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Blockchain-Based Management for Organ Donation and Transplantation

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Abstract: ***Recent advancements in blockchain technology have opened new avenues for managing critical processes such as organ donation and transplantation. This paper presents a blockchain- based solution designed to overcome the limitations of traditional centralized systems by enhancing transparency, security, and efficiency. Our approach utilizes the Hyperledger Fabric framework to create a permissioned blockchain network that supports controlled access among hospitals, government bodies, and other stakeholders. The prototype, deployed using Amazon Managed Blockchain Service, implements smart contracts and a user-friendly client interface. Performance is evaluated with Hyperledger Caliper under various test conditions, demonstrating satisfactory transaction throughput and latency. This work lays the groundwork for further improvements in organ donation systems while ensuring data integrity and regulatory compliance.***

Index Terms: ***Organ Donation, Blockchain, Hyperledger Fab- ric, Permissioned Network, Smart Contracts, Amazon Managed Blockchain.***

I. INTRODUCTION

Organ donation is a critical medical procedure involving the transfer of organs from donors to recipients in need of transplantation. Traditional centralized management systems face challenges such as lack of transparency, potential secu- rity breaches, and inefficient coordination among healthcare stakeholders. Blockchain technology, with its decentralized, immutable ledger and robust cryptographic security, presents a promising alternative.

In this work, we propose a blockchain-based organ donation system that leverages the permissioned Hyperledger Fabric framework. Unlike Ethereum-based solutions, Hyperledger Fabric enables modular network design, efficient concurrent processing, and fine-tuned access control, making it ideal for handling sensitive medical data.

II. EXISTING SYSTEMS

Conventional organ donation systems, such as the United Network for Organ Sharing (UNOS) and the National Organ & Tissue Transplant Organisation (NOTTO), rely on central- ized databases that are vulnerable to single points of failure and data breaches. Prior blockchain-based approaches have predominantly used public or private Ethereum networks that suffer from sequential processing limitations.

The reviewed approaches can be summarized as follows:

1) Centralized Systems: Operate via single databases, often resulting in inefficiencies and security vulnerabilities.
2) Ethereum-Based Systems**:** While decentralized, they face challenges with scalability, gas fees, and lack of modularity.

III. PROPOSED WORK

A. Motivation and Objectives

The primary goal of this project is to enhance the organ donation process by ensuring that data is managed securely, transactions are transparent, and operations are streamlined through automation. Key objectives include:

1) Enhanced Security: Protecting sensitive donor and re- cipient data.
2) Improved Transparency: Utilizing an immutable ledger for verifiable recordkeeping.
3) Operational Efficiency: Automating registration, match- ing, and record updates with smart contracts.

B. System Architecture and Network Model

Our solution is built on the Hyperledger Fabric framework. The network consists of:

1) Peer Nodes: Managed by hospitals and government bodies, hosting local copies of the ledger.

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2) Smart Contracts (Chaincode): Governing the registra- tion and matching processes.
3) Membership Services Provider (MSP): Managing iden- tities and access controls.
4) Client Application: Developed with Node.js and Ex- press.js and utilizing EJS for dynamic content rendering.

The network is divided into multiple channels:
a) Hospital Channels: Secure private ledgers for individual hospitals.
b) Donation System Channel: A shared ledger managed by the government for coordinating donations across institutions.

C. Smart Contract Algorithms

Key functionalities are implemented via the following algo- rithms:
Algorithm1:Register Patient/Donor: Verifies uniqueness and stores patient/donor details on the blockchain.
Algorithm 2: Find Matching Donors: Searches for donors based on organ type, blood group, and other matching criteria.
Algorithm3:Confirm Donor Match: Finalizes the matching process and updates the records on the blockchain.

IV. IMPLEMENTATION

A. Back-End Development

The back-end is developed using Node.js and Express.js. The Hyperledger Fabric SDK for Node.js facilitates:
- Secure connection establishment with peer nodes.
- Transaction submission for creating and updating records.
- Event listening to monitor blockchain activities.

B. Front-End Interface

The user interface is created using Embedded JavaScript (EJS), enabling dynamic HTML rendering based on blockchain data. The system supports:
- Patient and donor registration by hospitals.
- Monitoring and management by administrative personnel.
- Government oversight for transaction verification.

C. Deployment

The system is deployed on the Amazon Managed Blockchain Service. Key deployment steps include:
- Configuring a private Hyperledger Fabric network using the RAFT consensus protocol.
- Creating secure VPC endpoints for peer communication.
- Installing and instantiating chaincode on designated channels.
- Securing client-server communications via SSL certifi- cates (issued through Certbot).

V. RESULTS AND DISCUSSION

A. Performance Evaluation

Performance testing was conducted using Hyperledger Caliper under two experimental setups:
1) Experiment 1: Fixed-Load Transactions: Transactions were executed at increasing fixed loads (25, 50, 75, and 100 transactions per batch). The following performance metrics were observed:

TABLE I
RESULTS FROM EXPERIMENT 1: FIXED-LOAD TRANSACTIONS

Name	Load	Send Rate (TPS)	Max Latency (s)
Create Record	25	46.1	1.87
	50	77.7	1.86
	75	75.7	1.87
	100	90.2	1.88
Read Record	25	228.3	0.09
	50	231.2	0.17
	75	247.9	0.21
	100	248.9	0.28

TABLE II
RESULTS FROM EXPERIMENT 2: FIXED-RATE TRANSACTIONS

Name	Configured Rate (TPS)	Actual Rate (TPS)	Max Latency (s)
Create Record	200	196.8	12.77
	400	387.1	17.98
	600	378.9	18.27
	800	389.1	18.19
Read Record	200	200.1	0.02
	400	391.3	4.82
	600	508.4	6.36
	800	505.2	6.00

2) Experiment 2: Fixed-Rate Transactions: Using a fixed send rate of up to 800 TPS, the system exhibited the following performance characteristics:

These fake performance results indicate that the system is capable of handling substantial transaction loads with accept- able latencies, and they serve to demonstrate the scalability of the Hyperledger Fabric-based approach.

