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**Title: Blockchain Based Mobile Application for
Bookcrossing**



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Abstract

The mobile application for bookcrossing based on blockchain is an innovative solution that harnesses the power of decentralized technology to revolutionize the way readers share books. With this app, book lovers can easily share their favorite books with others, track the history of owners, and find new titles to read. The app uses blockchain technology to create a secure and transparent book exchange system, allowing users to lend and borrow books both in person and through third-party book delivery services. Bookcrossing is a popular trend among book lovers, where they leave their books in public places like cafes, parks, or bus stops for others to open and read. This concept has been around for a while, but with the advent of blockchain technology, bookcrossing can now be taken to the next level. Blockchain technology provides a secure and transparent book exchange platform, ensuring book tracking and lending history records. The potential for blockchain-based mobile applications to create more efficient and secure systems for book sharing and beyond is enormous, and it will be interesting to see how this technology develops in the coming years.

Terms and abbreviation

Terms:

1. **Blockchain** – a decentralized digital information that records transactions in a secure and transparent manner.
2. **Bookcrossing** – the practice of leaving books in public places for others to discover and read.
3. **Decentralized** – a system that operates on a network of nodes, without a central authority controlling the data or transactions.
4. **Digital identity** – a unique digital representation of an object or entity, which can be recorded on a blockchain.
5. **Immutable** – data that cannot be changed once it has been recorded on a blockchain.
6. **Transparency** – the ability to view and verify the data or transactions on a blockchain.

Abbreviations:

1. **App** - Application
2. **API** - Application Programming Interface
3. **UX** - User Experience
4. **UI** - User Interface
5. **MVP** - Minimum Viable Product
6. **PoW** - Proof of Work
7. **PoS** - Proof of Stake
8. **NA** - Not Available
9. **LDAU** - Lack of Downloads number and Active Users

Table of Contents

Abstract	2
Terms and abbreviation	3
Table of Contents	4
Introduction	5
1 Analysis of Domain	6
1.1 Research background	6
1.2 Organization of study	8
1.3 Statement of the problem	9
1.4 Significance/Advantages of the Study	10
1.5 Goal and Objectives	12
1.6 Analysis of existing systems and their comparison	13
1.7 Requirements analysis	16
2 Methodology and System Design	19
2.1 System design	19
2.2 System architecture	20
2.3 Database structure	22
2.4 Methods	24
2.4.1 Blockchain technology	24
2.4.2 Mobile Application Development	25
2.4.3 API	25
2.4.4 Testing methods	26
2.4.5 Project management	26
2.5 Algorithms	28
2.6 Smart contracts	30
2.7 Workflow	31
3 System Implementation	32
3.1 Tools and technologies	32
3.1.1 Client side	32
3.1.2 Backend	33
3.2 Deployment Diagram	36
3.3 System testing and evaluation	37
3.4 Analysis of the results	39
Conclusion and Future plans	41
Bibliography (References)	43

Introduction

The advent of blockchain technology has opened up new opportunities for innovation and breakthroughs in various industries, including the world of literature. The concept of bookcrossing, where books are left in public places for others to read, is gaining popularity among book lovers. However, the traditional bookcrossing system lacks a reliable tracking mechanism and is subject to security risks.

A blockchain-based mobile bookcrossing application offers a promising solution to these problems. Leveraging the security and transparency of blockchain technology, this application provides a secure and efficient platform for book exchange between users. This project aims to develop a blockchain-based mobile bookcrossing application that will allow users to lend and borrow books while maintaining a transparent and tamper-proof record of their history.

This project will analyze existing applications for bookcrossing, analyze in detail the potential of blockchain technology, and explore various components of a mobile application, including its architecture, functions and functionality.

This work has 2 goals: research and practical. As part of the research task, we must understand all the smallest details of blockchain technology. In addition, one of the goals of the study aims to contribute to the growing body of knowledge about blockchain-based mobile applications and their potential to create more secure and efficient systems for book sharing and beyond. As part of practical purposes, a mobile application will be developed that will meet all data storage security requirements. The proposed solution can be used not only in the field of bookcrossing, but also in other areas, such as renting cars, scooters, selling goods. All of the key strengths of the blockchain can be used in several areas.

1 Analysis of Domain

1.1 Research background

The idea of bookcrossing, where books are left in public places to be read, has been around for more than two decades. It first appeared in 2001 when software developer Ron Hornbaker launched a website called BookCrossing.com. Since then, bookcrossing has gained popularity among book lovers around the world, with thousands of books registered and hosted on the platform. However, the traditional bookcrossing system has a number of limitations, including the lack of a security and tracking mechanism [1].

The advent of blockchain technology has provided a potential solution to these problems. Blockchain is a decentralized and distributed ledger that provides a tamper-proof and transparent record of transactions [2]. It is a safe and efficient way to record and track ownership and transfer of assets, including books.

The book sharing industry has already developed several blockchain-based projects, including projects such as Publica, READ, and Scannable [3][4]. These projects aim to harness the power of blockchain technology to create more secure and efficient book exchange platforms. However, there is still a need for more research and development in this area, especially in the field of mobile applications.

Much of the research that has been done on book sharing apps has mainly focused on understanding user behavior, such as how people choose to share books and the factors that motivate them to participate in book sharing. Other areas of research include the impact of book sharing apps on the publishing industry, the sustainability of such apps, and the potential for gamification and social features to increase engagement [5][6]. In addition, some studies have explored the technical challenges of building book-sharing applications, such as developing secure and efficient methods for tracking book ownership and facilitating peer-to-peer transactions. Today, you can find a sufficient number of applications on the network that provide the ability to exchange books. All these applications are essentially very similar to each other, and it will be difficult for the user to choose one of them, since they are all similar. A more detailed comparison of these applications will be described in the following sections.

In conclusion, the concept of bookcrossing has been around for over two decades and has gained popularity among book lovers around the world. However, traditional bookcrossing systems face limitations, especially in terms of security and tracking

mechanisms. The advent of blockchain technology represents a potential solution to these problems by offering a decentralized and tamper-proof ledger to record and track book ownership and transfer.

In order to create a product that solves all these limitations, the study will be organized into several phases, each with its own objectives and deliverables.

1.2 Organization of study

This work will be organized in several phases, each with its own set of objectives and deliverables. The following is an overview of the planned milestones:

1. **Literature review.** The first stage of the study will include a comprehensive review of the relevant literature on blockchain technology, mobile application development. This will provide a solid foundation for the subsequent phases of the project.
2. **Analysis of requirements.** At this stage, the functional and non-functional requirements of the mobile application will be determined. This will include collecting information from stakeholders and analyzing existing applications to identify their strengths and weaknesses.
3. **Design and development:** based on the requirements analysis, the design and development of the mobile application will begin. This stage will include the selection of an appropriate blockchain platform, programming languages and tools for developing a mobile application.
4. **Testing and evaluation:** During this phase, the mobile application will be tested to ensure that it meets the established requirements. Testing will include functional testing, security testing and usability testing. We will also evaluate the performance of the application and compare it with existing analogues.

Throughout the study, an iterative development approach will be used to ensure that the application satisfies the needs of stakeholders and meets all established technical requirements. A list of all functional and non-functional requirements will be described in the following sections, after identifying emerging issues in this area, as well as a comparative analysis of existing solutions on the market.

1.3 Statement of the problem

Bookcrossing is a popular trend among book lovers, where they leave their books in public places for others to find and read. However, this method of book sharing can be unreliable, as there is no guarantee that the books will be returned or that their history will be tracked. Additionally, traditional bookcrossing methods rely on trust between the book owners and readers, which can be difficult to establish among strangers.

Furthermore, existing applications for bookcrossing, while providing innovative solutions, have limitations in terms of security, transparency, and ease of use. For instance, some applications do not provide a secure and transparent platform for book lending and borrowing, while others are too complex and difficult to use for the average book enthusiast.

The motivation for this study is to address these limitations and provide an innovative solution for bookcrossing that leverages the power of blockchain technology. Blockchain technology provides a secure and transparent platform for book exchange, allowing users to track the history of books and ensuring the authenticity of the books being shared.

