Foundation of Data Engineering

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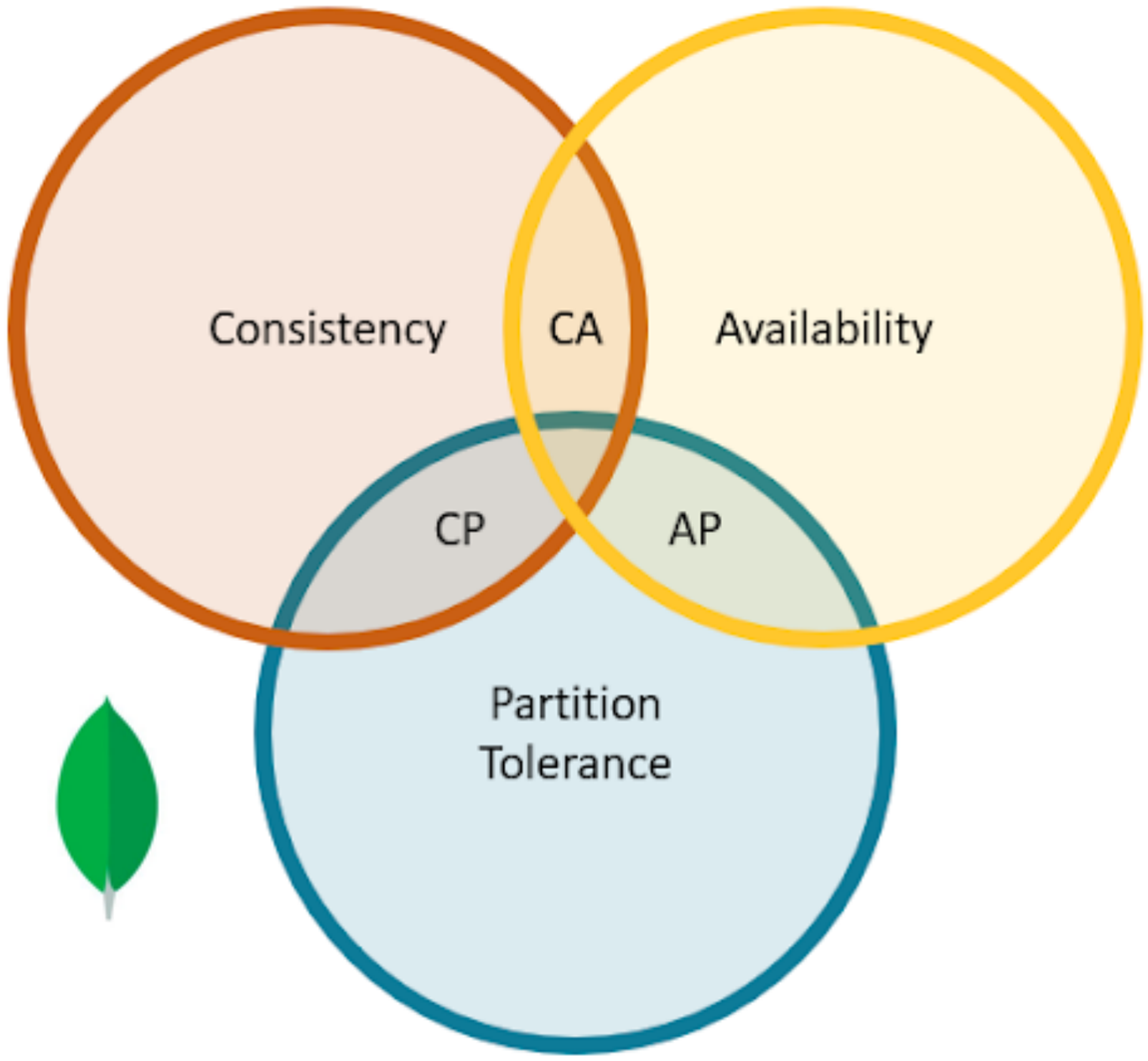
MongoDB

History and Motivation

- An open source and document-oriented database.
- Data is stored in JSON-like documents.
- Designed with both scalability and developer agility.
- Dynamic schemas.
- Automatic data sharding

What MongoDB is :

- An In-Memory Document Databases
- Strong consistency (**C**)
- *Tuneably* available (**A**)
- Horizontal Scalable (**P**)



What MongoDB is not

- Always Available[91]
- No Schemas
- No transactions
- No joins
- Max document size of 16MB[92]

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[91] Larger documents handled with GridFS

[92] there will always be downtime when (i) the new leader is getting elected or (ii) the client driver disconnects from the leader

Use Cases

- Capture **game** events, scaling to meet high-write workloads.
- Financial Services: Risk Analytics & Reporting, Trade Repository
- manufacturing, automotive, retail, and energy
- fast-changing sensor data captured from multiple devices and experiments

