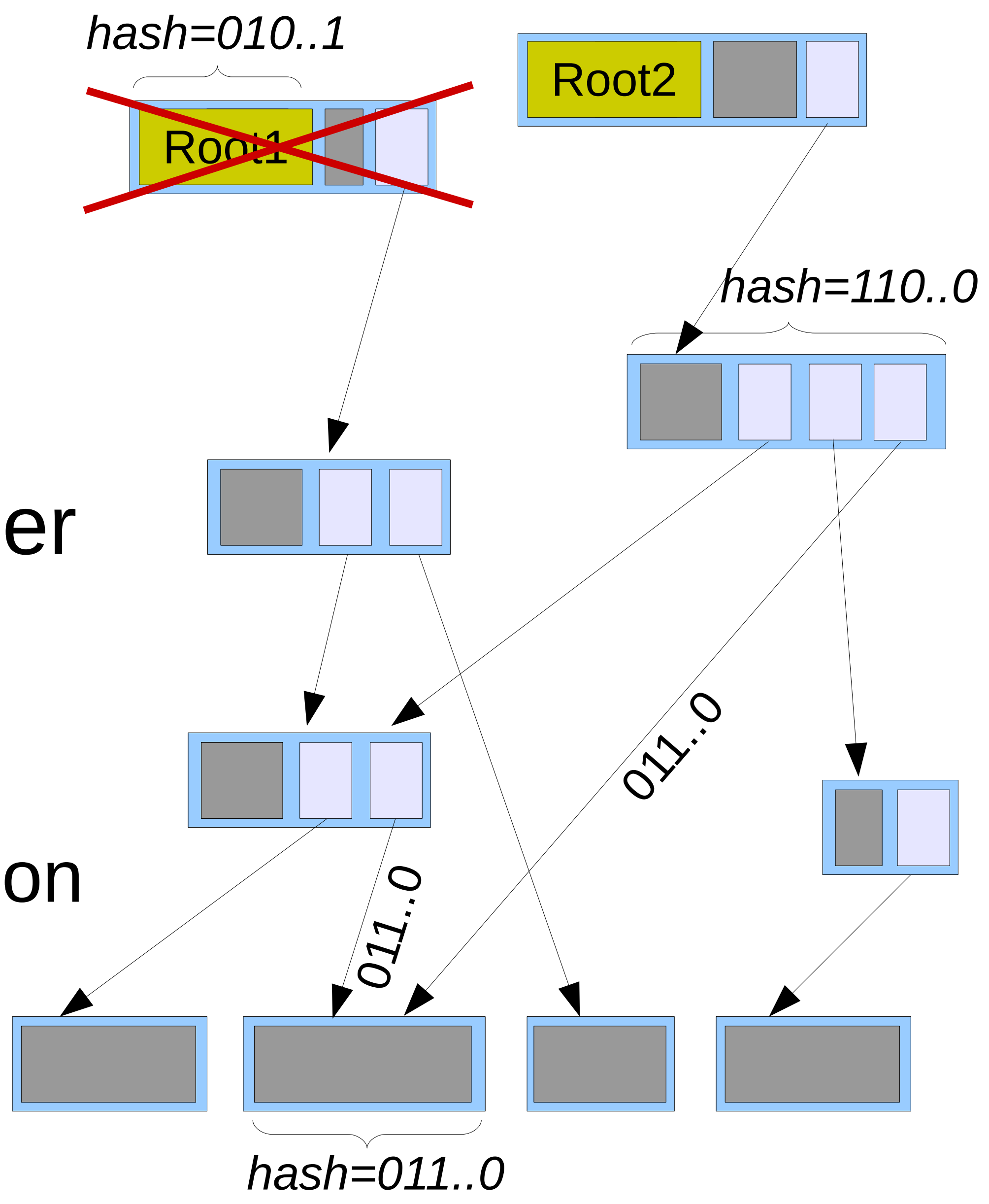

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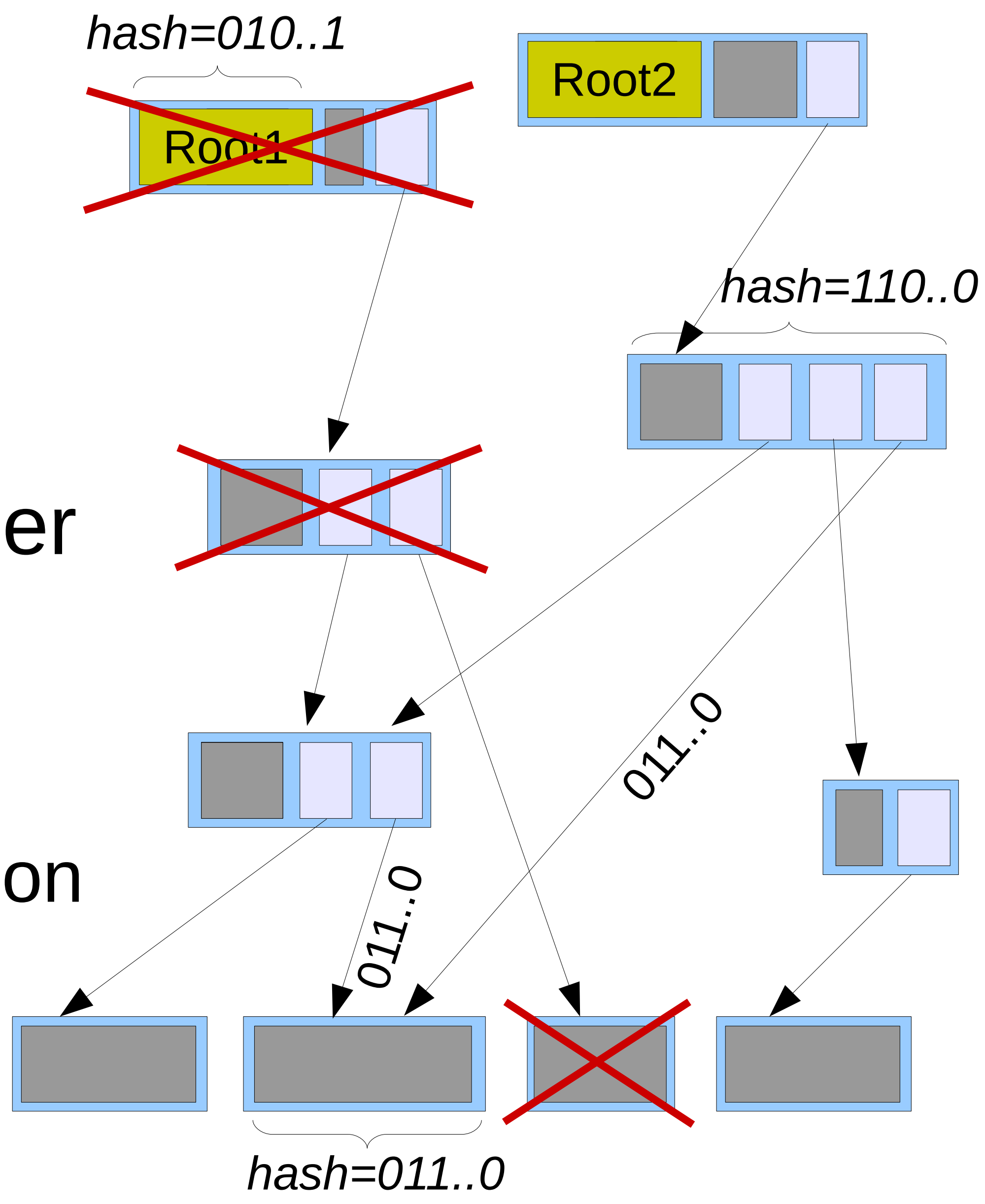

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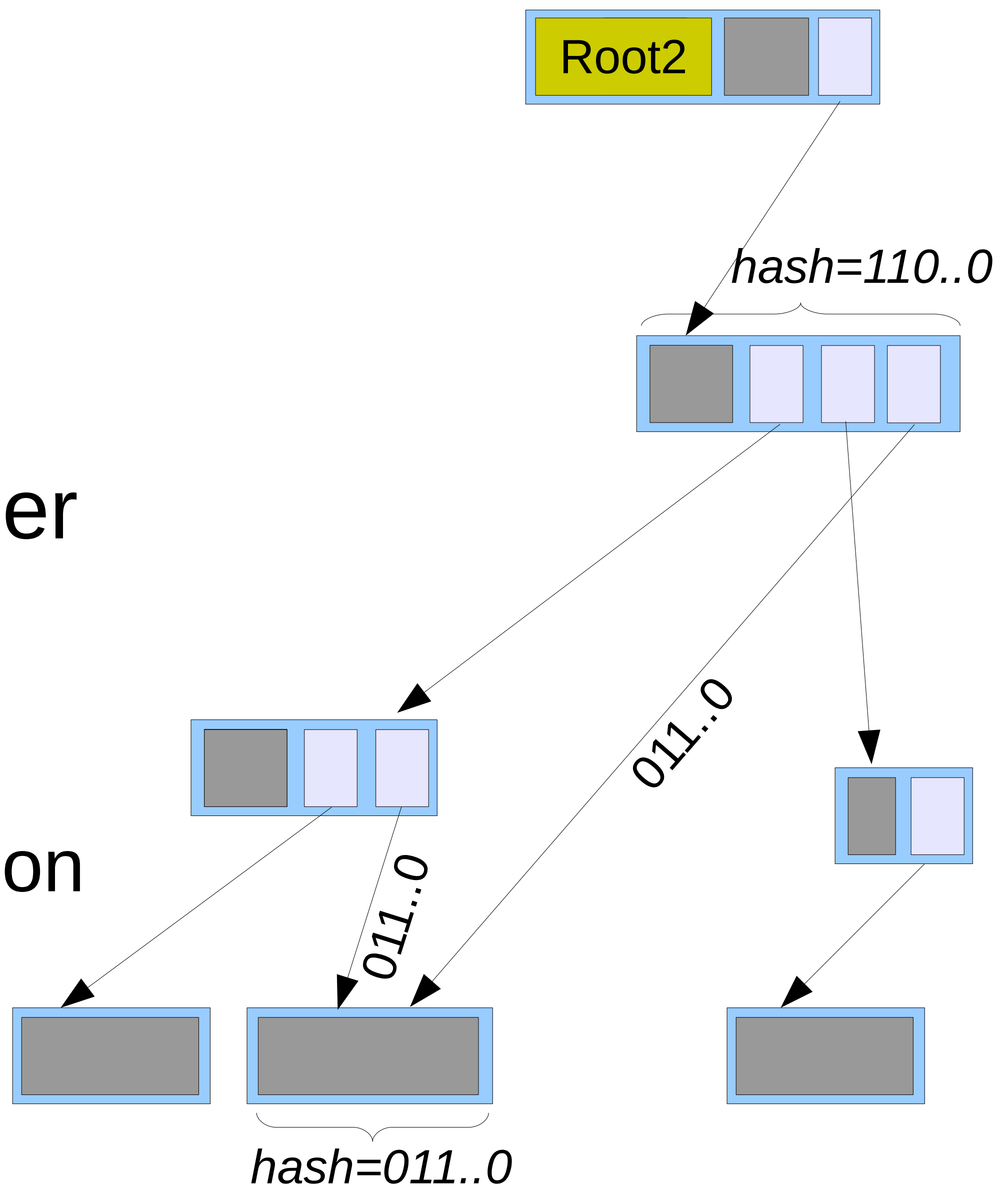
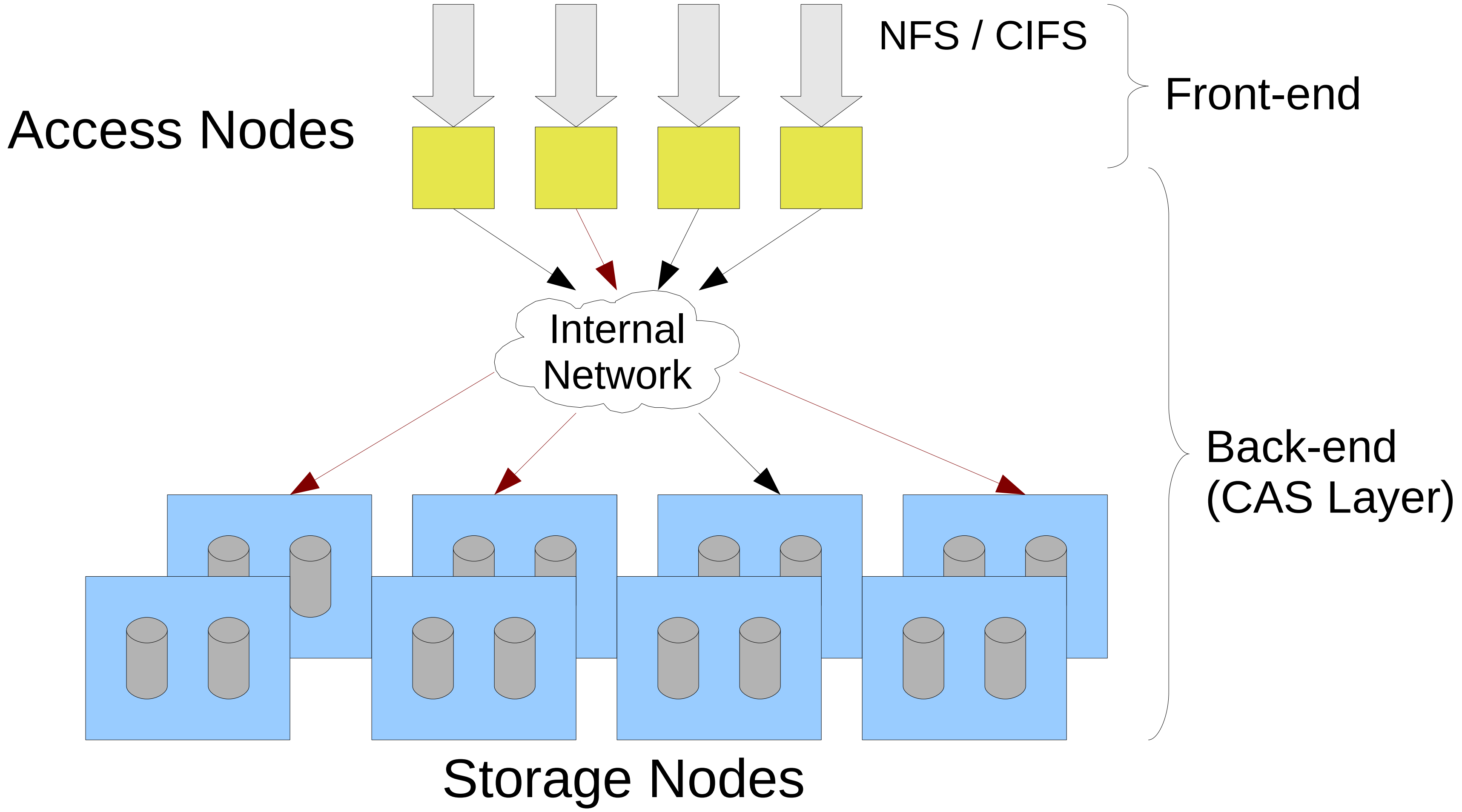


Architecture overview

- Standard server-grade hardware running Linux
- Scalability on data-center level



Data organization: selected requirements

Requirements on scalable storage	Required internal data services
Failure tolerance	• Identify data resilience reduction • Fast data rebuilding
High performance	• Preserve locality of data streams • Prefetching
Dynamic scalability	• Decentralized data management • Load balancing • Fast data transfer to new location
Deduplication	• Location of potential duplicates • Availability & resiliency verification
On-demand deletion	• Failure-tolerant, distributed deletion

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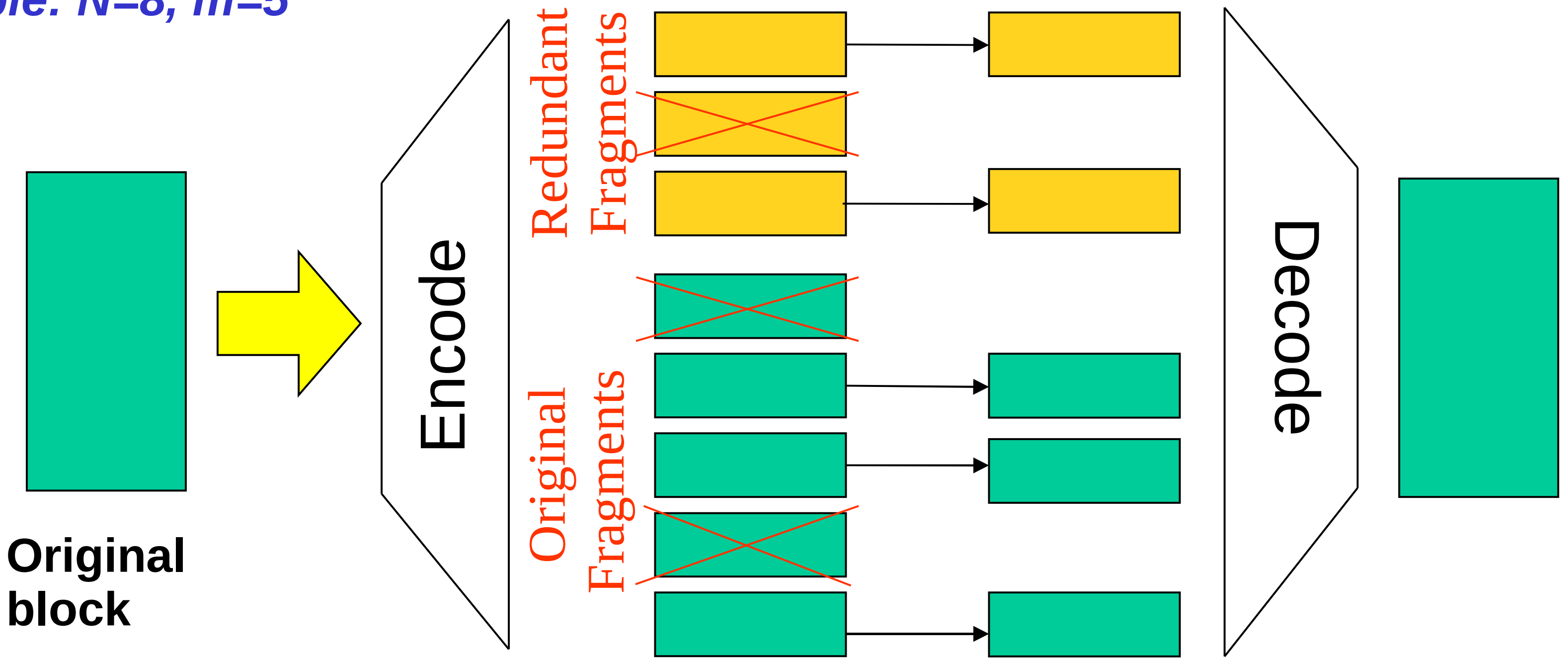
Failure tolerance: erasure coding

