O-O-O-O-O-O-O

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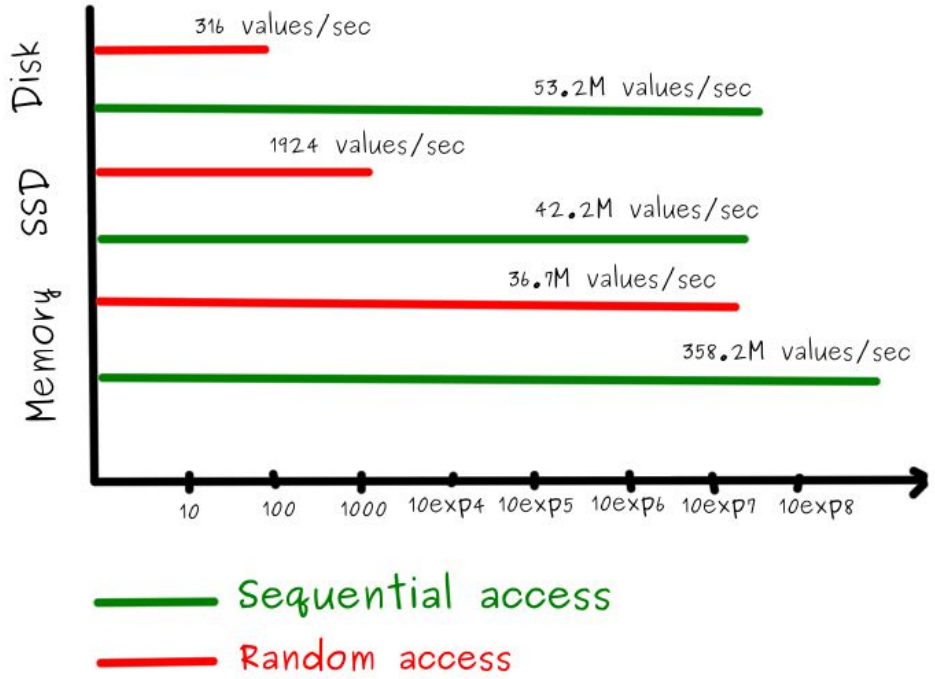
Persistence Axioms

- *Sequential reads and writes are typically faster* than random
- *Random record access on collections of fixed-size records (eg. get(index)) can be very efficient* when based on computing access offsets using mathematical formulas (eg. offset = index * record-size) rather than scanning the data - (O1)
- Data retrieval optimization is typically a matter of *I/O optimization* (eg. minimize # of blocks loaded to resolve a given query)
- Data publishing optimization is typically a matter of *I/O optimization* (eg. minimize # of blocks to upload). Typically data publishing !== data retrieval optimization.
- *Index-free adjacency is the key differentiator* of native graph processing (eg. edges to store direct pointers to adjacent nodes so that fast traversals are possible w/o the help of indices)

Sequential Access vs. Random Access



Benchmark published by Adam Jacobs, *The Pathologies of Big Data* in ACM Newsletter