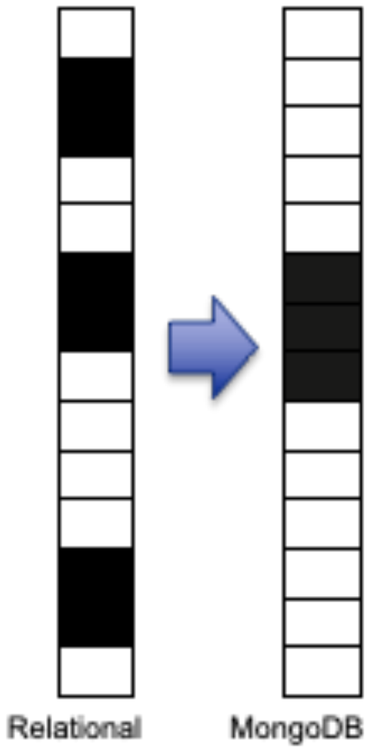
When to consider MongoDB

- When you don't need high availability of data
- when you need fast and instant data recovery
- when do not want to sustain schema migration costs

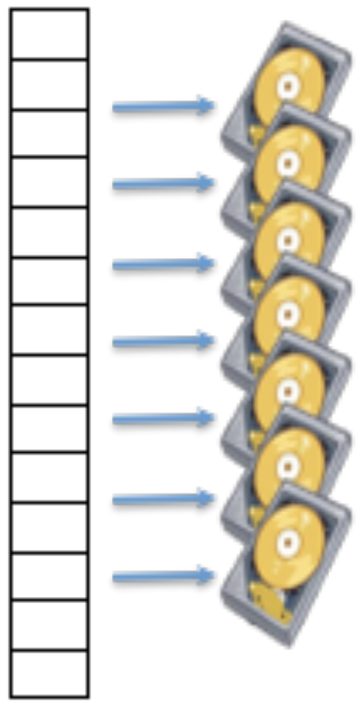
Advantages

- Full featured indexes
- Sophisticated query language
- Easy mapping to object-oriented code
- Native language drivers in all popular languages
- Simple to set up and manage
- Operates at in-memory speed wherever possible
- Auto-sharding built in
- Dynamically add / remove capacity with no downtime

