MongoDB 4.x

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CAP Theorem

The CAP theorem is a tool used to make system designers aware of the trade-offs while designing networked shared-data systems. The CAP theorem applies to distributed systems that stores the state. The theorem states that networked shared-data systems can only guarantee/strongly support two of the following three properties:

- **Consistency**
- **Availability**
- **Partition Tolerance**

CAP Theorem

- **Consistency**

A service that is consistent should follow the rule of ordering for updates that spread across all replicas in a cluster - “what you write is what you read”, regardless of location.

- **Availability**

A service should be available. There should be a guarantee that every request receives a response about whether it was successful or failed.

CAP Theorem

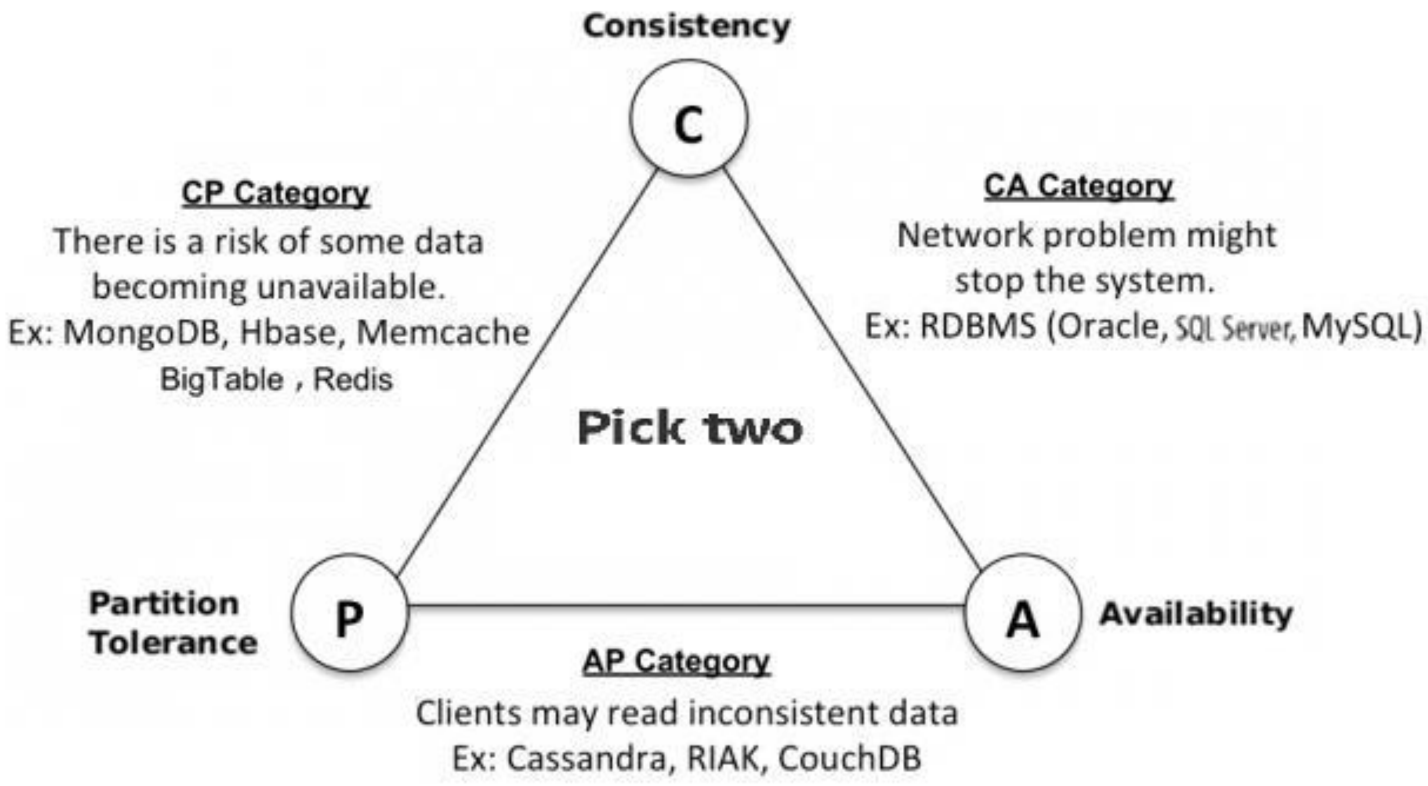
- **Partition Tolerance**

The system continues to operate despite arbitrary message loss or failure of part of the system.

<u>CAP Theorem Statement:</u>

Though its desirable to have Consistency, High-Availability and Partition-tolerance in every system, unfortunately no system can achieve all three at the same time.

