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Construction of a Hospital SPD Medical Consumables Management System Based on Blockchain Technology

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Abstract: This study seeks to bridge the gap in the application of blockchain technology integrated with the SPD(Supply /Processing /Distribution) system in the domain of medical consumables management. It specifically addresses the current challenges faced by the Dazhou Central Hospital in managing medical consumables by designing and implementing a blockchain-based SPD medical consumables management system. The results demonstrate that the system significantly enhances the efficiency, anti-counterfeiting capabilities. The findings herald the potential for broader applications of blockchain technology in the healthcare sector and lay a solid foundation for future exploration of its use and system expansion across hospitals.

Keywords: Blockchain; SPD; Medical Consumables; Management Information System; Dazhou Central Hospital

1. Background Introduction

In recent years, the rapid development of blockchain-based information systems has found extensive application in healthcare, particularly in addressing the collaborative challenges and regulatory gaps in current SPD management systems. Taking Dazhou Central Hospital in China as a case study—a "Class III Grade A" comprehensive hospital with a construction area of 100, 000 square meters, serving nearly seven million people in Dazhou and its surroundings, and holding significant influence in the region—the need for improved medical consumables management becomes evident. Integrating blockchain technology with the SPD management model to digitalize and refine consumables management emerges as a pressing need.

2. Research Status

Research indicates that traditional hospital consumables management models suffer from low levels of digitalization, irregular management processes, and high costs, while the SPD model can significantly enhance the precision management of hospital consumables (Li Zhichao, Lu Junying, Chen Xiaojun, & Ke Jia, 2022).

Building upon the SPD model, a consumables management system integrated with blockchain technology incorporates blockchain's inherent features of consistency, immutability, and traceability (Wang Qun, Li Fujian, Ni Xueli, Xia Lingling, & Liang Guangjun), forming a new, trustworthy, secure, and programmable network ecosystem.

While the SPD system and blockchain technology have begun to be applied to hospital consumables management, there is a paucity of research on their integration, particularly in the context of hospitals. The integration of SPD system data onto the blockchain requires concurrent efforts across system architecture, underlying algorithms, and supply chain data coordination, presenting certain challenges but also representing a highly forward-looking area of research.

3. Technical Architecture Proposal

The technical architecture of the proposed system will leverage the existing technological resources of the project team. The SPD system will employ a hybrid design combining Browser/Server and Client/Server structures, where the client side will function through a web browser. This setup will be augmented with AJAX technology and various scripting languages to enhance interactivity and enable real-time partial page updates. Moreover, the project will develop a blockchain interface, incorporating encryption algorithms to securely integrate the hash values of the underlying database data into the blockchain infrastructure.

4. System Development

The development of the system encompasses the design of the user interface, the integration of blockchain encryption interfaces, and the

development of various functional modules.

4.1 User Interface Design

To facilitate distributed operations, the SPD system will be embedded within the hospital's existing web portal, accessible via the homepage of the official website. The interface design will align with the portal's color scheme, adopting a streamlined and dignified aesthetic to enhance visual coherence and user experience. A sample of the system interface is depicted in Figure 1.

