MongoDB Sharding Documentation

1. Overview

This documentation outlines the steps taken to set up MongoDB sharding, create a sharded collection, insert data, and perform queries. The process involves setting up a MongoDB cluster using Docker Compose, enabling sharding on a database, creating a sharded collection, inserting data, and querying it.

2. Setup MongoDB Cluster with Docker Compose

First, a MongoDB cluster is set up using Docker Compose. This involves the following steps:

- Create MongoDB Instances: Define MongoDB instances for shard servers, config servers, and mongos routers in the Docker Compose file.
- Execute Docker Compose: Run Docker Compose to create and start MongoDB instances.

```
version: '3'
services:
 mongo-shard1-1:
   image: mongo:5
   ports:
     - "27101:27017"
   command: mongod --shardsvr --replSet mongo-shard1-rs --port 27017
--bind_ip_all
   networks:
     - mongodb-network

 mongo-shard1-2:
   image: mongo:5
   command: mongod --shardsvr --replSet mongo-shard1-rs --port 27017
--bind_ip_all
   networks:
     - mongodb-network

 mongo-shard1-3:
   image: mongo:5
   command: mongod --shardsvr --replSet mongo-shard1-rs --port 27017
--bind_ip_all
   networks:
     - mongodb-network

 mongo-shard2-1:
   image: mongo:5
   ports:
     - "27201:27017"
   command: mongod --shardsvr --replSet mongo-shard2-rs --port 27017
--bind_ip_all
   networks:
     - mongodb-network

 mongo-shard2-2:
   image: mongo:5
   command: mongod --shardsvr --replSet mongo-shard2-rs --port 27017
--bind_ip_all
   networks:
     - mongodb-network

 mongo-shard2-3:
   image: mongo:5
   command: mongod --shardsvr --replSet mongo-shard2-rs --port 27017
--bind_ip_all
   networks:
     - mongodb-network

 mongo-shard3-1:
   image: mongo:5
   ports:
     - "27301:27017"
   command: mongod --shardsvr --replSet mongo-shard3-rs --port 27017
--bind_ip_all
   networks:
     - mongodb-network

 mongo-shard3-2:
   image: mongo:5
   command: mongod --shardsvr --replSet mongo-shard3-rs --port 27017
--bind_ip_all
   networks:
     - mongodb-network

 mongo-shard3-3:
   image: mongo:5
   command: mongod --shardsvr --replSet mongo-shard3-rs --port 27017
--bind_ip_all
   networks:
```

```
    - mongodb-network

 mongo-config-server-1:
   image: mongo:5
   ports:
     - "27019:27017"
   command: mongod --configsvr --replSet mongo-config-server-rs --port
27017 --bind_ip_all
   networks:
     - mongodb-network

 mongo-config-server-2:
   image: mongo:5
   command: mongod --configsvr --replSet mongo-config-server-rs --port
27017 --bind_ip_all
   networks:
     - mongodb-network

 mongo-config-server-3:
   image: mongo:5
   command: mongod --configsvr --replSet mongo-config-server-rs --port
27017 --bind_ip_all
   networks:
     - mongodb-network

 mongos-router:
   image: mongo:5
   ports:
     - "27017:27017"
   command: mongos --configdb
mongo-config-server-rs/mongo-config-server-1:27017,mongo-config-server-2:27
017,mongo-config-server-3:27017 --bind_ip_all
   depends_on:
     - mongo-config-server-1
     - mongo-config-server-2
     - mongo-config-server-3
   networks:
     - mongodb-network

networks:
 mongodb-network:
   driver: bridge
```

```
zamlamb@ZamLaptop:~/mongodb$ vim docker-compose.yaml
zamlamb@ZamLaptop:~/mongodb$ docker-compose -up -d
```

Then connect the components to one another:
In the provided commands, several actions are being performed to set up a MongoDB sharded cluster. Let's break down each command and explain what it does:

1. MongoDB Shard Initialization

```
docker exec -it mongodb_mongo-shard1-1_1 mongosh --eval 'rs.initiate({_id:
"mongo-shard1-rs", members: [{_id: 0, host:
"mongodb_mongo-shard1-1_1:27017"}, {_id: 1, host:
"mongodb_mongo-shard1-2_1:27017"}, {_id: 2, host:
"mongodb_mongo-shard1-3_1:27017"}]})'
```

- This command initializes the first shard replica set (`mongo-shard1-rs`) by executing the `rs.initiate()` function.
- It specifies three members (`members`) for the replica set, each with an `_id` and `host` indicating the Docker container and port where the MongoDB instances are running.

