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Performance Evaluation of Blockchain-Based Human Resource Management Systems for Effective Organisational Performance Using Smart Contracts

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Abstract

This study conducts a performance evaluation of a blockchain-based Human Resource Management System (HRMS) utilizing smart contracts to enhance organizational efficiency and scalability. Despite blockchain's transformative potential through decentralization, transparency, and immutability, empirical research on its scalability for large-scale HRMS applications remains limited. This research addresses this gap by designing, implementing, and testing a blockchain-based HRMS prototype with a simulated dataset of 5000 users across five core HR modules: recruitment, employee management, payroll, leave, and exit/retirement. Leveraging the Ethereum development network, Solidity for smart contract development, and Hyperledger Caliper for performance benchmarking, the study evaluates transaction latency and throughput under escalating transaction loads (5 to 5000 transactions). Results demonstrate exceptional scalability, with consistently low average latency (0.07 - 2.11 seconds) and high throughput (2.4 - 78.1 TPS), affirming the system's robustness for high-volume HR operations. The findings provide evidence-based insights and recommendations for designing scalable blockchain solutions, contributing to advanced HR practices and organizational performance optimization.

Keywords

Blockchain, Human Resource Management System, Smart Contracts, Performance Evaluation, Organizational Performance, Scalability

1. Introduction

Effective management of Human Resources (HR) is vital for organizational suc-

cess. As the world progresses in the digital era, integrating new technologies with improved HRM principles becomes imperative to maintain core competitiveness (Bisht et al., 2022). However, challenges including data reliability, privacy breaches, applicant verification, skill authentication, talent management, and scalability limitations persist. These issues can lead to inefficiencies, such as inaccurate employee records or fraudulent qualifications, undermining organizational performance and trust.

Blockchain technology, characterized by its decentralized ledger system, ensures data immutability, eliminates intermediaries, and enhances transparency, making it an ideal solution for addressing HRMS challenges (Madhani, 2023). Smart contracts, self-executing programs deployed on blockchain platforms like Ethereum, automate HR processes, improving efficiency, transparency, and trust (Almakhour et al., 2020). Research by Fachrunnisa and Hussain (2020) highlights blockchain's potential to streamline recruitment, certificate verification, and performance evaluation, while Adel et al. (2022) demonstrated its efficacy in data sharing and transparency with a small user base of five users, achieving an 85% success rate using the System Usability Scale (SUS). However, these studies lack comprehensive empirical evaluations of scalability for large user bases, limiting their applicability to real-world organizational contexts.

Ethereum is recognized as a leading platform for smart contract deployment due to its flexibility, robust ecosystem, and support for decentralized applications (DApps) (Huang et al., 2021). Hyperledger Caliper, a benchmarking framework, is acknowledged for its ability to measure blockchain performance metrics, including latency, throughput, and resource consumption, across various platforms (Choi & Hong, 2021).

This project evaluates the performance and scalability of a blockchain-based HRMS using smart contracts, addressing the research question: Can a blockchain-based HRMS proficiently scale to manage extensive data and intricate processes inherent to HRM, and does it exhibit satisfactory performance under high-volume input and output operations? Building on Adel et al.'s (2022) study, which reported an 85% success rate for a blockchain-based HRMS with a small user base (five users), this research extends the evaluation to a simulated dataset of 5,000 users. By employing the Ethereum development network and Hyperledger Caliper, the study provides empirical insights into the system's performance across five critical HR functions—recruitment, employee management, payroll, leave, and exit/retirement—offering a foundation for scalable blockchain solutions in HRM.

The rest of the paper is structured as follows: section 2 summarizes reviews of existing literature; section 3 highlights the research methods; section 4 provides a detailed overview of the design, integration, testing, and validation of a blockchain-based HRMS prototype with a smart contract model designed; section 5 reports the evaluation of the performance of this system in terms of enhancing organizational performance; section 6 presents the conclusion and future work.

1.1. Motivation

The motivation for this study arises from the critical role of HRM in organizational success and the limitations of traditional HRMS in addressing data reliability, privacy, and scalability. Blockchain's attributes—decentralization, transparency, and security—offer significant potential to revolutionize HR processes, including recruitment, training, performance evaluation, and data sharing. However, the scarcity of comprehensive empirical studies on the scalability of blockchain-based HRMS for large user bases represents a critical research gap. This project aims to address this gap by evaluating the system's performance with a substantial dataset, providing actionable insights into designing adaptable blockchain solutions for organizations of varying sizes, ultimately enhancing data reliability, informed decision-making, and organizational performance.

1.2. Research Question and Hypotheses

Is the blockchain-based HRMS proficient in scaling and effectively managing the extensive amounts of data and intricate processes inherent to HRM? Furthermore, does the system exhibit satisfactory performance when subjected to the demanding conditions of high-volume input and output operations, meeting the demands of an HRM environment?

With the research questions, the following hypotheses are proposed for the project:

H1: The blockchain-based HRMS using smart contracts will show increasing throughput in handling an increasing number of transactions, revealing scalability for large user bases.

H2: The system will maintain stable, low-latency performance during high system loads, supporting efficient HRM operations with large data sets.

