



#nosql13

A Journey through the MongoDB Internals?

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Who Am I

- Driver Engineering lead at MongoDB Inc
- Work on the Mongo DB Node.js driver
- Started working for MongoDB Inc June 2011
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Why Pop the Hood?

- Understanding data safety
- Estimating RAM / disk requirements
- Optimizing performance

Storage Layout



Directory Layout

drwxr-xr-x	136	Nov 19 10:12	journal
-rw-----	16777216	Oct 25 14:58	test.0
-rw-----	134217728	Mar 13 2012	test.1
-rw-----	268435456	Mar 13 2012	test.2
-rw-----	536870912	May 11 2012	test.3
-rw-----	1073741824	May 11 2012	test.4
-rw-----	2146435072	Nov 19 10:14	test.5
-rw-----	16777216	Nov 19 10:13	test.ns

Directory Layout

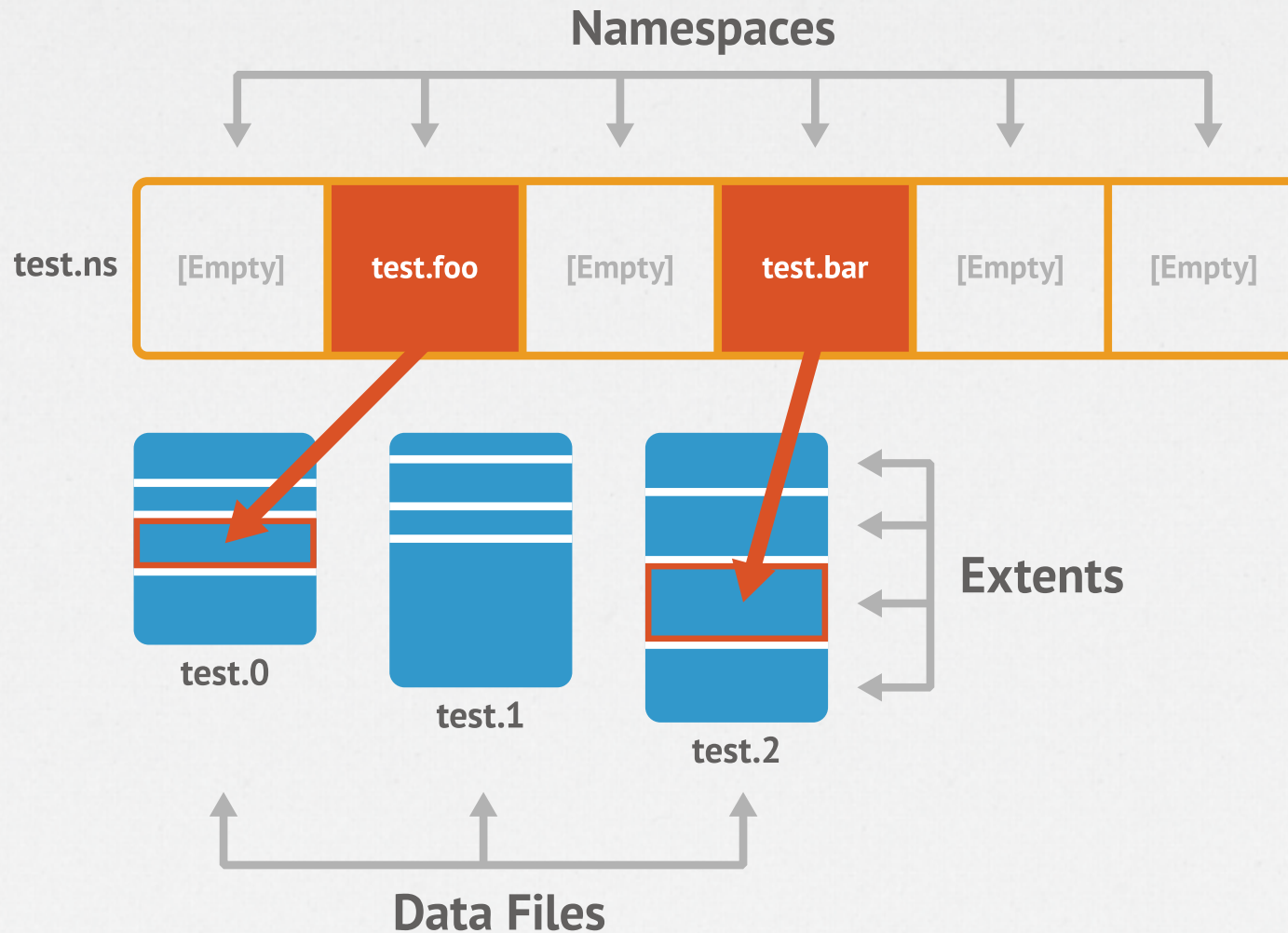
- Aggressive pre-allocation (always 1 spare file)
- There is one namespace file per db which can hold 18000 entries per default
- A namespace is a collection or an index

