UpGrad Rise

MongoDB - Session1

What do you learn ?

- ➔ What is MongoDB and the document model
- ➔ MongoDB Storage Engine and internals
- ➔ Indexes and optimizations
- ➔ CRUD operations
- ➔ Aggregation framework basics

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Introduction to MongoDB

- MongoDB is a Database
- It manages and keeps your data stored on a server
- Manages concurrency
- Manages security
- Optimises retrieval
- It is Distributed
- It can scale horizontally(sharding)
- It has native replication support and automatic fault tolerance

Comparison of MongoDB as popular general-purpose database with others

Cassandra:- is a nosql DB which can store data in a wide column format or store data in column family format. Also it acts as a multi master DB where you can read/write from multiple nodes at the same time.
Disadvantage:- It has inherent issues with consistency because of merging data from multiple master nodes.

Redis:- is also a popular Cache layer DB. All data is held in the cache layer and it helps data retrieval very fast.
Disadvantage:- If your DB aborts, then you lose all data as it is a volatile memory.

CosmosDB:- Is a DB from Microsoft which also uses the multimaster setup and it also is a growing NoSQL DB.
Disadvantage:- you cannot hold more than 2MB of data per document

MongoDB:- It is also a noSQL Database which tries to bridge the gap between the disadvantages of using one NoSQL technology over the other.

With MongoDB :-

- Schema matters and can be rigidly enforced by the server(schema validation)
- All values have a definite data type(string, integer, date etc)
- Data is stored in an efficient binary format on disk
- You can use extensive Indexing
- You can join data together
- You can perform atomic updates
- Transactions are supported
- You can calculate aggregations and summarize data
- You can query with SQL as well

Data Model Comparison

Tabular Data Model

- Relational data models are tabular in nature
- Records are called Rows
- One value per field
- Columns are called attributes

Example of an RDBMS table:-

firstname	lastname	dob
Soumen	Chatterjee	1990-10-01

Document data model

- Document model typically has groups of fields(sub-documents)
- List of values(arrays)

Example of a document model:-

```
{
name : { first: "Soumen", last: "Chatterjee" }, dob: Date("1990-10-01"),
nicknames: ["Rony","chatterbox"]
}
```

Why use the document model?

- Related data is stored together
- Faster to retrieve
- Faster and easier to query
- More efficient when distributed over different servers
- Programming languages now have container types like lists, hashes, dicts etc which is in a way native to how mongodb stores data

Evolving an RDBMS schema:-

For every change in schema it is a costly Alter table statement which is essentially blocking in nature. Also the changes need extensive testing in lower to higher environments.

Name	Age	Phone number
Soumen	34	123456

Name	Age	Phone Number	Address
Soumen	34	123456	India

Name	age	Phonenumber	Phone number 2	address
Soumen	34	123456	098765	India

MongoDB Schema evolution:-

You do not need to alter the key value pairs like you will alter the table in RDBMS
You will just need to push the “Address”:”India” key-value pair to the same document.

{
“Name”: “Soumen”,
“address”:India,
“Age”: 34,
“Phone Number” : 123456
},

{
Name:Soumen,
Age:34,
Phone number: 123434556,
Address: India
}

{
Name: Soumen,
Age:”34”
}

{
Name:Soumen,
Age:34,
Phone Number:[123456, 098765,876543,….]

Address:”India”
}

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.
- Data in mongoDB is handled as a JSON payload
- A JSON is nothing but a set of Key value pairs.
- MongoDB stores these JSON’s internally as BSON
- BSON:- Binary serialized object notation of your JSON

BSON

- MongoDB stores data as Binary JSON (BSON).
- MongoDB drivers send and receive data in this format.
- similar to native programming language objects
- 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.

Note

- E.g., a BSON object will be mapped to a dictionary in Python.
- native language is the language understood by the computer.
- similar to a Python dictionary, which consists of a collection of key-value pairs.

BSON Hello World example

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


// BSON
```

```
x16 x0 x0 x0       // document size
  x2               // type 2=string
  h e l l o x0     // name of the field, null terminated
  x6 x0 x0 x0      // size of the string value
  w o r l d x0     // string value, null terminated
x0                 // end of document
```

Note

- http://bsonspec.org/spec.html
- size of the string includes the null character at the end
- the driver automatically creates the BSON documents

Terminology Comparison:-

RDBMS	**MongoDB**
Table	Collection
Row	Document
Column	Field
Primary Key	_id (analogous but not exactly similar)

TestCollection:- (Table in RDBMS)
{
_id:1, ← Primary key equivalent in RDBMS(always unique for each document)
Name: Soumen, ← Field which is equivalent to Column in RDBMS
Age: 34,
Address: India
}
,
{
_id:2,
Name: Soumen,
Address: India
}
,
{
_id:3,
Name:Soumen,
Age:34,
Address: India,
Phone number: 1234565

```
}
,
{
_id:4,
Name: Soumen,
Age: “34”,
Address: “India”,
Phone Number:[123456,987654]
},

{
_id:5,
Name: Soumen,
Age: 34,
Contact: [{ Facebook Link: FBLINK#,
                FB opened since: 2010},
                {Linkedin: Link for linkedin,
                Linkedin opened since: 2012},
                {Twitter  link: twitter#,
                Twitter opened since: 2015}
                ]
Address: “India”,
Phone Number: [123456,987654]
}
```

Limitations:-

- 16 MB only BSON limit
- >16 MB documents? you have to use GRIDFS in MongoDB

Difference between _id and ObjectId

The _id Field

- All documents must have an _id field.
- It can be a string, number or sub-document.

- If no _id is specified when a document is inserted, MongoDB will add the _id field as an ObjectId.
- Most drivers will create the ObjectId if no _id is specified.
- acts as the Primary *key* for replication.
- Some restrictions:
    - The _id is immutable.
    - Cannot be an array.
    - The _id field must be unique within a collection.

ObjectId

An ObjectId consists of:

- a 4-byte value representing the seconds since the Unix epoch,
- a 5-byte random value, and
- a 3-byte counter, starting with a random value.

The combination of these parts makes an ObjectId value highly unlikely to have a collision in the World. It is not guaranteed to be unique.

Example :- ObjectId("58dc309ce3f39998099d6275")

This makes it a good candidate for the _id field of a collection, which must be unique within the collection.

Note

- An ObjectId is a 12-byte value.
- More info at : https://docs.mongodb.com/manual/reference/method/ObjectId/

MongoDB Internals

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.
- Talk through the diagram and how storage engines are used to abstract access to the data

WiredTiger Storage Engine

WiredTiger Features

- Notable features of the WiredTiger storage engine include:
    - Compression
    - Document-level concurrency
    - Checkpoints
    - Journaling

Note

- Compression in WT by default will compress collections and indexes using snappy. Alternative compression options are none, zstd or zlib.
- Document-level concurrency in WT allows for updates on different documents from multiple clients in a collection at the same time.
- WT uses MultiVersion Concurrency Control (MVCC) to isolate read and write operations to ensure clients see a consistent point in time view of the data at the start of an operation.
- WiredTiger checkpointing creates a consistent point-in-time snapshot of the data and occurs every 60 seconds. It involves writing all the data in the snapshot to disk and updating the related metadata.

WiredTiger Journaling

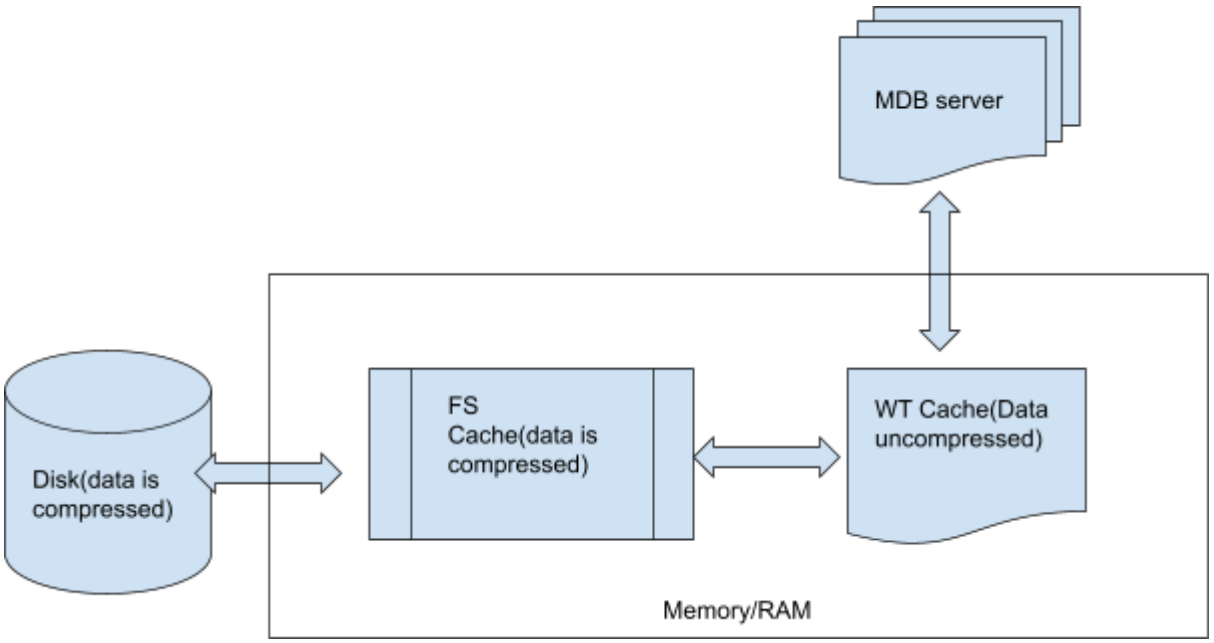
- WiredTiger uses a write-ahead log (journal) in combination with checkpoints to ensure durability. A write-ahead log stores modifications before they are applied.
- Regardless of storage engine, always use journaling in production.
- Journaling with checkpoint ensures there is no point in time where data might be lost if there was a failure of the mongod process.

Note

- By default, the WiredTiger journal is compressed using snappy.
- In terms of journaling, the file itself is written to disk every 50 milliseconds. A new journal file is created after every 100 MB of data has been processed, with the old file being then synced.

WiredTiger Data Persistence Mechanics

- WiredTiger commits a checkpoint to disk every 60 seconds.
- Between and during checkpoints the data files are always valid.
- The WiredTiger journal persists all data modifications between checkpoints.
- If MongoDB aborts between checkpoints, it uses the journal to replay all data modified since the last checkpoint.



CRUD - Basic database interactions

- Create - insertOne(), insertMany()
- Read - find()
- Update - updateOne(), updateMany()
- Delete - deleteOne(), deleteMany()

The Many variants apply to multiple documents, insertMany takes an array of documents.

InsertOne()

- Adds a new document
- Adds _id if you dont provide one
- Tells you if it succeeds

Examples:-

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

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

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

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

InsertMany()

- Adds multiple new documents
- Single network trip
- Tells you what succeeded
- Can be ordered if required
- Stops on error if ordered

Examples:-

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

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

find() and findOne()

- Get documents from the collections, returns a cursor typically
- Can filter by content(query)

- Can filter what is returned(projection)
- findOne() just returns the first document

Examples:-

```
RDBMS query:- SELECT a,b,c FROM sc.mytab WHERE x=1 AND y=2

mongoDB query:- db.mytab.find({x:1, y:2}, {a:1, b:1, c:1})

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

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

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

Find projections:-

- Use {fieldname: 1} to include a field
- Use {fieldname : 0} to exclude a field

Signature:-

```
db.collection.find( { <query> }, { <projection> } )
```

Examples:-

```
db.movies.insertOne(
{
   "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 Anegeles", "state" : "CA", "country" : "USA" }
   ],
   "box_office" : {
     "gross" : 557,
```

```
    "opening_weekend" : 24,
    "budget" : 55
  }
 })

// find movie where title equals forrest gump and project only title and rating fields
db.movies.findOne( { "title" : "Forrest Gump" },
                   { "title" : 1, "imdb_rating" : 1 } )
```

UpdateOne()

- Updates a single document within the collection based on the filter.
    - Only modifies the **first document found**.
- Takes two required parameters:
    - The query filter.
        - Uses the same query selectors as in the find() method.
    - The update specification which can be one of two possibilities:
        - A document that contains update operator expressions.
        - An aggregation pipeline with update stages.

$set and $unset

- $set replaces the value of a field with the specified value.

Syntax:-
{ $set: { <field1>: <value1>, ... } }

- If the field does not exist, $set will add a new field with the specified value.
- Only specified fields will change.
- Alternatively, remove a field using $unset

Examples:-

```
db.movies.insertMany( [
  {
    "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
  }
] )


db.movies.updateOne( { "title" : "Batman" },
                { $set : { "imdb_rating" : 7.7 } } )
db.movies.updateOne( { "title" : "Godzilla" },
                { $set : { "budget" : 1 } } )
db.movies.updateOne( { "title" : "Home Alone" },
                { $set : { "budget" : 15,
                           "imdb_rating" : 5.5 } } )
db.movies.updateOne( { "title" : "Home Alone" },
                { $unset :  { "budget" : 1 } } )
db.movies.find()
```

Update Operators

- $inc: Increments the value of the field by the specified amount.
- $mul: Multiplies the value of the field by the specified amount.
- $rename: Renames a field.
- $set: Sets the value of a field in a document.
- $unset Removes the specified field from a document.
- $min: Only updates the field if the specified value is less than the existing field value.
- $max: Only updates the field if the specified value is greater than the existing field value.
- $currentDate: Sets the value of a field to current date, either as a Date or a Timestamp.
- $setOnInsert: Assigns the specified values to the fields in the document only if upsert: true.

Examples:-

```
db.movies.updateOne( { title: "Batman" }, { $inc: { "imdb_rating" : 2 } } )
db.movies.updateOne( { title: "Home Alone" }, { $inc: { "budget" : 5 } } )
db.movies.updateOne( { title: "Batman" }, { $mul: { "imdb_rating" : 4 } } )
db.movies.updateOne( { title: "Batman" },
                { $rename: { budget: "estimated_budget" } } )
db.movies.updateOne( { title: "Home Alone" }, { $min: { budget: 5 } } )
db.movies.updateOne( { title: "Home Alone" },
    { $currentDate : { last_updated: { $type: "timestamp" } } } )
// increment movie rating by 1
db.movie_mentions.updateOne( { title: "Batman" },
    { $inc:  { "imdb_rating" : 1 } } )
```

updateMany()

- Takes the same arguments as updateOne()
- Updates all documents that match the specified filter for a collection.
    - updateOne stops after the first match.
    - updateMany runs until it has matched all documents for the given filter.

Warning

Without an appropriate index, you might end up scanning every document in the collection.

Examples:-

```
// let's start tracking the number of sequals for each movie
db.movies.updateOne( { }, { $set : { "sequels" : 0 } } )
db.movies.find()
// we need updateMany to change all documents
db.movies.updateMany( { }, { $set : { "sequels" : 0 } } )
db.movies.find()
```

deleteOne()

- Removes a single document from a collection, given a query filter as the argument.
- The first document in the collection matching the query filter will be deleted.
- Specify an empty document { } to delete the first document returned in the collection.
- This command requires the query filter argument.

deleteMany()

- Removes all documents that match the query filter from a collection.
- All documents in the collection matching the query filter will be deleted.
- To delete all documents in a collection, pass in an empty document { }.
- This command requires the query filter argument.

Examples:-

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

db.testcol.deleteMany( { a : 1 } )  // Delete 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.deleteMany( { a : { $lt : 5 } } )  // Remove three more

db.testcol.deleteOne( { a : { $lt : 10 } } )  // Remove one more

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

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

Student practice handouts and more examples on CRUD:-

```
***CRUD***

**Inserting Documents**

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

//Ordered Insertmany
db.movies.insertMany( [ { "_id" : "Batman", "year" : 1989 },
{ "_id" : "Home Alone", "year" : 1990 },{ "_id" : "Ghostbusters", "year" : 1984 },
{ "_id" : "Ghostbusters", "year" : 1984 } ] )

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

db.movies.find()

//The mongo Shell is a JS interpreter
for (i=1; i<=10000; i++) { db.stuff.insertOne( { "a" : i } )}
db.stuff.find()


//Deleteting Documents
```

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

db.testcol.deleteMany( { a : 1 } )
db.testcol.deleteMany( { a : { $lt : 5 } } )

db.testcol.deleteMany( { } )

Dropping a collection

db.testcol.drop()

//Dropping a database

use <databasename>
db  //to confirm we are in the intended db to be dropped

db.dropDatabase()


***Reading Documents***

//find() method
it returns a cursor but findOne() always returns a document

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

db.movies.find( { "year" : 1975 } )
db.movies.find( { "year" : 1989, "title" : "Batman" } )


//Querying Arrays
db.movies.find( { "category" : "action" } )
db.movies.find( { "category" : [ "action", "adventure", "sci-fi" ] } )
db.movies.find( { "category" : [ "action", "sci-fi" ] } ) // no documents

//qyerying with dot notation

db.movies.insertMany( [{
        "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
db.movies.find( { "box_office.gross" : 760 } ) // expected value

**Projections**
db.movies.insertOne(
{
   "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 Anegeles", "state" : "CA", "country" : "USA" }
   ],
   "box_office" : {
     "gross" : 557,
     "opening_weekend" : 24,
     "budget" : 55
} })

db.movies.findOne( { "title" : "Forrest Gump" },
                   { "title" : 1, "imdb_rating" : 1 } )



**Cursor methods**
//Count
db.testcol.drop()
for (i=1; i<=100; i++) { db.testcol.insertOne( { 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(  )


//Sort
db.testcol.drop()
for (i=1; i<=20; i++) {
    db.testcol.insertOne( { 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 } )
```

Query Operators

```
// insert sample data
db.movies.insertMany( [
  { "title" : "Batman",
    "category" : [ "action", "adventure" ],
    "imdb_rating" : 7.6,
    "budget" : 35,
    "roten_tomatoes": 7.1 },
  { "title" : "Godzilla",
    "category" : [ "action", "adventure", "sci-fi" ],
    "imdb_rating" : 6.6,
    "roten_tomatoes": 8.0},
  { "title" : "Home Alone",
    "category" : [ "family", "comedy" ],
    "imdb_rating" : 7.4,
    "roten_tomatoes": 6.3 } ] )

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" ] } } )
```

Logical operators

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

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

//$exists

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

Array Query operators

```
//Array field must contain all values listed.
db.movies.find( { "category" : { $all : [ "sci-fi", "action" ] } } )
//Array must have a particular size. E.g.,$size: 3 means 3 elements in the array
db.movies.find( { "category" : { $size : 3 } } )
```

$elemmatch

```
db.movies.insertOne( {
"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"
}}})
```

Updating Documents

```
db.movies.insertOne( { title: "Batman" } )
db.movies.find()
db.movies.replaceOne( { title : "Batman" }, { imdb_rating : 7.7 } )
db.movies.find()
db.movies.replaceOne( { imdb_rating: 7.7 },
                    { title: "Batman", imdb_rating: 7.7 } )
db.movies.find()
db.movies.replaceOne( { }, { title: "Batman" } )
db.movies.find() // back in original state

db.movies.replaceOne( { }, { _id : ObjectId() } ) // Can anyone tell why this will
fail??


db.movies.updateOne( { "title" : "Batman" },
                    { $set : { "imdb_rating" : 7.7 } } )
db.movies.updateOne( { "title" : "Godzilla" },
                    { $set : { "budget" : 1 } } )
db.movies.updateOne( { "title" : "Home Alone" },
                    { $set : { "budget" : 15,
                              "imdb_rating" : 5.5 } } )
db.movies.updateOne( { "title" : "Home Alone" },{$unset: {"budget":1}})
db.movies.find()
```

update operators

```
db.movies.updateOne( { title: "Batman" }, { $inc: { "imdb_rating" : 2 } } )
db.movies.updateOne( { title: "Home Alone" }, { $inc: { "budget" : 5 } } )
db.movies.updateOne( { title: "Batman" }, { $mul: { "imdb_rating" : 4 } } )
db.movies.updateOne( { title: "Batman" },
                    { $rename: { budget: "estimated_budget" } } )
db.movies.updateOne( { title: "Home Alone" }, { $min: { budget: 5 } } )
db.movies.updateOne( { title: "Home Alone" },
```

```
     { $currentDate : { last_updated: { $type: "timestamp" } } } )
// increment movie rating by 1
db.movie_mentions.updateOne( { title: "Batman" },
     { $inc:  { "imdb_rating" : 1 } } )
```

UpdateMany() Method
Updates all documents that match
– updateOne stops after the first match
– updateMany continues until it has matched all

Array updates

```
db.movie_mentions.insertOne(
   { "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, 0 ]
})
// update all mentions for the fifth hour of the day
db.movie_mentions.updateOne(
   { "title" : "E.T." } ,
   { "$set" :  { "mentions_per_hour.5" : 2300 } } )
```

Array Operators

```
db.movies.updateOne(
   { "title" : "Batman" },
   { $push : { "category" : "superhero" } } )
db.movies.updateOne(
   { "title" : "Batman" },
   { $pop : { "category" : 1 } } )
db.movies.updateOne(
   { "title" : "Batman" },
   { $pull : { "category" : "action" } } )
db.movies.updateOne(
   { "title" : "Batman" },
   { $pullAll : { "category" : [ "villain", "comic-based" ] } } )

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

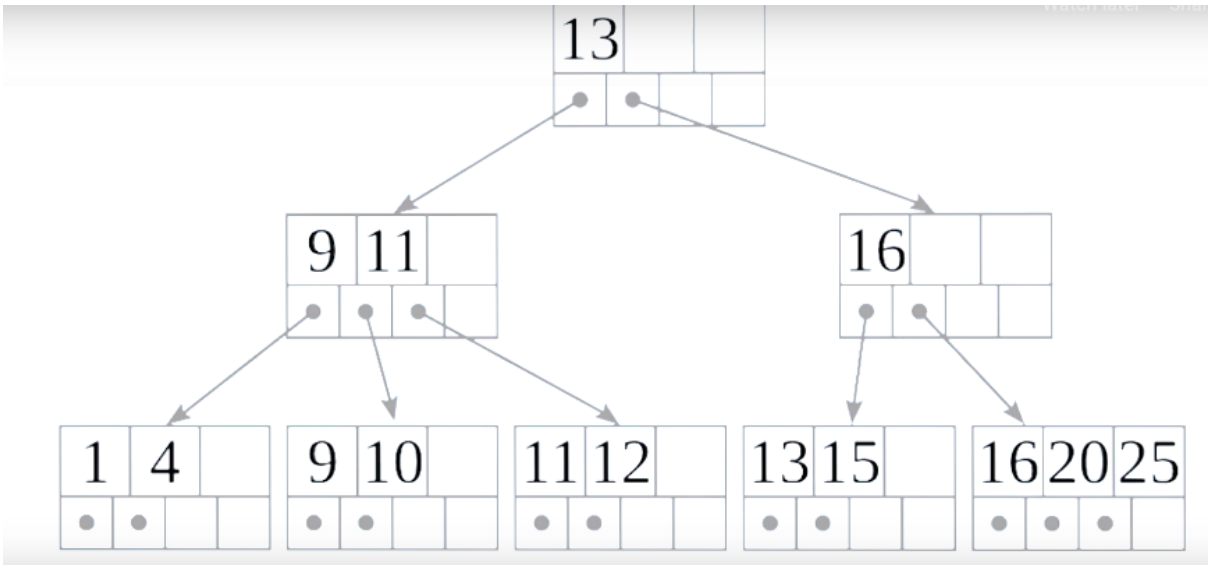
Positional Operator

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

Upserts

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

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


**findOneAndUpdate()**
//Makes a read and write atomic

db.worker_queue.findOneAndUpdate(
{ state : "unprocessed" },
{ $set: { "worker_id" : 123, "state" : "processing" } }, { upsert: true } )


**findOneAndDelete()**

db.foo.drop();
db.foo.insertMany( [ { a : 1 }, { a : 2 }, { a : 3 } ] ); db.foo.find();
// shows the documents.
 db.foo.findOneAndDelete( { a : { $lte : 3 } } ); db.foo.find();
```

MongoDB Indexing and Performance: -



Types of Indexes:-

- Single field
- Compound
- Multikey
- Geospatial
- Text
- Wildcard

Single field Index:-

Db.collection.createIndex({a:1})

{
_id:1,
Doc_identifier: “ixah”(hidden)
a:34
name:xyz,
…
}
,
{
_id:2,
Doc_identifier: “b12h”(hidden)
a:100,
name:lzxr,
…
}

Index field (a)	Document Identifier(pointer)
34	“ixah”
100	“b12h”

Query:- db.collection.find({a:100}) -> read the above index value and corresponding identifier and return the document which is as below:-

{
a:100,
name:lzxr,
…
}

Compound Index:-

a	b	c
12	356	109
34	876	546
986	32	876
12	11	234
1	11	870
56	23	409
78	54	307

a	b	c
1	11	234
12	11	870
12	356	109
34	876	546
56	23	409
78	54	307
986	32	876

Example:-

```
{
Identifier: XYZ
A: 1,
B: 100,
C:345
}

Db.collection.createIndex({a:1,b:1,c:1})<- here the order matters!
```

Quiz Time:-
Hint:- Index Prefix: a ; a,b ; a,b,c…. if there are index prefix in the query (in any order) then it can use the compound index otherwise not

```
Db.coll.find({a:1000})<-
Db.coll.find({b:23, c:98})<-
Db.coll.find({b:87, a:23})<-
Db.coll.find({b:67})<-
Db.coll.find({c:45})<-
Db.coll.find({c:23,a:89,b:100})<-
Db.coll.find({c:20, a:30})<-
```

- **You can create upto 64 indexes on a collection.**
- **In a Compound Index there can be at most 32 fields.**
- **The best practice should be not to create more than 10-12 indexes on a collection.**

Multikey Indexes:-

Any index created on an array field is called a multikey Index

{
a:100,
b:[“Red”, “Green”, “Blue”]
}
,
{
a:500,
b:[“India”, “Canada”, “UAE”]
}

db.collection.createIndex({b:1}) ← multikey index

All the fields within an array will be indexed, meaning all the fields of the array will be stored as the index keys.

Red	Pointer to the doc
Green	Pointer to the doc
Blue	Pointer to the doc

India	Pointer to the doc
Canada	Pointer to the doc
UAE	Pointer to the doc

{
A:100,
B:[
{
Name: “Soumen”,

```
        Age: 34
    },
    {
        Name: “Ravi”,
        Age: 26
    }
]
```

db.coll.find({“B.Name”:”Soumen”})

db.coll.createIndex({B:1})<- multikey index

{ Name: “Soumen”, Age: 34 }	Pointer to the same doc
{ Name: “Ravi”, Age: 26 }	Pointer to the same doc

Restriction on Multikey Indexes:-

You cannot define Multikey Indexes with 2 array fields at the same time

{
a:[1,2,3],
b:[“abc”,”xyz”,”qwerty”],
c: [123,876,098, 12, 76, 90, 45, 34, 097, 345, 23456, 987, ……1000000],
d: “Soumen”
}

db.col.createIndex({a:1,d:1}) <- allowed in mongoDB
{a:1, c:1} <- not allowed!
{a:1, b:1} <- not allowed!
{b:1, c:1} <- not allowed!

{a:1,b:1,c:1…….32 fields for each index}
total number of indexes on a single collection cannot exceed 64

db.collection.createIndex({a:1, b:1, c:1}) not allowed in mongoDB and this will throw an error
how many keys:- 10000000000000 not allowed because of space constraints!

mXn array in this case each field of the array will be indexed which makes the index huge in size and it is also unbounded.

[1,2,3,4,5,6,7,8…….] unbounded array

Partial Filter key Indexes :-

(sometimes called as Sparse Indexes)
You can pass query filter criteria for creating Indexes which will only Index those documents which actually meet the filter criteria and skip the others. This gives you a way to create more efficient indexes which are very lightweight and easy to maintain.

TTL Indexes(Time –to –Live Indexes)

Very useful in housekeeping activities
Can delete/drop documents based on a time period criteria.

Amazon big billion day sale example:-

Promotion collections:-
{
Prod_name : “Apple iphone”,
Discount: 60%
CreatedAt: now()<- current time
},
{
Prod_name:” Macbook air”,
Discount: 80%,
CreatedAt: now()<- current time
}

TTL index on CreateAt: expire after 24 hrs

More examples on Indexing:-

```
Geospatial Indexes:-
Used for Lat/long queries

***Geospatial Indexing 2dsphere indexes***
//Insert Data
db.places.insert(
   {
```

```
    loc : { type: "Point", coordinates: [ -73.97, 40.77 ] },
    name: "Central Park",
    category : "Parks"
  }
)

db.places.insert(
  {
    loc : { type: "Point", coordinates: [ -73.88, 40.78 ] },
    name: "La Guardia Airport",
    category : "Airport"
  }
)

//Create Index
db.places.createIndex( { loc : "2dsphere" } )

//Querying 2d sphere indexes
db.places.find( { loc :
                { $geoWithin :
                  { $geometry :
                    { type : "Polygon" ,
                      coordinates : [ [
                                      [ 0 , 0 ] ,
                                      [ 3 , 6 ] ,
                                      [ 6 , 1 ] ,
                                      [ 0 , 0 ]
                                    ] ]
            } } } } )

***Text Indexes***

//Insert Data
db.articles.insert(
  [
    { _id: 1, subject: "coffee", author: "xyz", views: 50 },
    { _id: 2, subject: "Coffee Shopping", author: "efg", views: 5 },
    { _id: 3, subject: "Baking a cake", author: "abc", views: 90  },
    { _id: 4, subject: "baking", author: "xyz", views: 100 },
    { _id: 5, subject: "Café Con Leche", author: "abc", views: 200 },
    { _id: 6, subject: "Сырники", author: "jkl", views: 80 },
    { _id: 7, subject: "coffee and cream", author: "efg", views: 10 },
    { _id: 8, subject: "Cafe con Leche", author: "xyz", views: 10 }
  ]
)

//create Index
db.articles.createIndex( { subject: "text" } )
```

```
//Serach a single word
db.articles.find( { $text: { $search: "coffee" } } )

//Match any of the search terms( space separated values are converted to logical
OR)
db.articles.find( { $text: { $search: "bake coffee cake" } } )

//Search for a phrase
db.articles.find( { $text: { $search: "\"coffee shop\"" } } )

//Case insensitive searches, both the below returns the same set of results
db.articles.find( { $text: { $search: " CAFE" } } )
db.articles.find( { $text: { $search: "cafe" } } )

//Performing case-sensitive search
db.articles.find( { $text: { $search: "Coffee", $caseSensitive: true } } )



**WildCard Indexes Example***
Lets assume we have a Movie being released in different countries:-

{
_id: 100,
Movie_name: “Titanic”,
Release_US: ISODate(“date1”),
Release_UK: ISODate(“date2”),
Release_China: ISODate(“date3”),
…
}

Attribute Pattern:- (schema design policy)
{
_id: 100,
Movie_name: “Titanic”,
Releases: [
                {Country: “USA” , TS: “ISODate(“date1”) },
                {Country: “UK” , TS: “ISODate(“date2”) },
                {Country: “China” , TS: “ISODate(“date3”) },
]
…
…

}
Db.coll.createIndex({releases:1}) <- Multikey Index
```

```
//For example, documents in the product_catalog collection may contain a
product_attributes field. The product_attributes field can contain arbitrary nested
fields, including embedded documents and arrays:

{
  "product_name" : "Spy Coat",
  "product_attributes" : {
    "material" : [ "Tweed", "Wool", "Leather" ]
    "size" : {
      "length" : 72,
      "units" : "inches",
     “width” : 36,

    }
  }
}

{
  "product_name" : "Spy Pen",
  "product_attributes" : {
     "colors" : [ "Blue", "Black" ],
     "secret_feature" : {
       "name" : "laser",
       "power" : "1000",
       "units" : "watts",
     }
  }
}

//The following operation creates a wildcard index on the product_attributes field:
db.products_catalog.createIndex( { "product_attributes.$**" : 1 } )

//The wildcard index can support arbitrary single-field queries on product_attributes
or its embedded fields
db.products_catalog.find( { "product_attributes.size.length" : { $gt : 60 } } )
db.products_catalog.find( { "product_attributes.material" : "Leather" } )
db.products_catalog.find( { "product_attributes.secret_feature.name" : "laser" } )

//You can also create Wildcard indexes on all fields
db.collection.createIndex( { "$**" : 1 } )

//Create a Wildcard Index on Multiple Specific Fields
db.collection.createIndex(
  { "$**" : 1 },
  { "wildcardProjection" :
    { "fieldA" : 1, "fieldB.fieldC" : 1 }
  }
)
```

```
***Index properties***

//create TTL indexes
db.log_events.createIndex( { "createdAt": 1 }, { expireAfterSeconds: 60 } )

***TTL Indexes***
// insert docs
db.log_events.insert( {
   "createdAt": new Date(),
   "logEvent": 2,
   "logMessage": "Success!"
} )

***Partial Indexing***
//Create a Partial Index On A Collection
//Consider a collection restaurants containing documents that resemble the
following

{
   "_id" : ObjectId("5641f6a7522545bc535b5dc9"),
   "address" : {
      "building" : "1007",
      "coord" : [
         -73.856077,
         40.848447
      ],
      "street" : "Morris Park Ave",
      "zipcode" : "10462"
   },
   "borough" : "Bronx",
   "cuisine" : "Bakery",
   "rating" : { "date" : ISODate("2014-03-03T00:00:00Z"),
                "grade" : "A",
                "score" : 2
              },
   "name" : "Morris Park Bake Shop",
   "restaurant_id" : "30075445"
}

//You could add a partial index on the borough and cuisine fields choosing only to
index documents where the rating.grade field is A
db.restaurants.createIndex(
   { borough: 1, cuisine: 1 },
   { partialFilterExpression: { 'rating.grade': { $eq: "A" } } }
)

//Index will be used by below query
db.restaurants.find( { borough: "Bronx", 'rating.grade': "A" } )
```

```
//Index wont be used by below query, why?
db.restaurants.find( { borough: "Bronx", cuisine: "Bakery" } )


***Case Insensitive Indexes***
//The following example creates a collection fruit, then adds an index on the type
field with a case insensitive collation

db.createCollection("fruit")

db.fruit.createIndex( { type: 1},
                      { collation: { locale: 'en', strength: 2 } } )

//To use the index, queries must specify the same collation
db.fruit.insert( [ { type: "apple" },
                   { type: "Apple" },
                   { type: "APPLE" } ] )

// does not use index, finds one result
db.fruit.find( { type: "apple" } )

// uses the index, finds three results
db.fruit.find( { type: "apple" } ).collation( { locale: 'en', strength: 2 } )

//You can specify a default collation while creating a collection also and then any
index you create on that will inherit the default collation

db.createCollection("names", { collation: { locale: 'en_US', strength: 2 } } )

db.names.createIndex( { first_name: 1 } ) // inherits the default collation

//insert data
db.names.insert( [ { first_name: "Betsy" },
                   { first_name: "BETSY"},
                   { first_name: "betsy"} ] )

db.names.find( { first_name: "betsy" } )
// inherits the default collation: { collation: { locale: 'en_US', strength: 2 } }
// finds three results


***Hidden Indexes***  mongodb v 4.4 +
//create hidden index
db.addresses.createIndex(
   { borough: 1 },
   { hidden: true }
)

// If you want to hide an existing index
```

```
db.restaurants.hideIndex( { borough: 1, ratings: 1 } ) // Specify the index key specification document

//Unhide a hidden index
db.restaurants.unhideIndex( { borough: 1, city: 1 } )  // Specify the index key specification document

Index1 , Collscan , Secondary Index

Optimizer always chooses Index 1 for a query

Hide Index1 and then run the query so that it uses Index2

$hint({student_id:1})
```

ESR principle:- (Equality, Sort and Range)

- Hold true for compound Indexes.
- High Cardinality means highly Unique Values for a field.
- Choose the highest cardinal field as the first field for your compound Index.
- Equality before Sort
- Sort before Range

MongoDB allocated only 32MB of RAM space for in-memory sort
If the sort fields go beyond the 32 MB size then the query will be aborted by MongoDB.
In-memory sort is not a good option in mongoDB.

Example:-

```
Query -> Db.collection.find({a:34}).sort({b:-1})
Index - >Db.collection.createIndex({a:1})
```

- MongoDB will try to fetch all the records/docs by reading the Index keys for a.
- It will run an in-memory sort on all the b field values for sorting it in descending order.

- It will gather the details/documents and return the result.
- Disclaimer:- If the 2nd Step takes more than 32MB space on RAM then the query will be aborted.

How can we avoid this?

We can create Index like the below:-

```
Db.collection.createIndex({a:1,b:-1})
```

Reading an explain Output from MongoDB:-

Explain("executionStats") → This gives you the output of the explain result along with details of how much time the query took and how many indexes it read, vs how many documents returned vs how many documents read.

Always look out for the below metrics or pointers:-

Ratio of nreturned vs total keysexamined
Totalkeysexamined/nreturned should always be 1 or less than 1

Additionaly, ratio of nreturned vs totaldocsexamined
Totaldocsexamined/nreturned should always be 1 or less than 1

If the above ratios are high like 100 or 1000 or more than it means that you are not using indexing properly or the query is running without indexes.

Golden Rules for Indexing in MongoDB:-

1. Ensure that you are using all of the indexes created in the project.
2. Ensure all or most of the queries are using indexes in the project.

MongoDB Optimizer:-

MongoDB optimizer is a non-statistics based optimizer, This means the optimizer works on Heuristics or practical experience to fetch a result set.

MongoDb has something called "Hints". You can use hints to give hints to the optimizer to chose a particular plan over the other.

ESR Examples student practice set:-

```
***Indexing in MongoDB ESR***
//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.insertMany(a)



//Create a simple Index
db.messages.createIndex( { timestamp : 1 }, { name : "myindex" } )

//Range queries
db.messages.find( { timestamp: { $gte: 2, $lte: 4 } } ).explain("executionStats")

//Analyse the above explain output, can we improve it?