This is also done for the other sets

2. Configuration Server Initialization

```
docker exec -it mongodb_mongo-config-server-1_1 mongosh --eval
'rs.initiate({_id: "mongo-config-server-rs", configsvr: true, members:
[{_id: 0, host: "mongodb_mongo-config-server-1_1:27017"}, {_id: 1, host:
"mongodb_mongo-config-server-2_1:27017"}, {_id: 2, host:
"mongodb_mongo-config-server-3_1:27017"}]})'
```

- This command initializes the configuration server replica set (`mongo-config-server-rs`) with the `configsvr: true` option, indicating that these servers will store cluster metadata.
- Similar to the shard initialization, it specifies three members for the replica set.

3. Adding Shards to the Router

```
docker exec -it mongodb_mongos-router-1_1 mongosh --eval
'sh.addShard("mongo-shard1-rs/mongodb_mongo-shard1-1_1:27017,mongodb_mongo-
shard1-2_1:27017,mongodb_mongo-shard1-3_1:27017")'
```

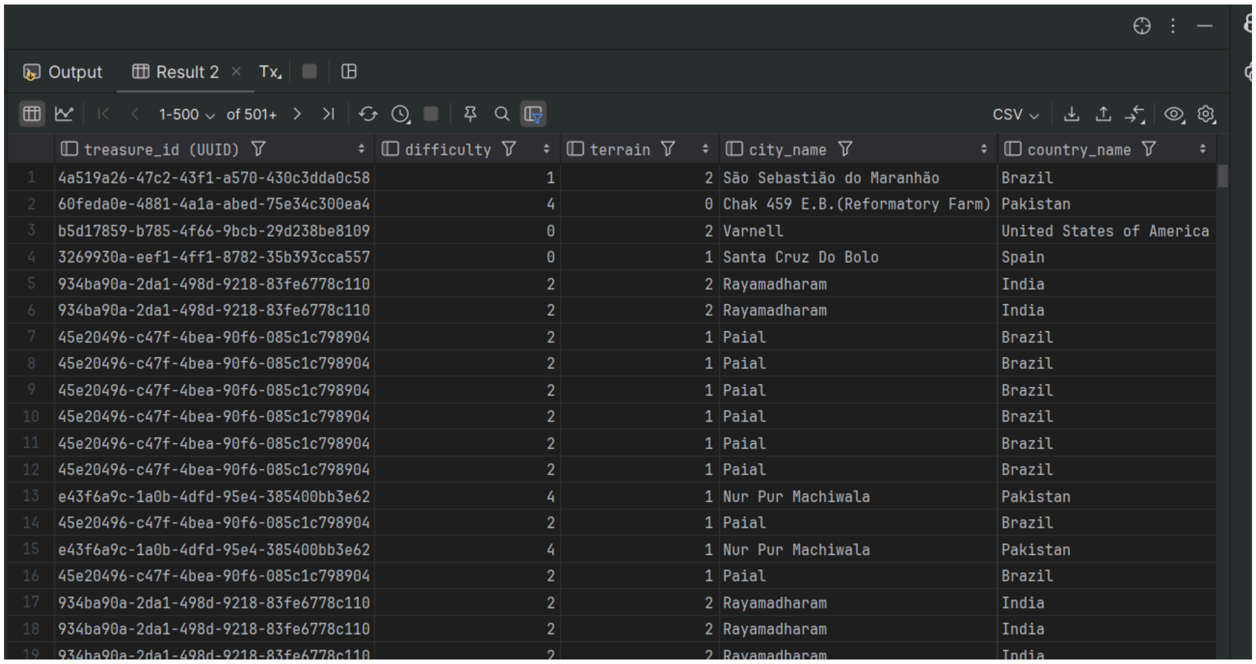
- This command adds the first shard (`mongo-shard1-rs`) to the mongos router. It specifies the hosts of the shard members.
- Similar commands are used to add the second and third shards (`mongo-shard2-rs` and `mongo-shard3-rs`) to the mongos router.

Overall, these commands initialize shard replica sets, configuration server replica set, and add shards to the mongos router, effectively setting up a MongoDB sharded cluster.

