Document Stores

Knowledge Objectives

1. Explain the main difference between key-value and document stores
2. Justify why indexing is a first-class citizen for document-stores and it is not for key-value stores

Application Objectives

1. Given an application layout and a small query workload, design a document-store providing optimal support according to a given set of criteria

Structuring the Value

- Essentially, they are key-value stores
  - Same design and architectural features
- The value is a document
  - XML (e.g., eXist)
  - JSON (e.g., MongoDB and CouchDB)
- Tightly related to the Web
  - Normally, they provide RESTful HTTP APIs
- So… what is the benefit of having documents?
  - New data model (collections and documents)
    - **New atom: from rows to documents**
  - Indexing

Designing Document Stores

- Follow one basic rule: 1 fetch for the whole data set at hand
  - Aggregate data model: check the data needed by your application simultaneously
    - **Do not think relational-wise!**
  - Use indexes to identify finer data granularities
- Consequences:
  - Independent documents
    - Avoid pointing FKs (i.e., pointing at other docs)
  - Massive denormalization
  - A change in the application layout might be dramatic
    - It may entail a massive rearrangement of the database documents

JSON Document-Stores

- JSON-like documents
  - MongoDB
  - CouchDB
- JSON is a lightweight data interchange format
  - Brackets ([]) represent ordered lists
  - Curly braces ({}) represent key-value dictionaries
    - Keys must be strings, delimited by quotes (")
    - Values can be strings, numbers, booleans, lists, or key-value dictionaries
- Natively compatible with JavaScript
  - Web browsers are natural clients

http://www.json.org/index.html

JSON Example

- Definition:

A document is an object represented with an unbounded nesting of array and object constructs


```
{
   "title": "The Social network",
   "year": "2010",
   "genre": "drama",
   "summary": "On a fall night in 2003, Harvard undergrad and computer
   programming genius Mark Zuckerberg sits down at his computer
   and heatedly begins working on a new idea. In a fury of blogging
   and programming, what begins in his dorm room soon becomes a global
   social network and a revolution in communication. A mere six years
   and 500 million friends later, Mark Zuckerberg is the youngest
   billionaire in history... but for this entrepreneur, success leads
   to both personal and legal complications.",
   "country": "USA",
  "director": {
     "last_name": "Fincher",
     "first_name": "David",
     "birth_date": "1962"
  },
  "actors": [
    {
       "first_name": "Jesse",
       "last_name": "Eisenberg",
       "birth_date": "1983",
       "role": "Mark Zuckerberg"
    },
    {
       "first_name": "Rooney",
       "last_name": "Mara",
       "birth_date": "1985",
       "role": "Erica Albright"
    },
    {
       "first_name": "Andrew",
       "last_name": "Garfield",
       "birth_date": "1983",
       "role": "  Eduardo Saverin "
    },
    {
       "first_name": "Justin",
       "last_name": "Timberlake",
       "birth_date": "1981",
       "role": "Sean Parker"
    }
  ]
}
```

MongoDB: Data Model

- Collections
  - *Definition*: A grouping of MongoDB documents
    - A collection exists within a single database
    - Collections do not enforce a schema
  - MongoDB Namespace: *database.collection*
- Documents
  - *Definition*: JSON documents (serialized as BSON)
    - Basic atom
    - Identified by *_id* (user or system generated)
    - Aggregated view of data
    - May contain
      - References (**<u>NOT FKs!</u>**) and
      - Embedded documents

MongoDB: Document Example

contact document

```
{
  _id: <ObjectId2>,
  user_id: <ObjectId1>,
  phone: "123-456-7890",
  email: "xyz@example.com"
}
```

user document

```
{
  _id: <ObjectId1>,
  username: "123xyz"
}
```

access document

```
{
  _id: <ObjectId3>,
  user_id: <ObjectId1>,
  level: 5,
  group: "dev"
}
```