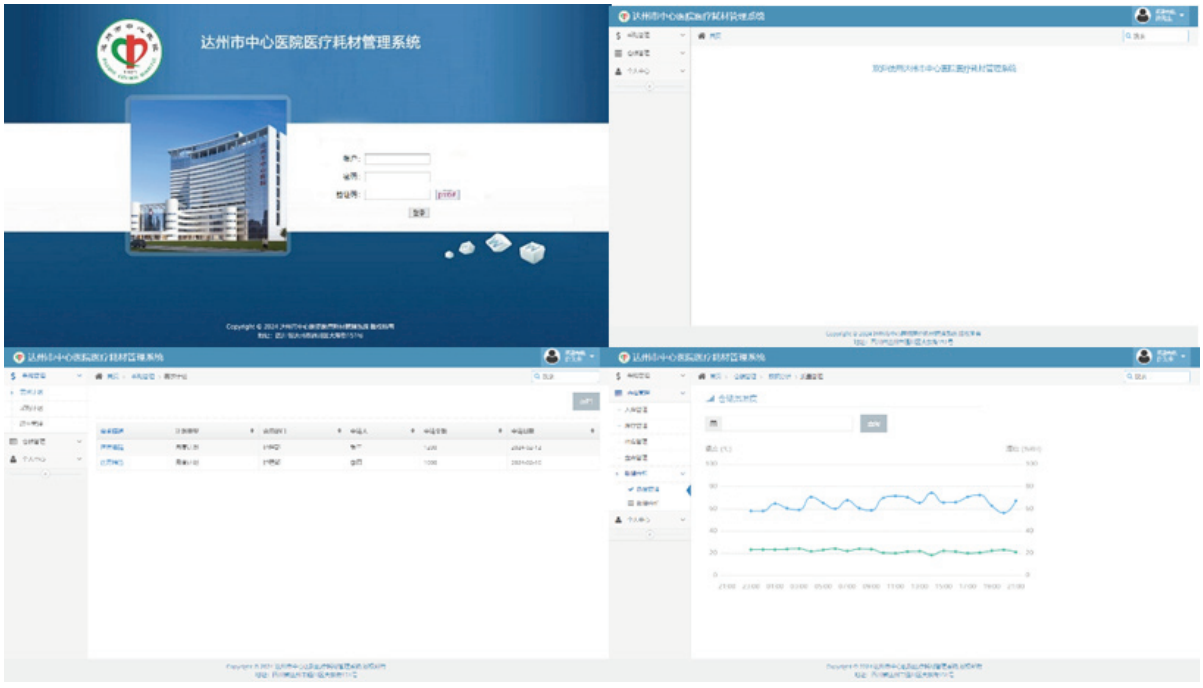

Figure 1. System interface

4.2 Blockchain Encryption Interface Design

This project will develop a blockchain-compatible smart encryption algorithm tailored to the hospital's needs. Data encryption will be performed on the hospital's servers, with the resulting hash values returned to an external blockchain infrastructure. The blockchain system will monitor these hash values for any alterations, thereby achieving both anti-counterfeiting and data protection. Moreover, the encryption interface in this study employs asymmetric encryption techniques, utilizing paired public and private keys to encrypt and decrypt medical consumables data.

4.3 Smart Contract Design

Smart contracts are a pivotal component of blockchain systems, for the hospital's SPD scenario, the objective is to enhance system transparency, security, and efficiency through automated business processes and data management.

4.3.1 Contract Content Design

4.3.1.1 Role Definition and Permissions Management

The smart contract not only categorizes stakeholders into roles such as hospital, supplier, and regulator but also delves into the specific responsibilities and operational permissions of each role. Fine-grained permissions management ensures that the hospital's procurement department can efficiently create and review orders, suppliers can promptly respond to orders and deliver compliant medical consumables.

4.3.1.2 Automation and Transparency in Business Processes

Smart contracts are integral to the SPD system, enabling end-to-end automation from order initiation, consumables warehousing, inventory management, usage tracking, to final payment settlement. The incorporation of blockchain technology adds an unprecedented level of transparency, with every transaction and operation recorded in real-time on the blockchain, creating an immutable and traceable data chain.

4.3.1.3 Data Security and Authentication Mechanisms

Data security and authentication mechanisms are foundational to the SPD system. Recognizing the sensitivity of information involved in medical consumables management—such as batch numbers, expiration dates, and supplier credentials—the system implements rigorous data authentication protocols and encryption mechanisms

4.3.2 Execution Logic Design

4.3.2.1 Business Process Orchestration

In the complex system of medical consumables management, the integration of smart contract technology signifies a profound transformation towards intelligent business process orchestration. This advancement automates the entire chain, from procurement requests to order generation, supplier confirmation, logistics verification, inventory updates, and warehouse approvals.

4.3.2.2 Data Recording and Verification

The deep integration of blockchain technology within the SPD system provides unprecedented security and transparency for data recording and verification processes. Blockchain's decentralized and immutable characteristics ensure that every transaction is permanently stored on a distributed ledger, safeguarding data authenticity and integrity. The built-in data verification mechanisms within smart contracts rigorously validate input data, ensuring compliance with business rules and data format requirements.

4.3.2.3 Permission Verification and Invocation

Smart contracts, guided by predefined permission models, rigorously authenticate and verify the identity and permissions of entities attempting to execute specific operations. This mechanism effectively prevents unauthorized access and actions, while blockchain-based identity verification technology further strengthens the authenticity and reliability of the invoking entity's identity.

