



# Secure Seaport Management System using Blockchain Technology

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(Received 21 January 2023; accepted 30 August 2023)

<https://doi.org/10.22153/kej.2023.08.001>

## Abstract

Worldwide, shipping documents are still primarily created and handled in the traditional paper manner. Processes taking place in shipping ports as a result are time-consuming and heavily dependent on paper. Shipping documents are particularly susceptible to paperwork fraud because they involve numerous parties with competing interests. With the aid of smart contracts, a distributed, shared, and append-only ledger provided by blockchain technology allows for the addition of new records. In order to increase maritime transport and port efficiency and promote economic development, this paper examines current maritime sector developments in Iraq and offers a paradigm to secure the management system based on a hyper-ledger fabric blockchain platform. The performance evaluation of the proposed system implies two scenarios: one organization and two organizations by examining throughput and latency. High transaction transmission rates on large block sizes produced positive results. Similarly, employing a small block size and higher send rates results in poor performance. Additionally, it was noted that throughput will decrease and latency will rise as the number of organizations increases. Block size and block timeouts should be high in applications with many concurrent transactions in order to maintain good throughput.

**Keywords:** Hyper ledger Fabric, Caliper Fabric, Maritime, Seaport Management, Port Community System.

## 1. Introduction

The backbone of a nation's foreign trade and its entryways into the globe are its ports. Along with playing a crucial role in accelerating the process of economic development, they are seen as the key link in the multimodal transport system. However, the maritime sector needs greater advancements in communication technology and the digitalization of seaport management systems in the age of

globalization and the expanding demand for novel technologies. [1]

Port Community System (PCS) refers to early initiatives to redesign the port and shipping management processes in a digital environment. Port authority, customs, terminal operator, consolidation center, and freight forwarder are just a few of the key players who have full or partial bases within the port site. PCS serves as its information hub. The primary goal of PCS is to

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make it possible for intelligent online information and document exchange compared to traditional procedures, which include using tangible methods like phone calls, faxes, and physical signatures. PCS converts the workflow to digital format in order to shorten the time that papers must wait for approvals using communication tracking and real-time data updates. Importantly, PCS employs a centralized strategy to maintain and reroute the document flow, which means there is only one main authority in charge of controlling data storage and confidentiality [2].

What type of data is shared throughout the globalized maritime supply chain? The majority of this data consists of port and shipping management systems. These details, such as whether a container has been gated, staffed, or what time it is expected to arrive (ETA) at its destination, are in fact port management and shipping key points. However, documents in maritime, both structured and unstructured such as PDFs, scans, photos, etc. go beyond that by making them ready for the parties involved in the supply chain. To develop workflow utilizing smart contracts, such as "smart" bills of lading, clearance, insurance, etc., they must be approved, updated, and accessible [3].

Just like any other "E-Systems", PCS suffer from security and privacy issues that must be addressed since any penetration could cause many problems in different fields. Blockchain technology has been researched in container transportation to prevent wasting time handling containers and minimize the cost of logistics tasks, boosting a country's ability to compete

internationally. In order to reduce the danger of document falsification and increase data and contract security, blockchain has been utilized to secure customs receipts and documents with trust procedures [4].

Six nations surround Iraq on all sides. To the south are Saudi Arabia and Kuwait, to the west are Jordan and Syria, to the north is Turkey, and to the east is Iran. Iraq has a limited coastline of only 48 kilometres, which is located between Kuwait and Iran's borders. All of its ports are located in Basra province. There are two oil terminals in Iraq, as well as Almaqil, Khor- Alzubayr, Abu-Flous, and Umm-Qasr Port, which is the country's principal port for international trade. As a transit point for oil being exported out to the Persian Gulf and for imports, the ports constitute a vital link in the economy of Iraq. Figure 1 shows the map of all Iraqi seaports [5].

