



# MongoDB Administrator Training



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# MongoDB Administrator Training

*Release 3.0*

**MongoDB, Inc.**

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## Contents

<b>1</b>	<b>Introduction</b>	<b>13</b>
1.1	Warm Up	13
	Introductions	13
	Getting to Know You	13
	MongoDB Experience	14
	10gen	14
	Origin of MongoDB	14
1.2	MongoDB Overview	15
	Learning Objectives	15
	MongoDB is a Document Database	15
	An Example MongoDB Document	15
	Vertical Scaling	16
	Scaling with MongoDB	16
	Database Landscape	17
	MongoDB Deployment Models	18
1.3	MongoDB Stores Documents	18
	Learning Objectives	18
	JSON	19
	A Simple JSON Object	19
	JSON Keys and Values	19
	Example Field Values	20
	BSON	20
	BSON Hello World	21
	A More Complex BSON Example	21
	Documents, Collections, and Databases	21
	The <code>_id</code> Field	22
	ObjectIds	22
	Storing BSON Documents	22
	Padding Factor	23
	<code>usePowerOf2Sizes</code>	23
1.4	Storage Engines	23
	Learning Objectives	23
	What is a Database Storage Engine?	24
	Storage Engine Journaling	24

How Storage Engines Affect Performance . . . . .	24
MongoDB Storage Engines . . . . .	25
Specifying a MongoDB Storage Engine . . . . .	25
Specifying a Location to Store Data Files . . . . .	25
MMAPv1 Storage Engine . . . . .	26
MMAPv1 Workloads . . . . .	26
Power of 2 Sizes Allocation Strategy . . . . .	26
Compression in MongoDB . . . . .	27
WiredTiger Storage Engine . . . . .	27
WiredTiger Compression Options . . . . .	27
Configuring Compression in WiredTiger . . . . .	28
Configuring Memory Usage in WiredTiger . . . . .	28
Storage Engine API . . . . .	28
Conclusion . . . . .	29
 1.5 Exercise: Installing MongoDB . . . . .	 29
Learning Objectives . . . . .	29
Production Releases . . . . .	30
Installing MongoDB . . . . .	30
Linux Setup . . . . .	30
Install on Windows . . . . .	31
Create a Data Directory on Windows . . . . .	31
Launch a <code>mongod</code> . . . . .	31
The MongoDB Data Directory (MMAPv1) . . . . .	32
The MongoDB Data Directory (WiredTiger) . . . . .	32
Import Exercise Data . . . . .	32
Launch a Mongo Shell . . . . .	33
Explore Databases . . . . .	33
Exploring Collections . . . . .	34
Admin Commands . . . . .	34
 <b>2 CRUD</b> . . . . .	 <b>35</b>
 2.1 Creating and Deleting Documents . . . . .	 35
Learning Objectives . . . . .	35
Creating New Documents . . . . .	35
Exercise: Inserting a Document . . . . .	36
Implicit <code>_id</code> Assignment . . . . .	36
Exercise: Assigning <code>_ids</code> . . . . .	36
Inserts will fail if... . . . .	37
Exercise: Inserts will fail if... . . . .	37
Bulk Inserts . . . . .	37
Ordered Bulk Insert . . . . .	38
Exercise: Ordered Bulk Insert . . . . .	38
Unordered Bulk Insert . . . . .	38
Exercise: Unordered Bulk Insert . . . . .	39
The Shell is a JavaScript Interpreter . . . . .	39
Exercise: Creating Data in the Shell . . . . .	39
Deleting Documents . . . . .	40
Using <code>remove()</code> . . . . .	40
Exercise: Removing Documents . . . . .	40
Dropping a Collection . . . . .	41
Exercise: Dropping a Collection . . . . .	41
Dropping a Database . . . . .	41

Exercise: Dropping a Database . . . . .	42
2.2 Reading Documents . . . . .	42
Learning Objectives . . . . .	42
The <code>find()</code> Method . . . . .	43
Query by Example . . . . .	43
Exercise: Querying by Example . . . . .	43
Querying Arrays . . . . .	44
Exercise: Querying Arrays . . . . .	44
Querying with Dot Notation . . . . .	44
Exercise: Querying with Dot Notation . . . . .	45
Exercise: Arrays and Dot Notation . . . . .	45
Projections . . . . .	46
Projection: Example (Setup) . . . . .	46
Projection: Example . . . . .	46
Projection Documents . . . . .	47
Exercise: Projections . . . . .	47
Cursors . . . . .	47
Exercise: Introducing Cursors . . . . .	48
Exercise: Cursor Objects in the Mongo Shell . . . . .	48
Cursor Methods . . . . .	49
Exercise: Using <code>count()</code> . . . . .	49
Exercise: Using <code>sort()</code> . . . . .	49
The <code>skip()</code> Method . . . . .	50
The <code>limit()</code> Method . . . . .	50
The <code>distinct()</code> Method . . . . .	50
Exercise: Using <code>distinct()</code> . . . . .	51
2.3 Query Operators . . . . .	51
Learning Objectives . . . . .	51
Comparison Query Operators . . . . .	51
Exercise: Comparison Operators (Setup) . . . . .	52
Exercise: Comparison Operators . . . . .	52
Logical Query Operators . . . . .	53
Exercise: Logical Operators . . . . .	53
Exercise: Logical Operators . . . . .	53
Element Query Operators . . . . .	54
Exercise: Element Operators . . . . .	54
Array Query Operators . . . . .	55
Exercise: Array Operators . . . . .	55
Exercise: <code>\$elemMatch</code> . . . . .	55
2.4 Updating Documents . . . . .	56
Learning Objectives . . . . .	56
The <code>update()</code> Method . . . . .	56
Parameters to <code>update()</code> . . . . .	56
<code>\$set</code> and <code>\$unset</code> . . . . .	57
Exercise: <code>\$set</code> and <code>\$unset</code> (Setup) . . . . .	57
Exercise: <code>\$set</code> and <code>\$unset</code> . . . . .	58
Exercise: Update Array Elements by Index . . . . .	58
Update Operators . . . . .	58
Exercise: Update Operators . . . . .	59
<code>update()</code> Defaults to one Document . . . . .	59
Updating Multiple Documents . . . . .	60

Exercise: Multi-Update . . . . .	60
Array Operators . . . . .	60
Exercise: Array Operators . . . . .	61
The Positional \$ Operator . . . . .	61
Exercise: The Positional \$ Operator . . . . .	62
Upserts . . . . .	62
Upsert Mechanics . . . . .	62
Exercise: Upserts . . . . .	63
save() . . . . .	63
Exercise: save() . . . . .	63
Be Careful with save() . . . . .	64
<b>3 Indexes</b> . . . . .	<b>65</b>
3.1 Index Fundamentals . . . . .	65
Learning Objectives . . . . .	65
Why Indexes? . . . . .	65
Types of Indexes . . . . .	66
Exercise: Using explain() . . . . .	66
Results of explain() . . . . .	66
Results of explain() - Continued . . . . .	67
explain() Verbosity Can Be Adjusted . . . . .	67
explain("executionStats") . . . . .	67
explain("executionStats") - Continued . . . . .	68
explain("executionStats") Output . . . . .	68
Other Operations . . . . .	69
db.<COLLECTION>.explain() . . . . .	69
Using explain() for Write Operations . . . . .	69
Single-Field Indexes . . . . .	70
Creating an Index . . . . .	70
Listing Indexes . . . . .	70
Indexes and Read/Write Performance . . . . .	71
Index Limitations . . . . .	71
Use Indexes with Care . . . . .	71
Additional Index Options . . . . .	72
Sparse Indexes in MongoDB . . . . .	72
Defining Unique Indexes . . . . .	72
Building Indexes in the Background . . . . .	73
3.2 Compound Indexes . . . . .	73
Learning Objectives . . . . .	73
Introduction to Compound Indexes . . . . .	73
The Order of Fields Matters . . . . .	74
Designing Compound Indexes . . . . .	74
Example: A Simple Message Board . . . . .	74
Load the Data . . . . .	75
Start with a Simple Index . . . . .	75
Query Adding username . . . . .	75
Include username in Our Index . . . . .	76
totalKeysExamined > n . . . . .	76
A Different Compound Index . . . . .	76
totalKeysExamined == n . . . . .	77
Let Selectivity Drive Field Order . . . . .	77
Adding in the Sort . . . . .	77

In-Memory Sorts . . . . .	78
Avoiding an In-Memory Sort . . . . .	78
General Rules of Thumb . . . . .	79
Covered Queries . . . . .	79
Exercise: Covered Queries . . . . .	79
3.3 Multikey Indexes . . . . .	80
Learning Objectives . . . . .	80
Introduction to Multikey Indexes . . . . .	80
Example: Array of Numbers . . . . .	81
Exercise: Array of Documents, Part 1 . . . . .	81
Exercise: Array of Documents, Part 2 . . . . .	82
Exercise: Array of Arrays, Part 1 . . . . .	82
Exercise: Array of Arrays, Part 2 . . . . .	82
How Multikey Indexes Work . . . . .	83
Multikey Indexes and Sorting . . . . .	83
Exercise: Multikey Indexes and Sorting . . . . .	83
Limitations on Multikey Indexes . . . . .	84
Example: Multikey Indexes on Multiple Fields . . . . .	84
3.4 Hashed Indexes . . . . .	85
Learning Objectives . . . . .	85
What is a Hashed Index? . . . . .	85
Why Hashed Indexes? . . . . .	85
Limitations . . . . .	86
Floating Point Numbers . . . . .	86
Creating a Hashed Index . . . . .	86
3.5 Geospatial Indexes . . . . .	86
Learning Objectives . . . . .	86
Introduction to Geospatial Indexes . . . . .	87
Easiest to Start with 2 Dimensions . . . . .	87
Location Field . . . . .	87
Find Nearby Documents . . . . .	88
Flat vs. Spherical Indexes . . . . .	88
Flat Geospatial Index . . . . .	88
Spherical Geospatial Index . . . . .	89
Creating a 2d Index . . . . .	89
Exercise: Creating a 2d Index . . . . .	89
Inserting Documents with a 2d Index . . . . .	90
Exercise: Inserting Documents with 2d Fields . . . . .	90
Querying Documents Using a 2d Index . . . . .	90
Example: Find Based on 2d Coords . . . . .	91
Creating a 2dsphere Index . . . . .	91
The geoJSON Specification . . . . .	91
geoJSON Considerations . . . . .	92
Simple Types of 2dsphere Objects . . . . .	92
Polygons . . . . .	92
Other Types of 2dsphere Objects . . . . .	93
Exercise: Inserting geoJSON Objects (1) . . . . .	93
Exercise: Inserting geoJSON Objects (2) . . . . .	94
Exercise: Inserting geoJSON Objects (3) . . . . .	94
Exercise: Creating a 2dsphere Index . . . . .	94
Querying 2dsphere Objects . . . . .	95

3.6	TTL Indexes . . . . .	95
	Learning Objectives . . . . .	95
	TTL Index Basics . . . . .	95
	Creating a TTL Index . . . . .	96
	Exercise: Creating a TTL Index . . . . .	96
	Exercise: Check the Collection . . . . .	96
3.7	Text Indexes . . . . .	97
	Learning Objectives . . . . .	97
	What is a Text Index? . . . . .	97
	Creating a Text Index . . . . .	97
	Exercise: Creating a Text Index . . . . .	98
	Creating a Text Index with Weighted Fields . . . . .	98
	Text Indexes are Similar to Multikey Indexes . . . . .	98
	Exercise: Inserting Texts . . . . .	99
	Querying a Text Index . . . . .	99
	Exercise: Querying a Text Index . . . . .	99
	Exercise: Querying Using Two Words . . . . .	100
	Search for a Phrase . . . . .	100
	Text Search Score . . . . .	100
4	<b>Replica Sets</b> . . . . .	101
4.1	Introduction to Replica Sets . . . . .	101
	Learning Objectives . . . . .	101
	Use Cases for Replication . . . . .	101
	High Availability (HA) . . . . .	102
	Disaster Recovery (DR) . . . . .	102
	Functional Segregation . . . . .	102
	Large Replica Sets . . . . .	103
	Replication is Not Designed for Scaling . . . . .	103
	Replica Sets . . . . .	103
	Primary Server . . . . .	104
	Secondaries . . . . .	104
	Heartbeats . . . . .	104
	The Oplog . . . . .	105
4.2	Elections in Replica Sets . . . . .	105
	Learning Objectives . . . . .	105
	Members and Votes . . . . .	105
	Calling Elections . . . . .	106
	Selecting a New Primary . . . . .	106
	Priority . . . . .	106
	Optime . . . . .	107
	Connections . . . . .	107
	When will a primary step down? . . . . .	107
	replSetStepDown Behavior . . . . .	108
	Exercise: Elections in Failover Scenarios . . . . .	108
	Scenario A: 3 Data Nodes in 1 DC . . . . .	108
	Scenario B: 3 Data Nodes in 2 DCs . . . . .	109
	Scenario C: 4 Data Nodes in 2 DCs . . . . .	109
	Scenario D: 5 Nodes in 2 DCs . . . . .	109
	Scenario E: 3 Data Nodes in 3 DCs . . . . .	110
	Scenario F: 5 Data Nodes in 3 DCs . . . . .	110



4.3	Replica Set Roles and Configuration	111
	Learning Objectives	111
	Example: A Five-Member Replica Set Configuration	111
	Configuration	111
	Principal Data Center	112
	Data Center 2	112
	What about dc1-3 and dc2-2?	112
	What about dc2-2?	112
4.4	The Oplog: Statement Based Replication	113
	Learning Objectives	113
	Binary Replication	113
	Tradeoffs	114
	Statement-Based Replication	114
	Example	114
	Replication Based on the Oplog	115
	Create a Replica Set	115
	ReplSetTest	115
	Start the Replica Set	116
	Status Check	116
	Connect to the Primary	116
	Create some Inventory Data	117
	Perform an Update	117
	View the Oplog	117
	Operations in the Oplog are Idempotent	118
	The Oplog Window	118
	Sizing the Oplog	118
4.5	Write Concern	119
	Learning Objectives	119
	What happens to the write?	119
	Answer	119
	Balancing Durability with Performance	120
	Defining Write Concern	120
	Write Concern: { w : 1 }	120
	Example: { w : 1 }	121
	Write Concern: { w : 2 }	121
	Example: { w : 2 }	121
	Other Write Concerns	122
	Write Concern: { w : "majority" }	122
	Example: { w : "majority" }	122
	Quiz: Which write concern?	123
	Further Reading	123
4.6	Read Preference	124
	What is Read Preference?	124
	Use Cases	124
	Not for Scaling	124
	Read Preference Modes	125
	Tag Sets	125
4.7	Exercise: Setting up a Replica Set	125
	Overview	125
	Create Data Directories	126

Launch Each Member . . . . .	126
Status . . . . .	127
Connect to a MongoDB Instance . . . . .	127
Configure the Replica Set . . . . .	127
Write to the Primary . . . . .	128
Read from a Secondary . . . . .	128
Review the Oplog . . . . .	128
Changing Replica Set Configuration . . . . .	129
Verifying Configuration Change . . . . .	129
Further Reading . . . . .	129
<b>5 Sharding</b>	<b>130</b>
5.1 Introduction to Sharding . . . . .	130
Learning Objectives . . . . .	130
Contrast with Replication . . . . .	130
Sharding is Concerned with Scale . . . . .	131
Vertical Scaling . . . . .	131
The Working Set . . . . .	131
Limitations of Vertical Scaling . . . . .	132
Sharding Overview . . . . .	132
A Model that Does Not Scale . . . . .	132
A Scalable Model . . . . .	133
Sharding Basics . . . . .	133
Sharded Cluster Architecture . . . . .	134
Mongos . . . . .	134
Config Servers . . . . .	134
Config Server Hardware Requirements . . . . .	135
When to Shard . . . . .	135
Possible Imbalance? . . . . .	136
Balancing Shards . . . . .	136
What is a Shard Key? . . . . .	136
Targeted Query Using Shard Key . . . . .	137
With a Good Shard Key . . . . .	137
With a Bad Shard Key . . . . .	138
Choosing a Shard Key . . . . .	138
More Specifically . . . . .	138
Cardinality . . . . .	139
Non-Monotonic . . . . .	139
Shards Should be Replica Sets . . . . .	139
5.2 Balancing Shards . . . . .	140
Learning Objectives . . . . .	140
Chunks and the Balancer . . . . .	140
Chunks in a Newly Sharded Collection . . . . .	140
Chunk Splits . . . . .	141
Pre-Splitting Chunks . . . . .	141
Start of a Balancing Round . . . . .	141
Balancing is Resource Intensive . . . . .	142
Chunk Migration Steps . . . . .	142
Concluding a Balancing Round . . . . .	142
5.3 Shard Tags . . . . .	143
Learning Objectives . . . . .	143

Tags - Overview . . . . .	143
Example: DateTime . . . . .	143
Example: Location . . . . .	144
Example: Premium Tier . . . . .	144
Tags - Caveats . . . . .	144
<b>5.4 Exercise: Setting Up a Sharded Cluster . . . . .</b>	<b>145</b>
Learning Objectives . . . . .	145
Our Sharded Cluster . . . . .	145
Sharded Cluster Configuration . . . . .	145
Build Our Data Directories . . . . .	146
Initiate a Replica Set . . . . .	146
Spin Up a Second Replica Set . . . . .	147
A Third Replica Set . . . . .	147
Status Check . . . . .	148
Launch Config Servers . . . . .	148
Launch the Mongos Processes . . . . .	149
Add All Shards . . . . .	149
Enable Sharding and Shard a Collection . . . . .	149
Observe What Happens . . . . .	150
<b>6 Security . . . . .</b>	<b>151</b>
6.1 Security . . . . .	151
Learning Objectives . . . . .	151
Overview . . . . .	151
Authentication Options . . . . .	152
Authorization via MongoDB . . . . .	152
Network Exposure Options . . . . .	152
Encryption (SSL) . . . . .	153
Native MongoDB Auth . . . . .	153
Exercise: Create an Admin User, Part 1 . . . . .	153
Exercise: Create an Admin User, Part 2 . . . . .	154
Using MongoDB Roles . . . . .	154
Exercise: Creating a readWrite User, Part 1 . . . . .	154
Exercise: Creating a readWrite User, Part 2 . . . . .	155
MongoDB Custom User Roles . . . . .	155
<b>7 MMS &amp; Ops Manager . . . . .</b>	<b>156</b>
7.1 MongoDB Management Service (MMS) & Ops Manager . . . . .	156
Learning Objectives . . . . .	156
MMS and Ops Manager . . . . .	156
Deployment Options . . . . .	157
Architecture . . . . .	157
MMS . . . . .	158
Ops Manager . . . . .	158
MMS and Ops Manager Use Cases . . . . .	158
Creating an MMS Account . . . . .	158
7.2 Automation . . . . .	159
Learning Objectives . . . . .	159
What is Automation? . . . . .	159
How Does Automation Work? . . . . .	159

Automation Agents . . . . .	160
Sample Use Case . . . . .	160
Upgrades Using Automation . . . . .	161
Automation: Behind the Scenes . . . . .	161
Configuration File . . . . .	161
Automation Goal State . . . . .	162
Demo . . . . .	162
7.3 Exercise: Cluster Automation . . . . .	162
Learning Objectives . . . . .	162
MMS Automation Support . . . . .	162
Exercise #1 . . . . .	163
Exercise #2 . . . . .	163
7.4 Monitoring . . . . .	163
Learning Objectives . . . . .	163
Monitoring in MMS / Ops Manager . . . . .	164
Monitoring Use Cases . . . . .	164
Monitoring Agent . . . . .	164
Agent Configuration . . . . .	165
Agent Security . . . . .	165
Monitoring Demo . . . . .	165
Navigating MMS Charts . . . . .	165
Metrics . . . . .	166
Alerts . . . . .	166
7.5 Exercise: Create an Alert . . . . .	166
Learning Objectives . . . . .	166
Exercise #1 . . . . .	167
7.6 Backups . . . . .	167
Learning Objectives . . . . .	167
Methods for Backing Up MongoDB . . . . .	167
Comparing MongoDB Backup Methods . . . . .	167
MMS / Ops Manager Backups . . . . .	168
Restoring from MMS / Ops Manager . . . . .	168
Architecture . . . . .	168
Snapshotting . . . . .	169
Backup Agent . . . . .	169
7.7 API . . . . .	169
Learning Objectives . . . . .	169
What is the MMS / Ops Manager API? . . . . .	170
API Documentation . . . . .	170
Sample API Uses Cases . . . . .	170
Ingest Monitoring Data . . . . .	170
Programatically Restore Environments . . . . .	171
Configuration Management . . . . .	171
7.8 Exercise: MMS API . . . . .	171
Learning Objectives . . . . .	171
Using the MMS API . . . . .	171
Exercise #1 . . . . .	172
Exercise #2 . . . . .	172

Exercise #3 . . . . .	172
7.9 Architecture (Ops Manager) . . . . .	172
Learning Objectives . . . . .	172
MongoDB Ops Manager . . . . .	173
Components . . . . .	173
Architecture . . . . .	173
Application Server . . . . .	174
Application Database . . . . .	174
Backup Infrastructure . . . . .	174
Blockstore Database . . . . .	175
Backup Daemon Process . . . . .	175
7.10 Security (Ops Manager) . . . . .	175
Learning Objectives . . . . .	175
Ops Manager User Authentication . . . . .	176
Authentication for the Backing Ops Manager Databases . . . . .	176
Authenticating Between an Ops Manager Agent and Cluster . . . . .	176
Encrypting Communications . . . . .	177
Ops Manager Groups . . . . .	177
User Roles By Group . . . . .	177
Global User Roles . . . . .	177
7.11 Exercise: Install Ops Manager . . . . .	178
Learning Objectives . . . . .	178
Install Ops Manager . . . . .	178
Install Ops Manager . . . . .	178
Exercise #1 . . . . .	178
Exercise #2 . . . . .	179
Exercise #3 . . . . .	179
Exercise #4 . . . . .	179
Exercise #5 . . . . .	180
<b>8 Performance Troubleshooting</b> . . . . .	<b>181</b>
8.1 Performance Troubleshooting . . . . .	181
Learning Objectives . . . . .	181
mongostat and mongotop . . . . .	181
Exercise: mongostat (setup) . . . . .	182
Exercise: mongostat (run) . . . . .	182
Exercise: mongostat (create index) . . . . .	183
Exercise: mongotop . . . . .	183
db.currentOp() . . . . .	184
Exercise: db.currentOp() . . . . .	184
db.<COLLECTION>.stats() . . . . .	185
Exercise: Using Collection Stats . . . . .	185
The Profiler . . . . .	185
The Profiler (continued) . . . . .	186
Exercise: Exploring the Profiler . . . . .	186
db.serverStatus() . . . . .	186
Exercise: Using db.serverStatus() . . . . .	187
Analyzing Profiler Data . . . . .	187
Performance Improvement Techniques . . . . .	187
Performance Tips: Write Concern . . . . .	188

Bulk Operations	188
Exercise: Comparing bulk inserts with <code>mongostat</code>	188
<code>mongostat</code> , bulk inserts with <code>{w: 1}</code>	189
Bulk inserts with <code>{w: 3}</code>	189
<code>mongostat</code> , bulk inserts with <code>{w: 3}</code>	190
Schema Design	190
Shard Key Considerations	190
Indexes and Performance	191
<b>9 Backup and Recovery</b>	<b>192</b>
9.1 Backup and Recovery	192
Disasters Do Happen	192
Human Disasters	193
Terminology: RPO vs. RTO	193
Terminology: DR vs. HA	194
Quiz	194
Backup Options	194
Document Level: <code>mongodump</code>	195
<code>mongodump</code>	195
File System Level	196
Ensure Consistency	196
File System Backups: Pros and Cons	196
Document Level: <code>mongorestore</code>	197
File System Restores	197
Backup Sharded Cluster	197
Restore Sharded Cluster	198
Tips and Tricks	198
Backup Options	199
MMS Backup	199
Sharded Clusters	199
Under the Hood	200
Key Benefits	200
Point in Time Backups	200
Easy to Restore	201
Unlimited Restores	201
Fully Managed	201
Getting Started	201

# 1 Introduction

*Warm Up (page 13)* Activities to get the class started

*MongoDB Overview (page 15)* MongoDB philosophy and features.

*MongoDB Stores Documents (page 18)* The structure of data in MongoDB.

*Storage Engines (page 23)* MongoDB storage engines.

*Exercise: Installing MongoDB (page 29)* Install mongodb experiment with a few operations.

## 1.1 Warm Up

### Introductions

- Who am I?
- My role at MongoDB
- My background and prior experience

*Notes:*

### Getting to Know You

- Who are you?
- What role do you play in your organization?
- What is your background?
- Do you have prior experience with MongoDB?

*Notes:*

## MongoDB Experience

- Who has never used MongoDB?
- Who has some experience?
- Who has worked with production MongoDB deployments?
- Who is more of a developer?
- Who is more of operations person?

*Notes:*

## 10gen

- MongoDB was initially created in 2008 as part of a hosted application stack.
- The company was originally called 10gen.
- As part of their overarching plan to create the 10gen platform, the company built a database.
- Suddenly everybody said: “I like that! Give me that database!”

*Notes:*

## Origin of MongoDB

- 10gen became a database company.
- In 2013, the company rebranded as MongoDB, Inc.
- The founders have other startups to their credit: DoubleClick, ShopWiki, Gilt.
- The motivation for the database came from observing the following pattern with application development.
  - The user base grows.
  - The associated body of data grows.
  - Eventually the application outgrows the database.
  - Meeting performance requirements becomes difficult.