1.3. Objectives

- Conduct a comprehensive review of the existing literature on blockchain-based HRMS within the HRM domain.
- Design and implement a smart contract model for a blockchain-based HRMS prototype, incorporating five core HR modules.
- Evaluate system performance using Hyperledger Caliper, focusing on transaction latency and throughput across recruitment, employee management, payroll, leave, and exit/retirement modules.
- Analyze scalability under high-volume transaction loads to provide evidence-based recommendations for blockchain adoption in HRM.

2. Literature Review

The literature review synthesizes research on HRM, organizational performance, and the integration of blockchain technology into HRMS.

2.1. Human Resource Management and Technology

HRM takes a strategic approach within the social and organizational context to

effectively handle employees, nurturing their commitment and capabilities. HRM encompasses four key functions: staffing (recruitment, compensation, and retention), performance management (training, rewards, and labour relations), change management (employee involvement, conflict resolution), and administrative activities (record-keeping, legal compliance) (Adel et al., 2022).

The rapid growth of society is fueled by advancements in information technology, with HR serving as the primary driving force (Bisht et al., 2022). Debter (2020) emphasized the importance of technology in HRM, stating that the future of HRM depends on it. To maintain core competitiveness, modern HRM must integrate new technologies with improved HRM principles, optimizing techniques to enhance the efficiency and impact of managing HR (Kandpal et al., 2023; Wang et al., 2017).

While various solutions and technologies address HR demands, integration often remains lacking. Blockchain technology has the potential to streamline job information and credential verification, saving time, resources, and costs. The unique qualities of blockchain technology hold great value in HRM (Yi et al., 2020; Anaam et al., 2023).

2.2. Blockchain Technology

In the current era of technology, organizations deal with substantial amounts of data. Various departments, such as HRM, have their own data sets that need to be stored for future reference. This vast amount of data plays a crucial role in supporting decision-making processes within the organization. To ensure a fair, unbiased, open, and transparent work environment, it is important to adopt measures that promote these values. Blockchain technology comes into play by storing this data in a decentralised manner with transparency.

Blockchain technology, also referred to as distributed ledger technology, is a decentralised system that effectively manages and records transactions. It operates within a peer-to-peer network, where transaction data is replicated across all network nodes. This replication ensures that the information remains unalterable, except through operations that require approval from most nodes. Blockchain possesses a fundamental characteristic of decentralisation, an attribute exceptionally difficult to replicate using alternative technologies (Choi et al., 2020; Pinna et al., 2020). This enables organizations to utilise the data to enhance their performance and make informed business decisions, ultimately aiding in the achievement of their goals and targets, leading to success Blockchain, an emerging disruptive technology, has the potential to revolutionise Information and Communication Technology (ICT) services and reshape businesses (Joshi, 2020; Martinez et al., 2019). With organizations handling vast amounts of data, including in HRM, blockchain offers a decentralized and transparent approach to data storage, enabling informed decision-making and fostering a fair and unbiased work environment. By adopting blockchain, organizations can strive toward achieving their goals and overall

success.

- **Platforms for Blockchain**

A blockchain platform is the technology required for a blockchain's operation, including client software, local data stores, and alternative clients for network access (Xu et al., 2019).

- **Hyperledger**: This is a blockchain implementation platform used to develop enterprise applications for participating parties, particularly in supply chain contexts. It operates with open-source, open standards, and transparent governance mechanisms. Hyperledger offers modular frameworks and tools that can be integrated together, with Hyperledger's Fabric blockchain being widely used for private permissioned blockchains (Zhang & Anand, 2022).
- **Ethereum:** This is an open-source blockchain platform that facilitates the creation and implementation of decentralised systems supporting smart contracts. It enables the deployment of permanent and unalterable decentralised applications, which users can interact with. Ethereum allows participants to establish their own ownership and operational rules, providing an alternative protocol for building efficient and secure decentralised applications. Ethereum is widely acknowledged as a prominent blockchain platform for executing smart contracts (Huang et al., 2021).

2.3. Smart Contracts

Smart contracts are computer programs that enforce and execute the terms of a contract, eliminating the need for a trusted third party. They operate within decentralised blockchain networks, providing deterministic, auditable, and verifiable contracts (Almakhour et al., 2020). Solidity, a high-level language, is commonly used for creating smart contracts on the Ethereum blockchain platform (Pal & Singh, 2019).

Smart contracts, written in programming languages, are deployed through network transactions. On Ethereum, recipient-less transactions are used for smart contract deployment. Once deployed, a smart contract receives its own address and can be called by sending transactions with code and parameters. They enable storing and documenting transactions in a shared ledger, reducing the risk of ledger loss (Saingre et al., 2020).

Research on smart contracts involves development and evaluation. Development includes creating contracts and platforms like Ethereum. Evaluation involves code analysis and performance assessment, recognizing the importance of efficient execution. As blockchain technology advances, smarter contract-based applications gain traction (Wang et al., 2018). Blockchain simplifies contract creation, allowing users to formalize trust relationships and agreements. Platforms like Ethereum automate contract execution, replacing intermediaries and trusted third parties, and facilitating economic activities (Cong & He, 2019).