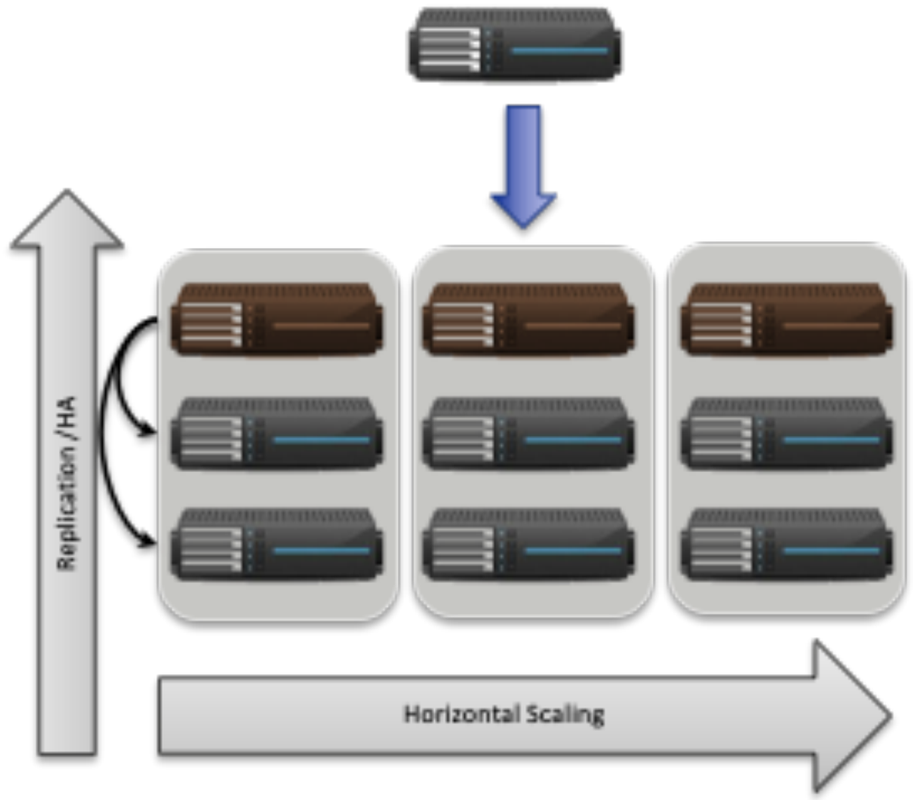
Better data locality



In-Memory Caching



Distributed Architecture



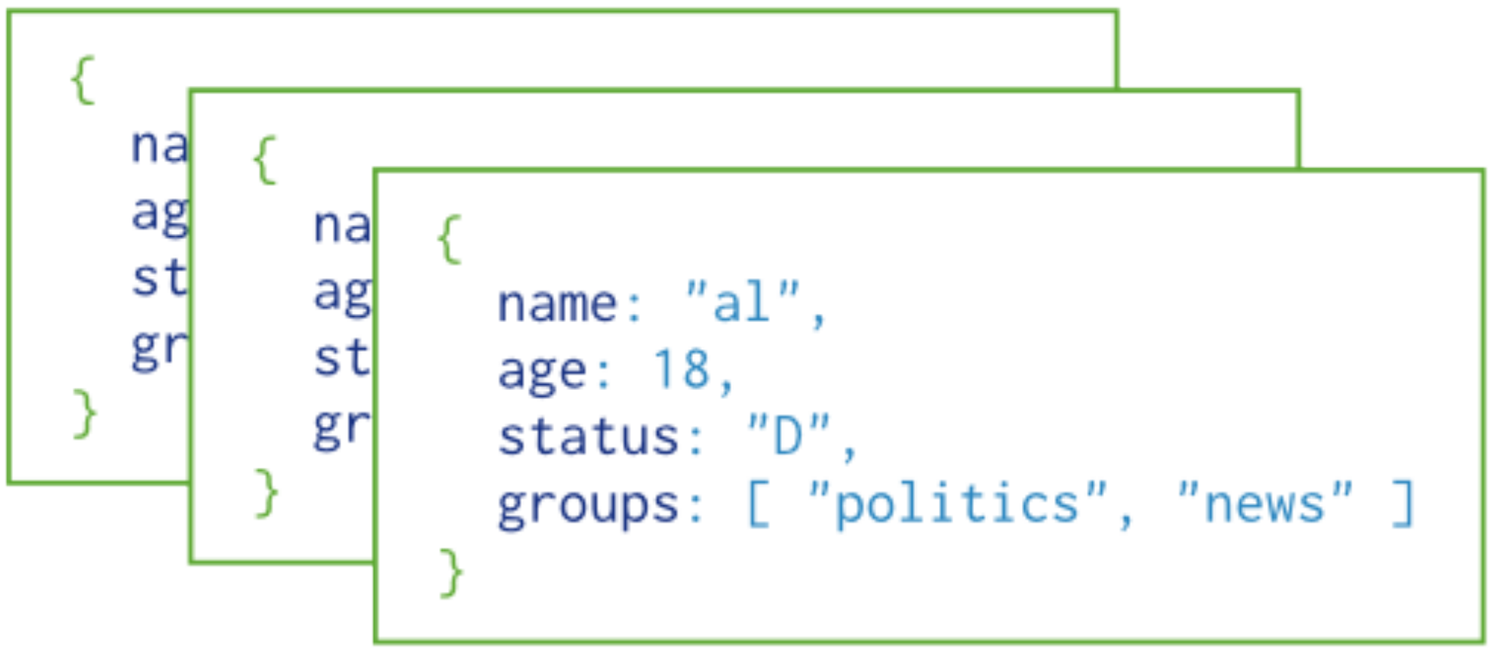
Terminology: SQL vs MongoDB

SQL Terms/Concepts	MongoDB Terms/Concepts
database	database
table	collection
row	document
column	field
index	index
table joins (e.g. select queries)	embedded documents and linking
Primary keys	_id field is always the primary key
Aggregation (e.g. group by)	aggregation pipeline

Data Model: Structure of a JSON-document:

The value of field:
- Native data types
- Arrays
- Other documents

Data Model: Collections of Documents



Rule: Every document must have an _id.

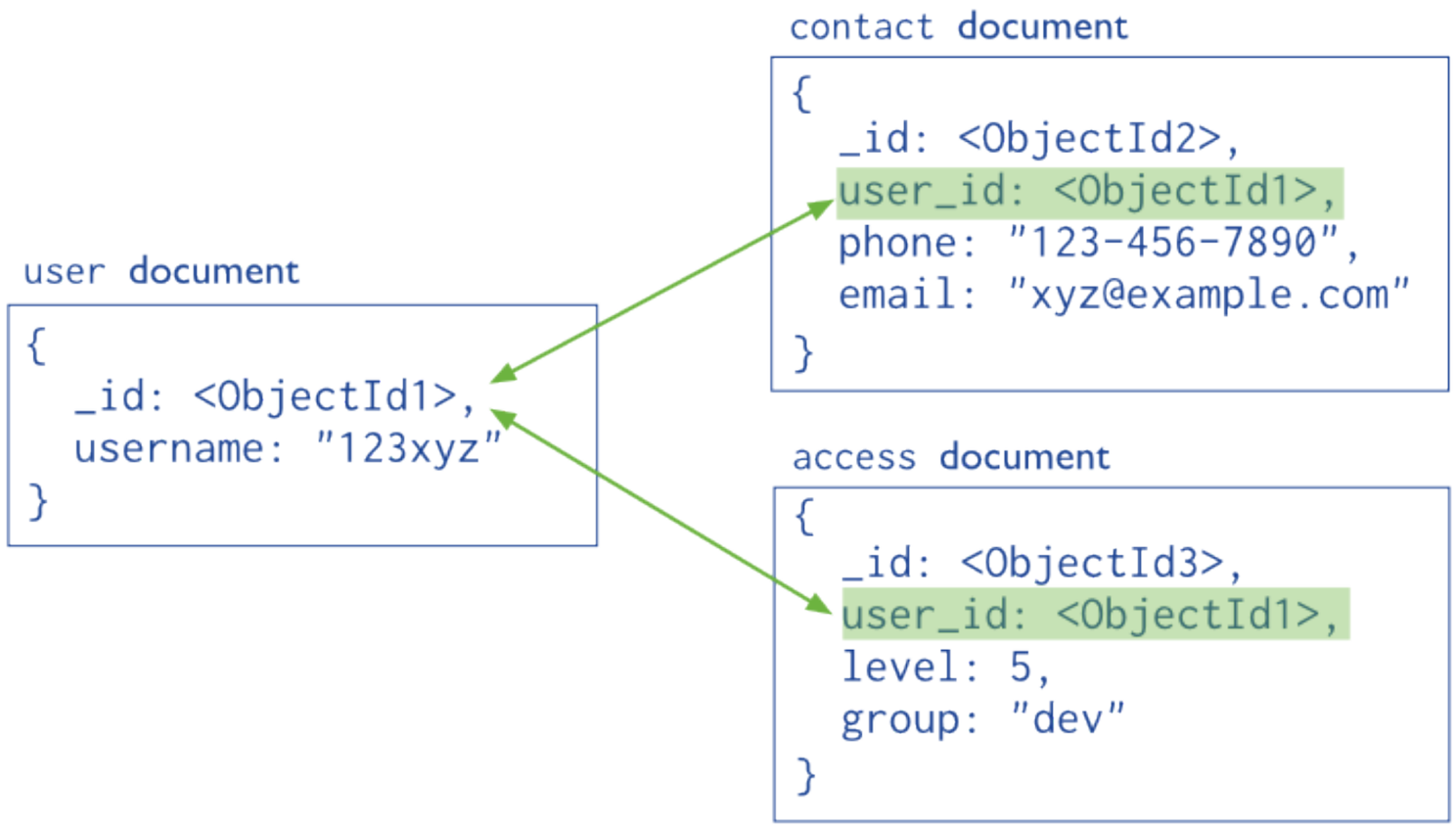
Data Model: Embedded documents:

```
{
  _id: <ObjectId1>,
  username: "123xyz",
  contact: {
              phone: "123-456-7890",
              email: "xyz@example.com"
            },
  access: {
              level: 5,
              group: "dev"
            }
}
```