*Notes:*



## 1.2 MongoDB Overview

### Learning Objectives

Upon completing this module students should understand:

- MongoDB vs. relational databases and key/value stores
- Vertical vs. horizontal scaling
- The role of MongoDB in the development stack
- The structure of documents in MongoDB
- Array fields
- Embedded documents
- Fundamentals of BSON

*Notes:*

### MongoDB is a Document Database

Documents are associative arrays like:

- Python dictionaries
- Ruby hashes
- PHP arrays
- JSON objects

*Notes:*

### An Example MongoDB Document

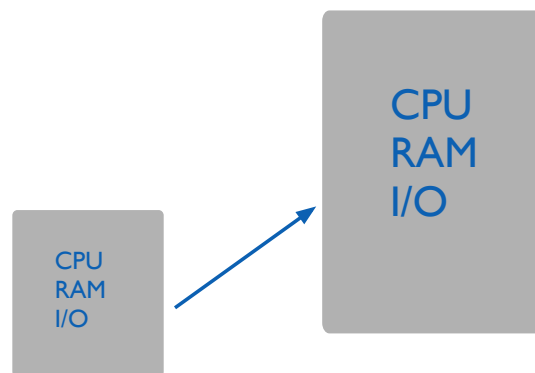
A MongoDB document expressed using JSON syntax.

```
{
  "_id" : "/apple-reports-second-quarter-revenue",
  "headline" : "Apple Reported Second Quarter Revenue Today",
  "date" : ISODate("2015-03-24T22:35:21.908Z"),
  "author" : {
    "name" : "Bob Walker",
    "title" : "Lead Business Editor"
  },
  "copy" : "Apple beat Wall St expectations by reporting ...",
  "tags" : [
    "AAPL", "Earnings", "Cupertino"
  ],
}
```

```
"comments" : [
  { "name" : "Frank", "comment" : "Great Story" },
  { "name" : "Wendy", "comment" : "When can I buy an Apple Watch?" }
]
```

*Notes:*

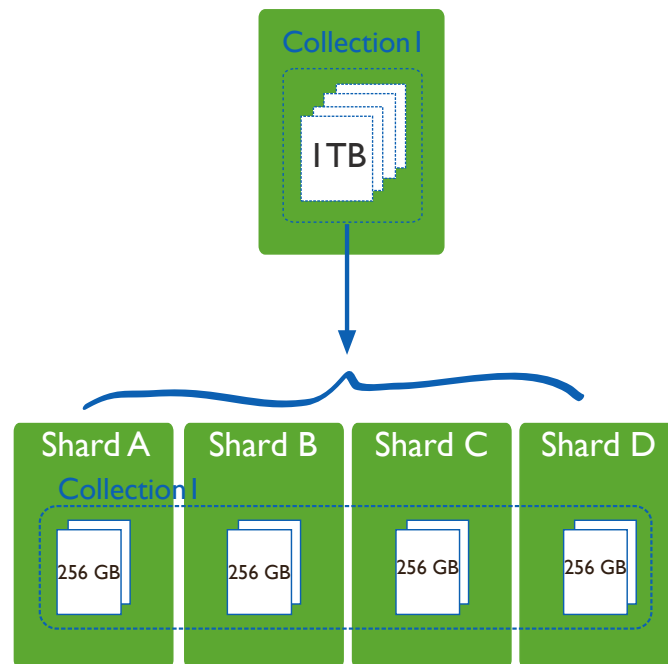
## Vertical Scaling



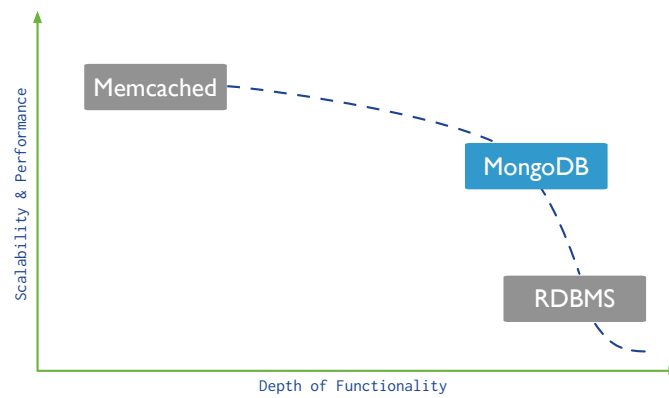
*Notes:*

## Scaling with MongoDB

*Notes:*

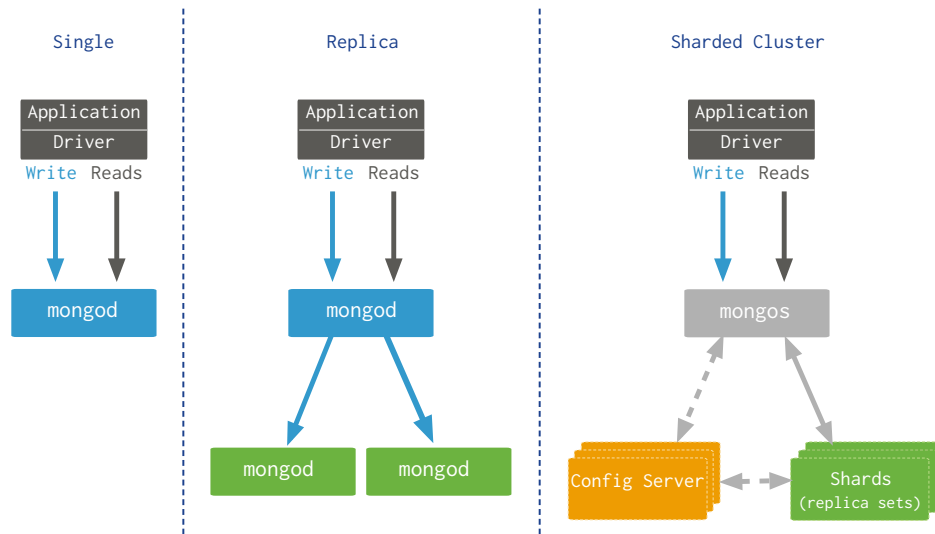


## Database Landscape



*Notes:*

## MongoDB Deployment Models



*Notes:*

## 1.3 MongoDB Stores Documents

### Learning Objectives

Upon completing this module, students should understand:

- JSON
- BSON basics
- That documents are organized into collections
- ObjectIds
- Padding Factor

*Notes:*

## JSON

- JavaScript Object Notation
- Objects are associative arrays.
- They are composed of key-value pairs.

*Notes:*

### A Simple JSON Object

```
{  
  "firstname" : "Thomas",  
  "lastname"  : "Smith",  
  "age"       : 29  
}
```

*Notes:*

### JSON Keys and Values

- Keys must be strings.
- Values may be any of the following:
  - string (e.g., “Thomas”)
  - number (e.g., 29, 3.7)
  - true / false
  - null
  - array (e.g., [88.5, 91.3, 67.1])
  - object
- More detail at [json.org](http://json.org/)<sup>1</sup>.

*Notes:*

---

<sup>1</sup><http://json.org/>

## Example Field Values

```
{
  "headline" : "Apple Reported Second Quarter Revenue Today",
  "date" : ISODate("2015-03-24T22:35:21.908Z"),
  "views" : 1234,
  "author" : {
    "name" : "Bob Walker",
    "title" : "Lead Business Editor"
  },
  "tags" : [
    "AAPL",
    23,
    { "name" : "city", "value" : "Cupertino" },
    [ "Electronics", "Computers" ]
  ]
}
```

*Notes:*

## BSON

- MongoDB stores data as Binary JSON (BSON).
- MongoDB drivers send and receive data in this format.
- They map BSON to native data structures.
- BSON provides support for all JSON data types and several others.
- BSON was designed to be lightweight, traversable and efficient.
- See [bsonspec.org](http://bsonspec.org)<sup>2</sup>.

*Notes:*

---

<sup>2</sup><http://bsonspec.org/#/specification>

## BSON Hello World

```
// JSON
{ "hello" : "world" }

// BSON
"\x16\x00\x00\x00\x02hello\x00
\x06\x00\x00\x00world\x00\x00"
```

*Notes:*

## A More Complex BSON Example

```
// JSON
{ "BSON" : [ "awesome", 5.05, 1986 ] }

// BSON
"\x3b\x00\x00\x00\x04BSON\x00\x26\x00
\x00\x00\x020\x00\x08\x00\x00
\x00awesome\x00\x011\x00\x33\x33\x33\x33\x33
\x14\x40\x102\x00\xc2\x07\x00\x00
\x00\x00"
```

*Notes:*

## Documents, Collections, and Databases

- Documents are stored in collections.
- Collections are contained in a database.
- Example:
  - Database: products
  - Collections: books, movies, music
- Each database-collection combination defines a namespace.
  - products.books
  - products.movies
  - products.music

*Notes:*

## The `_id` Field

- All documents must have an `_id` field.
- The `_id` is immutable.
- If no `_id` is specified when a document is inserted, MongoDB will add the `_id` field.
- MongoDB assigns a unique ObjectId as the value of `_id`.
- Most drivers will actually create the ObjectId if no `_id` is specified.
- The `_id` field is unique to a collection (namespace).

*Notes:*

## ObjectIds



*Notes:*

## Storing BSON Documents

- Each document may be a different size from the others.
- The maximum BSON document size is 16 megabytes.
- Documents are physically adjacent to each other on disk and in memory.
- If a document is updated in a way that makes it larger, MongoDB may move the document.
- This may cause fragmentation, resulting in unnecessary I/O.
- Strategies to reduce the effects of document growth:
  - Padding factor
  - `usePowerOf2Sizes`

*Notes:*



## Padding Factor



*Notes:*

### **usePowerOf2Sizes**

- When a document must move to a new location this leaves a fragment.
- MongoDB will attempt to fill this fragment with a new document eventually.
- As of MongoDB 2.6, collections have a setting called `usePowerOf2Sizes` enabled by default for newly created collections.
- This setting will round the size of the document up to the next power of 2.
- E.g, a document that 118 bytes will be allocated 128 bytes.
- If moved, the space can be filled with two 64-byte documents, four 32-byte documents, etc.

*Notes:*

## 1.4 Storage Engines

### **Learning Objectives**

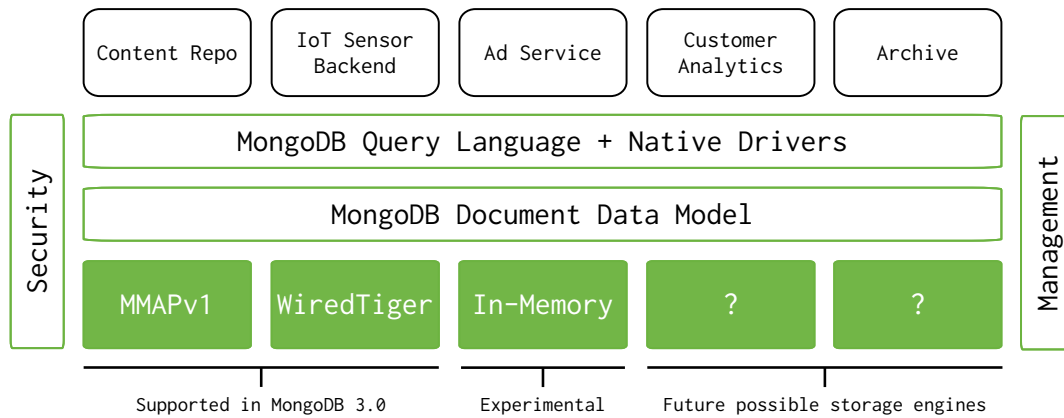
Upon completing this module, students should be familiar with:

- Available storage engines in MongoDB
- The default storage engine for MongoDB
- Common storage engine parameters
- The storage engine API

*Notes:*

## What is a Database Storage Engine?

A database storage engine is the underlying software component that a database management system uses to create, read, update, and delete data from a database.



*Notes:*

## Storage Engine Journaling

- Keep track of all changes made to data files
- Stage writes sequentially before they are committed to the data files
- Writes from the journal can be replayed to data files in the event of a failure (crash recovery)

*Notes:*

## How Storage Engines Affect Performance

- Writing and reading documents
- Concurrency
- Compression algorithms
- Index format and implementation
- On-disk format

*Notes:*

## MongoDB Storage Engines

With the release of MongoDB 3.0, two storage engine options are available:

- MMAPv1 (default)
- WiredTiger

*Notes:*

## Specifying a MongoDB Storage Engine

Use the `storageEngine` parameter to specify which storage engine MongoDB should use. E.g.,

```
mongod --storageEngine wiredTiger
```

*Notes:*

## Specifying a Location to Store Data Files

- Use the `dbpath` parameter

```
mongod --dbpath /data/db
```
- Other files are also stored here. E.g.,
  - `mongod.lock` file
  - `journal`
- See the MongoDB docs for a complete list of [storage options](http://docs.mongodb.org/manual/reference/program/mongod/#storage-options)<sup>3</sup>.

*Notes:*

---

<sup>3</sup><http://docs.mongodb.org/manual/reference/program/mongod/#storage-options>

## MMAPv1 Storage Engine

- MMAPv1 is MongoDB's original storage engine and currently the default.

```
mongod
```

- This is equivalent to the following command:

```
mongod --storageEngine mmapv1
```

- MMAPv1 is based on memory-mapped files, which map data files on disk into virtual memory.
- As of MongoDB 3.0, MMAPv1 supports collection-level concurrency.

*Notes:*

## MMAPv1 Workloads

MMAPv1 excels at workloads where documents do not outgrow their original record size:

- High-volume inserts
- Read-only workloads
- In-place updates

*Notes:*

## Power of 2 Sizes Allocation Strategy

- MongoDB 3.0 uses power of 2 sizes allocation as the default record allocation strategy for MMAPv1.
- With this strategy, records include the document plus extra space, or padding.
- Each record has a size in bytes that is a power of 2 (e.g. 32, 64, 128, ... 2MB).
- For documents larger than 2MB, allocation is rounded up to the nearest multiple of 2MB.
- This strategy enables MongoDB to efficiently reuse freed records to reduce fragmentation.
- In addition, the added padding gives a document room to grow without requiring a move.
  - Saves the cost of moving a document
  - Results in fewer updates to indexes

*Notes:*

## Compression in MongoDB

- Compression can significantly reduce the amount of disk space / memory required.
- The tradeoff is that compression requires more CPU.
- MMAPv1 does not support compression.
- WiredTiger does.

*Notes:*

## WiredTiger Storage Engine

- The WiredTiger storage engine excels at all workloads, especially write-heavy and update-heavy workloads.
- Notable features of the WiredTiger storage engine that do not exist in the MMAPv1 storage engine include:
  - Compression
  - Document-level concurrency
- Specify the use of the WiredTiger storage engine as follows.

```
mongod --storageEngine wiredTiger
```

*Notes:*

## WiredTiger Compression Options

- `snappy` (default): less CPU usage than `zlib`, less reduction in data size
- `zlib`: greater CPU usage than `snappy`, greater reduction in data size
- no compression

*Notes:*

## Configuring Compression in WiredTiger

Use the `wiredTigerCollectionBlockCompressor` parameter. E.g.,

```
mongod --storageEngine wiredTiger
       --wiredTigerCollectionBlockCompressor zlib
```

*Notes:*

## Configuring Memory Usage in WiredTiger

Use the `wiredTigerCacheSize` parameter to designate the amount of RAM for the WiredTiger storage engine.

- By default, this value is set to the maximum of half of physical RAM or 1GB
- If the database server shares a machine with an application server, it is now easier to designate the amount of RAM the database server can use

*Notes:*

## Storage Engine API

MongoDB 3.0 introduced a storage engine API:

- Abstracted storage engine functionality in the code base
- Easier for MongoDB to develop future storage engines
- Easier for third parties to develop their own MongoDB storage engines

*Notes:*

## Conclusion

- MongoDB 3.0 introduces pluggable storage engines.
- Current options include:
  - MMAPv1 (default)
  - WiredTiger
- WiredTiger introduces the following to MongoDB:
  - Compression
  - Document-level concurrency
- The storage engine API enables third parties to develop storage engines. Examples include:
  - RocksDB
  - An HDFS storage engine

*Notes:*

## 1.5 Exercise: Installing MongoDB

### Learning Objectives

Upon completing this exercise students should understand:

- How MongoDB is distributed
- How to install MongoDB
- Configuration steps for setting up a simple MongoDB deployment
- How to run MongoDB
- How to run the Mongo shell

*Notes:*

## Production Releases

64-bit production releases of MongoDB are available for the following platforms.

- Windows
- OSX
- Linux
- Solaris

*Notes:*

## Installing MongoDB

- Visit <http://docs.mongodb.org/manual/installation/>. Click on the appropriate link, such as “Install on Windows” or “Install on OS X” and follow the instructions there.
- Versions:
  - Even-numbered builds are production releases, e.g., 2.4.x, 2.6.x.
  - Odd-numbers indicate development releases, e.g., 2.5.x, 2.7.x.

*Notes:*

## Linux Setup

```
PATH=$PATH:<path to mongodb>/bin
```

```
sudo mkdir -p /data/db
```

```
sudo chmod -R 777 /data/db
```

*Notes:*



## Install on Windows

- Download and run the .msi Windows installer from [mongodb.org/downloads](http://mongodb.org/downloads).
- By default, binaries will be placed in the following directory.

```
C:\Program Files\MongoDB\Server\<VERSION>\bin
```

- It is helpful to add the location of the MongoDB binaries to your path.
- To do this, from “System Properties” select “Advanced” then “Environment Variables”

*Notes:*

## Create a Data Directory on Windows

- Ensure there is a directory for your MongoDB data files.
- The default location is `\data\db`.
- Create a data directory with a command such as the following.

```
md \data\db
```

*Notes:*

## Launch a mongod

Explore the `mongod` command.

```
<path to mongodb>/bin/mongod --help
```

Launch a `mongod` with the MMAPv1 storage engine:

```
<path to mongodb>/bin/mongod
```

Alternatively, launch with the WiredTiger storage engine.

```
<path to mongodb>/bin/mongod --storageEngine wiredTiger
```

Specify an alternate path for data files using the `--dbpath` option. (Make sure the directory already exists.) E.g.,

```
<path to mongodb>/bin/mongod --storageEngine wiredTiger  
                                --dbpath /test/mongodb/data/wt
```

*Notes:*

## The MongoDB Data Directory (MMAPv1)

```
ls /data/db
```

- The mongod.lock file
  - This prevents multiple mongods from using the same data directory simultaneously.
  - Each MongoDB database directory has one .lock.
  - The lock file contains the process id of the mongod that is using the directory.
- Data files
  - The names of the files correspond to available databases.
  - A single database may have multiple files.

*Notes:*

## The MongoDB Data Directory (WiredTiger)

```
ls /data/db
```

- The mongod.lock file
  - Used in the same way as MMAPv1.
- Data files
  - Each collection and index stored in its own file.
  - Will fail to start if MMAPv1 files found

*Notes:*

## Import Exercise Data

```
cd usb_drive
unzip sampledata.zip
cd sampledata
mongoimport -d sample -c tweets twitter.json
mongoimport -d sample -c zips zips.json
cd dump
mongorestore -d sample training
```

```
mongorestore -d sample digg
```

**Note:** If there is an error importing data directly from a USB drive, please copy the `sampladata.zip` file to your local computer first.

*Notes:*

## Launch a Mongo Shell

Open another command shell. Then type the following to start the Mongo shell.

```
mongo
```

Display available commands.

```
help
```

*Notes:*

## Explore Databases

Display available databases.

```
show dbs
```

To use a particular database we can type the following.

```
use <database_name>
```

```
db
```

*Notes:*

## Exploring Collections

```
show collections
```

```
db.<COLLECTION>.help()
```

```
db.<COLLECTION>.find()
```

*Notes:*

## Admin Commands

- There are also a number of admin commands at our disposal.
- The following will shut down the mongod we are connected to through the Mongo shell.
- You can also just kill with Ctrl-C in the shell window from which you launched the mongod.

```
db.adminCommand( { shutdown : 1 } )
```

- Confirm that the mongod process has indeed stopped.
- Once you have, please restart it.

*Notes:*

## 2 CRUD

*Creating and Deleting Documents (page 35)* Inserting documents into collections, deleting documents, and dropping collections.

*Reading Documents (page 42)* The `find()` command, query documents, dot notation, and cursors.

*Query Operators (page 51)* MongoDB query operators including: comparison, logical, element, and array operators.

*Updating Documents (page 56)* Using `update()` and associated operators to mutate existing documents.

### 2.1 Creating and Deleting Documents

#### Learning Objectives

Upon completing this module students should understand:

- How to insert documents into MongoDB collections.
- `_id` fields:
- How to remove documents from a collection
- How to remove a collection from a database
- How to remove a database from a MongoDB deployment

*Notes:*

#### Creating New Documents

- Create documents using `insert()`.
- For example:

```
// Specify the collection name
db.<COLLECTION>.insert( { "name" : "Mongo" } )

// For example
db.people.insert( { "name" : "Mongo" } )
```

*Notes:*

### Exercise: Inserting a Document

Experiment with the following commands.

```
use sample  
  
db.movies.insert( { "title" : "Jaws" } )  
  
db.movies.find()
```

*Notes:*

### Implicit `_id` Assignment

- We did not specify an `_id` in the document we inserted.
- If you do not assign one, MongoDB will create one automatically.
- The value will be of type `ObjectId`.

*Notes:*

### Exercise: Assigning `_ids`

Experiment with the following commands.

```
db.movies.insert( { "_id" : "Jaws", "year" : 1975 } )  
  
db.movies.find()
```

*Notes:*

## Inserts will fail if...

- There is already a document in the collection with that `_id`.
- You try to assign an array to the `_id`.
- The argument is not a well-formed document.

*Notes:*

## Exercise: Inserts will fail if...

```
// fails because _id can't have an array value
db.movies.insert( { "_id" : [ "Star Wars",
                             "The Empire Strikes Back",
                             "Return of the Jedi" ] } )

// succeeds
db.movies.insert( { "_id" : "Star Wars" } )

// fails because of duplicate id
db.movies.insert( { "_id" : "Star Wars" } )

// malformed document
db.movies.insert( { "Star Wars" } )
```

*Notes:*

## Bulk Inserts

- MongoDB 2.6 introduced bulk inserts.
- You may bulk insert using an array of documents.
- The API has two core concepts:
  - Ordered bulk operations
  - Unordered bulk operations
- The main difference is in the way the operations are executed in bulk.

*Notes:*

## Ordered Bulk Insert

- For ordered inserts MongoDB will stop processing inserts upon encountering an error.
- Meaning that only inserts occurring before an error will complete.
- The default setting for `db.<COLLECTION>.insert` is an ordered insert.
- See the next exercise for an example.

*Notes:*

## Exercise: Ordered Bulk Insert

Experiment with the following bulk insert.

```
db.movies.insert( [ { "_id" : "Batman", "year" : 1989 },
                    { "_id" : "Home Alone", "year" : 1990 },
                    { "_id" : "Ghostbusters", "year" : 1984 },
                    { "_id" : "Ghostbusters", "year" : 1984 } ] )

db.movies.find()
```

*Notes:*

## Unordered Bulk Insert

- Pass `{ ordered : false }` to insert to perform unordered inserts.
- If any given insert fails, MongoDB will still attempt the others.
- The inserts may be executed in a different order from the way in which you specified them.
- The next exercise is very similar to the previous one.
- However, we are using `{ ordered : false }`
- One insert will fail, but all the rest will succeed.

*Notes:*



## Exercise: Unordered Bulk Insert

Experiment with the following bulk insert.

```
db.movies.insert( [ { "_id" : "Jaws", "year" : 1975 },
                    { "_id" : "Titanic", "year" : 1997 },
                    { "_id" : "The Lion King", "year" : 1994 } ],
                  { ordered : false } )

db.movies.find()
```

*Notes:*

## The Shell is a JavaScript Interpreter

- Sometimes it is convenient to create test data using a little JavaScript.
- The mongo shell is a fully-functional JavaScript interpreter. You may:
  - Define functions
  - Use loops
  - Assign variables
  - Perform inserts

*Notes:*

## Exercise: Creating Data in the Shell

Experiment with the following commands.

```
for (i=1; i<=10000; i++) {
  db.stuff.insert( { "a" : i } )
}

db.stuff.find()
```

*Notes:*

## Deleting Documents

You may delete documents from a MongoDB deployment in several ways.

- Use `remove()` to delete documents matching a specific set of conditions.
- Drop an entire collection.
- Drop a database.

*Notes:*

### Using `remove()`

- Remove documents from a collection using `remove()`.
- This command has one required parameter, a query document.
- All documents in the collection matching the query document will be removed.
- Pass an empty document to remove all documents.
- Prior to MongoDB 2.6 calling `remove()` with no parameters would remove all documents.
- Limit `remove()` to one document using `justOne`.

*Notes:*

## Exercise: Removing Documents

Experiment with removing documents. Do a `find()` after each `remove()` command below.

```
for (i=1; i<=20; i++) { db.testcol.insert( { _id : i, a : i } ) }

db.testcol.remove( { a : 1 } ) // Remove the first document

// $lt is a query operator that enables us to select documents that
// are less than some value. More on operators soon.
db.testcol.remove( { a : { $lt : 5 } } ) // Remove three more

db.testcol.remove( { a : { $lt : 10 } },
                  { justOne : true } ) // Remove one more

db.testcol.remove() // Error: requires a query document.

db.testcol.remove( { } ) // All documents removed
```

*Notes:*

## Dropping a Collection

- You can drop an entire collection with `db.<COLLECTION>.drop()`
- The collection and all documents will be deleted.
- It will also remove any metadata associated with that collection.
- Indexes are one type of metadata removed.
- More on meta data later.

*Notes:*

## Exercise: Dropping a Collection

```
db.colToBeDropped.insert( { a : 1 } )  
show collections // Shows the colToBeDropped collection  
  
db.colToBeDropped.drop()  
show collections // collection is gone
```

*Notes:*

## Dropping a Database

- You can drop an entire database with `db.dropDatabase()`
- This drops the database on which the method is called.
- It also deletes the associated data files from disk, freeing disk space.
- Beware that in the mongo shell, this does not change database context.