Tuning with Options

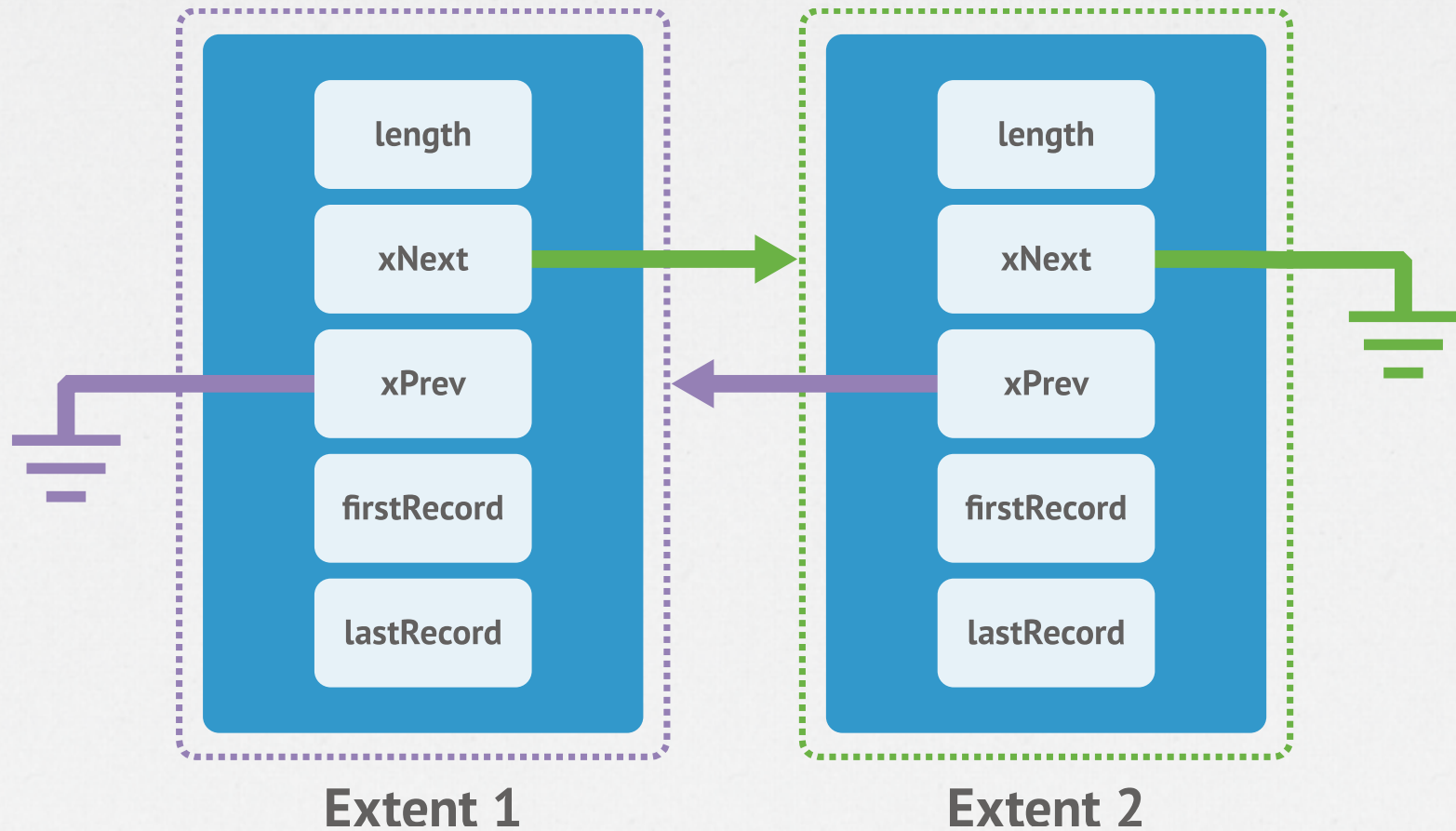
- Use *--directoryperdb* to separate dbs into own folders which allows to use different volumes (isolation, performance)
- Use *--smallfiles* to keep data files smaller
- If **using many databases**, use *--nopreallocate* and *--smallfiles* to reduce storage size
- If **using thousands of collections & indexes**, increase namespace capacity with *--nssize*