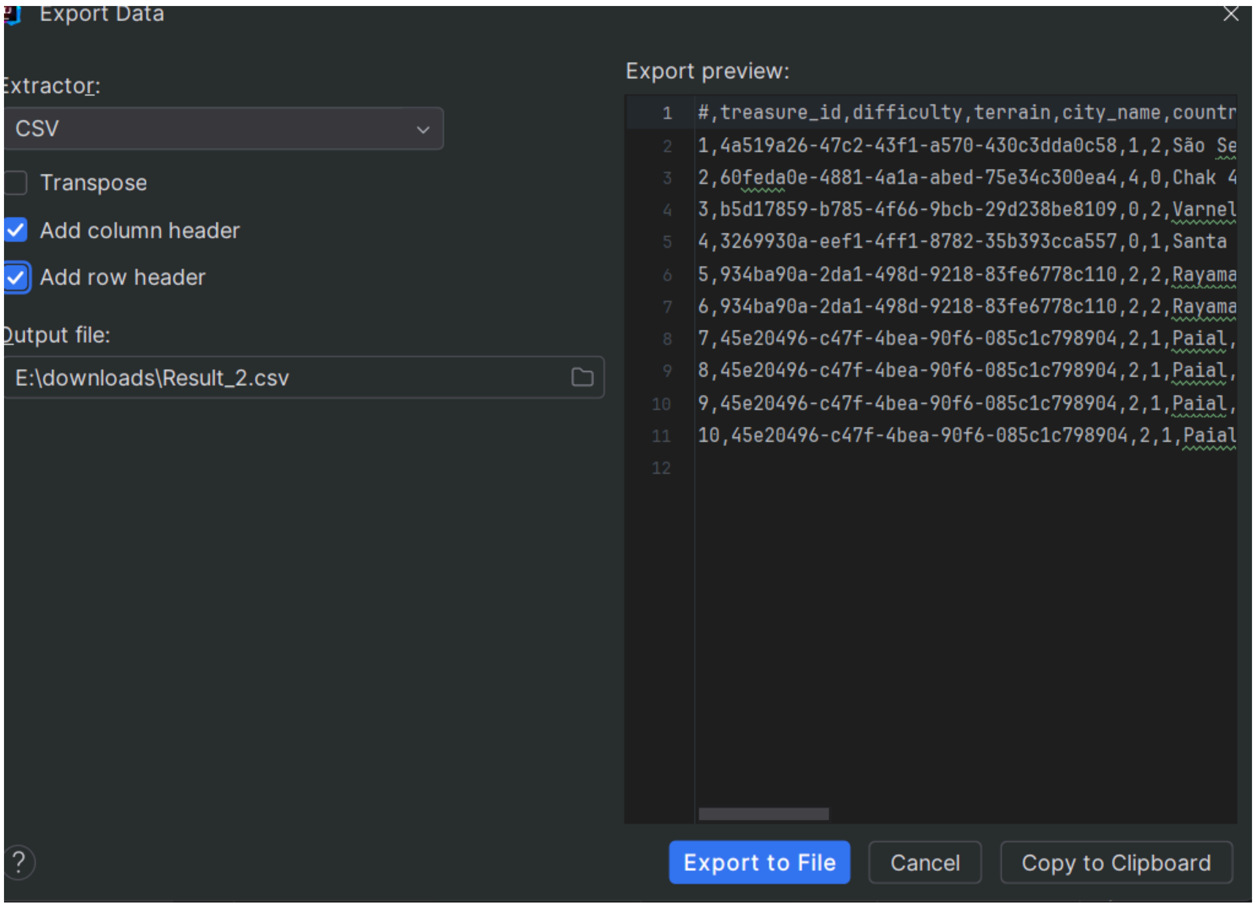
3. Insert Data from SQL Query

```
SELECT
   t.id AS treasure_id,
   t.difficulty,
   t.terrain,
   c.city_name,
   co.name AS country_name,
   co.code3 AS country_code,
   s.container_size,
   s.description AS stage_description,
   s.latitude AS stage_latitude,
   s.longitude AS stage_longitude,
   s.sequence_number,
   s.type AS stage_type,
   s.visibility
FROM
   treasure AS t
       INNER JOIN
   city AS c ON t.city_city_id = c.city_id
       INNER JOIN
   country AS co ON c.country_code = co.code
       INNER JOIN
   treasure_stages AS ts ON t.id = ts.treasure_id
       INNER JOIN
   stage AS s ON ts.stages_id = s.id
```