//Equality Plus Range Query
db.messages.dropIndex( "myindex" );
db.messages.createIndex( { timestamp : 1, username : 1 },
                    { name : "myindex" } )
db.messages.explain("executionStats").find( { timestamp : { $gte : 2, $lte : 4 },
                  username : "anonymous" } )

//Let's try a different compound index by Putting the equality condition as first part
of the index
db.messages.dropIndex( "myindex" );
db.messages.createIndex( { username : 1 , timestamp : 1 },
                    { name : "myindex" } )

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


//Equality, Range Query, And Sort
db.messages.explain("executionStats").find( {
                  timestamp : { $gte : 2, $lte : 4 },
                  username : "anonymous"
                } ).sort( { rating : -1 } );


//Let's investigate using In-Memory sort
db.messages.dropIndex( "myindex" );
db.messages.createIndex( { username : 1 , timestamp : 1, rating : 1 },
```

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


//How do we avoid in-memory sort by improving the index and optimizing the query further with ESR index build?
db.messages.dropIndex( "myindex" );
db.messages.createIndex( { username : 1, rating : 1, timestamp : 1 },
                    { name : "myindex" } );
db.messages.explain("executionStats").find( {
                  timestamp : { $gte : 2, $lte : 4 },
                  username : "anonymous"
                } ).sort( { rating : -1 } );
```

The Aggregation Pipeline

- An aggregation pipeline is analogous to a UNIX pipeline.
- A series of document transformations executed in stages:
    - original input is a collection
    - output is either a cursor or a collection
- A pipeline has the following syntax:

```
pipeline = [$stage1, $stage2, ...$stageN]
db.<COLLECTION>.aggregate( pipeline, { options } )
```

Aggregation Stages

- Each stage of the pipeline:
    - Receives a set of documents as input.
    - Performs an operation on those documents.
    - Produces a set of documents for use by the following stage.

Basic Aggregation Stages

- There are many aggregation stages but in this lesson we'll cover:

- $match: Similar to find()
- $project: Shapes documents
- $sort: Like the cursor method of the same name
- $group: Used to aggregate field values from multiple documents
- $limit: Used to limit the amount of documents returned

Similarities to SQL Operations

For those with a SQL background, the following is an overview of common SQL aggregation terms and functions and the corresponding MongoDB aggregation operators:

SQL Terms, Functions, and Concepts	MongoDB Aggregation Operators
WHERE	$match
GROUP BY	$group
SELECT	$match
ORDER BY	$sort
LIMIT	$limit

The Match Stage

- The $match operator works like the query phase of find()
- Documents in the pipeline that match the query document will be passed unmodified to the subsequent stages.
- $match is often the first operator used in an aggregation stage.
- Like other aggregation operators, $match can occur multiple times in a single pipeline.

Example:-

```
//Find the count of articles where score is between 70 and 90 or views is greater than equals 1000
db.articles.aggregate( [
  { $match: { $or: [ { score: { $gt: 70, $lt: 90 } }, { views: { $gte: 1000 } } ] } },
  { $group: { _id: null, count: { $sum: 1 } } }
```

```
] );
```

The Project Stage

- $project allows you to shape the documents into what you need for the next stage.
- The simplest form of shaping is using $project to select only the fields you are interested in.
- $project can also create new fields from other fields in the input document.
    - *E.g.*, you can pull a value out of an embedded document and put it at the top level.
    - *E.g.*, you can create a ratio from the values of two fields as pass along as a single field.
- $project produces 1 output document for every input document it sees.

Example:-

```
//pull out the address subdoc fields and project them as top level fields in the inspections collection under sample_training DB, also suppress the _id field.

db.inspections.aggregate({ $project:{ _id:0, "city":"$address.city", "zip": "$address.zip", "street":"$address.street" }}
```

The Add Fields Stage

- The $addFields operator outputs documents that contain all existing fields from the input documents and newly added fields.
- The $addFields stage is equivalent to a $project stage that explicitly specifies all existing fields in the input documents and adds the new fields.

Has the following form:

```
{ $addFields: { <newField>: <expression>, ... } }
```

Example:-

```
//Using the sample training database calculate the total homework, quiz  and finally add them all to find the total score

db.scores.aggregate( [
  {
    $addFields: {
      totalHomework: { $sum: "$homework" } ,
     totalQuiz: { $sum: "$quiz" }
    }
  },
 {
    $addFields: { totalScore:
     { $add: [ "$totalHomework", "$totalQuiz", "$extraCredit" ] } }
 }
] )
```

The Group Stage

- For those coming from the relational world, $group is similar to the SQL GROUP BY statement.
- $group operations require that we specify which field to group on.
- Documents with the same identifier will be aggregated together.
- With $group, we aggregate values using accumulators.

Group Aggregation Accumulators

Accumulators available in the group stage:

- $sum
- $avg
- $first
- $last
- $max
- $min
- $push
- $addToSet

Example:-

```
//Using the sample_training database, find the average trip duration for bikeid 14529
```

```
db.trips.aggregate([{$match:{ bikeid: 14529}}, {$group:{_id: "$bikeid",
"AvgTripsDuration":{$avg: "$tripduration"}}}])
```

Unwind Stage

E.g. if you have an inventory with the following document:

{ "_id" : 100, "item" : "Shirt", sizes: ["S", "M", "L"] }

You can use the $unwind stage to output a document for each element in the **sizes** array.

db.inventory.aggregate([{ $unwind : "$sizes" }])

This operation will return the following output:

{ "_id" : 100, "item" : "Shirt", "sizes" : "S" }
{ "_id" : 100, "item" : "Shirt", "sizes" : "M" }
{ "_id" : 100, "item" : "Shirt", "sizes" : "L" }

lookup Stage

- Pulls documents from a second collection into the aggregation pipeline.
    - In SQL terms, performs a left outer join.
    - The second collection must be **unsharded** and in the **same database**.
- To each input document, the $lookup stage adds a new array field whose elements are the matching documents from the **“joined”** collection.
- The $lookup stage passes these reshaped documents to the next stage.

Note

As a reminder: **SQL left outer join** is also known as **SQL left join**. Suppose, we want to join two tables: A and B. SQL left outer join returns all rows in the left table (A) and all the matching rows found in the right table (B). It means the result of the SQL left join always contains the rows in the left table.

$lookup Equality Match Syntax

Equality match between a field from the **input documents** with a field from the **documents of the "joined" collection**.

```
{
   $lookup:
     {
     from: <collection to join>,
     localField: <field from the input documents>,
     foreignField: <field from the documents of the "from" collection>,
     as: <output array field>
   }
}
```

Here is a corresponding pseudo-SQL statement:

```
SELECT *, <output array field>
FROM collection
WHERE <output array field> IN (SELECT *
            FROM <collection to join> WHERE <foreignField>=
<collection.localField>);
```

Example:-

```
db.classes.insert( [
   { _id: 1, title: "Reading is ...", enrollmentlist: [ "giraffe2", "pandabear", "artie" ], days: ["M",
"W", "F"] },
   { _id: 2, title: "But Writing ...", enrollmentlist: [ "giraffe1", "artie" ], days: ["T", "F"] }
])

db.members.insert( [
   { _id: 1, name: "artie", joined: new Date("2016-05-01"), status: "A" },
   { _id: 2, name: "giraffe", joined: new Date("2017-05-01"), status: "D" },
   { _id: 3, name: "giraffe1", joined: new Date("2017-10-01"), status: "A" },
   { _id: 4, name: "panda", joined: new Date("2018-10-11"), status: "A" },
   { _id: 5, name: "pandabear", joined: new Date("2018-12-01"), status: "A" },
   { _id: 6, name: "giraffe2", joined: new Date("2018-12-01"), status: "D" }
])









db.classes.aggregate([
   {
     $lookup:
       {
         from: "members",
         localField: "enrollmentlist",
         foreignField: "name",
         as: "enrollee_info"
```

```
    }
  }
])
```

Aggregations Optimizations

MongoDB will perform some optimizations automatically and others should be done keeping in mind the usecase:

- Try to limit the number of documents in the pipeline by puting the below stages in the beginning of the pipeline:-
    - $match
    - $skip
    - $limit
    - $sample
- Try to keep blocking operations at the end of the pipeline, they include:-
    - $sort without an index
    - $group
    - $bucket
    - $count
    - $facet
- Projection Optimization:
    - If the pipeline optimizer can determine all fields which are used by the pipeline it will only fetch the needed fields from the collection.
- Pipeline Sequence Optimization:
    - *Example:* A $sort followed by a $match will be executed as a $match followed by a $sort to reduce the number of documents to be sorted.
- Pipeline Coalescence Optimization:
    - *Example:* A $skip followed by a $limit will be executed as a $limit followed by a $skip
- A pipeline stage has a limit of 100 MBs of RAM.
- allowDiskUse : true allows you to get around this limit for all stages but $graphLookup which will ignore this option.
    - This will result in slower operations, as the results will be written to disk.

More examples and student practice handouts and exercises/answers:-

```
***grouping***

db.twitter.aggregate( [
   { "$group" : { "_id" : "$source",
                  "count" : { "$sum" : 1 } } },
```

```
    { "$sort" : { "count" : -1 } }
])


//distinct user screen name
db.twitter.aggregate([{$group:{_id:"$user.screen_name"}}])

//count of all documents in the twitter collection
db.twitter.aggregate([{$group:{_id:null , "count":{$sum:1}}}, {$project:{_id:0}}])

//the above can be verified by using below count query
db.twitter.find().count()



//sample dataset
db.sales.insertMany([
  { "_id" : 1, "item" : "abc", "price" : NumberDecimal("10"), "quantity" :
NumberInt("2"), "date" : ISODate("2014-03-01T08:00:00Z") },
  { "_id" : 2, "item" : "jkl", "price" : NumberDecimal("20"), "quantity" : NumberInt("1"),
"date" : ISODate("2014-03-01T09:00:00Z") },
  { "_id" : 3, "item" : "xyz", "price" : NumberDecimal("5"), "quantity" : NumberInt(
"10"), "date" : ISODate("2014-03-15T09:00:00Z") },
  { "_id" : 4, "item" : "xyz", "price" : NumberDecimal("5"), "quantity" :
NumberInt("20") , "date" : ISODate("2014-04-04T11:21:39.736Z") },
  { "_id" : 5, "item" : "abc", "price" : NumberDecimal("10"), "quantity" :
NumberInt("10") , "date" : ISODate("2014-04-04T21:23:13.331Z") },
  { "_id" : 6, "item" : "def", "price" : NumberDecimal("7.5"), "quantity": NumberInt("5"
) , "date" : ISODate("2015-06-04T05:08:13Z") },
  { "_id" : 7, "item" : "def", "price" : NumberDecimal("7.5"), "quantity":
NumberInt("10") , "date" : ISODate("2015-09-10T08:43:00Z") },
  { "_id" : 8, "item" : "abc", "price" : NumberDecimal("10"), "quantity" :
NumberInt("5" ) , "date" : ISODate("2016-02-06T20:20:13Z") },
])


//group by having
db.sales.aggregate(
  [
    // First Stage
    {
      $group :
        {
          _id : "$item",
          totalSaleAmount: { $sum: { $multiply: [ "$price", "$quantity" ] } }
        }
    },
    // Second Stage
    {
```

```
      $match: { "totalSaleAmount": { $gte: 100 } }
    }
  ]
)


Lookup //equivalent to left outer joins in RDBMS

lets say we have 2 collections

a and b

db.a.aggregate( [ {"$lookup": {
  from: "b", localField: "local", foreignField: "foreign", as: "results"  }
}])

//sample dataset

db.commentOnCategory.insertMany( [
   { category_id: "consulting",
     comment: "Consulting - giving advices" },
   { category_id: "consulting",
     comment: "Consulting - providing human resources" },
   { category_id: "enterprise",
     comment: "Enterprise - constructing starships" },
   { category_id: "finance",
     comment: "Finance - making money" },
   { category_id: "hardware",
     comment: "Hardware - from a hammer to a laptop" },
   { category_id: "software",
comment: "Software - everything else that is missing in order to have a solution¨→"
},
{ category_id: null,
comment: "Null - have not decided yet was the business is about" }] );

db.companies.aggregate( [
  { $match: { number_of_employees: { $gte: 200000 } } },
  { $sort : { number_of_employees: -1 } },
  { $lookup: {
      from: "commentOnCategory",
      localField: "category_code",
      foreignField: "category_id",
      as: "example_comments"
} },
{ $project: { _id :0, name: 1, number_of_employees: 1, example_comments: 1 } } ])


/* Facets, bucket and bucketAuto*/
```

```
db.vintage.insertMany([
  { "_id" : 1, "name" : "Tweed Trousers", "brand" : "Tweed", "year" : 1956,
    "price" : NumberDecimal("199.99"), "color" : "brown",
    "tags" : [ "pants", "trousers", "plaid" ]
  },
  { "_id" : 2, "name" : "Pink Panther", "brand" : "Skinner", "year" : 1926,
    "color" : "pink",
    "tags" : [ "silk", "pants"]
  },
  { "_id" : 3, "name" : "Pirate Shirt", "brand" : "Bohemian", "year" : 1972,
    "price" : NumberDecimal("99.99"), "color" : "white",
    "tags" : [ "cotton", "blouse" ]
  },
  { "_id" : 4, "name" : "Flapper Girl", "brand" : "JazzAge", "year" : 1922,
    "price" : NumberDecimal("299.99"), "color" : "red",
    "tags" : [ "silk", "dress"]
  },
  { "_id" : 5, "name" : "Casual Friday", "brand" : "Cardigan", "year" : 1955,
    "price" : NumberDecimal("199.99"), "color" : "blue",
    "tags" : [ "wool", "cardigan"  ] } ] )


db.vintage.aggregate( [
  {
    $facet: {
      "categorizedByTags": [  { $unwind: "$tags" },
                              { $sortByCount: "$tags" } ],
      // Filter out documents without a price e.g., _id: 7
      "categorizedByPrice": [ { $match: { price: { $exists: 1 } } },
                              { $bucket: {
                                 groupBy: "$price",
                                 boundaries: [  0, 150, 200, 300, 400 ],
                                 default: "Other",
                                 output: {
                                   "count": { $sum: 1 }} }} ],
      "categorizedByYears(Auto)": [ { $bucketAuto: {
                                      groupBy: "$year",
                                      buckets: 3 }} ] }} ]).pretty()

/* Graphlookup*/
use sample;
db.employees.insertMany([
  { "_id" : 1, "name" : "Dev" },
  { "_id" : 2, "name" : "Eliot", "reportsTo" : "Dev" },
  { "_id" : 3, "name" : "Ron", "reportsTo" : "Eliot" },
  { "_id" : 4, "name" : "Andrew", "reportsTo" : "Eliot" },
  { "_id" : 5, "name" : "Asya", "reportsTo" : "Ron" },
  { "_id" : 6, "name" : "Dan", "reportsTo" : "Andrew" }
])
```

```
db.employees.aggregate([
  {
    $match: { "name": "Dan" }
  }, {
    $graphLookup: {
      from: "employees",
      startWith: "$reportsTo",
      connectFromField: "reportsTo",
      connectToField: "name",
      as: "reportingHierarchy"
     }
  }
]).pretty()


//$indexStats used to analyse index usage in mongodb
db.collectionname.aggregate( [ { $indexStats: {} } ] )


***$expr stage***
//Consider monthly budget collection as below
db.monthlyBudget.insert({ "_id" : 1, "category" : "food", "budget": 400, "spent": 450
},
{ "_id" : 2, "category" : "drinks", "budget": 100, "spent": 150 },
{ "_id" : 3, "category" : "clothes", "budget": 100, "spent": 50 },
{ "_id" : 4, "category" : "misc", "budget": 500, "spent": 300 },
{ "_id" : 5, "category" : "travel", "budget": 200, "spent": 650 })

//The following operation uses $expr to find documents where the spent amount
exceeds the budget
db.monthlyBudget.find( { $expr: { $gt: [ "$spent" , "$budget" ] } } )

***$cond***
//The following example use a inventory collection with the following documents
db.inventory.insertMany([{ "_id" : 1, "item" : "abc1", qty: 300 },
{ "_id" : 2, "item" : "abc2", qty: 200 },
{ "_id" : 3, "item" : "xyz1", qty: 250 }])

//The following aggregation operation uses the $cond expression to set the
discount value to 30 if qty value is greater than or equal to 250 and to 20 if qty
value is less than 250
db.inventory.aggregate(
   [
     {
       $project:
        {
          item: 1,
          discount:
```

```
            {
              $cond: { if: { $gte: [ "$qty", 250 ] },
              then: 30,
              else: 20 }
            }
          }
      }
   ]
)

***$convert***
//Create a collection orders with the following documents
db.orders.insertMany( [
   { _id: 1, item: "apple", qty: 5, price: 10 },
   { _id: 2, item: "pie", qty: 10, price: NumberDecimal("20.0") },
   { _id: 3, item: "ice cream", qty: 2, price: "4.99" },
   { _id: 4, item: "almonds" },
   { _id: 5, item: "bananas", qty: 5000000000, price: NumberDecimal("1.25") }
] )

//convert the price to decimal and qty to integer
priceQtyConversionStage = {
   $addFields: {
      convertedPrice: { $convert: { input: "$price", to: "decimal", onError: "Error",
onNull: NumberDecimal("0") } },
      convertedQty: { $convert: {
         input: "$qty", to: "int",
         onError:{$concat:["Could not convert ", {$toString:"$qty"}, " to type integer."]},
         onNull: NumberInt("0")
      } },
   }
};

// run the aggregation stage on orders
db.orders.aggregate( [priceQtyConversionStage]).pretty()

***$let***
//A sales collection has the following documents
db.sales.insertMany([{ _id: 1, price: 10, tax: 0.50, applyDiscount: true },
{ _id: 2, price: 10, tax: 0.25, applyDiscount: false }])

//The following aggregation uses $let in the $project pipeline stage to calculate and
return the finalTotal for each document
db.sales.aggregate( [
   {
      $project: {
         finalTotal: {
            $let: {
               vars: {
```

```
                total: { $add: [ '$price', '$tax' ] },
                discounted: { $cond: { if: '$applyDiscount', then: 0.9, else: 1 } }
              },
              in: { $multiply: [ "$$total", "$$discounted" ] }
            }
          }
        }
      }
] )

***$map***
//create a sample collection named grades with the following documents
db.grade.insertMany([
  { _id: 1, quizzes: [ 5, 6, 7 ] },
  { _id: 2, quizzes: [ ] },
  { _id: 3, quizzes: [ 3, 8, 9 ] }
])

//The following aggregation operation uses $map with the $add expression to
increment each element in the quizzes array by 2
db.grade.aggregate(
   [
     { $project:
       { adjustedGrades:
         {
           $map:
             {
               input: "$quizzes",
               as: "grade",
               in: { $add: [ "$$grade", 2 ] }
             }
         }
       }
     }
   ]
)

//Convert celcius temp to Fahrenheit using Map
db.temperatures.insertMany([
  { "_id" : 1, "date" : ISODate("2019-06-23"), "tempsC" : [ 4, 12, 17 ] },
  { "_id" : 2, "date" : ISODate("2019-07-07"), "tempsC" : [ 14, 24, 11 ] },
  { "_id" : 3, "date" : ISODate("2019-10-30"), "tempsC" : [ 18, 6, 8 ] }
])

//Convert using map and ass a new field called "tempsF" using $addFields
db.temperatures.aggregate( [
   { $addFields:
     {
       "tempsF":
```

```
          { $map:
            {
              input: "$tempsC",
              as: "tempInCelsius",
              in: { $add: [ { $multiply: [ "$$tempInCelsius", 9/5 ] }, 32 ] }
            }
          }
      }
    },  {"$out" : "temperatures"}
] )

***$literal***
//records collection
db.records.insert(
{ "_id" : 1, "item" : "abc123", price: "$2.50" },
{ "_id" : 2, "item" : "xyz123", price: "1" },
{ "_id" : 3, "item" : "ijk123", price: "$1" })


//The following example uses a $literal expression to treat a string that contains a
dollar sign "$1" as a constant value.
db.records.aggregate( [
   { $project: { costsOneDollar: { $eq: [ "$price", { $literal: "$1" } ] } } }
] )


***$reduce***
//people collection
db.people.insertMany([
{ "_id" : 1, "name" : "Melissa", "hobbies" : [ "softball", "drawing", "reading" ] },
{ "_id" : 2, "name" : "Brad", "hobbies" : [ "gaming", "skateboarding" ] },
{ "_id" : 3, "name" : "Scott", "hobbies" : [ "basketball", "music", "fishing" ] },
{ "_id" : 4, "name" : "Tracey", "hobbies" : [ "acting", "yoga" ] },
{ "_id" : 5, "name" : "Josh", "hobbies" : [ "programming" ] },
{ "_id" : 6, "name" : "Claire" }])

// Concat all the hobbies into a single bio field as a string
db.people.aggregate(
   [
     // Filter to return only non-empty arrays
     { $match: { "hobbies": { $gt: [ ] } } },
     {
       $project: {
         "name": 1,
         "bio": {
           $reduce: {
             input: "$hobbies",
             initialValue: "My hobbies include:",
             in: {
```

```
            $concat: [
              "$$value",
              {
                $cond: {
                  if: { $eq: [ "$$value", "My hobbies include:" ] },
                  then: " ",
                  else: ", "
                }
              },
              "$$this"
            ]
          }
        }
      }
    }
  }
]
)
```

$replaceRoot
//$replaceRoot with a Document Nested in an Array
A collection named students contains the following documents

```
db.students.insertMany([
  {
    "_id" : 1,
    "grades" : [
      { "test": 1, "grade" : 80, "mean" : 75, "std" : 6 },
      { "test": 2, "grade" : 85, "mean" : 90, "std" : 4 },
      { "test": 3, "grade" : 95, "mean" : 85, "std" : 6 }
    ]
  },
  {
    "_id" : 2,
    "grades" : [
      { "test": 1, "grade" : 90, "mean" : 75, "std" : 6 },
      { "test": 2, "grade" : 87, "mean" : 90, "std" : 3 },
      { "test": 3, "grade" : 91, "mean" : 85, "std" : 4 }
    ]
  }
])

//output the grades as a top level documents
db.students.aggregate( [
  { $unwind: "$grades" },
  { $match: { "grades.grade" : { $gte: 90 } } },
  { $replaceRoot: { newRoot: "$grades" } }
] )
```

$redact

```
// insert documents into demo collection
db.demo.insertOne({"Value1":10,"Value2":20});
db.demo.insertOne({"Value1":40,"Value2":30,Value3:50});
db.demo.insertOne({"Value1":100,"Value2":200,Value3:null});
db.demo.insertOne({"Value1":400,"Value2":1000,Value3:null});
db.demo.insertOne({"Value1":400,"Value2":200,Value3:null});
db.demo.insertOne({"Value1":400,"Value2":1000,Value3:60});

//if value1 is less than value2 and value3 is not null then keep else prune

db.demo.aggregate( { "$redact": { "$cond": { "if": { "$and": [ {
   "$lt": [ "$Value1", "$Value2" ] }, { "$ifNull": [ "$Value3", false ] } ] },
   "then": "$$KEEP", "else": "$$PRUNE" } }
} )
```

****

Aggregation Practice queries

1.Use the aggregation framework to find the name of the individual who has made the most comments on a blog. Use the Posts collection under sample_training DB

2. Consider together cities in the states of California (CA) and New York (NY) with populations over 25,000. Calculate the average population of this sample of cities.

Please note:

- Different states might have the same city name.
- A city might have multiple zip codes.

Use the Zips collection under sample_training DB

3. Calculate the total number of people who live in a zip code in the US where the city starts with a digit. Use the Zips collection.

4. From the grades collection, find the class (display the class_id) with the highest average student performance on exams. To solve this problem you'll want an average of averages.

First calculate the average exam score of each student in each class. Then determine the average class exam score using these values. If you have not already done so, import the grades collection as follows.

5. For companies in our collection founded in 2004 and having 5 or more rounds of funding, calculate the average amount raised in each round of funding. Which company meeting these criteria raised the smallest average amount of money per funding round? You do not need to distinguish between currencies. Write an aggregation query to answer this question.