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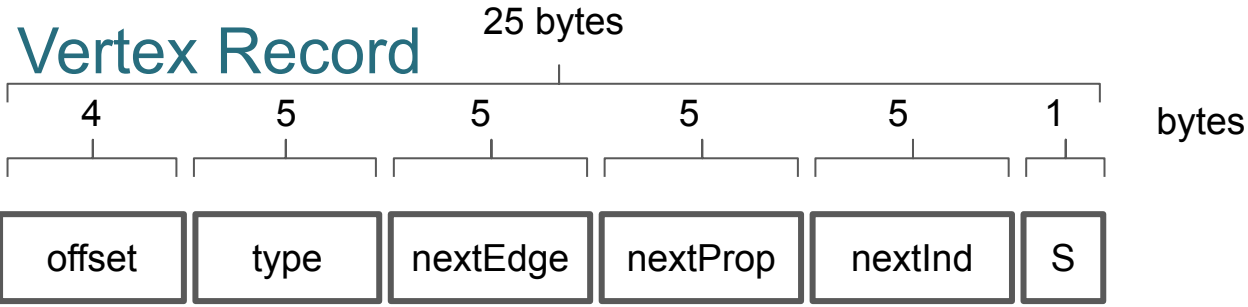
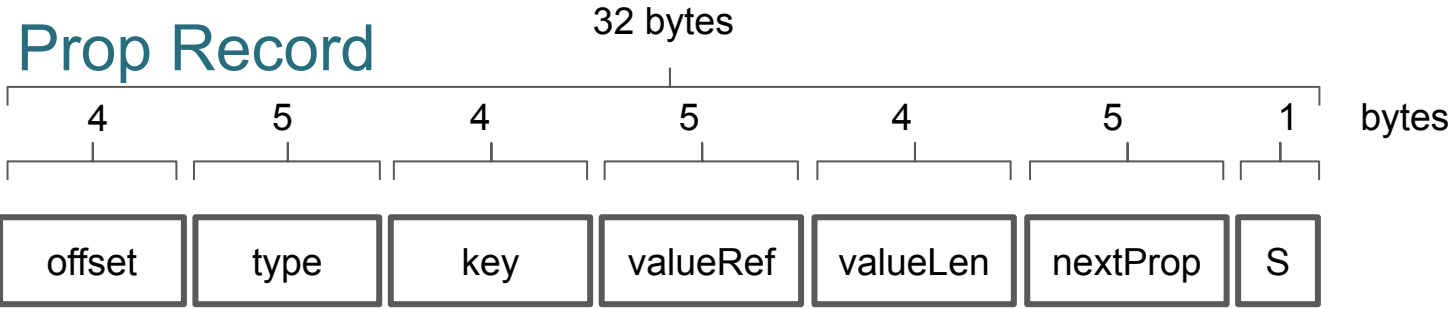
Persistence Format