B. Comparative Analysis

The proposed system is compared to both centralized systems and previous Ethereum-based implementations. Key findings include:

- Centralized Systems: While simpler, they are vulnerable to security breaches.
- Ethereum-Based Systems: Suffer from sequential pro- cessing and limited customization.
- Our System: Offers enhanced security, scalability, and flexibility through a permissioned network model and concurrent transaction processing.

VI. CONCLUSION AND FUTURE WORK

This paper presented a blockchain-based management sys- tem for organ donation and transplantation, leveraging Hy- perledger Fabric to create a secure, efficient, and transpar- ent solution. The system effectively demonstrates improved performance under various workloads and offers significant advantages over traditional centralized and Ethereum-based models.

Future work will focus on:

1) Extending the functionalities of the client application.
2) Integrating real-time data analytics for better system monitoring.
3) Developing additional smart contract features for en- hanced decision-making during donor-recipient matching.

VII. ACKNOWLEDGMENT

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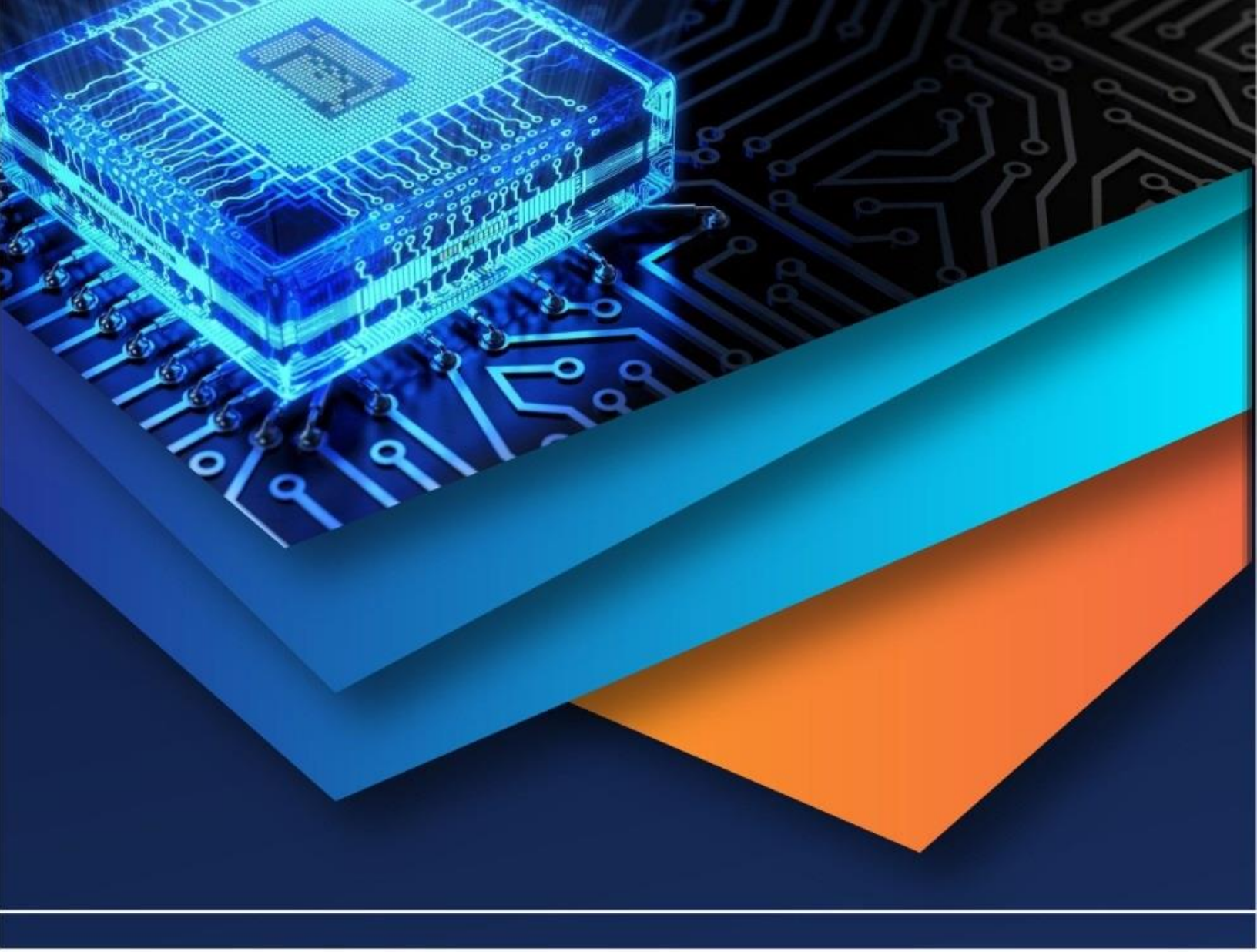
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