Exercises Answers:-

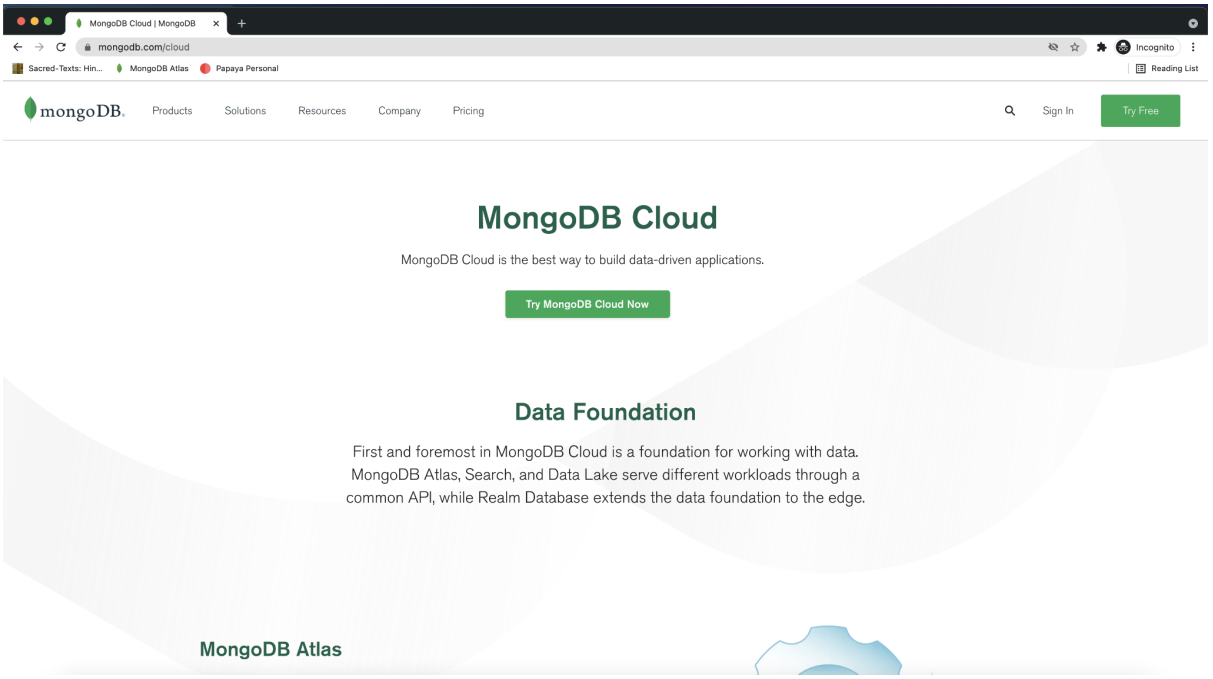
```
1. db.posts.aggregate([
  { "$unwind": "$comments" },
  { "$group":{
      _id: "$comments.author",
          num_comments: { $sum: 1 }
} },
      { "$sort": { "num_comments": 1 } },
      { "$limit": 10 }
    ])

2. db.zipcodes.aggregate( [
    { $match: { state: { $in: ["CA", "NY"] } } },
    { $group: { _id: { state: "$state", city: "$city" },
                pop: {$sum: "$pop"} } },
    { $match: { pop: {$gt: 25000} } },
{ $group: { _id: null,
pop: {$avg: "$pop"} } }
])

3. db.zips.aggregate( [
   { $project : {
       first_char: { $substr: [ "$city", 0, 1] },
       pop: 1,
       city: "$city",
       zip: "$_id",
state: 1 } },
   { $match : {
       first_char: { $in: [ '0', '1', '2', '3', '4', '5', '6', '7', '8', '9'] }
} }, {
"$group" : { _id: null,
population: { $sum : "$pop"} }
} ])
```

```
4. db.grades.aggregate([
   {$unwind: "$scores"},
   {$match: {"scores.type": "exam"}},
   {$group: {_id: {student_id: "$student_id", class_id: "$class_id"},
            student_avg: {$avg: "$scores.score"}}},
   {$group: {_id: {class_id: "$_id.class_id"},
            class_avg: {$avg: "$student_avg"}}},
   {$sort: {class_avg: -1}}
])

5. db.companies.aggregate( [
    { $match: { founded_year: 2004 } },
    { $project: {
        _id: 0,
        name: 1,
        funding_rounds: 1,
        num_rounds: { $size: "$funding_rounds" }
    } },
    { $match: { num_rounds: { $gte: 5 } } },
    { $project: {
        name: 1,
        avg_round: { $avg: "$funding_rounds.raised_amount" }
    } },
    { $sort: { avg_round: 1 } }
] ).pretty()
```

Appendix 1

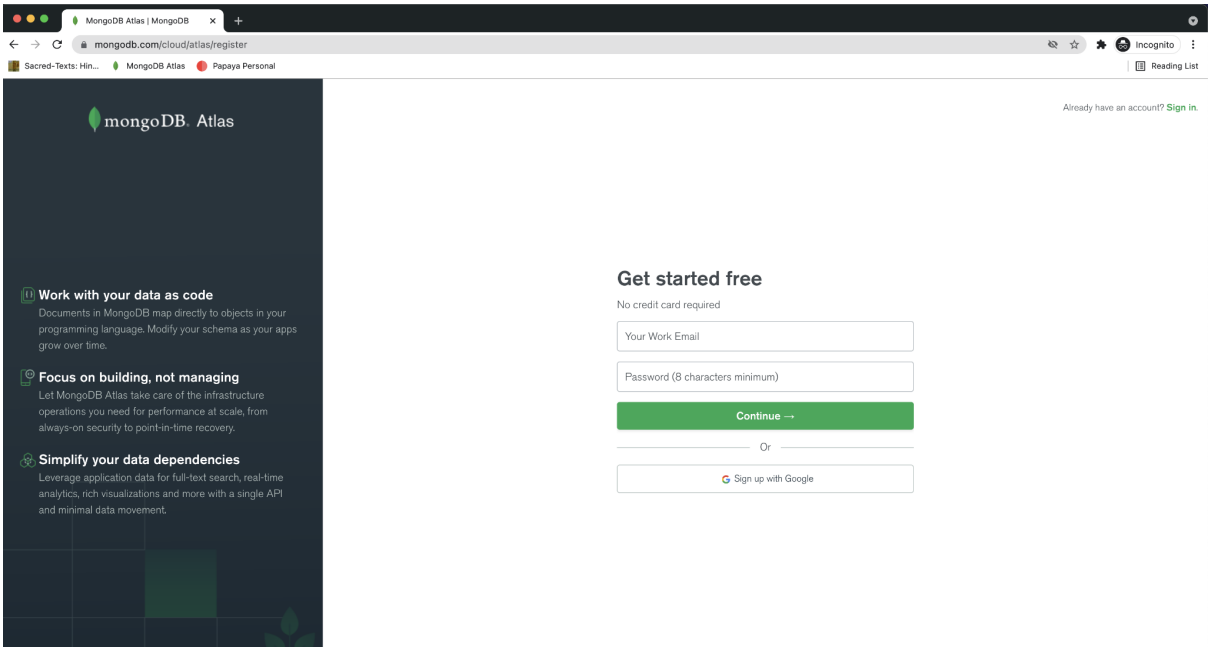
MongoDB Atlas Free tier setup for labs and hands on exercises

Go to MongoDB Cloud

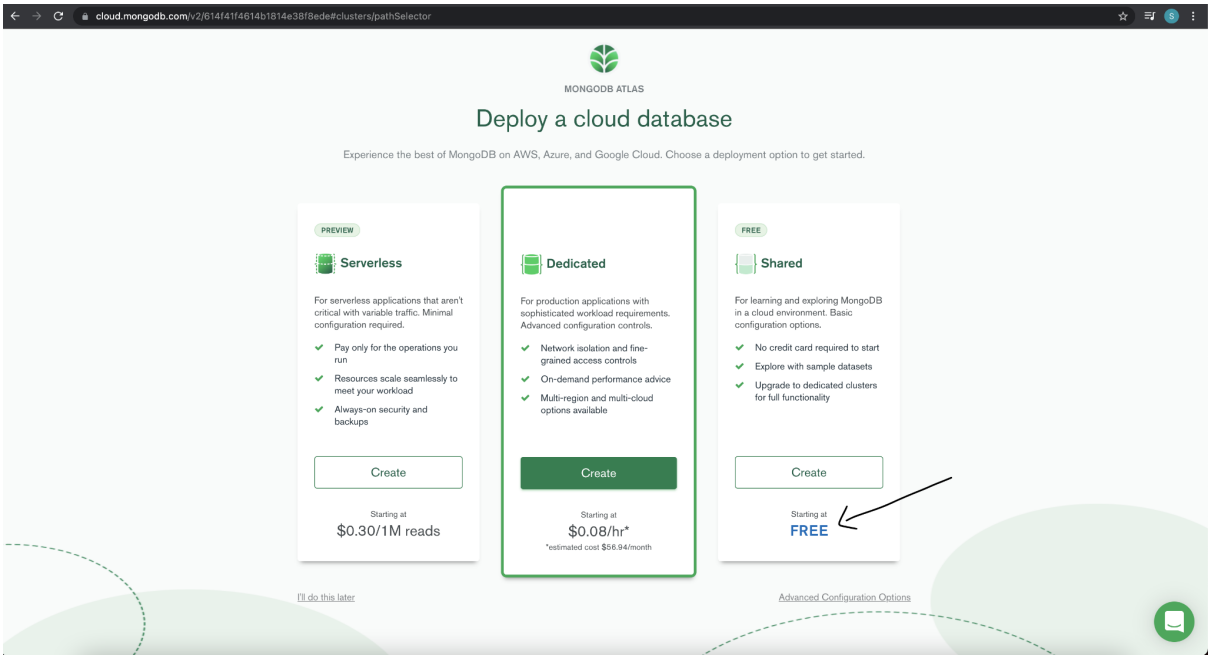


Url :- https://cloud.mongodb.com

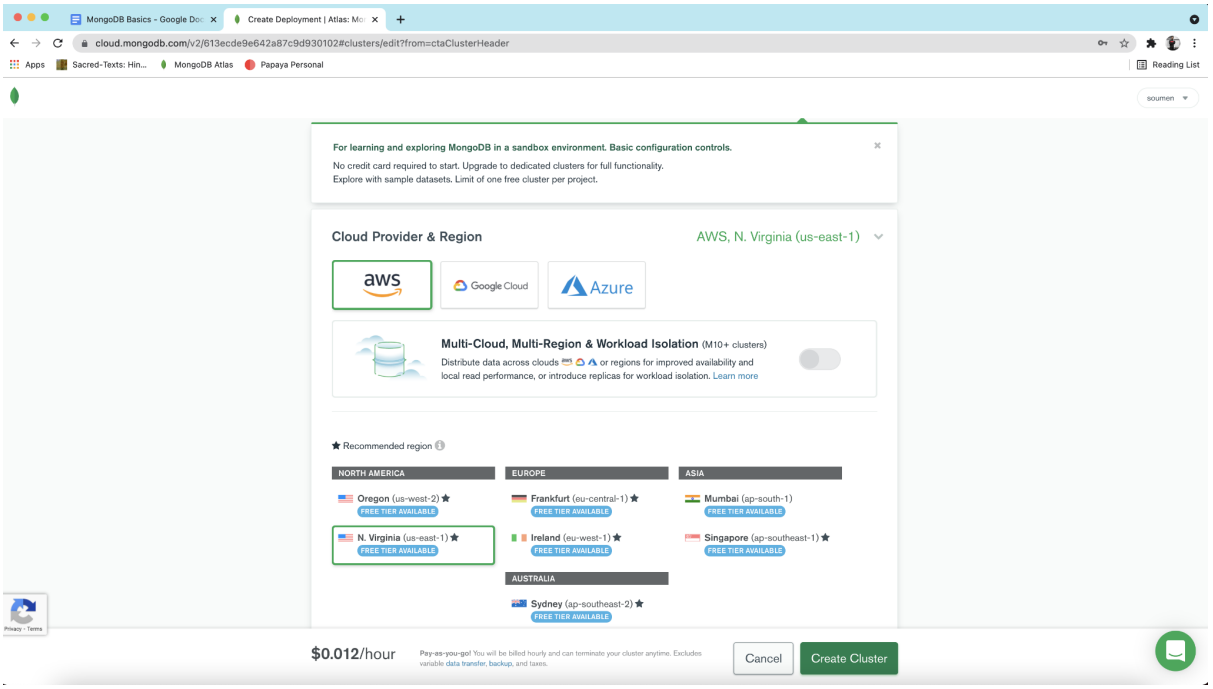
Signup or Sign In



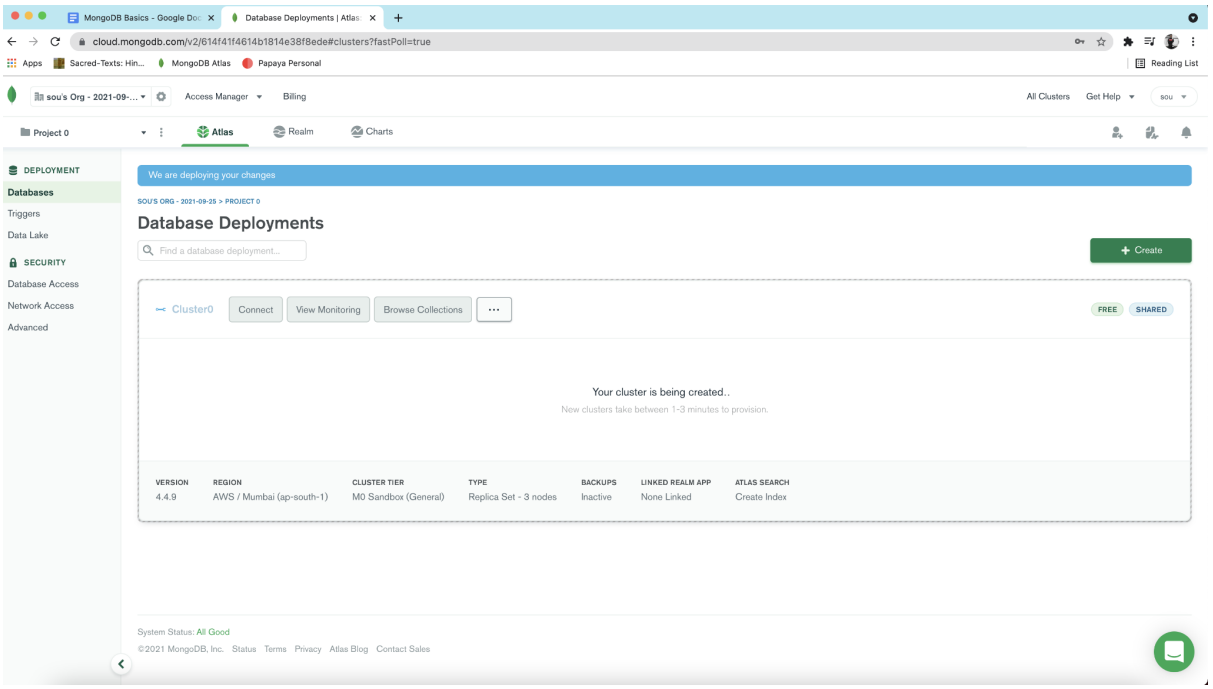
Choose a free tier cluster



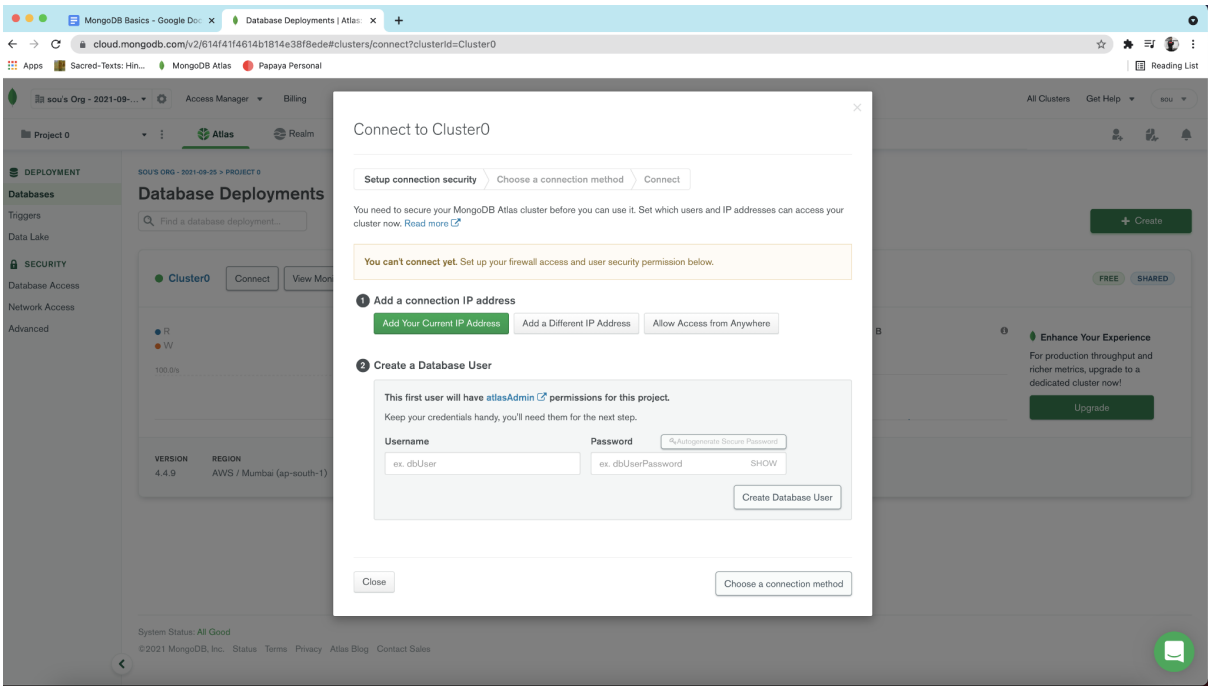
Select options and create(keep the others as default)



Wait for the cluster to startup(it typically takes around 7 mins to deploy)

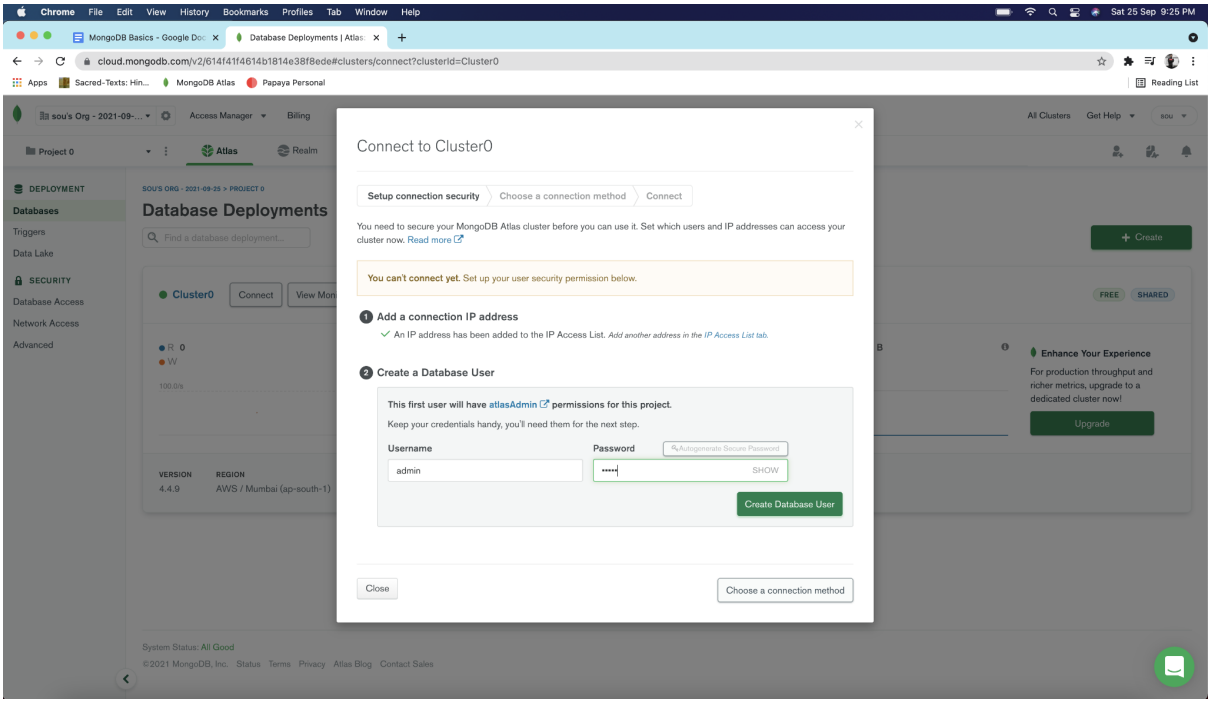


Setup the IP whitelisting and create a DB User

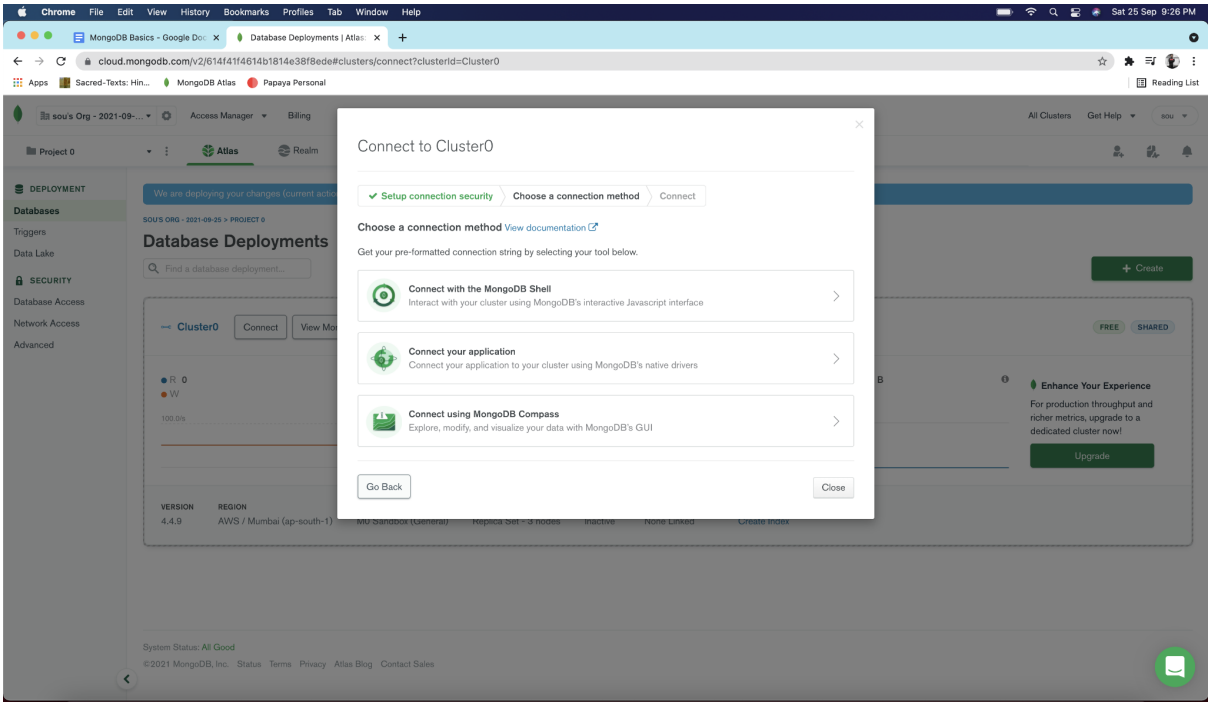


Click “Connect” . Atlas requires you to specify what hosts can connect to your cluster for security reasons. We recommend you to add your IP address

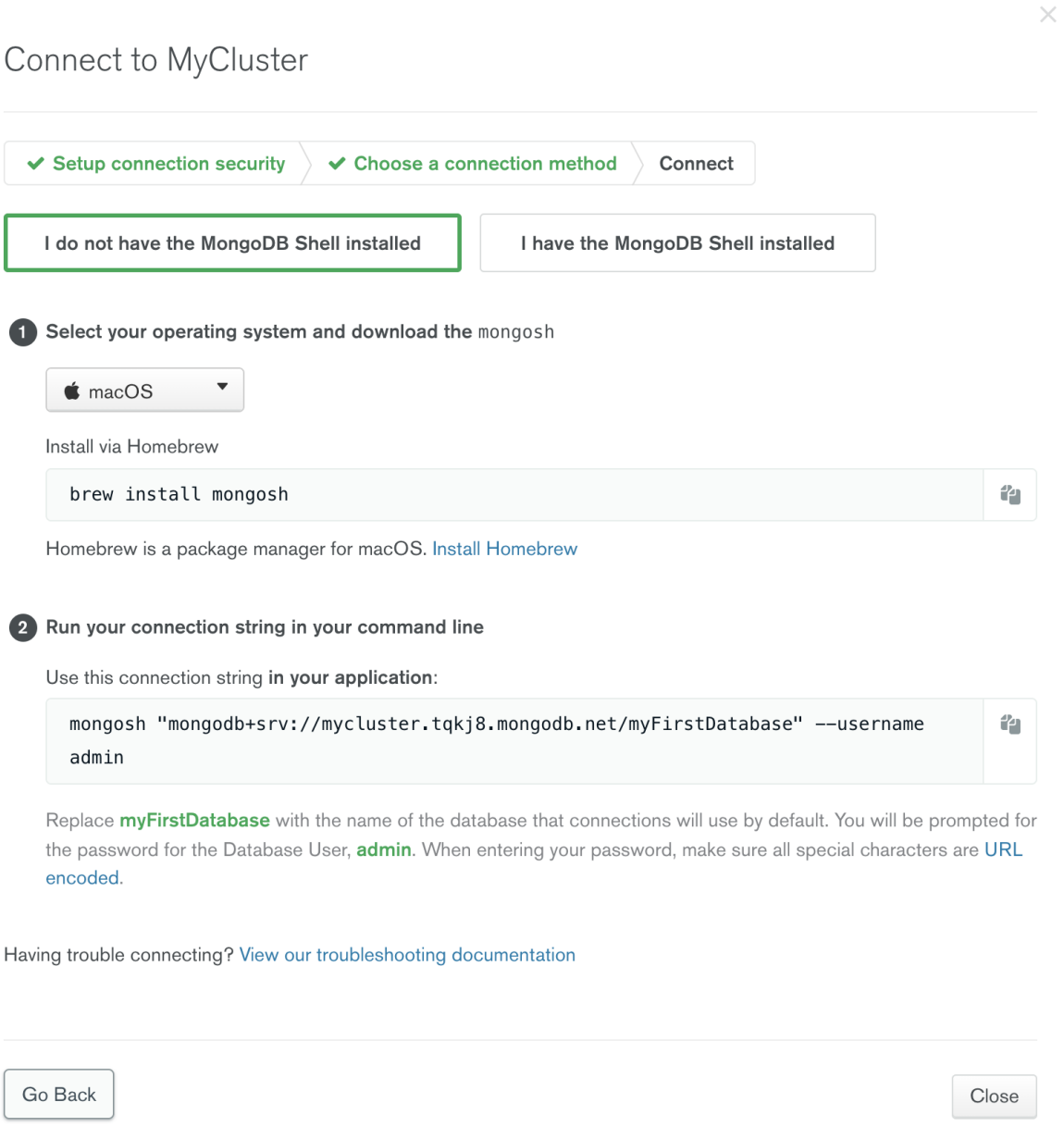
Setup the whitelisting and the user



Connect with the shell option



Connecting to Atlas



Open a terminal/cmd prompt and run the command copied from section 2 in the above dialog box.

Successful Connection

```
soumen@Soumens-MacBook-Pro ~ %
soumen@Soumens-MacBook-Pro ~ % mongosh "mongodb+srv://mycluster.tqkj8.mongodb.net/myFirstDatabase" --username admin
Enter password: *****
Current Mongosh Log ID: 614ec79c503e83c592b416af
Connecting to:          mongodb+srv://mycluster.tqkj8.mongodb.net/myFirstDatabase
Using MongoDB:          4.4.9
Using Mongosh:          1.0.6

For mongosh info see: https://docs.mongodb.com/mongodb-shell/

Atlas atlas-klenol-shard-0 [primary] myFirstDatabase>

Atlas atlas-klenol-shard-0 [primary] myFirstDatabase> show dbs
sample_airbnb       54.4 MB
sample_analytics     9.9 MB
sample_geospatial   1.55 MB
sample_mflix          51 MB
sample_restaurants  6.29 MB
sample_supplies      991 kB
sample_training     51.6 MB
sample_weatherdata   2.8 MB
admin                336 kB
local                3.8 GB
Atlas atlas-klenol-shard-0 [primary] myFirstDatabase>
```

How to Install mongo shell - Mac

Install homebrew(if you don't have it already)

Install mongoDB shell

```
brew install mongodb/brew/mongodb-community-shell
```

Shell is installed in usr/local/bin/ so already in path

You can also visit the below directories and install the shell manually using the tarball file.

https://www.mongodb.com/try/download/community
https://downloads.mongodb.com/compass/mongosh-1.0.7-darwin-arm64.zip

How to Install mongo shell - Windows

Download the zip file

On windows you can download the zip file from the community download center or from Atlas.
Open the explorer by double clicking and browse to the bin directory and drag mongo.exe to the desktop

Double click on the mongo leaf icon and agree that it's “OK” to run.

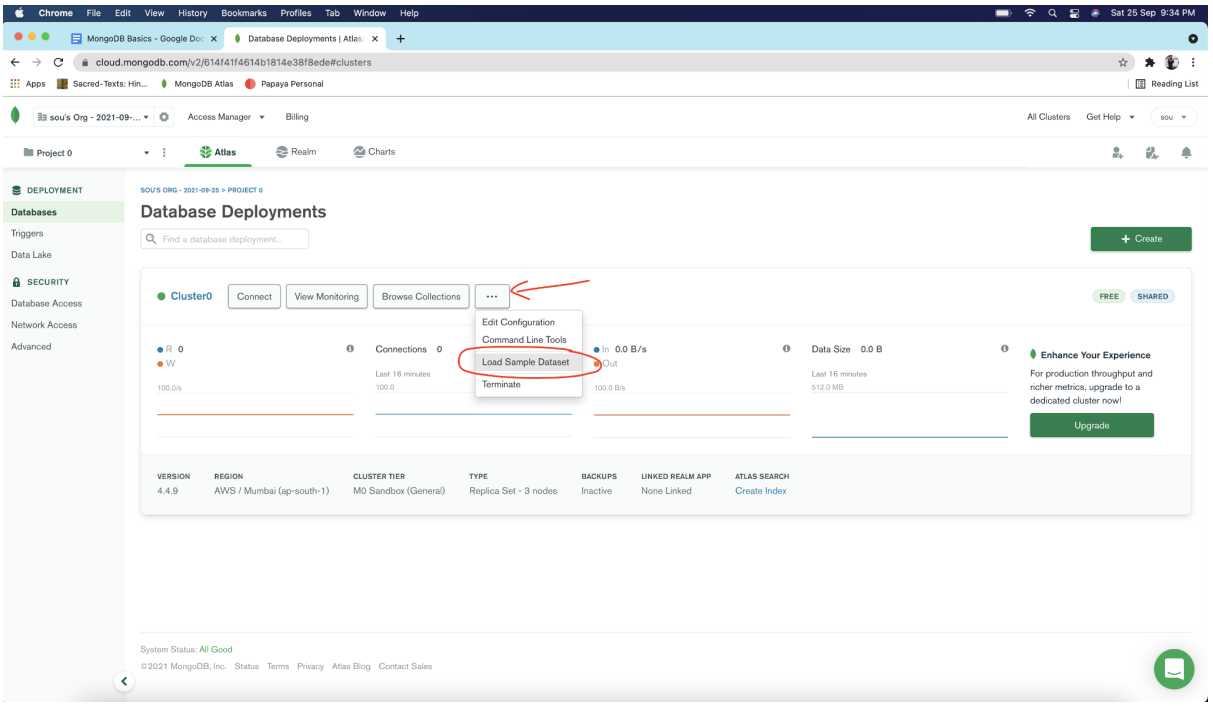
Finally add mongo shell to your path

Add mongo shell to your path

for mac/linux
mongo binary is in /usr/local/bin so already in your path

for windows
windows -R
cmd
setx PATH "%PATH%;c:%HOMEPATH%\Desktop"
exit

Load the sample dataset



UpGrad Rise

MongoDB - Session2

What do you learn ?

- ➔ Schema Design basics
- ➔ Replication
- ➔ Sharding
- ➔ Security
- ➔ Drivers and connections

Schema design in MongoDB

What is schema?

- The “Schema” is the way your data is organized
- Store the data in a way the application wants to see it
- Maps concepts and relationships to data
- Sets expectations for the data

Getting things in the right order

RDBMS	NoSQL
Model data	Define access to data
Write queries for data access	Model data

What is Good Schema Design?

A good schema can mean the difference between:

- Good, or poor performance.
- Doing few queries, or too many.
- Having data in RAM, or touching the disk.
- Having a data store that scales out, and one that doesn't.

MongoDB Considerations

With any system, you need to model to alleviate the constraints from the software and hardware.

With MongoDB:

- Max document size: 16 MB
- Simple update may result in a full document copy in the replication protocol
- Full documents get read and written from disk
- Atomic update at the document level
- Joins available through $lookup, but not that efficient
- Each update rewrites the whole document (MVCC)

Know your Access Patterns

- Identify,
- Quantify, and
- Qualify the workload of a system
- Identify fuzzy requirements and quantify them
- Prioritize the operations that mean the most to your application

Reduce your Queries

- Queries take a finite amount of time
    - Especially if you need to make round trips
- Fewer queries for all the data is a net win
- Good schema design tries to minimize the number of queries
- Data that gets queried together should be stored in the same document

Avoid Data you Won't Use

MongoDB brings complete documents in RAM.

- Documents in RAM will get queried faster than documents not in RAM
- The same is true of indexes
- RAM is measured in bytes
- Bytes of data you're not using will push out bytes of data you are

What you should Prioritize

- Prioritize for your most common queries
    - Optimizing these at the expense of others is a net win
- The patterns you see today are ways of prioritizing different operations
- Your schema depends on your access patterns.
- To figure out what you need, start by writing your queries. *Then* arrange the data so that they're answered efficiently.

Case Study

- A Library Web Application
- Different schemas are possible.

Author Schema

```
{   "_id",
    "firstName",
    "lastName",
    “age”
     ...
}
```

User Schema

```
{   "_id",
    "userName",
    "Password",
     “Email”,
     ...
}
```

Book Schema

```
{  "_id",
    "title",
    "author",
   ...
    "publisher": {
        "city",
    ...
        "name"
    },
    "subjects": [ ],
    "language",
    "reviews": [ { "user", "text"},
                { "user", "text"} ]
}
```

Example: Author

```
{   _id: ObjectId(a1234fbc567f),
    firstName: "Soumen",
    lastName: "Chatterjee",
    ...
}
```

Example: User

```
{   _id: ObjectId(9ut53nfg234k),
    userName: "Mahesh@orkut.com",
    password: "abc12345",
    ...
}
```

Example: Book

```
{
    _id: ObjectId(dlkfadflgkj86564g),
    title: "The Mahabharatha",
    author: 1,
    isbn: "345IBN98",
    pages: 2007,
    publisher: {
        name: "Indian printing house",
        date: ISODate("2001-05-22T00:00:00Z"),
        city: "Mumbai"
    },
    subjects: ["mythology", “vedic era”, “epics”],
    language: "Sanskrit",
    reviews: [
        { user: ObjectId(100...), text: "One of the best epic poems…" },
        { user: ObjectId(101...), text: "It's easy to…" },
        ...
    ]
}
```

Embedded Documents

- Sub-documents or embedded objects
- What advantages do they have?
- When should they be used?

Example: Embedded Documents

```
{
    publisher: {
        name: "Indian printing house",
        date: ISODate("2021-03-21T00:00:00Z"),
        city: "Bengaluru"
    },
    subjects:["mythology", “vedic era”, “epics”],
    language: "Sanskrit",
    reviews: [
      { user: ObjectId(100...), text: "One of the best epic poems…" },
```

```
    { user: ObjectId(101...), text: "It's easy to…" }
  ]
}
```

Embedded Documents: Pros and Cons

- Great for read performance
- One seek to find the document
- At most, one sequential read to retrieve from disk
- Writes can be slow if constantly adding to objects

Linked Documents

- What advantages does this approach have?
- When should they be used?

Example: Linked Documents

Here all reviews for a given author are kept separately and linked to the author.

```
{
  author: 1,
  reviews: [
    { user: ObjectId(100...), text: "One of the best epic poems…" },
    { user: ObjectId(101...), text: "It's easy to…" }
  ]
}
```

Linked Documents: Pros and Cons

- More, smaller documents
- Can make queries by ID very simple
- Accessing linked documents requires extra seeks + reads.
- What effect does this have on the system?

Arrays

- Array of scalars

- Array of documents

Array of Scalars

```
{
   subjects: ["mythology", “vedic era”, “epics”],
}
```

Array of Documents

```
{
   reviews: [
     { user: ObjectId(100...), text: "One of the best epic poems…" },
     { user: ObjectId(120...), text: "It's easy to…" }
   ]
}
```

Exercise: Users and Book Reviews

Design a schema for users and their book reviews. UserNames are immutable.