*Notes:*

## Exercise: Dropping a Database

```
use tempDB
db.testcol1.insert( { a : 1 } )
db.testcol2.insert( { a : 1 } )

show dbs // Here they are
show collections // Shows the two collections

db.dropDatabase()
show collections // No collections
show dbs // The db is gone

use sample // take us back to the sample db
```

*Notes:*

## 2.2 Reading Documents

### Learning Objectives

Upon completing this module students should understand:

- The query-by-example paradigm of MongoDB
- How to query on array elements
- How to query embedded documents using dot notation
- How the mongo shell and drivers use cursors
- Projections
- Cursor methods: `.count()`, `.sort()`, `.skip()`, `.limit()`

*Notes:*

## The `find()` Method

- This is the fundamental method by which we read data from MongoDB.
- We have already used it in its basic form.
- `find()` returns a cursor that enables us to iterate through all documents matching a query.
- We will discuss cursors later.

*Notes:*

## Query by Example

- To query MongoDB, specify a document containing the key / value pairs you want to match
- You need only specify values for fields you care about.
- Other fields will not be used to exclude documents.
- The result set will include all documents in a collection that match.

*Notes:*

## Exercise: Querying by Example

Experiment with the following sequence of commands.

```
db.movies.drop()
db.movies.insert([ { "title" : "Jaws", "year" : 1975, "imdb_rating" : 8.1 },
                   { "title" : "Batman", "year" : 1989, "imdb_rating" : 7.6 },
                   ] )
db.movies.find()

db.movies.find( { "year" : 1975 } )

// Multiple Batman movies from different years, find the correct one
db.movies.find( { "year" : 1989, "title" : "Batman" } )
```

*Notes:*

## Querying Arrays

- In MongoDB you may query array fields.
- Specify a single value you expect to find in that array in desired documents.
- Alternatively, you may specify an entire array in the query document.
- As we will see later, there are also several operators that enhance our ability to query array fields.

*Notes:*

## Exercise: Querying Arrays

Experiment with the following sequence of commands.

```
db.movies.drop()
db.movies.insert(
  [{ "title" : "Batman", "category" : [ "action", "adventure" ] },
    { "title" : "Godzilla", "category" : [ "action", "adventure", "sci-fi" ] },
    { "title" : "Home Alone", "category" : [ "family", "comedy" ] }
  ])

// Match documents where "category" contains the value specified
db.movies.find( { "category" : "action" } )

// Match documents where "category" equals the value specified
db.movies.find( { "category" : [ "action", "sci-fi" ] } ) // no documents

// only the second document
db.movies.find( { "category" : [ "action", "adventure", "sci-fi" ] } )
```

*Notes:*

## Querying with Dot Notation

- Dot notation is used to query on fields in embedded documents.
- The syntax is:  

```
"field1.field2" : value
```
- Put quotes around the field name when using dot notation.

*Notes:*

## Exercise: Querying with Dot Notation

```
db.movies.insert(
  [ {
    "title" : "Avatar",
    "box_office" : { "gross" : 760,
                    "budget" : 237,
                    "opening_weekend" : 77
                  },
  },
  {
    "title" : "E.T.",
    "box_office" : { "gross" : 349,
                    "budget" : 10.5,
                    "opening_weekend" : 14
                  },
  }
] )

db.movies.find( { "box_office" : { "gross" : 760 } } ) // no values

// dot notation
db.movies.find( { "box_office.gross" : 760 } ) // expected value
```

*Notes:*

## Exercise: Arrays and Dot Notation

Experiment with the following commands.

```
db.movies.insert( [
  { "title" : "E.T.",
    "filming_locations" :
      [ { "city" : "Culver City", "state" : "CA", "country" : "USA" },
        { "city" : "Los Angeles", "state" : "CA", "country" : "USA" },
        { "city" : "Cresecent City", "state" : "CA", "country" : "USA" }
      ],
    { type : "Star Wars",
      "filming_locations" :
        [ { "city" : "Ajim", "state" : "Jerba", "country" : "Tunisia" },
          { "city" : "Yuma", "state" : "AZ", "country" : "USA" }
        ]
    }
  ] } ] )

db.movies.find( { "filming_locations.country" : "USA" } ) // two documents
```

*Notes:*

## Projections

- You may choose to have only certain fields appear in result documents.
- This is called projection.
- You specify a projection by passing a second parameter to `find()`.

*Notes:*

### Projection: Example (Setup)

```
db.movies.insert(
{
  "title" : "Forrest Gump",
  "category" : [ "drama", "romance" ],
  "imdb_rating" : 8.8,
  "filming_locations" : [
    { "city" : "Savannah", "state" : "GA", "country" : "USA" },
    { "city" : "Monument Valley", "state" : "UT", "country" : "USA" },
    { "city" : "Los Angeles", "state" : "CA", "country" : "USA" }
  ],
  "box_office" : {
    "gross" : 557,
    "opening_weekend" : 24,
    "budget" : 55
  }
})
```

*Notes:*

### Projection: Example

```
db.movies.findOne( { "title" : "Forrest Gump" },
                  { "title" : 1, "imdb_rating" : 1 } )
{
  "_id" : ObjectId("5515942d31117f52a5122353"),
  "title" : "Forrest Gump",
  "imdb_rating" : 8.8
}
```

*Notes:*



## Projection Documents

- Include fields with `fieldName: 1`.
  - Any field not named will be excluded
  - except `_id`, which must be explicitly excluded.
- Exclude fields with `fieldName: 0`.
  - Any field not named will be included.

*Notes:*

## Exercise: Projections

```
for (i=1; i<=20; i++) {
    db.movies.insert( { "_id" : i, "title" : i,
                        "imdb_rating" : i, "box_office" : i } )
}
db.movies.find()
// no "box_office"
db.movies.find( { "_id" : 3 }, { "title" : 1, "imdb_rating" : 1 } )
// no "imdb_rating"
db.movies.find( { "_id" : { $gte : 10 } }, { "imdb_rating" : 0 } )
// just "title"
db.movies.find( { "_id" : 4 }, { "_id" : 0, "title" : 1 } )
// just "imdb_rating", "box_office"
db.movies.find( { "_id" : 5 }, { _id : 0, "title" : 0 } )
// Can't mix inclusion/exclusion except _id
db.movies.find( { "_id" : 6 }, { "title" : 1, "imdb_rating" : 0 } )
```

*Notes:*

## Cursors

- When you use `find()`, MongoDB returns a cursor.
- A cursor is a pointer to the result set
- You can get iterate through documents in the result using `next()`.
- By default, the mongo shell will iterate through 20 documents at a time.

*Notes:*

## Exercise: Introducing Cursors

Experiment with the following commands.

```
db.testcol.drop()
for (i=1; i<=10000; i++) {
    db.testcol.insert( { a : Math.floor( Math.random() * 100 + 1 ),
                        b : Math.floor( Math.random() * 100 + 1 ) } )
}
db.testcol.find()

it
it
```

*Notes:*

## Exercise: Cursor Objects in the Mongo Shell

```
// Assigns the cursor returned by find() to a variable x
var x = db.testcol.find()

// Displays the first document in the result set.
x.next()

// True because there are more documents in the result set.
x.hasNext()

// Assigns the next document in the result set to the variable y.
y = x.next()

// Return value is the value of the a field of this document.
y.a

// Displaying a cursor prints the next 20 documents in the result set.
x
```

*Notes:*

## Cursor Methods

- `count()`: Returns the number of documents in the result set.
- `limit()`: Limits the result set to the number of documents specified.
- `skip()`: Skips the number of documents specified.

*Notes:*

### Exercise: Using `count()`

```
db.testcol.drop()
for (i=1; i<=100; i++) { db.testcol.insert( { a : i } ) }

// all 100
db.testcol.count()

// just 41 docs
db.testcol.count( { a : { $lt : 42 } } )

// Another way of writing the same query
db.testcol.find( { a : { $lt : 42 } } ).count( )
```

*Notes:*

### Exercise: Using `sort()`

Experiment with the following sort commands.

```
db.testcol.drop()
for (i=1; i<=20; i++) {
  db.testcol.insert( { a : Math.floor( Math.random() * 10 + 1 ),
                      b : Math.floor( Math.random() * 10 + 1 ) } )
}

db.testcol.find()

// sort descending; use 1 for ascending
db.testcol.find().sort( { a : -1 } )

// sort by b, then a
db.testcol.find().sort( { b : 1, a : 1 } )

// $natural order is just the order on disk.
db.testcol.find().sort( { $natural : 1 } )
```

*Notes:*

### **The `skip()` Method**

- Skips the specified number of documents in the result set.
- The returned cursor will begin at the first document beyond the number specified.
- Regardless of the order in which you specify `skip()` and `sort()` on a cursor, `sort()` happens first.

*Notes:*

### **The `limit()` Method**

- Limits the number of documents in a result set to the first `k`.
- Specify `k` as the argument to `limit()`
- Regardless of the order in which you specify `limit()`, `skip()`, and `sort()` on a cursor, `sort()` happens first.
- Helps reduce resources consumed by queries.

*Notes:*

### **The `distinct()` Method**

- Returns all values for a field found in a collection.
- Only works on one field at a time.
- Input is a string (not a document)

*Notes:*

### Exercise: Using `distinct()`

Experiment with the following commands and note what `distinct()` returns.

```
db.movie_reviews.drop()
db.movie_reviews.insert( [ { "title" : "Jaws", "rating" : 5 },
                           { "title" : "Home Alone", "rating" : 1 },
                           { "title" : "Jaws", "rating" : 7 },
                           { "title" : "Jaws", "rating" : 4 },
                           { "title" : "Jaws", "rating" : 8 } ] )
db.movie_reviews.distinct( "title" )
```

*Notes:*

## 2.3 Query Operators

### Learning Objectives

Upon completing this module students should understand the following types of MongoDB query operators:

- Comparison operators
- Logical operators
- Element query operators
- Operators on arrays

*Notes:*

### Comparison Query Operators

- `$lt`: Exists and is less than
- `$lte`: Exists and is less than or equal to
- `$gt`: Exists and is greater than
- `$gte`: Exists and is greater than or equal to
- `$ne`: Does not exist or does but is not equal to
- `$in`: Exists and is in a set
- `$nin`: Does not exist or is not in a set

*Notes:*

## Exercise: Comparison Operators (Setup)

```
// insert sample data
db.movies.insert( [
  {
    "title" : "Batman",
    "category" : [ "action", "adventure" ],
    "imdb_rating" : 7.6,
    "budget" : 35
  },
  {
    "title" : "Godzilla",
    "category" : [ "action",
    "adventure", "sci-fi" ],
    "imdb_rating" : 6.6
  },
  {
    "title" : "Home Alone",
    "category" : [ "family", "comedy" ],
    "imdb_rating" : 7.4
  }
] )
```

*Notes:*

## Exercise: Comparison Operators

Experiment with the following.

```
db.movies.find()

db.movies.find( { "imdb_rating" : { $gte : 7 } } )

db.movies.find( { "category" : { $ne : "family" } } )

db.movies.find( { "title" : { $in : [ "Batman", "Godzilla" ] } } )

db.movies.find( { "title" : { $nin : [ "Batman", "Godzilla" ] } } )
```

*Notes:*

## Logical Query Operators

- `$or`: Match either of two or more values
- `$not`: Used with other operators
- `$nor`: Match neither of two or more values
- `$and`: Match both of two or more values
  - This is the default behavior for queries specifying more than one condition.
  - Use `$and` if you need to include the same operator more than once in a query.

*Notes:*

### Exercise: Logical Operators

Experiment with the following.

```
db.movies.find( { $or : [
  { "category" : "sci-fi" }, { "imdb_rating" : { $gte : 7 } }
] } )

// more complex $or, really good sci-fi movie or medicore family movie
db.movies.find( { $or : [
  { "category" : "sci-fi", "imdb_rating" : { $gte : 8 } },
  { "category" : "family", "imdb_rating" : { $gte : 7 } }
] } )

// find bad movies
db.movies.find( { "imdb_rating" : { $not : { $gt : 7 } } } )
```

*Notes:*

### Exercise: Logical Operators

Experiment with the following.

```
// find movies within an imdb_rating range
db.movies.find( { "imdb_rating" : { $gt : 5 , $lte : 7 } } ) // and is implicit

// queries can be nested, why are there no results?
db.movies.find( { $and : [
  { $or : [
    { "category" : "sci-fi", "imdb_rating" : { $gte : 8 } },
    { "category" : "family", "imdb_rating" : { $gte : 7 } }
  ] } ,
  { $or : [
    { "category" : "action", "imdb_rating" : { $gte : 6 } }
  ] }
] } )
```

```
    ] }  
  ] } )
```

*Notes:*

## Element Query Operators

- `$exists`: Select documents based on the existence of a particular field.
- `$type`: Select documents based on their type.
- See [BSON types](http://docs.mongodb.org/manual/reference/bson-types)<sup>4</sup> for reference on types.

*Notes:*

## Exercise: Element Operators

Experiment with the following.

```
db.movies.find( { "budget" : { $exists : true } } )
```

```
// type 1 is Double
```

```
db.movies.find( { "budget" : { $type : 1 } } )
```

```
// type 3 is Object (embedded document)
```

```
db.movies.find( { "budget" : { $type : 3 } } )
```

*Notes:*

---

<sup>4</sup><http://docs.mongodb.org/manual/reference/bson-types>



## Array Query Operators

- `$all`: Array field must contain all values listed.
- `$size`: Array must have a particular size. E.g., `$size : 2` means 2 elements in the array
- `$elemMatch`: All conditions must be matched by at least one element in the array

*Notes:*

## Exercise: Array Operators

Experiment with the following.

```
db.movies.find( { "category" : { $all : [ "sci-fi", "action" ] } } )

db.movies.find( { "category" : { $size : 3 } } )
```

*Notes:*

## Exercise: \$elemMatch

```
db.movies.insert( {
  "title" : "Raiders of the Lost Ark",
  "filming_locations" : [
    { "city" : "Los Angeles", "state" : "CA", "country" : "USA" },
    { "city" : "Rome", "state" : "Lazio", "country" : "Italy" },
    { "city" : "Florence", "state" : "SC", "country" : "USA" }
  ] } )

// This query is incorrect, it won't return what we want
db.movies.find( {
  "filming_locations.city" : "Florence",
  "filming_locations.country" : "Italy"
} )

// $elemMatch is needed, now there are no results, this is expected
db.movies.find( {
  "filming_locations" : {
    $elemMatch : {
      "city" : "Florence",
      "country" : "Italy"
    } } } )
```

*Notes:*

## 2.4 Updating Documents

### Learning Objectives

Upon completing this module students should understand

- The `update()` method
- The required parameters for `update()`
- Field update operators
- Array update operators
- The concept of an upsert and use cases.

*Notes:*

### The `update()` Method

- Mutate documents in MongoDB using `update()`.
- `update()` requires two parameters:
  - A query document used to select documents to be updated
  - An update document that specifies how selected documents will change
- `update()` cannot delete a document.

*Notes:*

### Parameters to `update()`

- Keep the following in mind regarding the required parameters for `update()`
- The query parameter:
  - Use the same syntax as with `find()`.
  - By default only the first document found is updated.
- The update parameter:
  - Take care to simply modify documents if that is what you intend.
  - Replacing documents in their entirety is easy to do by mistake.

*Notes:*

## \$set and \$unset

- Update one or more fields using the \$set operator.
- If the field already exists, using \$set will change its value.
- If the field does not exist, \$set will create it and set it to the new value.
- Any fields you do not specify will not be modified.
- You can remove a field using \$unset.

*Notes:*

### Exercise: \$set and \$unset (Setup)

```
db.movies.insert( [
  {
    "title" : "Batman",
    "category" : [ "action", "adventure" ],
    "imdb_rating" : 7.6,
    "budget" : 35
  },
  {
    "title" : "Godzilla",
    "category" : [ "action",
    "adventure", "sci-fi" ],
    "imdb_rating" : 6.6
  },
  {
    "title" : "Home Alone",
    "category" : [ "family", "comedy" ],
    "imdb_rating" : 7.4
  }
] )
```

*Notes:*

## Exercise: \$set and \$unset

Experiment with the following. Do a `find()` after each update to view the results.

```
db.movies.update( { "title" : "Batman" }, { $set : { "imdb_rating" : 7.7 } } )

db.movies.update( { "title" : "Godzilla" }, { $set : { "budget" : 1 } } )

db.movies.update( { "title" : "Home Alone" },
                  { $set : { "budget" : 15, "imdb_rating" : 5.5 } } )

// how will this query behave?
db.movies.update( { "title" : "Batman" }, { "imdb_rating" : 7.7 } )

db.movies.update( { "title" : "Home Alone" }, { $unset : { "budget" : 1 } } )
```

*Notes:*

## Exercise: Update Array Elements by Index

```
// add a sample document to track mentions per hour
db.movie_mentions.insert( { "title" : "E.T.",
                             "day" : ISODate("2015-03-27T00:00:00.000Z"),
                             "mentions_per_hour" : [ 0, 0, 0, 0, 0, 0, 0, 0,
                                                         0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
                                                         0, 0 ]
                           } )

// update all mentions for the fifth hour of the day
db.movie_mentions.update( { "title" : "E.T." },
                          { $set : { "mentions_per_hour.5" : 2300 } } )
```

*Notes:*

## Update Operators

- `$inc`: Increment a field's value by the specified amount.
- `$mul`: Multiply a field's value by the specified amount.
- `$rename`: Rename a field.
- `$set` (already discussed)
- `$unset` (already discussed)
- `$min`: Update only if value is smaller than specified quantity
- `$max`: Update only if value is larger than specified quantity

- `$currentDate`: Set the value of a field to the current date or timestamp.

*Notes:*

## Exercise: Update Operators

Experiment with the following update operators.

```
db.movies.update( { "title" : "Batman" }, { $inc : { "imdb_rating" : 2 } } )

db.movies.update( { "title" : "Home Alone" }, { $inc : { "budget" : 5 } } )

db.movies.update( { "title" : "Batman" }, { $mul : { "imdb_rating" : 4 } } )

db.movies.update( { "title" : "Batman" },
                  { $rename : { "budget" : "estimated_budget" } } )

db.movies.update( { "title" : "Home Alone" }, { $min : { "budget" : 5 } } )

db.movies.update( { "title" : "Home Alone" },
                  { $currentDate : { "last_updated" : { $type : "timestamp" } } } )

// increment movie mentions by 10
db.movie_mentions.update( { "title" : "E.T." },
                          { $inc : { "mentions_per_hour.5" : 10 } } )
```

*Notes:*

## `update()` Defaults to one Document

- By default, `update()` modifies the first document found that matches the query.
- The default use case is one where there is only one document that fits the query.
- This is to reduce the chances of unintended collection scans for updates.

*Notes:*

## Updating Multiple Documents

- In order to update multiple documents, we use the third (optional) parameter to `update()`.
- The third parameter is an options document.
- Specify `multi: true` as one field in this document.
- Bear in mind that without an appropriate index, you may scan every document in the collection.

*Notes:*

## Exercise: Multi-Update

Use `db.testcol.find()` after each of these updates.

```
// let's start tracking the number of sequels for each movie
db.movies.update( { }, { $set : { "sequels" : 0 } } )

// we need { multi : true } to change all documents
db.movies.update( { }, { $set : { "sequels" : 0 } },
                  { multi : true } )
```

*Notes:*

## Array Operators

- `$push`: Appends an element to the end of the array.
- `$pushAll`: Appends multiple elements to the end of the array.
- `$pop`: Removes one element from the end of the array.
- `$pull`: Removes all elements in the array that match a specified value.
- `$pullAll`: Removes all elements in the array that match any of the specified values.
- `$addToSet`: Appends an element to the array if not already present.

*Notes:*

## Exercise: Array Operators

Experiment with the following updates.

```
db.movies.update( { "title" : "Batman" },
  { $push : { "category" : "superhero" } } )
db.movies.update( { "title" : "Batman" },
  { $pushAll : { "category" : [ "villain", "comicbased" ] } } )

db.movies.update( { "title" : "Batman" },
  { $pop : { "category" : 1 } } )

db.movies.update( { "title" : "Batman" },
  { $pull : { "category" : "action" } } )
db.movies.update( { "title" : "Batman" },
  { $pullAll : { "category" : [ "villain", "comicbased" ] } } )

db.movies.update( { "title" : "Batman" }, { $addToSet : { "category" : "action" } } )
db.movies.update( { "title" : "Batman" }, { $addToSet : { "category" : "action" } } )
```

*Notes:*

## The Positional \$ Operator

- <sup>5</sup>\$ is a positional operator that specifies an element in an array to update.
- It acts as a placeholder for the first element that matches the query document.
- \$ replaces the element in the specified position with the value given.
- Example:

```
db.<COLLECTION>.update(
  { <array> : value ... },
  { <update operator> : { "<array>.$" : value } }
)
```

*Notes:*

---

<sup>5</sup><http://docs.mongodb.org/manual/reference/operator/update/positional>

## Exercise: The Positional \$ Operator

Experiment with the following commands.

```
// the "action" category needs to be changed to "action-adventure"
db.movies.update( { "category": "action", },
                  { $set: { "category.$" : "action-adventure" } },
                  { multi: true } )
db.movies.find()
```

*Notes:*

## Upserts

- By default, if no document matches an update query, the `update()` method does nothing.
- By specifying `upsert: true`, `update()` will insert a new document if no matching document exists.
- The `db.<COLLECTION>.save()` method is syntactic sugar that performs an upsert if the `_id` is not yet present
- Syntax:

```
db.<COLLECTION>.update( <query document>, <update document>,
                       { upsert: true } )
```

*Notes:*

## Upsert Mechanics

- Will update as usual if documents matching the query document exist.
- Will be an upsert if no documents match the query document.
  - MongoDB creates a new document using equality conditions in the query document.
  - Adds an `_id` if the query did not specify one.
  - Performs an update on the new document.

*Notes:*



## Exercise: Upserts

Experiment with the following upserts.

```
db.movies.update( { "title" : "Jaws" },
                  { $inc: { "budget" : 5 } },
                  { upsert: true } )

db.movies.update( { "title" : "Jaws II" },
                  { $inc: { "budget" : 5 } },
                  { upsert: true } )

db.movies.update( { "title" : "Jaws III", "category" : [ "horror" ] },
                  { $set : { "budget" : 1 } },
                  { upsert: true } )
```

*Notes:*

### save()

- Updates the document if the `_id` is found, inserts it otherwise
- Syntax:

```
db.<COLLECTION>.save( document )
```

*Notes:*

### Exercise: save()

- If the document does not contain an `_id` field, then the `save()` method calls the `insert()` method. During the operation, the mongo shell will create an `ObjectId` and assign it to the `_id` field.
- If the document contains an `_id` field, then the `save()` method is equivalent to an update with the upsert option set to true and the query predicate on the `_id` field.

```
// insert
db.movies.save( { "title" : "Beverly Hills Cops", "imdb_rating" : 7.3 } )

// update with { upsert: true }
db.movies.save( { "_id" : 1234, "title" : "Spider Man", "imdb_rating" : 7.3 } )
```

*Notes:*

## Be Careful with save ()

Be careful that you are not modifying stale data when using save (). For example:

```
db.movies.drop()
db.movies.insert( { "title" : "Jaws", "imdb_rating" : 7.3 } )

db.movies.find( { "title" : "Jaws" } )

// store the complete document in the application
doc = db.movies.findOne( { "title" : "Jaws" } )

db.movies.update( { "title" : "Jaws" }, { $inc: { "imdb_rating" : 2 } } )
db.movies.find()

doc.imdb_rating = 7.4
doc

db.movies.save(doc) // just lost our incrementing of "imdb_rating"
db.movies.find()
```

*Notes:*

## 3 Indexes

*Index Fundamentals* (page 65) An introduction to MongoDB indexes.

*Compound Indexes* (page 73) Indexes on two or more fields.

*Multikey Indexes* (page 80) Indexes on array fields.

*Hashed Indexes* (page 85) Hashed Indexes.

*Geospatial Indexes* (page 86) Geospatial indexes: both those on legacy coordinate pairs and those supporting queries that calculate geometries on an earth-like sphere.

*TTL Indexes* (page 95) Time-To-Live Indexes.

*Text Indexes* (page 97) Free text indexes on string fields.

### 3.1 Index Fundamentals

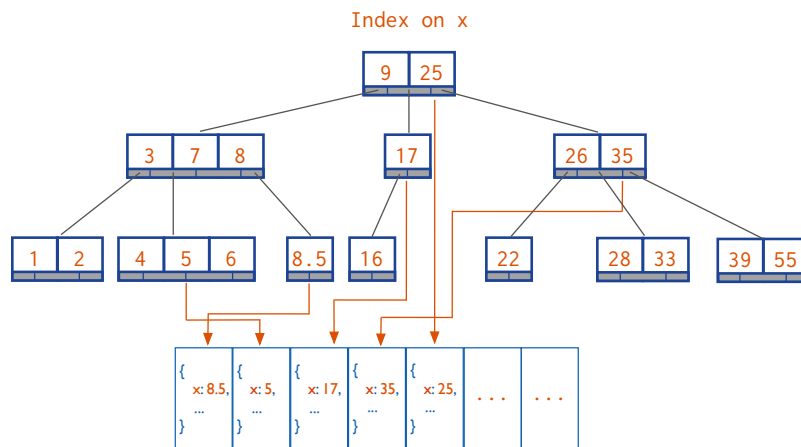
#### Learning Objectives

Upon completing this module students should understand:

- The impact of indexing on read performance
- The impact of indexing on write performance
- How to choose effective indexes
- The utility of specific indexes for particular query patterns

*Notes:*

#### Why Indexes?



*Notes:*

## Types of Indexes

- Single-field indexes
- Compound indexes
- Multikey indexes
- Geospatial indexes
- Text indexes

*Notes:*

## Exercise: Using `explain()`

Let's explore what MongoDB does for the following query by using `explain()`.

