Efficient Blockchain Decarbonization: A Hyperledger Besu Perspective on Emission Allowance Markets

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***Abstract*—In response to the urgent challenge of decarbonization and the intricate issues surrounding Transparency and Accountability in emission allowance markets, this study introduces a blockchain-driven solution employing Hyperledger Besu to address these challenges. The proposed architecture integrates Smart Contracts, On-Chain Storage, Identity Management, and a Proof-of-Authority (PoA) Consensus system. Performance evaluation shows peak throughput achieved by IBFT2.0 at 67.83 TPS, followed by QBFT and Clique at 70.31 TPS and 70.53 TPS, respectively. These results highlight Hyperledger Besu's efficacy in addressing the multifaceted challenges of emission trading within permissioned blockchain networks.**

***Index Terms*—Emission Allowance Markets, Hyperledger Besu, Permissioning, Proof of Authority Consensus.**

I. Introduction

Blockchain technology, known for its decentralized and secure architecture, emerges as a potent force addressing complex challenges. This study explores how blockchain technology and decarbonization in emission allowance markets interact, drawing insights from diverse implementations [1], [2]. In one scenario, blockchain optimizes federated learning, enhancing decentralization and security, while in another, it safeguards against e-prescription duplication using Non-Fungible Tokens (NFTs), ensuring uniqueness and preventing unauthorized distribution.

The need for emission control measures has become more pressing due to the rise in carbon emissions and their effects on climate change [3]. National development plans now incorporate carbon peaking and neutrality, with carbon trading recognized globally as a pivotal method for emission control, contributing to broader climate governance objectives.

In the initial exploration, a unified permissioned blockchain-based Peer-to-Peer Energy Trading (P2P-ET) architecture was proposed, showcasing superior performance metrics using Hyperledger Besu and the IBFT consensus algorithm [4]. Subsequently, a blockchain-based framework extended these insights, leveraging Hyperledger Besu and the IBFT 2.0 consensus algorithm for secure and efficient peer-to-peer energy trading [5]. This paper builds upon these works, focusing on the application of Hyperledger Besu in emission allowance markets and providing a comprehensive analysis of the system's efficiency in addressing decarbonization challenges.

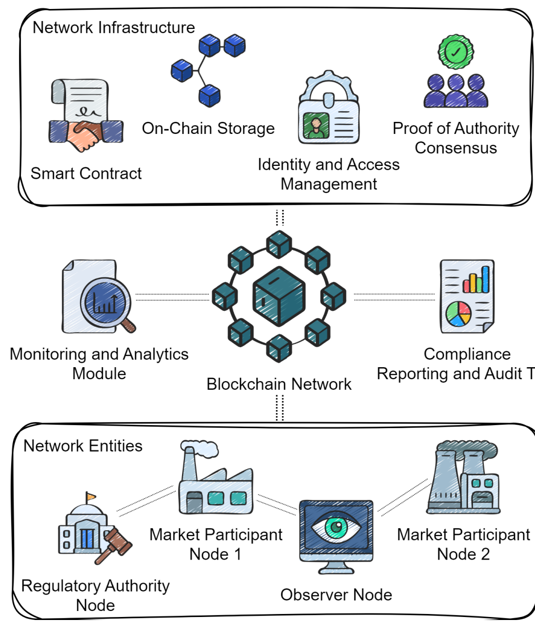

Fig. 1. System Architecture

II. Proposed System

At the intersection of blockchain and emission allowance markets, the system prioritizes transparency, efficiency, and regulatory compliance. Illustrated in Figure 1, the proposed system integrates Smart Contracts, On-Chain Storage, Identity Management, and a robust Proof-of-Authority (PoA) Consensus. Real-time insights are provided by the dynamic Monitoring and Analytics Module, while accountability and transparency are strengthened by the Compliance Reporting and Audit Trail feature. The choice of Hyperledger Besu, with its enterprise-grade features, harmoniously aligns with the vision for a meticulously controlled emission trading network, ensuring not only compatibility but also enhancing interoperability with the Ethereum ecosystem.