- Block erasure-coded into N fragments
- Storage overhead tunable

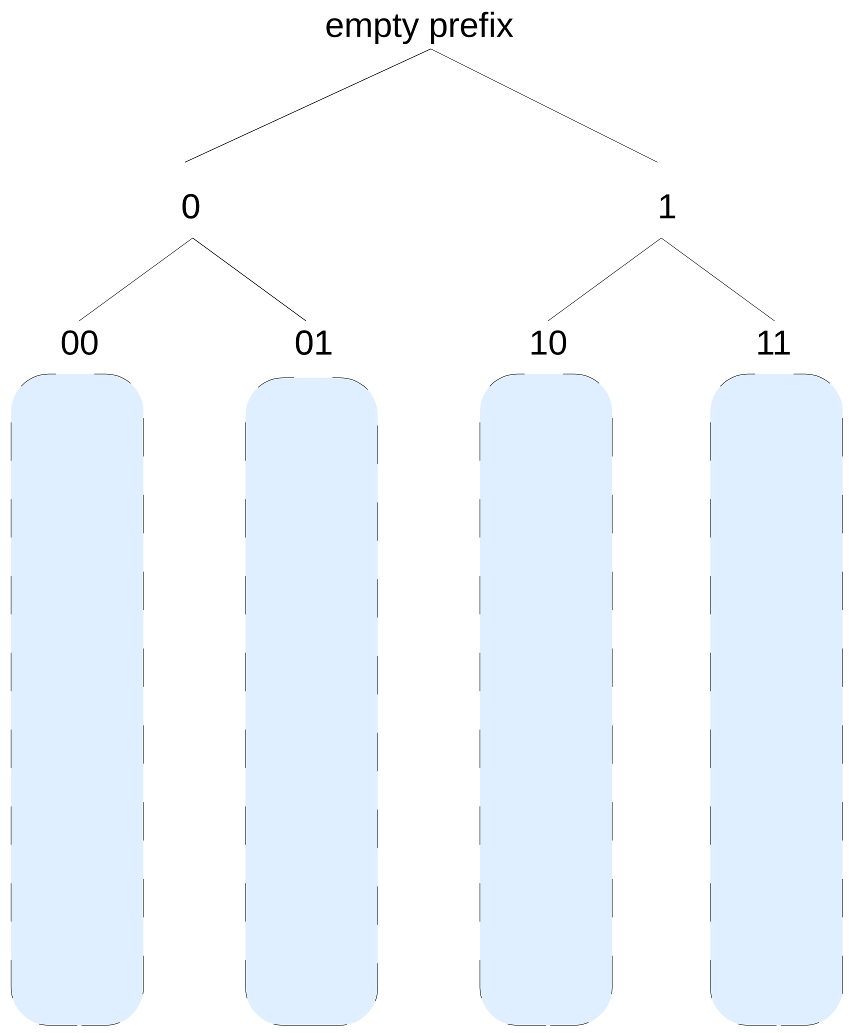
Example: N=8, m=5



Any 3 fragments can be lost

Scalability with DHT: data placement

- Block location: DHT with prefix routing



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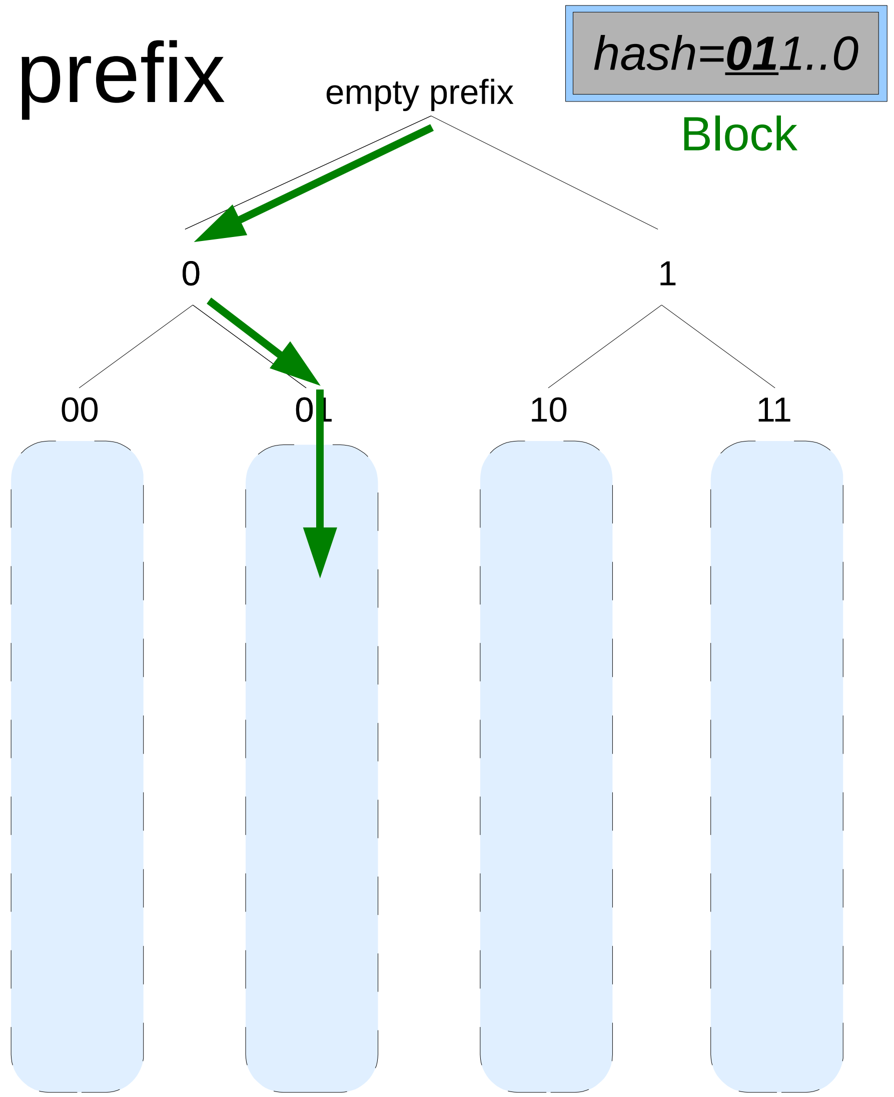

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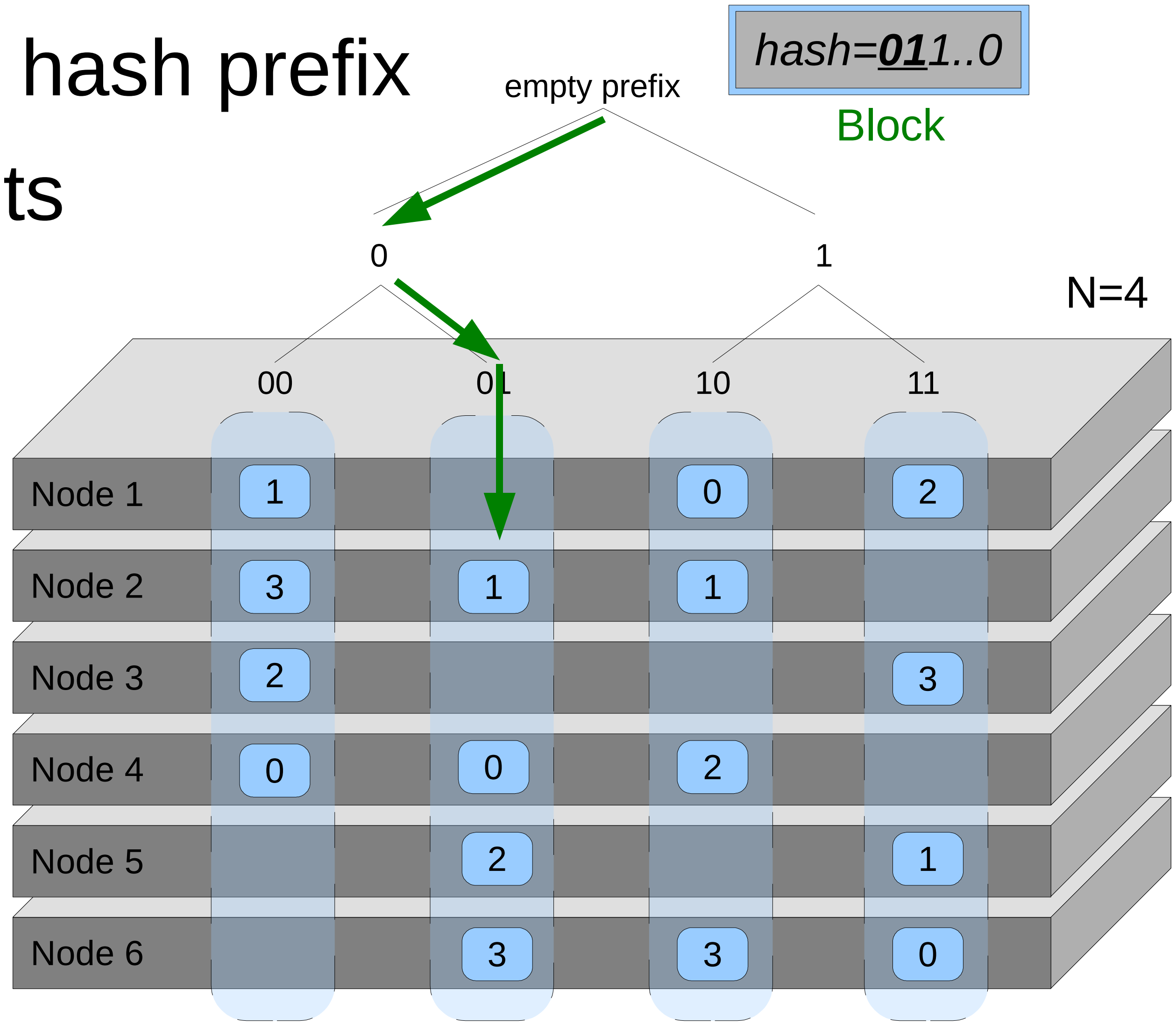

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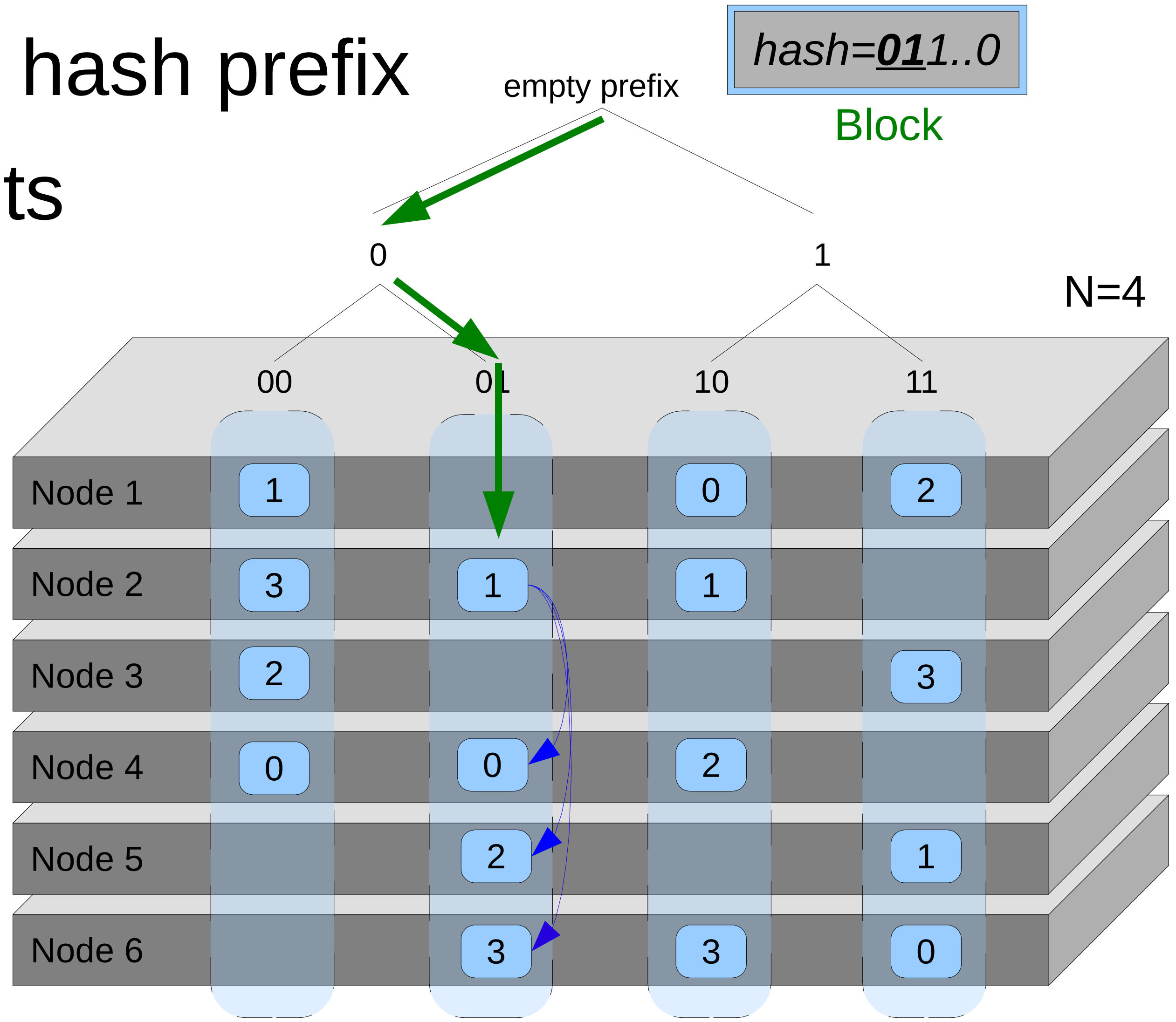

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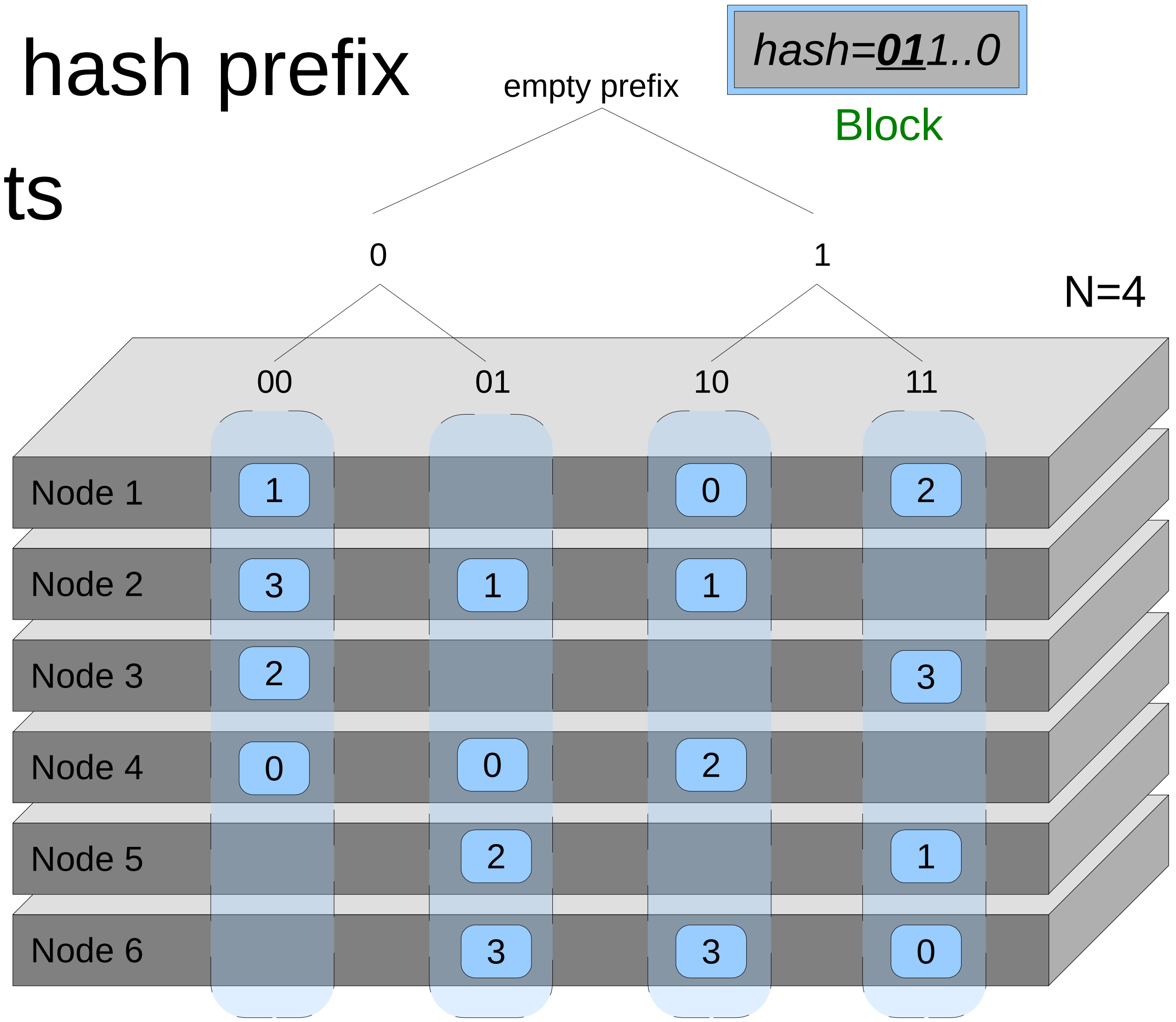

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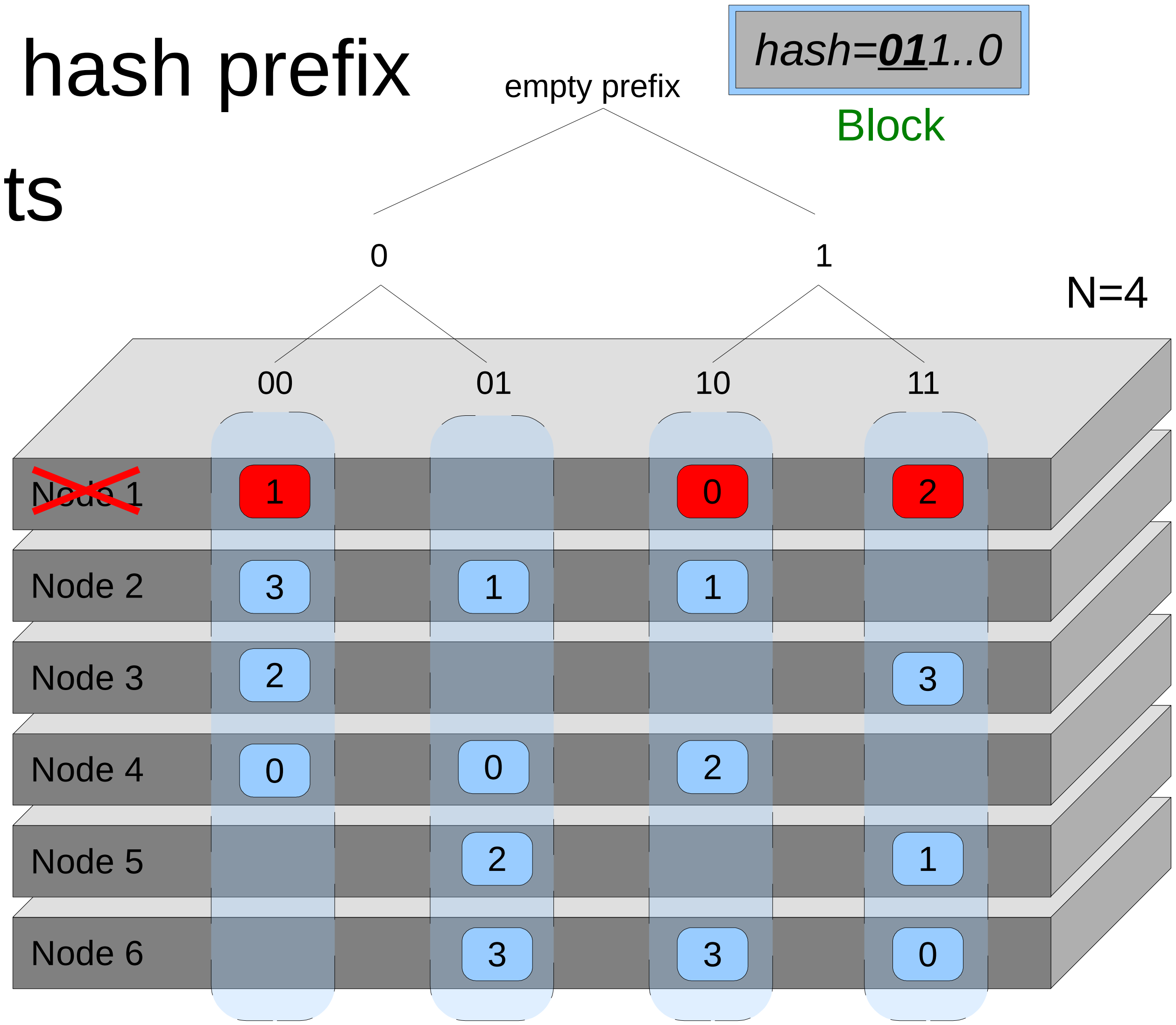

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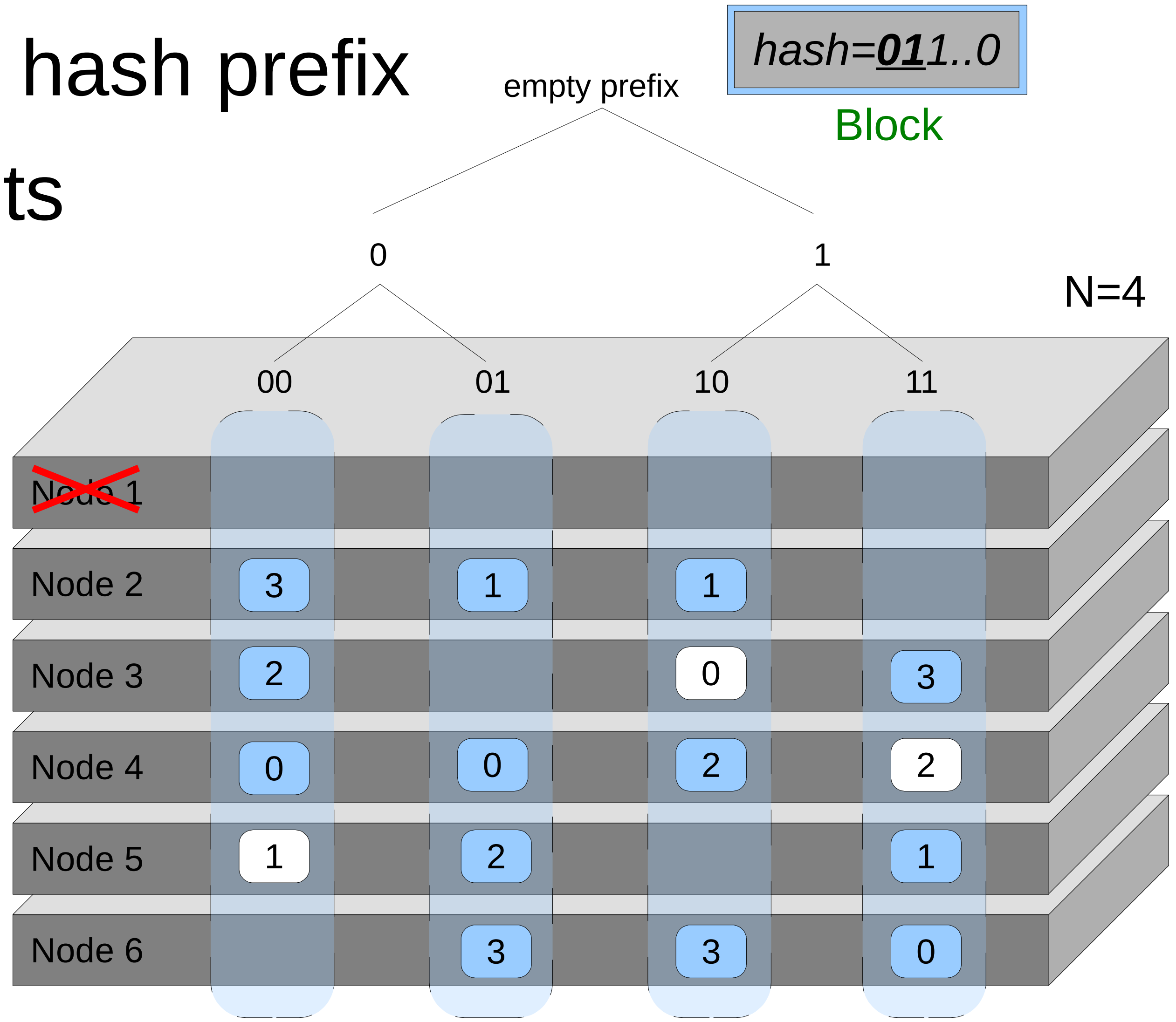

