



BIRMINGHAM CITY
University

CMP6207 - Assignment 1

IOThings Application Report

Lewis Higgins - Student ID 22133848

CMP6207 - Modern Data Stores

Module Coordinator: Konstantinos Vlachos

Contents

Introduction	1
1 Types of NoSQL databases	2
1.1 Document database	2
1.2 Key-value database	3
1.3 Wide-column database	4
1.4 Graph database	5
2 Comparing NoSQL and Relational databases	6
3 Database design and implementation	7
4 API Implementation and Documentation	8
Conclusion	9
Bibliography	11
Appendix A - Data types	12
A.1 JavaScript Object Notation (JSON)	12
A.2 Binary JSON (BSON)	12
A.3 Extensible Markup Language (XML)	12
Appendix B - MongoDB installation	13
B.1 Why MongoDB?	13
B.2 Downloading	13
B.2.1 Community Server	13
B.2.2 MongoDB Shell - mongosh	14

Introduction

The report will be based on the design and implementation of a MongoDB NoSQL database system for the company "IoThings Home Automation Solutions". There are two assignments in this module, where this report is worth **60%**, and a presentation is the remaining **40%**. This module will also incorporate elements of web design, with HTML and CSS also playing a role alongside the primary use of JavaScript.

- Konostas cares more for the functionality over aesthetics. While you should put effort into the HTML and CSS parts, they're a lesser concern than the overall usability of the system.
- A literature review is expected in this report.
- 4,000 word count, so 4,400 hard limit.
- The presentation is about this report. It must cover the design, implementation and data management.
 - You would show him your database cluster (local or Atlas?) as part of it.
- IT WILL BE THIRTY MINUTES. If the report contains all the screenshots (which it will) you might not need to make slides, though consider it anyway. You can still show the report alongside the slides where needed.
- He wants you to make an Atlas account even if you do it locally.
- You are creating the dataset for this assignment. You will describe it in an appendix rather than the report's main body.
- This is a "professional report", and as such the title page with the BCU logo and your info should probably change. It needs to also show the date.

Types of NoSQL databases

Structured Query Language, or SQL, was developed by IBM following Codd (1970)'s ground-breaking publication in the ACM journal, with the first commercial SQL implementation being published by Oracle in 1979 (Oracle, 2025). SQL powers many relational database systems even today, though the problems associated with its age, most notably in the speed of its operations, are beginning to show in modern systems. Therefore, NoSQL ("Not Only SQL") was developed as an extension of SQL, allowing data to be stored in a non-tabular, non-relational format for efficient storage of semi-structured and unstructured data in a flexible, functional and scalable model for faster operations than standard relational databases in most scenarios (Google Cloud, 2025; AWS, 2025d).

There are a wide variety of NoSQL database types - all of which vary in complexity, functionality and purpose, meaning that the identification of the most suitable type is paramount for maximum efficiency in terms of speed, storage and scalability.

1.1 Document database

Document databases are intuitive, flexible and horizontally scalable databases that work well in a wide variety of use cases for both transactional and analytical purposes, including IoT data and real-time analytics (MongoDB, 2025a). They store records as "documents", which store an object's data and metadata, in a format such as JSON, BSON, or XML¹. Details and examples of these file types can be found in Appendix A.

```
{
  "_id": {
    "$oid": "67abd1bdc98fd31d547cdb0d"
  },
  "name": "Liora",
  "age": 44,
  "gender": "F",
  "exp": 17,
  "subjects": [
    "MATHS",
    "PSK",
    "PSK"
  ],
  "type": "Full Time",
  "qualification": "Ph.D"
},
```

Figure 1.1: An example of a JSON Document.

¹JavaScript Object Notation, Binary JSON and Extensible Markup Language, respectively.

Figure 1.1 depicts an example JSON document in MongoDB², a popular DBMS for document databases. It contains the data of a singular example school teacher, storing details such as their name, age and subject expertise, as well as a unique internal object ID used by MongoDB to identify that document. The data itself is of varying types including strings, integers and arrays, which makes document databases easily integrable into a development workflow due to the direct storage of object types used in programming languages like Python and JavaScript.

