Large-Scale and Multi-Structured Databases

Social News

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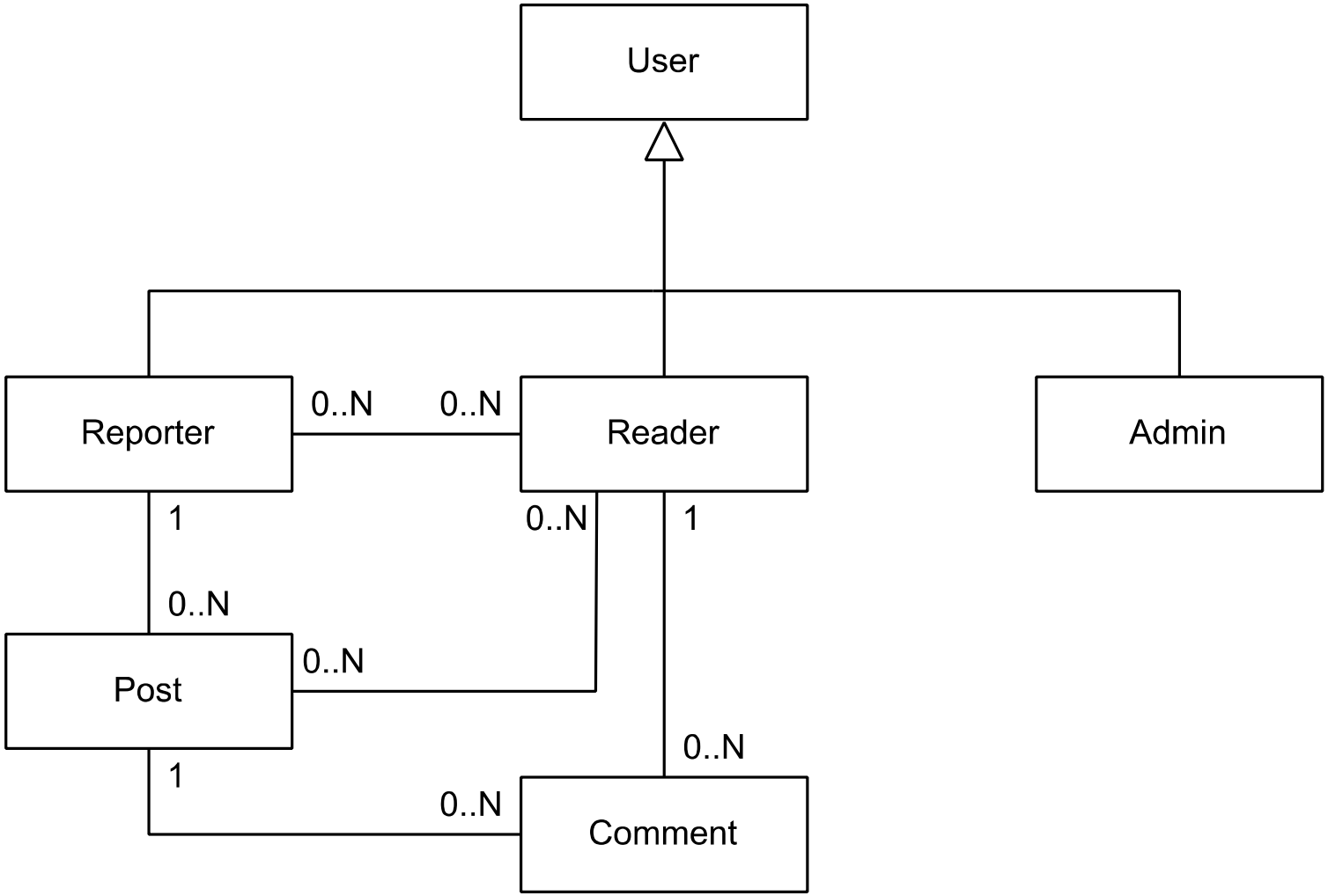
Application: Idea Introduction

Objective: Design and implementation of a WebApp named “SocialNews”. The application fosters interaction among readers, reporters, and administrators, providing relevant information and statistics for an enhanced user experience.

