UMD DATA605 - Big Data Systems

MongoDB and CouchDB

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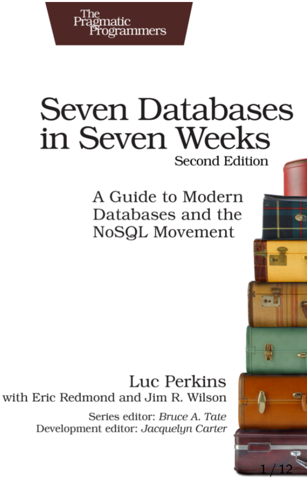
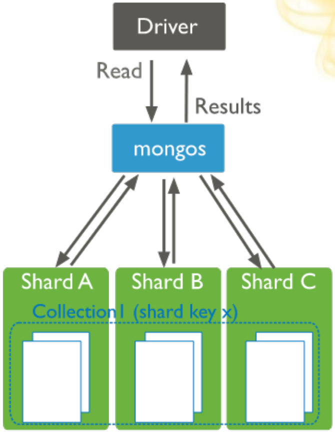
- All concepts in slides
- MongoDB tutorial
- Web
  - https://www.mongodb.com/
  - Official docs
  - pymongo
- Book
  - Seven Databases in Seven Weeks, 2e


The Pragmatic Programmers
Seven Databases in Seven Weeks
Second Edition
A Guide to Modern Databases and the NoSQL Movement
Luc Perkins
with Eric Redmond and Jim R. Wilson
Series editor: Bruce A. Tate
Development editor: Jacquelyn Carter

SCIENCE ACADEMY

MongoDB Processes and Configuration

- mongod: database instance (i.e., a server process)
- mongosh: interactive shell (i.e., a client)
    - Fully functional JavaScript environment for use with a MongoDB
- mongos: database router
    - Process all requests
    - Decide how many and which mongod instances should receive the query (sharding / partitioning)
    - Collate the results
    - Send result back to the client
- You should have:
    - One mongos (router) for the whole system no matter how many mongods you have; or
    - One local mongos for every client if you wanted to minimize network latency



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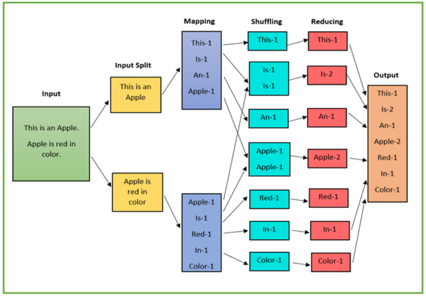
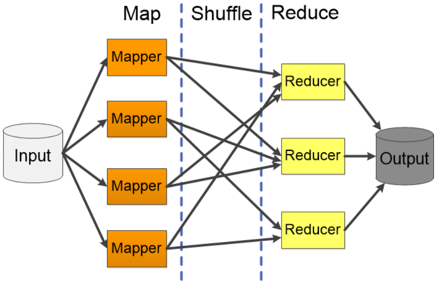
MapReduce Functionality

- Perform map-reduce computation given a collection of (keys, value) pairs
- Must provide at least a map function, reduction function, and the name of the result set

```
db.collection.mapReduce(
  <map\_function>,
  <reduce\_function>,
  {
    out: <collection>,
    query: <document>,
    sort: <document>,
    limit: <number>,
    finalize: <function>,
    scope: <document>,
    jsMode: <boolean>,
    verbose: <boolean>
})
```





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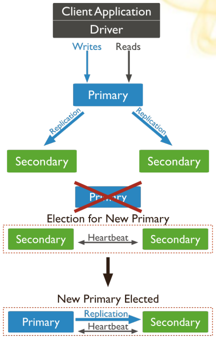
Data Replication

- Data replication ensure:
  - Redundancy
  - Backup
  - Automatic failover
- Replication occurs through groups of servers known as replica sets
  - Primary set: set of servers that client asks direct updates to
  - Secondary set: set of servers used for duplication of data
  - Different properties can be associated with a secondary set,
    - E.g., secondary-only, hidden delayed, arbiters, non-voting
- If the primary fails the secondary sets "vote" to elect the new primary set



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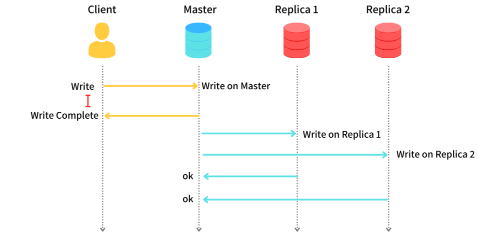
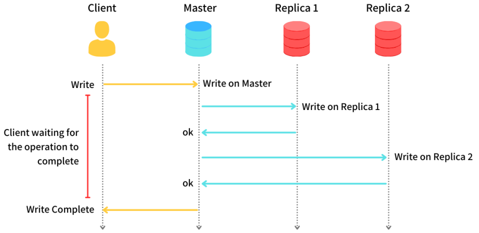
Sync vs Async Replication

- **Synchronous replication**: updates are propagated to other replicas as part of a single transaction
- Implementations
  - 2-Phase Commit (2PC)
  - Paxos
  - Both solutions are complex / expensive
- **Asynchronous replication**
  - The primary node propagates updates to replicas
  - The transaction is completed before replicas are updated (even if there are failures)
  - Commits are quick at cost of consistency