Internal Structure

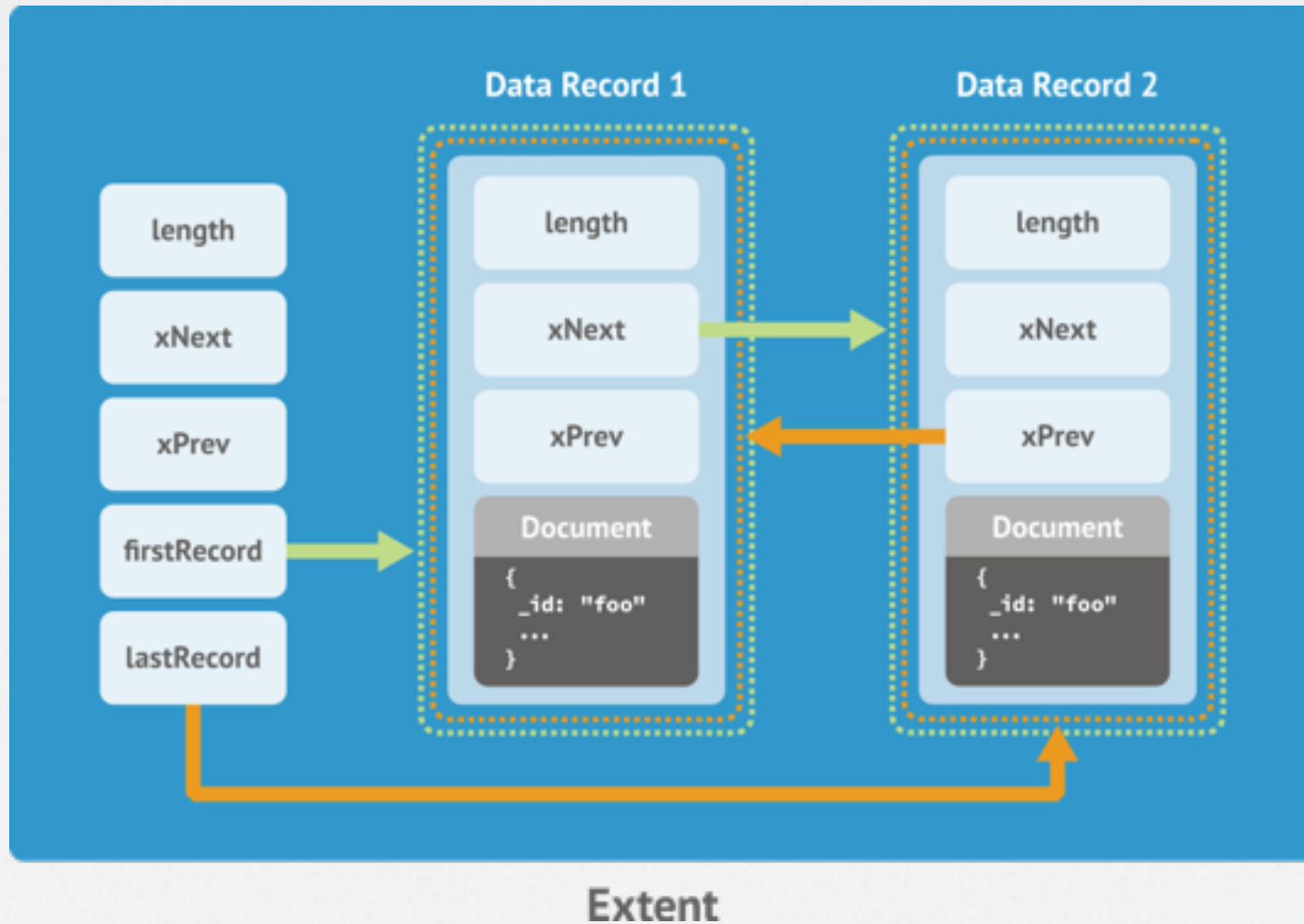
Internal File Format



Extent Structure



Extents and Records



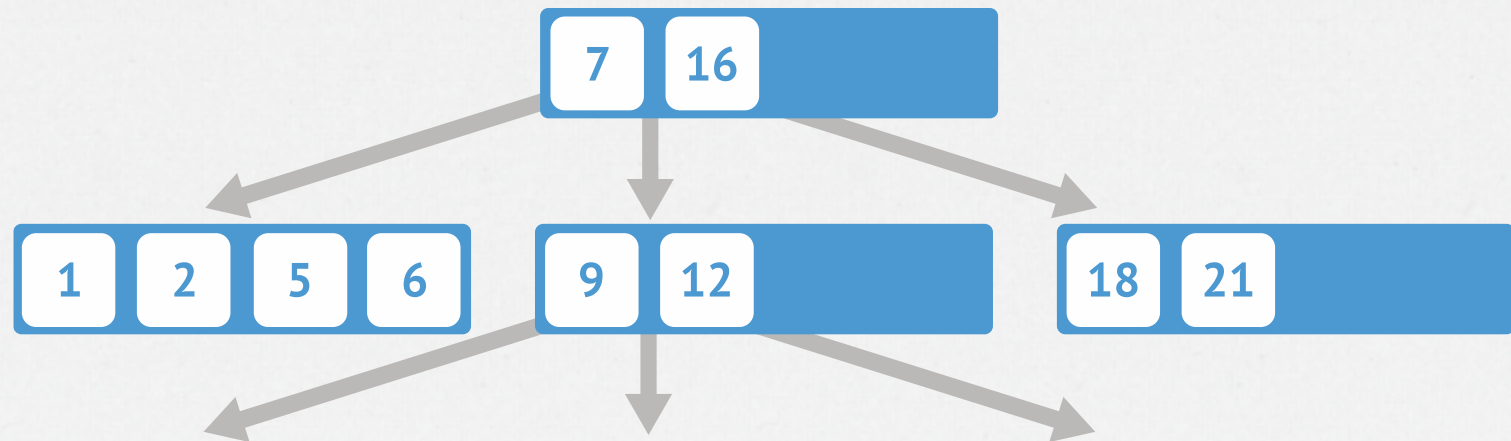
To Sum Up: Internal File Format

- Files on disk are broken into extents which contain the documents
- A collection has **one or more extents**
- Extent grow exponentially **up to 2GB**
- Namespace entries in the *ns* file point to the **first extent** for that collection

What About Indexes?

Indexes

- Indexes are **BTree** structures serialized to disk
- They are stored in the **same files as data** but using **own extents**



The DB Stats

```
> db.stats()
{
  "db" : "test",
  "collections" : 22,
  "objects" : 17000383, ## number of documents
  "avgObjSize" : 44.33690276272011,
  "dataSize" : 753744328, ## size of data
  "storageSize" : 1159569408, ## size of all containing
  extents
  "numExtents" : 81,
  "indexes" : 85,
  "indexSize" : 624204896, ## separate index storage
  size
  "fileSize" : 4176478208, ## size of data files on disk
  "nsSizeMB" : 16,
  "ok" : 1
}
```