4.3.2.4 Business Rule Validation

The smart contract's embedded business rule validation logic enables intelligent compliance checks on input data. This mechanism automatically identifies and rejects operations that violate business rules, significantly reducing the occurrence of non-compliant actions and risk events.

4.4 Functional Module Design

Considering the hospital's operational characteristics, the SPD medical consumables management system designed in this project comprises the portal layer, application layer, and data layer.

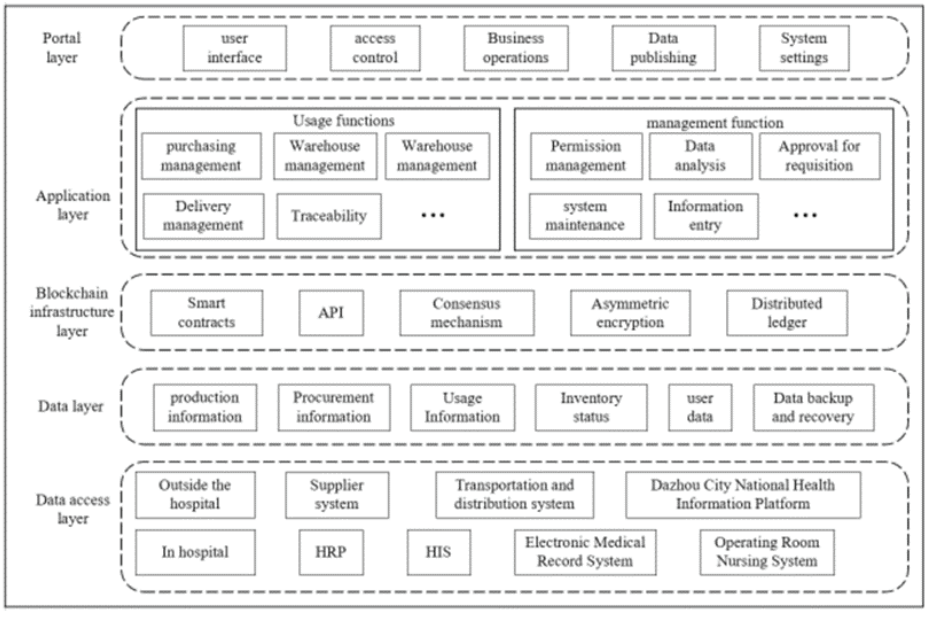

Figure 2. System functional modules

5. System Testing

The testing overview in this evaluation report begins by delineating the primary objective of the performance assessment. The scope of this evaluation is confined to the critical business modules of the new procurement system, including demand management, supply management, and order placement modules. The tools employed for this testing included the cloud-based load testing platform, LoadCloud, and the backend performance monitoring tool, JProfile.

5.1 Key Metrics

The central focus of this test was the verification of critical performance metrics. As illustrated in Figure 3, the primary indicators successfully met the predefined performance objectives.

Index	Expectations	Test result	Compliance status
Page response time	≤1s	0.8s	Meet the standard
Transaction throughput	≥1000/s	1200/s	Meet the standard
Concurrent support	≥5000	6000	Meet the standard
Error rate	≤1%	0.5%	Meet the standard

Figure 3. Test results

5.2 Performance Under Load Testing

Under conditions of significant load, the system exhibited the following performance characteristics:

With a concurrency level of 5, 000 users, the average response time remained stable at approximately 0.9 seconds.Throughput demonstrated a steady increase in correlation with the rise in concurrent user numbers, with no notable bottlenecks observed.CPU utilization stayed within normal parameters below 80%; however, once it reached 90%, the system began to experience queuing delays.No instances of service unavailability were recorded.Overall, the system performed admirably under stress, showcasing its scalability.

5.3 Stability Verification

During a 24-hour continuous stress test, the system's stability was confirmed as follows:

The average response time was 1.2 seconds, with fluctuations maintained within a range of 1 to 1.5 seconds.The average throughput rate stabilized at 1, 108 transactions per second, with variations kept under 5%.No incidents of system crashes or restarts were encountered.The system demonstrated consistent and reliable operation.

6. Conclusion

The testing results indicate that each functional module of the system operates effectively. This study has not only established the theoretical foundations and technical architecture of the system but has also thoroughly addressed the practical needs and workflows of the hospital's various departments. The findings confirm that the system significantly enhances the efficiency, anti-counterfeiting capabilities, and information management within the hospital, providing robust support for improving the hospital's overall management capabilities and strengthening its core competitiveness.

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