2.4. Blockchain Technology in Human Resource Management (HRM)

Several studies have examined the fusion of blockchain technology with HRM from different perspectives. Some propose that blockchain will transform how HRM employs, trains, and evaluates employee performance, while others suggest it will enhance the efficiency of social networks and reduce trust-building costs within organizations.

Onik et al. (2018) conducted a comprehensive literature review to explore the potential contributions of blockchain technology in HRM, aiming for a smart, cost-effective, efficient, transparent, and secure system in preparation for "Industry 4.0". Their proposed solution, the Blockchain-based Recruitment Management System (BcRMS) and Blockchain-based HRMS (BcHRMS) utilising the MultiChain 2.0 blockchain platform, aimed to verify and securely store recruitment and HRM-related information without the need for intermediaries. However, the study did not develop a fully functional real-time application or undergo verification, dynamic updates, and system learning.

Jeong and Choi (2019) presented a blockchain-based platform for certificate management, applicable for performance assessment during the recruitment process and evaluating applicants' qualifications, career management, and work history. They implemented a digital certification issuance platform using Ethereum blockchain and Bitcoin support with emphasis on the transparency and tamper-proof nature of blockchain-based certification, allowing applicants to provide evidence of their competencies through a digital backpack. Nevertheless, the study does not discuss the scalability and potential challenges in real-world implementation of the proposed platform.

Dhanala and D. (2020) emphasized the efficacy of blockchain in verifying and securing data, presenting a recruitment system that utilized smart contracts, Ethereum, MySQL, and Hyperledger software. Their system involved submitting candidate lists to a blockchain-based platform, which automatically verified candidate information from relevant databases. Approved and verified data were stored on the blockchain, enabling the company to evaluate and proceed with the recruitment process. However, the adoption of their proposed method, including a proof-of-work mechanism, led to increased expenses for data protection against potential attacks.

Shawon et al. (2021) introduced a Decentralized Application (DApp) called DIUcerts for verifying educational certificates. Their blockchain-based educational system simplified the issuance, review, and validation of academic credentials. By eliminating the need for central data storage and relying on the Ethereum platform, each certificate's information remained in its own file. However, the application lacked direct access for organizations without undergoing security testing.

Adel et al. (2022) developed a blockchain-based HRMS incorporating smart contracts with Ethereum. Their project aimed to create an employee profile system capturing skills, education, training, expertise, and achievements, while also

establishing an inter-organizational reputation system using smart contracts to track and verify all transactions and employee performance. The system's objectives were to improve job allocation, enable secure data sharing between organizations, foster partnerships, and identify high-performing employees through transaction and task tracking. The system was tested with a small group of 5 users, merging discount usability engineering and Rapid Iterative Testing and Evaluation (RITE) principles. The evaluation through the System Usability Scale (SUS) model yielded an 85% success rate. While these results were encouraging, future investigation with a larger user base is vital to assess blockchain's HRMS efficacy at scale. The limited research on blockchain HRMS scalability and efficiency when handling larger user loads necessitates further exploration, especially considering organizational growth and complexity over time.

An important area that needs more research involves examining how blockchain technology handles and processes user data in large-scale HRMS. Empirical studies and real-world applications are lacking, hindering the understanding of blockchain's effectiveness in this context. This gap raises questions about blockchain scalability, potential bottlenecks with increased transactions and data, and how blockchain-based HRMS performs as user numbers increase. Additionally, the impact of a larger user base on transaction throughput, scalability, and latency in blockchain-based HRMS requires more investigation. This knowledge is vital for organizations considering blockchain adoption in their HRMS, as it directly impacts the system's overall performance, efficiency, and usability.

The scalability and performance of blockchain-based HRMS are crucial factors for successful implementation and adoption in organizations. As organizations develop in size and complexity, there is a need for the HRMS to accommodate a larger number of workers, applicants, and other stakeholders. With the capability of blockchain technology to store and handle enormous volumes of HR-related data, it is crucial to evaluate how these systems operate as the volume of data and the number of users increase.

3. Methodology

The research applied positivist philosophy and a deductive approach, built from Adel et al. (2022) findings to prove blockchain-based HRMS scalability by testing a 5000-user simulated dataset. The research used quantitative experimental methods which followed the research onion framework (Saunders et al., 2012) to create a complete and organized research design. The positivist approach needs statistical methods to generate unbiased results that apply to all cases, while the deductive method uses established hypotheses from previous research to confirm and expand existing knowledge.

The artefact was designed as a blockchain-based HRMS prototype with essential modules: recruitment, employee management, payroll, leave management, and exit/retirement. The frontend development used the React JS framework for building the application, while Solidity handled smart contract development and

Ganache served as the Ethereum-based prototype for local development and testing. The Hyperledger Caliper tool performed performance benchmarking through simulated transactions, which operated on a 5000-user dataset.

The Solidity and JavaScript programmatic process created a simulated dataset which produced 5000 user records that duplicated actual HRM information in a structured format. The programmatic data generation process in Solidity and JavaScript created structured records that represented 5000 users' HRM information through a scripted process. The dataset expanded from 5 to 5000 records to evaluate how well the system handled different HR operations, including recruitment, employee management, payroll, leave management, and exit/retirement. The data generation process created different data types and volumes that mimic actual organizational environments to prove its ability to evaluate performance.

