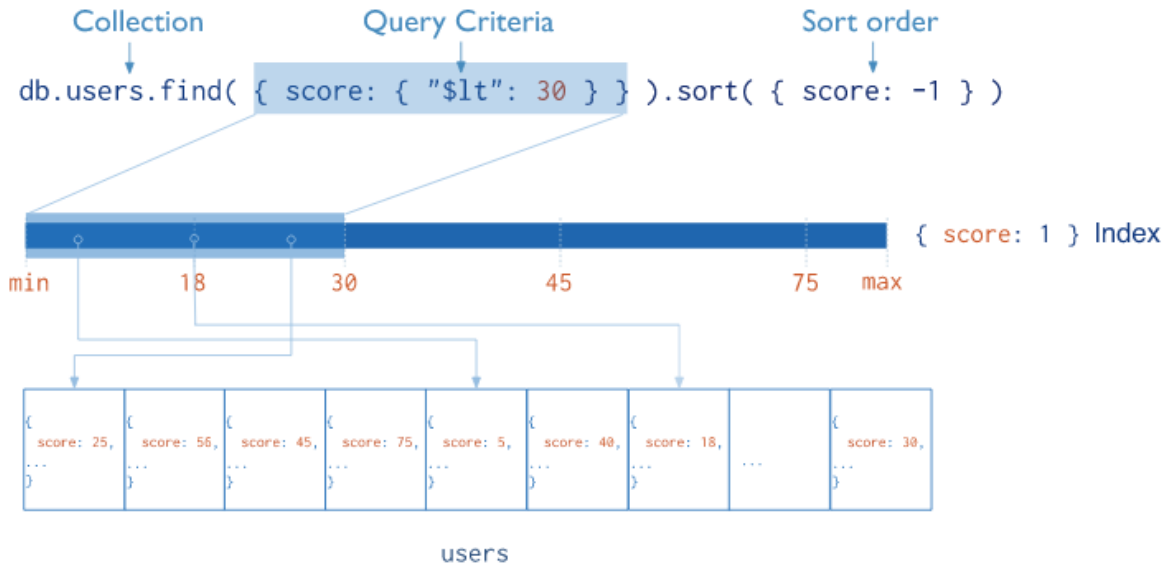
INDEXING in MongoDB

Indexes support the efficient execution of queries in MongoDB. Without indexes, MongoDB must perform a *collection scan*, i.e. scan every document in a collection, to select those documents that match the query statement. If an appropriate index exists for a query, MongoDB can use the index to limit the number of documents it must inspect.

Indexes are special data structures that store a small portion of the collection's data set in an easy to traverse form. The index stores the value of a specific field or set of fields, ordered by the value of the field. The ordering of the index entries supports efficient equality matches and range-based query operations. In addition, MongoDB can return sorted results by using the ordering in the index.

The following diagram illustrates a query that selects and orders the matching documents using an index:



Fundamentally, indexes in MongoDB are similar to indexes in other database systems. MongoDB defines indexes at the collection level and supports indexes on any field or sub-field of the documents in a MongoDB collection.

Default `_id` Index

MongoDB creates a unique index on the _id field during the creation of a collection. The `_id` index prevents clients from inserting two documents with the same value for the `_id` field. You cannot drop this index on the `_id`field..

Create an Index

To create an index in the Mongo Shell, use `db.collection.createIndex()`.

```
db.collection.createIndex( <key and index type specification>,
<options> )
```

The following example creates a single key descending index on the `name` field:

```
db.collection.createIndex( { name: -1 } )
```