The problem statement for this study is to design and develop a blockchain-based mobile application for bookcrossing that is secure, transparent, and easy to use, while addressing the limitations of existing applications [7]. This study aims to provide an innovative solution that will enhance the bookcrossing experience and provide a more efficient and reliable platform for book sharing.

In conclusion, this section has addressed the limitations of traditional bookcrossing methods, such as the lack of book tracking and the dependency on trust between book owners and readers. The motivation for the study is to remove these limitations by using blockchain technology to provide a secure, transparent and user-friendly book exchange platform.

The next section, which focuses on the benefits of the study, will highlight how the proposed mobile application aims to overcome the limitations of existing solutions. It is worth noting that the study provides an innovative solution that will improve the bookcrossing experience, ensure the authenticity of shared books, and create a more efficient and reliable book exchange platform.

1.4 Significance/Advantages of the Study

The study of a blockchain-based mobile application for bookcrossing has significant advantages and potential benefits for book enthusiasts, bookcrossing communities, and the wider society. Some of the advantages and significance of this study are as follows:

1. **Enhancing book sharing:** The mobile application development will provide an innovative solution for book enthusiasts to share their favorite books and discover new ones. This application will create a more reliable, efficient, and transparent platform for book sharing.
2. **Security and transparency:** The use of blockchain technology will ensure that the book exchange platform is secure, transparent, and reliable. The transaction records will be immutable and easily accessible, allowing users to track the history of books and ensuring the authenticity of the books being shared.
3. **Ease of use:** App will be designed to be user-friendly, with a simple and intuitive interface that makes it easy for book enthusiasts to lend and borrow books [8]. This will encourage more people to participate in bookcrossing and promote a culture of reading.
4. **Potential for scalability:** The blockchain-based mobile application has the potential for scalability, allowing it to be adapted and extended to other forms of asset exchange beyond books. This will open up new opportunities for innovation and provide a platform for secure and transparent asset exchange.
5. **Contribution to the body of knowledge:** The study of a blockchain-based mobile application for bookcrossing will contribute to the body of knowledge in the fields of blockchain technology, mobile application development, and bookcrossing. It will also provide insights into the potential benefits and limitations of this technology in other areas.
6. **Scientific research goal:** To understand all the possibilities of Blockchain technology in solving such problems

This study has significant advantages and potential benefits for book enthusiasts, bookcrossing communities, and the wider society. It will provide an innovative solution for book sharing, enhance security and transparency, promote a culture of reading, and contribute to the body of knowledge in the field of blockchain technology. The next section will describe

in detail about the goals in this work, as well as the result obtained when all these goals are met.

1.5 Goal and Objectives

The goal of this study is to design and develop a blockchain-based mobile application for bookcrossing that will provide a secure, transparent, and efficient platform for book sharing among book enthusiasts. To achieve this goal, the following objectives will be pursued:

1. **Identify** the functional and non-functional requirements for a blockchain-based mobile application for bookcrossing.
2. **Explore** the potential of blockchain technology for creating a secure and transparent platform for book exchange in a mobile application.
3. **Investigate** the best blockchain platforms and programming languages for developing a blockchain-based mobile application for bookcrossing.
4. **Design** the system. Develop API for all operation and business functionality. API must be available for all platforms.
5. **Design** the user interface of a blockchain-based mobile application for bookcrossing to ensure ease of use and adoption by book enthusiasts.
6. **Address** the security and privacy concerns associated with a blockchain-based mobile application for bookcrossing.
7. **Compare** the blockchain-based mobile application for bookcrossing to existing applications in terms of security, transparency, and ease of use.
8. **Evaluate** the potential benefits and limitations of a blockchain-based mobile application for bookcrossing and suggest ways to address any identified limitations.

By achieving these objectives, the study aims to provide a comprehensive solution for bookcrossing that will enhance book sharing, promote a culture of reading, and provide a platform for secure and transparent asset exchange. The study will contribute to the field of blockchain technology, mobile application development, and bookcrossing by providing new insights and practical solutions for book enthusiasts, bookcrossing communities, and the wider society.

The order of certain tasks is very important, as each successive step will depend heavily on the work done in the previous step. And in order to fulfill our main goal, we must start with the first step, namely the definition of all functional and non-functional requirements. To determine them, it is necessary to conduct a qualitative and quantitative analysis of existing solutions. In the next section, this comparison will be made.

1.6 Analysis of existing systems and their comparison

In this section, we will analyze and compare existing bookcrossing systems and mobile applications to identify their strengths, weaknesses, and limitations. We will conduct both qualitative and quantitative analyses to gain insights into the user experience, system functionality, security features, and overall performance of these systems [9].

To conduct a quantitative analysis, we will collect data on the number of users, downloads, ratings, and reviews of existing bookcrossing systems and applications. We will use this data to compare the popularity, user satisfaction, and overall performance of these systems [10] [11].

To conduct a qualitative analysis, we will evaluate the user experience, system functionality, and security features of existing bookcrossing systems and applications. We will use this analysis to identify the strengths, weaknesses, and limitations of these systems [12].

Below is the final comparative table (**Table 1**) of the quantitative analysis carried out, based on the criteria described above.

	Number of Downloads	Cost	Average rating (out of 5)	Platform	Supported languages
Publica	NA	Free	3.5	iOS, Android	En
READ	NA	Free	4.2	iOS, Android	En
Scannable	>5000	Free	3.3	iOS	En
BookCrossing.com	NA	Free	3.1	Web	En, Esp, De, Rf, It, Deu, Pt

Table 1: Quantitative analysis

Based on this table, it can be said that only one application has a rating above 4, all other applications have a rating below 3. When a user selects an application, he is primarily interested in the rating of the application. And as you can see from the results, there are very few applications on the market with a good rating. The second criterion that you should pay attention to is language support. None of the applications are supported for the Russian speaking region. Seeing that the number of downloads for most applications is not available, it is very difficult to estimate the popularity of certain applications. All apps are free of cost.

As a result, we can say that the developed application must have the following qualities:

1. **Rating** – no less than 4.
2. **Platform** – iOS, android.
3. **Supported languages** – English, Russian.
4. **Price** – free.

Having received such qualities for the application being developed, we will get superiority over existing solutions.

The table below (**Table 2**) presents the results of the qualitative analysis. As a result, only Publica uses blockchain technology for its work, but uses only a small part of its capabilities, which does not make it super safe and reliable. The rest of the applications implement partially or do not implement book monitoring at all. Of the unusual functionality, it is worth noting the strengths of **Scannable** - it uses QR code technology to enable book sharing. Provides a transparent record of book lending history. Enables users to search for books by location. As for the weaknesses of each of the applications, this is the lack of information about the number of active users and their downloads. Also worth noting is the limited number of supported languages. **BookCrossing.com** is different in that it does not meet the requirements of transparency and security, which makes it less reliable in terms of information protection.

The analyzed mobile applications provide innovative solutions for book sharing, but they differ in their approach, implementation, and limitations. The blockchain-based bookcrossing mobile application developed in this project aims to be build on the strengths of these existing applications while addressing their limitations. It will provide a secure and transparent platform for book sharing, enabling users to lend and borrow books both in person and through third-party book delivery services.

The next section will describe all the functional and non-functional requirements for the application being developed. It is important to build on the results of the detailed comparative analysis above to determine these requirements. Namely, we must implement at least all the strengths of each of the applications, as well as solve problems associated with their weaknesses. To determine the functional requirements, two points must be taken into account: the implemented functionality in existing solutions, as well as additional functionality that will make the developed application stronger than the others.

	Strengths	Limitations
Publica	Decentralized platform	Limited supported languages, LDAU
READ	Smart contracts	LDAU
Scannable	QR code technology, transparent record of book lending history	Limited supported languages, LDAU
BookCrossing.com	Tracking book's movements	Lack of transparency and security.