MongoDB: Document Example

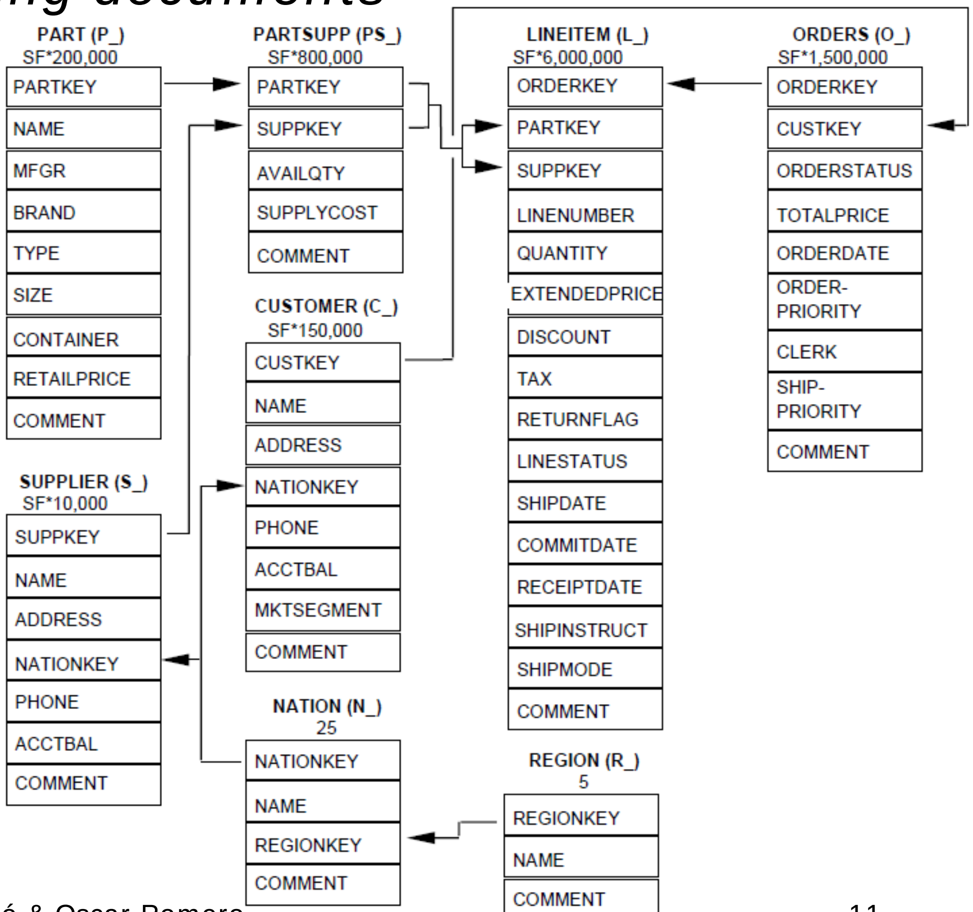
```
{
  _id: <ObjectId1>,
  username: "123xyz",
  contact: {
             phone: "123-456-7890",
             email: "xyz@example.com"
           },
  access: {
            level: 5,
            group: "dev"
          }
}
```

Embedded sub-document

Embedded sub-document

Activity

- Objective: Learn how to model documents
- Tasks:
  1. (15') Model the TPC-H using documents
  2. (5') Discussion



MongoDB Shell

- Show dbs
- Use <*database*>
- Show collections
- Show users
- coll = db.<*collection*>
- Find(*criteria, projection*)
- Insert(*document*)
- Update(*query, update, options*)
- Save(*document*)
- Remove(*query, justOne*)
- Drop()
- EnsureIndex(*keys, options*)

- Notes:
  - *db* refers to the current database
  - *query* is a document (query-by-example)

http://docs.mongodb.org/manual/reference/mongo-shell/

MongoDB: Querying

- Find and findOne methods

  database.collection.find()