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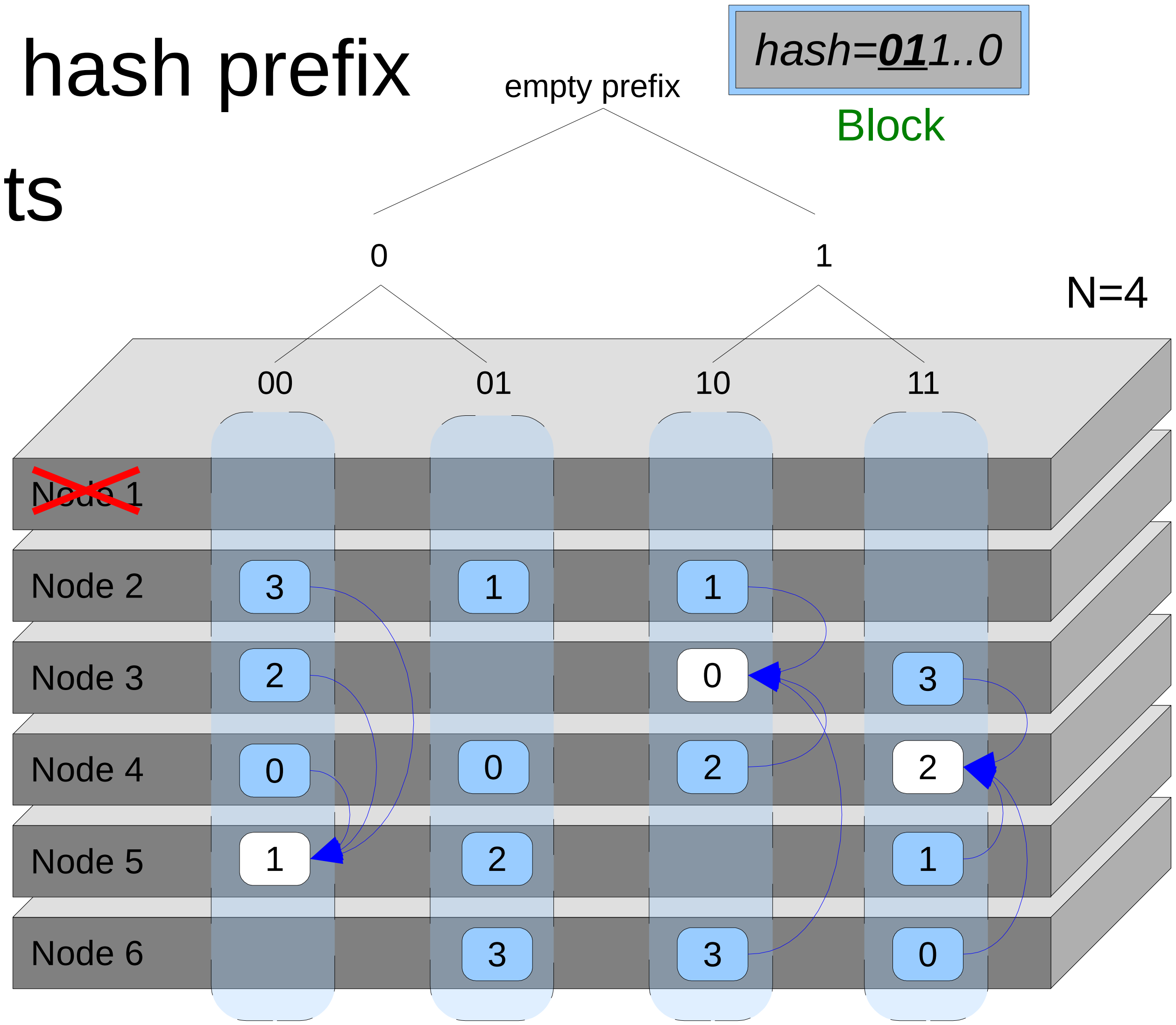

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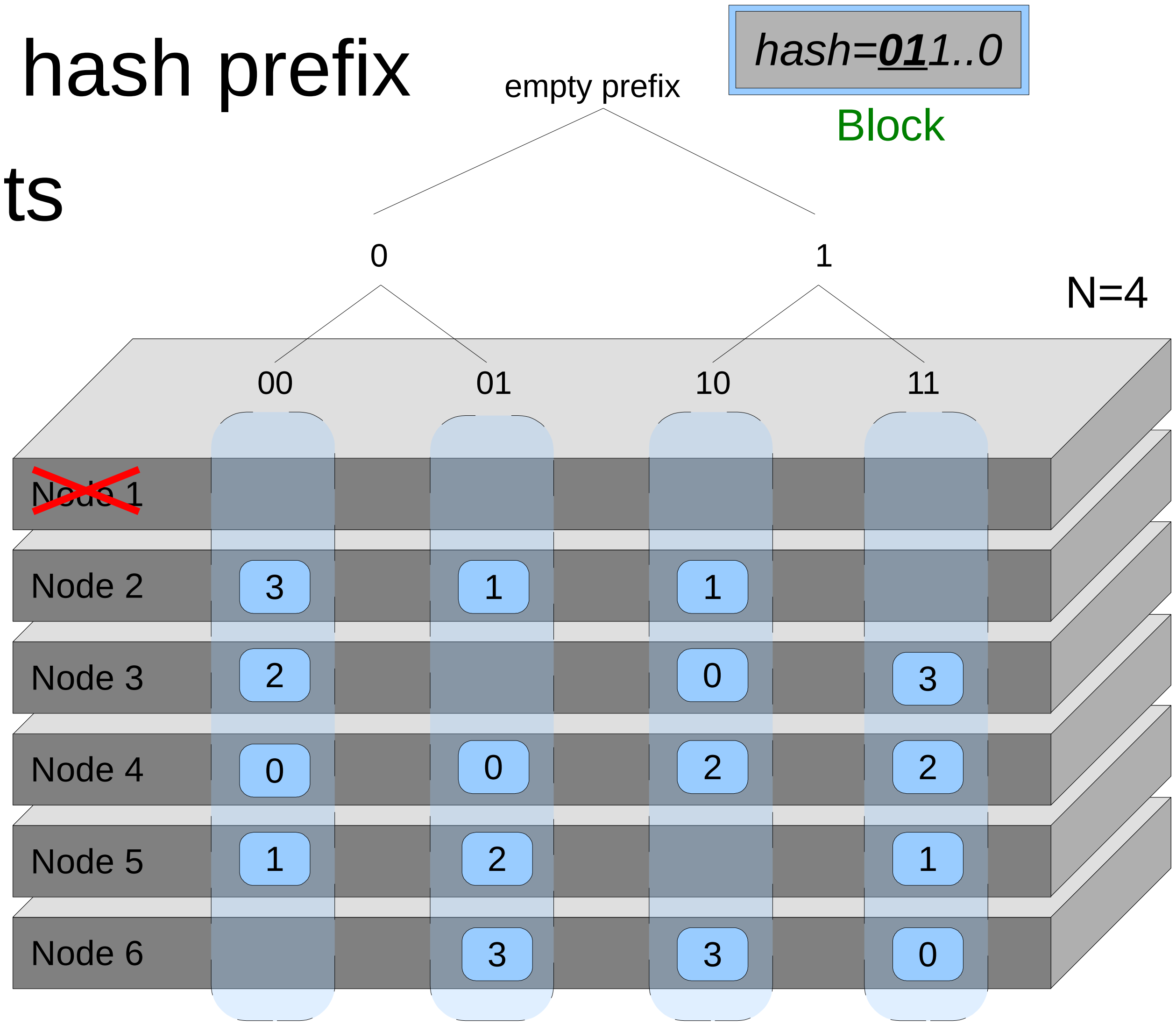
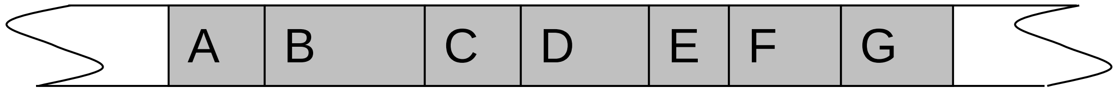


Data organization: synchrun chains



- Data stream split to blocks

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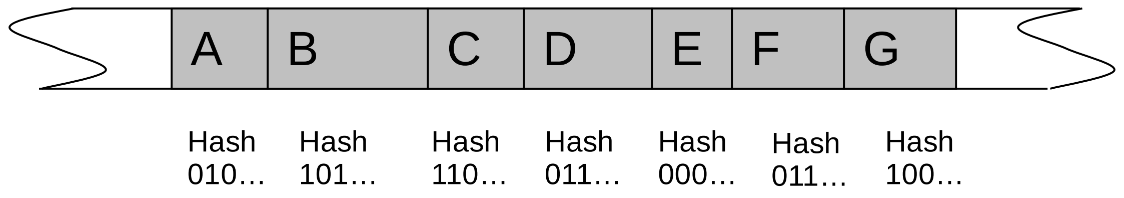

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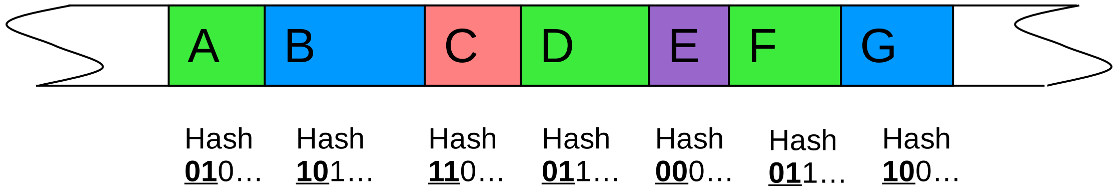

- Data stream split to blocks
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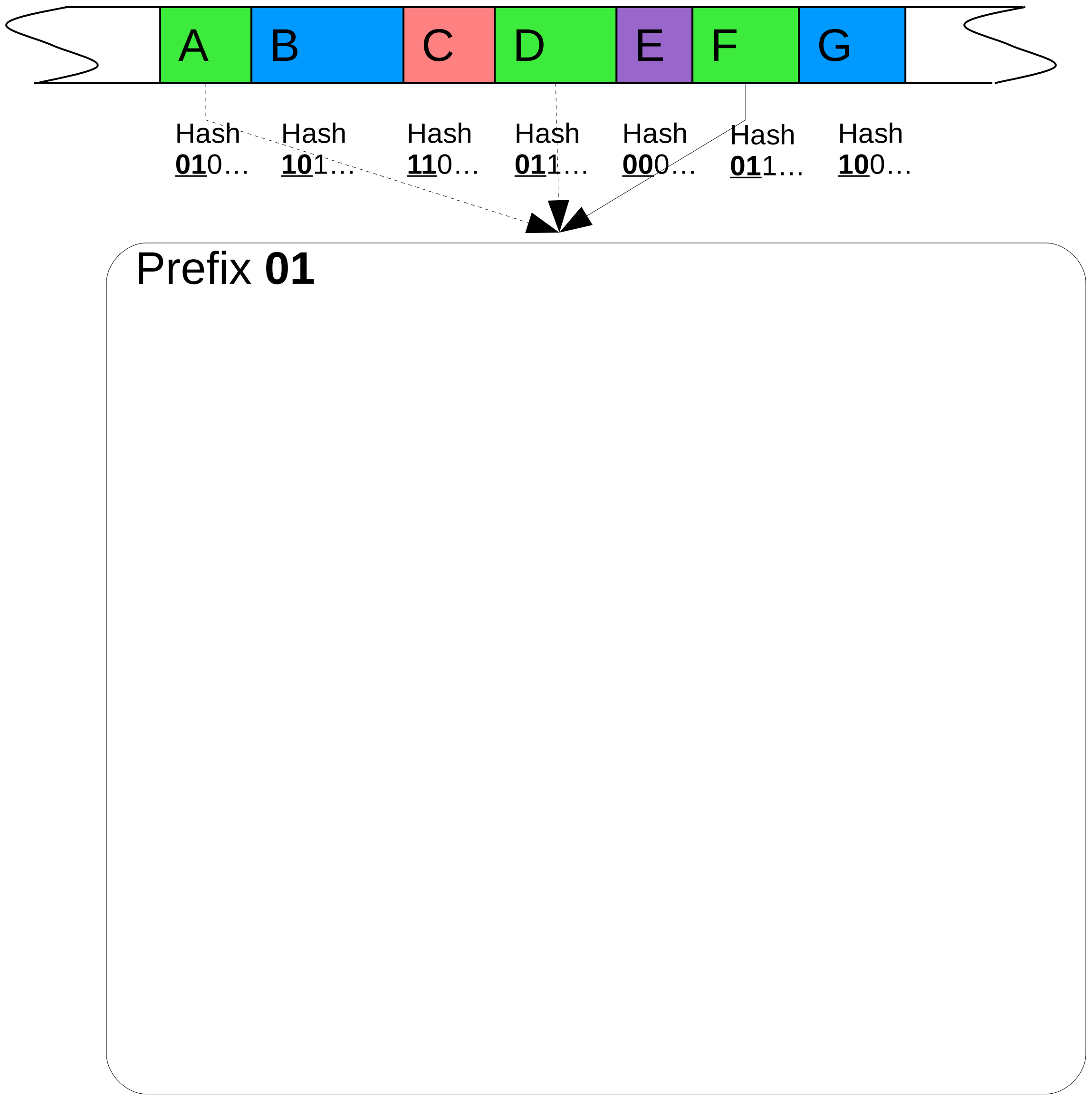

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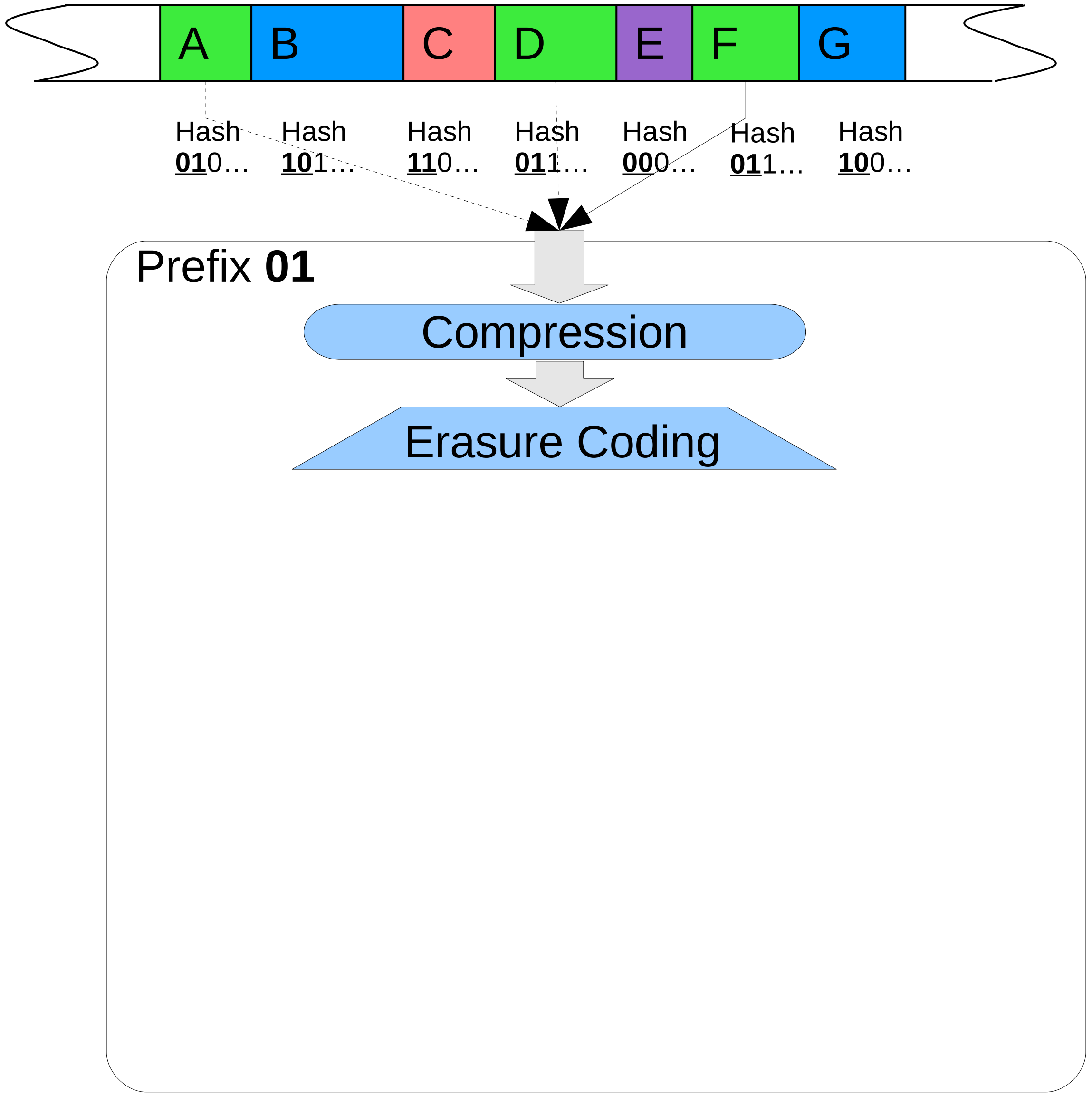

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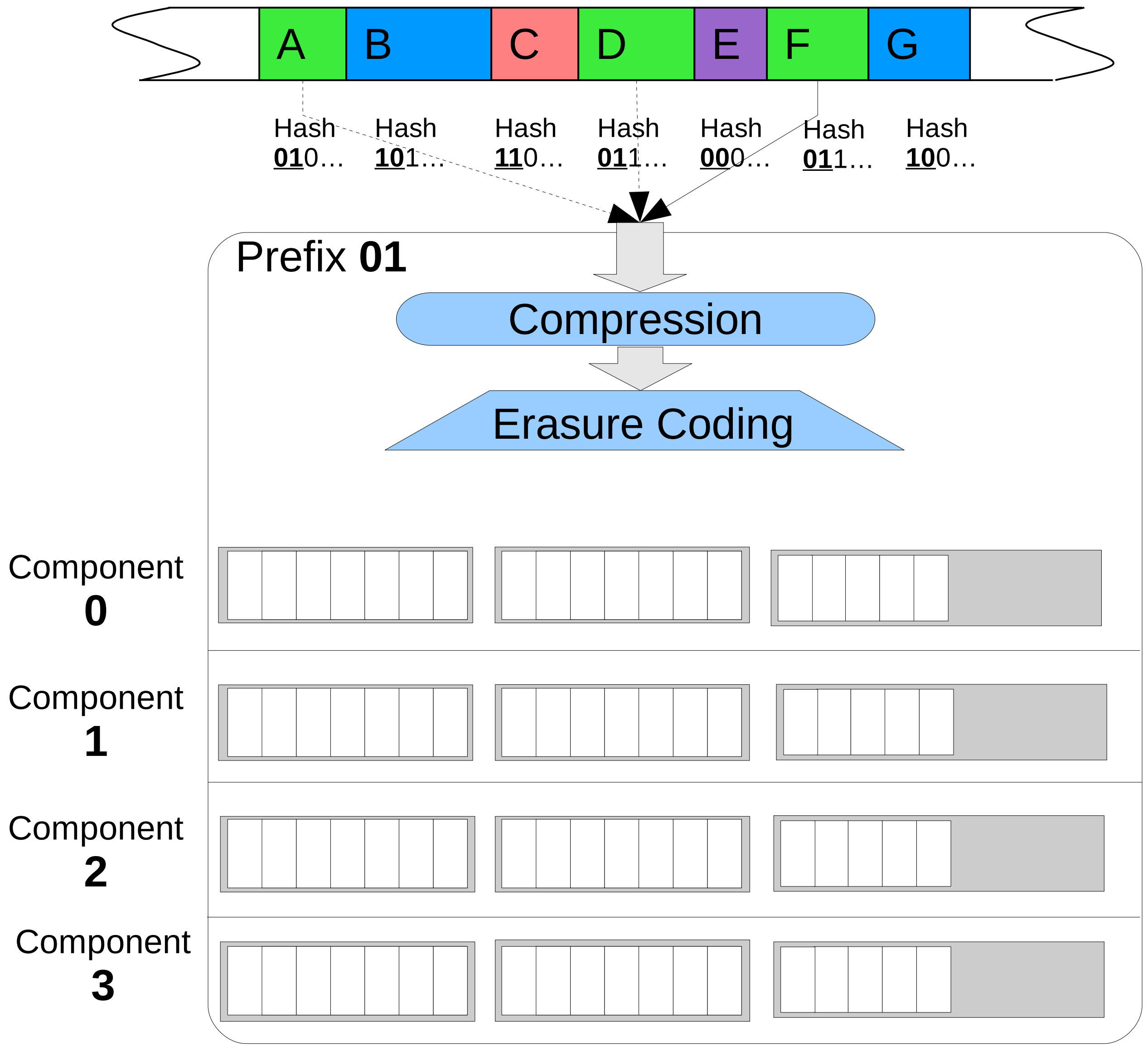