Embedded sub-document

Embedded sub-document

Reference documents



Storage: BSON Format

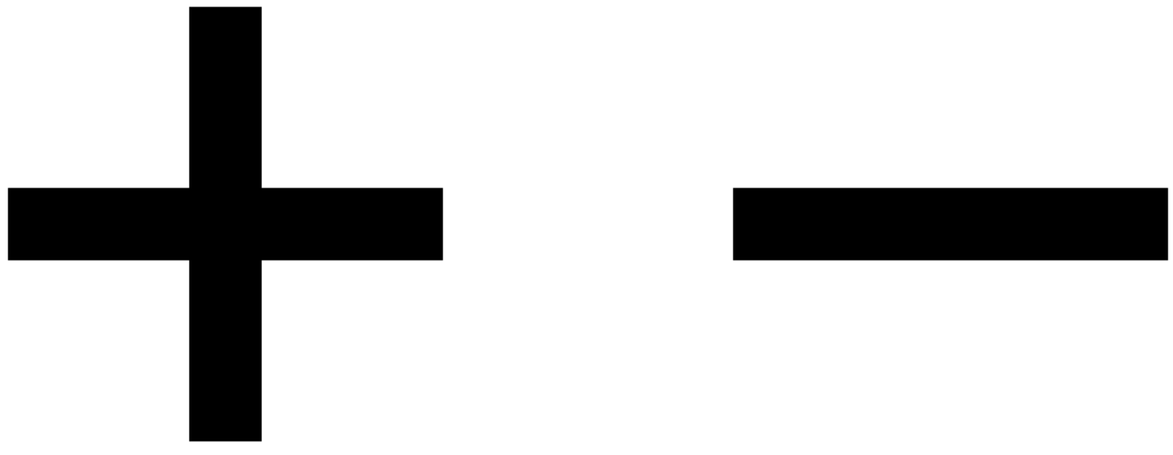
- Binary-encoded serialization of JSON-like documents optimized for space and speed
- BSON types are a superset of JSON types[94]
- Zero or more key/value pairs are stored as a single entity[93]
- Large entities are prefixed with a length field to facilitate scanning

BSON:

```
\x16\x00\x00\x00                    // total document size
\x02                                // 0x02 = type String
name\x00                            // field name
\x06\x00\x00\x00Devang\x00          // field value
\x00
```

[94] JSON does not have a date or a byte array type, for example

[93] Each entry consists of a field name, a data type, and a value



Operations

Create

Create a database

```
use database_name
```

Create a collection

```
db.createCollection(name, options)
```

Insert

```
db.<collection_name>.insert({"name": "nguyen". "age": 24, "gender": "male"})
```

```
db.employee.insert({
    name: "sally",
    salary: 15000,
    designation: "MTS",
    teams: [ "cluster-management" ]
})`
```

Read

```
db.<collection_name>.find().pretty()
```

```
db.employee                     #collection
    .find( {
    salary: {$gt:18000},        #condition
        {name:1}                #projection
    })
.sort({salary:1})               #modifier
```

Update

```
db.employee #collection
.update(
 {salary:{$gt:18000}}, #Update Criteria
 {$set: {designation: "Manager"}}, #Update Action
 {multi: true} #Update Option
)
```