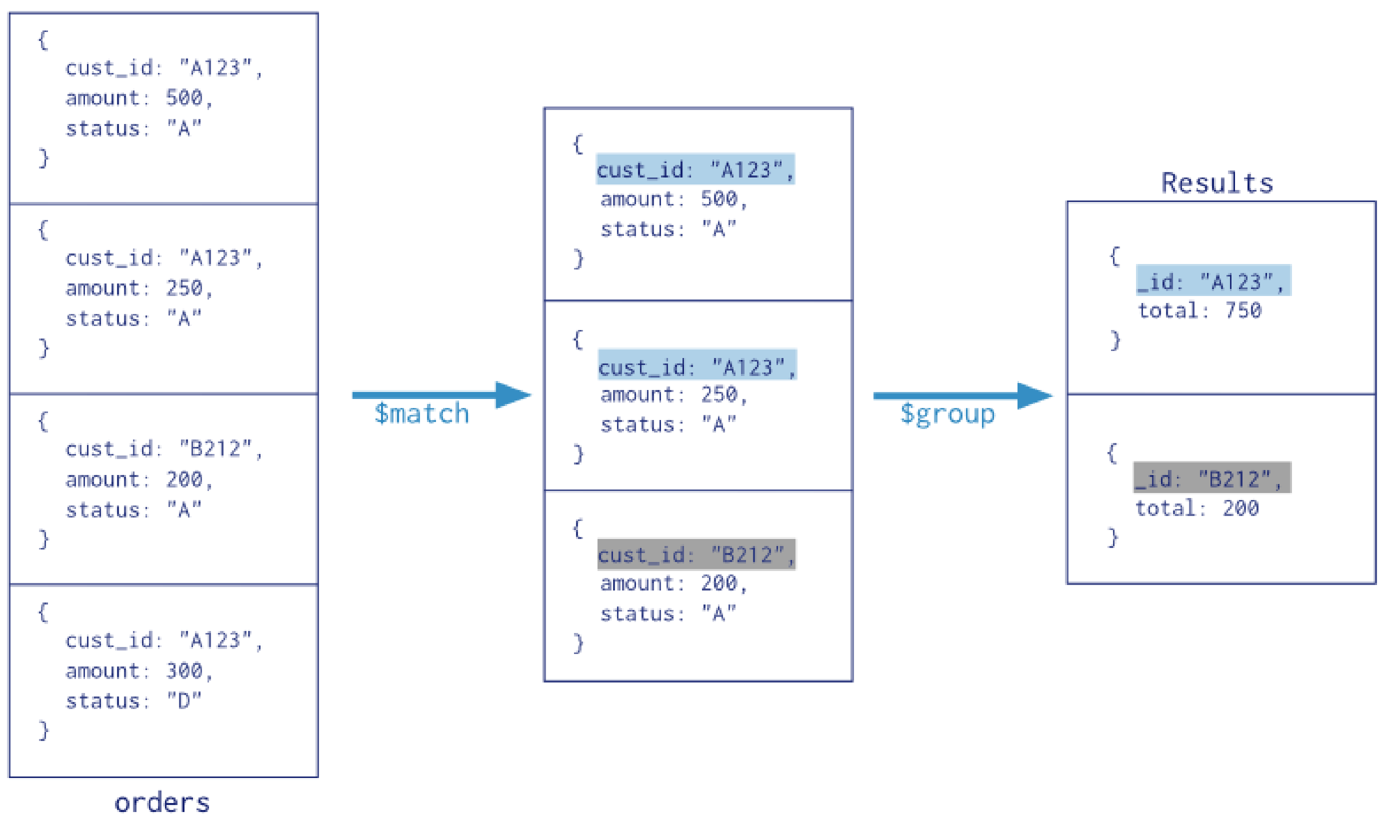
  database.collection.find(*{ qty: { $gt: 25 } }*)

  database.collection.find(*{ field: { $gt: value1, $lt: value2 } }*)

