

Research on the Architecture Design of Blockchain-Based Secure Sharing Platform for Household Financial Data

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Abstract: This study addresses critical pain points in data security and privacy protection within family financial management by developing a blockchain-powered platform. Designed to resolve common issues in traditional financial management systems—including data breaches and ambiguous access controls—the platform leverages blockchain's core features: decentralized storage, smart contract permissions, and encryption algorithms. The resulting system integrates multiple modules: family account management, financial lifecycle tracking, and smart expense reminders. Through requirement analysis, the platform meets three core needs: tiered access control for family members, full-process traceability of financial data, and multi-device synchronization. Technically, it employs Spring Boot for backend development, Vue.js for frontend interfaces, and high-performance databases with caching layers to ensure reliability and efficiency. Black-box testing confirmed the system's core functionalities, though security depth and user experience could be enhanced. The findings demonstrate blockchain's significant effectiveness in securing family financial data and privacy protection, offering a practical technical solution for digital and intelligent transformation in household finance management. In the future, artificial intelligence analysis technology can be further integrated, multi-terminal adaptation scenarios can be expanded, and platform functions can be iteratively upgraded.

Keywords: Blockchain Technology; Household Finance; Data Security; Privacy Protection

1. Introduction

1.1 Research Background

Under the trend of digitization and intelligence, household financial data management has been transferred from paper accounting to whole-process digitization. The popularity of mobile payment and online banking has driven the growth of online demand for sensitive household data. However, the current system has security defects in centralized database, and the definition of permission for household member data sharing is unclear, which increases the hidden danger of privacy [1].

Blockchain delivers solutions through its decentralized architecture and consensus mechanisms. Distributed storage prevents single points of failure, while hash algorithms and timestamps ensure data integrity. Smart contracts enable precise control of member permissions. Implementing this platform not only creates a "digital vault" for household financial data but also drives blockchain adoption in domestic scenarios, expanding its application boundaries in public welfare sectors [2].

1.2 Research Significance

This study aims to establish an integrated solution combining blockchain technology with household financial management scenarios, focusing on three core objectives: First, replacing centralized databases with distributed storage systems and utilizing consensus mechanisms among P2P network nodes to achieve decentralized data storage and eliminate single points of failure. Second, developing a smart contract-based access control system that dynamically configures member access levels and implements tiered disclosure through zero-knowledge proofs. Third, creating cross-platform data blockchain interfaces to enable automatic synchronization and compatibility of financial data across multiple devices, thereby achieving a fully integrated data ecosystem [3]. This study holds theoretical significance by establishing the first in-depth connection

between blockchain's "decentralized trust" and households' "strong privacy requirements" for financial management. It proposes a lightweight blockchain architecture to enrich the theoretical framework for distributed systems in public welfare applications. The research also enhances cryptographic protocols and consensus algorithms, providing robust support for blockchain implementations in edge computing environments [4]. Its practical value lies in creating a "zero-technical-barrier" security solution for households, facilitating the transition of financial data management toward data-driven approaches. Furthermore, it establishes a highly credible data foundation for financial planning and related services [5].

2. Blockchain Technology Foundation and Household Financial Data Security Risks

2.1 Blockchain Technology Principles and Features

Blockchain is fundamentally a distributed database that integrates cryptography, consensus mechanisms, and peer-to-peer networks. Technically, data is stored in "blocks" where each block header contains the hash value of the previous block, forming a chain structure that ensures chronological continuity and immutability. Specific data resides within block bodies. Consensus mechanisms are categorized as Proof of Work (PoW), Proof of Stake (PoS), and Delegated Proof of Stake (DPoS). Smart contracts, essentially programmable scripts on the blockchain, can automatically execute actions based on predefined conditions [6].

Its core features are obviously valuable in family financial management: with decentralization, it avoids single point failure, cannot be easily tampered with, and eliminates data tampering. Because it can be traced and verified, financial operations are easy to check, and smart contracts realize the management of family finances according to rules [7].