CAP Theorem



CP Category

There is a risk of some data becoming unavailable.
Ex: MongoDB, Hbase, Memcache
BigTable , Redis

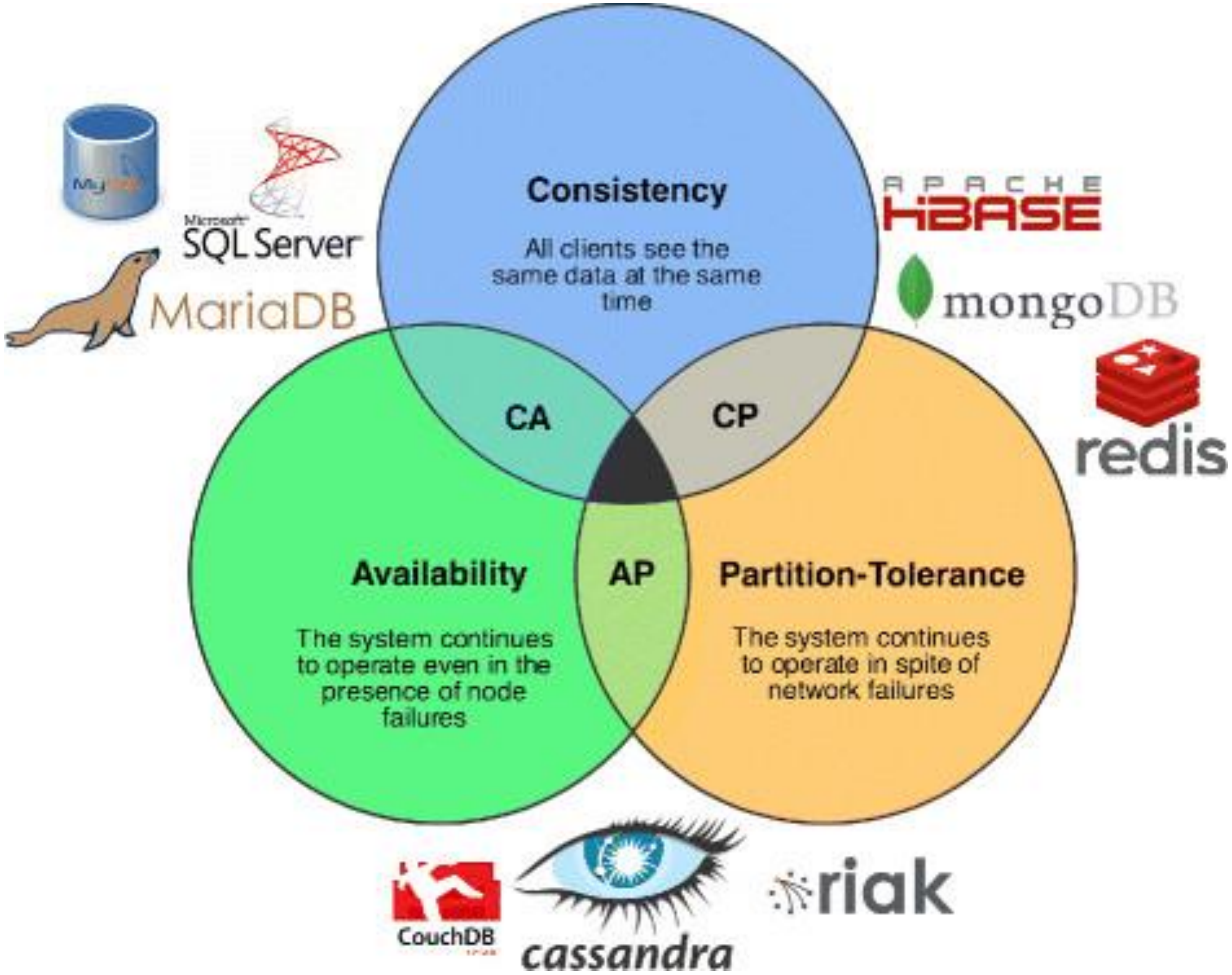
CA Category

Network problem might stop the system.
Ex: RDBMS (Oracle, SQL Server, MySQL)