Relationships in document databases can be modelled with great ease, with the ability for documents to contain other documents. For example, in MongoDB, a document for a social media user may contain the Object ID of each of their posts. Groups of documents can then be stored in **collections**, similar to tables in relational databases. These collections can be queried to perform all CRUD operations.

Popular services for document databases include Databricks (Databricks, 2023) Couchbase (Couchbase, 2025), and the previously mentioned MongoDB (MongoDB, 2025a).

1.2 Key-value database

Key-value databases are primarily reputed for their speed and simplicity, functioning by storing each record as a key-value pair. Rather than having to search through massive amounts of irrelevant data for a query, key-value databases can instead search through their stored keys to retrieve results within milliseconds or even microseconds if used in-memory (Redis, 2025a). While this is excellent for simple queries to retrieve specific known records, this same property also causes major limitations in that retrieving data based on values, such as finding all users over a given age, would require the entire database to be searched, making key-value databases best suited for real-time data access and caching where simpler queries are used (MongoDB, 2025d).

Key	Value
Paul	(091) 9786453778
Greg	(091) 9686154559
Marco	(091) 9868564334

Figure 1.2: An example key-value pair (Redis, 2025b).

Figure 1.2 depicts an example key-value pair, mapping names to phone numbers. If a query for "Greg" was given, the associated value would be returned. There is a significant similarity between key-value stores and document stores, though key-value stores can only store simple key-value pairs, whereas document stores can have flexible schemas of complex, nested structures. Furthermore, as previously mentioned, querying key-value databases is very limited to only simple queries if speed is a decisive factor.

²MongoDB actually stores data as BSON, though it translates between the two when queried. See Appendix B for more information.

Notable software options used across industry for key-value databases include Amazon's DynamoDB (AWS, 2025a), Redis (Redis, 2025b), and Memcached (memcached, 2025). MongoDB can also be used as a key-value store, though it is not primarily intended to do so.

1.3 Wide-column database

Wide-column databases, also known as wide-column stores, store data across columns rather than rows, which allows for data schemas built for these databases to be very flexible. Records stored in wide-column stores do not require the same columns for every row, which can greatly help to reduce duplication and redundancy, and storage requirements by extension. Instead, Figure 1.3 depicts how wide-column databases can store data in "column groups", which would be defined when the database is created.

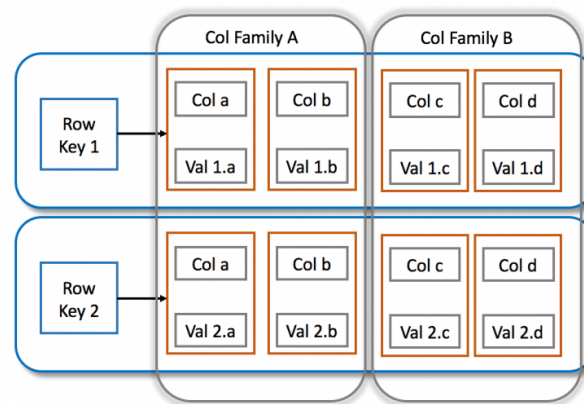


Figure 1.3: An example of wide-column store groups (Pore, 2018).

Column groups are greatly beneficial for **distributed databases**, which leverage sharding for horizontal scalability, a concept explored further in Chapter 2. For example, one node could store the columns of group A, whereas another stores group B. If done correctly, this can greatly help the speed of queries on the database, but it could also cause major slowdowns if the column groups are incorrectly defined, such as with data that would typically be queried together being split over multiple column groups. Therefore, column groups should consist of data that is frequently queried together, such as a group for personal information, then another for financial information (Cattell, 2011).

Because of this, wide-column stores are typically used for larger databases reaching petabytes in size, using software implementations such as Google's Bigtable (Chang et al., 2008) and Apache Cassandra (Apache, 2025).

1.4 Graph database

Graph databases differ heavily from the previously mentioned types, and are instead based on mathematical graph theory (AWS, 2025c). Rather than storing data as rows and columns (or keys and values), these databases store data as nodes and edges. Nodes are connected through their relationships to other nodes, which form the edges of the graph structure as depicted in Figure 1.4.