Multi-option allows multiple document update

Delete

```
db.employee.remove(
      {salary:{$lt:10000}}, #Remove Criteria
)
```

Aggregates

SQL-like aggregation functionality

Pipeline documents from a collection pass through an aggregation pipeline

Expressions produce output documents based on calculations performed on input documents

Example:

```
db.parts.aggregate(
    {$group : {_id: type, totalquantity :
    { $sum: quantity}
}})
```

Save

```
db.employee.save(
    {  _id:ObjectId('string_id'),
       "name": "ben",
       "age": 23,
       "gender":
       "male"
})
```

Drop

- Drop a database
- Drop it: `db.dropDatabase()`
- Drop a collection:

```
db.<collection_name>.drop()
```

Mapping to SQL

SQL Statement	MongoDB commands
SELECT * FROM table	db.collection.find()
SELECT * FROM table WHERE artist = ‘Nirvana’	db.collection.find({Artist:”Nirvana”})
SELECT* FROM table ORDER BY Title	db.collection.find().sort(Title:1)
DISTINCT	.distinct()
GROUP BY	.group()
>=, <	$gte, $lt

Comparison Operators

Name	Description
$eq	Matches value that are equal to a specified value
$gt, $gte	Matches values that are greater than (or equal to a specified value
$lt, $lte	Matches values less than or (equal to) a specified value
$ne	Matches values that are not equal to a specified value
$in	Matches any of the values specified in an array
$nin	Matches none of the values specified in an array
$or	Joins query clauses with a logical OR returns all
$and	Join query clauses with a loginal AND
$not	Inverts the effect of a query expression
$nor	Join query clauses with a logical NOR
$exists	Matches documents that have a specified field

source

Indexes

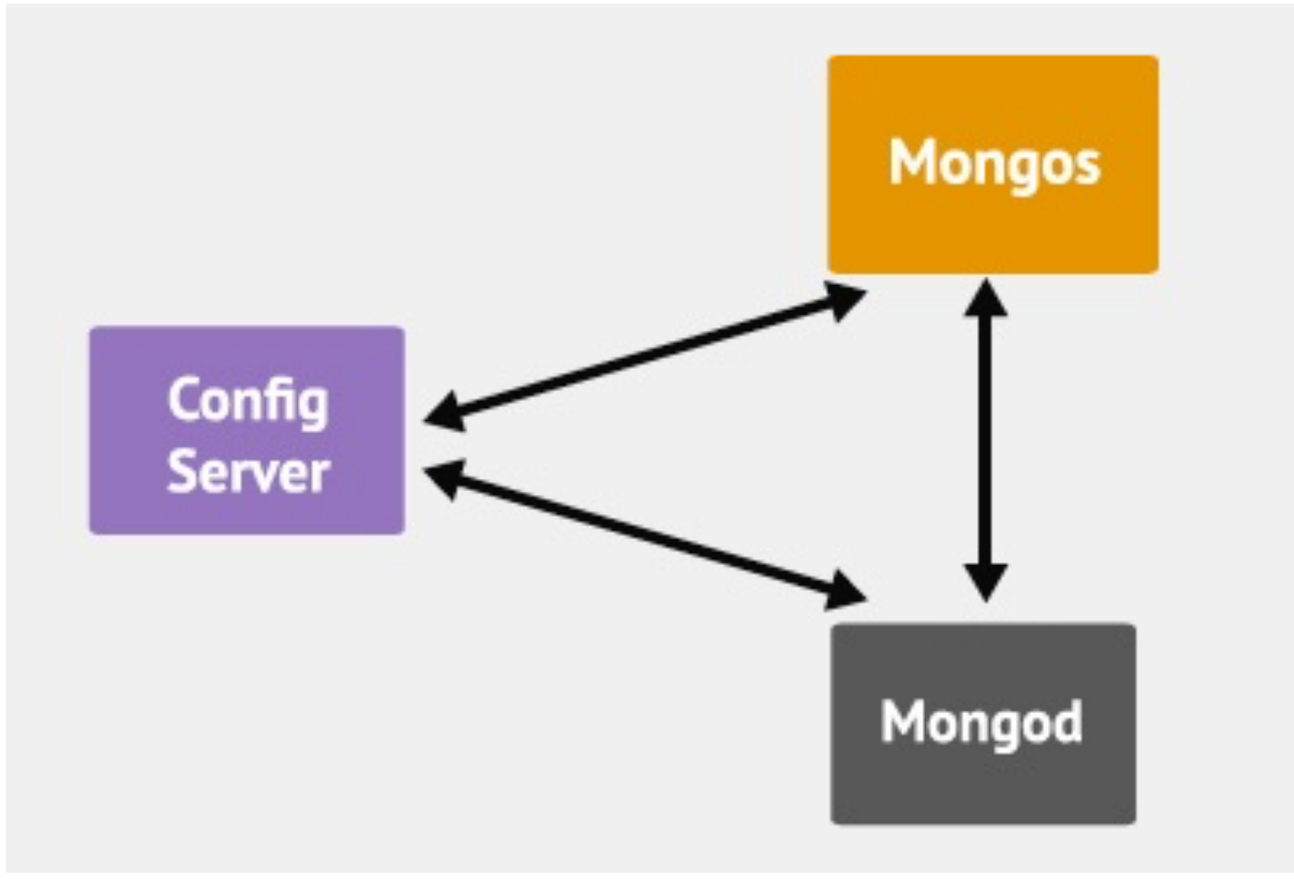
- B+ tree indexes
- An index is automatically created on the _id field (the primary key)
- Users can create other indexes to improve query performance or to enforce Unique values for a particular field
- Supports single field index as well as Compound index
- Like SQL order of the fields in a compound index matters
- If you index a field that holds an array value, MongoDB creates separate index entries for every element of the array

