Instal : Jurnal Komputer

E-ISSN: 2808-683X
Edisi : Volume 18 Nomor 01 | Tahun 2026

Available online at https://journalinstal.cattleyadf.org/index.php/Instal/index

Application of Smart Contracts to Ensure Data Immutability and User Privacy in Gojek

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ARTICLE INFO

Keywords:

Smart Contracts, Blockchain, Gojek, Data Immutability, User Privacy

ABSTRACT

The evolution of blockchain technology establishes a novel paradigm for digital data management, underscoring transparency, security, and immutability. Centralized user data systems in ride-hailing platforms like Gojek are susceptible to breaches and manipulation. This study investigates the deployment of smart contracts to safeguard data immutability and augment user privacy via decentralization. Adopting a systematic literature review of recent blockchain applications in digital transportation, the results reveal that smart contract integration obviates central server dependency, automates transaction validation, and grants users complete sovereignty over personal data.

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INTRODUCTION

In the increasingly complex digital ecosystem, data security and user privacy have become crucial issues. Ride-hailing applications like Gojek still rely on centralized systems to store transaction data, user identities, and trip records. This approach is vulnerable to manipulation, data breaches, and commercial exploitation of personal information [1]. Blockchain technology and smart contracts offer a decentralization-based alternative that ensures data immutability and full user control. As stated by Naik et al., smart contracts can enforce agreements between parties without intermediaries, while maintaining data integrity across the blockchain network. The objective of this research is to analyze how the implementation of smart contracts can be applied in the Gojek system to enhance security, transparency, and user privacy protection. Issues of data breaches and lack of transparency in centralized platforms can be addressed through the implementation of blockchain technology that distributes data securely and transparently [2]. Blockchain technology, with its decentralized nature, enables users to have full control over their data, ensuring integrity, confidentiality, and transaction transparency [3]. Furthermore, smart contracts can automate processes and

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enforce compliance with agreements without intermediaries, thereby improving operational efficiency and reducing the risk of human error.
Thus, the integration of blockchain technology possesses the capacity to fundamentally transform Gojek's operational paradigm, evolving the centralized platform into a decentralized ecosystem that emphasizes transparency, user-centricity, and the primacy of data security and privacy. This architecture mitigates single points of failure while fortifying security through cryptographic encryption and consensus-driven transaction validation, concurrently delivering indispensable transparency and auditability, as each transaction is immutably inscribed and verifiable by all network participants.
That transparency, coupled with blockchain's immutability, intrinsically reduces the risks of fraud and data tampering, as each record in the distributed ledger is validated by the entire network [4]. The intrinsic decentralization and encryption attributes of blockchain technology substantially enhance data security, establishing it as an ideal countermeasure to emerging cyber threats . Furthermore, blockchain integration offers the potential to foster trust among partners and improve team collaboration within Gojek's supply chain through its comprehensive transparency [5]. Utilizing advanced encryption techniques, such as AES, for sensitive data in the blockchain network protects user information confidentiality while preserving overall transaction integrity and transparency. The confluence of decentralization, encryption, and consensus-based verification among all participants facilitates secure, tamper-proof data storage, thereby alleviating risks of theft and manipulation [6].

METHODS

This research employs a systematic literature review approach. Data sources were obtained from academic databases such as Springer, MDPI, and Taylor & Francis, covering publications from the period 2023–2025. The analysis focused on smart contract implementation models in the mobility sector, data security and user privacy mechanisms, and the suitability of these concepts with the Gojek ecosystem in Indonesia. This methodology aims to identify research gaps and analyze relevant case studies to develop a comprehensive conceptual framework for integrating blockchain and smart contracts in ride-hailing applications .