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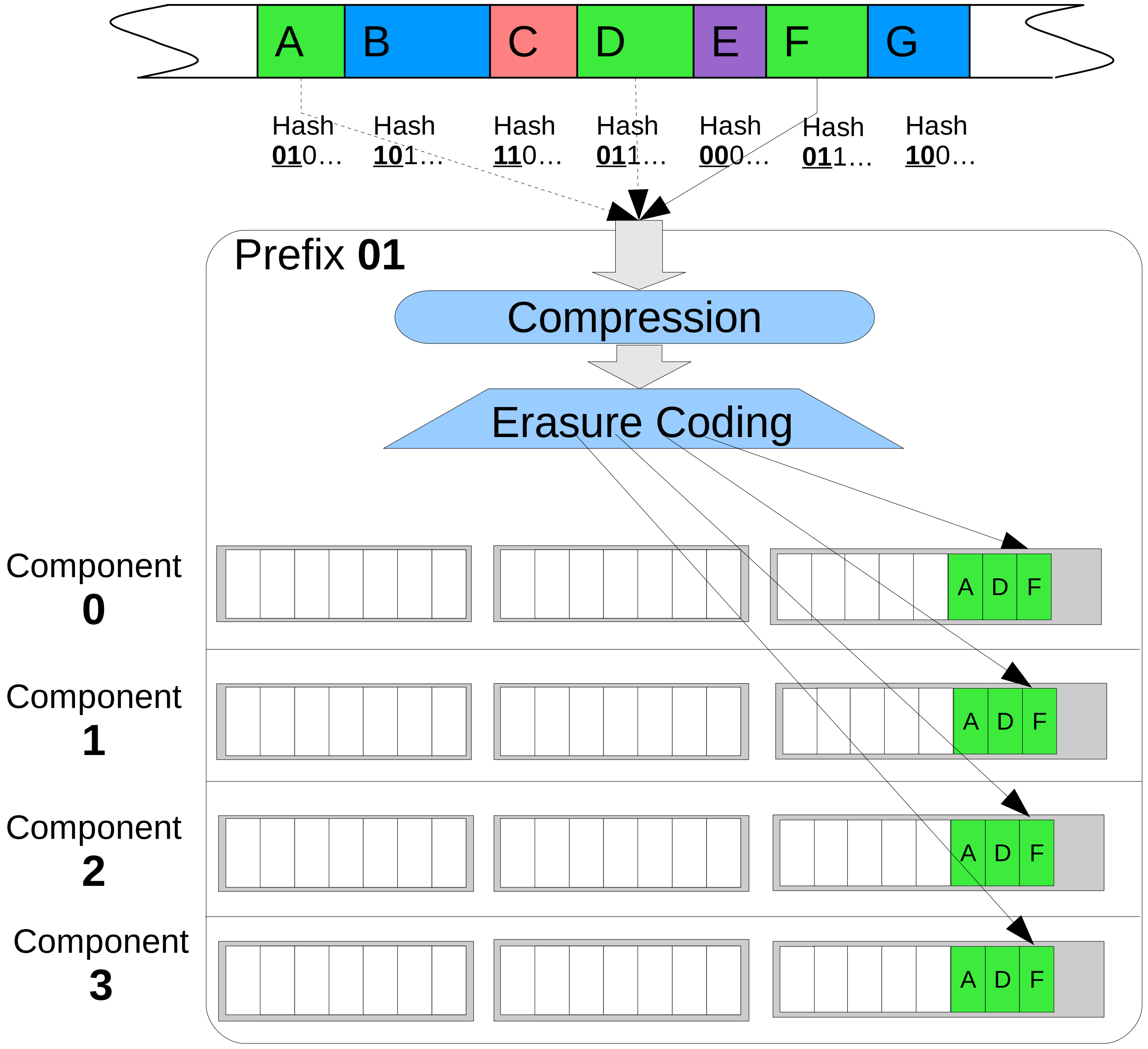

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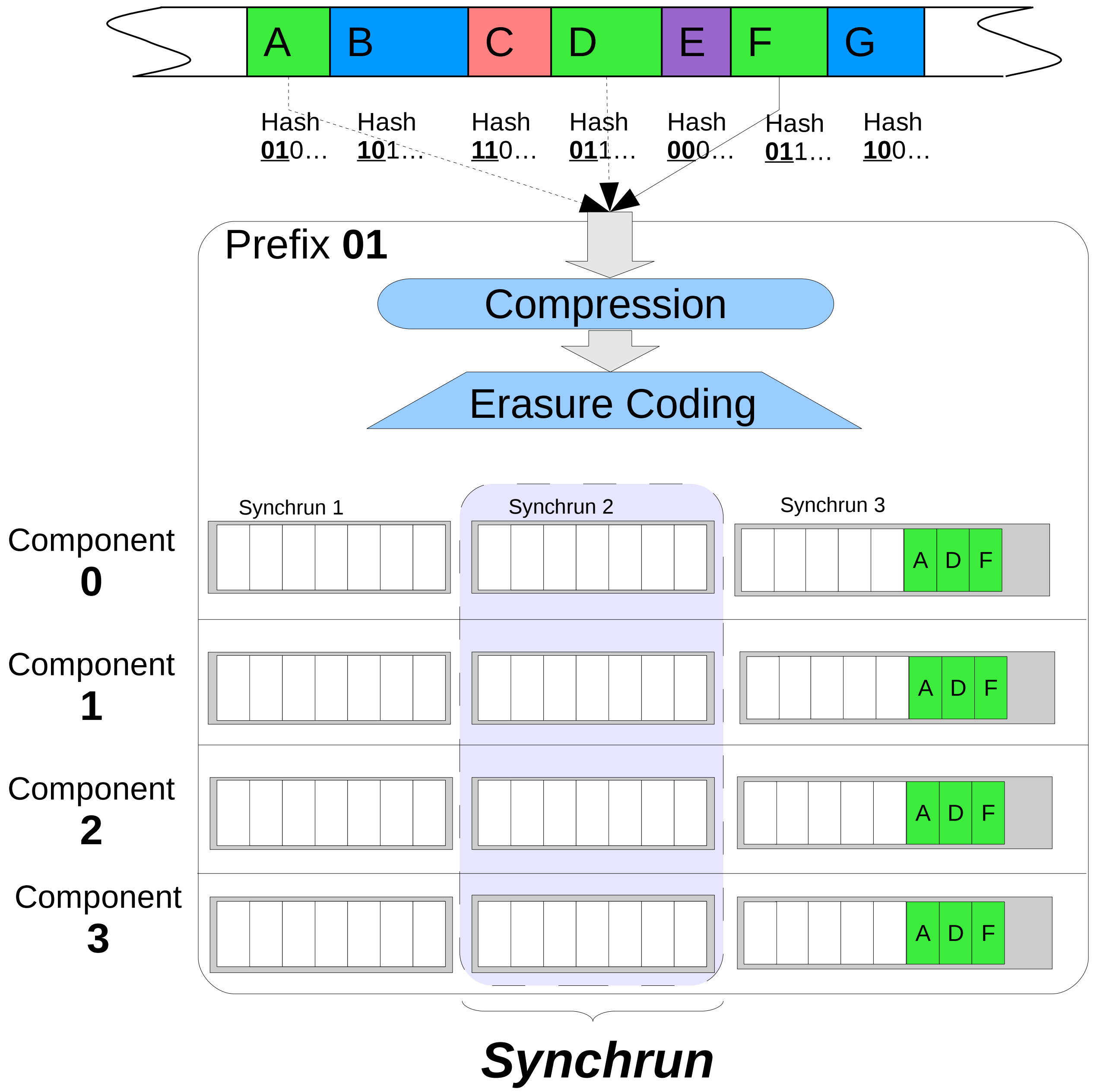

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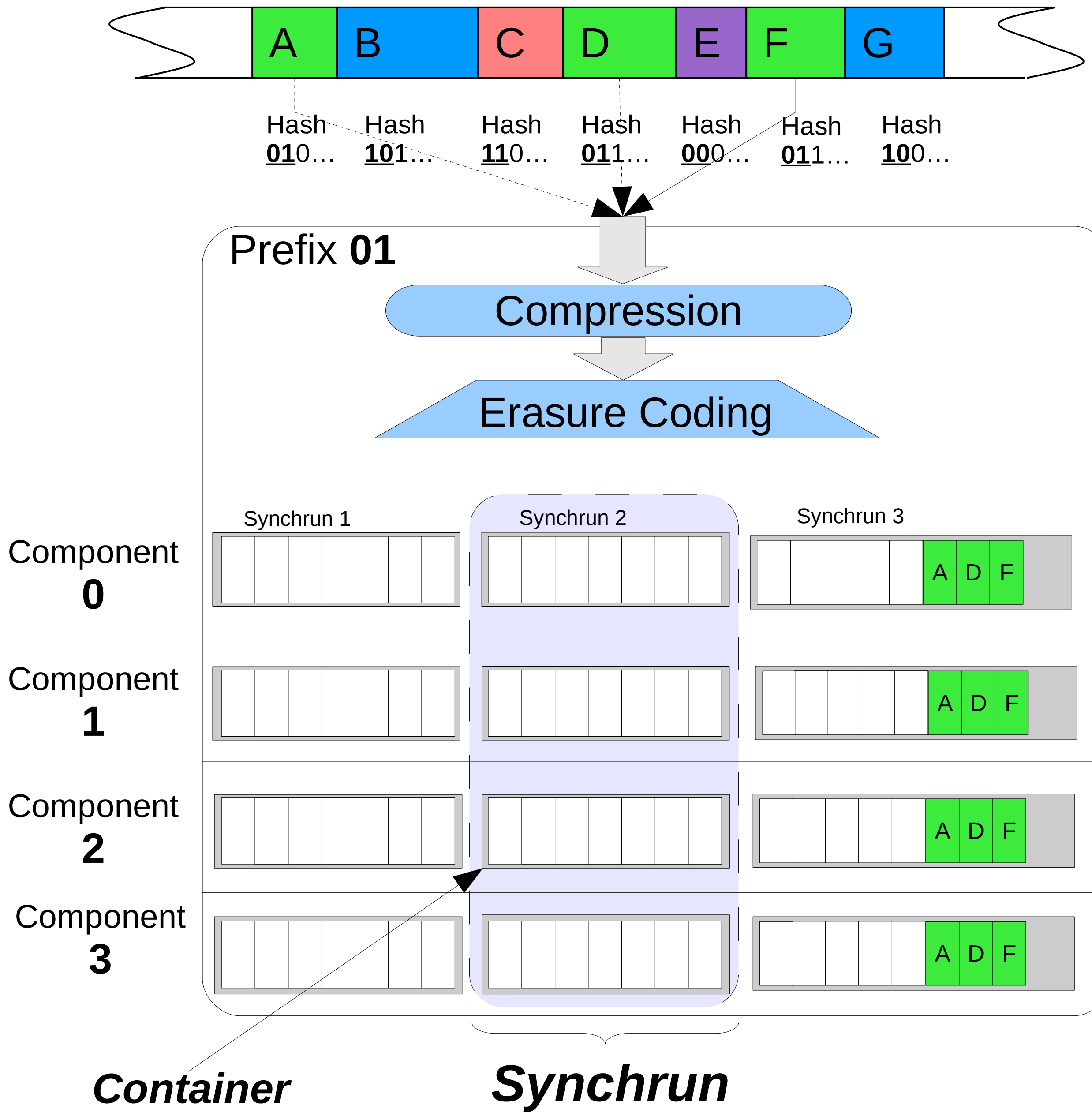

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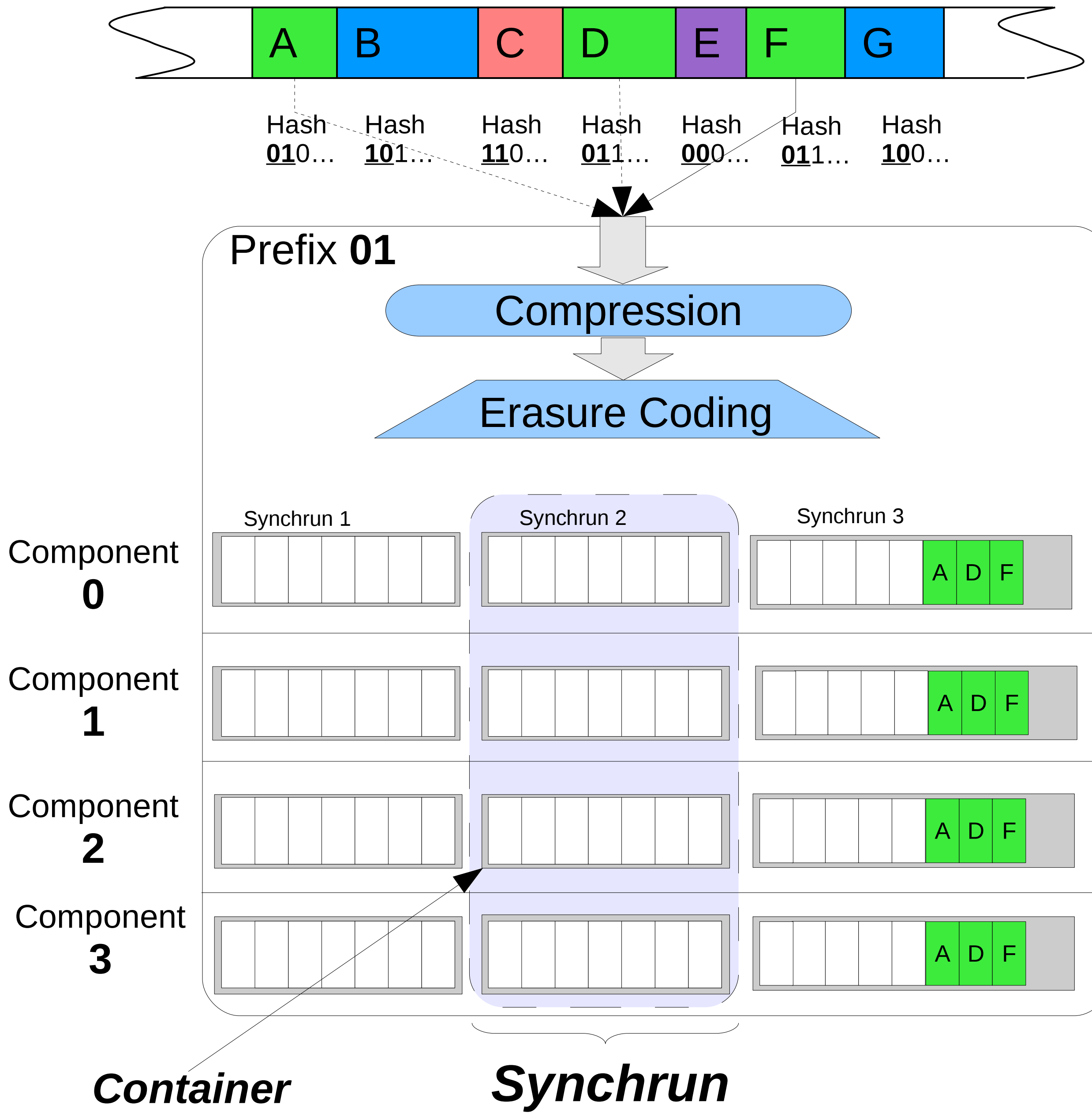

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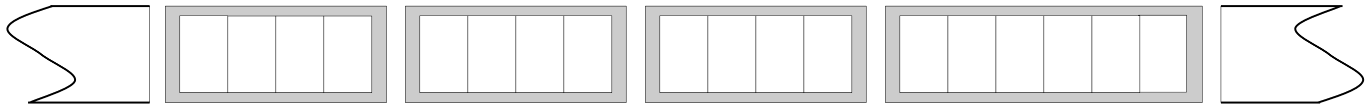
- Grouped into **synchruns**
- **Containers** stored on disks
  - Fragment metadata separately from data
- Ordered synchrun **chains**
  - Preserve order & locality
  - Manageable

Synchrun chains in a dynamic system

Component
01:**1**



System growth: split

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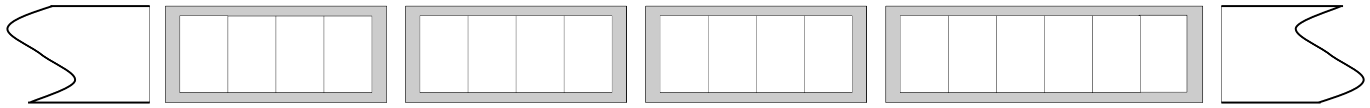

Component
010:**1**

Component
011:**1**

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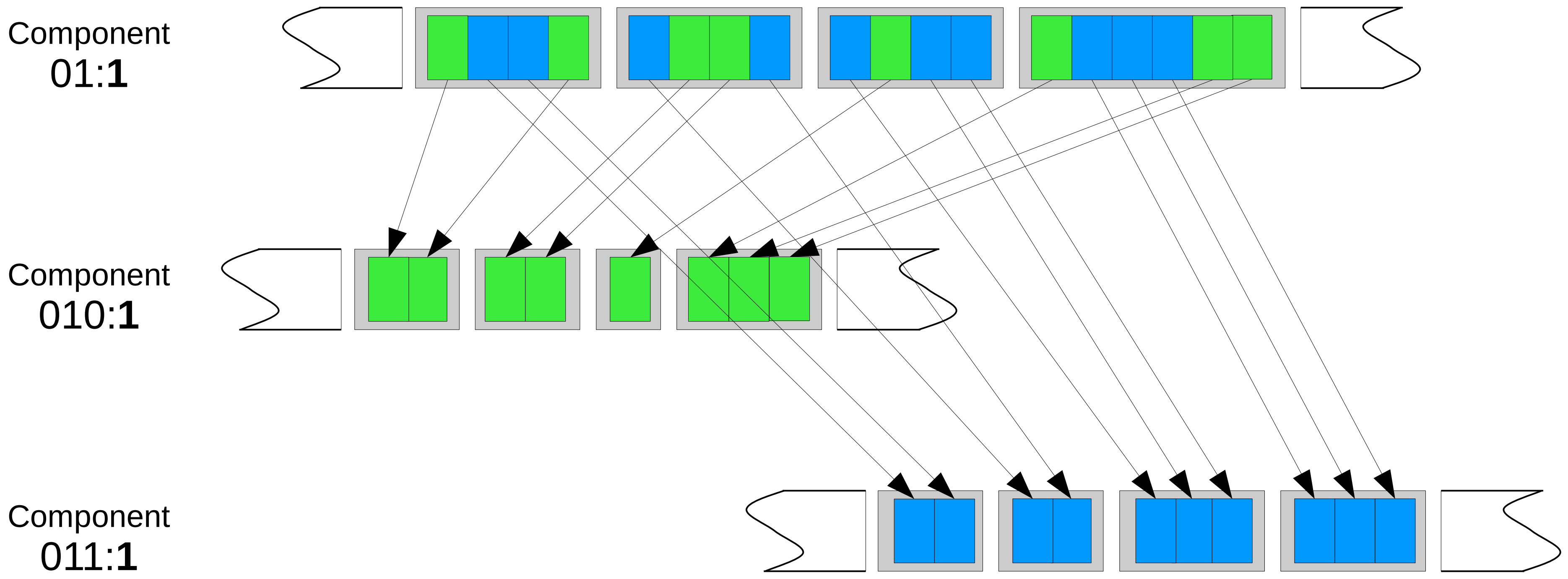

