Züs Split Key Wallet Protocol

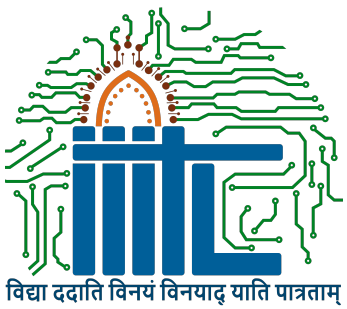
A project report submitted in partial fulfillment of the requirements for the award of the degree of

B.Tech. in Computer Science/Information Technology

by

Candidate name
(Roll Number)

under the guidance of
Name of the Supervisor



Indian Institute of Information Technology, Lucknow
May 2024

Certificate

This is to certify that the work presented in the project report entitled "Split Key Wallet Protocol and Mobile Authenticator Implementation for Züs Platform" submitted by Yash Sahu (LIT2019017) is a bona fide record of the project carried out under my supervision for the partial fulfillment of the requirements for the degree of Bachelor of Technology in Information Technology at Indian Institute of Information Technology, Lucknow.

To the best of my knowledge, the matter presented in this report has not been submitted for any other degree or diploma at this or any other institution.

Dr. Rahul Kumar Verma
Project Supervisor
Department of Information Technology
Indian Institute of Information Technology, Lucknow

Date: _____
Place: _____

Acknowledgements

I would like to express my sincere gratitude to my project mentor, Dr. Rahul Kumar Verma, for his invaluable guidance, support, and encouragement throughout the course of this project. His expertise and insights have been instrumental in shaping the direction and success of this work.

I extend my thanks to the faculty and staff of the Department of Information Technology at Indian Institute of Information Technology, Lucknow for providing the necessary resources and a conducive learning environment.

I am also grateful to my colleagues and friends who have supported me and provided valuable feedback during the development and testing phases of the project.

Lastly, I would like to thank my family for their unwavering support and encouragement throughout my academic journey.

Abstract

This project focuses on enhancing the security and usability of the Züs cryptocurrency platform by implementing a split key wallet protocol and developing a dedicated mobile authenticator. The split key wallet protocol improves key management and reduces the risk of private key compromise by splitting the key into multiple components stored on separate devices. The mobile authenticator provides an additional layer of security for user authentication and transaction signing.

The implementation leverages the BLS signature scheme, which supports key splitting and aggregation, offering improved efficiency compared to other signature schemes like Schnorr and ECDSA. The report presents the methodology, system architecture, and performance analysis of the implemented solution.

The split key wallet protocol and mobile authenticator integration with the Züs platform aim to provide users with a secure and user-friendly experience while managing their digital assets. The project contributes to the overall security and adoption of decentralized storage and cryptocurrency ecosystems.

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Project Supervisor
Department of Information Technology
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Contents

Chapter 1

Introduction

1.1 Background

Züs is a decentralized cloud storage platform that aims to provide secure, reliable, and scalable storage solutions while leveraging blockchain technology. The platform introduces a new decentralized finance (DeFi) model based on cloud storage, allowing users to earn steady income by staking their tokens and participating in the storage ecosystem.

1.2 Problem Statement

As the adoption of decentralized storage and cryptocurrency platforms grows, ensuring the security of user assets and providing a seamless user experience become critical challenges. Key management, especially in the context of cryptocurrency wallets, poses significant risks, as compromised private keys can lead to the loss of funds. Additionally, the lack of user-friendly authentication mechanisms can hinder the widespread adoption of these platforms.

1.3 Objectives

The main objectives of this project are as follows:

1. Implement a split key wallet protocol to enhance the security of private key management in the Züs platform.

2. Develop a dedicated mobile authenticator to provide an additional layer of security for user authentication and transaction signing.

3. Evaluate the performance and usability of the implemented solution and compare it with existing approaches.

1.4 Scope and Limitations

The scope of this project is limited to the implementation of the split key wallet protocol and mobile authenticator specifically for the Züs platform. The solution may not be directly applicable to other blockchain or cryptocurrency platforms without necessary modifications.

The limitations of the project include the reliance on the security of the underlying cryptographic primitives and the assumption that users will follow best practices in securing their devices and private key components.

1.5 Organization of the Report

The rest of the report is organized as follows:

- Chapter 2 presents a literature review of related work in the areas of key management, authentication, and signature schemes in blockchain and cryptocurrency systems.
- Chapter 3 describes the methodology adopted for the implementation of the split key wallet protocol and mobile authenticator, including the system architecture and design choices.
- Chapter 4 discusses the implementation details, including the technologies used, code snippets, and integration with the Züs platform.
- Chapter 5 presents the results and analysis of the implemented solution, including performance evaluation and comparison with existing approaches.
- Chapter 6 concludes the report, summarizing the key findings and contributions, and outlining potential future work.