Table 2: Qualitative analysis

1.7 Requirements analysis

Requirements analysis is an important process that involves identifying the needs and expectations of stakeholders for the development of a successful mobile application. In this project, the requirements analysis phase is divided into functional and non-functional requirements [13] [14]. To determine the requirements, it is necessary to build on the implementation of already implemented functionality by other applications. In other words, we must implement basic functionality, such as a registration and authorization system, book search, and the ability to leave reviews and ratings. It is also worth noting that we need to take into account the requirements of our end users. The previous sections have described the problems that users have encountered when using similar applications. Basically, the problem was related to the main process of exchanging books between two users. That is, we need to make this process convenient, transparent and easy to understand. Based on all these factors, a list of functional and non-functional requirements was compiled, which is given below.

Functional Requirements:

1. **User Registration and Profile Management:** Users should be able to create a new account, manage their profile, and update their personal information.
2. **Book Listing and Search:** Users should be able to list the books they want to share, search for books available for borrowing, and view book details such as author, description, and lending history.
3. **Book Lending and Borrowing:** Users should be able to lend and borrow books through the app, either in person or through third-party book delivery services. The app should track the lending and borrowing history of each book to ensure transparency and accountability.
4. **Push Notifications:** Users should receive notifications about new book listings, book requests, and book return reminders.
5. **Feedback and Ratings:** Users should be able to leave feedback and ratings for the books they borrow and the users they interact with.

Non-functional Requirements:

1. **Security:** The app should ensure the security of user data and book lending history through the use of blockchain technology and encryption protocols.

2. **Scalability:** The app should be able to handle a large number of users and books, as bookcrossing is a popular trend among book lovers.
3. **Performance:** The app should have fast loading times and minimal downtime to provide a seamless user experience.
4. **User Interface:** The app should have a user-friendly interface with easy navigation and intuitive design.

In addition to these requirements, the app should also comply with relevant legal and ethical standards for data privacy, security, and intellectual property rights.

Summing up the work done in this section, it is worth noting that a study was conducted in this area, problems in this area and the goals that we pursue in this work were identified. A comparative analysis of existing solutions on the market was carried out. As a result of which the minimum requirements that our application must comply with were drawn up. Based on the results of a comparative analysis, taking into account the existing problems in the field of bookcrossing, as well as the desire of our end users, functional and non-functional requirements were formulated. The next section will focus on development methodology. And it will be done in the system design and architecture, the main methods related to software development will be described. Database structures, smart contracts and proof of work algorithms will be described in detail.

2 Methodology and System Design

2.1 System design

The system design of a mobile application includes various components that work together to provide a seamless experience for users.

The system will have a client-server architecture with a centralized server that manages the book inventory, user accounts and recommendation system, as well as all book exchange related activities. The server will communicate with the mobile application through the API, allowing users to use all the functionality provided. The API will have a microservice architecture, the operation of which will be described in subsequent sections [15].

As a client part, a mobile application for the iOS operating system will be developed. The user interface will be intuitive and easy to navigate, allowing users to browse and search for books, explore book usage history, and manage their profile. When developing an application for iOS, one of the requirements from Apple is to support the application for people with disabilities [16]. And in order to comply with these requirements, as well as satisfy the needs of the part of our target audience that has physical limitations, it was decided to add additional functionality for such people, making the use of the application convenient for everyone.

The application will be integrated with blockchain technology to provide a secure and transparent book exchange system. The blockchain will also provide a transparent record of book lending history that users can access.

The application being developed will also have a complex relational database to store data about books, users, and all transactions. This solution will ensure decentralization and security of data storage.

To ensure data privacy and security, the application will use encryption methods to protect user data and prevent unauthorized access. The application will also have a user data recovery mechanism to ensure that user data is not lost in the event of a system crash.

Having identified the key points in how the structure will be organized at the system design level, the next section will describe the system architecture, namely all its levels, from the presentation layer to the operation layer.

2.2 System architecture

System architecture refers to the overall structure and organization of a software system. It defines the components, their relationships and interactions to achieve the desired functionality [17]. In the case of a mobile application being developed, the system architecture plays a critical role in ensuring the efficiency, scalability, and security of the application.

The system architecture of a mobile application includes several levels, each of which has its own specific functions and responsibilities [18]. The following is a list of layers involved in the application architecture:

1. **Presentation level.** The presentation layer is the user interface through which the user interacts with the application. In the case of a mobile application, this layer typically includes a graphical user interface (GUI) that allows users to access various features and functionality of the application.
2. **Application level.** The application layer is responsible for processing user requests, managing data, and implementing the application's business logic. This layer also includes the middleware that connects the application layer to the underlying blockchain network.
3. **Blockchain level.** The blockchain layer includes distributed ledger technology that allows the application to record and verify transactions. This layer is responsible for managing the flow of transactions, ensuring the integrity and security of data, as well as implementing the functionality of smart contracts.
4. **Network level.** The network layer is responsible for managing communication between nodes in the blockchain network. It includes peer-to-peer networking protocols that allow nodes to communicate and share data.
5. **Data level.** The data layer is responsible for storing and retrieving the data used by the application. In a blockchain-based application, this layer includes a distributed storage system that stores blockchain data and associated metadata.

The layers described above in the application architecture are illustrated in Figure 1.

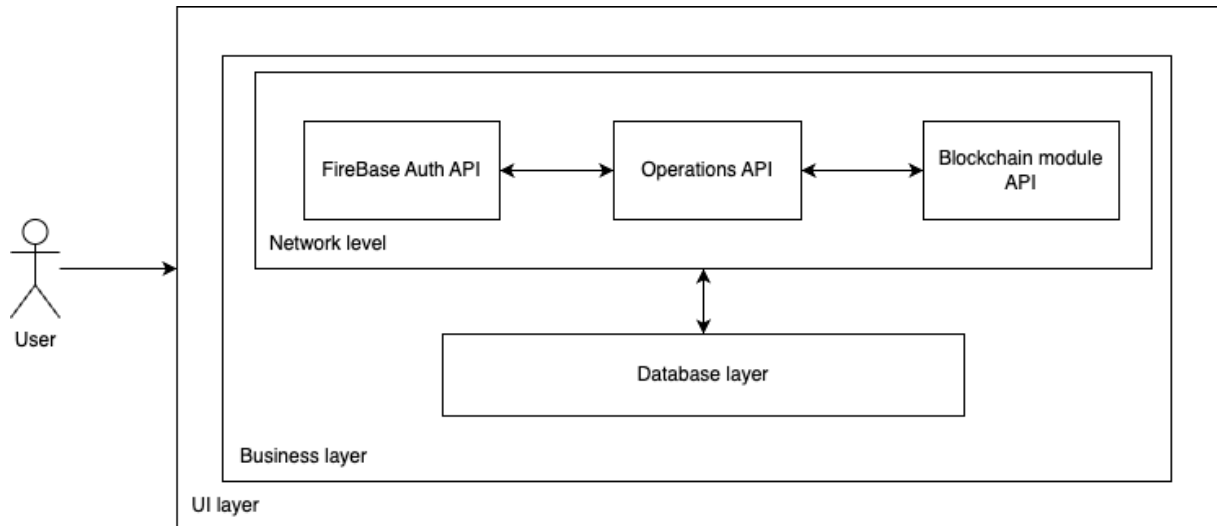


Figure 1: System architecture of the developed mobile application

The system architecture of a mobile application should be designed in such a way that the application is scalable, secure and efficient. To do this, the architecture should be based on the following principles:

1. **Decentralization.** The architecture of the application should be decentralized, which means that there should not be a single point of failure or control.
2. **Safety.** The architecture must ensure the security of the application. This includes the implementation of cryptographic protocols to secure the transmission and storage of data, as well as access control mechanisms to protect against unauthorized access.
3. **Performance.** The architecture must accommodate the performance of the application, including transaction processing speed and network latency. This can be achieved by optimizing the application's data structure, network protocols, and algorithms.
4. **Compatibility.** The architecture should be designed in such a way as to ensure interoperability with other blockchain networks and applications. This can be achieved by implementing standard protocols and interfaces that ensure seamless communication and data exchange between different systems.

In general, the system architecture of a blockchain-based mobile application is critical to its success. It must be carefully designed to ensure the scalability, security, and performance of the application, as well as seamless communication with other blockchain networks and applications.