Sparse Indexes

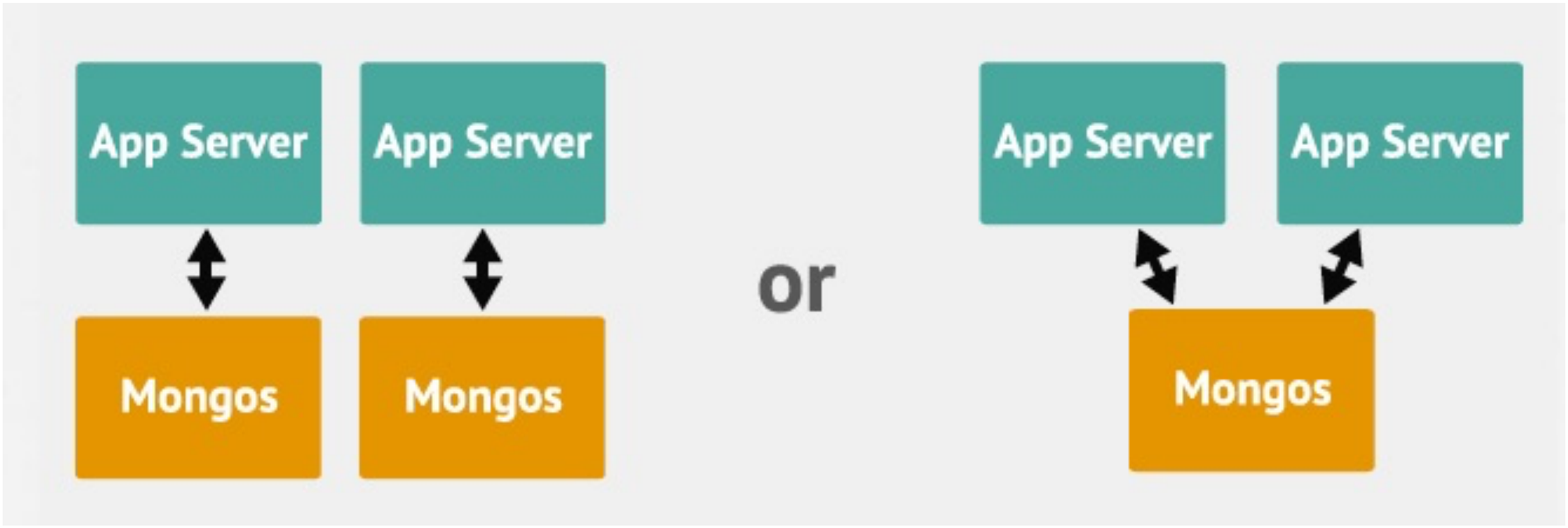
- Sparse_- property of an index ensures that the index only contain entries for documents that have the indexed field. (so ignore records that do not have the field defined)
- If an index is both unique and sparse – then the system will reject records that have a duplicate key value but allow records that do not have the indexed field defined

Architecture

- Mongod – Database instance
- Mongos - Sharding processes:
  - Like a database router processes all requests
  - Decides how many and which *mongod* should receive the query
  - No local data
  - Collects the results, and sends it back to the client.
- Config Server
  - Stores cluster chunk ranges and locations
  - Can have only 1 or 3 (production must have 3)



Mongod and Mongos



Client

- Mongo – an interactive shell (a client)
- Fully functional JavaScript environment for use with a MongoDB
- You can have one mongos for the whole system no matter how many mongods you have
- OR you can have one local mongos for every client if you wanted to minimize network latency.

Replication

For redundancy MongoDB provides asynchronous replication.

Only one database node is in charge of write operations at any given time (called primary server/node).

Read operations may go to this same server for strong consistency semantics or to any of its replica peers if eventual consistency is sufficient.

Master Slave Replication

Consists of two servers out of one which takes the role of a master handling write requests and replicating those operations to the second server, the slave.

Replica Sets

Consists of groups of MongoDB nodes that work together to provide automated failover.