In this paper, a performance evaluation of a proposed secure PCS system-based hyper-ledger fabric blockchain technology has been introduced, with a comparison of performance using one and two organizations. Two main metrics have been taken for system evaluation which are throughput and latency. The paper is organized as follows: section 2 shows related work, while Section 3 describes an overview of intelligent transport systems used in seaports. In section 4, the hyper-ledger fabric platform is described while section 5 shows the results of the performance evaluation. Finally, a conclusion about the proposed system is introduced in section 6.



Fig. 1. Iraqi seaport in Basra province [5].

## 2. Related Work

The use of blockchain technology and electronic voting has been covered in a number of publications. These papers outline various strategies and objectives that are reached through various methods. [2] demonstrated how a blockchain-based scenario for handling shipping documents has been developed as a precise answer to the problems that PCS was designed to address, including data security, accelerated communication, the removal of the role of the central gatekeeper, and the establishment of P2P communication for both transaction visibility and permission transparency. [6] introduced the use of smart contracts inspired by shipping port procedures that are implemented into the Ganache private blockchain, bringing the blockchain's immutable nature, trust, decentralization, and privacy into the entire shipping process. [7] showed what impact Industry 4.0 might have on seaports' use of more complex business models and how this impact is produced, paying special attention to the potential roles of technology push and market pull mechanisms. Then, this model is assessed using a preliminary study on Barcelona port. [4] provided a blockchain-based permission hyper-ledger network electronic voting system for the elections for the Iraqi Council of Representatives. Blockchain technology consists of an immutable

distributed ledger that is updated by each network participant. [5] build a website that will register inland ships and sailors and then let users access their information. The scheme proposes to use blockchain to give ships and sailors E-licenses. The suggested solution will assist in developing a portal for data collection and remote data viewing. The Ministry of Ports, Shipping, and Waterways will also post information about inland vessels and their owners in the database. [9] presented an intelligent decision support system (i-DMSS) that is particularly based on blockchain technology and directs into the information sharing construction defined for a particular strategical business process where the seaport is concerned with the capacity to share data with a partner seaport that is a part of the same inter-organisational system. [10] offered Blockshipping, a decentralized platform for smart booking and release of containers, as one of the blockchain-based maritime supply chain system (BMSCS) applications. Its actual advantages, weaknesses, and major players are explored along with the conceptual foundation of BMSCS. [8] Presented a blockchain with crowdsourcing for a port management system where the cognitive domains (CSTC), social, and cyber technological aspects of crowdsourcing technology, smart ports, and knowledge creation process are interrelated. Table 1. shows a comparison of the previous work compared with the present work.

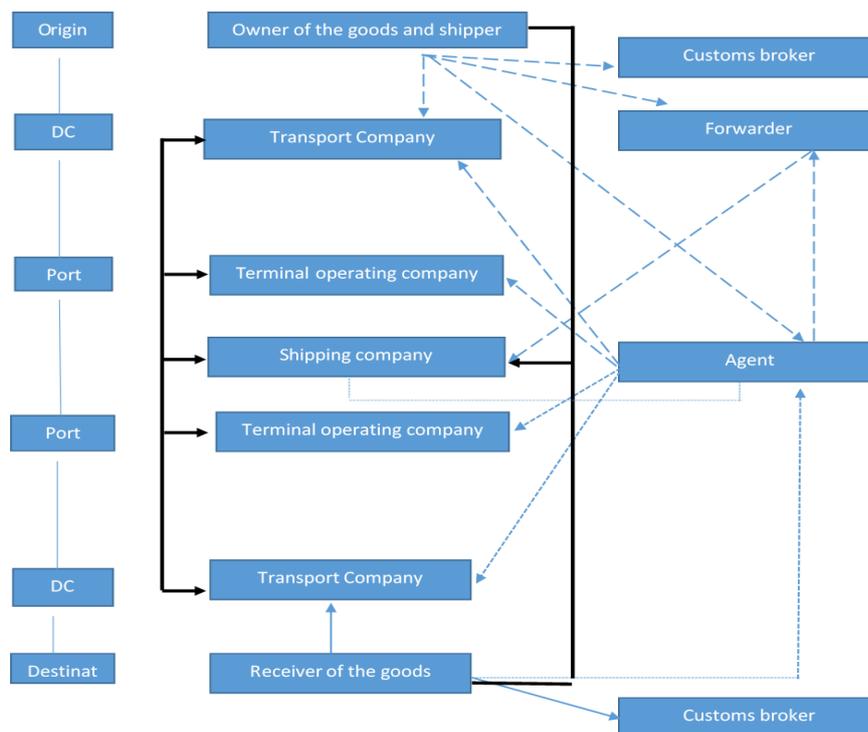
**Table 1,**  
**Comparison of previous work.**

