Using MongoDB Responsibly

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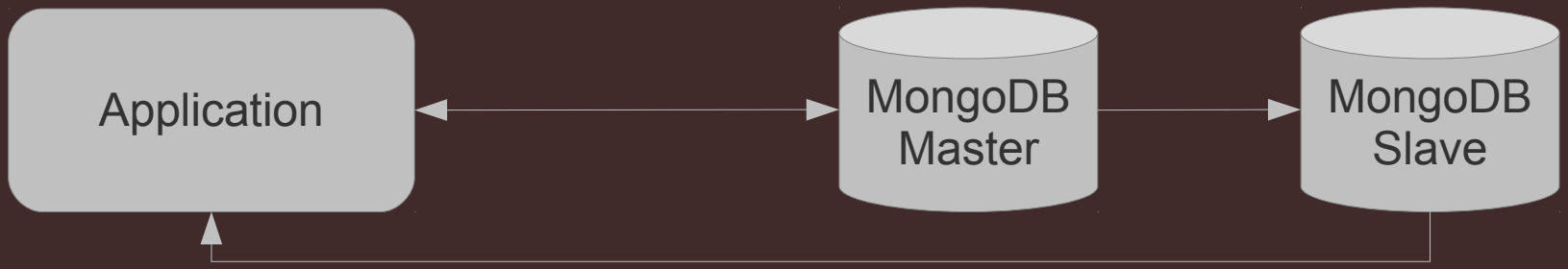
mongoDB

Topics

- Infrastructure
- Concurrency
- Indexing
- Query Optimization
- General Advice
- Case Study
- Map/Reduce
- Aggregation Framework
- Doctrine ODM
- MMS

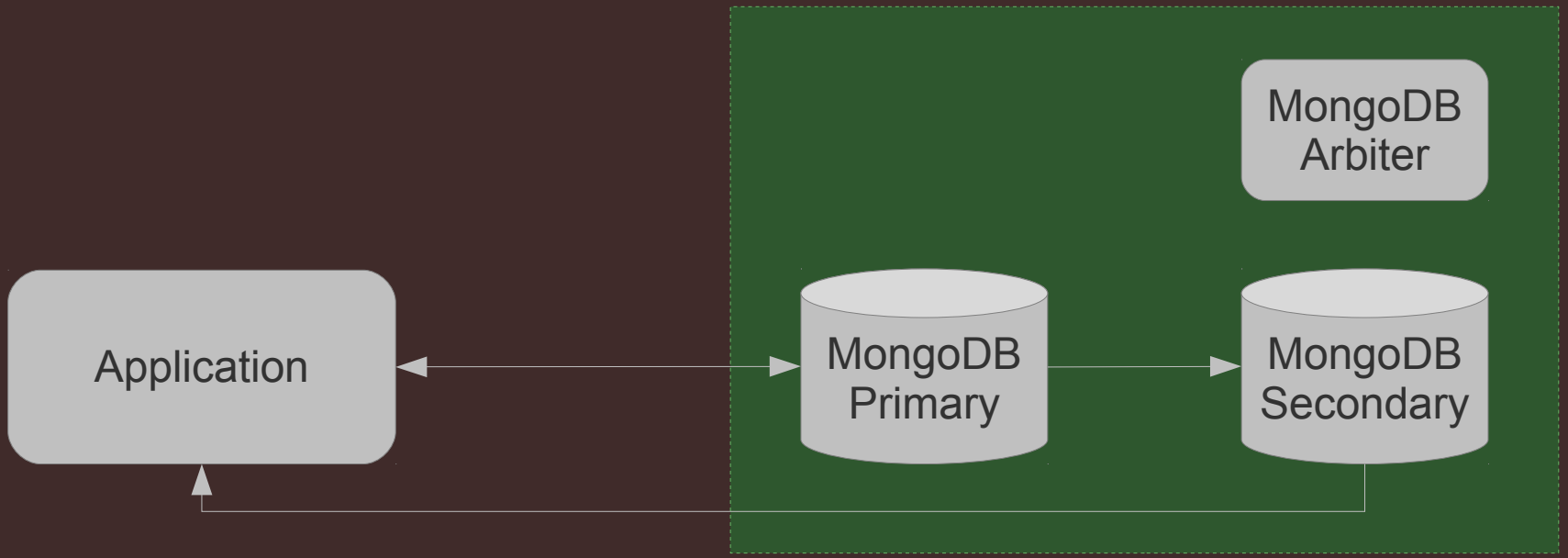
Infrastructure: Master/Slave

- Deprecated in favor of replica sets
- slaveOk allows queries to target slave
- Manual failover process