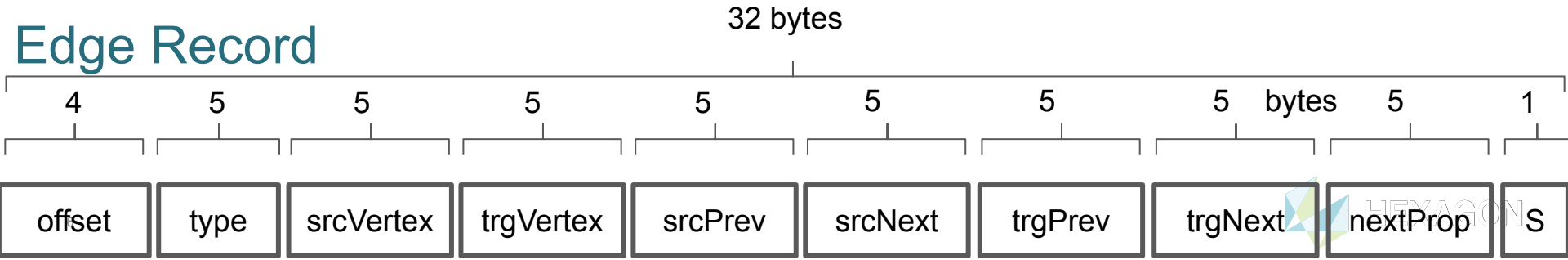
Vertex Record



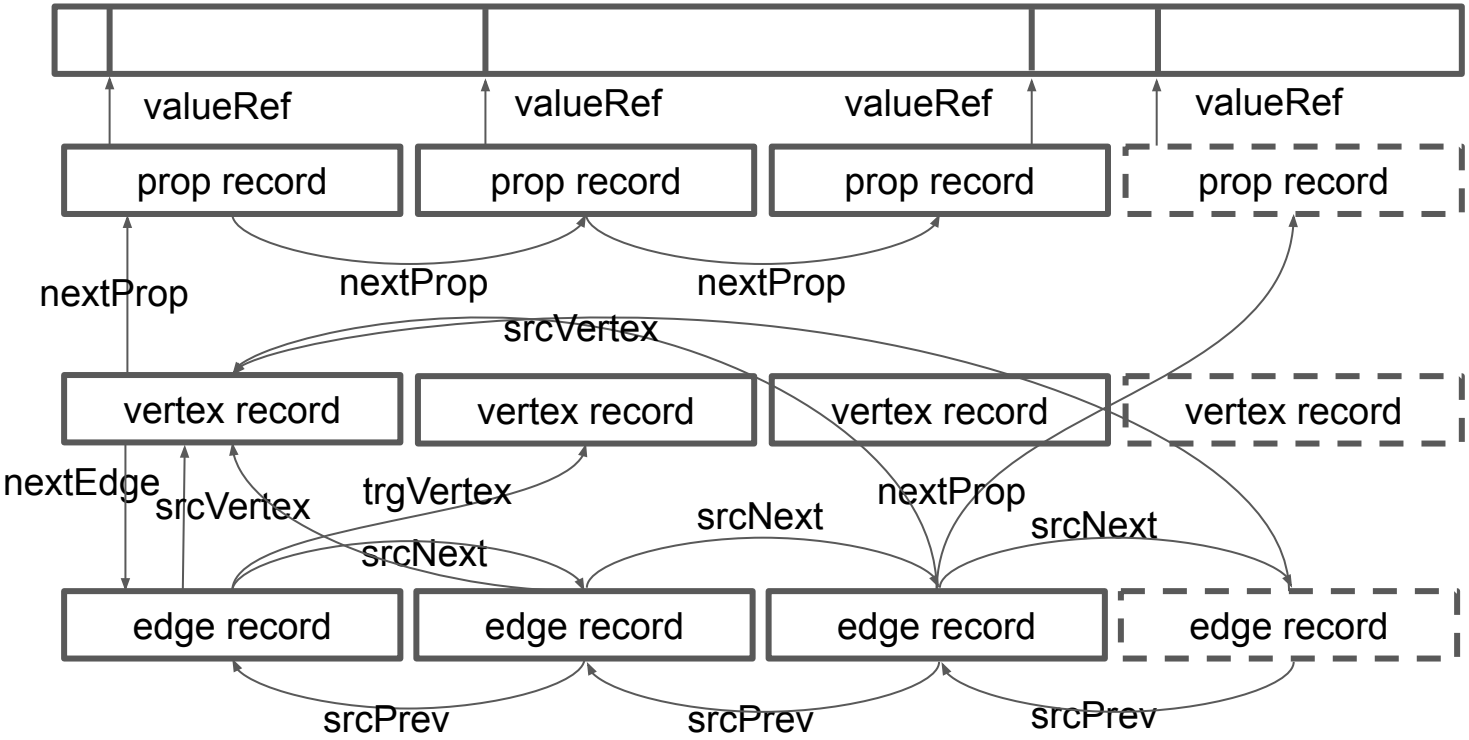
Prop Record



Edge Record



Arrays of Records



Prop values byte array

Props byte array

Vertices byte array

Edges byte array

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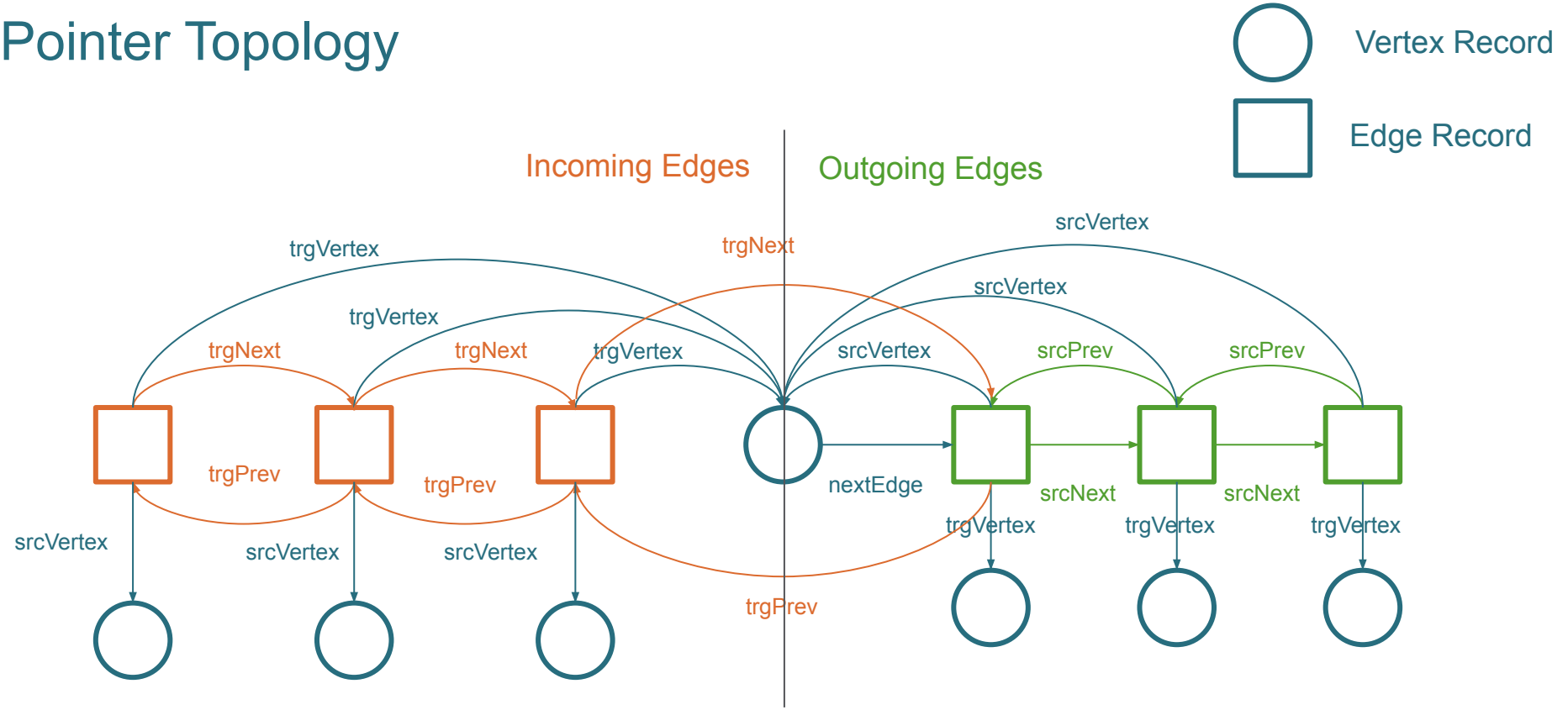
Pointer Topology