- Users
    - userName
    - email
- Reviews
    - text
    - rating
    - created_at

Solution 1: Users and Book Reviews

Reviews may be queried by user or book

```
//one document per user
{   _id: ObjectId("..."),
```

```
    userName: "Soumen",
    email: "soumen@rediff.com"
}
```

```
// one document per review
{   _id: ObjectId("..."),
    user: ObjectId("..."),
    book: ObjectId("..."),
    rating: 10,
    text: "This book is awesome!",
    created_at: ISODate("2020-11-10T21:14:07.096Z")
}
```

Solution 2: Users and Book Reviews

Optimized to retrieve reviews by user

```
// one document per user with all reviews
{   _id: ObjectId("..."),
    userName: "Soumen",
    email: "soumen@rediff.com",
    reviews: [
      {   book: ObjectId("..."),
          rating: 10,
          text: "This book is awesome!",
          created_at: ISODate("2020-10-10T21:14:07.096Z")
      }
    ]
}
```

Solution 3: Users and Book Reviews

Optimized to retrieve reviews by book

```
// one document per user
{   _id: ObjectId("..."),
```

```
    userName: "Soumen",
    email: "soumen@rediff.com"
}

// one document per book with all reviews
{   _id: ObjectId("..."),
    // Other book fields…
    reviews: [
      {   user: ObjectId("…"),
          rating: 10,
          text: "This book is awesome!",
          created_at: ISODate("2015-11-10T21:14:07.096Z")
      }
    ]
}
```

Top 3 Patterns

- Subset
- Attributes
- Bucket

Subset pattern

Sample Use Case

The Subset Pattern is very useful when we have a large portion of data inside a document that is rarely needed. Product reviews, article comments, actors in a movie are all examples of use cases for this pattern. Whenever the document size is putting pressure on the size of the working set and causing the working set to exceed the computer's RAM capacities, the Subset Pattern is an option to consider.

```
{
    _id: ObjectId(”507f1f77bcf86cd799439011”),
    name: “Super Widget”,
    description: “This is the most useful item in your toolbox.”
    price: { value: NumberDecimal("119.99"), currency: "USD" },
    reviews: [
          {
            review_id: 786,
            review_author: “Kristina”,
            review_text: “This is indeed an amazing widget.”,
            published_date: ISODate(”2019-02-18”)
          },
          {
            review_id: 785,
            review_author: “Trina”,
            review_text: “Very nice product, slow shipping.”,
            published_date: ISODate(”2019-02-17”)
          },
   ...
          {
            review_id: 1,
            review_author: “Hans”,
            review_text: “Meh, it’s okay.”,
            published_date: ISODate(”2017-12-06”)
          }
    ]
}
```

```
{
    _id: ObjectId(”507f1f77bcf86cd799439011”),
    name: “Super Widget”,
    description: “This is the most useful item in your toolbox.”
    price: { value: NumberDecimal("119.99"), currency: "USD" },
    reviews: [
         {
           review_id: 786,
           review_author: “Kristina”,
           stars: 5
           review_text: “This is indeed an amazing widget.”,
           published_date: ISODate(”2019-02-18”)
         },
...
         {
           review_id: 776,
           review_author: “Pablo”,
           stars: 5
           review_text: “Wow! Amazing.”,
           published_date: ISODate(”2019-02-16”)
         }
    ]
}
```

Product Collection

```
{
      review_id: 786,
      product_id: ObjectId(”507f1f77bcf86cd799439011”),
      review_author: “Kristina”,
      review_text: “This is indeed an amazing widget.”,
      published_date: ISODate(”2019-02-18”)
}

{
      review_id: 785,
      product_id: ObjectId(”507f1f77bcf86cd799439011”),
      review_author: “Trina”,
      review_text: “Very nice product, slow shipping.”,
      published_date: ISODate(”2019-02-17”)
}

{
      review_id: 1,
      product_id: ObjectId(”507f1f77bcf86cd799439011”),
      review_author: “Hans”,
      review_text: “Meh, it’s okay.”,
      published_date: ISODate(”2017-12-06”)
}
```

Review Collection

Attribute Pattern

Sample Use Case

The Attribute Pattern is well suited for schemas that have sets of fields that have the same value type, such as lists of dates. It also works well when working with the characteristics of products. Some products, such as clothing, may have sizes that are expressed in small, medium, or large. Other products in the same collection may be expressed in volume. Yet others may be expressed in physical dimensions or weight.

```
{
    title: "Star Wars",
    director: "George Lucas",
    ...
    release_US: ISODate("1977-05-20T01:00:00+01:00"),
    release_France: ISODate("1977-10-19T01:00:00+01:00"),
    release_Italy: ISODate("1977-10-20T01:00:00+01:00"),
    release_UK: ISODate("1977-12-27T01:00:00+01:00"),
    ...
}
{
    title: "Star Wars",
    director: "George Lucas",
    …
    releases: [
       {
```

```
        location: "USA",
        date: ISODate("1977-05-20T01:00:00+01:00")
        },
        {
        location: "France",
        date: ISODate("1977-10-19T01:00:00+01:00")
        },
        {
        location: "Italy",
        date: ISODate("1977-10-20T01:00:00+01:00")
        },
        {
        location: "UK",
        date: ISODate("1977-12-27T01:00:00+01:00")
        },
        …
    ],
    …
}
```

Indexing

```
{ "releases.location": 1, "releases.date": 1}
```

The Bucket Pattern

Sample Use Case

One example of making time-series data valuable in the real world comes from an IoT implementation by Bosch. They are using MongoDB and time-series data in an automotive field data app. The app captures data from a variety of sensors throughout the vehicle allowing for improved diagnostics of the vehicle itself and component performance.

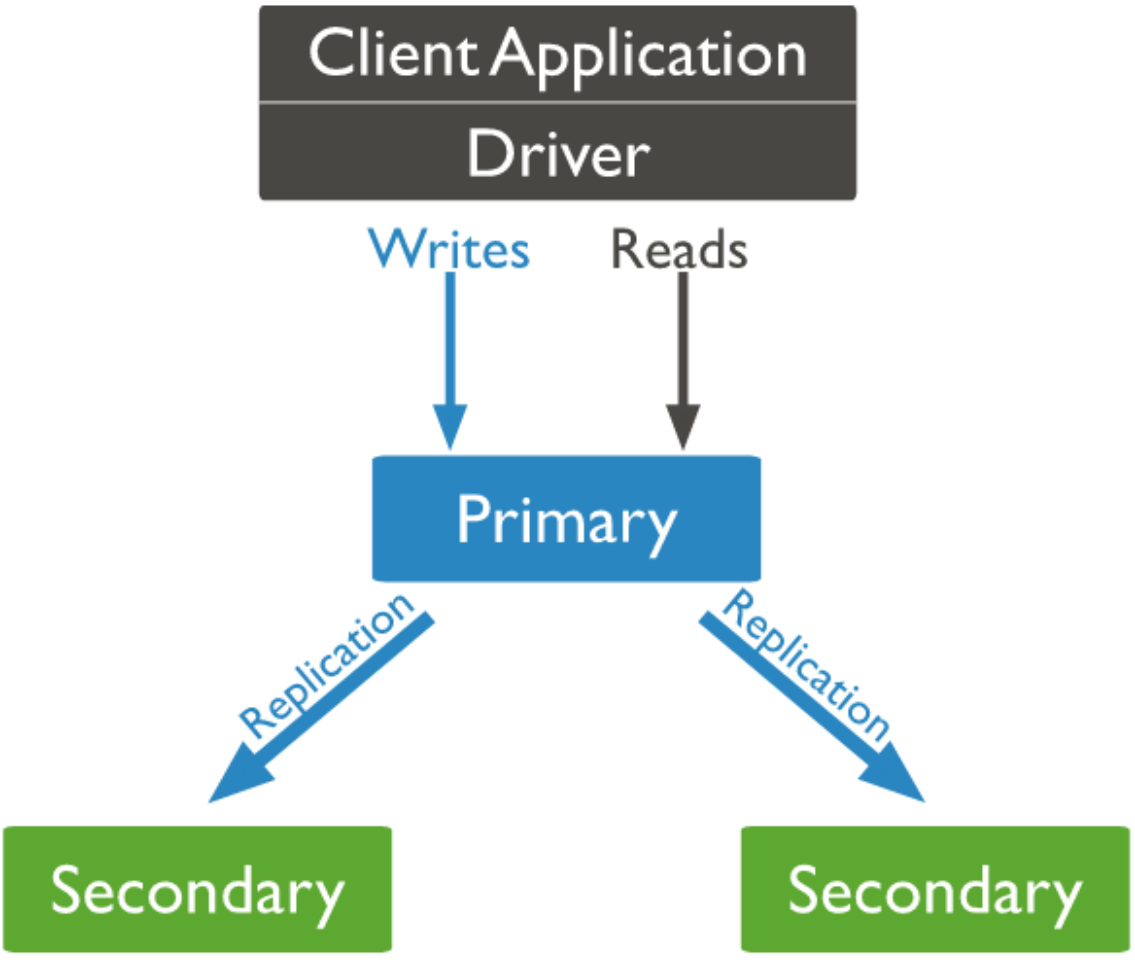
```
{
  sensor_id: 12345,
  timestamp: ISODate("2019-01-31T10:00:00.000Z"),
  temperature: 40
}

{
  sensor_id: 12345,
  timestamp: ISODate("2019-01-31T10:01:00.000Z"),
  temperature: 40
}

{
  sensor_id: 12345,
  timestamp: ISODate("2019-01-31T10:02:00.000Z"),
  temperature: 41
}
```

By applying the Bucket Pattern to our data model, we get some benefits in terms of index size savings, potential query simplification, and the ability to use that pre-aggregated data in our documents. Taking the data stream from above and applying the Bucket Pattern to it, we would wind up with:

```
{
   sensor_id: 12345,
   start_date: ISODate("2019-01-31T10:00:00.000Z"),
   end_date: ISODate("2019-01-31T10:59:59.000Z"),
   measurements: [
      {
      timestamp: ISODate("2019-01-31T10:00:00.000Z"),
      temperature: 40
      },
      {
```

```
      timestamp: ISODate("2019-01-31T10:01:00.000Z"),
      temperature: 40
      },
      …
      {
      timestamp: ISODate("2019-01-31T10:42:00.000Z"),
      temperature: 42
      }
   ],
   transaction_count: 42,
   sum_temperature: 2413
}
```

Replication Overview



Replication

- High Availability (HA)
- Replica Set Members
    - Data synchronisation and replication mechanics
- Replica Set Use Cases

High Availability (HA)

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

Members

A replica set consists of several nodes. There can be only one primary node with all other data bearing nodes being called secondaries. The primary node receives all the write operations for the replica set.

There are three types of replica set member:

- Primary Server
- Secondaries
- Arbiters

Primary

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

Secondaries

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

Data Synchronisation and Replication Mechanics

- When a replica set is created or a new member joins they need to get a full copy of the data which is done using an initial sync process.

- Once a replica set is created, the members are in continuous communication with the secondaries replicating the operations log (oplog) from the primary and performing these operations locally.
- Each member polls every other member every two seconds to keep track of their reachability (heartbeats).

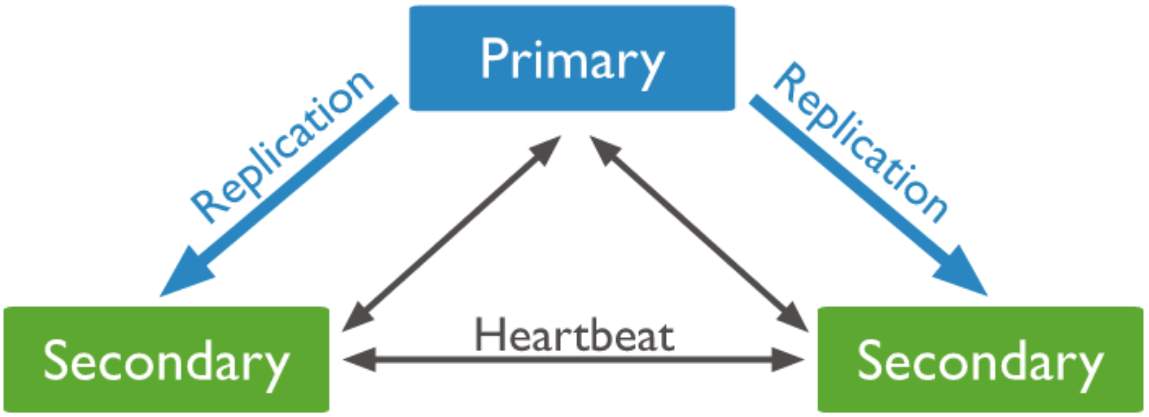
Initial Sync

- Occurs when a new server is added to a replica set, or we erase the underlying data of an existing server (--dbpath).
- All existing collections except the *local* collection are copied.
- As of MongoDB >= 3.6, network compression was enabled by default using the snappy compression library.

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.

Heartbeats



- The members of a replica set use heartbeats to determine if they can reach every other node.
- The heartbeats are sent every two seconds.

- If a node is unreachable, this may indicate server failure, a network partition, or simply too slow to respond. The heartbeat will timeout and retried several times before the state is updated.

Use Cases

Replica Set Use Cases

- Functional Segregation
- Redundancy and Data Availability
- Disaster Recovery

Functional Segregation

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

Redundancy and Data Availability

Replication provides redundancy and increases data availability. Each member holds a copy of the data and provides a degree of fault tolerance against the loss for any single member / database server.

Clients can sent read operations to different members and members can be dedicated to specific functions such as reporting or backup.

Disaster Recovery

A replica set provides some protection against a single-instance failure, however if all members are co-located in the same data center they could be susceptible to the site failing due to any number of reasons. Neither does it protect against user errors like deleting a whole database.

Distributing replica set members across geographically distinct data centers adds redundancy and provides fault tolerance if one of the data centers is unavailable.

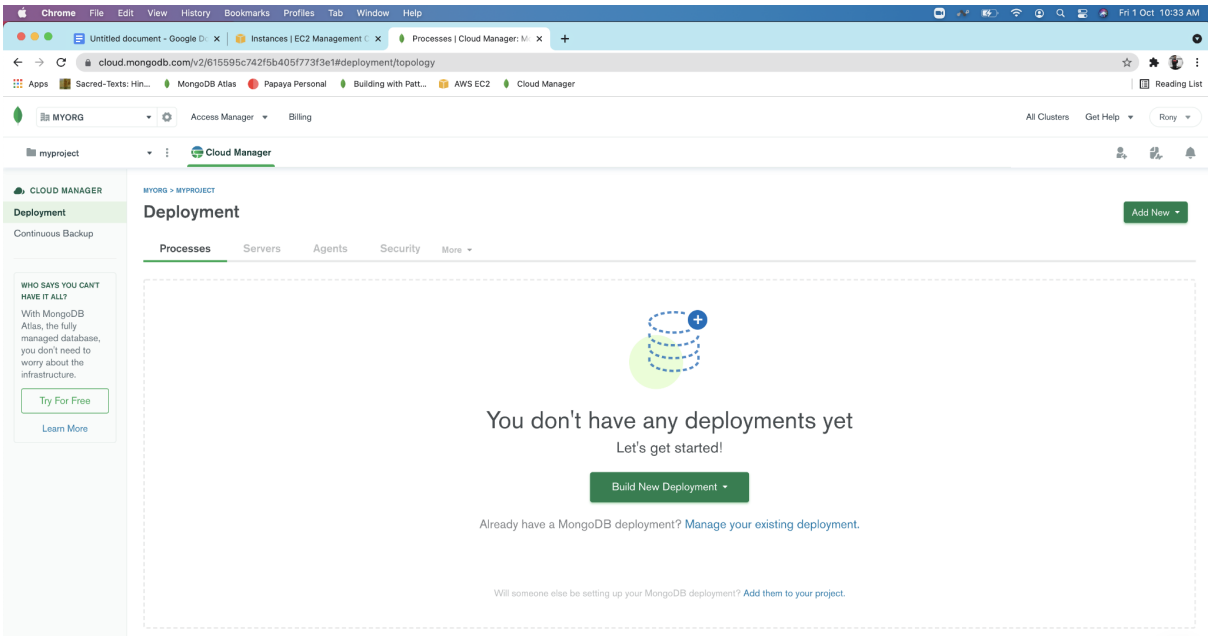
Lab to setup a 3 node Replica Set using Cloud Manager:-

Objective:-

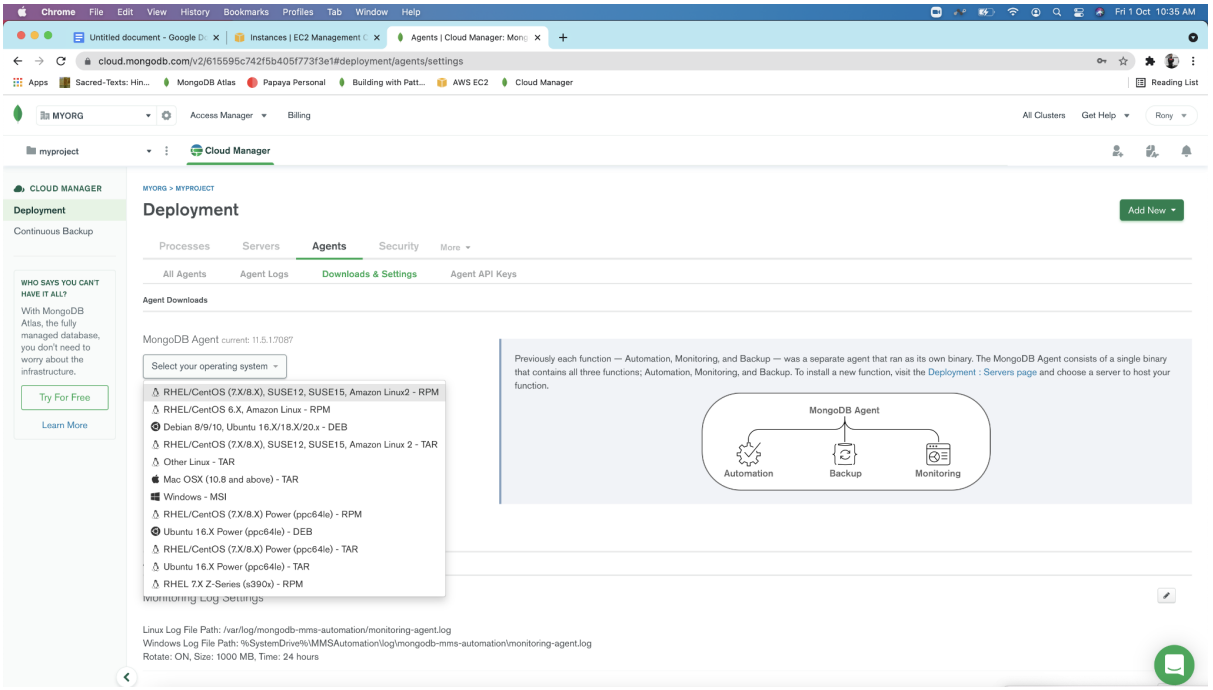
- Provision 3 aws nodes to launch a 3 node mongoDB replicaset(follow appendix)
- Setup a 3 node replicaset using cloud manager
- Insert a record in Primary and read the same from secondary member

Follow the screen captures below to achieve the above:-

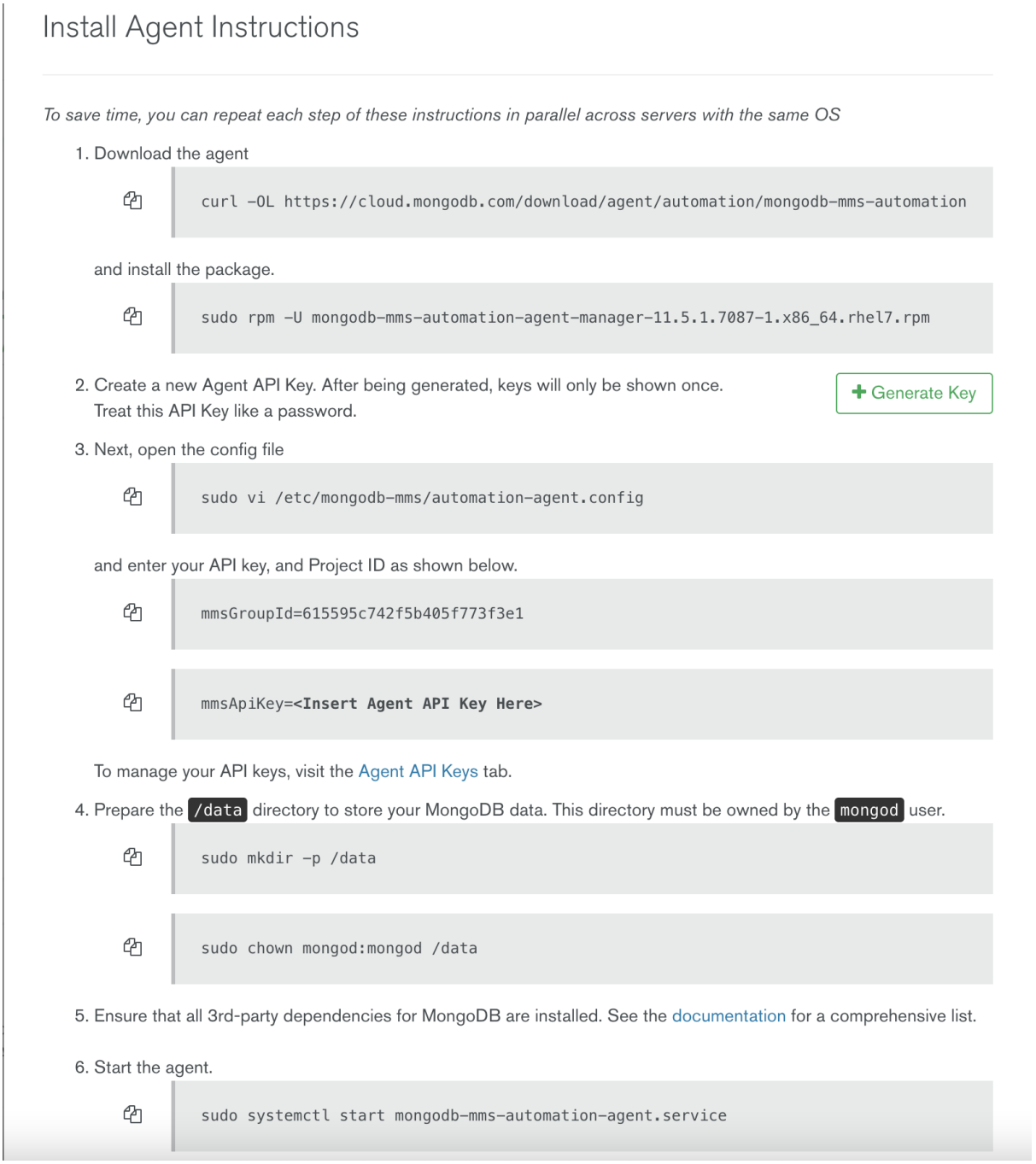
Login to cloud manager UI(follow the appendix on the initial setup information)



Click on Agents tab and then downloads&settings and choose your OS from the drop down

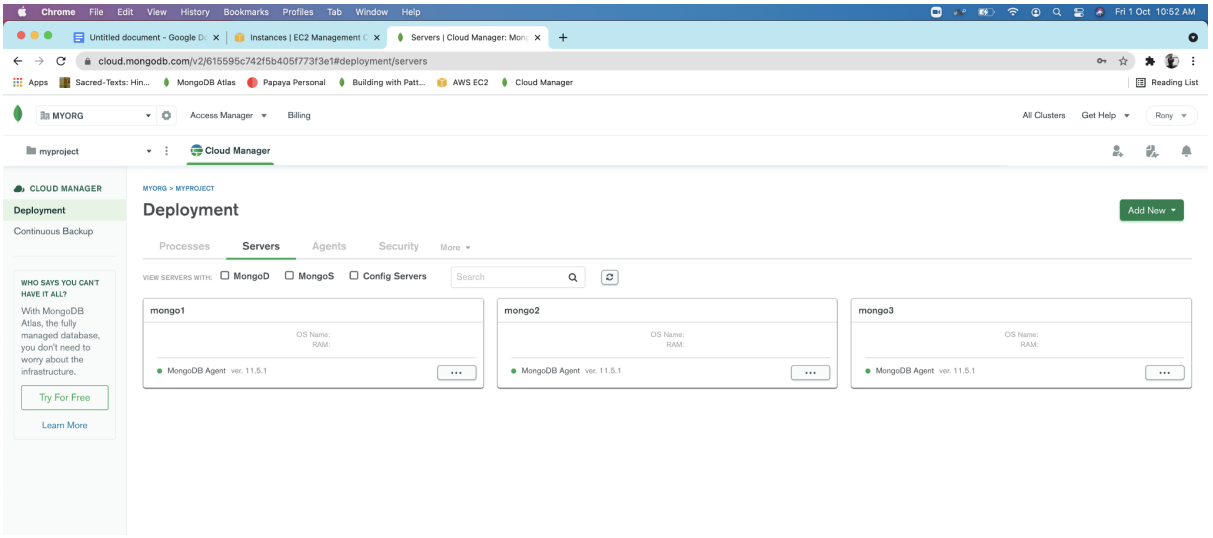


Follow the Agent installation steps on each of the provisioned nodes

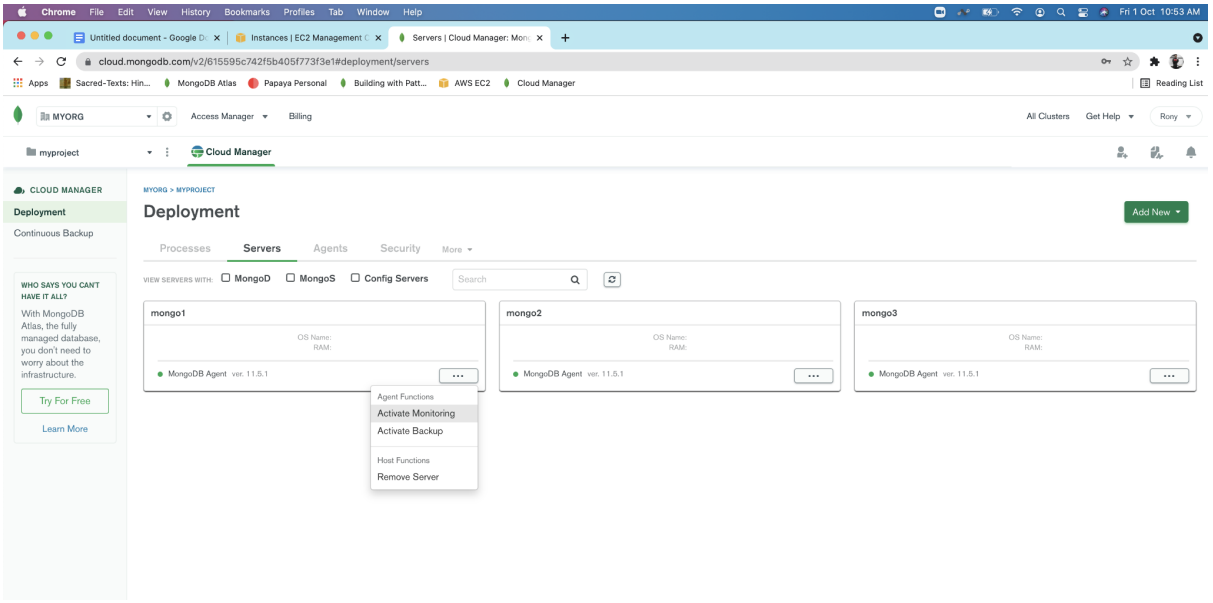


- Don't forget to click on the “+ generate key” button in the above to generate your agent API key
- Fill in the group id and API key details in the config file
- Create the /data directories and change the ownerships
- Finally, start the agent service on each node.

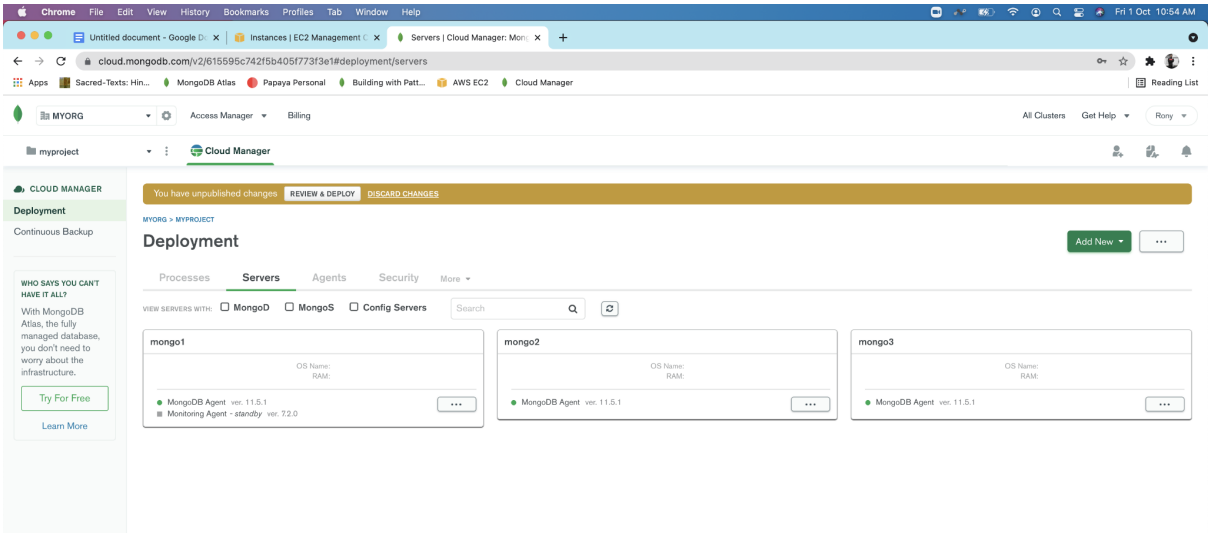
Once done, you should be able to see your servers under the server tab



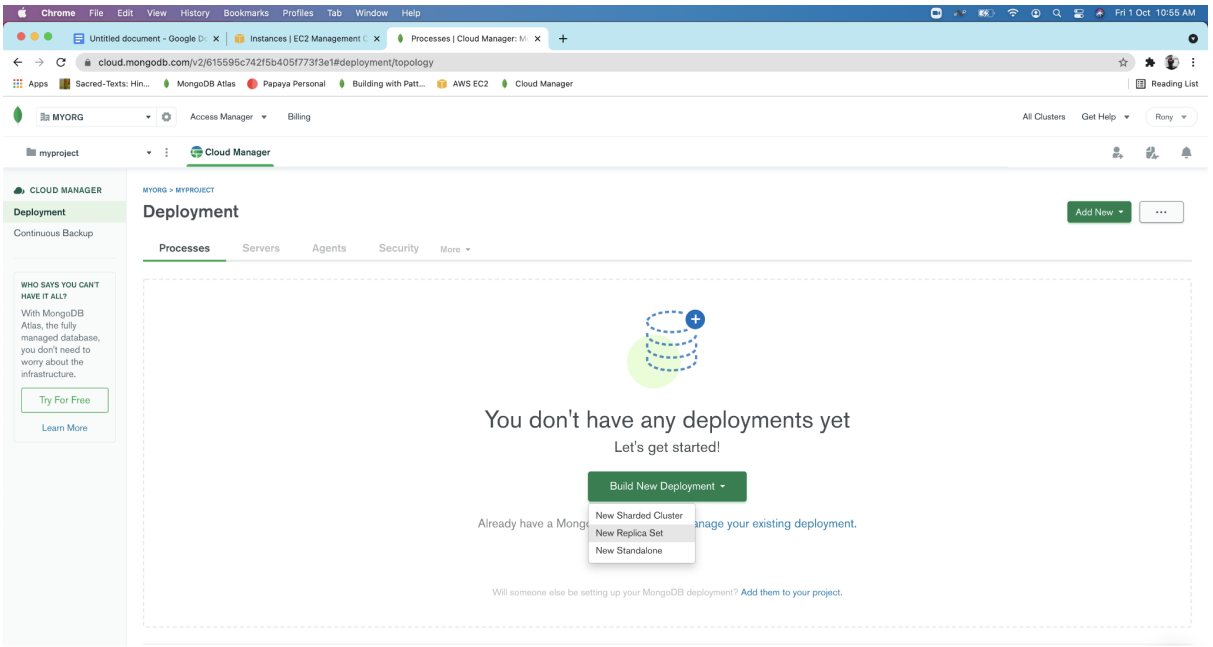
Click on the 3 dots button on any server and click on activate monitoring and then review and deploy