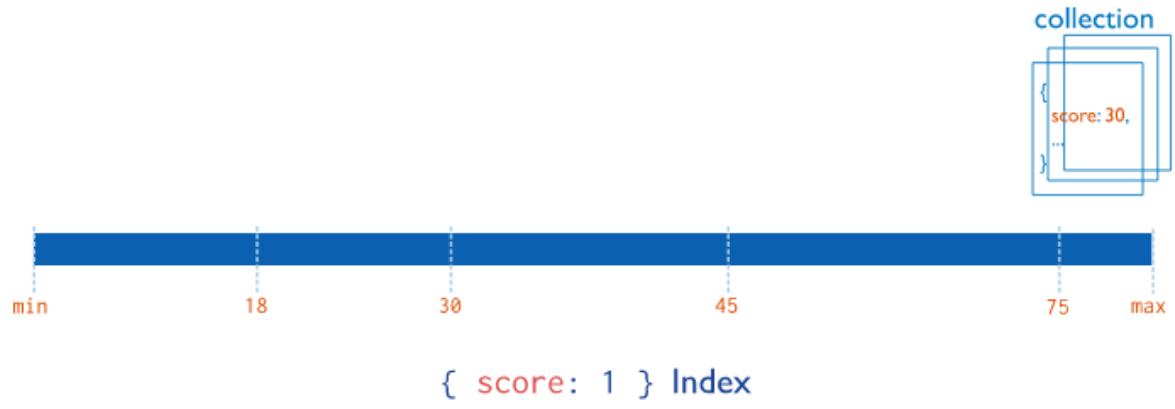
The `db.collection.createIndex` method only creates an index if an index of the same specification does not already exist.

Index Types

MongoDB provides a number of different index types to support specific types of data and queries.

Single Field

In addition to the MongoDB-defined `_id` index, MongoDB supports the creation of user-defined ascending/descending indexes on a single field of a document.

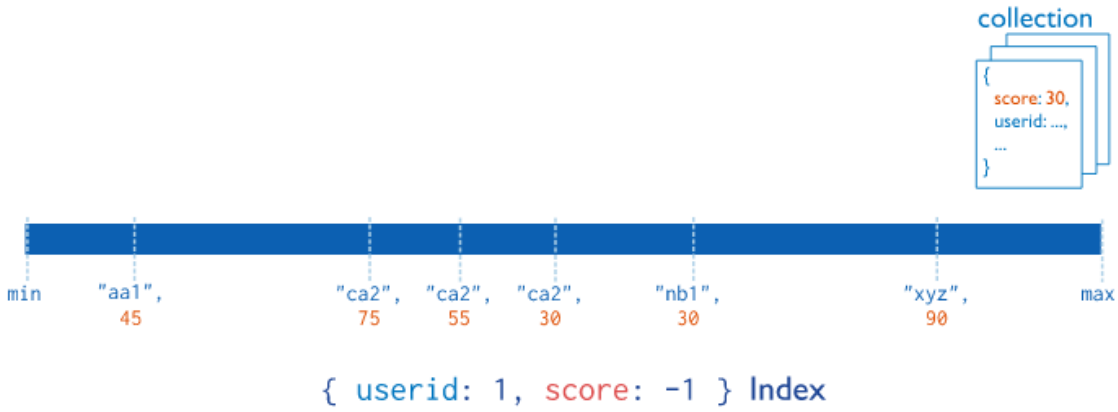


For a single-field index and sort operations, the sort order (i.e. ascending or descending) of the index key does not matter because MongoDB can traverse the index in either direction.

Compound Index

MongoDB also supports user-defined indexes on multiple fields, i.e. compound indexes.

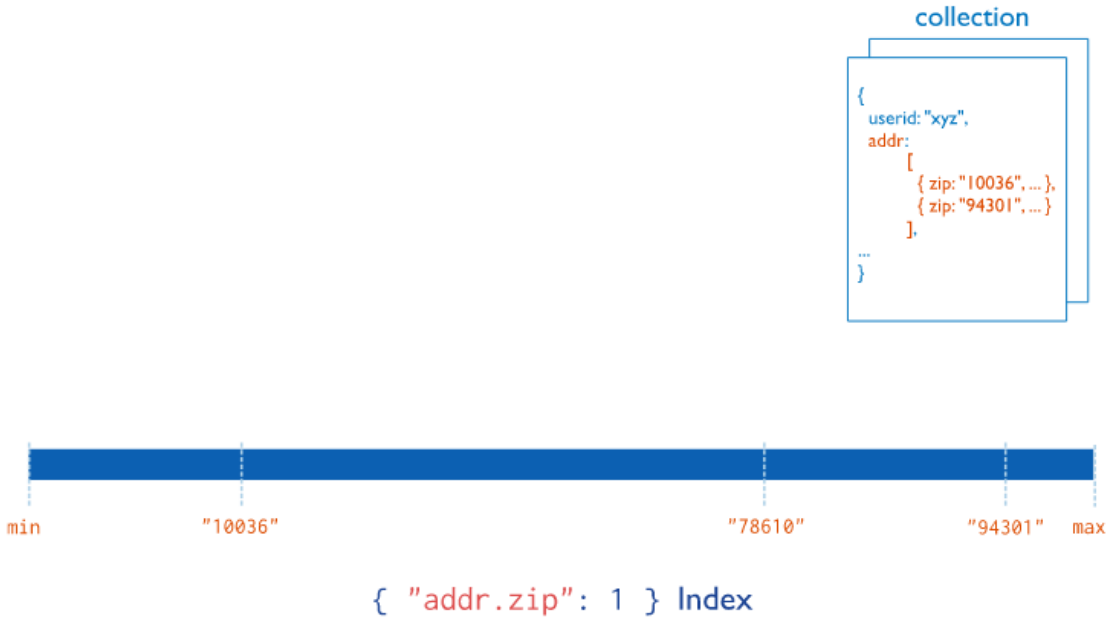
The order of fields listed in a compound index has significance. For instance, if a compound index consists of `{userid: 1, score: -1 }`, the index sorts first by `userid` and then, within each `userid` value, sorts by `score`.