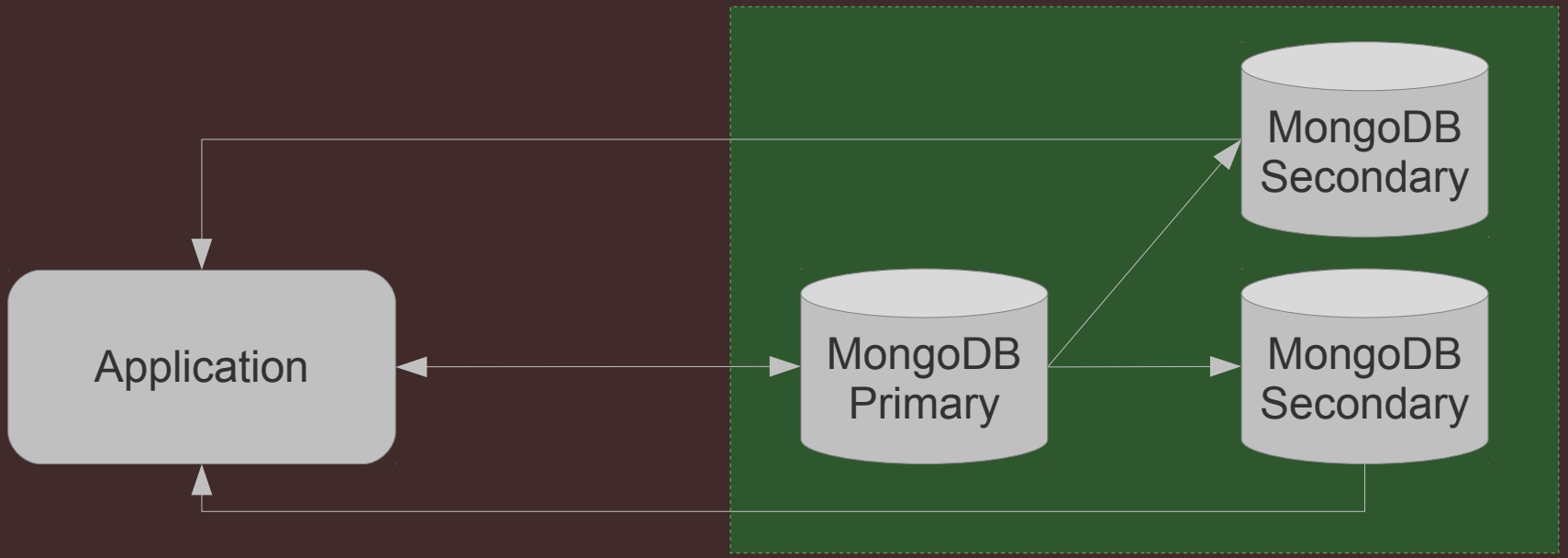
Infrastructure: Replica Set

- Primary, secondary and arbiter
- slaveOk allows queries to target secondary
- Automatic failover