AP Category

Clients may read inconsistent data
Ex: Cassandra, RIAK, CouchDB

CAP Theorem



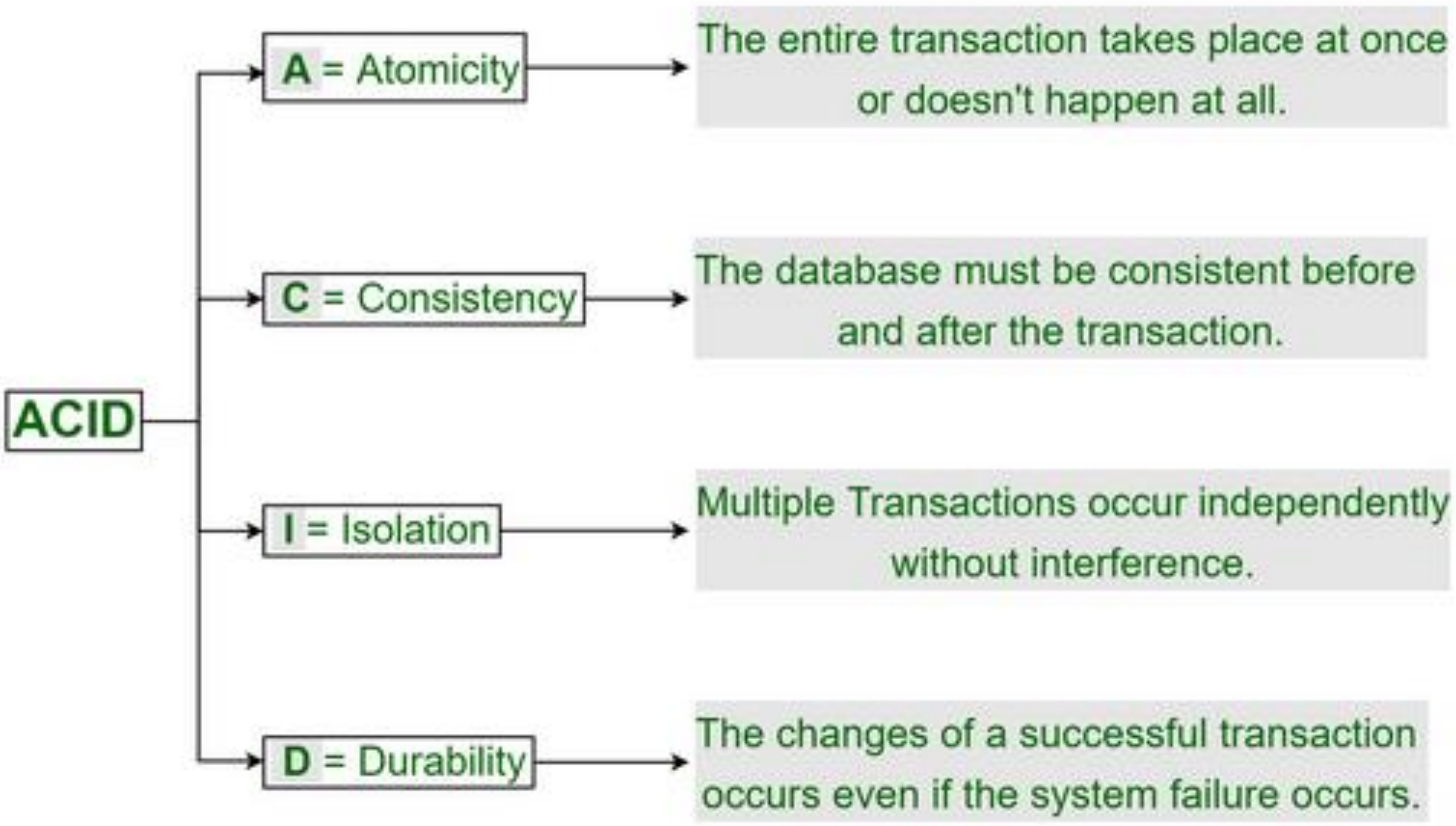
All clients see the same data at the same time

The system continues to operate even in the presence of node failures

The system continues to operate in spite of network failures

ACID properties

To ensure the integrity of data during a transaction, the database system maintains essential properties known as ACID properties.



ACID

A = Atomicity

The entire transaction takes place at once or doesn't happen at all.

C = Consistency

The database must be consistent before and after the transaction.

I = Isolation

Multiple Transactions occur independently without interference.

D = Durability

The changes of a successful transaction occurs even if the system failure occurs.

BASE Model

- **Basic Availability:**

Data will be available even in case of multiple failures. This is possible by spreading the data across many storage systems with a high degree of replication.

- **Soft state:**

The state of the system could change over time, so even during times without input there may be changes going on due to ‘eventual consistency,’ thus the state of the system is always ‘soft.’

- **Eventual consistency:**

The system will eventually become consistent once it stops receiving input. The data will propagate to everywhere it should sooner or later, but the system will continue to receive input and is not checking the consistency of every transaction before it moves onto the next one.

ACID vs. BASE

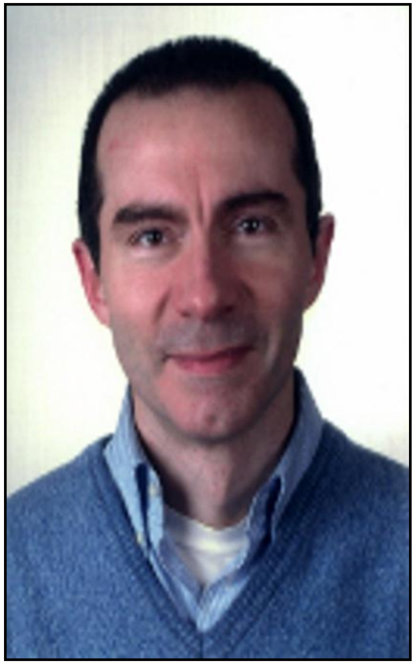
Sr.No.	ACID (used in RDBMS)	BASE (used in NoSQL)
1.	Strong consistency	Weak consistency (Stale data OK)
2.	Isolation	Last write wins
3.	Transaction	Program managed
4.	Robust database	Simple database
5.	Follows CA (Consistency & Availability)	Follows CP (Consistency & Parition-tolerant) or AP (Availability & Partition-tolerant)