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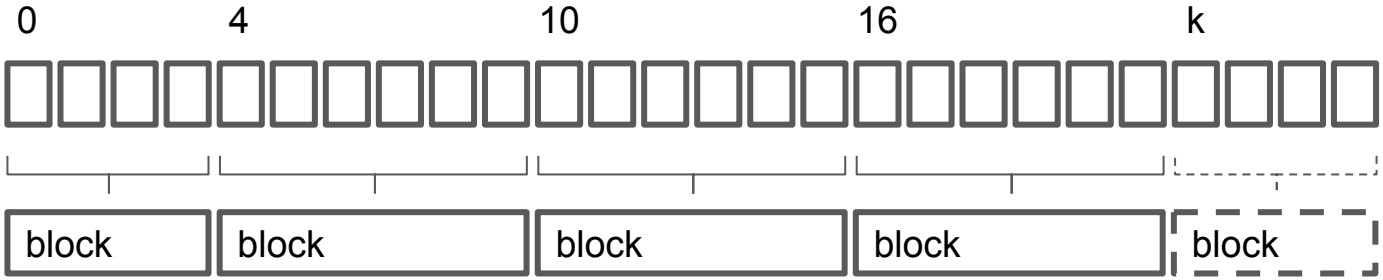
Chunking



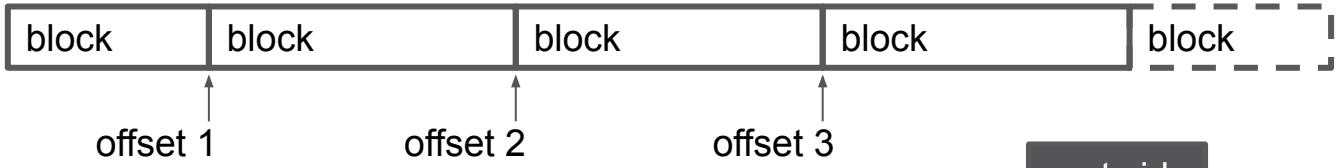
Stable Chunking: A method to partition any array of records to **support incrementality** (ie. generate stable chunks):

- Re-applying chunking alg. on the same data *should yield same chunks*
- Re-applying chunking alg. on a modified data set should *maximize reuse of older chunks and minimize the creation of new chunks*
- A modified chunk is considered new chunk (as it needs publishing)