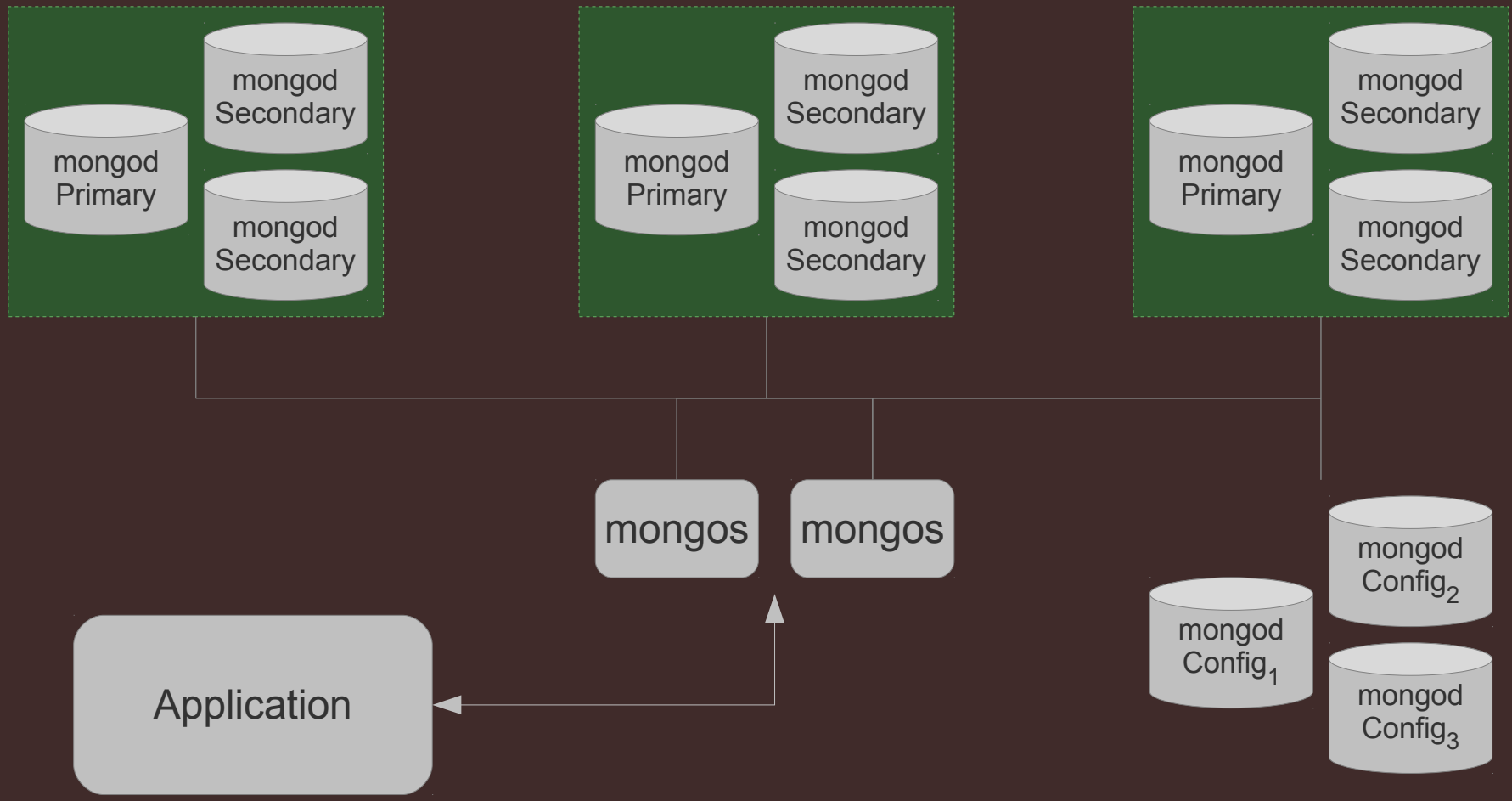


Infrastructure: Replica Set

- Primary with two secondaries
- Arbiter unnecessary for odd number of nodes



Infrastructure: Sharding



Infrastructure: Sharding

- mongos processes
  - Route queries to shards and merges results
  - Lightweight with no persistent state
- Config servers
  - Launched with mongod --configsvr
  - Store cluster metadata (shard/chunk locations)
  - Proprietary replication model

Sharding vs. Replication

Sharding is the tool for scaling a system.

Replication is the tool for data safety, high availability, and disaster recovery.