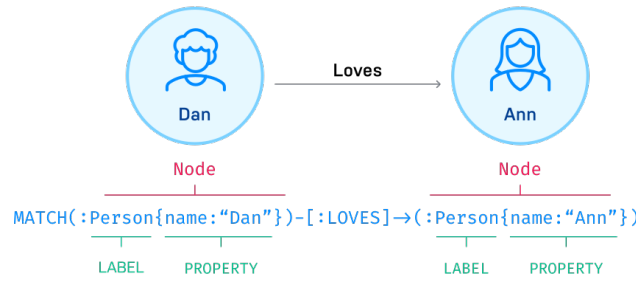


Figure 1.4: Two example nodes connected by a relationship. (Neo4j, 2025c)

Graph databases are best suited for data that is highly interconnected, and can achieve extremely fast query speeds in these scenarios due to graph traversal, where related nodes can be immediately read through the relationships between them rather than the extensive joins that would be required in a relational database equivalent (Corbellini et al., 2017). Typical use-cases of these databases include fraud detection, user recommendation systems and identity management (Neo4j, 2025b; AWS, 2025b; Memgraph, 2025a).

Software typically used for graph databases includes Neo4J (Neo4j, 2025a), Amazon Neptune (AWS, 2025b), and Memgraph (Memgraph, 2025b).

An additional key feature of graph databases is that they do not store collections of data together in groups or collections unlike other databases, with this functionality instead being dictated by labels, relationships or properties.

Label grouping

Nodes can be labelled with a tag (such as "User"), and queries can instead retrieve all nodes sharing a given label.

Relationship grouping

A node is created that represents the group, with all members of the group having a relationship with this parent node such as "Member of".

Property grouping

Nodes individually store a property such as a group ID which identifies their particular group. Queries can then fetch all nodes with the given property to identify members of the group.

Comparing NoSQL and Relational databases

- This section "shouldn't be too long, but enough to convince them."
- **This is NOT comparing *MongoDB* to relational databases.** The brief mentions that it should be "generic just in case after seeing your MongoDB database they decide to go with another software provider."

Database design and implementation

MongoDB, an acronym from "**h**um**o**ngous **DB**", aims to address some of SQL's antiquation issues. . .

API Implementation and Documentation

Conclusion

Overall, something was done. . .