The Network Infrastructure is a testament to the commitment to secure and automated transactions. Smart Contracts

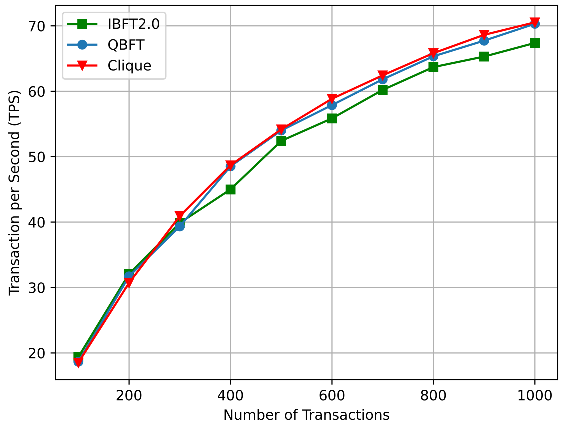

Fig. 2. Throughput Performance of Hyperledger Besu Network

```
python benchmarkv2.py
Error sending transaction with nonce 3: {'code': -32007,
 'message': 'Sender account not authorized to send trans
actions'}
```

Fig. 3. Denied Unauthorized Account Transaction

enforce transparency, On-Chain Storage acts as a secure repository, and Identity Management with Access Control fortifies the system against unauthorized access. The PoA Consensus, the heartbeat of the network, ensures rapid finality and high throughput, subjected to rigorous testing with consensus mechanisms IBFT2.0, QBFT, and Clique to pinpoint the optimal choice.

Within Network Entities, compliance and transparency are enhanced by the Regulatory Authority Node and the Observer Node. The active participation of Market Participant Nodes injects dynamism, reinforcing the decentralized essence of the emission allowance market. The dual-layered permissioning structure, embracing both local and on-chain mechanisms, empowers the system by allowing controlled access through whitelists for accounts and nodes. This permissioning strategy establishes a secure and regulated environment, enhancing the adaptability and resilience of the system in diverse emission trading scenarios.

III. Performance Analysis and Discussion

In the simulation environment, the system's performance is assessed using hardware specifications, including an Intel Core i5-7400 CPU at 3.00GHz, 16 GB of DDR4 RAM, and a Windows 10 platform. Storage utilized a 7200 RPM HDD. Hyperledger Besu v23.10.0, operating on Java 21, served as the blockchain framework, with QBFT, IBFT2.0, and Clique as tested consensus mechanisms, each involving four validators or signers. Notably, the block creation time was set at 2 seconds, contributing to a dynamic and realistic evaluation of the proposed system's efficiency.

The assessment of performance parameters and permissioning involved evaluating the system's throughput performance across varying transaction numbers, as illustrated in Figure 2. The peak Transactions Per Second (TPS) is determined at a transaction rate of 1000. Throughput, precisely defined by [6], measures successfully committed transactions or query operations per second, calculated as the ratio of the total number of transactions to the total time taken to execute them. Notable results shown by IBFT2.0 achieving a peak TPS of 67.38, QBFT demonstrating 70.31 TPS, and Clique exhibiting a maximum TPS of 70.53. This consistent throughput highlight the system's robust efficiency in handling diverse transaction volumes. Additionally, permissioning measures were validated by attempting a transaction from outside the whitelisted accounts, resulting in the expected response illustrated in Figure 3: "Sender account not authorized to send transaction." This affirms the effectiveness of access controls in preventing unauthorized external transactions within the proposed emission trading framework.

IV. Conclusion and Future Work

This study explores the intersection of blockchain and emission allowance markets, presenting a robust system leveraging Hyperledger Besu with demonstrated efficiency, particularly in throughput performance. The results highlight the system's capability to handle varying transaction volumes with notable peak TPS values for different consensus mechanisms. Moving forward, future work will delve into the integration of decentralized applications (DApps) to enhance the system's functionality and usability. Additionally, further testing on a larger network scale will be undertaken to validate and extend the findings in diverse and more extensive scenarios.

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