Source: Sharding Introduction (MongoDB docs)

Concurrency: Locks

- Read/write locks yielded periodically
  - Long operations (queries, multi-document writes)
  - Page faults (2.0+)
- Write locks
  - Greedy acquisition (priority over read locks)
  - Global or database-level (2.2+)
  - Collection-level forthcoming (SERVER-1240)

Concurrency: JavaScript

- JavaScript execution is not concurrent
  - $where queries
  - db.eval() commands
  - Map/reduce
- SpiderMonkey JS interpreter
  - Single-threaded
  - Possible multi-threading with V8 (SERVER-4258)

Concurrency: JavaScript

- db.eval() takes a write lock by default
  - Cannot execute other blocking commands
  - Atomically execute admin or dependent ops
    - Swapping two collection names
    - Complex find/modify
- Executing JS without blocking the node
  - {nolock: true} option with db.runCommand() (1.8+)
  - Use mongo command-line client

Concurrency: Map/Reduce

- JavaScript functions (lock yielded between calls)
- Collection reads (lock yielded every 100 documents)
- Write locks for incremental result storage
  - Temporary collection used between map and reduce
  - jsMode flag may bypass this for small datasets
- Write lock for atomic output of final collection
  - merge and reduce modes can take longer than replace
  - Consider {nonAtomic: true} output option (2.2+)

Concurrency: Indexing

- Foreground indexing
  - Default for index creation
  - Blocks all other database operations
- Background indexing
  - Use the {background: true} option with ensureIndex()
  - Slower than foreground indexing, but doesn't block DB
  - Watch db.currentOp() to track progress

Concurrency: Indexing

- Index replication uses foreground mode (pre-2.2)
  - Manually swap out secondaries for indexing
  - Documentation: Building Indexes with Replica Sets

Monitoring Foreground Indexing

```
> db.currentOp()
{
    "inprog" : [
        {
            "opid" : 10000054,
            "active" : true,
            "lockType" : "write",
            "waitingForLock" : false,
            "secs_running" : 4,
            "op" : "insert",
            "ns" : "test.system.indexes",
            "query" : {},
            "client" : "127.0.0.1:52340",
            "desc" : "conn",
            "threadId" : "0x7f4ce7f50700",
            "connectionId" : 1,
            "msg" : "index: (1/3) external sort 3685454/10000000 36%",
            "progress" : {
                "done" : 3685457,
                "total" : 10000000
            },
            "numYields" : 0
        }
    ]
}
```

Monitoring Foreground Indexing

```
> db.currentOp()
{
    "inprog" : [
        {
            "opid" : 10000054,
            "active" : true,
            "lockType" : "write",
            "waitingForLock" : false,
            "secs_running" : 15,
            "op" : "insert",
            "ns" : "test.system.indexes",
            "query" : {},
            "client" : "127.0.0.1:52340",
            "desc" : "conn",
            "threadId" : "0x7f4ce7f50700",
            "connectionId" : 1,
            "msg" : "index: (2/3) btree bottom up 1721606/10000000 17%",
            "progress" : {
                "done" : 1721606,
                "total" : 10000000
            },
            "numYields" : 0
        }
    ]
}
```

Monitoring Foreground Indexing

```
> db.currentOp()
{
     "inprog" : [
          {
               "opid" : 10000054,
               "active" : true,
               "lockType" : "write",
               "waitingForLock" : false,
               "secs_running" : 25,
               "op" : "insert",
               "ns" : "test.system.indexes",
               "query" : {},
               "client" : "127.0.0.1:52340",
               "desc" : "conn",
               "threadId" : "0x7f4ce7f50700",
               "connectionId" : 1,
               "msg" : "index: (3/3) btree-middle",
               "numYields" : 0
          }
     ]
}
```

Monitoring Background Indexing

```
> db.currentOp()
{
    "inprog" : [
        {
            "opid" : 10000075,
            "active" : true,
            "lockType" : "write",
            "waitingForLock" : false,
            "secs_running" : 12,
            "op" : "insert",
            "ns" : "test.system.indexes",
            "query" : {},
            "client" : "127.0.0.1:52340",
            "desc" : "conn",
            "threadId" : "0x7f4ce7f50700",
            "connectionId" : 1,
            "msg" : "bg index build 3258205/10000000 32%",
            "progress" : {
                "done" : 3258206,
                "total" : 10000000
            },
            "numYields" : 53
        }
    ]
}
```