The Collection Stats

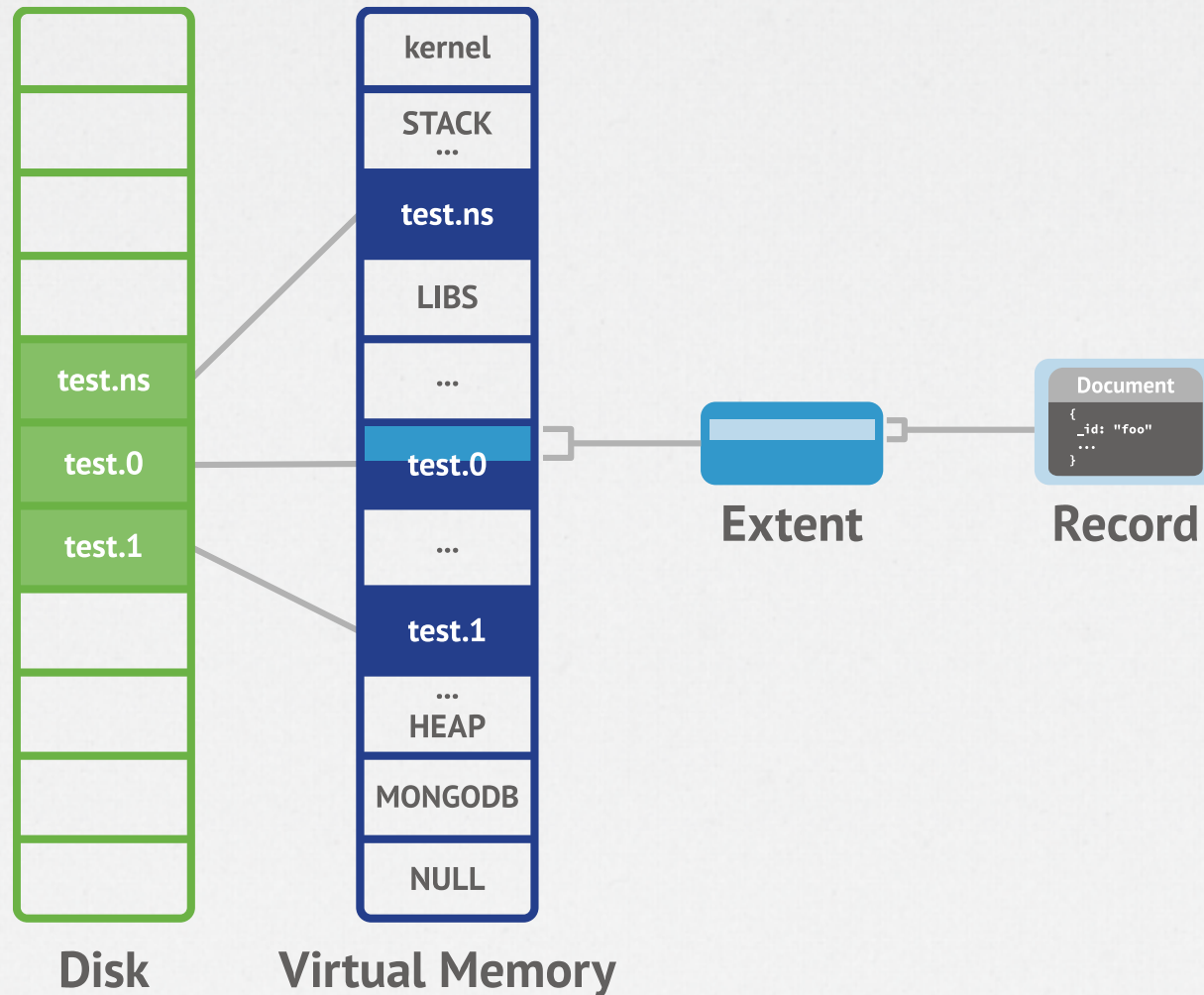
```
> db.large.stats()
{
  "ns" : "test.large",
  "count" : 5000000, ## number of documents
  "size" : 280000024, ## size of data
  "avgObjSize" : 56.0000048,
  "storageSize" : 409206784, ## size of all containing
  extents
    "numExtents" : 18,
    "nindexes" : 1,
    "lastExtentSize" : 74846208,
    "paddingFactor" : 1, ## amount of padding
    "systemFlags" : 0,
    "userFlags" : 0,
    "totalIndexSize" : 162228192, ## separate index storage
  size
    "indexSizes" : {
      "_id_" : 162228192
    },
    "ok" : 1
}
```

What's Memory Mapping?