Blockchain and Data Immutability

Blockchain is a distributed digital ledger system that stores transactions in the form of interconnected blocks verified cryptographically, where its decentralized nature and layered verification make blockchain ideal for ensuring data integrity in smart mobility systems [7]. The inherent decentralization of this technology eliminates the need for a central authority, while distributed consensus ensures that once data is recorded, it becomes immutable and cannot be altered or deleted, thereby significantly enhancing trust and data integrity. Blockchain's ability to store data immutably and transparently provides a robust solution to security and privacy issues commonly found in centralized systems, including the prevention of fraud and identity theft [8].

Smart Contracts

Smart contracts are automated programs that execute digital agreements without requiring intermediaries. In the context of ride-sharing applications, a spatial cloaking approach leveraging smart contracts can better protect user location data. This feature enables automatic and transparent agreements that bind all involved parties without third-party intervention. Therefore, smart contracts can serve as the backbone for managing complex business logic in applications like Gojek, automating payments, identity verification, and the secure execution of service terms.

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Privacy and Decentralization on Ride-Hailing Platforms

This decentralized model restores data control to users, reduces power imbalances on platforms like Gojek, and fosters a more inclusive digital economy. By implementing blockchain, ride-hailing systems can operate peer-to-peer without intermediaries, directly benefiting users and drivers financially. Additionally, blockchain's decentralized architecture ensures transaction data integrity and immutability, while enhancing transparency through audit capabilities and cryptographically implemented anonymity [9]. Furthermore, blockchain adoption prioritizes robust data security via decentralized encryption, with every transaction verified by the entire network, thereby mitigating cyber attack and data manipulation risks.

Smart Contract Implementation Model in the Mobility Sector

The implementation of smart contracts in the mobility sector enables automation and enforcement of digital agreements among various involved parties, such as passengers, drivers, and service providers, without requiring intermediaries. The following is the model that will be developed to integrate blockchain technology into the Gojek ecosystem.

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Figure 1. Flowchart Model for Implementing Smart Contracts in the Mobility Sector

This model aims to optimize operational efficiency and increase transparency in every transaction, aligning with the primary objectives of this research [10].

1. Initialization and Service Request
   - User opens the application and submits a service request.
   - Request data is sent to the blockchain system for verification.
   - Smart contract activates after the user approves the service terms.
2. Request Processing
   - The smart contract verifies the availability of the nearest driver through an automatic matching algorithm.
   - User and driver location data is encrypted to maintain privacy.
3. Validation and Approval
   - Smart contract performs automatic validation:
     - Ensures the fare complies with system policies.
     - Verifies user balance and driver status.

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4. Stores all transaction logs immutably on the blockchain. Service Execution
   - After validation is complete, the smart contract executes the commands:
     - Connects the user with the driver.
     - Locks the trip fare in blockchain escrow until the service is completed.
5. Completion and Payment
   - After the trip is completed, the driver marks the contract as completed.
   - Smart contract:
     - Automatically releases the payment funds.
     - Updates the transaction status on the blockchain.
     - Stores digital proof as a permanent audit trail.
6. Data Storage & Privacy
   - All transaction data, including location and time, is stored in encrypted form on the blockchain.
   - Users have full control over their personal data using private keys.
   - Regulators or third parties can only access metadata.

RESULTS AND DISCUSSION

4.1 Data Immutability in Gojek Architecture

The concept of data immutability in blockchain systems means that every transaction or record written to the network cannot be altered or deleted. In the architecture of ride-hailing applications like Gojek, digital transactions occur in various forms—from service bookings, location tracking, to payments. In the conventional model, all such data is stored on the company's centralized servers. This creates risks of internal and external data manipulation, as well as opportunities for user data misuse.

Through the integration of private or consortium blockchain, every transaction in Gojek can be stored in the form of blocks verified by a number of trusted nodes. This decentralized system allows every party to have an identical ledger copy, ensuring that no single entity can alter the data without consensus approval.

This implementation ensures that:

- Transactions cannot be deleted or manipulated, even by Gojek itself.
- Audit trail is always available to ensure transparency.
- User data is end-to-end encrypted before being recorded on the blockchain, preventing sensitive data leaks.