Review and deploy and then confirm and deploy on the yellow bar shown on top

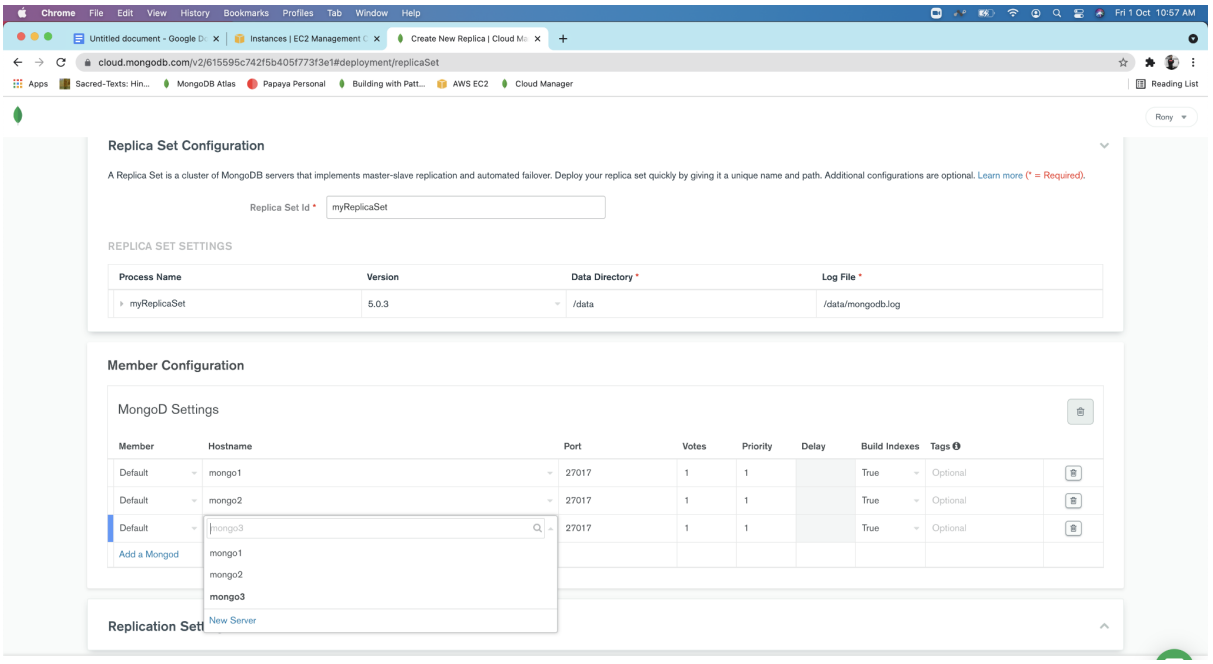


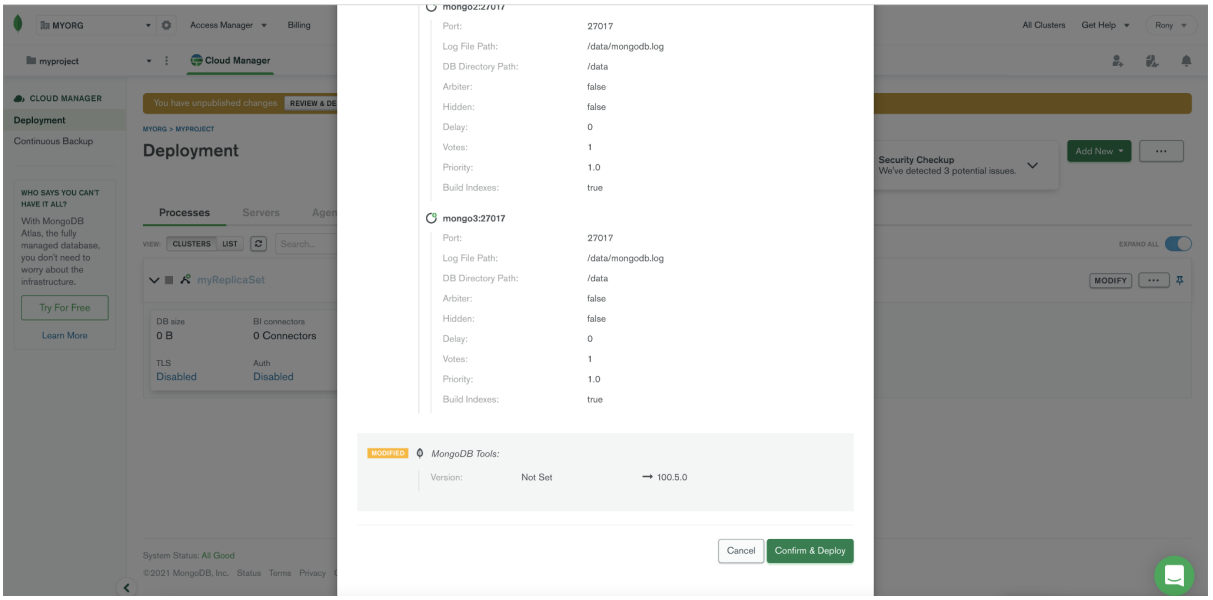
Click on the process tab and click on the build new deployment green button in the middle screen and then choose new replica set



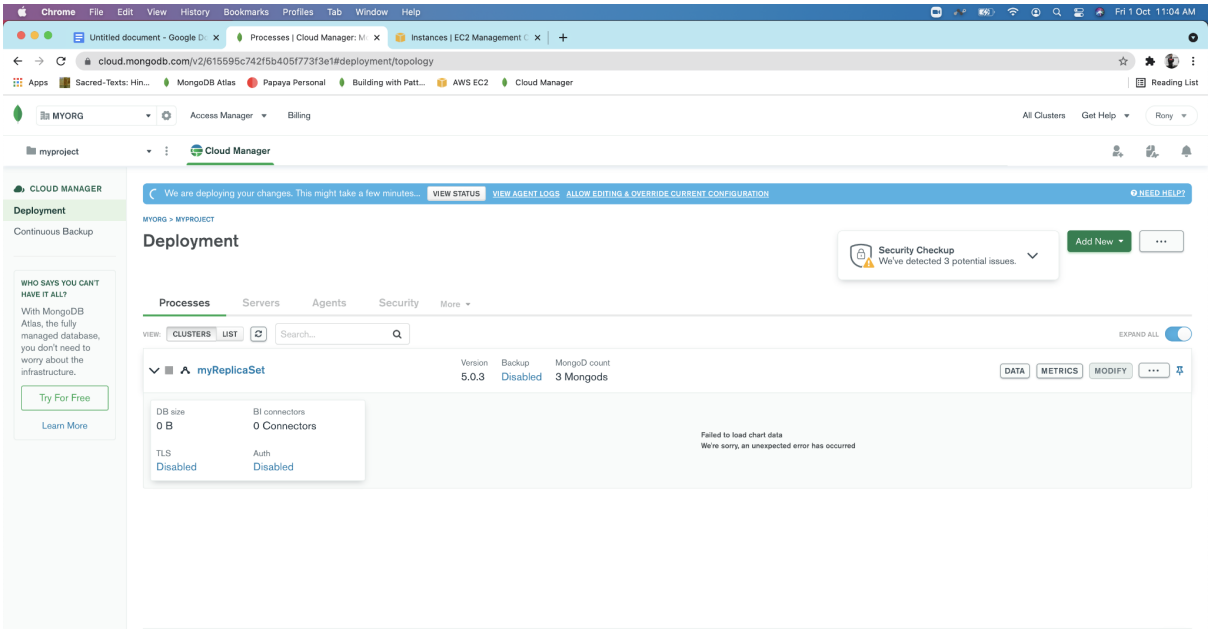
- Choose a replica set name from the replica set id field or leave default
- Choose the version of mongoDB you want to deploy under version field
- Fill in the data directory field with “/data” and the log file will be auto filled, if you want you can modify the file name and location.
- Under members configuration and mongoD settings choose the hostnames you have provisioned from the drop down and fill in the ports or keep default

- Keep rest of the settings as default
- Finally, hit the create replica set and then review and deploy and confirm and deploy

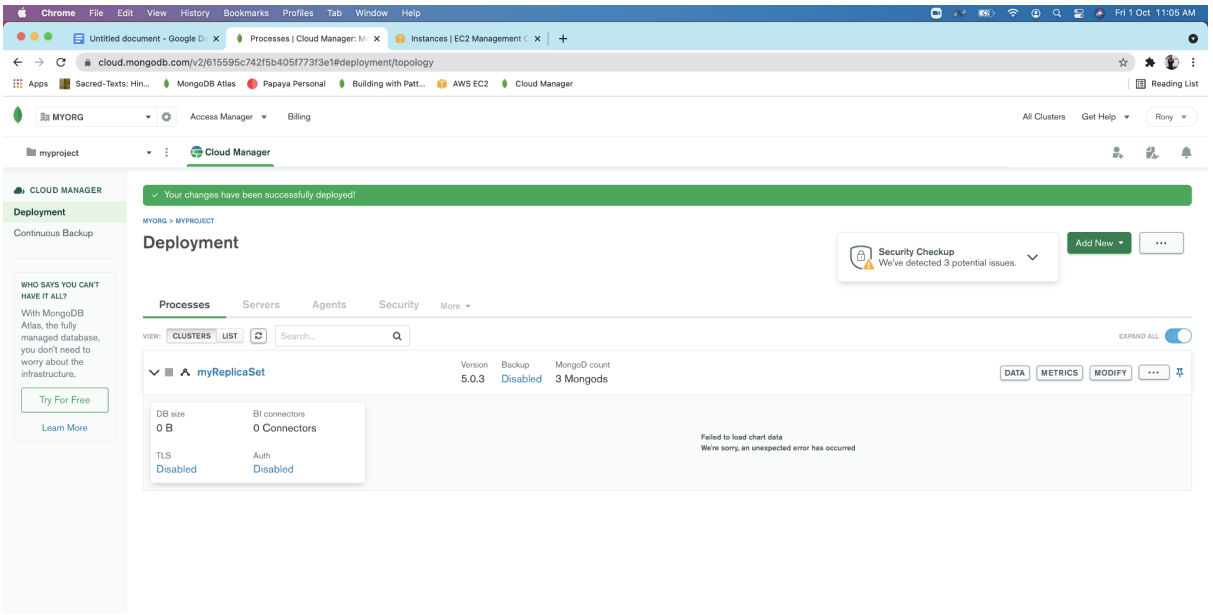




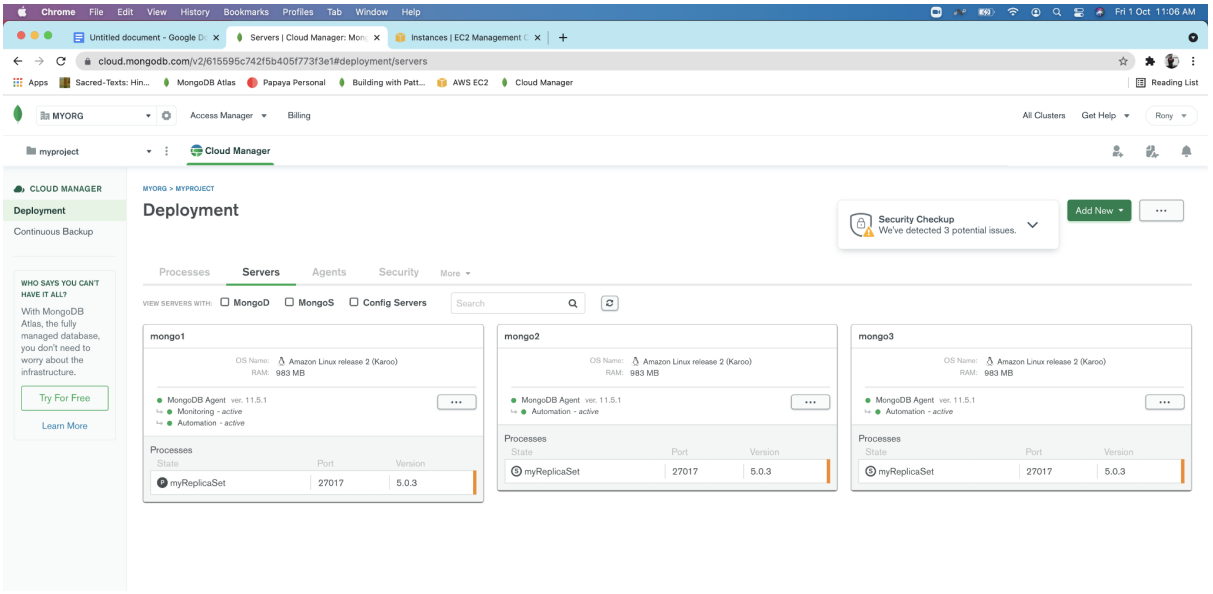
Wait for the cluster to get deployed, a blue bar on the top will appear to denote under process



Once done, the blue bar will automatically convert to green saying changes deployed



Click on the server tab and you can find the details on the nodes and their configuration



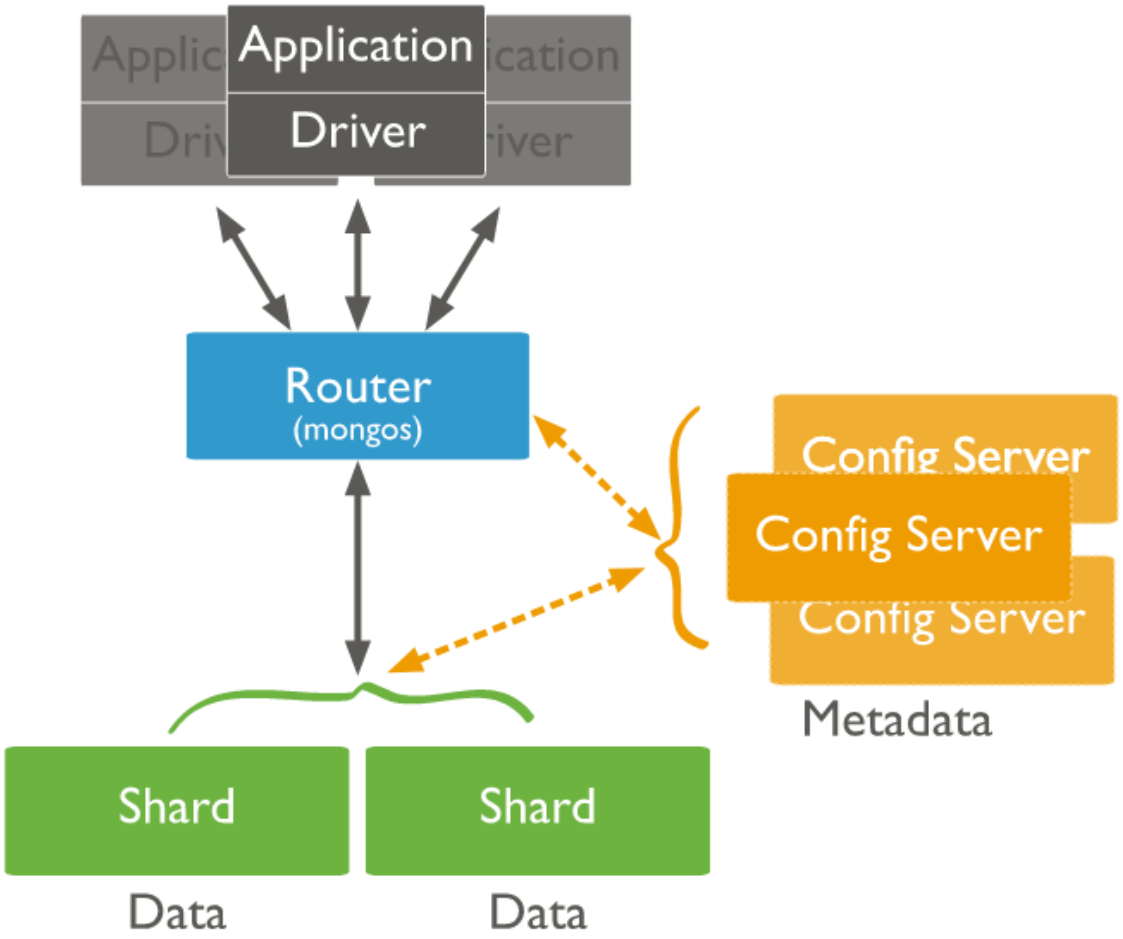
Insert a record in the primary server

```
soumen@Soumens-MacBook-Pro Documents % mongosh --host mongo1 --port 27017
Current Mongosh Log ID: 6156a25f56199036c8d3cdcc
Connecting to:          mongodb://mongo1:27017/?directConnection=true
Using MongoDB:          5.0.3
Using Mongosh:          1.0.6

For mongosh info see: https://docs.mongodb.com/mongodb-shell/

------
   The server generated these startup warnings when booting:
   2021-10-01T05:35:04.085+00:00: Access control is not enabled for the database. Read and write access to data and configuration is unrestricted
------

myReplicaSet [direct: primary] test>

myReplicaSet [direct: primary] test> db
test
myReplicaSet [direct: primary] test> use myDB
switched to db myDB
myReplicaSet [direct: primary] myDB> db.sample_collection.insertOne({"purpose": "Training"})
{
  acknowledged: true,
  insertedId: ObjectId("6156a2a056199036c8d3cdcd")
}
myReplicaSet [direct: primary] myDB>
```

Read the same record from secondary server

```
soumen@Soumens-MacBook-Pro Documents % mongosh --host 13.232.37.213 --port 27017
Current Mongosh Log ID: 6156a2fcbd9338c8149304e6
Connecting to:          mongodb://13.232.37.213:27017/?directConnection=true
Using MongoDB:          5.0.3
Using Mongosh:          1.0.6

For mongosh info see: https://docs.mongodb.com/mongodb-shell/

------
   The server generated these startup warnings when booting:
   2021-10-01T05:34:56.935+00:00: Access control is not enabled for the database. Read and write access to data and configuration is unrestricted
------

myReplicaSet [direct: secondary] test>

myReplicaSet [direct: secondary] test>

myReplicaSet [direct: secondary] test> use myDB
switched to db myDB
myReplicaSet [direct: secondary] myDB> show collections
sample_collection
myReplicaSet [direct: secondary] myDB>

myReplicaSet [direct: secondary] myDB> db.sample_collection.find()
MongoServerError: not primary and secondaryOk=false - consider using db.getMongo().setReadPref() or readPreference in the connection string
myReplicaSet [direct: secondary] myDB> rs.secondaryOk()
DeprecationWarning: .setSecondaryOk() is deprecated. Use .setReadPref("primaryPreferred") instead
Setting read preference from "primary" to "primaryPreferred"

myReplicaSet [direct: secondary] myDB> db.sample_collection.find()
[ { _id: ObjectId("6156a2a056199036c8d3cdcd"), purpose: 'Training' } ]
myReplicaSet [direct: secondary] myDB>
```

Sharding



What is Sharding ?

- This may also be called data partitioning. Sharding create a subset of the data, called a shard. Each shard is deployed as a replica set. This makes it possible to store more data and handle greater load without requiring more powerful machines.
- Config servers hold metadata about which data is part of which shard and mongos act as routing processes between client applications and the sharded cluster.

Scaling MongoDB - When to Shard

- As application load grows, you either add more resources to your hardware such as CPUs, memory, disk (*vertical scaling*) or you can add more machines to help (*horizontal scaling*).
- Sharding uses the latter concept and is designed to help with scenarios where you want to:
    - increase the read/write throughput of your application
    - decrease the memory pressure on your hardware

Shard Key

What is a Shard Key ?

- Based on one or more fields (like an index)
- Shard key defines a space of values
- Think of the key space like points on a line
- A key range is a segment of that line

Shard Key Ranges

- A collection is partitioned based on shard key ranges.
- 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.
- In MongoDB version <= 4.0, a shard key value was fixed once chosen.
- In MongoDB version >= 4.2, a shard key value can be changed unless it uses the immutable _id field.

Sharding Strategies

- MongoDB supports two approaches to distributing data across sharded clusters, **ranged sharding** and **hashed sharding**.
    - **Ranged Sharding** splits the data into ranges based on the shard key values. Each chunk is then assigned a range based on the shard key values.
    - **Hashed Sharding** computes a hash of the shard key field's value. Each chunk is then assigned a range based on the hashed shard key values.

Chunks

- MongoDB partitions data into chunks based on shard key ranges.
- This is just metadata.
- MongoDB attempts to keep the amount of chunks balanced across shards.
- This is achieved by migrating chunks from one shard to another as needed.
- There is nothing in a document that indicates its chunk.
- The document does not need to be updated if its assigned chunk changes.

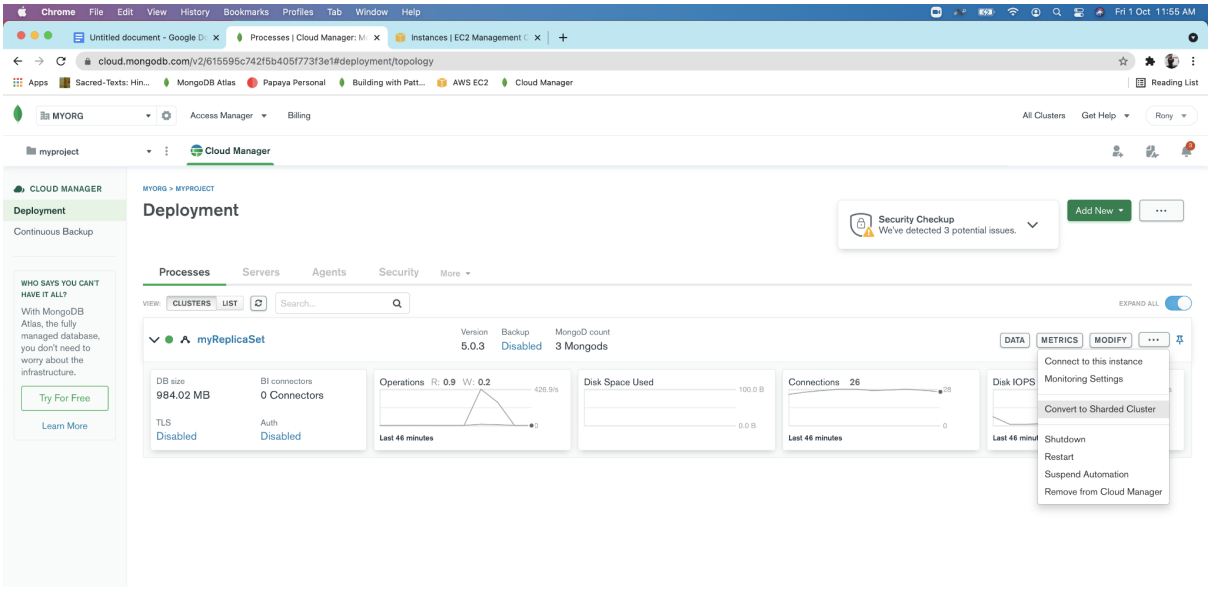
Lab to setup/Convert our replica set to a 2 shard cluster and then do hash sharding to check shard data distribution

Objectives:-

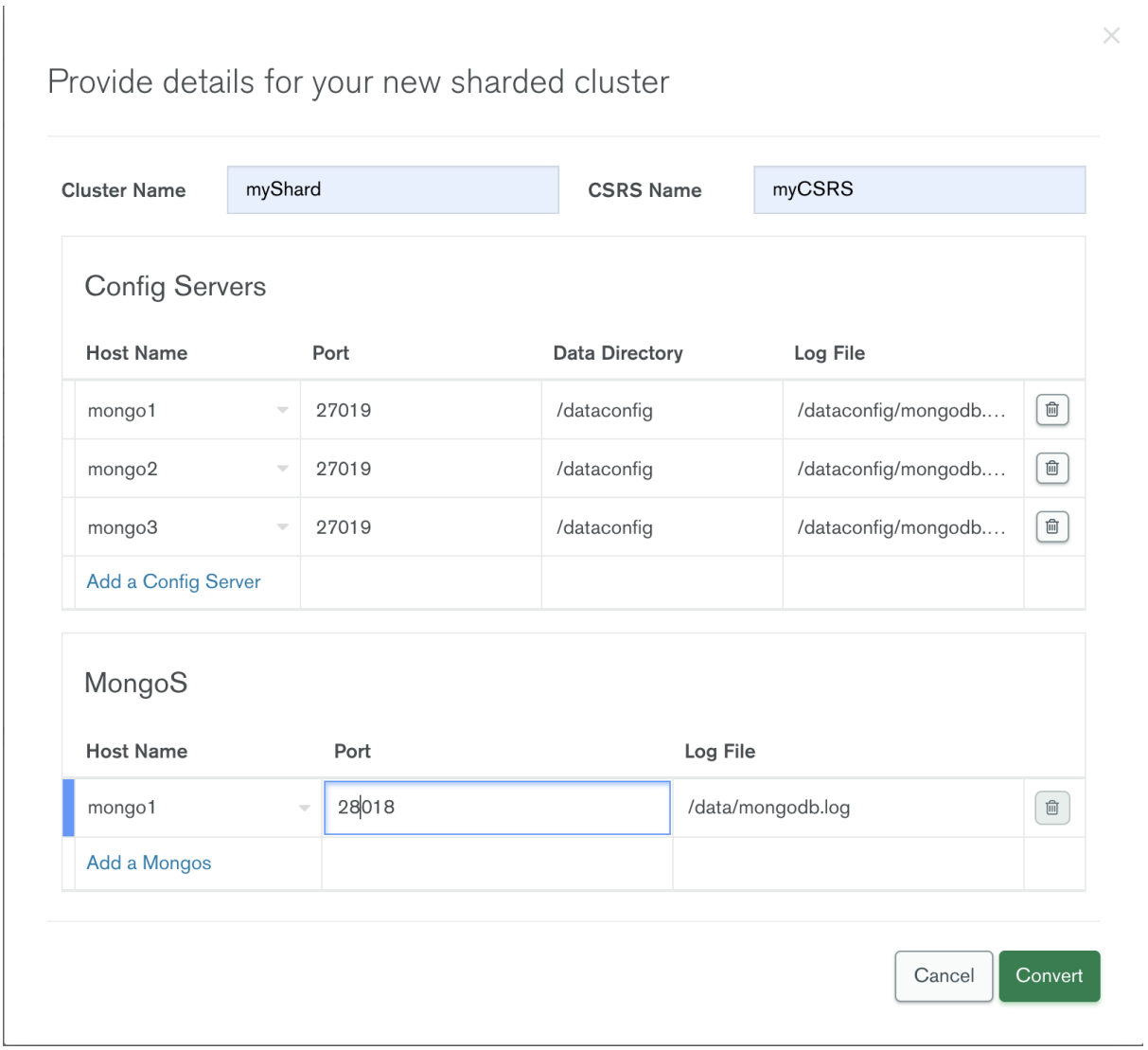
- Convert the replica set to a 2 shard cluster
- Load some sample data
- Shard the sample collection
- Check the shard distribution

You can follow the below steps to achieve the above objectives:-

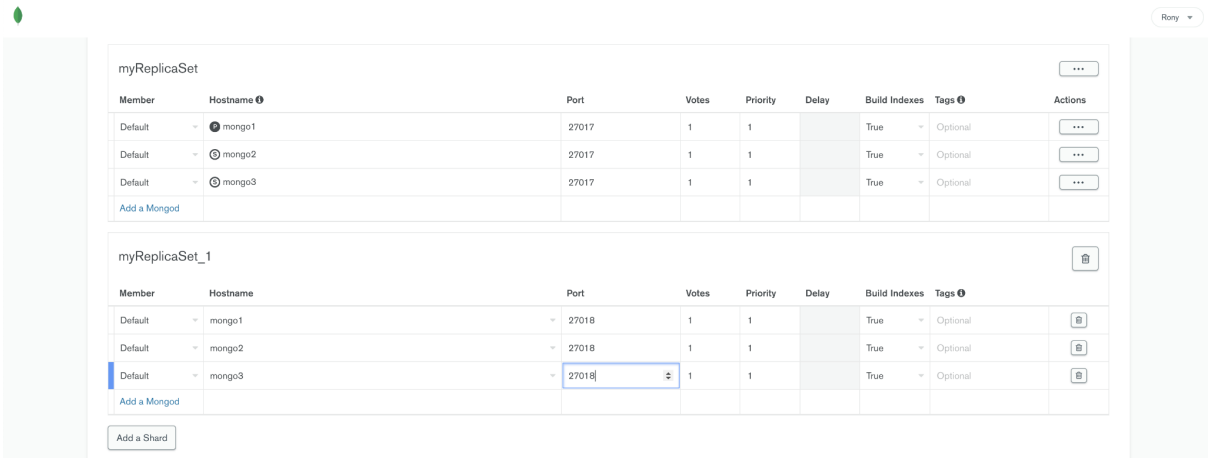
Go to process tab and click on the 3 dots button on the far right under the clusters view and select convert to sharded cluster

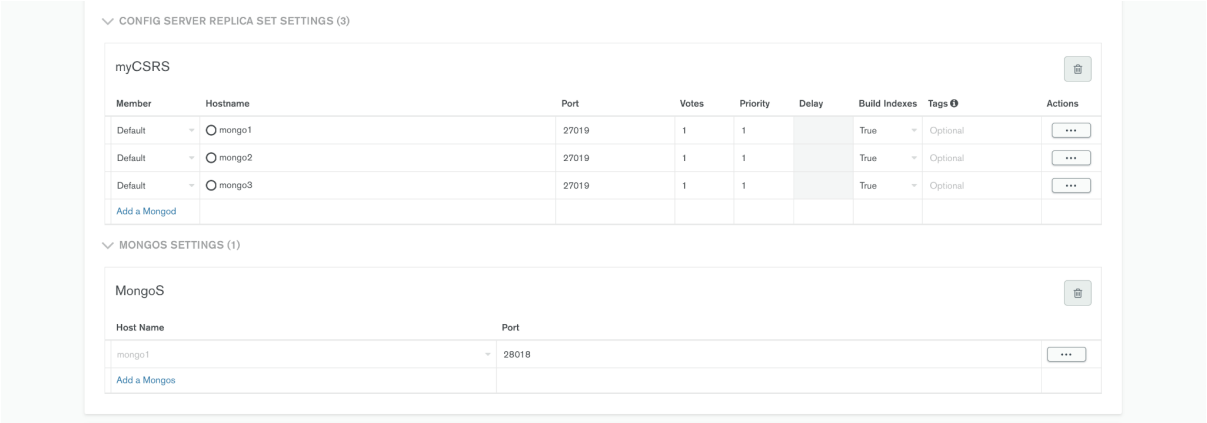


Fill in the details for sharded cluster config and click convert. Don't forget to modify the port numbers to something else apart from 27107.

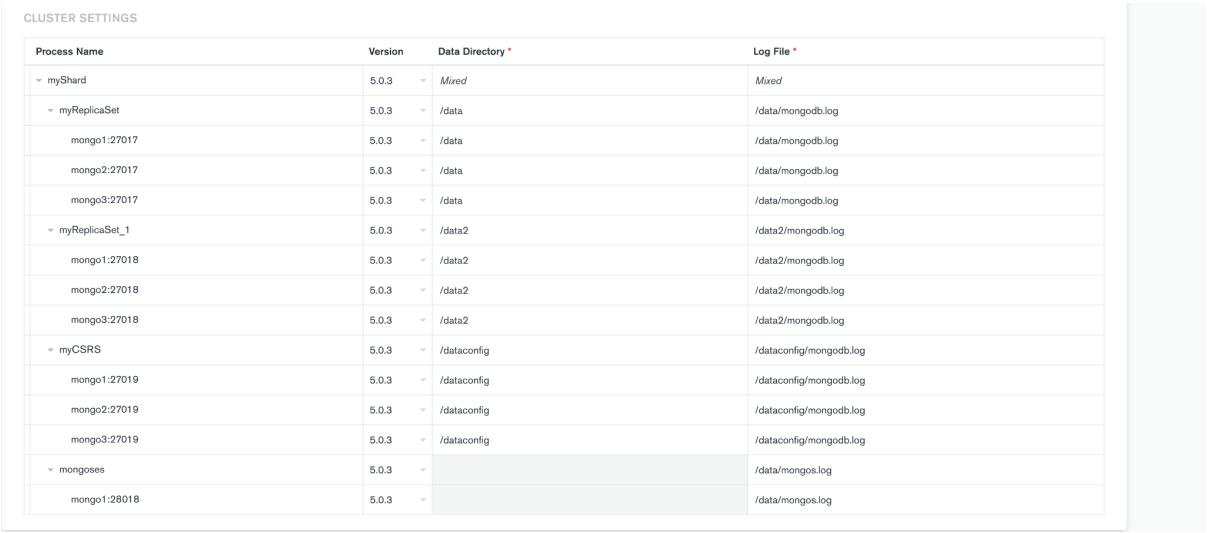


Under member configuration click on the add shard button and fill in the hostnames and port for another shard. Remember we already have a RS running on ports 27017 so choose a different port for the other replica set nodes.





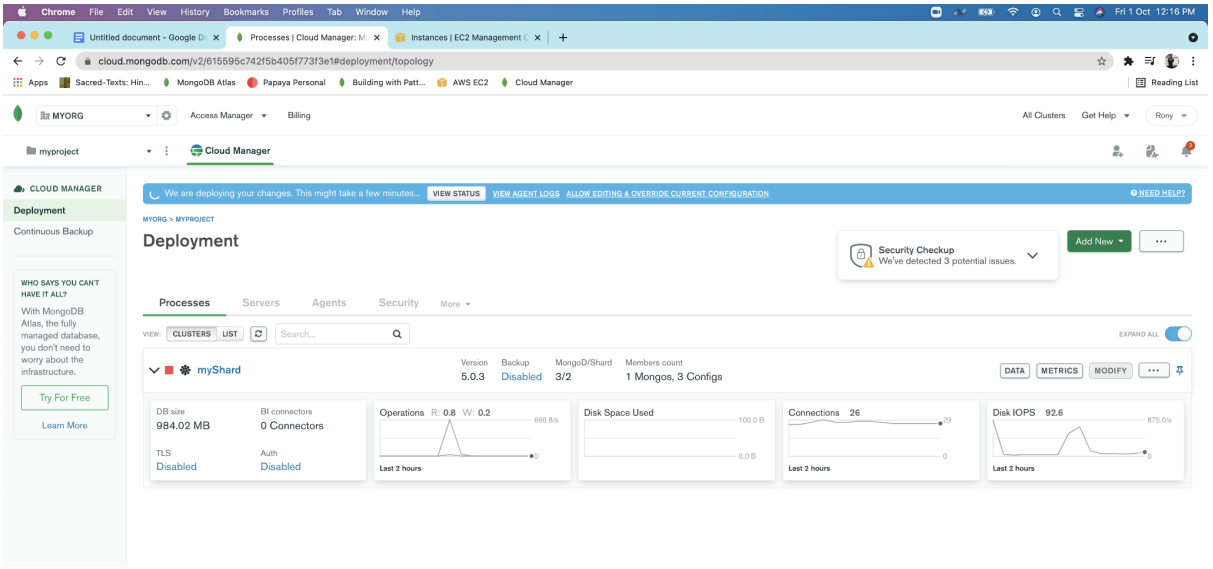
Verify the cluster settings from the top of the screen to check if RS1, RS2 and Config DBs have separate data directories. Here we need to create the additional “/data2” and “/dataconfig” directories for RS2 and configDB respectively.