The system used Hyperledger Caliper to evaluate performance through simulated transaction testing on the dataset, which measured latency and throughput at various transaction levels.

4. System Design and Implementation

The blockchain-based HRMS prototype was designed following industry-standard software development practices, adopting a modular, layered architecture to ensure scalability, maintainability, and high performance. The system comprises three interconnected layers, each serving distinct functions critical to the HRMS's operation:

1) Application Layer: Provides a user-friendly interface for HR managers, employees, and other stakeholders to interact with the system, facilitating data input, retrieval, and visualization. The interface prioritizes usability with strategically placed action buttons, intuitive navigation bars, and well-centered forms. Lightweight design libraries were selected to minimize bandwidth requirements, aligning with the project's focus on scalability and performance optimization. Accessibility features, such as a responsive design for various devices, were incorporated to ensure inclusivity.

- **Implementation**: Developed in Visual Studio Code using ReactJS, a JavaScript library for building component-based user interfaces, the frontend adopts a Single-Page Application (SPA) design for each of the five HR modules—recruitment, employee management, payroll, leave, and exit/retirement. This design enables users to create records and view them in a tabular format on the same page, enhancing usability and efficiency.
- **Integration**: The frontend connects to the blockchain network via MetaMask, a browser extension that facilitates secure interactions with Ethereum accounts. MetaMask validates network connections using account addresses and private keys, ensuring authenticated access to the smart contract layer. The integration supports seamless transaction confirmation, with users signing transactions to record data on the blockchain.

2) Smart Contract Layer: Summarises the business logic for HR processes, ensuring data validation, secure transaction recording, and automation on the blockchain. The smart contracts emit events upon successful transaction processing, enabling real-time monitoring and transparency. Validation rules are configurable for each function, ensuring data integrity before blockchain storage. The layer supports cross-module interactions, enhancing system interoperability.

- **Implementation**: Developed in Solidity, a high-level programming language optimized for Ethereum smart contracts, this layer includes dedicated smart contracts for each HR module. The contracts are organized in a single, well-commented Solidity file for ease of navigation, maintenance, and auditing. Each module's smart contract is tailored to specific HR processes, with rigorous validation rules to ensure data integrity:
  - **Recruitment Smart Contract**: Validates and stores applicant data, including name, qualifications, work experience, and contact details, ensuring that mandatory fields are complete before recording transactions. The contract supports large-scale hiring by storing immutable applicant records.
  - **Employee Smart Contract**: Manages comprehensive employee records, capturing essential data such as first name, last name, phone number, location, position, department, and employment status. Validation rules ensure data consistency and accuracy.
  - **Payroll Smart Contract**: Processes complex financial transactions, including salary payments, tax deductions, benefits, and bonuses, with rigorous validation to ensure compliance with financial regulations. The contract supports periodic high workloads, which are critical for payroll processing.
  - **Leave Smart Contract**: Records and validates leave requests, with cross-module synchronization to verify employee data against existing records, thus enhancing data consistency.
  - **Exit/Retirement Smart Contract**: Handles employee resignations and retirements, capturing essential data such as exit date and reason, with minimal validation due to its infrequent use. The contract ensures accurate record-keeping for end-of-employment processes.
- **Deployment**: Smart contracts were developed and tested in Remix IDE before deployment using Truffle. Migration commands generated JSON ABI files for network integration. The Ganache tool simulated a local Ethereum network, providing 10 preloaded accounts, each with 100 ETH, for transaction validation. Each transaction requires manual approval via MetaMask, deducting ETH from the account balance and ensuring secure and auditable operations.
- **Integration**: The backend interfaces with the frontend via MetaMask, which validates connections using account addresses and private keys. The smart contract layer emits events upon successful transaction processing, enabling real-time monitoring and transparency. The layer supports cross-module interactions, such as verifying employee data for leave requests, and enhancing system interoperability.

3) Analysis Layer: Benchmarks system performance by measuring transaction latency, throughput, and resource consumption under varying transaction loads, providing quantitative insights into scalability and efficiency.

- **Implementation**: Hyperledger Caliper, a benchmarking framework, was integrated to evaluate the smart contract functions. Hyperledger Caliper was configured to simulate transaction loads ranging from 5 to 5000, emulating real-world HR processes such as applicant profile creation, payroll processing, and leave requests. Configuration files specified workload parameters, including transaction count, duration, worker nodes, and test types.
- **Integration**: Hyperledger Caliper connects to the smart contract layer via the Ethereum Virtual Machine (EVM), with smart contracts converted to EVM bytecode for execution. The test network was deployed using Docker containers, ensuring a stable and reproducible environment for performance analysis. The integration supports smooth interaction between the blockchain network and the benchmarking framework.

The system architecture, illustrated in Figure 1, ensured smooth interaction between the application, smart contract, and analysis layers. The Ganache-simulated Ethereum network provided a secure, decentralized ledger with preloaded accounts, each with an ETH balance for transaction validation. Transactions require manual approval, ensuring secure and auditable operations. The architecture supported core blockchain principles: immutability, decentralization, and accessibility, while maintaining high performance and scalability, which are critical for large-scale HRMS applications.