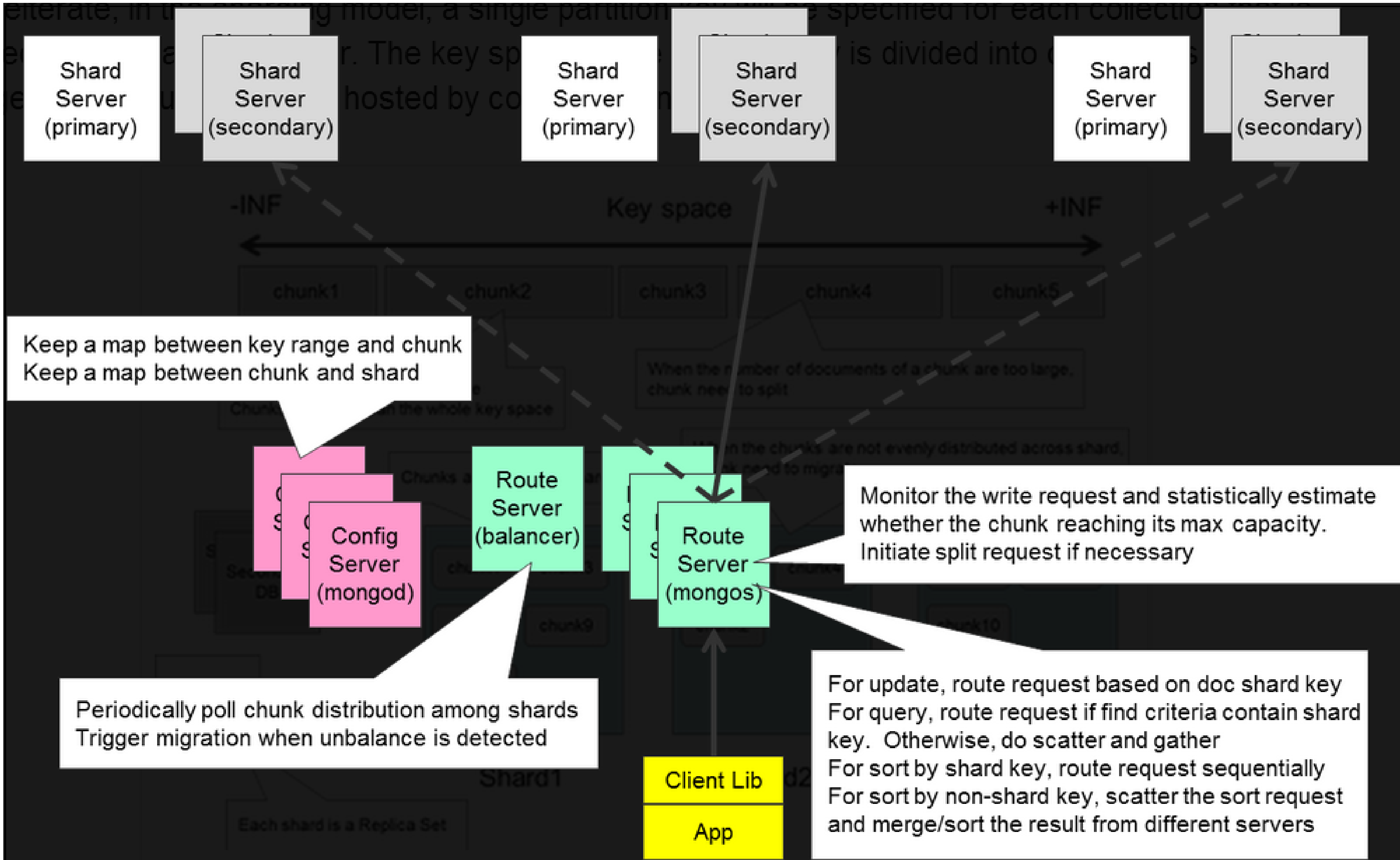
- Aggregation Framework
  - An aggregation pipeline
  - Documents enter a multi-stage pipeline that transforms them into an aggregated result
    - *Filters* that operate like queries
    - *Document transformations* that modify the form of the output
    - Grouping
    - Sorting
    - Other operations
- MapReduce

MongoDB: The Aggregation Framework

```
           Collection
              ↓
db.orders.aggregate(
     $match phase ──→{ $match: { status: "A" } },
     $group phase ──→{ $group: { _id: "$cust_id",total: { $sum: "$amount" } } }
)
```