We are projecting only `user.name` so that the results are easy to read.

```
db.tweets.find( { "user.followers_count" : 1000 },
                { "_id" : 0, "user.name": 1 } )

db.tweets.find( { "user.followers_count" : 1000 } ).explain()
```

*Notes:*

## Results of `explain()`

With the default `explain()` verbosity, you will see results similar to the following:

```
{
  "queryPlanner" : {
    "plannerVersion" : 1,
    "namespace" : "twitter.tweets",
    "indexFilterSet" : false,
    "parsedQuery" : {
      "user.followers_count" : {
        "$eq" : 1000
      }
    }
  },
```

*Notes:*

### Results of `explain()` - Continued

```
"winningPlan" : {
  "stage" : "COLLSCAN",
  "filter" : {
    "user.followers_count" : {
      "$eq" : 1000
    }
  },
  "direction" : "forward"
},
"rejectedPlans" : [ ]
},
...
}
```

*Notes:*

### `explain()` Verbosity Can Be Adjusted

- **default:** determines the winning query plan but does not execute query
- **executionStats:** executes query and gathers statistics
- **allPlansExecution:** runs all candidate plans to completion and gathers statistics

*Notes:*

### `explain("executionStats")`

```
> db.tweets.find( { "user.followers_count" : 1000 } )
  .explain("executionStats")
```

Now we have query statistics:

```
..
"executionStats" : {
  "executionSuccess" : true,
  "nReturned" : 8,
  "executionTimeMillis" : 107,
  "totalKeysExamined" : 0,
  "totalDocsExamined" : 51428,
  "executionStages" : {
```

```

"stage" : "COLLSCAN",
"filter" : {
  "user.followers_count" : {
    "$eq" : 1000
  }
},

```

*Notes:*

### **explain("executionStats") - Continued**

```

  "nReturned" : 8,
  "executionTimeMillisEstimate" : 100,
  "works" : 51430,
  "advanced" : 8,
  "needTime" : 51421,
  "needFetch" : 0,
  "saveState" : 401,
  "restoreState" : 401,
  "isEOF" : 1,
  "invalidates" : 0,
  "direction" : "forward",
  "docsExamined" : 51428
}
...
}

```

*Notes:*

### **explain("executionStats") Output**

- `nReturned` displays the number of documents that match the query.
- `totalDocsExamined` displays the number of documents the retrieval engine considered during the query.
- `totalKeysExamined` displays how many documents in an existing index were scanned.
- A `totalKeysExamined` or `totalDocsExamined` value much higher than `nReturned` indicates we need a different index.
- Given `totalDocsExamined`, this query will benefit from an index.

*Notes:*

## Other Operations

In addition to `find()`, we often want to use `explain()` to understand how other operations will be handled.

- `aggregate`
- `count`
- `group`
- `remove`
- `update`

*Notes:*

### `db.<COLLECTION>.explain()`

`db.<COLLECTION>.explain()` returns an `ExplainableCollection`.

```
> var explainable = db.tweets.explain()
> explainable.find( { "user.followers_count" : 1000 } )
```

equivalent to

```
> db.tweets.explain().find( { "user.followers_count" : 1000 } )
```

also equivalent to

```
> db.tweets.find( { "user.followers_count" : 1000 } ).explain()
```

*Notes:*

## Using `explain()` for Write Operations

Simulate the number of writes that would have occurred and determine the index(es) used:

```
> db.tweets.explain("executionStats").remove({ "user.followers_count" : 1000 })

> db.tweets.explain("executionStats").update({ "user.followers_count" : 1000 },
  { $set : { "large_following" : true } } )
```

*Notes:*

## Single-Field Indexes

- Single-field indexes are based on a single field of the documents in a collection.
- The field may be a top-level field.
- You may also create an index on fields in embedded documents.

*Notes:*

## Creating an Index

The following creates a single-field index on `user.followers_count`.

```
db.tweets.createIndex( { "user.followers_count" : 1 } )  
db.tweets.find( { "user.followers_count" : 1000 } ).explain()
```

`explain()` indicated there will be a substantial performance improvement in handling this type of query.

*Notes:*

## Listing Indexes

List indexes for a collection:

```
db.tweets.getIndexes()
```

List index keys:

```
db.tweets.getIndexKeys()
```

*Notes:*



## Indexes and Read/Write Performance

- Indexes improve read performance for queries that are supported by the index.
- Inserts will be slower when there are indexes that MongoDB must also update.
- The speed of updates may be improved because MongoDB will not need to do a collection scan to find target documents.
- An index is modified any time a document:
  - Is inserted
  - Is deleted
  - Is updated in such a way that its indexed field changes
  - If an update causes a document to move on disk

*Notes:*

## Index Limitations

- You can have up to 64 indexes per collection.
- You should NEVER be anywhere close to that upper bound.
- Write performance will degrade to unusable at somewhere between 20-30.

*Notes:*

## Use Indexes with Care

- Every query should use an index.
- Every index should be used by a query.
- Any write operation that touches an indexed field will require each index to be updated.
- Indexes require RAM.
- Be judicious about the choice of key.

*Notes:*

## Additional Index Options

- Sparse
- Unique
- Background

*Notes:*

## Sparse Indexes in MongoDB

Sparse indexes only contain entries for documents that have the indexed field.

```
db.<COLLECTION>.createIndex(  
  { field_name : 1 },  
  { sparse : true } )
```

*Notes:*

## Defining Unique Indexes

- Enforce a unique constraint on the index.
- Prevent duplicate values from being inserted into the database.
- No duplicate values may exist prior to defining the index.

```
db.<COLLECTION>.createIndex(  
  { field_name : 1 },  
  { unique : true } )
```

*Notes:*

## Building Indexes in the Background

- Building indexes in foreground is a blocking operation.
- Background index creation is non-blocking, however, takes longer to build.
- Initially larger, or less compact, than an index built in the foreground.

```
db.<COLLECTION>.createIndex(  
  { field_name : 1 },  
  { background : true } )
```

*Notes:*

## 3.2 Compound Indexes

### Learning Objectives

Upon completing this module students should understand:

- What a compound index is.
- How compound indexes are created.
- The importance of considering field order when creating compound indexes.
- How to efficiently handle queries involving some combination of equality matches, ranges, and sorting.
- Some limitations on compound indexes.

*Notes:*

### Introduction to Compound Indexes

- It is common to create indexes based on more than one field.
- These are called `compound indexes`.
- You may use up to 31 fields in a compound index.
- You may not use hashed index fields.

*Notes:*

## The Order of Fields Matters

Specifically we want to consider how the index will be used for:

- Equality tests, e.g.,

```
db.movies.find( { "budget" : 7, "imdb_rating" : 8 } )
```

- Range queries, e.g.,

```
db.movies.find( { "budget" : 10, "imdb_rating" : { $lt : 9 } } )
```

- Sorting, e.g.,

```
db.movies.find( { "budget" : 10, "imdb_rating" : 6 }  
                ).sort( { "imdb_rating" : -1 } )
```

*Notes:*

## Designing Compound Indexes

- Let's look at some guiding principles for building compound indexes.
- These will generally produce a good if not optimal index.
- You can optimize after a little experimentation.
- We will explore this in the context of a running example.

*Notes:*

## Example: A Simple Message Board

Requirements:

- Find all messages in a specified timestamp range.
- Select for whether the messages are anonymous or not.
- Sort by rating from highest to lowest.

*Notes:*

## Load the Data

```
a = [ { "timestamp" : 1, "username" : "anonymous", "rating" : 3 },
      { "timestamp" : 2, "username" : "anonymous", "rating" : 5 },
      { "timestamp" : 3, "username" : "sam", "rating" : 1 },
      { "timestamp" : 4, "username" : "anonymous", "rating" : 2 },
      { "timestamp" : 5, "username" : "martha", "rating" : 5 } ]
db.messages.insert(a)
```

*Notes:*

## Start with a Simple Index

Start by building an index on { timestamp : 1 }

```
db.messages.createIndex( { timestamp : 1 }, { name : "myindex" } )
```

Now let's query for messages with timestamp in the range 2 through 4 inclusive.

```
db.messages.find( { timestamp : { $gte : 2, $lte : 4 } } ).explain()
```

Analysis:

- Explain plan shows good performance, i.e. totalKeysExamined = n.
- However, this does not satisfy our query.
- Need to query again with { username : "anonymous" } as part of the query.

*Notes:*

## Query Adding username

Let's add the user field to our query.

```
db.messages.find( { timestamp : { $gte : 2, $lte : 4 },
                  username : "anonymous" } ).explain()
```

```
totalKeysExamined > n.
```

*Notes:*

## Include username in Our Index

```
db.messages.dropIndex( "myindex" );
db.messages.createIndex( { timestamp : 1, username : 1 },
                        { name : "myindex" } )
db.messages.find( { timestamp : { $gte : 2, $lte : 4 },
                  username : "anonymous" } ).explain()
```

totalKeysExamined is still > n. Why?

*Notes:*

**totalKeysExamined > n**

timestamp	username
1	"anonymous"
2	"anonymous"
3	"sam"
4	"anonymous"
5	"martha"

*Notes:*

## A Different Compound Index

Drop the index and build a new one with user.

```
db.messages.dropIndex( "myindex" );
db.messages.createIndex( { username : 1, timestamp : 1 },
                        { name : "myindex" } )

db.messages.find( { timestamp : { $gte : 2, $lte : 4 },
                  username : "anonymous" } ).explain()
```

totalKeysExamined is 2. n is 2.

*Notes:*

**totalKeysExamined == n**

username	timestamp
"anonymous"	1
"anonymous"	2
"anonymous"	4
"sam"	2
"martha"	5

*Notes:*

### Let Selectivity Drive Field Order

- Order fields in a compound index from most selective to least selective.
- Usually, this means equality fields before range fields.
- When dealing with multiple equality values, start with the most selective.
- If a common range query is more selective instead (rare), specify the range component first.

*Notes:*

### Adding in the Sort

Finally, let's add the sort and run the query.

```
db.messages.find( {  
    timestamp : { $gte : 2, $lte : 4 },  
    username : "anonymous"  
} ).sort( { rating : -1 } ).explain();
```

- Note that the winningPlan includes a SORT stage.
- This means that MongoDB had to perform a sort in memory.
- In memory sorts for queries that retrieve large numbers of documents can degrade performance significantly.
- This is especially true if they are used frequently.

*Notes:*

## In-Memory Sorts

Let's modify the index again to allow the database to sort for us.

```
db.messages.dropIndex( "myindex" );
db.messages.createIndex( { username : 1 , timestamp : 1 , rating : 1 },
                        { name : "myindex" } );
db.messages.find( {
    timestamp : { $gte : 2, $lte : 4 },
    username : "anonymous"
} ).sort( { rating : -1 } ).explain();
```

- The explain plan remains unchanged, because the sort field comes after the range fields.
- The index does not store entries in order by rating.
- Note that this requires us to consider a tradeoff.

*Notes:*

## Avoiding an In-Memory Sort

Rebuild the index as follows.

```
db.messages.dropIndex( "myindex" );
db.messages.createIndex( { username : 1, rating : 1, timestamp : 1 },
                        { name : "myindex" } );
db.messages.find( {
    timestamp : { $gte : 2, $lte : 4 },
    username : "anonymous"
} ).sort( { rating : -1 } ).explain();
```

- We no longer have an in-memory sort, but need to examine more keys.
- `totalKeysExamined` is 3 and `n` is 2.
- This is the best we can do in this situation and this is fine.
- However, if `totalKeysExamined` is much larger than `n`, this might not be the best index.

*Notes:*

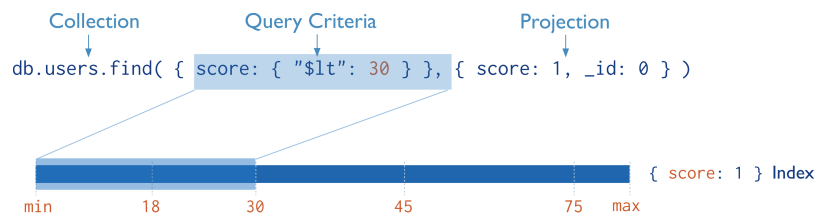


## General Rules of Thumb

- Equality before range
- Equality before sorting
- Sorting before range

Notes:

## Covered Queries



- When a query and projection include only the indexed fields, MongoDB will return results directly from the index.
- There is no need to scan any documents or bring documents into memory.
- These covered queries can be very efficient.

Notes:

## Exercise: Covered Queries

```
db.testcol.drop()
for (i=1; i<=20; i++) {
  db.testcol.insert({ "_id" : i, "title" : i, "name" : i,
    "rating" : i, "budget" : i })
};
db.testcol.createIndex( { "title" : 1, "name" : 1, "rating" : 1 } )

// Not covered because _id is present.
db.testcol.find( { "title" : 3 },
  { "title" : 1, "name" : 1, "rating" : 1 }
).explain("executionStats")

// Not covered because other fields may exist in matching docs.
db.testcol.find( { "title" : 3 },
  { "_id" : 0, "budget" : 0 } ).explain("executionStats")

// Covered query!
db.testcol.find( { "title" : 3 },
```

```
{ "_id" : 0, "title" : 1, "name" : 1, "budget" : 1 }  
) .explain("executionStats")
```

*Notes:*

## 3.3 Multikey Indexes

### Learning Objectives

Upon completing this module, students should understand:

- What a multikey index is
- When MongoDB will use a multikey index to satisfy a query
- How multikey indexes work
- How multikey indexes handle sorting
- Some limitations on multikey indexes

*Notes:*

### Introduction to Multikey Indexes

- A multikey index is an index on an array.
- An index entry is created on each value found in the array.
- Multikey indexes can support primitives, documents, or sub-arrays.
- There is nothing special that you need to do to create a multikey index.
- You create them using `createIndex()` just as you would with an ordinary single-field index.
- If there is an array as a value for an indexed field, the index will be multikey on that field.

*Notes:*

## Example: Array of Numbers

```
db.race_results.drop()
db.race_results.createIndex( { "lap_times" : 1 } )
a = [ { "lap_times" : [ 3, 5, 2, 8 ] },
      { "lap_times" : [ 1, 6, 4, 2 ] },
      { "lap_times" : [ 6, 3, 3, 8 ] } ]
db.race_results.insert( a )

// Used the index
db.race_results.find( { lap_times : 1 } ).explain()

// One document found.
// Index not used, because it is naive to position.
db.race_results.find( { "lap_times.2" : 3 } ).explain()
```

*Notes:*

## Exercise: Array of Documents, Part 1

Create a collection and add an index on the `x` field:

```
db.blog.drop()
b = [ { "comments" : [
      { "name" : "Bob", "rating" : 1 },
      { "name" : "Frank", "rating" : 5.3 },
      { "name" : "Susan", "rating" : 3 } ] },
      { "comments" : [
      { name : "Megan", "rating" : 1 } ] },
      { "comments" : [
      { "name" : "Luke", "rating" : 1.4 },
      { "name" : "Matt", "rating" : 5 },
      { "name" : "Sue", "rating" : 7 } ] } ]
db.blog.insert(b)

db.blog.createIndex( { "comments" : 1 } )
// vs
db.blog.createIndex( { "comments.rating" : 1 } )

// for this query
db.blog.find( { "comments.rating" : 5 })
```

*Notes:*

## Exercise: Array of Documents, Part 2

For each of the three queries below:

- How many documents will be returned?
- Will it use our multi-key index? Why or why not?
- If a query will not use the index, which index will it use?

```
db.blog.find( { "comments" : { "name" : "Bob", "rating" : 1 } } )
db.blog.find( { "comments" : { "rating" : 1 } } )
db.blog.find( { "comments.rating" : 1 } )
```

*Notes:*

## Exercise: Array of Arrays, Part 1

Add some documents and create an index simulating a player in a game moving on an X,Y grid.

```
db.player.drop()
db.player.createIndex( { "last_moves" : 1 } )
c = [ { "last_moves" : [ [ 1, 2 ], [ 2, 3 ], [ 3, 4 ] ] },
      { "last_moves" : [ [ 3, 4 ], [ 4, 5 ] ] },
      { "last_moves" : [ [ 4, 5 ], [ 5, 6 ] ] },
      { "last_moves" : [ [ 3, 4 ] ] },
      { "last_moves" : [ [ 4, 5 ] ] } ]
db.player.insert(c)
db.player.find()
```

*Notes:*

## Exercise: Array of Arrays, Part 2

For each of the queries below:

- How many documents will be returned?
- Does the query use the multi-key index? Why or why not?
- If the query does not use the index, what is an index it could use?

```
db.player.find( { "last_moves" : [ 3, 4 ] } )
db.player.find( { "last_moves" : 3 } )
db.player.find( { "last_moves.1" : [ 4, 5 ] } )
db.player.find( { "last_moves.2" : [ 2, 3 ] } )
```

*Notes:*

## How Multikey Indexes Work

- Each array element is given one entry in the index.
- So an array with 17 elements will have 17 entries – one for each element.
- Multikey indexes can take up much more space than standard indexes.

*Notes:*

## Multikey Indexes and Sorting

- If you sort using a multikey index:
  - A document will appear at the first position where a value would place the document.
  - It will not appear multiple times.
- This applies to array values generally.
- It is not a specific property of multikey indexes.

*Notes:*

## Exercise: Multikey Indexes and Sorting

```
db.testcol.drop()
a = [ { x : [ 1, 11 ] }, { x : [ 2, 10 ] }, { x : [ 3 ] },
      { x : [ 4 ] }, { x : [ 5 ] } ]
db.testcol.insert(a)

db.testcol.ensureIndex( { x : 1 } )

// x : [ 1, 11 ] array comes first. It contains the lowest value.
db.testcol.find().sort( { x : 1 } )

// x : [ 1, 11 ] array still comes first. Contains the highest value.
db.testcol.find().sort( { x : -1 } )
```

*Notes:*

## Limitations on Multikey Indexes

- You cannot create a compound index using more than one array-valued field.
- This is because of the combinatorics.
- For a compound index on two array-valued fields you would end up with  $N * M$  entries for one document.
- You cannot have a hashed multikey index.
- You cannot have a shard key use a multikey index.
- We discuss shard keys in another module.
- The index on the `_id` field cannot become a multikey index.

*Notes:*

## Example: Multikey Indexes on Multiple Fields

```
db.testcol.drop()
db.testcol.createIndex( { x : 1, y : 1 } )

// no problems yet
db.testcol.insert( { _id : 1, x : 1, y : 1 } )

// still OK
db.testcol.insert( { _id : 2, x : [ 1, 2 ], y : 1 } )

// still OK
db.testcol.insert( { _id : 3, x : 1, y : [ 1, 2 ] } )

// Won't work
db.testcol.insert( { _id : 4, x : [ 1, 2 ], y : [ 1, 2 ] } )
```

*Notes:*

## 3.4 Hashed Indexes

### Learning Objectives

Upon completing this module, students should understand:

- What a hashed index is
- When to use a hashed index

*Notes:*

### What is a Hashed Index?

- Hashed indexes are based on field values like any other index.
- The difference is that the values are hashed and it is the hashed value that is indexed.
- The hashing function collapses sub-documents and computes the hash for the entire value.
- MongoDB can use the hashed index to support equality queries.
- Hashed indexes do not support multi-key indexes, i.e. indexes on array fields.
- Hashed indexes do not support range queries.

*Notes:*

### Why Hashed Indexes?

- In MongoDB, the primary use for hashed indexes is to support sharding a collection using a hashed shard key.
- In some cases, the field we would like to use to shard data would make it difficult to scale using sharding.
- Using a hashed shard key to shard a collection ensures an even distribution of data and overcomes this problem.
- See [Shard a Collection Using a Hashed Shard Key](http://docs.mongodb.org/manual/tutorial/shard-collection-with-a-hashed-shard-key/)<sup>6</sup> for more details.
- We discuss sharding in detail in another module.

*Notes:*

---

<sup>6</sup><http://docs.mongodb.org/manual/tutorial/shard-collection-with-a-hashed-shard-key/>

## Limitations

- You may not create compound indexes that have hashed index fields.
- You may not specify a unique constraint on a hashed index.
- You can create both a hashed index and a non-hashed index on the same field.

*Notes:*

## Floating Point Numbers

- MongoDB hashed indexes truncate floating point numbers to 64-bit integers before hashing.
- Do not use a hashed index for floating point numbers that cannot be reliably converted to 64-bit integers.
- MongoDB hashed indexes do not support floating point values larger than  $2^{53}$ .

*Notes:*

## Creating a Hashed Index

Create a hashed index using an operation that resembles the following. This operation creates a hashed index for the active collection on the a field.

```
db.active.createIndex( { a: "hashed" } )
```

*Notes:*

## 3.5 Geospatial Indexes

### Learning Objectives

Upon completing this module, students should understand:

- Use cases of geospatial indexes
- The two types of geospatial indexes
- How to create 2d geospatial indexes
- How to query for documents in a region
- How to create 2dsphere indexes
- Types of geoJSON objects



- How to query using 2dsphere indexes

*Notes:*

## **Introduction to Geospatial Indexes**

We can use geospatial indexes to quickly determine geometric relationships:

- All points within a certain radius of another point
- Whether or not points fall within a polygon
- Whether or not two polygons intersect

*Notes:*

## **Easiest to Start with 2 Dimensions**

- Initially, it is easiest to think about geospatial indexes in two dimensions.
- One type of geospatial index in MongoDB is a flat 2d index.
- With a geospatial index we can, for example, search for nearby items.
- This is the type of service that many phone apps provide when, say, searching for a nearby cafe.
- We might have a query location identified by an X in a 2d coordinate system.

*Notes:*

## **Location Field**

- A geospatial index is based on a location field within documents in a collection.
- The structure of location values depends on the type of geospatial index.
- We will go into more detail on this in a few minutes.
- We can identify other documents in this collection with Xs in our 2d coordinate system.

*Notes:*

## Find Nearby Documents

- A geospatial index enables us to efficiently query a collection based on geometric relationships between documents and the query.
- For example, we can quickly locate all documents within a certain radius of our query location.
- In this example, we’ve illustrated a `$near` query in a 2d geospatial index.

*Notes:*

## Flat vs. Spherical Indexes

There are two types of geospatial indexes:

- Flat, made with a 2d index
- Two-dimensional spherical, made with the 2dsphere index
  - Takes into account the curvature of the earth
  - Joins any two points using a geodesic or “great circle arc”
  - Deviates from flat geometry as you get further from the equator, and as your points get further apart

*Notes:*

## Flat Geospatial Index

- This is a Cartesian treatment of coordinate pairs.
- E.g., the index would not reflect the fact that the shortest path from Canada to Siberia is over the North Pole (if units are degrees).
- 2d indexes can be used to describe any flat surface.
- Recommended if:
  - You have legacy coordinate pairs (MongoDB 2.2 or earlier).
  - You do not plan to use geoJSON objects such as LineStrings or Polygons.
  - You are not going to use points far enough North or South to worry about the Earth’s curvature.

*Notes:*

## Spherical Geospatial Index

- Spherical indexes model the curvature of the Earth
- If you want to plot the shortest path from the Klondike to Siberia, this will know to go over the North Pole.
- Spherical indexes use geoJSON objects (Points, LineString, and Polygons)
- Coordinate pairs are converted into geoJSON Points.

*Notes:*

## Creating a 2d Index

Creating a 2d index:

```
db.<COLLECTION>.createIndex(  
  { field_name : "2d", <optional additional field> : <value> },  
  { <optional options document> } )
```

Possible options key-value pairs:

- min : <lower bound>
- max : <upper bound>
- bits : <bits of precision for geohash>

*Notes:*

## Exercise: Creating a 2d Index

Create a 2d index on the collection `testcol` with:

- A min value of -20
- A max value of 20
- 10 bits of precision
- The field indexed should be `xy`.

*Notes:*

## Inserting Documents with a 2d Index

There are two accepted formats:

- Legacy coordinate pairs
- Document with the following fields specified:
  - `lng` (longitude)
  - `lat` (latitude)

*Notes:*

## Exercise: Inserting Documents with 2d Fields

- Insert 2 documents into the 'twoD' collection.
- Assign 2d coordinate values to the `xy` field of each document.
- Longitude values should be -3 and 3 respectively.
- Latitude values should be 0 and 0.4 respectively.

*Notes:*

## Querying Documents Using a 2d Index

- Use `$near` to retrieve documents close to a given point.
- Use `$geoWithin` to find documents with a shape contained entirely within the query shape.
- Use the following operators to specify a query shape:
  - `$box`
  - `$polygon`
  - `$center (circle)`

*Notes:*

### Example: Find Based on 2d Coords

Write a query to find all documents in the testcol collection that have an xy field value that falls entirely within the circle with center at [ -2.5, -0.5 ] and a radius of 3.

```
db.testcol.find( { xy : { $geoWithin : { $center : [ [ -2.5, -0.5 ], 3 ] } } } )
```

*Notes:*

### Creating a 2dsphere Index

You can index one or more 2dsphere fields in an index.

```
db.<COLLECTION>.createIndex( { <location field> : "2dsphere" } )
```

*Notes:*

### The geoJSON Specification

- The geoJSON format encodes location data on the earth.
- The spec is at <http://geojson.org/geojson-spec.html>
- This spec is incorporated in MongoDB 2dsphere indexes.
- It includes Point, LineString, Polygon, and combinations of these.

*Notes:*

## geoJSON Considerations

- The coordinates of points are given in degrees (latitude then longitude).
- The LineString that joins two points will always be a geodesic.
- Short lines (around a few hundred kilometers or less) will go about where you would expect them to.
- Polygons are made of a closed set of LineStrings.

*Notes:*

## Simple Types of 2dsphere Objects

**Point:** A single point on the globe

```
{ <field_name> : { type : "Point",  
                  coordinates : [ <longitude>, <latitude> ] } }
```

*Notes:* **LineString:** A geodesic line that is defined by its two end Points

```
{ <field_name> : { type : "LineString",  
                  coordinates : [ [ <longitude 1>, <latitude 1> ],  
                                  [ <longitude 2>, <latitude 2> ],  
                                  ...,  
                                  [ <longitude n>, <latitude n> ] ] } }
```

*Notes:*

## Polygons

Simple Polygon:

```
{ <field_name> : { type : "Polygon",  
                  coordinates : [ [ [ <Point1 coordinate pair> ],  
                                    [ <Point2 coordinate pair> ],  
                                    ...,  
                                    [ <Point1 coordinate pair again> ] ] ]  
                  } }
```

Polygon with One Hole:

```
{ <field_name> : { type : "Polygon",  
                  coordinates : [ [ <Points that define outer polygon> ],  
                                  [ <Points that define inner polygon> ] ]  
                  } }
```

*Notes:*

### Other Types of 2dsphere Objects

- **MultiPoint:** One or more Points in one document
- **MultiLine:** One or more LineStrings in one document
- **MultiPolygon:** One or more Polygons in one document
- **GeometryCollection:** One or more geoJSON objects in one document

*Notes:*

### Exercise: Inserting geoJSON Objects (1)

Create a coordinate pair for each the following airports. Create one variable per airport.