Background Indexing: PHP

```
$mongo = new MongoDB();
$collection = $mongo->example->foo;

$collection->ensureIndex(
    array('bar' => 1),
    array('background' => true)
);
```

Not to be confused with the safe option, which blocks until the operation succeeds or fails

Background Indexing: PHP

```
> db.foo.count()
1000000
> db.foo.find()
{ "_id" : ObjectId("4fc5136b22f0e13f6f000000"), "x" : 1 }
{ "_id" : ObjectId("4fc5136b22f0e13f6f000001"), "x" : 2 }
{ "_id" : ObjectId("4fc5136b22f0e13f6f000002"), "x" : 3 }
{ "_id" : ObjectId("4fc5136b22f0e13f6f000003"), "x" : 4 }
```

```
$ php benchmark.php
Insertion took 17.095013 seconds
Indexing with [] took 0.000175 seconds
Indexing with {"background":true} took 0.000159 seconds
Indexing with {"safe":true} took 1.649953 seconds
Indexing with {"background":true,"safe":true} took 3.877397 seconds
```

Benchmarking single-field index generation with safe and background options (https://gist.github.com/2829859)

Background Indexing: ODM

```php
<?php

use Doctrine\ODM\MongoDB\Mapping\Annotations as ODM;

/**
 * @ODM\Document(collection="foo")
 * @ODM\Indexes({
 *   @ODM\Index(keys={"x"="asc"}, options={"background"="true"})
 * })
 */
class Foo
```

```
$ app/console doctrine:mongodb:schema:create --index
Created index for all classes
```

Doctrine ODM adds safe by default (since 06d8bb1)

Indexing: Advice

- Kill 2+ ~~birds~~ queries with one ~~stone~~ index
- Compound key and multi-key indexes
- Avoid single-key indexes with low selectivity
- Mind your read/write ratio
- $exists, $ne and $nin can be inefficient
- $all and $in can be slow
- When in doubt, explain() your cursor

Indexing: Memory Usage

```
$ free -b
             total       used       free     shared    buffers     cached
Mem:    7307489280 6942613504  364875776          0  229281792 5872500736
-/+ buffers/cache:  840830976 6466658304
Swap:            0          0          0

$ mongo example --quiet
> var s = 0
0
> for each (var c in db.getCollectionNames()) {
... s += db[c].totalIndexSize();
... }
9784055680
```

7.3GB of RAM cannot hold 9.7GB of indexes, so expect intermittent page faults and disk access

Query Optimization with explain()

```
> for (i=0; i<1000000; i++) db.foo.insert({ x:i, y:Math.random() });

> db.foo.count()
1000000

> db.foo.find({x:5}).explain()
{
    "cursor" : "BasicCursor",
    "nscanned" : 1000000,
    "nscannedObjects" : 1000000,
    "n" : 1,
    "millis" : 301,
    "nYields" : 0,
    "nChunkSkips" : 0,
    "isMultiKey" : false,
    "indexOnly" : false,
    "indexBounds" : {},
    "server" : "localhost:27017"
}
```

Query Optimization with explain()

```
> for (i=0; i<1000000; i++) db.foo.insert({ x:i, y:Math.random() });

> db.foo.count()
1000000

> db.foo.find({x:5}).explain()
{
    "cursor" : "BasicCursor",
    "nscanned" : 1000000,
    "nscannedObjects" : 1000000,
    "n" : 1,
    "millis" : 301,
    "nYields" : 0,
    "nChunkSkips" : 0,
    "isMultiKey" : false,
    "indexOnly" : false,
    "indexBounds" : {},
    "server" : "localhost:27017"
}
```

- Table scan or index-enabled?
- Documents + index entries scanned
- Documents scanned
- Documents matched
- Query time
- Read lock yields
- Docs skipped due to active chunk migrations
- Was multi-key index used? (array values)
- Did query + result come from an index only?
- Key bounds used in index scanning