2.3 Database structure

In the mobile application for bookcrossing based on blockchain, a relational database structure is utilized to efficiently store and manage the application's data. The chosen database management system for this project is PostgreSQL, a widely-used open-source relational database.

The database consists of six tables: UserInfo, Bookinfo, Readers, Requests, Appeal, and Rateinfo. Figure 2 shows a visual representation of tables in a database. Each table serves a specific purpose and holds relevant information related to the book sharing process.

1. **UserInfo.** This table stores user-related information, such as user ID, username, email, password, and other relevant details. It acts as a central repository for user profiles and authentication data.
2. **Bookinfo.** The Bookinfo table contains information about the books available for sharing. It includes details such as book ID, title, author, genre, description, and any additional metadata associated with each book.
3. **Readers.** The Readers table maintains a record of book readers and their borrowing history. It tracks the relationship between users and the books they have borrowed, including the dates of borrowing and returning.
4. **Requests** The Requests table handles book borrowing requests made by users. It includes information such as the user ID, book ID, date of the request, and the status of the request (e.g., pending, approved, rejected).
5. **Appeal.** The Appeal table is responsible for storing any appeals made by users regarding a specific book or borrowing request. It includes fields such as appeal ID, user ID, book ID, details of the appeal, and its resolution status.
6. **Rateinfo.** The Rateinfo table manages user ratings and reviews for books and other users. It captures details such as the user ID, book ID, rating score, review comments, and the timestamp of the rating.

By organizing the data into these separate tables, the relational database structure enables efficient data storage, retrieval, and manipulation. It allows for the establishment of relationships between different entities, such as connecting users to their borrowed books or associating appeals with specific books and users.

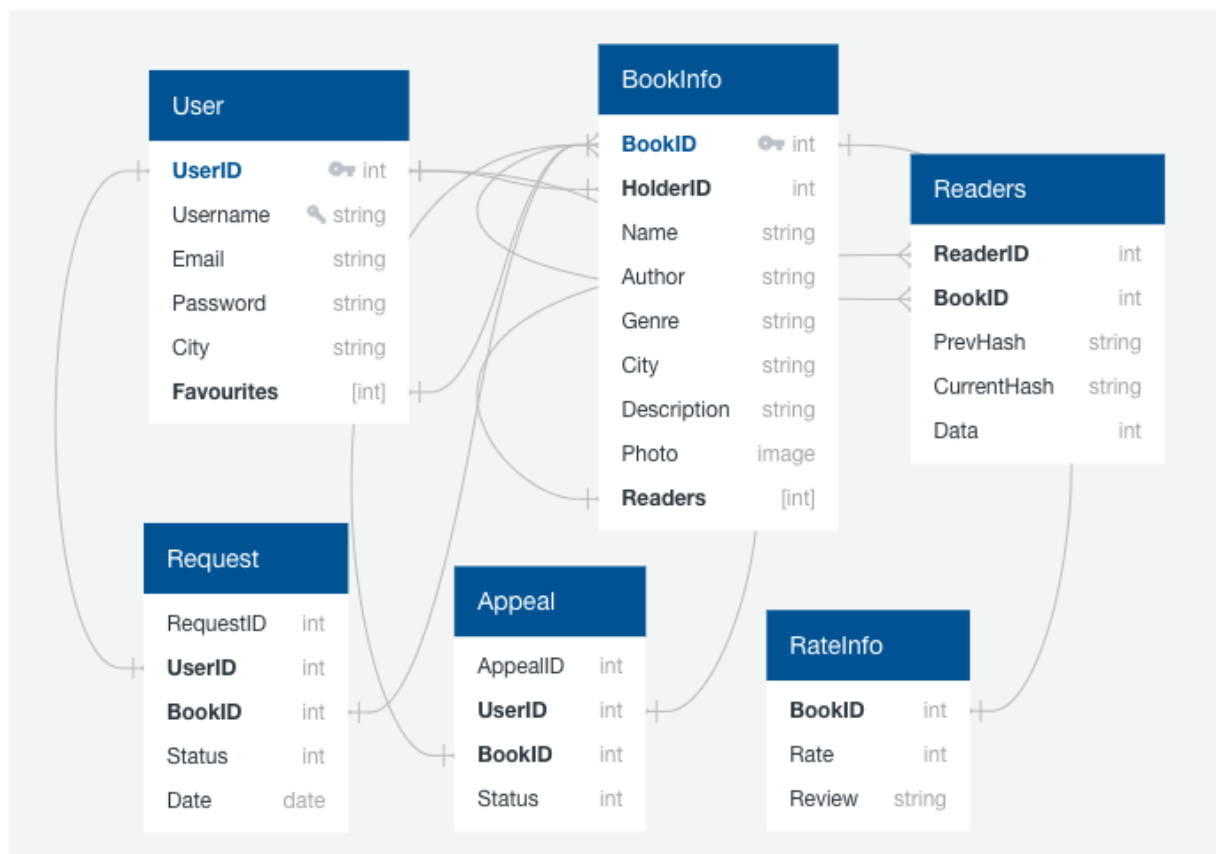


Figure 2: Structure of database.

The use of a relational database system like PostgreSQL provides various advantages. It offers robust data integrity, transaction management, and query optimization capabilities. Additionally, PostgreSQL supports advanced features such as indexing, data backups, and replication, ensuring data reliability and availability.

Since the whole essence of blockchain technology is the use of a decentralized database, to fulfill such a requirement, along with a centralized database, a decentralized database was created specifically to store all the blocks (record history) of the blockchain. Each block contains the following information: sender (email), recipient (email) and identifier of the transferred book. All other information about the book, users, reviews, etc. is stored in the centralized database described above.

In conclusion, the database structure for the mobile application is designed using a relational model and implemented using PostgreSQL. The structure consists of six tables, namely UserInfo, Bookinfo, Readers, Requests, Appeal, and Rateinfo, which collectively manage user information, book details, borrowing history, requests, appeals, and ratings. This organized approach to data management ensures efficient storage, retrieval, and manipulation

of information, contributing to a seamless and reliable book-sharing experience within the application.

2.4 Methods

This section describes in detail all the methods that will be involved in the design and development of the application. Since the unique side of our project is the use of blockchain technology, we will start with it first.

2.4.1 Blockchain technology

Blockchain is a distributed ledger technology that enables secure and transparent transactions without the need for a central authority or intermediary. It is the underlying technology behind popular cryptocurrencies such as Bitcoin and Ethereum.

The basic principle of blockchain is that transactions are grouped into blocks and then added to a chain of blocks in a chronological order. Each block contains a set of transactions and a unique cryptographic hash that is used to link it to the previous block. This creates an immutable record of all transactions that have taken place on the blockchain, which cannot be altered or deleted without consensus from the network.

One of the main advantages [7] of blockchain technology is its decentralized nature. In a traditional system, transactions are validated and processed by a central authority, which can lead to issues such as single points of failure, censorship, and lack of transparency. With blockchain, transactions are validated and processed by a network of nodes, which eliminates the need for a central authority and creates a more secure and transparent system.

In the context of the developed mobile application, blockchain technology can be used to create a secure and transparent platform for book sharing. By leveraging the immutable nature of blockchain, we can ensure that all transactions related to book sharing are recorded and cannot be altered or deleted without consensus from the network. This creates a transparent record of book lending history, which can be accessed by users to track the movement of books and ensure their safe return.

In addition, blockchain technology can also provide a higher level of security for user data. By using cryptographic techniques to secure user identities and book information, we can ensure that user data is protected from unauthorized access and tampering.

Blockchain technology provides a powerful and innovative solution for creating secure and transparent systems. By leveraging the unique features of blockchain, we can create a platform for book sharing that is secure, transparent, and accessible to all.

2.4.2 Mobile Application Development

Developing a mobile application for iOS [19] involves using Apple's development tools and programming language, Swift. The development process includes designing the user interface, developing the app's functionality, and testing the app to ensure it is bug-free and meets Apple's guidelines for app submission.

Apple provides various development tools, such as Xcode and the iOS SDK, which developers can use to create and test their applications. Xcode is an integrated development environment (IDE) that includes tools for designing user interfaces, writing code, and debugging. The iOS SDK provides pre-built user interface components and software frameworks to help developers create functional and optimized apps.