- LaGuardia (New York): 40.7772° N, 73.8726° W
- JFK (New York): 40.6397° N, 73.7789° W
- Newark (New York): 40.6925° N, 74.1686° W
- Heathrow (London): 52.4775° N, 0.4614° W
- Gatwick (London): 51.1481° N, 0.1903° W
- Stansted (London): 51.8850° N, 0.2350° E
- Luton (London): 51.9000° N, 0.4333° W

*Notes:*

### Exercise: Inserting geoJSON Objects (2)

- Now let's make arrays of these.
- Put all the New York area airports into an array called `nyPorts`.
- Put all the London area airports into an array called `londonPorts`.
- Create a third array for flight numbers: "AA4453", "VA3333", "UA2440".

*Notes:*

### Exercise: Inserting geoJSON Objects (3)

- Create documents for every possible New York to London flight.
- Include a `flightNumber` field for each flight.

*Notes:*

### Exercise: Creating a 2dsphere Index

- Create two indexes on the collection `flights`.
- Make the first a compound index on the fields:
  - `origin`
  - `destination`
  - `flightNumber`
- Specify 2dsphere indexes on both `origin` and `destination`.
- Specify a simple index on `name`.
- Make the second index just a 2dsphere index on `destination`.

*Notes:*



## Querying 2dsphere Objects

`$geoNear`: Finds all points, orders them by distance from a position.

```
{ <field name> : { $near : { $geometry : {  
    type : "Point",  
    coordinates : [ lng, lat ] },  
    $maxDistance : <meters> } } } }
```

`$near`: Just like `$geoNear`, except in very edge cases; check the docs.

`$geoWithin`: Only returns documents with a location completely contained within the query.

`$geoIntersects`: Returns documents with their indexed field intersecting any part of the shape in the query.

*Notes:*

## 3.6 TTL Indexes

### Learning Objectives

Upon completing this module students should understand:

- How to create a TTL index
- When a TTL indexed document will get deleted
- Limitations of TTL indexes

*Notes:*

### TTL Index Basics

- TTL is short for “Time To Live”.
- TTL indexes must be based on a field of type `Date` (including `ISODate`) or `Timestamp`.
- Any `Date` field older than `expireAfterSeconds` will get deleted at some point.

*Notes:*

## Creating a TTL Index

Create with:

```
db.<COLLECTION>.createIndex( { field_name : 1 },
                              { expireAfterSeconds : some_number } )
```

*Notes:*

## Exercise: Creating a TTL Index

Let's create a TTL index on the `ttl` collection that will delete documents older than 30 seconds. Write a script that will insert documents at a rate of one per second.

```
db.sessions.drop()
db.sessions.createIndex( { "last_user_action" : 1 },
                        { "expireAfterSeconds" : 30 } )

i = 0
while (true) {
    i += 1;
    db.sessions.insert( { "last_user_action" : ISODate(), "b" : i } );
    sleep(1000); // Sleep for 1 second
}
```

*Notes:*

## Exercise: Check the Collection

Then, leaving that window open, open up a new terminal and connect to the database with the mongo shell. This will allow us to verify the TTL behavior.

```
// look at the output and wait. After a ramp-up of up to a minute or so,
// count() will be reset to 30 once/minute.
while (true) {
    print(db.sessions.count());
    sleep(100);
}
```

*Notes:*

## 3.7 Text Indexes

### Learning Objectives

Upon completing this module, students should understand:

- The purpose of a text index
- How to create text indexes
- How to search using text indexes
- How to rank search results by relevance score

*Notes:*

### What is a Text Index?

- A text index is based on the tokens (words, etc.) used in string fields.
- MongoDB supports text search for a number of languages.
- Text indexes drop language-specific stop words (e.g. in English “the”, “an”, “a”, “and”, etc.).
- Text indexes use simple, language-specific suffix stemming (e.g., “running” to “run”).

*Notes:*

### Creating a Text Index

You create a text index a little bit differently than you create a standard index.

```
db.<COLLECTION>.createIndex( { <field name> : "text" } )
```

*Notes:*

## Exercise: Creating a Text Index

Create a text index on the “dialog” field of the `montyPython` collection.

```
db.montyPython.ensureIndex( { dialog : "text" } )
```

*Notes:*

## Creating a Text Index with Weighted Fields

- The default weight is 1 for each indexed field.
- The weight is relative to other weights in a text index.

```
db.<COLLECTION>.createIndex(  
  { "title" : "text", "keywords": "text", "author" : "text" },  
  { "weights" : {  
    "title" : 10,  
    "keywords" : 5  
  }})
```

- Term match in “title” field has 10 times (i.e. 10:1) the impact as a term match in the “author” field.

*Notes:*

## Text Indexes are Similar to Multikey Indexes

- Continuing our example, you can treat the `dialog` field as a multikey index.
- A multikey index with each of the words in `dialog` as values.
- You can query the field using the `$text` operator.

*Notes:*

## Exercise: Inserting Texts

Let's add some documents to our montyPython collection.

```
db.montyPython.insert( [
{ _id : 1,
  dialog : "What is the air-speed velocity of an unladen swallow?" },
{ _id : 2,
  dialog : "What do you mean? An African or a European swallow?" },
{ _id : 3,
  dialog : "Huh? I... I don't know that." },
{ _id : 45,
  dialog : "You're using coconuts!" },
{ _id : 55,
  dialog : "What? A swallow carrying a coconut?" } ] )
```

*Notes:*

## Querying a Text Index

Next, let's query the collection. The syntax is:

```
db.<COLLECTION>.find( { $text : { $search : "query terms go here" } } )
```

*Notes:*

## Exercise: Querying a Text Index

Using the text index, find all documents in the montyPython collection with the word “swallow” in it.

```
// Returns 3 documents.
db.montyPython.find( { $text : { $search : "swallow" } } )
```

*Notes:*

## Exercise: Querying Using Two Words

- Find all documents in the `montyPython` collection with either the word ‘coconut’ or ‘swallow’.
- By default MongoDB ORs query terms together.
- E.g., if you query on two words, results include documents using either word.

```
// Finds 4 documents, 3 of which contain only one of the two words.
db.montyPython.find( { $text : { $search : "coconut swallow" } } )
```

*Notes:*

## Search for a Phrase

- To match an exact phrase, include search terms in quotes (escaped).
- The following query selects documents containing the phrase “European swallow”:

```
db.montyPython.find( { $text: { $search: "\"European swallow\"" } } )
```

*Notes:*

## Text Search Score

- The search algorithm assigns a relevance score to each search result.
- The score is generated by a vector ranking algorithm.
- The documents can be sorted by that score.

```
db.<COLLECTION>.find(
  { $text : { $search : "swallow coconut" } },
  { textScore: { $meta : "textScore" } }
).sort(
  { textScore: { $meta: "textScore" } }
) )
```

*Notes:*

## 4 Replica Sets

*Introduction to Replica Sets (page 101)* An introduction to replication and replica sets.

*Elections in Replica Sets (page 105)* The process of electing a new primary (automated failover) in replica sets.

*Replica Set Roles and Configuration (page 111)* Configuring replica set members for common use cases.

*The Oplog: Statement Based Replication (page 113)* The process of replicating data from one node of a replica set to another.

*Write Concern (page 119)* Balancing performance and durability of writes.

*Read Preference (page 124)* Configuring clients to read from specific members of a replica set.

*Exercise: Setting up a Replica Set (page 125)* Launching members, configuring, and initiating a replica set.

### 4.1 Introduction to Replica Sets

#### Learning Objectives

Upon completing this module, students should understand:

- Striking the right balance between cost and redundancy
- The many scenarios replication addresses and why
- How to avoid downtime and data loss using replication

*Notes:*

#### Use Cases for Replication

- High Availability
- Disaster Recovery
- Functional Segregation

*Notes:*

## High Availability (HA)

- Data still available following:
  - Equipment failure (e.g. server, network switch)
  - Datacenter failure
- This is achieved through automatic failover.

*Notes:*

## Disaster Recovery (DR)

- We can duplicate data across:
  - Multiple database servers
  - Storage backends
  - Datacenters
- Can restore data from another node following:
  - Hardware failure
  - Service interruption

*Notes:*

## Functional Segregation

There are opportunities to exploit the topology of a replica set.

- Based on physical location (e.g. rack or datacenter location)
- For analytics, reporting, data discovery, system tasks, etc.
- For backups

*Notes:*



## Large Replica Sets

Functional segregation can be further exploited by using large replica sets.

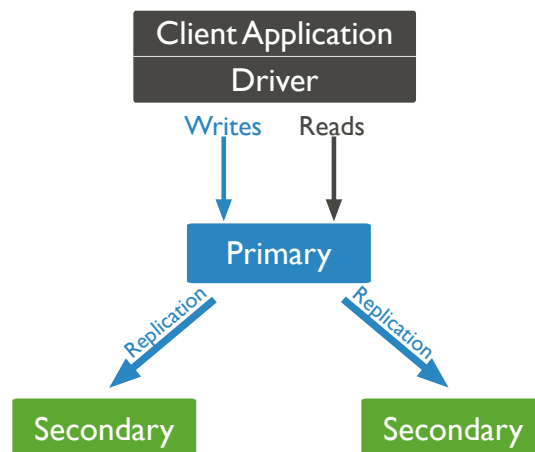
- 50 node replica set limit
- Useful for deployments with a large number of data centers or offices
- Read only workloads can position secondaries in data centers around the world (closer to application servers)

## Replication is Not Designed for Scaling

- Can be used for scaling reads, but generally not recommended.
- Drawbacks include:
  - Eventual consistency
  - Not scaling writes
  - Potential system overload when secondaries are unavailable
- Consider sharding for scaling reads and writes.

*Notes:*

## Replica Sets



*Notes:*

## Primary Server

- Clients send writes the primary only.
- MongoDB, Inc. maintains client drivers in many programming languages like Java, C#, Python, Ruby, and PHP.
- MongoDB drivers are replica set aware.

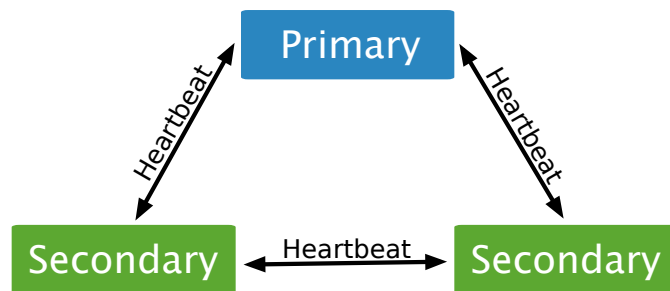
*Notes:*

## Secondaries

- A secondary replicates operations from another node in the replica set.
- Secondaries usually replicate from the primary.
- Secondaries may also replicate from other secondaries. This is called replication chaining.
- A secondary may become primary as a result of a failover scenario.

*Notes:*

## Heartbeats



*Notes:*

## The Oplog

- The operations log, or oplog, is a special capped collection that is the basis for replication.
- The oplog maintains one entry for each document affected by every write operation.
- Secondaries copy operations from the oplog of their sync source.

*Notes:*

## 4.2 Elections in Replica Sets

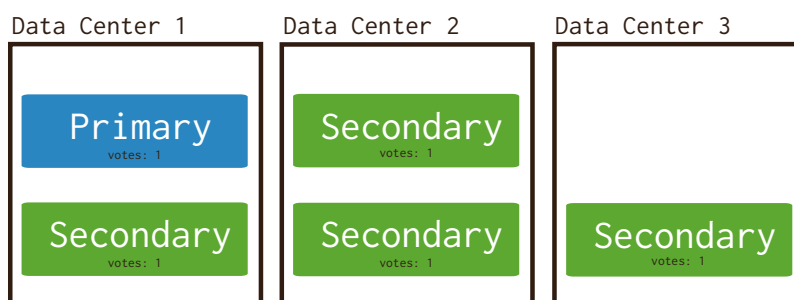
### Learning Objectives

Upon completing this module students should understand:

- That elections enable automated failover in replica sets
- How votes are distributed to members
- What prompts an election
- How a new primary is selected

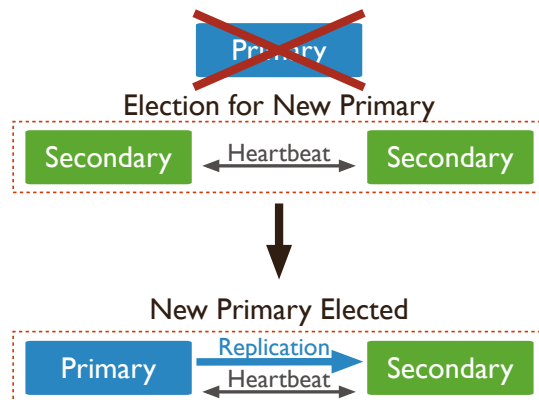
*Notes:*

### Members and Votes



*Notes:*

## Calling Elections



*Notes:*

## Selecting a New Primary

Three factors are important in the selection of a primary:

- Priority
- Optime
- Connections

*Notes:*

## Priority

- The higher its priority, the more likely a member is to become primary.
- The default is 1.
- Servers with a priority of 0 will never become primary.
- Priority values are floating point numbers 0 - 1000 inclusive.

*Notes:*

## Optime

- Optime: Operation time, which is the timestamp of the last operation the member applied from the oplog.
- To be elected primary, a member must have the most recent optime.
- Only optimes of visible members are compared.

*Notes:*

## Connections

- Must be able to connect to a majority of the members in the replica set.
- Majority refers to the total number of votes.
- Not the total number of members.

*Notes:*

## When will a primary step down?

- After receiving the `replSetStepDown` or `rs.stepDown()` command.
- If a secondary is eligible for election and has a higher priority.
- If it cannot contact a majority of the members of the replica set.

*Notes:*

## replSetStepDown Behavior

- Primary will attempt to terminate long running operations before stepping down
- Primary will wait for electable secondary to catch up before stepping down
- “secondaryCatchUpPeriodSecs” can be specified to limit the amount of time the primary will wait for a secondary to catch up before the primary steps down

*Notes:*

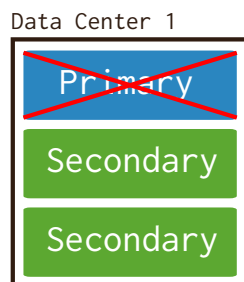
## Exercise: Elections in Failover Scenarios

- We have learned about electing a primary in replica sets
- Let’s look at some scenarios in which failover might be necessary.

*Notes:*

### Scenario A: 3 Data Nodes in 1 DC

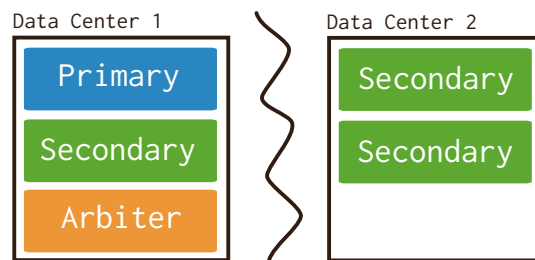
Which secondary will become the new primary?



*Notes:*

### Scenario B: 3 Data Nodes in 2 DCs

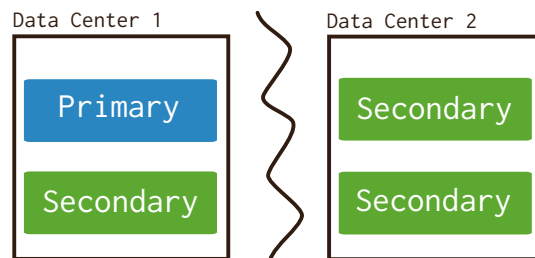
Which member will become primary following this type of network partition?



*Notes:*

### Scenario C: 4 Data Nodes in 2 DCs

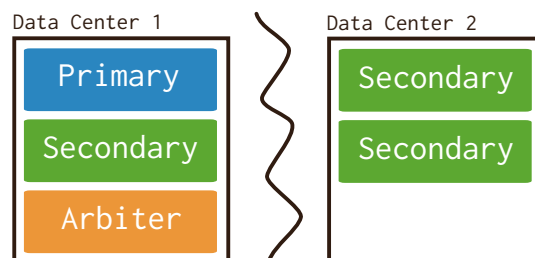
What happens following this network partition?



*Notes:*

### Scenario D: 5 Nodes in 2 DCs

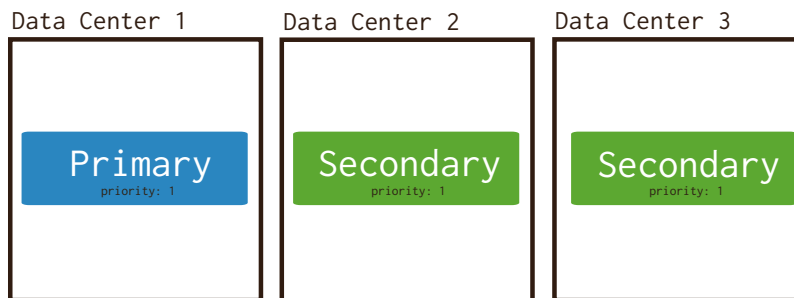
The following is similar to Scenario C, but with the addition of an arbiter in Data Center 1. What happens here?



Notes:

### Scenario E: 3 Data Nodes in 3 DCs

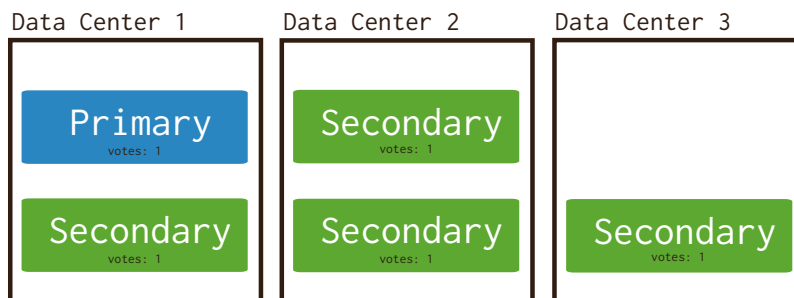
- What happens here if any one of the nodes/DCs fail?
- What about recovery time?



Notes:

### Scenario F: 5 Data Nodes in 3 DCs

What happens here if any one of the nodes/DCs fail? What about recovery time?



Notes:



## 4.3 Replica Set Roles and Configuration

### Learning Objectives

Upon completing this module students should understand:

- The use of priority to preference certain members or datacenters as primaries.
- Hidden members.
- The use of hidden secondaries for data analytics and other purposes (when secondary reads are used).
- The use of `slaveDelay` to protect against operator error.

*Notes:*

### Example: A Five-Member Replica Set Configuration

- For this example application, there are two datacenters.
- We name the hosts accordingly: `dc1-1`, `dc1-2`, `dc2-1`, etc.
  - This is just a clarifying convention for this example.
  - MongoDB does not care about host names except to establish connections.
- The nodes in this replica set have a variety of roles in this application.

*Notes:*

### Configuration

```
conf = {                                // 5 data-bearing nodes
  _id: "mySet",
  members: [
    { _id : 0, host : "dc1-1.example.net:27017", priority : 5 },
    { _id : 1, host : "dc1-2.example.net:27017", priority : 5 },
    { _id : 2, host : "dc2-1.example.net:27017" },
    { _id : 3, host : "dc1-3.example.net:27017", hidden : true },
    { _id : 4, host : "dc2-2.example.net:27017", hidden : true,
      slaveDelay: 7200 }
  ]
}
```

*Notes:*

## Principal Data Center

```
{ _id : 0, host : "dc1-1.example.net", priority : 5 },  
{ _id : 1, host : "dc1-2.example.net", priority : 5 },
```

*Notes:*

## Data Center 2

```
{ _id : 2, host : "dc2-1.example.net:27017" },
```

*Notes:*

## What about dc1-3 and dc2-2?

```
// Both are hidden.  
// Clients will not distribute reads to hidden members.  
// We use hidden members for dedicated tasks.  
{ _id : 3, host : "dc1-3.example.net:27017", hidden : true },  
{ _id : 4, host : "dc2-2.example.net:27017", hidden : true,  
  slaveDelay: 7200 }
```

*Notes:*

## What about dc2-2?

```
{ _id : 4, host : "dc2-2.example.net:27017", hidden : true,  
  slaveDelay : 7200 }
```

*Notes:*

## 4.4 The Oplog: Statement Based Replication

### Learning Objectives

Upon completing this module students should understand:

- Binary vs. statement-based replication.
- How the oplog is used to support replication.
- How operations in MongoDB are translated into operations written to the oplog.
- Why oplog operations are idempotent.
- That the oplog is a capped collection and the implications this holds for syncing members.

*Notes:*

### Binary Replication

- MongoDB replication is statement based.
- Contrast that with binary replication.
- With binary replication we would keep track of:
  - The data files
  - The offsets
  - How many bytes were written for each change
- In short, we would keep track of actual bytes and very specific locations.
- We would simply replicate these changes across secondaries.

*Notes:*

## Tradeoffs

- The good thing is that figuring out where to write, etc. is very efficient.
- But we must have a byte-for-byte match of our data files on the primary and secondaries.
- The problem is that this couples our replica set members in ways that are inflexible.
- Binary replication may also replicate disk corruption.

*Notes:*

## Statement-Based Replication

- Statement-based replication facilitates greater independence among members of a replica set.
- MongoDB stores a statement for every operation in a capped collection called the `oplog`.
- Secondaries do not simply apply exactly the operation that was issued on the primary.

*Notes:*

## Example

Suppose the following remove is issued and it deletes 100 documents:

```
db.foo.remove({ age : 30 })
```

This will be represented in the `oplog` with records such as the following:

```
{ "ts" : Timestamp(1407159845, 5), "h" : NumberLong("-704612487691926908"),  
  "v" : 2, "op" : "d", "ns" : "bar.foo", "b" : true, "o" : { "_id" : 65 } }  
{ "ts" : Timestamp(1407159845, 1), "h" : NumberLong("6014126345225019794"),  
  "v" : 2, "op" : "d", "ns" : "bar.foo", "b" : true, "o" : { "_id" : 333 } }  
{ "ts" : Timestamp(1407159845, 4), "h" : NumberLong("8178791764238465439"),  
  "v" : 2, "op" : "d", "ns" : "bar.foo", "b" : true, "o" : { "_id" : 447 } }  
{ "ts" : Timestamp(1407159845, 3), "h" : NumberLong("-1707391001705528381"),  
  "v" : 2, "op" : "d", "ns" : "bar.foo", "b" : true, "o" : { "_id" : 1033 } }  
{ "ts" : Timestamp(1407159845, 2), "h" : NumberLong("-6814297392442406598"),  
  "v" : 2, "op" : "d", "ns" : "bar.foo", "b" : true, "o" : { "_id" : 9971 } }
```

*Notes:*

## Replication Based on the Oplog

- One statement per document affected by each write: insert, update, or delete.
- Provides a level of abstraction that enables independence among the members of a replica set:
  - With regard to MongoDB version.
  - In terms of how data is stored on disk.
  - Freedom to do maintenance without the need to bring the entire set down.

*Notes:*

## Create a Replica Set

Let's take a look at a concrete example. Launch mongo shell as follows.

```
mongo --nodb
```

Create a replica set by running the following command in the mongo shell.

```
replicaSet = new ReplSetTest( { nodes : 3 } )
```

*Notes:*

## ReplSetTest

- ReplSetTest is useful for experimenting with replica sets as a means of hands-on learning.
- It should never be used in production. Never.
- The command above will create a replica set with three members.
- It does not start the mongods, however.
- You will need to issue additional commands to do that.

*Notes:*

## Start the Replica Set

Start the mongod processes for this replica set.

```
replicaSet.startSet()
```

Issue the following command to configure replication for these mongods. You will need to issue this while output is flying by in the shell.

```
replicaSet.initiate()
```

*Notes:*

## Status Check

- You should now have three mongods running on ports 31000, 31001, and 31002.
- You will see log statements from all three printing in the current shell.
- To complete the rest of the exercise, open a new shell.

*Notes:*

## Connect to the Primary

Open a new shell, connecting to the primary.

```
mongo --port 31000
```

*Notes:*

## Create some Inventory Data

Use the `store` database:

```
use store
```

Add the following inventory:

```
inventory = [ { _id: 1, inStock: 10 }, { _id: 2, inStock: 20 },
              { _id: 3, inStock: 30 }, { _id: 4, inStock: 40 },
              { _id: 5, inStock: 50 }, { _id: 6, inStock: 60 } ]
db.products.insert(inventory)
```

*Notes:*

## Perform an Update

Issue the following update. We might issue this update after a purchase of three items.

```
db.products.update({ _id: { $in: [ 2, 5 ] } },
                  { $inc: { inStock : -1 } },
                  { multi: true })
```

*Notes:*

## View the Oplog

The oplog is a capped collection in the `local` database of each replica set member:

```
use local
db.oplog.rs.find()
{ "ts" : Timestamp(1406944987, 1), "h" : NumberLong(0), "v" : 2, "op" : "n",
  "ns" : "", "o" : { "msg" : "initiating set" } }
...
{ "ts" : Timestamp(1406945076, 1), "h" : NumberLong("-9144645443320713428"),
  "v" : 2, "op" : "u", "ns" : "store.products", "o2" : { "_id" : 2 },
  "o" : { "$set" : { "inStock" : 19 } } }
{ "ts" : Timestamp(1406945076, 2), "h" : NumberLong("-7873096834441143322"),
  "v" : 2, "op" : "u", "ns" : "store.products", "o2" : { "_id" : 5 },
  "o" : { "$set" : { "inStock" : 49 } } }
```

*Notes:*

## Operations in the Oplog are Idempotent

- Each operation in the oplog is idempotent.
- Whether applied once or multiple times it produces the same result.
- Necessary if you want to be able to copy data while simultaneously accepting writes.