Ref	Platform	Application	Performance evaluation
[2]	None	Shipping documents	None
[4]	Hyper ledger fabric	E-voting	Throughput and latency
[5]	None	E-license to ships and seafarers	None
[6]	Ganache	Shipping documents	None
[7]	None	Seaport management	None
[8]	crowdsourcing	Port management	None
[9]	i-DMSS	Seaport capacity	None
[10]	Blockshipping	Smart booking for containers	None
Present work	Hyper ledger fabric	Maritime and seaport management	Scalability, throughput, and latency

### 3. Seaport IT Overview

With significant effects on all business sectors, digital transformation is of the utmost importance. Here, we use ports and maritime shipping logistics as examples of those advances. In other words, seaports are particularly impacted by technological change since they are participants in global supply networks. In Figure 2, a diagram of port supply chain operations is shown. Digital innovation is

crucial for ports to remain competitive because the logistics industry has such high standards for things like costs, efficiency, security, and sustainability. Historical trends demonstrate how digital innovation might influence port modernization. Reviewing the results of previous advances and their effects on port operations is necessary to comprehend the issues that will be faced in this area in the future.



**Fig. 2. Maritime supply chain [12].**

Associated information flows have a significant impact on the effectiveness and security of connected freight transfers. The use of information and communication technology (ICT) has advanced to become a crucial factor for the competitiveness and success of ports, decision-making, facilitating communication and enhancing the efficiency, visibility, productivity, and safety in port procedures that are impacted by various conditions [11].

The options are nearly unlimited, and as a result, the development of IoT and the utilization of big data raise the possibility that logistics will develop into a data-centric economy where information is valued more highly than the capacity to move cargo. There are new business models, alliances, and issues about who is best suited to lead these partnerships as a result of the increased interest in and advancements in the field of IoT and big data analytics. Big data analytics and IoT have an impact on many processes, thus many stakeholders must collaborate to make it work [12]. The conceptual model above illustrates a case study of the logistics process for a shipping contract, which includes the following steps: commercial agreement, space reservation, export processes, container storage, inspection of forest and agricultural products, coordination of land cargo, and reception in the destination port. Among other things, the cargo area, ship evacuation procedures, and bills of lading.

A portion of the document management system is displayed. This system is made up of the administrative entity, the terminals, the private businesses that offer logistics services to international trade, and the governmental organizations that have supervision responsibilities.

#### 4. Blockchain Technology

A distributed database called Blockchain (BC) enables a dispersed peer-to-peer network, guaranteeing participants safe and trustworthy link and communication. It is a novel technology that duplicates and disperses transactions across the network of computers involved in the blockchain by using distributed ledgers. a collection of public key-protected blocks with time-stamped transactions that have been validated by the network community. The owner's digital signature authorizes transactions in these blocks, authenticating and safeguarding them. As a result, the ledger's data is very secure [13][14]. Blockchain architecture and blockchain working methodology are the two components of blockchain technology. All of the data pertaining to legal transactions is contained in a block, which is the core data component of a blockchain system and is generated by cryptography. A basic "block" structure consists of two parts: the block header and the block content. The structure of the blockchain is depicted in Fig. 3 [37]:

- A. Block Header:** The block header contains the block number, previous hash block, current hash block, time stamp, block size, and nonce value.
- B. Block Data (Block Body):** This part of the block provides all the information about the block, including the number of transactions overall and the percentage of validated transactions in each block.
- C. Merkle tree:** The Merkle tree is used to hash and organize the block's transactions. By pairing and hashing two transactions, then repeating for the top level, one can extract the Merkle root.