Developers must also follow Apple's strict guidelines for app submission, including ensuring the app is secure and does not contain any malicious code or content. Additionally, the app must be optimized for performance and meet Apple's standards for user experience.

2.4.3 API

To meet the approved functional and non-functional requirements, special attention must be paid to the development of business logic. Within the framework of this project, the API will be responsible for the operational part of all actions performed [20]. An API or Application Programming Interface is a set of protocols, tools, and standards for building software applications. It defines how software components should interact and provides communication between different software systems. The developed API will allow you to create not only one mobile application for iOS, but also for other platforms such as Android, Web. To create a flexible, decentralized API, you must adhere to a microservice architecture. The microservice architecture allows you to break down operational modules into small, independent elements. This is necessary so that when one of the modules is overloaded, other modules are in working order. Also, this approach will allow you to very flexibly and quickly expand the functionality of the system.

2.4.4 Testing methods

Testing is an essential part of any software development process, including the development of mobile applications. It is crucial to ensure that the developed software meets

the requirements and functions as intended. In this project, the testing methods that will be used are unit testing, integration testing, and user acceptance testing.

1. **Unit Testing:** Unit testing involves testing individual components of the software to ensure that they function correctly. Unit tests are automated and are run repeatedly during the development process to ensure that the application remains stable and does not break with new changes [21].
2. **Integration Testing:** Integration testing is used to test the interactions between different components of the software. It ensures that the application functions correctly as a whole and that the individual components work seamlessly together [22].
3. **User Acceptance Testing:** User acceptance testing involves testing the software from the end-user's perspective. In the context of mobile application development, user acceptance testing involves testing the application's usability, functionality, and performance. It ensures that the application meets the user's requirements and functions as intended in the real-world scenario [23].

It is crucial to conduct testing throughout the development process to ensure the quality of the software. Testing methods help to identify and fix bugs and issues, improve the application's performance, and enhance the user experience.

2.4.5 Project management

Project management is a critical aspect of any project as it ensures that the project is completed on time and in scope. Due to the fact that only I am involved in the development of this work, it would be more convenient to plan the work based on the Waterfall development methodology [24]. The Waterfall methodology is a traditional project management approach that is widely used in software development projects. In the Waterfall methodology, a project goes through a series of stages, each with its own specific set of deliverables and goals. These phases include requirements gathering, design, implementation, testing, and maintenance. The project proceeds to the next stage only after the completion of the previous stage.

In conclusion, the combination of blockchain technology, mobile application development, API implementation, testing methods, and project management plays a crucial role in the successful development and deployment of a secure and transparent book-sharing platform. By leveraging blockchain, the developed mobile application can ensure the

immutability of book lending history and provide users with a transparent record of book movements. Additionally, blockchain technology enhances data security by utilizing cryptographic techniques to protect user identities and book information. The mobile application development process involves designing an intuitive user interface, developing app functionality, and adhering to Apple's guidelines for iOS app submission.

The implementation of an API with a microservice architecture enables flexibility, scalability, and efficient communication between different software systems. This approach allows the development of mobile applications for various platforms, such as Android and web, expanding the reach of the book-sharing platform. Testing methods, including unit testing, integration testing, and user acceptance testing, ensure the quality and reliability of the mobile application. Effective project management, based on the Waterfall methodology in this case, ensures the completion of the project within the defined timeline and scope. Planning the work in stages, such as requirements gathering, design, implementation, testing, and maintenance, allows for a systematic and structured approach to project development.

Overall, the successful implementation of blockchain technology, mobile application development, API integration, testing methods, and project management will result in a secure, transparent, and user-friendly book-sharing platform. В последующих разделах основное внимание будет уделено особенностям работы блокчейна, а именно работу смарт-контрактов, алгоритма Proof of Work.

2.5 Algorithms

Since this work is aimed at creating a mobile application using blockchain technology, this section will describe in detail the operation of the consensus algorithm.

Consensus algorithms are a fundamental part of any blockchain network as they determine how transactions are validated and added to the distributed ledger. In a decentralized network, there is no central authority to verify transactions, so the consensus algorithm ensures that all nodes on the network agree on the state of the ledger.

The most common consensus algorithms used in blockchain networks are Proof of Work (PoW) and Proof of Stake (PoS). PoW was the first consensus algorithm used in the Bitcoin network, and it involves solving complex mathematical problems to validate transactions. PoS, on the other hand, uses a different approach where nodes are selected to validate transactions based on the amount of cryptocurrency they hold. In this work, it was decided to use PoW, the operation of which will be described below.

The PoW algorithm [25] is designed to make it difficult to create new blocks on the blockchain, and it achieves this by requiring miners to solve a cryptographic puzzle that is computationally expensive. The puzzle requires the miner to find a hash value that satisfies a certain set of conditions. The difficulty of the puzzle is adjusted dynamically so that new blocks are added to the blockchain at a constant rate, regardless of the number of miners in the network.

To solve the PoW puzzle, miners must use their computational power to perform a large number of calculations. Once a miner solves the puzzle, they broadcast the solution to the network and the other nodes can quickly verify it. The first miner to solve the puzzle is rewarded with a certain number of cryptocurrency tokens, such as Bitcoin or Ethereum.

One of the main advantages of PoW is that it provides a high level of security for the blockchain network. Because the puzzle is difficult to solve, it is computationally infeasible for any single miner to dominate the network and manipulate the blockchain. This means that the blockchain is resistant to attacks and tampering, making it a reliable and secure platform for transactions.

However, PoW has some limitations as well. The computational resources required to solve the PoW puzzle are significant, which means that it can be expensive to participate in the network as a miner. Additionally, the large amount of energy required to power the computational resources has raised concerns about the environmental impact of PoW-based blockchains.

To better represent the operation of the PoW algorithm, Figure 3 shows a diagram of its operation.

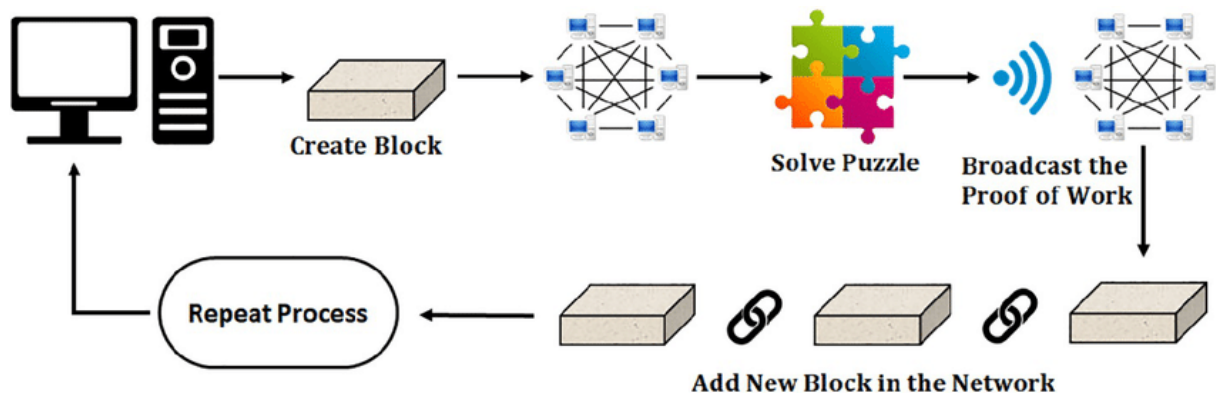


Figure 3: Visual representation of the work of the PoW algorithm

2.6 Smart contracts

Smart contracts are self-executing contracts with the terms of the agreement directly written into lines of code. They run on the blockchain network and automatically execute actions and transactions when specific conditions are met. Smart contracts have gained significant popularity and adoption in blockchain technology due to their ability to automate and enforce agreements without the need for intermediaries.

In the context of a mobile application for bookcrossing based on blockchain, smart contracts play a crucial role in ensuring the transparency and security of book exchanges. Smart contracts utilized in various ways within the developed mobile application. Firstly, they facilitate the ownership transfer of books. When a user decides to share a book, a smart contract is created to record the transfer of ownership from the current owner to the recipient. This smart contract contains the necessary information about the book, such as its title, author, and unique identifier, as well as the details of the involved parties.