In the technical context, Gojek can adopt the efficient Proof of Authority algorithm, suitable for networks with a limited but trusted number of nodes. PoA enables fast validation with low energy consumption, making it ideal for large-scale ride-hailing systems.

4.2 User Privacy through Smart Contracts

User privacy is a crucial issue in location-based services. Every time a user orders a Gojek service, the system accesses GPS data, phone number, payment method, and personal preferences. In a centralized system, this data can be used for commercial profiling or even sold to third parties.

With smart contracts, users can explicitly set access rights to their personal data. For example:

- Drivers can only access user location data during active trips.
- Transaction data can only be read by the payment system after the user provides digital authorization.
- After the transaction is completed, the smart contract automatically deactivates third-party access to user data.

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Integrating spatial cloaking into smart contracts enables the system to hide users' exact location coordinates by replacing them with an anonymous radius. This approach prevents individual tracking by external parties without disrupting driver matching efficiency.
Privacy-preserving ride-pooling mechanism, where user identities can only be accessed according to the contractual conditions specified by the smart contract. This means that no raw user data is stored on the central server; instead, only verification tokens are used for transaction validation.
For an additional layer of security, Gojek can integrate Zero-Knowledge Proof technology, which enables proving the truthfulness of data without revealing the actual data details. This aligns with the latest trends in the fintech and smart transportation sectors that emphasize privacy-by-design.

4.3 Case Study: Gojek Blockchain-Based Model

In the proposed conceptual model, Gojek transforms from a centralized platform into a decentralized network with the role as a service node provider. Each entity in the ecosystem has its own node that participates in the blockchain network.
Proposed system structure:

- **Transaction Layer**: All transactions are confirmed through smart contracts that execute automatically once the conditions are met.
- **Data Immutability Layer**: All transaction data is recorded on the blockchain using hash algorithms, ensuring that the data cannot be modified.
- **Privacy Layer**: User data is encrypted using public-private key cryptography and can only be accessed by parties with the corresponding keys.
- **Audit & Governance Layer**: Transportation regulators or auditors can access blockchain records without the ability to alter the data.

Based on the Biegon model, blockchain-based ride-sharing systems can also integrate tokenization for fairer revenue sharing. For example, drivers can receive tokens automatically after the contract is completed, without the need for traditional financial intermediaries.
In the context of Gojek, this means:

- No single party controls or manipulates transaction data.
- Users gain full transparency over who accesses their data.
- The system becomes more efficient as verification and payment processes are automated via smart contracts.

4.4 Analysis of Benefits and Implementation Challenges

Main benefits:

- High transparency through verifiable public data recording.
- Data security and reliability because every transaction is protected by cryptography.
- Operational efficiency due to contract automation reducing the need for human intervention.
- Increased user trust in the Gojek platform because privacy is guaranteed technologically, not just by policy.

Implementation challenges:

- Complexity of integrating legacy systems with blockchain.
- High computational infrastructure requirements to maintain node synchronization.
- Compliance with local data regulations, especially the Personal Data Protection Law in Indonesia.
- Educating users and partners to understand the new data ownership mechanism.

Decentralization of platforms like Gojek not only enhances privacy but also strengthens economic inclusivity by granting digital sovereignty to users and driver partners. Nevertheless, blockchain integration will require the development of robust interoperability

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protocols to ensure smooth transactions and widespread adoption across the entire Gojek ecosystem.

CONCLUSION

The implementation of smart contracts within the Gojek ecosystem has the potential to become an innovative solution for addressing data security and user privacy issues. Through blockchain technology integration, all transactions will be recorded permanently and immutably, while granting users full control over their personal data. For the subsequent implementation phase, it is recommended that Gojek establish a blockchain consortium with fintech partners and regulators, integrate privacy-preserving computing such as homomorphic encryption, and leverage smart contracts for the automated management of trip contracts and payments.

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