For compound indexes and sort operations, the sort order (i.e. ascending or descending) of the index keys can determine whether the index can support a sort operation. See Sort Order for more information on the impact of index order on results in compound indexes.

Multikey Index

MongoDB uses multikey indexes to index the content stored in arrays. If you index a field that holds an array value, MongoDB creates separate index entries for *every* element of the array. These multikey indexes allow queries to select documents that contain arrays by matching on element or elements of the arrays. MongoDB automatically determines whether to create a multikey index if the indexed field contains an array value; you do not need to explicitly specify the multikey type.



Text Indexes

MongoDB provides a `text` index type that supports searching for string content in a collection. These text indexes do not store language-specific *stop* words (e.g. “the”, “a”, “or”) and *stem* the words in a collection to only store root words.

Hashed Indexes

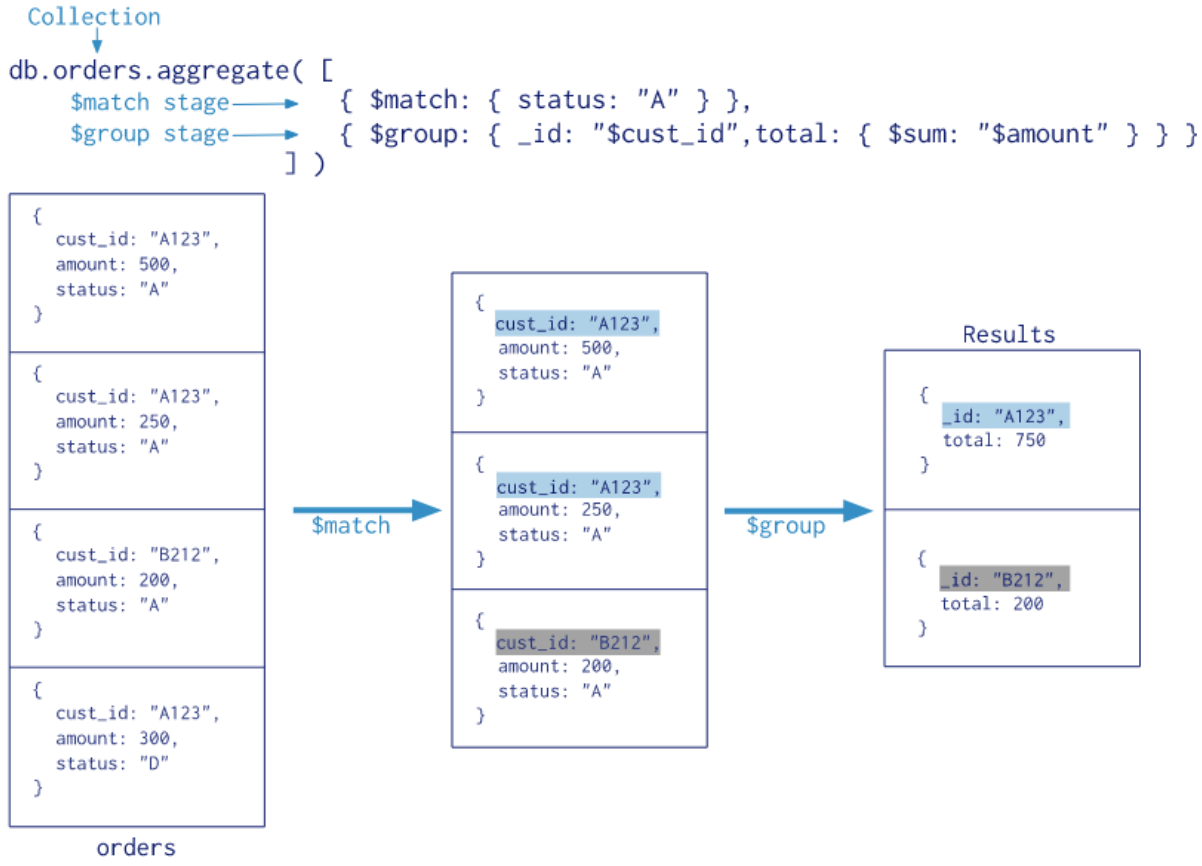
To support hash based sharding, MongoDB provides a hashed index type, which indexes the hash of the value of a field. These indexes have a more random distribution of values along their range, but *only* support equality matches and cannot support range-based queries.