RDBMS vs NoSQL

Sr.No.	RDBMS	NoSQL
1.	Handles Limited Data Volumes	Handles Huge Data Volumes
2.	Vertically scaled (Scale-in)	Horizontally scaled (Scale-out)
3.	SQL is used as query language	No declarative query language
4.	Predefined Schema	Schema less
5.	Supports relational data and its relationships are stored in separate tables	Supports unstructured and unpredictable data
6.	Based on ACID model	Based on BASE model
7.	Transaction Management is strong	Transaction Management is weak

NoSQL introduction

- ✓ NoSQL is a non-relational database management system, different from traditional RDBMS in some significant ways
- ✓ **Carlo** Strozzi used the term NoSQL in 1998 to name his lightweight, open-source relational database that did not expose the standard SQL interface



NoSQL introduction

- ✓ In 2009, **Eric** Evans reused the term to refer databases which are non-relational, distributed, and does not conform to ACID

- ✓ The NoSQL term should be used as in the Not-Only-SQL and not as No to SQL or Never SQL

When to use NoSQL

1. You need to handle extremely large data sets.
2. You need extremely fast in-memory data.
3. You need Schema less & de-normalized database.
4. You want to handle database in Object oriented fashion.

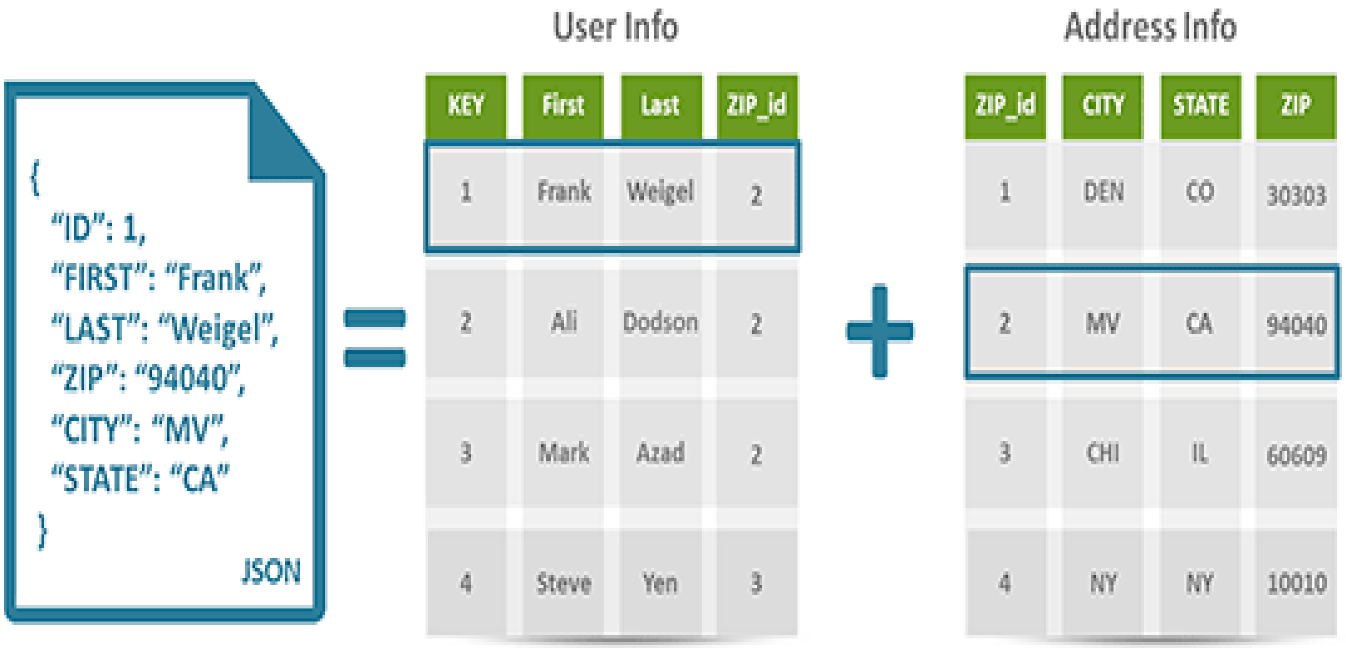
NoSQL (Not only SQL)

- **Document DBs**
  - MongoDB, CouchDB, …
- **Graph DBs**
  - Neo4j, FlockDB…
- **Column oriented DBs**
  - HBase, Cassandra, BigTable…
- **Key-Value DBs**
  - Memcache, MemcacheDB, **Redis**,
  Voldemort, Dynamo…

Document based DBs

The data which is a collection of key value pairs is compressed as a document store quite similar to a key-value store. However, the only difference is that the values stored (referred as “documents”) provide some structure and encoding of the managed data. XML, JSON, BSON (Binary JSON) are some common standard encodings.