After the MongoDB cluster is set up, data is inserted from a SQL query output CSV file (`result2.csv`).



	treasure_id (UUID)	difficulty	terrain	city_name	country_name
1	4a519a26-47c2-43f1-a570-430c3dda0c58	1	2	São Sebastião do Maranhão	Brazil
2	60feda0e-4881-4a1a-abed-75e34c300ea4	4	0	Chak 459 E.B.(Reformatory Farm)	Pakistan
3	b5d17859-b785-4f66-9bcb-29d238be8109	0	2	Varnell	United States of America
4	3269930a-eef1-4ff1-8782-35b393cca557	0	1	Santa Cruz Do Bolo	Spain
5	934ba90a-2da1-498d-9218-83fe6778c110	2	2	Rayamadharam	India
6	934ba90a-2da1-498d-9218-83fe6778c110	2	2	Rayamadharam	India
7	45e20496-c47f-4bea-90f6-085c1c798904	2	1	Paial	Brazil
8	45e20496-c47f-4bea-90f6-085c1c798904	2	1	Paial	Brazil
9	45e20496-c47f-4bea-90f6-085c1c798904	2	1	Paial	Brazil
10	45e20496-c47f-4bea-90f6-085c1c798904	2	1	Paial	Brazil
11	45e20496-c47f-4bea-90f6-085c1c798904	2	1	Paial	Brazil
12	45e20496-c47f-4bea-90f6-085c1c798904	2	1	Paial	Brazil
13	e43f6a9c-1a0b-4dfd-95e4-385400bb3e62	4	1	Nur Pur Machiwala	Pakistan
14	45e20496-c47f-4bea-90f6-085c1c798904	2	1	Paial	Brazil
15	e43f6a9c-1a0b-4dfd-95e4-385400bb3e62	4	1	Nur Pur Machiwala	Pakistan
16	45e20496-c47f-4bea-90f6-085c1c798904	2	1	Paial	Brazil
17	934ba90a-2da1-498d-9218-83fe6778c110	2	2	Rayamadharam	India
18	934ba90a-2da1-498d-9218-83fe6778c110	2	2	Rayamadharam	India
19	934ba90a-2da1-498d-9218-83fe6778c110	2	2	Rayamadharam	India



Extractor: CSV

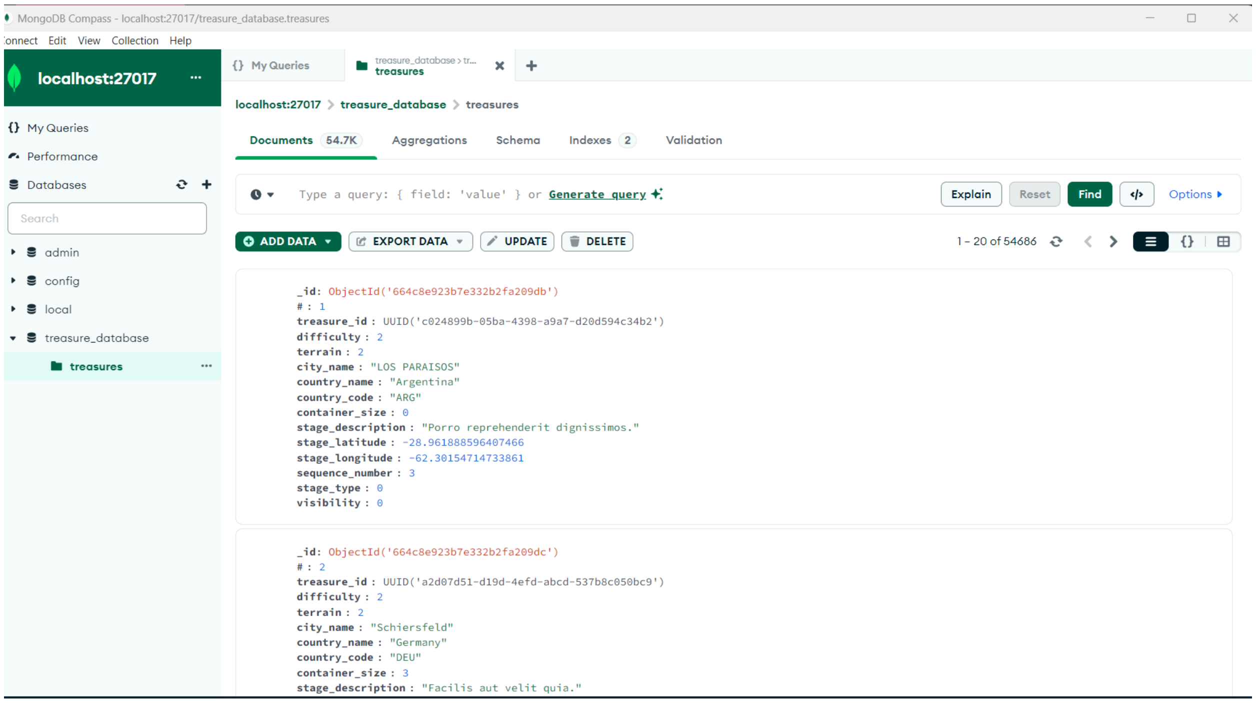
- [ ] Transpose
- [x] Add column header
- [x] Add row header