Query Optimization with explain()

```
> db.foo.ensureIndex({x:1, y:1})

> db.foo.find({x:5}, {_id:0, x:1, y:1}).explain()
{
    "cursor" : "BtreeCursor x_1_y_1",
    "nscanned" : 1,
    "nscannedObjects" : 1,
    "n" : 1,
    "millis" : 0,
    "nYields" : 0,
    "nChunkSkips" : 0,
    "isMultiKey" : false,
    "indexOnly" : true,
    "indexBounds" : {
        "x" : [ [5, 5] ],
        "y" : [ [{"$minElement" : 1}, {"$maxElement" : 1}] ],
    },
    "server" : "localhost:27017"
}
```

Query Optimization with explain()

```
> db.foo.find({x:5, y:{$gt:0.5}}).sort({y:1}).explain()
{
    "cursor" : "BtreeCursor x_1_y_1",
    "nscanned" : 1,
    "nscannedObjects" : 1,
    "n" : 1,
    "millis" : 0,
    "nYields" : 0,
    "nChunkSkips" : 0,
    "isMultiKey" : false,
    "indexOnly" : false,
    "indexBounds" : {
        "x" : [ [5, 5] ],
        "y" : [ [0.5, 1.7976931348623157e+308] ],
    },
    "server" : "localhost:27017"
}
```

General Advice

- Don't be afraid of denormalization
  - Dedicated collection, embedded document, both?
  - Make frequently needed data more accessible
- Store computed data/fields for querying
  - Count and length fields can be indexed and sorted
  - Easily updated with $set and $inc

General Advice

- Simple references (ObjectId only) over DBRefs
  - Concise storage if referenced collection is constant
- Use range queries over skip() for pagination
  - skip() walks through documents or index values
  - Range queries are limited to next/prev links
  - http://stackoverflow.com/a/5052898/162228

General Advice

- B-trees do not track counts for nodes/branches
  - Filtered counts require walking the index (at best)
  - Non-filtered collection counts are constant time
- Use snapshot() for find-and-update loops
  - Ensures documents are only returned once
  - Avoids duplicate processing of updated documents
  - No guarantee for inserted/deleted documents

DBRefs, Discriminators and mongo

```
> db.users.insert({
... name: "bob",
... address: {
...     $ref: "addresses",
...     $id: new ObjectId("4fcea14854298292394bd20a"),
...     $db: "test",
...     type: "shipping"
... }})

> db.users.findOne({name: "bob"}, {_id: 0, address: 1})
{ "address" : DBRef("addresses", ObjectId("4fcea14854298292394bd20a")) }

> db.users.findOne({name: "bob"}, {_id:0, "address.$db": 1})
{ "address" : { "$db" : "test" } }

> db.users.findOne({name: "bob"}, {_id:0, "address.type": 1})
{ "address" : { "type" : "shipping" } }
```

DBRefs, Discriminators and mongo

```
> db.users.findOne({name: "bob"}, {_id: 0, address: 1})
{ "address" : DBRef("addresses", ObjectId("4fcea148542982923 94bd20a")) }

> db.users.findOne({name: "bob"}, {_id:0, "address.$db": 1})
{ "address" : { "$db" : "test" } }

> db.users.findOne({name: "bob"}, {_id:0, "address.type": 1})
{ "address" : { "type" : "shipping" } }
```

Although $db is a valid, optional field for DBRefs, the mongo shell hides it by default; likewise for ODM discriminators.

Be mindful of this if you ever need to write data migrations!

Refactoring OrnicarMessageBundle

- User-to-user messaging (2+ participants)
- Message and thread documents
- Embedded metadata fields (hash type in ODM)
  - message.isReadByParticipant
  - thread.datesOfLastMessageWrittenByOtherParticipant
  - thread.datesOfLastMessageWrittenByParticipant
  - thread.isDeletedByParticipant

Refactoring OrnicarMessageBundle

```
function getNbUnreadMessageByParticipant($participant)
{
    $fieldName = 'isReadByParticipant.' . $participant->getId();

    return $this->repository->createQueryBuilder()
        ->field($fieldName)->equals(false)
        ->getQuery()
        ->count();
}
```

Counting the number of unread messages for a user entails scanning the entire collection from disk.