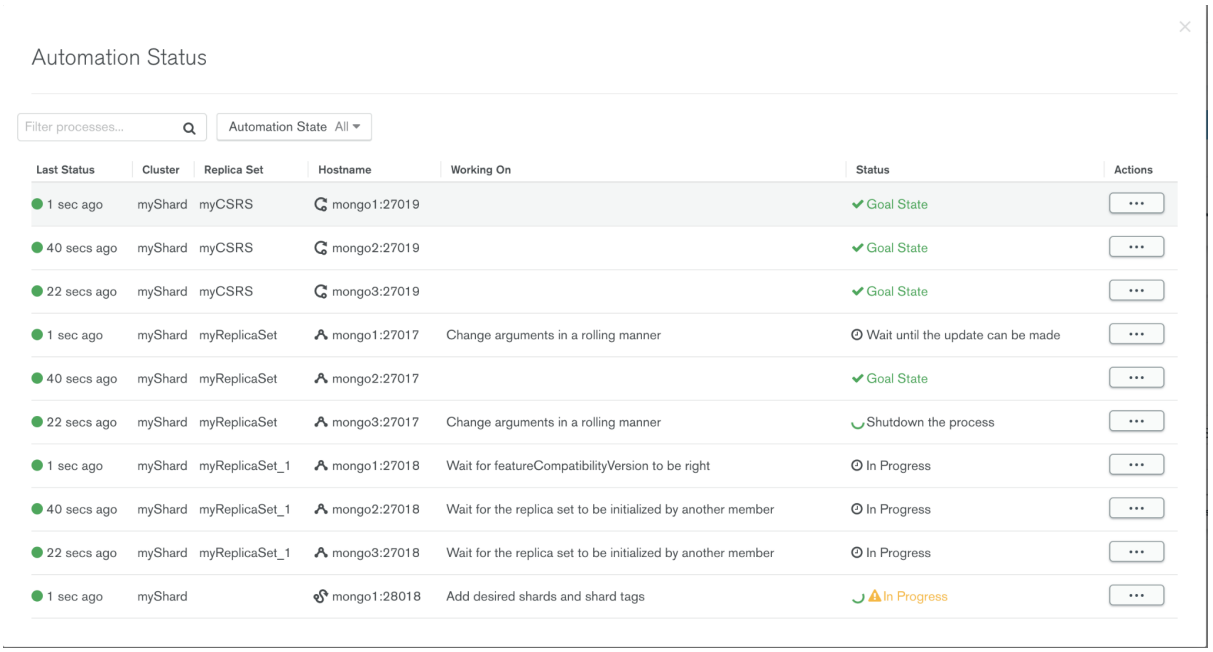
Do the below on all the 3 nodes:-

- sudo mkdir /dataconfig
- sudo chown -R mongod:mongod /dataconfig
- sudo mkdir /data2
- sudo chown -R mongod:mongod /data2

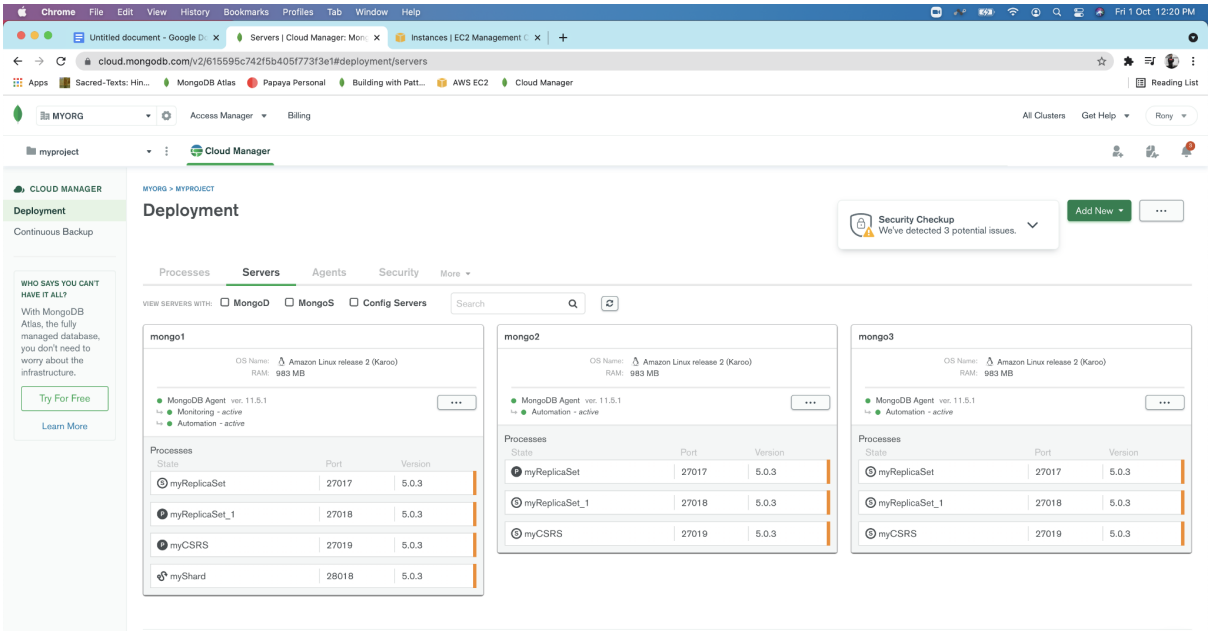
Click on save and then review and deploy and then confirm and deploy.



The process takes a while so please wait until all processes have reached goal state



Our cluster is now converted into a sharded cluster

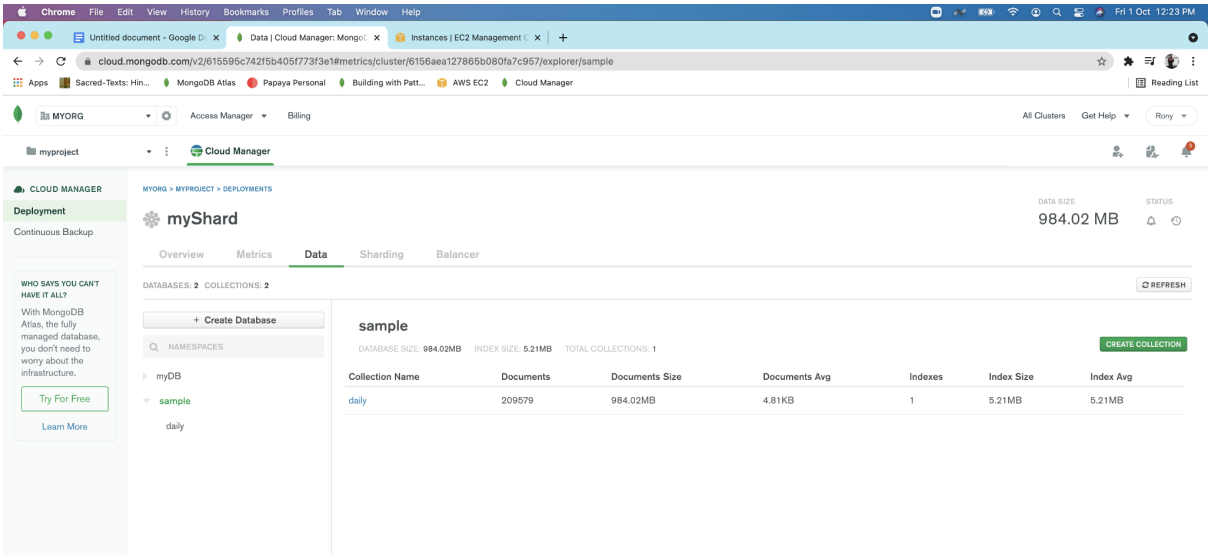


Load sample dataset

Command:-

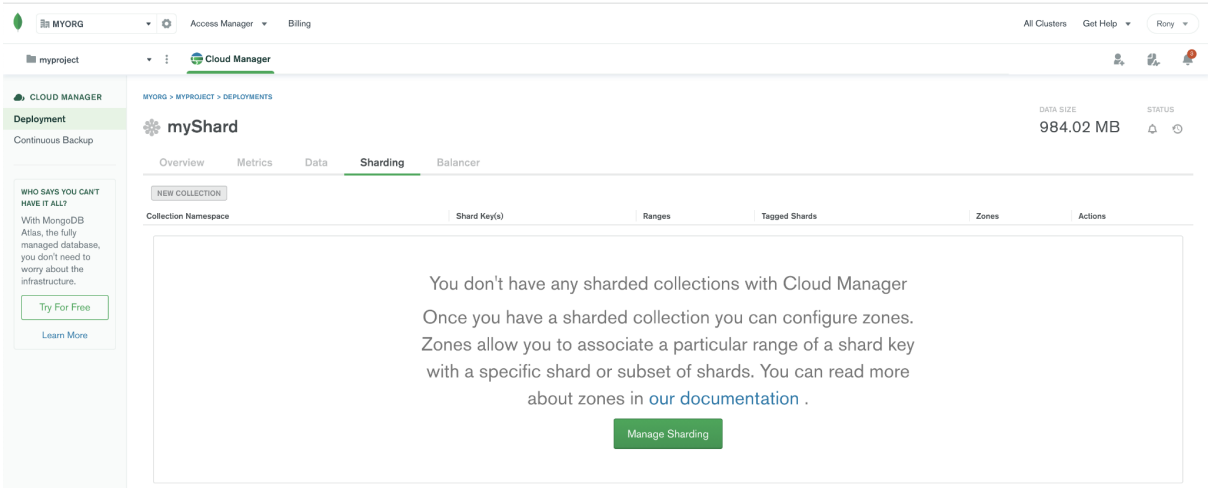
Mongoimport -d sample -c daily <your json dataset file location> --host <hostname> --port <port>

```
soumen@Soumens-MacBook-Pro bin %
soumen@Soumens-MacBook-Pro bin % ./mongoimport -d sample -c daily /Users/soumen/Downloads/daily_16.json --host mongo1 --port 27017
2021-10-01T11:37:37.561+0530    connected to: mongodb://mongo1:27017/
2021-10-01T11:37:40.561+0530    [........................] sample.daily 22.2MB/926MB (2.4%)
2021-10-01T11:37:43.561+0530    [#.......................] sample.daily 43.0MB/926MB (4.6%)
2021-10-01T11:37:46.561+0530    [#.......................] sample.daily 57.6MB/926MB (6.2%)
2021-10-01T11:37:49.561+0530    [#.......................] sample.daily 75.4MB/926MB (8.1%)
2021-10-01T11:37:52.561+0530    [##......................] sample.daily 93.0MB/926MB (10.0%)
2021-10-01T11:37:55.561+0530    [##......................] sample.daily 111MB/926MB (12.0%)
2021-10-01T11:37:58.561+0530    [###.....................] sample.daily 128MB/926MB (13.9%)
2021-10-01T11:38:01.561+0530    [###.....................] sample.daily 146MB/926MB (15.8%)
2021-10-01T11:38:04.561+0530    [####....................] sample.daily 159MB/926MB (17.2%)
2021-10-01T11:38:07.561+0530    [####....................] sample.daily 176MB/926MB (19.0%)
2021-10-01T11:38:10.561+0530    [#####...................] sample.daily 194MB/926MB (20.9%)
2021-10-01T11:38:13.561+0530    [#####...................] sample.daily 216MB/926MB (23.3%)
2021-10-01T11:38:16.561+0530    [######..................] sample.daily 234MB/926MB (25.3%)
2021-10-01T11:38:19.561+0530    [######..................] sample.daily 252MB/926MB (27.2%)
2021-10-01T11:38:22.561+0530    [######..................] sample.daily 265MB/926MB (28.6%)
2021-10-01T11:38:25.561+0530    [#######.................] sample.daily 283MB/926MB (30.5%)
2021-10-01T11:38:28.561+0530    [#######.................] sample.daily 301MB/926MB (32.4%)
2021-10-01T11:38:31.561+0530    [########................] sample.daily 319MB/926MB (34.4%)
2021-10-01T11:38:34.561+0530    [########................] sample.daily 341MB/926MB (36.8%)
2021-10-01T11:38:37.560+0530    [#########...............] sample.daily 361MB/926MB (38.9%)
2021-10-01T11:38:40.560+0530    [#########...............] sample.daily 377MB/926MB (40.7%)
2021-10-01T11:38:43.560+0530    [##########..............] sample.daily 395MB/926MB (42.6%)
2021-10-01T11:38:46.560+0530    [##########..............] sample.daily 412MB/926MB (44.5%)
2021-10-01T11:38:49.560+0530    [###########.............] sample.daily 430MB/926MB (46.4%)
2021-10-01T11:38:52.560+0530    [###########.............] sample.daily 448MB/926MB (48.4%)
2021-10-01T11:38:55.560+0530    [###########.............] sample.daily 466MB/926MB (50.3%)
2021-10-01T11:38:58.560+0530    [###########.............] sample.daily 483MB/926MB (52.2%)
2021-10-01T11:39:01.560+0530    [############............] sample.daily 501MB/926MB (54.1%)
2021-10-01T11:39:04.560+0530    [############............] sample.daily 522MB/926MB (56.4%)
2021-10-01T11:39:07.561+0530    [############............] sample.daily 540MB/926MB (58.3%)
2021-10-01T11:39:10.561+0530    [#############...........] sample.daily 553MB/926MB (59.7%)
2021-10-01T11:39:13.560+0530    [#############...........] sample.daily 571MB/926MB (61.6%)
```



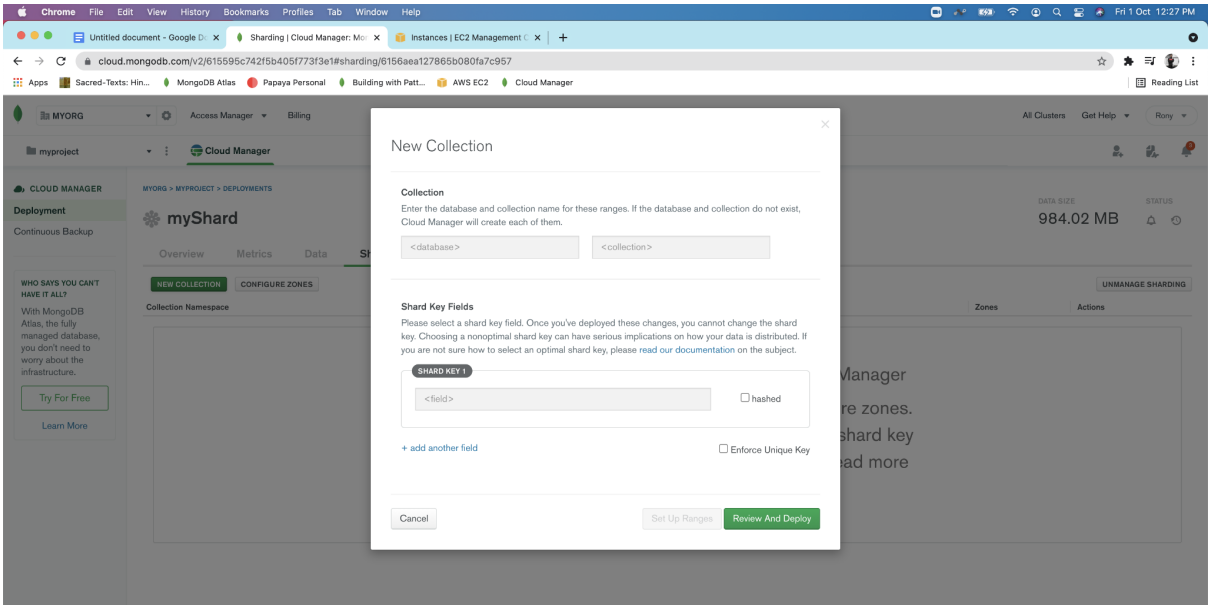
Now lets enable sharding on the sample DB and shard the daily collection which was loaded above

Click on the shard tab and then click on “Manage sharding”

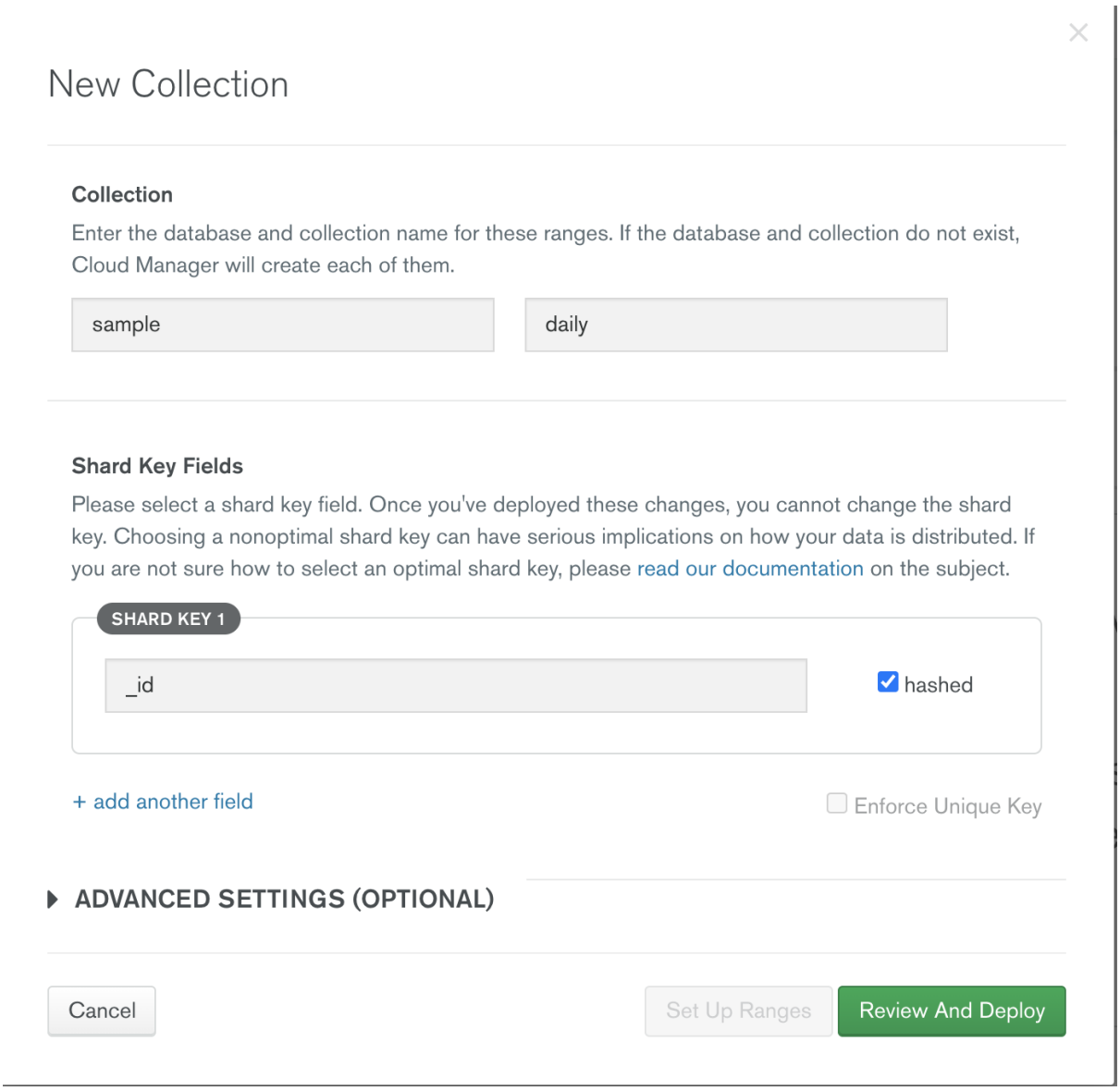


It will open a dialog box and will ask to import sharding info, click on that to complete then click continue and confirm and deploy.

Once done, click on the new collection and fill in the database, collection and shard key details for the one which you want to shard.



Here we will shard by the _id field and do a hashed sharding



Then click review and deploy and wait for it to shard the collection

You can now begin to check the shard status and sharding distribution

Commands:-

Login to the mongos mongosh --host mongo1 --port 28018

- sh.status()

```
[direct: mongos] sample> sh.status()
shardingVersion
{
  _id: 1,
  minCompatibleVersion: 5,
  currentVersion: 6,
  clusterId: ObjectId("6156aec3ba89e5e48b5d4c00")
}
---
shards
[
  {
    _id: 'myReplicaSet',
    host: 'myReplicaSet/mongo1:27017,mongo2:27017,mongo3:27017',
    state: 1,
    topologyTime: Timestamp({ t: 1633070984, i: 3 })
  },
  {
    _id: 'myReplicaSet_1',
    host: 'myReplicaSet_1/mongo1:27018,mongo2:27018,mongo3:27018',
    state: 1,
    topologyTime: Timestamp({ t: 1633070987, i: 2 })
  }
]
---
active mongoses
[ { '5.0.3': 1 } ]
---
autosplit
{ 'Currently enabled': 'yes' }
---
balancer
{
  'Currently running': 'no',
  'Currently enabled': 'yes',
  'Failed balancer rounds in last 5 attempts': 0,
  'Migration Results for the last 24 hours': {
    '1': "Failed with error 'aborted', from myReplicaSet to myReplicaSet_1",
    '306': 'Success'
  }
}
---
databases
[
  {
    database: { _id: 'config', primary: 'config', partitioned: true },
    collections: {
```

```
    'config.system.sessions': {
      shardKey: { _id: 1 },
      unique: false,
      balancing: true,
      chunkMetadata: [
        { shard: 'myReplicaSet', nChunks: 732 },
        { shard: 'myReplicaSet_1', nChunks: 292 }
      ],
      chunks: [
        'too many chunks to print, use verbose if you want to force print'
      ],
      tags: []
    }
  }
},
{
  database: {
    _id: 'myDB',
    primary: 'myReplicaSet',
    partitioned: false,
    version: {
      uuid: UUID("efad8fd7-2f8c-4d0d-b6b0-6695dba74d3c"),
      timestamp: Timestamp({ t: 1633070984, i: 4 }),
      lastMod: 1
    }
  },
  collections: {}
},
{
  database: {
    _id: 'sample',
    primary: 'myReplicaSet',
    partitioned: true,
    version: {
      uuid: UUID("36dcd5a9-1497-41fd-a7e2-1d9a0c142a28"),
      timestamp: Timestamp({ t: 1633070984, i: 7 }),
      lastMod: 1
    }
  },
  collections: {
    'sample.daily': {
      shardKey: { _id: 'hashed' },
      unique: false,
      balancing: true,
      chunkMetadata: [
        { shard: 'myReplicaSet', nChunks: 16 },
        { shard: 'myReplicaSet_1', nChunks: 15 }
```

```
      ],
      chunks: [
        'too many chunks to print, use verbose if you want to force print'
      ],
      tags: []
    }
  }
}
]
```

Security

Security Mechanisms

- MongoDB provides numerous security features:
    - Authentication
        - SCRAM-SHA-256
        - x.509 Certificate Authentication
        - Kerberos Authentication
        - LDAP Proxy Authentication
    - Authorization
        - Role-Based Access Control
    - Transport Encryption
        - Encryption at Rest
        - Auditing
    - Network Exposure Settings
    - You should only run MongoDB in a trusted environment.
    - You should run MongoDB from a non-root user.

Authorization vs Authentication

Authorization and Authentication are generally confused and misinterpreted concepts:

- Authentication is the mechanism by which users identify and are granted access to a system.
- Authorization defines the rules by which users can interact with a given system

Authentication

- Authentication is concerned with:
  - Validating identities
  - Managing certificates / credentials
  - Allowing accounts to connect and perform authorized operations

Authentication Mechanisms

MongoDB supports a number of authentication mechanisms:

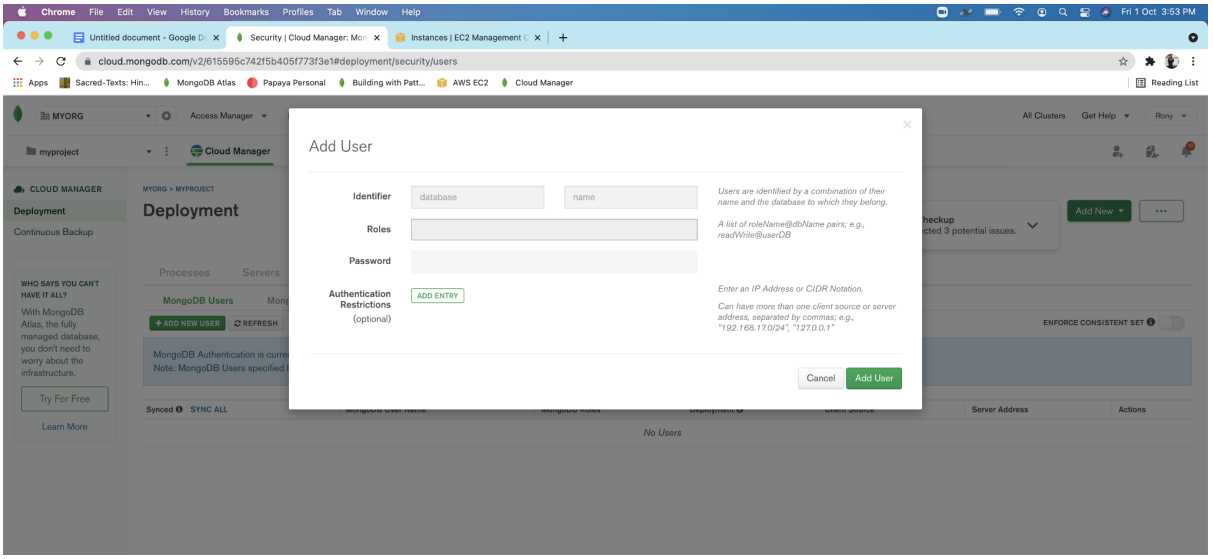
- Challenge/response authentication using SCRAM-SHA-256 (default >= 4.0)
- x.509 certificate authentication

MongoDB Enterprise only:

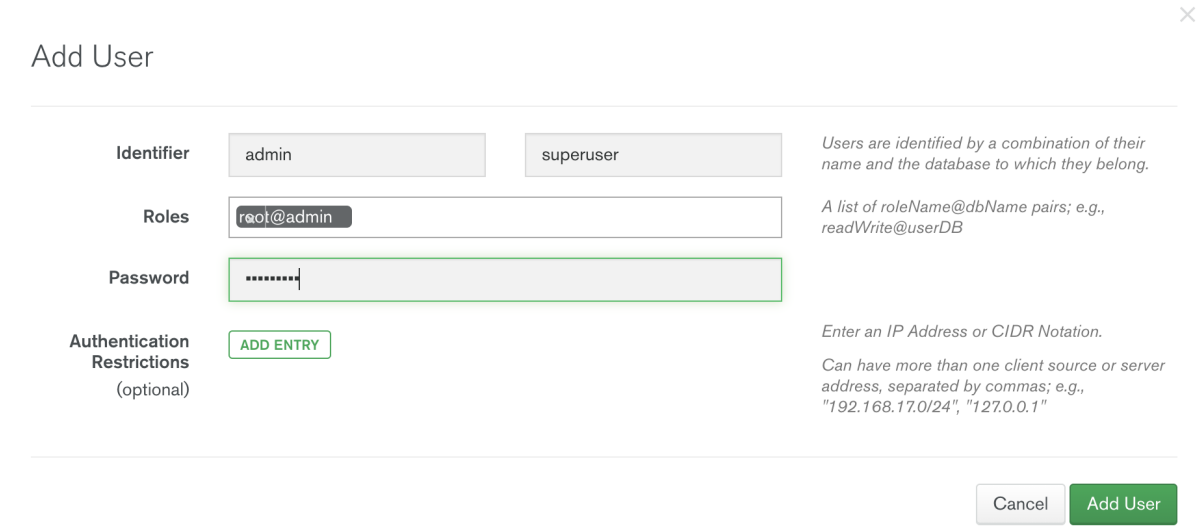
- LDAP Proxy authentication
- Kerberos

Lab: Creating an Admin User

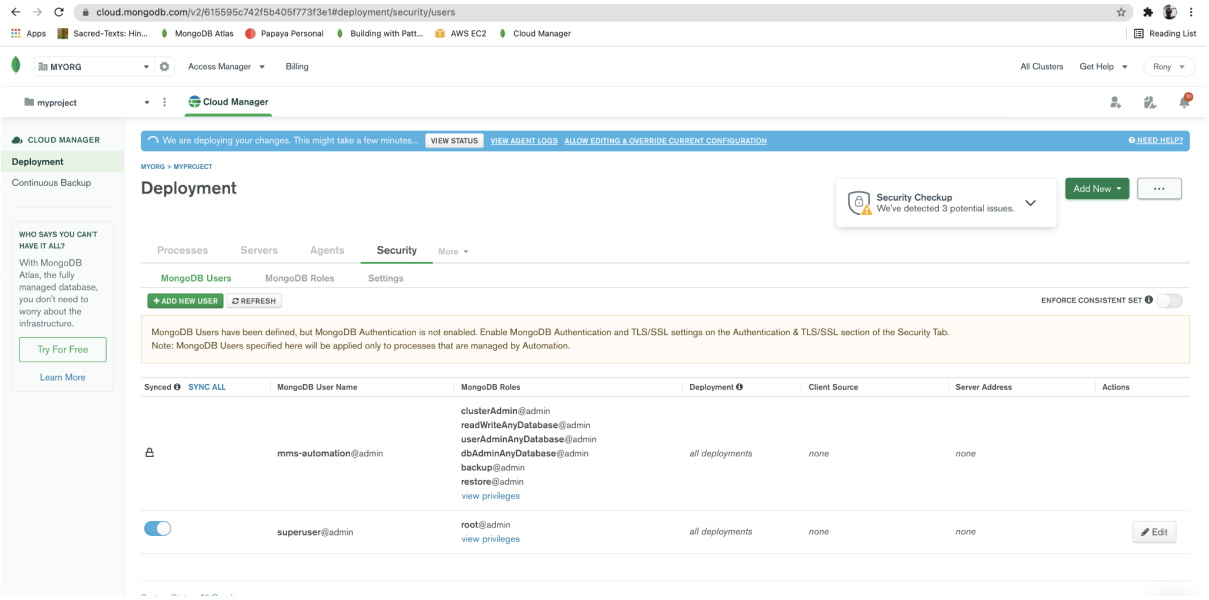
Click on the security tab and click on add new user



Provide the details then review and confirm and deploy

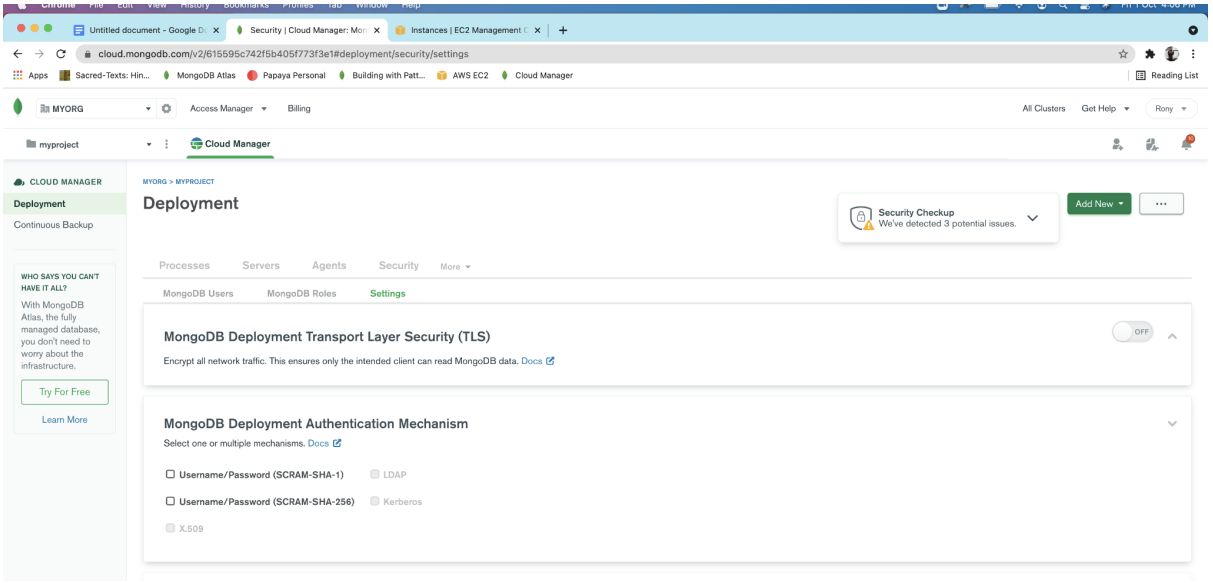


Once done, it will add the user we created



We can now use the user to login to our clusters

Finally, we need to activate the authentication and authorizations from the settings tab under security



Under the authentication mechanism choose the scram-sha-256 and then review and confirm and deploy

Authorization

Authorization via MongoDB

MongoDB grants access to data through a role-based authorization system:

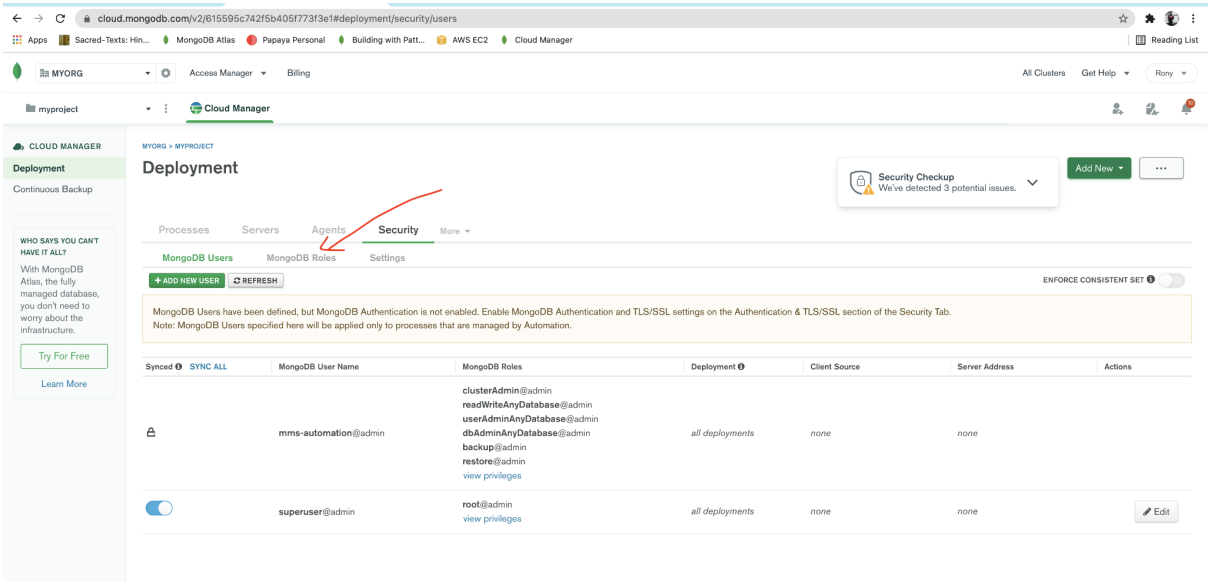
- Built-in roles: pre-canned roles that cover the most common sets of privileges users may require.
- User-defined roles: if there is a specific set of privileges not covered by the existing built-in roles you are able to create your own roles.
- Each user has a set of potential roles - read, readWrite, dbAdmin, etc.