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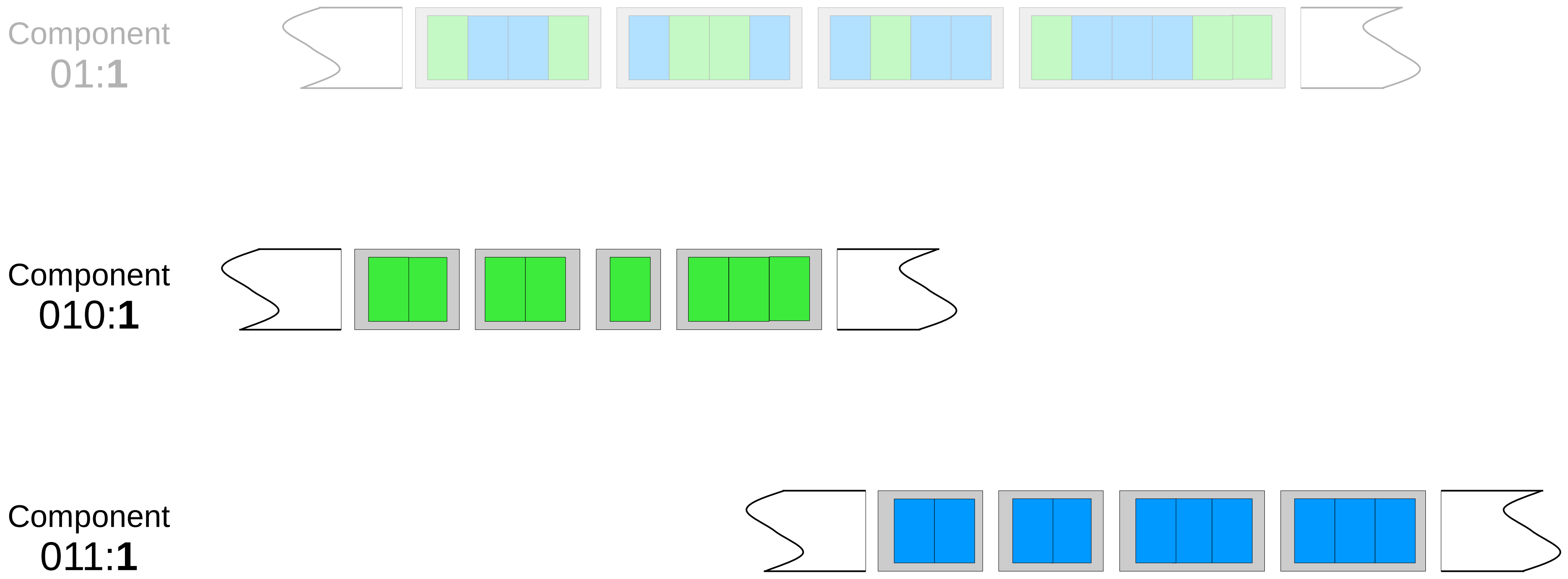
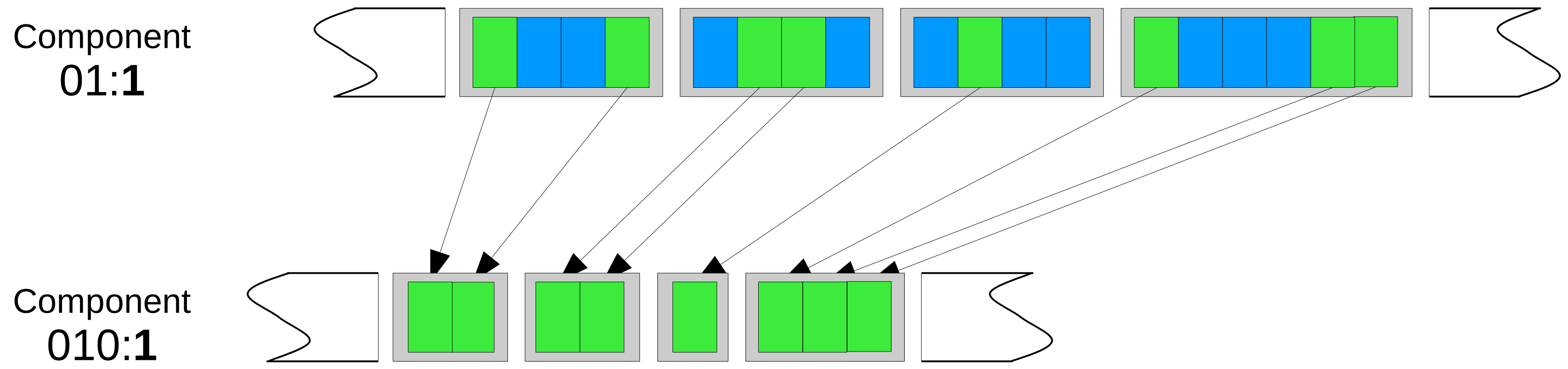


Concatenation



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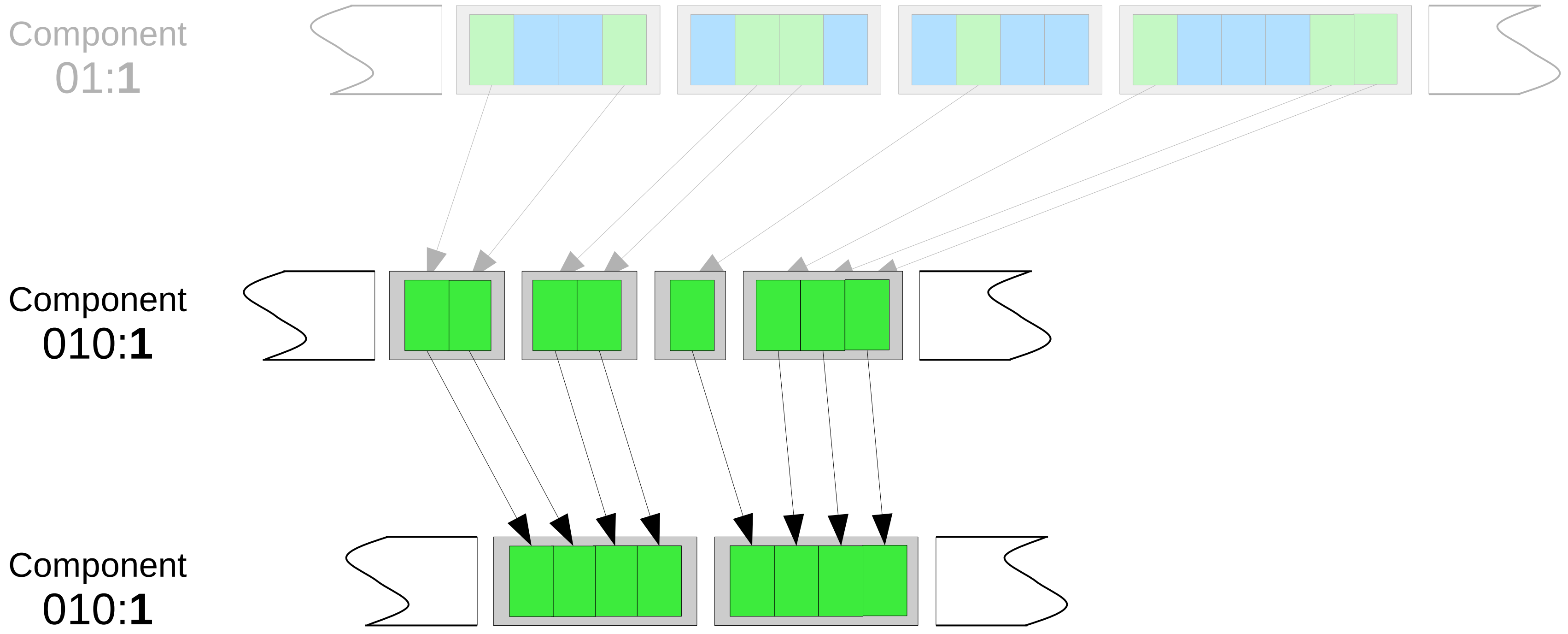
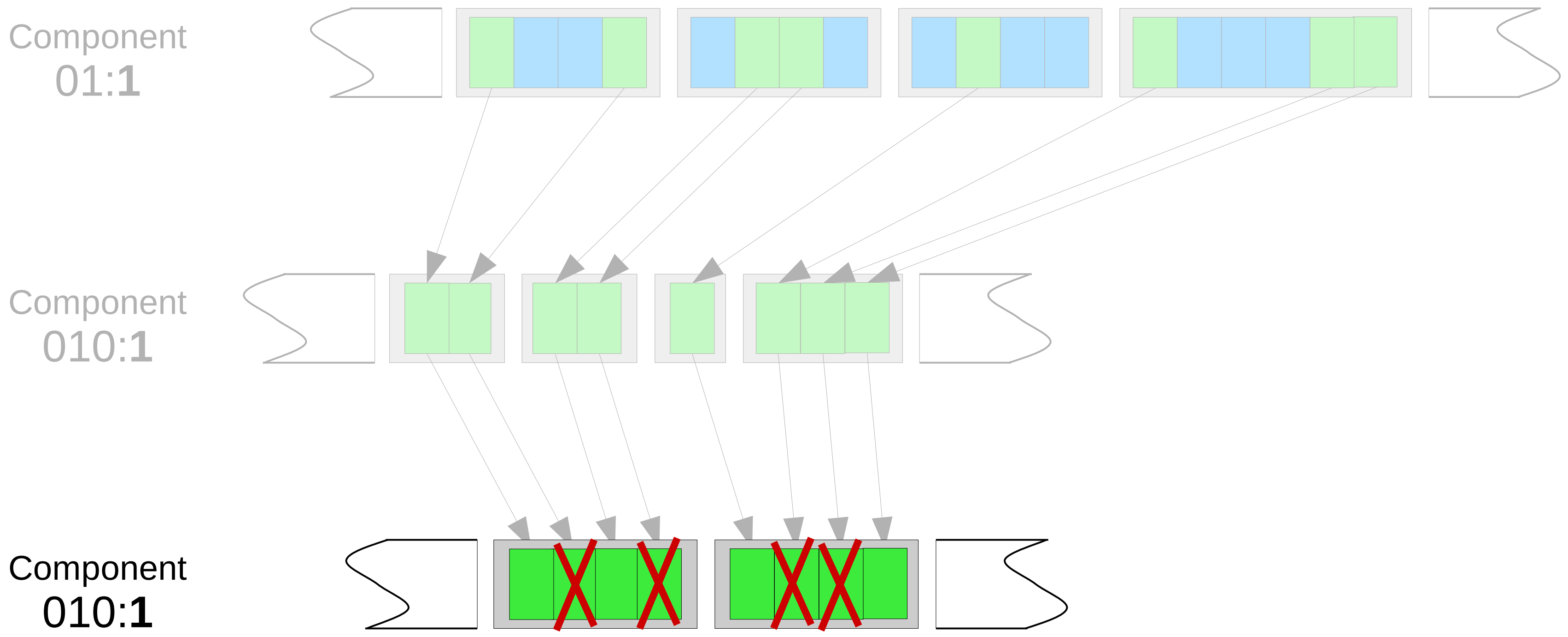
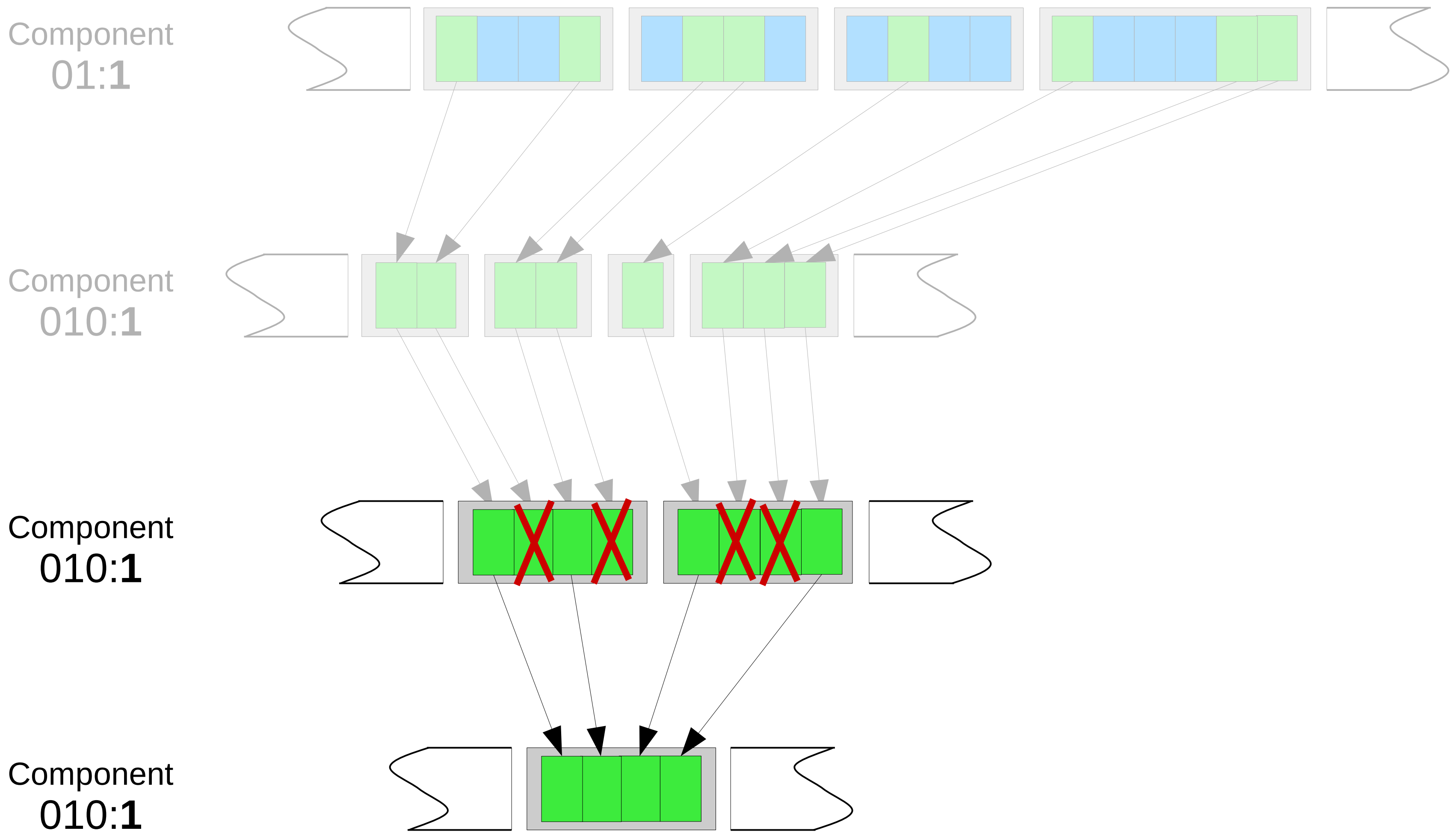


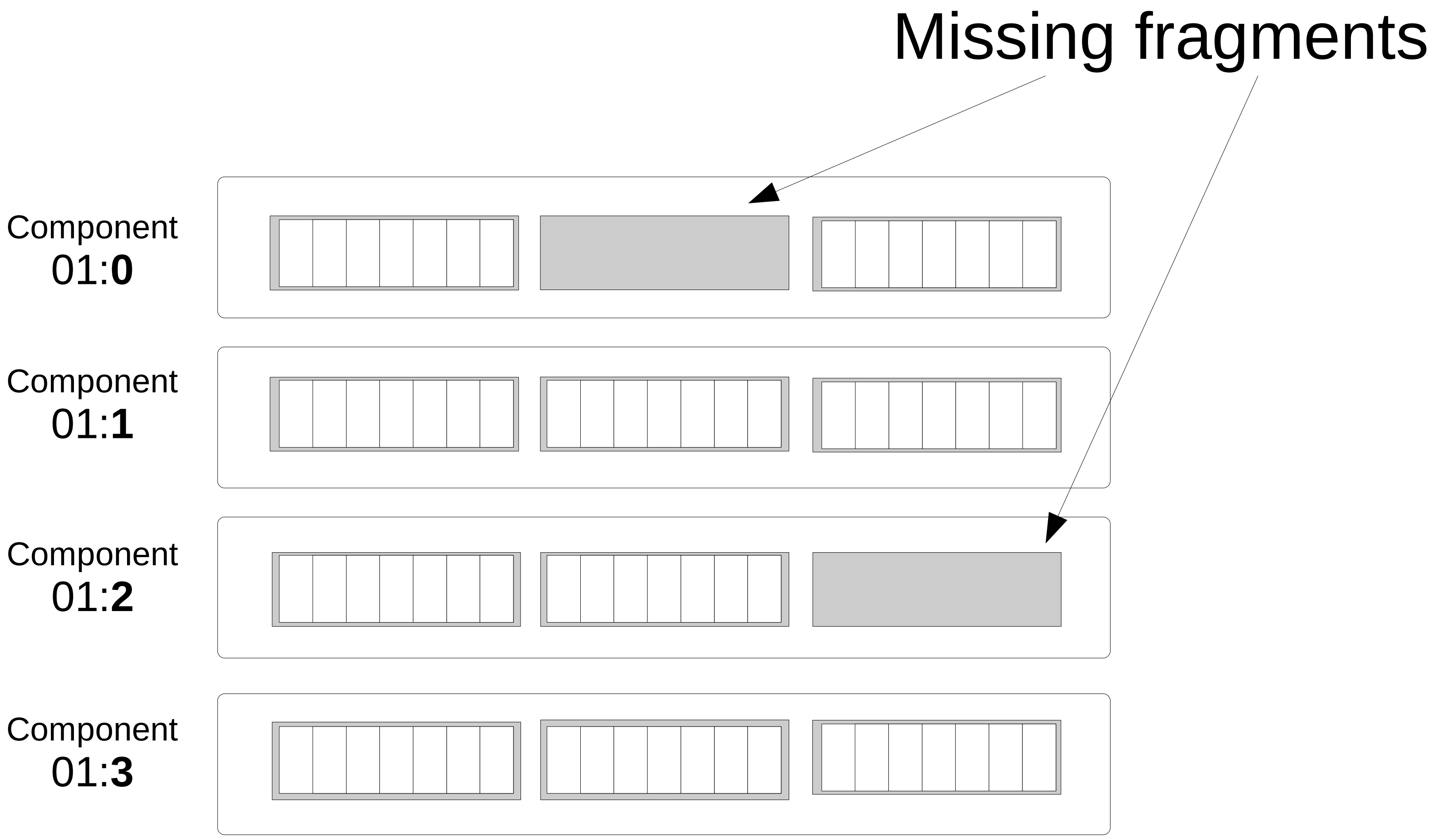
Marking blocks to reclaim



Space reclamation & Concatenation



Data Services:
Identification of data resiliency level



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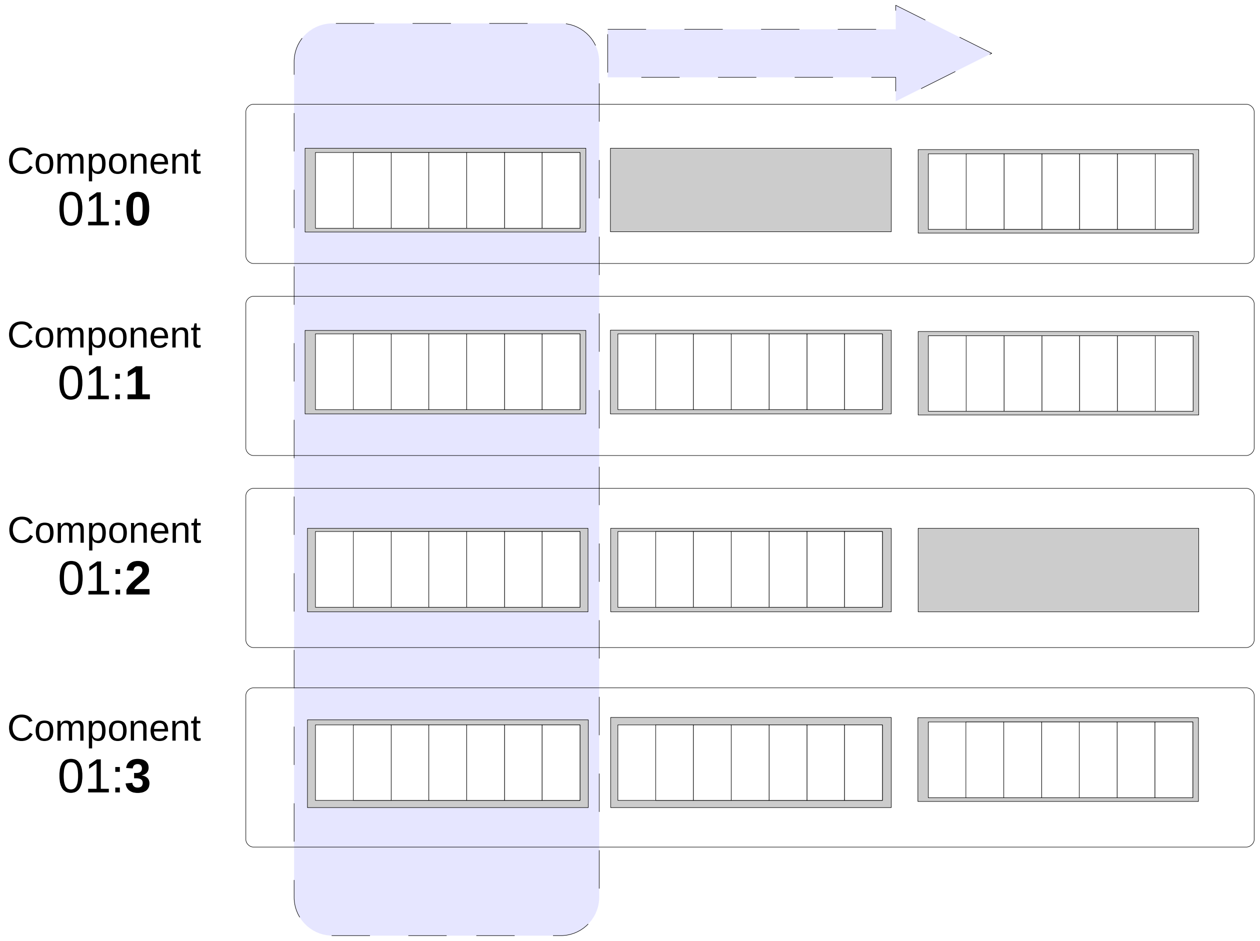