4.1. Smart Contract Testing

Smart contracts were tested to ensure functionality, reliability, and data integrity. Testing was conducted via command-line queries on the Hyperledger Caliper, integrated with the Ethereum Virtual Machine (EVM), confirming successful deployment and execution. Each smart contract function was invoked using test scripts in Remix IDE, with validation rules verifying data integrity before blockchain storage. Hardcoded sample data were compared with emitted transaction data to validate accuracy. The testing process confirmed that all smart contracts operated as intended, with no errors in data validation or transaction recording. Specific tests included:

- **Unit Testing**: Individual functions were tested for correct execution and event emissions.
- **Integration Testing**: Cross-module interactions were tested to ensure interoperability.
- **Error Handling**: Invalid inputs were tested to confirm proper error handling and rejection.

4.2. End-to-End Performance Testing

Hyperledger Caliper was configured to conduct comprehensive performance

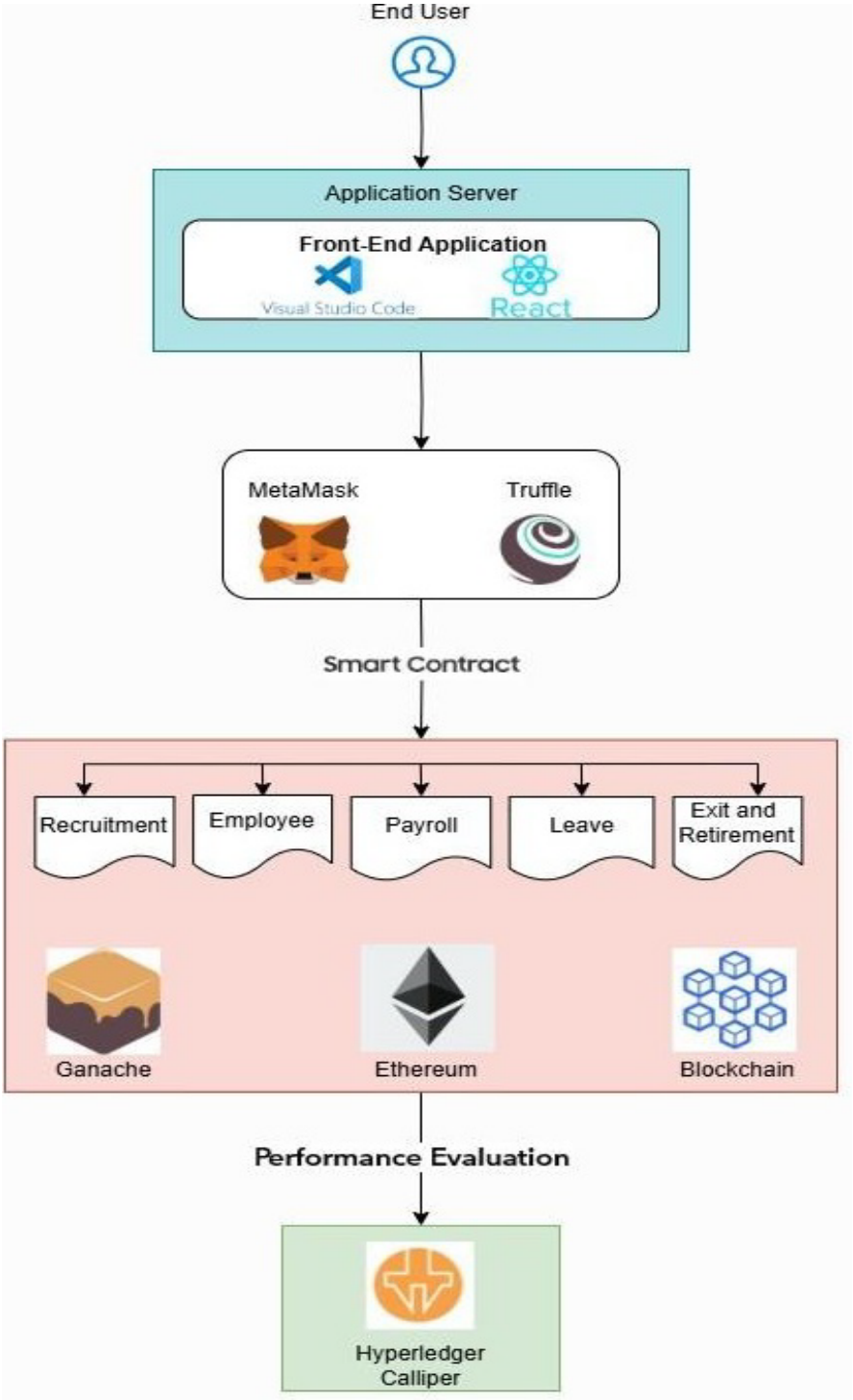

Figure 1. System architecture.

testing, evaluating smart contract functions across transaction loads of 5, 50, 100, 500, 1000, 2000, and 5000. The Ethereum Virtual Machine (EVM) was integrated into the Hyperledger Caliper, integrated with the Ethereum Virtual Machine (EVM), confirming successful deployment and execution. Each, with smart contracts converted to EVM bytecode for execution. The test network was deployed

using Docker containers, ensuring a stable and reproducible environment for performance analysis. The workload configuration file of the Hyperledger Caliper specified key parameters, including:

- **Transaction Count**: Number of transactions to simulate (5 to 5000).
- **Worker Nodes**: Five worker nodes were used to distribute the workload, simulating concurrent user activity.
- **Test Duration**: Specified for read operations to assess retrieval performance.
- **Test Types**: Two phases—record creation (write performance) and record retrieval (read performance).