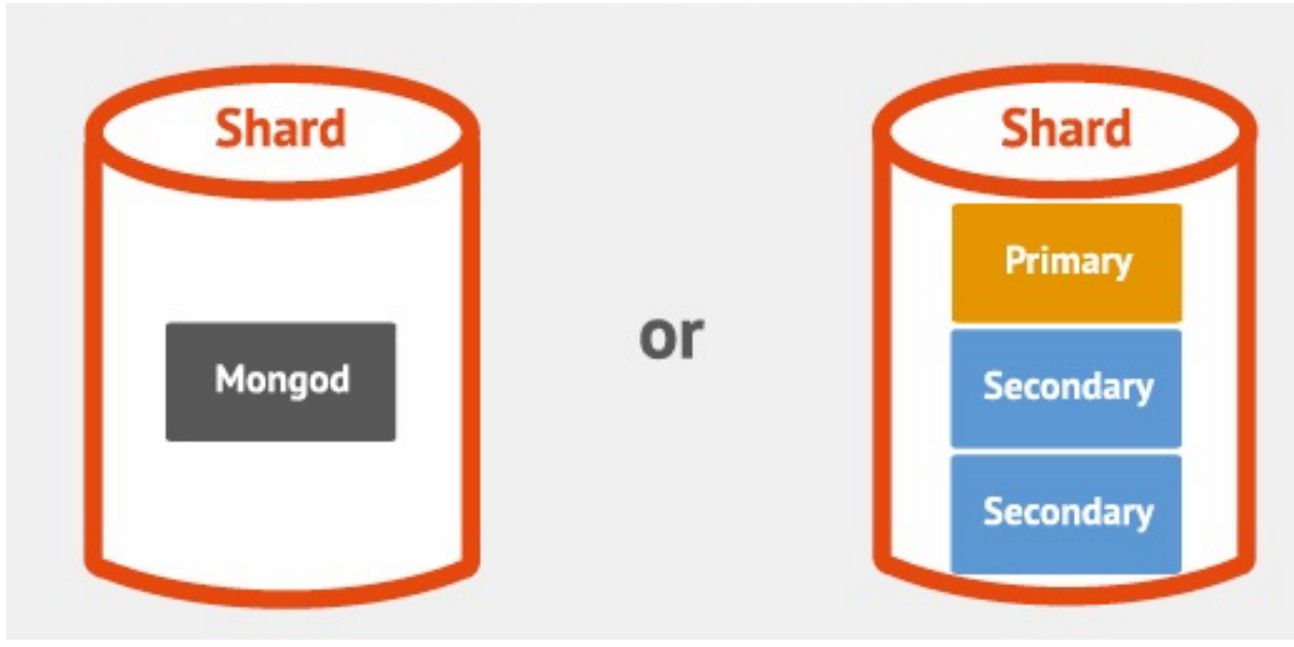
Replica Sets are described as an "an elaboration on the existing master/slave replication, adding **automatic failover** and automatic recovery of member nodes"

Partitioning

- called Sharding in MongoDB
- User defines shard key for partitioning
- Shard key defines range of data
- Key space is like points on a line
- Range is a segment of that line

What is a Shard?

- Shard is a node of the cluster
- Shard can be a single mongod or a replica set
- Default max chunk size: 64mb
- MongoDB automatically splits & migrates chunks when max reached



Auto-sharding

- Minimal effort required
  - Enable Sharding for a database
  - Shard collection within database
  - Decide Sharding Strategy

MongoDB Sharding Strategies

- Ranged
- Hashed
- Tag-aware

Range Sharding

- Splits shards based on sub-range of a key (or also multiple keys combined)
  - Simple Shard Key: {deviceId}
  - Composite Shard Key: {deviceId, timestamp}

Hash Sharding

- MongoDB applies a MD5 hash on the key when a hash shard key is used:
  - Hash Shard Key(deviceId) = MD5(deviceId)
  - Ensures data is distributed randomly within the range of MD5 values

Tag-aware sharding allows subset of shards to be tagged, and assigned to a sub-range of the shard-key.

Example: Sharding User Data belong to users from 100 “regions”