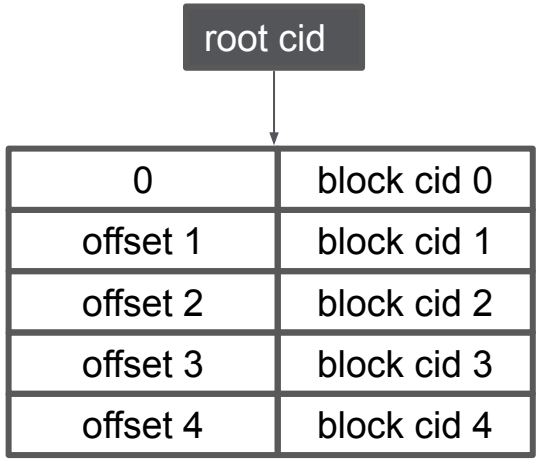
Algorithm Choices:

- Fixed size chunking, on arrays of fixed size records (eg. chunk-size = k * record-size, where k = number of records per chunk)
- Content-based chunking, works on any data*.

Index blocks by record offset



- The index describes unambiguously the array of records
- The index itself is an array of records which can be chunked recursively
- The index is immutable
- The index is content addressable



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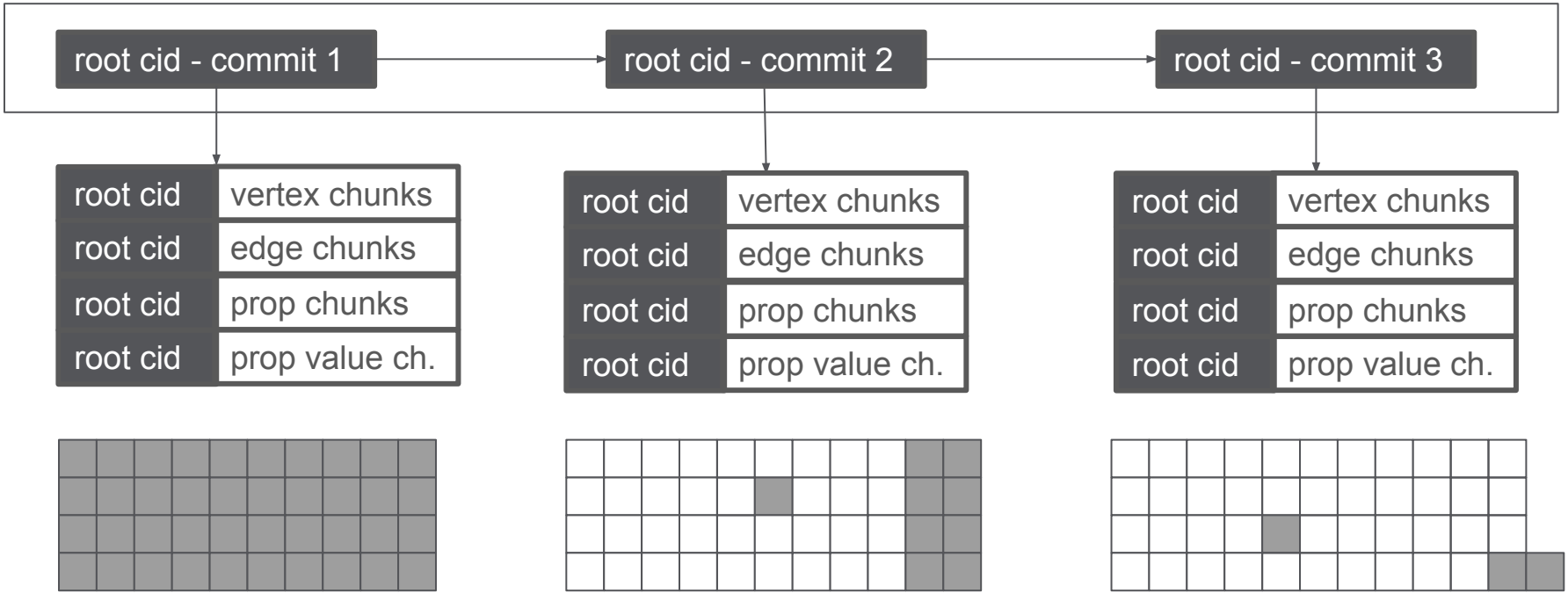
More Axioms

- *Content addressing* favors location independent storage, ie simplified replication across storage providers (ie. AZ blob storage, S3, browser local, etc.), supportive to collab. scenarios
- References represented as content identifiers *guarantee referred data integrity*: uniqueness, immutability and authenticity
- *Simplified & efficient block equality checks* w/o accessing referred data (eg. leverage the chunk index to identify changes to a given baseline)
- Supportive for chunk deduplication, supportive for versioning