Output file: E:\downloads\Result_2.csv

Export preview:

```
#,treasure_id,difficulty,terrain,city_name,countr
1,4a519a26-47c2-43f1-a570-430c3dda0c58,1,2,São Se
2,60feda0e-4881-4a1a-abed-75e34c300ea4,4,0,Chak 4
3,b5d17859-b785-4f66-9bcb-29d238be8109,0,2,Varnel
4,3269930a-eef1-4ff1-8782-35b393cca557,0,1,Santa
5,934ba90a-2da1-498d-9218-83fe6778c110,2,2,Rayama
6,934ba90a-2da1-498d-9218-83fe6778c110,2,2,Rayama
7,45e20496-c47f-4bea-90f6-085c1c798904,2,1,Paial,
8,45e20496-c47f-4bea-90f6-085c1c798904,2,1,Paial,
9,45e20496-c47f-4bea-90f6-085c1c798904,2,1,Paial,
10,45e20496-c47f-4bea-90f6-085c1c798904,2,1,Paial
```

The data is inserted into MongoDB using MongoDB Compass or similar tool by connecting to `mongodb://localhost:27017` where we create the treasure_database then create the treasures collections. Below is the output of the inserted data as documents:



```
_id: ObjectId('664c8e923b7e332b2fa209db')
# : 1
treasure_id : UUID('c024899b-05ba-4398-a9a7-d20d594c34b2')
difficulty : 2
terrain : 2
city_name : "LOS PARAISOS"
country_name : "Argentina"
country_code : "ARG"
container_size : 0
stage_description : "Porro reprehenderit dignissimos."
stage_latitude : -28.961888596407466
stage_longitude : -62.30154714733861
sequence_number : 3
stage_type : 0
visibility : 0

_id: ObjectId('664c8e923b7e332b2fa209dc')
# : 2
treasure_id : UUID('a2d07d51-d19d-4efd-abcd-537b8c050bc9')
difficulty : 2
terrain : 2
city_name : "Schiersfeld"
country_name : "Germany"
country_code : "DEU"
container_size : 3
stage_description : "Facilis aut velit quia."
```

4. Enable Sharding

Sharding is enabled on the target database (`treasure_database`) using `mongosh` or through docker. This is done using the following command:

```
sh.enableSharding("treasure_database")
```

5. Create Index

An index is created on the `city_name` field of the `treasures` collection. This index is essential for efficient querying and sharding based on city names. The command used to create the index is:

```
use treasure_database
db.treasures.createIndex({ "city_name": 1 })
```