Chain scanning

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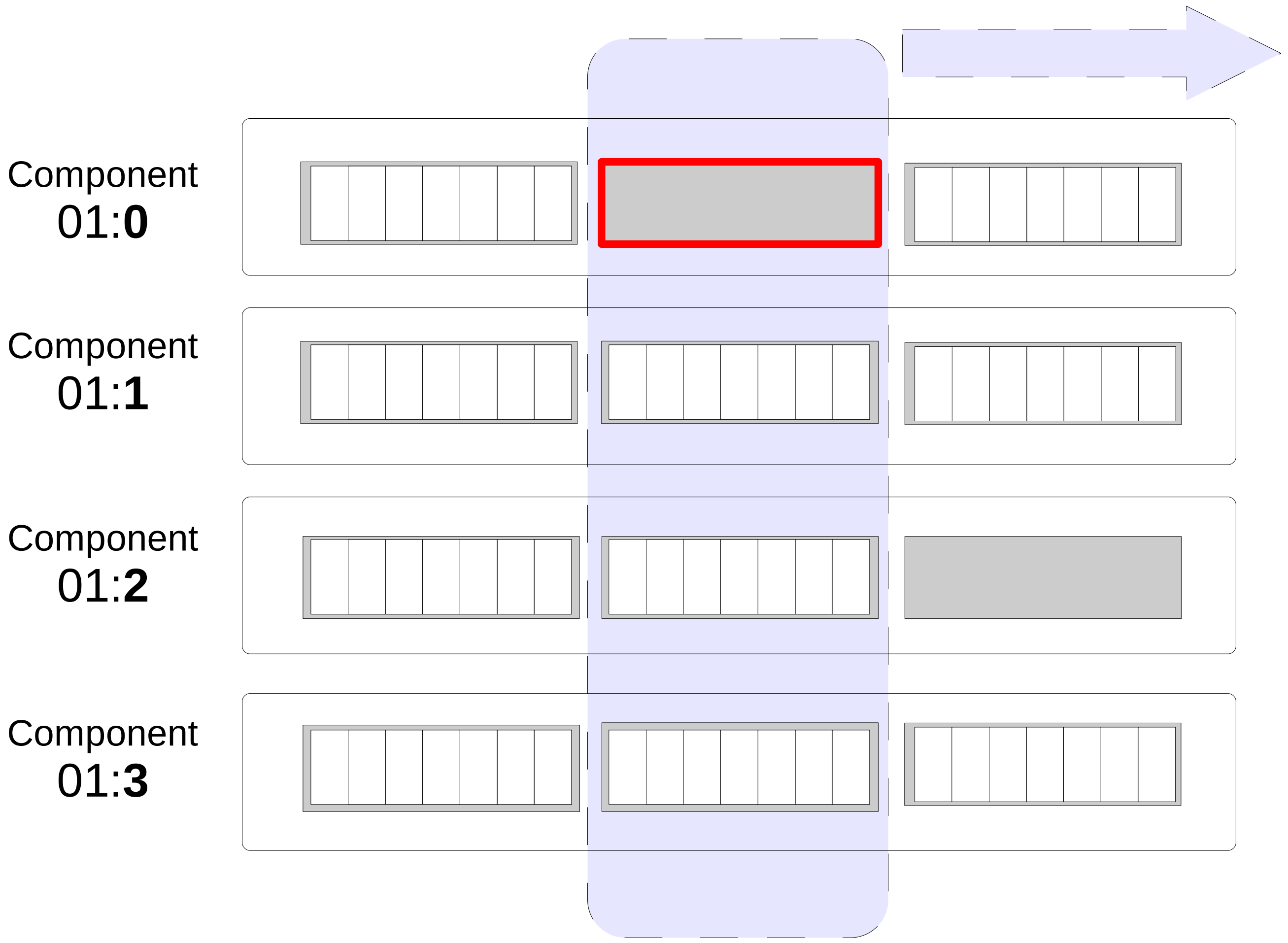

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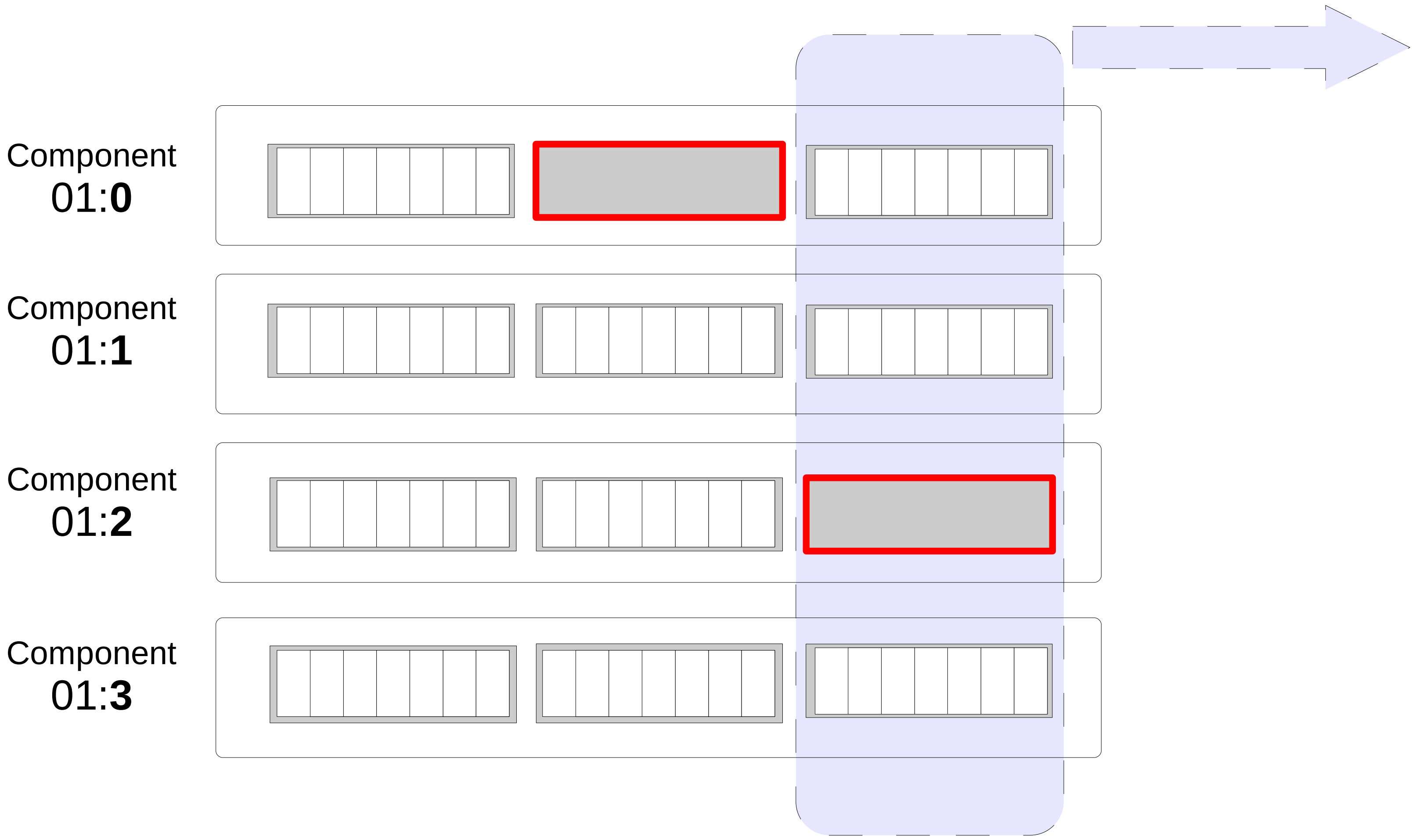

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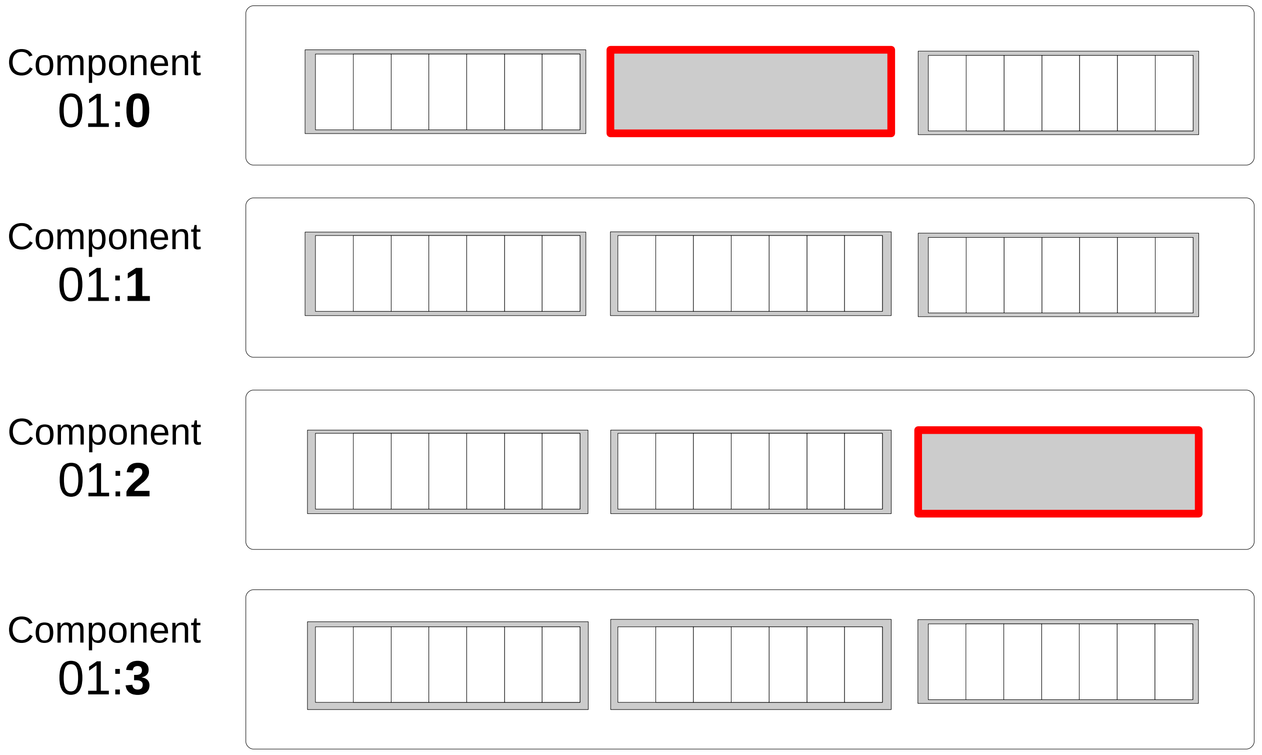

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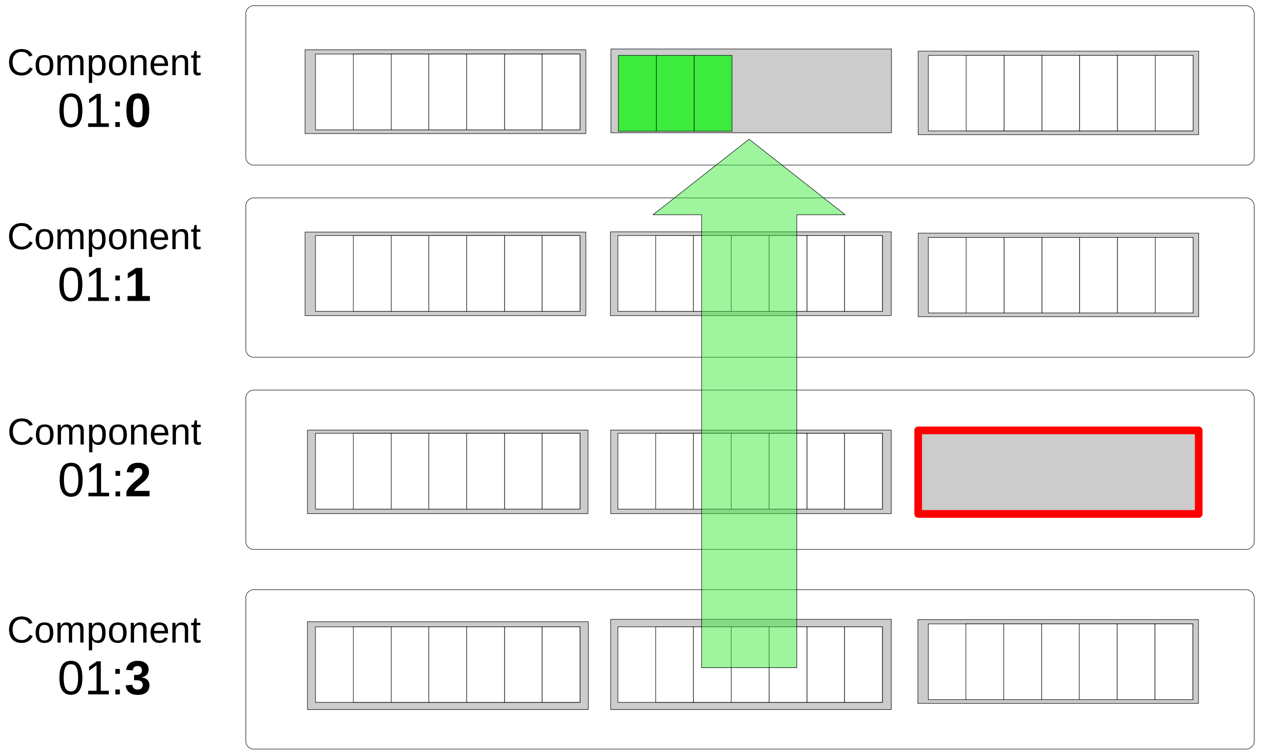
Data services: reconstruction



- Sequential read/write of entire Containers
- Erasure decoding and re-encoding

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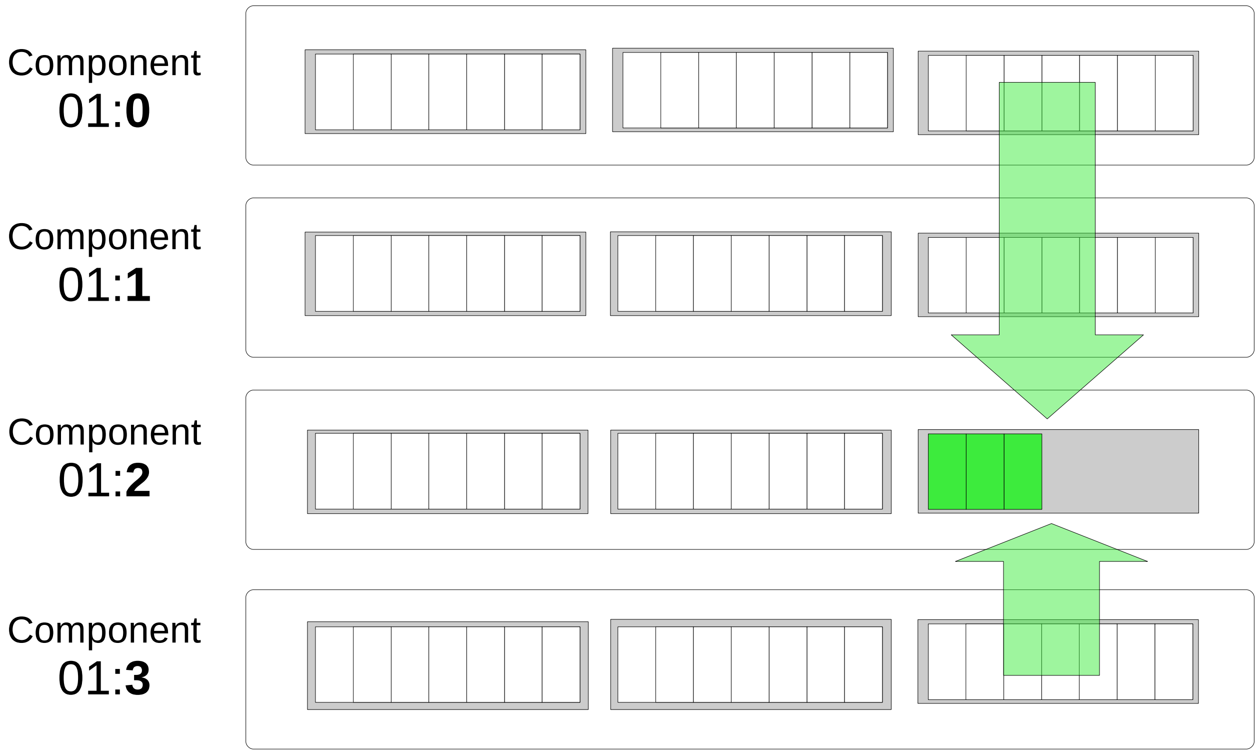

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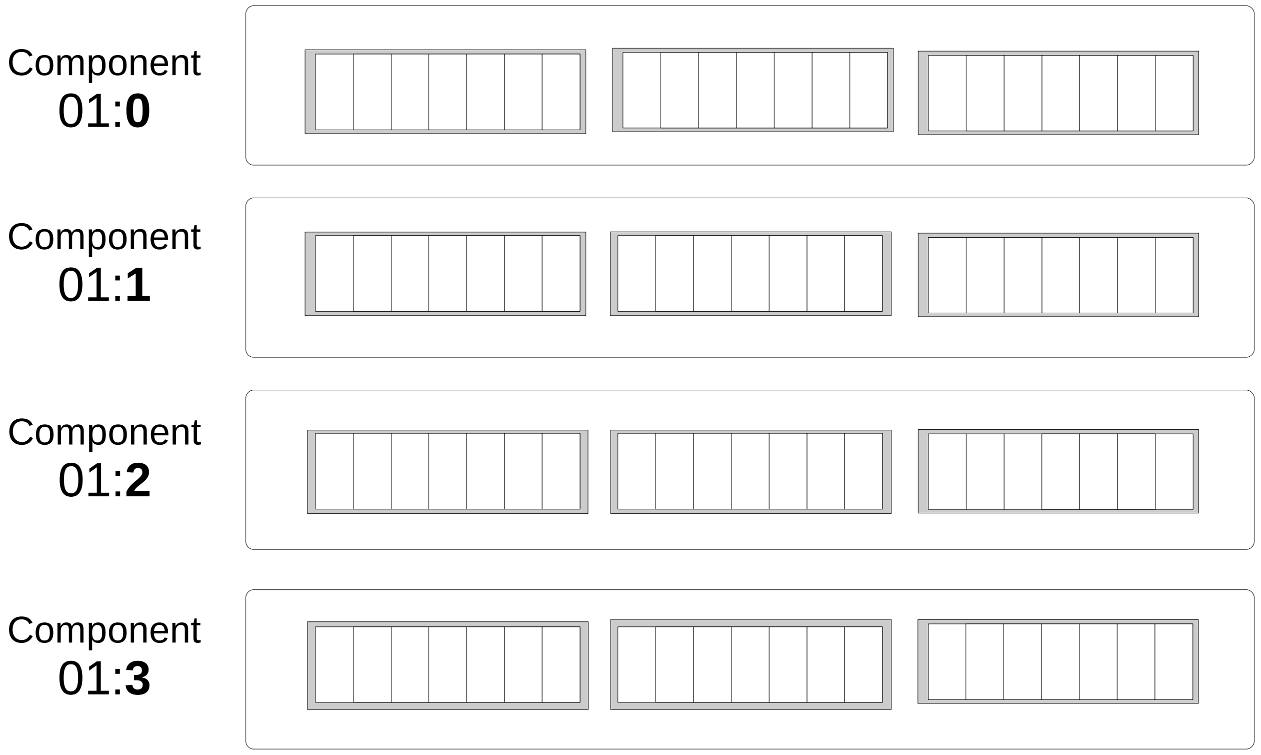

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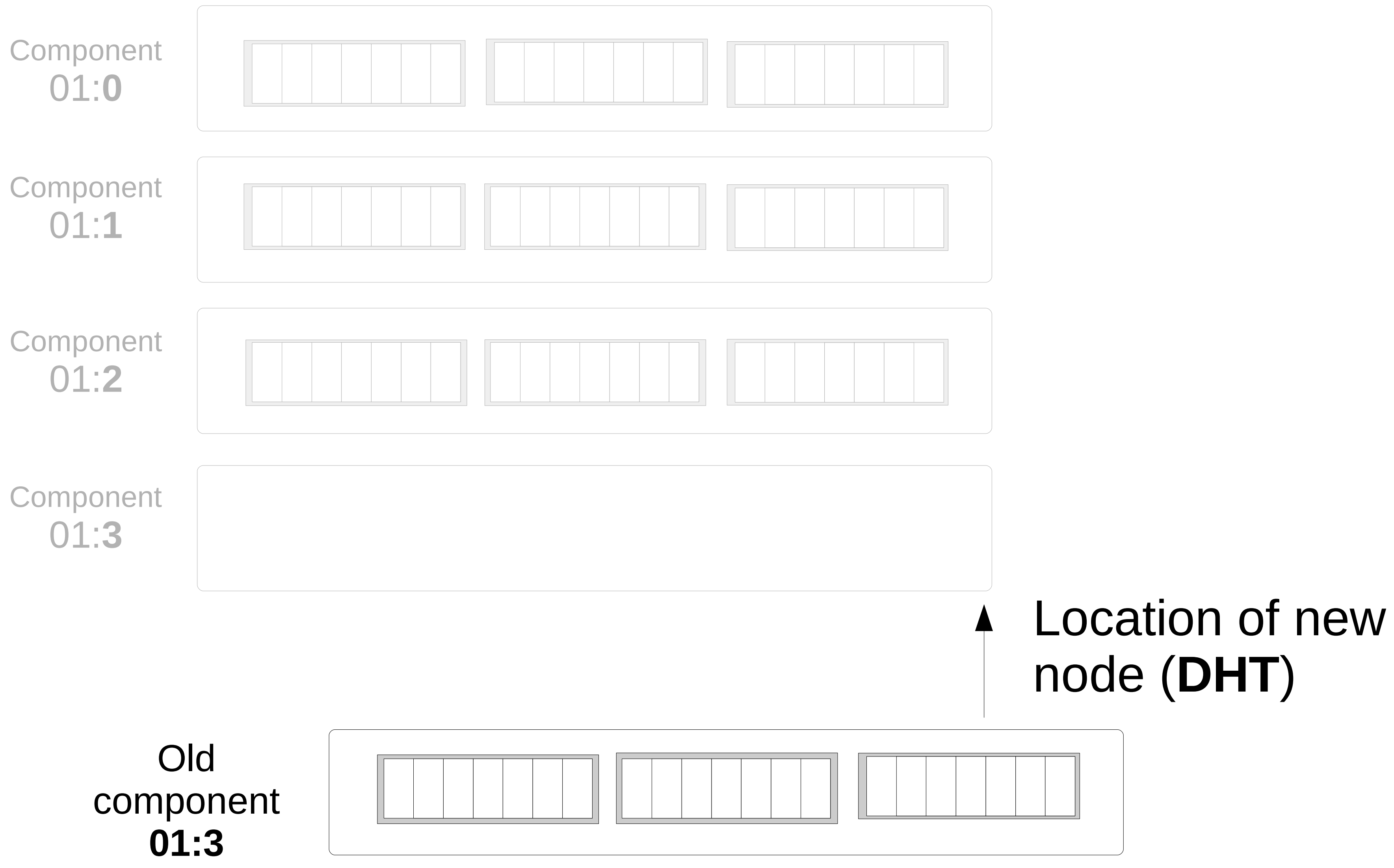