Create Graph

Add new sub-tree

Modify many Property Values on single Vertex



Reused chunk

New / Modified chunk

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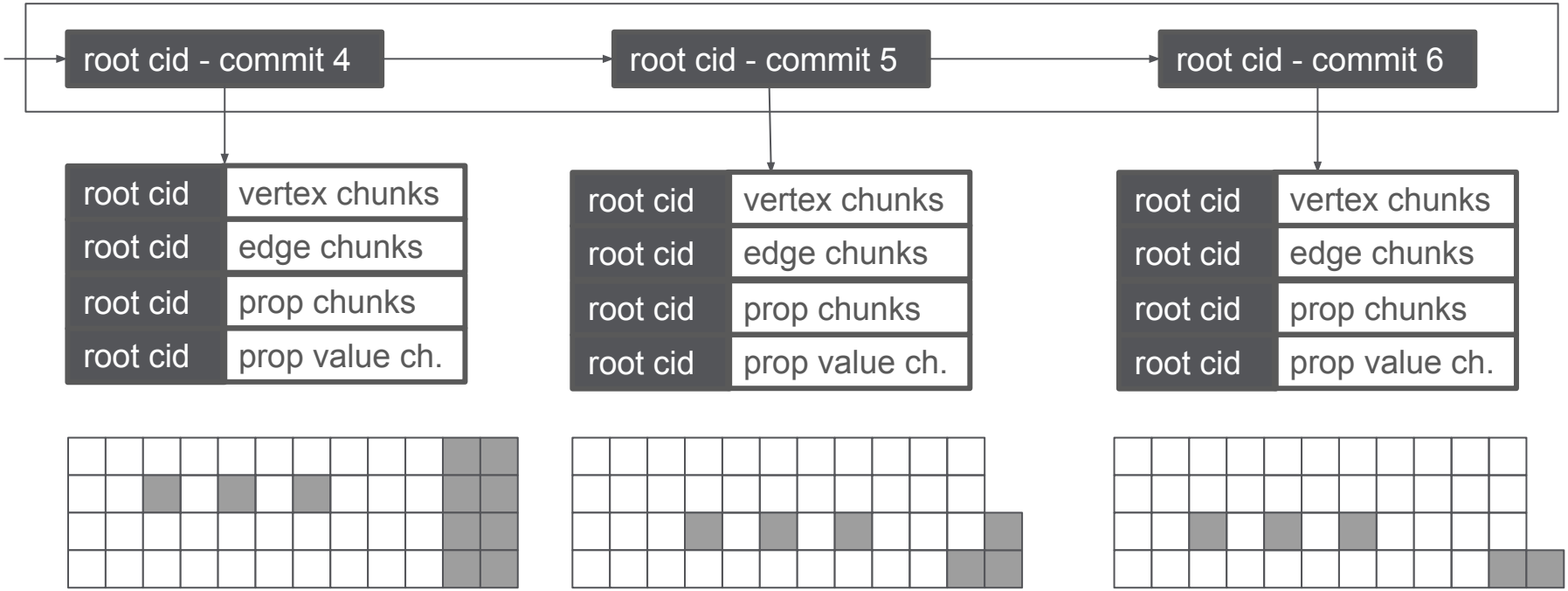
Add many new sub-trees

Add many Properties to many Vertices

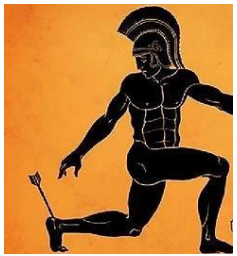
Modify many Property Values to many Vertices



Reused chunk

New / Modified chunk

Challenges



- **Incrementality vs. Fragmentation**
  - Incrementality requires to collocate data according to edits and preserve historical blocks (minimize writes), but adds fragmentation to the actual graph structure (possibly scattered read). CQRS?
- **Read**
  - Fragmentation can be a performance killer
  - Use-case based optimizer (batching blocks at retrieval time)
  - Caching blocks locally (relevant also for offline support)
- **Delete**
  - Logical only, will benefit from a strategy to reuse offsets from deleted records
- **Compaction**
  - To correct fragmentation, prune deleted records
  - Invasive (potentially replace many offsets and associated refs, introduce logical offsets?),
  - Complex to execute online