6. Shard the Collection

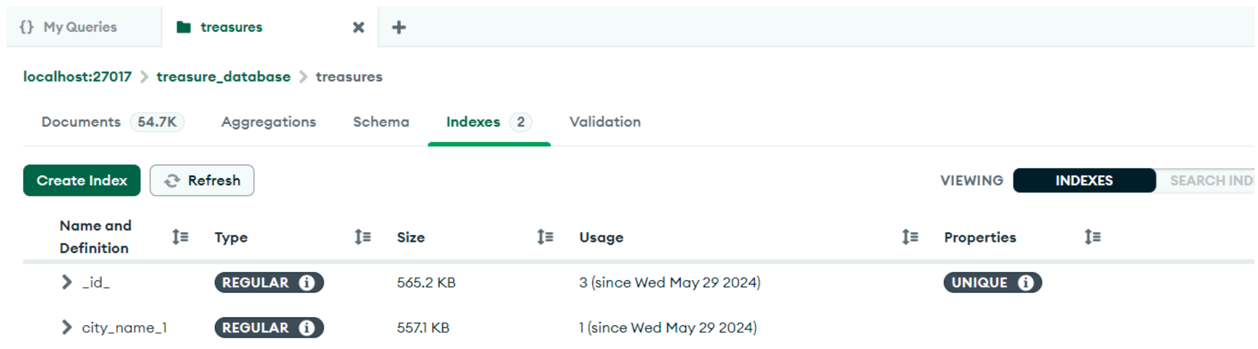
The `treasures` collection is sharded based on the `city_name` field. This ensures that data is distributed across shards based on city names, enabling efficient querying. The shard key used is `{ "city_name": 1 }`, indicating ascending order. The command to shard the collection is:

```
sh.shardCollection("treasure_database.treasures", { "city_name": 1 })
```

7. Query Data

Data is queried from the sharded collection to verify successful sharding and querying. The query used is to find treasures in the city of "Dörtağaç". The query is executed using the following command:

```
use treasure_database
db.treasures.find({ "city_name": /Dörtağaç/i }).pretty()
```



Name and Definition	Type	Size	Usage	Properties
_id_	REGULAR	565.2 KB	3 (since Wed May 29 2024)	UNIQUE
city_name_1	REGULAR	557.1 KB	1 (since Wed May 29 2024)	

8. Check Sharding Status

To ensure that sharding is set up correctly and to view the components and shards present, the `sh.status()` command is used on the mongos router and see that the shard key is also in use

docker exec -it mongodb_mongos-router-1_1 mongosh --eval 'sh.status()'

```
shardingVersion
{ _id: 1, clusterId: ObjectId('664c822e540d3f05ebe9c7bd') }
```

```
---
shards
[
  {
    _id: 'mongo-shard1-rs',
    host:
'mongo-shard1-rs/mongodb_mongo-shard1-1_1:27017,mongodb_mongo-shard1-2_1:27
017,mongodb_mongo-shard1-3_1:27017',
    state: 1,
    topologyTime: Timestamp({ t: 1716290109, i: 1 })
  },
  {
    _id: 'mongo-shard2-rs',
    host:
'mongo-shard2-rs/mongodb_mongo-shard2-1_1:27017,mongodb_mongo-shard2-2_1:27
017,mongodb_mongo-shard2-3_1:27017',
    state: 1,
    topologyTime: Timestamp({ t: 1716290113, i: 2 })
  },
  {
    _id: 'mongo-shard3-rs',
    host:
'mongo-shard3-rs/mongodb_mongo-shard3-1_1:27017,mongodb_mongo-shard3-2_1:27
017,mongodb_mongo-shard3-3_1:27017',
    state: 1,
    topologyTime: Timestamp({ t: 1716290116, i: 2 })
  }
]
---
active mongoses
[ { '5.0.26': 2 } ]
---
autosplit
{ 'Currently enabled': 'yes' }
---
balancer
{
  'Currently enabled': 'yes',
  'Currently running': 'no',
  'Failed balancer rounds in last 5 attempts': 0,
  'Migration Results for the last 24 hours': 'No recent migrations'
}
---
```

```
databases
[
  {
    database: { _id: 'config', primary: 'config', partitioned: true },
    collections: {
      'config.system.sessions': {
        shardKey: { _id: 1 },
        unique: false,
        balancing: true,
        chunkMetadata: [
          { shard: 'mongo-shard1-rs', nChunks: 342 },
          { shard: 'mongo-shard2-rs', nChunks: 341 },
          { shard: 'mongo-shard3-rs', nChunks: 341 }
        ],
        chunks: [
          'too many chunks to print, use verbose if you want to force
print'
        ],
        tags: []
      }
    }
  },
  {
    database: {
      _id: 'test',
      primary: 'mongo-shard1-rs',
      partitioned: false,
      version: {
        uuid: UUID('2975478d-560c-414b-a386-10b5e87dd68d'),
        timestamp: Timestamp({ t: 1716406088, i: 1 }),
        lastMod: 1
      }
    },
    collections: {}
  },
  {
    database: {
      _id: 'treasure_database',
      primary: 'mongo-shard1-rs',
      partitioned: true,
      version: {
        uuid: UUID('fbb2a25e-7a23-4cbc-8ffc-e5688877443b'),
        timestamp: Timestamp({ t: 1716406551, i: 1 }),
        lastMod: 1
      }
    },
    collections: {
      'treasure_database.treasures': {
        shardKey: { city_name: 1 },
        unique: false,
        balancing: true,
        chunkMetadata: [ { shard: 'mongo-shard1-rs', nChunks: 1 } ],
        chunks: [
          { min: { city_name: MinKey() }, max: { city_name: MaxKey() }, 'on
shard': 'mongo-shard1-rs', 'last modified': Timestamp({ t: 1, i: 0 }) }
        ],
        tags: []
      }
    }
  }
]
```