Aggregation

- Aggregation operations process data records and return computed results. Aggregation operations group values from multiple documents together, and can perform a variety of operations on the grouped data to return a single result.
- MongoDB provides three ways to perform aggregation: the aggregation pipeline, the map-reduce function, and single purpose aggregation methods.

Aggregation Pipeline

- MongoDB's aggregation framework is modeled on the concept of data processing pipelines. Documents enter a multi-stage pipeline that transforms the documents into an aggregated result.
- The most basic pipeline stages provide filters that operate like queries and document transformations that modify the form of the output document.
- Other pipeline operations provide tools for grouping and sorting documents by specific field or fields as well as tools for aggregating the contents of arrays, including arrays of documents. In addition, pipeline stages can use operators for tasks such as calculating the average or concatenating a string.
- The pipeline provides efficient data aggregation using native operations within MongoDB, and is the preferred method for data aggregation in MongoDB.
- The aggregation pipeline can operate on a sharded collection.
- The aggregation pipeline can use indexes to improve its performance during some of its stages. In addition, the aggregation pipeline has an internal optimization phase.



Map-Reduce

- MongoDB also provides map-reduce operations to perform aggregation.
- In general, map-reduce operations have two phases: a map stage that processes each document and emits one or more objects for each input document, and reduce phase that combines the output of the map operation.
- Optionally, map-reduce can have a finalizestage to make final modifications to the result. Like other aggregation operations, map-reduce can specify a query condition to select the input documents as well as sort and limit the results.
- Map-reduce uses custom JavaScript functions to perform the map and reduce operations, as well as the optional finalize operation. While the custom JavaScript provide great flexibility compared to the aggregation pipeline, in general, map-reduce is less efficient and more complex than the aggregation pipeline.
- Map-reduce can operate on a sharded collection. Map-reduce operations can also output to a sharded collection..

Single Purpose Aggregation Operations

MongoDB also provides `db.collection.estimatedDocumentCount()`, `db.collection.count()` and `db.collection.distinct()`.

All of these operations aggregate documents from a single collection. While these operations provide simple access to common aggregation processes, they lack the flexibility and capabilities of the aggregation pipeline and map-reduce.

Sharding

- Sharding is a method for distributing data across multiple machines. MongoDB uses sharding to support deployments with very large data sets and high throughput operations.