Following certification, the block is made available to all network users. A genesis block is a blockchain's very first entry.

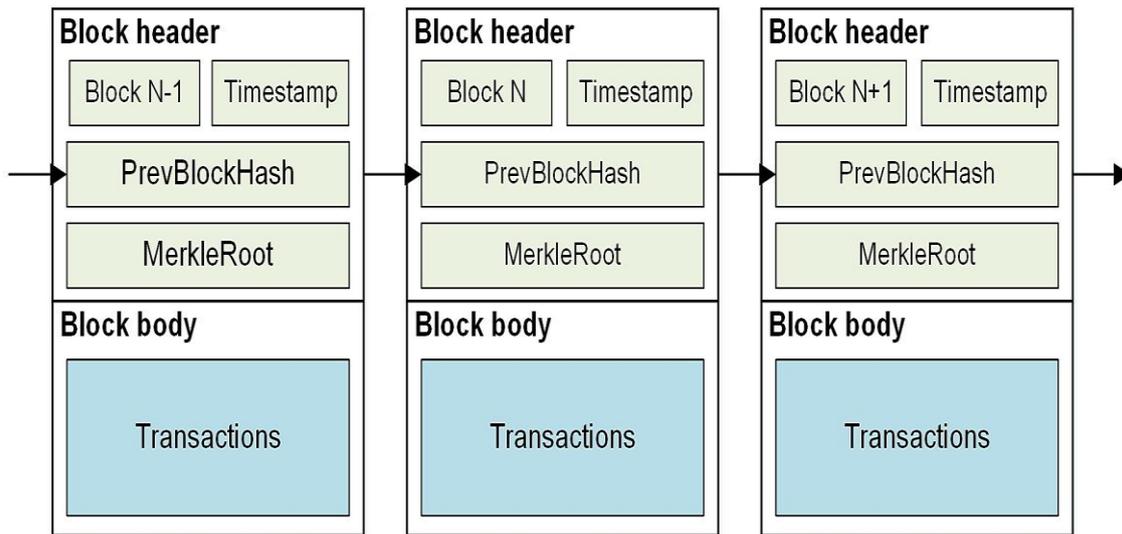


Fig. 3. The Structure of Blockchain [15].

### 5. Hyper Ledger Fabric Blockchain

A decentralized, distributed, and unchangeable database called the blockchain keeps track of transactions in time-stamped blocks joined by hashes. Participants in the P2P blockchain network are identifiable by their private and public keys. The cryptographic hash function of the previous block, the data transactions, which are frequently organized as a Merkle tree data structure, and the timestamp are the three main parts of a blockchain block. A block's transaction data cannot be changed after it has been recorded without also changing the blocks that came before it [16,17]. The target market for hyper-ledger fabric's permission blockchain technology is businesses [18]. To make deployment easier, Hyper-ledger Fabric was included in a microservices-based architecture. The ledger was built using a NoSQL database called CouchDB. The generation of smart contracts using general-purpose languages is supported by the hyper ledger fabric. All of the codes that can be called by transactions are listed in a chain code, which is a smart contract in the ledger fabric. Endorsement policies are included with chain codes and are applicable to the associated smart contracts. The confidentiality of transactions between network participants can be ensured via a channel isolation method. Each channel keeps a

separate ledger, ensuring that only member nodes in the channel may access the transaction and data. The elements that make up hyper-ledger peers, CouchDB, orderers, Certification Authority (CA), and chain code are the microservices that construct a hyper-ledger blockchain network. Each microservice's deployment method made use of Docker containers. Remote procedure calls are used to connect them [19, 20]. There are several aspects of the hyper-ledger fabric, including rich ledger queries, no transaction costs, and types of consensus (Solo, Raft, and Kafka).