Document based DBs continue…



```
{
  "ID": 1,
  "FIRST": "Frank",
  "LAST": "Weigel",
  "ZIP": "94040",
  "CITY": "MV",
  "STATE": "CA"
}
```

=

User Info

KEY	First	Last	ZIP_id
1	Frank	Weigel	2
2	Ali	Dodson	2
3	Mark	Azad	2
4	Steve	Yen	3

+

Address Info

ZIP_id	CITY	STATE	ZIP
1	DEN	CO	30303
2	MV	CA	94040
3	CHI	IL	60609
4	NY	NY	10010

Graph based DBs

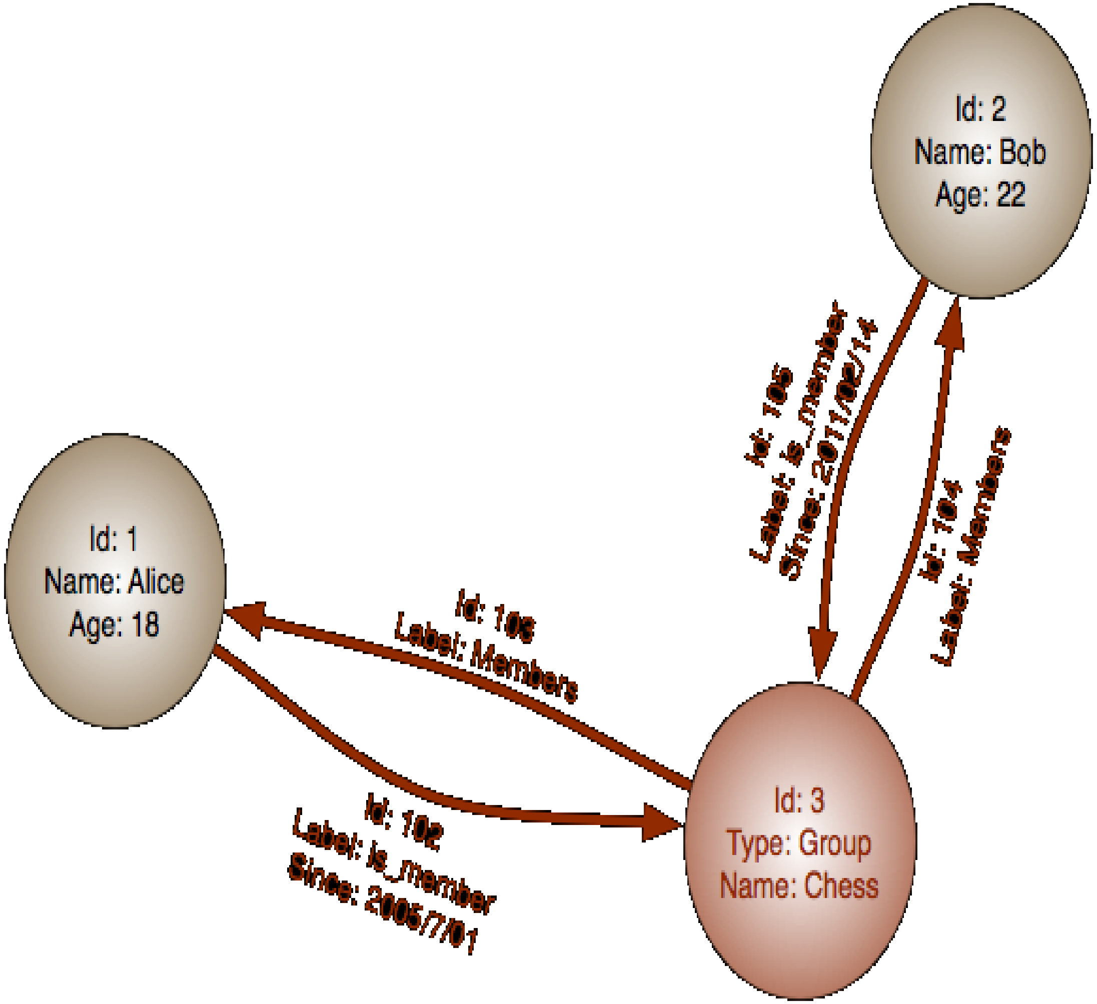
In Graph based databases, data is stored using flexible graph based representation. It uses the following terms:

Node: Nodes represent entities such as people, businesses, accounts, or any other item you might want to keep track of.

Properties: Properties are pertinent information that relate to nodes. For instance, if "Account" were one of the nodes, one might have it tied to properties such as "accno", "acc_name".

Edges: Edges are the lines that connect nodes to nodes or nodes to properties and they represent the relationship between the two.

