Data distribution

research document

for

HeardIT

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1. Introduction

The purpose of this document is to outline the research that was undertaken to determine the most suitable strategies and processes for handling data by the HeardIT application. The research is split into the following sections *– Main research question*, where the main question is defined, *Sub-questions*, where the sub-question derived from the main questions are defined and answered and *Conclusion*, where the answers to the sub-questions are combined in order to answer the main question. The final section is the *References* section where the sources of the information used during the research are presented.

1. Main question

In this section the main question will be established. In order to complete the research, the main question needs to have a concrete answer. For this reason, it is important to define the main question well. This will also allow us to create the sub-questions that will help us answer the main question.

The main research question is:

*What is the most suitable approach for distributing and storing the data used by HeardIT?*

Answering this question will allow us to determine the best way to store and handle the required data for the HeardIT application. In the next section I will establish the sub-questions that were derived from the main question and I will formulate an answer to each of them.

1. Sub-questions
2. What type of data is HeardIT working with?

The very first thing that needs to be established from the very beginning is what types of data HeardIT will have to utilize. HeardIT is a music streaming service that provides its users with tools to interact with the songs, artists and other users. It is an application that provides a more comprehensive way to experience music for its users providing different features that allow its users to not only listen but also get to learn the songs and communicate with the artists, or upload their own tracks and provide instructions and details on how to play them.

With this established, we can outline the three main subsets of data that has to be stored and handled:

* Songs data
* User data
* Extra supporting data

I decided to separate them in this way since these three main subsets can be aggregated into three different research sub-questions due to the complexities that are related to each.

Songs can be separated as their own special kind of data that has to be handled since they contain the most complex data type that has to be used: large files. These files can be of different sizes and types whose storing and handling becomes a difficult challenge that needs to be overcome to provide streaming to a large audience of users. This is one of the main obstacles that can determine whether the application is capable of meeting the requirements for enterprise level applications.

User data is just as important, since it can contain personal details that needs to be stored and handled safely and securely. This is another main challenge since in our modern internet environment is important more than ever to keep your users’ information secure while also not hampering the experience and allowing the users to have a pleasant time using the application. Moreover, improper storage and usage of user data can violate legal regulations and result in serious legal consequences. For this reason, user data handling and storing deserves its own discussion.

The last subset of data contains all of the supporting data will be uploaded and used on the web-application. This can contain data like lyrics, song note or tab sheets, user comments, pictures and other types of data that is not considered private or sensitive. I decided to aggregate these kinds of data into their own subset that can follow a more general type of storage and handling system.

With this I can conclude with determining the types of data HeardIT has to work with. In the following sections I will provide the research process and results that were created for each of the three main subsets of data.

Methods used:

* Domain modelling – this method was used when researching what kinds of data HeardIT will have to store and handle
* Problem analysis – this method was used to determine what kind of issues and problems can arise when working with the different kind of information

1. What is the most suitable approach for storing and handling the data for the songs?

Storing song data while also being easily accessible to HeardIT users is one of the main challenges. There are several types of files that can be used to record and keep music, like for example mp3 or wav. These files can also be large in size and contain a lot of data which the application needs to be able to stream in real time to the users. Since I have had little experience with handling and storing such kinds of data, I decided that the best course of action is to find out what other big song streaming services have done to tackle these issues.

The first two most popular music streaming web services that come to mind are Spotify and SoundCloud. These two music providers are renowned for their fast, stable and clever song streaming capabilities that has allowed them to become world-wide successes in the industry. It is only natural that I would want to learn from the best.

Let’s start by examining how these music streaming platforms handle the same issues that I have encountered while working on HeardIT. Both Spotify and SoundCloud follow a similar main design principle when storing the song data:

* **File storage system** – for storing the actual song files
* **Metadata database** – for storing the information about the songs (metadata)

The **file storage system** stores and handles the actual song files. As we have established already, these files can be of various sizes and it can become challenging to store them. A file storage system, is a kind of database that is specifically focused on keeping only the song files. These kinds of databases ensure that music files are available for streaming and can handle the large scale of data involved, with redundancy and replication to prevent data loss. They can also have sophisticated integrated methods for distributing and extracting the files stored within them. They are also designed to be scalable and cloud native. Creating such a system from scratch is not worth in this case since there are already cloud file storage systems that can be utilized such as Google Cloud Storage or Amazon S3. Spotify and SoundCloud use services like Google Cloud Storage and Amazon S3 to keep their song files and provide their users with a pleasant experience. (How Does Spotify Work? Spotify Tech Stack Explored, 2023)