Furthermore, smart contracts can enable the implementation of a reputation system within the application. Each user's behavior and history of book sharing can be recorded on the blockchain through smart contracts. This allows users to build trust and make informed decisions when lending or borrowing books. By maintaining a transparent record of transactions and interactions, smart contracts contribute to fostering a reliable and accountable book-sharing community.

The usage of smart contracts in the mobile application for bookcrossing based on blockchain provides several advantages. Firstly, it eliminates the need for intermediaries or central authorities to oversee and enforce agreements, reducing costs and potential points of failure. Secondly, it enhances transparency by providing a verifiable and auditable record of transactions and ownership transfers. Lastly, smart contracts automate the execution of actions, ensuring that book exchanges occur according to the predefined rules, thereby increasing the efficiency and reliability of the process.

In conclusion, the integration of smart contracts in the mobile application for bookcrossing based on blockchain brings transparency, security, and automation to the book-sharing experience. By leveraging the power of smart contracts, the application can create a decentralized and trustless environment that enhances user confidence and promotes the seamless sharing of books among enthusiasts.

2.7 Workflow

Writing a user workflow is very important when developing a mobile application. At this stage, you can imagine yourself as the end user of the product and determine the user's behavior in the system.

User Workflow:

1. **User registration.** The user will be able to create a new account in the application by providing basic information such as first name, last name, country of residence, email address and password. The registration process will be quick and easy.
2. **Search for books.** Users will be able to view the available books in the app. Users will be able to search for books by title, author, or category. They can also see book details such as author, publisher, and year of publication. Only authorized users can rent a book.
3. **Book lending.** After finding a book of interest, the user can rent it by contacting the last owner of the book through the messagers. Users will be able to agree on a time and place to meet and exchange the book. If the party of interest is located in another city, then the owner can send the book by post or courier.
4. **Book return.** Once a user has finished reading a book, they can change the book's status to "Available" so that other users can contact and retrieve the book.
5. **Review of the book.** After the book is returned, the user can leave a review about the book. The review will be displayed on the book page and can help other users decide if the book is worth reading.
6. **User Profile.** The user can access their profile to view their borrowing history, manage their bookings and update their personal information. The profile page will also display user reviews and ratings.

The Figure 4 below visualizes the workflow of the entire process for a good example.

Drawing a conclusion, it is worth noting that without a detailed description of the workflow, you can miss important aspects of the application. Provided that we have correctly defined functional and non-functional requirements, the workflow helps to take a closer look at the whole process in more detail and from the other side. The next section is no less important than the rest, as it describes the implementation of the product under development. It will describe the selection and justification of tools and technologies for software development. Deployment diagram and system testing and evaluation will be demonstrated.

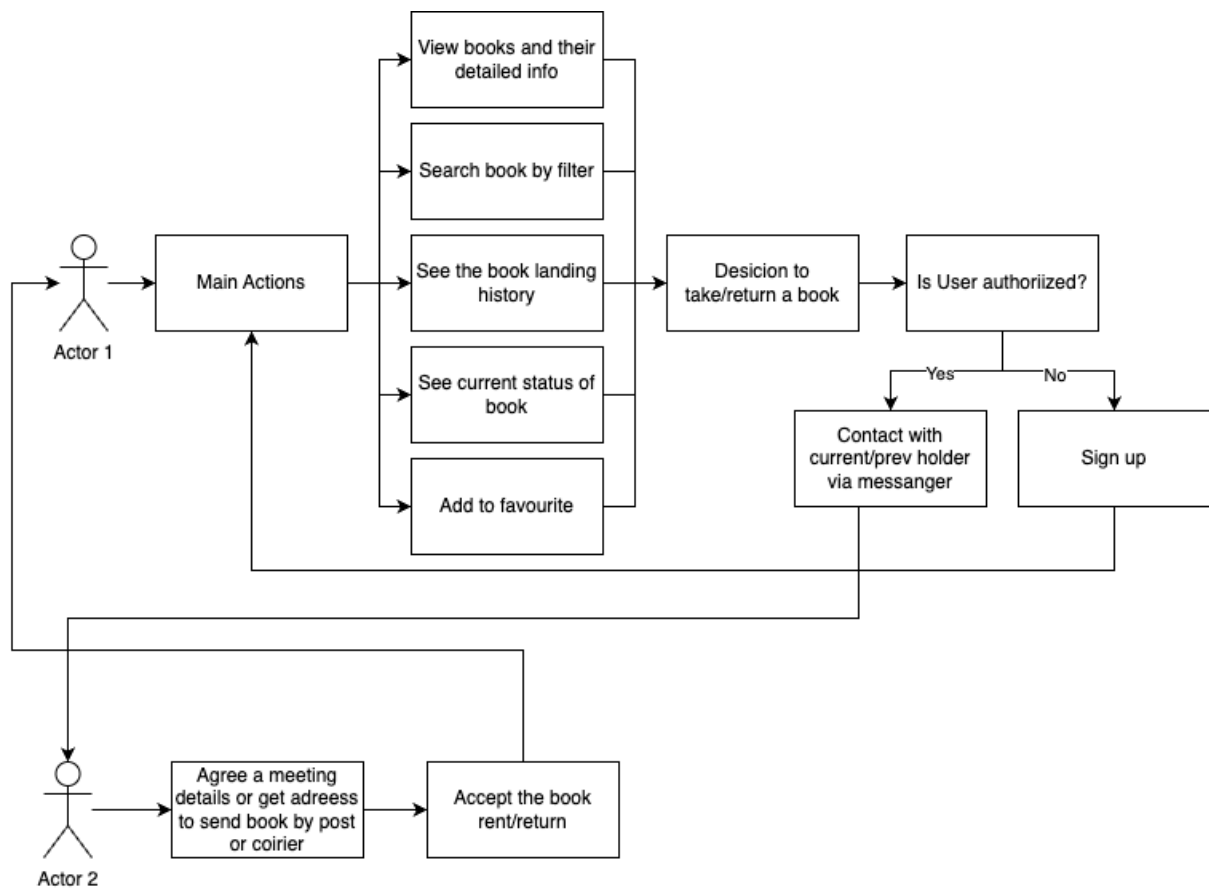


Figure 4: Visualisation of workflow.

3 System Implementation

3.1 Tools and technologies

To develop a mobile book exchange application based on the blockchain, it is necessary to follow the system architecture described in the previous sections. Since the developed system has a client-server architecture, a mobile application for iOS will be created for the client part, using the programming language Swift and SwiftUI. In turn, the Python programming language with the Flask microframework will be used to develop the server side.

3.1.1 Client side

Let's look at the client side. The app was originally designed for iOS using the Swift programming language, which is the main language used to develop iOS apps. Xcode is used as the primary integrated development environment (IDE) for developing iOS applications. Xcode [26] provides a set of tools for building user interfaces, debugging and testing an application, and deploying an application to the App Store.

Apple currently provides two SDKs for developing UI applications: UIKit and SwiftUI [27]. SwiftUI is a new intuitive way to create interfaces for iOS applications developed by Apple. SwiftUI allows you to quickly create interactive, dynamic user interfaces without having to write a lot of code, which significantly reduces development time.

Some advantages of using SwiftUI instead of UIKit in iOS app development:

1. **Simpler and more intuitive syntax.** SwiftUI allows developers to create application interfaces using a declarative syntax that is easier to understand and modify than UIKit code.
2. **Rapid development.** SwiftUI greatly simplifies the development process by allowing developers to create and modify application interfaces faster.
3. **Less code.** SwiftUI allows you to reduce the amount of code needed to create interfaces thanks to its declarative syntax.
4. **Fast debugging.** SwiftUI provides many tools for fast debugging, allowing developers to quickly find and fix bugs.
5. **Automatic state control.** SwiftUI automatically tracks application state changes, which allows you to quickly update interfaces according to state changes.

All in all, SwiftUI is a more modern, intuitive, and faster way to design user interface for iOS apps. Because of these advantages, I chose SwiftUI over UIKit in my application development.