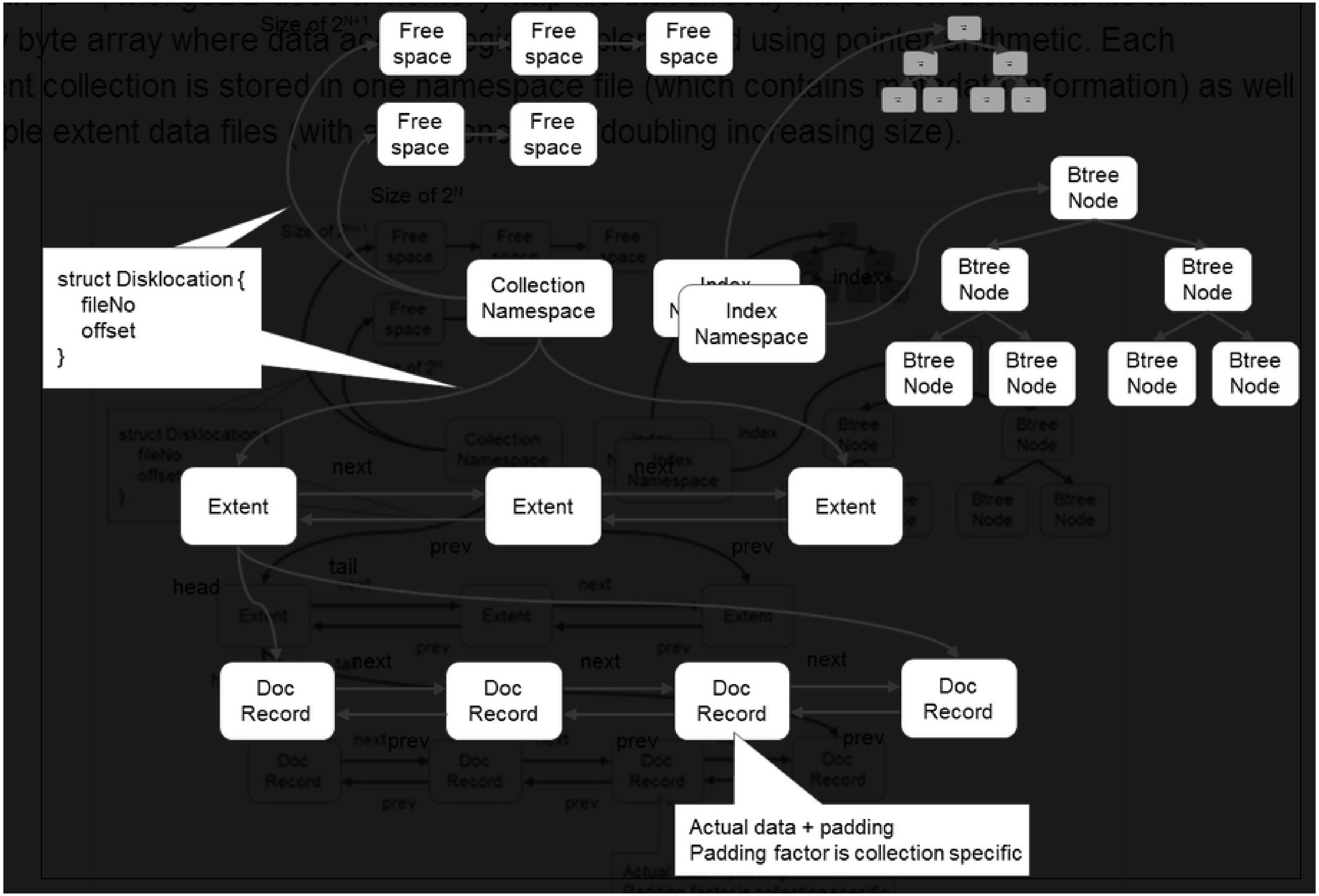


MongoDB: Architecture



http://horicky.blogspot.com.es/2012/04/mongodb-architecture.html

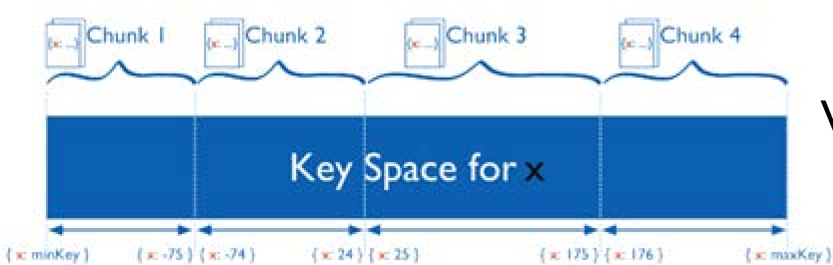
MongoDB: Storage



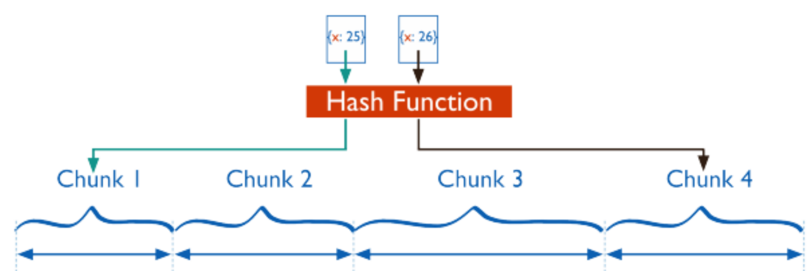
http://horicky.blogspot.com.es/2012/04/mongodb-architecture.html

MongoDB: Fragmentation

- Based on *sharding* (horizontal fragmentation)
  - Shard key: a mandatory field in all documents of the collection
  - Chunk: Hash-based or range-based horizontal fragmentation according to the shard key
    - Range-based: MongoDB determines the chunks by range
      - Adequate for range queries
    - Hash-based: Consistent hashing (a hash function determines the chunks)
      - A Hash-indexed field is required



Vs.



MongoDB: Notation

- Shard clusters
  - Shards: Nodes containing data
    - A shard may contain several chunks
  - Config Servers: Nodes containing the global catalog (e.g., hash directory)
  - Query routers: Nodes containing a copy of the hash directory to redirect queries

MongoDB: Shard Clusters Management

- Query routers are replicas of the config servers
  - Secondary versioning (config servers)
  - Eager replication (to both config servers and query routers)
    - 2PCP (potential distributed deadlocks!)
- Config Servers
  - The hash directory is mandatorily replicated to avoid single-point failures
    - MongoDB asks for 3 config servers
  - Writes happen if:
    - A shard splits
    - A chunk migrates between servers (e.g., adding servers)
- Query routers
  - Read from config servers
    - When they start (o restart)
    - Every time a split / migration happens

MongoDB: Splitting/Migrating Chunks

- Default chunk size: 64MB
- The query router (mongos) asks a shard to split
  - Inserts and updates trigger splits
- Shards rearrange the data (data migration)
  - During the migration requests to that chunk address the origin shard
  - Changes made during the migration are afterwards applied in the destination shard