The **metadata database** stores and handles all of the information about the songs, like the title, author, lyrics, album information and more. These databases do not deal with storing the actual files, thus allowing them to handle all of the information about the songs that needs to be stored. For these kinds of databases, Spotify and SoundCloud use relational databases like PostrgreSQL and NoSQL databases like Cassandra. (How Does Spotify Work? Spotify Tech Stack Explored, 2023)

A good question that can be asked at this point is: “*Is it not possible to store all of the data in one database, instead of creating two different kinds of databases that have to be constantly kept up to date?”*

This is great question that I asked myself while doing the research on the topic. The conclusion that I came up to while reading on the subject is that storing data in a single database is impractical due to the different requirements for audio files and their metadata. Audio files are large binary objects that are typically accessed in a read-heavy pattern, where the same file might be streamed by many users concurrently. This is best handled by scalable cloud storage solutions like Google Cloud Storage or Amazon S3 since they are focus and optimized for large-scale, cost-effective storage with high availability. Metadata on the other hand, which is structured data like song and album titles, artist names and so on, requires complex querying and transactional capabilities supported by relational or NoSQL databases. These kinds of databases can support operations like searching and filtering, often involving joining multiple tables, performing aggregations, and supporting transactional consistency.

Separating these database systems allows for independent optimization and scaling, which in turn ensures better performance, cost efficiency, resource utilization, higher availability and better disaster recovery. For these reasons, some of the largest music streaming platforms like Spotify and SoundCloud separate their songs and metadata into different databases. (How Does Spotify Work? Spotify Tech Stack Explored, 2023)

This has provided me with a good understanding of what I need to do in order to create a proper reliable, fast and efficient way to store song files and data. I split my databases into the two parts described above: **file storage management system** and **metadata database**.

To do this I decided that using Google Cloud Storage as my **file storage management system** would be a great opportunity to get to know how to use a real file storage system and gain experience working with the real product. It benefits me greatly since it allows me to store my song files securely and have fast and reliable access to them. Moreover, Google Cloud Storage has an integrated load balancer, that can automatically balance the load of file usage that makes my files storage management system scalable and even more reliable. Another factor for using Google Cloud is because it integrates well with my other services which are already deployed to Google Cloud. (Cloud Storage, n.d.)

For my **metadata database**, I decide that the best technology to use would be a MySQL database. I have plenty of experience creating MySQL databases that can perform fast while also being reliable. The database is containerized and deployed to my Kubernetes cluster as a part of my deployments. In the MySQL database I will keep all metadata about the songs which will allow me to have an efficient way to extract song information and also perform complex search algorithms. (MySQL, n.d.)

With this I conclude the approach that I am going to use to store some of the most important information on HeardIT which is related to the songs.

Methods used:

* Literature study – this method was used to determine the how do file management systems and other databases work
* Problem analysis – this method was used to determine exactly the challenges with storing song files
* Available product analysis – this method was used to determine what platforms like Spotify and SoundCloud do to tackle this problem
* Document analysis – this method was used to find out how to implement Google Cloud Storage as my file management system

1. What is the most suitable approach for storing and handling user data?

The next aspect of data storing and handling that I need to address is the user information. This includes user credentials, used for logging in and accessing some of HeardIT’ s features, and account information that they can upload and edit. These can include personal details and other sensitive information that has to be stored safely and securely. Personal data that is not meant to be made public must be inaccessible by other users.

Since the application will have to handle these kinds of data, it implies that the storage and handling of the users’ information needs to be done with security as its top priority. From my experience with creating secure user authentication, I can say that it is a very complex process that can have many unknown vulnerabilities. I personally, have not had the opportunity yet to get in-depth knowledge about the ever-expanding field of cyber-security and possible dangers that I need to be aware of. Due to time constraints, it does not seem feasible to have to develop and test against every possible danger out there. As such I decided to hand my authentication, authorization and account database protection to a trusted source that specializes in the cyber-security field of user data handling.