Refactoring OrnicarMessageBundle

```
> db.messages.findOne({}, {isReadByParticipant: 1})
{
    "_id" : ObjectId("4fce28482516ed983884b158"),
    "isReadByParticipant" : {
        "4fce05e42516ed9838756f17" : false,
        "4fce05e42516ed9838756f18" : true,
        "4fce05e42516ed9838756f19" : true,
        "4fce05e42516ed9838756f1a" : false,
        "4fce05e42516ed9838756f1b" : false
    }
}
```

Index isReadByParticipant? Entire object is indexed.

Index isReadByParticipant keys? We'd need 5+ indexes.

Refactoring OrnicarMessageBundle

```
> db.messages.findOne({}, {unreadForParticipants: 1})
{
    "_id" : ObjectId("4fce28482516ed983884b158"),
    "unreadForParticipants" : [
        "4fce05e42516ed9838756f17",
        "4fce05e42516ed9838756f1a",
        "4fce05e42516ed9838756f1b"
    ]
}
```

Index unreadForParticipants? One multi-key index.

Refactoring OrnicarMessageBundle

```
function getNbUnreadMessageByParticipant($participant)
{
    return $this->repository->createQueryBuilder()
        ->field('unreadForParticipants')->equals($participant->getId())
        ->getQuery()
        ->count();
}
```

Counting the number of unread messages for a user is now a single indexed query.

Map/Reduce

```
> db.articles.save({author: "bob", tags: ["business", "sports", "tech"]})
> db.articles.save({author: "jen", tags: ["politics", "tech"]})
> db.articles.save({author: "sue", tags: ["business"]})
> db.articles.save({author: "tom", tags: ["sports"]})
```

Generate a report with the set of authors that have written an article for each tag.

Map/Reduce

```
> db.articles.mapReduce(
...     function() {
...         for (var i = 0; i < this.tags.length; i++) {
...             emit(this.tags[i], { authors: [this.author] });
...         }
...     },
...     function(key, values) {
...         var result = { authors: [] };
...         values.forEach(function(value) {
...             value.authors.forEach(function(author) {
...                 if (-1 == result.authors.indexOf(author)) {
...                     result.authors.push(author);
...                 }
...             });
...         });
...         return result;
...     },
...     { out: { inline: 1 }}
... )
```

Map/Reduce

```
{
    "results" : [
        { "_id" : "business", "value" : { "authors" : ["bob", "sue"] } },
        { "_id" : "politics", "value" : { "authors" : ["jen"] } },
        { "_id" : "sports",   "value" : { "authors" : ["bob", "tom"] } },
        { "_id" : "tech",     "value" : { "authors" : ["bob", "jen"] } }
    ],
    "timeMillis" : 0,
    "counts" : {
        "input" : 4,
        "emit" : 7,
        "reduce" : 3,
        "output" : 4
    },
    "ok" : 1,
}
```

Is there an easier way?

Aggregation Framework

- Pipeline
  - Operators process a stream of documents
  - Transformations are applied in sequence
  - Expressions calculate values from documents
  - Defined in JSON (no JavaScript code)
- Invoked on collections
  - Use the $match operator for early filtering
  - Compatible with sharding

Aggregation Framework

- Operations
  - Projection (altering)
  - Match (filtering)
  - Limit
  - Skip
  - Unwind (array values)
  - Group
  - Sort
- Expressions
  - Boolean
  - Comparison
  - Arithmetic
  - String manipulation
  - Date handling
  - Accumulators
  - Conditionals

Aggregation Framework

```
> db.articles.aggregate(
...     { $project: { author: 1, tags: 1} },
...     { $unwind: "$tags" },
...     { $group: {
...         _id: { tags : 1 },
...         authors: { $addToSet : "$author" }
...     }}
... )

{
    "result" : [
        { "_id" : { "tags" : "politics" }, "authors" : ["jen"] },
        { "_id" : { "tags" : "tech" },     "authors" : ["jen", "bob"] },
        { "_id" : { "tags" : "sports" },   "authors" : ["tom", "bob"] },
        { "_id" : { "tags" : "business" }, "authors" : ["sue", "bob"] }
    ],
    "ok" : 1
}
```