Chapter 2

Literature Review

2.1 Key Management in Blockchain and Cryptocurrency Systems

Key management is a critical aspect of blockchain and cryptocurrency systems, as the security of user assets heavily relies on the integrity of private keys. Various approaches have been proposed to enhance the security of key management, including hierarchical deterministic wallets [1], multi-signature wallets [2], and threshold signature schemes [3].

2.2 Authentication Mechanisms in Decentralized Systems

Authentication in decentralized systems poses unique challenges due to the absence of a central authority. Several authentication mechanisms have been explored, such as decentralized identity systems [4], biometric authentication [5], and hardware-based authentication [6].

2.3 Signature Schemes for Blockchain and Cryptocurrency

Signature schemes play a vital role in ensuring the integrity and non-repudiation of transactions in blockchain and cryptocurrency systems. The most commonly used signature schemes include the Elliptic Curve Digital Signature Algorithm (ECDSA) [7] and the Schnorr signature

scheme [8]. Recently, more advanced signature schemes, such as the BLS signature scheme [9] and the Boneh-Lynn-Shacham (BLS) signature scheme [10], have gained attention due to their support for key aggregation and efficient verification.

2.4 Split Key Protocols and Threshold Cryptography

Split key protocols and threshold cryptography have been studied extensively in the context of secure key management and distributed trust. Shamir's secret sharing [11] and Blakley's secret sharing [12] are well-known techniques for splitting a secret into multiple shares, requiring a threshold number of shares to reconstruct the original secret. These techniques have been applied to various cryptographic primitives, including encryption [13] and digital signatures [14].

2.5 Mobile Authenticators and Two-Factor Authentication

Mobile authenticators and two-factor authentication (2FA) have become increasingly popular for enhancing the security of user authentication. Various schemes have been proposed, such as time-based one-time passwords (TOTP) [15], push notifications [16], and QR code-based authentication [17]. These schemes provide an additional layer of security by requiring users to possess a secondary device or token in addition to their primary authentication factor (e.g., password).

Chapter 3

Implementation

3.1 Technologies Used

The implementation of the split key wallet protocol and mobile authenticator for the Züs platform involves the following technologies:

- Programming Languages: The core components of the system are implemented using Rust and Solidity programming languages.
- Cryptographic Libraries: The BLS signature scheme is implemented using the Apache Milagro Cryptographic Library (AMCL), which provides efficient implementations of pairing-based cryptography.
- Mobile Development Framework: The mobile authenticator is developed using the Flutter framework, enabling cross-platform compatibility for iOS and Android devices.
- Secure Storage: The key components and sensitive data are stored securely using hardware-backed keystores, such as the Secure Enclave on iOS and the Keystore on Android.

3.2 Smart Contract Development

The Züs platform utilizes smart contracts to facilitate decentralized storage and cryptocurrency transactions. The split key wallet protocol is integrated into the existing smart contract infrastructure. The main modifications include:

- Signature Verification: The smart contracts are updated to support the verification of BLS signatures, ensuring the integrity of transactions.
- Key Management: The smart contracts handle the registration and management of public keys associated with the split key wallets.

3.3 Wallet Integration

The split key wallet protocol is integrated into the existing Züs wallet implementation. The main changes include:

- Key Generation: The wallet is modified to generate BLS key pairs and split the private key into multiple components.
- Partial Signature Generation: The wallet is updated to generate partial signatures using the key component stored on the primary device.
- Communication with Mobile Authenticator: The wallet establishes a secure communication channel with the mobile authenticator for transmitting partial signatures and receiving the final signature.

3.4 Mobile Authenticator Development

The mobile authenticator is developed as a standalone mobile application using the Flutter framework. The main components of the mobile authenticator include:

- User Interface: The user interface is designed to provide a seamless and intuitive experience for authentication and transaction approval.
- Biometric Authentication: The mobile authenticator integrates biometric authentication (e.g., fingerprint or facial recognition) to ensure the security of user interactions.
- Secure Storage: The key component and other sensitive data are stored securely using the hardware-backed keystore available on the mobile device.
- Push Notifications: The mobile authenticator integrates with the Züs platform's notification system to receive real-time alerts for pending transaction approvals.