Bibliography

- Apache (2025). *Apache Cassandra / Apache Cassandra Documentation*. Apache Cassandra. URL: <https://cassandra.apache.org/> (visited on 20/02/2025).
- AWS (2025a). *Fast NoSQL Key-Value Database – Amazon DynamoDB – AWS*. Amazon Web Services, Inc. URL: <https://aws.amazon.com/dynamodb/> (visited on 17/02/2025).
- AWS (2025b). *Managed Graph Database - Amazon Neptune - AWS*. Amazon Web Services, Inc. URL: <https://aws.amazon.com/neptune/> (visited on 21/02/2025).
- AWS (2025c). *What Is a Graph Database? - Graph DB Explained - AWS*. Amazon Web Services, Inc. URL: <https://aws.amazon.com/nosql/graph/> (visited on 20/02/2025).
- AWS (2025d). *What Is a NoSQL Database? - Nonrelational Databases Explained - AWS*. Amazon Web Services, Inc. URL: <https://aws.amazon.com/nosql/> (visited on 04/02/2025).
- Cattell, Rick (6th May 2011). ‘Scalable SQL and NoSQL Data Stores’. In: *SIGMOD Rec.* 39 (4), pp. 12–27. ISSN: 0163-5808. DOI: [10.1145/1978915.1978919](https://doi.org/10.1145/1978915.1978919).
- Chang, Fay, Jeffrey Dean, Sanjay Ghemawat, Wilson C. Hsieh, Deborah A. Wallach, Mike Burrows, Tushar Chandra, Andrew Fikes and Robert E. Gruber (1st June 2008). ‘Bigtable: A Distributed Storage System for Structured Data’. In: *ACM Trans. Comput. Syst.* 26 (2), 4:1–4:26. ISSN: 0734-2071. DOI: [10.1145/1365815.1365816](https://doi.org/10.1145/1365815.1365816).
- Codd, E. F. (1st June 1970). ‘A Relational Model of Data for Large Shared Data Banks’. In: *Commun. ACM* 13 (6), pp. 377–387. ISSN: 0001-0782. DOI: [10.1145/362384.362685](https://doi.org/10.1145/362384.362685).
- Corbellini, Alejandro, Cristian Mateos, Alejandro Zunino, Daniela Godoy and Silvia Schiaffino (1st Jan. 2017). ‘Persisting Big-Data: The NoSQL Landscape’. In: *Information Systems* 63, pp. 1–23. ISSN: 0306-4379. DOI: [10.1016/j.is.2016.07.009](https://doi.org/10.1016/j.is.2016.07.009).
- Couchbase (2025). *Couchbase: Best Free NoSQL Cloud Database Platform*. Couchbase. URL: <https://www.couchbase.com/> (visited on 17/02/2025).
- Databricks (13th Oct. 2023). *The Data and AI Company*. Databricks. URL: <https://www.databricks.com/> (visited on 17/02/2025).
- Google Cloud (2025). *What Is NoSQL? Databases Explained*. Google Cloud. URL: <https://cloud.google.com/discover/what-is-nosql> (visited on 04/02/2025).
- memcached (2025). *Memcached - a Distributed Memory Object Caching System*. URL: <https://www.memcached.org/> (visited on 18/02/2025).
- Memgraph (2025a). *Graph Database vs Relational Database*. URL: <https://memgraph.com/blog/graph-database-vs-relational-database> (visited on 21/02/2025).
- Memgraph (2025b). *Memgraph Database*. URL: <https://memgraph.com/memgraphdb> (visited on 21/02/2025).
- MongoDB (2025a). *Document Database - NoSQL*. MongoDB. URL: <https://www.mongodb.com/resources/basics/databases/document-databases> (visited on 16/02/2025).
- MongoDB (2025b). *MongoDB Enterprise Server Download*. MongoDB. URL: <https://www.mongodb.com/try/download/enterprise-advanced> (visited on 04/02/2025).
- MongoDB (2025c). *Try MongoDB Community Edition*. MongoDB. URL: <https://www.mongodb.com/try/download/community-edition> (visited on 04/02/2025).
- MongoDB (2025d). *What Is A Key-Value Database?* MongoDB. URL: <https://www.mongodb.com/resources/basics/databases/key-value-database> (visited on 17/02/2025).

- Neo4j (22nd Feb. 2025a). *Neo4j Graph Database*. Graph Database & Analytics. URL: <https://neo4j.com/product/neo4j-graph-database/> (visited on 21/02/2025).
- Neo4j (2025b). *Graph Database Use Cases*. Graph Database & Analytics. URL: <https://neo4j.com/use-cases/> (visited on 21/02/2025).
- Neo4j (2025c). *What Is a Graph Database - Getting Started*. Neo4j Graph Data Platform. URL: <https://neo4j.com/docs/getting-started/graph-database/> (visited on 20/02/2025).
- Oracle (2025). *History of SQL*. URL: https://docs.oracle.com/cd/B13789_01/server.101/b10759/intro001.htm (visited on 04/02/2025).
- Pore, Akshay (16th Feb. 2018). *NoSQL Data Architecture & Data Governance: Everything You Need to Know*. Dataversity. URL: <https://www.dataversity.net/nosql-data-architecture-data-governance-everything-need-know/> (visited on 20/02/2025).
- Redis (2025a). *Redis FAQ*. Docs. URL: <https://redis.io/docs/latest/develop/get-started/faq/> (visited on 17/02/2025).
- Redis (2025b). *What Is a Key-Value Database?* Redis. URL: <https://redis.io/nosql/key-value-databases/> (visited on 17/02/2025).

Appendix A - Data types

The types of data stored in databases vary dependent on their file format. Section 1.1 referred to three major file formats used in document databases - JavaScript Object Notation (JSON), Binary JSON (BSON), and Extensible Markup Language (XML). Each of these have their own distinct attributes, which will be thoroughly described in this appendix.

A.1 JavaScript Object Notation (JSON)

JSON files are...

A.2 Binary JSON (BSON)

BSON files are...