Asynchronous Replication



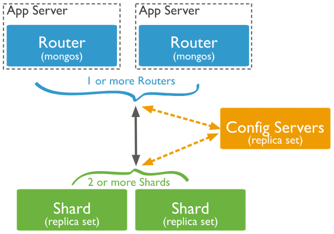
Synchronous Replication

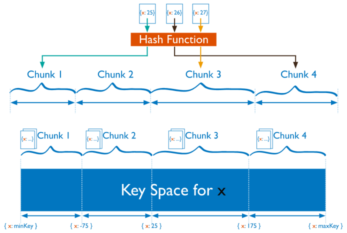
Data Consistency

- **Client decides how to enforce consistency for reads**
- Reads to a primary have **strict consistency**
  - Reads reflect the latest changes to the data
  - All writes and *consistent* reads go to the primary
- Reads to a secondary have **eventual consistency**
  - Updates propagate gradually
  - Client may read a previous state of the database
  - All *eventually consistent* reads are distributed among the secondaries

MongoDB: Sharding

- **Shard** = subset of data
  - A collection is split in pieces based on the shard key
  - Data distributed based on shard key or intervals [a, b)
- **Sharding** = method for distributing data across different machines
- **Horizontal scaling** can be achieved through sharding
  - Divide data and workload over multiple servers
  - Complexity in infrastructure and maintenance
- **mongos** acts as a query router interfacing clients and sharded cluster
  - Each shard can be deployed as a replica set
  - Config servers store metadata and configuration settings for cluster





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RDMBS Internals

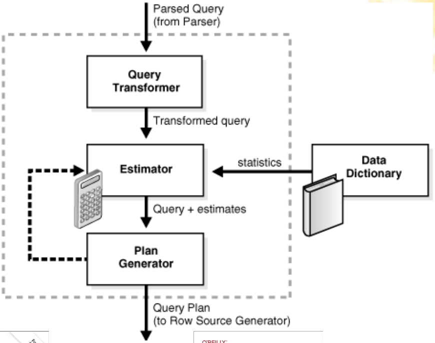
Storage hierarchy - How are tables mapped to files? - How are tuples mapped to disk blocks?

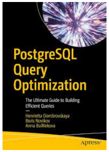
Buffer Manager - Bring pages from disk to memory - Manage the limited memory

Query Processing Engine - Given a user query, decide how to “execute” it - Specify sequence of pages to be brought in memory - Operate upon the tuples to produce results

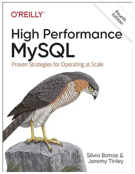
Query Optimizer

- **RDBMSs: query optimizer is static**
  - Assign a cost to each query plan
  - Estimate some cost params (e.g., time to access data)
  - Search for the best query
  - At least traditional RDBMs

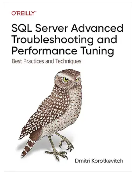




PostgreSQL Query Optimization
The Ultimate Guide to Building Efficient Queries
Henrietta Dombrovskaya
Boris Novikov
Anna Bailliekova
Apress



O'REILLY
Fourth Edition
High Performance MySQL
Proven Strategies for Operating at Scale
Silvia Botros & Jeremy Tinley



O'REILLY
SQL Server Advanced Troubleshooting and Performance Tuning
Best Practices and Techniques
Dmitri Korotkevitch

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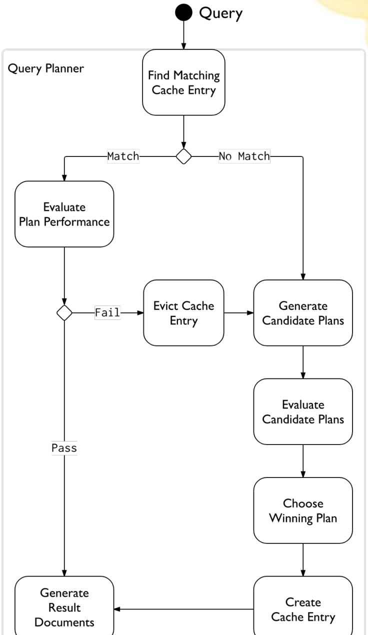
Query Optimizer

- MongoDB: query optimizer is dynamic
  - Try different query plans and learn which ones perform well
  - The space of query plans is not so large, because there are no joins
  - When testing new plans
    - Execute multiple query plans in parallel
    - As soon as one plan finishes, terminate the other plans
  - Cache the result
  - If a plan that was working well starts performing poorly try again different plans
    - E.g, data in the DB has changed, parameter values to a query are different



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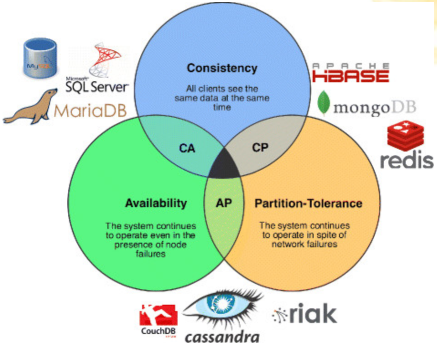
MongoDB: Strengths

- Provide a flexible and modern query language
- High-performance
  - Implemented in C++
- Very rapid development, open source
  - Support for many platforms
  - Many language drivers
- Built to address a distributed database system
  - Sharding
  - Replica sets of data
- Tunable consistency
- Useful for working with a huge quantity of data not requiring a relational model
  - The relationships between the elements does not matter
  - What matters is the ability to store and retrieve great quantities of data

MongoDB: Limitations

- No referential integrity
  - Aka foreign key constraint
- Lack of transactions and joins
- High degree of denormalization
  - Need to update data in many places instead of one
- Lack of predefined schema is a double- edged sword
  - You must have a data model in your application
  - Objects within a collection can be completely inconsistent in their fields
- CAP Theorem: targets consistency and partition tolerance, giving up on availability


Consistency
All clients see the same data at the same time
CA
CP
AP
Availability
The system continues to operate even in the presence of node failures
Partition-Tolerance
The system continues to operate in spite of network failures
SQL Server
MariaDB
APACHE HBASE
mongoDB
redis
CouchDB
cassandra
riak