Hyperledger Caliper measured the following key performance indicators:

- **Success/Failure Rate**: Number of successful and failed transactions, indicating system reliability.
- **Send Rate**: Rate of transaction issuance (transactions per second), reflecting workload intensity.
- **Latency (Min/Max/Average)**: Time to process transactions, measured in seconds from submission to confirmation on the blockchain, indicating system responsiveness.
- **Throughput (TPS)**: Average number of transactions processed per second, indicating system capacity.

Results were generated in an auto-generated report.html file, categorized by transaction load and module, with detailed visualizations to facilitate analysis.

4.3. Performance Evaluation

The performance evaluation analyzed transaction latency and throughput for each HR smart contract module, using Hyperledger Caliper reports. The tested smart contract function for each HR module and the results of the analysis were categorized using the transaction number, with latency and throughput recorded for each round of the test. The Ethereum-based prototype, deployed via Ganache emulation, was tested across loads from 5 to 5,000 transactions, with results summarized in Table 1.

Table 1. Testing with 5, 50, 100, 500, 1000, 2000, and 5000 simulation records.

Name (Smart Contract)	Succ	Fail	Send Rate (TPS)	Max Latency (S)	Min Latency (S)	Avg Latency (S)	Throughput (TPS)
Recruitment Records	5	0	2500.0	2.08	2.07	2.08	2.4
Employee Records	5	0	2500.0	2.09	2.09	2.09	2.4
Payroll Records	5	0	5000.0	2.11	2.11	2.11	2.4
Leave Application Records	5	0	5000.0	2.08	2.08	2.08	2.4
Exit and Retirement Records	5	0	2500.0	2.09	2.09	2.09	2.4
Recruitment Records	50	0	82.8	0.15	0.04	0.08	75.1
Employee Records	50	0	82.6	0.15	0.04	0.08	78.1

Continued

Payroll Records	50	0	82.6	0.15	0.04	0.08	77.5
Leave Application Records	50	0	82.9	0.16	0.04	0.09	76.5
Exit and Retirement Records	50	0	83.3	0.15	0.04	0.08	78.1
Recruitment Records	100	0	80.0	0.15	0.03	0.07	77.9
Employee Records	100	0	80.3	0.17	0.04	0.08	77.8
Payroll Records	100	0	79.1	0.17	0.03	0.08	77.2
Leave Application Records	100	0	79.8	0.14	0.04	0.08	77.1
Exit and Retirement Records	100	0	79.7	0.15	0.03	0.08	74.3
Recruitment Records	500	0	77.6	0.16	0.03	0.08	77.2
Employee Records	500	0	77.2	0.15	0.03	0.08	76.3
Payroll Records	500	0	76.4	0.28	0.03	0.10	75.5
Leave Application Records	500	0	77.3	0.16	0.03	0.08	77.0
Exit and Retirement Records	500	0	77.4	0.23	0.03	0.09	76.5
Recruitment Records	1000	0	77.3	0.23	0.03	0.08	77.1
Employee Records	1000	0	77.0	0.39	0.03	0.11	76.9
Payroll Records	1000	0	76.9	0.40	0.03	0.10	76.0
Leave Application Records	1000	0	77.0	0.39	0.03	0.11	76.0
Exit and Retirement Records	1000	0	77.5	0.17	0.03	0.08	77.3
Recruitment Records	2000	0	76.9	0.17	0.03	0.07	76.9
Employee Records	2000	0	76.9	0.20	0.03	0.07	76.6
Payroll Records	2000	0	76.8	0.30	0.02	0.08	76.7
Leave Application Records	2000	0	76.8	0.18	0.03	0.07	76.7
Exit and Retirement Records	2000	0	76.9	0.23	0.03	0.07	76.8
Recruitment Records	5000	0	76.6	0.18	0.03	0.07	76.6
Employee Records	5000	0	76.9	0.24	0.02	0.07	76.8
Payroll Records	5000	0	76.8	0.20	0.03	0.07	76.8
Leave Application Records	5000	0	76.9	0.27	0.02	0.07	76.9
Exit and Retirement Records	5000	0	77.0	0.18	0.03	0.07	76.9

Figure 2 and Figure 3 below, which were generated from the results for each module in Table 1, show charts of a positive correlation between transaction volume, throughput, and latency, along with the highlights on the evaluation of the results.