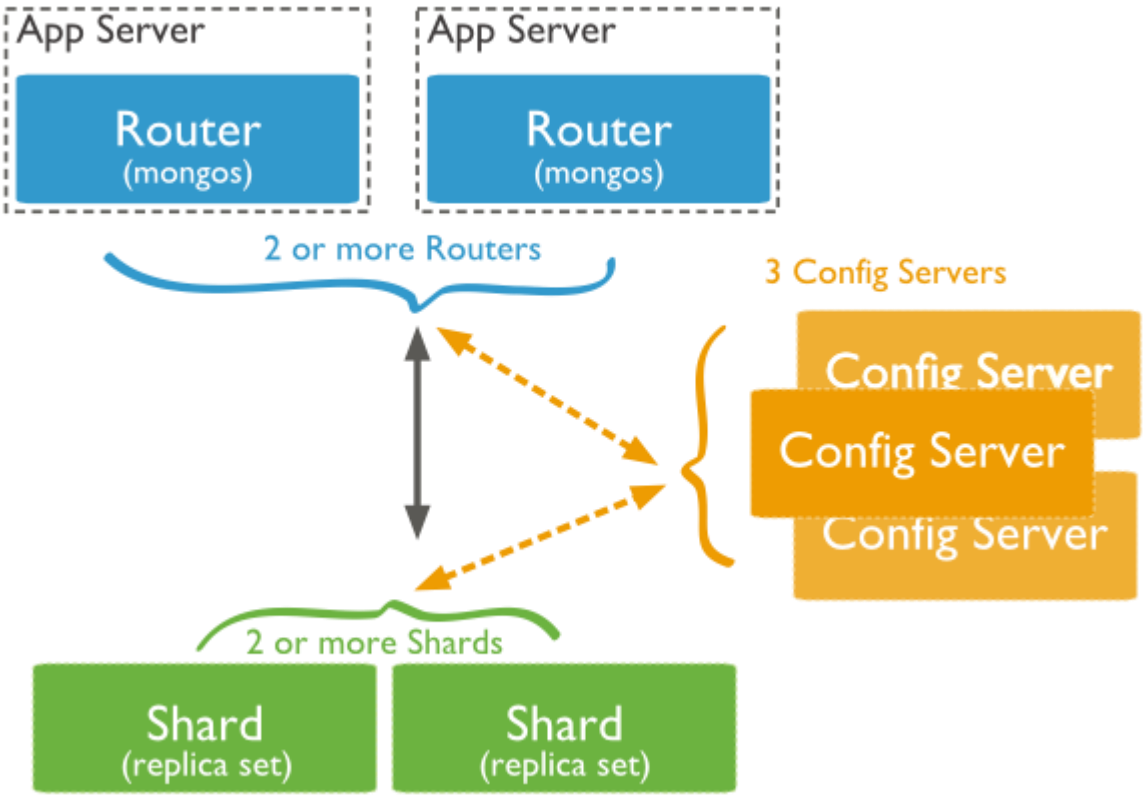
- Database systems with large data sets or high throughput applications can challenge the capacity of a single server. For example, high query rates can exhaust the CPU capacity of the server. Working set sizes larger than the system's RAM stress the I/O capacity of disk drives.

- There are two methods for addressing system growth: vertical and horizontal scaling.

- ***Vertical Scaling*** involves increasing the capacity of a single server, such as using a more powerful CPU, adding more RAM, or increasing the amount of storage space. Limitations in available technology may restrict a single machine from being sufficiently powerful for a given workload. Additionally, Cloud-based providers have hard ceilings based on available hardware configurations. As a result, there is a practical maximum for vertical scaling.

- ***Horizontal Scaling*** involves dividing the system dataset and load over multiple servers, adding additional servers to increase capacity as required. While the overall speed or capacity of a single machine may not be high, each machine handles a subset of the overall workload, potentially providing better efficiency than a single high-speed high-capacity server. Expanding the capacity of the deployment only requires adding additional servers as needed, which can be a lower overall cost than high-end hardware for a single machine. The trade off is increased complexity in infrastructure and maintenance for the deployment.

The following diagram shows the sharding in MongoDB using sharded cluster.



In the following diagram, there are three main components −

- **Shards** − Shards are used to store data. They provide high availability and data consistency. In production environment, each shard is a separate replica set.
- **Config Servers** − Config servers store the cluster's metadata. This data contains a mapping of the cluster's data set to the shards. The query router uses this metadata to target operations to specific shards. In production environment, sharded clusters have exactly 3 config servers.
- **Query Routers** − Query routers are basically mongo instances, interface with client applications and direct operations to the appropriate shard. The query router processes and targets the operations to shards and then returns results to the clients. A sharded cluster can contain more than one query router to divide the client request load. A client sends requests to one query router. Generally, a sharded cluster have many query routers.