**Auth0** is an identity management platform founded in 2013 by Eugenio Pace and Matias Woloski, later in 2021 acquired by Okta, providing authentication and authorization services. It provides user identity management with features like multifactor authentication, single sign-on and support for various identity providers (Google, Facebook, etc.). Auth0’s aim is to help developers integrate secure authentication while focusing on the core of their applications. For this reason, I decided to integrate Auth0’s capabilities in my application. This would allow me gain experience using an external authentication and authorization provider while also speeding up the process and allowing me to focus on the rest of my application. (Auth0: Secure Access for Everyone. But Not Just Anyone., n.d.)

Using Auth0 for user authentication and storage comes with a multitude of benefits. It ensures robust security with features like built-in multi-factor authentication and support for various identity providers like Google, Facebook and more. It also ensures maintained compliance with major regulations such as GDPR. Auth0’s infrastructure is scalable and designed for handling high traffic and automatically adjusting to meet the demand. Its platform enables easy and straightforward integration and supports modern authentication protocols like OAuth 2.0 and SAML which facilitates seamless integration with other services. It also provides customizable authentication flows and enables deep data analysis through built-in analytics. As a managed external service that focuses on the authentication and security of the users’ data, it reduces the operational burdens and complications by handling the maintenance, security updates and continuous improvements. With a very active and helpful community with plenty of documentation and support, Auth0 is a product that will greatly benefit my application by ensuring it has a safe, secure and well-maintained authentication, authorization and user storage database. It will also allow me to gain valuable experience using such a service which I see a beneficial part of my developer knowledge. (AuTH0: Key Features, Technical Overview, and Alternatives, 2024)

However, there are some drawbacks that need to be addressed. Since I am going to be using a third-party tool for such a vital of my application, it is expected that there can be some concerns. However, Auth0 has proven over the years that it provides adequate security measures and complies with the industry standards and GDPR. Its reputation as an industry leader and acquisition by Okta lead to its widespread adoption by organizations of all sizes and all around the globe. It ensures transparency, evidenced by regular audits, certifications and documentation of security practices. It also is committed to continuous improvements through regular updates and solutions. Because of these reasons, I believe I can trust Auth0 as my user authentication, authorization and data storage provider.

To summarize, for the data storage and handling of my user information, I am going to use Auth0 since it will allow me to have a modern and secure authentication and authorization service, while also providing secure database facilitation and management.

Methods used:

* Literature study – this method was used to determine how can I protect my users’ data
* Available product analysis – this method was used to determine what kind of authentication and authorization service providers there are
* Document analysis – this method was used for finding out how to integrate Auth0 into my application
* Ethical check – this method was used to determine the credibility of Auth0 and possible drawbacks of using a third-party service

1. What is the most suitable approach for storing and handling other kinds of needed data?

The final set of data that HeardIT is working with is the more general and less sensitive types of information. This includes published song metadata, playlist information, public comments and announcements and others. I have aggregated these kinds of data since they will follow a more general approach when it comes to storage, scalability and security. These types of data can be stored in relational databases like MySQL and can be safely imported into scalable deployments to meet the demand.

In fact, these types of databases are a great match for storing my metadata and public information since, a relational database like MySQL can be a great asset for performing complex search and recommendation algorithms. Relational databases are designed to be fast and efficient and can be advantageous due to its ensuring of data integrity and reliable transactions. It efficiently handles structured data with complex relationships and enables sophisticated querying through SQL transactions, making it ideal for applications requiring robust data management. MySQL's scalability, high performance optimization features and security capabilities make it a great choice for HeardIT. On top of that, I have had plenty of experience in the past creating complex applications that use MySQL for their databases. Even if I face issues regarding it, there is extensive community support that further support me and allow me to resolve my issues. Additionally, it being an open-source and cross-platform, MySQL is cost-effective and versatile, making it suitable for web development and enterprise solutions such as the HeardIT web-application. (MySQL, n.d.)

Methods used:

* Domain modelling – this method was used to determine the specifics of the kinds of metadata I will have to work with
* Community research - this method was used to see how can I best store and handle my metadata

1. What is the most suitable approach to distribute and synchronize the data in the databases?

Now that the types of information HeardIT is working with and the kinds of databases I am going to use to store and handle the information are established, the next step is to research what approaches can be utilized for distributing and synchronizing the data. This step will allow me to have a better understanding of how I can keep my data consistent while under high usage between all of the different databases that HeardIT is implementing. Properly setting up the synchronization and distribution of the information that is flowing through the application will also undoubtedly allow me to make the most out of the data and provide my users with the best possible experience on my platform.