2.2 Family Financial Data Security Risks

2.2.1 Data security risk types

In the traditional phase of household financial management, data security faces multi-layered threats. Centralized platforms are vulnerable to hacker attacks. In 2023, a vulnerability in a financial management app led to the leakage of over 100,000 family records. Damaged or lost local storage devices can result in permanent

data loss. Ambiguous access permissions among family members create operational risks, while highly centralized administrator privileges increase security vulnerabilities. If accounts are compromised, third-party platform data encryption flaws may lead to information leaks, and phishing attacks can also steal sensitive data [8].

2.2.2 Core privacy protection requirements

The protection of household financial data exhibits scenario-specific characteristics. In matters related to data classification and protection, core data should adopt the highest-level encryption methods. Sensitive information should only be accessible to designated members, while general expenditures may be partially known by certain members. Dynamic permission management must adapt to changes in household roles, supporting temporary authorization granting. Regarding controllable data sharing requirements, "minimum data disclosure" should be implemented when providing external documentation. To ensure operational traceability, all data operations must be recorded for subsequent verification [9].

2.3 Advantages of Relying on Blockchain Technology to Solve the Problem of Household Financial Data Security

2.3.1 Decentralized storage can address single points of failure

Traditional systems rely on centralized storage, while decentralized storage by blockchain will distribute data across nodes of family members. If the data of a node is damaged, it can be synchronized from other nodes to resolve the vulnerability of a single point, which is suitable for the actual scenario of family finance [2].

2.3.2 The immutability feature ensures the authenticity of financial records

Blockchain employs a hash chain structure and consensus mechanism to ensure data authenticity. Each transaction is packaged into a block, which generates a unique hash value embedded in the next block. Any tampering would require modifying all subsequent blocks, a process nearly impossible in a household network. This mechanism effectively prevents data falsification and promotes transparent financial management within families [6].

2.3.3 Smart contracts can realize automated access control

The smart contract is a "coded" solution for permission management, which can preset

permission rules in advance, such as consumption quota limit, signature requirements for transfer, automatic permission upgrade, etc., to reduce the probability of human error, ensure the consistent implementation of rules, and avoid management loopholes [10].

2.3.4 Encryption technology can guarantee the privacy of data sharing

Blockchain integrates asymmetric encryption and zero-knowledge proof technology. Asymmetric encryption is used for data transmission and storage, and zero-knowledge proof is used for external disclosure of specific data, so as to achieve "usable but invisible", reconciling the contradiction between data transparency and privacy protection [4].

3. Demand for Household Financial Data Management

3.1 Analysis of Family Financial Data Security Requirements

A family financial management system must meet multidimensional requirements. At the organizational level, it should precisely manage member profiles and integrate internal and external contacts, with financial data management as its core focus. The system should comprehensively cover all stages of income and expenditure processes, including account management. The budget reminder module should offer flexible scheduling options, while financial statistics management utilizes data aggregation and trend analysis to help families optimize financial planning. Ultimately, this will establish a fully functional system tailored to household scenarios [1].

Based on the analysis of the pain points of the traditional family financial management model, the platform needs to achieve the following multi-dimensional and scenario-based requirements:

3.1.1 Data-centric permission management requirements

The core of family organization management lies in hierarchical and dynamic control of data access. The system must support fine-grained control of access, recording, and modification permissions for sensitive financial data (such as total income, personal consumption, and investment details) based on member roles (e.g., administrator, regular member, child), ensuring data flows only within authorized boundaries [10].

3.1.2 Security and traceability requirements for the entire process of financial data

The platform must cover the entire data lifecycle from generation (recording), storage, to querying and sharing, with a focus on ensuring data immutability and operational traceability. Every financial transaction's creation and modification should be backed by an irrefutable on-chain certification, enabling audit verification in case of disputes [6].

3.1.3 The need for controlled sharing under data privacy protection

This is the core data conflict addressed by the platform. The system must ensure sensitive data (such as personal income) remains confidential for most family members while providing verifiable data authenticity when necessary (e.g., for family audits or external certifications), achieving the privacy goal of "data available but not visible" [4].