Collection: Users, Shard Key: {uId, regionCode}

Tag based on macro regions

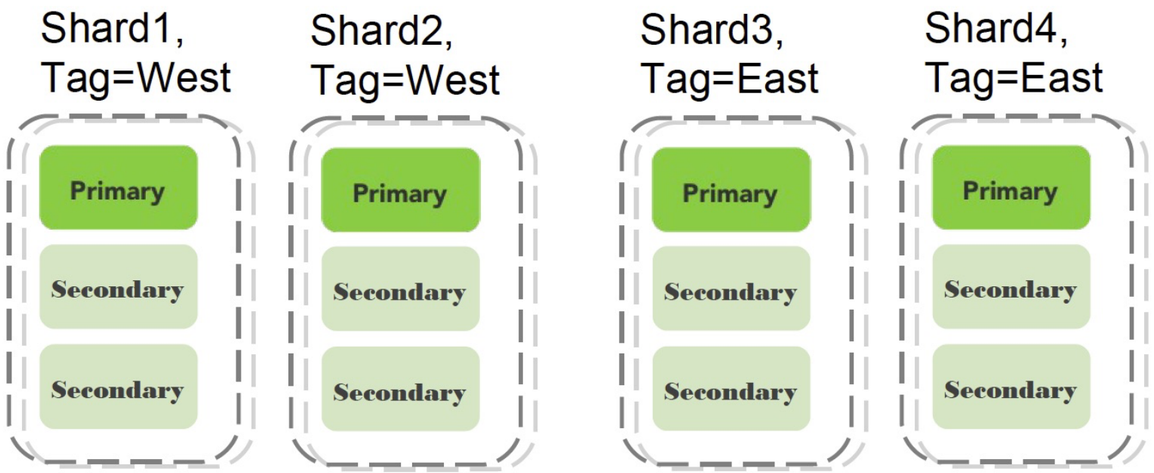
Tag Sharding Example

Collection: Users, **Shard Key:** {uId, regionCode}

Tag	Start	End
West	MinKey, MinKey	MaxKey,50
East	MinKey, 50	MaxKey, MaxKey

Assign Regions 1-50 to the West

Assign Regions 51-100 to the East

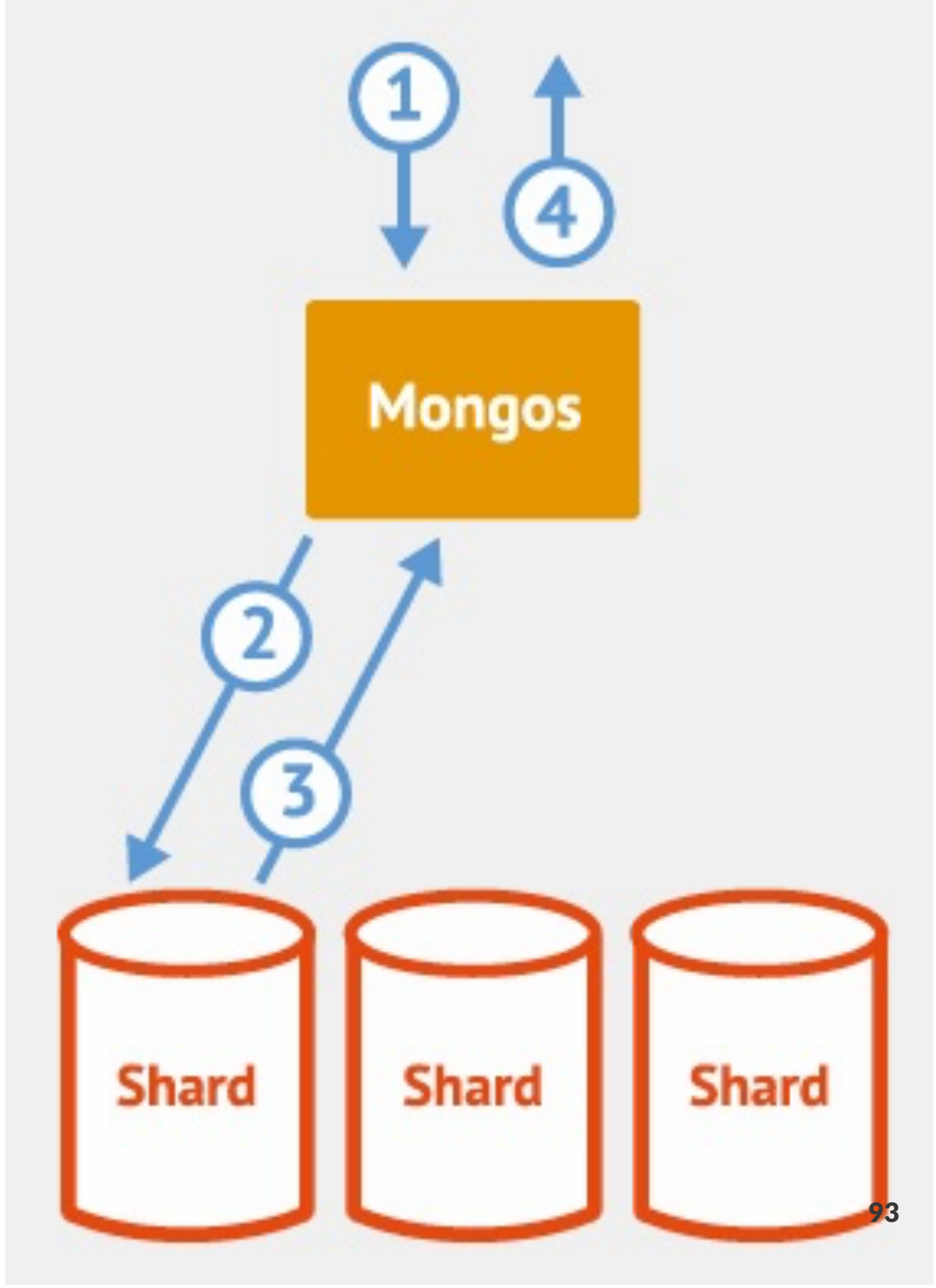


Which Sharding to use?

Usage	Required Strategy
Scale	Range or Hash
Geo-Locality	Tag-aware
Hardware Optimization	Tag-aware
Lower Recovery Times	Range or Hash

Routing and Balancing

- Queries routed to specific shards
- MongoDB balances cluster
- MongoDB migrates data to new nodes



MongoDB Security

- SSL
  - between client and server
  - Intra-cluster communication
- Authorization at the database level
  - Read Only/Read+Write/Administrator

References

- Mongodb.com
- No SQL Distilled by P. Sadalage and M. Fowler
- MongoDB Applied Design Patters by R. Copeland
- The Definitive Guide to MongoDB by Plugge, Membry and Hawkins

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