  - Finally, changes in the hash directory are made in the config servers
    - Query routers eagerly synchronized
- A *balancer* avoids uneven distributions

MongoDB: Replication

- Each *shard* (in a *shard cluster)* is a *replica set*
  - Maps to a *mongod* instance (with its config servers)
- Replica Set*:* Master versioning with lazy replication
  - One master
    - Write / Update / Delete
  - Several replicas
    - Reads
- Replica Set management
  - The master has recovery system
    - Writes / Updates / Deletes and index modifications are kept in memory (@master)
    - Specific recovery system (*journaling*): WAL redo logging
    - When the journal (i.e., log) is flushed to disk it is deleted
  - Members interconnected by heartbeats
  - If the master fails, voting phase to decide a new master
    - PAXOS (arbiters allowed)
  - If a replica fails, it catches up with the master once back

MongoDB: Well-Known Limitations

- Architectural Issues
  - Thumb rule: 70% of the database must fit in memory
  - Be careful with updates! (padding)
    - Holes caused by reallocation
    - Compact the database from time to time
- Document Issues
  - The resulting document of an aggregation pipeline cannot exceed the maximum document size (16Mb)
    - GridFS for larger documents
  - Attribute names are kept as they are (no catalog)
- Querying Issues
  - No transactions
    - Consistency only guaranteed at document level
    - Strong / loose consistency parametrizable
  - Thumb rule: A query must attack a single collection
  - The aggregation capabilities are still rather immature
  - No optimizer!

Summary

- Document-stores
  - Semi-structured value
  - Indexing
- Designing document-stores
- MongoDB

Bibliography

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- D. Battre et al. *Nephele/PACTs: A Programming Model and Execution Framework for Web Scale Analytical Processing.* SoCC’10
- L. Liu and M.T. Özsu (Eds.). *Encyclopedia of Database Systems*. Springer, 2009

Resources

- https://www.mongodb.org
- http://exist-db.org