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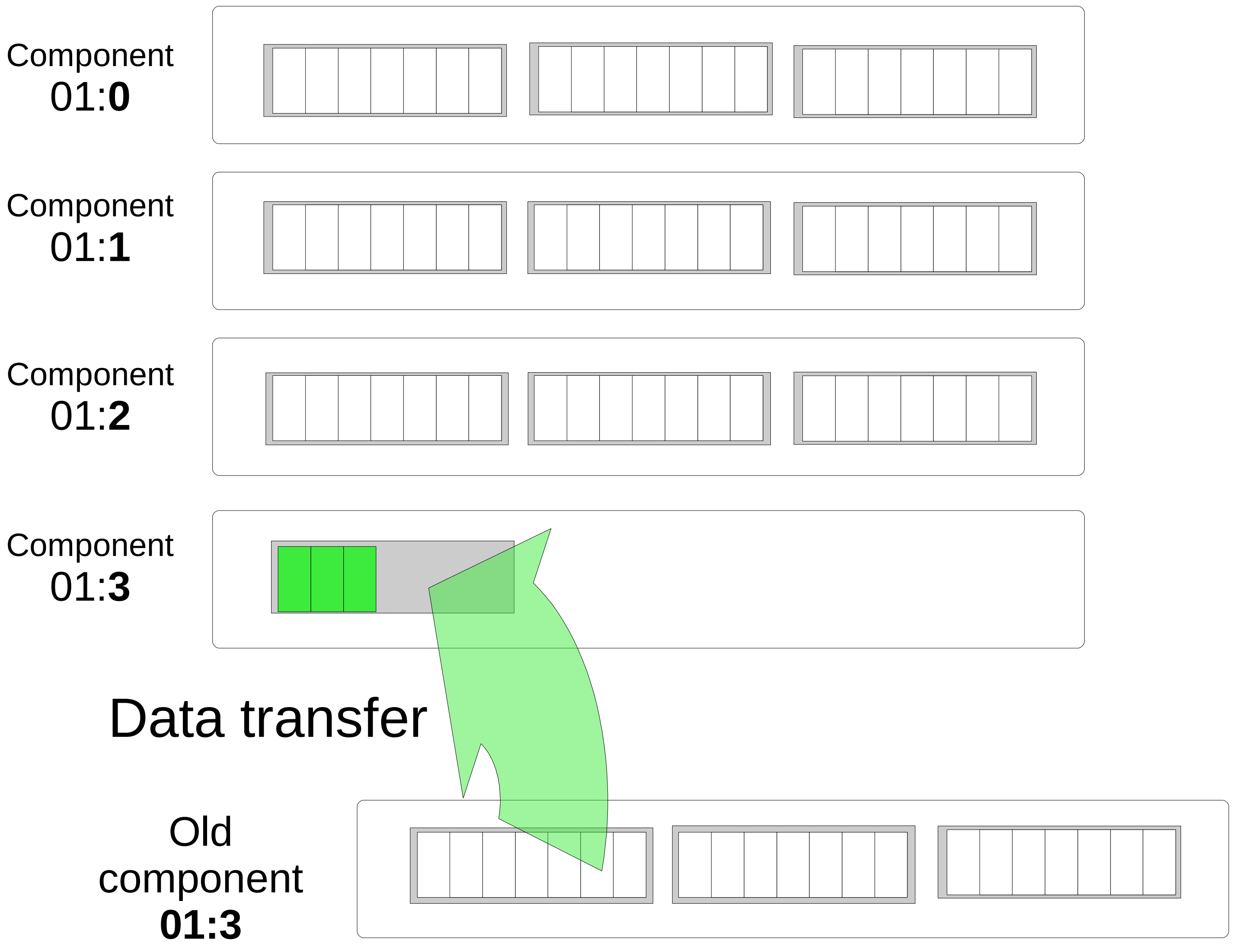

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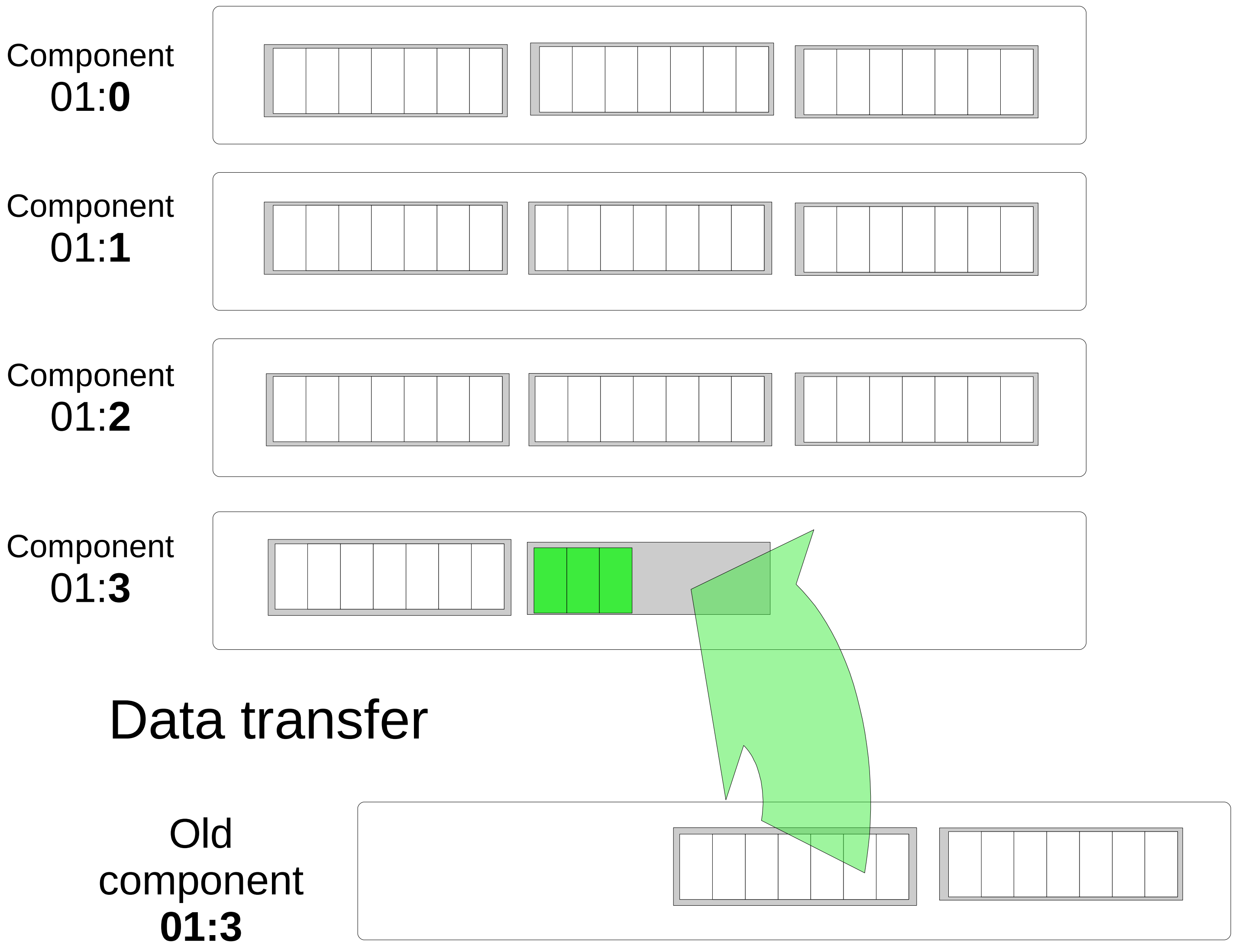
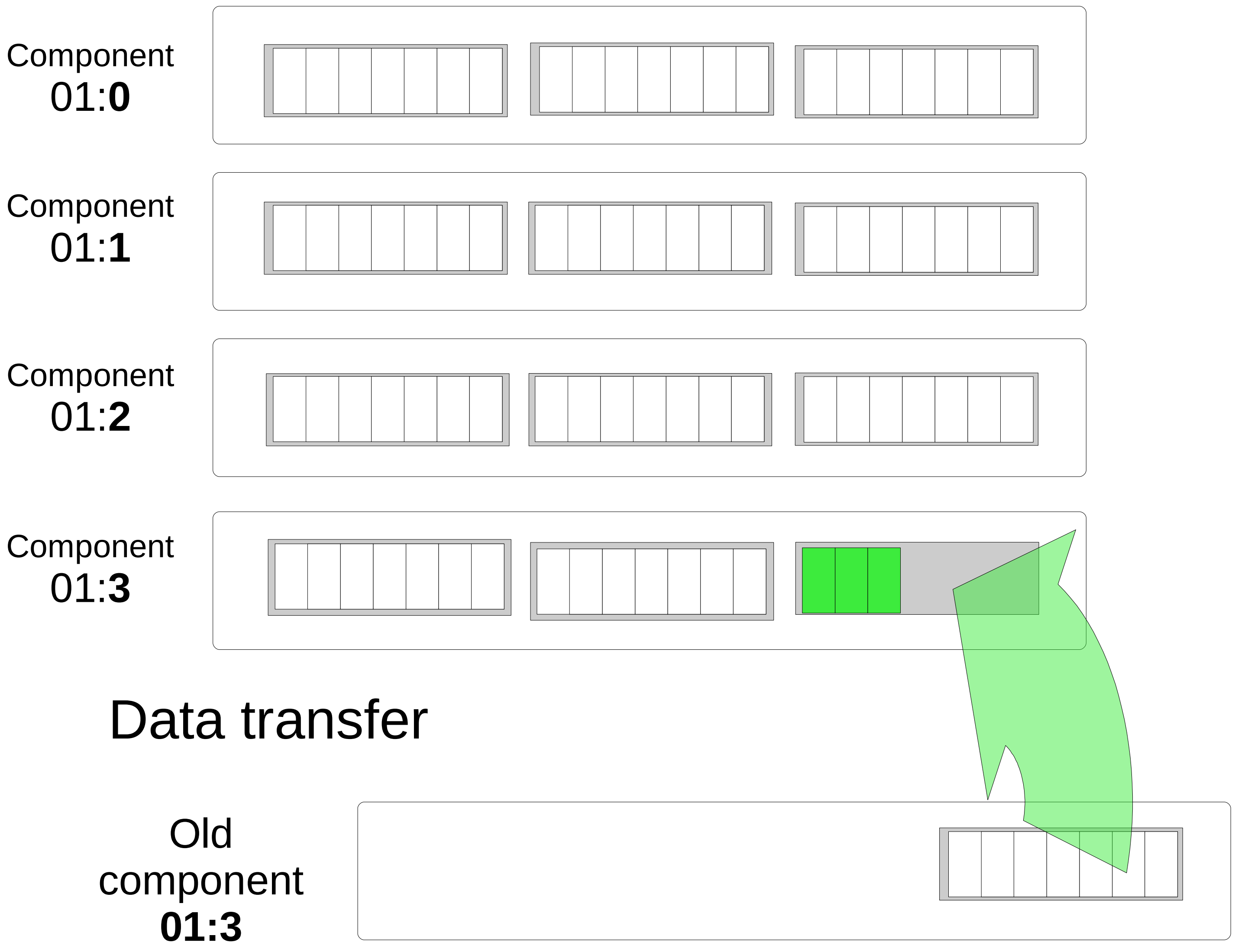
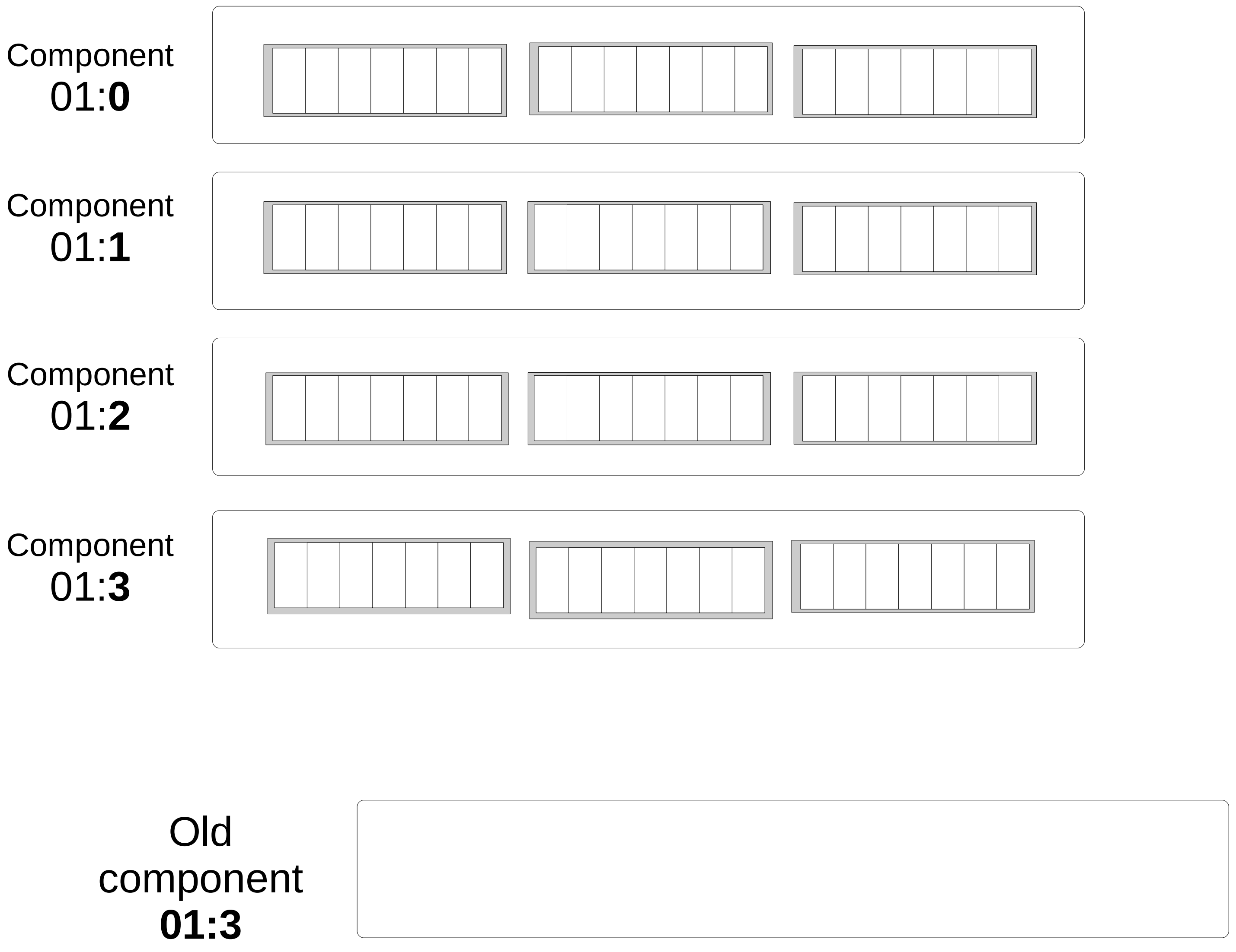


Data services: fast data transfer



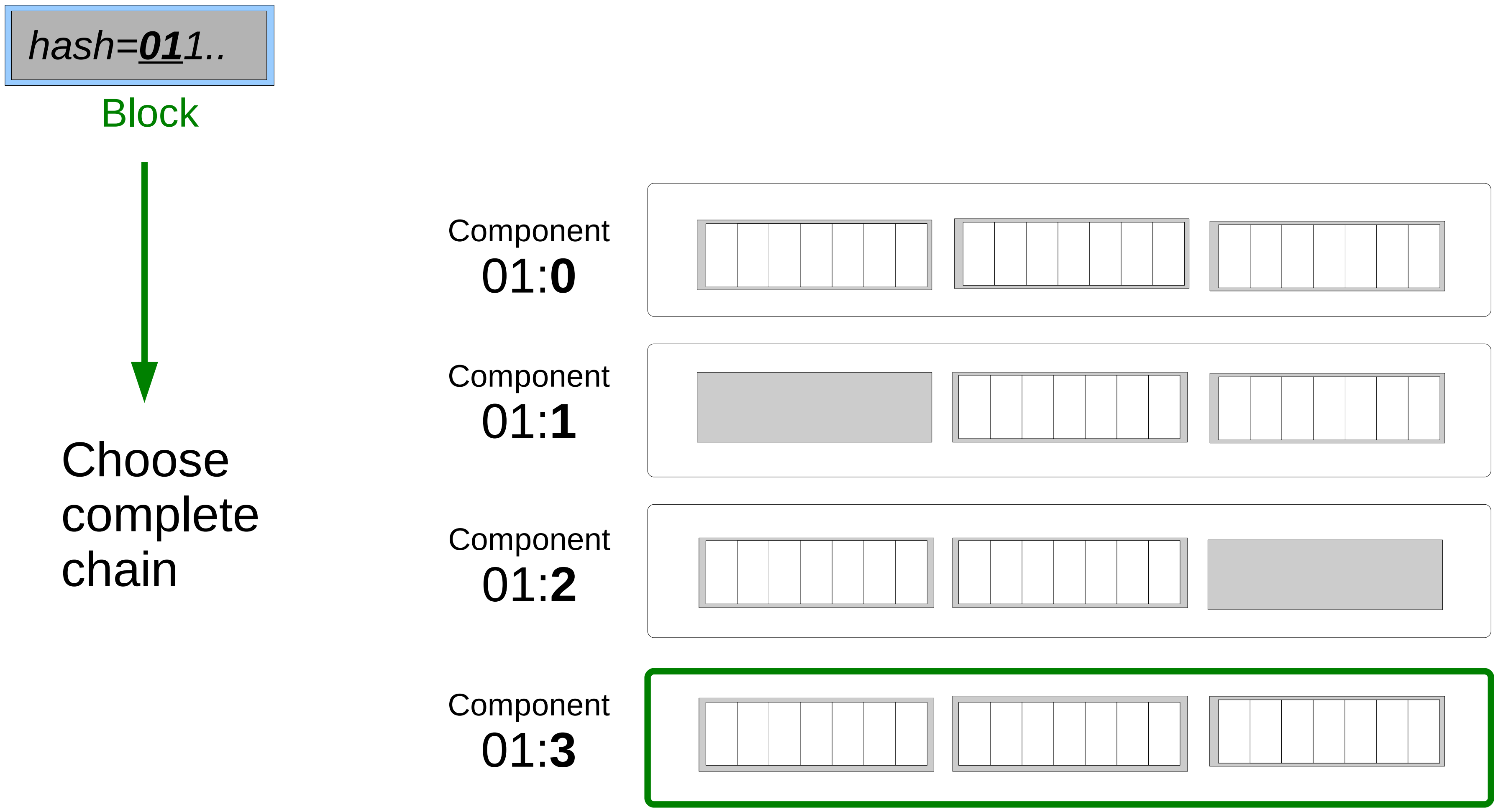
Data services: fast data transfer



Data services for deduplication

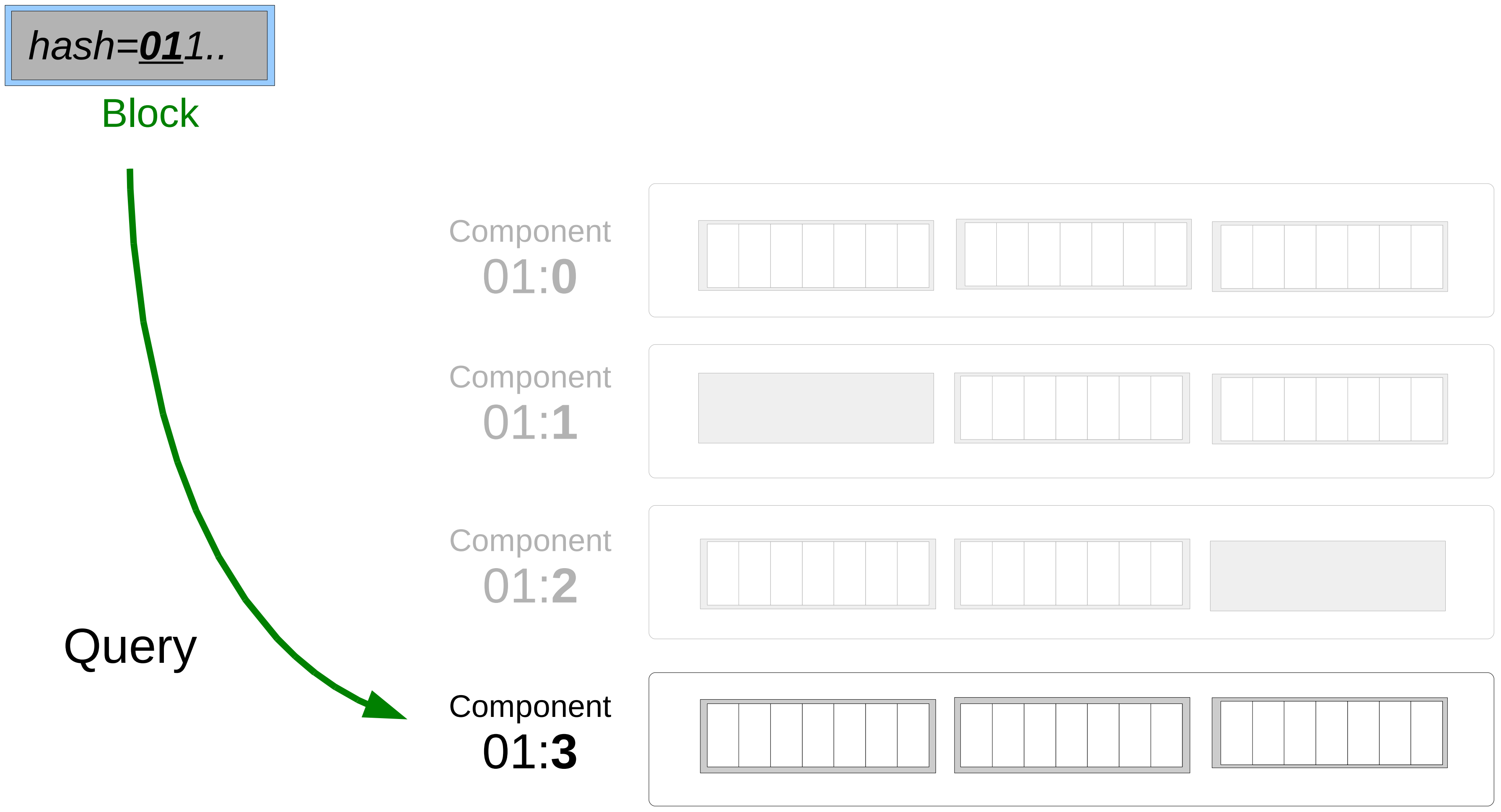
- Global: duplicates detected in entire system
- DHT routing based on content
- Inline deduplication: has to be high-performance
  - Prefetching Containers for streams of duplicates
  - Block hashes stored separately