Types of **users**: readers, reporters, and administrators.

- **Readers can** search for reporters or posts, view and comment on posts, delete a comment, follow reporters, view the most influential and popular reporters and view their own profile.
- **Reporters can** post and delete articles, view statistics about most active time of the day and their own most popular posts and view their own profile.
- **Administrators can** view statistics about readers and reporters, register new verified reporters, search and delete registered users and comments/posts.

UML analysis class diagram



Dataset Description

Source:

- https://github.com/jbencina/facebook-news
- https://www.kaggle.com/datasets/bwandowando/breaking-news-twitter-dataset
- https://randomuser.me/

Description:

- Facebook posts and comments on news outlets pages
- Breaking news tweets
- Randomly generated users

Volume:

- Post\Tweet and comments after being cleaned at least 104MB
- Generated users 150.000, estimated considering number of real authors of comments and posts

Variety:

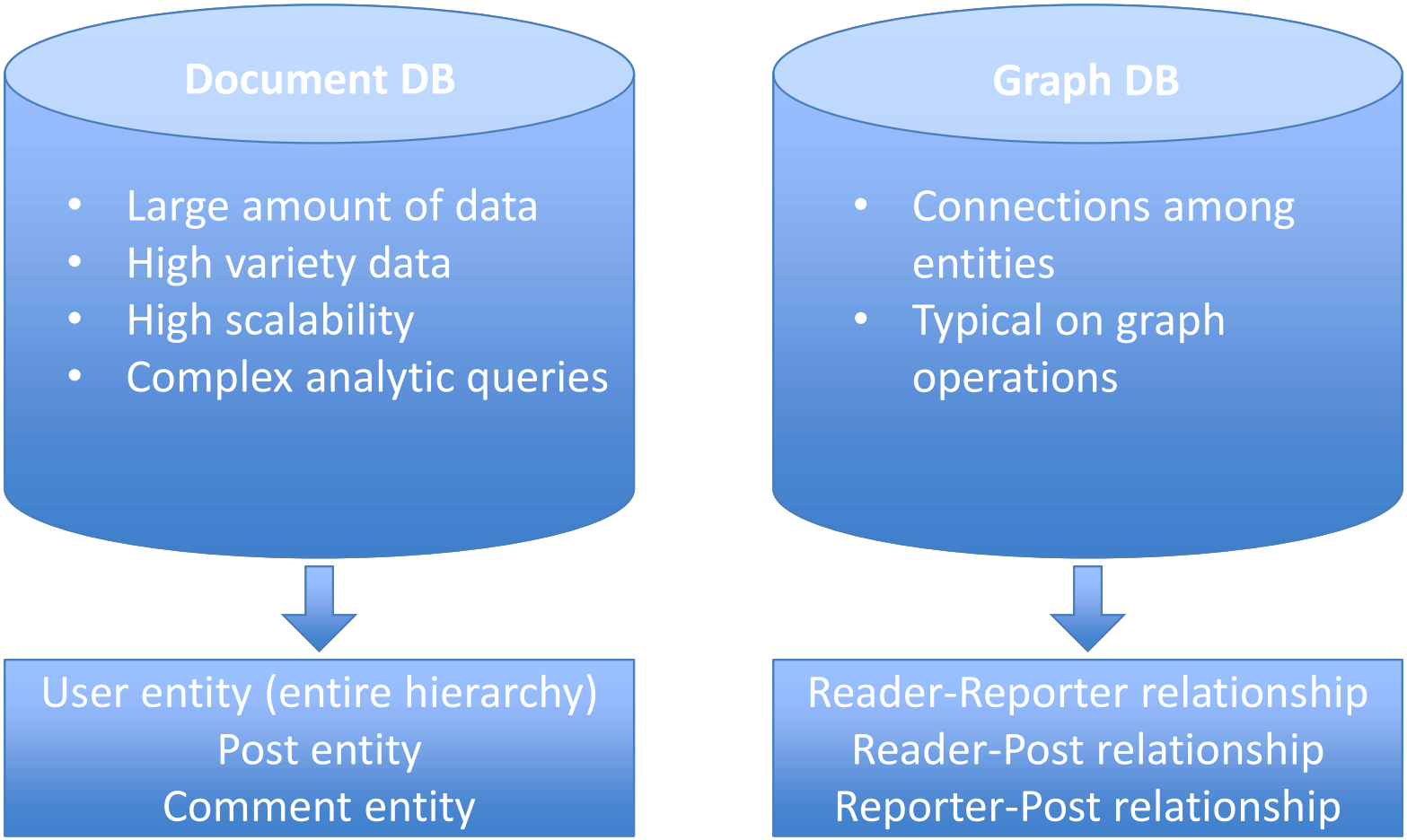
- Data comes from two different sources (Twitter and Facebook)
- Some data attributes are optional