Figure 2 shows the increase in throughput as the number of simulated transactions generated from the system increased. Figure 3, on the other hand, shows the decrease in latency as transaction numbers increased until it reached a steady point. The system displayed its highest latency during the 5-transaction test,

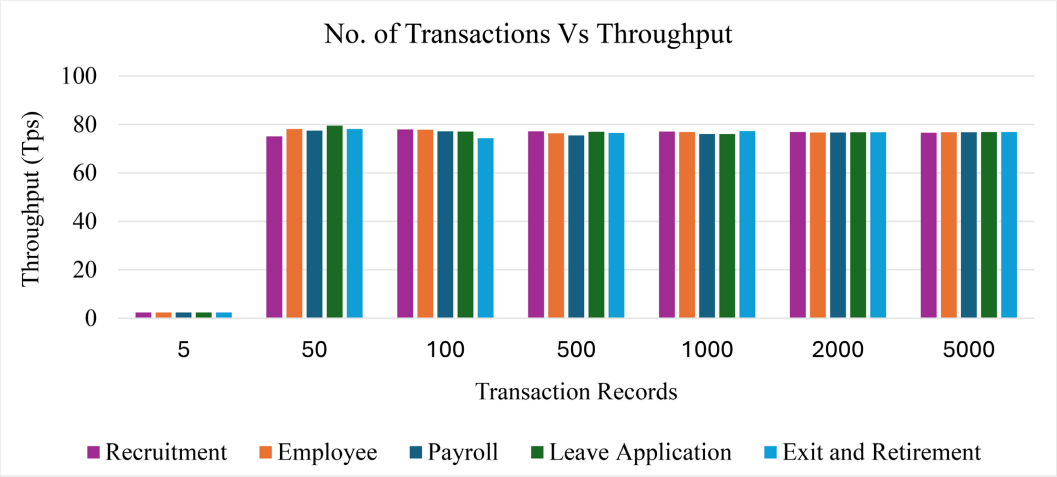

Figure 2. Transactions vs. throughput.

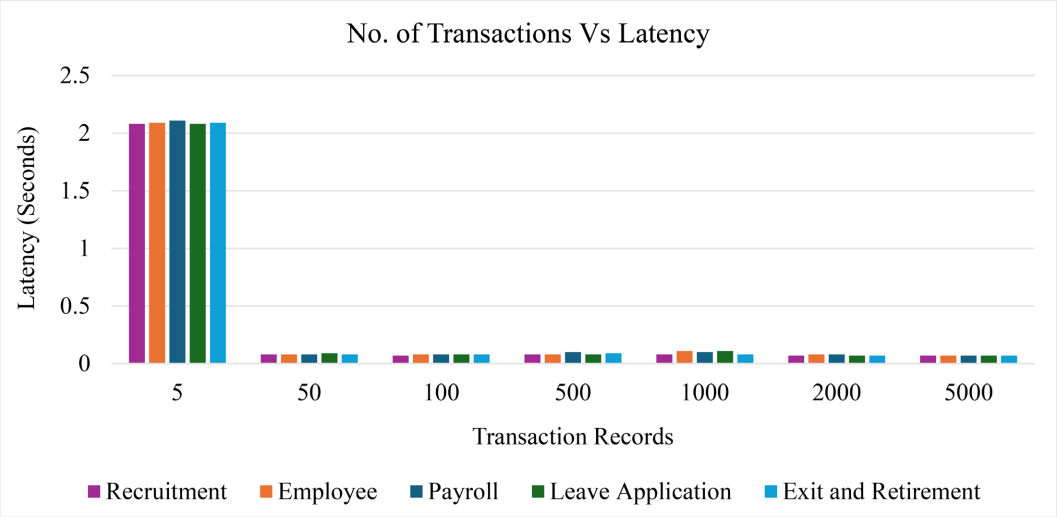

Figure 3. Transactions vs. latency.

attributable to potential system initialization overhead tasks, including contract deployment, Ganache node setup, and emulated resource distribution. The system showed that the initial system overhead diminishes when the transaction numbers increase, resulting in lower average latency.

Furthermore, the blockchain-based HRMS demonstrated remarkable scalability and performance, efficiently handling a simulated dataset of 5,000 users across five core HR modules.

- **Throughput Trends**: The throughput, measured in Transactions Per Second (TPS), exhibited a consistent upward trend across all HR modules as transaction loads increased from 5 to 5000. The modules demonstrated a rise in throughput, increasing from 2.4 TPS at 5 transactions to about 78.1 TPS at 5000 transactions, reflecting their capacity to handle complex financial computations efficiently. The throughput for the modules varies, and this is affected by different conditions in the execution of the smart contract. The payroll and em-

ployee management modules achieved a high throughput range depending on the transaction figures. The high TPS for the employee module underscores its ability to process extensive employee records. Across all modules, throughput increased proportionally with transaction volume, stabilizing at an average of 76.6 - 76.9 for higher loads, indicating healthy system performance under demanding conditions.

