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ENHANCING SUPPLY CHAIN INTEGRITY IN SMES THROUGH DOCKERIZED BLOCKCHAIN ARCHITECTURE

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Introduction. In today's digital economy, ensuring the security, transparency, and traceability of data has become vital, particularly within supply chain management (SCM). Blockchain technology, with its decentralized and immutable structure, has demonstrated potential in addressing inefficiencies and trust-related issues in SCM. Despite its advantages, small and medium-sized enterprises (SMEs) have faced significant barriers to blockchain adoption, including high deployment costs, operational complexity, and a lack of technical expertise [1]. This thesis proposes a dockerized blockchain architecture designed to mitigate these challenges and make blockchain more accessible to SMEs.

The proposed solution utilizes Docker containers to simplify the deployment and management of blockchain infrastructure [2]. By acting as an intermediary layer, the dockerized architecture integrates seamlessly with existing systems, allowing SMEs to benefit from enhanced data integrity and trust without the need for significant changes to their current operations. This study presents the architecture's design, functionality, performance considerations, and potential improvements to promote broader blockchain adoption among SMEs.

Literature review.

The literature reflects a growing recognition of blockchain's transformative potential in SCM, yet it also emphasizes the systemic barriers faced by SMEs in its implementation. High costs and technical complexity are frequently cited deterrents [3]. For instance, SMEs typically lack the infrastructure and expertise to deploy distributed ledger systems independently [1]. As a result, many promising blockchain solutions remain limited to larger enterprises.

Some studies have attempted to address these challenges through hybrid frameworks. For example, Khan et al. [4] proposed a multi-technology architecture combining blockchain, artificial intelligence, and the Internet of Things to support SME digitalization. Their system utilizes blockchain to manage transactions securely, emphasizing its role in ensuring data integrity in distributed environments. However, its implementation demands significant technical resources.

Jiang and Chen [2] presented a blockchain-supported e-commerce model for SMEs, emphasizing strategic pathways for adoption. Although informative, their model does not reduce technical entry barriers or streamline deployment processes, leaving a gap between theoretical frameworks and real-world applicability.

Nguyen et al. [5] recommended using private blockchains for SME applications, highlighting benefits such as enhanced privacy and scalability. Their framework supports limited-resource environments but assumes SMEs possess basic blockchain capabilities. These limitations underscore the need for a lightweight, deployable, and cost-effective architecture—such as the dockerized solution proposed in this research.

Proposed Model.

The proposed dockerized architecture adopts a hybrid blockchain approach that balances decentralization with centralized control. Its core components include a mediator server, blockchain node, optional observer server, NGINX reverse proxy, and, optionally, a bootnode. These elements are deployed using Docker, enabling rapid configuration and scalability.

Each SME in the supply chain operates a mediator server within a dockerized network. This server captures web requests, filters them, and records transaction metadata to the blockchain. The system avoids major alterations to the SMEs' existing infrastructure by intercepting and rerouting requests transparently.

The architecture distinguishes itself through partial decentralization. While the blockchain handles transaction logging, existing centralized systems continue managing business logic. This approach conserves computational resources and enhances integration flexibility.

The data flow is designed for dual-path processing. A single web request is both processed normally by the enterprise's server and concurrently logged on the blockchain via smart contracts. The mediator server strips sensitive information, such as authorization headers, before submitting data to the blockchain [6]. This ensures GDPR compliance and reduces potential data breaches.

Smart contracts serve as the logic filters, determining what data is stored. Their immutability ensures consistent behavior, transparency, and trust among participants. Furthermore, deploying smart contracts per SME or business function allows greater control over data relevancy.

The architecture is particularly effective in collaborative supply chains involving multiple SMEs. Each participant runs a dockerized node, forming a shared private blockchain. Real-world examples include SMEs collaborating on repair services or logistics, where transparency and traceability of service requests are essential.

The dockerized tool is executed via simple configuration and a docker-compose command. The system integrates with existing applications, requiring only minimal adjustments to web proxies or middleware..

Conclusion. This thesis has presented a dockerized blockchain architecture aimed at empowering SMEs to adopt distributed ledger technologies in supply chain operations. By reducing deployment complexity, minimizing hardware requirements, and enabling seamless system integration, the proposed architecture addresses the core challenges that have historically limited blockchain use among SMEs.

The system's modular design allows SMEs to build secure, traceable, and transparent data flows without restructuring their existing infrastructure. Through the use of smart contracts, the solution ensures consistent and verifiable transaction records, fostering trust between supply chain participants.

While the architecture is effective in reducing technical and financial barriers, several areas require further investigation. These include optimizing data storage, reducing blockchain latency, and incorporating customizable access control mechanisms. Real-world trials and performance testing will be

essential to validate the theoretical framework and refine the architecture for broader adoption.

In conclusion, dockerized blockchain offers a scalable, affordable, and secure method for integrating distributed technologies into SME ecosystems. With continued development and testing, it holds promise as a foundational tool for digital transformation in small business environments.

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