Additionally, the `.explain("executionStats")` method is used to analyze the query execution statistics.

treasure_database> db.treasures.find({ "city_name": /Dörtağaç/i }).pretty()

```
[
  {
    _id: ObjectId('664c8e923b7e332b2fa209de'),
    '#': 4,
    treasure_id: UUID('d15e24c4-db3e-45a4-b001-48548dbe0324'),
    difficulty: 1,
    terrain: 4,
    city_name: 'Dörtağaç',
    country_name: 'Turkey',
    country_code: 'TUR',
    container_size: 0,
    stage_description: 'Necessitatibus a ipsum totam est.',
    stage_latitude: 38.45152889714736,
    stage_longitude: 42.1584209983017,
    sequence_number: 2,
    stage_type: 0,
    visibility: 1
  },
  {
    _id: ObjectId('664c8e933b7e332b2fa21a36'),
    '#': 4188,
    treasure_id: UUID('d15e24c4-db3e-45a4-b001-48548dbe0324'),
    difficulty: 1,
    terrain: 4,
    city_name: 'Dörtağaç',
    country_name: 'Turkey',
    country_code: 'TUR',
    container_size: 0,
    stage_description: 'Dolores veritatis rerum at maxime tenetur.',
    stage_latitude: 38.446185355519056,
    stage_longitude: 42.16195164280413,
    sequence_number: 0,
    stage_type: 0,
    visibility: 0
  },
  {
    _id: ObjectId('664c8e953b7e332b2fa2912b'),
    '#': 34641,
    treasure_id: UUID('d15e24c4-db3e-45a4-b001-48548dbe0324'),
    difficulty: 1,
    terrain: 4,
    city_name: 'Dörtağaç',
    country_name: 'Turkey',
    country_code: 'TUR',
    container_size: 3,
    stage_description: 'Corporis id quos.',
    stage_latitude: 38.446255602924126,
    stage_longitude: 42.16170521034321,
    sequence_number: 1,
    stage_type: 0,
    visibility: 0
  },
  {
    _id: ObjectId('664c8e953b7e332b2fa295b1'),
    '#': 35799,
    treasure_id: UUID('d15e24c4-db3e-45a4-b001-48548dbe0324'),
    difficulty: 1,
    terrain: 4,
    city_name: 'Dörtağaç',
    country_name: 'Turkey',
    country_code: 'TUR',
    container_size: 0,
    stage_description: 'Nihil consequatur recusandae.',
    stage_latitude: 38.454396539541904,
    stage_longitude: 42.15389879750495,
    sequence_number: 3,
    stage_type: 0,
    visibility: 2
  }
]
treasure_database> db.treasures.find({ "city_name": /Dörtağaç/i
}).pretty().explain("executionStats")
{
  explainVersion: '1',
  queryPlanner: {
    namespace: 'treasure_database.treasures',
    indexFilterSet: false,
    parsedQuery: { city_name: { '$regex': 'Dörtağaç', '$options': 'i' } },
    queryHash: '87FC048A',
    planCacheKey: '528C6CB9',
    maxIndexedOrSolutionsReached: false,
    maxIndexedAndSolutionsReached: false,
    maxScansToExplodeReached: false,
    winningPlan: {
      stage: 'FETCH',
      inputStage: {
        stage: 'IXSCAN',
        filter: { city_name: { '$regex': 'Dörtağaç', '$options': 'i' } },
        keyPattern: { city_name: 1 },
        indexName: 'city_name_1',
        isMultiKey: false,
        multiKeyPaths: { city_name: [] },
        isUnique: false,
        isSparse: false,
        isPartial: false,
        indexVersion: 2,
        direction: 'forward',
        indexBounds: { city_name: [ '["", {})', '[/Dörtağaç/i,
/Dörtağaç/i]' ] }
      }
    },
    rejectedPlans: []
  },
  executionStats: {
    executionSuccess: true,
    nReturned: 4,
    executionTimeMillis: 143,
    totalKeysExamined: 54686,
    totalDocsExamined: 4,
    executionStages: {
      stage: 'FETCH',
      nReturned: 4,
      executionTimeMillisEstimate: 18,
      works: 54687,
      advanced: 4,
      needTime: 54682,
      needYield: 0,
      saveState: 54,
      restoreState: 54,
      isEOF: 1,
      docsExamined: 4,
      alreadyHasObj: 0,
      inputStage: {
        stage: 'IXSCAN',
        filter: { city_name: { '$regex': 'Dörtağaç', '$options': 'i' } },
        nReturned: 4,
        executionTimeMillisEstimate: 18,
        works: 54687,
        advanced: 4,
        needTime: 54682,
        needYield: 0,
        saveState: 54,
        restoreState: 54,
        isEOF: 1,
        keyPattern: { city_name: 1 },
        indexName: 'city_name_1',
        isMultiKey: false,
        multiKeyPaths: { city_name: [] },
        isUnique: false,
        isSparse: false,
        isPartial: false,
        indexVersion: 2,
        direction: 'forward',
        indexBounds: { city_name: [ '["", {})', '[/Dörtağaç/i,
/Dörtağaç/i]' ] },
        keysExamined: 54686,
        seeks: 1,
        dupsTested: 0,
        dupsDropped: 0
      }
    }
  },
  command: {
    find: 'treasures',
    filter: { city_name: /Dörtağaç/i },
    '$db': 'treasure_database'
  },
  serverInfo: {
    host: 'ZamLaptop',
    port: 27017,
    version: '7.0.9',
    gitVersion: '3ff3a3925c36ed277cf5eafca5495f2e3728dd67'
  },
  serverParameters: {
    internalQueryFacetBufferSizeBytes: 104857600,
    internalQueryFacetMaxOutputDocSizeBytes: 104857600,
    internalLookupStageIntermediateDocumentMaxSizeBytes: 104857600,
    internalDocumentSourceGroupMaxMemoryBytes: 104857600,
    internalQueryMaxBlockingSortMemoryUsageBytes: 104857600,
    internalQueryProhibitBlockingMergeOnMongoS: 0,
    internalQueryMaxAddToSetBytes: 104857600,
    internalDocumentSourceSetWindowFieldsMaxMemoryBytes: 104857600,
    internalQueryFrameworkControl: 'trySbeRestricted'
  },
  ok: 1
}
```