MongoDB Custom User Roles

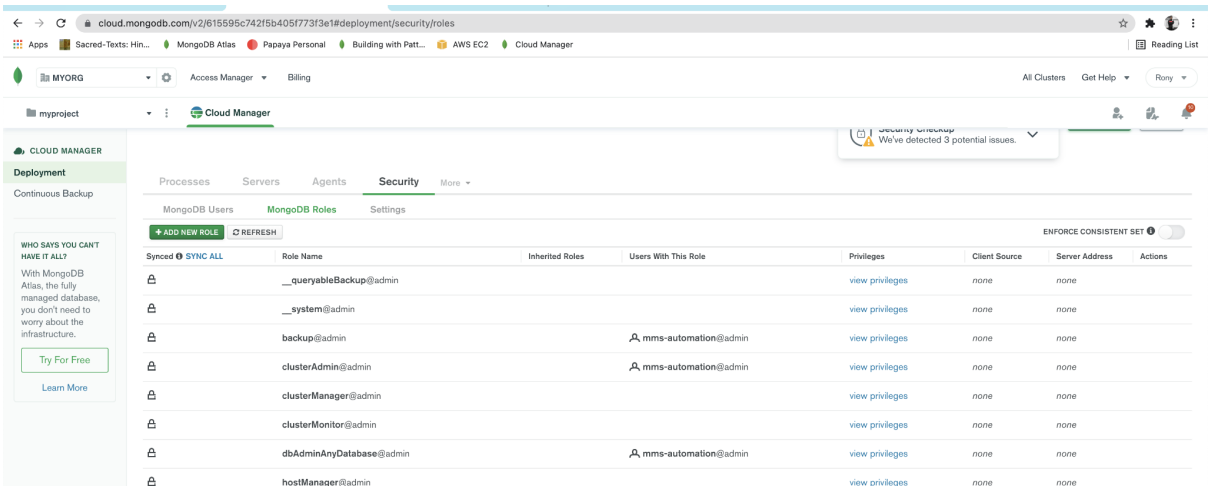
- You can create custom user roles in MongoDB.
- You do this using createRole, which modifies the system.roles collection.
- You can also inherit privileges from other roles into a given role.

Lab: Creating a user defined role

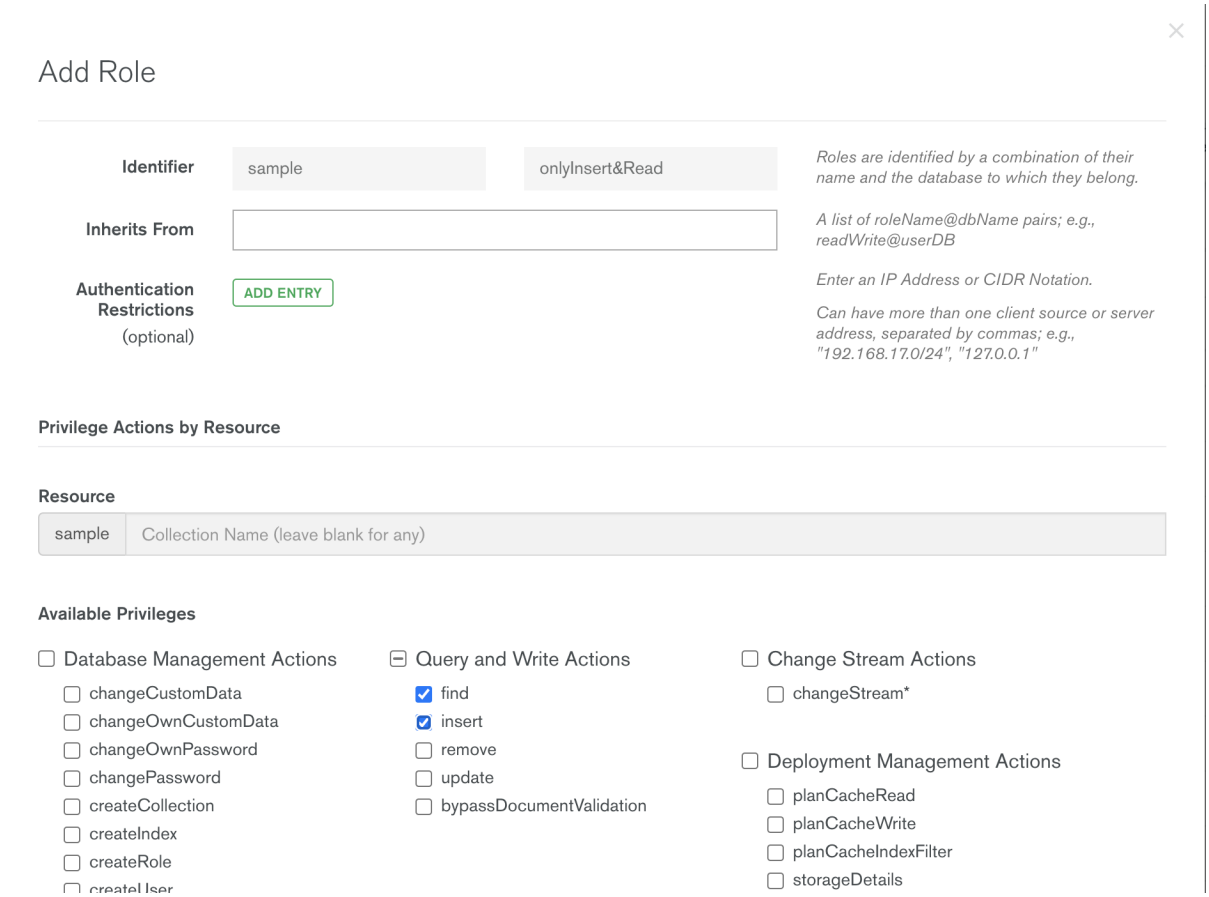
Click on the mongodb roles tab under security tab



Click on add new role

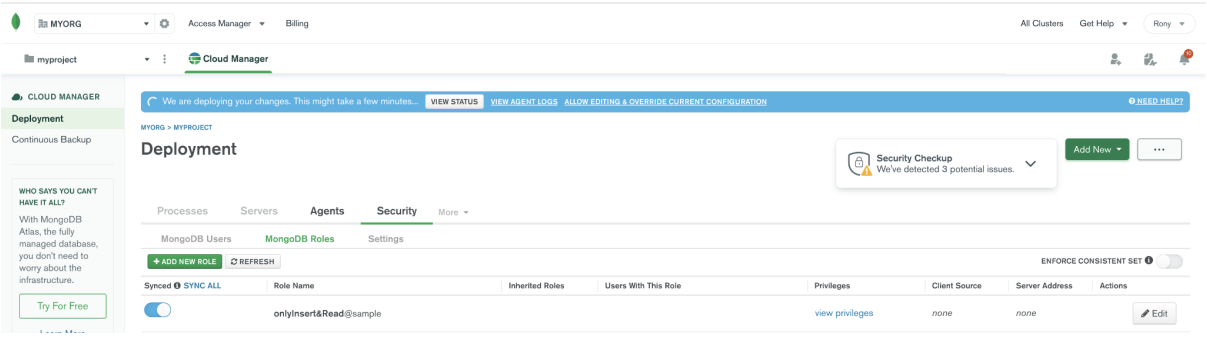


Provide the DB name and role name(we are creating an insert and read only role on the sample DB) and choose the required actions under Query and write actions.



Then click on add privilege and then add role and then review,confirm and deploy.

Once done, we will be able to see our role and privileges as below



Encryption

MongoDB offers

- Network encryption
- Encryption at Rest (MongoDB Enterprise)

Auditing

- MongoDB Enterprise includes an auditing capability for mongod and mongos instances.
- The auditing facility allows administrators and users to track system activity
- Important for deployments with multiple users and applications.

Drivers

MongoDB Supported Drivers

C	C++
C#	Java
Node.js	Perl
PHP	Python
Ruby	Scala
Go	others

MongoDB Community Supported Drivers

- 35+ different drivers for MongoDB:
    - Erlang, R, Clojure, D, Delphi, F#, Groovy, Lisp, Objective C, Prolog, Smalltalk, and more

Sample Driver Settings

Per Connection	• Connection timeout • Connections per host • maxWaitTime a thread block waiting for a connection • Socket keep alive
Per Operation	• Read preference • Write concern • Maximum operation time (maxTimeMS) • Batch size (batchSize) • Exhaust cursor (exhaust)

Retryable Reads

Retryable reads allow MongoDB drivers to automatically retry certain read operations a single time if they encounter certain network or server errors.

Prerequisites

Minimum Driver Version

Official MongoDB drivers compatible with MongoDB Server 4.2 and later support retryable reads.For more information on official MongoDB drivers, see MongoDB Drivers.

Minimum Server Version

Drivers can only retry read operations if connected to MongoDB Server 3.6 or later.

Enabling Retryable Reads

Official MongoDB drivers compatible with MongoDB Server 4.2 and later enable retryable reads by default. To explicitly disable retryable reads, specify retryReads=false in the connection string for the deployment.

Behavior

Persistent Network Errors

MongoDB retryable reads make only **one** retry attempt. This helps address transient network errors or replica set elections, but not persistent network errors.

Retrayable writes

Retryable writes allow MongoDB drivers to automatically retry certain write operations a single time if they encounter network errors, or if they cannot find a healthy primary in the replica sets or sharded cluster

Supported Deployment Topologies

Retryable writes require a replica set or sharded cluster, and do **not** support standalone instances.

Supported Storage Engine

Retryable writes require a storage engine supporting document-level locking, such as the WiredTiger or in-memory storage engines.

3.6+ MongoDB Drivers

Clients require MongoDB drivers updated for MongoDB 3.6 or greater:

Java 3.6+	C# 2.5+	Perl 2.0+PHPC 1.4+
Python 3.6+	Node 3.0+	Scala 2.2+
C 1.9+	Ruby 2.5+	

MongoDB Version

The MongoDB version of every node in the cluster must be 3.6 or greater, and the featureCompatibilityVersion of each node in the cluster must be 3.6 or greater. See setFeatureCompatibilityVersion for more information on the featureCompatibilityVersion flag.

Write Acknowledgment

Write operations issued with a Write Concern of `0` are **not** retryable.

Behavior

Persistent Network Errors

MongoDB retryable writes make only **one** retry attempt. This helps address transient network errors and replica set elections, but not persistent network errors.

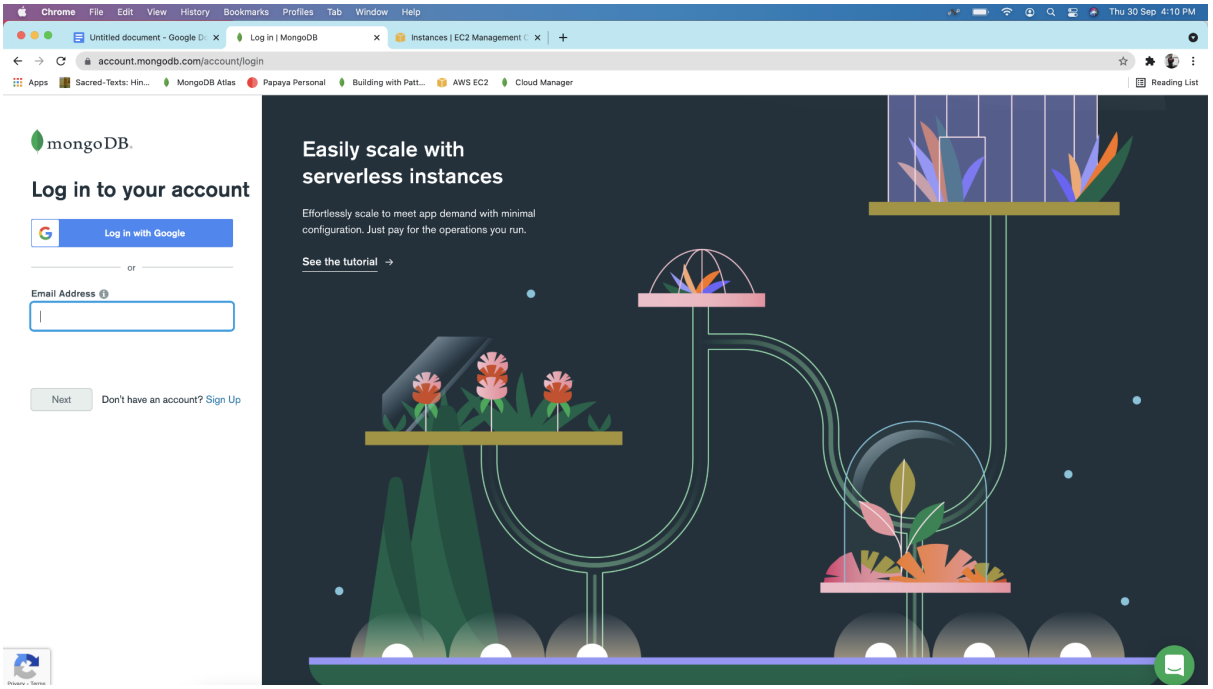
Application Considerations and Issues

- Exceptions need to be caught and handled by your application.
- Network errors, server failures, datacenter failures, command errors, outages and other events all need to be handled by your application.
- The best overall approach to address these type of events is to design your application to retry network errors and to make the operations sent by your application idempotent.
    - Idempotent operations will have the same outcome whether tried once or multiple times.
- Transactions provide the functionality to ensure atomicity of updates when multiple documents are involved. MongoDB supports transactions across databases, collections, operations, documents and shards.

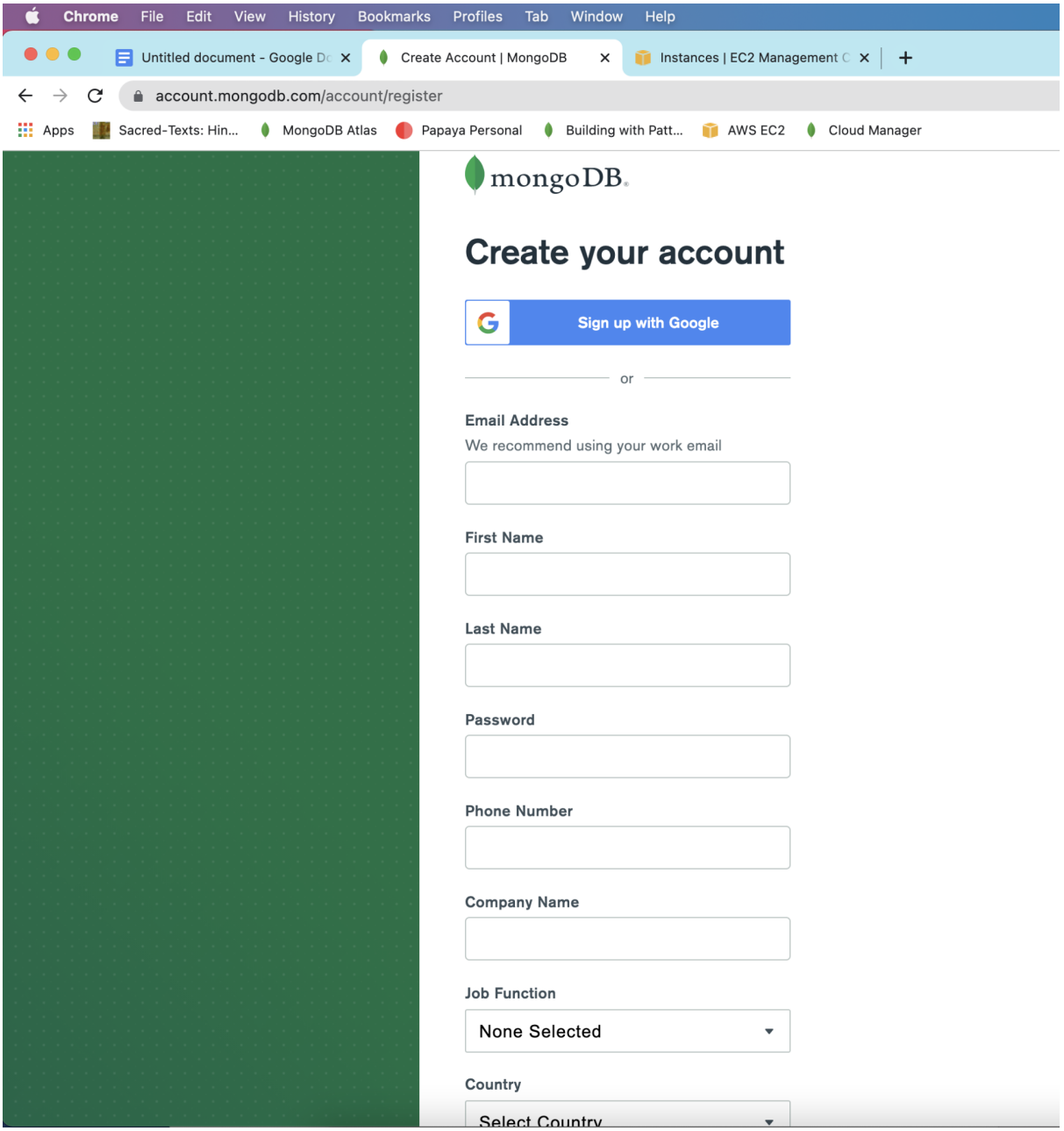
Appendix2

Setting up Cloud manager free trial account(for 30 days only) for Replicaset and sharded cluster setup and automation.

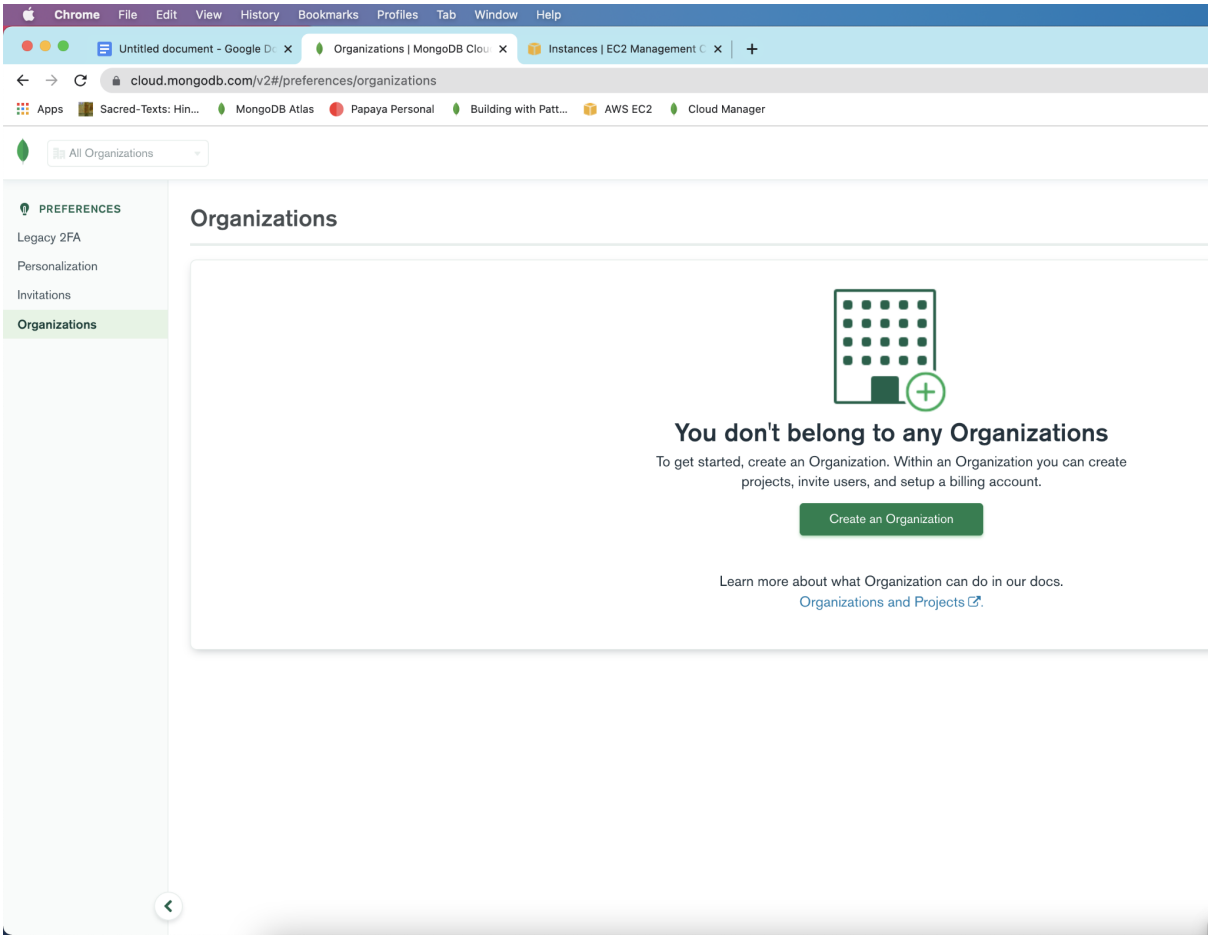
Log on to https://cloud.mongodb.com/



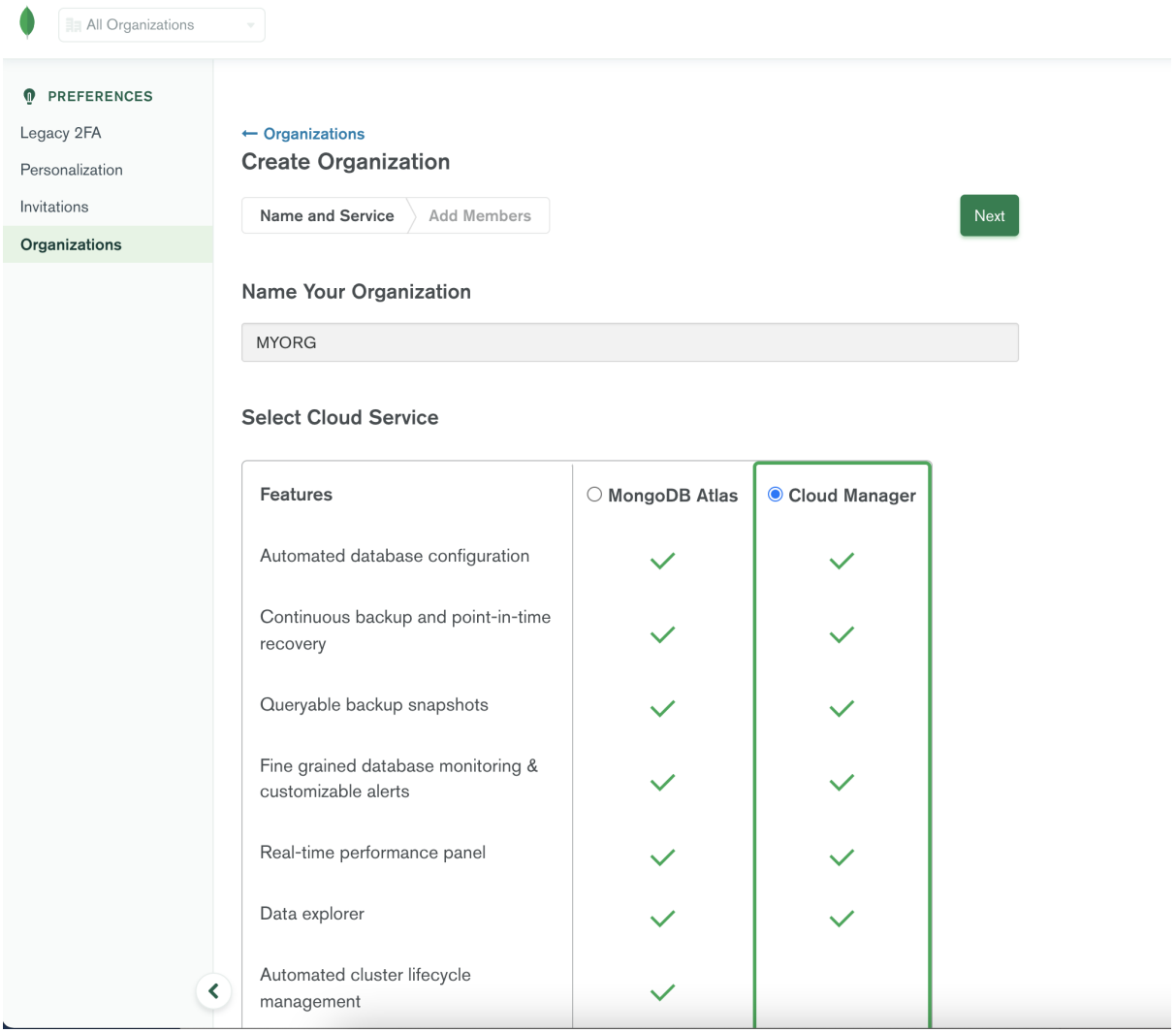
Click on sign up and enter your details and verify the email id.



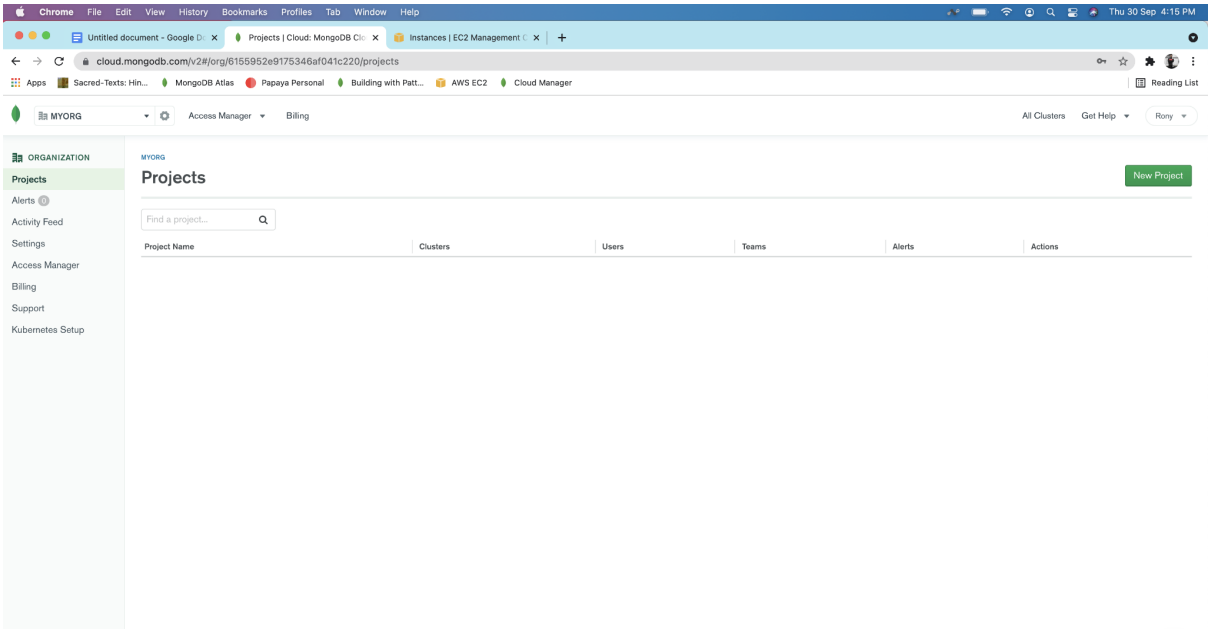
Create an organization and give it a name



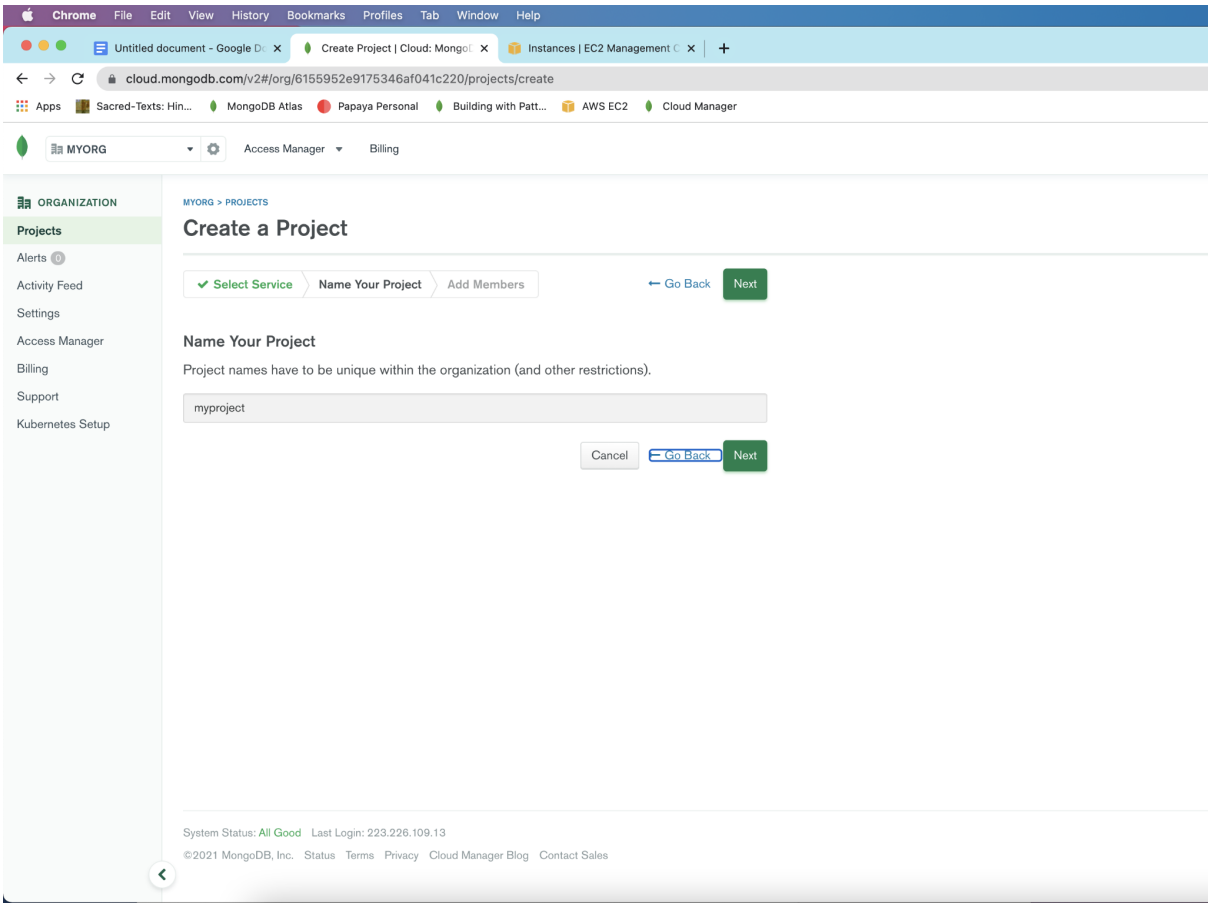
Choose cloud manager and enter your org name, click next and hit create organization.