- **Latency Stability**: Latency, encompassing minimum, maximum, and average values, remained consistently low and stable across all modules and transaction loads, ensuring rapid transaction processing. The average latency was high for the first 5 transactions, with no significant difference in the average latency values across all modules. There was also a significant rise in the max latency from 500 transactions, with the payroll module showing higher values than other modules. This is followed closely by the exit and retirement module and the leave application module. The minimal variation in latency across all loads underscores the system's ability to maintain quick and responsive performance, which is critical for real-time HR applications.
- **Scalability**: The blockchain-based HRMS demonstrated exceptional scalability, efficiently handling a simulated dataset of 5000 users across all modules without performance degradation. Each module scaled effectively to accommodate increasing transaction volumes, with throughput stabilizing at high levels (76.0 - 78.1 TPS) for the max load of 5000 transactions. The employee management module, as the core component, supported extensive employee databases, reaching 76.8 TPS, making it suitable for large organizations. The recruitment module's scalability, with throughput up to 76.6 TPS, catered to frequent and large-scale hiring needs. The payroll module's ability to achieve 76.8 TPS under high loads ensured reliable processing of periodic financial transactions. The leave and exit/retirement modules, with throughputs of 76.9 TPS, supported less frequent but critical HR processes, confirming the system's adaptability to diverse organizational scales and workloads.
- **Validation and Reliability**: All modules exhibited validation and reliability, with a 100% success rate across all transaction loads, ensuring data integrity and operational dependability. The recruitment module enforced strict validation rules for employee data, preventing inaccurate entries and supporting accurate hiring processes. The employee management module's validation ensured data consistency for comprehensive employee records, which is critical for organizational reliability. The payroll module incorporated validation for financial transactions, ensuring compliance with regulatory requirements and the accurate processing of salaries, taxes, and benefits. The leave module's cross-module synchronization with employee data enhances data integrity, preventing inconsistencies in leave request processing. The exit/retirement module, with minimal validation due to its infrequent use, maintained reliable record-keeping for end-of-employment processes.

The system proved reliable because it maintained continuous operation with

stable latency, which made it suitable for complex HR management operations in large organizations. The system operated at its best when processing large amounts of workloads, which confirmed research results and expanded upon Adel et al.'s (2022) previous study on blockchain-based HRMS success rates by achieving an 85% success rate with five users through scalability tests with a large, simulated user base.

Furthermore, project results demonstrated system scalability through empirical evidence, which solved the problem from previous studies and provided operational procedures for blockchain implementation in HRM systems. Organizations can enhance their performance through efficient HRM operations by using system metrics, which include throughput and latency, for better scalability. The system handles large user numbers without degradation, through its high throughput, which enables fast recruitment and talent management decision-making that boosts productivity while lowering costs. The system also processes transactions at high speed, resulting in fast payroll and leave approval processing that leads to better employee satisfaction and retention, as well as enhanced operational flexibility, which drives organizational success and competitiveness.

The system's modular design, smart contract functionality, and Hyperledger Caliper benchmarking efficiency made it suitable for different organisational contexts. The system demonstrated strong performance when handling high system loads, which validates the research questions and supports the proposed hypotheses while building upon Adel et al. (2022) by validating scalability through simulated user base testing.

5. Limitation

The project used Ganache to create a simulated Ethereum network, which enabled controlled testing but excluded real-world network congestion, variable node latency, and actual transaction costs. The simulation environment fails to demonstrate real-world network congestion, which would result in performance overestimation during actual system operation because peer-to-peer delays and consensus mechanisms could increase latency and reduce system throughput. Simulation models that lack transaction costs could also affect production scalability because organizations with limited budgets might avoid implementing the system. The research needs real-time system testing to prove its results in actual operational environments.

6. Conclusion

This study confirms that a blockchain-based HRMS, using smart contracts, can effectively scale to manage large datasets and complex HR processes, maintaining high performance under high-volume conditions. Through the design, implementation, and testing of a prototype on the Ethereum development network, this research has demonstrated the system's sturdiness in handling a simulated dataset representing 5000 users across five essential HR modules: recruitment, employee

management, payroll, leave, and exit/retirement. Key performance indicators, benchmarked using Hyperledger Caliper, revealed impressively low average latency ranging from 0.07 to 2.11 seconds and high throughput between 2.4 and 78.1 Transactions Per Second (TPS), underscoring the system's responsiveness and capacity to process operations without degradation.

These results not only affirm the viability of blockchain technology for large-scale HR environments but also highlight its potential to mitigate longstanding challenges in traditional HRMS, including scalability bottlenecks. By addressing the critical research gap in empirical scalability evaluations, evident in Adel et al.'s (2022) work, which achieved an 85% success rate but only with a mere five users, this work provides a solid foundation for designing adaptable blockchain solutions and offers evidence-based recommendations for organizations to improve HR practices, data integrity, and organizational performance.

7. Future Work

To advance the practical adoption of blockchain-based HRMS, future work should further explore the practical applications and scalability of blockchain-based HRMS in real organizational settings, potentially involving more complex HR processes and larger user bases. Conducting real-world implementations and gathering data from live HRMS deployments could provide valuable insights into performance under actual usage conditions. Future work can also conduct usability testing with real HR professionals to refine the interface, ensuring alignment with practical HR needs and enhancing user adoption.

This study establishes a solid groundwork for advancing blockchain's practical application in HRM, promising significant improvements in organizational performance, transparency, and data-driven decision-making. By addressing scalability, performance, and practical challenges, the research not only paves the way for future innovations in blockchain-based HR solutions but also inspires a shift toward decentralized, resilient systems that empower organizations to thrive in an increasingly global landscape.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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