*Notes:*

## The Oplog Window

- Oplogs are capped collections.
- Capped collections are fixed-size.
- They guarantee preservation of insertion order.
- They support high-throughput operations.
- Like circular buffers, once a collection fills its allocated space:
  - It makes room for new documents.
  - By overwriting the oldest documents in the collection.

*Notes:*

## Sizing the Oplog

- The oplog should be sized to account for latency among members.
- The default size oplog is usually sufficient.
- But you want to make sure that your oplog is large enough:
  - So that the oplog window is large enough to support replication
  - To give you a large enough history for any diagnostics you might wish to run.

*Notes:*



## 4.5 Write Concern

### Learning Objectives

Upon completing this module students should understand:

- How and when rollback occurs in MongoDB.
- The tradeoffs between durability and performance.
- Write concern as a means of ensuring durability in MongoDB.
- The different levels of write concern.

*Notes:*

### What happens to the write?

- A write is sent to a primary.
- The primary acknowledges the write to the client.
- The primary then becomes unavailable before a secondary can replicate the write

*Notes:*

### Answer

- Another member might be elected primary.
- It will not have the last write that occurred before the previous primary became unavailable.
- When the previous primary becomes available again:
  - It will note it has writes that were not replicated.
  - It will put these writes into a `rollback file`.
  - A human will need to determine what to do with this data.
- This is default behavior in MongoDB and can be controlled using `write concern`.

*Notes:*

## Balancing Durability with Performance

- The previous scenario is a specific instance of a common distributed systems problem.
- For some applications it might be acceptable for writes to be rolled back.
- Other applications may have varying requirements with regard to durability.
- Tunable write concern:
  - Make critical operations persist to an entire MongoDB deployment.
  - Specify replication to fewer nodes for less important operations.

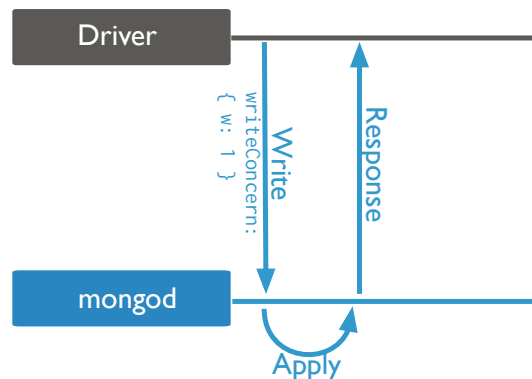
*Notes:*

## Defining Write Concern

- Clients may define the write concern per write operation, if necessary.
- Standardize on specific levels of write concerns for different classes of writes.
- In the discussion that follows we will look at increasingly strict levels of write concern.

*Notes:*

**Write Concern: { w : 1 }**



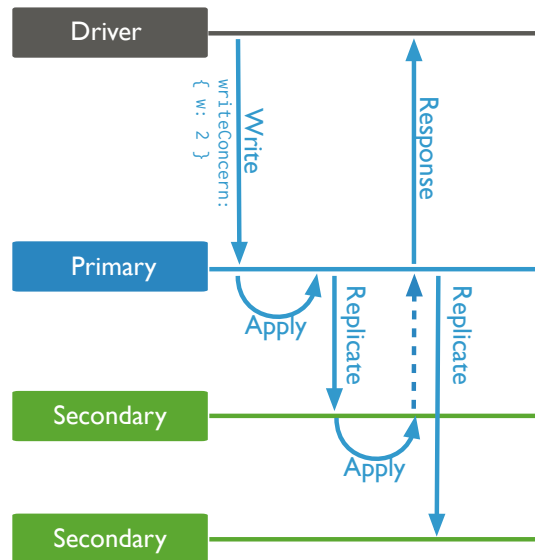
*Notes:*

### Example: { w : 1 }

```
db.edges.insert( { from : "tom185", to : "mary_p" },  
  { writeConcern : { w : 1 } } )
```

Notes:

### Write Concern: { w : 2 }



Notes:

### Example: { w : 2 }

```
db.customer.update( { user : "mary_p" },  
  { $push : { shoppingCart:  
    { _id : 335443, name : "Brew-a-cup",  
      price : 45.79 } } },  
  { writeConcern : { w : 2 } } )
```

Notes:

## Other Write Concerns

- You may specify any integer as the value of the `w` field for write concern.
- This guarantees that write operations have propagated to the specified number of members.
- E.g., `{ w : 3 }`, `{ w : 4 }`, etc.

*Notes:*

## Write Concern: `{ w : "majority" }`

- Ensures the primary completed the write (in RAM).
- Ensures write operations have propagated to a majority of a replica set's **voting** members.
- Avoids hard coding assumptions about the size of your replica set into your application.
- Using majority trades off performance for durability.
- It is suitable for critical writes and to avoid rollbacks.

*Notes:*

## Example: `{ w : "majority" }`

```
db.products.update({ _id : 335443 },
  { $inc : { inStock : -1 } },
  { writeConcern : { w : "majority" } })
```

*Notes:*

### Quiz: Which write concern?

Suppose you have a replica set with 7 data nodes. Your application has critical inserts for which you do not want rollbacks to happen. Secondaries may be taken down from to time for maintenance, leaving you with a potential 4 server replica set. Which write concern is best suited for these critical inserts?

- { w : 1 }
- { w : 2 }
- { w : 3 }
- { w : 4 }
- { w : “majority” }

*Notes:*

### Further Reading

See [Write Concern Reference](#)<sup>7</sup> for more details on write concern configurations, including setting timeouts and identifying specific replica set members that must acknowledge writes (i.e. [tag sets](#)<sup>8</sup>).

---

<sup>7</sup><http://docs.mongodb.org/manual/reference/write-concern>

<sup>8</sup><http://docs.mongodb.org/manual/tutorial/configure-replica-set-tag-sets/#replica-set-configuration-tag-sets>

## 4.6 Read Preference

### What is Read Preference?

- Read preference allows you to specify the nodes in a replica set to read from.
- Clients only read from the primary by default.
- There are some situations in which a client may want to read from:
  - Any secondary
  - A specific secondary
  - A specific type of secondary
- Only read from a secondary if you can tolerate possibly stale data, as not all writes might have replicated.

*Notes:*

### Use Cases

- Running systems operations without affecting the front-end application.
- Providing local reads for geographically distributed applications.
- Maintaining availability during a failover.

*Notes:*

### Not for Scaling

- In general, do *not* read from secondaries to provide extra capacity for reads.
- [Sharding](http://docs.mongodb.org/manual/sharding)<sup>9</sup> increases read and write capacity by distributing operations across a group of machines.
- Sharding is a better strategy for adding capacity.

*Notes:*

---

<sup>9</sup><http://docs.mongodb.org/manual/sharding>

## Read Preference Modes

MongoDB drivers support the following read preferences. Note that `hidden` nodes will never be read from when connected via the replica set.

- **primary**: Default. All operations read from the primary.
- **primaryPreferred**: Read from the primary but if it is unavailable, read from secondary members.
- **secondary**: All operations read from the secondary members of the replica set.
- **secondaryPreferred**: Read from secondary members but if no secondaries are available, read from the primary.
- **nearest**: Read from member of the replica set with the least network latency, regardless of the member's type.

*Notes:*

## Tag Sets

- There is also the option to use tag sets.
- You may tag nodes such that queries that contain the tag will be routed to one of the servers with that tag.
- This can be useful for running reports, say for a particular data center or nodes with different hardware (e.g. hard disks vs SSDs).

For example, in the mongo shell:

```
conf = rs.conf()
conf.members[0].tags = { dc : "east", use : "production" }
conf.members[1].tags = { dc : "east", use : "reporting" }
conf.members[2].tags = { use : "production" }
rs.reconfig(conf)
```

*Notes:*

## 4.7 Exercise: Setting up a Replica Set

### Overview

- In this exercise we will setup a 3 data node replica set on a single machine.
- In production, each node should be run on a dedicated host:
  - To avoid any potential resource contention
  - To provide isolation against server failure.

*Notes:*

## Create Data Directories

Since we will be running all nodes on a single machine, make sure each has its own data directory.

On Linux or Mac OS, run the following in the terminal to create the 3 directories ~/data/rs1, ~/data/rs2, and ~/data/rs3:

```
mkdir -p ~/data/rs{1,2,3}
```

On Windows, run the following command instead in Command Prompt or PowerShell:

```
md c:\data\rs1 c:\data\rs2 c:\data\rs3
```

*Notes:*

## Launch Each Member

Now start 3 instances of mongod in the foreground so that it is easier to observe and shutdown.

On Linux or Mac OS, run *each* of the following commands in its *own terminal window*:

```
mongod --replSet myReplSet --dbpath ~/data/rs1 --port 27017 --oplogSize 200 --smallfiles
mongod --replSet myReplSet --dbpath ~/data/rs2 --port 27018 --oplogSize 200 --smallfiles
mongod --replSet myReplSet --dbpath ~/data/rs3 --port 27019 --oplogSize 200 --smallfiles
```

On Windows, run *each* of the following commands in its *own Command Prompt or PowerShell window*:

```
mongod --replSet myReplSet --dbpath c:\data\rs1 --port 27017 --oplogSize 200 --smallfiles
mongod --replSet myReplSet --dbpath c:\data\rs2 --port 27018 --oplogSize 200 --smallfiles
mongod --replSet myReplSet --dbpath c:\data\rs3 --port 27019 --oplogSize 200 --smallfiles
```

*Notes:*



## Status

- At this point, we have 3 `mongod` instances running.
- They were all launched with the same `replSet` parameter of “myReplSet”.
- Despite this, the members are not aware of each other yet.
- This is fine for now.

*Notes:*

## Connect to a MongoDB Instance

- Connect to one of the MongoDB instances with the mongo shell.
- To do so run the following command in the terminal, Command Prompt, or PowerShell:

```
mongo      // connect to the default port 27017
```

*Notes:*

## Configure the Replica Set

```
rs.initiate()  
// wait a few seconds  
rs.add    ('<HOSTNAME>:27128')  
rs.addArb ('<HOSTNAME>:27129')  
  
// Keep running rs.status() until there's a primary and 2 secondaries  
rs.status()
```

*Notes:*

## Write to the Primary

While still connected to the primary (port 27017) with mongo shell, insert a simple test document:

```
db.testcol.insert({ a: 1 })
db.testcol.count()

exit    // Or Ctrl-d
```

*Notes:*

## Read from a Secondary

Connect to one of the secondaries. E.g.:

```
mongo --port 27018
```

Read from the secondary

```
rs.slaveOk()
db.testcol.find()
```

*Notes:*

## Review the Oplog

```
use local
db.oplog.rs.find()
```

*Notes:*

## Changing Replica Set Configuration

To change the replica set configuration, first connect to the primary via mongo shell:

```
mongo --port <PRIMARY_PORT> # e.g. 27017
```

Let's raise the priority of one of the secondaries. Assuming it is the 3rd node (e.g. on port 27019):

```
cfg = rs.conf()
cfg["members"][2]["priority"] = 10
rs.reconfig(cfg)
```

*Notes:*

## Verifying Configuration Change

You will see errors like the following, which are expected:

```
2014-10-07T17:01:34.610+0100 DBClientCursor::init call() failed
2014-10-07T17:01:34.613+0100 trying reconnect to 127.0.0.1:27017 (127.0.0.1) failed
2014-10-07T17:01:34.617+0100 reconnect 127.0.0.1:27017 (127.0.0.1) ok
reconnected to server after rs command (which is normal)
```

Verify that the replica set configuration is now as expected:

```
rs.conf()
```

The secondary will now become a primary. Check by running:

```
rs.status()
```

*Notes:*

## Further Reading

- [Replica Configuration](http://docs.mongodb.org/manual/reference/replica-configuration/)<sup>10</sup>
- [Replica States](http://docs.mongodb.org/manual/reference/replica-states/)<sup>11</sup>

---

<sup>10</sup><http://docs.mongodb.org/manual/reference/replica-configuration/>

<sup>11</sup><http://docs.mongodb.org/manual/reference/replica-states/>

## 5 Sharding

*Introduction to Sharding (page 130)* An introduction to sharding.

*Balancing Shards (page 140)* Chunks, the balancer, and their role in a sharded cluster.

*Shard Tags (page 143)* How tag-based sharding works.

*Exercise: Setting Up a Sharded Cluster (page 145)* Deploying a sharded cluster.

### 5.1 Introduction to Sharding

#### Learning Objectives

Upon completing this module, students should understand:

- What problems sharding solves
- When sharding is appropriate
- The importance of the shard key and how to choose a good one
- Why sharding increases the need for redundancy

*Notes:*

#### Contrast with Replication

- In an earlier module, we discussed Replication.
- This should never be confused with sharding.
- Replication is about high availability and durability.
  - Taking your data and constantly copying it
  - Being ready to have another machine step in to field requests.

*Notes:*

## Sharding is Concerned with Scale

- What happens when a system is unable to handle the application load?
- It is time to consider scaling.
- There are 2 types of scaling we want to consider:
  - Vertical scaling
  - Horizontal scaling

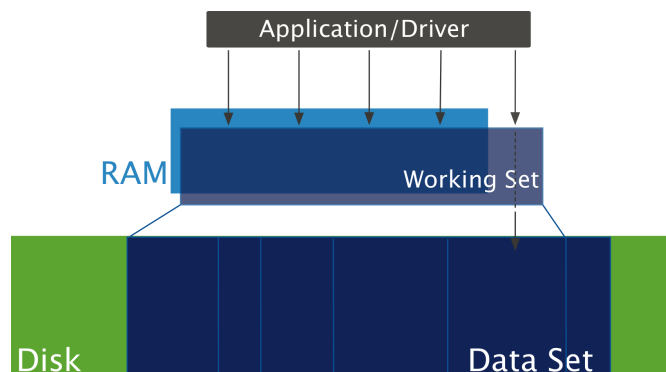
*Notes:*

## Vertical Scaling

- Adding more RAM, faster disks, etc.
- When is this the solution?
- First, consider a concept called the `working set`.

*Notes:*

## The Working Set



*Notes:*

## Limitations of Vertical Scaling

- There is a limit to how much RAM one machine can support.
- There are other bottlenecks such as I/O, disk access and network.
- Cost may limit our ability to scale up.
- There may be requirements to have a large working set that no single machine could possibly support.
- This is when it is time to scale horizontally.

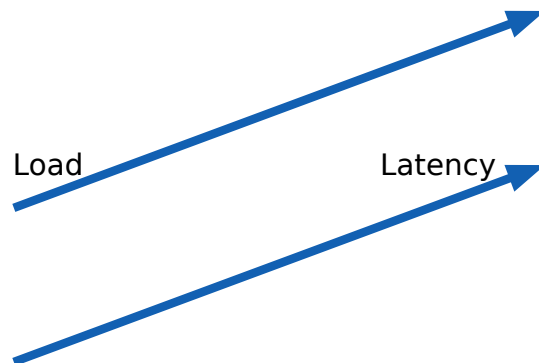
*Notes:*

## Sharding Overview

- MongoDB enables you to scale horizontally through sharding.
- Sharding is about adding more capacity to your system.
- MongoDB's sharding solution is designed to perform well on commodity hardware.
- The details of sharding are abstracted away from applications.
- Queries are performed the same way as if sending operations to a single server.
- Connections work the same by default.

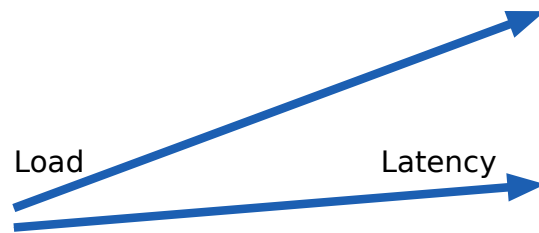
*Notes:*

## A Model that Does Not Scale



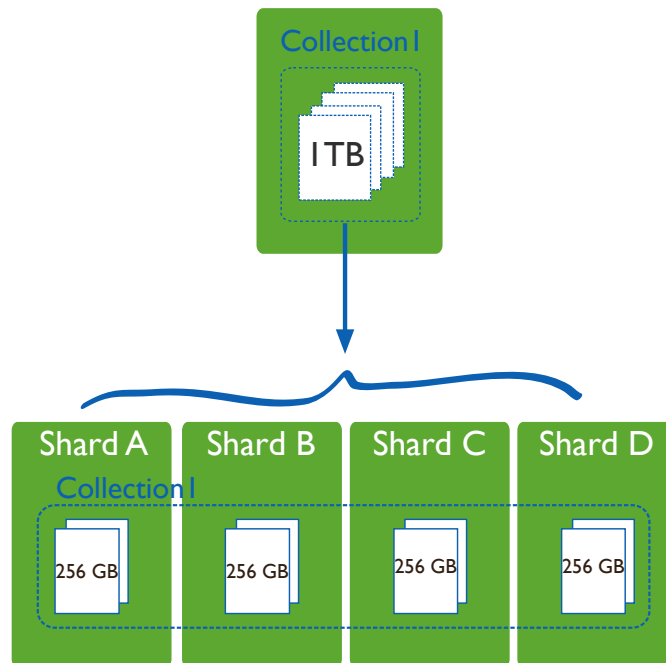
*Notes:*

## A Scalable Model



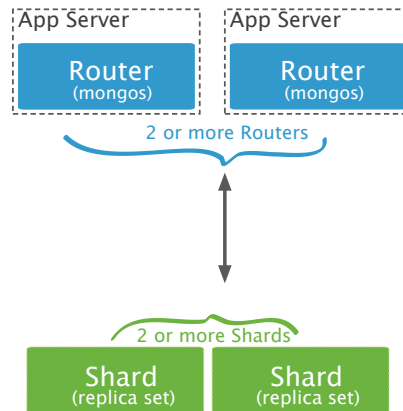
*Notes:*

## Sharding Basics



*Notes:*

## Sharded Cluster Architecture



*Notes:*

### Mongos

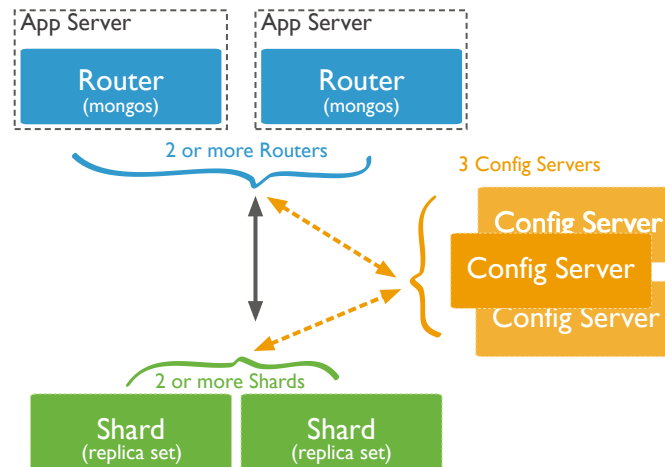
- A mongos is responsible for accepting requests and returning results to an application driver.
- In a sharded cluster, nearly all operations go through a mongos.
- A sharded cluster can have as many mongos routers as required.
- It is typical for each application server to have one mongos.
- Always use more than one mongos to avoid a single point of failure.

*Notes:*

### Config Servers

*Notes:*





### Config Server Hardware Requirements

- Quality network interfaces
- A small amount of disk space (typically a few GB)
- A small amount of RAM (typically a few GB)
- The larger the sharded cluster, the greater the config server hardware requirements.

*Notes:*

### When to Shard

- If you have more data than one machine can hold on its drives
- If your application is write heavy and you experiencing too much latency.
- If your working set outgrows the memory you can allocate to a single machine.

*Notes:*

## Possible Imbalance?

- Depending on how you configure sharding, data can become unbalanced on your sharded cluster.
  - Some shards might receive more inserts than others.
  - Some shards might have documents that grow more than those in other shards.
- This may result in too much load on a single shard.
  - Reads and writes
  - Disk activity
- This would defeat the purpose of sharding.

*Notes:*

## Balancing Shards

- MongoDB divides data into `chunks`.
- This is bookkeeping metadata.
  - There is nothing in a document that indicates its chunk.
  - The document does not need to be updated if its assigned chunk changes.
- If a chunk grows too large MongoDB will split it into two chunks.
- The MongoDB balancer keeps chunks distributed across shards in equal numbers.
- However, a balanced sharded cluster depends on a good shard key.

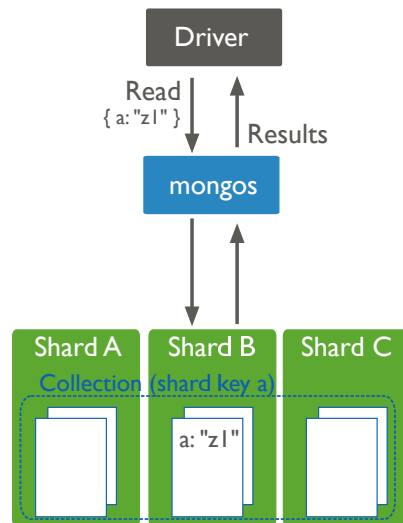
*Notes:*

## What is a Shard Key?

- You must define a shard key for a sharded collection.
- Based on one or more fields that every document must contain.
- Is immutable.
- The shard key determines where documents are located in the cluster.
- It is used to route operations to the appropriate shard.
- For reads and writes

*Notes:*

## Targeted Query Using Shard Key



*Notes:*

### With a Good Shard Key

You might easily see that:

- Reads hit only 1 or 2 shards per query.
- Writes are distributed across all servers.
- Your disk usage is evenly distributed across shards.
- Things stay this way as you scale.

*Notes:*

## With a Bad Shard Key

You might see that:

- Your reads hit every shard.
- Your writes are concentrated on one shard.
- Most of your data is on just a few shards.
- Adding more shards to the cluster will not help.

*Notes:*

## Choosing a Shard Key

Generally, you want a shard key:

- That has high cardinality
- That is used in the majority of read queries
- For which the values read and write operations use are randomly distributed
- For which the majority of reads are routed to a particular server

*Notes:*

## More Specifically

- Your shard key should be consistent with your query patterns.
- If reads usually find only one document, you only need good cardinality.
- If reads retrieve many documents:
  - Your shard key supports locality
  - Matching documents will reside on the same shard.

*Notes:*

## Cardinality

- A good shard key will have high cardinality.
- A relatively small number of documents should have the same shard key.
- Otherwise operations become isolated to the same server.
- Because documents with the same shard key reside on the same shard.
- Adding more servers will not help.
- Hashing will not help.

*Notes:*

## Non-Monotonic

- A good shard key will generate new values non-monotonically.
- Datetimes, counters, and ObjectIds make bad shard keys.
- Monotonic shard keys cause all inserts to happen on the same shard.
- Hashing will solve this problem.
- However, doing range queries with a hashed shard key will perform a scatter-gather query across the cluster.

*Notes:*

## Shards Should be Replica Sets

- As the number of shards increases, the number of servers in your deployment increases.
- This increases the probability that one server will fail on any given day.
- With redundancy built into each shard you can mitigate this risk.

*Notes:*

## 5.2 Balancing Shards

### Learning Objectives

Upon completing this module students should understand:

- Chunks and the balancer
- The status of chunks in a newly sharded collection
- How chunk splits automatically occur
- Advantages of pre-splitting chunks
- How the balancer Works

*Notes:*

### Chunks and the Balancer

- Chunks are groups of documents.
- The shard key determines which chunk a document will be contained in.
- Chunks can be split when they grow too large.
- The balancer decides where chunks go.
- It handles migrations of chunks from one server to another.

*Notes:*

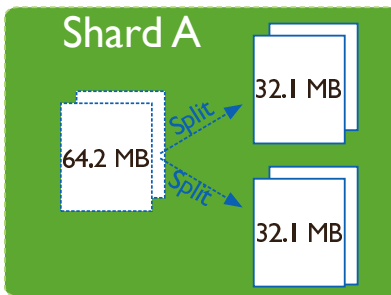
### Chunks in a Newly Sharded Collection

- The range of a chunk is defined by the shard key values of the documents the chunk contains.
- When a collection is sharded it starts with just one chunk.
- The first chunk for a collection will have the range:  

```
{ $minKey : 1 } to { $maxKey : 1 }
```
- All shard key values from the smallest possible to the largest fall in this chunk's range

*Notes:*

## Chunk Splits



*Notes:*

## Pre-Splitting Chunks

- You may pre-split data before loading data into a sharded cluster.
- Pre-splitting is useful if:
  - You plan to do a large data import early on
  - You expect a heavy initial server load and want to ensure writes are distributed.

*Notes:*

## Start of a Balancing Round

- A balancing round may be initiated by any mongos in the cluster.
- This happens when the difference in the number of chunks between two shards becomes too large.
- Specifically, the difference between the shard with the most chunks and the shard with the fewest.
- A balancing round starts when the imbalance reaches:
  - 2 when the cluster has < 20 chunks
  - 4 when the cluster has 20-79 chunks
  - 8 when the cluster has 80+ chunks

*Notes:*

## Balancing is Resource Intensive

- Chunk migration requires copying all the data in the chunk from one shard to another.
- MongoDB can migrate only a single chunk at a time.
- MongoDB creates splits only after an insert operation.
- For these reasons, it is possible to define a balancing window to ensure the balancer will only run during scheduled times.

*Notes:*

## Chunk Migration Steps

1. The balancer process sends the moveChunk command to the source shard.
2. The source shard continues to process reads/writes for that chunk during the migration.
3. The destination shard requests documents in the chunk and begins receiving copies.
4. After receiving all documents, the destination shard receives any changes to the chunk.
5. Then the destination shard tells the config db that it has the chunk.
6. The destination shard will now handle all reads/writes.
7. The source shard deletes its copy of the chunk.

*Notes:*

## Concluding a Balancing Round

- Each chunk will move:
  - From the shard with the most chunks
  - To the shard with the fewest
- A balancing round ends when all shards differ by at most one chunk.