Benchmarking Doctrine ODM

- Benchmark bulk document creation
  - Persist and flush
  - Query builder
  - Collection (Doctrine class)
    - Wraps driver class with event dispatching
  - MongoCollection (driver class)
- Track insertion time and memory usage

Benchmarking Doctrine ODM

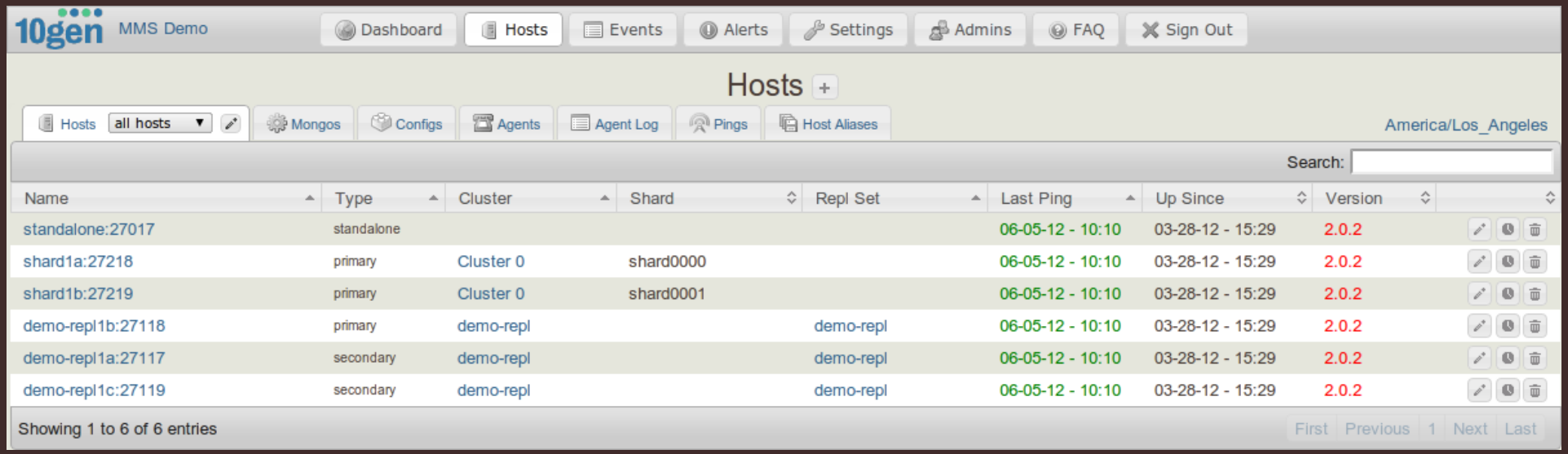
```
$ ./benchmark-odm-flush.php 100000
Flushing 100000 documents took 47.423843 seconds and used 576978944 bytes
150732800 bytes still allocated after benchmarking

$ ./benchmark-odm-query.php 100000
Inserting 100000 documents took 15.918296 seconds and used 3670016 bytes
8126464 bytes still allocated after benchmarking

$ ./benchmark-odm-driver.php 100000
Inserting 100000 documents took 4.305500 seconds and used 524288 bytes
6029312 bytes still allocated after benchmarking

$ ./benchmark-driver.php 100000
Inserting 100000 documents took 1.120347 seconds and used 524288 bytes
6029312 bytes still allocated after benchmarking
```

Source: https://gist.github.com/2725976

Mongo Monitoring Service (MMS)

- SaaS solution for monitoring MongoDB clusters
- Speeds up diagnosis for support requests
- MMS agent (lightweight Python script)
  - Reports all sorts of database stats
  - Additional hardware reporting with Munin
- Free!

Mongo Monitoring Service (MMS)



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