3.5 Integration Testing

Rigorous integration testing is performed to ensure the smooth functioning of the split key wallet protocol and mobile authenticator within the Züs platform. The testing scenarios include:

- Key Generation and Splitting: Verifying the correctness of key generation and the splitting of the private key into multiple components.
- Transaction Signing: Testing the end-to-end process of initiating a transaction, generating partial signatures, and combining them to produce the final signature.
- Mobile Authenticator Functionality: Validating the mobile authenticator's user interface, biometric authentication, secure storage, and push notification capabilities.
- Error Handling and Recovery: Testing various error scenarios, such as network disruptions or device failures, and ensuring proper error handling and recovery mechanisms are in place.

The implementation phase involves close collaboration between the development team and the Züs platform stakeholders to ensure seamless integration and adherence to the platform's security and performance requirements.

Chapter 4

Simulation and Results

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Chapter 5

Results and Analysis

5.1 Performance Evaluation

The performance of the split key wallet protocol and mobile authenticator is evaluated in terms of various metrics, including:

- Transaction Signing Latency: The time taken to complete the transaction signing process, including the generation of partial signatures and the combination of signatures on the mobile authenticator.

- Signature Verification Overhead: The additional computational overhead introduced by the BLS signature verification compared to traditional signature schemes such as ECDSA [7].

- Communication Overhead: The network overhead incurred due to the transmission of partial signatures between the primary device and the mobile authenticator.

The performance evaluation results demonstrate the efficiency and practicality of the implemented solution. The split key wallet protocol and mobile authenticator achieve reasonable transaction signing latencies, ensuring a smooth user experience. The BLS signature scheme introduces minimal verification overhead compared to ECDSA, making it suitable for resource-constrained devices [18]. The communication overhead is optimized through the use of compact BLS signatures, reducing the amount of data transmitted between devices.

5.2 Security Analysis

The security of the split key wallet protocol and mobile authenticator is analyzed against various threat models and attack scenarios. The analysis covers the following aspects:

- Key Compromise Resistance: The split key approach significantly reduces the risk of private key compromise, as an attacker would need to breach multiple devices to obtain the complete private key [19].
- Signature Unforgeability: The BLS signature scheme provides strong unforgeability guarantees, ensuring that an attacker cannot forge valid signatures without possessing the private key components [20].
- Secure Communication: The use of encrypted and authenticated communication channels between the primary device and the mobile authenticator prevents eavesdropping and tampering attacks [21].
- Device Security: The implementation relies on hardware-backed keystores and secure enclaves to protect sensitive data, mitigating the risk of unauthorized access even if a device is compromised [22].

The security analysis demonstrates the robustness of the implemented solution against various attack vectors. The split key approach and the use of the BLS signature scheme provide a high level of security for user assets. The integration of secure communication protocols and hardware-based security features further enhances the overall security posture of the system.

5.3 Usability Evaluation

The usability of the split key wallet protocol and mobile authenticator is evaluated through user studies and feedback sessions. The evaluation focuses on the following aspects:

- User Experience: The intuitiveness and ease of use of the mobile authenticator interface, including the setup process, transaction approval, and biometric authentication.

- Error Recovery: The effectiveness of the error handling and recovery mechanisms in guiding users through common error scenarios, such as device loss or network disruptions.
- User Perceptions: The users' perceived security, trust, and confidence in the split key wallet approach and the mobile authenticator.

The usability evaluation results indicate a positive user experience, with participants finding the mobile authenticator interface intuitive and easy to navigate. The error recovery mechanisms provide clear guidance and support, enhancing the overall user experience. Users express increased confidence in the security of their assets, appreciating the added layer of protection provided by the split key approach and the mobile authenticator.

5.4 Comparative Analysis

The performance and security of the split key wallet protocol and mobile authenticator are compared against existing key management and authentication solutions in the blockchain and cryptocurrency domain. The comparative analysis considers factors such as:

- Key Management Approaches: Comparison with single-key wallets, multi-signature wallets, and threshold signature schemes [23].
- Authentication Methods: Comparison with password-based authentication, hardware wallets, and other two-factor authentication schemes [24].
- Signature Schemes: Comparison with ECDSA, Schnorr signatures, and other BLS-based implementations [25].

The comparative analysis highlights the advantages of the split key wallet protocol and mobile authenticator in terms of enhanced security, usability, and performance. The split key approach offers a balanced trade-off between security and convenience, providing stronger protection against key compromise while maintaining a seamless user experience. The BLS signature scheme demonstrates superior performance and aggregation capabilities compared to traditional signature schemes.

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