Graph based DBs continue…



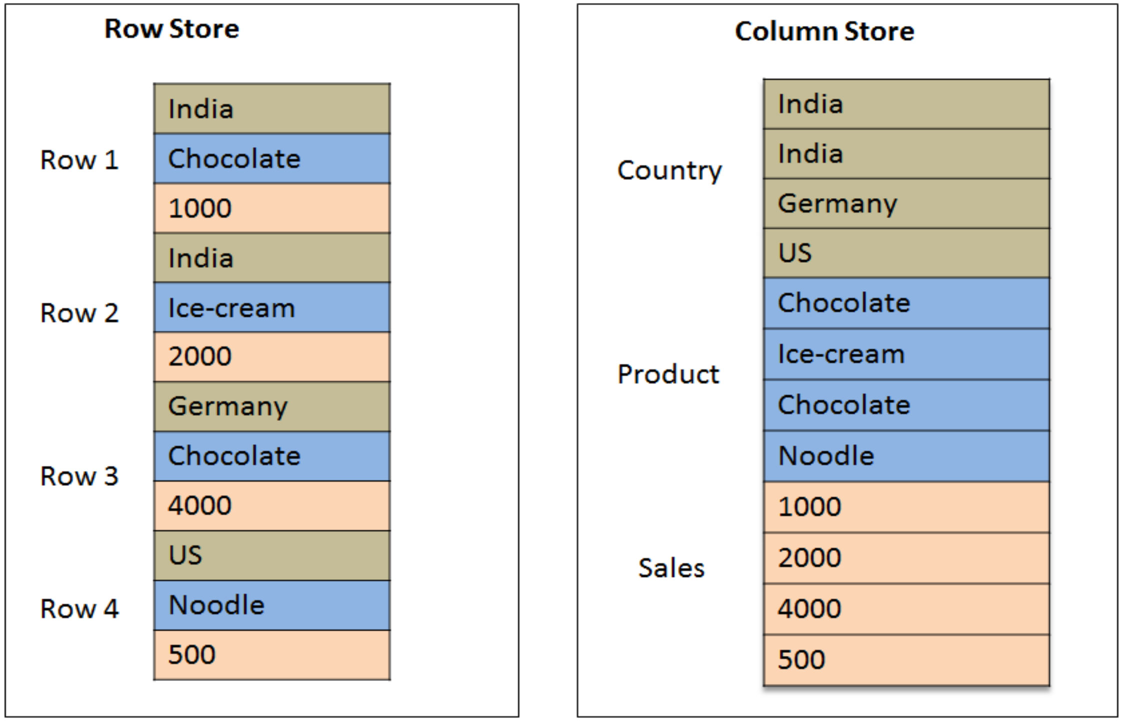
Column based DBs

In column-oriented NoSQL database, data is stored in cells grouped in columns of data rather than as rows of data. Columns are logically grouped into column families. Column families can contain a virtually unlimited number of columns that can be created at runtime or the definition of the schema. Read and write is done using columns rather than rows.

Column based DBs continue..

Table

	Country	Product	Sales
Row 1	India	Chocolate	1000
Row 2	India	Ice-cream	2000
Row 3	Germany	Chocolate	4000
Row 4	US	Noodle	500



Row Store

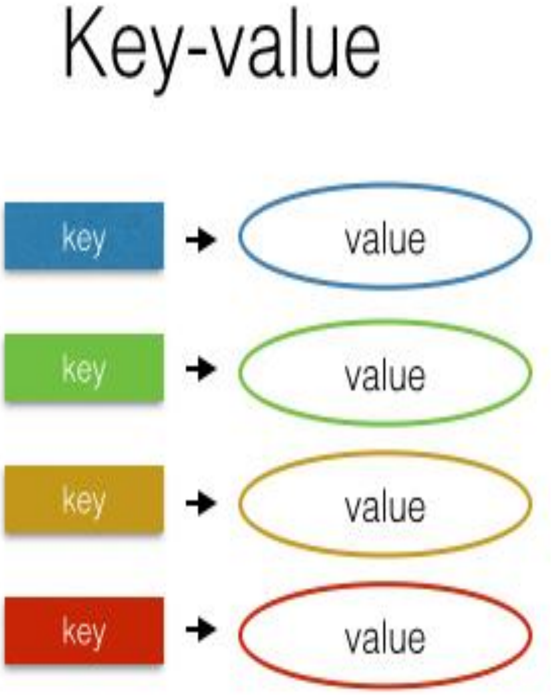
Row 1	India Chocolate 1000
Row 2	India Ice-cream 2000
Row 3	Germany Chocolate 4000
Row 4	US Noodle 500

Column Store

Country	India India Germany US
Product	Chocolate Ice-cream Chocolate Noodle
Sales	1000 2000 4000 500

Key-value based DBs

The key-value NoSQL database uses a hash table in which there exists a unique key and a pointer to a particular item of data.



Introduction to MongoDB

- MongoDB was developed in 2007 by a New York based organization '10gen' which is now called as MongoDB Inc.
- The word Mongo is derived from the word Humongous means very large.
- MongoDB is developed using C++ & JavaScript programming languages.
- Download MongoDB & refer its documentation at https://www.mongodb.org/
- Mongo works on default port 27017.