The main databases that I need to establish the proper synchronization and data distribution are the MySQL databases that handle the songs metadata and other extra information such as comments, post and so on. I am focusing on these databases since I am responsible for setting and configuring them. My file storage system and my user database are handled by Google and Auth0 respectively and they provide their own data distribution and synchronization methods that they are responsible for handling.

The main method of doing database synchronization and distribution in MySQL is through replication. (MySQL 8.4 Reference Manual::19 Replication, n.d.)

There are several types of replications that can be done each with its own perks and drawbacks.

These types of replications are as follows:

* Master-Slave Replication
  + The master server writes updates that are afterwards distributed to the slaves.
  + Slaves provide high availability and can be read only to handle greater loads.
  + Asynchronous replication between master and slaves, but specific slaves may lag a bit behind.
* Master-Master Replication
  + Two or more servers can act as both master and slave to each other.
  + Provides high availability and load balancing.
  + Requires conflict resolution mechanisms to handle simultaneous updates.
* Group Replication
  + Advanced form of replication where servers form a group and each server can accept writes.
  + Provides automatic failover and consistency guarantees.
  + Needs a well-implemented consensus algorithm to ensure data consistency across all nodes.

After careful consideration, I decided to implement the Master-Slave replication method since it fits my use case the best. The main arguments for this are that my application has manager services that update my databases and which handle all of the functions related with creating, updating and deleting data on the application. However, these databases should not be used for *reading* and *searching* services, such as my *search\_service,* since they are used much more often and a compromise in these databases will directly impact a great portion of my application’s functionality, my search\_service is used for finding the user’s desired songs. To do this I decided that splitting the databases that are used for all of the CRUD operations need to be separate, yet they need to be responsible for the synchronization of the searching services databases. This is best done using the Master-Slave replication method. (MySQL 8.4 Reference Manual::19 Replication, n.d.)

The MySQL master-slave database replication is a common method used for distributing and synchronizing data across multiple database servers. It offers numerous benefits in terms of performance, availability and scalability, by establishing a master server that is responsible for handling all write operations and updates to the database. One or more slave servers replicate this data and focus primarily on read operations. This division of tasks effectively distributes the load and significantly improves the performance and responsiveness of the databases, especially in a read-heavy services like my *search\_service*.

Let’s get a more in-depth overview of the advantages that the master-slave replication comes with. The first primary advantage is the high availability. By maintaining multiple copies of the database on slave servers, the system ensures that the data remains accessible even if the master server experiences downtime or failures. In some cases, a slave replica can also temporarily be promoted to master so that disruptions are minimum and continuous access remains. Slave replicas can exist on their own which means that, for example, if my master database is down, my search\_service will still be operational since it will connect to the slave databases. (MySQL 8.4 Reference Manual::19 Replication, n.d.)

Another significant advantage is the ability to scale and load balance more effectively. For an application like HeardIT, read operations are going to be used much more often thus requiring more resources. Offloading the reading to the slave servers, allows the master server to handle the CRUD operations more effectively and efficiently, reducing bottlenecks and improving overall throughput. In a high operation requests scenarios and under heavy loads, scalability can also be enhanced by adding additional slave servers without making significant reconfigurations, allowing to scale horizontally. This flexibility makes it easier to manager increasing loads and ensures that the database can grow while maintaining integrity and usability. (MySQL 8.4 Reference Manual::19 Replication, n.d.)

Master-slave replication can also be of great aid in disaster recovery scenarios. Slaves can be used to create up-to-date backups without affecting the master server’s performance. This approach also supports distributions of the databases over multiple regions, reducing latency and improving the user experience. Regular backup strategies still need to be in place to ensure that the data is safe and secure. (MySQL 8.4 Reference Manual::19 Replication, n.d.)

In conclusion, master-slave replication in MySQL is a robust and efficient solution for enhancing the performance, availability and scalability of a database system. This makes it a great choice and an essential component of modern database management.