Non-functional requirements

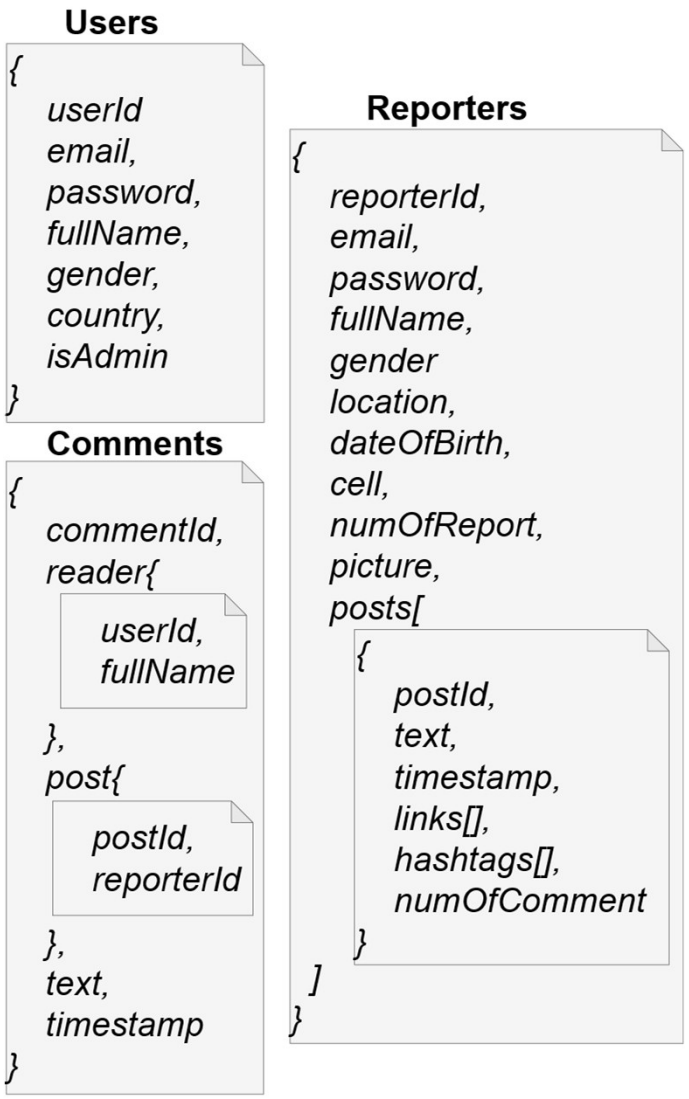
- The system must be a website application
- The system must encrypt users' passwords
- The system must communicate with any user by using a secure communication channel
- The system must be developed by using an OOP language
- The system will be available 24 * 7
- The system will ensure eventual consistency
- The system must be intuitive to use for users without any specific training
- The system must be able to run on at least the following main browsers: Google Chrome, Mozilla Firefox and Edge