Document workflow management brings comparable values but differs in terms of the suggested solution to the same problems as the previously announced Port Community System. The fundamental idea behind document workflow management is to incorporate blockchain into an already existing database, ERP, and accounting system, standardize documents, and bring the entire data flow online while swapping out paper approvals for digital ones. Approvals act as time stamps that can be used to trace faults or settle conflicts between parties, such as when items inside a container arrive damaged. The whole system's interconnectedness amongst the involved parties also serves to ensure security. Figure 4. Shows the workflow diagram of the hyper ledger fabric platform.

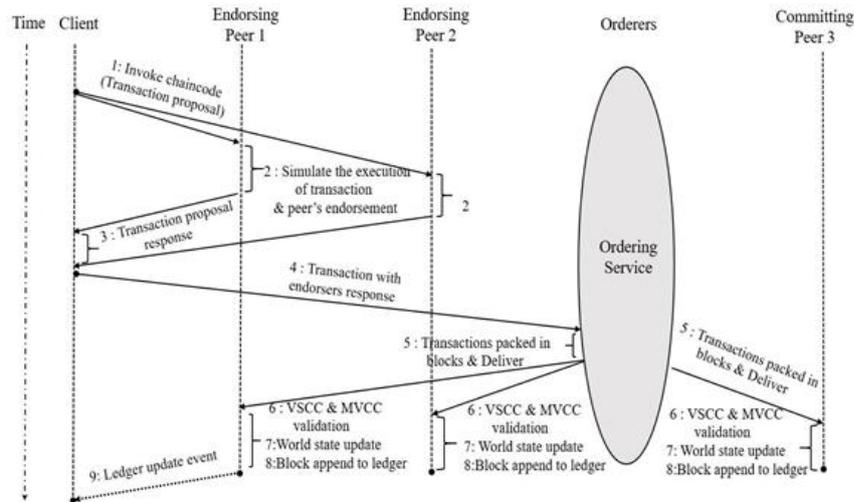


Fig. 4. Hyperledger fabric workflow [11].

## 6. Performance evaluation of proposed system

This section provides an analysis of the proposed permission hyper ledger fabric blockchain's throughput (measured in transactions per second, or "tps"), average latency (measured in seconds, or "sec"), and scalability (i.e., the number of participants that the blockchain network can serve). It is necessary to explain the effect on changeable fabric network components. Additionally, different transaction speeds and block sizes were used to execute the scenarios. The performance of the hyper-ledger fabric can be impacted by a number of fabric network components, each with a different level of configuration. These parts might be categorized as hardware or software. In the case of software, these factors include block size, block timeout, ordering service, smart contract programming language, ledger database, client count, TLS usage, number of peer endorsers, number of organizations, and endorsement policy. It displays CPU utilization, the hard drive's kind and speed, the amount of memory, the CPU speed, and the network speed for hardware. The calliper may generate a performance report that can be used to gauge and assess the degree to which various hyper-ledger blockchain platforms are successful, as well as the latency

(minimum, maximum, average, percentile), throughput, and resource usage (CPU, Memory, Network IO, etc.).