Advantages of MongoDB

- **Simplicity**

  Mongo adopts storage in JSON format makes it simple database rather than adding complexities that come with relational databases.
- **Data Replication and Reliability**

  MongoDB allow users to replicate data on multiple mirrored servers which ensures data reliability. In case a server crashes, its mirror is still available and database processing remains unaltered.
- **NoSQL Queries**

  Mongo JSON Based document oriented queries are extremely fast as compared to traditional sql queries.
- **Schema Free Migrations**

  In MongoDB, schema is defined by the code. Hence, in case of database migrations, no schema compatibility issue arises.
- **Open Source**

  MongoDB is a database server that is open source and customizable according to the requirements of the organization.

MongoDB installation

- Download MongoDB from https://www.mongodb.org/downloads
- Install the .msi file. Note that Mongo goes not support windows XP.
- Create a directory c:\data\db since MongoDB's default data directory is located there.
- You may override the default directory using following command:

```
%MONGO_HOME%\bin>mongod.exe –dbpath c:\mongodb\db
```

- In order to start mongodb, use the command mongod.exe.
- In order to fire queries, use the command mongo.exe
- More info at https://docs.mongodb.org/manual/tutorial/install-mongodb-on-windows/

MongoDB GUI clients

- MongoVUE (http://www.mongovue.com/)
- Robomongo (http://robomongo.org/)
- RockMongo (http://rockmongo.com/)
- MongoDB Compass (built-in with mongodb installation)

MongoDB Terminologies

RDBMS	MongoDB
Database	Database
Table	Collection
Tuple/Row	Document
Column	Field
Table Join	Embedded documents
Primary key	Primary key supplied by MongoDB itself

MongoDB datatypes

Double
String
Object
Array
Binary Data
ObjectId
Boolean
Date
Null
Integer
Timestamp

Mongo queries

1. Create new database: >use xordb

2. Find the current database: >db

3. List down all databases: >show dbs

4. Delete database: >use xordb THEN >db.dropDatabase()

5. Create collection: >db.createCollection("orders")

Mongo queries continued…

List all collection from database: >show collections

Drop collection: >db.COLLECTION_NAME.drop()

Insert document: >db.COLLECTION_NAME.insert({ name: 'Chairs', quantity: 35, price: 5000})

Display all documents within collection: >db.COLLECTION_NAME.find().pretty()

Mongo queries continued…

Find documents based upon filter criteria:

```
	>db.Orders.find({name: 'Bag Purchase'}).pretty()

	>db.Orders.find({price: {$lt: 60000}}).pretty()

	>db.Orders.find({$or: [ { price: {$lt: 60000}},
{name: 'Bag Purchase'} ] }).pretty()
```

Update document:

```
	>db.Orders.update({name: 'Car Purchase'},
{$set: {name: 'Car sale' }})
```

Mongo queries continued…

Save document:

```
        >db.Orders.save({
                "_id": ObjectId("565bbac2c95843b6ef06c00a"),
"name": "Handbag purchase", "price": 2300
                })
```

Delete document:

```
        >db.Orders.remove({ name: "Handbag purchase" })

        >db.Orders.remove({ name: "Handbag purchase" }, 1)

        >db.Orders.remove()
```

Mongo queries continued…

Projection in document:

```
>db.Orders.find({name: 'Laptop Purchase'}, {price: 1}).pretty()
```

Limiting documents:

```
>db.Orders.find().limit(2).pretty()
```

Skipping documents:

```
>db.Orders.find().limit(1).skip(1).pretty()
```

Sorting documents:

```
>db.Orders.find().sort({price: 1}).pretty()
```

Capped collections

- db.createCollection("logs",{capped:true,size:10000,max:1000})
- Capped collections are fixed-size circular collections.
- Capped collection will start deleting the oldest document in the collection without providing any explicit command.
- Capped collection follows FIFO(First in first out) model.
- If the size field is less than or equal to 4096, then the collection will have a cap of 4096 bytes.

Capped collections continue…

- We cannot delete a document from capped collection.

  db.logs.remove({status: ‘DONE’) // Error

- Convert existing collection to capped:

  db.runCommand({"convertToCapped":“logs",size:10000})

- Find out whether a collection is capped or not:

  db.logs.isCapped()

- Performing find() operation on capped collection gives results ordering same as the insertion order. However, if we wish to reverse it, for example I wish to find out last 5 logs from ‘logs’ collection then use:

  db.logs.find().sort({ $natural: -1 })

Mongo shell methods

Mongo provides extensive support of built-in methods that helps to write complex query. You can find the complete list of methods at:

https://docs.mongodb.org/manual/reference/method/

MongoDB Aggregation Framework

Sometimes Mongo developer wants to analyze and crunch it in interesting ways. Here we can use aggregation facility provided by Mongo.

Aggregation groups values from multiple documents together, and can perform a variety of operations on the grouped data to return a single result.

Aggregation Framework

The aggregation framework lets you transform and combine documents in a collection. Basically, you build a pipeline that processes a stream of documents through several building blocks: filtering, projecting, grouping, sorting, limiting, and skipping.