Database design

The system relies on two types of database, each storing the data that present the properties to obtain the maximum advantage from the selected database architecture:



Document DB: Design



The entities are stored in the document DB inside three collections:

- **Users**, maintains both readers and admins information
- **Reporters**, maintains both reporter's personal info and his published posts as embedded documents
- **Comments**, maintains all comments publish by readers, keeping a reference to original post via document linking and to reader via data duplication

The design of the "reporters" collection includes two redundancies:

- **numOfReport**, overall number of reports on posts published by the reporter
- **numOfComment**, number of comments on the post

Document DB: Main queries

1. ***Statistic:*** Most active readers
   Side: Admin
   Description: The statistic shows the first 10 active readers.
2. ***Statistic:*** Gender statistic
   Side: Admin
   Description: The statistic shows a graph about the numbers of women and men readers.
3. ***Statistic:*** Nationality statistic
   Side: Admin
   Description: The statistic shows a graph about the nationalities of the readers.
4. ***Statistic:*** Hot posts in the period
   Side: Reporter
   Description: The statistic shows the 10 hottest posts (of a certain period of time) of the reporter.
5. ***Statistic:*** Most active moment of the day
   Side: Reporter
   Description: The statistic shows the most active time moment of the day

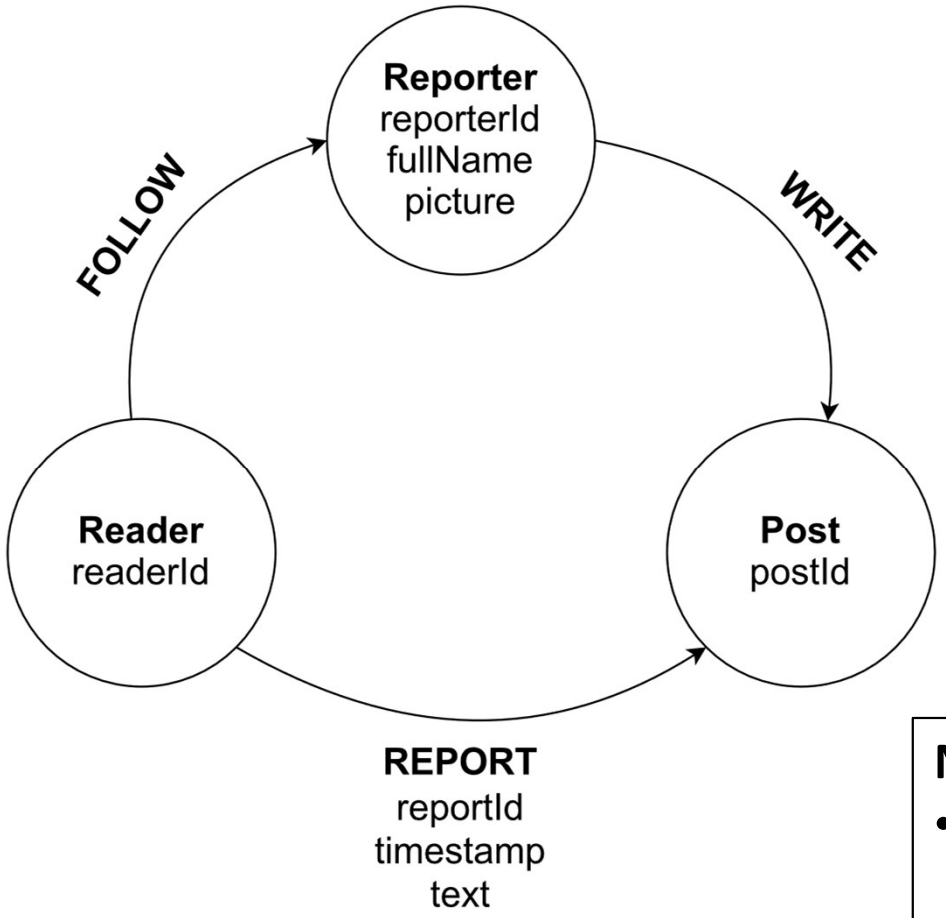
Document DB: indexes

A read-heavy system can obtain considerable advantages from indexes design:

- Based on implemented base queries, the ones most frequent
- Takes into account the pagination implemented by queries that would otherwise retrieve too many data

Collection	Index name	Field(s)	Type(s)
Users	sortByFullNamePagination	fullName, _id	Compound
Users	emailUnique	email	Single, unique
Reporters	searchByFullNamePagination	fullName, reporterId	Compound
Reporters	filterByReporterId	reporterId	Single
Reporters	filterByPostHashtag	posts.hashtags	Single, sparse
Reporters	emailActiveReporterUnique	email	Single, unique, sparse
Comments	searchByPostSortByTimestampPagination	post.id, timestamp, _id	Compound

Graph DB: Design



Types of edges:

- "**FOLLOW**" → unidirectional relationship from a "Reader" to a followed "Reporter"
- "**REPORT**" → unidirectional relationship from "Reader" to reported "Post"
- "**WRITE**" → unidirectional relationship from "Reporter" to their own "Post"

Notes:

- "reporter_id", "reader_id", "post_id" come from Document DB
- Reporter nodes contain name and picture to avoid double query (Document and Graph DBs) to take these information

Graph DB: Main queries

Domain-Specific	Graph-Centric
A reader user reports a post	Add an edge directed from a “Reader” node to a “Post” node
How many followers does a specific reporter have?	How many “FOLLOW” edges are incident to a specific reporter vertex?
Which reporters are suggested to a specific reader?	Reporter vertexes with highest number of incoming edges that haven’t yet a direct edge with the reader (for which the statistic is computed)
Take reports associated with a specific reporter	“REPORT” edges to “Post” nodes linked to the current reporter node with “WRITE” relationship
Which reporters are the most popular?	Reporter vertexes with highest number of "FOLLOW” edges
Remove a reporter account	Remove the “Reporter” node, all “Post” nodes linked with “WRITE” relationship and all ingoing edges (to deleted posts and reporter)

Graph DB: Indexes and contraints

No indexes

With indexes

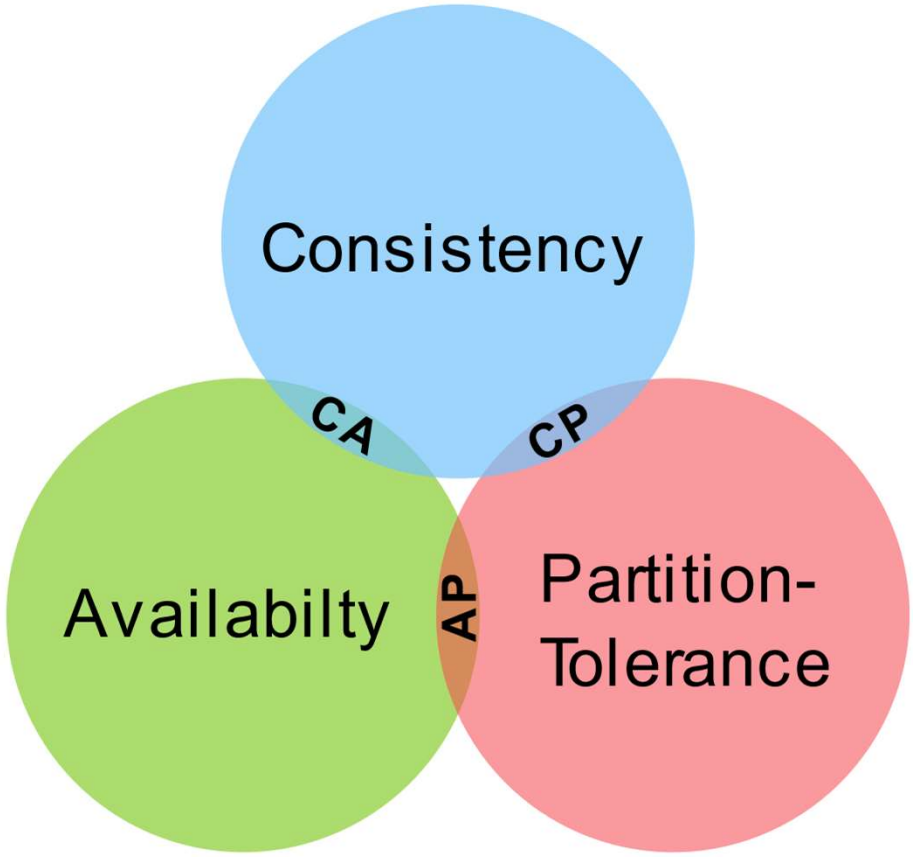
Indexes e constraints:

- Default token lookup indexes
- Range index on **report_id** (no associated constraint)
- Range index on **reporter_id** (associated with uniqueness constraint)
- Range index on ***post_id*** (associated with uniqueness constraint)
- Range index on ***reader_id*** (associated with uniqueness constraint)

Limitations due to Neo4J version and edition

CAP theorem side

- MongoDB cluster in the default configuration lies on CP side
- Configuration to speed up read operations move towards availability sacrificing a part of consistency
- The speed up is obtained setting read preferences as “nearest”
- Reading from nearest replica may return stale data due to the asynchronous replication mechanism



Data consistency

Redundancies:

- *numOfComment* to avoid join operation between different collections
- *numOfReport* to avoid loading data from different databases for a single page

Drawback:

Redundancies have to be updated for each comment/report insertion/deletion

Implemented Mechanism:

The mechanism is based on separate log files (for comment and report) and a periodic task to update redundant values

How it works:

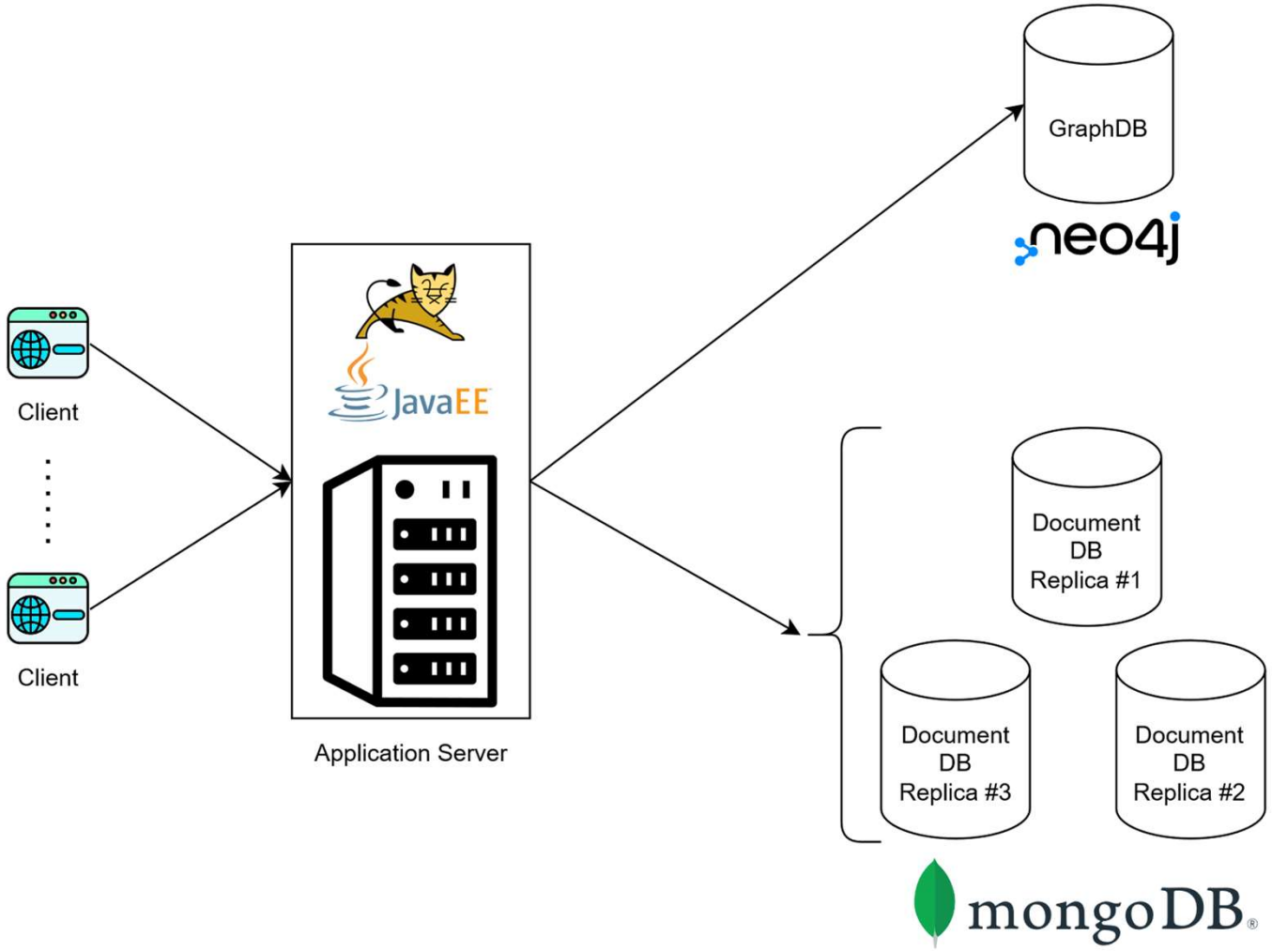
1. Operations performed are saved on separate log files (finer-grained synchronization and thread-safe file access)
2. Periodically, the log files are read, and their contents are extracted.
3. Operations must be summarised to reduce the number of operations in the database.
4. For each report and comment affected, the relative redundancy is updated
5. Unsuccessful update operations must be kept in the log in order to be retried in a subsequent attempt

Sharding

- Sharding in MongoDB allows to adopt a horizontal scaling approach
- The shard key determines the distribution of data across the shards of the cluster and thus the achievable benefits for the system
- Shard key must be selected taking into account the implemented queries

Collection	Field(s)	Brief explanation
Reporters	reporterId	Ensure that all the documents about the same reporter will be stored on the same shard
Comments	post._id	Ensure that all the documents about the comments on the same post will be store on the same shard
Users	_id	The "_id" field as shard key ensures a balanced distribution of the data