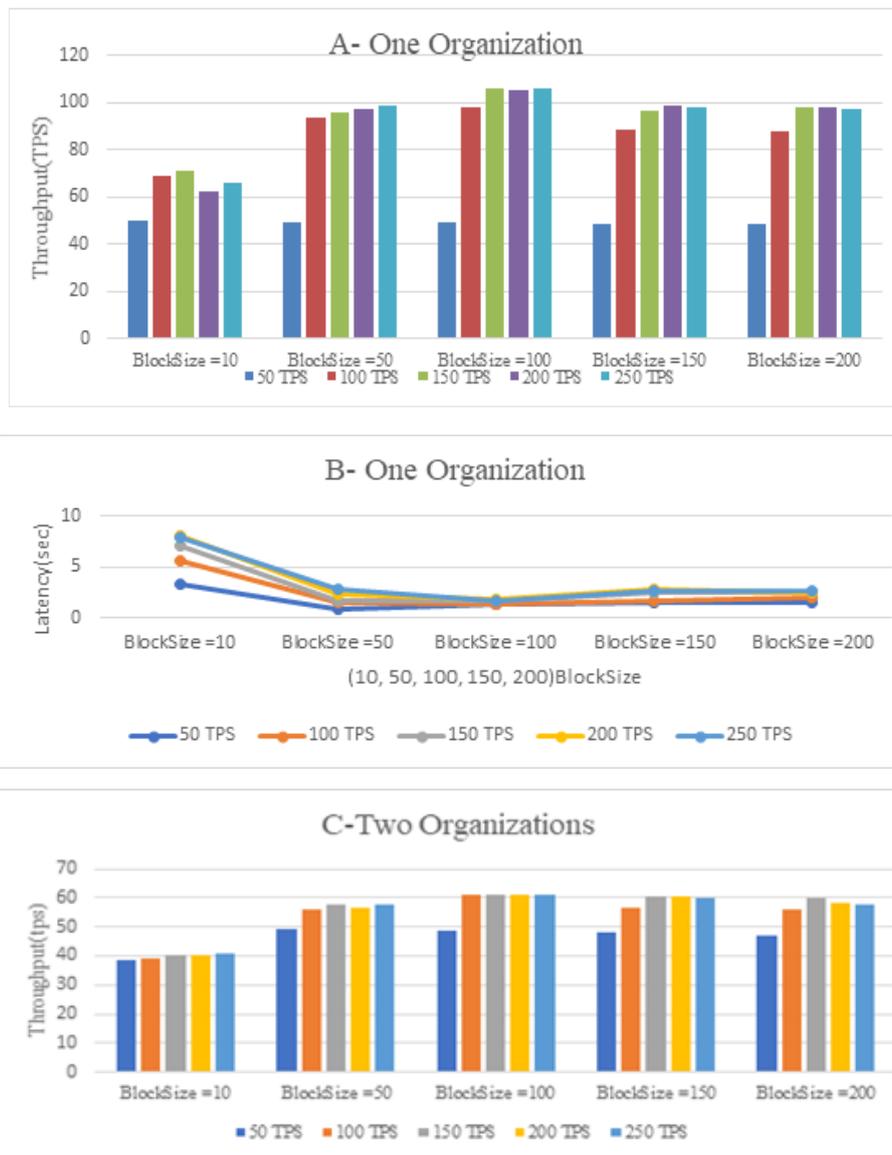
### 6.1 Case 1: One Organization

In this case, several block sizes and transaction send rates have been evaluated in terms of performance. Figure (5. a) depicts the transaction throughput, which rises with increasing block size to 100 transactions in each block. The greatest throughput attained was approximately 108 transactions per second (tps). It should be noticed that as the block size increased by 150 and 200 transactions, the throughput gradually started to decline. Figure (5. b) demonstrates that when the block size grows to 100 transactions, the average latency reduces. The average latency increases slightly when the block size is increased to 150 and 200 transactions, suggesting that this particular test setting does not significantly influence performance when the block size is increased to more than 100 transactions per block. Furthermore, with low transmit rates, such as 50 transactions per second, better latency and throughput have been observed when utilizing lower block sizes, such as 10 transactions; hence, increasing block sizes did not significantly affect performance, but it was still apparent.

### 6.2 Case 2: Two Organizations

In light of this hypothetical situation, research on the effective evaluation of different block sizes and transaction send rates has been put to the test. Figure (5. c) demonstrates that as block size was increased to 100 transactions, the transaction throughput rose, with (61 tps) being the greatest throughput attained. While the throughput somewhat dropped when the size of the block was increased to 150 and 200 transactions. Figure (5.d) demonstrates that the latency decreases as the block size increases up to 100 transactions, with a little greater growth in delay when the block size climbed to 150 and 200.