Methods used:

* Community research – this method was used to find out what methods other people and colleagues have done to distribute and replicate the database structure
* Available product analysis – this method was used to determine the capabilities of database replication and how it can benefit me
* Document analysis – this method was used to determine how to do database replication in MySQL
* IT architecture sketching – this method was used to determine why I need to replicate my databases and how the services interact with it

1. What is a suitable approach and technology for establishing communication between different services in the application?

Microservice architecture allows for modern web-applications to be more flexible and modular by decoupling their services and components. This allows for a more robust, reliable, scalable and efficient applications that can handle massive loads while also retaining integrity and usability. Services are separated from each-other and in general, do not depend on each-other to function properly. However, there are many cases, where services need to be able to communicate and exchange data with other services so that multiple parts of the application can be simultaneously updated and kept consistent. An example of such case would be, when a user has decided that they want to delete their account, a message broker is utilized to inform all manager services to delete the user’s information from all databases that the application uses. To enable this, there exist the so called: *message brokers*.

Message brokers act as an intermediary platform facilitating the communication between different parts of the application. They enable services to communicate through the usage of asynchronous messaging. It serves as a central hub where applications can send and receive messages, ensuring reliable and efficient exchange of data. Services can send (produce), themselves, and receive (consume) messages from another service through the broker, allowing for a seamless and convenient integration and communication across the various different parts of the application. Additionally, message brokers provide features such as message queuing, routing, delivery guarantees and others, enhancing the scalability, reliability, and performance of a microservice application such as HeardIT. (What Is a Message Broker? | VMware, 2023)

There a many different message brokers that can be applicable to my case such as Apache Kafka, RabbitMQ and ActiveMQ. Each of these message brokers will provide me with all of the required capabilities to establish asynchronous communication between my services. In the end, after careful consideration, I came to the conclusion that RabbitMQ is the preferred choice for me because of its ease of use, reliability and sufficient capabilities. Kafka and ActiveMQ are also fully capable of enabling the tasks that I require but come with a greater learning curve and also many functions which in my case would not be beneficial enough for HeardIT. (What Is a Message Broker? | VMware, 2023)

RabbitMQ offers a rich set of messaging options and routing based on exchanges and bindings. It has a relatively straightforward configuration process, suitable for varying application requirements. Efficient memory usage and lightweight deployments contribute to its flexibility and appeal. It supports multiple messaging protocols and ensures message reliability with durable queues while also supporting complex routing, configured for the specific scenarios. RabbitMQ also supports a comprehensive UI which simplifies monitoring and administration. These features and capabilities make it a solid choice for the message broker product that I am going to use for HeardIT. (RabbitMQ Tutorials | RabbitMQ, n.d.)

The last step is the implementation of RabbitMQ to HeardIT. I came to the conclusion that having a separate message broker service would be the best approach. This service is separate and specializes in handling communication between the services. This allows for a more scalable and reliable message broker that can handle many different requests and can be independent from the other services in the application. This service has multiple queues that each has messages for the different services which communicate. Services subscribe to these queues and can produce and consume messages. This way the communication between the services is established and can be easily extended and configured. The RabbitMQ message broker service is also automatically deployed as a separated service to the Google Kubernetes engine.

Methods used:

* Problem analysis – this method was used to determine what exactly I need and why I need to implement message brokers in my application
* Community research – this method was used to determine what other people have used for communication between services
* Document analysis - this method was used to find out how to use and implement RabbitMQ into my application

1. Conclusion

To conclude this research, I am going to design the HeardIT application’s data distributive system to include multiple different types of approaches. This will be done in order to allow for the best possible storage and handling performance, security, capacity and effectiveness of the database systems. For my music I am going to use a Google Cloud Storage database, where I will keep my song files, and a MySQL database for my songs’ metadata. For my users, I decided to take the opportunity to use a professional security provider - Auth0. They provide an excellent, secure, reliable and compliant with the modern standards for cyber-security services to store, handle and protect my user data, while also being more than sufficient at efficiency, scalability and performance. For the rest of my data, I am going to use the proven and reliable MySQL relational databases, that provide me with all of the needed functionality and utility for HeardIT’s data requirements. My MySQL databases for my metadata will be replicated using the master-slave replication method so that scalability and reliability is improved. For communication between the services, I am going to use RabbitMQ message broker to establish the needed asynchronous connection and data distribution between the services.

With this, I complete my data distribution research.

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