Elevating Transparency in Global Maritime Logistics through Blockchain Technology

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***Abstract*— Effective marine logistics are essential for international commerce in the age of globalization. Traceability, conflict resolution, and transparency are problems for traditional systems. This study presents a unique method to improve the efficiency and transparency of marine logistics using smart contracts and blockchain technology. The proposed technique uses a smart contract and the Ethereum blockchain to handle the cargo lifetime. Necessary parties involved in the system include exporters, logistics, customs authorities, and arbitrators. The performance review highlights the advantages of automated processes, security, and decentralization in marine logistics. The results demonstrate a more efficient procedure, fewer disagreements, and enhanced traceability. The findings of this study have the potential to transform how it approaches international trade completely.**

***Index Terms*—Maritime logistics, blockchain, smart contract.**

I. Introduction

Logistics efficiently delivers goods to meet customer needs. Good logistics flow uses land, air, and marine transportation. Maritime logistics uses multiple transportation options. This method has a long service chain, related sectors, and high resource utilization. Maritime transportation is vital for global trade, with 90% of international commodities and 70% of world commerce transported by sea [1]. Containerized freight accounts for half of this, with over 37 million twenty-equivalent units (TEUs) shipped in 2018. However, data sharing is limited due to the competitive nature of the business, leading to container loss and shipping process setbacks. The lack of real-time freight status visibility also increases shipping damage and loss disputes and expenses for all parties [1]. Counterfeit cargo is an increasing issue in the industry, costing the US cargo business $50 billion annually. CargoNet reported 359 fraud and theft cases in the quarter of 2021, most targeting US and Canadian facilities and in-transit cargo [2]. Completing and approving cargo agreements, contracts, customs clearance, cargo manifestos, and bills of lading during port operations is essential for international trade. However, processing paper documents using tools like EDI or courier services can take days to weeks, accounting for 20% of shipping sector costs. Such delays can affect time-sensitive cargo, and paper documents are vulnerable to falsification, data inconsistency, insufficient information, and human error. Blockchain technology can help monitor freight and associated procedures in a secure and transparent way [3]. This article presents a blockchain-based container tracing solution for maritime logistics that is decentralized, reliable, auditable, and secure. The proposed system uses the InterPlanetary File System (IPFS) to record all shipping container transactions off-chain to avoid storage constraints. Smart contracts and algorithms are created and tested for performance and execution cost [4]. The approach is safe against attacks and is compared to other systems to emphasize its originality.

II. Proposed Methedology

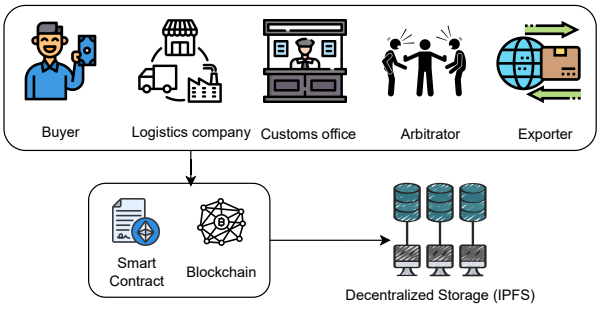

Fig. 1: Blockchain-based maritime logistic system

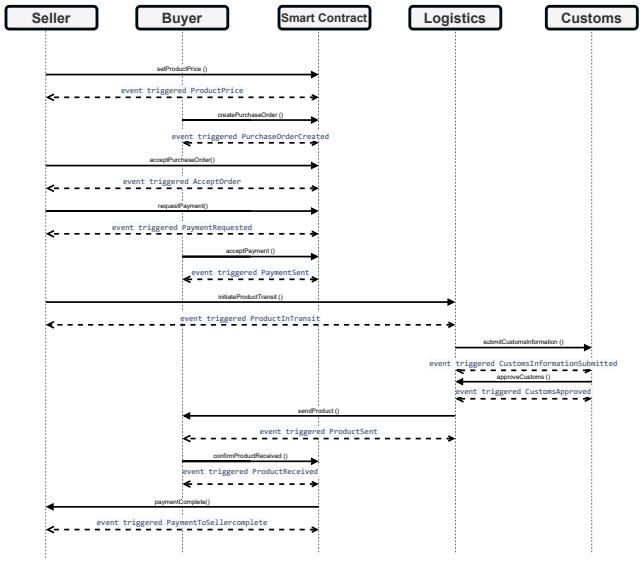

Fig. 2: Sequence diagram of smart contract execution

The proposed methodology fig. 1 leverages blockchain technology and Ethereum smart contracts to enhance maritime

logistics' efficiency, transparency, and trustworthiness. The Ethereum blockchain serves as the underlying infrastructure, providing decentralization, security, and transparency.

A. Smart Contract Integration

The proposed approach centers around the integration of Ethereum smart contracts fig. 2, specifically designed to orchestrate the entire lifecycle of a shipment. Smart contracts are deployed to manage key interactions among stakeholders, including exporters, logistics companies, customs offices, and arbitrators.

B. Actor Roles and Interactions

1) Exporter: Initiates the shipment process by creating a purchase order on the smart contract, specifying details such as buyer, product, and shipment cost.

2) Logistics Companies: Smart contract events facilitate the physical transit of the product, updating the contract at each transit stage.

3) Customs Offices: Verify and record shipment-related documents on the blockchain, ensuring transparency and traceability.

4) Arbitrators: Automatically resolve disputes through the smart contract, relying on predefined rules and transparent transaction history.

C. Smart Contract Automation

Smart contracts automate payment processes and enforce business rules, such as triggering logistics processes and automating dispute resolution based on predefined criteria.

III. Implementation and Validation

This section shows the practical implementation of secure maritime logistics using smart contracts. It has been tested and validated on the blockchain network with Remix IDE.

Fig. 3: Output of successful creation of purchase order by buyer

Fig. 4: Output of successful purchase order accepted by seller

Initially, the seller sets the product price using the setProductPrice() function in the smart contract, triggering a "ProductPrice" event visible to all. When a buyer expresses interest by invoking the createPurchaseOrder() function, a "PurchaseOrderCreated" event notifies the seller. If the seller accepts the order with acceptPurchaseOrder(), the smart contract generates an "AcceptOrder" event and sends a notification to the buyer. Upon the buyer's acceptance of the payment request from requestPayment(), the "PaymentSent" event occurs, holding the payment securely until the product reaches its destination.

Upon payment, the seller engages the logistics company via initiateProductTransit(), triggering a "ProductInTransit" event. The logistics company communicates with customs using submitCustomsInformation(), leading to a "CustomsInformationSubmitted" event. Upon customs approval through approveCustoms(), a "CustomsApproved" event occurs. The logistics company sends the product using sendProduct(), resulting in a "ProductSent" event. The buyer's confirmation of receipt via confirmProductReceived() triggers a "ProductReceived" event. The smart contract executes paymentComplete(), releasing payment to the seller and generating a "PaymentToSellerComplete" event, marking the completion of the shipment process.

These are the enum in the solidity code, which signifies the status of the shipment. Fig. 3 and Fig. 4 show some of the output results for the system.

IV. Conclusion and Future Work

This study introduces a creative approach to improving effectiveness and transparency in global maritime logistics. The Ethereum blockchain and smart contract implementation guarantee a robust and distributed architecture, fundamentally transforming conventional challenges related to traceability, dispute resolution, and transparency. This study has the potential to significantly transform the global maritime trade and usher in a new era defined by increased efficiency and trust in international marine commerce. Future direction involves integrating DApps and smart contracts catering to port authorities, shipping companies, regulatory bodies, and insurance providers for enhanced operational efficiency.

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