Memory Mapped Files

- All data files are **memory mapped** to Virtual Memory by the OS
- MongoDB **just reads / writes to RAM** in the filesystem cache
- **OS takes care of the rest!**
- Virtual process size = total files size + overhead (connections, heap)
- If journal is on, the virtual size will be roughly doubled

Virtual Address Space



Memory Map, Love It or Hate It

- Pros:
 - No complex memory / disk code in MongoDB, **huge win!**
 - The OS is very good at caching for **any type** of storage
 - Least Recently Used behavior
 - Cache **stays warm** across MongoDB restarts
- Cons:
 - RAM usage is affected by disk **fragmentation**
 - RAM usage is affected by high **read-ahead**
 - LRU behavior does not prioritize things (like indexes)

How Much Data is in RAM?

- **Resident memory** the **best indicator** of how much data in RAM
- Resident is: process overhead (connections, heap) + FS pages in RAM that were accessed
- Means that it resets to 0 upon restart even though **data is still in RAM** due to FS cache
- Use *free* command to check on FS cache size
- Can be affected by **fragmentation** and **read-ahead**

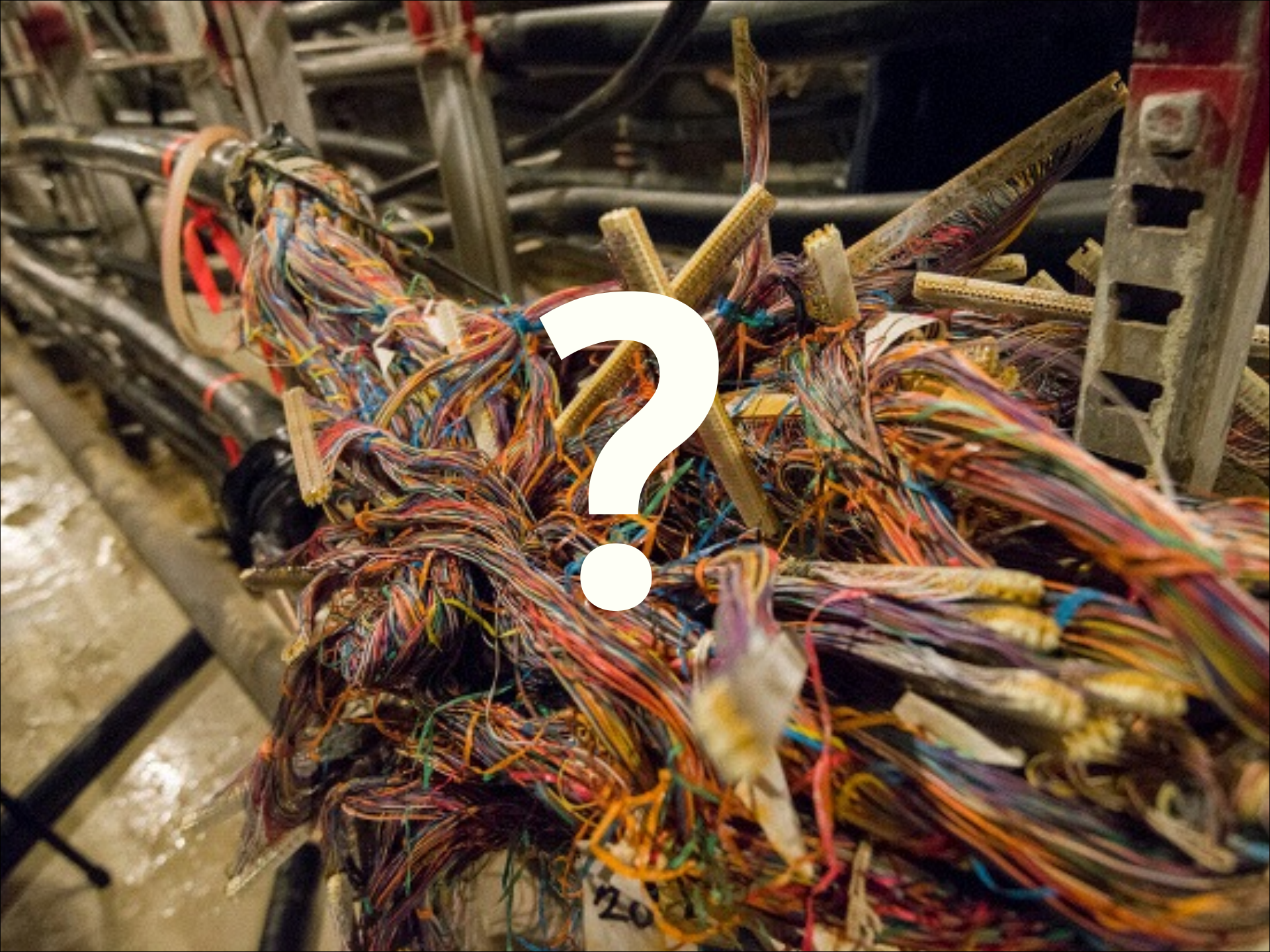
Journaling



The Problem

Changes in memory mapped files are not applied in order and different parts of the file can be from different points in time