Take an example of collection ‘Magazine’ having following fields:

```
{
   "_id" : ObjectId("565c22ba95c0b732f6f6eede"),
   "name" : "India Today",
   "price" : 150,
   "author" : “Ivan"
}
```

Query example

List down the first 3 authors based upon number of magazines they have published. In order to write Mongo query for this, lets first categorize the steps:

- Project the authors out of each magazine document.
- Group the authors by name, counting the number of occurrences.
- Sort the authors by the occurrence count, descending.
- Limit results to the first three.

Query example continued…

- In order to project the author from magazine, we use $project operator:

```
{"$project" : {"author" : 1}}
```

- Grouping by author name & count number of authors within collection, we use $group operator:

```
{"$group" : {"_id" : "$author", "count" : {"$sum" : 1}}}
```

- Sorting based number of upon magazines published by an author, we use $sort:

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

- Show only limited number of records, use $limit:

```
{"$limit" : 3}
```

Query example continued…

Final query:

```
db.magazine.aggregate(
        {"$project" : {"author" : 1}},
        {"$group" : {"_id" : "$author", "count" :
{"$sum" : 1}}},
        {"$sort" : {"count" : -1}},
        {"$limit" : 2}
)
```

Pipeline operations

The aggregation framework extensively uses pipeline operations. Here one operator generate document & it becomes input to another operator & so on.. Finally the last operator returns the result to the client.

The operators can be combined in any order & repeated many times as necessary.

Pipeline operators

$project

```
{ "$project" : {"author" : "$author"} }
```

$group

```
{ "$group": { "_id": "$author", "count": {"$sum": 1} } }
```

$sort

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

$limit

```
{ "$limit": 2 }
```

$skip

```
{ $skip : 5 }
```

$match

```
{ $match : { author : “Ivan" } }
```

$unwind

```
{ $unwind : "$prices" }
```

$group operators

$sum

"$group" : { "totalRevenue" : {"**$sum**" : "$revenue"} }

$avg

"$group" : {“averageRevenue" : {"**$avg**" : "$revenue"}}

$max, $min

"$group" : { “costlyBook”: {“**$max**”: “$bookPrice”} }

$first, $last

$group: { _id: "$item", firstSalesDate: { **$first**: "$date" } } }

$addToSet

$group: { _id: { day: { $dayOfYear: "$date"}, itemsSold: { **$addToSet**: "$item" } } }

$push

$group: { _id: { day: { $dayOfYear: "$date"}, itemsSold: { **$push**: { item: "$item", quantity: "$quantity" } } } }

Pipeline expressions

Pipeline expressions allow us to perform more powerful operations in aggregation framework like manipulating numeric values, playing with date fields, performing operations on strings, adding various logical conditions etc.

Pipeline expressions are divided into following types:

- Mathematical expressions
- Date expressions
- String expressions
- Logical expressions

Mathematical expressions

Mathematical expressions let you to manipulate numeric values.

$add

```
{ $project: { item: 1, total: { $add: [ "$price", "$fee" ] } } }
```

$subtract

```
{ $project: { item: 1, dateDifference: { $subtract: [ "$date", 5 * 60 * 1000 ] } } }
```

$multiply

```
{ $project: { date: 1, item: 1, total: { $multiply: [ "$price", "$quantity" ] } } }
```

$divide

```
{ $project: { name: 1, workdays: { $divide: [ "$hours", 8 ] } } }
```

$mod

```
{ $project: { remainder: { $mod: [ "$hours", "$tasks" ] } } }
```

Date expressions

Using date expressions, we can perform several operations on date field. For example, in order to find month for a date:

```
    month: { $month: "$date" }
```

$dayOfYear

$dayOfMonth

$dayOfWeek

$year

$month

$week

$hour

$minute

$second

$milisecond

$dateToString

String expressions

Spring expressions can be used to perform basic operations on string.

$substr

```
{"$substr" : ["$firstName", 0, 1]}
```

$concat

```
{“$concat”: [ “$firstName”, “$lastName” ] }
```

$toLower

```
{“$toLower”: “$firstName” }
```

$toUpper

```
{“$toUpper”: “$firstName” }
```

Logical expressions

Logical expressions are used to perform conditional operations.

$cmp

```
    isHighQuantity: { $cmp: [ "$qty", 250 ] }
```

$strcasecmp

```
    isNameMatching: { $strcasecmp: [ "$firstName", “TOM" ] }
```

$eq, $ne, $gt, $gte, $lt, $lte

```
    isQuantity250: { $eq: [ "$qty", 250 ] }
```

$and, $or

```
    result: { $or: [ { $gt: [ "$qty", 250 ] }, { $lt: [ "$qty", 200 ] } ] }
```

$not

```
    result: { $not: [ { $gt: [ "$qty", 250 ] } ] }
```

$cond

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

$ifNull

```
    description: { $ifNull: [ "$description", "Unspecified" ] }
```

Useful links

SQL to aggregation mapping chart:

- https://docs.mongodb.org/manual/reference/sql-aggregation-comparison/

Aggregation Pipeline Operators

- https://docs.mongodb.org/manual/reference/operator/aggregation/

Thank You..