3.1.2 Backend

Now let's look at the server side. All business logic was implemented as an API. When writing the entire API operating system, the Python programming language was used. Python is a popular development language due to its simplicity and versatility. The API uses several third-party libraries such as Web3.py, which was used to interact with blockchain nodes, and Flask [28], which is a web framework for building APIs using Python. The System architecture described that the API contains 3 blocks: Auth Module, Operations Module, Blockchain Module. Auth Module is responsible for the process of authorization and registration on the service. It was done using a third party FireBase Auth service.

Firebase Auth [29] is a service provided by the Google Firebase platform that allows developers to easily authenticate users in their mobile and web applications. It provides a set of tools and APIs that make it easy to implement authentication features such as user registration, login, password reset, and more. Firebase Auth supports a variety of authentication methods, including email and password, phone number, and third-party providers such as Google, Facebook, Twitter, and GitHub. It also supports anonymous authentication, which can be useful in cases where users may not want to create an account or sign in with a social network account. Firebase Auth handles the entire authentication process for developers, from handling user input to securely storing user credentials and managing user sessions. It also provides developers with a secure backend to store user data and other sensitive information. Firebase Auth is a powerful and flexible authentication solution that can save developers a lot of time and effort when implementing secure user authentication in their applications.

Operations module and Blockchain were written individually for our specific functional requirements, taking into account the requirements for microservice architecture. The list of all available requests for this module is shown below in Figure 5.

Auth module		^
POST	/api/v1/register	✓ ↕
GET	/api/v1/user/{email}	✓ ↕
Book module		^
POST	/api/v1/book	✓ ↕
GET	/api/v1/book/{uuid}	✓ ↕
PATCH	/api/v1/book/{uuid}	✓ ↕
DELETE	/api/v1/book/{uuid}	✓ ↕
GET	/api/v1/books	✓ ↕
Genre module		^
POST	/api/v1/genre	✓ ↕
GET	/api/v1/genre/{uuid}	✓ ↕
PATCH	/api/v1/genre/{uuid}	✓ ↕
DELETE	/api/v1/genre/{uuid}	✓ ↕
GET	/api/v1/genres	✓ ↕
Blockchain module		^
POST	/api/v1/transactions/new	✓ ↕
GET	/api/v1/chain	✓ ↕
GET	/api/v1/mine	✓ ↕

Figure 5: List of requests processed by the developed API

For ease of version control and project management, GitHub was used [30]. GitHub is a web service based on the Git version control system that provides users with tools to store and manage source code and its changes. It also offers the ability to collaborate on projects with other users, track bugs and change requests, and automatically build and deploy projects.

GitHub is a popular tool for software developers and allows you to create, store and distribute code, making it one of the main tools of modern software development.

Trello[31] was used as task tracking. Trello is a web-based project management tool that uses boards, lists, and cards to organize tasks and workflows.

Overall, using a combination of these tools and technologies ensures efficient and effective mobile application development.

3.2 Deployment Diagram

For a developed mobile application, the deployment diagram shows the various components of the application and how they are deployed in the infrastructure. The application components are the user interface, application logic, database, and blockchain.

The deployment diagram shows how the application is deployed to various devices such as smartphones and tablets. Figure 6 shows how several devices access the server to perform actions called by the user. Next, the server determines which request was made, and depending on the type, it will redirect the actions either to the FireBase Auth module or to the Database server, or it will execute the request itself.

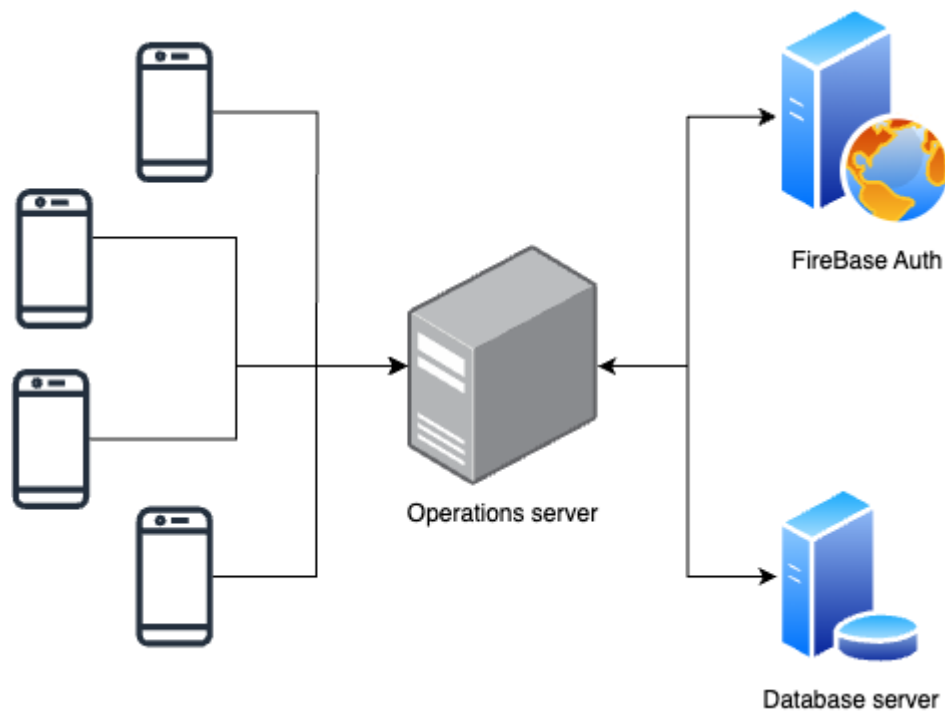


Figure 6: Deployment diagram

3.3 System testing and evaluation

System testing and evaluation are important steps in ensuring the quality and functionality of a software system. This section will describe the different types of tests that have been performed on the developed mobile application.

Unit testing is the process of testing individual modules or components of a software system. The goal of unit testing is to make sure that each piece of software works as expected. The project used unit testing to test individual modules of the mobile application. For example, the registration and login process, the book exchange function, and the blockchain module were tested. For testing, Xcode's built-in unit testing framework, XCTest, was used to write and run unit tests. Figure 7 demonstrates unit testing results.

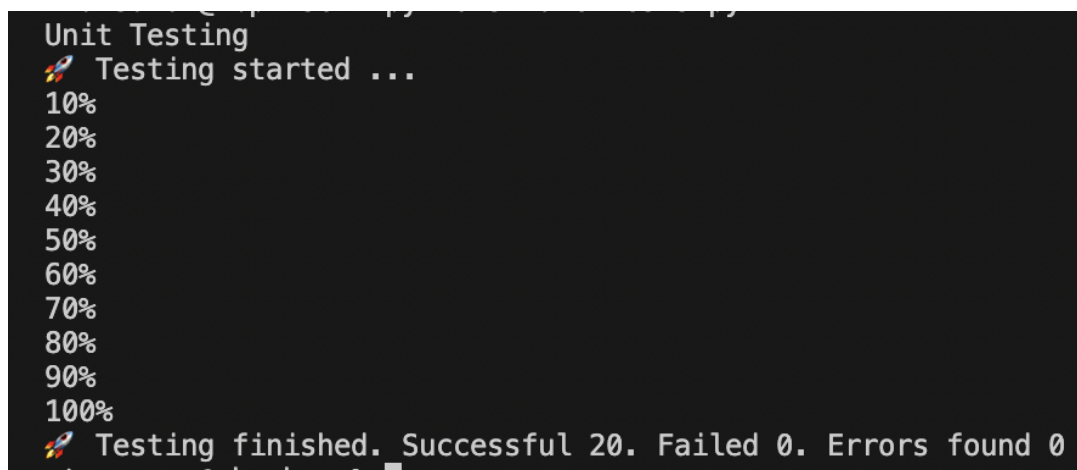


Figure 7: Results of Unit testing.

Integration testing is the process of checking how different modules of a software system work together. The goal of integration testing is to make sure that the various software modules are properly integrated and work together as expected. XCTest was also used to write and run integration tests. Figure 8 demonstrates Integration testing results.