System architecture: Software



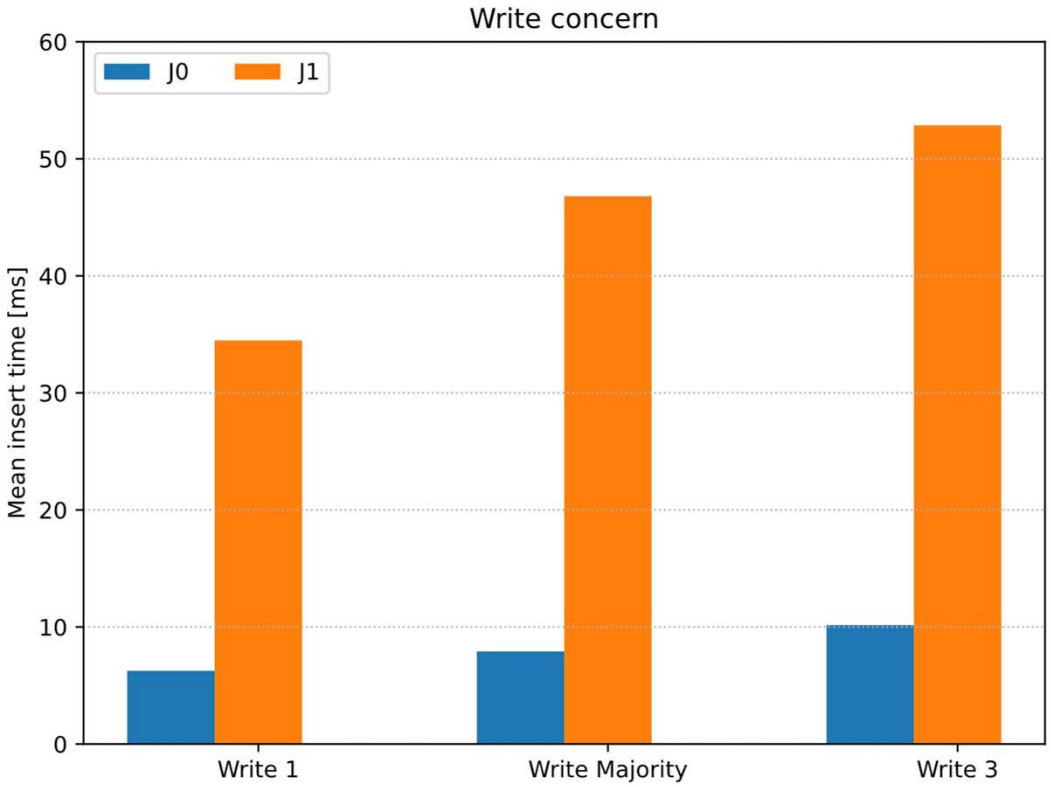
System architecture: Hardware

Component	Virtual Machine	Ip address
Apache Tomcat	Profile2022LARGE4	172.16.5.20
Mongo instance #1	Profile2022LARGE5	172.16.5.21
Mongo instance #2	Profile2022LARGE4	172.16.5.20
Mongo instance #3	Profile2022LARGE6	172.16.4.22
Neo4J	Profile2022LARGE6	172.16.5.22

Considerations:

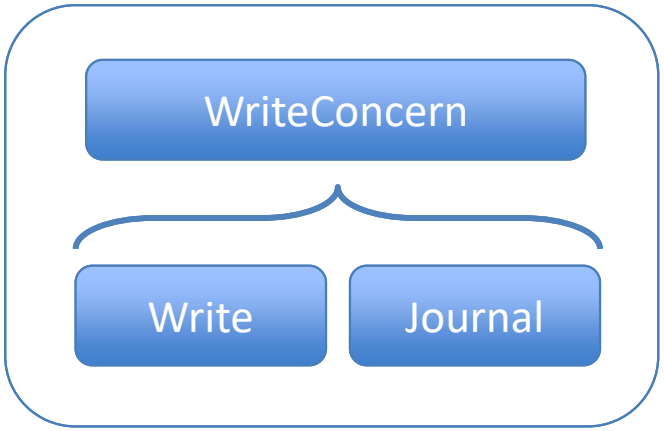
- The cluster available for the test deployment is a composed by three virtual machines, less than the number of application's components
- Mongo cluster has three replicas to be deployed in different machines
- Application server and Neo4J instance should be deployed in two different machines to guarantee the fairest load balancing
- Primary instance of the Mongo cluster should have an entire machine because it should handle a heavier load than the other replicas

Final considerations and results



The mongoDB replica set con be configured to tune performance and consistency trade-off

Write concern parameter



- The write parameter determines the number of acks waited by the primary before send back the result
- The journal parameter determines if the operation is logged only in volatile memory or even on persistent storage