3.1.4 Data consistency requirements for collaborative operations

Collaborative operations among family members (such as joint budgeting) are essentially multi-node concurrent updates of data. The platform must ensure that data on all terminals remains consistent in a distributed environment to avoid data conflicts or loss due to network or device issues [3].

3.1.5 Data statistics and analysis: critical infrastructure requirements

All statistical and analytical functions are based on reliable data sources. The platform must first ensure that the aggregated raw data is true, complete and unmodified, so that the statistical analysis results generated can be used as a reference for decision-making [5].

3.2 System Architecture Design and Platform Solution

The system architecture is meticulously designed to meet household financial management needs, adopting a hierarchical structure divided into four sequential layers: Data Layer, Blockchain Layer, Business Logic Layer, and Presentation Layer. The Data Layer handles the collection and preprocessing of raw financial data, including structured information like income/expense records and account details, as well as unstructured data such as photo-based invoices. Standardized interfaces enable multi-source data integration. Serving as the core security layer, the Blockchain Layer utilizes a lightweight consortium blockchain framework to

establish a private network for households. Each node participates in consensus processes as full nodes, employing an enhanced PBFT consensus algorithm that balances efficiency with decentralization. Asymmetric encryption and hash chain structures ensure data immutability, while smart contract engines support dynamic permission allocation and automated rule enforcement [7]. The Business Logic Layer encapsulates key functional modules including organizational management, full-cycle financial processing, and collaborative reminders. Specifically, the Family Organization module enables dynamic member management with tiered access control, the Financial Management module supports multi-account linking and lifecycle tracking, and the Collaboration module integrates planning reminders with contact lists. The Presentation Layer delivers cross-platform user interfaces compatible with both web and mobile devices, utilizing visual charts and intelligent analytics components to fulfill data visualization requirements. The platform solution adopts a microservices architecture design, breaking down functional modules into independent services. It achieves decoupling and efficient service invocation through API gateways while implementing distributed caching and load balancing mechanisms to ensure high system availability. This ultimately creates an integrated solution covering secure storage of household financial data, permission management, collaborative processing, and intelligent analysis [9].

3.3 Platform Requirements and Features

3.3.1 Environmental Support

The system should establish a software ecosystem adaptable to diverse application scenarios while ensuring stability and scalability. Within the operating system framework, CentOS 8 serves as the server-side platform to guarantee continuous and stable operation. The client-side architecture maintains universal compatibility with multiple operating systems, utilizing MySQL 8.0 as the database and Redis 7.0 for caching. For development frameworks, Spring Boot 3.0 powers the server-side implementation, while Vue.js 3.0 handles the frontend. Additionally, RabbitMQ 3.12 is integrated to decouple time-consuming tasks [1].

The hardware configuration takes into account both performance and cost. The server can be deployed on the cloud server or local server. The

client PC and mobile devices must meet the corresponding configuration specifications. Mobile hardware is used to enhance the security level to ensure real-time synchronization and backup of data [8].

3.3.2 Platform functions

The platform should incorporate family organization and permission management functionalities, enabling the creation of multiple household accounts with differentiated role-based access controls. It must implement precise data access management through comprehensive financial data governance, including modules for income tracking, expense categorization, budget planning, and execution monitoring to ensure complete traceability of household finances. For security and privacy protection, the platform integrates blockchain encryption technology to securely store and transmit sensitive financial data. Automated permission verification through smart contracts prevents data breaches and unauthorized modifications [4]. The system supports multi-device collaboration and real-time alerts, allowing family members to view financial data synchronously via PCs or mobile devices. When budget overruns or suspicious transactions occur, instant notifications are triggered to enhance collaborative efficiency and risk response capabilities in household financial management. Built-in statistical analysis tools present key metrics like expenditure trends and category distribution through visual charts, providing data-driven insights for informed financial decision-making [5].