According to the findings, performance is not greatly affected by increasing the block size to more than 100 transactions. Using a smaller block size, such as 50 transactions, resulted in better throughput and latency for a low send rate, like 50 tps, so performance was not significantly impacted by raising the block size, but it is still apparent. In this work, a block size up to 200 with tps up to 250 has been introduced with one and two organizations to investigate the effect of scalability on the proposed system design. As compared with previous work, a good result was obtained in terms of throughput and latency when using additional organizations.



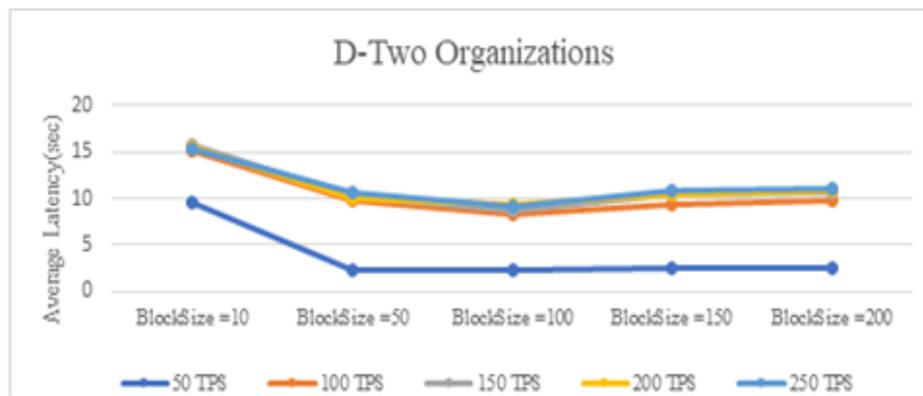


Fig. 5. Performance evaluation of proposed system.

## 7. Conclusion

This work aimed to provide fresh perspectives on the interactions between seaport management systems and the development of blockchain technology in relation to seaports. By adjusting the transaction transmit rate, block size, and block timeout, this study also examines the throughput and latency performance of the hyper-ledger fabric blockchain. To obtain high performance in systems that have large concurrent transactions, the block size and block timeout should be substantial. In conclusion, the suggested hyper-ledger fabric blockchain network, which is built on a secure management system, is appropriate and might satisfy security needs such as eligibility, traceability, unforgeability, anonymity, and data integrity. The network is reliant on device configuration, smart contract complexity and operation, and network design.

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### الخلاصة

في جميع أنحاء العالم ، لا يزال يتم إنشاء مستندات الشحن بشكل أساسي والتعامل معها بالطريقة الورقية التقليدية. ونتيجة لذلك ، تستغرق العمليات التي تتم في موانئ الشحن وقتاً طويلاً وتعتمد بشكل كبير على الورق. مستندات الشحن معرضة بشكل خاص للاحتيال في الأعمال الورقية لأنها تتضمن العديد من الأطراف ذات المصالح المتنافسة. بمساعدة العقود الذكية ، يسمح دفتر الأستاذ الموزع والمشارك والملحق فقط الذي توفره تقنية blockchain بإضافة سجلات جديدة. من أجل زيادة كفاءة النقل البحري والموانئ وتعزيز التنمية الاقتصادية ، تدرس هذه الورقة التطورات الحالية للقطاع البحري في العراق وتقدم نموذجاً لتأمين نظام الإدارة القائم على منصة blockchain النسيجية hyperledger. يتضمن تقييم أداء النظام المقترح سيناريوهين ؛ منظمة واحدة ومنظمتان من خلال فحص الإنتاجية و التأخير. أسفرت معدلات نقل المعاملات العالية على أحجام الكتل الكبيرة عن نتائج إيجابية. وبالمثل ، يؤدي استخدام حجم كتلة صغير ومعدلات إرسال أعلى إلى أداء ضعيف. بالإضافة إلى ذلك ، لوحظ أن الإنتاجية ستخفض و سيزداد وقت الاستجابة مع زيادة عدد المنظمات. يجب أن يكون حجم الكتلة ومهلة الحظر عالية في التطبيقات التي تحتوي على العديد من المعاملات المتزامنة من أجل الحفاظ على معدل نقل جيد.