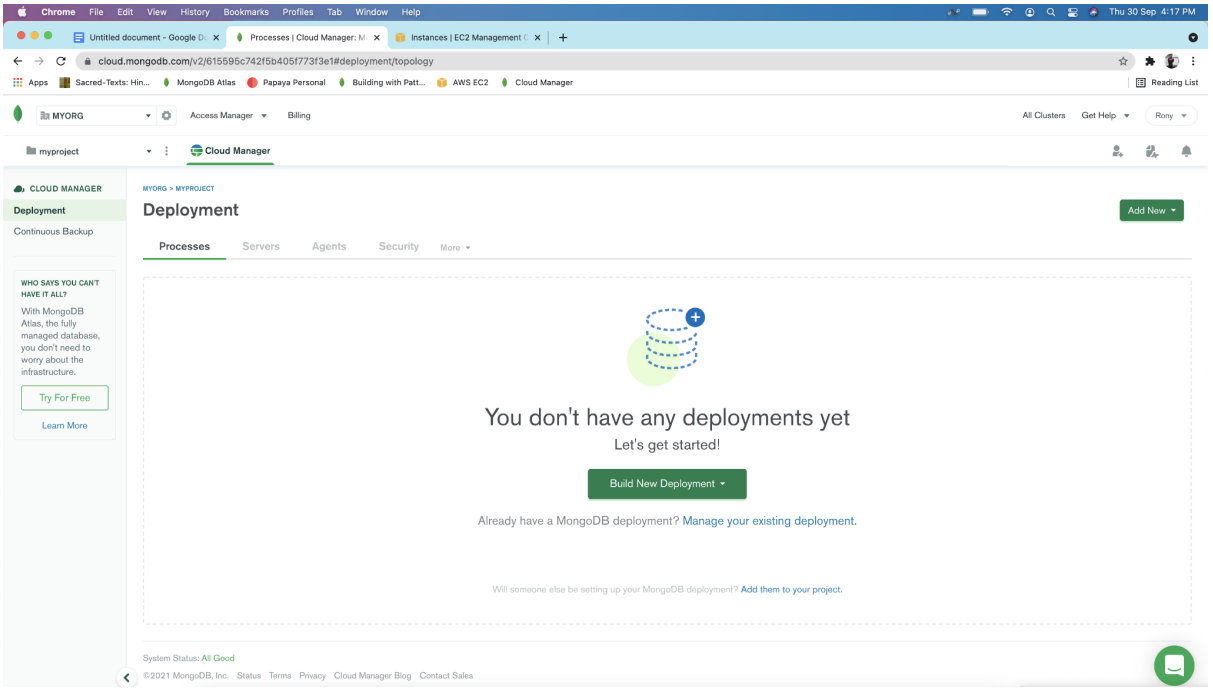
Then click on new project button on right hand side top corner as shown.



Give a name for your project and hit next and then create project.



Once you create project you will land in the clusters view page as below

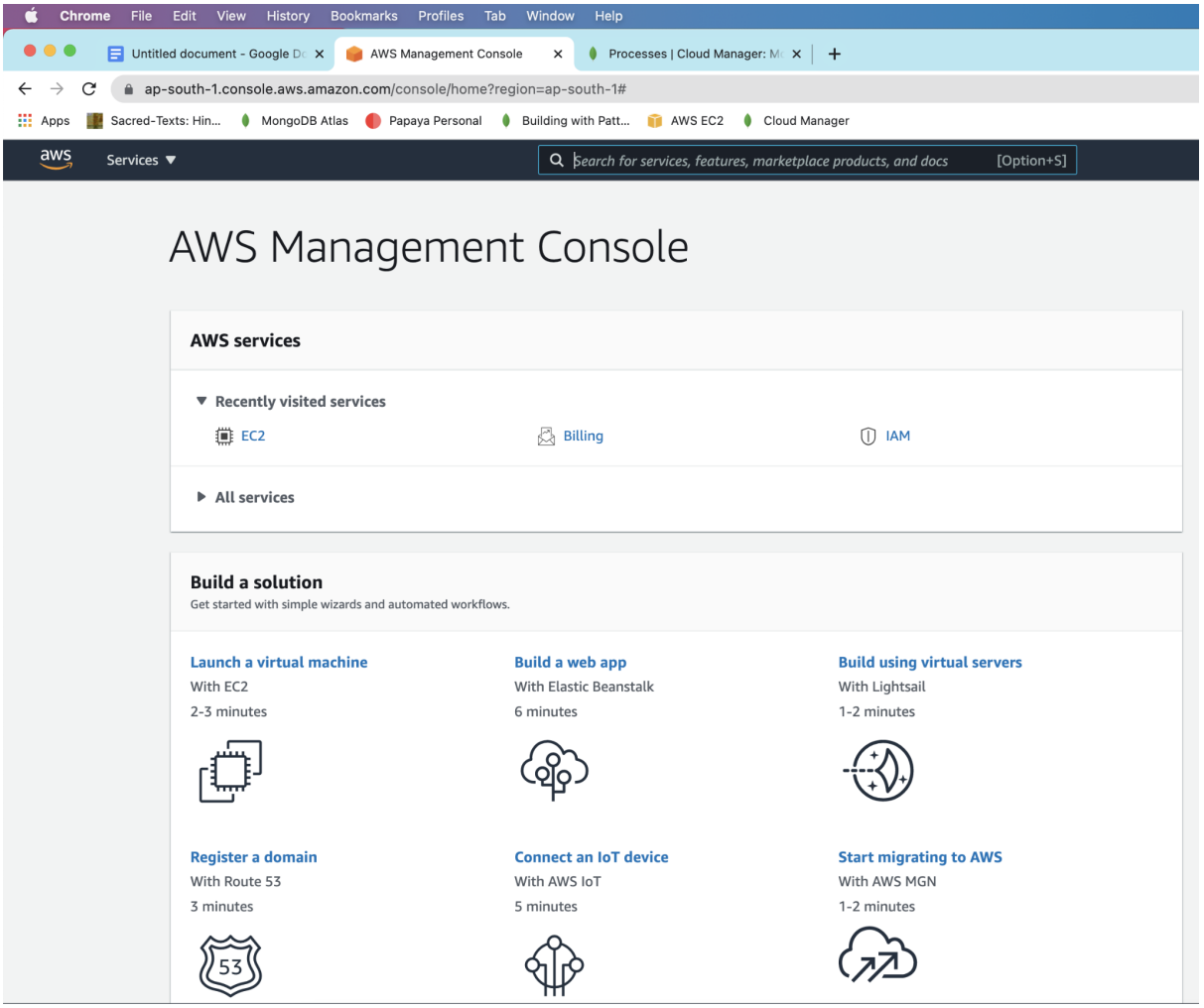


Amazon Free Tier EC2 instance setup for replicaset and sharded cluster nodes.

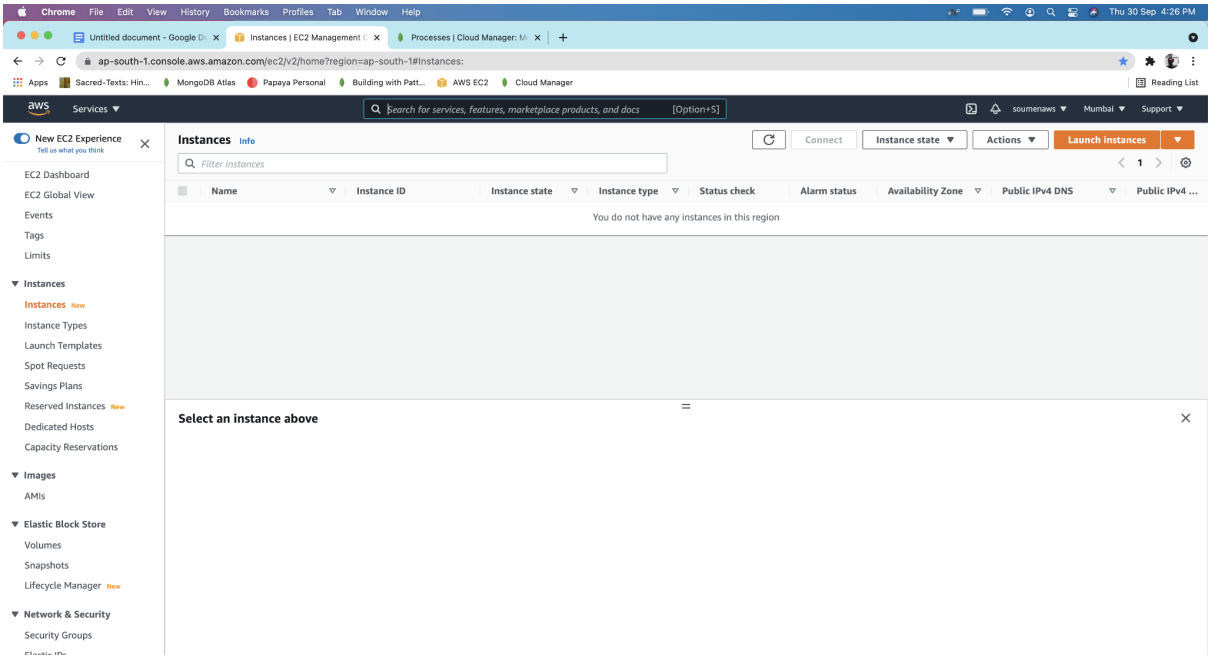
Login to https://aws.amazon.com

Create and set up an AWS account. If you already have one then you can directly go to the ec2 console otherwise please setup a new account and you will be entitled for free credits for 1 year.

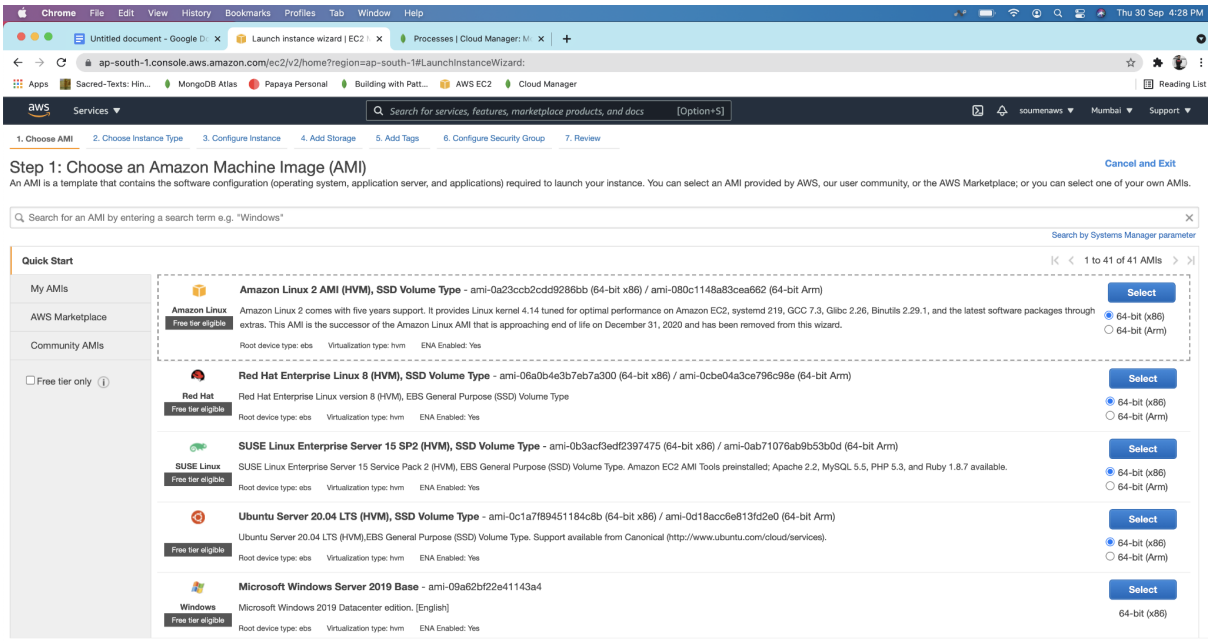
Navigate to the management console



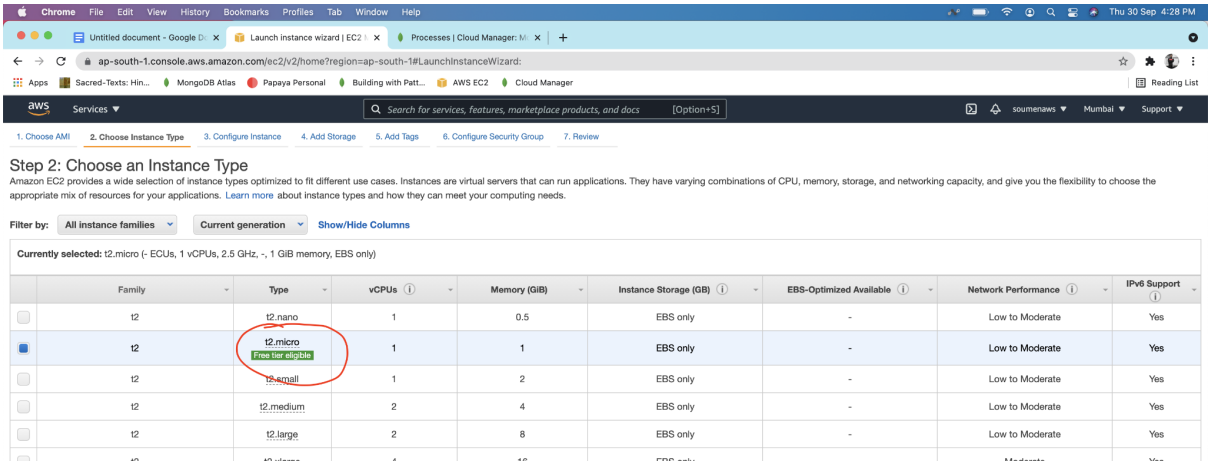
Click on EC2



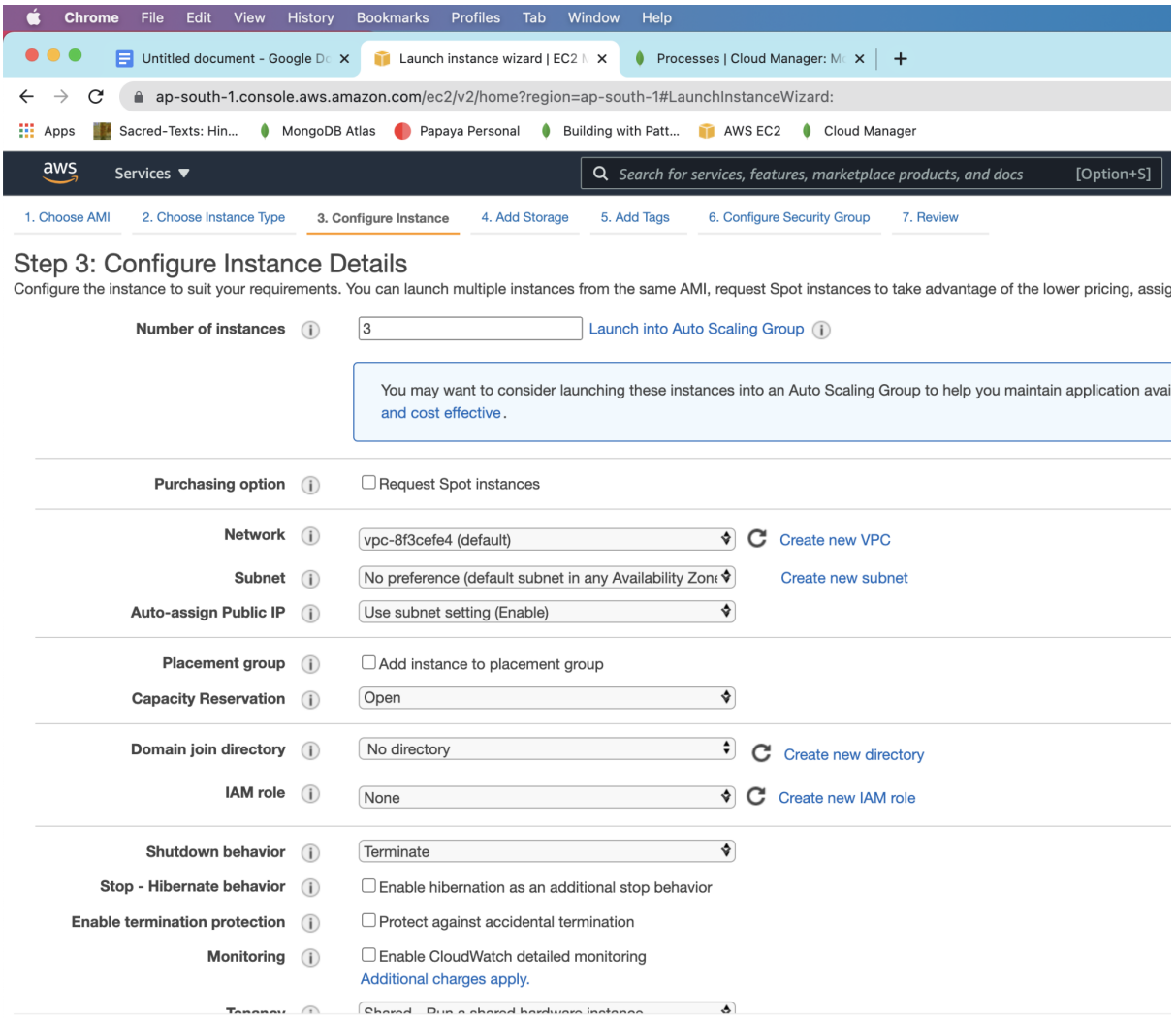
Click on launch instances on top right and choose amazon linux 2 under AMI selection menu



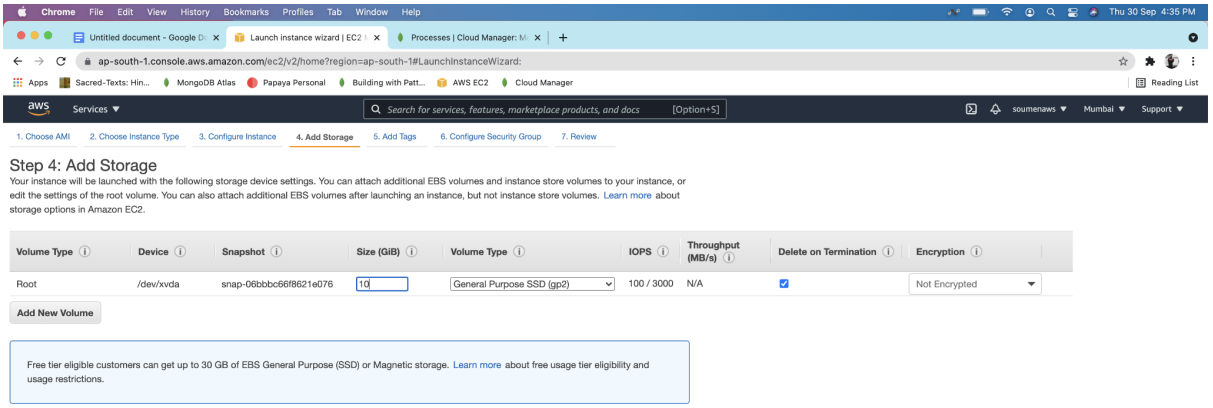
Choose t2.micro under instance type and click configure instance details



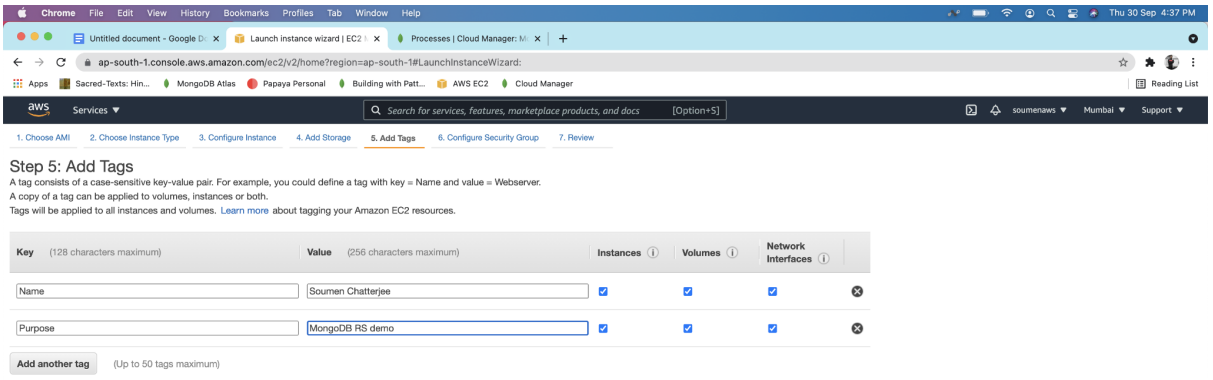
Under instance details select number of instances to ‘3’, shutdown behaviour to “terminate” and then click add storage



Increase the size from default 8 to 10 or more based on your requirement(upto 30 GB is free) and then click add tags

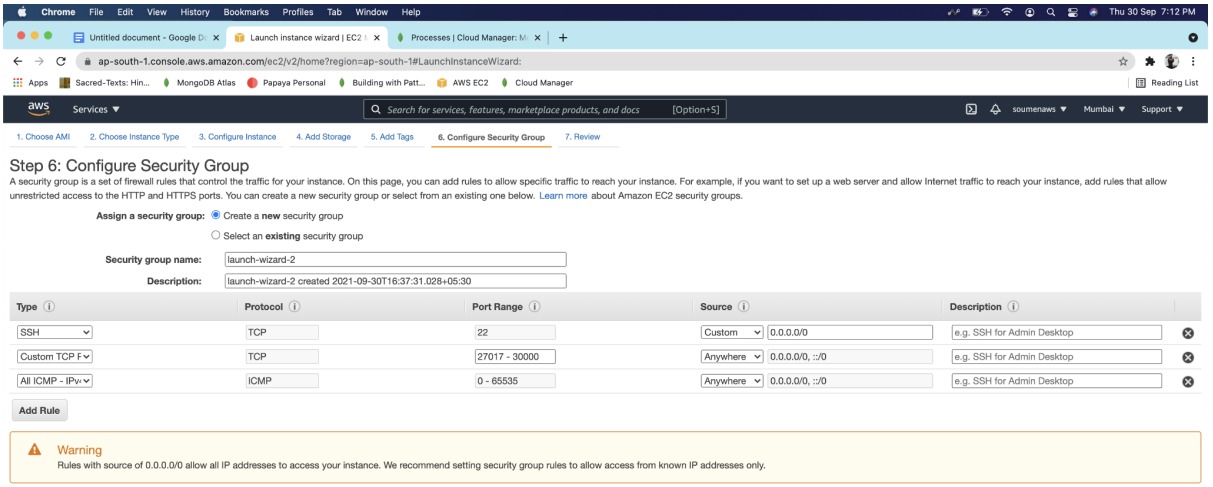


Add your tags as per your choice and click on security group configurations



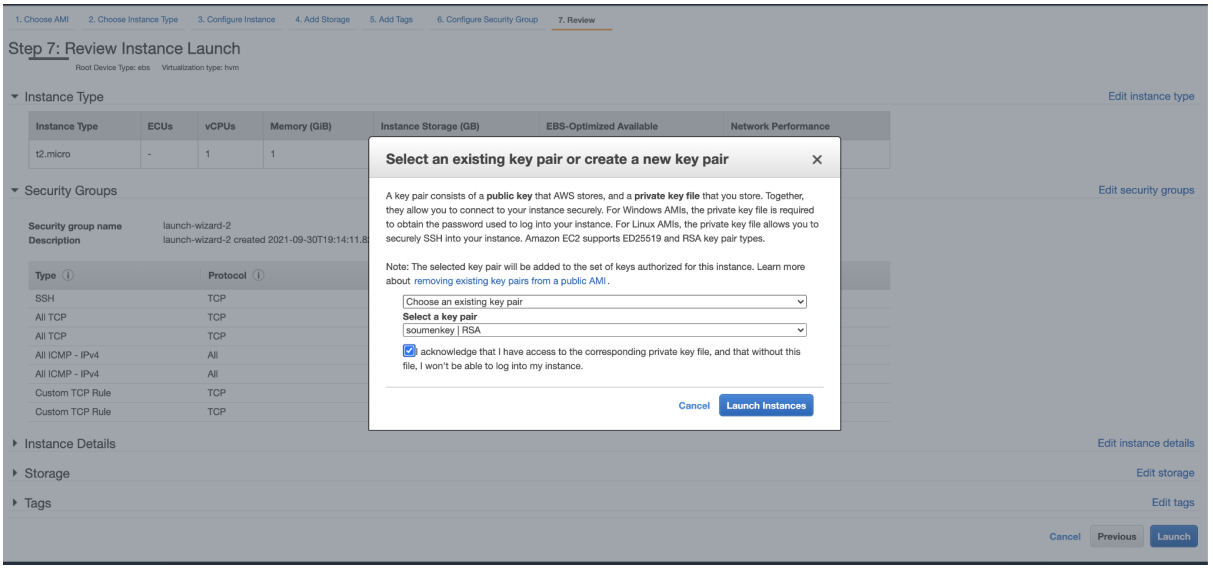
Click on Add rule and choose the below, then hit review and launch:-

- Custom TCP PORT - port range - 27017 - 30000, source - anywhere
- All ICMP - IPV4 - source - anywhere

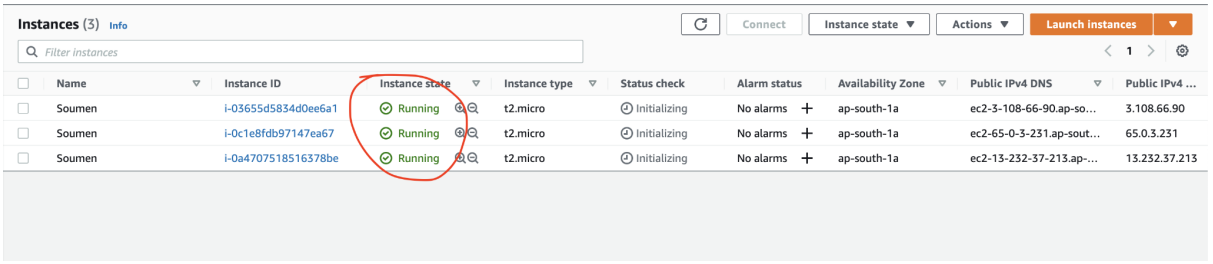


Finally, review and click launch

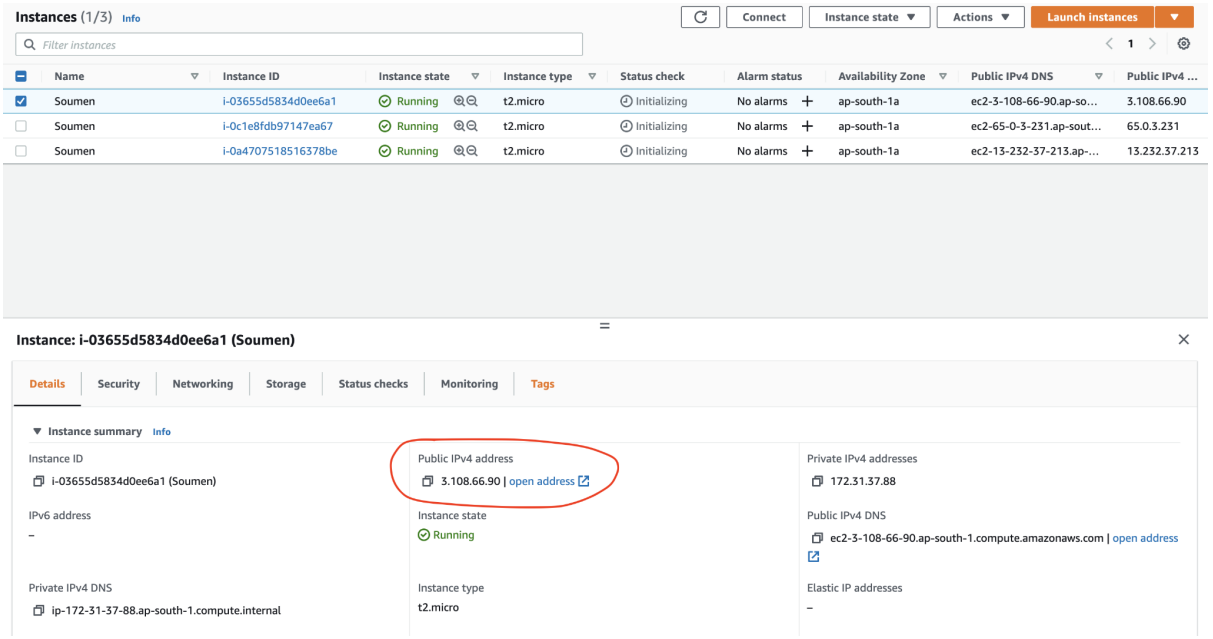
Choose a keypair if you already have or create a new one for accessing the nodes. Don't forget to down load your key pem file and save it in your local system.



Wait for the instances come online(the instance states should be all green and running)



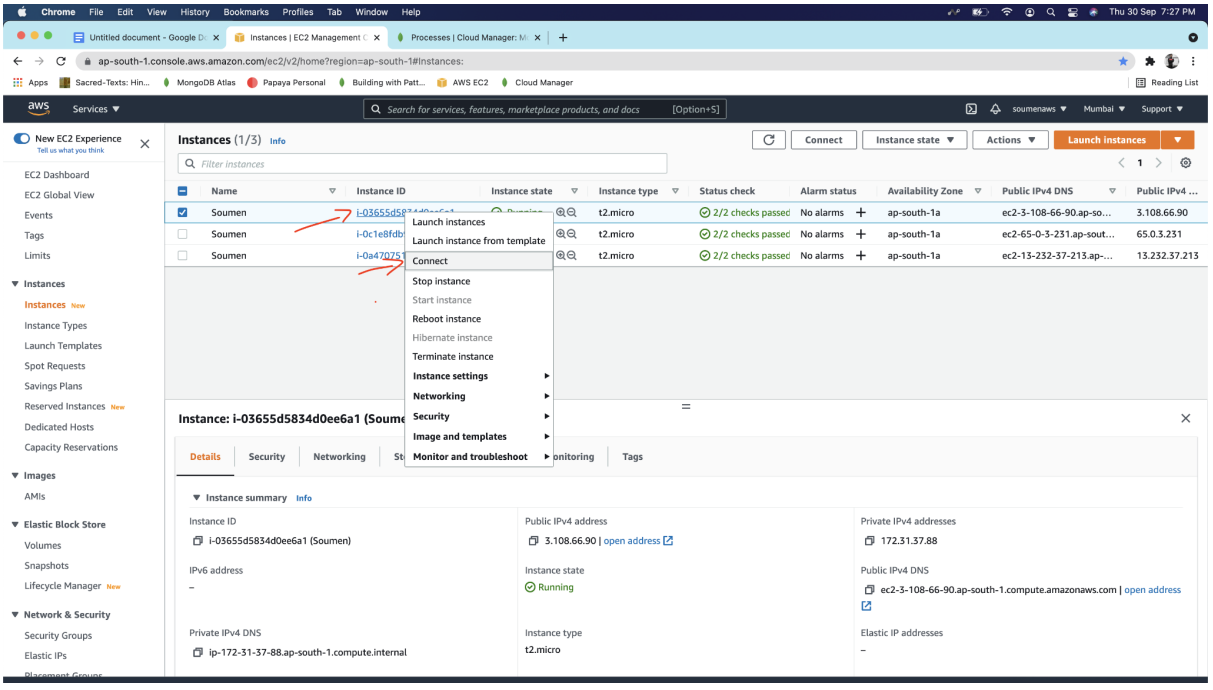
Click on each of the instances to fetch the public ip address



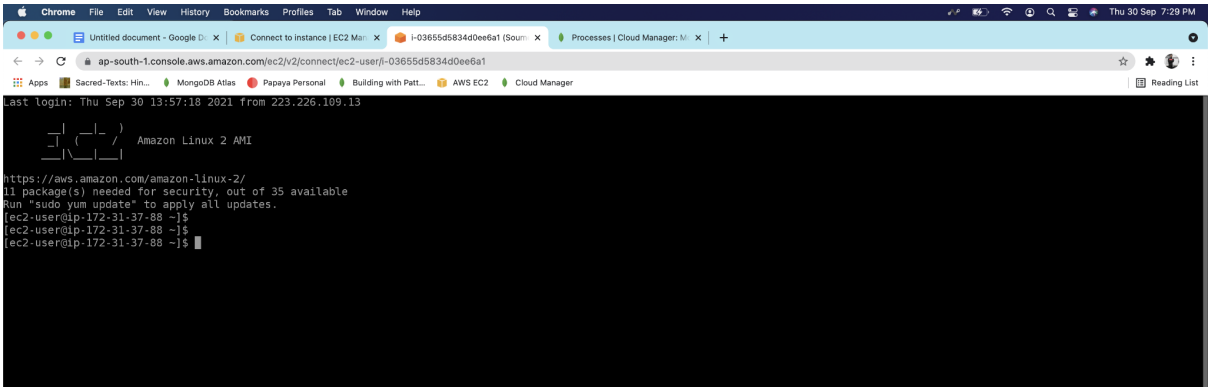
We will use the public ip for each instance to connect.

To connect to a node:-

Right click on the instance id and select connect



AWS will redirect you to a terminal and will automatically connect



Alternatively, you can launch a terminal on your local systems and type the following command to connect:-

```
ssh -i <your aws keypair pem key> ec2-user@<public_ip_address>
```

If you want to modify/set the FQDN of the node to something else then use the below commands:-

```
sudo hostnamectl set-hostname <your host fqdn here>
sudo reboot
```

Windows users, please follow the below link to setup putty to connect to linux instances.
https://docs.aws.amazon.com/AWSEC2/latest/UserGuide/putty.html

Add public ips and hostnames for your local DNS resolution(in the /etc/hosts file)

```
127.0.0.1 <hostname1>
<public ip 1> <hostname1>
<public ip 2> <hostname2>
<public ip 3> <hostname3>
```

Finally, you should apply the mongoDB production notes as a best practice to all the nodes.

https://docs.mongodb.com/manual/administration/production-notes/

Thank you! Questions?