*Notes:*



## 5.3 Shard Tags

### Learning Objectives

Upon completing this module students should understand:

- The purpose for shard tags
- Advantages of using shard tags
- Potential drawbacks of shard tags

*Notes:*

### Tags - Overview

- Shard tags allow you to “tie” data to one or more shards.
- A shard tag describes a range of shard key values.
- If a chunk is in the shard tag range, it will live on a shard with that tag.

*Notes:*

### Example: DateTime

- Documents older than one year need to be kept, but are rarely used.
- You tag those ranges as “LTS” for Long Term Storage.
- Tag specific shards to hold LTS documents.
- These shards can be on cheaper, slower machines.
- Invest in high-performance servers for more frequently accessed data.

*Notes:*

### Example: Location

- You are required to keep certain data in its home country.
- You include the country in the shard tag.
- Maintain data centers within each country that house the appropriate shards.
- Meets the country requirement but allows all servers to be part of the same system.

*Notes:*

### Example: Premium Tier

- You have customers who want to pay for a “premium” tier.
- The shard key permits you to distinguish one customer’s documents from all others.
- Tag the document ranges for each customer so that their documents will be located on shards of the appropriate tier.
- Shards tagged as premium tier run on high performance servers.
- Other shards run on commodity hardware.
- See [Manage Shard Tags](#)<sup>12</sup>

*Notes:*

### Tags - Caveats

- Because tagged chunks will only be on certain servers, if you tag more than those servers can handle, you’ll have a problem.
  - You’re not only worrying about your overall server load, you’re worrying about server load for each of your tags.
- Your chunks will evenly distribute themselves across the available chunks. You cannot control things more fine grained than your tags.

*Notes:*

---

<sup>12</sup><http://docs.mongodb.org/manual/tutorial/administer-shard-tags/>

## 5.4 Exercise: Setting Up a Sharded Cluster

### Learning Objectives

Upon completing this module students should understand:

- How to set up a sharded cluster including:
  - Replica Sets as Shards
  - Config Servers
  - Mongos processes
- How to enable sharding for a database
- How to shard a collection
- How to determine where data will go

*Notes:*

### Our Sharded Cluster

- In this exercise, we will set up a cluster with 3 shards.
- Each shard will be a replica set with 3 members (including one arbiter).
- We will insert some data and see where it goes.

*Notes:*

### Sharded Cluster Configuration

- Three shards:
  1. A replica set on ports 27107, 27108, 27109
  2. A replica set on ports 27117, 27118, 27119
  3. A replica set on ports 27127, 27128, 27129
- Three config servers on ports 27217, 27218, 27219
- Two mongos servers at ports 27017 and 27018

*Notes:*

## Build Our Data Directories

On Linux or MacOS, run the following in the terminal to create the data directories we'll need.

```
mkdir -p ~/data/cluster/config/{c0,c1,c2}
mkdir -p ~/data/cluster/shard0/{m0,m1,arb}
mkdir -p ~/data/cluster/shard1/{m0,m1,arb}
mkdir -p ~/data/cluster/shard2/{m0,m1,arb}
mkdir -p ~/data/cluster/{s0,s1}
```

On Windows, run the following commands instead:

```
md c:\data\cluster\config\c0 c:\data\cluster\config\c1 c:\data\cluster\config\c2
md c:\data\cluster\shard0\m0 c:\data\cluster\shard0\m1 c:\data\cluster\shard0\arb
md c:\data\cluster\shard1\m0 c:\data\cluster\shard1\m1 c:\data\cluster\shard1\arb
md c:\data\cluster\shard2\m0 c:\data\cluster\shard2\m1 c:\data\cluster\shard2\arb
md c:\data\cluster\s0 c:\data\cluster\s1
```

*Notes:*

## Initiate a Replica Set

```
mongod --replSet shard0 --smallfiles --nojournal --noprealloc \
  --dbpath ~/data/cluster/shard0/m0 \
  --logpath ~/data/cluster/shard0/m0/mongod.log \
  --fork --port 27107

mongod --replSet shard0 --smallfiles --nojournal --noprealloc \
  --dbpath ~/data/cluster/shard0/m1 \
  --logpath ~/data/cluster/shard0/m1/mongod.log \
  --fork --port 27108

mongod --replSet shard0 --smallfiles --nojournal --noprealloc \
  --dbpath ~/data/cluster/shard0/arb \
  --logpath ~/data/cluster/shard0/arb/mongod.log \
  --fork --port 27109

mongo --port 27107 --eval "\
  rs.initiate(); sleep(3000);\
  rs.add ('<HOSTNAME>:27108');\
  rs.addArb('<HOSTNAME>:27109')"
```

*Notes:*

## Spin Up a Second Replica Set

```
mongod --replSet shard1 --smallfiles --nojournal --noprealloc \
  --dbpath ~/data/cluster/shard1/m0 \
  --logpath ~/data/cluster/shard1/m0/mongod.log \
  --fork --port 27117

mongod --replSet shard1 --smallfiles --nojournal --noprealloc \
  --dbpath ~/data/cluster/shard1/m1 \
  --logpath ~/data/cluster/shard1/m1/mongod.log \
  --fork --port 27118

mongod --replSet shard1 --smallfiles --nojournal --noprealloc \
  --dbpath ~/data/cluster/shard1/arb \
  --logpath ~/data/cluster/shard1/arb/mongod.log \
  --fork --port 27119

mongo --port 27117 --eval "\
  rs.initiate(); sleep(3000);\
  rs.add ('<HOSTNAME>:27118');\
  rs.addArb('<HOSTNAME>:27119')"
```

*Notes:*

## A Third Replica Set

```
mongod --replSet shard2 --smallfiles --nojournal --noprealloc \
  --dbpath ~/data/cluster/shard2/m0 \
  --logpath ~/data/cluster/shard2/m0/mongod.log \
  --fork --port 27127

mongod --replSet shard2 --smallfiles --nojournal --noprealloc \
  --dbpath ~/data/cluster/shard2/m1 \
  --logpath ~/data/cluster/shard2/m1/mongod.log \
  --fork --port 27128

mongod --replSet shard2 --smallfiles --nojournal --noprealloc \
  --dbpath ~/data/cluster/shard2/arb \
  --logpath ~/data/cluster/shard2/arb/mongod.log \
  --fork --port 27129

mongo --port 27127 --eval "\
  rs.initiate(); sleep(3000);\
  rs.add ('<HOSTNAME>:27128');\
  rs.addArb('<HOSTNAME>:27129')"
```

*Notes:*

## Status Check

- Now we have three replica sets running.
- We have one for each shard.
- They do not know about each other yet.
- To make them a sharded cluster we will:
  - Build our config databases
  - Launch our mongos processes
  - Add each shard to the cluster
- To benefit from this configuration we also need to:
  - Enable sharding for a database
  - Shard at least one collection within that database

*Notes:*

## Launch Config Servers

```
mongod --smallfiles --nojournal --noprealloc \  
  --dbpath ~/data/cluster/config/c0 \  
  --logpath ~/data/cluster/config/c0/mongod.log \  
  --fork --port 27217 --configsvr  
  
mongod --smallfiles --nojournal --noprealloc \  
  --dbpath ~/data/cluster/config/c1 \  
  --logpath ~/data/cluster/config/c1/mongod.log \  
  --fork --port 27218 --configsvr  
  
mongod --smallfiles --nojournal --noprealloc \  
  --dbpath ~/data/cluster/config/c2 \  
  --logpath ~/data/cluster/config/c2/mongod.log \  
  --fork --port 27219 --configsvr
```

*Notes:*

## Launch the Mongos Processes

Now our mongos's. We need to tell them about our config servers.

```
mongos --logpath ~/data/cluster/s0/mongos.log --fork --port 27017 \
      --configdb localhost:27217,localhost:27218,localhost:27219

mongos --logpath ~/data/cluster/s1/mongos.log --fork --port 27018 \
      --configdb localhost:27217,localhost:27218,localhost:27219
```

*Notes:*

## Add All Shards

```
echo 'sh.addShard( "shard0/localhost:27107" ); \
      sh.addShard("shard1/localhost:27117" ); \
      sh.addShard( "shard2/localhost:27127" ); sh.status()' | mongo
```

---

**Note:** Instead of doing this through a bash (or other) shell command, you may prefer to launch a mongo shell and issue each command individually.

---

*Notes:*

## Enable Sharding and Shard a Collection

Enable sharding for the test database, shard a collection, and insert some documents.

```
echo 'sh.enableSharding("test"); \
      sh.shardCollection("test.testcol", { a : 1, b : 1 } )' | mongo

echo 'for (i=0; i<10000; i++) { docArr = []; for (j=0; j<1000; j++) { \
      docArr.push( { a : i, b : j, c : "Filler String 00000000000000000000 \
      000000000000000000000000000000000000000000000000000000000000000000000000 \
      0000000000000000" } ) }; db.testcol.insert(docArr) }' | mongo
```

*Notes:*

## Observe What Happens

Connect to either mongos using a mongo shell and frequently issue:

```
sh.status()
```

*Notes:*



## 6 Security

*Security (page 151)* An overview of security options for MongoDB.

### 6.1 Security

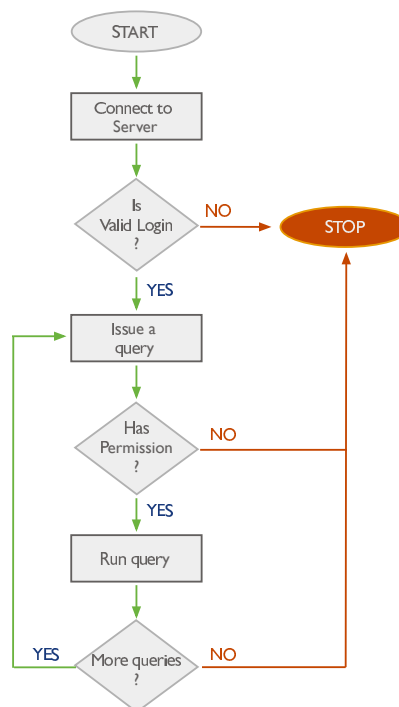
#### Learning Objectives

Upon completing this module students should understand:

- Security options for MongoDB
- Basics of native auth for MongoDB
- User roles in MongoDB
- How to manage user roles in MongoDB

*Notes:*

#### Overview



*Notes:*

## Authentication Options

- Challenge/response authentication using SCRAM-SHA-1 (username & password)
- x.509 Authentication (using x.509 Certificates)
- Kerberos (through an Enterprise subscription)
- LDAP

*Notes:*

## Authorization via MongoDB

- Each user has a set of potential roles
  - read, readWrite, dbAdmin, etc.
- Each role applies to *one* database
  - A single user can have roles on each database
  - Some roles apply to all databases
  - You can also create custom roles.

*Notes:*

## Network Exposure Options

- bindIp limits the ip addresses the server listens on.
- Using a non-standard port can provide a layer of obscurity.
- MongoDB should still be run only in a trusted environment.

*Notes:*

## Encryption (SSL)

- MongoDB can be configured at build time to run with SSL.
- To get it, build from the source code with `--ssl`.
- Alternatively, use MongoDB Enterprise.
- Allows you to use public key encryption.
- You can also validate with x.509 certificates.

*Notes:*

## Native MongoDB Auth

- Uses SCRAM-SHA-1 for challenge/response
- Sometimes called MongoDB-CR
- Start a mongod instance with `--auth` to enable this feature
- You can initially login using localhost
  - Called the “localhost exception”.
  - Stops working when you create a user.

*Notes:*

## Exercise: Create an Admin User, Part 1

- Launch a mongo shell.
- Create a user with the role, `userAdminAnyDatabase`
- Use name “roland” and password “12345”.
- Enable this user to login on the admin database.

*Notes:*

### Exercise: Create an Admin User, Part 2

- Launch a mongo shell without logging in.
- Attempt to create a user.
- Exit the shell.
- Log in again as roland.
- Ensure that you can create a user.

*Notes:*

### Using MongoDB Roles

- Each user logs in on *one* database.
- The user inputs their password on login.
  - Use the -u flag for username.
  - Use the -p flag to enter the password.
- userAdmins may create other users
- But they cannot read/write without other roles.

*Notes:*

### Exercise: Creating a readWrite User, Part 1

- Create a user named *vespa*.
- Give *vespa* readWrite access on the *test* and *druidia* databases.
- Create this user so that the login database is *druidia*.

*Notes:*

## Exercise: Creating a readWrite User, Part 2

Log in with the user you just created.

*Notes:*

## MongoDB Custom User Roles

- You can create custom user roles in MongoDB.
- You do this by modifying the `system.roles` collection.
- You can also inherit privileges from other roles into a given role.
- You won't remember how to do this, so if you need it, consult the [docs](http://docs.mongodb.org/manual/core/security-introduction/)<sup>13</sup>.

*Notes:*

---

<sup>13</sup><http://docs.mongodb.org/manual/core/security-introduction/>

## 7 MMS & Ops Manager

*MongoDB Management Service (MMS) & Ops Manager (page 156)* Learn about what MMS offers

*Automation (page 159)* MMS Automation

*Exercise: Cluster Automation (page 162)* Set up a cluster with MMS Automation

*Monitoring (page 163)* Monitor a cluster with MMS

*Exercise: Create an Alert (page 166)* Create an alert on MMS

*Backups (page 167)* Use MMS to create and administer backups

*API (page 169)* Using the MMS API

*Exercise: MMS API (page 171)* MMS API exercise

*Architecture (Ops Manager) (page 172)* Ops Manager

*Security (Ops Manager) (page 175)* Ops Manager Security

*Exercise: Install Ops Manager (page 178)* Install Ops Manager

### 7.1 MongoDB Management Service (MMS) & Ops Manager

#### Learning Objectives

Upon completing this module students should understand:

- Features of the MongoDB Management Service (MMS) & Ops Manager
- Available deployment options
- The components of MMS & Ops Manager
- MMS demo

*Notes:*

#### MMS and Ops Manager

All services for managing a MongoDB cluster or group of clusters:

- Monitoring
- Automation
- Backups

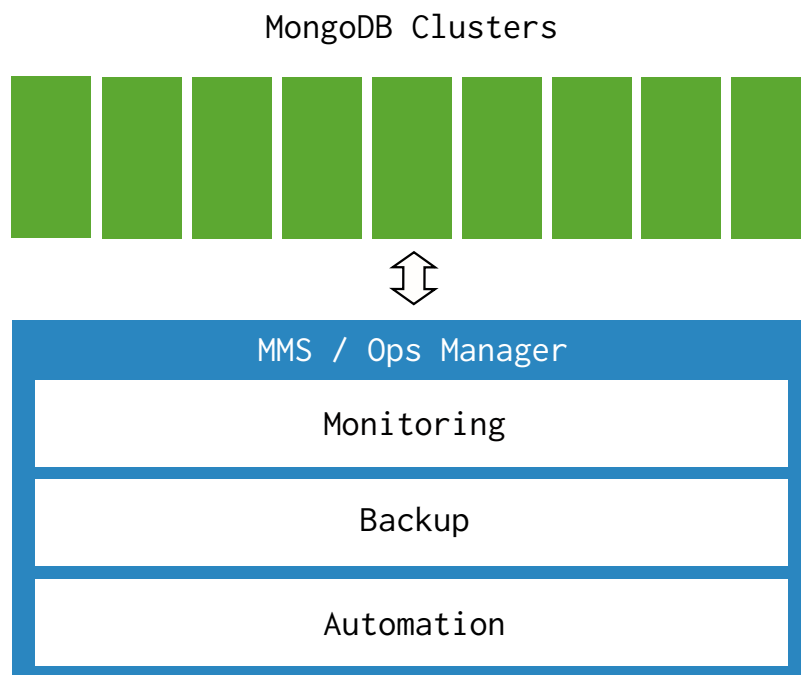
*Notes:*

## Deployment Options

- MMS: Hosted, <http://mms.mongodb.com>
- Ops Manager: On-premises

*Notes:*

## Architecture



*Notes:*

## **MMS**

- Manage MongoDB instances anywhere with a connection to MMS
- Option to provision servers via AWS integration

## **Ops Manager**

On-premises MMS, with additional features for:

- Alerting (SNMP)
- Deployment configuration (e.g. backup redundancy across internal data centers)
- Global control of multiple MongoDB clusters

*Notes:*

## **MMS and Ops Manager Use Cases**

- Manage a 1000 node cluster (monitoring, backups, automation)
- Manage a personal project (3 node replica set on AWS, using MMS)
- Manage 40 deployments (with each deployment having different requirements)

*Notes:*

## **Creating an MMS Account**

Free account at [mms.mongodb.com](https://mms.mongodb.com)

*Notes:*



## 7.2 Automation

### Learning Objectives

Upon completing this module students should understand:

- Use cases for MMS / Ops Manager Automation
- The MMS / Ops Manager Automation internal workflow

*Notes:*

### What is Automation?

Fully managed MongoDB deployment on your own servers:

- Automated provisioning
- Dynamically add capacity (e.g. add more shards or replica set nodes)
- Upgrades
- Admin tasks (e.g. change the size of the oplog)

*Notes:*

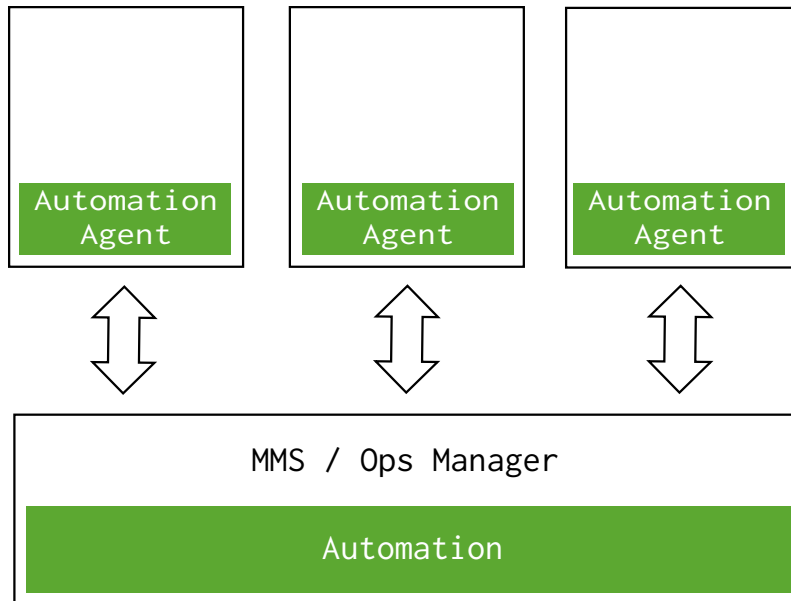
### How Does Automation Work?

- Automation agent installed on each server in cluster
- Administrator creates design goal for system (through MMS / Ops Manager interface)
- Automation agents periodically check with MMS / Ops Manager to get new design instructions
- Agents create and follow a plan for implementing cluster design
- Minutes later, cluster design is complete, cluster is in goal state

*Notes:*

## Automation Agents

### Machines in Data Center



*Notes:*

### Sample Use Case

Administrator wants to create a 100 shard cluster, with each shard comprised of a 3 node replica set:

- Administrator installs automation agent on 300 servers
- Cluster design is created in MMS / Ops Manager, then deployed to agents
- Agents execute instructions until 100 shard cluster is complete (usually several minutes)

*Notes:*

## Upgrades Using Automation

- Upgrades without automation can be a manually intensive process (e.g. 300 servers)
- A lot of edge cases when scripting (e.g. 1 shard has problems, or one replica set is a mixed version)
- One click upgrade with MMS / Ops Manager Automation for the entire cluster

*Notes:*

## Automation: Behind the Scenes

- Agents ping MMS / Ops Manager for new instructions
- Agents compare their local configuration file with the latest version from MMS / Ops Manager
- Configuration file in json
- All communications over SSL

```
{
  "groupId": "55120365d3e4b0cac8d8a52a737",
  "state": "PUBLISHED",
  "version": 4,
  "cluster": { ...
```

*Notes:*

## Configuration File

When version number of configuration file on MMS / Ops Manager is greater than local version, agent begins making a plan to implement changes:

```
"replicaSets": [
{
  "_id": "shard_0",
  "members": [
    {
      "_id": 0,
      "host": "DemoCluster_shard_0_0",
      "priority": 1,
      "votes": 1,
      "slaveDelay": 0,
      "hidden": false,
      "arbiterOnly": false
    },
    ...
  ],
  ...
},
...
```

*Notes:*

### **Automation Goal State**

Automation agent is considered to be in goal state after all cluster changes (related to the individual agent) have been implemented.

*Notes:*

### **Demo**

*Notes:*

## **7.3 Exercise: Cluster Automation**

### **Learning Objectives**

Upon completing this exercise students should understand:

- How to deploy, dynamically resize, and upgrade a cluster with MMS Automation

*Notes:*

### **MMS Automation Support**

Windows machines are not supported at this time.

*Notes:*

### Exercise #1

Using your personal computer, create a cluster using MMS automation with the following topology:

- 3 shards
- Each shard is a 3 node replica set (2 data bearing nodes, 1 arbiter)
- Version 2.6.8 of MongoDB
- **To conserve space on your local machine, set “smallfiles” = true and “oplogSize” = 10**

### Exercise #2

Modify the cluster topology from Exercise #1 to the following:

- 4 shards (add one shard)
- Version 3.0.1 of MongoDB (upgrade from 2.6.8 -> 3.0.1)

*Notes:*

## 7.4 Monitoring

### Learning Objectives

Upon completing this module students should understand:

- MMS / Ops Manager monitoring fundamentals
- How to set up alerts in MMS / Ops Manager

*Notes:*

## Monitoring in MMS / Ops Manager

- Identify cluster performance issues
- Identify individual nodes in cluster with performance issues
- Visualize performance through graphs and overlays
- Configure and set alerts

*Notes:*

## Monitoring Use Cases

- Alert on performance issues, to catch them before they turn into an outage
- Diagnose performance problems
- Historical performance analysis
- Monitor cluster health
- Capacity planning and scaling requirements

*Notes:*

## Monitoring Agent

- Requests metrics from each host in the cluster
- Sends those metrics to MMS / Ops Manager server
- Must be able to contact every host in the cluster (agent can live in a private network)
- Must have access to contact MMS / Ops Manager website with metrics from hosts

*Notes:*

## Agent Configuration

- Can use HTTP proxy
- Can gather hardware statistics via munin-node
- Agent can optionally gather database statistics, and record slow queries (sampled)

*Notes:*

## Agent Security

- SSL certificate for SSL clusters
- LDAP/Kerberos supported
- Agent must have “clusterMonitor” role on each host

*Notes:*

## Monitoring Demo

Visit [mms.mongodb.com](http://mms.mongodb.com)

*Notes:*

## Navigating MMS Charts

- Add charts to view by clicking the name of the chart at the bottom of the host’s page
- “i” icon next to each chart title can be clicked to learn what the chart means
- Holding down the left mouse button and dragging on top of the chart will let you zoom in

*Notes:*

## Metrics

- Minute-level metrics for 48 hours
- Hourly metrics for about 3 months
- Daily metrics for the life of the cluster

*Notes:*

## Alerts

- Every chart can be alerted on
- Changes to the state of the cluster can trigger alerts (e.g. a failover)
- Alerts can be sent to email, SMS, HipChat, or PagerDuty

*Notes:*

## 7.5 Exercise: Create an Alert

### Learning Objectives

Upon completing this exercise students should understand:

- How to create an alert in MMS

*Notes:*



## Exercise #1

Create an alert through MMS for any node within your cluster that is down.

After the alert has been created, stop a node within your cluster to verify the alert.

## 7.6 Backups

### Learning Objectives

Upon completing this module students should understand:

- How MMS / Ops Manager Backups work
- Advantages to MMS / Ops Manager Backups

*Notes:*

### Methods for Backing Up MongoDB

- mongodump
- File system backups
- MMS / Ops Manager Backups

*Notes:*

### Comparing MongoDB Backup Methods

Considerations	Mongodump	File System	MMS Backup (Cloud)	Ops Manager (On-prem MMS)
Initial Complexity	Medium	High	Low	High
Replica Set PIT	Yes**	Yes**	Yes	Yes
Sharded Snapshot	No	Yes**	Yes	Yes
Restore Time	Slow	Fast	Medium	Medium

**\*\*Requires advanced scripting**

*Notes:*

## MMS / Ops Manager Backups

- Based off oplogs (even for the config servers)
- Point-in-time recovery for replica sets, snapshots for sharded clusters
- Oplog on config server for sharded cluster backup
- Ability to exclude collections, databases (such as logs)
- Retention rules can be defined

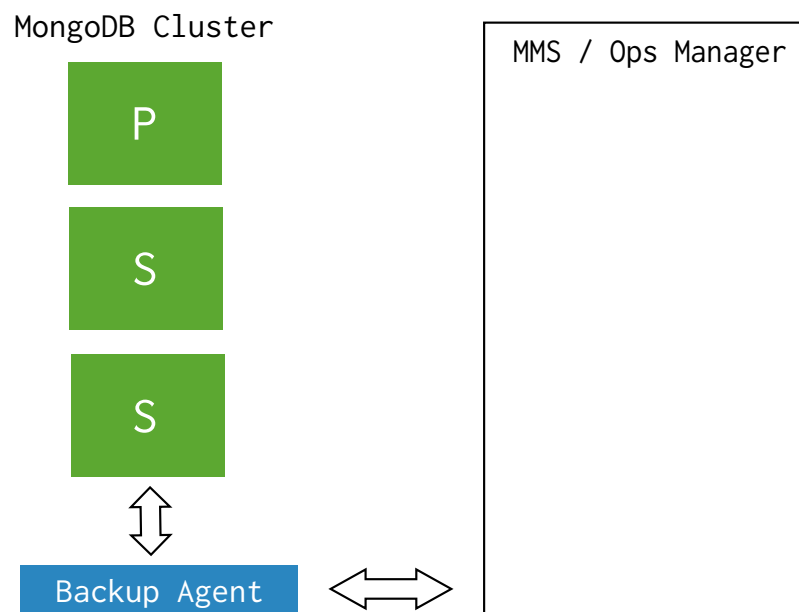
*Notes:*

## Restoring from MMS / Ops Manager

- Specify which backup to restore
- SCP push or HTTPS pull (one time use link) for data files

*Notes:*

## Architecture



*Notes:*

## Snapshotting

- Local copy of every replica set stored by MMS / Ops Manager
- Oplog entries applied on top of local copy
- Local copy is used for snapshotting
- Very little impact to the cluster (equivalent to adding another secondary)

*Notes:*

## Backup Agent

- Backup agent (can be managed by Automation agent)
- Backup agent sends oplog entries to MMS / Ops Manager service to be apply on local copy

*Notes:*

## 7.7 API

### Learning Objectives

Upon completing this module students should understand:

- Overview of the MMS / Ops Manager API
- Sample use cases for the MMS / Ops Manager API

*Notes:*

## **What is the MMS / Ops Manager API?**

Allows users to programmatically:

- Access monitoring data
- Backup functionality (request backups, change snapshot schedules, etc.)
- Automation cluster configuration (modify, view)

*Notes:*

## **API Documentation**

### **Sample API Uses Cases**

- Ingest MMS / Ops Manager monitoring data
- Programmatically restore environments
- Configuration management

*Notes:*

## **Ingest Monitoring Data**

The monitoring API can be used to ingest monitoring data into another system, such as Nagios, HP OpenView, or your own internal dashboard

*Notes:*

## **Programmatically Restore Environments**

Use the backup API to programmatically restore an integration or testing environment based on the last production snapshot.