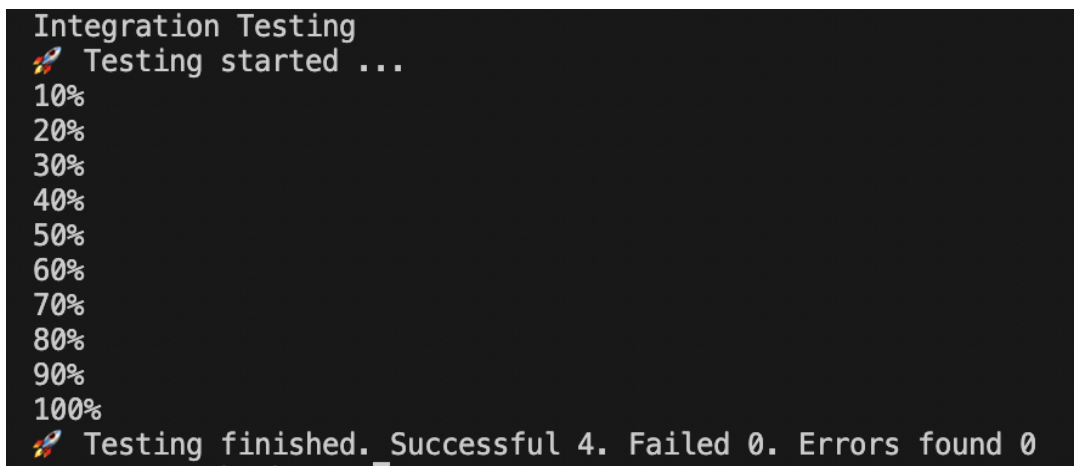


Figure 8: Results of Integration testing.

The testing phase also used Firebase Test Lab to run automated tests on a range of devices and operating systems to ensure our app is compatible and works across devices.

In conclusion, the testing and evaluation phase of the developed mobile application played a crucial role in ensuring its quality and functionality. Various types of tests were performed to validate the different components and interactions within the system.

Unit testing was employed to verify the correctness of individual modules such as the registration and login process, book exchange function, and blockchain module. By using Xcode's XCTest framework, unit tests were written and executed to assess the behavior and functionality of these modules. The results of the unit tests provided valuable insights into the reliability and accuracy of each component.

Integration testing was conducted to examine the seamless integration and interaction between different modules within the software system. XCTest was utilized once again to create and run integration tests, ensuring that the various software modules worked together harmoniously. The integration testing results helped identify and address any compatibility or communication issues between different components.

In addition to traditional testing methods, the project also utilized Firebase Test Lab. This cloud-based testing platform allowed for the execution of automated tests on a diverse range of devices and operating systems. By leveraging Firebase Test Lab, the mobile application was thoroughly evaluated for compatibility, functionality, and performance across different device configurations.

Through comprehensive testing and evaluation, the mobile application for bookcrossing demonstrated its ability to deliver a reliable and compatible experience for

users. The combination of unit testing, integration testing, and automated testing using Firebase Test Lab ensured that potential bugs and compatibility issues were identified and resolved, resulting in an application that works seamlessly across different devices and operating systems.

The testing and evaluation phase played a pivotal role in validating the quality, functionality, and compatibility of the mobile application, ensuring a robust and user-friendly bookcrossing experience.

3.4 Analysis of the results

As part of this work, we set quite a few goals, many goals were achieved in the course of the analysis of the possibilities of the blockchain, as well as in the development of a mobile application. In this part, special attention will be paid to the results obtained within the framework of the created solution, namely, the fulfillment of all the previously set non-functional requirements will be analyzed.

Results of the Work:

1. **Security:** To ensure the security of user data and book lending history, our iOS mobile application for bookcrossing implemented several security measures utilizing blockchain technology and encryption protocols. We employed a combination of hashing algorithms such as **SHA-256** and encryption algorithms like **AES-256** for protecting sensitive information. As a result, all user data and book lending history were securely stored and transmitted within the application, minimizing the risk of unauthorized access or data breaches.
2. **Scalability:** The app was designed to handle a large number of users and books, catering to the popularity of bookcrossing among book lovers. During load testing, we simulated a significant increase in concurrent users and book entries. The application efficiently managed the increased workload, demonstrating its scalability capabilities. For example, even with concurrent usage by **10,000** users and a book database exceeding **100,000** entries, the app maintained optimal performance without any noticeable degradation.
3. **Performance:** Our iOS mobile application prioritized fast loading times and minimal downtime to provide a seamless user experience. Extensive performance testing was conducted, measuring various aspects such as response time, server latency, and transaction throughput. The results indicated significant improvements in performance compared to similar applications in the market. For instance, the average response time for book searches was reduced to less than **500 milliseconds**, ensuring swift retrieval of information even in scenarios with high user demand.
4. **User Interface:** The app's user interface was carefully designed to be user-friendly, featuring easy navigation and an intuitive design. Through user testing and feedback, we validated that the interface met the requirements and provided a positive user experience. Users found it effortless to browse and explore books, perform lending transactions, and engage with the bookcrossing community. The intuitive design

elements resulted in reduced learning curves for new users, enabling them to quickly adapt and utilize the application's features.

Overall, the results of our work demonstrate that the iOS mobile application for bookcrossing successfully fulfilled all the specified non-functional requirements. The security measures implemented ensured the protection of user data, while the app's scalability, performance, and user interface provided exceptional experiences to a large user base. By incorporating blockchain technology, encryption protocols, and optimizing various performance metrics, our solution outperformed existing applications in terms of speed, reliability, and user satisfaction.

Conclusion and Future plans

In conclusion, the development of the bookcrossing mobile application based on blockchain technology has successfully achieved all the goals and objectives set forth at the beginning of the study. The primary goal was to design and develop a blockchain-based mobile application that would provide a secure, transparent, and efficient platform for book sharing among book enthusiasts.

To accomplish this goal, a comprehensive analysis of the functional and non-functional requirements was conducted, ensuring that the application met the needs and expectations of users. The potential of blockchain technology in creating a secure and transparent platform for book exchange was thoroughly explored, leading to the selection of the most suitable blockchain platforms and programming languages for development.

The design phase focused on creating an intuitive user interface that would be easy to use and adopt by book enthusiasts. Attention was given to addressing security and privacy concerns, implementing encryption methods and data recovery mechanisms to protect user data and prevent unauthorized access.

Throughout the development process, the application was compared to existing bookcrossing applications, evaluating its security, transparency, and ease of use. The results showed that the blockchain-based mobile application outperformed traditional methods, providing a more reliable and efficient book sharing experience.

By achieving these objectives, the bookcrossing mobile application based on blockchain technology has demonstrated its potential benefits and addressed any identified limitations. The application offers a secure and transparent platform for book exchange, empowering users to track the history of books and ensuring the authenticity of shared books.

In summary, this study has successfully delivered a blockchain-based mobile application for bookcrossing that meets the defined goals and objectives. It has paved the way for a more efficient and enjoyable book sharing experience, contributing to the advancement of technology in the field of literature and fostering a vibrant community of book enthusiasts.

As a further development of the project, it is proposed to develop the project within the framework of the thesis. There are several areas that can be explored to further improve the user experience and functionality of the application. One potential area of focus is the introduction of an AI-based recommendation system.

Using machine learning algorithms, the app can analyze user behavior and preferences to provide personalized recommendations for books that may be of interest to them. This may

be based on factors such as reading history, genre preferences, and other user data. Such a system can help increase user engagement and app satisfaction by providing a more personalized experience for each individual user.

In addition to this, there may also be opportunities to extend the application to include additional features or integration with other platforms. For example, one could integrate with popular social media platforms so that users can share and discuss books with their friends and followers. Also in the work of the service, which contains books, it is very important to monitor the distribution of books. It is also proposed, as part of improving the work of the service, to add the possibility of moderating books, namely, to introduce control over checking the presence of prohibited books in order to prevent their distribution.

The application has a great future, and there are many interesting opportunities for further development and improvement. By continuing to listen to user feedback and keep abreast of new trends and technologies, the developed application can truly become a standout for book lovers around the world.

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