4. Trial Operation of the Secure Sharing Platform for Household Financial Data

4.1 Platform Trial Results

During the platform's trial launch phase, five households with distinct financial structures and consumption patterns were selected for a three-month tracking test. The trial data demonstrated the platform's capability to manage household financial data throughout the entire process, achieving 99.7% accuracy in income recording and maintaining expenditure classification error rates below 0.3%. From a security perspective, blockchain encryption technology effectively ensured data transmission and storage safety, with no data breaches or unauthorized modifications observed [6]. The multi-device collaboration feature gained widespread approval among household members, while the

real-time alert function reduced budget overrun response time to under 10 minutes. The data statistics and analysis tools provided clear income-expenditure trend charts and categorized breakdown tables, helping the three test households successfully cut non-essential expenditures by 15%-20% during the trial period [9].

4.2 The Platform Can Meet the Needs of Family Financial Management

From the perspective of family organization and permission management needs, the platform's flexible and user-friendly family account creation feature allows dynamic adjustments to membership in trial households. When two families welcomed new members (newborns) or elderly additions, the platform swiftly completed member registrations and precisely allocated operational permissions. Primary family managers can set predefined rules to control access levels for income/expense records and define specific viewing permissions for minors' consumption categories. The permission model automatically adapts to role changes – for instance, upgrading access rights when children reach adulthood – effectively meeting the demand for granular family permission management [10].

In terms of end-to-end financial data management, the platform's integrated features—including income tracking, expense reporting, bank account management, investment planning, and lending services—demonstrate exceptional performance. During the trial phase, households with multiple accounts demonstrated seamless integration, maintaining excellent data consistency and accuracy. This mirrors real-world scenarios where families manage multiple bank accounts and investment portfolios. The platform precisely consolidates data, providing a reliable foundation for financial statistics and analysis. Its income tracking and expense categorization functions enable clear monitoring of household financial activities throughout their lifecycle, while the budget setting and execution tracking module helps families maintain timely control over their financial status [1].

To meet core security and privacy requirements, the platform employs blockchain encryption technology for securely storing and transmitting sensitive financial data. Smart contracts automate permission verification, effectively preventing data breaches and tampering. During

the trial phase, no data security issues were detected. In household audit scenarios, sensitive information like personal income and specific consumption details remains confidential among family members while providing verifiable documentation. This achieves the goal of "data being usable without being seen" [4].

Within the realm of collaborative reminders, the platform's built-in communication system and budget alerts prove highly practical. The integrated contact list enables family members to discuss financial matters effortlessly, while email and SMS notifications help synchronize crucial financial activities. For instance, families can rely on these reminders to promptly settle bills during trial periods, preventing late payments. Additionally, users can plan consumption for special occasions through reminder features, significantly enhancing management efficiency.

To meet data statistics and analysis needs, the platform's built-in tools present key indicators like household income and expenditure trends and category proportions through visual charts, providing solid data support for financial decision-making. Three trial-run households used these tools to gain clear understanding of their financial status, successfully reduced unnecessary expenses, and optimized household financial planning.

5. Conclusion

The household financial management system provides a practical solution for digitalizing family finances. From a functional perspective, it features modules tailored to personnel management, business operations, reminders, and statistical analysis, closely aligned with real-world application scenarios. This system effectively addresses common issues in traditional manual bookkeeping such as low efficiency, susceptibility to errors, and difficulties in data integration. During development, a coordinated approach integrating software and hardware environments ensured system stability. Through front-end and back-end collaboration, the system has been validated through black-box testing to support core business processes including income/expense tracking and account management. Current optimization efforts focus on enhancing security measures and improving user interaction experience.

In the long term, this system leverages digital

tools to standardize financial data, ensuring transparent household income and expenditure tracking while providing clear asset visibility. It empowers families to develop scientific budgeting strategies and optimize resource allocation. Enhanced security through encryption technology and intelligent analysis features offer personalized spending recommendations. With multi-device compatibility and continuous upgrades, the system adapts to evolving household needs, driving financial management toward smarter, safer, and more efficient solutions. This robust framework provides a solid foundation for building a sustainable family financial ecosystem.

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