*Notes:*

## **Configuration Management**

Use the automation API to integrate with existing configuration management tools (such as Chef or Puppet) to automate creating and maintaining environments.

*Notes:*

## **7.8 Exercise: MMS API**

### **Learning Objectives**

Upon completing this exercise students should understand:

- Have a basic understanding of working with the MMS API (or Ops Manager if the student chooses)

*Notes:*

### **Using the MMS API**

If Ops Manager is installed, it may be used in place of MMS for this exercise.

*Notes:*

## Exercise #1

Navigate the MMS interface to perform the following:

- Generate an API key
- Add your personal machine to the API whitelist

*Notes:*

## Exercise #2

Modify and run the following curl command to return alerts for your MMS group:

```
curl -u "username:apiKey" --digest -i  
"https://mms.mongodb.com/api/public/v1.0/groups/<GROUP-ID>/alerts"
```

*Notes:*

## Exercise #3

How would you find metrics for a given host within your MMS account? Create an outline for the API calls needed.

*Notes:*

## 7.9 Architecture (Ops Manager)

### Learning Objectives

Upon completing this module students should understand:

- Ops Manager overview
- Ops Manager components
- Considerations for sizing an Ops Manager environment

*Notes:*

## MongoDB Ops Manager

- On-premises version of MMS
- Everything stays within private network

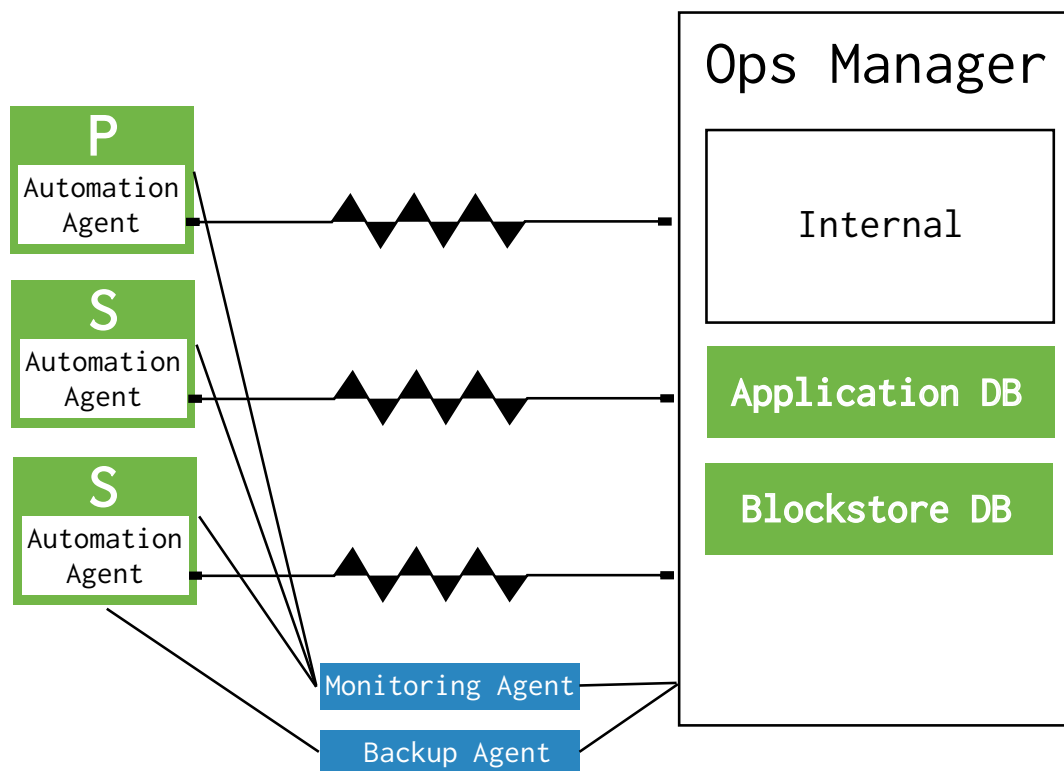
*Notes:*

### Components

- Application server(s): web interface
- Ops Manager application database: monitoring metrics, automation configuration, etc.
- Backup infrastructure: cluster backups and restores

*Notes:*

### Architecture



*Notes:*

### **Application Server**

- 15GB RAM, 50GB of disk space are required
- Equivalent to a m3.xlarge AWS instance

*Notes:*

### **Application Database**

- All monitoring metrics, automation configurations, etc. stored here
- Replica set, however, a standalone MongoDB node can also be used

*Notes:*

### **Backup Infrastructure**

- Blockstore database
- Backup daemon process (manages applying oplog entries, creating snapshots, etc.)

*Notes:*



## Blockstore Database

- Replica set, a standalone MongoDB node can also be used
- Must be sized carefully
- All snapshots are stored here
- Block level de-duping, the same block isn't stored twice (significantly reduces database size for deployment with low/moderate writes)

*Notes:*

## Backup Daemon Process

- The “workhorse” of the backup infrastructure
- Creates a local copy of the database it is backing up (references “HEAD” database)
- Requires 2-3X data space (of the database it is backing up)
- Can run multiple daemons, pointing to multiple blockstores (for large clusters)

*Notes:*

## 7.10 Security (Ops Manager)

### Learning Objectives

Upon completing this module students should understand:

- Ops Manager security overview
- Security and authentication options for Ops Manager

*Notes:*

## **Ops Manager User Authentication**

- Two-Factor authentication can be enabled (uses Google Authenticator)
- LDAP authentication option

*Notes:*

## **Authentication for the Backing Ops Manager Databases**

Ops Manager application database and blockstore database:

- MongoDB-CR (SCRAM-SHA1)
- LDAP
- Kerberos

*Notes:*

## **Authenticating Between an Ops Manager Agent and Cluster**

- LDAP
- MongoDB-CR
- Kerberos (Linux only)

*Notes:*

## Encrypting Communications

- All communications can be encrypted over SSL
- However, currently, if you are using Automation to manage a cluster, that cluster cannot use SSL or advanced auth.

## Ops Manager Groups

- Users can belong to many different groups
- Users have different levels of access per group

*Notes:*

## User Roles By Group

- Read Only
- User Admin
- Monitoring Admin
- Backup Admin
- Automation Admin
- Owner

*Notes:*

## Global User Roles

- Global Read Only
- Global User Admin
- Global Monitoring Admin
- Global Backup Admin
- Global Automation Admin
- Global Owner

*Notes:*

## 7.11 Exercise: Install Ops Manager

### Learning Objectives

Upon completing this exercise students should understand:

- The components needed for Ops Manager
- How to successfully install Ops Manager

*Notes:*

### Install Ops Manager

A Linux machine with at least 15GB of RAM is required

*Notes:*

### Install Ops Manager

We will follow an outline of the installation instructions here:

<https://docs.opsmanager.mongodb.com/current/tutorial/install-basic-deployment/>

*Notes:*

### Exercise #1

Prepare your environment for running all Ops Manager components: Monitoring, Automation, and Backups

- Set up a 3 node replica set for the Ops Manager application database (2 data bearing nodes, 1 arbiter)
- Set up a 3 node replica set for Ops Manager backups (2 data bearing nodes, 1 arbiter)
- Verify both replica sets have been installed and configured correctly

*Notes:*

## Exercise #2

Install the Ops Manager application

- Ops Manager application requires a license for commercial use
- Download the Ops manager application (after completing form): <http://www.mongodb.com/download>
- Installation instructions (from above): [docs.opsmanager.mongodb.com](https://docs.opsmanager.mongodb.com)
- Verify Ops Manager is running successfully

*Notes:*

## Exercise #3

Install the Ops Manager Backup Daemon

- The Ops Manager backup daemon is required for using Ops Manager for backups
- Download and install the backup daemon (using the link from the past exercise)
- Verify the installation was successful by looking at the logs in: `<install_dir>/logs`

*Notes:*

## Exercise #4

Verify the Ops Manager installation was successful:

<https://docs.opsmanager.mongodb.com/current/tutorial/test-new-deployment/>

*Notes:*

## Exercise #5

Use Ops Manager to backup a test cluster:

- Create a 1 node replica set via Ops Manager automation
- Add sample data to the replica set:

```
> for (var i=0; i<10000; i++) { db.blog.insert( { "name" : i } ) }  
WriteResult({ "nInserted" : 1 })  
> db.blog.count()  
10000
```

- Use Ops Manager to backup the test cluster
- Perform a restore via Ops Manager of the test cluster

*Notes:*

## 8 Performance Troubleshooting

*Performance Troubleshooting (page 181)* An introduction to reporting and diagnostic tools for MongoDB.

### 8.1 Performance Troubleshooting

#### Learning Objectives

Upon completing this module students should understand basic performance troubleshooting techniques and tools including:

- `mongostat`
- `mongotop`
- `db.setProfilingLevel()`
- `db.currentOp()`
- `db.<COLLECTION>.stats()`
- `db.serverStatus()`

*Notes:*

#### **mongostat and mongotop**

- `mongostat` samples a server every second.
  - See current ops, pagefaults, network traffic, etc.
  - Does not give a view into historic performance; use MMS for that.
- `mongotop` looks at the time spent on reads/writes in each collection.

*Notes:*

### Exercise: mongostat (setup)

In one window, perform the following commands.

```
db.testcol.drop()
for (i=1; i<=10000; i++) {
  arr = [];
  for (j=1; j<=1000; j++) {
    doc = { _id: (1000 * (i-1) + j), a: i, b: j, c: (1000 * (i-1) + j) };
    arr.push(doc)
  };
  db.testcol.insert(arr);
  var x = db.testcol.find( { b : 255 } );
  x.next();
  var x = db.testcol.find( { _id : 1000 * (i-1) + 255 } );
  x.next();
  var x = "asdf";
  db.testcol.update( { a : i, b : 255 }, { $set : { d : x.pad(1000) } });
  print(i)
}
```

*Notes:*

### Exercise: mongostat (run)

- In another window/tab, run mongostat.
- You will see:
  - Inserts
  - Queries
  - Updates

*Notes:*



### Exercise: mongostat (create index)

- In a third window, create an index when you see things slowing down:

```
db.testcol.createIndex( { a : 1, b : 1 } )
```

- Look at mongostat.
- Notice that things are going significantly faster.
- Then, let's drop that and build another index.

```
db.testcol.dropIndexes()  
db.testcol.createIndex( { b : 1, a : 1 } )
```

*Notes:*

### Exercise: mongotop

Perform the following then, in another window, run mongotop.

```
db.testcol.drop()  
for (i=1; i<=10000; i++) {  
  arr = [];  
  for (j=1; j<=1000; j++) {  
    doc = { _id: (1000*(i-1)+j), a: i, b: j, c: (1000*(i-1)+j) };  
    arr.push(doc)  
  };  
  db.testcol.insert(arr);  
  var x = db.testcol.find( {b: 255} ); x.next();  
  var x = db.testcol.find( { _id: 1000*(i-1)+255 } ); x.next();  
  var x = "asdf";  
  db.testcol.update( {a: i, b: 255}, { $set: {d: x.pad(1000)}} );  
  print(i)  
}
```

*Notes:*

## db.currentOp()

- currentOp is a tool that asks what the db is doing at the moment.
- currentOp is useful for finding long-running processes.
- Fields of interest:
  - microsecs\_running
  - op
  - query
  - lock
  - waitingForLock

*Notes:*

## Exercise: db.currentOp()

Do the following then, connect with a separate shell, and repeatedly run db.currentOp().

```
db.testcol.drop()
for (i=1; i<=10000; i++) {
  arr = [];
  for (j=1; j<=1000; j++) {
    doc = {_id: (1000*(i-1)+j), a: i, b: j, c: (1000*(i-1)+j)};
    arr.push(doc)
  };
  db.testcol.insert(arr);
  var x = db.testcol.find( {b: 255} ); x.next();
  var x = db.testcol.find( {_id: 1000*(i-1)+255 } ); x.next();
  var x = "asdf";
  db.testcol.update( {a: i, b: 255}, {$set: {d: x.pad(1000)}});
  print(i)
}
```

*Notes:*

## **db.<COLLECTION>.stats()**

- Used to view the current stats for a collection.
- Everything is in bytes; use the multiplier parameter to view in KB, MB, etc
- You can also use db.stats() to do this at scope of the entire database

*Notes:*

## **Exercise: Using Collection Stats**

Look at the output of the following:

```
db.testcol.drop()
db.testcol.insert( { a : 1 } )
db.testcol.stats()
var x = "asdf"
db.testcol2.insert( { a : x.pad(10000000) } )
db.testcol2.stats()
db.stats()
```

*Notes:*

## **The Profiler**

- Off by default.
- To reset, db.setProfilerLevel(0)
- At setting 1, it captures “slow” queries.
- You may define what “slow” is.
- Default is 100ms: db.setProfilerLevel(1)
- E.g., to capture 20 ms: db.setProfilerLevel(1, 20)

*Notes:*

## The Profiler (continued)

- If the profiler level is 2, it captures all queries.
  - This will severely impact performance.
  - Turns all reads into writes.
- Always turn the profiler off when done (set level to 0)
- Creates `db.system.profile` collection

*Notes:*

## Exercise: Exploring the Profiler

Perform the following, then look in your `db.system.profile`.

```
db.setProfilingLevel(0)
db.testcol.drop()
db.system.profile.drop()
db.setProfilingLevel(2)
db.testcol.insert( { a : 1 } )
db.testcol.find()
var x = "asdf"
db.testcol.insert( { a : x.pad(10000000) } ) // ~10 MB
db.setProfilingLevel(0)
db.system.profile.find().pretty()
```

*Notes:*

## `db.serverStatus()`

- Takes a snapshot of server status.
- By taking diffs, you can see system trends.
- Most of the data that MMS gets is from here.

*Notes:*

### Exercise: Using `db.serverStatus()`

- Open up two windows. In the first, type:

```
db.testcol.drop()
var x = "asdf"
for (i=0; i<=10000000; i++) {
  db.testcol.insert( { a : x.pad(100000) } )
}
```

- In the second window, type periodically:

```
var x = db.serverStatus(); x.metrics.document
```

*Notes:*

### Analyzing Profiler Data

- Enable the profiler at default settings.
- Run for 5 seconds.
- Slow operations are captured.
- The issue is there is not a proper index on the message field.
- Allow class to discover this as the data is examined.
- You will see how fast documents are getting inserted.
- It will be slow b/c the documents are big.

*Notes:*

### Performance Improvement Techniques

- Appropriate write concerns
- Bulk operations
- Good schema design
- Good Shard Key choice
- Good indexes

*Notes:*

## Performance Tips: Write Concern

- Increasing the write concern increases data safety.
- This will have an impact on performance, however.
- This is especially true when there are network issues.

*Notes:*

## Bulk Operations

- Using bulk operations can improve performance, especially when using write concern greater than 1.
- These enable the server to bulk write and bulk acknowledge.
- Can be done with both inserts and updates.

*Notes:*

## Exercise: Comparing bulk inserts with mongostat

Let's spin up a 3-member replica set:

```
mkdir -p /data/replset/{1,2,3}
mongod --logpath /data/replset/1/mongod.log \
      --dbpath /data/replset/1 --replSet mySet --port 27017 --fork
mongod --logpath /data/replset/2/mongod.log \
      --dbpath /data/replset/2 --replSet mySet --port 27018 --fork
mongod --logpath /data/replset/3/mongod.log \
      --dbpath /data/replset/3 --replSet mySet --port 27019 --fork

echo "conf = {_id: 'mySet', members: [{_id: 0, host: 'localhost:27017'}, \
    {_id: 1, host: 'localhost:27018'}, {_id: 2, host: 'localhost:27019'}]}; \
rs.initiate(conf)" | mongo
```

*Notes:*

### **mongostat, bulk inserts with {w: 1}**

Perform the following, with writeConcern : 1 and no bulk inserts:

```
db.testcol.drop()
for (i=1; i<=10000; i++) {
  for (j=1; j<=1000; j++) {
    db.testcol.insert( { _id : (1000 * (i-1) + j),
                        a : i, b : j, c : (1000 * (i-1) + j) },
                      { writeConcern : { w : 1 } } );
  };
  print(i);
}
```

Run mongostat and see how fast that happens.

*Notes:*

### **Bulk inserts with {w: 3}**

Increase the write concern to 3 (safer but slower):

```
db.testcol.drop()
for (i=1; i<=10000; i++) {
  for (j=1; j<=1000; j++) {
    db.testcol.insert(
      { _id: (1000 * (i-1) + j), a: i, b: j, c: (1000 * (i-1) + j) },
      { writeConcern: { w: 3 } }
    );
  };
  print(i);
}
```

Again, run mongostat.

*Notes:*

## **mongostat, bulk inserts with {w: 3}**

- Finally, let's use bulk inserts to our advantage:
- Note that writeConcern is still { w: 3 }

```
db.testcol.drop()
for (i=1; i<=10000; i++) {
  arr = []
  for (j=1; j<=1000; j++) {
    arr.push(
      { _id: (1000 * (i-1) + j), a: i, b: j, c: (1000 * (i-1) + j) }
    );
  }
  db.testcol.insert( arr, { writeConcern : { w : 3 } } );
  print(i);
}
```

*Notes:*

## **Schema Design**

- The structure of documents affects performance.
- Optimize for your application's read/write patterns.
- We want as few requests to the database as possible to perform a given application task.
- See the data modeling section for more information.

*Notes:*

## **Shard Key Considerations**

- Choose a shard key that distributes load across your cluster.
- Create a shard key such that only a small number of documents will have the same value.
- Create a shard key that has a high degree of randomness.
- Your shard key should enable a mongos to target a single shard for a given query.

*Notes:*



## Indexes and Performance

- Reads and writes that don't use an index will cripple performance.
- In compound indexes, order matters:
  - Sort on a field that comes before any range used in the index.
  - You can't skip fields; they must be used in order.
  - Revisit the indexing section for more detail.

*Notes:*

## 9 Backup and Recovery

*Backup and Recovery* (page 192) An overview of backup options for MongoDB.

### 9.1 Backup and Recovery

#### Disasters Do Happen



*Notes:*

## Human Disasters



*Notes:*

### Terminology: RPO vs. RTO

- **Recovery Point Objective (RPO):** How much data can you afford to lose?
- **Recovery Time Objective (RTO):** How long can you afford to be off-line?

*Notes:*

## Terminology: DR vs. HA

- **Disaster Recovery (DR)**
- **High Availability (HA)**
- Distinct business requirements
- Technical solutions may converge

*Notes:*

## Quiz

- Q: What's the hardest thing about backups?
- A: Restoring them!
- **Regularly test that restoration works!**

*Notes:*

## Backup Options

- Document Level
  - Logical
  - `mongodump`, `mongorestore`
- File system level
  - Physical
  - Copy files
  - Volume/disk snapshots

*Notes:*

## Document Level: mongodump

- Dumps collection to BSON files
- Mirrors your structure
- Can be run live or in offline mode
- Does not include indexes (rebuilt during restore)
- `--dbpath` for direct file access
- `--oplog` to record oplog while backing up
- `--query/filter` selective dump

*Notes:*

## **mongodump**

```
$ mongodump --help
```

Export MongoDB data to BSON files.

options:

<code>--help</code>	produce help message
<code>-v [ --verbose ]</code>	be more verbose (include multiple times for more verbosity e.g. <code>-vvvvv</code> )
<code>--version</code>	print the program's version and exit
<code>-h [ --host ] arg</code>	mongo host to connect to ( <code>/s1,s2</code> for
<code>--port arg</code>	server port. Can also use <code>--host hostname</code>
<code>-u [ --username ] arg</code>	username
<code>-p [ --password ] arg</code>	password
<code>--dbpath arg</code>	directly access mongod database files in path
<code>-d [ --db ] arg</code>	database to use
<code>-c [ --collection ] arg</code>	collection to use (some commands)
<code>-o [ --out ] arg (=dump)</code>	output directory or "-" for stdout
<code>-q [ --query ] arg</code>	json query
<code>--oplog</code>	Use oplog for point-in-time snapshotting

*Notes:*

## File System Level

- **Must use journaling!**
- Copy `/data/db` files
- Or snapshot volume (e.g., LVM, SAN, EBS)
- *Seriously, always use journaling!*

*Notes:*

## Ensure Consistency

Flush RAM to disk and stop accepting writes:

- `db.fsyncLock()`
- Copy/Snapshot
- `db.fsyncUnlock()`

*Notes:*

## File System Backups: Pros and Cons

- Entire database
- Backup files will be large
- Fastest way to create a backup
- Fastest way to restore a backup

*Notes:*

### **Document Level: mongorestore**

- mongorestore
- --oplogReplay replay oplog to point-in-time

*Notes:*

### **File System Restores**

- All database files
- Selected databases or collections
- Replay Oplog

*Notes:*

### **Backup Sharded Cluster**

1. Stop Balancer (and wait) or no balancing window
2. Stop one config server (data R/O)
3. Backup Data (shards, config)
4. Restart config server
5. Resume Balancer

*Notes:*

## Restore Sharded Cluster

1. Dissimilar # shards to restore to
2. Different shard keys?
3. Selective restores
4. Consolidate shards
5. Changing addresses of config/shards

*Notes:*

## Tips and Tricks

- mongodump/mongorestore
  - --oplog[Replay]
  - --objcheck/--repair
  - --dbpath
  - --query/--filter
- bsondump
  - inspect data at console
- LVM snapshot time/space tradeoff
  - Multi-EBS (RAID) backup
  - clean up snapshots

*Notes:*

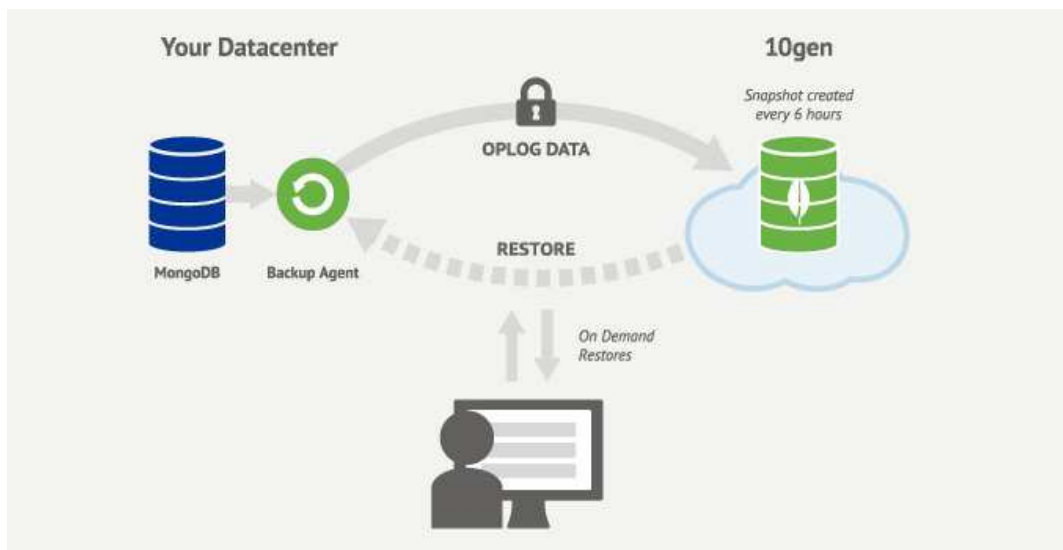


## Backup Options

- You can do it yourself as outlined in this section so far
- Or have the people who created MongoDB run your backups

*Notes:*

## MMS Backup



*Notes:*

## Sharded Clusters

- Balancer paused every 6 hours
- A no-op token is inserted across all shards, mongos instances, and config servers
- Oplog applied to replica sets until point in which token was inserted
- Provides a consistent state of database across shards

*Notes:*

## **Under the Hood**

- From the initial sync, we rebuild your data in our datacenters and take a snapshot
- We take snapshots every 6 hours
- Oplog is stored for 48 hours

*Notes:*

## **Key Benefits**

- Point in time backups
- Easy to restore
- Unlimited resources
- Fully managed

*Notes:*

## **Point in Time Backups**

- Oplog stored for 48 hours
- Restore your replica set to any point-in-time in the last 48 hours by creating a custom snapshot

*Notes:*

## Easy to Restore

- Pull from custom URL
- Push via scp

*Notes:*

## Unlimited Restores

- Confidence in your restore process
- Build development, QA, analytics environments without impacting production

*Notes:*

## Fully Managed

- Created by the engineers that build MongoDB
- No need to write or maintain custom backup scripts

*Notes:*

## Getting Started

- Go to <https://mms.mongodb.com> and sign up

*Notes:*







**Find out more**

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