Data services for deduplication

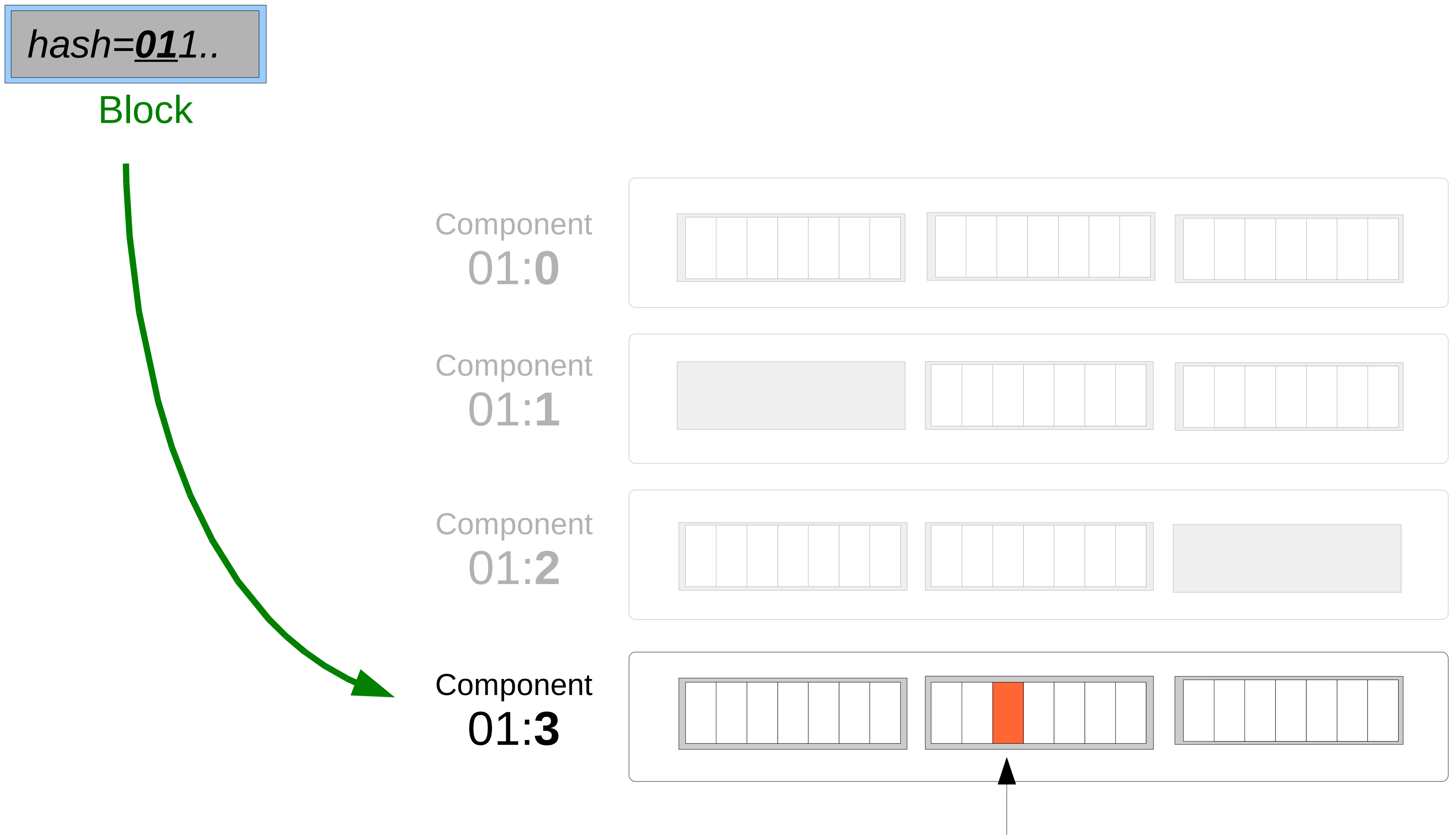


Completeness: “definitely not a duplicate”
Deletion interaction: wasn't the block scheduled for deletion?

Data services for deduplication

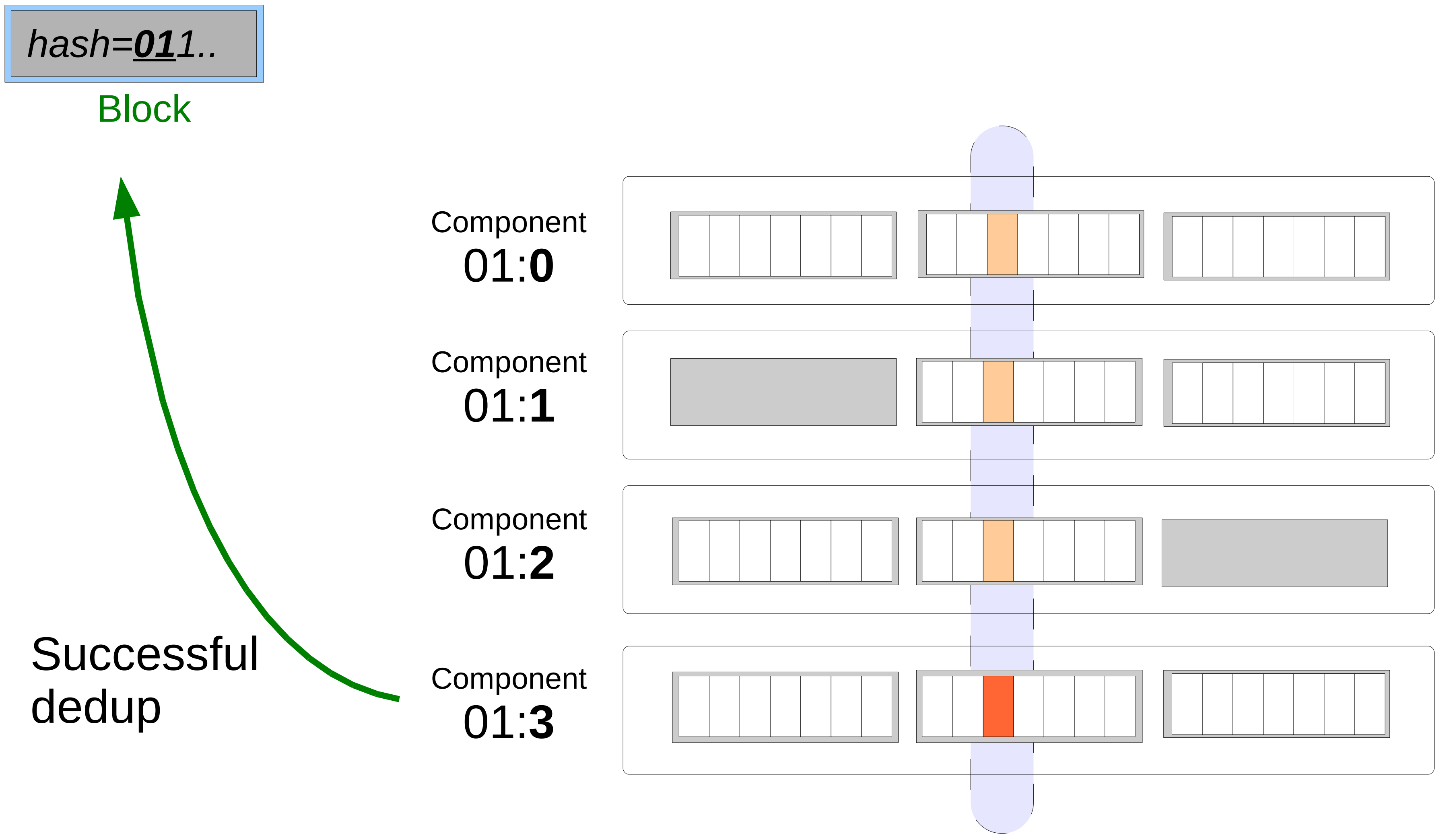


Data services for deduplication



Local candidate found

Data services for deduplication

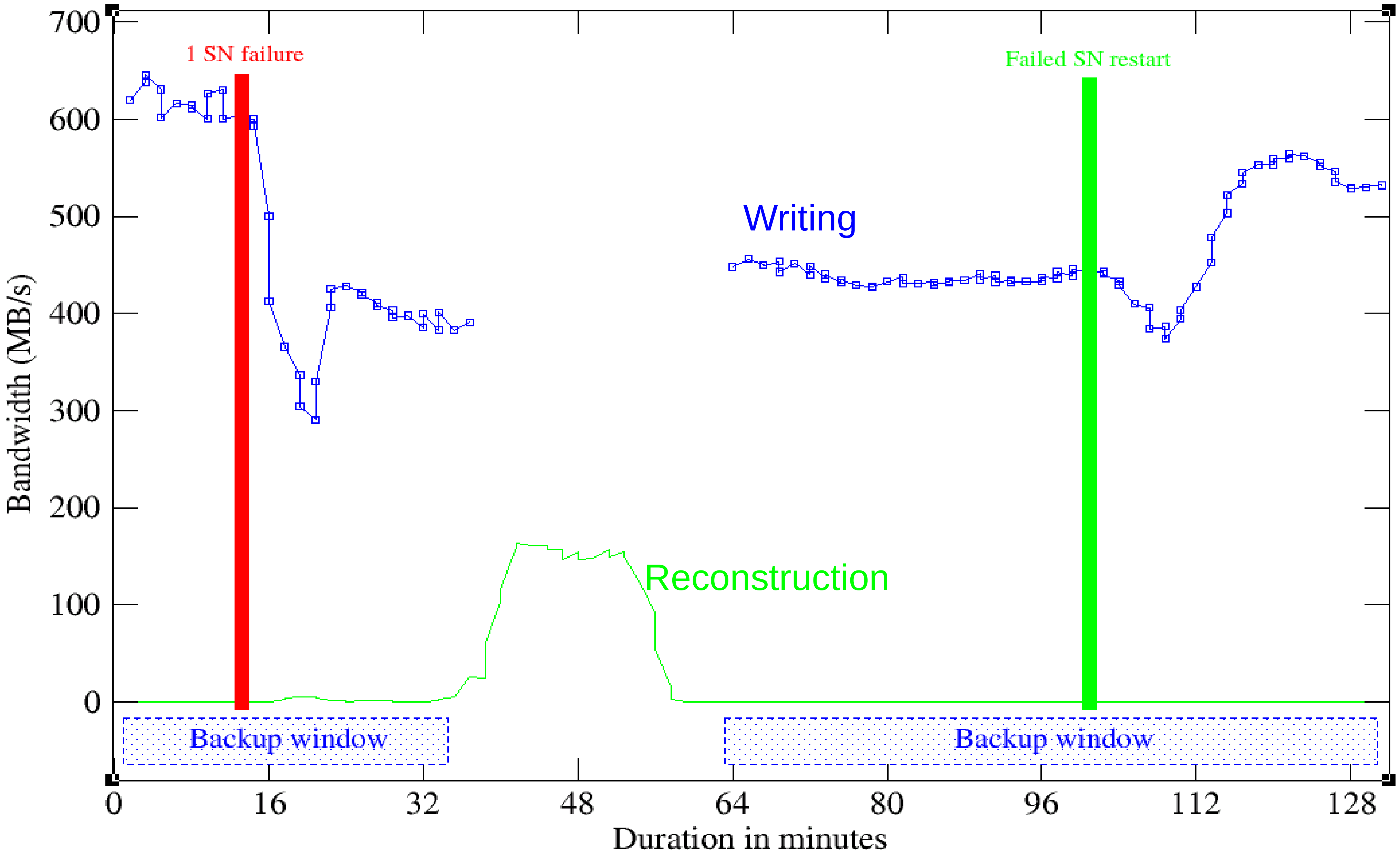


Candidate verification

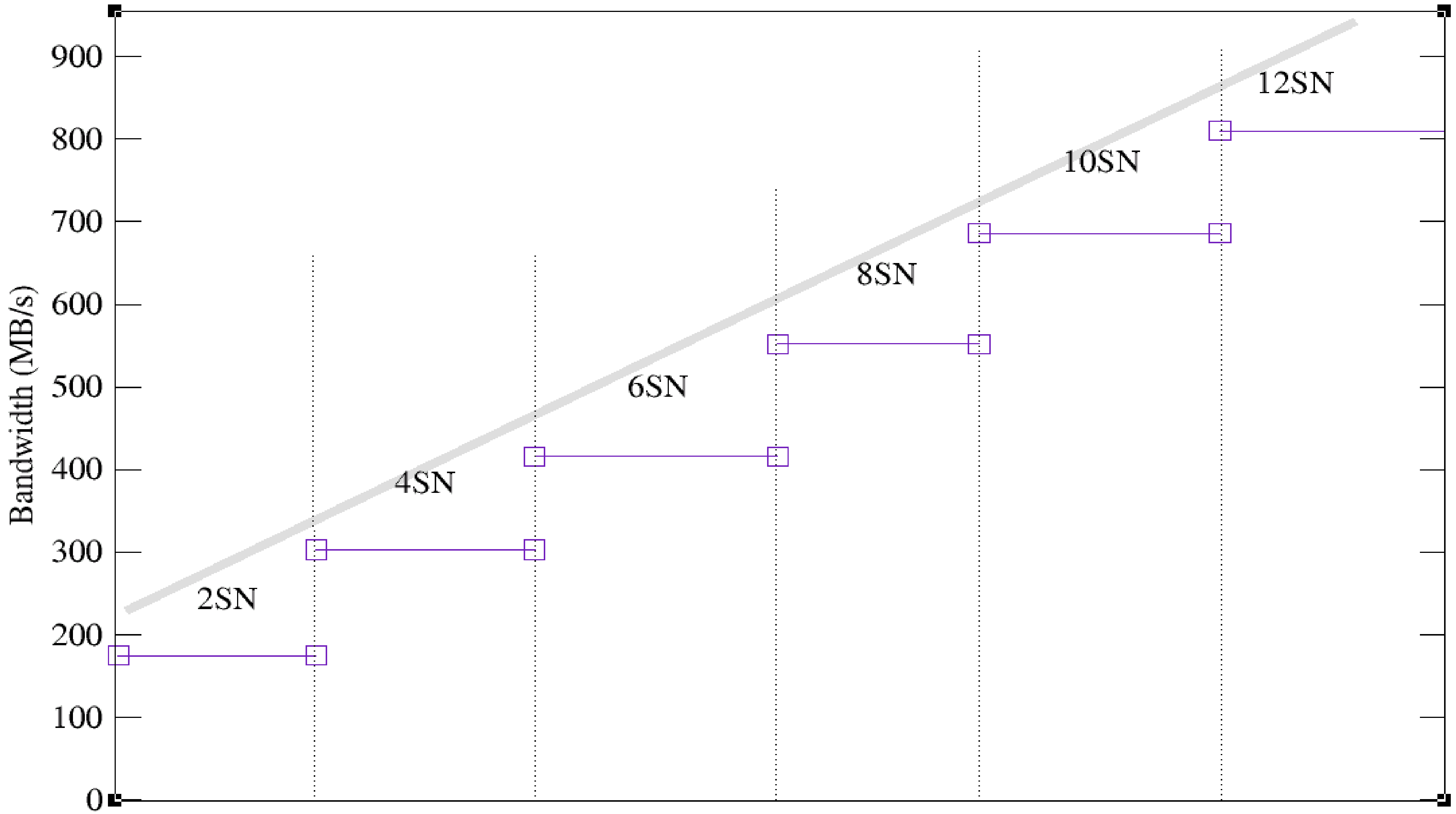
On-demand data deletion

- Distributed garbage collection
- Per-block reference counter stored per-fragment
- Failure-tolerant
  - Block reference counter calculated independently on peer Container chains
- Interference with duplicate elimination:
  - read-only phase for block tree traversal
  - space reclamation in background

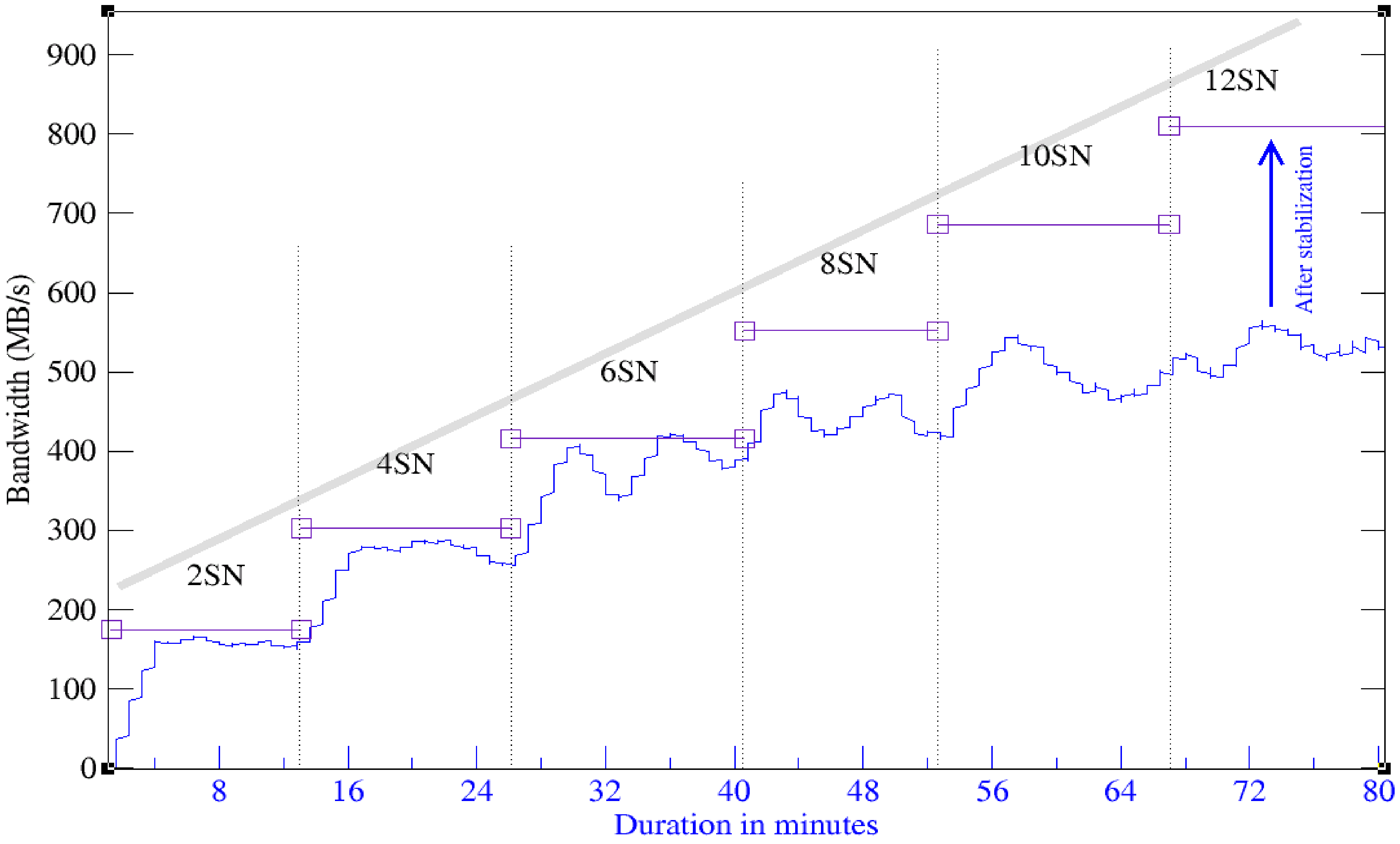
Writes during node failure



Write Scaling nodes added while writing



Write Scaling
nodes added while writing



Questions?