—

Why did I do it this way?

The reason is:

Shard Initialization: I initialized three shards using replica sets to ensure data redundancy and fault tolerance within each shard. This ensures that even if one replica goes down, data remains accessible from other replicas.

1. **Configuration Server Initialization**: I initialized the configuration server replica set to store metadata about the sharded cluster. This is essential for managing the cluster's configuration and metadata.
2. **Adding Shards to the Router**: I added each shard to the mongos router to allow the router to distribute queries across the shards. This enables efficient query routing and load balancing across the cluster.
3. **Checking Sharding Status**: I used sh.status() command on mongos router to verify the status of the sharded cluster. This provided important information about the cluster's components, including shards, active mongoses, and balancer status, ensuring that the cluster was set up correctly.
4. **Query Execution Analysis**: I executed a query to find documents with a specific city name in the treasures collection. I analyzed the query execution statistics to optimize performance and understand how MongoDB processes the query within a sharded environment.

Regarding the choice of using city_name as the shard key:

- **Data Distribution**: Shard key ensures even distribution of data based on geographical locations, preventing hotspots and ensuring efficient query execution.
- **Query Performance**: Efficient routing of queries targeting specific cities to the appropriate shard enhances query performance.
- **Scalability**: Horizontal scalability is enabled by sharding on city_name, allowing for the addition of more shards as the dataset grows.
- **Data Locality**: Improved data locality for queries related to specific cities, reducing network latency.
- **Natural Hierarchical Structure**: City names naturally form a hierarchical structure, making city_name a logical choice for efficient range-based sharding strategies.

In summary, my actions were aimed at ensuring proper setup, verification, and optimization of a MongoDB sharded cluster, with the choice of city_name as the shard key optimizing data distribution, query performance, and scalability for location-based data management.