You want a consistent point-in-time snapshot when restarting after a crash



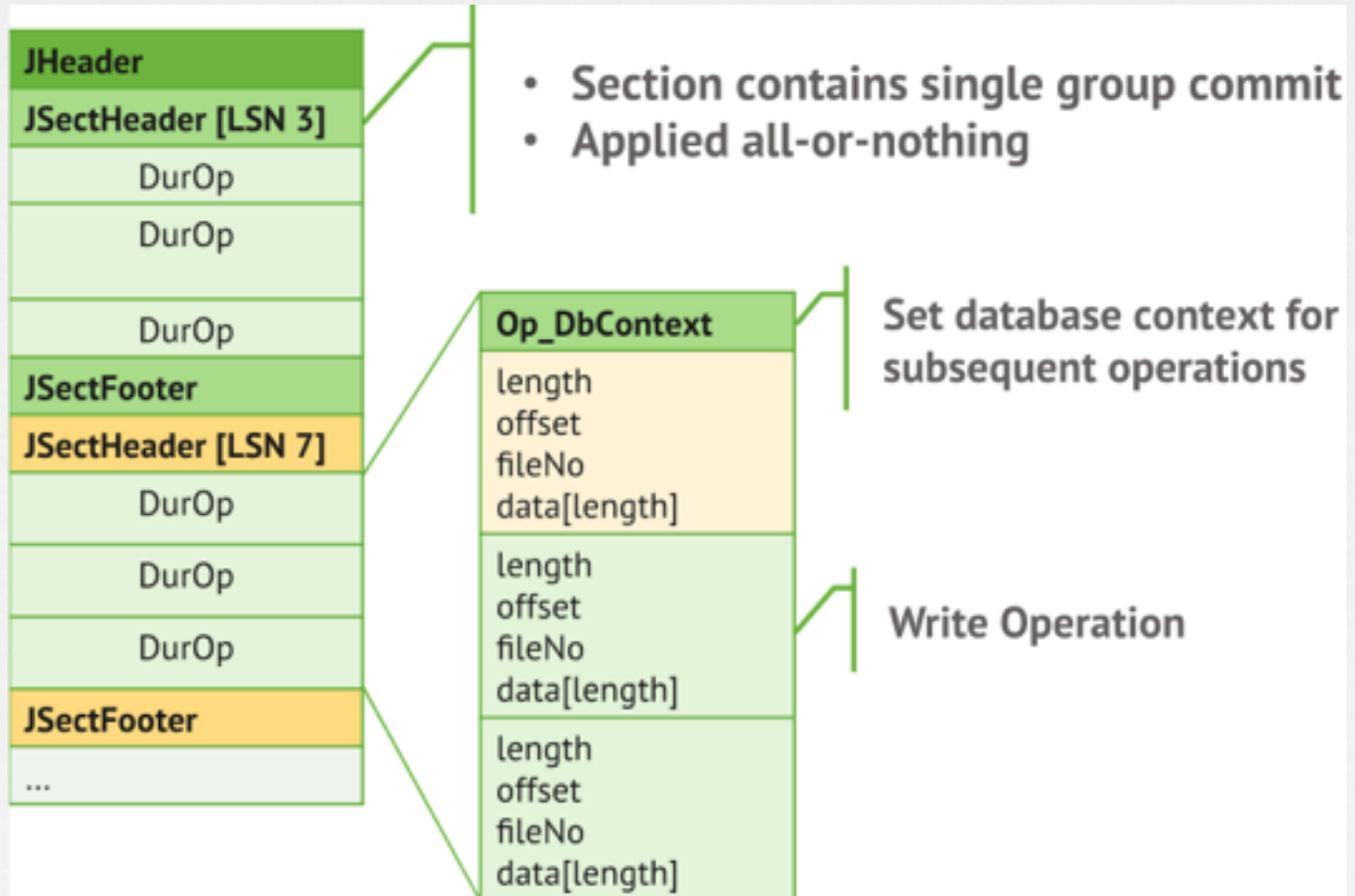


corruption

Solution – Use a Journal

- Data gets written to a journal before making it to the data files
- Operations written to a journal buffer in RAM that gets flushed every 100ms by default or 100MB
- Once the **journal** is written to disk, the **data** is safe
- Journal **prevents corruption** and allows **durability**
- Can be turned off, **but don't!**

Journal Format



Can I Lose Data on a Hard Crash?

- Maximum data loss is 100ms (journal flush). This can be reduced with *-journalCommitInterval*
- For **durability** (data is on disk when ack'ed) use the JOURNAL_SAFE write concern ("j" option).
- Note that replication can reduce the data loss further. Use the REPLICAS_SAFE write concern ("w" option).
- As write guarantees **increase**, latency **increases**. To maintain performance, use **more connections**!

What is the Cost of a Journal?

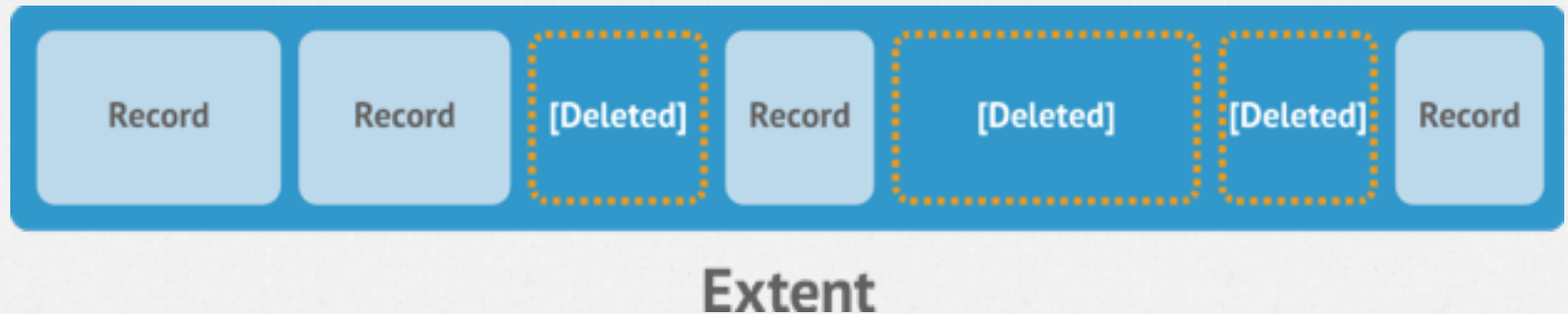
- On read-heavy systems, **no impact**
- Write performance is **reduced by 5-30%**
- If using separate drive for journal, **as low as 3%**
- For apps that are write-heavy (1000+ writes per server) there can be slowdown due to mix of journal and data flushes. Use **a separate drive!**

Fragmentation



What it Looks Like

Both on disk **and** in RAM!



Fragmentation

- Files can get fragmented over time if *remove()* and *update()* are issued.
- It gets worse if documents have varied sizes
- Fragmentation **wastes disk space and RAM**
- Also makes writes **scattered and slower**
- Fragmentation can be checked by comparing *size* to *storageSize* in the collection's *stats*.

How to Combat Fragmentation

- *compact* command (maintenance op)
- **Normalize** schema more (documents don't grow)
- **Pre-pad** documents (documents don't grow)
- Use **separate collections** over time, then use *collection.drop()* instead of *collection.remove(query)*
- *--usePowerOf2sizes* option makes disk buckets more reusable

In Review



In Review

- Understand disk layout and footprint
- See how much data is actually in RAM
- Memory mapping is cool
- Answer how much data is ok to lose
- Check on fragmentation and avoid it
- <https://github.com/10gen-labs/storage-viz>



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Questions?

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