A.3 Extensible Markup Language (XML)

XML files are not common in many databases in recent times. However, they do still have some benefits not found in JSON or BSON, such as the creation of Document Type Definitions (DTDs) where data can be validated as it is retrieved by forming constraints such as what elements exist or what attributes an element can or must have. DTDs do not allow for constraining data types (i.e. String, Integer, Float), which is a feature instead provided by XML Schemas, an updated schema language that addresses DTD drawbacks through allowing not only type definitions but also enforcing uniqueness and foreign key constraints as well as inheritance. Additionally, XML schemas are written using XML syntax unlike DTDs. The only considerable drawback of XML schemas are the complexity of writing them, as they can be considerably more complicated than DTDs.

Appendix B - MongoDB installation

B.1 Why MongoDB?

B.2 Downloading

MongoDB is used widely across industry, and as such, there are multiple versions of the software available dependent on the specific use case.

B.2.1 Community Server

This project makes use of the Community Server, a free download with most of MongoDB's key features. An alternative option would have been the Enterprise version, which is widely used across industry and requires users to sign up with a business account. In an actual production environment, the Enterprise version of the MongoDB server would be more beneficial due to its additional features including an in-memory storage engine as well as enhanced security options (MongoDB, 2025b), though the Community version still includes the necessary core functionality of MongoDB.

The community version was downloaded from the [official MongoDB website](#) (MongoDB, 2025c), using the appropriate installer for a 64-bit Windows 10 system as depicted in Figure B.1. Both ZIP and MSI options are available, with the MSI being used in this project for simplicity.

MongoDB Community Server Download

The Community version of our distributed database offers a flexible document data model along with support for ad-hoc queries, secondary indexing, and real-time aggregations to provide powerful ways to access and analyze your data.

The database is also offered as a fully-managed service with [MongoDB Atlas](#). Get access to advanced functionality such as auto-scaling, serverless instances, full-text search, and data distribution across regions and clouds. Deploy in minutes on AWS, Google Cloud, and/or Azure, with no downloads necessary.

[Give it a try with a free, highly-available 512 MB cluster](#), or get started from your terminal with the following two commands:

```
$ brew install mongodb-atlas  
$ atlas setup
```

Version
8.0.4 (current)

Platform
Windows x64

Package
msi

Download

Copy link

More Options

Figure B.1: The MongoDB Community Server download page.

B.2.2 MongoDB Shell - mongosh

With the community server installed, a method to interface with MongoDB such as the official MongoDB shell is necessary, which is available from the same download page.

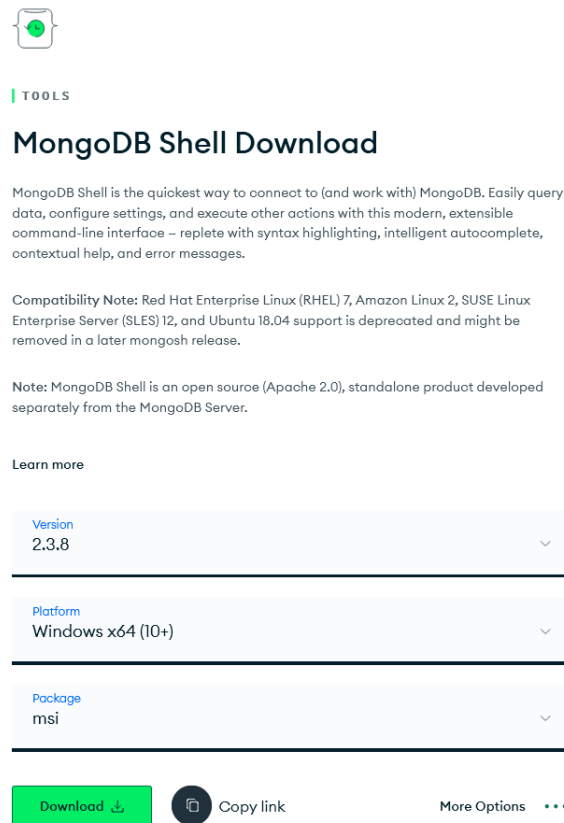


Figure B.2: The MongoDB Shell download page.

The MongoDB shell allows for direct connections to MongoDB, from which commands can be run. For example, Figure B.3 depicts the "show dbs" command, which lists all databases. From a fresh install, there are three databases stored in MongoDB, which all store meta information about the software itself.

```
test> show dbs
admin          40.00 KiB
config         92.00 KiB
local          40.00 KiB
```

Figure B.3: The results of the "show dbs" command in the MongoDB shell.